



BUDGET The United States
Department of the Interior
JUSTIFICATIONS

and Performance Information
Fiscal Year 2017

U.S. GEOLOGICAL SURVEY

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U.S. GEOLOGICAL SURVEY

FY 2017 BUDGET JUSTIFICATION

TABLE OF CONTENTS

Organization

Organization Chart and Regional Structure..... vi

A – Executive Summary

1.1 Introduction A-1

1.2 Budget Highlights..... A-4

1.3 Administration Priorities and Secretarial Initiatives A-21

Strengthening Tribal Nations and Insular Communities..... A-21

Powering Our Future and Responsible Use of Our Resources A-25

Engaging the Next Generation..... A-27

Ensuring Healthy Watersheds and Sustainable, Secure Water Supplies A-28

Building a Landscape-Level Understanding of Our Resources A-33

Building a 21st Century Department of the Interior A-34

Agency Priority Goals..... A-35

President’s Management Agenda A-39

1.4 National Challenges A-45

1.5 Strategic Objective Performance Summary A-59

B – Regional and Crosscutting Activities

Regional Overview B-1

Crosscutting Activities B-3

C – USGS Science Coordination

USGS Science Coordination C-1

D – 2017 Budget at a Glance

2017 Budget at a Glance Table D-1

E – Program Changes

2017 Program Changes Table E-1

Sustainable Water – WaterSMART E-2

Critical Landscapes E-13

All-of-the-Above Energy..... E-18

Natural Hazard Science for Disaster Resilience and Response..... E-25

Pollinators..... E-31

Table of Contents

F – Ecosystems

2017 Request Table	F-1
Justification of Program Change	F-2
Activity Summary	
Overview	F-2
Key Accomplishments in 2015	F-6
Strategic Actions	F-7
Status and Trends	F-9
Fisheries.....	F-19
Wildlife.....	F-27
Environments.....	F-35
Invasive Species	F-47
Cooperative Research Units	F-57

G – Climate and Land Use Change

2017 Request Table	G-1
Justification of Program Change	G-2
Activity Summary	
Overview	G-2
Key Accomplishments in 2015	G-6
Strategic Actions	G-9
Climate Variability	
National Climate Change and Wildlife Science Center /DOI Climate Science Centers	G-11
Climate Research and Development	G-27
Carbon Sequestration	G-37
Land Use Change	
Land Remote Sensing	G-47
Land Change Science.....	G-65

H – Energy and Mineral Resources, and Environmental Health

2017 Request Table	H-1
Justification of Program Change	H-2
Activity Summary	
Overview	H-2
Key Accomplishments in 2015	H-4
Strategic Actions	H-5
Energy and Minerals	
Mineral Resources	H-15
Energy Resources	H-27
Environmental Health	
Contaminant Biology.....	H-47
Toxic Substances Hydrology	H-65

I – Natural Hazards

2017 Request Table	I-1
Justification of Program Change	I-1
Activity Summary	
Overview	I-2
Key Accomplishments in 2015	I-5
Strategic Actions	I-7
Earthquake Hazards	I-9
Volcano Hazards	I-21
Landslide Hazards	I-31
Global Seismographic Network	I-39
Geomagnetism	I-43
Coastal and Marine Geology	I-51

J – Water Resources

2017 Request Table	J-1
Justification of Program Change	J-1
Activity Summary	
Overview	J-2
Key Accomplishments in 2015	J-4
Strategic Actions	J-8
Water Availability and Use Science Program	J-11
Groundwater and Streamflow Information Program	J-33
National Water Quality Program	J-49
Water Resource Research Act Program	J-75

K – Core Science Systems

2017 Request Table	K-1
Justification of Program Change	K-1
Activity Summary	
Overview	K-1
Key Accomplishments in 2015	K-5
Strategic Actions	K-7
National Geospatial Program	K-9
National Cooperative Geologic Mapping Program	K-23
Science Synthesis, Analysis, and Research	K-31

L – Science Support

2017 Request Table	L-1
Justification of Program Change	L-1
Activity Summary	
Overview	L-1
Key Accomplishments in 2015	L-2
Strategic Actions	L-4

Table of Contents

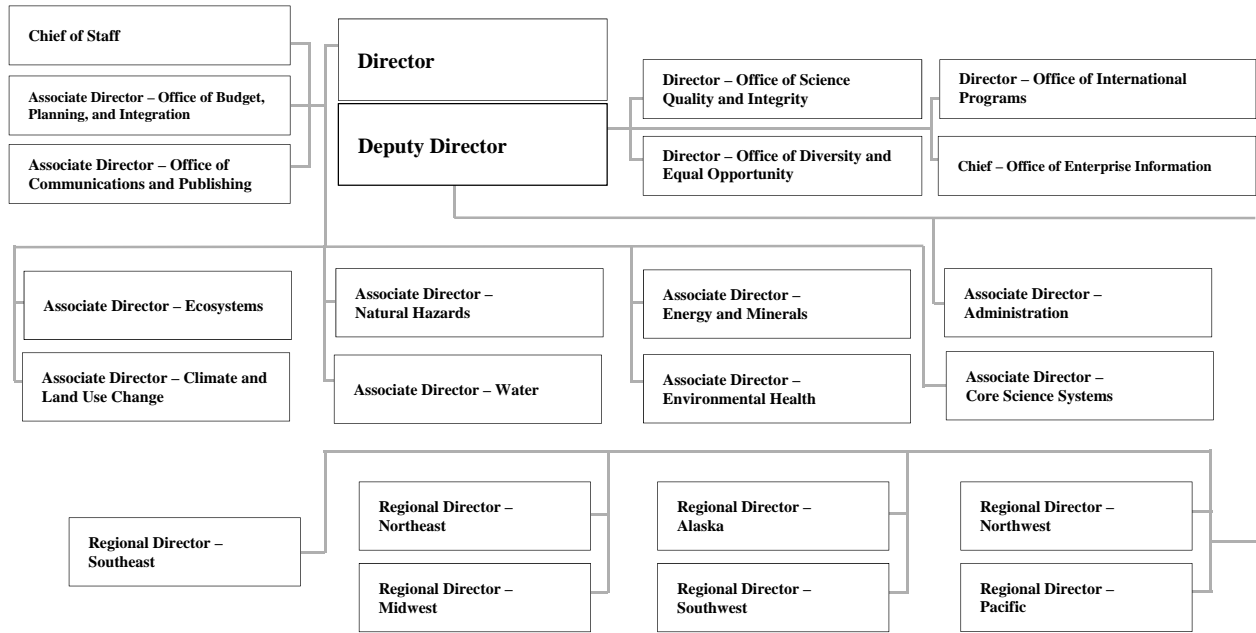
Administration and Management	L-6
Information Services	L-18
M – Facilities	
2017 Request Table	M-1
Justification of Program Change	M-1
Activity Summary	
Overview	M-1
Key Accomplishments in 2015	M-5
Strategic Actions	M-6
Rental Payments and Operations and Maintenance	M-9
Deferred Maintenance and Capital Improvements	M-15
N – USGS Working Capital Fund	
Working Capital Fund Overview	N-1
Appropriation Language and Citations	N-4
Program and Financing	N-6
Balance Sheet	N-7
Object Classification	N-8
Employment Summary	N-8
O - USGS Exhibits	
Appropriation Language.....	O-1
Appropriation Language and Citations	O-2
Expiring Authorization.....	O-3
Administrative Provisions Language	O-8
Administrative Provisions Language and Citations	O-9
Summary of Requirements	O-10
USGS Justification of Fixed Costs and Internal Realignment	O-12
P – Account Exhibits	
Summary of Requirements by Object Class.....	P-1
Program and Financing	P-3
Object Classification	P-6
Employment Summary	P-8
Q – Sundry Exhibits	
Funding of U.S. Geological Survey Programs (Obligations)	Q-1
Contributed Funds	Q-9
Special Trust Fund Receipts	Q-11
Program and Financing	Q-11
Object Classification	Q-12
Employment Summary	Q-12
Employee Count by Grade	Q-13

Section 403 Compliance..... Q-14
DOI Working Capital Fund Revenue Centralized Billing..... Q-14
DOI Working Capital Fund Revenue Direct Billing Q-20
Payments to Other Federal Agencies Q-22
Shared Program Costs Q-22

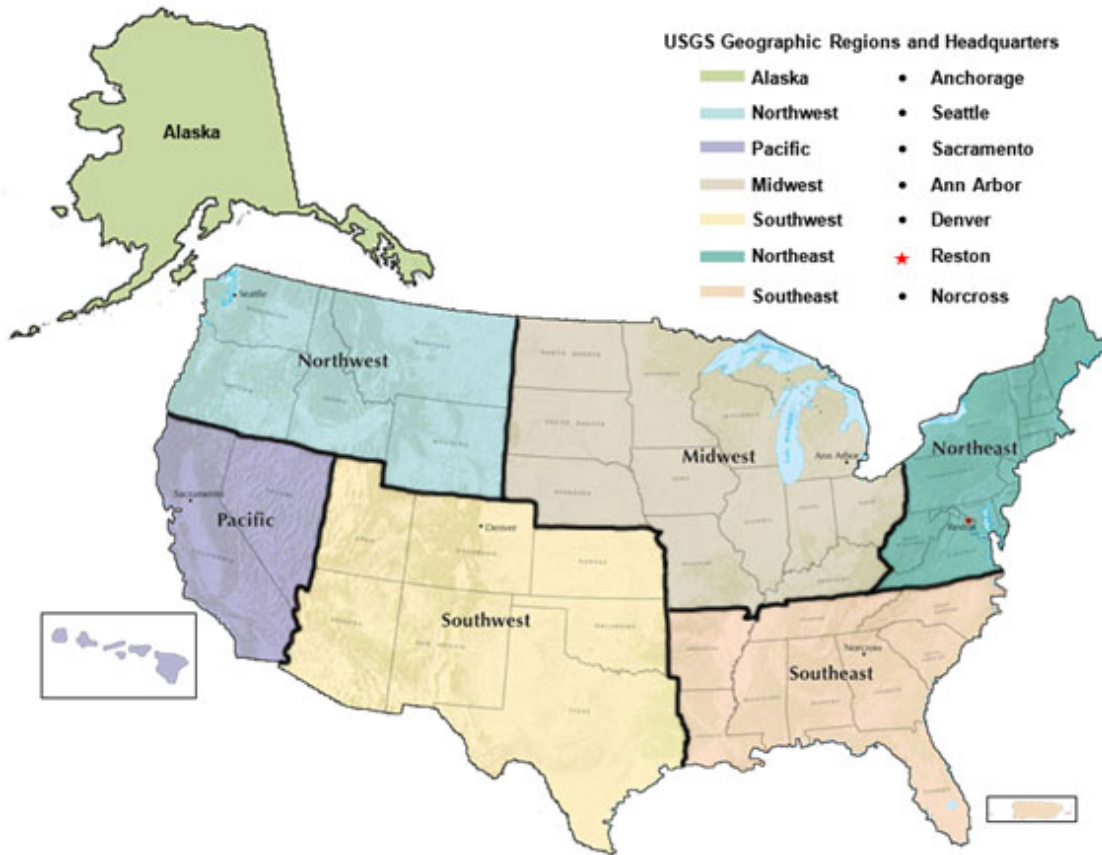
R - Appendix

Acronyms R-1

U.S. Geological Survey



USGS Regional Structure



Executive Summary

Executive Summary

Total 2017 Budget Request <i>(Dollars in Thousands)</i>			
Budget Authority	2015 Actual	2016 Enacted	2017 Request
Current	1,045,000	1,062,000	1,168,803
Permanent	37,198	1,864	955
Operation & Maintenance of Quarters	43	56	53
Spectrum Relocation Fund	35,680	0	0
Contributed Funds	1,475	1,808	902
Total Current and Permanent	1,082,198	1,063,864	1,169,758
<i>FTEs</i>	<i>4,843</i>	<i>4,975</i>	<i>5,132</i>

FTE	2015 Actual	2016 Enacted	2017 Request
Direct	4,843	4,975	5,132
Reimbursable	2,702	2,702	2,702
Working Capital Fund	228	111	111
Allocation Account	95	80	38
Contributed Funds	5	5	5
Total	7,873	7,873	7,988

Introduction

This year, the U.S. Geological Survey (USGS) celebrates 137 years of providing the Nation with reliable scientific information used to describe and understand the Earth, minimize loss of life and property from natural disasters, manage water, ecosystem, energy and mineral resources and enhance and protect quality of life. The USGS plays a key role in the President's ongoing commitment to scientific discovery and innovation that supports a robust economy and decision making related to critical societal needs.

The 2017 President's Budget for the USGS is \$1.2 billion, an increase of \$106.8 million over the 2016 Enacted budget. The USGS budget addresses key societal needs related to our planet. Changes to our home planet combined with increasing human demands threaten our health and safety, our national security, our economy, and our quality of life. As a Nation, we face unprecedented challenges: loss of critical and unique ecosystems, the effects of climate change, increasing demand for limited energy and mineral resources, increasing vulnerability to natural hazards, the effects of emerging diseases on wildlife and human health, and growing needs for clean water.

The USGS provides science for the Department of the Interior (Interior) bureaus to provide their employees and other decision makers with vital information that they need to fulfill their mission. The diversity of USGS scientific expertise enables the bureau to carry out large-scale, multi-disciplinary investigations and provide impartial scientific information to resource managers and planners. Scientific

Executive Summary

coordination and collaboration within Interior and across the government is an important part of the work the USGS does. By leveraging efficiencies across Federal, State, local, and tribal governments, the private sector, and non-governmental organizations, the USGS is able to provide science and information that is thorough, accurate, and tailor-made to address some of the most pressing challenges of the 21st century. The investments in the 2017 budget allow the USGS to continue to make progress advancing many priority directions outlined in the USGS Science Strategy, including the developing the ground station for Landsat 9; informing the management of Water for the 21st Century; conducting research on critical minerals, energy development, rapid disaster response, fire responses and prevention, and climate change; developing enhanced mapping tools and products; advancing landscape science; investigating new and emerging invasive species and disease; and engaging the next generation of Earth scientists.

The budget preserves core USGS science programs, supports Interior's mission, and focuses on societal needs. These core USGS programs provide valuable services to our Nation and include the science and related infrastructure that help decision makers minimize loss of life and property, manage natural resources, and protect and enhance quality of life. Core USGS science helps:

- Protect our water supply and forecast extreme hydrological events, such floods, by maintaining a stable national streamgauge network.
- Manage our energy portfolio by providing estimates of where resources exist and approximate the quantities of those resources that could be produced using current technologies.
- Provide Earth observations and other geographic information to allow us to understand our changing landscape, from tracking changes in land use and human development to documenting the devastation caused by storms and wildfire.
- Understand and mitigate factors associated with endangered and listed species and help resource managers understand the impacts of climate change.
- Understand and prepare for natural hazards such as earthquakes, volcanoes, and landslides.
- Provide coastal communities with the information they need to become more resilient in order to prepare for the impact of storms, plan future development, and protect treasured landscapes and habitats.
- Understand emerging contaminants and the impacts they are having on our communities, ecosystems, and health.

Science support, including the facilities we operate in, helps to provide the foundation that our scientists need to operate in and conduct their independent research. Each day, USGS scientists strive to promote excellence and execute our science mission with discipline and consistency. Part of this effort relies on having a strong science support capability. Our science support efforts include oversight and quality review of our science, as well as the all-important foundational functions, including meeting mandates and statutory requirements, that keep the USGS running effectively and efficiently, such as human resources, acquisition, information technology, cyber security support, facilities, and financial management. Adequate funding in these support areas allow the scientists within the USGS to fully focus on their science mission.

Enhancements to the USGS Budget Justification

Science Coordination: This year the USGS has added discussion within various write-ups of how it collaborates and coordinates with the other Interior bureaus, as well as with other agencies. This discussion is in both a Science Coordination chapter and within the Mission Area chapters. This discussion should help to answer questions that have been raised on how the USGS is working with the other Interior bureaus and ameliorate concerns of whether science is being duplicated across bureaus. The science collaboration discussion within the Mission Area chapters provides a holistic view of the science being performed.

Crosscut Activities: The USGS has included a crosscutting activities section in the budget justification that shows the funding levels for and work that the USGS is performing in various high-profile activities of interest to the Administration and Congress.

Organization of the Budget Justification: The USGS 2017 Budget Request is organized into sections as follows:

- Executive Overview – Summarizes the budget changes by Mission Area and aligns the summary of budget changes to the strategic objectives, and highlights Secretarial initiatives, Agency Priority Goals, and National Challenges.
- Program Changes – Groups the budget in the Program Change section by multi-mission USGS activities and by Mission Area.
- Crosscuts – Highlights the funding amounts and work that the USGS is performing in various high-profile activities of interest to the Administration and Congress.
- Science Coordination – Discusses how the USGS works with other Interior bureaus and how the USGS avoids duplication of science.
- Mission Area Chapters – Provides the detail on what the USGS is doing with base funding, program changes, and science coordination activities.

Fixed Costs

The fixed costs for the USGS in 2017 are \$4.7 million, which include increases and decreases for the various components of fixed costs. Fixed costs are needed and used by all of the USGS Mission Areas and pay for uncontrollable cost increases associated with things such as annual general increases for employee pay, payments to the Department of Labor for the workers and unemployment compensation, as well as increases in rent costs. Without funding for fixed costs increases, mission areas will bear the increases in these costs, reducing the investment in science. Fixed costs for 2017 include:

- A net increase of \$4.8 million for pay and salaries and benefits
- A decrease of \$1.2 million for the Department's Working Capital Fund.
- An increase of \$0.1 million for workers' compensation.
- A decrease of \$0.1 million for unemployment compensation.

Executive Summary

- A decrease of \$2.1 million for rent savings.
- An increase of \$3.3 million for O&M increase from moves out of GSA space.

More information on the USGS contribution to the Department's Working Capital Fund is located in Sundry Exhibits, Section Q. The fixed costs calculations are located in the USGS Accounts Exhibits, Section O. Cost saving projects have resulted in a smaller facilities footprint and helped the USGS control rent costs. More information on rented facilities, owned facilities and their operation and maintenance, and cost saving projects is located in the Facilities Chapter.

Budget Highlights

Budget Change Summary <i>(\$ in Thousands)</i>	
2016 Enacted	\$1,062,000
Program Change	\$102,074
Fixed Costs	\$4,729
2017 Budget Request	\$1,168,803

2017 Budget Request <i>(Dollars in Thousands)</i>					
Budget Authority	2015 Actual	2016 Enacted	2017		
Surveys, Investigations, and Research			Fixed Costs	Program Changes	Budget Request
Ecosystems	157,041	160,232	701	13,005	173,938
Climate and Land Use Change	135,975	139,975	304	31,165	171,444
Energy and Mineral Resources, and Environmental Health	92,271	94,511	453	4,519	99,483
Natural Hazards	135,186	139,013	519	10,169	149,701
Water Resources	211,267	210,687	957	16,348	227,992
Core Science Systems	107,228	111,550	408	6,437	118,395
Science Support	105,611	105,611	164	4,817	110,592
Facilities	100,421	100,421	1,223	15,614	117,258
USGS Total	1,045,000	1,062,000	4,729	102,074	1,168,803

The USGS proposes changes of \$106.8 million from the 2016 Enacted budget to advance priority directions outlined in the USGS Science Strategy and in support of the Secretarial Initiatives: Strengthening Tribal Nations and Insular Communities, Powering Our Future, Ensuring Healthy Watersheds and Water Supplies, Landscape-Level Understanding, and Engaging the Next Generation.

Ecosystems

The 2017 Budget Request for Ecosystems is \$173,938,000, a net change of +\$13,706,000 from the 2016 Enacted level.

- Develops and provides standard scientific methods to measure changing biodiversity, and forecast and plan for future biodiversity scenarios for inventory and monitoring programs at land management bureaus (Bureau of Land Management - BLM, National Park Service - NPS, Fish and Wildlife Service - FWS).
- Develops an interagency monitoring framework focused on evaluating the effectiveness of fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage grouse.
- Expands capabilities to evaluate the effectiveness of fire suppression actions, such as fuel breaks, and to test new techniques for reducing fuel loads by controlling or eliminating cheatgrass and other invasive plants.
- Transfers technologies ready for use in the field to relevant partners and allows USGS scientists to adapt these new detection, containment, and control tools to the many areas in the Nation where invasive species have been detected.

Highlights of changes are as follows with additional detail in the Mission Area section:

Status and Trends Program +1,794,000 for a total of \$22,267,000:

- Pollinators +\$1,705,000 for a total of \$2,055,000: Increase research and interaction between the USGS and Interior bureaus on pollinators to support land managers in ensuring that populations on native species are maintained.
- Fixed Costs +89,000

Fisheries Program +\$3,197,000 for a total of \$24,083,000:

- Great Lakes Fisheries Assessments +\$250,000 for a total of \$4,210,000: Piloting a change in the way that fisheries assessments are done in the Great Lakes, moving to the use of Long Range Autonomous Underwater Vehicles and piloting a project where offshore sample processing of water in the Great Lakes would be used to provide an early warning system regarding Harmful Algal Blooms.
- Unconventional Oil and Gas Research – Ecological Effects +\$350,000 for a total of \$1,458,000: Expanding research to identify potential ecological impacts associated with UOG development and the area's most vulnerable to impact through wastewater toxicity testing and landscape scale vulnerability assessments.
- WaterSmart: Ecological Flows +\$2,500,000 for a total of \$3,000,000: Develop Decision Support tools, which are an essential step in enhancing capacity for water regulators across the United States.
- Fixed cost +\$97,000

Executive Summary

Wildlife Program +\$368,000 for a total of \$46,125,000:

- Renewable Energy – Wind and Solar +\$150,000 for a total of \$1,645,000: Support development of new mitigation technologies to reduce the interaction of wildlife with renewable energy infrastructure.
- Fixed Cost +\$218,000

Environments Program +\$4,937,000 for a total of \$43,352,000:

- Arctic +\$1,000,000 for a total of \$2,030,000: Partner with agencies to analyze potential changes to distributions and condition of fish and wildlife populations and their habitats as a result of climate changes and human activities.
- Sage Steppe Landscape +\$3,000,000 for a total of \$4,181,000: Expand research to fire regimes, drought, and shifting climates; control the spread of invasive cheatgrass; design conservation and management strategies for greater sage-grouse; and effectively restore and adaptively manage the sage steppe landscape.
- Science to Support Drought +\$300,000 for a total of \$300,000: Conduct research on how drought interacts with other environmental stressors such as invasive vegetation and wildfires to affect landscape composition, structure, and function.
- Rangeland Fire Response and Prevention +\$500,000 for a total of \$1,042,000: Expand capabilities of USGS to more fully address the priority science needs to reducing the growing threat of rangeland fire and improve effectiveness of actions to stabilize, rehabilitate, and restore ecosystems after fire. Work will include the study of large-scale efforts to control flammable vegetation, development of climate-adapted revegetation strategies, creation of tools to support a new conservation and restoration strategy that will provide landscape prioritization for both fire and land managers, and development of new monitoring techniques to assess effectiveness of fire management actions and post-fire rehabilitation efforts.
- Fixed cost +\$137,000

Invasive Species Program +\$2,547,000 for a total of \$19,877,000:

- New and Emerging Invasive Species of National Concern +\$2,500,000 for a total of \$8,212,000: For development, evaluation, and improvement of tools for early detection and control of existing and emerging invasive species. The USGS would develop and improve the power of advanced molecular detection tools to detect invasive species at very low densities in the field, such as sea lamprey.
- Fixed cost +\$47,000

Cooperative Research Units +\$863,000 for a total of \$18,234,000:

- Cooperative Research Units (CRU) - Enhanced Support and Scientists for Tomorrow +\$750,000 for a total of \$18,121,000: The CRU involvement in youth programs has traditionally been focused on graduate education. CRU will use the requested increase to provide undergraduate students, from groups under-represented in the conservation workforce, with mentoring and

hands-on experience designed as a pathway to Interior recruitment. In addition, the CRU will enhance support towards training, mentoring, and support of Science, technology, engineering, and mathematics (STEM) graduate and post-doctoral associates from under-represented groups.

- Fixed cost +\$113,000

Climate and Land Use Change (CLU)

The 2017 Budget Request for CLU is \$171,444,000, a net change of +\$31,469,000 from the 2016 Enacted level.

- Supports Administration priorities, including the USGCRP, the President's Climate Action Plan and other government-wide strategies such as the National Fish, Wildlife, and Plants Climate Adaptation Strategy.
- Plans for a Landsat 9 launch in 2021, minimizing impacts to data continuity and ensuring access to the Nation's remotely sensed land data (Landsat and other).
- Provides the climate science resource and land managers need to adapt to climate and mitigate its effects, as defined in Secretarial Orders 3289 and 3330 respectively.
- Advances the strategic goals for climate and land use change science in the USGS 10-year plan.

Highlights of changes are as follows with additional detail in the Mission Area section:

Climate Variability +\$5,714,000 for a total of \$63,003,000

National Climate Change and Wildlife Science Center/DOI Climate Science Centers (CSCs) +\$4,473,000 for a total of \$30,908,000:

- Great Lakes Climate Science Center +\$1,500,000 for a total of \$1,500,000: Establish a new Center to help increase and improve focus on the many climate-related natural resource challenges in the Great Lakes region due to the distinct bio-geographic provinces between the Great Lakes region and the Northeastern United States.
- Tribal Climate Science Partnerships +\$1,411,000 for a total of \$1,411,000: To address the needs of Tribes to better understand the potential climate change effects on culturally-important fish and wildlife resources, and help integrate tribal and indigenous traditional ecological knowledge with more conventional science in management decisions.
- WaterSMART Drought: +\$1,030,000 for a total of \$1,030,000: To develop a science-based decision process for understanding and managing the impacts of drought on various parts of the Central and Western United States, including California. Much research is available on the effects of drought on human systems, notably agriculture, but the ecological effects are not as well studied.
- Critical Landscapes: Arctic +\$500,000 for a total of \$500,000: To develop a process to estimate total glacier loss in Alaska and potential changes in freshwater input that affect economically and culturally important species such as salmon and caribou, and build on existing research in interior

Executive Summary

Alaska to better understand the potential for larger scale and more frequent effects of ecological drought.

- Fixed cost +\$32,000

Climate Research and Development Program +\$1,219,000 for a total of \$22,714,000:

- WaterSMART: Drought +\$1,125,000 for a total of \$1,125,000: To understand long-term and medium-term patterns and impacts of drought in the Western and Southeastern United States.
- Fixed cost +\$94,000

Carbon Sequestration +\$22,000 for a total of \$9,381,000:

- Fixed cost +22,000

Land Use Change +\$25,755,000 for a total of \$108,441,000

Land Remote Sensing Program +\$24,312,000 for a total of \$96,506,000:

- Landsat 9 +\$15,400,000 for a total of \$19,700,000: Develop the Landsat 9 ground system and delivering the completed system to support accelerating the launch date to 2021.
- Sentinel-2 +\$2,200,000 for a total of \$2,200,000: Acquire, store, and disseminate the information from European Space Agency.
- Big Earth Data: Data Cube +\$600,000 for a total of \$600,000: Initiate the development of a pilot study for enhancing Landsat data access and delivery services that would allow the user to define a geographic area of interest, timeframe, and specific parameters derived from the data (e.g., vegetation index) rather than the current scene-based products of prescribed geographic extent and digital numbers provided by the USGS.
- Critical Landscapes: Arctic +\$1,857,000 for a total of \$1,857,000: Develop predictive models, which support the evaluation of changes to the environment resulting from the conversion of historically sequestered ice and snow to liquid and gaseous water.
- Landsat Products for Climate and Natural Resources Assessments +\$2,992,000 for a total of \$2,992,000: To develop the computing and online storage resources necessary to rapidly produce and widely disseminate a set of Landsat-based information products.
- Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis +\$500,000 for a total of \$500,000: Develop new datasets to support dynamic coastal land change analyses for improved coastal resource management and resilience planning.
- WaterSMART: Drought +\$250,000 for a total of \$250,000: Identify gaps and close the gaps between remote sensing data and derivative products in order to meet the needs of scientists and decision makers in the conservation and land management communities.
- Water SMART: Remote Sensing +\$400,000 for a total of \$400,000: Use remote sensing data to allow monitoring of water storage in smaller storage features such as ponds, thereby improving drought status monitoring.

- Fixed cost +\$113,000

Land Change Science Program +\$1,443,000 for a total of \$11,935,000:

- WaterSMART: Remote Sensing +\$400,000 for a total of \$400,000: Conduct an innovative data integration approach that combines satellite-derived reservoir surface area and digital elevation models (DEM) to monitor height and volumetric storage changes in water reservoirs.
- WaterSMART: New Tools and Models to Better Manage Water Nationwide +\$1,000,000 for a total of \$1,000,000: Develop automated methods and tools supporting near real-time, satellite-based, drought monitoring. Assessed characteristics would include soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers identify the onset and severity of drought events and effectively allocate scarce water resources.
- Fixed cost +\$43,000

Energy and Mineral Resources, and Environmental Health (EMEH)

The 2017 Budget Request for EMEH is \$99,483,000, a net change of +\$4,972,000 from the 2016 Enacted level.

EMEH provides valuable, objective science and information about our Nation's energy and mineral resources, as well as reliable, impartial science critical to understanding the interaction between the physical environment, the living environment, and human health.

Mineral and Energy Resources +\$1,857,000 for a total of \$74,923,000

Mineral Resources Program +\$324,000 for a total of \$48,695,000:

- Critical Minerals and Materials Flow Initiative +\$1,022,000 for a total of \$9,484,000: Increase work on identifying and evaluating new sources of critical minerals and continue lifecycle work on critical minerals.
- R&D to Address Environmental Impacts of Minerals Development +\$559,000 for a total of \$5,559,000: For development of new science and tools to reduce the impacts of minerals extraction, production, and recycling on the global environment and human health, including research on supply chain, life cycle, resource sustainability, and minimizing environmental impacts of mineral extraction.
- Geophysical and Remote Sensing Activities -\$1,500,000 for a total of \$1,500,000: A decrease is proposed to help offset increases. This would terminate some geophysical and remote sensing work in different regions of the United States, including Alaska, California, and the mid-continent.
- Fixed costs +\$243,000

Executive Summary

Energy Resources Program +\$1,533,000 for a total of \$26,228,000:

- Alternative Energy Permitting on Federal Lands – Geothermal +\$229,000 for a total of \$654,000: Conduct studies on the favorability of geothermal resources, and develop research and technology such as miniature unmanned aerial systems (UAS) to study the potential impacts of geothermal resource development through heat mapping. Information will be used to inform alternative energy permitting decisions and land use planning decisions on Federal lands by the Bureau of Land Management and other agencies.
- Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment +\$211,000 for a total of \$286,000: Evaluating and developing plans to enhance coastal infrastructure resilience by using an economic approach that uses assessment and valuation of ecosystem services for effective resource management. Utilize the same economic approach to evaluate the use of green infrastructure investments in urban settings.
- Unconventional Oil and Gas Research +\$975,000 for a total of \$6,825,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the ERP would: expand research to help predict the quality and quantity of waste fluids associated with energy production; conduct annual field research in Alaska to support the assessment of undiscovered UOG on the North Slope; expand domestic assessment of shale and tight oil and gas to increase the number of evaluations performed by about two per year; increase cooperative efforts with state geologic surveys to acquire fundamental data needed for UOG assessments; and expand petroleum processes research to improve understanding of the nature of UOG resources.
- Fixed costs +\$118,000

Environmental Health +\$3,115,000 for a total of \$24,560,000

Contaminant Biology Program +\$1,268,000 for a total \$11,465,000:

- Critical Landscapes: Columbia River +\$50,000 for a total of \$100,000: Expand studies of contaminant exposure and the cycling of mercury pesticides in food webs to address important tribal and endangered species of concern in the Columbia River Basin.
- Environmental Impacts of Uranium Mining +\$273,000 for a total of \$673,000: Study the amount of uranium metal and its radiation in birds, mammals, and reptiles, as well as water and dust, near targeted active mines in the Grand Canyon region. The 2017 results will then be compared to the baseline data to measure the environmental impacts of uranium mining and its associated release of radiation beyond what is naturally occurring. This research will support the 15-year multiagency science plan established to inform the decision on whether to lift the Secretary of Interior’s moratorium on new uranium mining in the Grand Canyon region until 2032.
- Unconventional Oil and Gas Research +\$900,000 for a total of \$930,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the CBP would expand testing to help add to a body of collaborative research needed for assessment of potential biological effects of UOG development on living organisms, including humans.
- Fixed costs +\$45,000

Toxic Substances Hydrology Program +1,847,000 for a total of \$13,095,000:

- **Critical Landscapes: Columbia River +\$50,000 for a total of \$100,000:** Continue to investigate the effects of contaminants such as pesticides and mercury on the fish and wildlife in the Columbia River.
- **Environmental Impacts of Uranium Mining +\$1,750,000 for a total of \$2,500,000:** Expand upon scientific research in the Grand Canyon region on baseline, pre-mining levels of uranium contamination in soils for comparison to contamination levels in soils following uranium mining activities. This research will support the 15-year multiagency science plan established to inform the decision on whether to lift the Secretary of Interior’s moratorium on new uranium mining in the Grand Canyon region. Expanded studies will include additional sites and environmental settings (e.g., water), and will include biological sampling. The TSHP will also interpret and analyze the datasets compiled.
- **Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast +\$1,300,000 for a total of \$1,300,000:** To support coastal resiliency efforts, establish real-time water quality monitoring capabilities in key locations associated with a prototype contaminant network along the northeast coast, and support the development of standard operating procedures for the rapid deployment and mobilization of field crews to collect environmental samples following a hurricane or other coastal disaster.
- **Unconventional Oil and Gas Research +\$250,000 for a total of \$1,020,000:** In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the TSHP would study the environmental contamination associated with spills and other releases of liquid and solid wastes from unconventional oil and gas development activities at sites in West Virginia (Marcellus Shale) and North Dakota (Williston Basin).
- **Emerging Contaminants and Chemical Mixtures -\$750,000 for a total of \$0:** A decrease is proposed to help offset proposed increases. The TSHP would discontinue research on environmental contaminants (e.g., mercury, pharmaceuticals, pesticides, etc.), which are used to inform resource management and regulatory decisions about contaminants in drinking and recreational water, as well as water quality of streams, rivers, and groundwater, and to understand environmental and human health risks posed by those contaminants and their mixtures.
- **Fate and Transport of Contaminants in the Subsurface -\$800,000 for a total of \$0:** A decrease is proposed to help offset proposed increases. Research on the movement of contaminants from their point of origin, through the environment, and to their pathways of exposure would be discontinued.
- **Fixed costs +\$47,000**

Natural Hazards

The 2017 Budget Request for Natural Hazards is \$149,701,000, a net change of +\$10,688,000 from the 2016 Enacted level.

- Provides hazard science to help protect the safety, security, and economic well-being of the Nation.
- Provides scientific observations, analyses, and research that are critical for the Nation to become more resilient to natural hazards.
- Develops user driven tools (e.g., EEW, ShakeCast, Ash 3D, Our Coasts, Our Future) to support societal needs; and enable partners with USGS science, products, and data.

Highlights of changes are as follows with additional detail in the Mission Area section:

Earthquake Hazards Program +\$1,693,000 for a total of \$62,196,000:

- Unconventional Oil and Gas Research: Induced Seismicity Earthquake Risk Assessments +\$700,000 for a total of \$3,200,000: To reduce the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts.
- Central and Eastern U.S. Seismic Network Adoption +\$800,000 for a total of \$800,000: To improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159 stations.
- Fixed costs +\$193,000

Volcano Hazards Program +\$117,000 for a total of \$26,238,000:

- Fixed costs +\$117,000

Landslide Hazards Program +\$516,000 for a total of \$4,054,000:

- Natural Hazard Science for Disaster Response: Landslide Response +\$500,000 for a total of \$1,600,000: For improving landslide response by expanding post-wildfire debris flow hazard assessments and growing capability to respond to landslide crises.
- Fixed costs +\$16,000

Global Seismographic Network +\$869,000 for a total of \$7,322,000:

- GSN Primary Sensor Deployment +\$860,000 for a total of \$2,460,000: To deploy and install the new borehole sensors and to improve the physical infrastructure of select GSN sites.
- Fixed costs +\$9,000

Geomagnetism Program +\$1,710,000 for a total of \$3,598,000:

- Improved Geomagnetic Monitoring +\$1,700,000 for a total of \$1,700,000: To provide enhancements in electrical field (E-field) monitoring, the direct measurement of currents in the Earth's crust; and the gathering and integration of existing global magnetic field data. These activities are integral to implementation of the National Space Weather Strategy.
- Fixed costs +\$10,000

Coastal and Marine Geology Program +5,783,000 for a total of \$46,293,000:

- Scenarios for Arctic Actions to Address Imminent Coastal Impacts +\$3,500,000 for a total of \$4,925,000: To allow the USGS to shift research staff to work in the Arctic and selected Pacific Islands dealing with impacts of sea-level rise, severe storms and/or melting permafrost on their coastal communities and economies.
- Building Landscape-Level Resilience to Coastal Hazards +\$2,109,000 for a total of \$6,235,000: The proposed increase would be used to apply research and modeling findings in the Hurricane Sandy (2012) affected areas to other parts of the U.S. coastline.
- Fixed costs +\$174,000

Water Resources

The 2017 Budget Request for the Water Resources Mission Area is \$227,992,000, a net change of +\$17,305,000 from the 2016 Enacted level.

- Aligns with administration priorities related to water challenges and public lands.
- Protects and enhances key operational networks and their information management and delivery systems (i.e., streamgages).
- Protects core mission needs.
- Enhances decision-support tools that use data from key hydrologic networks and USGS science in order to allow for more informed decision making.

Highlights of changes are as follows with additional detail in the Mission Area section:

Water Availability and Use Program +12,336,000 for a total of \$54,388,000:

- WaterSMART: Near Real Time Assessment of Water Use During Drought +\$4,000,000 for a total of \$4,000,000: To develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures.
- WaterSMART: Water Use Information +\$3,000,000 for a total of \$3,000,000: To integrate water information that is fragmented among multiple agencies into a national water data framework on a geospatial platform. This funding would support periodic comprehensive analysis of the data to

report on water use trends and provide national water-use indicator analysis, and maps of water stress indicators. In addition, it provides additional funding through grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making.

- WaterSMART: Water Use Research +\$1,000,000 for a total of \$1,000,000: To support cooperative matching funds to maximize use of State water use datasets in the water availability and use assessment. In addition, directed work is required to develop better methods of sampling, estimating, aggregating, and presenting water use data. This includes research into new methods that use remote sensing and spatial datasets in water use estimation.
- WaterSMART: Drought +\$1,000,000 for a total of \$1,984,000: Conduct a more comprehensive evaluation of data needs and model capabilities for quantifying water budgets across snow-dominated regions of the United States.
- WaterSMART: Streamflow Information +\$400,000 for a total of \$1,075,000: To implement StreamStats in three additional States and improve methods for proving the estimates would continue to be investigated.
- WaterSMART: National Hydrologic Model +\$750,000 for a total of \$750,000: There is a need to assemble community modeling resources (i.e., datasets, models, use cases) to economize and enhance model development and verification activities across the community. Model development assumes continued community use of legacy models and datasets rather than proposing a new model framework. Such an activity would improve and modernize access to resources that support development, verification, or model application for specific decision situations.
- Critical Landscapes: Arctic +\$1,950,000 for a total of \$2,200,000: To assess systems and anticipate future system changes and explore opportunities for predictions that allows extrapolation from monitored to unmonitored locations.
- Fixed costs +\$236,000

Groundwater and Streamflow Information Program +1,422,000 for a total of \$72,957,000:

- Tribes +\$500,000 for a total of \$2,500,000: While the USGS is not directly involved with Indian Water Rights settlement, the USGS provides technical information needed to support water rights settlement work that is then given to decision makers. To support cooperative matching funds to enhance streamflow information to support tribal needs and decisions. Monitoring, along with assessments and research, would help address availability issues on tribal lands including such topics as water rights, water use, hydrologic conditions, and water-quality issues.
- Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages +\$700,000 for a total of \$3,260,000: To expand the use of flood inundation mapping and Rapid Deployment Gages (RDGs). Implemented together, the flood-inundation and RDGs systems will provide crucial flood data needed to help manage flood response activities.
- Fixed costs +\$222,000

National Water Quality Program +\$3,547,000 for a total of \$94,147,000:

- Support NAWQA Cycle 3 +1,881,000 for a total of \$63,881,000: Two-thirds, or \$1.262 million will be used to restore and enhance long-term surface water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for Cycle 3. One-third, or \$620,730 will be used to restore and enhance long-term groundwater water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for Cycle 3.
- Enhanced Cooperative Activities and Urban Waters +\$717,000 for a total of \$717,000: To support cooperative matching funds that enable similar types of streamflow and water-quality data collection that provide science-based information used by state and local partners to develop plans for economic revitalization, urban water restoration, and educational outreach for the general public.
- Unconventional Oil and Gas Research +\$450,000 for a total of \$650,000: To develop and disseminate science-based information and tools needed for a fundamental understanding of the processes that affect the occurrence, transport, fate, and effects of contaminants in streams and groundwater affected by UOG extraction activities.
- Fixed cost +\$499,000

Water Resources Research Act - No changes for a total of \$6,500,000.

Core Science Systems

The 2017 Budget Request for Core Science Systems (CSS) is \$118,395,000, a net change of +\$6,845,000 from the 2016 Enacted level.

- Grows 3D Elevation Program (3DEP) & Alaska Mapping
- Implements NHDPlus High-Resolution Hydrography Data
- Maintains 3D Geologic Frameworks and Standards Use
- Furthers Innovation Projects through High Performance Computing
- Implements the Community for Data Integration
- Supports the John Wesley Powell Center for Analysis & Synthesis
- Sustains Big Earth Data Goals

Highlights of changes are as follows with additional detail in the Mission Area section:

Science Synthesis, Analysis and Research +\$631,000 for a total of \$24,930,000:

- Pollinators +\$350,000 for a total of \$350,000: To create maps and analyses of habitats of critical concern for pollinators with areas of greatest potential for mitigation and restoration activities. Existing online repositories would be enhanced to capture national distributions and ranges for

Executive Summary

pollinators to inform climate change. The work will be conducted in collaboration with the Ecosystems Mission Area.

- WaterSMART - Drought +\$200,000 for a total of \$200,000: To build on existing capabilities in gap analysis and collaborations with the Land Change Science Program to provide species modeling for specific habitats, identifying species most at risk from drought-related effects.
- Fixed cost +\$81,000

National Cooperative Geological Mapping program +\$89,000 for a total of \$24,486,000:

- Fixed Cost +\$89,000

National Geospatial Program +\$6,125,000 for a total of \$68,979,000:

- Alaska Mapping and Map Modernization +\$1,500,000 for a total of \$6,722,000: To increase collection of ifsar (interferometric synthetic aperture radar) in Alaska and improve mapping products. These maps and improved data are urgently needed for aircraft navigation, since weather conditions in Alaska deteriorate quickly and pilots frequently need to fly using only their instruments and GPS. Involvement with the Alaska Mapping Executive Committee and coordination with other Federal and state agencies will facilitate identification of priority needs and partnering opportunities.
- National Enhancement, Landscape-scale 3-D Maps +\$2,387,000 for a total of \$21,887,000: To increase acquisition of lidar data and expand publicly available 3DEP holdings. Accelerating the national coverage of lidar will enable decision making in management of infrastructure and construction, more accurate and cost effective application of chemicals in farming, development of energy projects, and support of aviation safety and vehicle navigation.
- Coastal Lidar +\$500,000 for a total of \$500,000: To collect enhanced elevation data using lidar in U.S. coastal zones to understand and mitigate the negative effects of coastal erosion and storm surge, to map existing and potential landslide hazards, and to monitor biomass.
- NHD/Landscape Level Assessments – Chesapeake Bay +\$500,000 for a total of \$500,000: To systematically collect and manage high-quality lidar data to understand landscape processes at a parcel and local level and support the sustainable development and management of the Chesapeake Bay's natural resources.
- WaterSMART: National Hydrography Database +\$1,000,000 for a total of \$1,000,000: To complete national NHDPlus high-resolution (1:24,000 scale) coverage for the conterminous 48 States, Hawaii, and Puerto Rico and, when combined with 3DEP products, would be used to integrate water information into a simplified and connected national water data framework that would underpin innovation, modeling, data sharing, and solution development.
- Fixed cost \$238,000

Science Support

The 2017 Budget Request for Science Support is \$110,592,000, a net change of +\$4,981,000 from the 2016 Enacted level.

- Provides the functions that make it possible to conduct USGS science. The Science Support Activity provides business and information systems including acquisitions and grants, finance, internal control, communications, budget, monitoring and evaluation of science quality and integrity, education, technology services and human capital, each of which are crucial to conducting quality science. Science Support includes the executive leadership and management that provide guidance, direction and oversight for all USGS science activities.
- The changes are related to supporting the Science Missions, and improving infrastructure support to sustain science; DOI and Tribal Science Coordination; increasing the number of Mendenhall postdoc scientists; further development of outreach to underserved communities; and improved youth and education in Science.
- Priorities include deploying a world-class workforce; providing Open Data; enhancing Lab-to-Market initiatives; pursuing strategic Sourcing and Shared Services opportunities; enhancing Customer Service; developing Smarter IT Delivery; promoting STEM Education; and focusing on Cybersecurity.

Highlights of changes are as follows with additional detail in the Mission Area section:

Administration and Management +\$4,338,000 for a total of \$86,319,000:

- Enhancing Science Support Capability to Support Science Mission Goals +\$1,997,000 for a total of \$1,997,000: Improve service delivery by supporting closer collaboration between service providers and scientists.
- Tribal Science Coordination +\$300,000 for a total of \$732,000: For enhancing and expanding outreach coordination efforts among Tribes and USGS regions to connect Tribes with science information needed to make critical decisions.
- DOI Science Coordination +\$200,000 for a total of \$200,000: Provides a dedicated scientist to coordinate USGS science efforts with other Interior bureaus and support Interior's science integrity process overall.
- Mendenhall Program Postdocs +\$500,000 for a total of \$500,000: To recruit Mendenhall Fellows to carry out research that covers the entire spectrum of USGS science.
- Youth in Underserved Communities +\$200,000 for a total of \$200,000: To grow outreach programs to youth in underserved communities to develop future scientists.
- Youth and Education in Science +\$1,000,000 for a total of \$2,530,000: To sustain and build on existing youth hiring and outreach activities to develop future scientists.
- Fixed cost +\$141,000

Executive Summary

Information Services +\$643,000 for a total of \$24,273,000:

- Enhancing Science Support Capability to Support Science Mission Goals +\$620,000 for a total of \$620,000: To develop and improve information technology tools and systems.
- Fixed costs +23,000

Facilities

The 2017 Budget Request for Facilities is \$117,258,000, a net change of +\$16,837,000 from the 2016 Enacted level.

The Facilities program provides science needs by optimizing facility locations, distributions, and use, to control or reduce costs. Includes:

- Facility planning to provide safe, high-quality workspace aligned with science needs.
- Develop Asset Business Plans to meet asset management goals, annual surveys, and cyclic condition assessments.
- Meeting performance targets for improving space utilization, controlling rent and operating costs, and releasing unneeded space.
- Achieve sustainability goals; reducing deferred maintenance by renovating and constructing buildings and other facilities to replace assets otherwise no longer cost effective to operate.
- Establishing an effective maintenance program at each owned facility to meet industry best practices.
- Increasing co-location consistent with science program objectives.

Highlights of changes are as follows with additional detail in the Mission Area section:

Rental Payments and Operations and Maintenance +\$16,837,000 for a total of \$109,978,000:

- Operations and Maintenance Stewardship +\$2,712,000 for a total \$2,712,000: To improve facility operations by repairing and replacing broken equipment in support of science needs.
- Reducing the Facilities Footprint and Cost Savings and Innovation Plan (RTF/CSIP) +\$10,902,000 out of \$10,902,000: To fund prioritized CSIP/RTF projects with the shortest payback period while significantly reducing the bureau's footprint and cost.
- Sustainability Investments +\$2,000,000 for a total of \$2,000,000: To improve aging energy systems.
- Fixed cost +\$1,223,000

Deferred Maintenance and Capital Improvements \$0 for a total of \$7,280,000.

Summary

The USGS has been under-resourced to fully accomplish our mission objectives. The 2017 budget helps to counter the strain the USGS has felt for many years of having too much workload for too few resources. The USGS fosters collaboration with other Interior bureaus and other Federal Agencies to leverage resources to produce actionable science. Science is needed to predict outcomes and preserve our future.

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Administration Priorities and Secretarial Initiatives

The 2017 budget supports Secretarial initiatives and agency priorities in the areas of climate resilience, landscape-level understanding, energy, water, engaging youth, and building a 21st century Department of the Interior. The section below highlights increases and addresses recent USGS achievements to support and advance the Secretarial priorities in 2017.

Secretarial Priority	2015 Actual	2016 Enacted	2017	
			Program Changes	2017 Request
Strengthening Tribal Nations and Insular Communities	3,811	3,811	1,711	5,522
Powering our Future and Responsible Use of our Resources	37,066	34,721	4,333	39,054
Engaging the Next Generation	23,715	23,715	2,563	26,278
Ensuring Healthy Watersheds and Sustainable, Secure Water Supplies	28,106	30,335	18,855	49,190
Building a Landscape-Level Understanding of Our Resources	69,497	79,619	35,966	115,585
Total	162,195	172,201	64,317	236,518

Strengthening Tribal Nations and Insular Communities (+\$1.7 million)

The USGS has recognized the importance of Native knowledge and living in harmony with nature as complements to the USGS mission to better understand the Earth. Combining traditional ecological knowledge with empirical studies allows the USGS and Native American governments, organizations, and people to increase their mutual understanding and respect for this land. The USGS provides information to Tribes as part of our basic mission of providing unbiased scientific information to the Nation and the Federal Trust Responsibility to Tribes. In addition, the USGS continues to support opportunities for the integration of indigenous knowledge systems and Western science, develop innovative programs such as the Native Youth in Science – Preserving Our Homelands summer camp, and engage in USGS tribal outreach efforts, such as those for Tribes affected by Hurricane Sandy, that demonstrate to Indian Country how the USGS “gold standard” of research can help to address tribal science needs. The USGS 2017 budget request invests \$5.5 million in Strengthening Tribal Nations, which includes increases for Tribal Science Coordination and Tribal Climate Science Partnerships. Increased funding for tribal science coordination would allow the development of a USGS data portal to allow Tribes to access historical and projected data for inclusion in FEMA emergency services grants. It would also allow for the expansion of the Native Youth in Science program, which brings USGS

scientists and tribal culture keepers together to teach tribal youth about the ecology of their homelands and how scientific research can help determine the health of ecological systems. Funds would be used for the expansion of USGS collaborations with tribal colleges and universities to enhance their science programs, which would ensure students are equipped to understand the changing environmental conditions impacting the health of their tribal lands, and prepare them for employment within their respective tribal natural resource departments.

Assistance to Hurricane Sandy Affected Tribes – A multi-disciplinary USGS team is completing Hurricane Sandy recovery efforts by assisting the four affected Tribes (The Mashpee Wampanoag Tribe, the Wampanoag Tribe of Gay Head-Aquinnah, the Narragansett Indian Tribe, and the Shinnecock Indian Nation) by providing natural resource assessments that include providing baseline data on anadromous fish species likely to be impacted by future storm events, and information on guidelines to monitor restoration efforts in affected areas. Lidar training will be presented for these Tribes in November that will use lidar data collected earlier as part of the initial round of Hurricane Sandy relief funding. In addition, the USGS New York Water Science Center has two ongoing studies with the Shinnecock Indian Nation. The first is a hydrologic assessment of the shallow groundwater-flow system beneath the Shinnecock Indian Reservation, and the second is an assessment of human- and ecological-health concerns related to transport and persistence of contaminants on Shinnecock tribal lands. The USGS New York Water Science Center will be providing training to the Shinnecock Indian Tribe using funding awarded from the USGS Office of Tribal Relations (OTR) Technical Training in Support of Native American Relations (TESNAR) grant. The training will provide the Tribe with field-data collection and geographic information system (GIS) dataset creation and analysis, and will be focused on the Tribe's Environmental Division data needs such as groundwater levels, water-quality parameters, surveying of their oyster beds, and mapping of their other coastal resources.

Water Resources Activities – USGS scientists work closely with tribal leaders around the Country to address water availability related to quantity and quality on tribal lands. The USGS information is used by tribal managers to address water issues related to water rights and supply, flood-warning predictions, contamination, and sustainability of critical habitats and health ecosystems. In general, USGS coordinated efforts with Tribes span a wide variety of monitoring and research activities, involving, for example, an extensive network of streamgages and groundwater monitoring stations, and scientific assessments on how natural, climatic, land use, water use, and other human factors can affect the water cycle, water resources, and ecosystems. Specific current studies are with (1) the Kootenai Tribe of Idaho and other Federal and State agencies that evaluate hydraulic, geomorphic, and sedimentation conditions in the Kootenai River in northern Idaho to enhance spawning substrate for the endangered Kootenai White Sturgeon; (2) the Osage Nation in Oklahoma to model groundwater transport and quantify connections between water supply and demand; and (3) with the Keweenaw Bay Indian Community (KBIC) in the Upper Peninsula of Michigan to determine current water-quality, hydrologic, and ecological conditions of the Yellow Dog and Salmon Trout Rivers in the Yellow Dog Plains area, which may have been degraded by mining activity, road construction, and other related development.

Climate and Land Use Change Activities – The Department of the Interior Climate Science Centers (CSC) were established to increase understanding of climate change and coordinate an effective response to climate change effects on Native American Tribes and natural and cultural resources that Interior

manages. The eight regional CSCs work closely with natural resource management agencies, university researchers, and others such as Tribes and private landowners on climate change issues.

The CSCs provide training to tribal college and university students on climate change, as in the case of the South Central CSC who partnered with the Choctaw Nation of Oklahoma, Chickasaw Nation, National Conservation Training Center, Nextthought, Mesonet, Bureau of Indian Affairs, Pueblo of Pojoaque, and the Bureau of Reclamation to conduct vulnerability assessment training. The training was developed for tribal staff and students on how to assess vulnerability of species and habitats.

Designed to facilitate dialogue regarding climate change and Native Americans in the South Central United States, the soon to be released video *Listening for the Rain*, documents the experiences of participants who attended five workshops on Tribes and climate change held in Oklahoma and New Mexico in 2013, funded by the South Central CSC. These workshops were conceptualized by Paulette Blanchard, an Absentee Shawnee and graduate student at the University of Oklahoma, who also narrates the video.

The Northwest CSC and National Climate Change and Wildlife Science Center funded a collaborative project between the Coeur d'Alene Tribe of Idaho and the University of Idaho. Tribal professionals and elders and university faculty worked as co-investigators to demonstrate the value and applicability of indigenous knowledge and practice as complementary to conventional science in addressing climate change. A case study focuses on the Coeur d'Alene Tribe's knowledge and practice associated with their traditional root food and the effect of climate related water level changes on its location and development. A new curriculum for high school and first-year college students teaches how indigenous knowledge and Western science can complement each other to address climate change.

The Northeast CSC is working with the College of Menominee Nation and Michigan State, with the goal of helping five Tribes—four in Michigan and one in Wisconsin—adapt their natural lands and cultural values to climate change. The Northeast CSC initiated discussions with the Huron-Potawatomi Tribe in south central Michigan on the impact a warming climate has on their wild rice production and sturgeon populations. With the Little Traverse Bay Band in the northern lower peninsula of Michigan, we are helping to organize workshops in 2016, to engage both adults and young people in adaptation planning for climate change, particularly as it affects birch bark, cotton, and tobacco harvesting, as well as walleye and other freshwater fish.

Technical Support of Native American Relations (TESNAR) – The TASNAR Program accepts proposals from USGS scientists for support in designing and conducting technical training for tribal employees or inter-tribal organizations. Proposals are selected based on an internal review process. The purpose of the TASNAR program is to strengthen the technical capacity of federally recognized Tribes for managing tribal natural resources, and to establish and maintain positive relationships between the USGS and tribal governments.

Tribal Colleges and Universities – The USGS continues to work with Tribal Colleges and Universities (TCUs) to help support the next generation of Native scientists. The USGS Montana Water Science Center, with funding provided by the USGS OTR, continues to work with Salish Kootenai College's (SKC) Hydrology Program to provide workshops that are integrated into the program curriculum.

Executive Summary

Workshops include instruction on how to map channel migration using aerial photography and SPOT imagery, which teaches basics about preprocessing unreferenced imagery and the advantages and disadvantages of conducting analyses with high spatial/low spectral resolution imagery. Students also learn how to estimate evapotranspiration using Landsat 8 imagery and use remote sensing analyses to calculate the amount of water tribal crops are utilizing. In the fall of 2016, workshops will teach the students how to create and develop custom GIS tools using ArcDesktop 10.2 that will calculate inflowing and outflowing surface water within a particular area of interest. Additionally, this workshop will introduce them to USGS streamflow data and the National Hydrography Dataset. These, and previous geospatial workshops conducted by the USGS, have been incorporated into the new GIS certificate program, and in courses required for the completion of the four-year Hydrology degree offered at SKC.

The USGS is working with the Northwest Indian College (NWIC) Native Environmental Science Program and Western Washington University's Huxley College of the Environment Spatial Institute to develop and implement GIS curricula focusing on assessing coastal climate change and impact modeling affecting Native American communities, their foods, infrastructure, and valued ecosystems. The USGS is crafting curricula and GIS workflows for the NWIC classroom modeled after the Puget Sound Coastal Resilience Tool and coastal vulnerability assessments aimed at assessing coastal vulnerability and opportunities for enhancing resilience. This effort answers several Tribes' requests for technical assistance and instruction in coastal hazard impact modeling and will help build capacity among tribal students and Tribal Natural Resource and Fishery Departments who are actively engaged in climate change adaptation planning across the Pacific Northwest.

The USGS also collaborated with Haskell Indian Nations University (HINU), NASA, NOAA, and U.S. National Center for Atmospheric Research in conducting the NASA Tribal College and University Experiential Learning Opportunity Summer Research Experience for Undergraduates (REU). The REU consisted of three weeks of instruction and mentoring at HINU (Lawrence, KS) and included training in GIS, remote sensing, climate change, and the social dimensions of climate impacts. Students then returned to carry out project development on each student's reservation or in a related tribal community. The students and their mentors were chosen from the 37 TCUs.

USGS Student Interns in Support of Native American Relations Program (SISNAR) – The SISNAR program provides student interns work opportunities on current USGS projects directly related to, and preferably on, Native American or Alaska Native lands, assisting Tribes with research issues regarding water, hazards, resources, and climate change. On average, 50 percent of the interns are Native. These mutually beneficial projects also serve to build upon or create new relationships with Native American or Alaska Native Tribes. Through an internal competitive process, the USGS OTR tribal liaison team solicits proposals and selects USGS projects that most benefit the Tribes and provide meaningful internship experiences that prepare students for management of tribal natural resources.

Mentoring and Engaging Youth – The USGS has partnered with the Alaska Native Science and Engineering Program (ANSEP) since 2009, starting with direct hires of student interns. ANSEP's goal is to increase the number of indigenous American students in STEM degrees. ANSEP follows a pipeline approach, providing inspiration, guidance, and opportunity ranging from middle school through the PhD, essential for creating a cadre of future scientists that are highly prepared and trained with the required

skills critical for the USGS workforce. The Alaska Region continues to support the ANSEP program by hiring summer interns through the Summer Bridge and University Success programs. During the course of this partnership, the USGS Alaska Regional office provides mentoring, training opportunities, and hands-on experiences for many ANSEP students. The USGS also has a cooperative agreement with ANSEP, which has a proven success record working with underserved students promoting degrees in science that are of high interest to the USGS and other science organizations. In July 2014, the USGS Alaska Regional Office worked with the Department of Interior's Special Assistant for Alaska regarding the creation of a Youth Program Manager position. The person who filled the position began work with Alaska Interior bureaus in 2015 to develop a comprehensive strategy to engage youth, while also working towards advancing a more diverse workforce, with an emphasis on Alaska Native and American Indians.

In 2014, the Pacific and Alaska regions partnered to start a new strategic youth program, the Native Hawaiian Science and Engineering Mentorship Program, focused on engaging Native Hawaiians through an alliance with the Native Hawaiian Science and Engineering Mentorship Program (NHSEMP) at the University of Hawaii, Manoa. In 2015, interns worked with the Pacific Island Water Science Center learning and assisting with streamgaging efforts, building and maintaining field equipment, and learning how USGS water studies provide critical information to communities. Interns also worked with the Hawaiian Volcano Observatory scientists on projects mapping the lava flows on the north flank of Mauna Loa, the world's most active volcano, helping a group of international students learn the basics of volcano monitoring. Plans are in place to grow this program in out years with other Tribes.

The USGS OTR and USGS scientists continue their commitment to tribal programs, and provided support for the fourth year of the Native Youth in Science – Preserving Our Homelands summer science camp. The USGS partnered with the Mashpee Wampanoag Tribe and their Departments of Education and Natural Resources, the USGS Woods Hole Coastal and Marine Science Center, and the Waquoit Bay Estuarine Research Reserve to develop and execute the science camp. This unique project pairs USGS scientists with tribal culture keepers, which ensures that course material on geology, hydrology and ecology is presented to tribal youth that incorporates aspects of Western science, traditional ecological knowledge (TEK), and the environmental health of local lands. In 2016, there are plans to partner with the Shinnecock Indian Nation to develop a Native Youth in Science program for their tribal youth. These developmental efforts are investments in the USGS workforce of the future, and provide opportunities to introduce Native Youth to the Earth and biological sciences.

Powering Our Future and Responsible Use of Our Resources (+\$4.3 million)

The economy and national security of the United States depend on an adequate and reliable energy supply. As our Nation attempts to reduce its greenhouse gas emissions, curb its dependence on foreign energy resources, and promote the growth of new industry in the U.S., an understanding of our energy resource supply, including both conventional and renewable resources, is essential to the genesis of a new energy frontier. Additionally, understanding the potential impacts of energy development is an integral part of planning prudently for our Nation's secure energy future.

The USGS provides unbiased and reliable science to better understand our Nation's energy resource supply and the environmental impacts of development. USGS data and information are essential tools for

decision makers presented with the challenges of understanding where energy resources are located, both domestically and globally; how much of a particular resource is available and recoverable; what types of energy resources comprise our domestic energy mix and in what proportions; what the environmental impacts are of developing various types of energy resources; and how those impacts can be mitigated. The USGS provides the information that decision makers need to ensure responsible use of our Nation's resources and planning for future energy needs, including science to support the advancement of clean energy. The 2017 budget proposes \$39.1 million, an increase of \$4.3 million to support energy related research activities that include the following:

- Characterize geothermal resources, and provide science support to agencies responsible for geothermal energy resource management on Federal Lands. The President's Climate Action Plan highlights the promotion of American leadership in renewable energy, and emphasizes the acceleration of clean energy permitting for resources such as geothermal as a priority objective. Additionally, both OMB and OSTP have emphasized the advancement of clean energy in their *Multi-Agency Science and Technology Priorities for the FY 2017 Budget* memorandum of July 9, 2015.
- Support the collaborative interagency research and development effort by the USGS, the Department of Energy (DOE), and the Environmental Protection Agency (EPA) to conduct a national science, research, and development program aimed at understanding and reducing the potential environmental, health, and safety impacts of unconventional oil and gas resource development, and addressing the most urgent questions and decision-support needs surrounding hydraulic fracturing and associated waste disposal activities.
- Develop multidisciplinary resource analyses (MRA) that facilitate considerations of resource tradeoffs and support informed decision making on the landscape. The MRA assembles a wide range of energy, environmental, and economic data to assist with the analysis of complex resource-development options. Descriptions and models of resource interactions support better-integrated analysis of how changes in one resource affect others. The MRA assists with land use and land management planning by local, State, and Federal agencies, by showing potential effects of development or resource protection scenarios on natural resources in an area of interest.
- Evaluate landscape impacts from solar energy development construction, operations and maintenance, and conduct research on the impacts of wildlife mortality from wind turbines to support interagency collaborative efforts to develop mitigation tools and techniques and improve siting efficiency.

Engaging the Next Generation (+\$2.6 million)

The USGS actively participates in the Interior's Engaging the Next Generation Secretarial priority and three of its goals: (1) Learn – Provide educational opportunities to at least 10 million of the Nation's K-12 student population annually; (2) Serve – Engage one million volunteers annually on public lands, effectively tripling the numbers we have now; and (3) Work – To develop the next generation of lifelong conservation stewards and ensure our own skilled and diverse workforce pipeline, Interior will provide 100,000 work and training opportunities to young people (ages 15-35) within our bureaus and through public-private partnerships.

The USGS meets monthly with Interior bureaus to coordinate and leverage resources, participate in youth activities and mentorship, and communicate on projects that partner to engage the next generation. Increased funding would allow the Youth and Education in Science (YES) program to increase the number of internships funded to allow mission areas to mentor and accomplish USGS science goals; coordinate and support outreach to underserved communities through internships with pipeline programs like GeoFORCE and the Alaska Native Science and Engineering Program (ANSEP); increase the number of Mendenhall postdoctoral candidates who are essential to the USGS in identifying emerging problems and solutions through innovative, fluid, and trans-discipline thinking – possibly providing the next big breakthrough; and increase the number of students participating in the Cooperative Research Units, providing them an opportunity to pursue a graduate degree and receive unparalleled scientific training and applied work experience. By training the next generation of natural resource scientists, we enable the sound management of the Nation's natural resources. (Discussed in more detail under Agency Priority Goals – Engaging the Next Generation.)

Learn Goal: The USGS contributes to the Learn goal, engaging a broad age range of youth. Typically, outreach learning activities and science camps are aimed at elementary and secondary school students. In 2015, the USGS provided learning opportunities to 113,375 students and teachers, in activities that included science fairs; science camps; fishing derbies; hands-on learning experiences with scientists in water, ecosystems, hazards, and climate based studies; and mentoring opportunities. The USGS Education Web site offers teachers of K-12 students science resources for use in their classrooms. In 2015, the Education Web site received 285,012 hits for educational materials. As the USGS Education Web site is structured mainly for use by teachers, it is projected that, if any given K-12 teacher using this resource has a classroom of 25 students, millions of students would be directly engaged by USGS educational materials annually. The USGS anticipates that the number of teachers, and those who home school, accessing the USGS Education Web site will continue to grow. While this activity remains consistent, the number and variety of science learning experiences increases each year.

Serve Goal: Volunteers are an important component to the continuity of science research and complement the USGS workforce. The Volunteer for Science Program is primarily comprised of citizen scientists, Scientists Emeriti, and individuals and groups who are providing service to the USGS without compensation. The USGS is actively working with citizen scientists to discover, collect, and organize a variety of scientific data that is critical for the future of understanding broad trends and findings across diverse categories. Citizen science (also known as crowd or crowd-sourced science) has been defined as scientific research conducted, in whole or in part, by amateur or nonprofessional scientists. Citizen

scientists allow the USGS to gather data through mechanisms such as: (1) the Earthquake Hazards Program *Did You Feel It?* interactive map; (2) the Landslide Hazards Program *Did You See It?* reporting tool; and (3) the Patuxent Wildlife Center's North American Bird Phenology Program reporting network, to name a few. The Scientist Emeritus Program has been an important component of the USGS since its inception in 1986 as part of the USGS Volunteer for Science Program. It currently is coordinated in the USGS Office of Science Quality and Integrity. The purpose of the Scientist Emeritus Program is for retired USGS scientists and technical experts to volunteer their expertise, intellect, and creativity in efforts that allow them to remain active in the geoscience community, enhance the programmatic activities of the USGS, and serve the public. Many other volunteers engage with the USGS to provide service because they enjoy and believe in our science mission. The USGS engaged 10,302 volunteers in 2015, who provided 316,107 hours of service to our science mission. The USGS has developed databases to capture volunteer activities and their impact on the USGS in 2016 and 2017.

Work Goal: Please see Agency Priority Goals where the work goal is discussed.

Ensuring Healthy Watersheds and Sustainable, Secure Water Supplies (+18.9 million)

Sustainable water resources are an increasingly important societal issue. The Federal government, in addition to State and local governments, plays a key role in providing access to qualities and quantities of water that support a variety of services including public supply, agriculture, power generation, and recreation, while sustaining ecosystems. Interior has a major role in ensuring sustainable water supplies. As competition for water resources grows, the need for sound technical data, analysis, decision support, and models that characterize the past, current and future hydrologic landscape are vital for resource management. Measuring and estimating components of the water budget (precipitation, evapotranspiration, runoff, etc.), both natural and anthropogenic, are the basis for developing an understanding of the long-term variability and resilience of systems, their connection to infrastructure capacity, and the recovery potential of aquatic species or communities.

WaterSMART

Meeting the water resource needs of the Nation is an increasing challenge because of rapidly changing drivers of water availability, such as climate change, population increases, and water use and land use changes. At a time when ensuring sustainable water supplies is more important than ever, the change in the frequency and magnitude of extreme hydrologic events, such as floods and droughts, are creating uncertainty for water managers. As competition for water resources grows for irrigation of crops, cities and communities, energy production, and the environment, so does the need for information and tools to aid water and natural resource managers. WaterSMART is an Interior initiative that leverages and directs existing expertise and resources within the USGS and the Bureau of Reclamation (Reclamation) toward addressing complex, national- and regional-scale water challenges. The SECURE Water Act (P.L. 111-11, Subtitle F, Sections 9507 – 9509) dictates the USGS role: Provide science to help water managers understand and address competing demands for water. The primary focus of this initiative includes developing a National Water Census that will allow resource managers to gain a better understanding of water budgets in their area of concern, which in turn, will support sustainable and environmentally sound water management. Leveraging expertise across multiple USGS mission areas enables a broader focus to

address these challenging issues in a time of growing competition for water resources. The USGS possesses the skills and foundational resources to provide water resource, ecosystem, and land use managers the decision-support tools to make informed decisions. The goal of this effort is to improve the data and understanding associated with groundwater, surface water, human water use, and the ways in which these and other water budget components influence water availability, and to develop tools that will allow managers to apply the new understanding and data. The Nation will be well served through this effort, by gaining the ability to balance water resource sustainability through consideration of water quantity, quality, and uses, including ecological uses.

The 2017 budget request includes increases of \$18.4 million. The Water Availability and Use Science Program is requesting \$4.0 million to develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures. These products can be used by resource managers to assess vulnerability of specified basins or water suppliers. The Water Availability and Use Science Program is also requesting \$4.0 million for Water Use Research and Information which, coupled with the grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making, will help the USGS to quantify water supply and demand consistently across the entire Country, and compile water information that is now fragmented among multiple bureaus into a national water data framework on a geospatial platform, a place-based database. The Fisheries Program is requesting \$2.5 million to develop decision-support systems that have the capacity to provide a diverse set of management options—both monetary and non-monetary—to water regulators and stakeholders for making decisions that balance human and ecosystem needs. These include maintenance of important species, and protecting and restoring the functions of natural systems. The Land Change Science Program is requesting \$1.0 million to develop automated methods and tools supporting near real-time, satellite-based drought monitoring that would help water managers identify the onset and severity of drought events and effectively allocate scarce water resources.

In addition, the National Geospatial Program is requesting \$1.0 million to complete the initial production of the National Hydrography Database High Resolution dataset in an effort to streamline and consolidate national datasets as the USGS, the Environmental Protection Agency, the U.S. Forest Service, and the Bureau of Land Management all are using hydrography datasets of differing functionality and scales. Developing a single, scalable hydrographic referencing system will integrate currently fragmented water information into a connected, national water data framework to underpin innovation, modeling, data sharing, and solution development. The Land Remote Sensing Program and the Land Change Science Program are collectively requesting \$0.8 million to integrate new Landsat-based science products (including estimates of surface water extent) and use remote sensing to identify and quantify water storage in smaller storage features (e.g. ponds and reservoirs). Understanding and reporting on these features could provide benefit for drought status monitoring, understanding climate variability, and streamflow estimation, particularly in areas without streamgages.

The Water Availability and Use Science Program is also requesting \$750,000 to collaborate with other Federal agencies to accelerate the development of a nationwide hydrologic model that will advance understanding and forecasting of the water budget, to effectively manage water resources, and to adapt to

Executive Summary

a changing climate. The USGS currently has a national scale hydrologic model that addresses the major components of the water budget, but human water use is not addressed explicitly. The Water Availability and Use Science Program is requesting \$0.4 million to provide streamflow statistics via the USGS StreamSTATs decision support tool in three additional States and improve methods for proving the estimates. Streamflow information is required for water-resources management, and changing streamflow conditions require continuity of information for flood and drought response and routine water allocations.

Finally, multiple programs in the Ecosystems, Climate and Land Use Change, Water Resources, and Core Science Systems collectively are requesting \$3.9 million for drought research. Given the persistent drought in multiple regions of the United States, the USGS proposes to quantify water availability, determine how snowmelt factors into the hydrologic cycle, and investigate drought effects on reproduction and survival of select plant and animal species. Providing access to these data will allow managers to determine impacts of drought on ecological systems. The USGS will develop actionable science approaches, by convening regionally based working groups of decision makers and natural resource managers to develop coordinated adaptive management plans for the complex consequences of severe and prolonged drought. The funding requested for this work would provide tools for fish and wildlife managers as well as water resource managers.

Indian Water Rights Settlements

The USGS is not directly involved with Indian Water Rights settlements. The USGS provides technical information needed to support water rights settlement work that is given to decision makers. USGS scientists work closely with tribal leaders around the Country to address water availability issues related to quantity and quality on tribal lands. The USGS coordinated efforts with Tribes span a wide variety of activities across the Nation, involving, for example, monitoring within an extensive network of USGS streamgages and groundwater monitoring stations; training; data management; Geographic Information Systems (GIS); quality control; development of models and decision-making tools; and scientific research on how natural, climatic, land use, water use, and other human factors can affect the water cycle, water quantity, and quality. The USGS information is used by tribal managers to address such topics as water rights, water supply, flood-warning predictions, contamination, and sustainability of critical habitats and health ecosystems. In 2017, the USGS is requesting an additional \$0.5 million to work on this effort. It is important to note that this funding is cooperative matching funds and in 2015, there was \$4.0 million of reimbursable funding tied to these activities, with similar amounts expected in 2016 and 2017.

Colorado River Operations

The 1964 U.S. Supreme Court decree, *Arizona v. California*, is specific about the responsibility of the Secretary of the Interior to account for consumptive use of water from the main stem of the Colorado River. The USGS Arizona Water Science Center (AzWSC) serves as an independent third party entity in the Supreme Court Decree Accounting to provide data and interpretive science that support, in several ways, Reclamation's operation of the River. As part of this support, the USGS operates a network of 74 streamflow gaging stations that provide Reclamation with critical flow data in the main stem Colorado River, delivery canals, and agricultural drains. In 2017, Reclamation will fund the USGS at \$1.1 million

for gaging operations from Lees Ferry to the Northerly International Boundary with Mexico. The majority of this funding is for accounting of the water and to ensure no entity is using more than their allotted withdrawal. The GWSIP provides an additional \$0.4 million for accounting of the Colorado River. In addition, several other cooperators (e.g., Coachella Irrigation and Water District; Imperial Irrigation District; U.S. Army Corps of Engineers; U.S. Fish and Wildlife Service; and Metropolitan Water District of California) also contribute funding that totals \$140,000 for gages along the Colorado River, contributories, and withdrawal canals.

Along the Lower Colorado River, consumptive use in the 1964 decree is defined to include “water drawn from the mainstream by underground pumping.” In response to the requirement to account for diversions resulting from groundwater pumping, the AzWSC works with Reclamation to inventory points of diversion including river pumps diverting river water and wells on the lower Colorado River flood plain and adjacent areas in Arizona, California, Nevada, and Utah. Work on the project began in April 1994 to locate sites, provide current information for each well, and provide precise position information in order to apply the accounting-surface method and include the appropriate wells in water accounting along the river. Water levels are required where possible for all wells in areas adjacent to the flood plain. Over 10,000 wells have been inventoried in the river aquifer along the lower Colorado River. Data have been entered into the U.S. Geological Survey National Water Information System (NWIS). Site and water level data are available on the Web at <http://waterdata.usgs.gov/nwis> and data are uploaded quarterly to an interactive mapping link at <http://az.water.usgs.gov/projects/LCRS/>. Total funding for inventory of groundwater diversions total \$600,000 in 2016.

In addition, elevated salinity levels increase costs associated with treating and using water in municipal and industrial settings, and reduce agricultural yields from crops. Damages from elevated salinity levels in Colorado River water have been estimated at nearly \$400 million annually during recent years. USGS scientists quantified salinity sources and transport in the Colorado River basin using a digital model developed by the National Water Quality Program. USGS scientists continue to improve the model and perform other Colorado River salinity studies through a mix of reimbursable and appropriated funding. Results from these USGS salinity studies are being used by Reclamation, Natural Resource Conservation Service, and the Bureau of Land Management to target specific locations for salinity reduction programs that mitigate economic damages.

San Francisco Bay-Delta

The San Francisco Bay and Sacramento-San Joaquin Delta (Bay-Delta) form one of the largest estuaries in the United States. The California Bay-Delta system provides water to more than 25 million California residents and vast farmlands, as well as key habitat for birds, fish, and other wildlife. To help ensure the function and sustainability of this crucial estuary, the USGS—in close cooperation with partner agencies and organizations—is providing science essential to addressing societal issues associated with water availability, environmental contamination, animals and habitat, natural hazards, land subsidence, and climate impacts. The USGS is a major partner in Bay-Delta science, with a projected total 2015 monitoring and research portfolio of about \$20 million, including \$8.6 million from the USGS and about \$12 million in reimbursable support from local and Federal partners.

Through a mix of reimbursable and appropriated funding, the USGS operates management-critical programs that monitor hydrodynamics, salinity, suspended sediment, nutrient levels, and primary production in the Estuary. These data are used daily by State and Federal water managers to balance the needs of California's communities, agriculture, and endangered species, as well as for long-term strategic planning for water development. The USGS conducts essential research on ecosystem functioning to inform species recovery and habitat-restoration in the Bay-Delta. Studies include monitoring the health and status of aquatic and terrestrial species and understanding the impacts of habitat loss, contamination, invasive species, sea level rise, and temperature and salinity change. In addition to work under Priority Landscapes, USGS research is better defining the risks that natural hazards pose to California Bay-Delta communities, infrastructure (such as buildings, bridges, roads, utilities, levees, and waterways), and habitats. Threats to the region include earthquakes, land subsidence, flooding, landslides, wildfires, and climate impacts such as drought and sea-level rise. USGS scientists are studying the causes and impacts of land subsidence to help protect Bay-Delta communities from flooding and ensure the integrity of water-conveyance systems in California's Central Valley. Subsidence weakens levees and threatens crucial aqueducts that supply water for public and agricultural use. Finally, USGS science is providing information crucial to understanding how extended drought and potential climate-change impacts to the Bay-Delta may affect fish and wildlife habitat locally and agriculture and water availability in much of California. Sea level rise, drought, and reduced statewide snowpack are major climate change threats to the State.

Most of the USGS's portfolio of work in the California Bay-Delta supports ongoing Central Valley Project and State Water Project operations and State and Federal planning for California's water future. In 2015, the *Bay-Delta Conservation Plan* (BDCP) was split into two distinct and separate projects: *California WaterFix* and *California EcoRestore* programs. Whereas these new proposals represent a different permitting strategy for the North Delta Diversion project, and associated Delta restoration, the projects address the same problems as the BDCP. As such, the USGS's objective, unbiased monitoring and scientific investigative support for *California WaterFix* and *EcoRestore*, and ongoing water operations remain as critically important to successful management of the California Bay-Delta system as ever before.

Klamath Basin Restoration

Expenditure of USGS appropriated funds in the Klamath Basin is estimated to be \$1.4 million in 2017, spread among multiple data collection activities and scientific studies. In all cases, studies and data collection were aimed at providing Federal, State, and tribal agencies information needed to manage resources, guide restoration actions, monitor ecosystem health, and reduce risks to humans and biota. The USGS will fund and operate 13 streamflow gaging stations in Oregon and California for purposes of flood forecasting and warning, managing water for agriculture, and maintaining instream flows and lake levels for threatened and endangered species. The USGS will operate three continuous turbidity/sediment stations in the upper basin in order to calculate concentrations and loads of sediment and nutrients entering Upper Klamath Lake. The USGS will operate a groundwater monitoring network in the upper Klamath Basin in order to manage the use of groundwater used to augment surface-water irrigation supplies during dry years.

In addition, the USGS is developing improved estimates of evapotranspiration (ET) from vegetated surfaces and water bodies. Improved estimates of ET are used to reduce uncertainty in water-supply models and to calibrate satellite methods the USGS uses to measure consumptive use of water on farms. The USGS is also developing an understanding of the groundwater regional flow system in the basin and development of a management model to help resource managers optimize when, where, and how much groundwater can be pumped in the upper basin. USGS research on water quality throughout the basin continues in order to guide restoration efforts to reduce nutrient loads, sediment transport, and the development of toxic algal blooms that degrade aquatic habitat for fish and humans. The USGS is developing and applying genetic tests that can rapidly detect harmful algal blooms so public health agencies can warn against human contact with water in Upper Klamath Lake. The USGS is also conducting studies that quantify the health of shortnose and Lost River sucker populations in Upper Klamath and Clear Lakes. These endangered suckers continue to decline; studies are aimed at understanding the cause of this decline in order to target restoration actions to protect them. The USGS is researching arsenic in Upper Klamath Lake, as relatively high concentrations of the more toxic forms of arsenic could be a factor in the decline of two endangered sucker species in the lake. Finally, the USGS is also researching juvenile salmon disease in the lower Klamath River in order to test river management strategies that could reduce fish mortality and improve adult salmon harvest.

Building a Landscape-Level Understanding of Our Resources (+\$35.3 million)

Land uses are increasingly interconnected and often compete with one another on a landscape scale. Interior, other Federal and State agencies, local communities, Tribes, regional entities, non-governmental organizations, and others need integrated information and tools to manage resources at the landscape scale. The 2017 USGS budget includes \$14.9 million in program increases for science to further understand the Nation's landscapes, to inform decisions related to managing public lands, siting and mitigating resource development, and supporting conservation, recreation, and other land uses. Science activities include research for specific landscapes such as the Arctic (+\$8.8 million), Sage Steppe habitat (+\$3.0 million), Rangeland Fire and Response (+\$0.5 million), Columbia River (+\$0.1 million) and addressing challenges associated with invasive species detection, containment, and control (+\$2.5 million). In addition, USGS research continues to support critical landscapes such as Chesapeake Bay, Everglades, Puget Sound, Upper Mississippi River, Great Lakes, and California Bay Delta.

Foundational to all work in landscapes and across the other science themes are data, tools, scientists, and managers. Examples of these include activities in the Arctic that contribute to the accelerated development of predictive models, which support the evaluation of changes to the environment resulting from the conversion of permanently sequestered ice and snow to liquid and gaseous water. Multi-temporal and multi-resolution remote sensing data from satellites and airborne systems (Landsat, Classified Systems, Aircraft, and Unmanned Aerial Systems) would be used in combination with field level studies and in-situ observations to measure changes of ice and snow volumes and support the development of predictive models of the impacts from climate-induced changes. The National Geospatial Program will accelerate the national coverage of lidar to enable smart decision making in a number of areas. These data and tools help land and resource managers make informed decisions on an assortment of issues across the landscape, such as management of infrastructure and construction, more accurate and cost effective application of chemicals in farming, development of energy projects, and support of

aviation safety and vehicle navigation. USGS science will benefit in numerous ways including support for habitat change studies, identification and mitigation of seismic and landslide hazards, improved dynamic flood inundation maps and applications for flood response and mitigation, study of contaminant transport to identify vulnerable environmental settings, and monitoring of land change. The 2017 budget includes program increases totaling \$20.4 million for foundational data and tools needed to support landscape level understanding. These activities include land imaging, such as mapping and expanded lidar collection through the 3D Elevation Program (+\$4.9 million), and making data easier to access and use. In addition, the requested \$15.4 million for Landsat 9 will be used to support development work on the Landsat 9 ground system and to accelerate the anticipated launch date from 2023 (as per the Sustainable Land Imaging plan) to 2021.

Building a 21st Century Department of the Interior

Facilities Consolidations and Savings

The Reduce the Footprint (RTF) program and the Cost Savings and Innovation Plan (CSIP) have provided the USGS with the ability to reduce its footprint by more than 730,000 rentable square feet (RSF) from 2012 through 2016. The USGS goals are to reduce its footprint and costs, and move toward a 180-SF per person utilization standard.

By 2017, the USGS anticipates an additional reduction of 24,500 RSF, bringing the overall footprint reduction to 755,000 RSF. This will be a 13 percent decrease of the USGS space portfolio since 2012. These efforts focused on the USGS three major centers in Reston, VA, Denver, CO, and Menlo Park, CA. Each of these centers were successful in taking on major consolidation projects, reducing space requirements, actively seeking co-location opportunities, and vacating more expensive space. The achieved results were the direct impact of the bureau's footprint reduction activity.

In 2017, the bureau will continue its progress toward accomplishing the savings targets set by Interior by continuing its consolidation efforts at the three major centers in Reston, VA, Denver, CO, and Menlo Park, CA. At the USGS National Center in Reston, VA, the USGS supports Interior and other agencies by providing more than 278,670 SF or 25 percent of released space to other Federal partners. In 2017, the USGS will continue to consolidate and actively seek additional Federal partners to improve the space utilization at the National Center. In Denver, CO, on the Denver Federal Center, consolidation efforts include moving out of an older GSA-owned building into a newer and more suitable building, such as Building 25, Building 95, and Building 810. These consolidations will further reduce the USGS space requirement by an additional 22,000 SF. Consolidation efforts continue at the Menlo Park Campus with Building 15 as the USGS explores the plan to potentially return to GSA 22,000 SF at Building 3 by the end of 2017. The USGS is also looking into colocation options with other federal agencies. Additionally, the USGS will continue to fund a colocation project with the Bureau of Reclamation, in Boulder City, NV. This project will significantly reduce the rent cost as well as lessen the Interior's overall footprint by 3,000 SF.

In 2017, the USGS is requesting an increase of \$10.9 million to accomplish RTF/CSIP projects. This increase is the first dedicated funding provided to the USGS for the accomplishment of footprint

reduction projects. Since 2012, the USGS has redirected \$2.2 million annually from its Deferred Maintenance and Capital Improvement (DMCI) funding for investment in CSIP projects. Diverting DMCI funding for these projects is not a sustainable process. The USGS Deferred Maintenance backlog has increased by an average of \$7.5 million annually over the last four years. Thus, the USGS will no longer be able to divert funding from DMCI to CSIP. The USGS RTF/ CSIP projects have directly saved federal funding by reducing the USGS long term rent requirements.

Improvements to the USGS Scientific Information Product Review and Approval Process

The Information Product Data System (IPDS) is a Web-based application that tracks and manages the scientific information product review and approval process. The newly designed IPDS was launched in June of 2013. This system was designed to provide immediate access to relevant process data and controls for all users, but especially authors. Streamlined workflows have reduced the amount of time users must engage with the system while improving data quality and availability. This has enhanced the ability of scientists and their cost centers to track progress, make decisions, and address issues that arise during the information product review, approval and dissemination lifecycle. In addition, this system gathers critical bibliographic metadata that is used in the final information-product dissemination process. Improvements to the user interface and the implementation of a streamlined data model, which includes the assignment of Digital Object Identifiers, have resulted in more-timely release of information products that can be accessed and cited by researchers, resource managers, and the public.

Agency Priority Goals

Climate Change Adaptation Management

The USGS is a contributor to the Climate Change Adaptation Agency Priority Goal (APG), which is: *By September 30, 2017, the Department of the Interior will mainstream climate change adaptation and resilience into program and regional planning, capacity building, training, infrastructure, and external programs, as measured by scoring at least 300 of 400 points using the Strategic Sustainability Performance Plan scorecard.*

Bureau Contribution: The Climate and Land Use Mission Area is the primary contributor from the USGS to this APG. The USGS funding for climate change in 2015 is \$57.6 million, \$57.2 million in 2016, and \$63.0 million in the 2017 President's budget request.

Implementation Strategy/Performance Metrics: The Climate Change Adaptation APG presents an opportunity to unite climate change research and science conducted by Interior bureaus. USGS contributions to Interior's implementation strategy for the Climate Change Adaptation APG include:

- Mainstream and integrate climate change adaptation into both agency-wide and regional planning efforts, in coordination with other Federal agencies as well as State and local partners, tribal governments, and private stakeholders: The USGS will develop tools and models that can be used by other Interior bureaus to integrate climate change adaptation in planning efforts. The National Climate Change and Wildlife Science Center (NCCWSC) is developing tools and

models and the Climate Science Centers (CSCs) are funding researchers across the Country to help managers adapt to climate change. The USGS Biological Carbon Sequestration project (Land Carbon) works with other Interior bureaus in identifying and modeling practices and policies that land management agencies may implement to enhance biological carbon sequestration. Researchers funded by the Climate Research and Development Program work with other Interior agencies and academic researchers funded by the National Science Foundation and other sources to conduct research needed to understand, model, and forecast how climate variability and change affect different habitats and sectors. For example, interdisciplinary research documenting the impact of changing sea level on habitats within the Savannah National Wildlife Refuge is providing new information on the rates and patterns of vegetational change and carbon cycling over annual, decadal, and centennial timescales. By improving understanding of the processes that influence coastal habitats, these studies provide a basis to aid development of management strategies.

- Ensure agency principals demonstrate commitment to adaptation efforts through internal communications and policies: The USGS will revise and, as necessary, develop new components to provide a unified cross-USGS Strategic Science Plan. Each of the CSCs relies on a Strategic Science Plan for making decisions about research priorities and funding actions. These actions were developed, and are updated as needed, with significant input from regional resource managers and stakeholders. The NCCWSC also maintains national priorities for the CSC network to help focus the primary goals of the program. The NCCWSC and the CSCs are responsive to changing conditions at the regional and local level and provide science in a timely fashion based on the needs of managers (e.g., our recent focus on drought in response to the real-time impacts of drought being seen across the Country).
- Ensure workforce protocols and policies reflect projected human health and safety impacts of climate change: The USGS will assess climate risks for workforce activities and operations and update safety and health policies as applicable to ensure consistency with occupational safety and health requirements and Interior guidance.
- Design and construct new or modify/manage existing agency facilities and infrastructure with consideration for the potential impact of projected climate change: The USGS is working with Interior on a vulnerability assessment tool to address the USGS real property inventory. The focus of the vulnerability tool is to evaluate the effects of climate change such as sea level rise, storm surge frequency and elevation, air temperature changes, and precipitation changes on the USGS real property portfolio.
- Update agency external programs and policies to incentivize planning for and addressing the impacts of climate change: The USGS will develop and complete implementation of a series of projects focused on ecological drought impacts for resource managers. In 2015, the NCCWSC initiated projects related to understanding ecological drought. Five new projects are being funded in 2015 by the NCCWSC on the drought impacts of wildlife, including trout and migratory waterbirds, forest management strategies to promote forest resistance to drought, and the influence of drought on stream drying in the Western United States. Regional projects are also being funded by the CSCs to focus on regional impacts of drought on fish and wildlife, primarily in the South-central and Southwestern parts of the United States. A working group is also being

developed to synthesize the current understanding of multi-year drought impacts to ecosystems, biota, and ecological services with close association to human health or well-being.

Engaging the Next Generation

The USGS is a contributor to the Engaging the Next Generation APG, meant to build the next generation of conservation and community leaders by supporting employment of youth and Millennials at the Department of the Interior. The goal: *By September 30, 2017, the Department of the Interior will provide 100,000 work and training opportunities over four fiscal years (FY2014 through 2017) for individuals age 15 to 35 to support Interior's mission.*

Bureau Contribution and Implementation Strategy: The USGS has a proud history of mentoring and engaging youth, providing a broad array of research and learning experiences to young people in the Earth sciences, focused on inspiring the pursuit of scientific careers and increasing science literacy. In 2015 and 2016, the budget included \$23.7 million for Engaging the Next Generation. The 2017 budget proposes \$26.3 million, an increase of \$2.6 million.

The USGS has long been invested in developing the next generation of Earth scientists and has robust internship programs that employ high school, undergraduate, and graduate students and engage partner hires in mentored science mission experiences. Base funding within programs is utilized to hire interns to pursue science, technology, engineering, and mathematics (STEM) careers and receive mentorship from world-class scientists. Funding from the YES Office leverages those resources and provides a conduit to assist managers in navigating the hiring process. The USGS has increased its engagement with Corps organizations, as partners to meet mission and workforce planning goals.

The USGS/National Association of Geoscience Teachers Cooperative Field Training Program, which celebrated its 50th year in 2015 as the longest continuously running internship program in the geosciences, is an outstanding internship program, and an excellent example of how the USGS implements the work goal. EDMAP, the educational component of the National Cooperative Geologic Mapping Program, has realized its return on investment by educating Earth science students in the skills of geologic field mapping and scientific research, while providing them the necessary experiences to become successful in STEM career fields. The program works closely with GeoFORCE, a University of Texas/Austin program that engages high school students from underserved communities in the Earth sciences by encouraging the graduates of this four-year high school science experience to work with the USGS throughout their college education. Programs like the Cooperative Research Units (CRU) engage in scientific research, technical assistance to natural resources managers, and training for future natural resource professionals. These objectives are achieved using undergraduate and graduate students, and postdoctoral associates. CRU scientists advised and mentored 534 STEM graduate students in 2015. The CRU also sponsors undergraduate and graduate education programs that focus on minority student recruitment and career training in natural resources, such as the Doris Duke Conservation Scholars Program, whose mission is to increase the number of undergraduate students from groups currently underrepresented in the workforce who choose to pursue studies and a career in conservation. The USGS participates in partnerships with organizations like the Alaska Native Science and Engineering Program, whose focus is to increase the number of indigenous American students in STEM degree programs

through pipeline programs like Summer Bridge in high school to University Success. University Success is a component in an academic learning community composed of students, faculty, staff, and external partners who are focused on the academic success, as well as the personal and professional development of each student. The USGS hires postgraduate students that include young scientists between the ages of 26-35, as in the Mendenhall Research Fellowship Program, which provides an opportunity for postdoctoral fellows to conduct concentrated research alongside USGS scientists, often as a final element to their formal career preparation. The Program brings state-of-the-art scientific expertise to assist in the implementation of the USGS Strategic and Science Strategy Plans. Mendenhall Fellows are expected to publish their results in peer-reviewed scientific outlets. The Presidential Early Career Award for Scientists and Engineers (PECASE)—the highest honor bestowed by the United States Government on science and engineering professionals in the early stages of their independent research careers—has been awarded to young USGS scientists each year since 2009.

Performance Metrics: The USGS employed 2,759 young people between the ages of 15 and 35 in 2015, who worked 3,198,666 hours toward the USGS science mission. The USGS increased the number of partner hires in 2015 to 875, who worked 459,071 hours. The USGS expects to continue that trend into 2016 and 2017. The number of advanced graduate degrees awarded to CRU students in 2015 was 79 (60 M.S. and 19 PhD). The EDMAP program is in its 19th year, and has provided funding for 1,160 students that have gone on to STEM careers in higher education, industry, and government. In 2015, YES funds supported 233 youth as interns (70 in Pathways Career and 19 in Pathways Recent Graduate appointments), temporary field assistants, term, student contractors and AmeriCorps members in support of the USGS Science Strategy at 58 science centers and program offices across the Nation. YES funds supplemented the USGS Director's Office funding to provide cost efficient and valuable research assistance on 51 USGS science projects through NAGT internships. In 2016 and 2017, the YES office will continue working with the USGS Office of Diversity and Equal Opportunity (DEO), and the Office of Human Resources on the diversity goals in the USGS Workforce Plan, developing relationships with recruiting sources for generating a highly-qualified diverse applicant pool. The YES funds and the USGS Ecosystems Mission Area collaborated with the YES program office to support the Doris Duke Conservation Scholars Program by providing six graduate student mentors through the CRU. The bureau will continue to analyze the data collected for youth hiring and use it to better understand workforce demographics and how it impacts our workforce and succession planning efforts. The USGS will continue to engage the next generation of young people by working with science centers and offices; leveraging resources internally and externally; investing strategically to accomplish bureau workforce planning goals; and contributing to the development of a future STEM workforce, who will be participants in building the economy of our Nation.

President's Management Agenda

The Department of the Interior supports the President's Management Agenda to build a better government, one that delivers continually improving results for the American people and renews their faith in government. The U.S. Geological Survey is actively involved in the government-wide effort to bring forward the most promising ideas to improve government effectiveness, efficiency, spur economic growth, and promote people and culture. The U.S. Geological Survey supports achievement of the President's Management Agenda objectives in these four pillars as described below.

Effectiveness:

The USGS is committed to achieving the Administration's challenge for gaining greater Federal effectiveness by focusing on agency top priorities, cutting waste, improving information technology, promoting accountability and innovation through open government, and attracting and motivating top talent. To meet this goal, the USGS is reviewing programs for savings opportunities and effectiveness, and implementing new ideas to increase the effectiveness and efficiency of bureau operations.

Noteworthy accomplishments include:

Significant improvements to increase the discoverability, accessibility, and usability of Earth observation data across the USGS and Interior were completed, including populating the USGS Science Data Catalog (the official USGS public data listing under the Open Data Policy) with more than 6,200 metadata records, and supporting the DOI catalog (data.doi.gov), and agency contributions to Data.gov. All USGS and DOI data systems identified in the EOA1 (Earth Observing Assessment 1) are available in the DOI data catalog and a quarterly reporting mechanism on the status of Big Earth Data Initiative (BEDI) treatment activities for the USGS was implemented.

More than 20 science projects across the USGS are using shared high performance computing capabilities to conduct science ranging from studying sturgeons to supporting lidar analysis. Model running times are often decreased from several days to a few hours or less, saving research scientists significant time while vastly increasing their analysis capacity. Major National Cooperative Geologic Mapping Program (NCGMP) research products included: (1) the first digital National Karst Map that recognizes those areas in the Nation where our groundwater resources are most vulnerable to potential contamination and where sinkhole hazards can impact infrastructure and lives; (2) Geological Society of America Special Paper 509, summarizing our knowledge and understanding of the 2011 Mineral, VA, earthquake in 23 major research articles; and (3) the Geologic Map of the Greater Portland, OR, area that provides a framework for understanding the tectonic history of that region.

USGS publications and data are being made more accessible to other scientists, decision makers and the public by implementing Digital Object Identifiers and registering them in CrossRef, a universal, cloud-based "card catalogue" for scientific and other data. The Digital Object Identifier System is a technical infrastructure that enables publications and data to be individually identified and permanently discoverable. Because this system is not platform dependent, links will not be lost when Web pages are deleted or information is reorganized. These Digital Object Identifier identified documents are part of a permanent reference library. In conjunction with the USGS's ongoing Web reengineering work, the use

of Digital Object Identifiers on USGS series publications will enhance the discovery and usability of USGS science by the science community and the public. This supports the White House Digital Strategy and provides open access to federally funded research.

The *Ecosystems.data.gov* portal was launched in support of the EcoINFORMA implementation, based on recommendations from the President's Council of Advisors on Science and Technology (PCAST). Providing data hubs, data catalog, and a map viewer, this portal is a significant step in providing public access to federally held biological data. More than 50 million additional biological observations from 25 discrete datasets were integrated into the Biodiversity Information Serving our Nation (BISON), which now holds over 250 million biological observations. BISON provides critical support to the EcoINFORMA biodiversity hub.

The USGS has reduced its footprint by more than 615,000 rentable square feet (RSF) from 2012 through 2015, in accordance with its Cost Savings and Innovation Plan (CSIP). By the end of 2016, it is anticipated that the reduction will be up to 730,000 RSF and up to 755,400 RSF by the end of 2017. These efforts focused on the USGS three major centers in Reston, VA, Denver, CO, and Menlo Park, CA, with centers successfully taking on major consolidation projects, reducing space requirements, actively seeking co-location opportunities and vacating more-expensive space.

Supporting the President's Management Agenda and Cross-Agency Priorities:

High Value Datasets – To enhance public access to USGS data, Information Services established collaborative partnerships with the USGS Mission Areas in order to achieve the Administration's Open Data goals of increasing cross-agency and public access to government data. Through these collaborative relationships, the USGS has submitted more than 5,057 collections of data to data.gov as of January 2016, representing over 1.4 million individual high-value datasets. The USGS continues to lead Federal Agencies in total provision of data to data.gov, and several USGS datasets routinely feature in the most-accessed data in data.gov.

The USGS also continued its focus on preserving science for future generations by ensuring that data from 20 scientific projects were preserved as one-of-a-kind, high-value datasets, documents, reports, maps, imagery and other information. The Records Program analog to digital preservation activity is the culmination of a six-year effort that has successfully stored and made publicly accessible data from 113 USGS projects that span more than 100 years of research in energy resource availability, water, ecosystems, climate, hazards, and geography. Now preserved and digitally accessible, these data are being made available to the science community, stakeholders, and the public for the first time, serving diverse scientific and marketplace needs today and for future generations.

Efficiency:

Energy Efficiency and Environmental Management – Under the Energy Savings Performance Contract (ESPC), the USGS expects that energy savings of over \$650,000 per year and water savings of over \$17,000 per year will pay for facility improvements at three USGS locations. When completed, the energy conservation measures are expected to reduce facility energy consumption and greenhouse gas

emissions. The ESPC will reduce the USGS's energy consumption by 15 percent, and will reduce potable water use by five percent. The ESPC is paid with energy savings so there is no capital investment from Federal funding. This effort supports the President's Performance Contracting Challenge.

Space Action Approval and Waiver Process – The Space Action Approval and Waiver (SAAW) process allows for all space actions to be evaluated, ensuring they meet policy, regardless of how the space is acquired. The SAAW has preset thresholds for utilization rate, cost, term, and square footage increase/decrease that include five levels of management analysis. The SAAW form is used to determine whether the space action adheres to bureau policy that the action must (1) have a utilization of 180 usable square feet per person or less; (2) not increase the footprint; (3) not increase cost by more than 25 percent; and (4) must have cancellation rights.

This broad-based approach allows the bureau to manage all the space in the portfolio holistically and ensures each space action does not increase the bureau's footprint, works toward the utilization standard, and keeps costs under control. The process also allows the USGS to provide the data and analysis required to manage space according to the new departmental and OMB policies.

Economic Growth:

Orbiting Earth more than 400 miles away in space, far from human view; recording repeated images of land around the globe for more than 42 years; offering petabytes of historical and current data for free to users; is the Landsat program of Earth observing.

The Landsat Advisory Group of the National Geospatial Advisory Committee has been taking a hard look at the value of Landsat to the U.S. economy. This team of commercial, State and local government, and non-governmental organization (NGO) geospatial information experts recently updated a critical review of the value of Landsat information that has recently been released to the public. This team of leading experts from places like Google, ESRI, and Stanford University found that the economic value of just one year of Landsat data far exceeds the multi-year total cost of building, launching, and managing Landsat satellites and sensors.

The Landsat Advisory Group reviewed previous studies of the value of Landsat. In a 2013 study, "Landsat and Beyond, Sustaining and Enhancing the Nation's Land Imaging," the National Research Council found, "The economic and scientific benefits to the United States of Landsat imagery far exceed the investment in the system." This conclusion echoed the results of studies done in 2007, by the American Society of Photogrammetry and Remote Sensing and, in 2012, by Booz Allen Hamilton at the request of the USGS.

These studies were followed by a report by the USGS in 2013, "Users, Uses, and Value of Landsat Satellite Imagery— Results from the 2012 Survey of Users," which featured a survey of 11,275 Landsat users on the uses and value of Landsat satellite imagery. This customer-oriented investigation found that the economic benefit of Landsat data, for the year 2011 alone, was estimated to be \$2 billion for U.S. users and \$400 million for international users, resulting in a total annual value of more than \$2 billion.

Executive Summary

Even though directly observed information about the Earth from Landsat is recognized around the globe as crucial to science, resource management, commerce, agriculture, and education, how does one begin to quantify the worth of freely provided data? Further, these freely provided data are often used to produce broad societal benefits, such as scientific research or the mitigation of natural hazards. Such benefits are particularly difficult to measure.

The Landsat Advisory Group tackled that challenge by considering the costs of alternatives to Landsat for current uses of the data. People use Landsat because it is more efficient than some other technology to accomplish the same decision support requirement. How would the information that Landsat provides be acquired if Landsat did not exist?

The team of experts outlined 16 decision processes that would be significantly more expensive without an operational Landsat-like program. Many of these processes are associated with the U.S. Government and save significant amounts of money compared to other methods of accomplishing the same objective. They also include science applications where scarce research dollars cannot be wasted on inefficient technologies.

Summary Table: Estimated Productivity Savings from Uses of Landsat

Landsat Application	Estimated Annual Efficiency Savings
1. USDA Risk Management Agency	over \$100 million
2. U.S. Government Mapping	over \$100 million
3. Monitoring Consumptive Agricultural Water Use	\$20 – \$80 million
4. Monitoring Global Security	\$70 million
5. Landsat Support for Fire Management	\$28 – \$30 million
6. Forest Fragmentation Detection	over \$5 million
7. Forest Change Detection	over \$5 million
8. World Agriculture Supply and Demand Estimates	over \$3 – \$5 million
9. Vineyard Management and Water Conservation	\$3-5 million/year
10. Flood Mitigation Mapping	over \$4.5 million
11. National Agricultural Commodities Mapping	\$1.9 million/year
12. Waterfowl Habitat Mapping and Monitoring	\$1.9 million/year
13. Coastal Change Analysis Program	\$1.5 million
14. Forest Health Monitoring	\$1.9 million/year
15. NGA Global Shoreline	over \$90 million (one time)
16. Wildfire Risk Assessment	\$25-50 million (one time)

These 16 Landsat applications alone produce savings of \$350 million to over \$436 million per year for Federal and State governments, NGOs, and the private sector. Further annual savings, societal benefits, and commercial applications are described in the Landsat Advisory Group report.

Landsat is widely considered a crucial national asset, comparable to the satellite-based GPS system and National Weather Service satellites. Ready access to Landsat images supplies a reliable common record of Earth conditions that fosters the mutual understanding of environmental challenges by citizens, researchers, and decision makers worldwide.

The decades-long, consistent view of Earth from space provided by Landsat sparks advances in science, enables more efficient natural resources management, and promotes profitable applications of the data in commerce and industry. In step with the National Research Council and other objective reviews, the non-Federal Landsat Advisory Group has found that the broad benefits of Landsat far outweigh the cost.

People and Culture:

Building a Highly Motivated Workforce and Attracting Top Talent – The USGS promotes a culture of employee engagement. High levels of employee participation helped make the USGS among the best places to work, even in a period of fiscal austerity. In 2014, the USGS ranked 60 out of 315 agency subcomponents for “The Best Places to Work” in the Federal Government, as reported by the Partnership for Public Service, drawing on data from the OPM Federal Employee Viewpoint Survey (FEVS). In addition, the USGS was the second highest Interior bureau on the same survey. In addition, the Office of Communications (OCAP) was awarded first place in three award categories by the National Association of Government Communicators in 2015. OCAP also had one second-place award and one Award of Excellence in this peer-reviewed national contest. The first place awards were for a news release on earthquake hazards, social media programs using a minimal budget, and for a public affairs program on the 1964 Great Alaska Earthquake.

The Office of Science Quality and Integrity combined the Youth and Education Offices to form the Youth and Education in Science Office in 2015. This office (1) facilitates a strong coordinated effort across the USGS to leverage resources and support the engagement, mentoring, and employment of youth; (2) develops youth and education strategic directions as they relate to the USGS science and workforce planning goals; (3) expands USGS education and internship programs for students underrepresented in STEM, tribal colleges, and to veterans; (4) develops and enhances current STEM programs that are pipelines to STEM careers (i.e., EDMAP); and (5) provides opportunities to expand partnerships in support of the 21st Century Conservation Service Corps. As part of this strategy, the Youth and Education in Science Council has been developed, which will help leverage youth engagement opportunities by partnering with USGS science centers, offices, and stakeholders to achieve mission goals.

The USGS attracts top scientists through the Mendenhall Research Fellowship Program. This Program was established in 2001 to bring new PhD-level talent to the Survey to help carry out the USGS scientific mission. The Mendenhall Program provides an opportunity for postdoctoral fellows to conduct concentrated research in association with selected members of the USGS professional staff, often as a final element to their formal career preparation. The Program is also intended to provide research experiences that enhance their personal scientific stature and credentials. During the 14th recruitment cycle, the USGS received a record number of applications and had a record 29 Fellows hired for a single recruitment round.

Executive Summary

In 2012 and 2013, the USGS conducted workforce planning at higher levels in the organization, specifically in mission areas, regions, and offices, to assist the USGS in identifying future skills and competencies to facilitate broader programmatic changes and identify the future workforce needed to meet the requirements associated with those changes. Multiple higher-level workforce plans identified Voluntary Early Retirement Authority (VERA) and Voluntary Separation Incentive Payment (VSIP) as tools that would facilitate their ability to reshape their workforces with new skills and capabilities to accomplish their missions and programs while avoiding a potential furlough or reduction in force (RIF) actions. As a result of the USGS's workforce planning effort, the USGS leadership recognized a compelling need for developing broader VSIP authority requests for mission area, region, and office levels, and for pursuing a bureau-wide VERA. These tools were used to begin reshaping the USGS workforce with new skills and capabilities to accomplish the science mission and programs while avoiding potential furlough or RIF actions. The bureau's usage of integrated requests from mission areas, regions, and offices demonstrates a broad, strategic, and coordinated approach to organizational re-engineering to achieve a technically diverse, competent, and flexible workforce that will further the USGS's strategic direction. In 2014 and 2015, the USGS received approval from the Office of Personnel Management (OPM), with OMB concurrence, for several requests for VSIP and VERA, covering entire mission areas, regions, and offices, and later for a bureau-wide VERA. In 2014, 81 individuals accepted VSIPs and 117 individuals accepted VERAs. To date in 2015, 44 individuals have accepted VSIPs and 25 individuals have accepted VERAs. For 2016, the Southeast Region and the Midwest Region have VSIP/VERA authority.

In 2014, the USGS synthesized major themes from the workforce plans at the mission area, region, and office levels into a bureau-wide USGS workforce plan. Completed in 2015, the USGS Workforce Plan 2015-2020 identifies actions at the bureau level to ensure the USGS has the workforce needed to continue its leadership in Earth science. It includes an overview of the current workforce, projections for future needs, perceived gaps, and strategies to begin addressing the gaps. The action plan section includes tasks that should be initiated or completed in the next two years to address the specific gaps and strategies described, with the goal of setting the stage for significant workforce outcomes over the next three to five years. Soon after the plan was completed, a workforce plan implementation team was established and is making progress on the action items.

National Challenges

The USGS is uniquely suited to provide cutting-edge science to meet many of the most challenging issues of our time, be they drought, hazards, invasive species, habitat degradation, energy and minerals development, or public health challenges from environmental conditions. With the full suite of capabilities in biological and earth sciences, combined with advanced technologies like 3DEP and other remote sensing, modeling, and forecasting, the USGS is at the forefront of understanding the causes of and solutions to a wide variety of critical challenges. The challenges facing our Nation today and efforts to address them include: Sustainable Land Imaging; Water Science for the 21st Century – Drought; Critical Minerals; Unconventional Oil and Gas; Natural Hazards and Resilience; Understanding the Environmental Health Impacts of Disasters; Enhanced Mapping for the Nation; Innovative Tools to Prevent and Manage Invasive Species and Wildlife Disease; Climate Adaptation and Carbon Sequestration; and Climate Change and Indigenous Peoples.

Sustainable Land Imaging

Challenge: As the world is ever changing, there is a growing need to understand the dynamics of land use change and climate change and support efficient water resource management, agricultural crop monitoring and forecasting, forest health and wildfire recovery monitoring, and disaster management. For example, year after year, somewhere on Earth, natural or manmade disasters cause loss of life and widespread destruction, frequently spawning refugee situations. Though the risk of a disaster may be low in any one particular place, earthquakes, volcanoes, floods, fires, landslides, oil spills, and hurricanes—when considered together on a global scale—regularly menace people, property, and natural resources. Major disasters can temporarily make existing maps obsolete, rewriting river boundaries, shorelines, and land features in an instant. When disasters strike and first responders need to understand new situations on the ground, the best source of information often comes from the sky. Satellites can tell responders what damage disasters have done, providing timely insight into flood extents, fire boundaries, lava flow directions, road traversability, and oil slick movements.

Action: The USGS Land Remote Sensing Program, within the Climate and Land Use Change (CLU) Mission Area, manages the operation and delivery of land-surface information using data acquired by satellite and airborne instruments. Since 1972, Landsat satellites have provided the only continuous, authoritative global record of changes to the Earth’s land surface at a scale allowing the differentiation between natural and human-induced change. Under the Land Remote Sensing Policy Act of 1992, and associated Presidential Decision Directives, Interior and the USGS share responsibility for Landsat program management with NASA. Within this successful partnership, NASA develops and launches Landsat satellites while the USGS develops the associated ground systems and, following launch and on-orbit checkout by NASA, assumes ownership and operation of the satellites. Further, the USGS manages and maintains the data stream produced by the Landsat satellites and makes data products available to support decision makers.

In 2013, the USGS released a report on “The Users, Uses, and Value of Landsat Satellite Imagery – Results from the 2012 Survey of Users” (<http://pubs.usgs.gov/of/2013/1269/>). Responses from over 11,000 current users of Landsat data indicate an ongoing and increasing demand for Landsat imagery, and

the report provides a conservative estimate of Landsat's annual economic benefits within the United States at approximately \$2 billion, far above the multi-year cost to design, build and launch any two Landsat satellites. Also in 2013, the National Research Council released a report, "Landsat and Beyond: Sustaining and Enhancing the Nation's Land Imaging Program"

(<http://www.nap.edu/catalog/18420/landsat-and-beyond-sustaining-and-enhancing-the-nations-land-imaging>), which makes a strong case for sustained land-imaging satellite operations in order to ensure continuation of the Landsat data stream.

The budgets of both the USGS and NASA provide funding to sustain the Landsat data stream, which is critical to understanding global landscapes. The 2017 President's budget request includes funding for the USGS share of the Administration's joint National Aeronautics and Space Administration (NASA) and USGS Sustainable Land Imaging (SLI) program, at a funding level of \$75.2 million. This includes the current 2016 base level of \$57.6 million for Landsat satellite operations (for Landsats 7 & 8), plus the 2017 request for an additional \$15.4 million, for a total of \$19.7 million for Landsat 9 and \$2.2 million needed to operate the USGS ground archive and distribution system for Sentinel-2 data.

The proposed funding is sufficient to accelerate the launch into 2021, as is currently being planned by NASA and the USGS, and as called in the 2016 Omnibus. The 2021 launch date is critical for Landsat 9 to replace Landsat 7 *without a break* in near-weekly revisit data collection, a requirement of tens of thousands of Landsat users around the Nation. Should Landsat 7, now operating on backup systems, not survive that long, this acceleration will help to ensure the shortest possible gap in the loss of data from a near-weekly Landsat revisit over any spot on the Earth, and provides some insurance against a complete data gap should Landsat 8 fail. The total project cost for the USGS ground systems portion of Landsat 9 development is estimated at \$117.7 million through the 2021 launch date. This amount is in addition to costs for ongoing satellite operations.

The 2017 President's budget request also supports the USGS work on the Sentinel-2 ground archive and data distribution system. The USGS request allows for completion of the ground system development and all operations and maintenance of the system hardware and software. Providing Sentinel-2 data will enable the routine use of the dataset that is most like Landsat for tens of thousands of U.S. users requiring more rapid revisit over areas of interest. The requested funding would be used for work associated with acquiring, storing, and disseminating the information from the European Space Agency's Sentinel-2 satellite.

Water Science for the 21st Century - Drought

Challenge: In many places, America's water resources are being stressed by increasing demand for water, decreasing water supplies, and reduced water quality. Most areas of the Nation are vulnerable to both droughts and floods, with both having major and long-lasting economic impacts. It has been estimated by the *Center for Watershed Sciences at the University of California-Davis* that, in 2014 alone, the California drought resulted in the loss of 17,000 jobs and \$2.2 billion in direct economic losses. The stresses of increasing demand for water are heightened by changes in land use and climate change. Despite the substantial investments made by Federal, State, and local governments and by regional water authorities, the Nation does not have a comprehensive, integrated perspective of our varied water

resources, limiting the ability of water managers and communities to be proactively responsive to drought.

Water-resources scientists and managers now have access to a huge variety of water and water-related data through various sources. In some cases, however, data still are archived on hand-written notes stored in agency and corporate files. In other cases, data that are stored on computers of individual investigators may never be published. Approaches that are more modern allow users to download data from Web sites that can be updated at specified intervals ranging from sporadic to near real-time. The most modern approach for accessing data is through Web services—which are applications that allow the automated exchange of data between different computer platforms and different applications without human intervention, such as USGS Water Services (<http://waterservices.usgs.gov/>). Presently, these types of services are relatively rare in the water community.

Actions: USGS data and science are instrumental in assisting water managers' response to the current Western drought. In particular, USGS real-time groundwater information helps managers make key decisions for drought management. Groundwater, a key water reserve during droughts, is one of the last aspects of the hydrologic system to recover after a drought. The USGS recently completed a regional groundwater assessment of the Central Valley in California, one of the world's most productive agricultural regions. As a part of this assessment, a model was developed that accounts for integrated, variable water supply and demand, and simulates surface-water and groundwater flow, as well as land subsidence, across the entire Central Valley Aquifer system. These groundwater availability studies emphasize the use of USGS long-term groundwater monitoring data, in combination with groundwater models, to improve understanding of the flow systems across a range of hydrologic conditions, including drought, to assess the status and trends in groundwater resources in the context of a changing water budget for the aquifer system.

Recognizing challenges in sharing Federal, State, local, and tribal data for water management, including drought response, the USGS, in partnership with other agencies, initiated the Federal Government's Open Water Data Initiative (OWDI). The USGS leadership in the OWDI promoted open data goals with an initial objective of presenting valuable water data in a more user-friendly, readily discoverable, easily accessible format taking advantages of geospatial interfaces. Such a framework is leading to the distributed development of more sophisticated automated data processing, including models that automatically ingest updated data streams to produce estimates of water-resources conditions in near real-time.

Outcomes: The USGS Central Valley Aquifer System groundwater model was updated to assess current land subsidence resulting from increased groundwater withdrawals during the ongoing drought. The model also was used to anticipate increased subsidence for possible future withdrawal scenarios. In conjunction with the modeling, additional streamflow measurements were made to provide enhanced information to water availability. Release of the USGS five-year water use compilation for California also was accelerated to provide water managers with the latest information on withdrawals.

The USGS released the California Drought tool, which provides a visual of the conditions and impacts of drought on water resources in the State (http://cida.usgs.gov/ca_drought/). Using a similar approach, a visualization of the entire lower Colorado River Basin (<https://www.doi.gov/water/owdi.cr.drought/en/>),

Executive Summary

which has been in an approximately 15-year drought, has been developed. These tools are part of the multi-agency Open Water Data Initiative (OWDI). The Colorado River and its tributaries provide water to nearly 40 million people for municipal use, supply water to irrigate nearly 5.5 million acres of land, and are the lifeblood for at least 22 federally recognized Tribes, 7 national wildlife refuges, 4 national recreation areas, and 11 national parks. The OWDI California and Colorado River drought visualization tools demonstrate how publically available data may be integrated and displayed graphically to help describe the effects of drought on water resources in California and the lower Colorado River Basin during the last 15 years.

Finally, multiple programs in the Ecosystems, Climate and Land Use Change, Water Resources, and Core Science Systems collectively are requesting \$3.9 million for drought research. Given the persistent drought in multiple regions of the United States, the USGS proposes to quantify water availability, determine how snowmelt factors into the hydrologic cycle, and investigate drought effects on reproduction and survival of select plant and animal species. Providing access to these data will allow managers to determine impacts of drought on ecological systems. The USGS will develop actionable science approaches, by convening regionally based working groups of decision makers and natural resource managers to develop coordinated adaptive management plans for the complex consequences of severe and prolonged drought. The funding requested for this work would provide tools for fish and wildlife managers as well as water resource managers.

Critical Minerals

Challenge: Global demand for critical minerals such as rare earth elements is on the rise, with increasing applications in consumer products, computers, automobiles, aircraft, and renewable energy. Much of this demand growth is driven by new technologies that use a changing mix of critical minerals to increase energy efficiency, decrease reliance on fossil fuels, and help combat global warming. At the same time that demand is rising, there is increased concern about resource adequacy and potential supply chain disruptions.

Action: The White House Office of Science and Technology Policy convened multiple working groups to guide national policy concerning critical minerals, including developing methodologies to track information and determine what is critical. This is parallel to pending congressional legislation (Energy Policy Modernization Act of 2015) that authorizes the USGS to take a lead role in researching and assessing critical minerals. The USGS, through the National Minerals Information Center (NMIC), is the primary Federal and international source of information about critical minerals, and leads a national effort on criticality in conjunction with other Federal agencies, including the Department of Commerce, the Department of Energy, and the Department of State.

Outcome: Building on existing strengths, the USGS is leading the national effort to better understand the origin, distribution, and supply chains of critical minerals, including the following:

Defining Criticality and Minerals of Strategic Importance: In 2014, the United States was 100 percent dependent on foreign suppliers for 19 mineral commodities and more than 50 percent dependent on foreign sources for an additional 24 mineral commodities. In 2008, a National Research Council

committee, in partnership with the USGS, developed a “criticality matrix” that combines supply risk with importance of use as a first step toward determining which mineral commodities are essential to the Nation’s economic and national security. The criticality matrix has been updated by subsequent studies and ongoing work by the USGS and its partners. This work to define criticality and identify mineral resources of strategic importance is currently being carried out by NMIC at the USGS.

Understanding the Supply of Rare Earth Elements: The USGS completed an inventory of known domestic rare-earth reserves and resources, documenting 28 deposits located on a mix of public and private lands in 14 States, with information on location, exploration status, past production, and estimated resources. The USGS also released multiple reports on critical minerals, including reports on China’s rare earth elements industry and on end-use and recyclability of rare earth elements, as well as supply chain mapping.

Tracking Minerals Development on Federal and Tribal Lands: An ongoing USGS project called the USGS Mineral Deposit Database Project (USMIN) tracks minerals development information across the Nation to enable effective management of Federal lands. The Bureau of Land Management (BLM) administers over 245 million surface acres of public land primarily located in 12 Western States, including Alaska, as well as 700 million acres of sub-surface mineral estate throughout the Nation. The BLM manages mineral development under a number of Federal legislative authorities, which, along with BLM regulations and guidance, provides a legal framework for the development of minerals, including critical minerals, on Federal and tribal lands. Information from the USMIN project is crucial to providing a thorough understanding of mineral development activities on Federal and tribal lands so the BLM and other decision makers have reliable, up-to-date information for making land management decisions. In 2017, the Mineral Resources Program is requesting an increase of \$1.0 million to support the development of methodologies to track minerals information and determine criticality of minerals commodities. The proposed increase would also support the continuation of lifecycle work on critical minerals as well as increased work on new sources of critical minerals. The proposed increase would also allow for compliance with pending congressional legislative mandates on the research and assessment of critical minerals in the United States.

Unconventional Oil and Gas

Challenge: As unconventional oil and gas activities become a larger part of our domestic energy development portfolio, research to produce decision-ready information to ensure the prudent development of unconventional oil and gas (UOG) resources while protecting human and environmental health is becoming increasingly necessary.

Action: In 2012, the Department of the Interior and the USGS began a multiagency collaborative effort with the Environmental Protection Agency and the Department of Energy to develop a national research strategy on unconventional oil and gas.

Outcome: The USGS is leading several of the priority issues addressed by the Research Strategy, all of which support the Department of Interior's Secretarial Priority on Powering our Future and Responsible Use of Our Resources, and include the following:

Understanding the Scale and Nature of U.S. UOG Resources: The USGS has conducted assessments of undiscovered, technically recoverable UOG resources for selected basins. The assessments are being used to better understand where resource development is likely and how the development may impact water availability, groundwater and surface water quality, air quality, landscape and ecosystem changes, and induced seismicity hazards. The USGS will provide assessment data as input to well optimization studies, which may lead to a smaller environmental footprint for UOG development.

Water Quality: The USGS is monitoring and analyzing groundwater, surface water, and industry wastewaters at sites across the Nation. USGS scientists are developing new analytical methods to detect manmade chemical additives used in hydraulic fracturing fluid mixtures; geochemical methods and models to evaluate contamination of water supplies; and models to characterize groundwater flow paths. The findings of these studies will be useful in documenting pathways (e.g., spills and pipeline leaks) through which chemicals associated with hydraulic fracturing wastewater management can enter the environment.

Water Availability: The USGS is studying the amount and quality of water needed to meet human and ecosystem needs, the impacts of water withdrawn from surface and groundwater systems for UOG activities, and water produced during the active phase of a UOG operation. The USGS has completed a new methodology for estimating water and sand usage and volumes of water produced with oil and gas from UOG development. The methodology will be applied to assess water and sand proppant needs, and to project water use in the Williston Basin of North Dakota. The predicted volume of water produced can also be used to evaluate potential induced seismicity hazards from wastewater injection in deep wells.

Ecological Effects: The USGS is using wastewater toxicity testing to enhance available ecological toxicity data for chemicals that pose the greatest potential risk to terrestrial and aquatic ecosystems and species of concern. Results of brine contamination research in the Williston Basin represent an initial evaluation of measured and potential environmental impacts to aquatic resources from oil and gas development in the region. The USGS is using the information to select field sites for ongoing amphibian research and for identification and characterization of the fate and transport of contaminants spilled in oil and gas waste.

Induced Seismicity: Recent scientific research has shown that the injection of fluids into the Earth's crust may trigger earthquakes. Since 2001, the frequency of seismic activity has continued to rise in the mid-continent, including a number of moderate-size, lightly damaging earthquakes. In 2014, the rate of occurrence of earthquakes with magnitudes of 3.0 and larger in Oklahoma was greater than that of California. Specific links to wastewater injection have been documented in a number of cases but proving that a specific earthquake was triggered by a particular drilling activity is often difficult, due to a lack of local data on microseismicity and on the volume and timing of injection activity. Recently published USGS research indicates that hazards and risk posed by induced seismicity increases with the

total volume of fluids injected. Findings from these studies will be used to better understand the relationships between fluid injection and the potential for induced seismicity. The data will inform the development of models that may potentially allow fluid disposal companies to inject fluids without inducing earthquakes. The information could be used by State permitting agencies and Federal regulatory agencies in approving permits to allow for the subsurface disposal of produced fluids. In 2017, the Earthquake Hazards Program is requesting an increase of \$700,000 to improve short-term earthquake hazard forecasts related to unconventional oil and gas activities.

Natural Hazards and Resilience

Challenge: Every year the United States faces natural and human disasters that threaten the Nation through loss of life and property, degradation of human health and the environment, and threats to national security and economic vitality. In domestic and global events, the Nation's emergency managers and public officials look to USGS science to inform them of the various risks different hazards pose to human and natural systems, as well as how to reduce losses and improve responses. The USGS has the lead Federal responsibility for issuing alerts about earthquakes, volcanic eruptions, and landslides. These effective forecasts and warnings, which are based on the best possible scientific information, are intended to enhance public safety, reduce losses, and facilitate effective response and recovery.

Action: Research and program resources are targeted at the highest-hazard areas of the Country. Events over the past 18 months, where the USGS was actively engaged in response, include the recent contaminant spill in the Animas River (CO), landslides in Washington State and Colorado, Midwest flooding, Kilauea's eruption in Hawaii, geomagnetic storms, wildfires in the Western United States, and earthquakes in Napa, CA (M6.0), and Gorkha, Nepal (M7.8). Although natural hazard events like these are unavoidable, the impacts and consequences can be lessened by actions informed by science. The USGS responses to hazard events are part of a continuous and sustained effort to ensure science is available for effective application in anticipation of future events. For example, substantial research efforts continue in the aftermath of Hurricane Sandy to develop and provide coastal communities with forecasts of their vulnerability to future storms, coastal erosion, and sea-level rise. The USGS makes a difference by working with partners, cooperators, and customers to deliver actionable assessments and early warning to these hazards, to develop effective strategies to increase their resilience and reduce losses from disasters, to improve the use of existing USGS natural hazards information, to identify and address information needs and gaps, and to develop new products that increase the use and impact of USGS science.

Outcome: Ongoing efforts to increase hazard resilience include the USGS and its partners developing an earthquake early warning system for the U.S. west coast, called *ShakeAlert*, which is a part of the Advanced National Seismic System (ANSS). The USGS is working with the States of California, Washington, and Oregon, to further develop the *ShakeAlert* system for earthquake early warning, completing a "production prototype" system and expanding coverage through upgrades to existing seismic and geodetic stations and associated communications. The USGS National Seismic Hazard Maps are the basis for the seismic provisions of building codes and affect domestic construction costs estimated at \$1 trillion per year. Ongoing efforts to reduce the uncertainties in earthquake hazard and risk assessments will have significant economic benefits to the Nation. The USGS will also continue to

expand the development of volcanic ashfall modeling that gives responders and the public information on when and how much ash will accumulate during volcanic activity and will continue to improve and maintain the volcano monitoring network for those volcanoes classified as high and very high-threat. The USGS is working with other Federal agencies to expand the availability and accessibility of tools to anticipate and respond to coastal change hazards throughout the Nation and to enhance coastal resilience. In addition, the USGS is also expanding efforts to conduct post-wildfire debris flow assessments as part of landslide warning and assessment efforts.

In 2017, the USGS is requesting \$700,000 for activities related to induced seismicity earthquake risk assessments; \$800,000 for the adoption of the Central and Eastern U.S. Seismic Network; \$500,000 for improving landslide response by expanding post-wildfire debris flow hazard assessments and growing capability to respond to landslide crises; and \$5.6 million for developing scenarios for Arctic coastal impacts and activities related to building resilience to coastal hazards.

Understanding the Environmental Health Impacts of Disasters

Challenge: The economic costs and the human and environmental health consequences of natural and manmade disasters can be enormous. Each year, more people, resources, and infrastructure are put at risk as populations increase in coastal areas vulnerable to sea level rise and storm events. Recent studies have shown that nearly half of all Americans are susceptible to potentially damaging earthquakes and could be exposed to the contaminants or pathogens that may be released. In the aftermath of the 1989 Loma Prieta earthquake in California, approximately 20 percent of post-earthquake injuries were caused by exposure to toxic materials. Experience with recent disasters and health threats (e.g., the Animas River toxic mine spill, flooding in Colorado, Hurricane Sandy, the Deepwater Horizon oil spill, and Hurricane Katrina, among others) have highlighted the critical need for improved information on the human and environmental health risks associated with increased exposure to environmental contaminants and changes in the distribution and spread of infectious agents related to natural and manmade disasters. In addition, other environmental disturbances (e.g., wind and water erosion, changing land and chemical use, habitat modifications, etc.) also influence human and environmental health risks from contaminants and infectious agents.

Action: The USGS has a prominent role among Federal agencies in assessing how disasters affect the exposure of humans and animals to environmental contaminants and influence the distribution and spread of infectious diseases among wildlife, people, and domesticated animals. The USGS provides a strong foundation of tools and expertise to address scientific gaps in areas of decision making related to natural resources, public health, agriculture, emergency management, and national security. This information contributes to the well-being and security of the Nation and its economic resources.

Outcome: Coastal communities are uniquely vulnerable to sea level rise and severe storms such as hurricanes. These events enhance the dispersion and concentration of natural and manmade chemicals and pathogenic microorganisms, which could adversely impact the health and resilience of coastal communities and ecosystems. Historically, assessing contaminants associated with disasters has been conducted by deploying field crews following a disaster. Using this method, the USGS has produced high-quality information on post-event contamination of soils, water, and sediment that is useful to public

health agencies and land managers in making well-informed decisions following disasters. This approach was used to assess human and ecological exposures to contaminants released by Hurricane Sandy. A limitation of such an approach, however, is that it does not provide the scope of information needed to mitigate future health threats from disasters. To address this limitation, the USGS Toxic Substances Hydrology Program (TSHP) is developing a framework now being tested along the northeast coast of the United States to provide information on contaminants in the environment before and after hurricanes. This effort, for which TSHP is requesting \$1.3 million in 2017, will identify and map contaminants from their sources to points of potential human and ecological exposure, allowing for a more complete picture of the occurrence, transport, and fate of contaminants prior to and following disasters—comprehensive information that will better lend itself to the mitigation of public and environmental health threats from future disasters.

Enhanced Mapping for the Nation

Challenge: Technology can enable nationwide coverage of accurate terrain information (light detection and ranging [lidar] and interferometric synthetic aperture radar [ifsar]), which can be used to save lives, protect property, increase agricultural production, and reduce flood risk exposure. Better elevation data would improve our knowledge of water supply and quality. Emergency responders could be better prepared for natural disasters. Addressing these needs depend on sustained collaboration and significant investments to collect terrain data.

The USGS National Geospatial Program produces high quality public domain maps and the foundational geospatial data for Global Positioning Systems (GPS), emergency response during disasters, wind and solar power facilities siting, natural resource management, and many other business applications of government and the private sector. The USGS has begun remapping Alaska with high-quality maps. These modernized maps are critical in Alaska where persistent cloud cover compromises safe air travel. The 9,000 registered aircraft in Alaska often rely on Instrument Flight Rules using old and highly inaccurate maps.

Action: The 3D Elevation Program (3DEP) is designed around results of the 2011 National Enhanced Elevation Assessment (NEEA) study. The NEEA identified more than 600 requirements for enhanced elevation data to address mission-critical information needs of Federal agencies, and State, tribal and local governments. Begun in 2015, the USGS and a growing list of partner organizations are implementing 3DEP. Ifsar data have been collected over more than 50 percent of Alaska and, to date, the USGS has produced over 1,200 high-resolution digital topographic maps for the Nation’s largest State. High quality lidar data are being collected across 49 States but at a pace that is well below the rates needed to provide needed data in a reasonable time frame.

In 2017, the Core Science Systems is requesting an increase of \$4.9 million in the National Geospatial Program (NGP) to increase acquisition of lidar (light detection and ranging) and ifsar (interferometric synthetic aperture radar) data and expanding publicly available 3DEP holdings. Based on the leveraging of USGS funds in 2015, the increase could attract as much as \$20.0 million in additional partner funding. The leveraged funds will result in nearly 75,000 square miles of new data. Accelerating the national coverage of lidar will enable decision making in management of infrastructure and construction, more

Executive Summary

accurate and cost effective application of chemicals in farming, development of energy projects, and support of aviation safety and vehicle navigation. The NGP will increase collection of ifsar in Alaska and improve mapping products. Involvement with the Alaska Executive Committee and coordination with other Federal and State agencies will facilitate identification of priority needs and partnering opportunities. The NGP would acquire about 12,500 additional square miles of data. With leveraging, this could increase to as much as 25,000 square miles and accelerate completion of data coverage for the State.

Outcome: The value of lidar data was proven over and over again when the devastating landslide occurred in Oso, Washington, catastrophic floods hit the Colorado Front Range, and Hurricane Sandy struck the Atlantic coast. Elevation models created from lidar data determined the extent of damage and are helping today to support ongoing recovery in all three areas. Nationwide 3DEP data coverage could return more than \$1.2 billion annually in new benefits to the public and private sectors and citizens. The top benefits expressed by respondents to NEEA include flood risk management, infrastructure and construction management, natural resources conservation, agriculture and precision farming, water supply and quality, and wildfire management, planning, and response.

Innovative Tools to Prevent and Manage Invasive Species and Wildlife Disease

Challenge: Wildlife disease and invasive species are hugely costly to the United States. One estimate puts the cost of managing invasive species in the United States at \$120 billion annually, from invasions such as aquatic species that out-compete commercially valuable fish species to mussels clogging intake valves to cheatgrass replacing the iconic sagebrush of the West. Diseases are costly as well. The deaths of 5.5 million bats from white-nose syndrome (WNS) was not only devastating to natural communities, but is estimated to have cost agriculture billions of dollars in harmful insect reduction. The current outbreak of avian influenza in poultry, which originated in wild birds, has had serious repercussions on the Nation's nearly \$50 billion poultry industry. Since its detection in wild birds in December 2014, highly pathogenic avian influenza (HPAI) has spread to over 20 States and resulted in a three percent decline in turkey production and a loss of over 10 percent of egg-laying chickens. Early detection is key to preventing disease outbreaks and stemming the establishment and spread of invasive plants and animals. The current ability of managers to detect invasive species is limited, especially in aquatic environments, for difficult-to-detect species, and those in remote locations.

Action: USGS scientists are using advanced remote sensing equipment to detect invasive buffelgrass in rugged terrain in the Southwest and honing analytical methods and tools to analyze environmental samples for DNA of invasive species such as Asian carp, Burmese pythons, and zebra and quagga mussels, and diseases such as *Batrachochytrium salamandrivorans* (Bsal), an emerging lethal fungus devastating European salamander populations.

The USGS also provides extensive digital records and map visualizations of aquatic invasive species in the United States, allowing for reporting of additional sightings, and sends species alerts to registered users (Nonindigenous Aquatic Species database: <http://nas.er.usgs.gov>). For current disease threats, the USGS has developed an online data visualization tool for managers to assess disease risks based on historical occurrence (<https://www.nwhc.usgs.gov/whispers/>).

Risk assessments conducted by USGS scientists continue to aid contributing partners in decision making. For example, USGS scientists completed a risk assessment map to understand the likely entry points for Bsal and native salamander populations most at risk, risk models for transmission at the wild bird-poultry interface in China that will inform new U.S.-based transmission models to target disease management efforts, and Fluegg, a model developed to identify areas likely to support spawning areas for Asian carp.

USGS scientists are working with partners to contain and control invasive species. Recent research on Asian carp includes testing carbon dioxide and complex sound to prevent further spread of Asian carp, to enhance removal of Asian carp by other means using algal attractants, and developing a toxin designed to kill only Asian carp.

USGS scientists are developing integrated methods to control common reed (*Phragmites*), a wetland plant invasive in many parts of the United States, using gene silencing. In addition, USGS researchers continue to develop and refine diagnostic tests (such as snake fungal disease and WNS) and treatments for wildlife disease using non-invasive ultra-violet (UV) light surveillance to detect WNS in hibernating bats. The USGS continues to work with partners to identify invasive species and diseases of management concern, and develop tools to aid managers to better prevent and manage these costly threats to our fish and wildlife populations.

Outcome: Natural resource managers have been using the USGS's scientific information and decision tools to better detect, visualize, forecast, contain, and control invasive microbes, plants, and animals. The Nonindigenous Aquatic Species database is an important tool for USGS partners, with over 100,000 computer visits to the Web site per month. The online data visualization tool is used by managers to forecast disease outbreaks and target surveillance and control efforts.

USGS scientists completed a risk assessment map to understand the likely entry points for Bsal and the native salamander populations most at risk.

The methods and approaches developed for Asian carp are now being applied to contain and control zebra and quagga mussels and grass carp.

In 2017, the Invasive Species Program is requesting an increase of \$2.5 million that would allow the USGS to enhance ongoing efforts focused on the development, evaluation, and improvement of tools for early detection and control of existing and emerging invasive species.

The USGS would develop and improve the power of advanced molecular detection tools (such as eDNA and fecal source tracking) to detect invasive species at very low densities in the field, such as sea lamprey. These USGS research endeavors would provide information for assessments of risk and predictions; determine effects of invasive species; develop tools and innovative methods for control and management; and deliver information management tools to more effectively integrate and use available data on invasive species. In addition, capabilities and capacities of the USGS Nonindigenous Aquatic Species database would be improved and upgraded, and a phone application would be released to allow reporting of nonindigenous aquatic species. The end result would be a collection of early detection tools for invasive species to enhance capability for early detection and control of currently established and emerging

invasive species and to ensure that the Nation is better prepared for the next—yet unknown—generation of invasive species. This research would address invasive species and ecosystems of concern for our Interior partner agencies and would be coordinated with the National Invasive Species Council.

In addition, a portion of the increase would allow the USGS and Bureau of Reclamation to continue to share research findings and information with decision makers, scientists and stakeholders to improve the effective management of mussel populations in the future. This increase would allow the USGS to further apply newly developed tools to better detect, contain, and control invasive species to other infested areas around the Country as well as to adapt them and other management tools to emerging invasive species of great concern such as Argentine black and white tegu, a South American lizard established and spreading in Florida; grass carp and black carp, Asian carp species of growing concern to managers in the United States; and Bsal, a newly-emerging chytrid fungus lethal to salamanders but not yet detected in the United States that threatens our diverse native salamander fauna.

Climate Adaptation and Carbon Sequestration

Challenge: Developing and implementing adaptation plans for climate impacts will be a critical activity for natural resource managers over the next few years. Along with steps to adapt to the impacts of climate change, natural resource managers will implement land and water management activities that maximize carbon sequestration potential. Carbon sequestration is used to describe both natural- and human-induced processes by which carbon dioxide (CO₂) is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediment), and geologic formations. The Energy Independence and Security Act (EISA) of 2007 (P.L. 110-140) required the Secretary of the Interior to complete a quantitative national assessment of the carbon stored in and released from ecosystems. Otherwise known as the national biological carbon assessment, it is a national inventory of the capacity of land-based and aquatic ecosystems to naturally store or sequester carbon. Biologic carbon sequestration refers to the assimilation and storage of atmospheric carbon in vegetation, soils, woody products, and aquatic environments, i.e., carbon stored largely in plants and in the sediments and lakes.

Action: The Climate and Land Use Change (CLU) Mission Area in conjunction with scientists from the Ecosystems, Energy and Mineral Resources, and Environmental Health, and Water Resources Mission Areas have led a national effort to estimate the total amount of biological carbon sequestration potential and project future potential.

Outcome: In 2014, the USGS released the final report for the lower 48 States for the national biological carbon sequestration assessment, estimating that there is potential to increase carbon storage in the Eastern United States by up 37.5 percent over baseline years. The Great Plains, Western United States, and Eastern United States assessments confirmed that all three regions are “carbon sinks,” meaning their ecosystems take up more carbon than they emit. Eastern ecosystems are the strongest regional carbon sinks in the conterminous United States, sequestering more carbon than the rest of the area combined and there is potential to increase carbon storage in this region by up 37.5 percent over baseline years. On a national scale, the amount of carbon that is currently stored per year in the ecosystems of the conterminous United States is over 20 percent of the Nation’s total greenhouse gas emissions. The USGS

anticipates releasing the biological carbon sequestration assessment for Alaska and the Pacific Islands in 2016. However, estimating potential is only one step toward implementing biological carbon sequestration measures. The USGS is currently working with three U.S. Fish and Wildlife Service National Wildlife Refuges (Great Dismal Swamp, Alligator River, Pocosin Lakes) in the mid-Atlantic to develop decision-support tools. These tools will enable land managers to explore potential impacts of land and water management activities on carbon stocks and other goods people want from the environment (biodiversity, water quality, wildlife, etc.), and to better develop carbon management and climate adaptation planning. Finally, the USGS is working with land and water managers to understand their needs and timelines, and develop and apply refined geospatial models and estimation techniques for biological carbon sequestration, and tools supporting carbon management objectives and tradeoffs with other components of the natural system. The USGS released the LandCarbon Atlas online tool (www.landcarbon.org) to the public, enabling managers and the public to view, analyze, and download carbon sequestration data via the Internet. This tool is a significant step forward in supporting ecological carbon sequestration management. Further development of this tool in 2016 will allow land managers to ask “what-if” questions regarding the impacts of potential land management activities on carbon stocks and sequestration capacity, as well as on other ecosystem services (such as biodiversity, water quality, etc.). Data products (including carbon stock and sequestration estimates, emissions and fluxes in and out of ecosystems, land use change, and wildland fire) for the conterminous United States are now available for analysis and download.

Climate Change and Indigenous Peoples

Challenge: For centuries, Native Americans, Alaska Natives, Native Hawaiians, Pacific Islanders, and other indigenous peoples and communities have relied on natural resources to sustain their families, communities, traditional ways of life, and cultural identities. The relationship with both land and water ecosystems makes indigenous people and cultures particularly vulnerable to the impacts of climate change, which can include drought, increased wildfires and extreme weather, sea-level rise and melting glaciers. Many communities are already facing problems such as loss of important freshwater resources and agricultural lands due to ocean inundation in the Pacific Islands, the decimation of an important food sources, potentially related to climate change, in Alaska, and vulnerability to extreme weather events in the South Central United States.

Action: The USGS, through leadership in the Climate and Land Use Change (CLU) Mission Area and the Department of the Interior Climate Science Centers (CSC) are working with Tribes and indigenous communities to better understand their specific vulnerabilities to climate change and to help them adapt to these impacts. This work is conducted through research projects, outreach events, training workshops, stakeholder meetings, youth internships, and other coordination activities.

Outcome: These efforts support the Department of Interior’s Secretarial Priority on Strengthening Tribal Nations and Insular Communities. Examples of the work that the USGS is doing with Tribes and indigenous communities to better understand climate change vulnerabilities and adaptations are listed below.

Executive Summary

In the Northwestern United States, researchers from the Natural Hazards and CLU Mission Area partnered with members of the Swinomish Indian Tribal Community and the North Pacific Landscape Conservation Cooperative (LCC) to conduct a pioneering study to combine assessments of ecological health with newly developed community health indicators to identify priority adaptation tactics. The Swinomish rely on salmon, shellfish, marine mammals, forage fish, wild game, and berries to support their traditions and community well-being. Changes in availability of these resources will impact the well-being of tribal members.

In Alaska, scientists, biologists, sociologists and anthropologists from the USGS have joined together with partners from the U.S. Fish and Wildlife Service, Bureau of Ocean Energy Management, the Alaska Department of Fish and Game, the Aleutian and Bering Sea Islands LCC, and the Universities of Alaska-Fairbanks and Washington to evaluate potential vulnerabilities among economic and cultural resources that are vital to the Bering Sea region's nine island communities. Results from this research has shown how new weather patterns and warmer ocean waters threaten the viability of traditional subsistence harvesting in many areas, while changes in sea ice and fish stocks promise to bring tremendous changes to commercial shipping and fishing industries.

The USGS has also engaged with tribal communities through workshops and climate related training classes. In the South Central United States, several events have been held (and more are planned) to introduce tribal groups to USGS and CSC resources working through a partnership with the Chickasaw Nation. The goal of this effort is to educate members about the impacts of climate change, understand Traditional Knowledge in relation to climate change, and assist tribal environmental professionals in developing and implementing climate change adaptation plans. The Bureau of Indian Affairs (BIA) is in the process of placing Tribal Climate Scientist/Technical Support Coordinators at several of the CSCs to help identify climate information and research needs of Tribes and indigenous communities, and work with Federal partners to address those needs.

The USGS will continue these science and outreach efforts to support climate change preparedness and adaptation among tribal and indigenous communities. Many programs within the USGS have already developed formal tribal engagement strategies, and plans for expanding these efforts are underway throughout the United States. In 2017, the USGS is requesting an increase of \$1.4 million for work that would affect tribal and indigenous people. The increased funding would be used for the following types of activities: 1) New research, co-produced with Tribes, with a focus on key climate concerns to the Tribes and their cultural heritage; and 2) Building Tribal capacity with multiple age groups to manage climate change effects on natural resources; funds would be used to expand climate change science training for Tribal natural resource managers, and to increase Native youth climate change internships

Strategic Objective Performance Summary

In 2014, Interior published the 2014–2018 DOI Strategic Plan (Plan), in compliance with the principles of the Government Performance and Results Act (GPRA) Modernization Act of 2010. The Plan provides a collection of mission objectives, goals, strategies, and corresponding metrics that enable an integrated and focused approach for tracking performance across a wide range of Interior programs. The Plan for 2014–2018 is the foundational structure for the description of program performance measurement and planning for the 2017 President’s budget; further details for achieving the Strategic Plan’s goals are presented in the Interior Annual Performance Plan and Report (APP&R). The USGS science strategy plans are fully consistent with the goals, outcomes, and measures described in the Plan and related implementation information in the APP&R.

The Interior conducts an annual strategic objective review, which focuses on areas that are making significant improvements and those that have challenges. The USGS formulated the 2017 budget by increasing funding in critical areas that required attention to address national and state challenges. The following table aligns the USGS Goals with funding increases necessary to implement the goals and strategies:

DOI Strategic Plan	Budget Account	2016 Enacted	2017 Changes	2017 Request
Goal 1: Provide Shared Landscape-Level Management and Planning Tools				
Ensure the use of landscape-level capabilities and mitigation actions	Core Science Systems	62,854	6,125	68,979
Goal 2: Provide Science to Understand, Model and Predict Ecosystem, Climate and Land Use Change				
Identify and predict ecosystem changes at targeted and landscape-levels (biota, land cover, and Earth and ocean systems)	Ecosystems	160,232	13,706	173,938
Assess and forecast climate change and its effects	CLU	139,975	31,469	171,444
Goal 3: Provide Scientific Data to Protect, Instruct, and Inform Communities				
Monitor and assess natural hazard risk and resilience	Natural Hazards	139,013	10,688	149,701
Provide environmental health to guide decisionmaking	Environmental Health	21,445	3,115	24,560
Goal 4: Provide Water and Land Data to Customers				
Monitor and assess water availability and quality	Water Resources	210,687	17,305	227,992
Generate geologic maps	Core Science Systems	24,397	89	24,486
Assess national and international energy and mineral resources	Mineral & Energy Resources	73,066	1,857	74,923

Note: Not included above: CSS Science Synthesis, Analysis and Research program, Science Support and Facilities

Performance and Results:

Goal #1: Provide Shared Landscape-Level Management and Planning Tools

Strategy #1: Ensure the use of landscape-level capabilities and mitigation actions

The USGS works with its many partners to deliver a comprehensive and high resolution characterization of the Nation’s land surface. Modern mapping methods used by the USGS include Earth observations from many platforms (such as satellites and aircraft) as part of a continuously evolving suite of technologies to sense and map the landscape and features to be integrated and delivered as part of The National Map. The benefits these data provide to the general public, other Federal agencies, and industry

are substantial. Nationwide high resolution elevation data coverage, for example, stands to return more than \$690 Million annually to the private sector and citizens through the 3D Elevation Program as outlined in the National Enhanced Elevation Assessment. These benefits are realized through improved flood risk management, infrastructure and construction management, natural resource conservation, and agriculture practices, among others. USGS hydrography data and hydrographic mapping products are used to perform water quantity and quality mapping, as well as by government partners to reference hydrologic features and observations, and provide the national hydrologic transport network to support Federal and State reporting of surface water conditions as required under the Clean Water Act. U.S. Topographic maps produced by the USGS remain a critical part of many business processes and applications across the Country, particularly for outdoor recreation, wildfire management and suppression, and aerial navigation.

The 2017 Budget Request for National Geospatial Program is \$68,979,000, and net change of +\$6,125,000 from the 2016 Enacted level:

- Alaska Mapping and Map Modernization +\$1,500,000 for a total of \$6,722,000. To increase collection of ifsar (interferometric synthetic aperture radar) in Alaska and improve mapping products. These maps and improved data are urgently needed for aircraft navigation, since weather conditions in Alaska deteriorate quickly and pilots frequently need to fly using only their instruments and GPS
- National Enhancement, Landscape -scale 3-D Maps +\$2,387,000 for a total of \$21,887,000: To increase acquisition of lidar data and expand publicly available 3DEP holdings. Accelerating the national coverage of lidar will enable decision making in management of infrastructure and construction, more accurate and cost effective application of chemicals in farming, development of energy projects, and support of aviation safety and vehicle navigation.
- Coastal Lidar +\$500,000 for a total of \$500,000: To collect enhanced elevation data using lidar in U.S. coastal zones to understand and mitigate the negative effects of coastal erosion and storm surge, to map existing and potential landslide hazards, and to monitor biomass.
- NHD/Landscape Level Assessments – Chesapeake Bay +\$500,000 for a total of \$500,000: To systematically collect and manage high-quality lidar data to understand landscape processes at a parcel and local level and support the sustainable development and management of the Chesapeake Bay’s natural resources.
- WaterSMART: National Hydrography Database +\$1,000,000 for a total of \$1,000,000: To complete national NHDPlus high-resolution (1:24,000 scale) coverage for the conterminous 48 States, Hawaii, and Puerto Rico and, when combined with 3DEP products, would be used to integrate water information into a simplified and connected national water data framework that would underpin innovation, modeling, data sharing and solution development.
- Fixed cost \$238,000

Goal #2: Provide Science to Understand, Model, and Predict Ecosystem, Climate, and Land Use Changes at Targeted and Landscape levels

Strategy #1: Identify and predict ecosystem and land use change

The USGS data holdings and observation networks are vital to understanding the status and trends and health of our Nation's ecosystems and natural resources. Many of these databases include decades-long records of observations, collected under strict standards of quality assurance and quality control. These programs fill a key role in adaptive management for the Nation's ecosystems. Data from Landsat and other land-observing systems operated by the USGS are vital for scientists to understand changes occurring on the Earth's land surface, and to model their impacts for land and resource managers. Socioeconomic data shows a significant return on Landsat investments, with productivity enhancements and cost savings in the public and private sectors. For example, a study demonstrates the potential for approximately \$100 million annual savings by using Landsat-derived applications for better water management for irrigated agriculture in the Western United States. The National Land Cover Database (NLCD) supports thousands of science applications in the private, public, and academic sectors, and offers the only national database portraying land cover change spatially as a comprehensive "wall-to-wall" 30-meter cell database. It also provides a critical data layer in national assessments of biological carbon sequestration, water-quality monitoring, wildfire monitoring and modeling, and biodiversity conservation efforts.

The 2017 Budget Request for Ecosystems is \$173,938,000, a net change of +\$13,706,000 from the 2016 Enacted level.

- Develops and provides standard scientific methods to measure changing biodiversity, and forecast and plan for future biodiversity scenarios for inventory and monitoring programs at land management bureaus (BLM, NPS, FWS).
- Develops an interagency monitoring framework focused on evaluating the effectiveness of fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage-grouse.
- Expands capabilities to evaluate the effectiveness of fire suppression actions, such as fuel breaks, and to test new techniques for reducing fuel loads by controlling or eliminating cheatgrass and other invasive plants.
- Transfers technologies ready for use in the field to relevant partners and allow USGS scientists to adapt these new detection, containment, and control tools to the many areas in the Nation where invasive species have been detected.

Highlights of changes are as follows with additional detail in the Mission Area section:

Status and Trends Program +1,794,000 for a total of \$22,267,000:

- Pollinators +\$1,705,000 for a total of \$2,055,000: Increase research and interaction between the USGS and Interior bureaus on pollinators to support land managers in ensuring that populations on native species are maintained.
- Fixed Costs +89,000

Executive Summary

Fisheries Program +\$3,197,000 for a total of \$24,083,000:

- Great Lakes Fisheries Assessments +\$250,000 for a total of \$4,210,000: Piloting a change in the way that fisheries assessments are done in the Great Lakes, moving to the use of Long Range Autonomous Underwater Vehicles and piloting a project where offshore sample processing of water in the Great Lakes would be used to provide an early warning systems regarding Harmful Algal Blooms.
- Unconventional Oil and Gas Research – Ecological Effects +\$350,000 for a total of \$1,458,000: Expanding research to identify potential ecological impacts associated with UOG development and the area’s most vulnerable to impact through wastewater toxicity testing and landscape scale vulnerability assessments.
- WaterSmart: Ecological Flows +\$2,500,000 for a total of \$3,000,000: Develop Decision Support tools, which are an essential step in enhancing capacity for water regulators across the United States.
- Fixed cost +\$97,000

Wildlife Program +\$368,000 for a total of \$46,125,000:

- Renewable Energy – Wind and Solar +\$150,000 for a total of \$1,645,000: Support development of new mitigation technologies to reduce the interaction of wildlife with renewable energy infrastructure.
- Fixed Cost +\$218,000

Environments Program +\$4,937,000 for a total of \$43,352,000:

- Arctic +\$1,000,000 for a total of \$2,030,000: Partner with agencies to analyze potential changes to distributions and condition of fish and wildlife populations and their habitats as a result of climate changes and human activities.
- Sage Steppe Landscape +\$3,000,000 for a total of \$4,181,000: Expand research to fire regimes, drought, and shifting climates; control the spread of invasive cheatgrass; design conservation and management strategies for greater sage-grouse; and effectively restore and adaptively manage the sage steppe landscape.
- Science to Support Drought +\$300,000 for a total of \$300,000: Conduct research on how drought interacts with other environmental stressors such as invasive vegetation and wildfires to affect landscape composition, structure, and function.
- Rangeland Fire Response and Prevention +\$500,000 for a total of \$1,042,000: Expand capabilities of the USGS to more fully address the priority science needs to reducing the growing threat of rangeland fire and improve effectiveness of actions to stabilize, rehabilitate, and restore ecosystems after fire.
- Fixed cost +\$137,000

Invasive Species Program +\$2,547,000 for a total of \$19,877,000:

- New and Emerging Invasive Species of National Concern +\$2,500,000 for a total of \$8,212,000: For development, evaluation, and improvement of tools for early detection and control of existing and emerging invasive species. The USGS would develop and improve the power of advanced molecular detection tools to detect invasive species at very low densities in the field, such as sea lamprey.
- Fixed cost +\$47,000

Cooperative Research Units +\$863,000 for a total of \$18,234,000:

- Cooperative Research Units (CRU) – Enhanced Support and Scientists for Tomorrow +\$750,000 for a total of \$18,121,000: The CRU involvement in youth programs has traditionally been focused on graduate education. CRU will use the requested increase to provide undergraduate students, from groups under-represented in the conservation workforce, with mentoring and hands-on experience designed as a pathway to Interior recruitment. In addition, the CRU will enhance support towards training, mentoring, and support of Science, technology, engineering, and mathematics (STEM) graduate and post-doctoral associates from under-represented groups.
- Fixed cost +\$113,000

Goal #2: Provide Science to Understand, Model, and Predict Ecosystem, Climate, and Land Use Changes at Targeted and Landscape levels

Strategy #2: Assess and forecast climate change and its effects

The USGS provides scientific research on patterns and impacts of climate and land use change on Earth and human systems. The understanding of these impacts is communicated through peer-reviewed journal articles, vulnerability assessments, resource assessments, forecasts, models, and maps to advance the science of climate change and to support land and resource managers and policy makers in their decision making to manage and mitigate the impacts of climate change.

The 2017 Budget Request for CLU is \$171,444,000, a net change of +\$31,469,000 from the 2016 Enacted level.

- Aligns with Administration priorities including the USGCRP, the President’s Climate Action Plan and other government-wide strategies such as the National Fish, Wildlife, and Plants Climate Adaptation Strategy.
- Accelerates the planned Landsat 9 Launch from 2023 to 2021 to minimize impact to data continuity and ensure access to the Nation’s remotely sense land data (Landsat and other).
- Provides the climate science resource and land managers need to adapt to climate and mitigate its effects, as defined in Secretarial Orders 3289 and 3330 respectively.
- Advances the strategic goals for climate and land use change science in the USGS 10-year plan.

Executive Summary

Highlights of changes are as follows with additional detail in the Mission Area section:

Climate Variability +\$5,714,000 for a total of \$63,003,000

National Climate Change and Wildlife Science Center/DOI Climate Science Centers (CSCs) +\$4,473,000 for a total of \$30,908,000:

- Great Lakes Climate Science Center +\$1,500,000 for a total of \$1,500,000: Establish a new Center to increase and improve focus on the many climate-related natural resource challenges in the Great Lakes region due to the distinct bio-geographic provinces between the Great Lakes region and the Northeastern United States.
- Tribal Climate Science Partnerships +\$1,411,000 for a total of \$1,411,000: To address the needs of Tribes to better understand the potential climate change effects on culturally-important fish and wildlife resources, and help integrate tribal and indigenous traditional ecological knowledge with more conventional science in management decisions.
- WaterSMART Drought: +\$1,030,000 for a total of \$1,030,000: To develop a science-based decision process for understanding and managing the impacts of drought on various parts of the Central and Western United States, including California. Much research is available on the effects of drought on human systems, notably agriculture, but the ecological effects are not as well studied.
- Critical Landscapes: Arctic +\$500,000 for a total of \$500,000: To develop a process to estimate total glacier loss in Alaska and potential changes in freshwater input.
- Fixed cost +\$32,000

Climate Research and Development Program +\$1,219,000 for a total of \$22,714,000:

- WaterSMART: Drought +\$1,125,000 for a total of \$1,125,000: To understand long-term and medium-term patterns and impacts of drought in the Western and Southeastern United States.
- Fixed cost +\$94,000

Carbon Sequestration +\$22,000 for a total of \$9,381,000:

- Fixed cost +\$22,000

Land Use Change +\$25,755,000 for a total of \$108,441,000

Land Remote Sensing Program +\$24,312,000 for a total of \$96,506,000:

- Landsat 9 +\$15,400,000 for a total of \$19,700,000: Develop the Landsat 9 ground system and delivering the completed system to support accelerating the launch date to 2021.
- Sentinel-2 +\$2,200,000 for a total of \$2,200,000: Acquire, store, and disseminate the information from ESA.

- Big Earth Data: Data Cube +\$600,000 for a total of \$600,000: Initiate the development of a pilot study for enhancing Landsat data access and delivery services that would allow the user to define a geographic area of interest, timeframe, and specific parameters derived from the data (e.g., vegetation index) rather than the current scene-based products of prescribed geographic extent and digital numbers provided by the USGS.
- Critical Landscapes: Arctic +\$1,857,000 for a total of \$1,857,000: Develop predictive models, which support the evaluation of changes to the environment resulting from the conversion of historically sequestered ice and snow to liquid and gaseous water.
- Landsat Products for Climate and Natural Resources Assessments +\$2,992,000 for a total of \$2,992,000: Develop the computing and online storage resources necessary to rapidly produce and widely disseminate a set of Landsat-based information products.
- Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis +\$500,000 for a total of \$500,000: Develop new datasets to support dynamic coastal land change analyses for improved coastal resource management and resilience planning.
- WaterSMART: Drought +\$250,000 for a total of \$250,000: Identify gaps and close the gaps between remote sensing data and derivative products in order to meet the needs of scientists and decision makers in the conservation and land management communities.
- Water SMART: Remote Sensing +\$400,000 for a total of \$400,000: Use remote sensing data to allow monitoring of water storage in smaller storage features such as ponds, thereby improving drought status monitoring.
- Fixed cost +\$113,000

Land Change Science Program +\$1,443,000 for a total of \$11,935,000:

- WaterSMART: Remote Sensing +\$400,000 for a total of \$400,000: Conduct an innovative data integration approach that combines satellite-derived reservoir surface area and digital elevation models (DEM) to monitor height and volumetric storage changes in water reservoirs.
- WaterSMART: New Tools and Models to Better Manage Water Nationwide +\$1,000,000 for a total of \$1,000,000: Develop automated methods and tools supporting near real-time, satellite-based, drought monitoring. Assessed characteristics would include soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers identify the onset and severity of drought events and effectively allocate scarce water resources.
- Fixed cost +\$43,000

Goal #3: Provide Scientific Data to Protect, Instruct, and Inform Communities

Strategy #1: Monitor and assess natural hazards risk and resilience

The USGS works with its many partners to characterize the potential impact and consequences of natural hazard events on human activity, health, the economy, and the environment. The USGS supports national and global monitoring capabilities and long-term investigations of earthquakes, volcanic eruptions, landslides and geomagnetic storms. Timely and relevant data, maps and assessments are provided to support emergency response and decrease loss of life and property due to a wide range of natural hazards.

The 2017 Budget Request for Natural Hazards is \$149,701,000, a net change of +\$10,688,000 from the 2016 Enacted level.

- Provides hazard science to help protect the safety, security, and economic well-being of the Nation.
- Provides scientific observations, analyses, and research that are critical for the Nation to become more resilient to natural hazards.
- Develops user driven tools (e.g., EEW, ShakeCast, Ash 3D, Our Coasts, Our Future) to support societal needs; and Enable Partners with USGS science, products, and data.

Highlights of changes are as follows with additional detail in the Mission Area section:

Earthquake Hazards Program +\$1,693,000 for a total of \$62,196,000:

- Unconventional Oil and Gas Research: Induced seismicity Earthquake Risk Assessments +\$700,000 for a total of \$3,200,000: To reduce the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts.
- Central and Eastern U.S. Seismic Network Adoption +\$800,000 for a total of \$800,000: To improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159 stations.
- Fixed costs +\$193,000

Volcano Hazards Program +\$117,000 for a total of \$26,238,000:

- Fixed costs +\$117,000

Landslide Hazards Program +\$516,000 for a total of \$4,054,000:

- Natural Hazard Science for Disaster Response: Landslide Response +\$500,000 for a total of \$1,600,000: For improving landslide response by expanding post-wildfire debris flow hazard assessments and growing capability to respond to landslide crises.
- Fixed costs +\$16,000

Global Seismographic Network +\$869,000 for a total of \$7,322,000:

- GSN Primary Sensor Deployment +\$860,000 for a total of \$2,460,000: To deploy and install the new borehole sensors and to improve the physical infrastructure of select GSN sites.
- Fixed costs +\$9,000

Geomagnetism Program +\$1,700,000 for a total of \$3,598,000:

- Improved Geomagnetic Monitoring +\$1,700,000 for a total of \$1,700,000: To provide enhancements in electrical field (E-field) monitoring, the direct measurement of currents in the Earth's crust; and the gathering and integration of existing global magnetic field data. These activities are integral to implementation of the National Space Weather Strategy.
- Fixed costs +\$10,000

Coastal and Marine Geology Program +5,783,000 for a total of \$46,293,000:

- Scenarios for Arctic Actions to Address Imminent Coastal Impacts +\$3,500,000 for a total of \$4,925,000: To allow USGS to shift research staff to work in the Arctic and selected Pacific Islands dealing with impacts of sea-level rise, severe storms, and/or melting permafrost on their coastal communities and economies.
- Building Landscape-Level Resilience to Coastal Hazards +\$2,109,000 for a total of \$6,235,000: The proposed increase would be used to apply research and modeling findings in the Hurricane Sandy (2012) affected areas to other parts of the U.S. coastline.
- Fixed costs +\$174,000

Goal #3: Provide Scientific Data to Protect, Instruct, and Inform Communities

Strategy #2: Provide environmental health science to guide decision making

The USGS Environmental Health program provides data, knowledge, and tools on the occurrence, behavior, and effects of environmental contaminants, including their impacts on susceptible ecosystems and implications for human health and the health of aquatic and terrestrial organisms. These capabilities help: inform decision making made by Federal, State, local, and tribal governments, industry, and the public; resource managers and policy makers assess environmental risks and prevent contamination; regulatory entities make decisions on the licensing and approval of chemicals; and manage, protect, and restore natural resources, contaminated lands, and important natural ecosystems, including trust resources of the Department of the Interior.

The 2017 Budget Request for Environmental Health is \$ 24,560,000 a net change of +\$3,115,000 from the 2016 Enacted level.

Executive Summary

Contaminant Biology Program +\$1,268,000 for a total \$11,465,000:

- Critical Landscapes: Columbia River +\$50,000 for a total of \$100,000: Expand studies of contaminant exposure and the cycling of mercury pesticides in food webs to address important tribal and endangered species of concern in the Columbia River Basin.
- Environmental Impacts of Uranium Mining +\$273,000 for a total of \$673,000: Study the amount of uranium metal and its radiation in birds, mammals, and reptiles, as well as water and dust, near targeted active mines in the Grand Canyon region. The 2017 results will then be compared to the baseline data to measure the environmental impacts of uranium mining and its associated release of radiation beyond what is naturally occurring. This research will support the 15-year multiagency science plan established to inform the decision on whether to lift the Secretary of Interior's moratorium on new uranium mining in the Grand Canyon region until 2032.
- Unconventional Oil and Gas Research +\$900,000 for a total of \$930,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the CBP would expand testing to help add to a body of collaborative research needed for assessment of potential biological effects of UOG development on living organisms, including humans.
- Fixed costs +\$45,000

Toxic Substances Hydrology Program +1,847,000 for a total of \$13,095,000:

- Critical Landscapes: Columbia River +\$50,000 for a total of \$100,000: Continue to investigate the effects of contaminants such as pesticides and mercury on the fish and wildlife in the Columbia River.
- Environmental Impacts of Uranium Mining +\$1,750,000 for a total of \$2,500,000: Expand upon scientific research in the Grand Canyon region on baseline, pre-mining levels of uranium contamination in soils for comparison to contamination levels in soils following uranium mining activities. This research will support the 15-year multiagency science plan established to inform the decision on whether to lift the Secretary of Interior's moratorium on new uranium mining in the Grand Canyon region. Expanded studies will include additional sites and environmental settings (e.g., water), and will include biological sampling. The TSHP will also interpret and analyze the datasets compiled.
- Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast +\$1,300,000 for a total of \$1,300,000: To support coastal resiliency efforts, establish real-time water quality monitoring capabilities in key locations associated with a prototype contaminant network along the northeast coast, and support the development of standard operating procedures for the rapid deployment and mobilization of field crews to collect environmental samples following a hurricane or other coastal disaster.
- Unconventional Oil and Gas Research +\$250,000 for a total of \$1,020,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the TSHP would study the environmental contamination associated with spills and other releases of liquid and solid wastes from unconventional oil and gas development activities at sites in West Virginia (Marcellus Shale) and North Dakota (Williston Basin).

- Emerging Contaminants and Chemical Mixtures -\$750,000 for a total of \$0: A decrease is proposed to help offset proposed increases. The TSHP would discontinue research on environmental contaminants (e.g., mercury, pharmaceuticals, pesticides, etc.), which are used to inform resource management and regulatory decisions about contaminants in drinking and recreational water, as well as water quality of streams, rivers, and groundwater, and to understand environmental and human health risks posed by those contaminants and their mixtures.
- Fate and Transport of Contaminants in the Subsurface -\$800,000 for a total of \$0: A decrease is proposed to help offset proposed increases. Research on the movement of contaminants from their point of origin, through the environment, and to their pathways of exposure would be discontinued.
- Fixed costs +\$47,000

Goal #4: Provide Water and Land Data to Customers

Strategy #1: Monitor and assess water availability and quality

The USGS Water Science Strategy (Strategy), outlined in Circular 1383-G Observing, Understanding, Predicting, and Delivering Water Science to the Nation, identifies water science goals and objectives that serve the Nation and address the water challenges for the future. The Strategy outlines areas where hydrologic science can make substantial contributions to the Nation and identifies opportunities for the USGS to better use its hydrologic science capabilities to address Administration priorities to ensure healthy watersheds and sustainable, secure water supplies. In doing so, the Strategy is intended to inform long-term approaches to the USGS program planning, technology investment, partnership development, and workforce and human capital strategies. The choice of strategic water science priority actions, goals and objectives is based on the guiding principles to observe, understand, predict and deliver water information that allows society to meet the water challenges of the Nation, current and future. While the Strategy does not cover all facets of the USGS work in hydrology, it builds on a hierarchy of planning documents and provides a science-based response to the overarching issues of water availability, water quality, and hydrologic hazards.

Water science actively promotes the use of information by decision makers to: minimize loss of life and property as a result of water-related natural hazards, such as floods, droughts, and land movement; effectively manages groundwater and surface water resources for domestic, agricultural, commercial, industrial, recreational, and ecological uses; protect and enhance water resources for human health, aquatic health, and environmental quality; and contribute to the wise physical and economic development of our Nation's resources for the benefit of present and future generations.

The 2017 Budget Request for the Water Resources Mission Area is \$227,992,000, a net change of +\$17,305,000 from the 2016 Enacted level.

- Aligns with administration priorities related to water challenges and public lands.
- Protects and enhances key operational networks and their information management and delivery systems (i.e., streamgages).
- Protects core mission needs.

Executive Summary

- Enhances decision-support tools that use data from key hydrologic networks and USGS science in order to allow for more informed decision making.

Highlights of changes are as follows with additional detail in the Mission Area section:

Water Availability and Use Program +12,336,000 for a total of \$54,388,000:

- **WaterSMART: Near Real Time Assessment of Water Use During Drought +\$4,000,000 for a total of \$4,000,000:** To develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures.
- **WaterSMART: Water Use Information +\$3,000,000 for a total of \$3,000,000:** To integrate water information that is fragmented among multiple agencies into a national water data framework on a geospatial platform. This funding would support periodic comprehensive analysis of the data to report out on water use trends and provide national water-use indicator analysis, and maps of water stress indicators. In addition, it provides additional funding through grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making.
- **WaterSMART: Water Use Research +\$1,000,000 for a total of \$1,000,000:** To support cooperative matching funds to maximize use of their water use datasets in the water availability and use assessment. In addition, directed work is required to develop better methods of sampling, estimating, aggregating, and presenting water use data. This includes research into new methods that use remote sensing and spatial datasets in water use estimation.
- **WaterSMART: Drought +\$1,000,000 for a total of \$1,984,000:** Conduct a more comprehensive evaluation of data needs and model capabilities for quantifying water budgets across snow-dominated regions of the United States.
- **WaterSMART: Streamflow Information +\$400,000 for a total of \$1,050,000:** To implement StreamStats in three additional States and improve methods for proving the estimates would continue to be investigated.
- **WaterSMART: National Hydrologic Model +\$750,000 for a total of \$750,000:** There is a need to assemble community modeling resources (i.e., datasets, models, use cases) to economize and enhance model development and verification activities across the community. Model development assumes continued community use of legacy models and datasets rather than proposing a new model framework. Such an activity would improve and modernize access to resources that support development, verification, or model application for specific decision situations.
- **Critical Landscapes: Arctic +\$1,950,000 for a total of \$2,200,000:** To assess systems and anticipate future system changes and explore opportunities for predictions that allows extrapolation from monitored to unmonitored locations.
- **Fixed costs +\$236,000**

Groundwater and Streamflow Information Program +1,422,000 for a total of \$72,957,000:

- Tribes +\$500,000 for a total of \$2,500,000: While the USGS is not directly involved with Indian Water Rights settlement, the USGS provides technical information needed to support water rights settlement work that is then given to decision makers. To support cooperative matching funds to enhance streamflow information to support tribal needs and decisions. Monitoring, along with assessments and research, would help address availability issues on tribal lands including such topics as water rights, water use, hydrologic conditions, and water-quality issues.
- Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages +\$700,000 for a total of \$3,260,000: To expand the use of flood inundation mapping and Rapid Deployment Gages (RDGs). Implemented together, the flood-inundation and RDGs systems will provide crucial flood data needed to help manage flood response activities.
- Fixed costs +\$222,000

National Water Quality Program +\$3,547,000 for a total of \$94,147,000:

- Support NAWQA Cycle 3 +1,881,000 for a total of \$63,881,000: Two-thirds, or \$1,262,000 will be used to restore and enhance long-term surface water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for Cycle 3. One-third, or \$620,730 will be used to restore and enhance long-term groundwater water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for the Cycle 3.
- Enhanced Cooperative Activities and Urban Waters +\$717,000 for a total of \$717,000: To support cooperative matching funds that enable similar types of streamflow and water-quality data collection that provide science-based information used by state and local partners to develop plans for economic revitalization, urban water restoration and educational outreach for the general public.
- Unconventional Oil and Gas Research +\$450,000 for a total of \$650,000: To develop and disseminate science-based information and tools needed for a fundamental understanding of the processes that affect the occurrence, transport, fate and effects of contaminants in streams and groundwater affected by UOG extraction activities.
- Fixed cost +\$499,000

Water Resources Research Act - No changes for a total of \$6,500,000.

Goal #4: Provide Water and Land Data to Customers

Strategy #2: Generate Geologic Maps

The USGS conducts national-focused Earth-system science, along with its many partners, to deliver an understanding of the Earth's complex geologic structure. Products include geologic maps, three-dimensional geologic models, interpretive studies, and scientific publications, all of which are essential for informed public policy decision making and economic development. Detailed, accurate information about the nature and origin of the geology of an area, portrayed through geologic maps and three-

dimensional frameworks, is essential for identifying mineral, oil, and gas resources, finding and protecting groundwater, guiding earthquake damage prediction, identifying landslide and post-wildfire hazards, guiding transportation planning, and generally improving the quality of life and economic vitality of the Nation.

The Core Science System request is for an increase of \$89,000 in fixed costs for a total of \$24,486,000. Funds will be used to generate maps.

Goal #4: Provide Water and Land Data to Customers

Strategy #3: Assess national and international energy and mineral resources

The USGS provides research, assessments, maps, and data to understand and communicate national and global energy and mineral resource formation, distribution, and potential. These products are provided to resource managers and policy makers to support informed policy and management decisions on land and resource use and the evaluation of trade-offs and environmental risks.

The 2017 Budget Request for Energy and Minerals is \$74,923,000, a net change of +\$1,857,000 from the 2016 Enacted level.

EMEH provides valuable, objective science and information about our Nation's energy and mineral resources, as well as reliable, impartial science critical to understanding the interaction between the physical environment, the living environment, and human health.

Mineral Resources Program +\$324,000 for a total of \$48,695,000:

- Critical Minerals and Materials Flow Initiative +\$1,022,000 for a total of \$9,484,000: Increase work on identifying and evaluating new sources of critical minerals and continue lifecycle work on critical minerals.
- R&D to Address Environmental Impacts of Minerals Development +\$559,000 for a total of \$5,559,000: For development of new science and tools to reduce the impacts of minerals extraction, production, and recycling on the global environment and human health, including research on supply chain, life cycle, resource sustainability, and minimizing environmental impacts of mineral extraction.
- Geophysical and Remote Sensing Activities -\$1,500,000 for a total of \$1,500,000: A decrease is proposed to help offset increases. This would terminate some geophysical and remote sensing work in different regions of the United States, including Alaska, California, and the mid-continent.
- Fixed costs +\$243,000

Energy Resources Program +\$1,533,000 for a total of \$26,228,000:

- Alternative Energy Permitting on Federal Lands – Geothermal +\$229,000 for a total of \$654,000: Conduct studies on the favorability of geothermal resources, and develop research and technology such as miniature unmanned aerial systems (UAS) to study the potential impacts of geothermal

resource development through heat mapping. Information will be used to inform alternative energy permitting decisions and land use planning decisions on Federal lands by the Bureau of Land Management and other agencies.

- Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment +\$211,000 for a total of \$286,000: Evaluating and developing plans to enhance coastal infrastructure resilience by using an economic approach that uses assessment and valuation of ecosystem services for effective resource management. Utilize the same economic approach to evaluate the use of green infrastructure investments in urban settings.
- Unconventional Oil and Gas Research +\$975,000 for a total of \$6,825,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the ERP would: expand research to help predict the quality and quantity of waste fluids associated with energy production; conduct annual field research in Alaska to support the assessment of undiscovered UOG on the North Slope; expand domestic assessment of shale and tight oil and gas to increase the number of evaluations performed by about two per year; increase cooperative efforts with state geologic surveys to acquire fundamental data needed for UOG assessments; and expand petroleum processes research to improve understanding of the nature of UOG resources.
- Fixed costs +\$118,000

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Crosscutting Activities

Regional and Crosscutting Activities

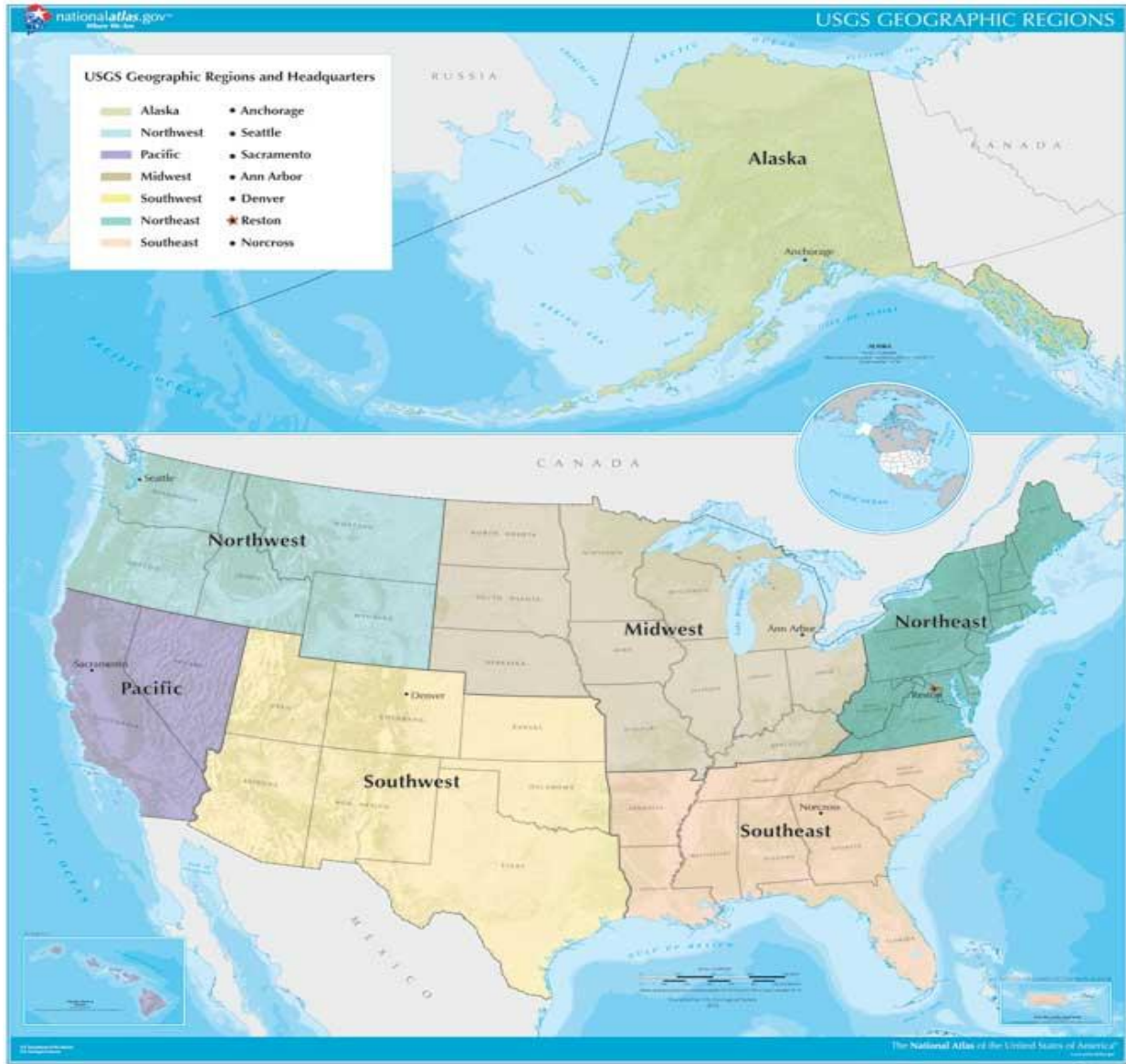
Regional Overview

The U.S. Geological Survey's (USGS) regional construct focuses on priorities and issue-based, integrated science to align the USGS with partners at the local and regional level, and enhances partnerships with Department of Interior (Interior) bureaus and other Federal, State, tribal, and local agencies. The USGS has seven regions and each is led by a Regional Director. The regions receive funding from the science mission areas through programs. Proximity of USGS regional offices and science centers to the Interior field offices and to other partners allows USGS scientists and managers to understand and address land and resource management issues and increase opportunities for partnerships, and leverage resources. Science Centers, located within the regions, ensure the USGS mission science is implemented with the high priority land management, urban planning, and heightened security needs of stakeholders and decision makers.

The regions are significant contributors to Administration and Secretarial crosscutting priorities, such as the Engaging the Next Generation goals, which focus on building the USGS workforce for tomorrow, and engaging citizen scientists who assist the USGS in accomplishing its science mission. The USGS is at the scientific forefront of crosscutting priorities by monitoring and predicting the likelihood and severity of natural disasters, as in the Nation's coastal areas, landslides, earthquake early warning, and volcano effects on air traffic and communities. Restoration efforts built on USGS science in the Chesapeake Bay, the Puget Sound, the San Francisco Bay and Delta, the Florida Everglades, sage steppe, and the Great Lakes improve the health and resilience of ecosystem environments. "In addition to environmental benefits, Federal funds invested in restoration activities cycle through local economies, generating business sales and supporting jobs and income."¹ The USGS engages in research and monitoring of invasive species through regional efforts such as the Burmese pythons in the Everglades, Asian carp in the Great Lakes and Upper Mississippi, and Quagga and Zebra mussels throughout the Nation. The USGS contributes to the Nation's understanding of fish and wildlife health and its impact on communities and businesses, as well as enhancing our understanding of the environmental and human health impacts of resource development on communities throughout the United States. Water challenges are and will continue to impact the United States, whether it is because of drought, flood, availability and use, or quality, and the USGS is invested in helping decision makers by providing real-time information to support and inform management decisions.

¹ New Science Feature: The Economic Impacts of Restoration, USGS Fort Collins Science Center, https://www.fort.usgs.gov/news_item/99588

Regional geographic boundaries and office locations



Crosscutting Activities

As Interior's science bureau, the USGS conducts research fundamental to numerous intradepartmental and interagency crosscutting activities. This work is conducted across all 50 States, Puerto Rico, U.S. Virgin Islands, American Samoa, Commonwealth of Northern Mariana Islands, Guam, and on tribal lands. The USGS reports funding information on over 25 crosscutting activities. A description of each crosscut can be found below. The numbers shown on the table below represent USGS funding being put towards the effort.

Crosscuts (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 Budget Request	Change from 2016 (+/-)
Arctic/Rest of Alaska	51,143	53,393	63,200	+9,807
Asian Carp	5,620	5,620	5,620	0
California Bay Delta/CALFED	8,626	8,626	8,626	0
Chesapeake Bay	12,620	11,991	12,491	+500
Climate Resilience	2,705	2,705	7,191	+4,486
Columbia River/Salmon	3,751	3,751	3,567	-184
Cooperative Landscape Conservation	57,589	57,289	63,003	+5,714
Engaging the Next Generation	30,215	30,215	32,778	+2,563
Everglades	7,313	7,313	7,313	0
Great Lakes	18,826	18,826	19,076	+250
Gulf Coast	31,249	31,249	31,249	0
Indian Water Rights Settlements	2,000	2,000	2,500	+500
Invasive Species	17,831	18,831	21,378	+2,547
Klamath	732	732	982	+250
Maintaining America's Heritage	35,732	35,732	40,816	+5,084
Native American	3,811	3,811	5,522	+1,711
Powering Our Future	37,066	34,721	39,054	+4,333
Ocean, Coastal, and Great Lakes	96,380	96,354	103,137	+6,783
Puget Sound	4,277	4,277	4,277	0
Quagga & Zebra Mussels	478	478	478	0
Research and Development	665,845	676,914	736,323	+59,409
Sage Steppe Landscape	3,511	3,511	6,511	+3,000
Upper Mississippi River	7,568	7,568	7,568	0
Water Challenges	16,480	18,709	37,064	+18,355
White-nose Syndrome	1,001	1,501	1,501	0

Regional and Crosscutting Activities

Arctic/Rest of Alaska

Region: Alaska

State: Alaska

DOI Cooperators: Bureau of Indian Affairs, Bureau of Land Management, Bureau of Ocean Energy Management, National Park Service, and U.S. Fish and Wildlife Service

Arctic/Rest of Alaska (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	11,928	11,928	12,928	+1,000
Climate and Land Use Change	6,542	6,542	8,899	+2,357
Energy and Mineral Resources, and Environmental Health	6,475	6,975	6,475	-500
Natural Hazards	20,073	20,073	23,573	+3,500
Water Resources	2,225	2,653	4,603	+1,950
Core Science Systems	3,900	5,222	6,722	+1,500
Total	51,143	53,393	63,200	+9,807

The Arctic is being altered by climate change faster than any other region on Earth, and the resulting environmental, social, and economic impacts are significant. Rapid coastal erosion threatens villages and critical infrastructure, greenhouse gas emissions from thawing permafrost are increasing, invasive species are a growing threat, and the cultural and natural resources upon which the people of the Arctic rely are facing dramatic change. The United States is one of eight Arctic nations responsible for the stewardship of the polar region, and the USGS is focused on landscape scale climate, ecosystem, and resource issues to provide a scientific foundation for understanding the physical processes that shape the Arctic. Whether leading the first effort to digitally map Alaska, understanding the effects of sea-ice loss on endangered polar bears, or creating the first publicly available assessment of the petroleum resources north of the Arctic Circle, USGS science is informing the Nation's resource management policies and improving the stewardship of the Arctic region. The proposed increases in 2017 would be used to fund research to support actionable science to communities and land managers about how changes in the Arctic affect the broader physical environment: altering stream flows, disrupting ocean currents and the fisheries that depend on them, and changing ecosystems and the availability of resources. As development continues for many parts of the Arctic, but especially Alaska's Arctic Slope, this investment honors commitments to communities and observes our stewardship responsibilities for resources in an environment of great change.

Asian Carp

Regions: Midwest, Northeast, Northwest, Southeast, Southwest

States: Illinois, Indiana, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Wisconsin

DOI Cooperators: U.S. Fish and Wildlife Service

Asian Carp (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	5,620	5,620	5,620	0
Total	5,620	5,620	5,620	0

Brought to the United States in the 1970s to control algae and as food for people, Asian carp are now a troublesome invader in waterways in the Mississippi River Basin, and are now threatening the Great Lakes. These fish compete with and often beat out native fish for food sources, dramatically changing the environment in which they live and threatening the survival of native fish, some of which have great economic value or are at-risk species. Silver carp, a species of Asian carp, also leap from the water when startled, posing a safety threat to boaters, water skiers, and other recreationalists. The USGS is providing critical information to resource managers to help control and prevent Asian carp invasions. Using satellite images, scientists are able to detect where algae, a carp food source, could sustain carp populations in Lake Erie, evaluating the likelihood of eggs hatching in rivers in the Upper Mississippi Basin, and investigating carp deterrent techniques, including recordings of boat motors and other sounds played underwater. The USGS carries out these efforts as part of the Administration’s Asian Carp Regional Coordinating Committee, a group of Federal, State, and local agencies and other private stakeholders, to protect and maintain the integrity and safety of the Great Lakes ecosystem from an Asian carp invasion. Asian carp science is also a priority of the multi-agency Great Lakes Restoration Initiative, for which the USGS plays an instrumental role.

California Bay-Delta

Region: Pacific

State: California

DOI Cooperators: Bureau of Reclamation, U.S. Fish and Wildlife Service

California Bay Delta/CALFED (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Delta Science Program Oversight	662	662	662	0
Ecosystems	1,442	1,685	1,685	0
Energy and Mineral Resources, and Environmental Health	116	116	116	0
Natural Hazards	659	659	659	0
Water Resources	4,837	4,594	4,594	0
Core Science Systems	910	910	910	0
Total	8,626	8,626	8,626	0

The San Francisco Bay and Sacramento-San Joaquin Delta (Bay-Delta) form one of the largest estuaries in the United States. The California Bay-Delta system provides water to more than 25 million California residents and vast farmlands, as well as key habitat for birds, fish, and other wildlife. The Bay-Delta forms one of the largest estuaries in the Nation, providing unique habitat for a great variety of birds, fish, and other wildlife. Yet the Bay-Delta also faces significant stressors. California is in one of the worst droughts in its history. Earthquakes and subsidence (the collapsing of the Earth’s surface due to farming on peat soils and/or groundwater pumping and other factors) both threaten the levees in the Delta and the infrastructure that carries much of that water to the more populated parts of the State in the Bay Area and Southern California. To help ensure the function and sustainability of this crucial estuary, the USGS—in close cooperation with partner agencies and organizations—is providing science essential to addressing societal issues associated with water availability, environmental contamination, animals and habitat, natural hazards, land subsidence, and climate impacts. Through a mix of reimbursable and appropriated funding, the USGS operates management-critical programs that monitor the effect of salt-water intrusion, contamination, and pesticide runoff. USGS experiments have successfully reversed subsidence due to peat oxidation, and scientific research is projecting the hazards posed by earthquakes and the effects of sea level rise on the stability of the water-transporting levee system, and is assessing the health of threatened species and commercially important fish in the Bay-Delta. These data are used daily by State and Federal water managers to balance the needs of California’s communities, agriculture, and endangered species, as well as for long-term strategic planning for water development. The USGS is a major partner in Bay-Delta science, with a total 2015 monitoring and research portfolio of about \$20 million, including more than \$8.6 million from the USGS and about \$12 million in reimbursable support from local and Federal partners.

Chesapeake Bay

Region: Northeast

States: Delaware, District of Columbia, Maryland, New York, Pennsylvania, Virginia, West Virginia

DOI Cooperators: National Park Service and U.S. Fish and Wildlife Service

Chesapeake Bay (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	5,009	5,009	5,009	0
Climate and Land Use Change	1,679	1,679	1,679	0
Energy and Mineral Resources, and Environmental Health	1,669	1,669	1,669	0
Water Resources	4,263	3,634	3,634	0
Core Science Systems	0	0	500	+500
Total	12,620	11,991	12,491	+500

Stretching from southern New York State to southern Virginia, the Chesapeake Bay watershed is home to almost 20 million people, more than double the region’s population in 1950, and the Bay itself is America’s largest estuary and the source for a seafood industry and other services worth about \$1 billion. Balancing the needs of a massive population while restoring the Bay’s natural resources presents a great challenge, as water quality, the seafood economy, wildlife, and coastal communities have suffered from pollution, rapid development, rising sea levels, disease, invasive species, and more. The importance of the Bay, along with the significance of the threats it faces, were underscored by President Obama’s signing of an Executive Order to restore and protect the Bay and its watershed, and USGS science is helping make wise decisions in response. Whether it is monitoring the nutrients causing the oxygen-deficient “dead zones” in the Bay, identifying contaminants causing male fish to develop female physical traits, or forecasting how the loss of tidal marshes will threaten coastal communities with rising sea levels, the USGS is working to help decision makers, land managers, and citizens meet their resource needs and protect the natural abundance and beauty of Chesapeake Bay. The proposed 2017 budget increase would support systematically collecting high-quality lidar over the Eastern Shore of the Chesapeake Bay. New, more accurate baseline elevation data will provide information on landscape processes at the parcel and local scales, allowing regional decision makers to design and improve sustainable development and natural resources management strategies.

Climate Resilience

Regions: All

States: Nationwide

DOI Cooperators: Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service

Climate Resilience (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	1,030	1,030	1,570	+540
Climate and Land Use Change	0	0	1,003	+1,003
Natural Hazards	1,425	1,425	3,315	+1,890
Water Resources	250	250	1,303	+1,053
Total	2,705	2,705	7,191	+4,486

The incidence of natural disasters has increased by nearly five times since the 1970s according to a report by the World Metrological Organization, a specialized agency of the United Nations. Nearly 3,500 natural disasters occurred just during the first decade of the 21st century. The changing climate has been tied to the increased occurrence of natural disasters including floods, drought, wildfire, and mega-storms. Our Nation's coasts are particularly vulnerable to natural hazards, as is the Arctic. The need to understand the nature of coastal, social, and economic environments and their interaction is critical in ensuring a sustainable future thus needing to build resilience. The USGS provides critical science needed to inform decision making for environmental management and for mitigating and adapting to climate change. The projects proposed in this crosscut will help build resilient landscapes that will be better able to ward off damage from hurricanes, wildfires, sea level rise, and other natural disasters.

Columbia River/Salmon

Region: Northwest

States: Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

DOI Cooperators: Bureau of Indian Affairs, Bureau of Reclamation, and U.S. Fish and Wildlife Service

Columbia River/Salmon (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	3,274	3,274	3,274	0
Climate and Land Use Change	284	284	0	-284
Energy and Mineral Resources, and Environmental Health	100	100	200	+100
Water Resources	93	93	93	0
Total	3,751	3,751	3,567	-184

The Columbia River system, spanning from British Columbia to Nevada and from Wyoming to Oregon, is home to about eight million people, including tribal Nations, as well as one of the most important salmon habitats in the world, including 13 federally listed salmonids. Urbanization, recreation, commercial fishing, hydropower, and agriculture have all had profound impacts on the Basin’s aquatic habitat and fish populations, with salmon a particular concern. Hydropower generation is a key feature of this landscape. The USGS is working to help political, land and water management, and tribal leadership all better manage this ecosystem by assessing the effects of dam operations, tracking salmon populations by using revolutionary techniques to gather DNA right from the water, assisting in restoration of tribal first foods including lamprey, discovering chemicals in other fish species that are harmful to humans, and informing Interior’s Columbia River Treaty recommendations to the Department of State. Considerable research on Columbia River climate change issues has occurred over the past five years, including producing fine-scale regional climate models that advance the next generation of climate-hydrology simulations, and producing a map of priority areas for the riparian and riverine landscape, with a stressors and threats analysis, and an assessment of resiliency to climate change.

To help managers address immediate threats, which would increase the resiliency of the system to climate change effects, the USGS is now focusing its efforts in the Columbia River Basin on research related to contaminants. USGS Environmental Health researchers, funded by the Contaminant Biology Program and the Toxic Substances Hydrology Program, are conducting contaminant exposure studies to better understand the effects of pesticides, mercury, and other potential disease agents in fish, and are examining the potential for these contaminants to travel through food webs in this critical Pacific Northwest ecosystem. In 2017, the Contaminant Biology Program (CBP) and the Toxic Substances Hydrology Program (TSHP) are each requesting an additional \$50,000, for a total of \$100,000, to expand research on the effects of mercury and pesticides on food webs and on fish and wildlife in the Columbia River Basin. Specifically, with the proposed increase, the CBP would conduct new studies focusing on sturgeon, and would collect, archive, and study small mouth bass for potential exposure to endocrine disrupting chemicals, and the TSHP would expand their existing studies on aquatic and terrestrial organisms potential impacted by mercury as well as endocrine disrupting chemicals. This work, combined with that

Regional and Crosscutting Activities

of other USGS mission areas, contributes to a scientific body of knowledge valuable to environmental and public health stewardship in the Columbia River Basin.

Cooperative Landscape Conservation/U.S. Global Change Research Program

Region: All

States: Nationwide

DOI Cooperators: Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service

Cooperative Landscapes Conservation (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Climate and Land Use Change	57,589	57,289	63,003	+5,714
Total	57,589	57,289	63,003	+5,714

Understanding the causes and consequences of climate change, and the vulnerability and resilience of natural and human environments is a complex challenge. The USGS is taking on that challenge by providing information and tools that focus on past and present responses of habitats to a range of climate and environmental changes throughout history in order to model and forecast impacts of future changes. The Cooperative Landscape and Conservation crosscut provides the scientific information and tools needed to understand the impacts of a changing climate, the causes and consequences of climate change and the vulnerability and resilience of the Earth system to such changes. The research focuses on past and present responses of ecosystems and habitats to a range of climate and environmental changes throughout history in order to model and forecast impacts of future changes. This work also supports partnerships with natural and cultural resource managers and scientists from inside and outside of government to gather the information and build the tools needed to help fish and wildlife and their habitats and ecosystems adapt to the impacts of climate change, and prioritize the delivery of science, research data products, and decision-support tools that are usable and focused on key priorities—as defined by managers—and are delivered to users effectively. The 2017 proposed increase includes activities to support WaterSMART Drought, implement a Great Lakes regional Climate Science Center, and helps Tribes to better understand the potential climate change effects on culturally-important fish and wildlife resources, and integrate tribal and indigenous traditional ecological knowledge with more traditional science in management decisions.

Engaging the Next Generation

Region: All
States: Nationwide
DOI Cooperators: All

Engaging the Next Generation (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Mendenhall Research Fellows Program	4,500	4,500	5,000	+500
Ecosystems	17,371	17,371	18,234	+863
Water Resources	6,500	6,500	6,500	0
Core Science Systems	507	507	507	0
Science Support	1,337	1,337	2,537	+1,200
Total	30,215	30,215	32,778	+2,563

The USGS is committed to growing the next generation of Earth scientists and will continue to invest in programs that develop science, technology, engineering, and mathematics (STEM) skills to ensure the success of that goal. The USGS captures major investments from programs that develop our future workforce by hiring, mentoring, and engaging young people between the ages of 15 and 35, in the science and science support mission of the USGS. Programs like the Cooperative Research Units (CRU), located in the Ecosystems mission area, engage in scientific research, technical assistance to natural resources managers, and training for future natural resource professionals. These objectives are achieved using undergraduate and graduate students, and postdoctoral associates. CRU scientists advised and mentored 534 STEM graduate students in 2015. The CRU also sponsors undergraduate and graduate education programs that focus on minority student recruitment and career training in natural resources, such as the Doris Duke Conservation Scholars Program, whose mission is to increase the number of undergraduate students from groups currently underrepresented in the workforce who choose to pursue studies and a career in conservation. EDMAP, the educational component of the National Cooperative Geologic Mapping Program located in Core Science Systems, has realized its return on investment by educating Earth science students in the skills of geologic field mapping and scientific research, while providing them the necessary experiences to become successful in STEM career fields. The program works closely with GeoFORCE, a University of Texas/Austin program that engages high school students from underserved communities in the Earth sciences, by encouraging the graduates of this four-year high school science experience to work with the USGS throughout their college education. The program in its 19th year has provided funding for 1,160 students who have gone on to STEM careers in higher education, industry, and government. The Water Resources Research Act (WRRRA) of 1984 established a Federal–State partnership in water resources research, education, and information transfer through a matching grant program. The WRRRA Program plans, facilitates, and conducts research to aid in the resolution of State and regional water problems. The program promotes technology transfer and the dissemination of research results while providing for the training of the next generation of scientists and engineers through their participation in research. The Mendenhall Research Fellowship Program (Mendenhall Program) is the flagship postdoctoral research program for the USGS. Established in 2001, this program has grown into one of the most prestigious and coveted postdoc programs in science. Through the Mendenhall

Regional and Crosscutting Activities

Program, the USGS obtains some of the best available new PhD talent to address the needs of its science mission. Every year, the prestigious Mendenhall Program draws outstanding student scientists mentored by USGS senior scientists. Other youth programs such as the Student Interns in Support of Native American Relations (SISNAR) target and attract a wide range of diverse and incredibly talented young people to cultivate a robust future USGS workforce. The USGS Youth and Education in Science Office partners with programs to help fund the hiring of interns and provides a conduit to assist managers in navigating the hiring process. The crosscut also includes youth activities to challenge students to develop new ways of thinking and being studious about their surroundings, adopting habits and skills for understanding how science works. For example, participants of the Native Youth in Science – Preserving our Homelands summer program, are introduced to science in coordination with traditional ecological knowledge (TEK), to use as a tool to protect and preserve the ecosystems and homelands of their Tribe. The USGS has developed relationships with other organizations, such as the National Science Foundation, to implement programs like the Graduate Research Internship Program (GRIP) in 2016. The USGS will continue to leverage initiative funding with program base funding to: (1) maximize impact when hiring and engaging young people to partner on outreach efforts to reach teachers and students in learning activities (Education Web site); (2) maximize our volunteer and citizen scientist contributions; and (3) build our future workforce. The Ecosystems, Core Science Systems, Water Resources and Science Support Mission Areas report funding for the Engaging the Next Generation crosscut activity.

The proposed 2017 increase in outreach to underserved communities (\$200,000) would be used to provide undergraduate students, from groups underrepresented in the science and conservation workforce, such as the Native Youth in Science summer camp, Alaska Native Science and Engineering Program (ANSEP) Summer Bridge and University Success programs, the Doris Duke Conservation Scholars Program, and Native Hawaiian Internship program with mentoring and hands-on experiences designed as a pathway to Interior recruitment. In addition, the CRUs would enhance support toward the training, mentoring, and support of science, technology, engineering, and mathematics (STEM) graduate and post-doctoral associates from underrepresented groups (\$863,000). The funding increase for the Mendenhall Research Fellowship Program (\$500,000) would be used to recruit Mendenhall Fellows to carry out postdoctoral research projects that cover the entire spectrum of USGS science. This increased funding will provide stability to the program, insightful and critical thinking to USGS science mission areas, and the opportunity for the establishment of a consistent high standard for projects and researchers. The requested increase would enable the Youth and Education in Science program (\$1.0 million) to build on existing youth hiring and outreach activity investments within science mission areas, as noted above, which contribute directly to STEM capabilities for the Nation, and introduce future scientists to the value of public service in the Earth and biological sciences.

Everglades

Region: Southeast

State: Florida

DOI Cooperators: Bureau of Indian Affairs, National Park Service, and U.S. Fish and Wildlife Service

Everglades (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	5,365	7,313	7,313	0
Water Resources	1,948	0	0	0
Total	7,313	7,313	7,313	0

The Everglades ecosystems contain diverse environments that stretch from the middle of the Florida peninsula to Florida Bay. The unique resources and conditions the Everglades helped to shape the course of history and development in South Florida and remain a key component of the physical and economic landscape. In addition to supporting a \$300.0 million sport fishery and a \$100.0 million commercial fishery, the Florida Bay waters are home to many marine animals such as dolphins, manatees, and sea turtles. In addition to their importance in Florida, the Everglades ecosystems have been designated as a World Heritage Site and an International Biosphere Reserve, drawing tourists and nature enthusiasts from around the world. South Florida is particularly vulnerable to the introduction and spread of invasive plants and animals and is highly colonized by a wide variety of exotic species such as water hyacinth, melaleuca, old world climbing fern, Burmese python, and the Tegu lizard. The USGS conducts research to fill key science information gaps and to assist in the sustainable use, protection, and restoration of the South Florida ecosystem through the Comprehensive Everglades Restoration Plan (CERP) and in partnership with the South Florida Ecosystem Restoration Task Force (SFERTF). Research efforts include investigations of wildlife habitat responses to natural and human disturbances, including modeling of flow impacts, studies of specific vertebrate species, invasive species (plant and animal) impacts on the native ecosystem, vegetation responses, and linking science results to support adaptive management.

Great Lakes

Regions: Midwest and Northeast

States: Great Lakes Basin – Illinois, Indiana, Minnesota, Michigan, New York, Ohio, Pennsylvania, Wisconsin

DOI Cooperators: Bureau of Indian Affairs, National Park Service, and U.S. Fish and Wildlife Service

Great Lakes (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	12,919	12,919	13,169	+250
Climate and Land Use Change	250	250	250	0
Water Resources	5,657	5,657	5,657	0
Total	18,826	18,826	19,076	+250

The Great Lakes are the largest group of freshwater lakes on Earth and serve as an important source of drinking water, transportation, power, and recreational opportunities for the United States and Canada. They also support an abundant commercial and recreational fishery that generates \$7.0 billion annually, are crucial for agriculture, and are essential to the economic vitality of the region. The Great Lakes support a wealth of biological diversity, including over 200 globally rare plants and animals and more than 40 species that are found nowhere else in the world. However, more than a century of environmental degradation has taken a substantial toll on the Great Lakes. To revitalize and preserve a healthy Great Lakes region for the people, plants, and animals that rely on the freshwater system, the USGS is working with Interior bureaus and other agencies to provide scientific tools for strategic decision making in restoration efforts. USGS research includes long-term, consistent, lake-wide assessments of forage fish stocks that support sport and commercial fish species; monitoring invasive species for protection and restoration of Great Lakes fisheries; beach health and monitoring; and developing scientific and technological monitoring tools to assess and conserve aquatic species. The USGS also operates five large research vessels, ranging in length from 70 to 107 feet, with one vessel stationed on each of the Great Lakes. These vessels are essentially floating laboratories to conduct ecosystems research through the USGS Great Lakes Science Center. The proposed 2017 budget request would allow the USGS to pilot a change in the way that fisheries assessments are done in the Great Lakes, moving to the use of Long Range Autonomous Underwater Vehicles and pilot a project where offshore sample processing of water in the Great Lakes would be used to provide an early warning system regarding Harmful Algal Blooms. In addition to the appropriated work reflected in the Great Lakes crosscut, the USGS also receives reimbursable funds from the Environmental Protection Agency, which administers the Great Lakes Restoration Initiative (GLRI). The GLRI targets the highest priority environmental issues in the Great Lakes, such as contaminated sediments and toxics, habitat degradation and loss, invasive species, and rainfall/snowmelt water pollution from many diffuse sources, which is the leading remaining cause of water-quality problems. The USGS has led over 133 projects to tackle these challenges, and continues to work closely with community stakeholders and GLRI partners to provide water managers at State and local levels with valuable information to make informed decisions regarding the potential effects of future water use. Over the course of three fiscal years (2013-2015), the USGS has received \$54.1 million in

reimbursable funds for work performed by the Ecosystems and Water Resources Mission Areas. In 2016, it is anticipated that the USGS will be receiving an additional \$14.0 million in GLRI reimbursable funds.

Gulf Coast

Region: Southeast

States: Alabama, Florida, Louisiana, Mississippi, Texas

DOI Cooperators: Bureau of Indian Affairs, Bureau of Ocean Energy Management, National Park Service, and U.S. Fish and Wildlife Service

Gulf Coast (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	7,531	7,531	7,531	0
Climate and Land Use Change	2,177	2,177	2,177	0
Water Resources	18,300	18,300	18,300	0
Core Science Systems	3,241	3,241	3,241	0
Total	31,249	31,249	31,249	0

The Gulf Coast is an economically important yet ecologically vulnerable region that is home to more than 20 million people and a rich assortment of wildlife. The yearly Gross Domestic Product of the five Gulf Coast States combined exceeds \$2 trillion and the economy of the region, which is highly dependent on its natural resources, is driven by crude oil production, commercial fishing, and recreation and tourism. The USGS supports the Gulf through various scientific initiatives including coastal restoration and landscape analysis, climate change impact studies, and indigenous and invasive species research. USGS science—including critical water sampling and mapping data to help understand the effects of the Deepwater Horizon oil spill; contributions to the National Oceanic and Atmospheric Administration’s annual Gulf of Mexico hypoxia zone survey, which measures the size of the oxygen-deficient, uninhabitable area of the Gulf; and research on a diverse cross section of invasive species like nutria, Burmese pythons, Argentine tegu and lionfish to determine their effects, methods of detection, and means of control—has provided great insight into this vital region.

Indian Water Rights Settlements

Regions: All

States: Arizona, California, Colorado, Florida, Idaho, Iowa, Maine, Michigan, Minnesota, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Oklahoma, Oregon, South Dakota, Washington, Wisconsin, Wyoming

DOI Cooperator: Bureau of Indian Affairs

Other Cooperators: Federally recognized Tribes, other Federal agencies, States, localities

Water Rights Settlements (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Water Resources	2,000	2,000	2,500	+500
Total	2,000	2,000	2,500	+500

The USGS is not directly involved with Indian Water Rights settlement. The USGS instead provides technical information needed to support water rights settlement work that is then given to decision makers. USGS scientists work closely with tribal leaders around the country to address water availability issues related to quantity and quality on tribal lands. USGS coordinated efforts with Tribes span a wide variety of activities across the Nation involving, for example, monitoring within an extensive network of USGS streamflow gages and groundwater monitoring stations; training; data management; Geographic Information Systems (GIS); quality control; development of models and decision-making tools; and scientific research on how natural, climatic, land use, water use, and other human factors can affect the water cycle, water quantity, and quality. It is important to note this funding is cooperative matching funds and so there is another \$4.0 million of reimbursable funding tied to these activities. The 2017 budget request includes an increase to continue to work closely with tribal leaders to conduct water resource investigations to address such topics as water rights, water supply, flood-warning predictions, contamination, and sustainability of critical habitats and healthy ecosystems.

Invasive Species

Regions: All

States: Nationwide

DOI Cooperators: Bureau of Land Management, Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service

Invasive Species (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Early Detection/Rapid Response				
Ecosystems	2,971	2,971	3,804	+833
Research				
Ecosystems	14,860	15,860	17,574	+1,714
Total	17,831	18,831	21,378	+2,547

More than 6,500 invasive species, including nutria, Burmese pythons, Chinese mystery snails, sea lamprey, lionfish, cheatgrass, common reed, Chinese tallow trees, and cactus and gypsy moths are established in the United States. The annual environmental, economic, and health-related costs of invasive species exceed \$120 billion. Invasive species adversely affect every State in the country, including urban centers and wilderness areas. Increased global travel and trade provide pathways for both intentional and unintentional introductions of invasive species. Key components of USGS invasive species activities include prevention, monitoring and forecasting threats, and control and management of established invaders. USGS researchers work collaboratively on all significant groups of invasive organisms in terrestrial and aquatic ecosystems in all regions of the United States to prevent their spread, invasion, and harmful effects on native species, ecosystems, and human health. The proposed 2017 increase would allow development, evaluation, and improvement of tools for early detection and control of existing and emerging invasive species. The USGS would develop and improve the power of advanced molecular detection tools to detect invasive species at very low densities in the field, such as sea lamprey.

Klamath

Regions: Northwest, Pacific

States: California, Oregon

DOI Cooperators: Bureau of Indian Affairs, Bureau of Reclamation, and U.S. Fish and Wildlife Service

Klamath with KBRA (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Upper Klamath	570	570	820	+250
Ecosystems	271	271	521	+250
Water Resources	299	299	299	0
Lower Klamath	163	163	163	0
Ecosystems	13	13	13	0
Water Resources	150	150	150	0
Total	732	732	982	+250

The Klamath Basin covers more than 15,000 square miles in southern Oregon and northern California. Upper Klamath Lake, the primary body of freshwater within the basin, is home to federally recognized endangered species as well as the source of water for agricultural irrigation. The Klamath Tribes have a stake in maintaining instream flows for fish and wildlife. The USGS work in the Klamath region includes research on endangered suckerfish, the effects of harmful algal blooms, and general fish health studies in addition to monitoring streamgages, runoff modeling, and climate variability studies. The USGS studies and data collection are aimed at providing information to Federal, State, and tribal decision makers in managing resources, guiding restoration actions, monitoring ecosystem health, and reducing risks to humans and biota. For example, the USGS funds and operates 13 streamflow gaging stations in Oregon and California for purposes of flood forecasting and warning, managing water for agriculture, and maintaining instream flows and lake levels for threatened and endangered species. The proposed 2017 budget request would allow the USGS to pilot a change in the way that fisheries assessments are done in the Great Lakes, moving to the use of Long Range Autonomous Underwater Vehicles and pilot a project where offshore sample processing of water in the Great Lakes would be used to provide an early warning system regarding Harmful Algal Blooms. Once successfully developed in the Great Lakes, these technologies can be applied to a wide range of fisheries, water quality, and beach health issues, and will have wide-ranging application and transfer potential to monitoring and research in other freshwater and marine environments such as the Klamath Basin.

Maintaining America’s Heritage

Regions: All

States: Nationwide

Maintaining America's Heritage (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
DMCI Projects	5,972	5,972	5,865	-107
Operations and Maintenance	28,452	28,452	28,824	+372
Operations and Maintenance Stewardship	0	0	2,712	+2,712
Sustainability Investments	0	0	2,000	+2,000
Renovate/Repair Cableways	240	240	240	0
Replace Earthquake Network Stations	200	200	200	0
Condition Assessments (CA)	210	210	315	+105
Facility Maintenance Mgmt. Systems (FMMS)	350	350	360	+10
Project and Management Support	308	308	150	-158
Sustainability	0	0	150	+150
Facilities Total	35,732	35,732	40,816	+5,084

The USGS maintains a unique portfolio of scientific research facilities and equipment. The USGS has among its facilities:

- One of only two biosafety level-3 labs in the country at the National Wildlife Health Center (NWHC) in Madison, WI. This purpose-built lab allows the NWHC to work to protect wildlife much like the Centers for Disease Control and Prevention works to protect human health.
- A premier facility for examining, sampling and analyzing ice cores from some of the most remote places on Earth at the National Ice Core Laboratory (NICL) in Denver, CO. NICL scientists use core samples to better understand the effects of climate change by studying past climate fluctuations. The NICL is not a facility owned by the USGS, but it our responsibility to operate and maintain it for the National Science Foundation.
- One of the largest computer complexes within the Department at the Earth Resources Observation Science Center (EROS) in Sioux Falls, SD. EROS is specifically located and equipped to collect, process, and distribute remotely sensed land data and archive for users worldwide as Landsat satellites pass over the United States.

Deferred Maintenance and Capital Improvements (DMCI)—which includes facilities projects, equipment maintenance, maintenance management, condition assessment, and project planning—and operations and maintenance work hand-in-hand to provide an environment where groundbreaking science can happen. The proposed 2017 increase would provide the bureau the ability to complete annual operations and maintenance responsibilities and would ultimately have a positive impact on the science programs, decreasing the amount of science dollars needed to cover the existing rent and operations and maintenance shortfall. The increase would also help the USGS meet the Energy and Greenhouse Gas

Regional and Crosscutting Activities

reduction goals of Executive Order 13693: Planning for Federal Sustainability in the Next Decade, and improve the aging energy systems at USGS owned facilities that are approaching or have already exceeded their useful life.

Native American Activities

Regions: All

States: Alaska, Arizona, California, Colorado, Florida, Hawaii, Idaho, Louisiana, Massachusetts, Minnesota, Missouri, Montana, Nebraska, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Oregon, South Dakota, Virginia, Washington, Wisconsin

DOI Cooperators: Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, National Park Service, U.S. Fish and Wildlife Service

Native American Activities (Dollars in Thousands)	2015 Base	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
USGS	3,811	3,811	5,522	+1,711
Total	3,811	3,811	5,522	+1,711

Combining traditional ecological knowledge with empirical studies allows the USGS and Native American governments, organizations, and people to increase their mutual understanding and respect for this land. The USGS provides information to Tribes as part of our basic mission of providing unbiased scientific information to the Nation, and as part of the Federal Trust Responsibility to Tribes. USGS coordinated efforts with Tribes span a wide variety of monitoring and research activities involving, for example, an extensive network of streamgages and groundwater monitoring stations and scientific assessments on how natural, climatic, land use, water use, and other human factors can affect the water cycle, water resources, and ecosystems. In addition, the USGS continues to support opportunities for the integration of indigenous knowledge systems and Western science, develop innovative programs such as the Native Youth in Science – Preserving Our Homelands summer camp, and engage in USGS tribal outreach efforts, such as those for Tribes affected by Hurricane Sandy, that demonstrate to Indian Country how the USGS “gold standard” of research can help to address tribal science needs. The USGS works with partners, such as Alaska Native Science and Engineering Program, to increase the number of indigenous Americans in science, technology, engineering and mathematics (STEM) degrees.

The 2017 funding increase will enable Climate Science Centers, and the Office of Tribal Relations, to address the needs of Tribes to better understand the potential climate change effects on culturally-important fish and wildlife resources, and help integrate tribal and indigenous traditional ecological knowledge with more traditional science in management decisions. The Office of Tribal Relations will also make existing partnerships more robust by enhancing and expanding outreach coordination efforts among Tribes and USGS regions. This is essential to fulfilling the Federal Tribal Trust Responsibility, in light of the fact that tribal communities are disproportionately affected by environmental challenges and frequently operate on minimal budgets, and thus benefit greatly from the science information.

Powering Our Future

Regions: All

States: Arizona, California, Colorado, Hawaii, Idaho, Iowa, Kansas, Massachusetts, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, New York, North Dakota, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Washington, West Virginia, Wyoming

DOI Cooperators: Bureau of Indian Affairs, Bureau of Land Management, Bureau of Ocean Energy Management, National Park Service, and U.S. Fish and Wildlife Service

Powering Our Future (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Conventional Energy	30,557	28,212	31,966	+3,754
Ecosystems	1,108	1,108	1,458	+350
Energy and Mineral Resources, and Environmental Health	22,944	21,669	24,123	+2,454
Natural Hazards	2,500	2,500	3,200	+700
Water Resources	1,820	750	1,200	+450
Core Science Systems	2,185	2,185	2,185	0
Renewable Energy	6,509	6,509	6,888	+379
Ecosystems	2,196	2,196	2,346	+150
Climate and Land Use Change	154	154	154	0
Energy and Mineral Resources, and Environmental Health	3,806	3,806	4,035	+229
Natural Hazards	353	353	353	0
Total	37,066	34,721	38,854	+4,133

As the Nation works to ensure a steady supply of energy resources through responsible and sustainable resource development, reliable energy science is more important than ever to ensuring our Nation’s economic security and environmental health. USGS scientists provide unbiased, reliable energy assessments needed to better understand our Nation’s energy resource supply and the impacts of its development on wildlife, ecosystems, and land and water resources. Both conventional energy sources (including fossil fuels) and renewable energy sources (including wind, solar, biofuels, and geothermal energy) comprise our Nation’s domestic energy supply mix. Understanding the availability of these domestic resources, and how to develop them safely and responsibly, is critical to reducing our climate-changing greenhouse gas emissions, curbing our dependence on foreign energy resources, promoting growth of new industries in the United States, and protecting human health and the health of our environment. In addition to energy resource assessments, the USGS conducts research aimed at understanding and reducing the potential environmental, health, and safety impacts of resource development related to unconventional oil and gas and renewable energy development activities. Federal regulatory agencies and policymakers alike rely on unbiased data from the USGS to make significant decisions that influence national energy policy, economic security, and human and environmental health. The 2017 budget request provides program increases across USGS mission areas to support science to advance understanding of conventional and unconventional energy resources, including increases for

Regional and Crosscutting Activities

science to inform geothermal energy permitting on Federal lands and research to understand the scale and nature of unconventional oil and gas resources, as well as the potential environmental and human health impacts of unconventional oil and gas development.

Ocean, Coastal, and Great Lakes

Regions: *Coastal Regions and Great Lakes Region*

States: *Alabama, Alaska, California, Connecticut, District of Columbia, Florida, Georgia, Hawaii, Illinois, Indiana, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Virginia, Washington, Wisconsin, and also U.S. Territories, Free Associated States, and the Exclusive Economic Zone (EEZ), which is America's submerged lands out to 200 nautical miles.*

DOI Cooperators: *Bureau of Ocean Energy Management, National Park Service, and U.S. Fish and Wildlife Service*

Ocean, Coastal, and Great Lakes (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	34,972	34,972	34,972	0
Climate and Land Use Change	3,550	3,550	3,550	0
Energy and Mineral Resources, and Environmental Health	1,500	1,500	1,500	0
Natural Hazards	50,669	50,843	56,626	+5,783
Water Resources	950	750	750	0
Core Science Systems	4,739	4,739	5,739	+1,000
Total	96,380	96,354	103,137	+6,783

More than half of our Nation's population lives within 50 miles of the coast, along estuaries and extensive coastlines of the Gulf of Mexico, the Atlantic and Pacific Oceans, the Great Lakes, and the Caribbean Sea. Healthy coastal and offshore resources are vital to our Nation's economy, which relies on coastal regions for energy development, commerce and shipping, fisheries, tourism and recreation. Scientists and technical staff within the USGS study coastal and ocean resources from shorelines and estuaries to the continental shelf and deep sea, providing expertise, tools, products, and data that address and inform a broad array of resource challenges facing our Nation. In the Coastal and Marine Geology Program, the proposed 2017 increase would allow the USGS to shift research staff to work in the Arctic and selected Pacific Islands dealing with impacts of sea level rise, severe storms and/or melting permafrost on their coastal communities and economies. In addition, the proposed increase would be used to apply research and modeling findings in the Hurricane Sandy (2012) affected areas to other parts of the U.S. coastline. In the Core Science Systems Mission Area, the proposed increase would allow completion of the NHDPlus high-resolution (1:24,000 scale) coverage for the conterminous 48 States, Hawaii, and Puerto Rico.

By studying coastal change, through sea and lake floor mapping, coastal modeling, and field measurements; ocean resources, including gas hydrates; coastal and marine ecosystem science; and

geological hazards, using hurricane and extreme storm impact studies and probabilistic earthquake forecasting, the USGS is helping develop a comprehensive overview of the coast and its resources.

Puget Sound

Region: Northwest

States: Washington

DOI Cooperators: Bureau of Indian Affairs, National Park Service, and U.S. Fish and Wildlife Service

Puget Sound (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	2,323	2,323	2,323	0
Water Resources	1,758	1,758	1,758	0
Core Science Systems	196	196	196	0
Total	4,277	4,277	4,277	0

Puget Sound, the second largest estuary in the United States, provides diverse benefits to a growing regional human population. The Sound is a natural resource treasure, supporting hundreds of species of fish, sea birds, and marine mammals, many of which are of enormous economic and cultural importance to the region. For example, more than 20 Native American Tribes are protected in perpetuity in their uses of salmon that live within the waters. However, salmon are in decline due to reductions in habitat quantity and quality. Human development and land use changes will likely affect the future sustainability of the Puget Sound, particularly watershed and shoreline alterations that are likely to reduce critical habitat for species and reduce water quality. Recent USGS research found that protection and restoration of floodplains along the 17 major rivers in the Puget Sound Basin could increase the health of rivers and their ecological value. USGS scientists also analyzed flood-related risks to people on these floodplains and determined that these important habitats can be managed to protect people from future natural flooding disasters.

Quagga and Zebra Mussels

Regions: Midwest, Pacific, Southeast

States: Minnesota, Washington, Wisconsin

DOI Cooperators: Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service

Quagga and Zebra Mussels (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	478	478	478	0
Total	478	478	478	0

Quagga and zebra mussels are invasive species that harm native mussel species, compromise food webs (by attaching to other animals and jeopardizing their survival), and create substantial problems for raw water users, such as water treatment facilities and power plants, by clogging intake pipes and other

Regional and Crosscutting Activities

structures. The highly invasive zebra mussel also causes billions of dollars in damage every year to North American boats, docks, hydroelectric systems and other vital infrastructure and resources. Since their introduction in the 1980s, quagga and zebra mussels spread rapidly throughout the Great Lakes region, then in the large navigable rivers of the Mississippi River drainage, and have recently continued their spread through Lake Mead, Lake Havasu, and other important Western waters. As filter feeders, mussels accumulate toxic chemicals at levels exponentially greater than in the environment, toxic chemicals that can then be passed to humans when they eat the meat of fish and waterfowl that feed on the mussels. Another side effect of their filter feeding is that mussels make the bodies of water that they inhabit clearer, allowing more sunlight to reach further down into the water and promote extensive algae growth. This results in further consequences such as creating a marine environment favorable to the harmful avian botulism, a food poisoning fatal to many birds and harmful to humans who ingest improperly smoked fish. The USGS continues to document geographic distribution of zebra and quagga mussels and to understand the complicated ecological effects they cause in areas they have invaded. In 2015, the USGS entered into an effort with the Bureau of Reclamation to form an Invasive Mussel Collaborative with scientific partners within the Great Lakes Restoration Initiative. The Collaborative will utilize Integrated Pest Management principles to continue to develop goals, control tools, and improve the effective management of mussel populations in the future.

Research and Development

Regions: All

States: Nationwide

DOI Cooperators: All

Research and Development (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Basic Research	53,319	53,846	59,600	+5,754
Ecosystems	10,993	11,216	12,176	+960
Climate and Land Use Change	6,964	6,977	7,862	+885
Energy and Mineral Resources, and Environmental Health	5,501	5,603	5,861	+258
Natural Hazards	10,579	10,714	11,883	+1,169
Water Resources	15,622	15,676	18,145	+2,469
Core Science Systems	3,660	3,660	3,673	+13
Applied Research	506,401	512,363	551,140	+38,777
Ecosystems	140,815	143,688	155,997	+12,309
Climate and Land Use Change	60,935	61,269	69,943	+8,674
Energy and Mineral Resources, and Environmental Health	82,849	85,007	89,345	+4,338
Natural Hazards	76,074	77,405	83,216	+5,811
Water Resources	100,885	100,021	106,799	+6,778
Core Science Systems	44,843	44,973	45,840	+867
Developmental Research	106,125	110,705	125,583	+14,878
Ecosystems	5,233	5,328	5,765	+437
Climate and Land Use Change	32,092	33,466	42,491	+9,025
Energy and Mineral Resources and Environmental Health	3,921	3,901	4,277	+376
Natural Hazards	24,614	25,235	26,116	+881
Water Resources	5,110	5,155	5,849	+694
Core Science Systems	34,727	37,147	40,600	+3,453
Science Support	428	473	485	+12
Total	665,845	676,914	736,323	+59,409

Investments in Research and Development (R&D) promote economic growth and innovation and ensure American competitiveness in a global market. For the USGS, R&D is the core of the agency's mission to help the Nation understand the Earth, minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our citizens' quality of life. The USGS is able to carry out this mission because of the diverse integration of USGS mission area scientific expertise and multi-disciplinary scientific investigations. To ensure that R&D funding is tracked consistently, each program identifies the percentage of the program that fits into the categories of

Regional and Crosscutting Activities

basic, applied, and developmental research. The percentage is then applied to total funding provided. The percentages are revisited periodically to ensure that they accurately reflect the research portfolio. This approach provides a manageable and consistent manner to track R&D costs across science activities and fiscal years. All USGS basic, applied, and developmental research ultimately supports the goal of providing the scientific framework for Earth science and natural resource decision making. In 2015, the USGS spurred conversation about innovation at its centers across the country to explore how the Bureau can even better equip itself to take on the Nation's biggest Earth science challenges. Efforts in 2016 will underscore the need to harness bold and creative ideas that will move the natural sciences in this direction in 2017.

Sage Steppe Landscape

Regions: Northwest, Pacific, Southwest

States: California, Colorado, Idaho, Missouri, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming

DOI Cooperators: Bureau of Land Management, U.S. Fish and Wildlife Service

Sage Steppe Landscape (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	3,511	3,511	6,511	+3,000
Total	3,511	3,511	6,511	+3,000

The sage steppe landscape extends across 11 Western States and two Canadian Provinces, and 60 percent of that landscape is on public lands, half of which are managed by Interior. This area is dominated by sagebrush, which is priority habitat for over 350 wildlife species, most notably the greater sage grouse, an at-risk and iconic species of this landscape. Alterations in the sage steppe landscape, including changing fire regimes, spread of invasive grasses, climate change, and development, have led to new challenges to these species and the landowners and public that lives and recreate in this area. Land and species managers, landowners, and other stakeholders need scientific information to improve their ability to understand and address these challenges and to implement landscape-scale management decisions, regardless of surface management or ownership. To address the science needs of this landscape, the USGS's 2015 research efforts focused on describing rangeland fire frequency and size, developing buffer and mitigation strategies, understanding how wildfire and habitat fragmentation affect greater sage grouse populations, forecasting distributions of sagebrush in the face of climate change, evaluating the effectiveness of restoration techniques, and developing conservation and restoration strategies to benefit greater sage grouse. Building on these efforts, research in 2016 will focus on determining the best management practices for sagebrush restoration, mapping landscapes dominated by cheatgrass, expanding efforts to understand the threat of rangeland fire, and developing predictive models to understand the influence of climate changes, fire, and cheatgrass on greater sage grouse populations. The proposed increase in 2017 would be used to fund expanded research to support the priority needs of managers to address changing fire regimes, drought, and shifting climates; control the spread of invasive cheatgrass; design conservation and management strategies for greater sage grouse; and effectively restore and adaptively manage the sage steppe landscape. Rangelwide geospatial analyses will be conducted to provide mapping of sagebrush habitat, fire, and invasive plants to help inform long-term, landscape-scale

management planning. Pilot studies will be implemented to test strategies for preventing spread of and controlling cheatgrass. Testing and application of restoration and post-fire rehabilitation techniques will be initiated with a goal of developing cost-effective methodologies to restore sagebrush. The USGS will also develop an interagency monitoring framework focused on evaluating the effectiveness of fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage grouse. Resultant data and information will be used to inform long-term conservation and management strategies for the sage steppe landscape and to support the process of adaptive management.

Upper Mississippi River

Region: Midwest

States: Illinois, Iowa, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Wisconsin

DOI Cooperators: National Park Service, U.S. Fish and Wildlife Service

Upper Mississippi River (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	2,815	2,815	2,815	0
Water Resources	4,753	4,753	4,753	0
Total	7,568	7,568	7,568	0

The Upper Mississippi River System is a 1,300-mile waterway linking five States to the Gulf Coast export markets, supporting a tremendous range of uses. More than 30 million residents rely on the river for public and industrial supplies, power plant cooling, wastewater assimilation, and other uses. In addition, commercial navigation, recreation, and fish and wildlife all flourish on the Upper Mississippi, with millions of people visiting the area every year to participate in water activities and annual recreation expenditures exceeding \$1.2 billion. More barge traffic than ever before transports a wide variety of essential goods on the Upper Mississippi River System. However, such heavy reliance on the System is taking its toll—the Mississippi River backwaters that provide fish and wildlife as well as plant production and habitats may be lost due to a deteriorating floodplain ecosystem. USGS research is examining how natural and human factors affect ecosystem sustainability, restoration, and resilience. The USGS conducts research on living resources (including aquatic invasive species), human uses, and impact mitigation in the Upper and Middle Mississippi River Basins. The USGS also provides decision support and analysis to develop resource management goals critical to wise future management of river flow and material sources on the landscape. Scientists have recently established the river’s own potential to decrease its load of unfavorable nitrate and have identified how certain basic river management practices could increase that potential. The USGS Upper Midwest Environmental Sciences Center is the science leader of the Long Term Resource Monitoring (LTRM) element of the U.S. Army Corps of Engineers’ Upper Mississippi River Restoration Program. The LTRM is the nation's largest river monitoring program with six remote State-operated field stations.

Water Challenges/WaterSMART

Regions: All

States: All

DOI Cooperators: Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service

Water Challenges (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	466	466	3,266	+2,800
Climate and Land Use Change	3,479	3,479	7,684	+4,205
Natural Hazards	250	250	250	0
Water Resources	12,285	14,514	24,664	+10,150
Core Science Systems	0	0	1,200	+1,200
Total	16,480	18,709	37,064	+18,355

Meeting the water resource needs of the Nation is an increasing challenge because of rapidly changing drivers of water availability, such as climate change, population increases, and water use and land use changes. At a time when ensuring sustainable water supplies is more important than ever, the change in the frequency and magnitude of extreme hydrologic events, such as floods and droughts, are creating uncertainty for water managers. As competition for water resources grows for irrigation of crops, cities and communities, energy production, and the environment, so does the need for information and tools to aid water and natural resource managers. WaterSMART is an Interior initiative that leverages and directs existing expertise and resources within the USGS and Reclamation toward addressing complex, national- and regional-scale water challenges. The SECURE Water Act (P.L. 111-11, Subtitle F, Sections 9507 – 9509) dictates the USGS role: Provide science to help water managers understand and address competing demands for water. The primary focus of this initiative includes developing a National Water Census, which will allow resource managers to gain a better understanding of water budgets in their area of concern that, in turn, will support sustainable and environmentally sound water management. Leveraging expertise across multiple USGS mission areas enables a broader focus to address these challenging issues in a time of growing competition for water resources. Coordination between the USGS and Reclamation has been going on from the very beginning of WaterSMART. For example, the USGS worked with Reclamation to draft the WaterSMART Secretarial Order in February 2010. The USGS and Reclamation are currently co-leading one of three uses cases with the USGS to visualize historic and projected future water interactions in the Lower Colorado River Basin for the Open Water Data Initiative. Finally, the USGS is working very closely with Reclamation on preparations for new assessments in the Rio Grande and Red River basins (2016-2018). In addition, the NPS and the FWS have employees on the National Water Census Ad Hoc Committee as some of the USGS WaterSMART work falls on their lands.

The USGS possesses the skills and foundational resources to provide water resource, ecosystem, and land use managers the decision-support tools to make informed decisions. The goal of this effort is to improve the data and understanding associated with groundwater, surface water, human water use, and the ways in which these and other water budget components influence water availability, and to develop tools that will allow managers to apply the new understanding and data. The Nation will be well served through

this effort, by gaining the ability to balance water resource sustainability through consideration of water quantity, quality, and uses, including ecological uses.

The 2017 budget request includes increases of \$18.4 million. The Water Availability and Use Science Program is requesting \$4.0 million to develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures. These products can be used by resource managers to assess vulnerability of specified basins or water suppliers. The Water Availability and Use Science Program is also requesting \$4.0 million for Water Use Research and Information which, coupled with the grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making, will help the USGS to quantify water supply and demand consistently across the entire Country. This effort will also compile water information that is now fragmented among multiple bureaus into a national water data framework on a geospatial platform, a place-based database. The Fisheries Program is requesting \$2.5 million to develop decision-support systems that have the capacity to provide a diverse set of management options—both monetary and non-monetary—to water regulators and stakeholders for making decisions that balance human and ecosystem needs. These include maintenance of important species, and protecting and restoring the functions of natural systems. The Land Change Science Program is requesting \$1.0 million to develop automated methods and tools supporting near real-time, satellite-based drought monitoring that would help water managers identify the onset and severity of drought events and effectively allocate scarce water resources.

In addition, the National Geospatial Program is requesting \$1.0 million to complete the initial production of the National Hydrography Database High Resolution dataset in an effort to streamline and consolidate national datasets as the USGS, the Environmental Protection Agency, the U.S. Forest Service, and the Bureau of Land Management all are using hydrography datasets of differing functionality and scales. Developing a single, scalable hydrographic referencing system will integrate currently fragmented water information into a connected, national water data framework to underpin innovation, modeling, data sharing, and solution development. The Land Remote Sensing Program and the Land Change Science Program are collectively requesting \$800,000 to integrate new Landsat-based science products (including estimates of surface water extent) and use remote sensing to identify and quantify water storage in smaller storage features (e.g. ponds and reservoirs). Understanding and reporting on these features could provide benefit for drought status monitoring, understanding climate variability, and streamflow estimation, particularly in areas without streamgages.

The Water Availability and Use Science Program is also requesting \$750,000 to collaborate with other Federal agencies to accelerate the development of a nationwide hydrologic model that will advance understanding and forecasting of the water budget, to effectively manage water resources, and to adapt to a changing climate. The USGS currently has a national scale hydrologic model that addresses the major components of the water budget, but human water use is not addressed explicitly. The Water Availability and Use Science Program is requesting \$400,000 to provide streamflow statistics via the USGS StreamSTATs decision support tool in three additional States and improve methods for proving the estimates. Streamflow information is required for water-resources management, and changing

Regional and Crosscutting Activities

streamflow conditions require continuity of information for flood and drought response and routine water allocations.

Finally, multiple programs in the Ecosystems, Climate and Land Use Change, Water Resources, and Core Science Systems collectively are requesting \$3.9 million for drought research. Given the persistent drought in multiple regions of the United States, the USGS proposes to quantify water availability, determine how snowmelt factors into the hydrologic cycle, and investigate drought effects on reproduction and survival of select plant and animal species. Providing access to these data will allow managers to determine impacts of drought on ecological systems. The USGS will develop actionable science approaches, by convening regionally based working groups of decision makers and natural resource managers to develop coordinated adaptive management plans for the complex consequences of severe and prolonged drought. The funding requested for this work would provide tools for fish and wildlife managers as well as water resource managers.

White-Nose Syndrome

Regions: Northeast most severely affected, spreading southward and westward

States: First detected in upstate New York; now confirmed in 26 States

DOI Cooperators: National Park Service, U.S. Fish and Wildlife Service

White-nose Syndrome (Dollars in Thousands)	2015 Actual	2016 Enacted	2017 President's Request	Change from 2016 (+/-)
Ecosystems	1,001	1,501	1,501	0
Total	1,001	1,501	1,501	0

White-nose syndrome (WNS) is a fatal fungal growth in the wings and muzzles of hibernating bats in North America, including 26 U.S. States and five Canadian provinces. The disease, for which there is no known cure, has already killed over 5 million bats since 2006, a bat population decline exceeding 80 percent in the Northeast, and may lead to extinction of certain bat species. Diseases among free-ranging wildlife are difficult to stop once they have become established in wildlife populations, and many caves in affected States have been closed to human recreational use to help reduce the spread of this fungus that is so fatal to bats. While WNS is not known to affect people, insect-eating bats that are susceptible to the disease perform valuable services to humans. Research by the USGS and partners shows that through their free pest-control services, these bats save the agricultural industry at least \$3 billion each year. The loss of millions of bats in the Northeast has resulted in an estimated 1.4 to 2.9 million pounds of insects no longer being eaten each year by bats in the region. USGS research includes surveillance for WNS; bat and bat monitoring databases; effects of WNS on bat populations; and control and management of WNS. The USGS recently created a model for how the disease progresses from initial infection to death in bats during hibernation, providing for the first time scientific mechanisms critical for properly timed and effective disease mitigation strategies. USGS research on WNS greatly enhances the ability of decision makers to develop management strategies to preserve vulnerable bat populations and the ecosystem services that they provide in North America.

USGS Science Coordination

USGS Science Coordination

Introduction

The core mission of the U.S. Geological Survey (USGS) is to provide reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; support the sustainable stewardship of land and water; and manage biological, energy, and mineral resources. To that end, the USGS collects, monitors, analyzes scientific data and information, and provides scientific understanding about natural resource conditions, issues, and problems. The diversity of USGS scientific expertise enables the Bureau to carry out large-scale, multi-disciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers. Scientific coordination and collaboration is an important part of the USGS science mission work.

By leveraging efficiencies across Federal, State, local, and tribal governments, the private sector, and non-governmental organizations, the USGS is able to provide science and information that is thorough, accurate, and tailor-made to address some of the most pressing challenges of the 21st century. The USGS enters into scientific partnerships, making the best use of limited resources to further national priorities. The USGS derives value from its scientific partners and also contributes valuable expertise to collaborations, filling in the knowledge gaps that the USGS is uniquely capable of addressing. USGS science coordination efficiently leverages the strengths of all partners to enhance and complement the Federal science enterprise needed to address our most critical national challenges. USGS scientists and the Department of the Interior (Interior) land and resource managers in the field work collaboratively to identify issues of importance to Interior and answer scientific questions to address those issues. The USGS scientists, stationed at nearly 400 locations around the Nation, work with partners to build a scientific knowledge base at the local level. The scope of this reach, both in geographic breadth and depth of local expertise, uniquely qualifies the USGS to efficiently and effectively address science needs at the national, regional, and local level. These field-level interactions solve on-the-ground science problems, leveraging the tools and expertise available from all partners involved.

“Today, collaboration between NPS and USGS helps to inform managers and the public about the condition of park resources and the science needed to support informed decision making. The interagency cooperation and sharing of new and state-of-the-art technologies have enabled evaluation and study of parks and their resources that could never be contemplated when NPS was founded in 1916.” Vince Santucci, Senior Geologist, National Park Service, 2014, George Wright Forum vol. 31 no. 2

Science coordination at the USGS not only occurs at the field level, but also at the leadership level. For example, the USGS Director chairs the Interior Science Advisors Council. The Council identifies science priorities and ensures communication, continuity, and collaboration among Interior bureaus, including the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), and the Bureau of Land Management (BLM), so that science efforts are complementary and address the highest priority needs. The Director also sits on a number of national scientific coordinating bodies, such as the National Science and Technology Council’s Science Committee, the U.S. National Committee for Geoscience, the U.S. Group on Earth Observations Senior Steering Committee, and multiple National Academy of Science roundtables and boards. These organizations ensure that high priority research and development needs are being met in a way that leverages unique capabilities and strengths within the Federal science community.

The USGS has a reputation for independent, high-quality science. The USGS plays a central role in monitoring scientific integrity, and is a significant reason why external organizations look to the USGS for partnership opportunities. As a non-regulatory entity, the USGS provides objective, credible scientific research and analysis that agencies and bureaus with regulatory responsibilities use to make informed



Figure 1: An interorganizational research team carrying out geophysical surveys of Okmok Volcano in Alaska. The team includes the USGS scientists as well as academic partners. From left to right: Tim Parker (IRIS/PASSCAL), Kerry Key (Scripps Institution of Oceanography), Matt Haney (USGS), Ninfa Bennington (University of Wisconsin), Summer Ohlendorf (University of Wisconsin), Georgianna Zelenak (Scripps Institute of Oceanography), Paul Bedrosian (USGS), Sam Egli (Pilot, Egli Air Haul), and Shawn Davis (mechanic, Egli Air Haul). Source: Paul Bedrosian, USGS.

decisions based on sound science. The USGS also plays a central role in monitoring the integrity of science products across Interior through direct coordination with the Deputy Secretary and the Assistant Secretary for Policy, Management, and Budget on science integrity policy. Furthermore, the USGS brings to its partnerships and collaborations a multi-disciplinary and innovative approach to complex societal challenges that require versatility. The varied expertise of the USGS mission areas provides a holistic approach to solving both national- and local-scale problems. Partners recognize the unique capacity of the USGS to address multi-faceted problems through its varied scientific expertise and continue to rely on the USGS for strategic, integrated science to meet both immediate challenges and future needs.

As the Nation seeks to solve these challenges, the USGS also provides sound decision-ready science in a timely manner to inform multi-entity collaborations on issues affecting public health and safety, community resilience, and sustainable economies, as illustrated in our crosscutting activities. Examples include:

- Conducting enhanced monitoring and assessments of hazards, and developing community-based tools, such as earthquake early warning.
- Understanding and mitigating the impacts of unconventional oil and gas development.
- Creating the foundation for addressing multiple emerging community needs through the 3-D Elevation program.
- Assessing the distribution and life cycle of critical minerals that are increasing in importance with the emergence of new technologies.
- Understanding the factors affecting some of the most vulnerable landscapes, such as the Arctic, insular areas, and the coasts.
- Providing the tools for communities to plan for increased pressures on available water supplies, including drought.

- Providing tools for early detection and control of invasive species.
- Engaging the next generation to build a 21st century workforce.

The USGS addresses these challenges, and others, using strategic collaborative science. The USGS nurtures a culture of innovation by creating avenues to bring existing creative approaches to light. Part of the USGS's approach to innovation is exemplified in how it addresses science challenges by engaging in non-traditional partnerships between the public and private sectors to develop the next generation of tools, technologies, and analyses. For example, the USGS engages postdoctoral candidates through its Mendenhall Research Fellowship Program, who approach issues through a trans-discipline view, are fluid thinkers, and freely collaborate. For example, a Mendenhall Fellow may address the broad goal of understanding and mitigating the hazard due to injection-induced earthquakes. To achieve this broad goal, a Mendenhall Fellow may need to understand the evolution of earthquake activity through space and time. This could involve the application of knowledge from different scientific disciplines such as geophysics, geology, hydrology, engineering, and statistics. Fellows often conduct such research in collaboration with expert scientists not just from the USGS, but also from universities, other Federal agencies, and State agencies. Through unbiased and objective science and with the reciprocity of multiple collaborative science partnerships, the USGS is uniquely positioned to provide the integrated science that is relevant to the Nation and local communities.

Examples of USGS Science Coordination and Collaborations

Below are several examples from among many areas in which the USGS is collaborating with its partners to provide valuable science for decision making. It should be noted that this is not a comprehensive list of all of the USGS collaborations; rather, the list provides a cross-section of science coordination activities across the Bureaus. Some of these activities encompass the National Challenges and Crosscutting Activities. Additional science coordination activities not described here are discussed in each mission area chapter as well as in the Crosscutting Activities chapter.

Effective Management of the Sage Steppe Landscape – The USGS has a broad research program focused on providing the science needed by the BLM, FWS, and other Federal and State agencies to effectively manage the sage steppe landscape. Much of this research provides the scientific underpinnings for recent Interior actions, including the FWS greater sage grouse listing determination, the BLM Approved Resource Management Plan Amendments, the Rangeland Fire Secretarial Order 3336 and post fire management, and strategies for native seeds and pollinators. The research builds on the knowledge and expertise needed to conserve and manage the sage steppe landscape. New and ongoing research on fire behavior and risk, restoration techniques, invasive species control, sage grouse ecology, pollinators, climate change, and forecasting will continue to support and advance management to reduce the threat of rangeland fire, restore healthy sagebrush habitat, and conserve greater sage grouse.

FWS greater sage grouse listing determination – The USGS worked closely with the FWS to provide timely research, including mapping the distribution of sage grouse across their range, assessing connectivity between priority habitat designations, and modeling the influence of fire

on sage grouse population dynamics. These products, combined with the other efforts listed here, provided key scientific information to inform their listing determination.

BLM Approved Resource Management Plan Amendments (ARMPA) – USGS science has helped inform some of the concepts outlined in the ARMPA, and is providing information and tools to facilitate implementation. Specific examples include identification of conservation buffer distances, sage grouse habitat mapping, development of the Surface Disturbance and Reclamation Tracking Tool (SDARTT), and contributions to the development of the Fire and Invasives Assessment Tool (FIAT).

- USGS scientists participated in the FIAT Development Team and provided the science at the core of the FIAT. USGS foundational research included determining the linkage between soil temperature and moisture and the resistance of sage steppe to invasion by exotic annual grasses and its resilience following disturbance, and defining the amount of sagebrush habitat needed to support sage grouse populations. These collaborations continue with the ongoing development of the Sagebrush Management Resilience and Resistance Tool (SMRRT), which will extend these concepts to the eastern portion of the sage grouse range.
- The USGS developed a report that summarized published scientific studies that evaluate effective conservation buffer distances from human activities and infrastructure that influence greater sage grouse populations. This report was developed to help decision makers establish buffer distances for use in conservation measures for greater sage grouse. The ARMPAs utilized the buffer distance recommendations outlined in the report as a guide for approving actions on the landscape.
- USGS science was the primary source used to develop sage grouse habitat management areas for the Nevada/California Planning Area. USGS research on sage grouse habitat selection and space-use provided the geospatial information used by BLM planners to identify the priority and general habitats included in the plan amendment.
- The USGS has worked with BLM to provide science to inform management actions outlined in the plan amendments. These included improved understanding of factors contributing to invasion of sagebrush habitat by cheatgrass and subsequent changes to habitat condition and fire risk; developing treatment options for controlling cheatgrass; identifying the impact of conifer expansion on sage grouse populations and develop effective strategies to remove trees from the landscape; and understanding those factors contributing to restoration success and developing techniques to improve future restoration actions.
- The USGS has worked with BLM to develop the SDARTT, which provides a tool for BLM to meet their obligations outlined in the ARMPAs. The SDARTT allows offices and public land users to submit geospatial data on disturbance, reclamation activities, and land-use planning efforts for BLM to review priority management habitat area caps and make project determinations.

Rangeland Fire Secretarial Order – The USGS is working with BLM, FWS, the Office of Wildland Fire, and other Federal and State agencies to implement the Rangeland Fire Secretarial order and to provide the science and management tools needed to understand and reduce the threat of rangeland fire, and restore fire impacted lands. Key actions include: (1) developing geospatial information for the Great Basin that will facilitate landscape-scale management decisions; (2) developing a consistent and cost-effective monitoring strategy to determine the effectiveness of fire prevention, fire suppression, invasive species control, and habitat restoration; (3) developing a science plan that will guide research to support the highest-priority needs to support fire prevention, fire suppression, invasive species control, and effective restoration; and (4) developing a science-based approach for testing the efficacy of applying biocontrols to control cheatgrass.

Post Fire Management – The USGS is working with BLM and other Federal and State agencies to inform fire management and improve effectiveness of post-fire management actions. USGS assessments of historical fire frequency and size and investigation of how grazing, exotic plant species, and altered fire regimes influence fuel loads are helping to understand future fire risk. The USGS is also evaluating the effectiveness of post-fire treatments, assessing the post-fire response of sage grouse to those treatments, and developing decision-support tools to provide managers with information about where, when, and how to implement restoration actions that will be cost-effective and benefit sage grouse.

National Seed Strategy – The USGS and BLM are key partners in the recently developed National Seed Strategy, working with the Plant Conservation Alliance, the U.S. Department of Agriculture (USDA), and multiple other partners. The USGS is a member of the Seed Strategy team, and provides research in areas such as native plant ecology, genetics, and fire ecology to help inform the conservation tactics implemented under the strategy. Scientific understanding that comes out of the National Seed Strategy will directly inform restoration actions in the Rangeland Fire Secretarial Order and the BLM ARMPAs.

Pollinator Science Coordination – Many Interior bureaus, including the USGS, FWS, BLM, NPS, Office of Surface Mining Reclamation and Enforcement (OSMRE), and Reclamation, are active members of the Interior Pollinator Working Group. This team was set up in 2014 to support the Federal Pollinator Health Task Force, which was established by the Executive Memorandum on Pollinator Health. These bureaus worked together to develop a Department Pollinator Action Plan, each bringing the perspective and capabilities of their unique missions. The USGS serves as the lead Interior bureau, coordinating the working group, and appreciates the collective contributions.

The monarch butterfly serves as an excellent example of how USGS science informs management. The monarch butterfly is an iconic North American species, and is one of the few insects known to migrate long distances. The monarch's eastern population flies to Mexico for the winter, and then travels to the United States and southern Canada to breed during the spring and summer. Recently the monarch has experienced significant population declines, with numbers on the wintering grounds down about 90 percent. To address these declines, the governments of the United States, Mexico, and Canada have agreed to work together to conserve the phenomena of monarch migration. To support recovery, the

USGS convened a partnership of key scientists and stakeholders to answer prominent questions and to provide science that will guide management and conservation actions. This partnership, initiated in 2014, has already produced two important preliminary products: (1) a population model designed to understand which factors are most important in driving the size of the population, and (2) an extinction risk assessment to understand how vulnerable the species is. These models are in final review and will be completed in 2016. The FWS will use these models to establish a desired target population to sustain the species.

National Climate Change and Wildlife Science Center and Department of Interior Climate Science Centers – The mission of National Climate Change and Wildlife Science Center (NCCWSC) is to provide natural resource managers with the tools and information they need to develop and execute management strategies that address the impacts of climate change on fish, wildlife and their habitats. In response to Interior Secretarial Order 3289, in 2010 the USGS established eight regional Climate Science Centers (CSCs) and serves as the managing entity for the CSCs. The NCCWSC and CSCs are committed to a partnership-driven model. At the national and regional level, major guidance on priorities and activities is provided by ongoing interactions with stakeholders from the management, science, and public communities. Each CSC has a Federal director and a host university, but works with other universities throughout their region. The CSCs are conducting work in partnerships with other Interior bureaus, Federal agencies, the respective States, tribal and indigenous partners, and the Department of Interior Landscape Conservation Cooperatives (LCCs). Interior established the Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS) to provide advice on the operations, partnerships, and science conducted by the NCCWSC and the CSCs. ACCCNRS includes representatives of other Federal agencies, States, tribal and indigenous partners, local governments; non-governmental organizations; private sector entities; and academic institutions. In accordance with the recommendations of the ACCCNRS, the CSCs continue to focus efforts on the co-production of actionable science, whereby researchers work closely with the end users of the science information (e.g., natural resource managers), from developing the research question through the analysis and production of the research output. In this way, the CSCs can provide information that directly meets the needs of decision makers.

Earth Observation and Remote Sensing – The Land Remote Sensing (LRS) Program advances the science and methods for collecting, analyzing, and understanding user needs in order to motivate agility in its product and service portfolio. It establishes and maintains business policies and cooperative support structures that encourage and expand partnerships with Federal, commercial, academic, and foreign cooperators. The program collaborates with many Federal partners including Interior bureaus and National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), USDA and the National Geospatial Intelligence Agency (NGA) on remote sensing science; data science business partners; commercial satellite data providers; the Group on Earth Observations (GEO); the Committee on Earth Observing Satellites (CEOS); the European Space Agency (ESA) on data, science, and technology leveraging; Geoscience Australia on Data Cube science; and other international remote sensing science cooperators, to expand the understanding of, access to, and value of LRS products and services. Through the Interior Remote Sensing Working Group and other venues, LRS works with various Interior bureaus to better understand their needs for land imaging observations, products and services, and to seek input from Interior on its new products and land imaging initiatives. LRS also leads the development of an annual Interior Remote Sensing Report to highlight and share key

remote sensing technology applications that support science and land management across Interior's mission areas <http://eros.usgs.gov/doi-remote-sensing-activities/2015/Home>. Through its various activities and collaborations, the LRS program is helping define the future of land remote sensing.

Environmental Impacts of Uranium Mining – In 2012, the Secretary of the Interior issued a Record of Decision withdrawing about one million acres of Federal land near the Grand Canyon from additional uranium mining development until the year 2032. The USGS, through the Contaminant Biology Program and the Toxic Substances Hydrology Program, is developing science to address critical gaps in the data and knowledge on the potential effects of uranium mining in the Grand Canyon region, and is leading a team of Interior bureaus—including the BLM, the NPS, and the FWS—as well as the U.S. Forest Service (USFS), on this important effort. The USGS uranium mining studies are designed to assess water quality and quantity, to understand the potential toxicological and radiological effects of mining on wildlife, and to evaluate potential impacts on cultural and tribal resources. Results will help inform the Secretary's decision to continue, modify, or end the mining withdrawal in 2032.

Together with the BLM, the NPS, the FWS, and the USFS, the USGS has put together a detailed joint 15-year science plan outlining the exact scientific information needed to inform decisions on future mining activities in the region. The partners are jointly executing the science called for in the plan. The cooperative effort produces the information more cost-effectively than individual agency-specific studies, reduces duplication, and leverages the strengths and expertise of each agency. Opportunities for partnerships with private industry are considered in the science plan, allowing for more complete data on the mining sites. In addition to the Federal agencies identified above, several State, local, and tribal entities also have land-management or regulatory interests in the region. The USGS has identified 19 studies to better characterize the impacts of uranium and other trace elements on water resources, native flora and fauna, and cultural and recreational uses—all of which constitute important and highly relevant information for these entities. The 19 identified studies will also leverage the expertise from each participating entity to help meet the goals of the studies. The reciprocal relationships among Federal, State, local, and private industry partners will allow for cost savings and targeted, useful research toward the balance of environmental and industry interests in the Grand Canyon region.

Tools for Understanding Coastal Change and Habitats – The USGS Coastal and Marine Geology Program (CMGP) delivered the iPlover (a smartphone application) in 2015, for the FWS and the NPS coastal units in the Northeast. This new tool helps scientists understand how piping plovers use coastal habitat. The USGS analyzed datasets documenting piping plover habitat and developed a plover behavior model quantitatively tied to variables including elevation, slope, frequency of inundation and overwash, and amount of vegetation. The USGS also developed a habitat evolution model by relating the datasets documenting changes in the habitat (e.g., topography, shoreline position, vegetation) to changes in sea level and storminess. Coupling plover behavior and habitat evolution will allow scientists to evaluate historical observations and then model future scenarios to analyze alternative conservation strategies against plausible sea level and other future climate variables.

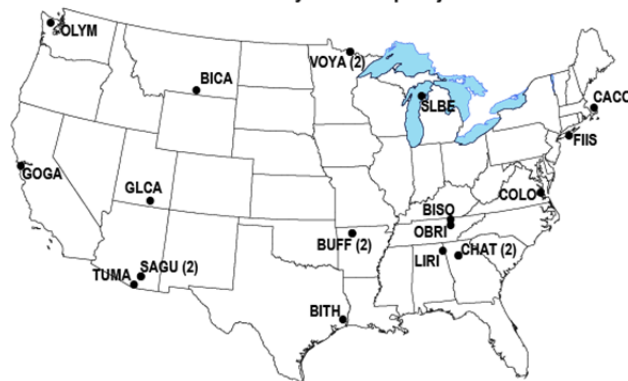
Development of Coastal Resiliency Network – The CMGP has worked with the U.S. Army Corps of Engineers (USACE) to leverage USGS expertise about beach processes and responsibilities for forecasting beach change and USACE role in coordinating beach nourishment projects. During 2015, the

USGS and USACE worked with American Shore and Beach Preservation Association to discuss plans for development of a new Coastal Resiliency Network. The goal is to use the wealth of data that already exists in the Corps, the USGS, and other Federal agencies to quantify coastal resiliency and predict changes through time. Additionally, the USGS and USACE collaborated on identifying ways to streamline and improve procedures for transforming raw lidar data into useful data products.

National Park Service Partnership – The NPS manages many of our Nation’s most highly valued aquatic systems across the Country, including portions of the Great Lakes, ocean and coastal zones, historic canals, reservoirs, large rivers, high-elevation lakes and streams, geysers, springs and wetlands. Since 1998, the USGS has worked in partnership with the NPS to conduct studies aimed at providing data and information that will assist the NPS in addressing high priority water quality issues of concern. New projects are proposed each year by USGS scientists working in collaboration with NPS staff in specific Parks. Project selection is highly competitive, with an average of only eight new projects funded each year out of approximately 75 proposals submitted.

Researchers have completed more than 200 projects since the beginning of the NPS Partnership and conducted these studies in 115 national parks, extending from Denali in Alaska to the Everglades in Florida and from Acadia in the Northeast to Kaloko-Honokohau National Historical Park in Hawaii in the west. Projects range from monitoring periodic streams for contaminants affecting human health or aquatic life to interpretive studies evaluating the effect(s) or vulnerability of NPS resources to visitor usage and other natural and anthropogenic activities.

Locations of USGS-NPS Water Quality Partnership Projects initiated in 2015 and 2016



In 2016, the partnership is initiating eight new projects. One project in the Chattahoochee River National Recreation Area (Georgia) is monitoring potentially harmful bacteria levels and identifying their sources to protect recreational users. At the Jamestown Island Colonial National Historic Park (Virginia), USGS scientists are monitoring network design, protocols and water quality data needed to help the park protect vital archeological, cultural, and biological resources threatened by increasing groundwater and groundwater salinity levels. A project at Fire Island National Seashore (New York) will provide the NPS with information on the sources, and movement of nutrients, hormones, and pharmaceutical and other contaminants common to septic systems in shallow groundwater that could impact ponds, wetlands and the Great South Bay estuary located within the Park. At Glen Canyon National Recreation Area (Arizona and Utah) a partnership project is determining the effectiveness of recently implemented personal watercraft regulations intended to reduce hydrocarbon contamination to the waters of Lake Powell.

Within Golden Gate National Recreation Area (California), a partnership project is working to identify the specific causes of recent fish kills, including those affecting two federally listed endangered/threatened species and to identify appropriate management actions to ameliorate the problem. Within Saguaro National Park (Arizona), a project is evaluating the impacts to this sensitive ecosystem from aerially applied herbicides used to control damaging invasive species of grasses. At Kabetogama Lake, Voyageurs National Park (Minnesota), USGS scientists are using molecular tools to understand the causes of and to help predict harmful algal blooms and their toxicity levels within the lake.

In 2017, the partnership plans seven new projects following an extensive review and prioritization of proposed projects with the NPS. Projects focus on providing the NPS with critical information needed for management decisions to protect and improve water quality and ecosystem health related to historic land use and reclamation, regional development, nutrient loading impacts, visitor use impacts and contaminants of emerging concern.

3D Elevation Program (3DEP) – The USGS National Geospatial Program (NGP) works with other Interior bureaus, States, and other Federal agencies such as the Federal Emergency Management Agency, the USDA Natural Resources Conservation Service, the USFS, and the USACE, through the 3DEP Executive Forum and Working Group, to establish a systematic and unified approach toward acquisition and dissemination of 3D elevation data. The USGS NGP collaborates with these entities to strengthen Federal interagency coordination and share applications and technology development. In 2015, the NGP held a 3DEP Stakeholders meeting to share program status and explore joint strategies for implementing the program, and assisted all 50 States and many Federal agencies via public webinars on how to participate in interagency data acquisition partnerships.

Big Earth Data – The Big Earth Data Initiative makes earth science data more discoverable, accessible, and usable. The USGS leads the U.S. Group on Earth Observations data management working group and provides many big Earth data systems allowing smaller datasets to be integrated for delivery, which reduces duplication of effort and makes earth science data more readily available to better inform conservation decisions. The level of sophisticated data use across disciplines and with very large datasets is requiring that scientific decision support software is able to operate efficiently against big data assets using high performance computing and related resources. The Science Synthesis, Analysis and Research Program works in concert with all Interior bureaus, NASA, NOAA, and USDA to implement the Common Framework for Earth Observation data that establishes standards and practices to make possible the efficient use of our big data resources.

The **Federal Geographic Data Committee – Office of the Secretariat** supports cross-government initiatives, including the Geospatial Platform, per the OMB Circular A-16. The FGDC is a 32-member interagency committee comprised of representatives from the Executive Office of the President, as well as cabinet-level and independent Federal agencies. The Geospatial Platform, a managed portfolio of common geospatial data, services, and applications that are contributed and administered by trusted sources and hosted on a shared infrastructure for use by Federal and non-Federal partners in meeting mission needs, has been identified by the Department of the Interior in its Strategic Plan to help develop a landscape-level understanding of natural resources. The Geospatial Platform's shared capability through which other bureaus can register data, services, and applications increases geospatial data discovery,

USGS Science Coordination

access, use, and registration of decision-support tools in support of decision making and data sharing. The registry is integrated with solutions supporting the Administration's priorities, including the Open Data policy and Data.gov.

Budget at a Glance

Budget at a Glance						
(Dollars in Thousands)						
	2015 Actual	2016 Enacted	Fixed Costs	Internal Transfers	Program Changes	2017 Budget Request
Surveys, Investigations, and Research						
<u>Ecosystems</u>						
Status and Trends Program	20,473	20,473	+89	0	+1,705	22,267
Pollinators					[+1,705]	
Fisheries Program	20,886	20,886	+97	0	+3,100	24,083
Unconventional Oil and Gas Research - Ecologic Effects					[+350]	
Great Lakes Fisheries Assessments					[+250]	
WaterSMART: Ecological Flows					[+2,500]	
Wildlife Program	45,257	45,757	+218	0	+150	46,125
All-of-the-Above Energy: Renewable Energy - Wind & Solar					[+150]	
Environments Program	36,224	38,415	+137	0	+4,800	43,352
Critical Landscapes: Arctic					[+1,000]	
Critical Landscapes: Sage Steppe Landscape					[+3,000]	
Natural Hazard Science for Disaster Response: Wildfire Response					[+500]	
WaterSMART: Drought					[+300]	
Invasive Species Program	16,830	17,330	+47	0	+2,500	19,877
New and Emerging Invasives of National Concern					[+2,500]	
Cooperative Research Units	17,371	17,371	+113	0	+750	18,234
CRU Enhanced Support and Scientists for Tomorrow					[+750]	
Total, Ecosystems	157,041	160,232	701	0	13,005	173,938
<u>Climate and Land Use Change</u>						
<i>Climate Variability</i>						
National Climate Change and Wildlife Science Center/DOI Climate Science Centers (CSCs)	26,735	26,435	+32	0	+4,441	30,908
Critical Landscapes: Arctic					[+500]	
Tribal Climate Science Partnerships					[+1,411]	
WaterSMART: Drought					[+1,030]	
Great Lakes Climate Science Center					[+1,500]	
Climate Research and Development Program	21,495	21,495	+94	0	+1,125	22,714
WaterSMART: Drought					[+1,125]	
Carbon Sequestration	9,359	9,359	+22	0	+0	9,381
Subtotal: Climate Variability	57,589	57,289	148	0	5,566	63,003

Budget at a Glance

Budget at a Glance						
(Dollars in Thousands)						
	2015 Actual	2016 Enacted	Fixed Costs	Internal Transfers	Program Changes	2017 Budget Request
Surveys, Investigations, and Research						
<i>Land Use Change</i>						
Land Remote Sensing Program	67,894	72,194	+113	0	+24,199	96,506
Big Earth Data: Data Cube					[+600]	
Critical Landscapes: Arctic					[+1,857]	
Landsat 9					[+15,400]	
Landsat Science Products for Climate and Natural Resources Assessments					[+2,992]	
Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis					[+500]	
Sentinel-2					[+2,200]	
WaterSMART: Drought					[+250]	
WaterSMART: Remote Sensing					[+400]	
Land Change Science	10,492	10,492	+43	0	+1,400	11,935
WaterSMART: New Tools and Models to Better Manage Water Nationwide					[+\$1,000]	
WaterSMART: Remote Sensing					[+400]	
Subtotal: Land Use Change	78,386	82,686	156	0	25,599	108,441
Total, Climate and Land Use Change	135,975	139,975	304	0	31,165	171,444
Energy and Mineral Resources, and Environmental Health						
<i>Mineral and Energy Resources</i>						
Mineral Resources Program	45,931	48,371	+243	0	+81	48,695
Critical Minerals and Materials Flow Initiative					[+1,022]	
Geophysical and Remote Sensing Activities					[-1,500]	
R&D to Address Environmental Impacts of Minerals Development					[+559]	
Energy Resources Program	24,895	24,695	+118	0	+1,415	26,228
Alternative Energy Permitting on Federal Lands - Geothermal					[+229]	
Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment					[+211]	
Unconventional Oil and Gas Research					[+975]	
Subtotal: Mineral and Energy Resources	70,826	73,066	361	0	1,496	74,923

Budget at a Glance						
(Dollars in Thousands)						
	2015 Actual	2016 Enacted	Fixed Costs	Internal Transfers	Program Changes	2017 Budget Request
Surveys, Investigations, and Research						
<i>Environmental Health</i>						
Contaminant Biology Program	10,197	10,197	+45	0	+1,223	11,465
Critical Landscapes: Columbia River					[+50]	
Environmental Impacts of Uranium Mining					[+273]	
Unconventional Oil and Gas Research					[+900]	
Toxic Substance Hydrology Program	11,248	11,248	+47	0	+1,800	13,095
Critical Landscapes: Columbia River					[+50]	
Emerging Contaminants & Chemical Mixtures					[-750]	
Environmental Impacts of Uranium Mining					[+1,750]	
Fate and Transport of Contaminants in the Subsurface					[-800]	
Resilient Coastal Landscapes and Communities: Contaminant Network Along Northeast Coast					[+1,300]	
Unconventional Oil and Gas Research					[+250]	
Subtotal: Environmental Health	21,445	21,445	92	0	3,023	24,560
Total, Energy and Mineral Resources, and Environmental Health	92,271	94,511	453	0	4,519	99,483
Natural Hazards						
Earthquake Hazards Program	59,503	60,503	+193	0	+1,500	62,196
Central/Eastern U.S. Seismic Network Adoption					[+800]	
Unconventional Oil and Gas Research - Induced Seismicity Earthquake Risk Assessments					[+700]	
Volcano Hazards Program	25,121	26,121	+117	0	+0	26,238
Landslide Hazards Program	3,485	3,538	+16	0	+500	4,054
Natural Hazard Science for Disaster Response: Landslide Response					[+500]	
Global Seismographic Network	4,853	6,453	+9	0	+860	7,322
GSN Primary Sensor Deployment					[+860]	
Geomagnetism Program	1,888	1,888	+10	0	+1,700	3,598
Improved Geomagnetic Monitoring to Support Space Weather nowcasting					[+1,700]	
Coastal and Marine Geology Program	40,336	40,510	+174	0	+5,609	46,293
Building Landscape-Level Resilience to Coastal Hazards					[+2,109]	
Scenarios for Arctic Actions to Address Imminent Coastal Impacts					[+3,500]	
Total, Natural Hazards	135,186	139,013	519	0	10,169	149,701

Budget at a Glance

Budget at a Glance						
(Dollars in Thousands)						
	2015 Actual	2016 Enacted	Fixed Costs	Internal Transfers	Program Changes	2017 Budget Request
Surveys, Investigations, and Research						
<u>Water Resources</u>						
Water Availability and Use Science Program	40,919	42,052	+236	0	+12,100	54,388
Critical Landscapes: Arctic					[+1,950]	
WaterSMART: Drought					[+1,000]	
WaterSMART: National Hydrologic Model					[+750]	
WaterSMART: Streamflow Information					[+400]	
WaterSMART: Water Use Information					[+3,000]	
WaterSMART: Water Use Research					[+1,000]	
WaterSMART: Near Real Time Assessment of Water Use During Drought					[+4,000]	
Groundwater and Streamflow Information Program	69,707	71,535	+222	0	+1,200	72,957
Natural Hazard Science for Disaster Response: Expand Use of Streamgages					[+700]	
Tribes					[+500]	
National Water Quality Program	94,141	90,600	+499	0	+3,048	94,147
Enhanced Cooperative Activities and Urban Waters					[+717]	
Support NAWQA Cycle Three					[+1,881]	
Unconventional Oil and Gas Research					[+450]	
Water Resources Research Act Program	6,500	6,500	+0	0	+0	6,500
Total, Water Resources	211,267	210,687	957	0	16,348	227,992
<u>Core Science Systems</u>						
National Geospatial Program	58,532	62,854	+238	0	+5,887	68,979
3D Elevation: Alaska Mapping and Map Modernization					[+1,500]	
3D Elevation: Coastal lidar					[+500]	
3D Elevation: National Enhancement					[+2,387]	
3D Elevation: NHD/Landscape Level Assessments - Chesapeake Bay					[+500]	
WaterSMART: National Hydrography Database					[+1,000]	
National Cooperative Geologic Mapping Program	24,397	24,397	+89	0	+0	24,486
Science Synthesis, Analysis and Research Program	24,299	24,299	+81	0	+550	24,930
Pollinators					[+350]	
WaterSMART: Drought					[+200]	
Total, Core Science Systems	107,228	111,550	408	0	6,437	118,395

Budget at a Glance						
(Dollars in Thousands)						
	2015 Actual	2016 Enacted	Fixed Costs	Internal Transfers	Program Changes	2017 Budget Request
Surveys, Investigations, and Research						
Science Support						
Administration and Management	84,192	81,981	+141	0	+4,197	86,319
DOI Science Coordination					[+200]	
Mendenhall Program Postdocs					[+500]	
Outreach to Underserved Communities					[+200]	
Support Science Mission, Infrastructure					[+1,997]	
Capacity to Support Science					[+300]	
Tribal Science Coordination					[+1,000]	
Youth & Education in Science						
Information Services	21,419	23,630	+23	0	+620	24,273
Support Science Mission, Infrastructure					[+620]	
Capacity to Support Science						
Total, Science Support	105,611	105,611	164	0	4,817	110,592
Facilities						
Rental Payments and Operations & Maintenance	93,141	93,141	+1,223	0	+15,614	109,978
Operations and Maintenance Stewardship					[+2,712]	
Reducing the Facilities Footprint - Cost Savings and Innovation Plan (CSIP)					[+10,902]	
Sustainability Investments					[+2,000]	
Deferred Maintenance and Capital Improvement	7,280	7,280	+0	0	+0	7,280
Total, Facilities	100,421	100,421	1,223	0	15,614	117,258
Total, SIR	1,045,000	1,062,000	4,729	0	102,074	1,168,803

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Program Changes

Program Changes

Dollars in Thousands	Multi-Mission Changes					Mission Area Program Changes	Total Program Change
	Sustainable Water - WaterSMART	Critical Landscapes	All-of-the-Above Energy	Natural Hazard Science for Disaster Response	Pollinators		
Ecosystems	2,800	4,000	500	500	1,705	3,500	13,005
Climate and Land Use Change	4,205	2,357	0	0	0	24,603	31,165
Energy and Mineral Resources, and Environmental Health	0	100	4,377	1,300	0	(1,258)	4,519
Natural Hazards	0	3,500	700	5,969	0	0	10,169
Water Resources	10,150	1,950	450	700	0	3,098	16,348
Core Science Systems	1,200	0	0	0	350	4,887	6,437
Science Support	0	0	0	0	0	4,817	4,817
Facilities	0	0	0	0	0	15,614	15,614
USGS Total	18,355	11,907	6,027	8,469	2,055	55,261	102,074

This Chapter is broken into two sections – Multi-Mission Changes and Mission Area Program Changes.

The Multi-Mission Changes section breaks out the program changes within the 2017 budget by areas of work where multiple USGS Mission Areas are contributing to the overall effort. This section shows a holistic view of the additional level of effort that is needed to further the work of the activities discussed.

The Mission Area Program Changes section summarizes all the program changes within each Mission Area. The changes represented in the Multi-Mission Changes Section are repeated within this section. More information on the program changes and what related program funding is paying for in 2015, 2016, and 2017 can be found in the Mission Area Chapters.

Multi-Mission Changes

The budget changes represented in this Multi-Mission Changes section represent areas where the USGS is actively working across the bureau, in multiple Mission Areas, to find solutions, obtain needed information, or further critical research through our work. Please note that the program changes being addressed in this section may not necessarily have a 1:1 correlation with the numbers that you see in the Crosscutting Activity chapter, though the name of the project may be similar.

The Multi-Mission Changes discussed in this section include:

1. Sustainable Water - WaterSMART
2. Critical Landscapes
3. All-of-the-Above Energy
4. Natural Science for Disaster Resilience and Response
5. Pollinators

Sustainable Water – WaterSMART **(+\$18,355,000)**

Near Real-Time Assessment of Water Use During Drought	(+\$4,000,000)
Water Use Information	(+\$3,000,000)
Ecological Flows	(+\$2,500,000)
Water Use Research	(+\$1,000,000)
National Hydrography Database	(+\$1,000,000)
New Tools and Models to Better Manage Water Nationwide	(+\$1,000,000)
Remote Sensing	(+\$800,000)
National Hydrologic Model	(+\$750,000)
Streamflow Information	(+\$400,000)
Science to Support Drought	(+\$3,905,000)

Overview

Meeting the water resource needs of the Nation is an increasingly difficult challenge because of rapid changes in water availability, driven by climate change, population, water use, and land use changes. Ensuring sustainable water supplies is more important than ever as changes in the frequency and magnitude of extreme hydrologic events, such as flood and drought, create uncertainty for water managers. As demand for water resources grows for irrigation of crops, cities and communities, energy production, and the environment, so does the need for information and tools to aid water and natural resource managers. WaterSMART is a Department of the Interior (Interior) initiative that leverages and directs existing expertise and resources within the U.S. Geological Survey (USGS) and the Bureau of Reclamation (Reclamation) to address complex, national- and regional-scale water challenges. The SECURE Water Act (P.L. 111-11, Subtitle F, Sections 9507 – 9509) dictates the USGS role: Provide science to help water managers understand and address competing demands for water. The primary focus

of this initiative includes developing a National Water Census that will allow resource managers to gain a better understanding of water budgets in their area of concern, which supports sustainable and environmentally sound water management. Leveraging expertise across multiple USGS mission areas broadens the initiative to address these challenging issues. The USGS possesses the skills and foundational resources to provide water resource, ecosystem, and land use managers the decision-support tools to make informed decisions. The goal of this effort is to improve the data and understanding associated with groundwater, surface water, human water use, and the ways in which these and other water budget components influence water availability, and to develop tools that will allow managers to apply the new understanding and data. The Nation will be well served through this effort, by gaining the ability to balance water resource sustainability through consideration of water quantity, quality, and uses, including ecological uses.

Near Real-Time Assessment of Water Use During Drought **(+\$4,000,000)**

Water Resources

Water Availability and Use Science Program (+\$4,000,000 for a total of \$4,000,000)

Information on past and present water use is needed during drought conditions to allow resource managers to assess vulnerability and determine the effectiveness of conservation measures. The USGS will use the increase to develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures. These products can be used by resource managers to assess vulnerability of specified basins or water suppliers.

The USGS currently has water use information, by county, for eight sectors of water use, for compilation years 1985, 1990, 1995, 2000, 2005, and 2010, in the Aggregated Water Use Database (AWUDS) (<http://water.usgs.gov/watuse/>). This data represents a time series of annual data, for eight sectors of water use, every five years over a 25-year time span. These six sets of data provide an opportunity for estimating water use in drought-stricken areas on a more frequent basis than our traditional “five year compilations.” The USGS would divide the Country into groups of counties that have similar hydroclimatology and water use trends to determine if the county groups can be used as water use monitoring regions. Key questions to answer are: (1) do the county groups respond similarly in their patterns of water use over the 25-year time frame; and (2) is there a subgroup that can be monitored more frequently during a drought that would allow estimation of water use for the entire group of counties. After these subgroups are established, the USGS would monitor the water use condition intensively in the subgroups and use statistical methods to estimate quarterly water use for the entire county group. This effort will require a strategy to build database interoperability, agreement on common data elements, and other water availability supporting information between States and the USGS. The WUDR program will be critical to support States’ efforts to build capacity for providing the necessary data. These steps will allow the USGS to interact effectively with States to obtain a near real-time picture of water use during the drought. The USGS has been working with the Western States Water Council staff on WaDE (Water Data Exchange). Under leadership of the Western States Water Council, WaDE brings water use data from 17 States together in a common portal and with common data elements,

Program Changes

allowing evaluation of this data across State lines. This type of system is needed nationally to manage water usage on a near real-time basis.

Water Use Information

(+\$3,000,000)

Water Resources

Water Availability and Use Science Program

(+\$3,000,000 for a total of \$3,000,000)

Since 1950, the USGS has been the primary Federal agency responsible for providing a comprehensive understanding of water use across the Nation, with consistent reporting every five years through the USGS series of circulars: Estimated Use of Water in the United States. As required under the SECURE Water Act (P.L. 111-11), and the President's Climate Action Plan, the USGS is working to expand its efforts and provide comprehensive, high-resolution water use information (on an annual basis and at a location) that will support a host of decision-support systems. This high-resolution water use information will allow resource modelers and managers to understand the influence that human water use has on the hydrologic cycle, the degree to which human consumptive uses influence the sustainability of water supplies, and allows comparison of human water demands to the sustainability of environmental water needs. The USGS has already begun work under the National Science and Technology Council's (NSTC) Committee on the Environment, Natural Resources, and Sustainability to coordinate activities with other Federal agencies and State agencies to scope the effort for providing this high-resolution water use information. The USGS is to begin coordinating an effort with Reclamation, the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), and the Department of Energy (DOE) to improve their ability to feed base data into the water use databases.

The 2017 requested increase would allow the USGS to participate in a multiagency, Open Water Data Initiative that will integrate water information that is fragmented among multiple agencies into a national water data framework on a geospatial platform, improving the water use information mentioned above. The Open Water Data Initiative will leverage existing partnerships and infrastructure to allow for greater data accessibility and better tools and solution development.

The requested increase would also allow the USGS to continue to provide grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making. The data would be formatted to allow easy input of water use to the National Hydrologic Model, as well as other models utilized by the USGS and others. The USGS would coordinate these activities with other Federal agency efforts, provide grants to and coordination with State Water Resources Agencies on their data delivery, and maintain the comprehensive Site-specific Water Use Data System and Aggregate Water-Use Data System databases. Finally, this funding would support periodic comprehensive analysis of the data to report on water use trends and provide national water-use indicator analysis and maps of water stress indicators.

Comprehensive water use information would be provided on an annual and ongoing basis for the following sectors of water use: irrigation, public water supplies, thermoelectric cooling water, industrial self-supplied water, and aquaculture.

Ecological Flows **(+\$2,500,000)**

Ecosystems

Fisheries Program (+\$2,500,000 for a total of \$3,000,000)

In 2015 and 2016, the USGS Fisheries Program has successfully developed a suite of tools, science products, and visualization aids to help water managers understand the needs and response of economically, ecologically, and culturally important fish and other aquatic resources to changes in water flow and quality for use in making water allocation decisions. This information is particularly critical as competition for water resources increases and water supplies are being impacted by extreme weather events such as drought and flood.

The 2017 requested increase would allow the Fisheries Program to greatly expand these efforts by transferring this capability from the three pilot systems (Delaware River, Apalachicola-Chattahoochee-Flint Basin, Colorado River) to other river systems across the United States, with the ultimate goal of creating a National Ecological Flow Evaluation Tool for use by all water managers in all systems where resolving water allocation conflicts is a priority. Effort will entail the development of a broadly applicable “generic” suite of modular tools that integrate existing data on natural resources, models to estimate water flow in ungaged systems, and advances in remote sensing of geographic features such as bathymetric lidar. Initial focus will be on Western systems impacted by drought, Midwestern and Southern systems impacted by alternating years of extreme flood and drought, Arctic systems impacted by permafrost thaw, and development of tools to incorporate ecological flow considerations into the Principles and Requirements for Federal Investments in Water Resources. The end result is to develop a system that is fully integrated with the National Streamgauge Network that enables water managers to simultaneously evaluate allocation scenarios while considering all facets of the water budget and facilitate more informed decisions on living resources, habitat, and other values.

Water Use Research **(+\$1,000,000)**

Water Resources

Water Availability and Use Science Program (+\$1,000,000 for a total of \$1,000,000)

Water use information that identifies the impacts of human water withdrawals and return-flows is critical for the National Water Census’s water budget analysis. This information, which is mostly collected at State, tribal, regional, and local governmental levels, must be obtained on a site-specific scale in order to be fully useful in the National Water Census analyses. The WAUSP would work directly with State, tribal, regional, and local cooperators to match this funding and make maximum use of their water use datasets in the water availability and use assessment. Working collaboratively with State, tribal, regional, and local cooperators to determine work that is beneficial to both groups is required to develop better methods of sampling, estimating, aggregating, and presenting water use data. This includes research into new methods that use remote sensing and spatial datasets in water use estimation. The research and networks and analysis functions of the USGS would work together to advance the development of those methods for use within the WaterSMART initiative. The USGS would integrate this information with

Program Changes

decision support tools that facilitate use of that information in a manner that is relevant to water resource management decision making.

USGS monitoring, assessments, and research would continue and expand related to WaterSMART and impacts on water use. Additional focus will be placed on tracking site-specific, public supply and other water use information; developing consumptive use measurements and methodology (particularly associated with irrigated agriculture); assessing watershed water budgets (including developing estimates for streamflow at ungaged sites for more accurate water budgets); developing water use/budget models to track long-term patterns in groundwater and surface water flow; and advancing evapotranspiration measurements and assessment techniques. This funding being requested would be part of the cooperative matching funds.

National Hydrography Database **(+\$1,000,000)**

Core Science Systems

National Geospatial Program (+\$1,000,000 for a total \$1,000,000)

The National Geospatial Program (NGP) has worked for many years with the National Water Quality Program and StreamStats to continuously create and improve the National Hydrography Dataset (NHD). Along with the Watershed Boundary Dataset, the NHD is used to portray surface water on The National Map. The NHD represents the drainage network with surface water features such as rivers, streams, canals, lakes, ponds, coastline, dams, and streamgages. Efficiently tracking water use and the relationship between manmade diversions and streamflow requires that the points of withdrawal and discharge be mapped within the stream network. Currently, hydrography datasets of differing functionality and scales are used by agencies including the USGS, the Environmental Protection Agency, the U.S. Forest Service, and the Bureau of Land Management. The water resource community, including Federal, State, tribal and local water resource managers; and private and non-profit organizations would benefit from using a single, scalable hydrographic referencing system with robust functionalities. Other potential users include the National Fish Passage Program and the State of California Division of Water Rights Electronic Water Rights Information Management System (eWRIMS).

With these funds, the NGP would complete national NHDPlus high-resolution (1:24,000 scale or better) coverage for the conterminous 48 States, Hawaii, and Puerto Rico. Taking this step now positions the USGS to fully utilize lidar data as they become available through 3DEP. This achievement would create an integrated elevation-hydrography dataset for water resource managers throughout the Nation. Future lidar-derived integrated elevation-hydrography data would fit into the same structure and use the same utilities. This full integration of elevation and hydrography would simplify hydrography data and streamline the user experience, application development, and stewardship of the data. It would also support the National Water Census and enable an initial step in delivering the Open Water Data Initiative. Developing a single, scalable hydrographic referencing system would integrate currently fragmented water information into a connected, national water data framework to underpin innovation, modeling, data sharing, and solution development.

New Tools and Models to Better Manage Water Nationwide **(+\$1,000,000)**

Climate and Land Use Change

Land Change Science (+\$1,000,000 for a total of \$1,000,000)

The proposed increase would be used to develop automated methods and tools supporting near real-time, satellite-based, drought monitoring. This effort will take advantage of Landsat’s data processing and classification system that will provide image data every eight days. Assessed characteristics will include soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers identify the onset and severity of drought events and effectively allocate scarce water resources. This information would allow for early detection of drought conditions and extent and enable comprehensive water management by linking water supply sources with its users.

Remote Sensing **(+\$800,000)**

Climate and Land Use Change

Land Remote Sensing Program (+\$400,000)

Land Change Science (+\$400,000)

Climate and Land Use Change

Land Remote Sensing Program (+\$400,000 for a total of \$400,000)

The National Water Census already benefits from the use of remote sensing data and analysis, including Landsat data. In 2017, the USGS would expand work across its land use and water programs to support additional aspects of the National Water Census. The National Water Census is at a place in its development to access operational Landsat products, generated as frequently as every eight days. Several new Landsat-based science products (e.g., dynamic surface water extent) are becoming mature enough to be integrated with the National Water Census.

In the United States, good information on the amount of water in large storage features such as reservoirs and lakes is available; however, there is a significant gap in identifying and quantifying water storage in smaller storage features. These water storage features influence the flow characteristics of streams in each watershed. Understanding and reporting on these features could provide benefit for drought status monitoring, understanding climate variability, and streamflow estimation, particularly in areas without streamgages. Moreover, information on changes in surface water storage is essential in order to accurately estimate the total amount of water in a basin—a central need for the National Water Census.

The increase would support the development of these estimates in a nationally consistent manner, by creating a geo-rectified remote sensing datasets (e.g., dynamic surface water extent) that track changes in the number and size of these surface features within a year and across decades. Detection, documentation and monitoring of temporary water storage features is only feasible through the use of a remote sensing system such as Landsat, which frequently and routinely images the land surface over long periods of time. In a watershed such as the Apalachicola, Chattahoochee, and Flint such monitoring would provide an

Program Changes

objective and systematic methodology for comprehensively assessing the state of the watershed, allowing multiple political entities to coordinate water usage and management.

Climate and Land Use Change

Land Change Science (+\$400,000 for a total of \$400,000)

The proposed increase would be used to conduct an innovative data integration approach that combines satellite-derived reservoir surface area from the Land Remote Sensing Program's dynamic surface water extent Landsat dataset and digital elevation models (DEM) to monitor height and volumetric storage changes in water reservoirs. In the United States, good information on the amount of water in large storage features such as documented reservoirs and lakes is available; however, there is a significant gap in identifying and quantifying water storage in undocumented or ephemeral storage features. Despite their smaller size, these water storage features influence the flow characteristics of streams.

Understanding and reporting on these features could provide information for drought monitoring, climate variability, and streamflow estimation, particularly in areas without streamgages. Volume information is not currently available for the ungaged reservoirs, and even for gaged reservoirs, it is important to express the height information within a form of a standardized index that will express the "fullness" level.

National Hydrologic Model (+\$750,000)

Water Resources

Water Availability and Use Science Program (+\$750,000 for a total of \$750,000)

The Committee on the Environment, Natural Resources, and Sustainability has recognized the need for a National Hydrologic Modeling Framework to advance understanding and forecasting of the water budget, to effectively manage water resources, and to adapt to a changing climate. The USGS currently has a national scale hydrologic model that addresses the major components of the water budget; however, human water use is not addressed explicitly. Moreover, information needed to operate the model must be obtained in a labor-intensive method. There is a need to assemble community modeling resources (i.e., datasets, models, use cases) to economize and enhance model development and verification activities across the community. Model development assumes continued community use of legacy models and datasets rather than proposing a new model framework. Such an activity would improve and modernize access to resources that support development, verification, or model application for specific decision situations.

This work, conducted in collaboration with the EPA and the National Oceanic and Atmospheric Administration (NOAA) on major modeling and data generation activities, would accelerate collaborative development of a nationwide hydrologic model that accounts for all aspects of the water budget. Initially, the USGS would work to incorporate remote sensing, including lidar and geophysical data, to refine landscape-scale topography, landcover, geologic framework, soil moisture, evapotranspiration estimates, and changes in depression storage. The USGS would begin steps to improve linkages between surface and groundwater hydrologic models by accommodating variable grid sizes and time steps, nesting existing fine-scale models within coarse-scale regional models. Finally, initial steps would be taken to

refine operation of surface water models in sub-daily mode to better forecast flood response in smaller basins.

Streamflow Information **(+\$400,000)**

Water Resources

Water Availability and Use Science Program (+\$400,000 for a total of \$1,075,000)

Streamflow information is required for water-resources management, and changing streamflow conditions require continuity of information for flood and drought response and routine water allocations. A goal of the National Water Census effort is to provide estimates of streamflow statistics throughout the Nation. The USGS StreamStats decision-support tool allows the USGS and partners to develop these estimates. In 2017, the WAUSP is requesting a funding increase to implement StreamStats in three additional States and to continue to improve methods for providing the estimates. (The States selected will depend on which States supply cooperative funding to help support this work.)

Science to Support Drought **(+\$3,905,000)**

Ecosystems

Environments Program (+\$300,000)

Climate and Land Use Change

National Climate Change and Wildlife Science Center/

DOI Climate Science Centers (CSCs) Program (+\$1,030,000)

Climate Research and Development Program (+\$1,125,000)

Land Remote Sensing Program (+\$250,000)

Water Resources

Water Availability and Use Science Program (+\$1,000,000)

Core Science Systems

Science Synthesis, Analysis, and Research Program (+\$200,000)

Responding to drought and managing limited water resources are primary drivers for many land and water management agencies. Given the persistent drought in multiple regions of the United States, the USGS proposes to quantify streamflow for all areas of the Country, make precipitation data readily available, and determine groundwater availability under drought conditions. Providing access to these data will allow managers to determine impacts of drought on ecological systems. The USGS will develop actionable science approaches, by convening regionally based working groups of decisionmakers and natural resource managers to develop coordinated adaptive management plans for the complex consequences of severe and prolonged drought. The funding requested for this work would provide tools for fish and wildlife managers as well as water resource managers.

Ecosystems

Environments Program (+\$300,000 for a total of \$300,000)

In 2017, the Environments Program is requesting a funding increase that would allow the USGS to conduct research on how a drought interacts with other environmental stressors such as invasive

Program Changes

vegetation and wildfires to affect landscape composition, structure, and function. Information and data would be provided to resource managers who can then evaluate the tradeoffs between land management strategies to determine which would most likely lead to desired condition for managing the vegetation. This is a multi-disciplinary effort within the USGS and the next focus areas will be the Rio Grande and the Red River. This work will contribute to the National Water Census.

Climate and Land Use Change

National Climate Change and Wildlife Science Center/

DOI Climate Science Centers (CSCs) Program

(+\$1,030,000 for a total of \$1,030,000)

Understanding thresholds and tipping points caused by droughts is critical in providing managers with early action options. The National Water Census Data Portal serves information on streamflow, precipitation, and water use that can be utilized by the National Climate Change and Wildlife Science Center (NCCWSC)/DOI Climate Science Centers (CSCs) Program to provide the foundational data needed to build decision support tools that will explain what the tools will do, why they are important, who will use them. The NCCWSC would use the requested funding increase to continue to develop a science-based decision process for understanding and managing the impacts of drought on various parts of the Central and Western United States, including California. Much research is available on the effects of drought on human systems, notably agriculture, but the ecological effects are not as well studied. The program proposes to bring a diverse group of stakeholders together to identify science priorities and to co-produce science that allows managers to effectively respond to drought impacts on their resources. The USGS's goal is to use one or two drought stricken regions as examples to understand the impacts and then develop a decision-making process for managing limited water supplies in places like central California and the South Central United States. The USGS would develop working groups in places impacted by drought, consisting of USGS scientists, partners, and regional stakeholder networks to identify the science needs. Scientists attached to these working groups will develop models that integrate the social and economic impacts from drought and the USGS will use the North Central CSC's visualization facility (located in the Fort Collins Science Center) to allow the working groups to analyze scenarios using different decision points. In the requested increase, the program would expand the actionable science approach to other regions of the Country that are prone to drought. Through collaboration with the Land Remote Sensing (LRS) program, current land change assessment and drought monitoring products like the Vegetation Drought Response Index (VegDRI) will be evaluated, via the visualization facility, for their adequacy to support integrated drought projection models. The program would integrate results from LRS land change assessment products with climate driven drought projection models into models of ecological flow and wildlife impact to understand which areas of the Country are more vulnerable to drought impacts. By focusing on the ecological impacts of drought, this project complements ongoing activities focused on water availability/supply and the agricultural and municipal effects of drought such as those under the National Integrated Drought Information Systems, U.S. Bureau of Reclamation basin studies, and other partners' efforts.

Climate and Land Use Change**Climate Research and Development Program** (+\$1,125,000 for a total of \$1,125,000)

The Climate Research and Development (R&D) Program would use the requested funding increase to understand long-term and medium-term patterns and impacts of drought in the Western and Southeastern United States. Understanding patterns of drought is critical to develop sustainable plans for use of limited water resources by management agencies. These efforts would focus on generating new records needed to fully understand long-term patterns of United States hydroclimate in the two regions, including amount of precipitation, seasonality of precipitation (rain vs. snow), and variability in water availability over annual, decadal, and longer-time scales. This research would provide a context to assess the magnitude and regional impacts of current and future droughts, and provide information on how ecosystems of the Western and Southeastern United States have responded to past intervals of drought. These studies would provide resource managers with real-world results that could be used to test results from a range of climate and ecosystem models.

In the Pacific Northwest and Alaska, water availability and water quality are influenced by glacier dynamics. Increased funding would be used to expand ongoing research on alpine glaciers. Development of new and improved techniques to measure changes in the amount of water contained in alpine glaciers would improve the understanding of long-term patterns of glacier change and their influence on water availability and the transport of carbon and nutrients to streams, estuaries, and oceans. Such evidence would provide data needed by resource managers to better forecast changes in streamflow and ecosystem function in watersheds fed by alpine glaciers. The data and information collected by the Climate R&D Program can be compared to the current data that is collected and served through the National Water Census. This type of comparison would allow resource managers to use past examples to help understand current conditions in their area.

Climate and Land Use Change**Land Remote Sensing Program** (+\$250,000 for a total of \$250,000)

The LRS program would use the requested increase to work with the NCCWSC and the North Central CSC to investigate the relationship between drought and climate change on wildlife populations and their food sources. Drought-related climate indices and land cover change information would be used to model and predict how drought and climate change are impacting the phenology of animal migration and the forage quality of Western habitats. Current land change datasets and drought products like the Vegetation Drought Response Index (VegDRI) will be evaluated for their adequacy to support management decisions for wide-ranging ungulate (e.g., Mule deer, Big Horn Sheep) populations and key habitats. This collaborative effort would identify gaps in remote sensing data and derivative products, collect new data for model validation, and recommend new methodologies to meet the needs of scientists and decision makers in the conservation and land management communities. VegDRI is an operational drought model and map created weekly and is used by numerous organizations for drought mitigation decision support. VegDRI information will be integrated with the evapotranspiration outputs that the National Water Census is already delivering to the public via the National Water Census Data Portal. The use of these and related capabilities would be extended into the habitat modeling community. This collaborative effort would evaluate current remote sensing data and derivative products such as VegDRI to reliably

Program Changes

model land change indicators for projecting drought. Remote sensing data gaps would be identified, and new data sets collected and assembled to enhance model validation. This would allow the development of new methodologies for integrating land change assessment models and drought products with climate driven drought projection models used by NCCWSC to decrease product uncertainties.

Water Resources

Water Availability and Use Science Program (+\$1,000,000 for a total of \$1,801,000)

Seasonal snowpack serve as large natural reservoirs that store water through the winter, and release it during spring and summer months, when demand is greatest—often supplying water to meet demands hundreds of miles away. The quantity of water that is stored in the seasonal snowpack and then released as snowmelt is one of the most important inputs used for forecasting annual runoff and water supply in these regions. There is an urgent need to improve our understanding of the role of snow in water budgets at the regional and national scales. Key questions include: (1) What is the contribution of snow to the annual water budget; (2) How much snowfall ends up in streams and rivers; (3) Can models and remotely sensed data be used to accurately estimate snow water content and to simulate snowpack processes across the landscape; (4) How can observations help guide the development of snowpack models and remote sensing techniques, and what temporal and spatial resolution is required for those observations; and (5) How do the dynamics of snow accumulation and snowmelt change in response to changing climate conditions? Given the uncertainties in modeling snow water content and its seasonal evolution, and the importance of snowmelt in the annual water balance, it is essential to conduct a more comprehensive evaluation of data needs and model capabilities for quantifying water budgets across snow-dominated regions of the United States. This increase will allow for the critical evaluation of research on the assimilation of remote sensing observations and ground-based snow measurements into snowmelt runoff models that is needed to provide more accurate forecasts of snowmelt runoff.

Core Science Systems

Science Synthesis, Analysis, and Research Program (+\$200,000 for a total of \$200,000)

The Science Synthesis, Analysis, and Research Program, in collaboration with the Land Change Science Program, would use this funding to build upon existing expertise to synthesize scientific research on species most at risk from the effects of drought, model the effects of drought on the habitat for those species, and create maps that show areas most viable for mitigation activities. These outputs would improve the USGS support to ecosystem conservation planners by identifying species at risk and habitats of critical concern for drought effects, and those areas most promising for mitigation actions. Resource managers would be able to use climate scenarios to help determine appropriate mitigation strategies to address drought effects on habitats and species at risk.

Critical Landscapes **(+\$11,907,000)**

The Changing Arctic	(+\$8,807,000)
Columbia River	(+\$100,000)
Science for the Sage Steppe Landscape	(+\$3,000,000)

Overview

Knowledge of ecosystems is critical to the well-being of the Nation because ecosystems supply the natural resources and other goods and services that humans require. The scope of science needed to improve conservation and restoration of ecosystems is complex. In many ecosystems, regional environmental resource issues challenge decision makers and place them at a critical juncture to balance human needs with ecosystem health. The multidisciplinary approach applied by the USGS is necessary to develop an understanding of both individual ecosystem processes and holistic ecosystem level evaluations of responses to actual and proposed restoration alternatives and plans. Science enables resource managers to make informed decisions to help resolve and prevent resource management conflicts, and to support Interior’s public trust stewardship responsibilities for the Nation’s lands and waters.

Increases in 2017, support research and development efforts focused in the Arctic, Columbia River, and Sage Steppe Landscape. In addition to these increases, USGS research will continue to support other priority ecosystems such as Chesapeake Bay, Everglades, Great Lakes, California Bay Delta, Puget Sound, Upper Mississippi River, and the Gulf Coast. These multi-disciplinary projects are designed to serve local ecosystem management needs and provide knowledge and approaches transferable to similar ecosystems across the Nation.

The Changing Arctic	(+\$8,807,000)
Ecosystems, Environments Program	(+\$1,000,000)
Climate and Land Use Change	
National Climate Change and Wildlife Science Center/DOI Climate Science Centers	(+500,000)
Land Remote Sensing Program	(+\$1,857,000)
Natural Hazards, Coastal and Marine Geology Program	(+\$3,500,000)
Water Resources, Water Availability and Use Science Program	(+\$1,950,000)

Ecosystems	
Environments Program	(+\$1,000,000 for a total of \$2,030,000)

The Environments program would use the requested funding to work with scientists from other parts of the USGS and partner agencies to analyze potential changes to distributions and condition of fish and wildlife populations and their habitats as a result of climate changes and human activities. Management options designed to offset these changes are hampered by uncertainty in how climate change will affect both species’ occurrence (i.e., distribution) and within-season timing (e.g., growth, reproduction, migration). The program will seek to develop quantitative methods to assess plant and animal responses simultaneously at species and community levels to explicitly incorporate shifts in species’ responses to climate variables. Such methods have application beyond taxa in Alaska and could be applied across

Program Changes

systems where there is a desire to predict the species changes and shifts in life history timing in response to climate change or development.

Additionally, the USGS will use computer simulations of data gathered in Western Hudson Bay, the Chukchi Sea, and the Southern Beaufort Sea to evaluate various strategies for estimating polar bear populations. The USGS would evaluate study design strategies aimed at monitoring polar bear populations in order to estimate population parameters (e.g., survival and breeding) and their relationships with environmental conditions, estimate population size for the purposes of managing sustainable removals, and detect changes in these parameters. Methodological and analytical advancements have become available that could be integrated into polar bear population studies to make them practical to implement in challenging environments, financially feasible and minimally disturbing to animals. USGS scientists and their collaborators have analyzed nearly 30 years of bear capture data from the Western Hudson Bay population. This analysis has suggested areas for improvement that would reduce the costs and improve the efficacy of polar bear studies throughout the Arctic. These improvements would be analyzed and modelled further in order to make final recommendations.

Climate and Land Use Change

National Climate Change and Wildlife Science Center

DOI Climate Science Centers (CSCs)

(+500,000 for a total of \$500,000)

The NCCWSC/AK Climate Science Center would use the requested funding increase to develop a process to estimate total glacier loss in Alaska and potential changes in freshwater input. These estimates would be used along with projections of future changes in climate, fire regimes, vegetation, and water flows, produced by the program's recently completed Alaska Integrated Ecosystem Model (AIEM). Glacier loss can have a significant effect on river systems and ecosystem dynamics, affecting economically and culturally important species such as salmon and caribou. The funding would also build on existing research investments in interior Alaska to better understand the potential for larger scale and more frequent effects of ecological drought in the region. The tool is capable of providing scenarios that depict changes in landscape structure and function, thereby allowing resource managers to assess the effects of climate change on natural resources.

Climate and Land Use Change

Land Remote Sensing Program

(+\$1,857,000 for a total of \$1,857,000)

The Land Remote Sensing (LRS) program would use the requested increase for the development of predictive models, which support the evaluation of changes to the environment resulting from the conversion of historically sequestered ice and snow to liquid and gaseous water. Multi-temporal and multi-resolution remote sensing data from satellites and airborne systems (Landsat, Classified Systems, Aircraft, and Unmanned Aerial Systems) would be used in combination with field-based studies and in-situ observations to measure changes of ice and snow volumes, and support the development of predictive models describing the impacts from climate-induced changes. Although initial research work to measure the extent of permafrost is currently being conducted, for the first time, this initiative would enable the development of predictive models for permafrost melt, providing the means to prepare local communities

across the Arctic for the effects of the thawing land beneath them, while also improving global climate modeling.

Natural Hazards

Coastal and Marine Geology Program (+\$3,500,000 for a total of \$4,925,000)

The proposed increase will allow the USGS to shift research staff to work in the Arctic and selected Pacific Islands where underserved communities are dealing with impacts of sea level rise, severe storms and melting permafrost on their coastal communities and economies. The cost of field studies and equipment use in these regions is more expensive than in the lower 48 States, therefore, this increase will nearly triple activities conducted in 2015 and 2016. The USGS will use unmanned autonomous vehicles (UAVs) to collect images of coastal areas to deploy structure from motion technology to monitor seasonal coastal land changes in remote areas. This work will build off of pilot studies using UAVs for Flaxman and Barter Islands, AK, and kites for Anahola Valley, HI. The USGS will utilize long-term coastal change models to forecast changing coastal conditions and vulnerability based upon different climate, sea level, and storm scenarios over the next 10–25 years. The resulting science-based scenarios will be shared with local communities to ensure consistency with their specific priorities, whether related to siting of infrastructure, use of natural resources, planning of communities, or other topics. Supported activities will leverage existing USGS tools and delivery mechanisms currently unavailable to these communities outside the open-ocean coastal regions of the coterminous United States.

Water Resources

Water Availability and Use Science Program (+\$1,950,000 for a total of \$2,200,000)

The increase would address interactions among water-mediated processes in a warming Arctic, assess system feedbacks (e.g., effects of warming on hydrology and biogeochemical cycling which subsequently affects climate and hydrology), and better anticipate future system change via these assessments of the cryosphere. The work funded by this increase would expand monitoring of hydrologic (groundwater, surface water, thermos-karst features) and related biogeochemical (particularly carbon, nutrient, and mercury) cycles, and explore opportunities for predictions that allow extrapolation from monitored to unmonitored locations.

The WAUSP would also support the expansion and enhancement of monitoring of sentinels of change including permafrost temperature, streamflow, biogeochemical and other materials exported from watersheds, and carbon dioxide and methane exchange between land and water surfaces and the atmosphere. In particular, increased methane (a powerful greenhouse gas) emissions in high latitudes will be directly mapped to the availability and redistribution of liquid water as a result of permafrost thaw. This emphasizes the need for improved modeling of permafrost thaw. Ponds produced by thaw of ice-rich permafrost will likely be sites of high methane production, which will be supported by the Precipitation Runoff Modeling System model of Alaska will support modeled pond development.

Program Changes

Columbia River	(+\$100,000)
Energy and Mineral Resources, and Environmental Health	
Contaminant Biology Program	(+\$50,000)
Toxic Substances Hydrology Program	(+\$50,000)

Energy and Mineral Resources, and Environmental Health	
Contaminant Biology Program	(+\$50,000, for a total of \$100,000)

The Columbia River Basin, which includes parts of seven states and 13 recognized tribal reservations, remains a critical part of the Pacific Northwest's ecosystems, economy, and culture. In 2017, the Contaminant Biology Program would use the proposed increase to expand studies of contaminant exposure and the cycling of mercury and pesticides in food webs to address important tribal and endangered species of concern in the Columbia River Basin. With the proposed funding increase, new studies focusing on sturgeon will begin. In addition, the proposed funding increase would allow for the collection, archival, and study of samples of small mouth bass for potential exposure to endocrine disrupting chemicals. This work is vital for maintaining the health of this critical ecosystem, which has considerable implications for the region's economy and the health of the millions of people living in the region.

Energy and Mineral Resources, and Environmental Health	
Toxic Substances Hydrology Program	(+\$50,000, for a total of \$100,000)

The Columbia River is the largest river in the Pacific Northwest, and plays an important role in the region's culture and economy through tribal fisheries, irrigation, power production, and recreation, among other goods and services. This ecosystem has been affected by a number of manmade changes, including the introduction of environmental contaminants. With the proposed increase, the Toxic Substances Hydrology Program would continue to investigate the effects of contaminants such as pesticides and mercury on the fish and wildlife in the Columbia River. This work is essential to the protection of the health of aquatic and terrestrial wildlife in the region, and would also provide the basis for understanding the interactions of these contaminants with fish and wildlife in similar ecosystems in other regions.

Science for the Sage Steppe Landscape **(+\$3,000,000)**

The sage steppe landscape extends across 11 Western States and two Canadian Provinces, and 60 percent of that landscape is on public lands, half of which are managed by Interior. This area is dominated by sagebrush, which is priority habitat for over 350 wildlife species, most notably the greater sage grouse. Alterations in the sage steppe landscape including changing fire regimes, spread of invasive grasses, climate change, and energy development have led to new challenges to these species and the landowners and public that lives and recreates in this area. Land and species managers, landowners, and other stakeholders need scientific information to improve their ability to understand and address these challenges and to implement landscape-scale management decisions, regardless of surface management or ownership. The recently issued Secretarial Order 3336, which emphasizes the need for enhanced

strategies to prevent and manage rangeland fire and restore sagebrush habitat, is bringing renewed focus to the threat of fire in the sage steppe landscape.

To address the science needs of this landscape, the USGS's 2015 research efforts focused on understanding how wildfire and habitat fragmentation affect greater sage grouse populations, developing buffer and mitigation strategies, forecasting distributions of sagebrush in the face of climate change, describing rangeland fire frequency and size, evaluating the effectiveness of restoration techniques, and developing conservation and restoration strategies to benefit greater sage grouse. In 2016, research efforts will remain focused on understanding how wildfire affects greater sage grouse and the sage steppe landscape, determining best management practices for sagebrush restoration, and evaluating the effectiveness of restoration techniques. Efforts will also include development of predictive models to understand the influence of fire, cheatgrass, and other landscape factors on greater sage grouse populations.

Ecosystems

Environments Program

(+\$3,000,000 for a total of \$4,181,000)

The Environments Program is requesting an increase in 2017 that would be used to fund expanded research to support the priority needs of managers to address changing fire regimes, drought, and shifting climates; control the spread of invasive cheatgrass; design conservation and management strategies for greater sage grouse; and effectively restore and adaptively manage the sage steppe landscape. Rangewide geospatial analyses will be conducted to provide mapping of sagebrush habitat, fire, and invasive plants to help inform long-term, landscape-scale management planning. Pilot studies will be implemented to test strategies for preventing spread of and controlling cheatgrass. Testing and application of restoration and post-fire rehabilitation techniques will be initiated with a goal of developing cost-effective methodologies to restore sagebrush. The USGS will also develop an interagency monitoring framework focused on evaluating the effectiveness of fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage grouse. Resultant data and information will be used to inform long-term conservation and management strategies for the sage steppe landscape and to support the process of adaptive management. This information is relevant to State and Federal agencies, including but not limited to State land, fish and wildlife agencies, the USFS, BLM, NPS, and FWS. All the research will be planned and implemented in close collaboration with Interior bureaus (BLM, NPS, and FWS).

Program Changes

All-of-the-Above Energy **(+\$6,027,000)**

Unconventional Oil and Gas Research	(+\$3,625,000)
Renewable Energy	(+\$379,000)
Environmental Impacts of Uranium Mining	(+\$2,023,000)

Overview

The economy and national security of the United States depend on an adequate and reliable energy supply. Understanding how much of an energy resource is available and recoverable is a key part of planning for our Nation's secure energy future. USGS data and information are essential tools for decision makers presented with the challenges of understanding where energy resources are located, both domestically and globally; how much of a particular resource is available and recoverable; what types of energy resources comprise our domestic energy mix and in what proportions; what the environmental impacts are of developing various types of energy resources; and how those impacts can be mitigated. Unconventional oil and gas (UOG) research, research on renewable energy sources such as geothermal, wind, and solar, and research to understand the environmental impacts of uranium mining provide decision makers with information critical to the formation of our Nation's energy policy, both in terms of present supply and consumption, as well as to support short- and long-term planning efforts to provide for a secure energy future.

Unconventional Oil and Gas Research **(+\$3,625,000)**

Energy and Mineral Resources, and Environmental Health	
Energy Resources Program	(+\$975,000)
Toxic Substances Hydrology Program	(+\$250,000)
Contaminant Biology Program	(+\$900,000)
Water Resources	
National Water Quality Program	(+\$450,000)
Ecosystems	
Fisheries Program	(+\$350,000)
Natural Hazards	
Earthquake Hazards Program	(+\$700,000)

USGS unconventional oil and gas research supports the existing multiagency collaborative effort among the Department of the Interior (via USGS), the Department of Energy (DOE), and the Environmental Protection Agency (EPA), which is aimed at understanding unconventional oil and gas resource availability and recoverability, and reducing the potential environmental, health, and safety impacts of UOG resource development. These research efforts address the most urgent research questions (as identified in the multiagency *Research Strategy*) and decision-support needs surrounding UOG activities, including those regarding hydraulic fracturing and associated waste disposal processes. The seven major research topics identified in the multiagency *Research Strategy* include: (1) Understanding the Scale and Nature of U.S. Unconventional Oil and Gas Resources; (2) Water Quality; (3) Water Availability; (4) Air Quality; (5) Effects on Human Health; (6) Ecological Effects; and (7) Induced Seismicity. The USGS

provides science for six of the seven research areas (air quality research is provided by DOE and EPA), and is proposing increases in five of those areas in the 2017 request, as outlined below.

Understanding the Scale and Nature of U.S. Unconventional Oil and Gas Resources

Energy and Mineral Resources, and Environmental Health

Energy Resources Program (+975,000, for a total of \$6,825,000)

With the proposed increase, the ERP would expand its work on the evaluation of the nature of brines produced from unconventional oil and gas (UOG) accumulations deep below near-surface aquifers to help predict the quality and quantity of waste fluids associated with energy production. The proposed increase would also allow the ERP to conduct annual field research in Alaska to support the assessment of undiscovered UOG on the North Slope. Domestic assessment of shale and tight oil and gas would expand to increase the number of evaluations performed by about two per year. Furthermore, the Energy Resources Program would increase cooperative efforts with state geologic surveys to acquire fundamental data needed for UOG assessments. Finally, petroleum processes research would expand to improve understanding of the nature of UOG resources and provide needed organic carbon data for UOG assessments. All of this proposed work would support the Energy Resources Program's ongoing contributions to the Federal Multiagency Collaboration on Unconventional Oil and Gas Research, in its *Research Strategy* goal to understand the scale and nature of U.S. UOG resources. The ERP's proposed research will support sound policy decisions by Federal, State, and local agencies responsible for ensuring the prudent, safe, and sustainable development of unconventional oil and gas resources.

Water Quality

Water Resources

National Water Quality Program (+\$450,000 for a total of \$650,000)

One of the widespread public concerns regarding unconventional oil and gas and associated activities is the potential for the impact to water quality of streams and groundwater. Water co-produced with both conventional and unconventional oil and gas production can be highly saline and can contain other naturally occurring contaminants such as radium and arsenic that can contaminate aquifers used as a source of water supply as well as stream ecosystems. In 2017, the National Water Quality Program is requesting to develop and disseminate science-based information and tools needed for a fundamental understanding of the processes that affect the occurrence, transport, fate and effects of contaminants in streams and groundwater affected by unconventional oil and gas extraction activities.

Energy and Mineral Resources, and Environmental Health

Toxic Substances Hydrology Program (+\$250,000, for a total of \$1,020,000)

In support of the existing Federal multiagency collaborative effort between the Department of Energy, the Department of the Interior (via USGS), and the U.S. Environmental Protection Agency to conduct science, research, and development aimed at understanding and mitigating the potential environmental and public health and safety impacts of unconventional oil and gas (UOG) development, the Toxic

Program Changes

Substances Hydrology Program (TSHP) would use the proposed increase to study the environmental contamination associated with spills and other releases of liquid and solid wastes from unconventional oil and gas development activities at sites currently under study in West Virginia (Marcellus Shale) and North Dakota (Williston Basin). This research provides valuable, unbiased science and information that decision makers can use to ensure the safe and prudent development of unconventional oil and gas resources.

Effects on Human Health

Energy and Mineral Resources, and Environmental Health

Contaminant Biology Program

(+\$900,000, for a total of \$930,000)

In collaboration with its partners in the Federal Multiagency Collaboration on Unconventional Oil and Gas Research, the CBP would use the proposed increase to assess the potential environmental, wildlife, and human health impacts associated with unconventional oil and gas (UOG) development. As UOG activities continue to proliferate at a rapid rate in the United States, decision makers rely on unbiased, sound science to understand whether those activities might impact human and environmental health and to inform the prevention or mitigation of those potential impacts. In order to keep pace with rapidly evolving technology and development practices, the proposed increase in 2017 would allow for the CBP to expand testing to help add to a body of collaborative research needed for assessment of potential biological effects of UOG development on living organisms, including humans. The CBP would expand its UOG-related research and effectively prioritize those research sites, which will provide the greatest amount of data. Research results would be shared with Federal partners in the Multiagency Collaboration on UOG, and those partnerships would be leveraged to maximize the usability and interoperability of the data. The CBP is uniquely positioned to collaborate with the environmental and public health communities to conduct timely, critical, and cutting-edge research vital to the development of sound energy and health policy and safe industrial practices related to UOG.

Ecological Effects

Ecosystems

Fisheries Program

(+\$350,000, for a total of \$1,458,000)

In 2017, the USGS Fisheries Program is requesting an increase to expand toxicity testing to novel compounds of concern in UOG development, including naturally occurring radioactive materials, biocides, methane, iodide, bromide, and shale-related microbes, and to begin development of genetic and genomic tools for early detection of physiologic and ecologic stress in aquatic organisms and communities due to UOG contamination. These tools will be used by State and Federal resource management agencies as a means to rapidly test and monitor large geographic areas for possible leakage from UOG facilities with earlier detection, containment, and correction than possible with current chemical monitoring techniques, thus avoiding expensive and often difficult remediation and restoration.

The multiagency *Research Strategy* identified four priority research needs for ecological impacts of UOG development: information gap analysis; wastewater toxicity testing; vulnerability assessments; and

cumulative impact modeling. In 2015 and 2016, the USGS initiated work on information gap analysis, assessed acute and chronic toxicity of UOG produced waters on fish and aquatic invertebrates with particular focus on salts from the Williston/Bakken, identified species and habitats most at risk in regions of UOG development across the United States, and assessed effects of UOG activities on headwater streams and terrestrial species in the Marcellus.

Induced Seismicity – Earthquake Risk Assessments

Earthquake Hazards Program (+\$700,000, for a total of \$3,200,000)

The proposed increase would fund a project aimed at reducing the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts. Currently, areas of induced seismicity have been removed from USGS assessments of national earthquake hazards because they are assumed short-term perturbations of the hazard. A USGS advisory committee has recommended that the USGS issue annual forecasts of earthquake probabilities for these areas in a separate product, which will serve the needs of decision makers (including government regulators, petroleum companies, and communities) seeking to manage earthquake risk, (e.g., incorporating changes into building codes based on hazard forecasts). This product would also further USGS efforts toward short-term earthquake probability forecasts, which would be useful for all earthquake sequences.

Renewable Energy Research	(+\$379,000)
Geothermal Energy	(+\$229,000)
Energy and Mineral Resources, and Environmental Health	
Energy Resources Program	(+\$229,000)
Wind and Solar Energy	(+\$150,000)
Ecosystems	
Wildlife Program	(+\$150,000)

As geothermal energy represents a largely untapped source of renewable energy for the United States, research to characterize our Nation’s geothermal resources, as well as the science relied on by agencies responsible for geothermal energy resource management on Federal Lands, is becoming increasingly useful to decision makers in forming energy policy. Additionally, the recent expansion of the wind and solar power sectors in the United States has brought with it a need to objectively evaluate landscape impacts from solar energy development construction, operations and maintenance, as well as a need for research on the impacts of wildlife mortality from wind turbines. The results of this research will be used to support interagency collaborative efforts to develop mitigation tools and techniques and improve siting efficiency.

Program Changes

Renewable Energy – Geothermal (+\$229,000)

Energy and Mineral Resources, and Environmental Health

Energy Resources Program

(+\$229,000, for a total of \$654,000)

The majority of domestic geothermal resources are on public lands in the Western United States; hence, the USGS works closely with BLM and USFS. The proposed increase for Alternative Energy Permitting on Federal Lands – Geothermal would expand the ERP’s collaborative efforts with BLM to conduct geothermal resource favorability mapping studies, as well as research and technology development to study potential impacts from geothermal development. The ERP will develop, test, and deploy miniature unmanned aerial systems to perform future thermal infrared—or “heat mapping”—studies to monitor changes potentially associated with an expansion in geothermal production. Outcomes from this research could also support science and information needs identified by the BLM, the U.S. Fish and Wildlife Service, and other state partners in the draft Desert Renewable Energy Conservation Plan (DRECP), which is a “landscape-scale plan that uses science to inform the siting of renewable energy development projects and the conservation of species, creating systematic habitat protection and connectivity improvements across the Mojave and Colorado/Sonoran desert regions” (DRECP Executive Summary, September 2014). The BLM and other bureaus can use information from this proposed increase for land use planning and potentially a targeted environmental impact statement for high potential use areas. This is part of the All-of-the-Above Energy Strategy and part of the Secretary of the Interior’s Powering Our Future initiative.

Renewable Energy – Wind and Solar

(+\$150,000)

Ecosystems

Wildlife Program

(+\$150,000, for a total of \$1,645,000)

The Wildlife Program requests an increase in 2017 that would support development of new mitigation technologies to reduce the interaction of wildlife with renewable energy infrastructure. For example, earlier studies showed that ultrasonic sounds and altering turbine operations had the potential to reduce the number of bird and bat fatalities. New research will be focused on developing these technologies and management strategies to reduce the chances that birds and bats interact with renewable energy facilities and reduce associated fatalities that come with these interactions. This research will directly support the goals of State and Federal agencies, Tribes, and energy managers to develop mitigation strategies at wind and solar facilities to avoid or reduce impacts on wildlife.

Environmental Impacts of Uranium Mining

(+\$2,023,000)

Energy and Mineral Resources, and Environmental Health

Contaminant Biology Program

(+\$273,000)

Toxic Substances Hydrology Program

(+\$1,750,000)

In 2012, the Secretary of the Interior issued a Record of Decision withdrawing about one million acres of Federal land near the Grand Canyon from additional uranium mining development until the year 2032.

The USGS, through the Contaminant Biology Program and the Toxic Substances Hydrology Program, is developing science to address critical gaps in the data and knowledge on the potential effects of uranium mining in the Grand Canyon region, and is leading a team of Interior bureaus—including the Bureau of Land Management, the National Park Service, and the U.S. Fish and Wildlife Service—as well as the U.S. Forest Service, on this important effort. The USGS uranium mining studies are designed to assess water quality and quantity, to understand the potential toxicological and radiological effects of mining on wildlife, and to evaluate potential impacts on cultural and tribal resources. Results will help inform the Secretary’s decision to continue, modify, or end the mining withdrawal in 2032.

Together with the BLM, the NPS, the FWS, and the USFS, the USGS has put together a detailed joint 15-year scientific research plan outlining the exact scientific information needed to inform decisions on future mining activities in the region. The partners are currently jointly executing the science called for in the shared plan. The information gleaned from this cooperative effort will be produced more cost-effectively than each individual agency undertaking individual agency-specific studies, and will reduce duplication and leverage the strengths and expertise of each agency. Opportunities for partnerships with private industry are also discussed in the science plan, allowing for more complete data on the mining sites. In addition to the Federal agencies identified above, several State, local, and tribal entities have land-management or regulatory interests in the region as well. The USGS has identified 19 studies designed to better characterize the impacts of uranium and other trace elements on water resources, native flora and fauna, and cultural and recreational uses—all of which constitute important and highly relevant information for these entities. The 19 identified studies will also leverage the expertise from each participating entity to help meet the goals of the research. The reciprocal relationships among Federal, State, local, and private industry partners will allow for cost savings and targeted, useful research toward the balance of environmental and industry interests in the Grand Canyon region.

Energy and Mineral Resources, and Environmental Health

Contaminant Biology Program (+\$273,000, for a total of \$673,000)

As part of a 15-year multiagency research plan with the Bureau of Land Management, the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Forest Service, USGS scientists in the Contaminant Biology Program are currently conducting research on baseline radiation levels for natural uranium sites in the Grand Canyon that are not currently being mined. This research is relevant to the Secretary of Interior’s 2012 Record of Decision withdrawing about one million acres of Federal land near the Grand Canyon from additional uranium mining development until the year 2032. The 15-year plan was created to address the exact scientific information needed to inform decisions on future mining activities in the region. In 2016, the CBP will begin analyzing the levels of uranium and radiation in dust, water, and biota at the inactive mine sites, and will begin modeling the natural transport and occurrence of uranium and radiation in native animals and plants. With the proposed increase in 2017, the CBP would study the amount of uranium metal and its radiation in birds, mammals, and reptiles, as well as water and dust, near targeted active mines. The 2017 results will then be compared to the baseline data to measure the environmental impacts of uranium mining and its associated release of radiation beyond what is naturally occurring. Biological samples will also be collected at springs near reclaimed mine sites to determine if residual contamination is cause for concern for humans and wildlife. Results will be used to develop a modeling tool to assess ecosystem health before, during, and eventually after uranium

Program Changes

extraction. The knowledge gained from these studies will be used for developing prevention and mitigation strategies to ensure that the health and sustainability of natural resources are balanced with economic development. The studies will provide science needed by the Secretary of the Interior for making sound decisions regarding extraction activities on Federal lands.

Energy and Mineral Resources, and Environmental Health

Toxic Substances Hydrology Program (+\$1,750,000, for a total of \$2,500,000)

A key factor in the Secretary's decision to withdraw the land in the Grand Canyon region from future mining was lack of scientific information. Toxic Substances Hydrology Program (TSHP) work has thus far focused on developing a baseline for pre-mining levels of contamination in soils for comparison to post-mining contamination in the region, as it is important to understand the levels of naturally-occurring uranium in soils in order to understand what may have been introduced during or following mining activities. With the proposed increase, the TSHP would expand upon this scientific research by including additional sites and environmental settings (e.g., water), and by conducting biological sampling. Additionally, the TSHP would use the proposed increase for interpretation and analysis of the datasets compiled thus far, culminating in the publication of the sources and environmental risks of uranium and other contaminants that may be released to the environment. This research is critical for future decision making on withdrawal of lands from mining in the region, and will help inform the development, mitigation, reclamation, and ecological restoration of mines on valid existing claims, if applicable.

Natural Hazard Science for Disaster Resilience and Response (+\$8,469,000)

Building Landscape-Level Resilience to Coastal Hazards	(+\$2,109,000)
Central/Eastern U.S. Seismic Network Adoption	(+\$800,000)
Global Seismic Network Primary Sensor Deployment	(+\$860,000)
Improved Geomagnetic Monitoring to Support Space Weather Nowcasting	(+\$1,700,000)
Landslide Response	(+\$500,000)
Wildfire Response	(+\$500,000)
Contaminant Network Along the Northeast Coast	(+\$1,300,000)
Expand Use of Streamgages	(+\$700,000)

Note: Proposed funding increase of \$4,000,000 for Near Real-Time Assessment of Water Use During Drought is shown under WaterSMART

Overview

Across a wide range of natural hazards, the Nation’s emergency managers and public officials look to USGS science to inform them of the risks hazards pose to human and natural systems, how to reduce losses and improve rapid disaster response. The USGS provides scientific information and tools to better understand and respond to hazards such as volcanoes, earthquakes, flooding, tsunamis, solar flares, landslides, wildfires, and other events to reduce potential fatalities, injuries, and other social and economic impacts. Recent events included the landslides in Washington State and Colorado, Midwest flooding, Hurricane Sandy, the South Napa earthquake in California, wildfires, and volcanic eruptions in Alaska and Hawaii. In addition, rising sea level has significant impacts on society, infrastructure, and coastal habitats that serve as buffers from storm surges and severe weather events because of the high concentration of the U.S. population along the Nation’s coastline. Faced with rising expectations for rapid, robust information in response to these events, the USGS needs to strengthen its capabilities both before and after disasters strike, harnessing new technology and promoting partnerships. The USGS role in responding to natural hazard events is leveraged by other agencies, including Interior bureaus, the Federal Emergency Management Agency, National Oceanic and Atmospheric Agency, U.S. Agency for International Development, and many others.

Building Landscape-Level Resilience to Coastal Hazards **(+\$2,109,000)**

Natural Hazards	
Coastal and Marine Geology Program	(+\$2,109,000 for a total of \$6,235,000)

The proposed increase would be used to apply research and modeling findings in the Hurricane Sandy (2012) affected areas to other parts of the U.S. coastline. The funds will be directed in three specific areas:

- Applying research findings and forecast model improvements from the Hurricane Sandy supplemental work to New England, southeast Atlantic, Gulf of Mexico, and contiguous Pacific States. Researchers will extend the availability of high-resolution information, which combines

Program Changes

trends from historic change data with high-resolution elevation data, National Weather Service surge forecasts, USGS coastal response models, and interagency regionalized sea level rise projections. The new regionally-scaled tools and forecasts of coastal vulnerability and change in response to erosion, coastal storms, and sea level rise will be available through the USGS Coastal Change Hazards Portal.

- Offering demonstrations and hands-on workshops to regional planners and emergency managers to increase their abilities to appropriately apply regional storm impact tools to both pre-storm planning to protect lives and livelihood and to longer-term planning to better address vulnerabilities and options for improving resilience to coastal storms.
- Leveraging regional funds and efforts, such as RESTORE in the Gulf of Mexico, to increase use of USGS tools and ensure easy data access and usability through Web-based delivery tools on marine.usgs.gov, data.gov and the climate resilience toolkit.

Central/Eastern U.S. Seismic Network Adoption (+\$800,000)

Natural Hazards

Earthquake Hazards Program (+\$800,000 for a total of \$800,000)

The proposed increase would allow the USGS to significantly improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159 seismic stations in the Central and Eastern U.S. Seismic Network (CEUSN), which was constructed with NSF funding that ends in 2017. If the USGS does not assume operations of these seismic stations, the monitoring equipment will be removed by NSF and added to their inventory of portable equipment, which they use for research purposes, and the ability to retain this increased USGS monitoring capability will be lost. In 2012, the USGS and NSF worked with OSTP, NRC, DOE, and OMB to develop a plan for the CEUSN under which the USGS would assume long-term operation of the network; partial funding was provided to the USGS in 2014. This request is for the remaining funds needed for the USGS to assume the long-term operations of the network according to the multi-agency agreement.

Global Seismic Network Primary Sensor Deployment (+\$860,000)

Natural Hazards

Global Seismographic Network (+\$860,000 for a total of \$2,460,000)

The requested increase will allow the GSN to continue a five-year effort to deploy and install over 40 borehole sensors and to improve the physical infrastructure of select GSN sites. Some borehole sites are compromised and need re-drilling and about 20 of the GSN vaults need repairs in order to improve data quality. The needed improvements to the physical infrastructure at the sites are deferred maintenance tasks that have been prioritized by Global Seismographic Network Standing Committee and are necessary to fully benefit from the new instrumentation. The resulting improvements will help ensure that the GSN remains the core global system for earthquake and tsunami monitoring, nuclear treaty research and verification, earth science and research and education.

Improved Geomagnetic Monitoring to Support Space Weather Nowcasting (+\$1,700,000)

Natural Hazards

Geomagnetism Program (+\$1,700,000 for a total of \$1,700,000)

Large magnetic storms (solar flares) represent a potential hazard for the activities and infrastructure of our modern, technologically based society, particularly due to impacts to the electrical grid. The long-term monitoring and real-time reporting of geomagnetic storms that is provided by USGS geomagnetic observatories has significant potential to advance space weather impact forecasting and research. The two most needed enhancements are in electrical field (E-field) monitoring; the direct measurement of currents in the Earth's crust; and the gathering and integration of existing global magnetic field data. Electrical currents are induced in the Earth's crust by geomagnetic storms, which can induce currents in the electric power grid that can cause transformers to overheat and fail. Routine collection of E-field measurements are important for modeling hazardous induced currents in the grid, and for assessing compliance by the electrical power industry with a recent ruling by the Federal Energy Regulatory Commission. There is tremendous potential represented in the global magnetic field data collected by other countries, but acquiring and managing these data and modernizing the data collection efforts of many countries has been largely volunteer effort. The interagency National Space Weather Program has given the USGS the mandate to acquire these data, and this proposal would provide the funding needed for this effort. The USGS proposes the following investments to provide enhanced monitoring of geomagnetic- and E-field activity at ground level:

- Expanded monitoring: Improve magnetic and electrical field monitoring by installing new observatories and variometer stations in the continental United States, adding a Wake Island and South Pole observatory, providing support for the existing Samoan observatory, and monitoring the crustal electric field at every observatory.
- E-field monitoring: Begin a national project for detailed geographic and depth-dependent mapping of U.S.-regional lithospheric electrical conductivity, based upon magneto-telluric (MT) methods that exploit known geological structures, the existing USGS magnetic observatory network, and the network expansion proposed above.
- INTERMAGNET: Work in collaboration with academic and government institutes worldwide to integrate global observatory data with statistical and dynamical models of the magnetosphere and ionosphere to improve regional predictions of hazardous geomagnetic-field activity.
- Scenario testing: Work in collaboration with electric-power companies, the oil and gas drilling industry and the U.S. Air Force to compile information on magnetic-storm effects and make assessments of geomagnetic hazard vulnerability and risk to technological systems and continuity of operations.

The result of this investment will be a national capability for mapping time-dependent geomagnetic hazards for assessing national space weather vulnerability and risk, with the potential for significantly improving forecasts of space weather and its impacts.

Program Changes

Landslide Response

(+\$500,000)

Natural Hazards

Landslide Hazards Program

(+\$500,000 for a total of \$1,600,000)

As the population moving into potentially hazardous areas grows, the overall exposure to landslide impacts rises. The requested increase would build on investments in 2015 and 2016, to expand post-wildfire debris flow-hazard assessments and grow capability to respond to landslide crises. The USGS product for situational awareness for post-fire debris flows is comprised of two components: debris-flow hazard assessments and debris-flow warnings issued by the National Weather Service NWS based on rainfall criteria developed by the USGS. Proposed additional funding would be used to monitor rainfall and post-fire debris-flow activity in as many as six wildfires in Arizona, Colorado, and New Mexico. These data would support two systematic studies of rainfall conditions for post-wildfire debris-flow initiation and would be used to develop early-warning criteria for these two States. Expansion of USGS capability to respond to landslide crises, such as the SR530 landslide near Oso, WA, is also needed. Additional resources would be used to develop an integrated system to monitor landslide movement and processes combining in-situ and remote-sensing observations with topographic and geologic data. This system could be deployed in response to a landslide crisis in the first year of development. Results and lessons learned would be documented in a systematic study used to improve the system. Partners include the NWS, Burned Area Emergency Response (BAER) teams, Federal, State and local emergency management, State geological surveys, and the private sector.

Wildfire Response

(+\$500,000)

Ecosystems

Environments Program

(+\$500,000 for a total of \$1,042,000)

The 2015 fire season was the worst in recorded history, with over 10-million acres burned, resulting in significant impact to human safety and health, property damage, and loss of fish, wildlife, timber, rangeland, and other natural resources. Accurate and timely scientific information is critical to ensure appropriate management response to wildfires and effective investments in stabilization, rehabilitation, and restoration of landscapes immediately after wildfires occur. Currently, fire management organizations lack adequate scientific information to prioritize burned regions for suppression and restoration activities. Information regarding priorities for suppression empowers fire managers to maximize their resources and employ strategies that can result in long-term resource benefits such as reducing hazardous fuels and minimizing fire size and intensity. Restoration efforts rely on research-based information to reduce the post-fire effects on water quality and supply, critical wildlife habitat, invasive species, and ecosystem services such as livestock grazing, timber production, and recreational value. Demands for strategic preparation and rapid science delivery during and immediately after wildfires are increasing, and frequently surpass the current capacity for the USGS to adequately provide science to support a cohesive wildfire response by Federal, State, tribal, and local organizations.

In 2017, the Environments Program requests an increase to expand capabilities of the USGS to address the priority science needed to reduce the growing threat of rangeland fire and improve effectiveness of

actions to stabilize, rehabilitate, and restore ecosystems after fire. Work will include the study of large-scale efforts to control flammable vegetation, development of climate-adapted revegetation strategies, creation of tools to support a new conservation and restoration strategy that will provide landscape prioritization for both fire and land managers, and development of new monitoring techniques to assess effectiveness of fire management actions and post-fire rehabilitation efforts. Along with these efforts, the requested increase would provide an opportunity for the USGS to develop a proactive rapid science response capacity for wildfires. This increased capacity would allow the USGS to rapidly provide needed geospatial information, monitoring strategies, and other relevant scientific information to wildfire response organizations for real-time response to a fire, especially Federal land management agencies in the Interior and the U.S. Forest Service (USFS). These combined efforts will increase the USGS's ability to support Federal wildfire-management policy, including the Federal Land Assistance, Management and Enhancement (FLAME), by providing the scientific information and tools to ensure that fire management planning and response are based on the best available science.

Contaminant Network Along the Northeast Coast **(+\$1,300,000)**

Energy and Mineral Resources, and Environmental Health

Toxic Substances Hydrology Program (+\$1,300,000 for a total of \$1,300,000)

As part of the Hurricane Sandy supplemental, the USGS received \$2.0 million for this effort in 2014, and has established a prototype contaminant vulnerability assessment network and standard operating procedures based on a prioritized monitoring and modeling infrastructure supported with extensive landscape-scale assessments of potential contaminant sources. The requested increase would continue that work by: (1) enabling the establishment of real-time water quality monitoring capabilities in key locations associated with the prototype contaminant network along the northeast coast, and (2) supporting the development of standard operating procedures for the rapid deployment and mobilization of field crews to collect environmental samples (including water, soils, fish, and sediment). These capabilities will be developed in close collaboration with local, State, tribal, and other Federal partners, including public health agencies commonly engaged in first response actions. Network monitoring sites will be co-located, where possible, in partnership with a separate USGS effort led by the Water Resources Mission Area, which is establishing a Surge, Wave, and Tide Hydrodynamics (SWaTH) network along the northeast coast. The requested increase will enable real-time water quality sensors to be sited on a subset of SWaTH sites. Interpretation of these data in context with the associated landscape-scale assessments of contaminant sources and modeling will provide supporting information required to mitigate those sources in the short term and minimize their impact for future events. Lessons learned from the establishment and field testing of this prototype network can be applied to other coastal areas of the United States. Ultimately, these data would be used to minimize contaminant threats due to future hurricanes and sea level rise by supporting decisions aimed at creating more resilient coastlines.

Program Changes

Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages

(+\$700,000 for a total of \$700,000)

Water Resources

Groundwater and Streamflow Information Program

(+\$700,000 for a total of \$700,000)

The USGS would use the increase to expand the use of flood inundation mapping and Rapid Deployable Streamgages (RDGs). There is an urgent need to develop the means for providing the same information to flood-threatened communities that lack a permanent USGS streamgage. The increase supports a focused, expansion to further test and operationalizes this RDG technology. For example, USGS field crews measured record flooding on rivers and streams in 12 States across the United States using both streamgages and RDGs in December 2015 and January 2016. These data are used by the National Weather Service to develop flood forecasts, the U.S. Army Corps of Engineers to manage flood control and local agencies in their flood response activities

(http://water.usgs.gov/floods/photo_vid_archive/2016_winter/bob_holmes_twc_12_31.mp4).

Implemented together, the flood-inundation and RDGs systems provide crucial flood data needed to help manage flood response activities.

The increase would be used to expand the present library of flood-inundation maps based on present technologies. Effective flood-damage mitigation and flood response also requires timely, reliable, and real-time information about river levels, flood flows, and geospatial understanding of the extent and timing of potential flood inundation, all of which the USGS is uniquely positioned to provide. The USGS, NOAA, the Federal Emergency Management Agency, and the U.S. Army Corps of Engineers engaged in joint efforts to standardize new flood-inundation mapping processes, enabling emergency management officials at the Federal, State, tribal, and local level to assess, in both real time and in advance, the threat that flooding poses to public facilities, businesses, and homes. For the first time, emergency officials and the public can know the forecasted height of floodwaters, and can see on a street-by-street basis, the expected extent of a flood hours or even days before it occurs. However, these maps require extensive field-data collection to develop and calibrate.

Pollinators **(+\$2,055,000)**

Ecosystems	(+\$1,705,000)
Core Science Systems	(+\$350,000)

Overview

Pollinators are crucial contributors to our environment and society by enhancing plant diversity in wild lands and providing food for humans in agricultural settings. Some three-fourths of all native plants in the world require pollination by an animal, most often an insect, and most often a native bee. Pollinators, most often honeybees, are also responsible for one in every three bites of food you take, and increase our Nation’s crop values each year by more than \$15 billion. For example, the honey bees gather pollen and nectar for their survival; they pollinate crops such as apples, cranberries, melons, and broccoli. Some crops, including blueberries and cherries, are 90 percent dependent on honey bee pollination and one crop, almonds, depends entirely on the honey bee for pollination at bloom time. For many others, crop yield and quality would be greatly reduced without honey bee pollination.

The USGS is providing science to better understand the status of pollinator species through field studies, habitat models, and population analyses. Most projects are conducted with key partners and stakeholders, including U.S. Department of Agriculture (USDA), U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency (EPA), Bureau of Land Management (BLM) and National Park Service (NPS), and are coordinated through the Federal Pollinator Health Task Force and the Monarch Butterfly High Level Working Group.

The USGS and other scientists are documenting alarming declines in pollinators. In 2017, the USGS, in collaboration with the U.S. Department of Agriculture, will study land use, land condition, and land cover as they relate to pollinator habitat needs, including restoration efforts; study the use of pesticides; and provide data and tools to the American people to promote healthy habitats across the Country.

Ecosystems	
Status and Trends Program	(+\$1,705,000 for a total of \$2,055,000)

The 2017 requested increase would allow the Status and Trends Program to provide science to support restoration and enhancement of pollinators and pollinator habitat across the Nation. Specific activities would include:

- Study the patterns, processes, and consequences of changes in land use, land condition, and land cover as they relate to pollinator habitat needs including forage, nesting, and other requirements.
- Develop protocols, tools and models to inform conservation and restoration of healthy monarch butterfly populations.
- Conduct research on the cumulative impacts of pesticides.
- Refine and test the National Protocol Framework for the Inventory and Monitoring of Bees.

Program Changes

- Improve capacity for identification and taxonomy of native bees.
- Work with the Core Science System Mission Area to create maps and analyses for habitats of critical concern for pollinators with areas of greatest potential for mitigation and restoration activities.
- Enhance existing online repositories of pollinator occurrence data to capture national distributions, ranges and potential ranges for important pollinator species including predicted ranges in light of climate change.
- Expand collaborative and interagency pollinator research activities (e.g., with USDA), and strengthen communities of practice and public-private partnerships working to understand and protect managed and native pollinators (e.g., Pollinator Partnership, Monarch Joint Venture).
- Provide science support to the development of effective strategies for restoration of pollinators and pollinator habitats, including development and testing of tools and protocols to monitor effectiveness of restoration activities.
- Provide information and tools to support Federal agency outreach and education activities to promote healthy habitats across the Country.

Core Science Systems

Science Synthesis, Analysis and Research Program

(+\$350,000 for a total of \$350,000)

The Pollinators Initiative addresses research priorities identified through the 2014 Presidential Memorandum on Pollinator Health, through decision tools for land and resource management agencies. The 2017 requested increase would allow the Science Synthesis, Analysis and Research program to create maps and analyses for habitats of critical concern for pollinators with areas of greatest potential for mitigation and restoration activities. Existing online repositories would be enhanced to capture national distributions and ranges for pollinators to inform climate change. The work would be conducted in collaboration with the Ecosystems Mission Area. Conservation and land managers would use these maps and analyses to make more informed decisions on pollinator habitat mitigation and restoration strategies.

Mission Area Program Changes

This section addresses other program changes within each of the USGS Mission Areas.

Ecosystems

The 2017 Budget Request for Ecosystems is \$173,938,000, a net change of +\$13,706,000 from the 2016 Enacted level.

- Develops and provides standard scientific methods to measure changing biodiversity, and forecast and plan for future biodiversity scenarios for inventory and monitoring programs at land management bureaus (Bureau of Land Management - BLM, National Park Service - NPS, Fish and Wildlife Service - FWS).
- Develops an interagency monitoring framework focused on evaluating the effectiveness of fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage grouse.
- Expands capabilities to evaluate the effectiveness of fire suppression actions, such as fuel breaks, and to test new techniques for reducing fuel loads by controlling or eliminating cheatgrass and other invasive plants.
- Transfers technologies ready for use in the field to relevant partners and allow USGS scientists to adapt these new detection, containment, and control tools to the many areas in the Nation where invasive species have been detected.

Highlights of changes are as follows with additional detail in the Mission Area section:

Status and Trends Program +1,794,000 for a total of \$22,267,000:

- Pollinators +\$1,705,000 for a total of \$2,055,000: Increase research and interaction between the USGS and Interior bureaus on pollinators to support land managers in ensuring that populations on native species are maintained.
- Fixed Costs +89,000

Fisheries Program +\$3,197,000 for a total of \$24,083,000:

- Great Lakes Fisheries Assessments +\$250,000 for a total of \$4,210,000: Piloting a change in the way that fisheries assessments are done in the Great Lakes, moving to the use of Long Range Autonomous Underwater Vehicles and piloting a project where offshore sample processing of water in the Great Lakes would be used to provide an early warning system regarding Harmful Algal Blooms.
- Unconventional Oil and Gas Research – Ecological Effects +\$350,000 for a total of \$1,458,000: Expanding research to identify potential ecological impacts associated with UOG development and the area's most vulnerable to impact through wastewater toxicity testing and landscape scale vulnerability assessments.

Program Changes

- WaterSMART: Ecological Flows +\$2,500,000 for a total of \$3,000,000: Develop Decision Support tools, which are an essential step in enhancing capacity for water regulators across the United States.
- Fixed cost +\$97,000

Wildlife Program +\$368,000 for a total of \$46,125,000:

- Renewable Energy – Wind and Solar +\$150,000 for a total of \$1,645,000: Support development of new mitigation technologies to reduce the interaction of wildlife with renewable energy infrastructure.
- Fixed Cost +\$218,000

Environments Program +\$4,937,000 for a total of \$43,352,000:

- Arctic +\$1,000,000 for a total of \$2,030,000: Partner with agencies to analyze potential changes to distributions and condition of fish and wildlife populations and their habitats as a result of climate changes and human activities.
- Sage Steppe Landscape +\$3,000,000 for a total of \$4,181,000: Expand research to fire regimes, drought, and shifting climates; control the spread of invasive cheatgrass; design conservation and management strategies for greater sage grouse; and effectively restore and adaptively manage the sage steppe landscape.
- Science to Support Drought +\$300,000 for a total of \$300,000: Conduct research on how drought interacts with other environmental stressors such as invasive vegetation and wildfires to affect landscape composition, structure, and function.
- Rangeland Fire Response and Prevention +\$500,000 for a total of \$1,042,000: Expand capabilities of the USGS to more fully address the priority science needs to reducing the growing threat of rangeland fire and improve effectiveness of actions to stabilize, rehabilitate, and restore ecosystems after fire. Work will include the study of large-scale efforts to control flammable vegetation, development of climate-adapted revegetation strategies, creation of tools to support a new conservation and restoration strategy that will provide landscape prioritization for both fire and land managers, and development of new monitoring techniques to assess effectiveness of fire management actions and post-fire rehabilitation efforts.
- Fixed cost +\$137,000

Invasive Species Program +\$2,547,000 for a total of \$19,877,000:

- New and Emerging Invasive Species of National Concern +\$2,500,000 for a total of \$8,212,000: For development, evaluation, and improvement of tools for early detection and control of existing and emerging invasive species. The USGS would develop and improve the power of advanced molecular detection tools to detect invasive species at very low densities in the field, such as sea lamprey.
- Fixed cost +\$47,000

Cooperative Research Units +\$863,000 for a total of \$18,234,000:

- Cooperative Research Units (CRU) - Enhanced Support and Scientists for Tomorrow +\$750,000 for a total of \$18,121,000: The CRU involvement in youth programs has traditionally been focused on graduate education. CRU will use the requested increase to provide undergraduate students, from groups under-represented in the conservation workforce, with mentoring and hands-on experience designed as a pathway to Interior recruitment. In addition, the CRU will enhance support towards training, mentoring, and support of Science, technology, engineering, and mathematics (STEM) graduate and post-doctoral associates from under-represented groups.
- Fixed cost +\$113,000

Climate and Land Use Change (CLU)

The 2017 Budget Request for CLU is \$171,444,000, a net change of +\$31,469,000 from the 2016 Enacted level.

- Supports Administration priorities, including the USGCRP, the President's Climate Action Plan and other government-wide strategies such as the National Fish, Wildlife, and Plants Climate Adaptation Strategy.
- Plans for a Landsat 9 launch in 2021, minimizing impacts to data continuity and ensuring access to the Nation's remotely sensed land data (Landsat and other).
- Provides the climate science resource and land managers need to adapt to climate and mitigate its effects, as defined in Secretarial Orders 3289 and 3330 respectively.
- Advances the strategic goals for climate and land use change science in the USGS 10-year plan.

Highlights of changes are as follows with additional detail in the Mission Area section:

Climate Variability +\$5,714,000 for a total of \$63,003,000

National Climate Change and Wildlife Science Center/DOI Climate Science Centers (CSCs) +\$4,473,000 for a total of \$30,908,000:

- Great Lakes Climate Science Center +\$1,500,000 for a total of \$1,500,000: Establish a new Center to help increase and improve focus on the many climate-related natural resource challenges in the Great Lakes region due to the distinct bio-geographic provinces between the Great Lakes region and the Northeastern United States.
- Tribal Climate Science Partnerships +\$1,411,000 for a total of \$1,411,000: To address the needs of Tribes to better understand the potential climate change effects on culturally-important fish and wildlife resources, and help integrate tribal and indigenous traditional ecological knowledge with more conventional science in management decisions.
- WaterSMART Drought: +\$1,030,000 for a total of \$1,030,000: To develop a science-based decision process for understanding and managing the impacts of drought on various parts of the Central and Western United States, including California. Much research is available on the

Program Changes

effects of drought on human systems, notably agriculture, but the ecological effects are not as well studied.

- Critical Landscapes: Arctic +\$500,000 for a total of \$500,000: To develop a process to estimate total glacier loss in Alaska and potential changes in freshwater input that affect economically and culturally important species such as salmon and caribou, and build on existing research in interior Alaska to better understand the potential for larger scale and more frequent effects of ecological drought.
- Fixed cost +\$32,000

Climate Research and Development Program +\$1,219,000 for a total of \$22,714,000:

- WaterSMART: Drought +\$1,125,000 for a total of \$1,125,000: To understand long-term and medium-term patterns and impacts of drought in the Western and Southeastern United States.
- Fixed cost +\$94,000

Carbon Sequestration +\$22,000 for a total of \$9,381,000:

- Fixed cost +22,000

Land Use Change +\$25,755,000 for a total of \$108,441,000

Land Remote Sensing Program +\$24,312,000 for a total of \$96,506,000:

- Landsat 9 +\$15,400,000 for a total of \$19,700,000: Develop the Landsat 9 ground system and delivering the completed system to support accelerating the launch date to 2021.
- Sentinel-2 +\$2,200,000 for a total of \$2,200,000: Acquire, store, and disseminate the information from European Space Agency.
- Big Earth Data: Data Cube +\$600,000 for a total of \$600,000: Initiate the development of a pilot study for enhancing Landsat data access and delivery services that would allow the user to define a geographic area of interest, timeframe, and specific parameters derived from the data (e.g., vegetation index) rather than the current scene-based products of prescribed geographic extent and digital numbers provided by the USGS.
- Critical Landscapes: Arctic +\$1,857,000 for a total of \$1,857,000: Develop predictive models, which support the evaluation of changes to the environment resulting from the conversion of historically sequestered ice and snow to liquid and gaseous water.
- Landsat Products for Climate and Natural Resources Assessments +\$2,992,000 for a total of \$2,992,000: To develop the computing and online storage resources necessary to rapidly produce and widely disseminate a set of Landsat-based information products.
- Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis +\$500,000 for a total of \$500,000: Develop new datasets to support dynamic coastal land change analyses for improved coastal resource management and resilience planning.

- WaterSMART: Drought +\$250,000 for a total of \$250,000: Identify gaps and close the gaps between remote sensing data and derivative products in order to meet the needs of scientists and decision makers in the conservation and land management communities.
- Water SMART: Remote Sensing +\$400,000 for a total of \$400,000: Use remote sensing data to allow monitoring of water storage in smaller storage features such as ponds, thereby improving drought status monitoring.
- Fixed cost +\$113,000

Land Change Science Program +\$1,443,000 for a total of \$11,935,000:

- WaterSMART: Remote Sensing +\$400,000 for a total of \$400,000: Conduct an innovative data integration approach that combines satellite-derived reservoir surface area and digital elevation models (DEM) to monitor height and volumetric storage changes in water reservoirs.
- WaterSMART: New Tools and Models to Better Manage Water Nationwide +\$1,000,000 for a total of \$1,000,000: Develop automated methods and tools supporting near real-time, satellite-based, drought monitoring. Assessed characteristics would include soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers identify the onset and severity of drought events and effectively allocate scarce water resources.
- Fixed cost +\$43,000

Energy and Mineral Resources, and Environmental Health (EMEH)

The 2017 Budget Request for EMEH is \$99,483,000, a net change of +\$4,972,000 from the 2016 Enacted level.

EMEH provides valuable, objective science and information about our Nation's energy and mineral resources, as well as reliable, impartial science critical to understanding the interaction between the physical environment, the living environment, and human health.

Mineral and Energy Resources +\$1,857,000 for a total of \$74,923,000

Mineral Resources Program +\$324,000 for a total of \$48,695,000:

- Critical Minerals and Materials Flow Initiative +\$1,022,000 for a total of \$9,484,000: Increase work on identifying and evaluating new sources of critical minerals and continue lifecycle work on critical minerals.
- R&D to Address Environmental Impacts of Minerals Development +\$559,000 for a total of \$5,559,000: For development of new science and tools to reduce the impacts of minerals extraction, production, and recycling on the global environment and human health, including research on supply chain, life cycle, resource sustainability, and minimizing environmental impacts of mineral extraction.

Program Changes

- Geophysical and Remote Sensing Activities -\$1,500,000 for a total of \$1,500,000: A decrease is proposed to help offset increases. This would terminate some geophysical and remote sensing work in different regions of the United States, including Alaska, California, and the mid-continent.
- Fixed costs +\$243,000

Energy Resources Program +\$1,533,000 for a total of \$26,228,000:

- Alternative Energy Permitting on Federal Lands – Geothermal +\$229,000 for a total of \$654,000: Conduct studies on the favorability of geothermal resources, and develop research and technology such as miniature unmanned aerial systems (UAS) to study the potential impacts of geothermal resource development through heat mapping. Information will be used to inform alternative energy permitting decisions and land use planning decisions on Federal lands by the Bureau of Land Management and other agencies.
- Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment +\$211,000 for a total of \$286,000: Evaluating and developing plans to enhance coastal infrastructure resilience by using an economic approach that uses assessment and valuation of ecosystem services for effective resource management. Utilize the same economic approach to evaluate the use of green infrastructure investments in urban settings.
- Unconventional Oil and Gas Research +\$975,000 for a total of \$6,825,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the ERP would: expand research to help predict the quality and quantity of waste fluids associated with energy production; conduct annual field research in Alaska to support the assessment of undiscovered UOG on the North Slope; expand domestic assessment of shale and tight oil and gas to increase the number of evaluations performed by about two per year; increase cooperative efforts with state geologic surveys to acquire fundamental data needed for UOG assessments; and expand petroleum processes research to improve understanding of the nature of UOG resources.
- Fixed costs +\$118,000

Environmental Health +\$3,115,000 for a total of \$24,560,000

Contaminant Biology Program +\$1,268,000 for a total \$11,465,000:

- Critical Landscapes: Columbia River +\$50,000 for a total of \$100,000: Expand studies of contaminant exposure and the cycling of mercury pesticides in food webs to address important tribal and endangered species of concern in the Columbia River Basin.
- Environmental Impacts of Uranium Mining +\$273,000 for a total of \$673,000: Study the amount of uranium metal and its radiation in birds, mammals, and reptiles, as well as water and dust, near targeted active mines in the Grand Canyon region. The 2017 results will then be compared to the baseline data to measure the environmental impacts of uranium mining and its associated release of radiation beyond what is naturally occurring. This research will support the 15-year multiagency science plan established to inform the decision on whether to lift the Secretary of Interior's moratorium on new uranium mining in the Grand Canyon region until 2032.

- Unconventional Oil and Gas Research +\$900,000 for a total of \$930,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the CBP would expand testing to help add to a body of collaborative research needed for assessment of potential biological effects of UOG development on living organisms, including humans.
- Fixed costs +\$45,000

Toxic Substances Hydrology Program +1,847,000 for a total of \$13,095,000:

- Critical Landscapes: Columbia River +\$50,000 for a total of \$100,000: Continue to investigate the effects of contaminants such as pesticides and mercury on the fish and wildlife in the Columbia River.
- Environmental Impacts of Uranium Mining +\$1,750,000 for a total of \$2,500,000: Expand upon scientific research in the Grand Canyon region on baseline, pre-mining levels of uranium contamination in soils for comparison to contamination levels in soils following uranium mining activities. This research will support the 15-year multiagency science plan established to inform the decision on whether to lift the Secretary of Interior's moratorium on new uranium mining in the Grand Canyon region. Expanded studies will include additional sites and environmental settings (e.g., water), and will include biological sampling. The TSHP will also interpret and analyze the datasets compiled.
- Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast +\$1,300,000 for a total of \$1,300,000: To support coastal resiliency efforts, establish real-time water quality monitoring capabilities in key locations associated with a prototype contaminant network along the northeast coast, and support the development of standard operating procedures for the rapid deployment and mobilization of field crews to collect environmental samples following a hurricane or other coastal disaster.
- Unconventional Oil and Gas Research +\$250,000 for a total of \$1,020,000: In support of the Federal Multiagency Collaboration on Unconventional Oil and Gas, the TSHP would study the environmental contamination associated with spills and other releases of liquid and solid wastes from unconventional oil and gas development activities at sites in West Virginia (Marcellus Shale) and North Dakota (Williston Basin).
- Emerging Contaminants and Chemical Mixtures -\$750,000 for a total of \$0: A decrease is proposed to help offset proposed increases. The TSHP would discontinue research on environmental contaminants (e.g., mercury, pharmaceuticals, pesticides, etc.), which are used to inform resource management and regulatory decisions about contaminants in drinking and recreational water, as well as water quality of streams, rivers, and groundwater, and to understand environmental and human health risks posed by those contaminants and their mixtures.
- Fate and Transport of Contaminants in the Subsurface -\$800,000 for a total of \$0: A decrease is proposed to help offset proposed increases. Research on the movement of contaminants from their point of origin, through the environment, and to their pathways of exposure would be discontinued.
- Fixed costs +\$47,000

Program Changes

Natural Hazards

The 2017 Budget Request for Natural Hazards is \$149,701,000, a net change of +\$10,688,000 from the 2016 Enacted level.

- Provides hazard science to help protect the safety, security, and economic well-being of the Nation.
- Provides scientific observations, analyses, and research that are critical for the Nation to become more resilient to natural hazards.
- Develops user driven tools (e.g., EEW, ShakeCast, Ash 3D, Our Coasts, Our Future) to support societal needs; and enable partners with USGS science, products, and data.

Highlights of changes are as follows with additional detail in the Mission Area section:

Earthquake Hazards Program +\$1,693,000 for a total of \$62,196,000:

- Unconventional Oil and Gas Research: Induced Seismicity Earthquake Risk Assessments +\$700,000 for a total of \$3,200,000: To reduce the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts.
- Central and Eastern U.S. Seismic Network Adoption +\$800,000 for a total of \$800,000: To improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159 stations.
- Fixed costs +\$193,000

Volcano Hazards Program +\$117,000 for a total of \$26,238,000:

- Fixed costs +\$117,000

Landslide Hazards Program +\$516,000 for a total of \$4,054,000:

- Natural Hazard Science for Disaster Response: Landslide Response +\$500,000 for a total of \$1,600,000: For improving landslide response by expanding post-wildfire debris flow hazard assessments and growing capability to respond to landslide crises.
- Fixed costs +\$16,000

Global Seismographic Network +\$869,000 for a total of \$7,322,000:

- GSN Primary Sensor Deployment +\$860,000 for a total of \$2,460,000: To deploy and install the new borehole sensors and to improve the physical infrastructure of select GSN sites.
- Fixed costs +\$9,000

Geomagnetism Program +\$1,710,000 for a total of \$3,598,000:

- Improving Geomagnetic Monitoring +\$1,700,000 for a total of \$1,700,000: To provide enhancements in electrical field (E-field) monitoring, the direct measurement of currents in the Earth's crust; and the gathering and integration of existing global magnetic field data. These activities are integral to implementation of the National Space Weather Strategy.
- Fixed costs +\$10,000

Coastal and Marine Geology Program +5,783,000 for a total of \$46,293,000:

- Scenarios for Arctic Actions to Address Imminent Coastal Impacts +\$3,500,000 for a total of \$4,925,000: To allow the USGS to shift research staff to work in the Arctic and selected Pacific Islands dealing with impacts of sea level rise, severe storms and/or melting permafrost on their coastal communities and economies.
- Building Landscape-Level Resilience to Coastal Hazards +\$2,109,000 for a total of \$6,235,000: The proposed increase would be used to apply research and modeling findings in the Hurricane Sandy (2012) affected areas to other parts of the U.S. coastline.
- Fixed costs +\$174,000

Water Resources

The 2017 Budget Request for the Water Resources Mission Area is \$227,992,000, a net change of +\$17,305,000 from the 2016 Enacted level.

- Aligns with administration priorities related to water challenges and public lands.
- Protects and enhances key operational networks and their information management and delivery systems (i.e., streamgages).
- Protects core mission needs.
- Enhances decision-support tools that use data from key hydrologic networks and USGS science in order to allow for more informed decision making.

Highlights of changes are as follows with additional detail in the Mission Area section:

Water Availability and Use Program +12,336,000 for a total of \$54,388,000:

- WaterSMART: Near Real Time Assessment of Water Use During Drought +\$4,000,000 for a total of \$4,000,000: To develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures.
- WaterSMART: Water Use Information +\$3,000,000 for a total of \$3,000,000: To integrate water information that is fragmented among multiple agencies into a national water data framework on a geospatial platform. This funding would support periodic comprehensive analysis of the data to

Program Changes

report out on water use trends and provide national water-use indicator analysis, and maps of water stress indicators. In addition, it provides additional funding through grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making.

- WaterSMART: Water Use Research +\$1,000,000 for a total of \$1,000,000: To support cooperative matching funds to maximize use of their water use datasets in the water availability and use assessment. In addition, directed work is required to develop better methods of sampling, estimating, aggregating, and presenting water use data. This includes research into new methods that use remote sensing and spatial datasets in water use estimation.
- WaterSMART: Drought +\$1,000,000 for a total of \$1,984,000: Conduct a more comprehensive evaluation of data needs and model capabilities for quantifying water budgets across snow-dominated regions of the United States.
- WaterSMART: Streamflow Information +\$400,000 for a total of \$1,075,000: To implement StreamStats in three additional States and improve methods for proving the estimates would continue to be investigated.
- WaterSMART: National Hydrologic Model +\$750,000 for a total of \$750,000: There is a need to assemble community modeling resources (i.e., datasets, models, use cases) to economize and enhance model development and verification activities across the community. Model development assumes continued community use of legacy models and datasets rather than proposing a new model framework. Such an activity would improve and modernize access to resources that support development, verification, or model application for specific decision situations.
- Critical Landscapes: Arctic +\$1,950,000 for a total of \$2,200,000: To assess systems and anticipate future system changes and explore opportunities for predictions that allows extrapolation from monitored to unmonitored locations.
- Fixed costs +\$236,000

Groundwater and Streamflow Information Program +1,422,000 for a total of \$72,957,000:

- Tribes +\$500,000 for a total of \$2,500,000: While the USGS is not directly involved with Indian Water Rights settlement, the USGS provides technical information needed to support water rights settlement work that is then given to decision makers. To support cooperative matching funds to enhance streamflow information to support tribal needs and decisions. Monitoring, along with assessments and research, would help address availability issues on tribal lands including such topics as water rights, water use, hydrologic conditions, and water-quality issues.
- Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages +\$700,000 for a total of \$3,260,000: To expand the use of flood inundation mapping and Rapid Deployment Gages (RDGs). Implemented together, the flood-inundation and RDGs systems will provide crucial flood data needed to help manage flood response activities.
- Fixed costs +\$222,000

National Water Quality Program +\$3,547,000 for a total of \$94,147,000:

- Support NAWQA Cycle 3 +1,881,000 for a total of \$63,881,000: Two-thirds, or \$1.262 million will be used to restore and enhance long-term surface water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for Cycle 3. One-third, or \$620,730 will be used to restore and enhance long-term groundwater water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for the Cycle 3.
- Enhanced Cooperative Activities and Urban Waters +\$717,000 for a total of \$717,000: To support cooperative matching funds that enable similar types of streamflow and water-quality data collection that provide science-based information used by state and local partners to develop plans for economic revitalization, urban water restoration and educational outreach for the general public.
- Unconventional Oil and Gas Research +\$450,000 for a total of \$650,000: To develop and disseminate science-based information and tools needed for a fundamental understanding of the processes that affect the occurrence, transport, fate and effects of contaminants in streams and groundwater affected by UOG extraction activities.
- Fixed cost +\$499,000

Water Resources Research Act - No changes for a total of \$6,500,000.

Core Science Systems

The 2017 Budget Request for Core Science Systems (CSS) is \$118,395,000, a net change of +\$6,845,000 from the 2016 Enacted level.

- Grows 3DEP & Alaska Mapping
- Implements NHDPlus High-Resolution Hydrography Data
- Maintains 3D Geologic Frameworks and Standards Use
- Furthers Innovation Projects through High Performance Computing
- Implements the Community for Data Integration
- Supports the John Wesley Powell Center for Analysis & Synthesis
- Sustains Big Earth Data Goals

Highlights of changes are as follows with additional detail in the Mission Area section:

Science Synthesis, Analysis and Research +\$631,000 for a total of \$24,930,000:

- Pollinators +\$350,000 for a total of \$350,000: To create maps and analyses for habitats of critical concern for pollinators with areas of greatest potential for mitigation and restoration activities. Existing online repositories would be enhanced to capture national distributions and ranges for

Program Changes

pollinators to inform climate change. The work will be conducted in collaboration with the Ecosystems Mission Area.

- WaterSMART - Drought +\$200,000 for a total of \$200,000: To build on existing capabilities in gap analysis and collaborations with the Land Change Science Program to provide species modeling for specific habitats, identifying species most at risk from drought-related effects.
- Fixed cost +\$81,000

National Cooperative Geological Mapping program +\$89,000 for a total of \$24,486,000:

- Fixed Cost +\$89,000

National Geospatial Program +\$6,125,000 for a total of \$68,979,000:

- Alaska Mapping and Map Modernization +\$1,500,000 for a total of \$6,722,000: To increase collection of ifsar (interferometric synthetic aperture radar) in Alaska and improve mapping products. These maps and improved data are urgently needed for aircraft navigation, since weather conditions in Alaska deteriorate quickly and pilots frequently need to fly using only their instruments and GPS. Involvement with the Alaska Mapping Executive Committee and coordination with other Federal and state agencies will facilitate identification of priority needs and partnering opportunities.
- National Enhancement, Landscape-scale 3-D Maps +\$2,387,000 for a total of \$21,887,000: To increase acquisition of lidar data and expand publicly available 3DEP holdings. Accelerating the national coverage of lidar will enable decision making in management of infrastructure and construction, more accurate and cost effective application of chemicals in farming, development of energy projects, and support of aviation safety and vehicle navigation.
- Coastal Lidar +\$500,000 for a total of \$500,000: To collect enhanced elevation data using lidar in U.S. coastal zones to understand and mitigate the negative effects of coastal erosion and storm surge, to map existing and potential landslide hazards, and to monitor biomass.
- NHD/Landscape Level Assessments – Chesapeake Bay +\$500,000 for a total of \$500,000: To systematically collect and manage high-quality lidar data to understand landscape processes at a parcel and local level and support the sustainable development and management of the Chesapeake Bay's natural resources.
- WaterSMART: National Hydrography Database +\$1,000,000 for a total of \$1,000,000: To complete national NHDPlus high-resolution (1:24,000 scale) coverage for the conterminous 48 States, Hawaii, and Puerto Rico and, when combined with 3DEP products, would be used to integrate water information into a simplified and connected national water data framework that would underpin innovation, modeling, data sharing and solution development.
- Fixed cost \$238,000

Science Support

The 2017 Budget Request for Science Support is \$110,592,000, a net change of +\$4,981,000 from the 2016 Enacted level.

- Provides the functions that make it possible to conduct USGS science. The Science Support Activity provides business and information systems including acquisitions and grants, finance, internal control, communications, budget, monitoring and evaluation of science quality and integrity, education, technology services and human capital, each of which are crucial to conducting quality science. Science Support includes the executive leadership and management that provide guidance, direction and oversight for all USGS science activities.
- The changes are related to supporting the Science Missions, and improving infrastructure support to sustain science; DOI and Tribal Science Coordination; increasing the number of Mendenhall postdoc scientists; further development of outreach to underserved communities; and improved youth and education in Science.
- Priorities include deploying a world-class workforce; provide Open Data; enhancing Lab-to-Market initiatives; pursuing strategic Sourcing and Shared Services opportunities; enhancing Customer Service; developing Smarter IT Delivery; promote STEM Education; and focusing on Cybersecurity.

Highlights of changes are as follows with additional detail in the Mission Area section:

Administration and Management +\$4,338,000 for a total of \$86,319,000:

- Enhancing Science Support Capability to Support Science Mission Goals +\$1,997,000 for a total of \$1,997,000: Improve service delivery by supporting closer collaboration between service providers and scientists.
- Tribal Science Coordination +\$300,000 for a total of \$732,000: For enhancing and expanding outreach coordination efforts among Tribes and USGS regions to connect Tribes with science information needed to make critical decisions.
- DOI Science Coordination +\$200,000 for a total of \$200,000: Provides a dedicated scientist to coordinate USGS science efforts with other Interior bureaus and support Interior's science integrity process overall.
- Mendenhall Program Postdocs +\$500,000 for a total of \$500,000: To recruit Mendenhall Fellows to carry out research that covers the entire spectrum of USGS science.
- Youth in Underserved Communities +\$200,000 for a total of \$200,000: To grow outreach programs to youth in underserved communities to develop future scientists.
- Youth and Education in Science +\$1,000,000 for a total of \$2,530,000: To sustain and build on existing youth hiring and outreach activities to develop future scientists.
- Fixed cost +\$141,000

Program Changes

Information Services +\$643,000 for a total of \$24,273,000:

- Enhancing Science Support Capability to Support Science Mission Goals +\$620,000 for a total of \$620,000: To develop and improve information technology tools and systems.
- Fixed costs +23,000

Facilities

The 2017 Budget Request for Facilities is \$117,258,000, a net change of +\$16,837,000 from the 2016 Enacted level.

The Facilities program provides science needs by optimizing facility locations, distributions, and use, to control or reduce costs. Includes:

- Facility planning to provide safe, high-quality workspace aligned with science needs.
- Develop Asset Business Plans to meet asset management goals, annual surveys, and cyclic condition assessments.
- Meeting performance targets for improving space utilization, controlling rent and operating costs, and releasing unneeded space.
- Achieve sustainability goals; reducing deferred maintenance by renovating and constructing buildings and other facilities to replace assets otherwise no longer cost effective to operate.
- Establishing an effective maintenance program at each owned facility to meet industry best practices.
- Increasing co-location consistent with science program objectives.

Highlights of changes are as follows with additional detail in the Mission Area section:

Rental Payments and Operations and Maintenance +\$16,837,000 for a total of \$109,978,000:

- Operations and Maintenance Stewardship +\$2,712,000 for a total \$2,712,000: To improve facility operations by repairing and replacing broken equipment in support of science needs.
- Reducing the Facilities Footprint and Cost Savings and Innovation Plan (RTF/CSIP) +\$10,902,000 out of \$10,902,000: To fund prioritized CSIP/RTF projects with the shortest payback period while significantly reducing the bureau's footprint and cost.
- Sustainability Investments +\$2,000,000 for a total of \$2,000,000: To improve aging energy systems.
- Fixed cost +\$1,223,000

Deferred Maintenance and Capital Improvements \$0 for a total of \$7,280,000.

Ecosystems

Activity: Ecosystems

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
<i>FTE</i>	<i>930</i>	<i>950</i>		<i>40</i>	<i>990</i>	<i>40</i>
Status and Trends Program	\$20,473	\$20,473	\$89	\$1,705	\$22,267	\$1,794
<i>FTE</i>	<i>119</i>	<i>119</i>		<i>6</i>	<i>125</i>	<i>6</i>
Fisheries Program	\$20,886	\$20,886	\$97	\$3,100	\$24,083	\$3,197
<i>FTE</i>	<i>133</i>	<i>133</i>		<i>5</i>	<i>138</i>	<i>5</i>
Wildlife Program	\$45,257	\$45,757	\$218	\$150	\$46,125	\$368
<i>FTE</i>	<i>281</i>	<i>282</i>		<i>1</i>	<i>283</i>	<i>1</i>
Environments Program	\$36,224	\$38,415	\$137	\$4,800	\$43,352	\$4,937
<i>FTE</i>	<i>180</i>	<i>198</i>		<i>18</i>	<i>216</i>	<i>18</i>
Invasive Species Program	\$16,830	\$17,330	\$47	\$2,500	\$19,877	\$2,547
<i>FTE</i>	<i>74</i>	<i>75</i>		<i>6</i>	<i>81</i>	<i>6</i>
Cooperative Research Units	\$17,371	\$17,371	\$113	\$750	\$18,234	\$863
<i>FTE</i>	<i>143</i>	<i>143</i>		<i>4</i>	<i>147</i>	<i>4</i>

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Status and Trends Program	+ 1,705	+ 6	F-9
Pollinators	+ 1,705	+ 6	F-12
Fisheries Program	+ 3,100	+ 5	F-19
Unconventional Oil and Gas Research	+ 350	+ 1	F-23
Great Lakes Fisheries Assessments	+ 250	+ 0	F-22
WaterSMART: Ecological Flows	+ 2,500	+ 4	F-24
Wildlife Program	+ 150	+ 1	F-27
All-of-the-Above Energy: Renewable Energy - Wind & Solar	+ 150	+ 1	F-31
Environments Program	+ 4,800	+ 18	F-35
Critical Landscapes: Arctic	+ 1,000	+ 5	F-38
Critical Landscapes: Sage Steppe Landscape	+ 3,000	+ 9	F-39
Rangeland Fire Response and Prevention	+ 500	+ 2	F-44
WaterSMART: Drought	+ 300	+ 2	F-43
Invasive Species Program	+ 2,500	+ 6	F-47
New and Emerging Invasives of National Concern	+ 2,500	+ 6	F-50
Cooperative Research Units	+ 750	+ 4	F-56
CRU Enhanced Support and Scientists for Tomorrow	+ 750	+ 4	F-61
Total Program Change	+ 13,005	+ 40	

Justification of Program Change

The 2017 Budget Request for the Ecosystems Mission Area is \$173,938,000 and 990 FTE, a net change of +\$13,706,000 and +40 FTE from the 2016 Enacted level.

Overview

Federal, State, local, and tribal resource managers and policymakers are faced with countless decisions each year on issues as diverse as species listing and delisting, fish and game regulations, land conservation and restoration, water allocations, and permitting for economic activities such as energy development, transmission lines, mining, timbering, agriculture, and residential and commercial development. Uncertainty in the outcome and ramifications of those decisions on the Nation's natural resources is complicated by environmental changes associated with natural disasters, changing weather patterns, increasing occurrence of extreme weather events, invasive species, emerging wildlife diseases, and human demands for water, land, food, energy, transportation, mineral, and living resources. The urgency for objective science to support sound decision making is increasing dramatically as competition for resources intensifies and the world is being transformed at an unprecedented pace and in uncertain directions.

Ecosystem science – the study of how living organisms react to changes in their environment, is essential to help inform land and resource managers who are facing decisions of increasing complexity and urgency to conserve biological diversity, restore and rehabilitate damaged ecosystems, adapt to climate change, resolve conflicts of resource allocation, and assess the changing condition of living resources and their habitats. Without the best available science to help inform the decision process, our Nation's environmental capital—the goods and services provided by resilient ecosystems that are vital to the health and well-being of human societies—are placed at risk. The USGS Ecosystems Mission Area provides unbiased science, tools, and decision support to our Nation's natural resource managers, with particular focus on the science needs of the Department of Interior bureaus to fulfill Federal trust responsibilities for conservation of species, lands, and priority ecosystems, fulfill treaty obligations with Tribes, provide water for irrigation and human consumption, and manage energy and mineral resource extraction on public lands and the Outer Continental Shelf.

The Ecosystems activity is comprised of six subactivities—

- Status and Trends (http://www.usgs.gov/ecosystems/status_trends)
- Fisheries Program (<http://www.usgs.gov/ecosystems/fisheries/index.html>)
- Wildlife Program (<http://www.usgs.gov/ecosystems/wildlife/index.html>)
- Environments Program (<http://www.usgs.gov/ecosystems/environments/index.html>)
- Invasive Species (http://www.usgs.gov/ecosystems/invasive_species/index.html)
- Cooperative Research Units (<http://www.coopunits.org/Headquarters>)

Ecosystems Mission Area funded work is conducted within 16 Science Centers, 60 field stations, and 40 Cooperative Research Units dispersed across the United States. This distributed workforce enables our scientists to work directly with resource managers on the species and lands for which they are making critical management decisions. Within these centers, scientists conduct a combination of short- and long-term biological research, survey and monitoring, data analysis and applications, new tool and technology development and application, decision support, and adaptive management to address the most pressing resource management issues of our time. Partnerships with other Federal, State, tribal, and private research organizations leverage millions of dollars in additional financial and in-kind support to greatly increase the effectiveness and relevancy of the Ecosystems research program. Research activities are categorized into eight lines of work that address science needs for species management, land and water management, and detection and control of biological threats to those species and lands. In addition, the Mission Area maintains the Cooperative Research Units (CRU) to support State research needs and train and mentor the next generation of scientists and resource managers.



Map of Ecosystem Science Centers, Field Stations and Laboratories (Note: Map excludes the 40 Cooperative Research Units (CRU) – refer to the CRU Subactivity Section for those locations.

(USGS created)

The section below describes each major line of work within the Ecosystems Activity. Subsequent sections detail program performance for these key lines of work within each subactivity.

1. Research for Species Management

Species Biology – Research into life history, successful conservation, and recovery of ***threatened and endangered species*** listed under the Endangered Species Act; ***trust species*** that are protected by law; ***sensitive species*** that are declining, rare, or uncommon and are identified as candidates for future listing consideration; and ***species of management concern*** that warrant management or conservation attention as identified by a natural resource management agency. This category includes a variety of species, including those that are considered at-risk, have economic or intrinsic value, or are overly abundant and therefore leading to management conflicts; ***biological systematics*** to understand the evolutionary interrelationships of living things, trying to interpret the way in which life has diversified and changed over time; and ***decision science***, a collaborative approach involving mathematical formulae, business tactics, technological applications, and behavioral sciences to help management make data driven decisions.

Species Stressors - Research into the cause and mitigation of environmental and anthropogenic stressors that potentially impact the health and reproductive capacity of species of management concern. Current focal areas include conventional and unconventional energy development (oil, gas, wind, solar, hydroelectric), ecological flows, land use, and agriculture.

2. Research for Land and Water Management

Priority Landscapes – Place-based research to understand the biological and physical processes that influences change and management options across large geographic areas of management concern. Current areas of focus includes the Arctic, Chesapeake Bay, Columbia River, Colorado River, Everglades, Great Lakes, Klamath River, Mississippi River, Mojave Desert, Pacific Islands, Puget Sound, Sagebrush Steppe, and San Francisco Bay. Also includes landscape scale assessments such as the Wyoming Landscape Conservation Initiative and development of Rapid Ecoregional Assessments.

Landscape Ecology – Research into how ecosystems work and how chemical, geological, agronomical, hydrological, and biological processes interact and change with human and natural alterations. This work forms the basic understanding of ecological function



An adult female polar bear and her two cubs travel across the sea ice of the Arctic Ocean north of the Alaska coast. The polar bear is an example of a Federal species of concern, which is protected under the Marine Mammal Protection Act and listed as threatened under the Endangered Species Act.

USGS Photo



USGS scientists are conducting research to support the FWS and energy industry efforts to reduce impacts to golden eagles from wind energy operations, including, collision with the turbine blades, habitat disruption, and disturbance from construction and operations.

Photographer George Gentry, USFWS

required for both place-based management and landscape mitigation and restoration. Current focus is on aquatic and terrestrial ecology, coastal resilience, soil ecology and dust in arid lands, and ecosystem services.

Ecological Stressors – Research into the cause and mitigation of environmental and anthropogenic stressors that potentially impact the health and productivity of lands and waters of management concern. Current focal areas include wildland fire, extreme storm events (droughts, floods, and hurricanes), climate change (sea level, warming, and precipitation), mining, and timbering.

Management and Restoration – Research into the theory, practice, and outcomes of ecological restoration and rehabilitation. It is the study of the traditional and developing practices of renewing, restoring, and adaptively managing degraded, damaged, or destroyed ecosystems through human intervention and action to re-establish ecosystem functions and services. This line of work includes the design of monitoring strategies and assessment of the effectiveness of restoration actions in support of adaptive management.

3. Research on Biological Threats

Invasive Species – Research, monitoring, and technology development for containment or eradication of non-indigenous species that have potential to cause significant ecologic or economic damage and those that impact human health. Scientists test and develop methods to better detect invasive species, determine the likelihood of their spread and impact, report distribution to track their spread, methods to contain and control harmful invasive species, as well as means to restore ecosystems after control efforts. Recent emphasis has been on using advanced technologies such as remote sensing and genetics methods to develop species-specific detection and control tools for terrestrial and aquatic species, with recent focus on Asian carp, sea lamprey, and snakes. Includes studies on ecologic impacts, invasion biology, and basic life history to help determine risk and develop control strategies.

Fish and Wildlife Disease – The USGS is the lead Federal agency for wildlife disease surveillance to support natural resource management and Federal biosecurity efforts. This line of work includes research on the ecology of fish and wildlife diseases and the development of surveillance, control, and risk-assessment tools. Investigations of wildlife mortality events support Federal, State and tribal wildlife



*Parts of Sonoran Desert may become unsuitable for tortoise survival due to changes in temperature and precipitation.
Photographer Jeff Lovich, USGS*



*USGS conducts research on the anatomy and physiology of Asian carp to guide the development of potential biological and chemical controls as part of an integrated pest management approach for natural resource managers.
Photographer Jon Ambert, USGS*

management agencies. Field and laboratory studies along with epidemiological models assess the effects of pathogens on freshwater, marine and terrestrial wildlife populations. This focal area has recently included the launch of online disease surveillance and risk assessment tools, molecular analyses to understand the global spread of pathogens, immunology studies to identify the underlying factors associated with wildlife disease resistance and susceptibility, and the development of wildlife vaccines.

4. Graduate Student Education

Cooperative Research Units – The Cooperative Research Unit (CRU) program is a unique and cooperative relationship among the USGS, State fish and wildlife agencies, host universities, and the Wildlife Management Institute. The program is designed to leverage cooperative partnerships with Federal and State agencies to address mutual needs of all partners in a cost effective manner. The USGS stations Federal scientists at universities to help identify and respond to natural resource information needs through pooling of resources among agencies, participate in advanced scientific training and mentoring of university graduate students to represent the various agencies workforce of the future, and provide Federal and other natural resource managers' access to university expertise and facilities.

2015 Key Mission Area Accomplishments

- Published significant research on sage steppe and greater sage grouse in support of the FWS greater sage grouse listing determination and the BLM Approved Resource Management Plan Amendments, including conservation buffers, habitat requirements, population modeling and forecasting, impacts of wildfire and invasive cheatgrass, and habitat restoration strategies.
- Developed a model that is being used by the FWS as part of the preconstruction permitting process to predict golden eagle fatalities at wind facilities prior to construction.
- Conducted field trials of oral plague vaccine for prairie dogs in Western States and Canada to aid in conservation of black-footed ferrets.
- Developed and tested tools for early detection, control, and risk assessments for numerous invasive species, including Asian carp, Burmese pythons, Brown Treesnakes, and tegu.
- Described potential disruption to long distance migration corridors for several ungulate species in Wyoming due to energy development and other land development.
- Developed and piloted new tools to deter bats from approaching wind turbines and, thereby reduce fatalities.
- Reported on climate change effects to cold water stream communities in the upper Chesapeake Basin.
- Reported on impacts of changing hydrology and biogeochemistry from permafrost thawing on Arctic wildlife and environmental health issues.
- Provided scientific tools and products for landscapes such as the Arctic, Columbia River, Puget Sound, Upper Mississippi River, Great Lakes, and coastal landscapes.
- Worked with DOI, Department of Agriculture, and State agencies to develop and begin implementing the Rangeland Fire Secretarial Order 3336 that is providing the science and

management tools needed to understand and reduce the threat of rangeland fire, and restore fire impacted lands.

- Developed and applied advanced tools and technologies for addressing the threat from invasive species and diseases, including *Bsal* fungus, White Nose Syndrome, and snake fungal diseases.
- Provided scientific information and tools to assist the Department and industry in siting and new alternative energy facilities that will minimize impacts to sensitive wildlife species, such as golden eagles.
- Worked in partnership with the Doris Duke Foundation and several universities to develop the second cohort of Doris Duke Conservation Scholars where undergraduate students from diverse backgrounds and under-represented segments are mentored by Cooperative Research Unit scientists and graduate students as a pathway towards career science positions in the Department.
- Worked in partnership with the FWS Northeast Region National Wildlife Refuge System to develop a pilot project for recruiting students from diverse backgrounds and under-represented segments into the Refuge system through mentoring by USGS scientists and Refuge managers.

Strategic Actions

Ecosystems science supports the Department of the Interior's (Interior) 2014-2018 Strategic Plan Mission Area – Building a Landscape-level Understanding of Our Resources and other Administration and Interior priorities by:

Strategic Actions for 2016

- Pilot regional and sector assessments of ecosystem services; including gap assessments, tests of alternative methodologies, and codification of standards and practices for natural resource decision making.
- Conduct research on existing high priority invasive species and forecast new invaders.
- Assist energy development by providing information on the sustainability of our ecosystems for use in management decisions, particularly for renewable energy.
- Conduct research and monitoring on understanding ecosystem structure, function, and services. Generate and distribute information needed for conservation and management of the Nation's fish, wildlife and other biological resources.
- Develop technological frameworks for incorporating cost and benefit values into natural resource management objectives and inform through scientific investigations.
- Communicate, coordinate and collaborate with Federal and non-Federal partners on conducting research and developing tools for ecological modeling and forecasting, and adaptive management approaches for natural resource science, decision making, and management .

Strategic Actions for 2017

- Develop and provide standard scientific methods to measure changing biodiversity, and forecast and plan for future biodiversity scenarios for inventory and monitoring programs at land management bureaus (BLM, NPS, FWS).
- Develop an interagency monitoring framework focused on evaluating the effectiveness of wildland fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage grouse.
- Expand capabilities to evaluate the effectiveness of fire suppression actions, such as fuel breaks, and to test new techniques for reducing fuel loads by controlling or eliminating cheatgrass and other invasive plants.
- Transfer technologies ready for use in the field to relevant partners and allow USGS scientists to adapt these new detection, containment, and control tools to the many areas in the Nation where invasive species have been detected.

Activity: Ecosystems

Subactivity: Status and Trends Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
FTE	930	950		40	990	40
Status and Trends Program	\$20,473	\$20,473	\$89	\$1,705	\$22,267	\$1,794
FTE	119	119		6	125	6
<i>Pollinators</i>	<i>[\$350]</i>	<i>[\$350]</i>		<i>[\$1,705]</i>	<i>[\$2,055]</i>	<i>[\$1,705]</i>

Justification of Program Change

The 2017 Budget Request for the Status and Trends Program is \$22,267,000 and 125 FTE, a net change of +\$1,794,000 and +6 FTE from the 2016 Enacted level.

Overview

The living resources of the United States, and the habitats on which they depend, are undergoing constant change due to human and natural influences. To protect, conserve, and restore the living resources—plants, animals, habitats, ecosystems—entrusted to their care, land and resource managers must understand the condition, or status (e.g., abundance, distribution, productivity, health), of those resources as well as their trends (i.e., how these variables change over time). Credible information about the status and trends of natural resources is required at a variety of spatial and temporal scales to detect changes that may signal degradation or improvement of natural systems, or to identify new or emerging conditions that signal the need for management action or further investigative research. In addition, status and trends information is required to evaluate the effectiveness of specific management actions, to validate research results and models, and to promote a broad understanding and appreciation of the natural resources that support our society. An understanding of the status and trends of natural resources is also critical to adaptive resource management, a sequential decision-making process for continually improving management policies and practices by learning from the outcomes of previous decisions and management actions.

Specific goals of the Program are to:

- Describe and track the abundance, distribution, productivity, and health of the Nation's plants, animals, and ecosystems.
- Develop and evaluate inventory and monitoring methods, designs, tools, models, and technologies to measure and track biological status and trends.

Ecosystems

- Collaborate with partners to collect, manage, and share data and information to determine and understand biological status and trends.
- Describe and deliver information and synthesis products to meet the needs of stakeholders including natural resource managers, policy- and decision makers, researchers, and the public.

Program funding supports studies on the changing condition of genomes, organisms, biological communities; linkages between populations; predictive modeling; and patterns of resources over time using historic and current data and analyses. The program also supports advances in methods for accurate and unbiased estimates of population status and change through cutting-edge sampling design and statistical methods. Program activities are designed to better understand effectiveness of management practices to improve conditions for key species, and to track and understand the trends of species affected by changes in land use and other environmental drivers. These data are useful for resource managers who need to know how and where to focus their efforts and resources.

In 2017, the Status and Trends Program is requesting an increase in funding to expand research efforts for pollinators.

Program Performance

The Status and Trends Program includes research activities in five lines of work: Species Biology, Landscape Ecology, Ecological Stressors, Management and Restoration, and Fish & Wildlife Disease.

Species Biology

Effective species conservation requires an understanding of the distribution, abundance, and health of organisms across a variety of spatial and temporal scales. Because animals, plants and habitats of management concern are often broadly distributed, or are rare or uncommon in space and time, it is important to new methods and technologies to measure and track status and trends of organisms at local to continental scales. The following paragraphs provide several examples of how the USGS tracks the status and trends of diverse organisms, including birds, pollinators, and fish across a variety of spatial scales in a diversity of ecological systems.

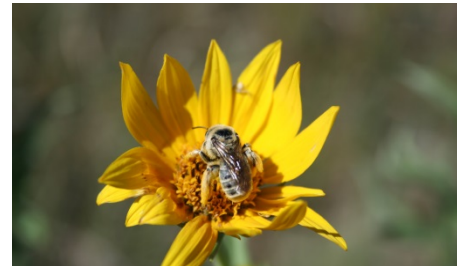
Managing Avian Biodiversity in a Changing World: With 2015 marking its 50th anniversary, the North American Breeding Bird Survey (BBS) continues to provide critical science-based estimates of population change on more than 600 continental bird species annually to improve our understanding of how these federally entrusted species respond to environmental variation and ecosystem change. The BBS is managed by the USGS in partnership with the Canadian Wildlife Service and Mexican National Commission for the Knowledge and Use of Biodiversity, and



The BBS is developing indicators to forecast changes in the distributional range of critical bird species. The Carolina Wren, pictured here, is predicted to expand northward significantly between now and 2050. Photo credit: USGS, Chan Robbins.

relies on trained volunteer observers, or “citizen scientists,” to collect bird-count data in a statistically robust national sample framework. BBS data have already contributed to hundreds of peer-reviewed publications, and are critical to inform wildlife managers of significant changes in bird population levels. In 2015, USGS produced national-scale estimates of species relative abundance and trends over time that were used by the U.S. Fish and Wildlife Service (FWS), Canadian Wildlife Service, Partners in Flight and many State wildlife agencies to assess and establish national and regional avian conservation priorities, and to drive model-based bird conservation planning. In 2016, the USGS will develop a robust indicator framework for birds using dynamic, correlated occupancy models, and will expand access to BBS data in cooperation with the USGS Core Science Systems (CSS) Mission area to facilitate machine learning research approaches. In 2016 and 2017, as new analytical methods and spatial technologies emerge, USGS will move towards the development of advanced modeling techniques to account for dependent variable effects and to allow estimation of trend precision. The USGS will also develop a spatially explicit analytical model to account for geographic variation and to permit tailored monitoring and trend estimation for targeted ecosystems or subpopulations. Consistent with the priorities of Landscape Science, the USGS will also work to establish the BBS throughout northern Mexico, a significant step toward making the BBS a truly North American program and to providing critical population data for bird species shared across our southern border.

Pollinators – Science for Restoration: Pollinators are crucial contributors to our environment and society by enhancing plant diversity in wild lands and providing food for humans in agricultural settings. Some three-fourths of all native plants in the world require pollination by an animal, most often an insect, and most often a native bee. Pollinators, most often honey bees, are also responsible for one in every three bites of food you take, and increase our Nation’s crop values each year by more than 15 billion dollars. The USGS is providing science to better understand the status of pollinator species through field studies, habitat models, and population analyses. Most projects are conducted with key partners and stakeholders, including U.S. Department of Agriculture (USDA), FWS, U.S. Environmental Protection Agency (EPA), Bureau of Land Management (BLM) and National Park Service (NPS), and are coordinated through the Federal Pollinator Health Task Force and the Monarch Butterfly High Level Working Group. In 2015, the USGS began to address research priorities identified through the 2014 Presidential Memorandum on Pollinator Health, through the development of studies, monitoring programs, and decision tools for land and resource management agencies, such as the National Protocol Framework for the Inventory and Monitoring of Bees and pollinator habitat models. Workshops conducted in collaboration with a variety of resource management organizations – both Federal, including NPS and FWS, and non-Federal including Xerces Society – developed conceptual and information frameworks, including advanced models, to identify priority monarch butterfly habitat to support conservation decision-making by a variety of stakeholders. In 2016, the USGS will continue to develop our community of practice focused on pollinator research, and will continue our focus on habitat characteristics, ecosystem services, disease and pesticides. In collaboration with FWS, the USGS will develop a conceptual framework and monitoring protocols in support of assessment of efficacy of



Native bee – Photographer Mark Vendeveer, USGS scientist

landscape-scale conservation and restoration of Monarch Butterfly habitat across the Monarch migratory flyway that encompasses most of the eastern United States.

2017 Program Change

Pollinators (+\$1,705,000 for a total of \$2,055,000): Insects, birds, and mammals, that are pollinators, are critical to agriculture and the economy. The USGS and other scientists are documenting alarming declines in pollinators. Pollinators, most often honey bees, are critical to one-third of the Nation’s food production, and increase our Nation’s crop values each year by more than 15 billion dollars. For example, the honey bees gather pollen and nectar for their survival; they pollinate crops such as apples, cranberries, melons, and broccoli. Some crops, including blueberries and cherries, are 90 percent dependent on honey bee pollination and one crop, almonds, depends entirely on the honey bee for pollination at bloom time. For many others, crop yield and quality would be greatly reduced without honey bee pollination. The USGS is providing science to better understand the status of pollinator species through field studies, habitat models, and population analyses. The 2017 increase would provide science to support restoration and enhancement of pollinators and pollinator habitat across the Nation. The work will be conducted in collaboration with the Core Science System Mission Area. Specific activities would include:

- Study the patterns, processes, and consequences of changes in land use, land condition, and land cover as they relate to pollinator habitat needs including forage, nesting, and other requirements.
- Develop protocols, tools and models to inform conservation and restoration of healthy monarch butterfly populations.
- Conduct research on the cumulative impacts of pesticides.
- Refine and test the National Protocol Framework for the Inventory and Monitoring of Bees.
- Improve capacity for identification and taxonomy of native bees.
- Create maps and analyses for habitats of critical concern for pollinators with areas of greatest potential for mitigation and restoration activities.
- Enhance existing online repositories of pollinator occurrence data to capture national distributions, ranges and potential ranges for important pollinator species including predicted ranges in light of climate change.
- Expand collaborative and interagency pollinator research activities (e.g., with USDA), and strengthen communities of practice and public-private partnerships working to understand and protect managed and native pollinators (e.g., Pollinator Partnership, Monarch Joint Venture).
- Provide science support to the development of effective strategies for restoration of pollinators and pollinator habitats, including development and testing of tools and protocols to monitor effectiveness of restoration activities.
- Provide information and tools to support Federal agency outreach and education activities to promote healthy habitats across the Country.

Taking to the skies to restore the freshwater seas: During the 19th and first part of the 20th century, ciscos, a small salmonid fish, were the most harvested commercial fish in the Great Lakes. Yields exceeded the salmon fisheries on the U.S. Pacific coast. Overfishing and environmental changes decimated populations of cisco. USGS scientists hypothesize that restoration of cisco populations may depend on rates of survival of newly hatched fish, and are investigating environmental controls on this process, called “recruiting to the fishery.” In nutrient-poor high-latitude lakes like Lake Superior, ice cover,

“Such innovative research by the USGS is critical to restoring these once magnificent fisheries.” Dr. Charles Bronte, Fish Biologist and Data Analyst, U.S. Fish and Wildlife Service

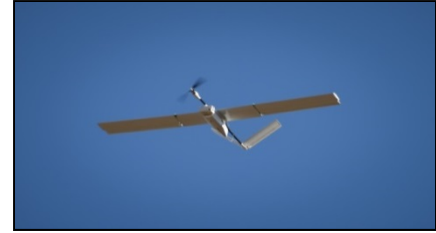
spring warming, the timing of plankton blooms (which are the major food source of newly hatched cisco), and the hatching and survival of autumn-spawned cisco appear linked. Lower amounts of winter ice could be causing a mismatch between plankton blooms and the hatching of larval cisco, leading to starvation of cisco. Evaluation of the linkages between water temperature, larval cisco populations, and the availability of plankton has been a major challenge because of the spatial patchiness of larval cisco and of plankton, which makes conventional sampling from research vessels impractical because of the enormous scale of the Great Lakes. To overcome

this challenge, traditional vessel-based sampling in 2015 was paired with simultaneous unmanned aerial system (UAS) overflights to provide data for understanding the timing and abundance of plankton blooms and larval cisco densities. Results of preliminary studies will enable independent UAS surveys in 2016 and 2017.

Landscape Ecology

Plants and animals tend to vary greatly in their distribution and abundance across space, and in their activity over time. Understanding these patterns across heterogeneous environments – from rivers to forests to mountain ranges – over time-frames ranging from days to decades, requires scientific investigations at the scale of landscapes. Landscape ecology facilitates understanding of complex environmental controls over species and ecosystems, and their vulnerability to internal and external stressors and drivers. The following examples describe how the USGS assesses ecological patterns and processes within important ecological systems, and how we collaborate with key partners to understand the status and trends of organisms and habitats at large spatial scales to support restoration of important ecological systems.

Gulf of Mexico Coastal Ecological Vulnerability: Coastal ecosystems along the Gulf of Mexico greatly influence the livelihood and resilience of coastal communities and cities to external stressors such as storms or sea level change. Though difficult to measure, some coastal ecosystems



A Falcon Fixed Wing unmanned aerial system is used over the Great Lakes to survey fish and plankton populations. Photo credit: USGS



Coastal wetland in the Laguna Atascosa National Wildlife Refuge (Texas). Photo Credit: Michael Osland (USGS)

(e.g., wetlands) provide goods and services that have been valued at up to \$78,500 per acre per year (R. Costanza and others, Global Environmental Change 2014). In addition to providing fish and wildlife habitat, coastal ecosystems protect coastlines from storms, store carbon in sediments, improve water quality, and maintain productive coastal fisheries. In the 21st century, drivers such as sea level rise, extreme weather events, changes in the flow rate of rivers, and human development of coastal habitats will affect coastal landscapes and ecosystems across the region. Since 2011, the USGS has collaborated with the FWS, four Gulf Coast Landscape Conservation Cooperatives (LCCs), and other governmental and non-governmental organizations to conduct vulnerability assessments of these coastal ecosystems. In 2015, this collaboration resulted in the Gulf Coast Vulnerability Assessment (GCVA) which evaluated the sensitivity, exposure, and adaptive capacity of coastal species and ecosystems. The collaborative team also produced a tool used to identify portions of the coast (within Texas, Louisiana, Mississippi, Alabama, and Florida) where the distribution of tidal wetlands may shift depending on alternative scenarios of sea level rise and urbanization. In 2016, the USGS will produce initial county-level assessments of wetland vulnerability, and in 2017 the USGS will refine these assessments by further considering how changes in temperature or rainfall may affect wetland vulnerability and restoration activities. Collectively, these products can be used to develop future-focused conservation and restoration projects that increase coastal resilience to storms, sea level change, or changes in weather or climate. Maximizing the adaptive capacity of coastal ecosystems helps ensure that future generations will have access to the many goods and services that these ecosystems provide and support.



U.S. Geological Survey (USGS) wildlife ecologist, Steve Germaine, with an adult pygmy rabbit just fitted with a global positioning system unit to track its movements. Photo by Joslin Heyward, USGS.

Integrated Studies of Wildlife and Habitat on the Energy Frontier: The Wyoming Landscape Conservation Initiative (WLCI) is a long-term, science-based program focused on assessing, conserving, and enhancing fish and wildlife habitats while facilitating responsible energy development through local collaboration and partnerships. Formal partners in the WLCI include the USGS, BLM, FWS, NPS, U.S. Forest Service (FS), U.S. Natural Resources Conservation Service (NRCS), Wyoming Game and Fish Department, Wyoming Department of Agriculture, six Wyoming Counties, and nine Wyoming



Male greater sage grouse strutting on a lek in early spring. Sage grouse require different habitats for breeding, nesting, brood-rearing, and winter survival. Photo by Marie Dematatis, Cherokee Services Group, contracted to the U.S. Geological Survey.

Conservation Districts. The USGS provides multidisciplinary scientific and technical information to WLCI partners and to advance the overall scientific understanding of ecosystems in southwestern Wyoming. In 2015, USGS research and science delivery for southwestern Wyoming included producing new geospatial data of energy resources, oil and gas well pad surface disturbance, aspen and conifer woodlands, habitat and restoration treatments, and inorganic mineral resources. The USGS continued to conduct studies that examine the effects of energy development on priority species including greater sage grouse, sagebrush obligate songbirds, mule deer, pygmy

rabbits, and native fishes. The USGS developed new products that inform resource planners and decision makers about the species distribution data and how the density of well pads and energy infrastructure influences the distribution and abundance of pygmy rabbits and sagebrush songbirds within energy fields. This information is used by resource planners and decision makers involved with National Environmental Policy Act (NEPA) planning, environmental assessments and in developing local siting and monitoring protocols. The USGS also conducted studies and developed products that support and evaluate “on the ground” conservation actions in priority habitats. This information is used by local working groups, State and Federal resource specialist, non-governmental organizations, local weed and pest districts and county conservation districts. In 2016 and 2017, the USGS will expand upon mechanistic wildlife studies and infrastructure mapping to investigate the potential effects of different oil and gas development alternatives on habitat for priority species. The USGS will also assess the condition of more than 16,000 acres of mountain shrub patches and evaluate the potential for using landscape-scale remote sensing to detect the extent and severity of sagebrush mortality. Real-time continuous surface-water stage, discharge, water temperature and specific conductance data, groundwater level and discrete water-quality results will be published online. Studies will continue to evaluate sage grouse persistence and the effectiveness of the core area strategy in Wyoming used to protect sage grouse.

Ecological Stressors

The status and trends of organisms, habitats and ecosystems is often controlled by environmental and anthropogenic stressors that have the potential to impact the health and productivity of lands and waters of management concern. The following examples describe how the Program provides science and shares data to understand impacts of drought and changing climates on important ecological systems.

Drought vulnerability of Southwestern dryland ecosystems:

Pronounced drought and associated reductions in water availability to plants and ecosystems have emerged as predominant characteristics of climate in the Southwestern United States at the beginning of the 21st century. Climatological forecasts suggest that drying conditions will characterize the southwest for decades to come. As such, understanding how broad-scale climate drivers will impact ecosystems at local scales is of paramount importance for designing effective management strategies to mitigate and minimize undesired ecosystem changes. USGS scientists are working closely with Interior partners to address many of the uncertainties and knowledge gaps posed by droughts drylands of the Southwestern United States. In 2015, The USGS partnered with BLM and the USDA-NRCS to synthesize 46 years of vegetation monitoring data in order to understand how climate and management actions affect long-term vegetation dynamics. To better understand mechanisms driving vegetation dynamics, the USGS combined climate and soil properties with a mechanistic soil water model to explain changes in perennial grass cover over several decades, and to forecast future drought vulnerabilities. Projections of water balance variables under future climates indicates that conditions which currently support perennial grasses will be less common in



USGS scientists work with DOI bureaus to understand the vulnerability of Southwestern drylands to drought. Photo Credit: USGS.

the future. Collectively, these results will help Interior bureaus understand important potential future changes in dryland ecosystems of the Southwestern United States and develop mitigation strategies. The USGS is working closely with Interior partners (BLM, NPS, and FWS) in disseminating results and seeking management solutions for addressing identified vulnerabilities. In 2016 and 2017, the USGS will complete integrated analyses of field observations, modelling, and remote sensing to understand drought vulnerabilities at broader scales.

Citizen Science: Taking the Pulse of Our Planet: The USA National Phenology Network is a national-scale science and monitoring initiative focused on phenology, which is the study of seasonal life-cycle events such as leafing, flowering, reproduction and migration, as a tool to understand how plants, animals and landscapes respond to environmental variation and change. Stakeholders include researchers, resource managers, educators, communication specialists, non-profit organizations, human health organizations, science networks, and the public who make decisions about resource management and adaptation to variable and changing climates and environments. Timely and widely-distributed phenological information at national scales is critical for the management of wildlife, invasive species and

“...if USA National Phenology Network had not been there already, there would have been a need to invent it, as it documents signal changes and relies on phenology data to understand and demonstrate that things are changing.” Mark Schaffer, National Climate Change Policy Advisor to the Director, U.S. Fish and Wildlife Service ~ January 17, 2014.

agricultural pests, for understanding drought and wildfire risk, and for managing risks to human health and welfare, including

allergies, asthma, and vector-borne diseases. In 2015, the USGS collaborated with NPS, FWS, USFS and many other Federal and non-Federal organizations, as well as “citizen scientists” to collect phenological data at landscape scales across the Nation. The use of

standardized protocols and strict quality assurance and quality control techniques created a first-rate dataset on seasonal plant and animal activity to aid resource management decision-making under changing environments. For example, data and associated models were used to document a 4 percent extension of the growing season in the eastern United States over the last three decades, which has implications (both positive and negative) for local activities and economies, such as maple syrup and honey production, bird migrations, cultural festivals, harvesting of native herbs and biological sequestration of carbon and agricultural activities that require advanced information on the dates of specific stages of crop development. Network activities in 2016 will be focused on understanding the sensitivity of native species to climate change and variation across National Parks and National Wildlife Refuges. Through 2016 and 2017, the Network will continue to engage groups of people typically underrepresented in science (e.g., minorities, urban youth), and will leverage on emerging collaborations with Bureau of Indian Affairs (BIA), Tribes, and tribal universities to develop a conceptual monitoring framework to support Native American capacity in understanding seasonal changes across tribal landscapes.



The timing of leafing and flowering of lilac shrubs across the Nation – here in SE AZ -- is one set of data collected by professional and citizen scientists as part of the USA National Phenology Network. Photo Credit: LoriAnne Barnett.

Management and Restoration

Successful restoration or rehabilitation of degraded species, habitats and ecosystems requires assessments of the status and trends of the impacted system before, during and after restoration. In addition, an ecological understanding is required to inform changes in resource management activities to support restoration, as well as to assess the relative success of the restoration and to adjust activities using adaptive approaches. The following paragraph outlines how USGS science supports an adaptive management approach to conservation of sensitive species and ecosystems in southern California.

Adaptive assessment of landscape conservation plans:

The USGS, in collaboration with other DOI bureaus (FWS, BLM, and NPS), the State of California, and other non-governmental organizations, is leading an adaptive assessment of landscape conservation plans in southern California. These plans aim to conserve endangered and threatened species, as well as species of concern; maintain ecological integrity and processes within urbanized landscapes; and provide regulatory certainty to jurisdictions implementing their general plans (e.g., development, infrastructure, and recreation). USGS-led adaptive assessments focus on both natural (e.g., drought, fire) and anthropogenic processes (human influences) that fragment chaparral ecosystems (dense shrub vegetation) that form the majority of conserved habitat. This multi-partner team – now entering its third decade – studies sensitive vertebrate species (e.g., endangered frogs and toads) to test the viability of conservation reserves that might be affected by natural stressors such as drought, and is also focused on population dynamics of Golden Eagles, bobcats, and American Badgers to better understand how ecosystems respond to anthropogenic drivers (such as land-use change). In 2015, the USGS studied the effects of road development on movement of individual bobcats, and how populations of bobcats responded to disease caused by exposure to domesticated cats across the landscape. The USGS also developed models of arroyo toad breeding habitat to guide the implementation of drought monitoring stations from 2015-2017. Over the next two years, the USGS will publish initial three-dimensional movement data for Golden Eagles as related to 25 years of land use change since implementation of the planning effort. In addition, the USGS will implement occupancy-based monitoring for eagle recruitment with partners from across the three largest conservation plans in the region. In preparation for a resurvey of the small vertebrate community structure study 2016-2017 with analyses being conducted to determine wildfire responses, so that funding can be secured for sampling to begin in 2018.



Biologists prepare to release wild caught male Golden Eagle outfitted with a GPS telemetry unit that will collect movement data including speed and elevation every 30 seconds. Photo credit: USGS

Fish & Wildlife Disease

Health status can often affect the size and distribution of plant and animals population across landscapes. As such, the Program supports research, monitoring, and technology development for the

identification, surveillance, diagnosis, risk assessment, treatment, and prevention of fish and wildlife diseases. The following example describes how the USGS collects, manages, and shares data and information on wildlife health, and how we describe and deliver information and synthesis products to meet the needs of stakeholders including natural resource managers, policy- and decision makers, researchers, and the public.

Supporting fish and wildlife health by mapping wildlife diseases: White-nose syndrome, chronic wasting disease, snake fungal disease and chytrid fungi are some of the diseases affecting North American wildlife. Wildlife can also carry diseases – such as avian influenza and West Nile virus – that impact agriculture and public health. Mandated by Presidential Policy Directive 8, the National Preparedness Framework recognizes the USGS as the lead Federal agency for wildlife disease surveillance. This mission-essential function is conducted by the USGS National Wildlife Health Center through investigations of wildlife mortality events for Federal, State and tribal partners. The Center’s first detection of highly pathogenic avian influenza in wild birds is an example of how these investigations benefit society by providing an early warning of diseases that can affect agriculture and public health. In 2015, a Web-enabled national wildlife mortality event reporting system went online; the site includes a searchable tool that enables management partners to track spatiotemporal spread of disease across broad landscapes to improve disease response planning and preparedness. In 2016 and beyond, the USGS will continue to grow the mortality database, will conduct disease surveillance, and will assess wildlife disease trends and their impact on wildlife populations (e.g., amphibian chytrid fungi including Bd and Bsal; white-nose syndrome in bats).

Science Collaboration: As demonstrated in the above program performance section, the Status and Trends Program responds to the monitoring and information needs and requirements of resource management bureaus within Interior and other science and resource management organizations by working with them to design, develop, and support research, monitoring, and assessment activities required for resource management and policy decisions by a variety of stakeholders.

Activity: Ecosystems

Subactivity: Fisheries Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
<i>FTE</i>	<i>930</i>	<i>950</i>		<i>40</i>	<i>990</i>	<i>40</i>
Fisheries Program	\$20,886	\$20,886	\$97	\$3,100	\$24,083	\$3,197
<i>FTE</i>	<i>133</i>	<i>133</i>		<i>5</i>	<i>138</i>	<i>5</i>
<i>Great Lakes Fisheries Assessments</i>	<i>[\$3,960]</i>	<i>[\$3,960]</i>		<i>[\$250]</i>	<i>[\$4,210]</i>	<i>[\$250]</i>
<i>Unconventional Oil and Gas Research</i>	<i>[\$1,108]</i>	<i>[\$1,108]</i>		<i>[\$350]</i>	<i>[\$1,458]</i>	<i>[\$350]</i>
<i>WaterSMART: Ecological Flows</i>	<i>[\$500]</i>	<i>[\$500]</i>		<i>[\$2,500]</i>	<i>[\$3,000]</i>	<i>[\$2,500]</i>

Justification of Program Change

The 2017 Budget Request for the Fisheries Program is \$24,083,000 and 138 FTE, a net change of +\$3,197,000 and +5 FTE from the 2016 Enacted level.

Overview

Thriving fisheries and healthy watersheds are vital to America's food supply, outdoor recreation, and diverse and abundant ecosystems. Over 46 million recreational fishers annually generate approximately \$48 billion for the American economy in equipment, fuel purchases, guide services, and travel and lodging (American Sportfishing Association, 2015).

Unfortunately, in many places around the United States, fish and the habitats on which they depend are in trouble, with almost 40 percent of the Nation's freshwater species at risk of decline or vulnerable to extinction (National Fish Habitat Action Plan, 2012).

The USGS Fisheries Program employs world-class scientists to work on cutting-edge research that leads to the protection and restoration of our Nation's fisheries and aquatic resources, the habitats that support them, and the services they provide. USGS capacity and expertise are applied to the priorities of species conservation, habitat restoration, energy development, and water quantity and quality needs.



Angler catches a fish during a Panfish Fishing Tournament on June 6, 2015 on Brownlee Reservoir in Oregon. Fish serve as an important recreational, commercial, and cultural resource in the United States and Canada. Credit: Baker County Tourism

In 2017, the Fisheries Program is requesting an increase in funding for Great Lakes Fisheries, Unconventional Oil and Gas, and WaterSMART: Ecological Flows. The Great Lakes supports a \$7.0 billion per year commercial and recreational fishery, and the USGS is responsible for providing the science for sound management of this critical resource. Funding is required to advance development of the tools and technologies needed to generate better, faster, cheaper, and safer data for timely and informed decisions. Within the field of energy development, new technologies such as hydraulic fracturing are rapidly expanding the amount of recoverable natural gas to US markets, and the Fisheries Program is developing the science to project risk and develop mitigation and avoidance strategies to reduce or eliminate impact to aquatic systems. Additional funding is required to develop tools using the latest genetic technologies for rapid and widespread monitoring of aquatic ecosystem health as an early warning system for industry and resource management agencies. Within the field of water management, extensive drought in the Western United States is stressing many aquatic ecosystems, with direct impacts to the health and viability of commercially and recreationally important fish. The Fisheries Program has been developing decision support tools for use in water allocation decisions in eastern US watersheds. Additional resources are needed to transfer and adapt those tools to western systems for immediate use in water management decisions during extreme drought conditions.

Program Performance

The Fisheries Program includes research activities in four lines of work: Species Biology, Species Stressors, Management and Restoration, and Fish and Wildlife Disease.

Species Biology

Fisheries Biology: USGS scientists conduct studies on life history, population ecology, and conservation and restoration strategies for at-risk species, Federal and State listed species, migratory species, interjurisdictional species, and the habitat requirements of those resources. These investigations lead to more effective and viable conservation actions that reduce the need for formal listing and support the goal of down-listing or delisting. Research includes development and application of advanced technologies such as remote sensing and molecular genetics to assess population status and health. For example, in 2015, USGS applied acoustic telemetry to describe the movements of fish in the St. Clair-Detroit River System on the border between Michigan and Ontario, Canada. Fish were captured, surgically-implanted with high-powered acoustic tags, and released back into the environment. Networks of acoustic receivers throughout the Detroit-St. Clair



A USGS scientist holds a five-year-old stocked lake sturgeon recaptured during a survival assessment in the Genesee River, New York. Lake sturgeon were once a highly abundant fish species in the Great lakes, but populations are currently only about one percent of their historic abundance due to overfishing in the 1800s and early 1900s. USGS staff and partners have been working for the past twenty years to restore lake sturgeon to multiple rivers and lakes.

River System, Lake Huron, and Lake Erie then enabled scientists to track the movements of hundreds of acoustic-tagged individuals at broad scales. These studies revealed that lake sturgeon migration and habitat use differs considerably from what was previously thought, with broad implications for fisheries management. In 2016 and beyond, the USGS will work with regional partners to expand this acoustic telemetry network to new areas of the Great Lakes.

The USGS conducts research across the United States to determine the status of imperiled species including anadromous fishes such as sturgeon, Atlantic salmon, and freshwater mussels, and studies of species of management concern including lake trout, coregonids (whitefish and bloaters), eels, and sturgeon. In 2015, the USGS has increased application of genetics, genomics, and molecular tools, such as eDNA, for species detection in aquatic systems. The development and application of advanced technology and tools coupled with the development of standard practices and data integration efforts will allow the USGS to address landscape level research questions by studying biodiversity of aquatic communities. In 2016 and beyond, the USGS will continue to put priority on developing these advanced technologies and practices to more quickly assess and better apply our understanding of species conservation to the health of species populations and aquatic communities.

Great Lakes Fisheries Assessments: As recognized by the President's Great Lakes Restoration Initiative, the Great Lakes are a key strategic resource and driver of economic vitality that are threatened by multiple stressors, including overfishing, invasions of exotic species, habitat degradation, pollution, climate change, and harmful algal blooms. Under the 1954 Convention on Great Lakes Fisheries, the Department of Interior is responsible for conducting a comprehensive research and monitoring program to support multi-jurisdictional recreational and commercial fisheries, tribal harvest, allocation decisions, and fish stocking activities worth \$7.0 billion annually. Research may include, but is not limited to deepwater ecosystem sciences, biological and food web components, fish movement and behavior investigations, fish population structure, and fish habitat investigations. All of these studies require constant development and adaptation of advanced tools and technologies to provide better information in real-time to allow managers the ability to rapidly assess changes to a very dynamic fishery. In 2017, the USGS proposes to further the use of advanced technologies in the Great Lakes in through:

- Adaptation of long-range autonomous underwater vehicles to collect samples and monitor deep and unsafe environments.
- Adaptation of marine environmental sample processors to provide automatic collection and analysis of water quality from the subsurface locations.
- Adaptation and development of environmental DNA (eDNA) technologies for remote identification of biological species and communities.

Successful development and application of these technologies will allow the USGS to meet its obligations for science support to Great Lakes managers by providing more data, faster, and over larger geographic areas in a cheaper and safer manner. Examples of projects that could be initiated with successful development of these technologies include monitoring for presence of specific fish species over large geographic areas, assessment of total fish biomass in multiple lakes, understanding lake-wide implications of invasive species on fisheries production, understanding factors that contribute to development of Harmful Algal Blooms (HABS), and piloting an early warning system for detection of

human pathogens that cause millions of dollars in annual economic losses to the U.S. coastal tourism industry. In addition, all technologies developed in the Great Lakes would have wide application and transferability to other national and global freshwater and marine environments.

2017 Program Change

Great Lakes Fisheries Assessments (+\$250,000 for a total of \$4,210,000): The increase would be used to initiate a program to adapt technologies developed or being developed for monitoring oceans and marine fisheries to the Great Lakes environment. The USGS conducts a research and monitoring program to support inter-jurisdictional management of a \$7 billion recreational and commercial fishery in the Great Lakes. To meet this responsibility, the USGS has made significant investment over the past 10 years to upgrade, replace, and modernize a fleet of research vessels and shore-based support facilities that serve all five Great Lakes and their connecting waterways. However, the delivery of the best scientific information to resource managers is hampered by a dependency on old technology such as trawl nets to conduct survey and monitoring studies from these vessels. Recent advancements in remote technologies such as autonomous underwater vehicles and samplers, satellite data transmission, and environmental DNA now allow the possibility to provide better, faster, cheaper, and safer environmental data in real or near-real time over large geographic regions and under adverse and unsafe conditions, such as ice cover or extreme storms. This proposed increase would enable the USGS to further the use of these advanced technologies. Research would be carried out in collaboration with multiple Federal, university, and industry partners and include development of long range unmanned and untethered vehicles for sampling deepwater and dangerous environments, environmental sample processors to provide automatic collection and analysis of water quality from the subsurface locations, and application of environmental DNA (eDNA) for remote identification of biological species and communities. Once successfully developed, these technologies can be applied to a wide range of fisheries, water quality, and beach health issues, and will have wide-ranging application and transfer potential to monitoring and research in other freshwater and marine environments.

Species Stressors

The USGS Fisheries Program investigates a range of anthropogenic and natural environmental stressors that affect populations and health of aquatic species of management interest. Stressors include energy development from conventional and unconventional oil and gas, hydropower, hydrokinetics, dams and other barriers to fish migration, and water removal for domestic, industrial, and agricultural use. USGS research focuses on fish physiology and behavioral characteristics, vulnerability assessments, and development of indicator tools that can be used to inform decisions with the goal of sustaining and enhancing fisheries resources in concert with human uses.

Unconventional Oil and Gas: In 2014, the Interior, EPA, and DOE released a research strategy for assessing potential impacts of Unconventional Oil and Gas (UOG) within the *Federal Multiagency*

Collaboration on Unconventional Oil and Gas Research, which identified four priority research needs for ecological impacts of UOG development:

1. Information Gap Analysis - review and synthesis of literature, data sources, and monitoring protocols relevant to evaluating UOG impacts
2. Wastewater Toxicity Testing - characterization and building upon the available ecologic toxicity data for wastewater chemicals that pose the greatest risk to ecosystems
3. Vulnerability Assessments - identification and prioritization of key geographic regions, ecosystems, and aquatic communities with greatest potential for impact from UOG activities
4. Cumulative Impact Models - estimation of total cumulative impact of the full life cycle of UOG exploration, development, and delivery on species and ecosystems

In 2015, the USGS began information gap analysis, assessed acute and chronic toxicity of UOG produced waters on fish and aquatic invertebrates with particular focus on salts from the Williston/Bakken, identified species and habitats most at risk in regions of UOG development across the USA, and assessed effects of UOG activities on headwater streams and terrestrial species in the Marcellus to help inform Federal and State regulatory agencies and industry on risks and best management practices during natural gas development. Research activities will continue in 2016 with completion of the information gap analysis and salt toxicity studies, and additional risk analyses for the Marcellus and Williston/Bakken. Information from these studies will help inform State regulatory agencies and the Bureau of Land Management (BLM) during siting and permitting decisions for new gas wells and distribution lines.

2017 Program Change

Unconventional Oil and Gas Research – Ecological Effects (+\$350,000 for a total of \$1,458,000):

In 2017, the USGS Fisheries Program is requesting an increase to expand toxicity testing to novel compounds of concern in UOG development, including naturally occurring radioactive materials, biocides, methane, iodide, bromide, and shale-related microbes, and to begin development of genetic and genomic tools for early detection of physiologic and ecologic stress in aquatic organisms and communities due to UOG contamination. These tools will be used by State and Federal resource management agencies as a means to rapidly test and monitor large geographic areas for possible leakage from UOG facilities with earlier detection, containment, and correction than possible with current chemical monitoring techniques, thus avoiding expensive and often difficult remediation and restoration.

In 2014, the DOI, EPA, and DOE released a research strategy for assessing potential impacts of Unconventional Oil and Gas (UOG) within *the Federal Multiagency Collaboration on Unconventional Oil and Gas Research*, which identified four priority research needs for ecological impacts of UOG development: information gap analysis; wastewater toxicity testing; vulnerability assessments; and cumulative impact modeling. In 2015 and 2016 USGS initiated work on information gap analysis, assessed acute and chronic toxicity of UOG produced waters on fish and aquatic invertebrates with particular focus on salts from the Williston/Bakken, identified species and habitats most at risk in regions of UOG development across the USA, and assessed effects of UOG activities on headwater streams and terrestrial species in the Marcellus.

Ecological Flows: Meeting water needs of the Nation is an increasing challenge as competition for domestic and industrial use, irrigation, energy production, and the environment grows at a time when the magnitude and frequency of extreme hydrologic events such as floods and droughts is increasing the uncertainty for water managers and creating conflict among different user groups. This is particularly true in the western United States where long-term drought is currently stressing both the ability to deliver adequate water for human use and impacting the health, migration, and reproduction of culturally and economically important fish, such as Pacific salmon and steelhead. The USGS Fisheries Program is developing the tools and science to help water managers evaluate tradeoffs in monetary and non-monetary costs of water allocation decisions, and understand how changes in water quantity, quality, and timing affect fisheries and aquatic resources of concern. In 2015, the USGS developed a suite of tools, science products, and visualization aids to help water managers in the Delaware River, Apalachicola-Chattahoochee-Flint basin, and the Colorado River understand and model response of federally listed and recreationally important species to different water allocation scenarios for incorporation into management decisions. In 2016, the USGS will incorporate additional species and aquatic communities into these models, and begin to develop a module that quantifies relationships between flow and total ecosystem services provided by river systems for human benefit. This information will help Federal and State agencies and river basin commissions make informed decisions on economic ramifications and tradeoffs of water allocation decisions.

2017 Program Change

WaterSMART: Ecological Flows (+\$2,500,000 for a total of \$3,000,000): In 2017, the Fisheries Program is requesting an increase to greatly expand these efforts by transferring this capability from the three pilot systems (Delaware River, Apalachicola-Chattahoochee-Flint Basin, Colorado River) to other river systems across the United States, with the goal of creating a National Ecological Flow Evaluation Tool for use by all water managers in all systems where resolving water allocation conflicts is a priority. Effort will entail the following:

- Development of a broadly applicable suite of modular tools that integrate existing data on natural resources, models to estimate water flow in ungaged systems, and advances in remote sensing of geographic features such as bathymetric lidar.
- Initial focus will be on Western systems impacted by drought, Midwestern and Southern systems impacted by alternating years of extreme flood and drought, Arctic systems impacted by permafrost thaw, and development of tools to incorporate ecological flow considerations into Principles and Requirements for Federal Investments in Water Resources.
- End result is to develop a system that is fully integrated with the National Streamgauge Network that enables water managers to simultaneously evaluate allocation scenarios while considering all facets of the water budget and facilitate more informed decisions on living resources, habitat, and other values.

In 2015 and 2016, the USGS Fisheries Program has successfully developed a suite of tools, science products, and visualization aids to help water managers understand the needs and response of economically, ecologically, and culturally important fish and other aquatic resources to changes in water flow and quality for use in making water allocation decisions. This information is particularly critical as competition for water resources increases and water supplies are being impacted by extreme weather events such as drought and flood.

Management and Restoration

Aquatic Restoration: The USGS studies the ecology and biodiversity of large rivers and aquatic ecosystems to understand impacts of changing land and water use on fish, other aquatic communities, and their habitats; and develop techniques to understand, conserve, and restore fish communities.

The USGS conducts research in large rivers including the Columbia River, Connecticut River, Klamath River, Elwha River, the Upper Mississippi River system, Missouri and Platte Rivers, Delaware River, and the Great Lakes and its coastal wetlands and urban coasts. Research to assess habitats and ecological functions lead to restoration activities in these aquatic systems in cooperation with partners including the Bureau of Land Management, US Fish and Wildlife Service, the US Corps of Engineers, and NOAA.

Natural Resources Damage Assessment and Restoration (NRDAR): The USGS provides support to the Department of Interior's NRDAR Program in partnership with affected State, tribal, and Federal trustee agencies to conduct damage assessments of oil spills or hazardous substance releases into the environment. The assessments, which determine the nature and extent of the resource injuries, are the first step toward restoring the injured resources. There are hundreds of NRDAR cases and the Program also negotiates legal settlements or actions that are used for restoration. In 2015, the USGS was involved in 16 cases in the assessment phase representing 20 States and led restoration projects in 5 settled cases. Injury determination studies for assessment cases (oil spills, industrial releases, mining releases) were related to aquatic (fish, mussels) and terrestrial (migratory birds) DOI trust resources. Restoration activities focused on benthic invertebrate and avian communities. The USGS also supported DOI NRDAR by assisting in developing the public Damage Assessment and Restoration Tracking System (DARTS) and completing an analysis estimating the economic impacts of ecosystem restoration. New assessment activities (\$1.0 million) in 2016 include additional research related to freshwater mussel, fish, and avian injuries.

Fish and Wildlife Disease

The USGS investigates pathogen discovery, causes, and drivers; researches disease ecology and immunology; and develops advanced tools for surveillance, risk assessment, and control of diseases that impact aquatic organism health to support the management, conservation, and restoration of aquatic species. Fish disease research includes both basic and applied science focused on understanding the factors that control the distribution and severity of infectious diseases affecting aquatic organisms and wild fish populations. The USGS has unique capabilities to conduct fish disease research and currently has the sole World Animal Health Organization Reference Laboratory for infectious hematopoietic necrosis virus. By maintaining an aquatic high biocontainment laboratory (BSL-3) and pathogen-free stock of rainbow trout, Pacific salmon species, koi, yellow perch and Pacific herring, the USGS is able to study the interaction between pathogens and fish and contribute to global fish management.



Fish Virus Field Sampling Team at the Lake Quinault Tribal Fish Hatchery - collecting lake water samples to test for a new fish virus that is emerging and causing epidemics in steelhead trout on the Olympic Peninsula.

Detection, Characterization and Mitigation of Fish Diseases: Steelhead trout are highly prized in the Pacific Northwest for their economic and cultural values as they support important recreational and tribal fisheries, but are highly susceptible to a strain of infectious hematopoietic necrosis virus (IHNV). The largest steelhead trout conservation hatchery in Idaho lost over 50 percent of its juvenile population being reared for release in 2009, a \$1.5 million lost investment. The USGS has conducted extensive research on the ecology and evolution of infectious hematopoietic necrosis virus (IHNV); outbreaks of which can kill up to 90 percent of juvenile salmon (sockeye, Chinook) and trout (steelhead, rainbow) along the coast of Western North America, impacting Federal (FWS, NOAA), State, provincial and tribal hatcheries. The USGS developed and transferred a non-lethal method to detect hematopoietic necrosis virus to Idaho and other partners including the Department of Fisheries and Oceans Canada. In 2015, USGS scientists worked with FWS and the Army Corp of Engineers to identify the source of the virulent and redesign hatchery water systems to mitigate the disease and increase trout survival. In 2016 and beyond, the USGS will continue to transfer the technology to other partners to respond to this global issue, as we recently have with partners in China.

Antibiotic Alternatives to Manage Bacterial Kidney Disease in Salmon: Bacterial kidney disease (BKD), a global concern, can cause significant disease and death in salmonids. In the past, management focused on the use of antibiotics (injections of adults, disinfection of eggs, and medicated feed for juveniles) but non-antibiotic methods would be preferable. Because BKD can be transmitted from mother to offspring, the USGS has provided managers with a new mitigation strategy, a non-lethal test for broodstock, which has allowed reduction or elimination of antibiotic use in hatcheries and a cost savings in excess of \$100,000 per year in Idaho alone. Implementation of a similar program by fisheries managers in States surrounding the Great Lakes is largely credited with helping to restore the recreational salmon fishery, valued at over \$2 billion dollars annually, following widespread losses of Chinook salmon in the lakes due to BKD during the early 1990s. In 2016 and beyond, the USGS will continue to support fish disease management through the development of detection, diagnostic, and control tools. The technology will be transferred to international, Federal, State, and tribal partners to support the health of fish populations.

Summary of Science Collaboration

The Fisheries Program focuses on the study of aquatic organisms and aquatic habitats. Aquatic invertebrates, mussels, fishes, and their unique aquatic communities are investigated to provide scientific information to natural resource managers and decision makers. The USGS works closely with its partners in Department of Interior bureau's and other resource management agencies to provide scientific information to meet management needs. For instance, the USGS provides fisheries research information for FWS to restore and enhance fish habitat and understand fish diseases. Endangered species and those that are imperiled receive special research interest. Aquatic Invasive Species research is aiding FWS in early detection and control measures, as well as understanding impacts these invaders have on aquatic environments. Research on *species diversity, life history, health and diseases, aquatic community ecology, and habitat requirements of fish* and other aquatic organisms supports the management, conservation, and *restoration* of our Nation's aquatic resources.

Activity: Ecosystems

Subactivity: Wildlife Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
<i>FTE</i>	<i>930</i>	<i>950</i>		<i>40</i>	<i>990</i>	<i>40</i>
Wildlife Program	\$45,257	\$45,757	\$218	\$150	\$46,125	\$368
<i>FTE</i>	<i>281</i>	<i>282</i>		<i>1</i>	<i>283</i>	<i>1</i>
<i>All-of-the-Above Energy: Renewable Energy - Wind & Solar</i>	<i>[\$1,495]</i>	<i>[\$1,495]</i>		<i>[\$150]</i>	<i>[\$1,645]</i>	<i>[\$150]</i>

Justification of Program Change

The 2017 Budget Request for the Wildlife Program is \$46,125,000 and 283 FTE, a net change of +\$368,000 and +1 FTE from the 2016 Enacted level.

Overview

Abundant wildlife populations and the habitats upon which they depend are an enduring part of the United States' rich natural heritage. Their presence boosts the economy directly through hunting, bird watching, and other recreational opportunities, and they contribute to food security, medical research, and genetic diversity. Healthy habitats that support wildlife also provide healthy soils, clean water, carbon storage, and storm mitigation. The Interior has responsibility for the conservation and management of many wildlife species through the Endangered Species Act (ESA), the Migratory Bird Treaty Act (MBTA), the Marine Mammal Protection Act (MMPA), and other Federal statutes. The USGS Wildlife Program conducts research to inform management under these responsibilities, by providing rigorous and unbiased information on migratory birds, terrestrial and marine mammals, amphibians and reptiles, terrestrial plants, threatened and endangered species, wildlife disease, and on wildlife issues resulting from human activities such as energy development, including wind and solar energy. Research spans all functional aspects of the ecosystems that these wildlife species require to survive. Our science contributes toward a more complete understanding of the Nation's ecosystems and landscapes, helping Federal, tribal, and State managers and policymakers make informed, cost-effective, and balanced decisions of economic, social, ecological, and cultural importance.

In 2017, the Wildlife Program is requesting an increase in funding for Renewable Energy – Wind and Solar to focus efforts on developing new mitigation technologies. Our science has worked to understand how development of alternative energy production systems can impact wildlife species. This increase

will allow the USGS to further focus efforts on mitigation technologies designed to reduce interaction of wildlife with energy infrastructure and therefore decrease harm to wildlife.

Program Performance

The Wildlife Program includes research activities in four lines of work: Species Biology, Species Stressors, Priority Landscapes, and Fish and Wildlife Disease.

Species Biology

Interior has primary responsibility for implementation of the Endangered Species Act, Marine Mammal Protection Act, Migratory Bird Treaty Act, and other laws designed to maintain sustainable wildlife populations for the benefit of the citizens. Wildlife Program scientists devote significant attention to species covered by these acts. Studies are designed to improve accuracy of population sizes and trends assessments, factors limiting abundance, and effectiveness of management actions which all help management agencies make more informed decisions.

Genetic Study Confirms Growth of Yellowstone Grizzly Bear Population: In 2015, the USGS completed research on grizzly bears to help determine if protection under the Endangered Species Act (ESA) is warranted. Grizzly bears in the lower 48 States were listed as threatened under the Endangered Species Act (ESA) in 1975. In 2007, the Yellowstone population of grizzly bears was removed from the ESA, but in 2009 subsequent litigation and a court ruling reversed the rule, placing it back under ESA protection. Research by the USGS led Interagency Grizzly Bear Study Team (IGBST) is being used by FWS to decide whether or not to once again propose delisting the grizzly bear. Recently, USGS members of IGBST used genetic data to show that the number of individual Yellowstone grizzly bears that contribute offspring to the next generation, known as effective population size, has increased 4-fold over a 25-year period with no loss in genetic diversity. This provides evidence that the grizzly bear population is approaching the effective size necessary for long-term genetic viability. USGS researchers used several cutting edge genetic techniques to assess trends in effective population size from 729 grizzly bears in the Greater Yellowstone Ecosystem. The study demonstrated how genetic monitoring can complement traditional, long term demographic-based monitoring providing a valuable tool for wildlife managers for current and future studies. It also underscores the effectiveness of long-term studies to create useable science for natural resource management decision making. The USGS continues to work cooperatively with other members of the IGBST and the Interagency Grizzly Bear Committee including NPS, BLM, FWS, Forest Service, Montana, Idaho, Wyoming, Washington, Eastern Shoshone and Northern Arapaho Tribal Fish and Game Department, and multiple non-governmental organizations to monitor the status of the grizzly bear population in the Greater Yellowstone Ecosystem.

Sea Otter Population Numbers Encouraging, but Shark Bites Still Problematic for Recovery:

In 2015, an analysis of California sea otter data concluded that populations are increasing overall, while also identifying reasons for slower growth in some locations. The USGS has surveyed the federally-threatened, southern sea otter annually since 1982, using aircraft and ground-based observers to census their entire range in central California. USGS scientists use survey results in combination with data from radio-tagging studies and examinations of stranded, dead otters to monitor trends in abundance and evaluate ecosystem impacts of sea otter



USGS science on sea otters has described the multi-faceted relationship between otters and their marine environment. Given these complex interactions, conservation of this imperiled species is far from simple.

recovery. The trend over the last five years indicates about 2 percent increase in sea otter abundance per year, with the official population index climbing to 3,054 this year. The population index has to exceed 3,090 for three consecutive years to warrant consideration for delisting by the U.S. Fish and Wildlife Service. Analyses of demographic and dietary data indicate that the recent population growth is concentrated in the center of the sea otter's range in California, spanning from Monterey south to Cambria, and may be related to an unprecedented surge in the abundance of sea urchins, a key prey species, over the last several years. At the same time, sea otter numbers have actually declined north and south of this central region, and research published by scientists from the USGS and California Department of Fish and Wildlife indicates that increased mortality from white shark bites is the primary source of mortality in these areas. This long-term USGS research program has provided information on ecosystem services of restored sea otter populations, and the results are used to guide Federal and State management efforts to facilitate recovery and subsequently achieve the goal of delisting this keystone predator.

Species Stressors

Wildlife species share their environments with other species, including people. Often what is good for one species is not necessarily good for another, producing stress for the second population and possibly leading to smaller numbers. Stressors may also come from environmental factors such as fire, drought, or invasive species. When a population is declining, the Wildlife Program conducts studies to understand which stressors are driving the change to help managers reverse those trends.

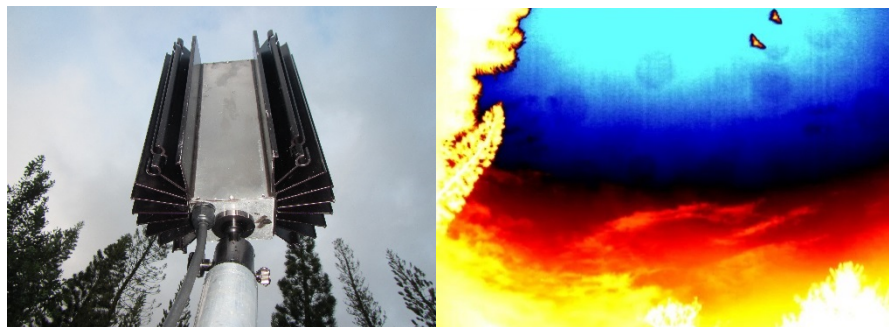
Renewable Energy – Wind and Solar: Development of renewable energy is a strategy for diversifying the energy supply in the United States. The presence of renewable energy facilities can have detrimental effects on wildlife, particularly bird and bat populations. Scientists are applying their knowledge of wildlife, modelling, and statistical tools to help wildlife practitioners and facility managers avoid or reduce these impacts to allow energy production. Public and private managers are seeking efficient and effective ways to reduce wildlife interactions with solar and wind operations and to mitigate for possible impacts. To address this, USGS scientists are applying recent findings on wildlife behavior to guide development of innovative methods to reduce or offset negative interactions between wildlife and wind and solar operations. Tools that can predict the degree of potential fatalities prior to construction of wind and solar energy facilities are being developed and refined to inform siting and permitting decisions for future facilities.



Concentrating solar power facility in the desert southwest (Photo by Robb Diehl, USGS)

In 2015, the USGS, working in close collaboration with the FWS, has developed a predictive model of bird “take” that enables ecologists, managers, policy makers, and industry to predict bird fatalities at a wind facility prior to construction. This new model was specifically developed to assess golden eagle fatalities and FWS now uses this model to work with facility applicants at the design and permitting stages and following construction. This model will enable adaptive management, ensuring further development of clean energy sources while minimizing negative effects on wildlife. In addition the USGS, in collaboration with FWS, developed a statistical software tool that helps wind energy and resource managers estimate actual mortality in the absence of carcasses. This tool contributed to the development of multiple Habitat Conservation Plans for wind projects, which are critical for future wind energy development.

In 2016, the USGS plans to continue research that provides information that resource managers can use for evidence-based decision-making. In addition, the USGS will test novel and cost-effective strategies



Testing the use of dim, invisible ultraviolet light as a means of deterring bat activity. UV light source (left image, thermal image of bats and surrounding trees (right image). Photos by Paul Cryan, USGS.

needed to minimize wind energy impacts on bats, such as the potential use of ultra-violet light as deterrent for bats at turbines. In addition, the USGS will begin to adapt existing monitoring and statistical tools used in estimating wildlife fatalities at wind turbines to large-scale solar energy facilities. For example, the USGS is examining the efficacy of bird flight monitoring technologies at solar facilities.

In 2017, the USGS will further enable wind and solar energy development by adapting existing tools and developing new tools and strategies, such as fatality prediction models and estimating sustainable levels of take, to minimize potential negative effects of an expanding renewable energy infrastructure. Research on wildlife behavior, abundance, and sources of mortality will improve our understanding of the specific effects of renewable energy on wildlife and habitats. This knowledge will guide the development of effective strategies to minimize the impact of renewable energy development on wildlife. In addition, the USGS plans to improve and develop software models and statistical tools that can be used to measure the effectiveness of mitigation strategies and help avoid siting projects in areas with high wildlife fatality potential and habitat disturbance. These tools and additional data collected from monitoring activities will improve the ability of resource managers to determine how and where future facilities are built and operated. Implementing these strategies will facilitate environmentally responsible renewable energy development and help maximize societal benefits of renewable energy while also helping to conserve our Nation's natural resources.

2017 Program Change

Renewable Energy – Wind and Solar (+\$150,000 for a total of \$1,645,000): The increase would support development of new mitigation technologies to reduce the interaction of wildlife with renewable energy infrastructure. For example, earlier studies showed that ultrasonic sounds and altering turbine operations had the potential to reduce the number of bird and bat fatalities. New research will be focused on developing these technologies and management strategies to reduce the chances that birds and bats interact with renewable energy facilities and reduce associated fatalities that come with these interactions. This research will directly support the goals of State and Federal agencies, Tribes, and energy managers to develop mitigation strategies at wind and solar facilities to avoid or reduce impacts on wildlife.

Priority Landscapes

Changing Arctic Ecosystems – The Arctic is warming faster than any other region on Earth, leading to significant environmental changes such as sea ice melt, permafrost loss, and changes in vegetation structure. Over the long term, these changes can have important impacts on both people and wildlife. The USGS recognizes these changes and has designed the Changing Arctic Ecosystems Initiative to enhance the science foundation needed to address the many critical societal and biological concerns in the rapidly changing Arctic system. USGS work is focused largely on Federal trust resources, such as marine mammals, migratory birds, and other natural resources found on Federal lands, targeting the decisions that Federal managers must make in the near term. This effort builds on a rich legacy of Federal science in the Arctic, while also capitalizing on capacity from the broader research community. Topics being addressed include:

- Information on wildlife species and their responses to ecosystem change to inform management decisions related to development of oil, gas and mineral resources on Bureau of Land Management lands and on the Outer Continental Shelf managed by Bureau of Ocean Energy Management
- Forecasting and mapping products to assist DOI land managers with maintaining viable natural ecosystems in the Arctic
- Data and forecasting tools to inform critical DOI actions related to regulation or policy, such as related to the Endangered Species Act, Marine Mammal Protection Act, native subsistence and co-management actions
- Projections of habitat change and potential species responses to help agencies design new monitoring protocols or modify strategies to support adaptive management in a changing Arctic

In 2015, the Changing Arctic Ecosystem Initiative published science on a range of topics and species, including birds, marine mammals, and Arctic landscape science. Among other subjects, our research has described how permafrost is influenced by the occurrence of wildfire in Alaskan lowland forests, documented how environmental changes are negatively impacting some species (such as polar bears) and positively impacting others (such as snow geese), and modeled how climate projections may influence walrus and polar bear populations. This information will help support State, tribal, and local entities and communities, as well as Federal and international partners, in planning and making decisions.

Fish and Wildlife Disease

Wildlife disease is an important driver of wildlife populations. Each year, wildlife managers across the United States are confronted with sick and dead animals, frequently on a large scale. Minimizing such wildlife losses depends on effective technical support, knowledgeable guidance, and timely intervention. Our wildlife health capabilities provide research, information, and technical assistance needed to manage wildlife through disease events. The USGS maintains a unique national capability through the National Wildlife Health Center which monitors disease and assesses the impact of disease on wildlife populations; defines ecological relationships leading to the occurrence of disease; transfers technology for disease prevention and control; and provides guidance, training and on-site assistance for reducing wildlife losses when outbreaks occur.

Avian Influenza – Detection, Characterization and Risk Assessment: The USGS is the lead Federal agency for wildlife disease surveillance. In 2015 the USGS made significant progress in describing the virus' ecology and understanding its potential economic and environmental impact on society. In 2015 the USGS National Wildlife Health Center investigated a migratory waterfowl die off in the State of Washington. While a fungal disease was determined as the primary cause-of-death, the USGS also detected the presence of highly pathogenic avian influenza (HPAI) virus in the dead birds. This was the first detection of HPAI in the US, the finding provided USDA, poultry producers, and public health officials with an early warning and allowed them to take measures designed to help control an HPAI outbreak that ensued in 2015. Genetic research on the HPAI virus found in Washington concluded it was likely introduced via wild birds migrating from between Asia and North America. This was the first time scientists demonstrated that the virus moves through this flyway and provides insight into possible spread.

Internationally, the USGS has conducted avian influenza research in Russia, China, Japan, and Iceland. In collaboration with the Food and Agriculture Organization of the United Nations, the USGS examined the risk of HPAI moving between wild birds and poultry in China. In 2015, an interactive web-based HPAI transmission risk model went online (<http://www.pwrc.usgs.gov/ai/>). In 2016, the USGS plans to collaborate with USDA to develop a similar model and data visualization tool for the United States.

In 2016 and beyond, the USGS will strengthen its capability to conduct wildlife disease surveillance and genetic characterization of pathogens. The USGS will enhance its avian influenza research portfolio by implementing a new HPAI strategic science plan to develop decision support tools, understand the implications of avian ecology on HPAI spread, and determine the mechanisms of HPAI spread in wildlife and the physical environment.

Fungal Diseases – Supporting Management and Control of White-Nose Syndrome in Bats and Amphibian Chytrid Fungus: Emerging fungal diseases are a new challenge for management of North American wildlife. The USGS discovered the cause of White-Nose Syndrome (WNS) in bats, developed rapid detection tools, and is researching intervention strategies to support Interior management agencies. In 2015, the USGS improved methods for molecular detection of the fungal agent that causes WNS. The USGS also continued to support Federal and State management agencies by conducting WNS laboratory testing for surveillance. In 2015, the USGS developed spatial models to assess the recovery potential of little brown bats from WNS. In 2016 and beyond, the USGS will investigate the protective role of the microbiome on bat skin and disease-suppressive soils that can decrease the fungal load in caves. Innovatively, the USGS will also assess the feasibility of an oral WNS vaccine, building on successes from similar work on sylvatic plague vaccine development. Additionally, the USGS will support management agencies by developing decision support tools and assessing the impact of WNS on bat populations.

An emerging salamander fungus, known as Bsal (*BEE-sal*), has devastated fire salamander populations in the Netherlands and Belgium. North America is the global hotspot for salamander biodiversity and experimental research suggests Bsal is lethal to some US salamanders. In 2015, the USGS's Amphibian Research and Monitoring Initiative (ARMI) led the first international workshop to proactively address the threat of Bsal to salamander populations in the US, with over 30 scientists from Federal agencies (USFWS, USFS, DOD, NPS), State agency partners (AFWA) and academic research institutions in Australia, Netherlands, Switzerland, UK, and the US. The working group was organized into a Bsal Task Force (<http://www.salamanderfungus.org/>) and began development of an emergency response plan for management agencies and decision analysis tools. The USGS ARMI is the lead for the surveillance and monitoring working group of the Bsal Task Force. The USGS's NWHC developed a risk assessment model for Bsal introduction into the US. In 2016 and beyond, the USGS will



The red-spotted newt, native to the Eastern US, is susceptible to the lethal invasive salamander chytrid fungus (Bsal).

coordinate national Bsal surveillance, and initiate development of diagnostic testing standards and decision support tools for management agencies.

Science Collaboration

Science conducted by the USGS Wildlife Program helps sustain our Nation's natural resources. The Wildlife Program focuses on the study of wildlife populations, their habitats, and the factors that influence their health. Birds, mammals, amphibians, reptiles, and other organisms are studied to provide scientific information to natural resource managers and decision makers. As discussed in the sections above, the USGS works closely with its partners in Department of Interior management bureau's and other resource management agencies to provide scientific information to meet management needs. The Wildlife Program works closely with the U.S. Fish and Wildlife Service, National Park Service, and Bureau of Land Management to understand their information needs and tailor our science accordingly.

Activity: Ecosystems

Subactivity: Environments Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
<i>FTE</i>	<i>930</i>	<i>950</i>	<i>0</i>	<i>40</i>	<i>990</i>	<i>40</i>
Environments Program	\$36,224	\$38,415	\$137	\$4,800	\$43,352	\$4,937
<i>FTE</i>	<i>180</i>	<i>198</i>		<i>18</i>	<i>216</i>	<i>18</i>
<i>Critical Landscapes: Arctic</i>	<i>[\$1,030]</i>	<i>[\$1,030]</i>		<i>[\$1,000]</i>	<i>[\$2,030]</i>	<i>[\$1,000]</i>
<i>Critical Landscapes: Sage Steppe Landscape</i>	<i>[\$1,181]</i>	<i>[\$1,181]</i>		<i>[\$3,000]</i>	<i>[\$4,181]</i>	<i>[\$3,000]</i>
<i>WaterSMART: Drought</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$300]</i>	<i>[\$300]</i>	<i>[\$300]</i>
<i>Rangeland Fire Response and Prevention</i>	<i>[\$542]</i>	<i>[\$542]</i>		<i>[\$500]</i>	<i>[\$1,042]</i>	<i>[\$500]</i>

Justification of Program Change

The 2017 Budget Request for the Environments Program is \$43,352,000 and 216 FTE, a net change of +\$4,937,000 and +18 FTE from the 2016 Enacted level.

Overview

The Environments Program assists in meeting Interior stewardship responsibilities across the large landscapes it manages by providing the science to support informed decision making and adaptive management for sustainable resource use and conservation. The USGS conducts research to assess, understand, model, and forecast the impacts of natural and human-induced changes to our ecosystems and natural resources, and how those changes may be mitigated. Informed forecasting of landscape structure, function, composition, and condition requires an understanding of the factors that control, constrain, and regulate ecosystem dynamics. USGS science is focused on understanding these driving factors using ecological research, long-term field studies and ecosystem modeling. Additionally, the USGS works with partners to provide alternative strategies for land management, land use, mitigation, conservation, and restoration to benefit ecosystems, landscapes, infrastructure, and economies.

The Environments Program integrates ecological science with research from other mission areas and universities, government agencies, and non-governmental organizations to produce research and deliver scientific findings that are integrated and applied.

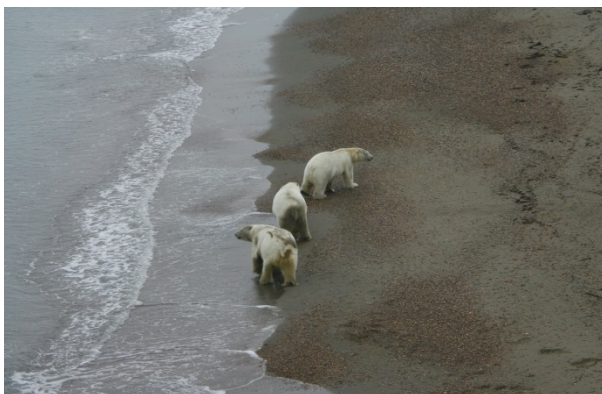
In 2017, the Environments Program is requesting increases in funding for critical landscapes such as the Arctic and Sage Steppe along with increases to support science for Wildfire Response and WaterSMART: Drought.

Program Performance

The Environments Program includes research activities in four lines of work: Priority Landscapes, Landscape Ecology, Ecological Stressors, and Management and Restoration

Priority Landscapes

Arctic – The current warming trend in the Arctic is unlike anything previously recorded and is affecting the region faster than any other place on Earth, bringing dramatic reductions in sea ice, altered weather, and thawing permafrost. Implications of these changes include rapid coastal erosion which threatens villages and critical infrastructure, degradation to wildlife habitat, increased greenhouse-gas emissions from thawing permafrost, and threats from invasive species; all of which have potentially significant impacts on subsistence activities and cultural resources. Changing habitats and related impacts to species are of great importance to land and wildlife managers as well as indigenous peoples. Federal, State, and tribal managers need to understand how climate is impacting the lands and species for which they are responsible, and what actions may be warranted to protect those resources for. As development continues to be proposed for many parts of Alaska, such as the Arctic Slope, managers must understand the trajectories of change and attempt to forecast additional impacts from development to honor commitments to Native Americans and to manage natural resources. The USGS is committed to providing the information, models, and other tools that managers need to support decision-making.



Polar bears on land ~ USGS picture.

In addition, polar bears face threats throughout their range due to the loss of sea ice habitat associated with climatic warming. Some polar bear populations are already experiencing the negative effects, while other populations are expected to experience the effects in coming decades. This means that there will have to be spatial and temporal variation in the conservation and management of polar bear populations. This has to be incorporated into the management of subsistence harvest by Native peoples, for whom the bears are nutritionally and culturally critical.

Reliable population data are necessary to conserve polar bears in a changing Arctic and support harvest management. However, the complex life history of polar bears, remoteness of sea ice habitat, and low densities (three bears per 1000 km²) present challenges for estimating the status and trends of their populations. One or more of these factors limits the strength of estimated population sizes and demographic patterns in all existing long-term polar bear datasets. The International Union for Conservation of Nature (IUCN) Polar Bear Specialist Group has identified improving the design of demographic studies for polar bears as a global priority for the species. In recent years, methodological and analytical advancements have become available that could be integrated into polar bear population studies to make them practical to implement in challenging environments, financially feasible and minimally disturbing to animals. USGS scientists and their collaborators have analyzed nearly 30 years of bear capture data from the Western Hudson Bay

population. This analysis has indicated areas for improvement to the design and analysis of polar bear population studies, which would reduce the costs and improve the efficacy of polar bear studies throughout the Arctic. However, these improvements require further analysis before final recommendations are made.

In 2015, USGS scientists conducted research on a variety of topics along the dynamic Alaska Coast. Estimates on the status of sea otters and several species of sea ducks were provided to the four National Parks along the Alaska coast: Glacier Bay, Katmai, Lake Clark, and Kenai Fjords. Additionally, research tracked the lingering effects of the Exxon Valdez Oil Spill and informed a recent decision by the Department of Justice and State of Alaska to close their claim against ExxonMobil due to the population recovery of sea otters and harlequin ducks.



Sea otter in Alaska ~ Picture by Joe Tomoleonia

Research continued on how polar bear populations are changing and in turn, how these populations are using the changing landscape. In 2016 and 2017, in addition to research on the factors driving the status of sea otters and sea ducks, we will conduct research on how sea ice loss affects the distribution and habitat selection by polar bears. Specifically, how sea ice loss has the potential to limit the bear's access to the highly productive continental shelf. The Southern Beaufort Sea population of polar bears has declined over recent decades and this has implications for harvest in the United States and Canada.

2017 Program Change

Arctic (+\$1,000,000 for a total of \$2,030,000): The increase would be used to analyze potential changes to distributions and condition of fish and wildlife populations and their habitats as a result of climate changes and human activities. Management options designed to offset these changes are hampered by uncertainty in how climate change will affect both species' occurrence (i.e., distribution) and within-season timing (e.g., growth, reproduction, migration). The program will seek to develop quantitative methods to assess plant and animal responses simultaneously at species and community levels to explicitly incorporate shifts in species' responses to climate variables. Such methods have application beyond taxa in Alaska and could be applied across systems where there is a desire to predict the species changes and shifts in life history timing in response to climate change or development.

Additionally, the USGS will use computer simulations of data gathered in Western Hudson Bay, the Chukchi Sea, and the Southern Beaufort Sea to evaluate various strategies for estimating polar bear populations. The USGS would evaluate study design strategies aimed at monitoring polar bear populations in order to estimate population parameters (e.g., survival and breeding) and their relationships with environmental conditions, estimate population size for the purposes of managing sustainable removals, and detect changes in these parameters. Methodological and analytical advancements have become available that could be integrated into polar bear population studies to make them practical to implement in challenging environments, financially feasible and minimally disturbing to animals. USGS scientists and their collaborators have analyzed nearly 30 years of bear capture data from the Western Hudson Bay population. This analysis has suggested areas for improvement which would reduce the costs and improve the efficacy of polar bear studies throughout the Arctic. These improvements would be analyzed and modelled further in order to make final recommendations.

Sage Steppe Landscape – The Sage Steppe Landscape extends across 11 Western States and two Canadian Provinces and over 60 percent of that landscape is on public lands, half of which are managed by the Interior. This area is dominated by sagebrush, which is priority habitat for over 350 wildlife species, most notably the greater sage grouse. Alterations in the sage steppe landscape including changing fire regimes, spread of invasive grasses, climate change, and energy development have led to new challenges to these species and the landowners and public that lives and recreates in this area. Land and species managers, landowners, and other stakeholders need scientific information to improve their ability to understand and address these challenges and to implement landscape-scale management decisions, regardless of surface management or ownership. The recently issued Secretarial Order 3336, which emphasizes the need for enhanced strategies to prevent and manage rangeland fire and restore sagebrush habitat, is bringing renewed focus to the threat of fire in the sage steppe landscape.

To address the science needs of this landscape, the USGS's 2015 research efforts focused on understanding how wildfire and habitat fragmentation affect greater sage grouse populations, developing buffer and mitigation strategies, forecasting distributions of sagebrush in the face of climate change, describing rangeland fire frequency and size, evaluating the effectiveness of restoration techniques, and developing conservation and restoration strategies to benefit greater sage grouse. In 2016, research efforts will remain focused on understanding how wildfire affects greater sage grouse and the sage steppe

landscape, determining best management practices for sagebrush restoration, and evaluating the effectiveness of restoration techniques. Efforts will also include development of predictive models to understand the influence of fire, cheatgrass, and other landscape factors on greater sage grouse populations.

2017 Program Change

Sage Steppe Landscape (+\$3,000,000 for a total of \$4,181,000): The proposed increase in 2017 would be used to fund expanded research to support the priority needs of managers to address changing fire regimes, drought, and shifting climates; control the spread of invasive cheatgrass; design conservation and management strategies for greater sage grouse; and effectively restore and adaptively manage the sage steppe landscape. Rangewide geospatial analyses will be conducted to provide mapping of sagebrush habitat, fire, and invasive plants to help inform long-term, landscape-scale management planning. Pilot studies will be implemented to test strategies for preventing spread of and controlling cheatgrass. Testing and application of restoration and post-fire rehabilitation techniques will be initiated with a goal of developing cost-effective methodologies to restore sagebrush. The USGS will also develop an interagency monitoring framework focused on evaluating the effectiveness of fuel treatments, invasive plants control, and restoration efforts, and the effects these actions have on habitat conditions and greater sage grouse. Resultant data and information will be used to inform long-term conservation and management strategies for the sage steppe landscape and to support the process of adaptive management. This information is relevant to State and Federal agencies, including but not limited to State land, fish and wildlife agencies, the USFS, BLM, NPS, and FWS. All the research will be planned and implemented in close collaboration with Interior bureaus (BLM, NPS, and FWS).



Image of the Chesapeake Bay taken from Landsat satellite data.

Chesapeake Bay – The USGS continued to conduct research that has a critical role in providing scientific information to improve the understanding and management of the Nation’s largest estuary—the Chesapeake Bay ecosystem. The 64,000-square-mile watershed supports over 3,600 species of fish, wildlife, and plants and provides spawning grounds for many ecologically and economically important species including striped bass and blue crabs. The Bay watershed lies in the heart of the Atlantic Flyway and 29 species of waterfowl, about 1 million birds, over-winter in the region. The size of the Chesapeake seafood harvest is third in the Nation, only behind the Atlantic and Pacific Oceans. Along

with agricultural production, tourism, and recreation, the estimated economic value of the services from the Chesapeake Bay watershed is about \$100 billion annually. However, the health of the Bay ecosystem began to decline at the beginning of the 20th century due to overfishing and increasing human population with the associated changes in land use. The USGS works with Federal, State, and academic science partners to provide monitoring, research, and communication of results to improve ecosystem management for the Chesapeake and other National ecosystems. This complex ecosystem requires information from a combination of aquatic and terrestrial ecosystem research projects. For example, in 2015, USGS researchers developed models FWS can use to compare among different options for wetlands restoration on their refuges to support black ducks. USGS research in 2015 also discovered that

a majority of streams in the Chesapeake Bay region are warming; rose an average of 1.4° C between 1960 and 2010. This has implications for fish populations such as brook trout which is a key species for restoration in the watershed and the eastern United States. In 2015, the USGS expanded studies on the effects and sources of endocrine-disrupting compounds (EDCs) on fish and wildlife in the Bay watershed. The USGS made significant progress on a database of historical information to better examine the role of EDCs, other toxic compounds, and land-use conditions on fish kills occurring in Virginia, Maryland, West Virginia, and Pennsylvania. In 2016 and 2017, the USGS will continue to provide the research and ecological monitoring developed for and used by Federal, and State partners to restore the Chesapeake ecosystem. The USGS Chesapeake Science Strategy guides science activities to address the Chesapeake Bay Watershed Agreement (2014–2025) which supports the Interior’s involvement in the Bay restoration efforts.

Everglades – The USGS Greater Everglades Priority Ecosystems Program provides science to support management and restoration of America’s Everglades. This program supports multi-year monitoring, modeling, and research projects that span the entire range of scientific disciplines. A recent emphasis has been on climate change effects. The USGS, in cooperation with Florida Atlantic University Center for Environmental Studies and Florida Sea Grant, convened a two-day technical workshop in April 2015 on downscaling of global climate models for south Florida (<http://www.ces.fau.edu/usgs/downscaling/index.php>). This workshop was the fourth in a series of climate change-related workshops examining the potential impacts of climate change on Everglades hydrology and ecology. A previous workshop had revealed that even modest decreases in annual precipitation may have major impacts on Everglades hydrology and restoration efforts, especially if coupled with increases in temperature and evapotranspiration (the process by which water is transferred from the land to the atmosphere by evaporation). However, predictions of precipitation changes due to climate change are fairly uncertain due to the course resolution of global-scale models. This workshop brought together experts in statistical and dynamic model downscaling to determine the state of the science and future research needed to reduce uncertainty. In 2016 and 2017, the USGS will continue to provide science in support of Everglades restoration and management. Research topics include biogeochemistry, invasive species detection and ecology, impacts of climate change, threatened and endangered species, ecosystem modeling, and monitoring water flow and quality. The USGS will continue its collaboration with DOI bureaus and other partners to link science and management.



Scientists working during workshop in climate change effects on Everglades hydrology ~ USGS picture.

San Francisco Bay-Delta (also referred to as the California Bay-Delta) – In 2015, USGS scientists made great strides in refining and extending the capabilities of the Computational Assessments of Scenarios of Change for the Delta Ecosystem (CASCaDE II model systems); a collaboration among the USGS and

several academic and international organizations. This paved the way for more reliable and objective evaluations of the ecosystem consequences of management actions and climate change than have been possible. CASCaDE II is an integrated system that models linkages between climate, hydrology, hydrodynamics, sediment, water quality, and several biological and ecological processes occurring in the Estuary. This will improve the ability for scientists and planners to anticipate and diagnose Bay-Delta ecosystem responses to both planned and unplanned changes including modifications of water infrastructure, tidal marsh restoration, and climate change. Project scientists expect to complete the current phase of model development in 2016. In 2017, the USGS will start collaboration with management agencies and stakeholders to apply the CASCaDE tools to answer questions critical to California's water future and preservation of the Bay-Delta, such as how climate change and the new conveyance infrastructure and increased tidal marsh will alter drinking water quality.

Puget Sound – In 2015, USGS scientists strategically augmented each of the tasks within the USGS Coastal Habitats in Puget Sound (CHIPS) initiative, which is a multi-disciplinary scientific collaboration that seeks to expand our understanding of the physical, chemical, and biological processes that build and maintain nearshore habitats and support ecosystem health in Puget Sound. This work is essential to our Puget Sound ecosystem restoration partners, including the Puget Sound Partnership and other State agencies, Federal agencies (EPA, NOAA, U.S. Fish and Wildlife, the US Army Corps, FEMA, and others), Tribes, local governments, and NGOs. This work supports salmon recovery efforts, integrated floodplain/estuary restoration, flood hazard mitigation, sea level rise vulnerability assessments, and climate change adaptation. In 2016, USGS scientists will begin science to support managers who must address climate change hazards affecting streams and rivers. The USGS will map diminishing regional cold water sources needed by salmon and other key species and develop forecast models for the changing sources of cold water (including snow melt and ground water) to support resource and hazard management decisions. In 2017, we will work with partners to develop useful model-based climate-change and ground water supply scenarios to help guide regional salmon population and ecosystem recovery.

Columbia River – In FY 2015, a key focus for USGS scientists in the Columbia River Basin was to provide products that describe the ecological effects of flow management, an issue important to policy makers for the modernization of the Columbia River Treaty. This work included the characterization of the effects of flow management on the habitat potential of culturally and economically important aquatic species such as white sturgeon and Pacific salmon that rely on habitats in the mainstem Columbia River to complete their life histories. The research provides synergy and leverages existing efforts that are local (e.g., Columbia Gorge National Scenic Area), regional (e.g., Great Northern LCC, Columbia River Toxics Reduction Workgroup) and national (e.g., USGS Ecological Flow research, Large River Monitoring Forum, USGS Coastal National Elevation Database). In FY 2016 USGS scientists will collect and compile information needed to develop a sediment transport model for an ecosystem classification and will collaborate on laying the groundwork for an integrated approach to understanding the effects of multiple stressors on ecosystem function in the Columbia River and its floodplain. In FY 2017 we will build upon the FY 2016 work to provide resource managers with an integrated understanding of how landscape level stressors affect ecosystem processes in the Columbia River Basin.

Landscape Ecology

Sustaining Environmental Capital Initiative: Integrating Ecosystem Services in Public Land and Water Management – The goal of the Sustaining Environmental Capital Initiative (SECI) is to develop, integrate, and enhance natural resource management decision tools and information to better enable managers to account for the benefits people receive from ecosystem services (such as clean water and pollination, etc.) and provide guidance for using ecosystem service information in management decisions. The SECI addresses ecosystem service science and policy issues in coordination with resource managers; and includes an on-line website (the Sustaining Environmental Capital (SEC) Dashboard) designed to coordinate efforts and distribute usable results across agencies.

In 2015, pilot studies were launched in the Chesapeake Bay Watershed, Delaware River Headwaters, and the Willamette and Puget Sound watersheds. The pilots are developing and demonstrating ecosystem service practices, data, and tools that can be applied to other ecological environments. A stakeholder engagement and gap analysis process was initiated to assess ecosystem service tools and decision making needs among Federal agencies. These efforts informed the conceptual design and beta-version development of the on-line dashboard.

In 2016 and 2017, multiple ecosystem service valuation methods will be applied across the pilot studies including: 1) benefit transfer to estimate economic values by transferring available information from completed studies; 2) primary data collection to generate detailed values for specific services; 3) ecological endpoint descriptions to incorporate values in decision making processes; 4) and methods to capture less tangible benefits such as cultural and subsistence values. The SECI Dashboard user interface will be launched along with a stakeholder engagement process to continue refining the application content and user interface. Results from the three pilot studies will be available to address resource management decisions in the specific pilot study locations, augment existing decision support systems tools, and be incorporated into the SEC Dashboard.

Dryland Rehabilitation – The complex soil, vegetation patterns, and low and variable moisture conditions in dryland regions makes rehabilitation and restoration challenging. Researchers in the USGS are using a multifaceted approach to help address the knowledge gaps and challenges associated with restoration and rehabilitation in drylands. In 2015, USGS scientists published lessons learned from a very large post-wildfire restoration effort in Utah. This study reported that near-surface sediment fluxes were several orders of magnitude higher in treated areas than in unburned or burned areas where no rehabilitation occurred. Dry conditions and high surface sediment flux limited the establishment of seeded species in rehabilitation areas for nearly 3 years. The USGS has followed up these discoveries with experiments aimed at developing new restoration approaches to overcome challenges observed in the post-wildfire analysis. In 2016 and 2017, the USGS will apply these new approaches to a landscape-scale restoration effort in Canyonlands National Park in a collaborative project with the National Park Service.

Ecological Stressors

Drought: Persistent and recurring drought in the Western United States is threatening water supply for domestic and industrial use, irrigation, power generation, and fish and wildlife and increasing occurrence

and severity of wildland fire and dust storms. Understanding the ecological effects of drought and the tradeoffs in water allocation decisions on the landscape will help inform water and natural resource management decisions. The funding requested for this work would provide tools for fish and wildlife managers as well as water resource managers.

2017 Program Change

WaterSMART: Drought (+\$300,000 for a total of \$300,000): The proposed increase would allow the Environments Program to conduct research on how drought interacts with other environmental stressors such as invasive vegetation and wildfires to affect landscape composition, structure, and function. Information and data would be provided to resource managers who can then evaluate the tradeoffs between land management strategies to determine which would most likely lead to desired condition for managing the vegetation. This is a multi-disciplinary effort within the USGS and the next focus areas will be the Rio Grande and the Red River. This work will contribute to the National Water Census.

Rangeland Fire Science – The 2015 fire season was the worst in recorded history, with over 10 million acres burned, resulting in significant impact to human safety and health, property damage, and loss of fish, wildlife, timber, rangeland, and other natural resources. Accurate and timely scientific information is critical to ensure appropriate management response to wildfires and effective investments in stabilization, rehabilitation, and restoration of landscapes immediately after wildfires occur. Currently, fire management organizations lack adequate scientific information to prioritize burned regions for suppression and restoration activities. Information regarding priorities for suppression empowers fire managers to maximize their resources and employ strategies that can result in long-term resource benefits such as reducing hazardous fuels and minimizing fire size and intensity. Restoration efforts rely on research-based information to reduce the post-fire effects on water quality and supply, critical wildlife habitat, invasive species, and ecosystem services such as livestock grazing, timber production, and recreational value. Demands for strategic preparation and rapid science delivery during and immediately after wildfires are increasing, and frequently surpass the current capacity for the USGS to adequately provide science to support a cohesive wildfire response by Federal, State, tribal, and local organizations.



Burning Sagebrush at Hart Mountain National Antelope Refuge

The importance of a coordinated Federal, State, and Local response to the threat of rangeland fire was highlighted with the January 2015 release of Secretarial Order 3336 (Order). The Order emphasized the need to enhance strategies for preventing and managing rangeland fire. A key to the success of the Order will be providing timely scientific information needed by managers to understand and effectively reduce the threat of rangeland fire and rapidly respond post-fire to implement actions to restore the sagebrush-steppe landscape to a healthy and sustainable condition. A healthy sagebrush-steppe ecosystem provides a valuable resource for ranchers and outdoor enthusiasts who use the ecosystem, as well as the 350 wildlife species that depend on this habitat for their survival. In the absence of improved post-fire

restoration the likely replacement for sagebrush-steppe is exotic annual grasslands, which pose a substantially greater fire risk and provide negligible benefits to the numerous users of sagebrush-steppe.

In 2015, the USGS's research efforts focused on describing historical rangeland fire frequency and size to inform models of future fire risk, assessing the post-fire response of sage grouse populations (a species of significant management focus), evaluating the effectiveness of restoration treatments, and developing tools to assess changing soil temperature and moisture regimes; these soil properties are important physical characteristics of the landscape that provide managers information regarding the resilience of the land to disturbance and resistance to invasion by exotic annual grass species.

In 2016, the USGS will continue to research the post-fire response of sage grouse and other important components of a healthy sagebrush ecosystem and assess effectiveness of management actions, provide tools for land managers to respond quickly and efficiently to implement emergency stabilization actions, and provide science-based strategies for long-term recovery of the natural vegetation community for the use and enjoyment by ranchers and recreationalists. Efforts will also include the development of initial products to support landscape prioritization for fire planning and operations.

2017 Program Change
<p>Rangeland Fire Response and Prevention (+\$500,000 for a total of \$1,042,000): The proposed increase in 2017 would expand capabilities of the USGS to address the priority science needed to reduce the growing threat of rangeland fire and improve effectiveness of actions to stabilize, rehabilitate, and restore ecosystems after fire. Work will include the study of large-scale efforts to control flammable vegetation, development of climate-adapted revegetation strategies, creation of tools to support a new conservation and restoration strategy that will provide landscape prioritization for both fire and land managers, and development of new monitoring techniques to assess effectiveness of fire management actions and post-fire rehabilitation efforts. Along with these efforts, the requested increase would provide an opportunity for the USGS to develop a proactive rapid science response capacity for wildfires. This increased capacity would allow the USGS to rapidly provide needed geospatial information, monitoring strategies, and other relevant scientific information to wildfire response organizations for real-time response to a fire, especially Federal land management agencies in the Interior and the U.S. Forest Service (USFS). These combined efforts will increase the USGS's ability to support Federal wildfire-management policy, including the Federal Land Assistance, Management and Enhancement (FLAME), by providing the scientific information and tools to ensure that fire management planning and response are based on the best available science.</p>

Management and Restoration

Mangrove forests – Mangrove forests provide storm protection for coastlines, improve water quality, and sequester biological carbon. However, many of them have been degraded throughout the globe, including those along the Florida coast. Approaches to restore the forests which focused on replanting the trees have had little success. Instead, USGS scientists have focused on restoring the hydrological flows to patches of denuded mangrove forests, and are reporting signs of a successful restoration. The USGS has begun evaluating the progress of a restoration project which reconnected the tidal flows into dead

mangrove areas at the Rookery Bay National Estuarine Research Reserve, adjacent to Ten Thousand Islands National Wildlife Refuge in Florida. In 2015, scientists began sampling the soil, forest structure, surface elevation change, faunal community dynamics, and food-webs which will change as these forests become established. Already, where tidal flows have been partially restored, mangroves are actively re-colonizing the fringes where dead trees currently stand. In 2016 and 2017, the USGS will continue to research the status of mangrove forests being restored along the United States coast to evaluate and improve the techniques. Restoring ecological flows has a strong potential to enhance the services provided by coastal wetlands on a number of Interior-managed lands throughout the Southeast. This research not only has implications for the management of Interior and State lands, but for international governments with mangrove forests along their coasts, which seek to invest in carbon, crediting projects domestically and abroad.



USGS scientist researching recovery of mangrove forest in southern Florida - USGS picture.

Science Collaboration:

As demonstrated in the above program performance section, the Environments Program responds to the needs and requirements of resource management bureaus within the Interior and other science and resource management organizations by designing, developing and conducting research required for the resource management and policy decisions made by a variety of stakeholders.

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Activity: Ecosystems

Subactivity: Invasive Species Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
FTE	930	950	0	40	990	40
Invasive Species Program	\$16,830	\$17,330	\$47	\$2,500	\$19,877	\$2,547
FTE	74	75		6	81	6
<i>New and Emerging Invasives of National Concern</i>	<i>[\$5,212]</i>	<i>[\$5,712]</i>		<i>[\$2,500]</i>	<i>[\$8,212]</i>	<i>[\$2,500]</i>

Justification of Program Change

The 2017 Budget Request for the Invasive Species Program is \$19,877,000 and 81 FTE, a net change of +\$2,547,000 and +6 FTE from the 2016 Enacted level.

Overview

Invasive plants and animals cause significant economic losses and diminish opportunities for beneficial uses of valued resources such as forests, croplands, rangelands, and aquatic resources. Costly effects include clogging of water facilities from quagga and zebra mussels and clogging of waterways from aquatic plants such as the weed hydrilla and giant fern salvinia, disease transmission (e.g., West Nile virus and avian influenza), harm to fisheries (e.g., Asian carp, snakeheads, whirling disease, and hemorrhagic septicemia), and increased fire vulnerability and diminished grazing value (e.g., leafy spurge, cheatgrass, brome, and buffelgrass). Invasive species are contributing factors in 40 percent of all threatened and endangered species listings. It is estimated that fighting the economic, ecological and health threats posed by over 6,500 invaders (<http://www.nature.nps.gov/biology/invasivespecies/>) costs over \$120 billion in damages annually to the United States economy. Increased global travel and trade continue to provide additional pathways for both intentional and unintentional introductions of invasive species. The USGS works on all significant groups of invasive organisms in terrestrial and aquatic ecosystems throughout the United States. In 2017, the Invasive Species Program is requesting an increase in funding for New and Emerging Invasive Species.

Program Performance

The Invasive Species Program includes research activities in two lines of work: Invasive Species and Management and Restoration.

Invasive Species

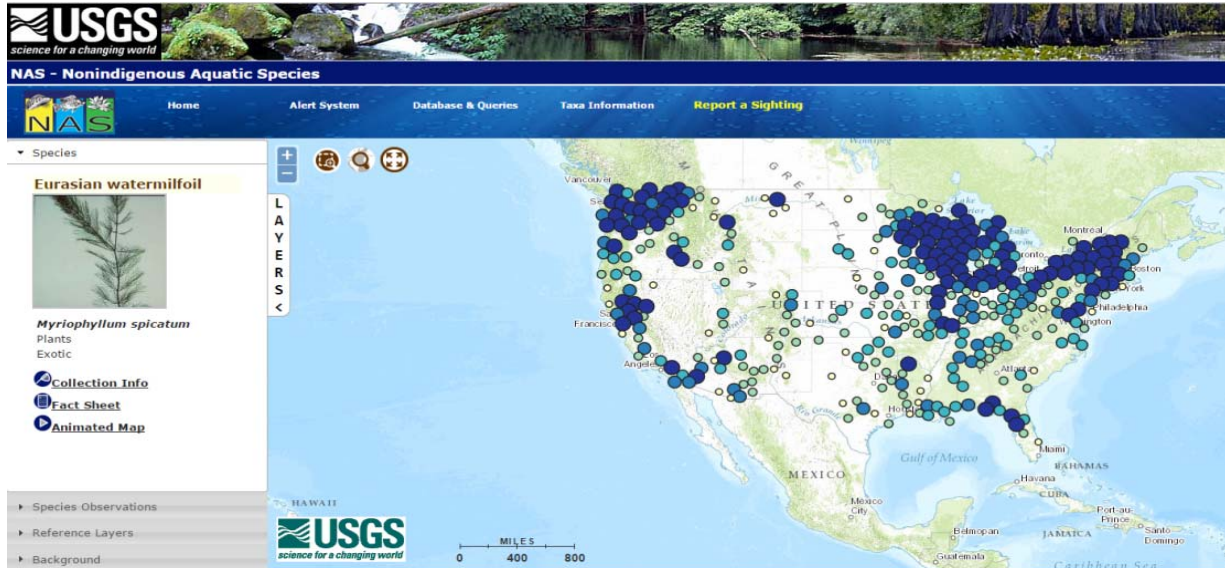
New and Emerging Invasive Species – Invasive species cost the United States economy \$120 billion each year. Focus on early detection and rapid response (EDRR), as a way to improve the resilience of ecosystems, is a cost-effective way to address the threat posed by invasive plants and animals. In recent years, the USGS has focused on EDRR and made advances in applying technology to address new and emerging invasives, while continuing to address high priority invasives such as Asian carp, zebra and quagga mussels, sea lamprey, Burmese pythons, tamarisk, common reed and buffelgrass.

Since 2010, detection, containment, and control of Great Lakes invasive species, particularly Asian carps, has improved markedly. For example, USGS scientists worked with industry to develop a portable device to analyze water samples for the presence of Asian carp DNA in the field with results in less than 45 minutes (refer to Asian Carp section below for more information regarding this portable device). USGS scientists continued testing the effectiveness of using sound energy and carbon dioxide barriers to contain Asian carp and examining methods of reducing their populations such as using algal extracts to attract Asian carp to an area for further control using nets or fish toxins designed to only kill Asian carp. USGS scientists are now working to move these new detection, containment and control tools to field use and, where applicable, adapting these tools to combat other high priority invasive species. For example, in 2015, the USGS entered into an effort with Bureau of Reclamation (BOR) to form an Invasive Mussel Collaborative with scientific partners within the Great Lakes Restoration Initiative (www.invasivemusselcollaborative.net). In 2016 and 2017 USGS scientists will continue research to assess the efficacy and impacts of applying Zequanox®, a toxin approved for use in open waters to control invasive mussels and continue to co-lead and grow the Invasive Mussel Collaborative to help Interior and other partners manage invasive mussels in open waters.



Native mussels encrusted with live zebra mussels before treatment with Zequanox® and dead zebra mussels after treatment

Also, in 2015 with additional funding, the USGS was able to respond to our DOI and other partners' needs by serving occurrence data and species profiles on aquatic plants as part of the Nonindigenous Aquatic Species (NAS) database (<http://nas.er.usgs.gov>), capabilities were improved to better develop and validate the next set of new early detection tools (metagenomics and Next Generation Sequencing) to better identify new invasive species, a project was begun to use new mapping techniques to better predict potential distribution of newly invading species, and another to examine range expansion by Burmese pythons in south Florida.



Species occurrence map for Eurasian watermilfoil, an invasive aquatic plant that was recently restored to the USGS Nonindigenous Aquatic Species database as a result of receiving additional funding. Maps can be created using real-time data and various user-selected data layers.

In 2016 and 2017, the USGS will continue to revise, update, and make available data and information on aquatic plant species in the NAS database, begin a project using new capabilities to detect newly invading species, link USGS scientists across the Country working on new and emerging invasive species issues in a community of practice, and develop and implement a strategic plan for nationally important and relevant research on new and emerging invasive species that encompasses plants and animals as well as terrestrial and aquatic ecosystems.

2017 Program Change

New and Emerging Invasive Species of National Concern (+\$2,500,000 for a total of \$8,212,000):

This increase would enhance ongoing efforts to better detect, contain and control new, emerging, and invasive species of great concern such as Argentine black and white tegu, a South American lizard established and spreading in Florida; grass carp and black carp, Asian carp species of growing concern to managers in the United States; and *B. sal*, a newly-emerging chytrid fungus lethal to salamander not yet detected in the United States that would devastate diverse native salamander fauna. Specific activities would include the following:

- Develop and improve the power of advanced molecular detection tools (such as eDNA and fecal source tracking) to detect invasive species at very low densities in the field
- Improve and upgrade capabilities and capacities of the USGS Nonindigenous Aquatic Species (NAS) database (<http://nas.er.usgs>) which would include a mobile application to allow reporting of nonindigenous aquatic species.
- Enhance USGS and BOR collaboration to share research findings and information with decisionmakers, scientists and stakeholders to improve the effective management of mussel populations in the future.

This new collection of early detection and rapid response tools would enable natural resources managers to more effectively allocate monetary resources to maximize the impact of management actions to ensure that the Nation is better prepared for the next—yet unknown—generation of invasive species.

Asian Carp – The USGS research strategy for Asian carp is comprehensive and focuses on improving methods of early detection, conducting risk assessments to identify high-risk areas for recruitment or survival, and developing methods for containment and control. Essential to these efforts is the application

of our extensive knowledge of Asian carp life history and hydrologic expertise that guide our design, development, and application strategies. USGS scientists continue to work closely with DOI and other partners to ensure research approaches and products are structured to be relevant to manager needs. The USGS is working toward tailoring our tools and methods so they can be applied to control other invasive species, and working toward direct transferability outside the Great Lakes basin (e.g. Upper Mississippi River and Ohio River basins).



Portable analyzer that provides results of eDNA testing for Asian carp in less than an hour. Possible applications include aiding law enforcement officers and testing of baitfish.

In 2015, USGS scientists published results of a study demonstrating that dead Asian carp, slime residue, and predator feces can contain detectable Asian carp DNA. The significance of this study helped to improve the power of eDNA analysis by explaining sources of DNA in water. The USGS also partnered with industry to introduce a portable

device that can analyze water samples for the presence of Asian carp DNA in less than an hour. The USGS completed studies examining the risk of successful Asian carp spawning, including application of the Fluegg model, a model developed to identify areas in which Asian carp could successfully reproduce, to the St. Joseph River in Michigan. The USGS also collaborated with U.S. Fish and Wildlife Service (FWS), the Great Lakes Fishery Commission and Fisheries and Oceans Canada to draft a Binational Risk Assessment for Grass Carp in the Great Lakes, which will be released in 2016. A similar risk assessment for Black Carp is also being conducted and released in 2016. Studies continue examining the utility of pure and complex sound as a deterrent to Asian carp movement. In 2015, carbon dioxide was tested as a barrier to movement of Asian carp in a backwater of the Illinois River. Data analysis will continue into 2016. The USGS held a partners' meeting on the use and registration of carbon dioxide to contain Asian carp and are working with regulatory and management agencies to streamline that process. The USGS will provide regulatory support to FWS if a registration is pursued. An Asian carp cell line was established in 2015 to rapidly test toxicity of chemicals to Asian carp. That project continues into 2016 and 2017. Based on the results of pond experiments combining the use of microparticles and algal attractants, microparticles and delivery methods will be fine-tuned before being re-tested in 2016.

Informing Resource Decisions – Today's natural resource managers must make effective decisions about broad-scale ecosystem processes occurring across the landscape, with complex interactions, numerous competing stakeholder demands, and highly uncertain outcomes. USGS scientists are applying tools from decision science such as structured decision making, adaptive management, and modeling that examines the outcome of a variety of management alternatives to invasive species issues to help managers make more informed resource allocation and management decisions. In 2015, the USGS published a decision tool developed to help the Bureau of Land Management (BLM) decide the appropriate course of action to control invasive African buffelgrass in the Sonoran Desert at the Ironwood Forest National Monument in Arizona. This work will continue in 2016. In 2015, the USGS initiated three projects applying structured decision making and adaptive management to invasive species issues: (1) containment of Black and White Tegus (large-bodied lizards from South America) in South Florida; (2) treatment of Melaluca (a fast-growing tree from Australia) in the Everglades; and (3) effective management of common reed (Phragmites) in the Great Lakes region. A structured-decision making workshop was held for the first project and initial products are forthcoming. All three projects will continue into 2016 and 2017.

Prevention, Early Detection, and Rapid Assessment – USGS research focuses on developing and enhancing capabilities to forecast and predict invasive species establishment and spread. Early detection helps resource managers identify and report new invasive species, especially for cryptic species and those in very low abundance, to better assess risks to natural areas.

Modeling and Forecasting – The USGS assists resource managers and other decision makers by developing and testing spatial models, maps, and decision support tools. These tools can be used to target monitoring efforts, predict potential ranges, simulate application of management alternatives, and predict effects of invasive species. In 2015, USGS scientists demonstrated expertise in modeling invasive species distribution by publishing a number of papers and book chapters discussing and improving methods of conducting invasive species distribution modeling. Models were published on the northward spread of Africanized honeybees, the spread of *Prosopis juliflora*, an invasive plant in Ethiopia, and the potential spread of reed canary grass in the Upper Mississippi River System. In 2016, USGS scientists

will continue on-going studies modeling potential spread of high impact invasive species such as buffelgrass, incorporating implications of future climate scenarios on their predictions, as appropriate.

Early Detection of Invasive Species – Tracking the establishment and spread of existing and new invasive species is critical to effectively manage invasive species. In addition to standard means of monitoring, the



Brown treesnake entering a baited trap on Guam. USGS conducts research to assess and improve snake detection and control efforts.

USGS is developing new tools, particularly molecular techniques, to assist in the early detection of invasive species. For example, in 2015, USGS scientists expanded research developing and validating the use of environmental DNA (eDNA) to detect and improve occurrence estimates of invasive species such as New Zealand mudsnails and Burmese pythons. The USGS also continued exploring use of remote sensing to detect invasive species such as buffelgrass in remote locations using drone aircraft and thermal imaging to detect feral hogs. The USGS brown treesnake Rapid Response Team on Guam was deployed to Rota to search for brown treesnakes after one was found on the island. USGS scientists conducted modeling to determine the appropriate amount of searching

time necessary to detect a brown treesnake with given desired of certainty. In 2016 and 2017 technology adapted to detect Asian carp DNA from water samples in 45 minutes using a portable device will be adapted to detect other invasive species such as zebra and quagga mussels, vectors enabling the northern expansion of Burmese pythons will be examined, and the utility of using remote sensing to detect invasive species will be pursued.

Nonindigenous Aquatic Species Database – The online USGS (<http://nas.er.usgs.gov>) NAS database continues to grow. The NAS program monitors, analyzes, and records sightings of non-native aquatic species throughout the United States to help fill information gaps on introduction pathways, geographic distribution, ecology, and impacts of NAS. These data empower our partners (Interior, Federal and State agencies) to target monitoring and control efforts with real time spatially explicit data. The database now contains over 173,000 records of over 1,000 aquatic species occurring outside of their native range. This information is used widely for a variety of purposes including risk assessments of the United States Army Corp of Engineer's (USACE) water resource management actions, invasive species monitoring design, and predictive modeling of future invasions. Over 900 resource managers, scientists, and concerned members of the public have signed up for automated alerts on newly sighted species in their region or community. In 2015, the 30 year anniversary of the NAS, the database became the official DOI portal to report sightings of nonindigenous aquatic species. Two botanists were hired to revamp and make available data and information on invasive aquatic plants. They reached out to States and are working with regional panels of the Aquatic Nuisance Species Task Force to prioritize the species list. In 2016, the NAS will work with NatureServe to become the resource for native fish ranges and the USGS continues to upload large datasets from other sources such as the Global Biodiversity Information Facility

(<http://www.gbif.org/>) and Early Detection and Distribution Mapping System (<https://www.eddmaps.org/>).

Biology, Ecology and Population Dynamics of Invasive Species – The USGS conducts research on the biology of many species including Burmese Pythons, Nutria, Asian carp, buffelgrass, brome, cheatgrass, tamarisk, leafy spurge, snakeheads, brown treesnakes, zebra and quagga mussels, northern pike, Asian Swamp Eels, American Bullfrogs, feral pigs, and others to provide the information needed by management agencies. In 2015, USGS scientists also published a risk assessment of Burmese Pythons to humans and the first empirical evidence showing Burmese Pythons caused declines of Marsh Rabbits in the Everglades. Information gained from studies completed in 2015 by USGS scientists, such as determining size at maturity and home range size of Burmese Pythons and habitat use throughout the year by Black and White Tegus in South Florida, will help managers working to minimize impacts of these invasive reptiles.

Control and Management of Invasive Species – USGS research improves existing invasive species control methods and develops and tests new chemical, physical, molecular, and biological methods of control, stressing integrated control strategies where applicable. These tools permit managers to understand and minimize environmental impacts of invasive species at landscape, regional, and local scales. The USGS has ongoing research to develop and test control methods for a wide variety of invasive species, including Asian carp, brown treesnakes, Burmese pythons and other invasive reptiles,



Native mussels used in a field application assessing the efficacy and effects of Zequanox®, a zebra mussel control tool.

sea lamprey, zebra and quagga mussels, Chinese mystery snails, lake trout, American bullfrogs, among others. For example, in 2015 the USGS continued to co-lead the Great Lakes Phragmites Collaborative (<http://greatlakesphragmites.net/>) to facilitate communication among stakeholders and serve as a resource center for information on Phragmites biology, management, and research. USGS scientists continued to further development of gene silencing (regulation of gene expression) and microbial symbionts (a microorganism living in a symbiotic relationship in or on a host organism) as tools to control common reed (*Phragmites* sp.) This ground-breaking work will continue in 2016. Also in 2015, USGS scientists continued to research the use of sex and alarm pheromones to control sea lamprey. The male sea lamprey sex pheromone was approved for use by the EPA and research on the potential uses of this compound will continue in 2016.

Zebra and Quagga Mussels – It has been 25 years since invasive zebra and quagga mussels (dreissenids) were first found in the Great Lakes. In 2015, USGS scientists completed and published a variety of studies examining the impact of these mussels on fish, native unionid biology and distribution, and food web structuring in the Great Lakes. Also in 2015, the USGS collaborated with State and academic partners to test the efficacy and impacts of a new control tool for these mussels in open water

(Zequanox®). USGS scientists participated in field tests of Zequanox in Lake Minnetonka, Minnesota, and Lake Erie, Michigan. They also completed several laboratory studies examining effects of this treatment tool on native fish and mussels. Further testing of Zequanox and other control tools such as the use of spawning inhibitors to reduce mussel productivity, will continue in 2016.

Invasive Species in Hawaii and the Pacific Islands – Invasive species often pose the primary threat to biodiversity in the Pacific. USGS research focuses on the ecology, reducing impacts, and controlling highly invasive plants (e.g., miconia, faya tree, strawberry guava, Kahili ginger), animals (e.g., mouflon, rats, feral pigs, Argentine ant, invasive wasps), and wildlife disease organisms. In 2015 USGS scientists published studies on home range and habitat use by feral goats and studies examining the effect of climate change on plant species distribution (native and invasive). Also in 2015, the U.S. Department of Agriculture (USDA) and National Park Service (NPS) asked the USGS to provide expertise to understand and control the emerging fungus causing a syndrome known as Rapid ‘Ohi’a Death (ROD) that is attacking and killing ecologically, socially, and economically important ‘o’hia trees (*Metrosideros polymorpha*) on the Island of Hawai’i. Infected trees die within months of infection. The spread of ROD could be a significant setback to decades of forest restoration and management efforts by Interior agencies and partners. In 2016 and 2017 USGS scientists will use existing data to construct models describing the association of ROD to multiple environmental variables using statistical and machine learning methods and then use the models to predict areas that may be at risk of further invasion. The USGS will also develop genetic assays to quantify fungal infection in wood, soil, potential insect vectors, and other relevant environmental samples and to rapidly confirm presence of the fungus in the field. Hawaiian forest bird populations have been negatively affected by the non-native avian malaria parasite. In 2015, the USGS was a partner in the development of models to (1) understand avian malaria dynamics in different species and at different elevations and (2) forecast avian malaria risk in light of climate change. Malaria infections are highest at low elevations and over 90 percent of infected scarlet Hawaiian honeycreepers (I’iwi) die from this disease. Climate change and disease is expected to decrease the suitable habitat for ten forest bird species by over 50 percent. In 2016 and beyond, USGS scientists are assessing novel mosquito control tools (e.g., bacterial endosymbiont *Wolbachia*). Mosquitoes carry diseases that affect people (e.g., West Nile virus, dengue); therefore, the benefits of this science go beyond avian conservation to public health.

Management and Restoration

Restoration of Invaded Habitats – The USGS develops strategies and techniques to understand and facilitate restoration of native species and habitats affected by invasive species. This is critical because control without restoration can leave the ecosystem vulnerable to subsequent reinvasion by the same or additional invasive species.

Invasive terrestrial and riparian plants in the Western United States – The USGS conducts



Defoliated tamarisk after movement of tamarisk leaf beetle through the area.

multi-scale, integrated assessments to map infestations and accurately monitor the spread of invasive plants in

Western forests, arid rangelands and along river corridors; predicts areas most vulnerable to invasive species; assesses the effects of management practices and natural disturbances on invasive species; evaluates how invasive plants alter the frequency and intensity of wild fires; and improves methods to restore public rangelands affected by invasion of terrestrial plants. The USGS is evaluating techniques to control populations of invasive plants (e.g., cheatgrass, Sahara mustard, buffelgrass, brome, tamarisk) and is addressing some of the most compelling research questions related to these and other non-native plant species that occur in the Western United States. In 2015, the USGS scientists published studies on the distribution of invasive and native riparian woody plants across Western United States in relation to climate, river flow, flood plain geometry, and patterns of introduction; and on short-term vegetation response following mechanical control of tamarisk on the Virgin River. The field component of a 5-year study on the efficacy and effect of biocontrol of tamarisk was also completed in 2015 and in 2016 these data will be analyzed. Also in 2015, the USGS will continue to study the spread of Siberian elm in the West and to better understand lag times associated with the invasion.

Science Collaboration – USGS scientists partner with State and Federal agencies, Tribes, agriculture, natural resource managers, and the private sector to help solve problems posed by invasive species. The USGS joins Federal efforts to combat invasive species by providing information on early detection and assessment of newly established invaders; monitoring invading populations; improving understanding of the ecology of invaders and factors in resistance of habitats to invasion; developing and testing prevention and management and control alternatives, stressing integrated control management approaches where appropriate; and assessing approaches for restoring disturbed habitats after control. The Interior bureaus work in partnership with other Federal agencies, State, local, and tribal governments, and private sources to conduct activities related to prevention, early detection and rapid response, control and management, restoration, and organizational collaboration.

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Activity: Ecosystems

Subactivity: Cooperative Research Units Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Ecosystems	\$157,041	\$160,232	\$701	\$13,005	\$173,938	\$13,706
<i>FTE</i>	930	950	0	40	990	40
Cooperative Research Units	\$17,371	\$17,371	\$113	\$750	\$18,234	\$863
<i>FTE</i>	143	143		4	147	4
<i>Enhanced Support and Scientists for Tomorrow</i>	[\$17,371]	[\$17,371]		[\$750]	[\$18,121]	[\$750]

Justification of Program Change

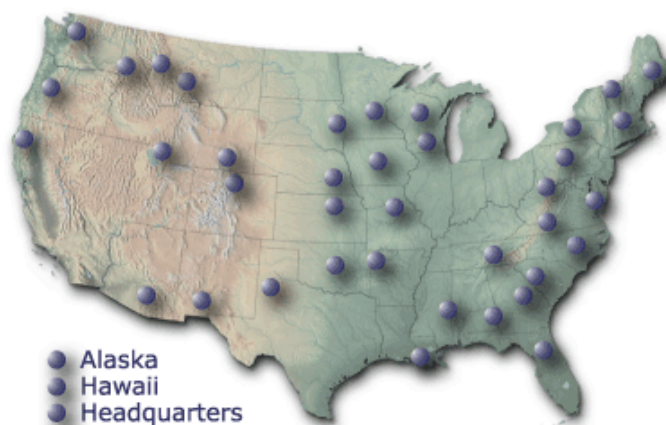
The 2017 Budget Request for the Cooperative Research Units is \$18,234,000 and 147 FTE, a net change of +\$863,000 and +4 FTE from the 2016 Enacted level.

Overview

The Cooperative Research Unit (CRU) program is a unique and cooperative relationship among the USGS, State fish and wildlife agencies, host universities, and the Wildlife Management Institute. The U.S. Fish and Wildlife Service (FWS) is a formal cooperator in most of the individual Units. Since 1935, this cooperative relationship has provided a strong connection between the USGS, State and Federal management agencies, and the national university community. Individual resources of each cooperator are leveraged to deliver program outcomes that far exceed what any one cooperator could achieve alone.

The goals of the CRU program are to sustain and maintain—

- A cost-effective, national network of Federal, State, and university partnerships pursuant to the Cooperative Research Units Act of 1960, with a legislated mission of research, education, and technical assistance focused on fish, wildlife, ecology, and natural resources.



Locations of the Cooperative Research Units

Ecosystems

- A customer-oriented network of expertise for actionable science, research, teaching, and technical assistance that is responsive to information needs of State and Federal resource agency decision-makers.
- Science capabilities responsive to resource management needs of Interior bureaus.
- A premier program for graduate education, mentoring, and training of future natural resources professionals having skills to serve the broad natural resources management community successfully.

The CRU program is comprised of 40 CRUs located at universities in 38 States, with a headquarters office in Reston, VA. The program is designed to leverage cooperative partnerships with Federal and State agencies to address mutual needs of all partners in a cost effective manner. The USGS stations Federal scientists at universities to help identify and respond to natural resource information needs through pooling of resources among agencies, participate in advanced scientific training and mentoring of university graduate students to represent the various agencies workforce of the future, and provide Federal and other natural resource managers' access to university expertise and facilities.

Federal support of the CRUs is multiplied by State and university cooperator contributions of expertise, equipment, facilities, and project funding, thereby enhancing the program's cost-effectiveness. Through university affiliations, CRU scientists train future natural resource professionals and provide opportunities through graduate education to diversify the Federal workforce.

Each CRU is directed by a Coordinating Committee comprised of Federal, State, university, and Wildlife Management Institute representatives. Each Coordinating Committee establishes goals and expectations for its unit within the program's mission of research, education, and technical assistance. The mix of priorities is established locally and is updated annually based on needs of cooperators and available funding. Program accountability measures, performance standards, and oversight of Federal scientists are used to ensure research and the resulting scientific information products support the goals of the USGS and Interior.

University and State agency contributions to the program remain strong, as does Federal, State, and local government reimbursable funding for research and technical assistance. Cooperator-focused satisfaction surveys continue to indicate a satisfaction rate of 95 percent or greater with CRU program execution. The program's appropriated dollars continue to be matched by State, university, Federal, and other entities' contributions at a ratio of three matching dollars to each appropriated dollar.

The CRU program is dependent on participation and contributions of all signatory parties. In 2015, the CRU invested over 90 percent of program funding in scientists salaries and six percent in administration, with all funding for research projects supplied by program partners. Of the 119 research scientist positions authorized for the program, 93 are currently funded and staffed. Improvements in program performance in the form of science guidance to State and Federal natural resource decision-makers, increased publications, students mentored and graduated, courses taught, and other product-oriented elements of scientific outreach are related to science staffing levels. Reinvesting in science capacity to fully-staff vacant Unit positions that, through attrition, now affect Units in 21 States will have a direct and

near immediate benefit in improving the number of students the program can support and the distribution of scientific expertise available to address contemporary resource management needs.

In 2017, the Cooperative Research Unit is requesting an increase of funding for Enhanced Support and Scientists for Tomorrow.

Program Performance

To meet future natural resource management challenges, the program continually invests in new approaches to help State and Federal cooperators implement science-based decision making more effectively. These approaches will further provide a framework for cooperators to work together across State and regional boundaries and address large-scale, trans-boundary issues. The CRU program is recognized by Interior as the primary source of technical expertise on structured decision making and adaptive management and is actively working with Interior bureaus to bring science to bear on regulatory and management decisions. Interior bureaus are faced with significant resource decisions and complexities in the face of unpredictable effects of climate change. Currently, expert knowledge and application of structured decision making and adaptive management is limited and does not meet management's need for this expertise.

To meet this need, the CRU continues its partnership with Oregon State University to develop and deliver an online, graduate level course in structured decision making and adaptive management. To date, 23 graduate students, competitively selected from across the Nation, have completed this course and have incorporated learned principles into their research projects. This online course has expanded the opportunity for CRU graduate students to learn



Duke Scholars

systematic and innovative approaches to science-based natural resources management. As these graduates populate the workforce of our State and Federal partners, an increased capacity will be realized across all agencies, which will foster collaboration and promote rapid adoption of the overall approach. Since many CRU graduates find employment within Interior, these efforts will ensure the Department is better positioned to achieve its strategic goal of enhancing science-based natural resources decision making, and supports the Interior's Strategic Plan goal of building a 21st century workforce.

To meet youth and diversity goals, the CRU is engaged in the Doris Duke Conservation Scholars Program (<http://programs.ifas.ufl.edu/ddcsp>), which is a new partnership between five CRU host universities (University of Florida, Cornell University, University of Arizona, University of Idaho, and North Carolina State University). The program provides undergraduate students from groups under-represented in the conservation workforce with hands-on experience. Students are mentored by CRU supported

graduate students and research scientists. Students attend leadership training programs, work with scientists and graduate students on selected research projects, and complete paid internships with local, State, Federal, and tribal agencies or Nongovernmental organizations (NGOs). During the summer of 2015, the second cohort of participating scholars was fully engaged in experiential learning activities provided through research of CRU scientists and directed in the field by the graduate student mentors. Students address contemporary research topics including the application of science and analytical tools for decision-making, energy development, fire ecology, ecosystem sustainability, threatened & endangered species, invasive species, and water quality and use. Other programs under development in partnership with the FWS will support graduate and undergraduate students conducting research on National Wildlife Refuges as a means to develop and recruit Federal scientists and natural resource managers. A pilot project with funding from FWS has been initiated in the Northeast.

2017 Program Change

CRU Enhanced Support and Scientists for Tomorrow (+\$750,000 for a total of \$18,121,000):

Youth Scientists for Tomorrow– The Cooperative Research Units (CRU) involvement in youth programs has traditionally been focused on graduate education. CRU will use the requested increase to provide undergraduate students, from groups under-represented in the conservation workforce, with mentoring and hands-on experience designed as a pathway to Interior recruitment. The CRU Program will use its existing cooperative network to work with Interior partners to improve and increase youth involvement in Interior science and resources management. In collaboration with the Doris Duke Foundation, undergraduate students at five CRU host universities will be mentored by CRU supported graduate students and research scientists. Students will attend leadership training programs, work with scientists and graduate students on selected research projects, and complete paid internships with local, State, Federal, and tribal agencies or Nongovernmental Organizations (NGOs). The increase will be used to support internships and staff time. Also, in collaboration with the FWS, funding will support graduate and undergraduate students conducting research on National Wildlife Refuges as a means to develop and recruit Federal scientists and natural resource managers. Students will address research topics of importance to the USGS and the National Wildlife Refuge System including landscape connectivity, fish and wildlife health, human uses, and wildlife population management. The proposed increase would enhance opportunities to provide advanced scientific training and professional mentorship leading to Masters and PhD. Funding will focus on the training of students on contemporary research topics including the application of science and analytical tools for decisionmaking, energy development, fire ecology, ecosystem sustainability, threatened and endangered species, invasive species, and water quality and use. Student support includes safety training and equipment in addition to financial and research support. Implementation will be through enhancement of existing partnerships with universities and NGOs serving Native American and Hispanic communities and other underrepresented groups.

Science, technology, engineering, and mathematics (STEM) - The CRU program engages in scientific research, technical assistance to natural resource managers, and training of future natural resource professionals. The CRU will apply a portion of the requested increase towards training, mentoring, and support of STEM graduate and post-doctoral associates from under-represented groups. Unit scientists are particularly poised to advise and mentor STEM graduate students, and the requested increase will expand capacity and provide focus on minority recruitment. Students will address thematic science of importance to the USGS and Interior bureaus including the application of science and analytical tools for decisionmaking, energy development, fire ecology, ecosystem sustainability, threatened and endangered species, invasive species, and water quality and use.

Plans to develop new ways of working across State and regional boundaries have been incorporated as a key goal of the decision support initiative. In fact, CRU cooperators fully support broad-scale research projects aimed at understanding mechanisms affecting species and habitats at unprecedented scales. For example, trans-boundary collaboration is currently being used to address concurrent overlapping issues, including climate change, the conservation challenge currently presenting the greatest uncertainty to natural resource managers. CRUs in Kansas, New Mexico, and Texas have been conducting large scale (spatial and temporal) ecological investigations on Lesser Prairie Chickens (LPC). The LPC is a species occupying several hundreds of thousands of acres of habitat across five States in the central plains of the

United States. The species' broad distribution across sparsely populated and remote areas presents many challenges to managers to understand population trends, environmental drivers of life history, and conservation alternatives. At the same time, the species has recently been listed by the FWS as a "threatened species" under the Endangered Species Act (ESA) (May 2014). Answering the many information needs has thus become critical if this iconic species is to persist on the landscape. CRU has responded to a demand for information on LPC populations to assist with conservation planning, assessment of species status, measuring responses to management strategies, and restoration techniques and has worked individually and collaboratively with others to provide authoritative findings on many aspects of LPC life history and ecology that are critical to management. An annotated biography of LPCs (compiled by CRU) was used by the *Western Governors Association of Fish and Game Agencies* during their preparation of the *Comprehensive Management Plan for Lesser Prairie-Chickens*.

CRUs in Wyoming, Utah, and Montana, in conjunction with multiple Western States, are coordinating an assessment of elk data across their geographic range to identify options for managing elk herds in ways not possible from a single-State perspective. This type of trans-boundary approach to wildlife research is an important precursor to the multitude of landscape-level wildlife-management research issues that will arise as climate changes. A similar trans-boundary, multi-agency approach to address the effects of climate change on moose is currently being explored. CRU's extensive work in climate change research directly supports and aligns with Interior and the USGS strategic science vision that in many cases will require a trans-boundary approach, an approach CRUs are uniquely positioned to facilitate.



Migration Assessment

Through 2015, CRU scientists used the approaches as described to support National and Interior interests in balanced energy development, climate change, and threatened fish and wildlife conservation. The continuing effort to strengthen science capacity in the CRU will ultimately lead to enhancement and expansion of graduate education and science training as mandated in the Cooperative Units Act, and thereby contribute to the science expertise and capacity needed to meet future natural resource challenges.

The CRU program has more than 800 active projects and many of these projects exemplify how CRU scientists are bringing decision support tools to Interior agencies for making important decisions on managing our Nation's natural resources. Consistent with the program initiatives highlighted above, many of the projects are using structured decision making or adaptive management to address landscape level issues associated with climate change and energy development. CRU scientists at 23 Units currently have 52 active research projects (48 are in support of Interior) to better understand and predict the potential effects of climate change on the future availability of habitat and resulting distribution of species in the future. Similarly, five Units have nine projects related to understanding the impact of energy projects on the distribution and life history of a variety of ecologically or economically important species.

These studies are not only critical for understanding the biological and environmental processes but also for informing decisions that integrate the underlying biology with societal needs and values.

Examples of CRU Ongoing Research Projects

Following are research projects that highlight how CRU scientists are helping our State and Federal partners make science-based management decisions are highlighted under thematic areas below:

Endangered Species Act

The CRU scientists work with Federal and State cooperators to provide answers to science questions that inform decision-making in implementing the Endangered Species Act (ESA). The role of the CRU is to provide the scientific underpinning, monitoring protocols and decision science so critical to the efforts designed to achieve prelisting conservation. Following are some specific examples of CRU work that relate to species across the United States. The Oregon Unit demography study of the northern spotted owl reports on the effects of habitat, climate, and barred owls. The northern spotted owl was listed as federally threatened by the FWS in 1990 principally because of declines in its old growth forest habitat throughout the Pacific Northwest. In 1994, the Northwest Forest Plan (NWFP) was developed and implemented to conserve late-successional forest resources on Federal lands to aid conservation of the spotted owl and other old-growth forest dependent species. At that time, a long-term effectiveness monitoring program was developed to monitor the status of the spotted owl and through regular evaluation of the monitoring data, determine whether the NWFP was aiding in the species' recovery. This research reports on the most recent effort to evaluate the status and trends in spotted owl demographic rates on 11 study areas across the species' range from 1985-2013. The Alabama Unit's work on Rio Grande cut-throat trout and arctic grayling led to not-warranted findings. The California Units' work on tidewater goby informed the decision to downlist from a federally endangered species to a threatened species. The Montana Fisheries Unit work on the endangered pallid sturgeon identified the mechanism responsible for the species decline in the Missouri River. The Virginia Unit's work on the endangered Roanoke logperch is contributing to a coordinated recovery strategy. The Washington Unit's work on Chinook salmon in the Salish Sea contributed to the listing as a threatened species.

Harvest & Population Management

The management of fish and wildlife populations for the benefit of current and future generations of all Americans is the foundation of this Nation's conservation heritage. The CRU program assists cooperator through a variety of actions, from the development and implementation of basic monitoring protocols to complex population modeling. These efforts serve to facilitate the conservation and restoration of rare and declining species, and to sustainably manage harvests of game and furbearer species. Following are examples of the different research projects currently being conducted related to harvest and population management across the United States. The Pennsylvania Unit is conducting work on fall harvest guidelines for wild turkey, and on population and harvest management of black bears and white-tailed deer. The Massachusetts Unit is conducting research to support the State's black bear management plan. The Idaho Unit is developing angler survey methods for chinook and steelhead and studying spawning ecology of kokanee. The Montana and Wyoming Units are collaborating with several Western States to better understand elk population and harvest dynamics at a geographic scale. The Missouri Unit is conducting a research project to

examine the effects of the Light Goose Conservation Order regulations on the distribution and behavior on non-target waterfowl. The South Dakota Unit is studying the value of using an Internet-based survey to replace the traditional angler mail surveys conducted by South Dakota Game, Fish and Parks. The Montana Unit is studying the movements of rainbow and brown trout, very popular sport fish, to better understand the spatial scale populations and harvest needs.

Landscape Ecology

Contemporary conservation challenges require inquiry and management at larger geographic scales. Landscape ecology is the field of science that explores spatial patterns and interrelationships of ecological processes and spatial patterns across ecosystems at various scales. Landscape ecology emphasizes the interactions of pattern, process, and temporal and spatial scale and their influence on ecological flows. The diversity of expertise and the university connection to multidisciplinary experts position CRUs to be leaders in landscape ecology. The Utah Unit is involved in a number of projects investigating landscape patterns of vegetation changes resulting from climate and other factors and their impacts on wildlife. The Wyoming Unit is investigating population dynamics and movements of ungulates at the geographic scale, and identifying factors driving migrations and inhibiting them. The Kansas, New Mexico, and Texas Units are studying lesser prairie chicken population and habitat ecology at landscape scales never achieved before. The Massachusetts Unit is investing moose and black bear population and habitat dynamics at the landscape scale, assessing key landscape components critical to the conservation of these wide-ranging large mammals in a human dominated landscape. The Georgia Unit is leading an effort on native prairie adaptive management: a multi-region adaptive approach to invasive plant management on FWS owned native prairies.

Species of Greatest Conservation Need

State Wildlife Action Plans identify Species of Greatest Conservation Need (SGCN) in their State, and identify information needs and management actions necessary to keep these species common. The CRU conducts research to assist States with their conservation goals. For example, the North Carolina Unit has been studying the effects of a variety of human activities on nesting American Oystercatchers at Cape Lookout and Cape Hatteras National Seashores on the Outer Banks of North Carolina since 1997. Using low cost, low power, digital audio and video recording devices, the researchers have been able to quantify animal behavior in ways that were not previously possible. The Nebraska Units is studying various aspects of reintroduced river otters in the State, including habitat use, movements, genetics, and impacts of non-native vegetation. The New York Unit has developed a decision tool to help the State identify SGCN. The Pennsylvania Unit is developing river otter spatial capture-recapture models to see how population estimates might change with better defined models. The Virginia Unit is using acoustic detectors to study bat habitat associations and distributions. The Washington Unit is identifying and diagnosing key factors that influence marine survival of Puget Sound Salmon and Steelhead, developing improved run forecasting predictions, and informing effective habitat and population restoration programs

Ecosystem Services

An ecosystem service is any positive benefit provided to society by fish, wildlife, or components of ecosystems through their functions. Public and private support for natural resource conservation can be fostered through increased awareness and understanding of the multitude of benefits healthy

ecosystems provide to society. Ecosystem Services can be documented through monetary or cultural values. Cultural ecosystem services are more difficult to quantify, but extremely important in understanding natural resource values to society. The Virginia Unit has developed a spatially explicit framework for mapping the capacities of ecosystems to provide freshwater recreational fishing, an important cultural service, including societal demand for freshwater recreational fishing based on license data and are demonstrating how maps of relative capacity and relative demand could be interfaced to estimate sustainability of a cultural ecosystem service.

2015 in Review – Achieving the Unit Mission

In 2015, Unit scientists and their cooperators advanced the mission of the CRU program through joint research, education, technical assistance, and science support. Unit scientists continued their productivity in 2015, with 811 active projects with Federal and State partners. Unit scientists and their students remained actively engaged in service to professional societies delivering 901 presentations. In addition, Unit scientists gave 43 invited seminars, indicating their research activities and findings are held in high regard by the scientific and management communities. The CRU's service to university cooperators continued to be strong, with 68 academic classes taught in 2015, and 27 additional workshops and short courses delivered to partners and cooperators.

Productivity Summary	2011	2012	2013	2014	2015
Peer Reviewed Publications	349	358	369	329	358
Invited Seminars	56	69	51	39	43
Workshops and Short Courses	25	33	25	34	27
Total Projects (State+Fed+other)	793	862	881	876	811
Papers Presented	684	840	684	808	901
Academic Courses Taught	75	74	73	75	68
Total Number of Students	550	555	563	564	534
Master's Degrees Awarded	61	60	59	72	60
Doctoral Degrees Awarded	23	23	12	19	19

Each year, over 500 students engage in graduate education and training in natural resources conservation through the CRU program. The number of advanced graduate degrees awarded to Unit students in 2015 was 79 (60 M.S. and 19 PhD). The vast majority of these students enroll at a college or university each year and enter the natural resources management workforce as employees of State and Federal agencies, non-governmental organizations, and universities.

Science Collaboration

The unique role of the CRU is in the nature of the partnership and its integration into management decision making. Each Unit is owned collectively by that State's cooperators made up of the Interior, the State natural resource agency, and the university. There is inherent trust in the integrity of the science and the mentoring of the next generation of professionals among all cooperators, since each has an active role. As such, the impact of the science is enormous because it is being driven by need and developed collaboratively. Most CRUs have decade-long relationships between the Unit scientists and their non-Federal and Federal partners, resulting in a foundation of legacy science that enables current and future inquiries. The long-term and geographically broad scales of science fostered through this long-standing institution allow scientists and managers to probe research questions that otherwise would not be feasible. The applied nature of the research as driven by the actionable needs of resource managers ensures the outcome of CRU work is science that matters.

Climate and Land Use Change

Activity: Climate and Land Use Change

Dollars in thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Climate and Land Use Change	\$135,975	\$139,975	\$304	\$31,165	\$171,444	\$31,469
FTE	388	388		29	417	29
Climate Variability	\$57,589	\$57,289	\$148	\$5,566	\$63,003	\$5,714
<i>FTE</i>	<i>190</i>	<i>190</i>		<i>14</i>	<i>204</i>	<i>14</i>
National Climate Change and Wildlife Science Center/DOI Climate Science Centers (CSCs)	\$26,735	\$26,435	\$32	\$4,441	\$30,908	\$4,473
<i>FTE</i>	<i>49</i>	<i>49</i>		<i>9</i>	<i>58</i>	<i>9</i>
Climate Research and Development Program	\$21,495	\$21,495	\$94	\$1,125	\$22,714	\$1,219
<i>FTE</i>	<i>110</i>	<i>110</i>		<i>5</i>	<i>115</i>	<i>5</i>
Carbon Sequestration	\$9,359	\$9,359	\$22	\$0	\$9,381	\$22
<i>FTE</i>	<i>31</i>	<i>31</i>		<i>0</i>	<i>31</i>	<i>0</i>
Land Use Change	\$78,386	\$82,686	\$156	\$25,599	\$108,441	\$25,755
<i>FTE</i>	<i>198</i>	<i>198</i>		<i>15</i>	<i>213</i>	<i>15</i>
Land Remote Sensing Program	\$67,894	\$72,194	\$113	\$24,199	\$96,506	\$24,312
<i>FTE</i>	<i>145</i>	<i>145</i>		<i>9</i>	<i>154</i>	<i>9</i>
Land Change Science	\$10,492	\$10,492	\$43	\$1,400	\$11,935	\$1,443
<i>FTE</i>	<i>53</i>	<i>53</i>		<i>6</i>	<i>59</i>	<i>6</i>

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Climate Variability	+ 5,566	+ 14	
National Climate Change and Wildlife Science Center/DOI Climate Science Centers	+ 4,441	+ 9	G-11
Critical Landscapes: Arctic	+ 500	+ 4	G-25
Support Climate Science Centers	+ 1,500	+ 3	G-18
Tribal Climate Science Partnerships	+ 1,411	0	G-20
WaterSMART: Drought	+ 1,030	+ 2	G-22
Climate Research and Development Program	+ 1,125	+ 5	G-27
WaterSMART: Drought	+ 1,125	+ 5	G-32
Land Use Change	+ 25,599	+ 15	
Land Remote Sensing Program	+ 24,199	+ 9	G-47
Big Earth Data: Data Cube	+ 600	0	G-60
Critical Landscapes: Arctic	+ 1,857	+ 4	G-61
Landsat 9	+ 15,400	0	G-54
Sentinel-2	+ 2,200	0	G-55
Landsat Science Products for Climate and Natural Resources Assessments	+ 2,992	+ 1	G-60
Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis	+ 500	+ 2	G-61
WaterSMART: Drought	+ 250	+ 1	G-61
WaterSMART: Remote Sensing	+ 400	+ 1	G-62

Climate and Land Use Change

Request Component	(\$000's)	FTE	Page
Land Change Science	+ 1,400	+ 6	G-65
WaterSMART: New Tools and Models to Better Manage Water Nationwide	+ 1,000	+ 4	G-69
WaterSMART: Remote Sensing	+ 400	+ 2	G-70
Total Program Change	+ 31,165	+ 29	

Justification of Program Change

The 2017 Budget Request for Climate and Land Use Change is \$171,444,000 and 417 FTE, a net change of +\$31,469,000 and + 29 FTE from the 2016 Enacted level.

Overview

The Climate and Land Use (CLU) Change Mission Area plays a crucial role in developing a scientific foundation that enables society to anticipate and adapt to global change. CLU Mission Area scientists are world leaders in understanding Earth climate history and how changes in climate influence land use and land cover, ecosystems, natural resources and human communities. The CLU Mission Area designs and conducts the scientific research, remote sensing, modeling and forecasting that directly supports natural resource managers and other policy makers who need a science basis for decision making. The data, information, tools and applications produced by the CLU Mission Area are widely used both within and outside of the USGS and the Federal government as a whole; they are also used at the State, local, tribal, and international levels.

The CLU Mission Area is comprised of two subactivities: Climate Variability and Land Use Change. The following programs fall under those subactivities:

Climate Variability

- National Climate Change and Wildlife Science Center/Department of the Interior Climate Science Centers (CSCs) (<https://nccwsc.usgs.gov/>)
- Climate Research and Development (http://www.usgs.gov/climate_landuse/clu_rd/)
- Carbon Sequestration (http://www.usgs.gov/climate_landuse/carbon_seq/)

Land Use Change

- Land Remote Sensing (<http://remotesensing.usgs.gov/>)
- Land Change Science (http://www.usgs.gov/climate_landuse/lcs/)

Each program within the CLU Mission Area is intertwined, working in sync with one another and complimenting the work of numerous Federal and university partners. Work conducted within the CLU programs is also a vital source of information for many other programs within the USGS; it provides the data, knowledge and expertise needed for the other mission areas to conduct their science.

The CLU Mission Area supports the following Interior 2014 – 2018 Strategic Plan goal to “Provide Science to Understand, Model, and Predict Ecosystem, Climate, and Land Use changes at Targeted and Landscape levels (biota, land cover, and Earth and ocean systems).” In particular, the CLU Mission Area supports the following two strategies: (1) “Identify and predict ecosystem and land use change,” and (2) “Assess and forecast climate change and its effects.” The goal of CLU programs is to be a primary provider of science needed for adaptation to and mitigation of the impacts of climate and land use change on Earth and human systems. Managers of U.S. land, water, wildlife and other natural and cultural resources use the results of USGS science to inform their planning and management decisions. Agencies within the Department of the Interior, which manage roughly one quarter of all U.S. lands and their associated natural resources, are primary partners with CLU Mission Area scientists in the co-production of science for natural resource management.

There have been various Federal government reports addressing the negative effects of a changing climate, citing infrastructure, energy supply, human safety and health, the economy and national security as areas of concern. Reports by the Department of Defense, the Department of Homeland Security, and the Executive Office of the President have addressed the impacts of a changing climate on national security. Activities within the CLU Mission Area help address these societal challenges and support National priorities. The CLU Mission Area programs contribute to government-wide activities including, the Climate Action Plan, the United States Global Change Research Program (USGCRP), and the National Fish, Wildlife and Plants Climate Adaptation Strategy, to name a few.

The Climate Action Plan highlights three goals for the USGS: addressing U.S. carbon emissions, preparing the Nation for the impacts of climate change, and leading international efforts to address global climate change. The information on the proceeding pages, which describe each program within the CLU Mission Area, will demonstrate how each CLU program provides science and data that advance progress on each of these goals.

The Climate Action Plan also encourages interagency coordination on climate change activities, which the CLU Mission Area does through the participation in working groups of the USGCRP and the Council on Environmental Quality that are addressing topics such as fresh-water resources management, climate change-adaptation decision support, and carbon sequestration. The CLU Mission Area manages eight regional Interior Climate Science Centers (CSCs) on behalf of the Department. Another aspect of the Climate Action Plan is the mandate for actionable climate science, also a primary goal of the USGCRP, and one that the CSCs are designed to meet through their climate vulnerability studies and database and through their “climate-adaptation strategies that promote resilience in fish and wildlife populations, forests and other plant communities, freshwater resources, and the ocean.” CSC researchers (e.g., Federal, State, and university scientists) work closely with resource managers to define issues, identify science gaps, and co-conduct the research so the outcomes are directly usable.

According to the U.S. Global Change Research Act of 1990, global change refers to large-scale changes in the environment that may alter the Earth’s capacity to sustain life and human endeavor. The effects of changes in the climate are most profound in the frequency and intensity of extreme weather events. The science programs within the CLU Mission Area are designed to help society anticipate and adapt to global change.

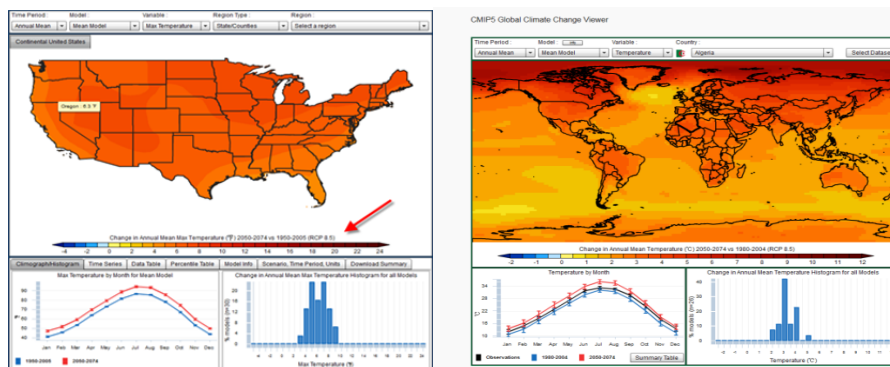
The 2017 President's Budget request includes funding to:

- Continue the Landsat 9 mission with the National Aeronautics and Space Administration (NASA).
- Acquire, store, and disseminate the information from the European Space Agency's (ESA) Sentinel-2 satellite.
- Initiate a Great Lakes Climate Science Center (CSC) that will focus on climate science and adaptation for the region to improve understanding of the potential for climate driven changes in invasive species in the Great Lakes and surrounding ecosystems and adaptive management of habitat restoration in the region under extreme weather and climate.
- Expand research activities in the Arctic, including developing a process to estimate total glacier loss in Alaska and potential changes in freshwater input and accelerating the development of predictive models, which support the evaluation of changes to the environment resulting from the conversion of permanently sequestered ice and snow to liquid and gaseous water.
- Requested increases also support WaterSMART activities including understanding threshold and tipping points caused by drought, identifying and quantifying water storage in smaller storage features, and developing automated methods and tools supporting near real-time, satellite-based, drought monitoring.

The *USGS Climate and Land Use Change Science Strategy: A Framework of Understanding and Responding to Global Change* (<http://pubs.usgs.gov/circ/1383a/>) outlines a number of high-level goals for CLU programs and is a vehicle for scientists and partners to get a general overview of our activities. The plan outlines seven broad themes for USGS climate change science for the coming decade:

- Rates, causes, and impacts of past global changes
- The global carbon cycle
- Biogeochemical cycles and their coupled interactions
- Land use and land cover change rates, causes and consequences
- Droughts, floods, and water availability under changing land use and climatic conditions
- Coastal response to sea level rise, climatic change and human development
- Biological responses to global change

The CLU Mission Area is developing data and tools that can be used by resource managers and city planners to support resilience planning for communities and ecosystems. One example is the National Climate Change Viewer, which allows users to visualize projections of temperature and precipitation out to the year 2100 (http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp). The CLU Mission Area also created and manages the Global Climate Change Viewer, (<http://regclim.coas.oregonstate.edu/gccv/index.html>), which provides the Department of State and the U.S. Agency for International Development (amongst many others) with valuable information they need to conduct their work.



The National Climate Change Viewer (figure to the left) allows users to visualize projected temperature and precipitation changes at State and county levels; the Global Climate Change Viewer (figure to the right) allows users to visualize projected temperature and precipitation changes at the country level.

Another example is the global ecosystems mapping (<http://rmgsc.cr.usgs.gov/ecosystems/index.shtml>), commissioned by the Group on Earth Observations. This project provides critical data needed for land and aquatic management, urban planning and ecosystems science vital for human survival.

The series of Landsat satellites is another vital tool and data stream provided by the CLU Mission Area. The Landsat satellite mission has provided data used by resource managers around the world since 1972, to make water resource decisions, track forest health, and manage agriculture. Landsat data are used to document how local land use practices contribute to global change and, conversely, how changes in climate affect land cover. For example, Landsat data were the first to quantify tropical deforestation, an insight that fundamentally changed Earth scientists' and public perception of the connection between land use and climate change. Landsat satellites have produced an archive of over 43 years of images depicting changes to the landscape. Landsat is the only operational civil satellite with both thermal and shorter-wavelength sensors. At the time of publication of budget justification, the Landsat series has two operational satellites in orbit: Landsat 7 (which launched in 1999) and Landsat 8 (which launched in 2013). Landsat 7 collects roughly 475 new series per day and Landsat 8 collects approximately 725 new series per day; combined the series allows for an eight day revisit for respective images.



This image depicts Landsat 7 and Landsat 8 orbiting the Earth.

The CLU Mission Area is in the process of developing Landsat-based science products that show surface temperature, fire disturbance, snow covered area, and green biomass. The datasets support both natural

resource managers and the climate monitoring community. A report by industry experts, *Users, Uses and the Value of Landsat Satellite Imagery*, (<http://pubs.usgs.gov/of/2013/1269/>) assessed the minimum annual value at roughly \$2 billion in economic return on public investment in the Landsat satellite system. Following extensive study, the Administration has established a plan for a long-term Sustainable Land Imaging program that would extend the four-decade long Landsat series of measurements of the Earth's land surfaces for another two decades. The USGS and the National Aeronautics and Space Administration (NASA) are currently working on Landsat 9 to replace Landsat 7, which is reaching the end of its usable life. Landsat 9 will largely replicate its predecessor Landsat 8.

The Landsat Program is a joint effort of the USGS and NASA. The scope of Landsat development and operations activities within the CLU Mission Area includes overall project management and system engineering for successor-mission Landsat ground segment development (i.e., Landsat 9) and on-orbit mission and flight operations (i.e., Landsat 7 and 8), including coordination with NASA who will build, launch and conduct the on the orbit check-out. Fundamental to the success of these interagency Landsat Program activities is collecting and documenting user requirements in terms of what needs to be observed; seeking technical and scientific input on issues critical to the success of the Landsat program through the Landsat Science Team; and managing the Landsat International Cooperator (IC) Network. Although CLU's Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD, is perhaps best known as the USGS receiving station for Landsat satellite images, data from many other satellites and other remote sensing platforms also are archived and distributed by EROS. Receiving, calibrating and validating, processing, archiving, and distributing these data are primary tasks performed at EROS. In addition, EROS is defining requirements and specifications for future instruments, developing and implementing ground systems for future Earth observing missions, and developing national and international partnerships.

2015 Key Accomplishments

Tsunami Vulnerability Assessments – CLU Mission Area researchers developed an analytical framework describing variations in community vulnerability to tsunami hazards. The framework integrates: geospatial approaches identifying the number and characteristics of people in hazard zones; models estimating evacuation travel times to safety; and cluster analyses classifying communities with similar vulnerability. The framework was used to analyze 49 incorporated cities, seven tribal reservations, and 17 counties from northern California to northern Washington that are directly threatened by tsunami waves associated with a Cascadia subduction zone earthquake. Results suggest three primary community groupings: (1) relatively low numbers of exposed populations with varied demographic sensitivities; (2) high numbers of exposed populations but sufficient time to evacuate before wave arrival; and (3) moderate numbers of exposed populations with insufficient time to evacuate. These results can be used to enhance general hazard-awareness efforts with targeted interventions, such as education and outreach tailored to local demographics, evacuation training, and/or constructing vertical evacuation refuges.

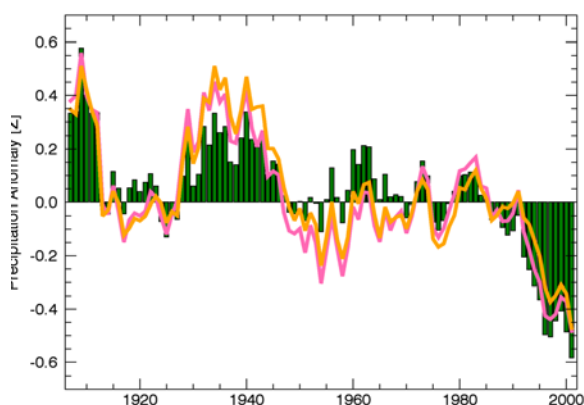
Effects of Severe Droughts on Forests in the Western United States – Forests provide humans with economically important and often irreplaceable ecosystem products and services, such as clean water, wood products, food and medicines, biodiversity, and recreational opportunities. Changes in climate,

land use, and disturbance regimes can alter the composition and distribution of forests. A better understanding of the processes that drive forest dynamics is needed for society to anticipate and mitigate these types of threats to forests. CLU Mission Area scientists collaborated with U.S. Forest Service and university scientists to synthesize data on the health of temperate forests and their response to recent severe droughts in the Western United States. Their findings suggest that increased drought severity, rising temperatures, and decreased snowpack are causing an increase in forest mortality. The types of forest transformations documented by this research provide evidence for potential impacts of future changes, and valuable information needed for the development of tools that will be used to evaluate the vulnerability of forests to a range of climate and environmental stressors.

Development of a Natural Gas Database – CLU Mission Area scientists, in collaboration with the Bureau of Land Management worked to build a combined natural gas geochemistry database that can be used to assess the occurrence and distribution of naturally occurring helium and carbon dioxide (CO₂) in natural gas reservoirs in the United States. Naturally occurring helium is used in various applications including industrial, research, military and national security applications; for many of these there is no substitute. Helium, a non-renewable resource, is produced from only a few geologic reservoirs globally all of which are being depleted. Therefore, a reliable supply of helium is crucial to the economic well-being and national security of the United States. Natural CO₂ is primarily used in enhanced oil recovery operations, and natural CO₂ is primarily used in enhanced oil recovery operations. Estimates of the remaining subsurface accumulations of natural CO₂, and their geographic distribution, will aid in determining how much anthropogenic CO₂ will need to be captured for ongoing and future enhanced oil recovery operations.

Web Portal to Track Effects of Stream Temperature and Flow – Changes in the climate are expected to alter stream temperature and flow regimes over the coming decades, and in turn influence distributions of aquatic species in those freshwater ecosystems. To better anticipate these changes, there is a need to compile both short- and long-term stream temperature data for managers to gain an understanding of baseline conditions, historic trends, and future projections. Unfortunately, many agencies lack sufficient resources to compile, conduct quality assurance and control, and make accessible stream temperature data collected through routine monitoring. Yet, pooled data from multiple sources, even if temporally and

spatially inconsistent, can have great value both in the realm of stream temperature and aquatic response. *The NorEaST Web portal* was developed to meet this need, serving as a coordinated, multiagency regional framework to map and store continuous stream temperature locations and data for New England, Mid Atlantic, and Great Lakes States.



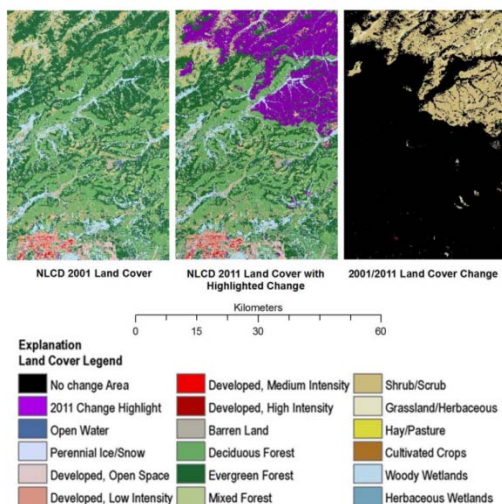
Comparison of Centennial Trends, March-June, Greater Horn of Africa depicting precipitation time series, Global Precipitation Climatology Center gridded data, and station observations. All three time-series show a concerning decline in precipitation.

Early Warning for Food Security – CLU Scientists developed data products and algorithms to carry out integrated, multitemporal, and multiscale research that serves as a basis for the Famine Early Warning System Network (FEWS

NET), which is collaborative project that relies on analyses of climate, remotely sensed land data, and related information to provide operational monitoring and early warning forecasts and assessments of threats to food security. In support of climate services in the Greater Horn of Africa, the USGS FEWS NET team developed a centennial trends rainfall dataset: a 1900-2014 set of monthly gridded 0.1 precipitation observations. This dataset is being used in conjunction with USGS climate analysis tools to help East Africans prepared themselves for future climate extremes. When combined with the two USGS-developed software tools (i.e., GeoMod and GeoClim), the Centennial Trends dataset allows East African scientists to map, plot, and model very long variations in precipitation and temperature. USGS FEWS NET scientists have performed training sessions on Centennial Trends, GeoClim, and GeoMod in Tanzania, Burundi, Rwanda, Uganda, Ethiopia, and Kenya. African scientists are now using these resources to identify climate change ‘hot spots’: places where warming and drying interact with high vulnerability, land cover and land use change, and population growth. These efforts, supported by the \$35.0 million USAID Policy, Adaptation, Research and Economic Development (PREPARED) climate adaptation project, are helping these food-insecure countries mainstream climate change adaption. By enhancing the technical capabilities of the national meteorological agencies, USGS science is helping these organizations provide valuable climate services. Assisted by more effective climate services, these countries will be better able to respond to climate extremes and climate change on seasonal and decadal time scales. FEWS NET partners include USAID, USGS, NASA, NOAA, USDA, and Chemonics International, which has been implementing field activities for FEWS NET since 2000.

Release of Provisional Climate Data Record and Essential Climate Variable Products – The USGS Land Remote Sensing Program has been supporting the development of Landsat science products, climate data records (CDRs) and essential climate variables (ECVs), derived from historical and current Landsat data acquired by the thematic mapper (TM), enhanced thematic mapper plus (ETM+), and operational land imager (OLI) instruments. The objectives are to provide continuity of observations and measurements to support modeling and decision support for land management, construct long term data records to establish historical trends and enable future projections of landscape state and condition, enable

scientific assessments of land surface change, and to remove the burden of processing from the end user. Specific to 2015, we have released a provisional Landsat 8 OLI surface reflectance CDR product, and provisional TM/ETM+ burned area and dynamic surface water extent ECV products.



Land cover change in the vicinity of Fairbanks, Alaska, from 2001 to 2011. The left panel shows the status of the land cover in 2001 (forests in green, shrublands in brown, wetlands in blue, and urban in red). The middle panel shows the updated land cover.

National Land Cover Database for Alaska – CLU Mission Area scientists, working in partnership with the interagency Multi-Resolution Land Characteristics (MRLC) Consortium, completed the production of the National Land Cover Database (NLCD, 2011) for Alaska. The NLCD serves as the definitive Landsat base, 30-meter pixel resolution, land cover database for the Nation. NLCD 2011 products derived from nominal 2011 Landsat data depict 19 classes of

land cover in Alaska and also define the degree of surface imperviousness in urban areas. Working in partnership over the past two years with the U.S. Forest Service, a tree canopy product was also completed for coastal Alaska. New for Alaska NLCD 2011 is the creation of a land cover change product quantifying 10 years of land cover change since 2001 (Figure below). This innovation integrates NLCD 2001 and 2011 to provide a 10-year land cover change story for the State. The dominant driver of change in the State over the last 10 years has been wildland fire. Overall, NLCD remains a significantly evolving and important database to a wide range of users, making it essential to thousands of applications. It is used to inform a variety of investigations, from monitoring forests to modeling water runoff in urban areas.

Geological Sequestration Project – Potential Carbon Dioxide Storage Assessment for Federal Lands – The geologic carbon sequestration project released a report on how much CO₂ could be stored beneath Federal lands based on the national assessment of geologic CO₂ storage resources. Following the geologic basin-scale assessment of technically accessible CO₂ storage resources in onshore areas and State waters of the United States mandated by the Energy Information and Security Act of 2007, the USGS estimated that an area of about 130 million acres (or about 200,000 square miles) of Federal lands overlies these storage resources. Consequently, about 18 percent of the assessed area associated with storage resources is federally managed. Assessed areas are under four other general land-ownership categories: State managed about 4.5 percent, tribal lands constitute about 2.4 percent, private and other lands constitute about 72 percent, and offshore areas constitute about 2.6 percent.

Strategic Actions for 2016

- The Land Remote Sensing (LRS) program will continue to develop ground systems for the Landsat Sustained Land Imaging Architecture to include Landsat 9 and Sentinel-2.
- The National Climate Change and Wildlife Science Center/Interior Climate Science Center (NCCWSC/CSC) Program will develop a science-based decision process for understanding and managing the impacts of drought on various parts of the Central and Western United States. The program proposes to bring a diverse group of stakeholders together to gain a science-based, integrative understanding of drought impacts to their resource management responsibilities, and of their potential adaptive management responses. Results from climate driven drought projection models will be incorporated into models of ecological flow and wildlife impact to understand which areas of the Country are more vulnerable to drought impacts.
- The Carbon Sequestration program will prepare the new Carbon Dioxide Enhanced Oil Recovery (CO₂-EOR) assessment methodology scientifically ready for review by experts from industry, academia, and government.
- The NCWSC/CSC Program will expand its delivery of ready-to-use science, expand support for Tribes planning for climate change, and link Federal science efforts regionally to achieve maximum results with minimum duplication.
- The Climate Research and Development (R&D) Program will continue work started in 2015 to better understand the connections between land use and land cover change (LULCC) and climate. To improve modeling of the climate and LULCC forcings and feedbacks, analyses of historic LULCC in the Southeastern United States will be integrated into climate model simulations. The

resulting models ultimately will be coupled with hydrologic and other models to improve capabilities of resource managers to forecast impacts of different land and water scenarios.

- The Carbon Sequestration Program will work toward implementing a carbon inventory and tracking system for carbon stocks and flows on all Interior lands, complete with online tools to support regional natural resource decision making.

Strategic Actions for 2017

- The LRS Program would continue working on the Landsat 9 mission with NASA to: (1) develop Mission Systems Engineering (MSE) support for Landsat 9 instrument; (2) conduct instrument calibration and validation engineering; and (3) support the evaluation of spacecraft competitive studies and spacecraft contract award. In addition, the USGS will conduct Landsat 9 ground system activities such as: (1) refining requirements and system design; and (2) the procurement of data processing, ground network, and mission operations center initial software and hardware capabilities.
- The LRS Program would acquire, store, and disseminate the information from the European Space Agency's (ESA) Sentinel-2 satellite. ESA successfully launched the Sentinel-2A satellite in June 2015, and expects to launch the Sentinel-2B satellite in 2016. Availability of the Sentinel-2 data may partially mitigate the risk of losing the eight-day revisit coverage during the period between the decommissioning of Landsat 7 and the launch and operations of Landsat 9.
- The LRS Program would support Big Earth Data; Data Cube, Critical Landscapes; The Arctic, and Resilient Coastal Landscapes and Communities; Imagery Datasets and Analytical Tools for Coastal Analysis; and ground systems development for the Landsat Sustained Land Imaging Architecture.
- The NCCWSC/CSC Program would initiate a Great Lakes Climate Science Center (CSC), in conjunction with university, State, tribal, and other partners in the region. The new CSC will focus on climate science and adaptation for the region to improve understanding of the potential for climate driven changes in invasive species in the Great Lakes and surrounding ecosystems and adaptive management of habitat restoration in the region under extreme weather and climate.
- The Carbon Sequestration Program would conduct a national assessment of technically recoverable hydrocarbons resulting from CO₂-EOR. Other work related to induced seismicity, economics of CO₂ storage, and study natural CO₂ reservoirs as analogues for anthropogenic CO₂ storage will continue.
- The Climate R&D Program would continue national-scale research documenting medium- and long-term patterns of water availability and expand efforts in the Western and Southeastern United States. The results, showing how past and current drought have affected these regions, will be used for model validation, verification, and improvement, and inform managers of potential impacts of future climate and land use change.

Activity: Climate and Land Use Change

Subactivity: Climate Variability

Program Element: National Climate Change and Wildlife Science Center/Department of Interior Climate Science Centers

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Climate and Land Use Change	\$135,975	\$139,975	\$304	\$31,165	\$171,444	\$31,469
<i>FTE</i>	<i>388</i>	<i>388</i>		<i>29</i>	<i>417</i>	<i>29</i>
Climate Variability	\$57,589	\$57,289	\$148	\$5,566	\$63,003	\$5,714
<i>FTE</i>	<i>190</i>	<i>190</i>		<i>14</i>	<i>204</i>	<i>14</i>
National Climate Change and Wildlife Science Center/DOI Climate Science Centers	\$26,735	\$26,435	\$32	\$4,441	\$30,908	\$4,473
<i>FTE</i>	<i>49</i>	<i>49</i>		<i>9</i>	<i>58</i>	<i>9</i>
Scientific Data and Tools for Resource Managers	\$6,636	\$6,636		\$0	\$6,636	\$0
Regional/National Science Synthesis	\$13,345	\$13,345		\$1,500	\$14,845	\$411
<i>Great Lakes Climate Science Centers</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,500]</i>	<i>[\$1,500]</i>	<i>[\$1,500]</i>
Next Generation Scientists/Managers	\$0	\$0		\$0	\$0	\$0
Tribal and Indigenous Partners	\$107	\$107		\$1,411	\$1,518	\$1,411
<i>Tribal Climate Science Partnerships</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,411]</i>	<i>[\$1,411]</i>	<i>[\$1,411]</i>
Climate Driven Hydrologic Extremes and Impacts	\$3,000	\$2,700		\$1,030	\$3,730	\$1,030
<i>WaterSMART: Drought</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,030]</i>	<i>[\$1,030]</i>	<i>[\$1,030]</i>
Arctic	\$3,647	\$3,647		\$500	\$4,147	\$500
<i>Critical Landscapes: Arctic</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$500]</i>	<i>[\$500]</i>	<i>[\$500]</i>

Justification of Program Change

The 2017 Budget Request for the National Climate Change and Wildlife Science Center/Department of Interior Climate Science Centers is \$30,908,000 and 58 FTE, a net change of +\$4,473,000 and +9 FTE from the 2016 Enacted level.

Overview

Managers of natural and cultural resources need to understand the impacts of a changing climate, which can exacerbate ongoing stresses such as habitat alteration and invasive species, in order to design effective response strategies. The National Climate Change and Wildlife Science Center (NCCWSC) was

Climate and Land Use Change

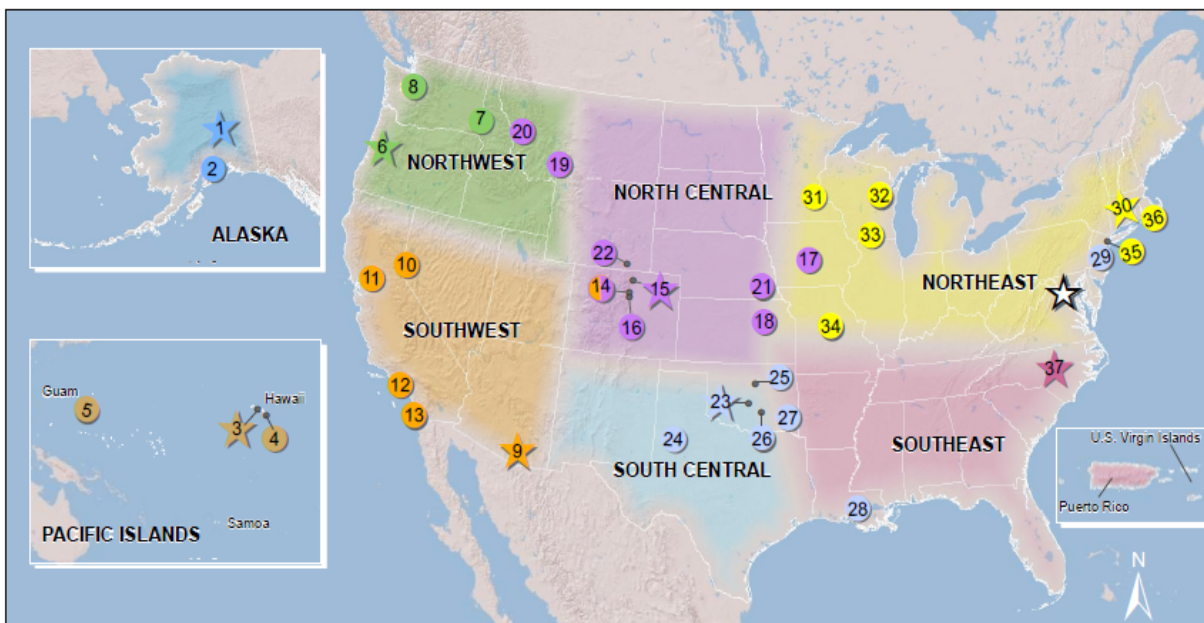
created by Congress, in 2008, to address environmental challenges resulting from climate and land-use change and to provide natural resource managers with rigorous scientific information and effective tools for decision making. This mission of NCCWSC is to provide natural resource managers with the tools and information they need to develop and execute management strategies that address the impacts of climate change on fish, wildlife and their habitats. The scientific work done within NCCWSC is responsive to the following guiding principles:

- Inspired by and responsive to the needs of the resource management community.
- Place priority on evaluation, translation, and synthesis of climate impact research findings.
- Promote rigorous, objective, and integrated research that advances fundamental understanding of climate impacts to natural resources.
- Ensure broad dissemination of results and foster professional scrutiny, critique, and learning.
- Encourage seeking out and promoting institutional efficiencies and leveraging opportunities in climate impact research.

In response to Interior Secretarial Order 3289, in 2010, NCCWSC established eight regional Climate Science Centers (CSCs) and serves as the managing entity for the CSCs, as well as conducting research on the effects of climate change on natural resources at a national level. Roughly, 75 percent of the NCCWSC annual budget is spent on work conducted by the eight regional CSCs. The CSCs focus on the impacts of climate change on key natural and cultural resources in their respective regions. Each CSC has a Federal director and a host university, but work with other universities in their region. The following table shows the Department's CSCs.

DOI CSC (date established)	Host Institution
Alaska (2010)	University of Alaska
Northwest (2010)	Multi-institution consortium headed by Oregon State University
Southeast (2010)	North Carolina State University
Southwest (2011)	Multi-institution consortium headed by University of Arizona
North Central (2011)	Multi-institution consortium headed by Colorado State University
South Central (2012)	Multi-institution consortium headed by University of Oklahoma
Northeast (2012)	Multi-institution consortium headed by University of Massachusetts, Amherst
Pacific Islands (2012)	Multi-institution consortium headed by University of Hawaii, Manoa
<i>Great Lakes (2017)*</i>	<i>To Be Determined</i>

** The 2017 Budget request includes a \$1.5 million increase that would be used to establish a Great Lakes CSC. The current Northeast CSC region encompasses such a diverse array of resource management concerns that a Great Lakes CSC would help to focus science on the Great Lakes region's pressing issues.*



Base from ESRI, 2009, Albers Equal Area Conic Projection, North American Datum of 1983

- | | | | |
|---|---|--|--|
| <ul style="list-style-type: none"> ★ National Climate Change and Wildlife Science Center ★ CSC Lead Institutions ② CSC Institutions Alaska CSC <ul style="list-style-type: none"> 1. University of Alaska - Fairbanks 2. University of Alaska - Anchorage Pacific Islands CSC <ul style="list-style-type: none"> 3. University of Hawaii at Manoa 4. University of Hawaii at Hilo 5. University of Guam | <p>Northwest CSC</p> <ul style="list-style-type: none"> 6. Oregon State University 7. University of Idaho 8. University of Washington <p>Southwest CSC</p> <ul style="list-style-type: none"> 9. University of Arizona 10. Desert Research Institute (Nevada) 11. University of California - Davis 12. University of California - Los Angeles 13. Scripps Institute of Oceanography 14. University of Colorado | <p>EXPLANATION</p> <p>North Central CSC</p> <ul style="list-style-type: none"> 14. University of Colorado 15. Colorado State University 16. Colorado School of Mines 17. Iowa State University 18. Kansas State University 19. Montana State University 20. University of Montana 21. University of Nebraska - Lincoln 22. University of Wyoming <p>South Central CSC</p> <ul style="list-style-type: none"> 23. University of Oklahoma 24. Texas Tech University 25. Oklahoma State University 26. Chickasaw Nation 27. Choctaw Nation of Oklahoma 28. Louisiana State University 29. NOAA Geophysical Fluid Dynamics Laboratory | <p>Northeast CSC</p> <ul style="list-style-type: none"> 30. University of Massachusetts Amherst 31. University of Minnesota 32. College of Menominee Nation 33. University of Wisconsin - Madison 34. University of Missouri Columbia 35. Columbia University 36. Marine Biological Laboratory <p>Southeast CSC</p> <ul style="list-style-type: none"> 37. North Carolina State University |
|---|---|--|--|

The map above shows the locations of the regional USGS National Climate Change and Wildlife Science Centers, the eight Interior Climate Science Centers, and their respective university partners.

The NCCWSC/CSC Program is closely linked to other USGS and larger Federal science capabilities and consists of cooperative Federal-university research centers to provide the varied science expertise needed to address key resource management problems. Strategic science planning at the CSCs begins with input from natural and cultural resource management partners in the region. Each CSC has a Stakeholder Advisory Committee (SAC) with representatives from the Department of the Interior Landscape Conservation Cooperatives (LCCs), other State and Federal agencies, and Tribes, as well as other science providers in the region. All CSCs have five-year strategic plans that outline regional science priorities. These plans, along with ongoing stakeholder input, are used to guide annual science planning and funding decisions. The NCCWSC has created a national strategic science plan to provide a framework for the climate change-impact research conducted or coordinated by the NCCWSC. This plan also establishes a context for regional and national synthesis of science products and information across the CSC network. The NCCWSC Federal Advisory Committee, the Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS), provided input to this national science plan, including developing recommendations on ways to increase the “actionable science” produced by CSCs, guidelines for

interacting with tribal nations, and methods for evaluating the performance and effectiveness of the NCCWSC/CSC program.

The NCCWSC and CSCs provide a new approach to the way science is planned, conducted, and delivered. The NCCWSC and CSCs, under advisement from the Federal Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS), continues to coordinate with natural resources managers and decision makers to provide the critical information that is needed to inform management actions. The following sections contain more information on the valuable work the program does including (but not limited to) working with tribal communities to bring climate science to adaptation efforts, determining the effects of drought on fish and wildlife species, and the effects of glacier loss (including the release of carbon from melting glaciers).

In 2017, the NCCWSC/CSC Program is requesting an increase of \$4,441,000 for activities to contribute to WaterSMART drought work, implementing a CSC in the Great Lakes, and improving tribal science partnerships with the Bureau of Indian Affairs, Native American Tribes, Alaska Natives, and indigenous peoples.

Program Performance

The NCCWSC/CSC Program comprises five program components: Scientific Data and Tools for Resource Managers, Regional/National Science Synthesis, Tribal and Indigenous Partners, Climate Driven Hydrologic Extremes and Impacts, and Arctic.

Scientific Data and Tools for Resource Managers

(2015 Actual, \$6.6 million; 2016 Enacted, \$6.6 million; 2017 Request, \$6.6 million)

Scientific Data and Tools for Resources Managers program component focuses primarily on developing tools that can be used by natural resource managers, decision makers, and researchers in multiple agencies and organizations to integrate climate change science into management of fish, wildlife, and ecosystems. Climate change information is produced by many entities, and it is often challenging for resource managers and planners to locate and analyze the data in a timely and cost efficient manner. Many agencies lack sufficient resources to compile, conduct quality assurance and control, and

NCCWSC/CSC Science Fact:

Researchers at the Northeast Climate Science Center are working with resource managers, maple syrup producers (including Native Americans), and other scientists to develop a better understanding of how the quality of maple syrup may change in the future. Maple syrup producers have noticed change in the tapping season, and climate models predict shorter seasons in the United States. Sugar maple tree health has also declined in recent decades and climate likely plays a role, as climate stress has the potential to affect sap quality. Demand for the delicious syrup is rapidly increasing, but because the tapping season is dependent on weather conditions, there is concern about the sustainability of maple sugaring as climate changes throughout the region.



Jars of Maple Syrup.
Photo Credit J. Rapp

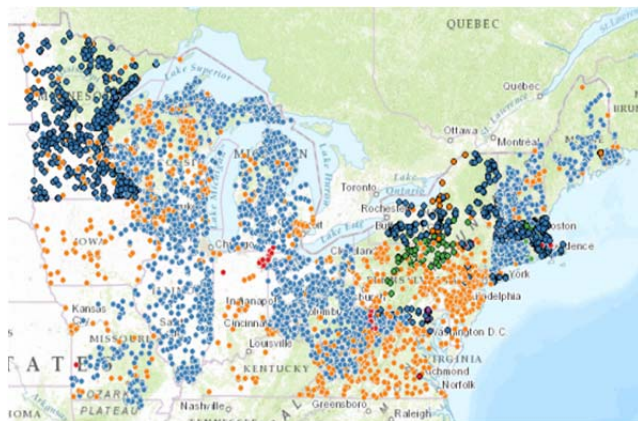
make accessible the plethora of climate-related data that is kept by data producers amongst different agencies, universities, and non-governmental organizations. Through various activities, NCCWSC and the CSCs develop tools that offer a single entry point to assess the climate change science information produced by different sources, leverage resources (funding and time) with partners to collaborate on collating and analyzing the data and, as the need arises, produce decision-support tools that can be directly used by the resource manager to adapt to climate change.

In 2015, the NCCWSC, together with a number of Federal and non-Federal partners, released a new online registry for vulnerability assessments. The Climate Registry for the Assessment of Vulnerability (CRAVe) is a new Web-based community resource that houses information on assessments of the vulnerability of various natural and cultural resources to a changing climate. CRAVe allows users to enter information about their vulnerability assessments and includes a public search of existing assessments for specific geographic regions, assessment targets or endpoints, managing entities, and other factors. Vulnerability assessments (VAs) can provide insights on resources that are most likely to be affected by climate change. Consequently, vulnerability assessments are an important tool for informing climate change adaptation planning. Although there are a large number of vulnerability studies that are currently being conducted across governments, there is no available method to identify VAs conducted in specific regions or on specific resources. Thus, it is highly likely that new assessments are being launched without knowledge of relevant ongoing or completed assessments. Further, data and knowledge gathered by completed assessments are likely not being used by managers outside the entity conducting the assessment. By addressing this lack of coordination, the NCCWSC and its partners are reducing costs and increasing the value of existing assessment investments.

The security, vulnerability, and resilience of the physical, ecological, and human components of coastal systems are intimately linked. Enhancing resilience and reducing vulnerability requires data, knowledge, and tools to assess coastal vulnerability. One such project that helps managers reduce vulnerability was the Sea Level Rise Handbook for Non-Scientists, developed by the Southeast Climate Science Center. This new USGS handbook gives coastal managers and planners access to a comprehensive description of

the various models used to study and predict sea level rise and its potential impacts on coasts. Designed for the benefit of land managers, coastal planners, and policy makers in the United States and around the world, the handbook explains many of the contributing factors that account for sea level change. It also highlights the different data, techniques, and models used by scientists and engineers to document historical trends of sea level and to forecast future rates and the impact to coastal systems and communities.

Additionally, The Northeast Climate Science Center developed a Northeast stream temperature inventory and decision support tool (NorEaST). The NorEaST Web portal serves as



This map from the NorEaST Web portal depicts the current stream temperature data sites collected by universities, as well as Federal, State, and local agencies. Stream temperature monitoring locations and metadata can be viewed for more than 10,000 locations and metadata can be viewed across 30 States, contributed by 40 different organizations.

a coordinated, multi-agency regional framework to map and store continuous stream temperature locations and data for New England, Mid Atlantic, and Great Lakes States. With this portal, Federal, State, and local agencies can leverage monitoring efforts, share data across agencies, help improve data quality, prevent data loss, and provide opportunities for regional analyses such as determining the effect of water temperature changes on fish populations, and be able to make better-informed management decisions for aquatic species.

In 2016, the NCCWSC plans to work with an existing interagency/State coordination group and Tribes to continue development of a public cross-agency database and field guide to vulnerability assessments. This project would support Interior and other agencies in establishing standards and best practices, tracking progress for such assessments, and strategically prioritizing adaptive management actions.

Further, the NCCWSC and CSCs are working closely with the Coastal and Marine Geology Program (CMGP), to bring structured decision-making approaches that integrate the latest sea level rise projections to refuge and other land managers in the Southeastern United States, the Hawaiian Islands, and the west coast. Specifically, the program would identify management endpoints for land managers in coastal zones and develop approaches that link climate outputs with models to inform the decision-making process. The land managers would then use this information in decision making in areas such as restoration of habitat or protection or conservation of species.

In 2017, the NCCWSC would continue building the CRAVe database as it collaborates with existing and new partners to incorporate vulnerability assessments into the database. The CSCs would also explore the use of more efficient methods for data collection; Unmanned Aerial Systems (UAS) are a new and relatively untapped resource for coastal surveying within the USGS and the scientific community, and offer a number of advantages over ground-based surveys and manned aerial systems, including the ability to rapidly deploy and efficiently collect remote sensing data and derive high-resolution elevations over variable terrain. The project is designed to provide a low-risk, low-cost means to explore the utility of UAS for coastal mapping on beaches and marshes, and develop the methodology and capacity to acquire, process, and analyze data.

Regional/National Science Synthesis

(2015 Actual, \$13.3million; 2016 Enacted, \$13.3 million; 2017 Request, \$14.8 million)

Interagency coordination and turning scientific knowledge into practical application ready products (often referred to as “translational science”) is at the core of the work done within Regional/National Science Synthesis.

Assuring that Federal, State, and other scientific activities are efficiently and effectively devoted to high-priority needs requires an increased level of coordination. The need for links between Federal and other science activities in each region is acute given recent investments by Interior (CSCs and Landscape Conservation Cooperatives), the ongoing National Oceanic and Atmospheric Administration (Regional Integrated Sciences Assessments), and the U.S. Department of Agriculture (Climate Hubs) to avoid duplication of effort. Projects that fall into this category involve the CSCs working with regional partners to identify common priorities and develop multiagency strategies that ensure coordinated implementation

of public science investments to target the most critical management needs. Cross-agency dialogues convened by the CSCs represent a critical component of an effective and efficient Federal response to the climate science needs of managers. Investment in better coordination allows the USGS to leverage the capacity and expertise of existing institutions, eliminate redundancy, make maximum use of existing data, and better support the needs of decision makers.

“Translational science” is about ensuring that scientific knowledge about climate change is translated into practical application-ready products for the end user, in this case natural resource managers and other decision-makers in the fish and wildlife community. ACCCNRS recommended that the NCCWSC and CSCs make further investments into developing actionable science approaches. The ongoing collaboration between research scientists and land managers is essential to the successful production of actionable science and to assure science is used in decisions.

In 2015, a collaborative effort between the Wildlife Conservation Society, North Atlantic Landscape Conservation Cooperative, Northeast Climate Science Center (U.S. Geological Survey), and the University of Maryland Center for Environmental Science, and the Massachusetts Division of Fisheries and Wildlife involved a scenario planning exercise focused on climate change, land use, and moose in the Northeast United States. Phase 1 of the scenario planning process involved the identification of key features and drivers within the Northeast region, as well as the associated uncertainties. The synthesis was part of a larger project aimed at providing (1) information on climate change impacts and adaptation options that can be incorporated into State Wildlife Action Plans and/or other relevant management plans affecting boreal species and habitats in the Northeast; and (2) proof of concept and a learning opportunity on how scenario planning can be used to bring existing research and analyses to bear on timely management decision making and planning by State agencies. Another collaborative effort among the USGS, the University of Wyoming, Utah Division of Wildlife Resources, Colorado Parks and Wildlife, and Wyoming Game and Fish Department, involved the examination of the effects of climate and growing-season of the vegetation moose eat and the subsequent effects on supplying the next generation of (8–9 months old) of young. Climate plays a fundamental role in limiting the range of a species, and is thought to be involved in declines of moose populations in recent decades. Moose are important to both subsistence and sport hunting economies.

In addition, the Northeast Climate Science Center (NE CSC) released a report synthesizing the latest information on the vulnerability of species and ecosystems to climate change in a 22-State region in the Northeast and Midwest United States. The report, *Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans*, is a tool to assist in the revision of 10-year State Wildlife Action Plans, due in October 2015. State coordinators have been challenged to incorporate climate change impacts and species responses into their current revisions. The document includes maps, charts and synthesis tables; and provides summaries of climate change assessments and projections for more than 30 climate factors such as air temperature, precipitation, soil moisture and sea level rise. The report also has a regional overview of existing vulnerability assessments, plus information on species and habitats at greatest risk to climate impacts. The report output offers short- and long-term adaptation strategies and actions available to natural resource agencies for conserving wildlife and ecosystems.

In 2016, the NCCWSC and CSCs plan to work with multiple Western universities, and other Interior bureaus to begin work on forecasting the effect of climate change on the distribution and abundance of big sagebrush in order to inform conservation planning, and sage grouse management in particular, across the Intermountain West. The future of sage grouse depends on the future of sagebrush, and currently, there is limited ability to anticipate the impacts of climate change on sagebrush populations. The focus of the work will be the synthesis of models based on spatial, temporal, and mechanistic relationships between climate and sagebrush cover. The project will bring together land managers and researchers to draft management recommendations. Given limited funding, the USGS will take advantage of mechanisms already in place to efficiently disseminate this report to management agencies. NCCWSC and the CSCs will also continue to coordinate with the LCCs and State fish and wildlife agencies to the extent practicable in order to ensure the research that is done is relevant and useful.

In 2017, NCCWSC would implement a new CSC, the Great Lakes Climate Science Center. The new CSC would provide staff and dedicated partnering efforts toward Great Lakes climate change issues. Currently, Great Lakes Climate Science issues are covered by the Northeast CSC and, given the complexity of the Northeast region, fully supporting all the needs is difficult. Creation of a Great Lakes CSC would allow focus on areas of concern within the Great Lakes and the surrounding area.

2017 Program Change

Great Lakes Climate Science Center (+\$1,500,000) for a total of \$1,500,000: With the increase, the USGS would begin to implement a Great Lakes CSC. With university, State, tribal, and other partners the USGS would focus on climate science and adaptation in the Great Lakes Region. Currently the Great Lakes region is covered by the Northeast CSC, but the distinctive bio-geography of the Great Lakes region and the different nature of scientific questions and management requires a separate CSC to focus on the many climate-related natural resource challenges in the region. The CSC's projects would focus on developing a better understanding of the potential impact of climate on cold-water species (salmon, trout and lake whitefish), potential for climate driven changes in invasive species in the Great Lakes and surrounding ecosystems and response of ungulates to climate change and adaptive management of habitat restoration in the region under extreme weather and climate. The science conducted at this center would inform management decisions (such as harvest and stocking practices) about cold-water fisheries (salmon, trout and lake whitefish).

Tribal and Indigenous Partners

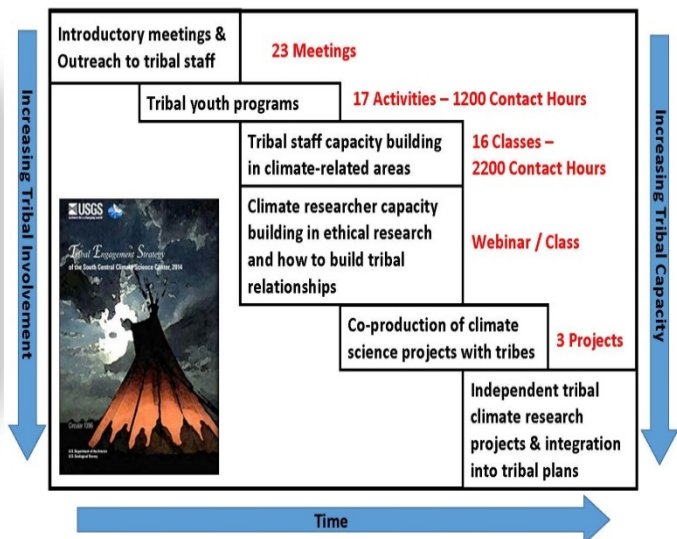
(2015 Actual, \$0.1 million; 2016 Enacted, \$0.1 million; 2017 Request, \$1.5 million)

Native American communities are increasingly engaging with the USGS and other partners to develop climate adaptation programs, and their needs for scientific and planning information are likewise increasing. Tribes have a presence in the advisory committees of most of the CSCs as well as the national Advisory Committee on Climate Change and Natural Resources Science. In early 2014, the ACCCNRS recommended that the USGS convene tribal and indigenous partners from across the CSC network to identify common and high-priority tribal needs, and are highlighted in a 2015 ACCCNRS report. This recommendation complemented the work at each of the CSCs, where scientists work with Tribes to identify high-priority tribal resource management concerns and build a science portfolio that provides information directly responsive to these needs. The CSCs have provided climate change adaptation support in numerous ways, from providing training for Tribes, to supporting research internships at tribal colleges, and assisting tribal advisory councils.

In 2015, the CSCs participated in the National Adaptation Forum Traditional Ecological Knowledge session. The South Central CSC hosted 16 climate-related interactive training classes to build tribal climate science capacity. Training topics included Climate 101, Vulnerability Assessments, Environmental Problem Solving, Adaption Planning and Grant Writing. The Northwest CSC helped the Tribal Leadership Forum assess their policy and technical capacity, and the needs of the 15 Columbia River Basin Tribes and three inter-tribal organizations to address climate change. The North Central CSC partnered with BIA to bring the National Conservation Training Center’s Climate Smart Training to Tribes, as well as collaborating with the Inter-Tribal Buffalo Council (ITBC) to support efforts on the USDA-funded Conservation Innovation Grant on Drought Resilience and Adaptation. The Northeast CSC partnered with the College of Menominee Nation to host the *Shifting Seasons Summit*, where 153 members from 13 Tribes and many Federal organizations, including four CSCs, convened to identify the tribal needs and Federal resources available to Tribes to aid in climate change adaptation.



One of the 16 interactive climate-related training classes organized by the South Central CSC as one of the steps of the Tribal Engagement Strategy (see image to the right for summary).



Summary of the SC CSC Tribal Engagement Strategy.

Climate and Land Use Change

In 2016, the NCCWSC and CSCs plan to work with the BIA closely to bring tribal climate liaisons into the CSCs. The implementation of the BIA program to locate tribal climate science liaisons in five CSCs will provide additional capacity to both identify needs and communicate results to tribal users. The CSCs will build on existing training and educational efforts within the network to work with Tribes in the development of climate adaptation strategies. In addition, we will develop a “Working in Indian Country” guidebook to be utilized by researchers so they better understand sovereignty, traditional knowledges, and how to respectfully work in Indian Country

In 2017, the NCCWSC and CSCs would expand support for Tribes planning for climate change and efforts to increase Science, Technology, Engineering and Mathematics (STEM) education opportunities.

2017 Program Change

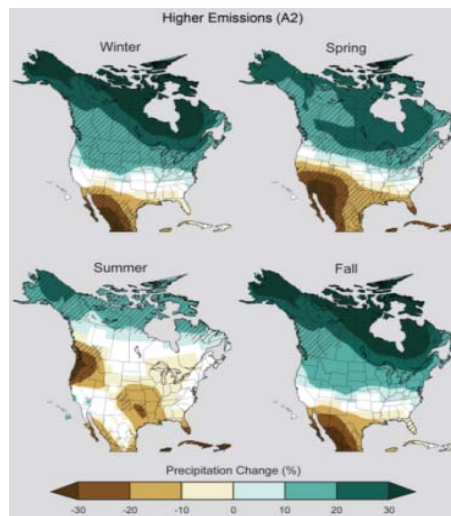
Tribal Climate Science Partnerships (+\$1,411,000) for a total of \$1,518,000: Traditional ecological knowledge (TEK) is the primary tribal and indigenous way of understanding relationships among species, ecosystems, and ecological processes. TEK can play a vital role in climate resilience and adaptation efforts. The NCCWSC and the CSCs would help identify and implement best practices for integrating TEK with more traditional science in management decisions. These efforts would be guided and supported by participation of tribal interests on CSC stakeholder committees and on ACCCNRS as well as be coordinated with the Bureau of Indian Affairs (BIA) climate programs, tribal governments, and other Federal climate efforts in Indian Country. The CSCs would continue to work with the BIA, Native American Tribes, Alaska Natives, and indigenous peoples to expand their capacity to adapt to climate change, as well as have research projects focused on addressing the needs of Tribes to better understand the potential climate change effects on culturally-important fish and wildlife resources. The increased funding would be used for the following types of activities: (1) New research, co-produced with Tribes, with a focus on key climate concerns to the Tribes and their cultural heritage; one such example is to identify those “First Foods” and similar culturally valued interests (plants, animals) whose existence or access is threatened by climate change; and (2) Building tribal capacity with multiple age groups to manage climate change effects on natural resources; funds would be used to expand climate change science training for tribal natural resource managers, and to increase Native youth climate change internships.

Climate Driven Hydrologic Extremes and Impacts

(2015 Actual, \$3.0 million; 2016 Enacted, \$2.7 million; 2017 Request, \$3.7 million)

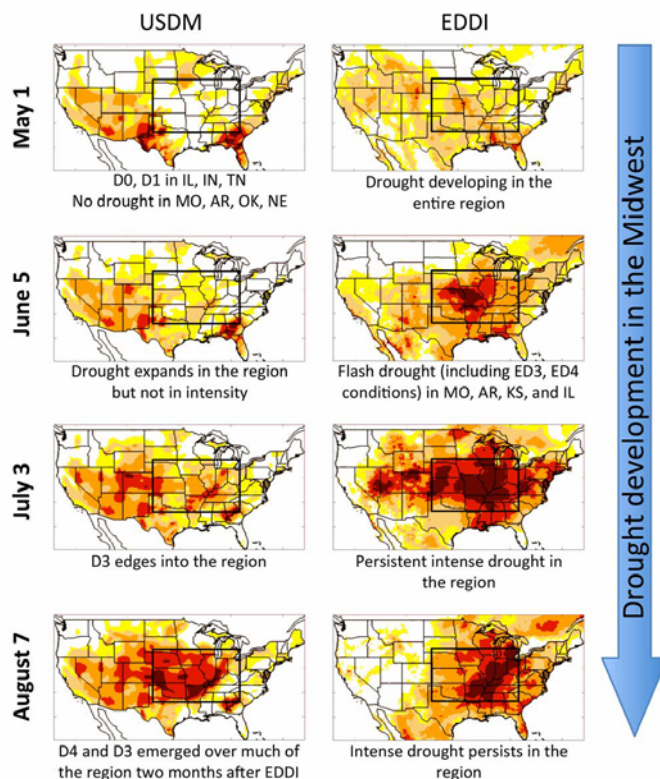
Drought has the potential to affect a number of natural resources, including changing primary productivity, increasing frequency and severity of fire and insect outbreaks, altering rates of carbon, nutrient, and water cycling, and causing local species extirpations. Ecological drought is a particularly important line of new research because very little information exists on the magnitude or persistence of potential impacts of drought on ecosystems and the species within. The frequency of ecological droughts is anticipated to increase in the future as temperatures rise and precipitation variability increases. Regions of the United States that currently benefit from ample water availability have been shown to be particularly sensitive to drought impacts, as indicated by the results of the 1960s drought in the Northeast region of the United States. The general purpose of this national initiative is to provide baseline

information on the ecological impacts of multi-year drought events on fish and wildlife species at landscape scales for the purpose of informing natural resource management and adaptation planning. In collaboration with regional stakeholder networks and multidisciplinary science groups, including other USGS mission areas, projects were initiated that will ultimately develop a science-based, shared understanding of future changes in water supply and consumptive water use not only under current drought conditions but also future scenarios for regional drought impacts across the midcontinent. On the opposite side of hydrologic extremes are prolonged high rainfall and inundation events that also have impacts on fish and wildlife resources. Due to the changing hydrologic patterns that are occurring due to climate change, there is much that is currently unknown about how this unpredictability of hydrologic extremes can affect ecosystems, and thus makes managing water and natural resources particularly challenging. This component seeks to reduce the uncertainties in understanding impacts to fish and wildlife so that resource managers can make better risk-informed decisions.



Projected Precipitation Change by 2100.

In 2015, the NCCWSC assembled a team of drought researchers, land managers, aquatic and terrestrial ecologists, hydrologists, economists, and agriculturists to author a national synthesis on ecological drought. This Ecological Drought Working Group is one of several new groups launching this year in the Science for Nature and People (SNAP; www.snap.is) program, a scientific collaboration among The Nature Conservancy, the Wildlife Conservation Society, and the National Center for Ecological Analysis and Synthesis to “deliver rapid results that will make a real-world difference” toward providing long-term solutions for natural resource challenges. The following new research in ecological drought was also initiated: Assessing Vulnerability to Drought in Dryland Ecosystems of the Western United States; River’s end: drought-related influences on stream drying in the Western United States; An Integrated



Development of a flash drought in the Midwest in 2012. The two-week EDDI (right) is compared at five-week intervals to the U.S. Drought Monitor (USDM) (left). EDDI captures the severe drought condition two months ahead of the USDM.

Image: Mike Hobbins

Assessment of Drought Impacts on Migratory Waterbirds in Key Conservation Regions of the Western US; and Forest management strategies to promote drought resistance and resilience.

In 2016, the NCCWSC Program plans to link Federal science-efforts regionally to address the scientific and management issues associated with impacts of extreme and extended drought across multiple CSC regions in the midcontinent. The Ecological Drought Working Group will continue to work on the synthesis framework. The synthesis framework developed as a result of this effort will initially focus in regions that are of key concern with regards to drought, including the Rio Grande Valley, California and Southwestern United States. A team specializing in science synthesis, integration, and communication will assist with the development of ecological drought synthesis products to ensure they capture key information in a visual format and are effective for decision making. The NW CSC is initiating research related to developing innovative tools or adaptations intended to lessen the ecological impacts of drought (or ecological drought) as they relate to climate change.

In 2017, the NCCWSC would expand the development of a science-based decision process for understanding and managing the impacts of drought to all of the eight CSC regions. Results from climate driven drought projection models will be incorporated into models of ecological flow and wildlife impact to understand which areas of the Country are more vulnerable to drought impacts.

2017 Program Change

WaterSMART Drought: (+\$1,030,000) for a total of \$1,030,000: Understanding thresholds and tipping points caused by droughts is critical in providing managers with early action options. The National Water Census Data Portal serves information on streamflow, precipitation, and water use that can be utilized by the National Climate Change and Wildlife Science Center (NCCWSC)/DOI Climate Science Centers (CSCs) Program to provide the foundational data needed to build decision support tools that will (explain what the tools will do, why they are important, who will use them). The NCCWSC would use the requested funding increase to continue to develop a science-based decision process for understanding and managing the impacts of drought on various parts of the Central and Western United States, including California. Much research is available on the effects of drought on human systems, notably agriculture, but the ecological effects are not as well studied. The program proposes to bring a diverse group of stakeholders together to identify science priorities and to co-produce science that allows managers to effectively respond to drought impacts on their resources. The USGS's goal is to use one or two drought stricken regions as examples to understand the impacts and then develop a decision-making process for managing limited water supplies in places like central California and the South Central United States. The USGS would develop working groups in places impacted by drought, consisting of USGS scientists, partners, and regional stakeholder networks to identify the science needs. Scientists attached to these working groups will develop models that integrate the social and economic impacts from drought and the USGS will use the North Central CSC's visualization facility (located in the Fort Collins Science Center) to allow the working groups to analyze scenarios using different decision points. In the requested increase, the program would expand the actionable science approach to other regions of the Country that are prone to drought. Through collaboration with the Land Remote Sensing (LRS) program, current land change assessment and drought monitoring products like the Vegetation Drought Response Index (VegDRI) will be evaluated,

2017 Program Change

via the visualization facility, for their adequacy to support integrated drought projection models. The program would integrate results from LRS land change assessment products with climate driven drought projection models into models of ecological flow and wildlife impact to understand which areas of the Country are more vulnerable to drought impacts. By focusing on the ecological impacts of drought, this project complements ongoing activities focused on water availability/supply and the agricultural and municipal effects of drought such as those under the National Integrated Drought Information Systems, U.S. Bureau of Reclamation basin studies, and other partners' efforts.

Arctic

(2015 Actual, \$3.6 million; 2016 Enacted, \$3.6 million; 2017 Request, \$4.1 million)

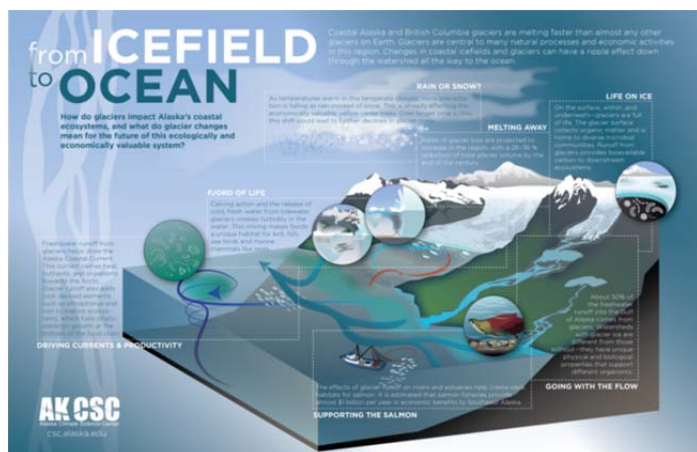
The focus of this component is to improve the understanding of the relative vulnerability of key Alaska ecosystems and goods and services people expect from the system to the effects of climate variability and climate change, including: (1) fresh water supplies; (2) landscapes, including wildlife habitat; (3) native and cultural resources; and (4) ocean health; and the specific threats to those resources, including invasive species, wildfire risk, sea level rise, and melting ice/permafrost. The information produced under this component is intended to support effective management, sustainable use, and sustainable communities. Science priorities are guided by the Alaska Climate Change Executive Roundtable (ACCER), established jointly by the U.S. Fish and Wildlife Service and the U.S. Geological Survey in 2007, and comprising both Federal and non-Federal senior level agency executives from throughout Alaska, whose respective agencies have responsibilities and capacities for addressing climate change or its impacts on Alaska's natural and cultural resources.

In 2015, an interdisciplinary, collaborative effort culminated in the synthesis paper *Icefield-to-Ocean Linkages across the Northern Pacific Coastal Temperate Rainforest Ecosystem* in the journal *Bioscience*.

It presents an ecosystem-wide understanding of Alaska glacier systems, including implications of ongoing glacier change for scientists, resource managers, and policy makers in coastal Alaska.

Alaska and British Columbia glaciers are among the fastest changing glaciers on Earth, and glaciers are central to many natural processes and economic activities in this region. Changes in coastal icefields and glaciers can ripple through the watershed all the way to the ocean.

The paper combines what many scientists currently know about the physical, chemical, and biological connections that link high-elevation icefields to glaciers,



This image depicts the effects of climate change on icefields, and the cascading effects to the ocean ecosystem.

freshwater runoff streams, and the ocean. The project led to a conceptual graphic that received international recognition and was awarded *People's Choice* in the 2015 Visualization Challenge (Vizzie)

awards sponsored by Popular Science and the National Science Foundation.

The Alaska CSC provided input and support for the Alaska Region (one of 10 regional chapters) as well as the technical report section of the third National Climate Assessment. The USGS anticipates that stakeholders will use the 2014 NCA national report and the Alaska regional report as a definitive source of baseline information on observed changes and anticipated trends in climate and ecosystems.

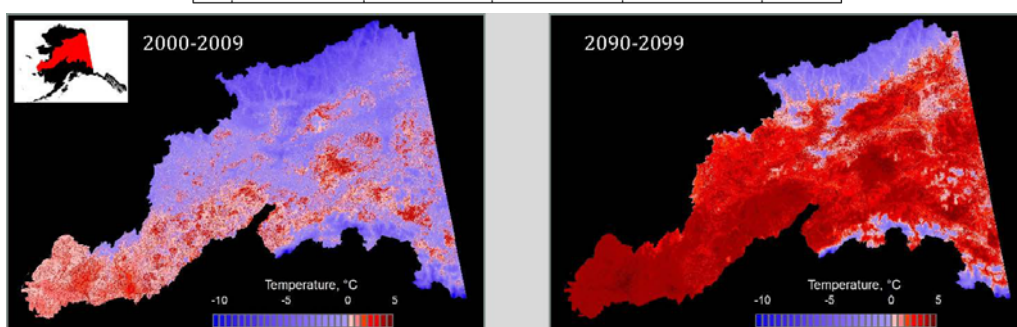
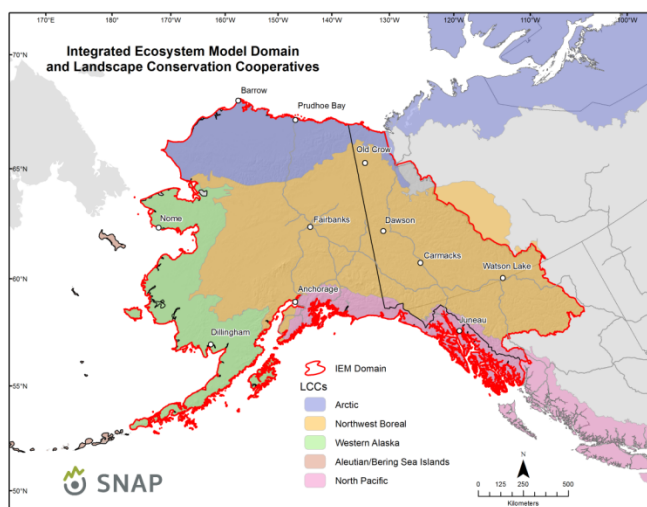


Caribou foraging in the Arctic.
Photo Credit: Jay Elhard, Denali National Park/
Park

Finally, three new studies were initiated:

1. Climate change and impacts on large ungulates; this project integrates expected effects of climate change on lichen and shrub production, wildfire, and resulting plant community change, which in turn affects caribou and moose populations. This study is particularly important, as the changes may affect subsistence and sport hunters.
2. Permafrost, climate change, and infrastructure, which focuses on the impacts of changing permafrost on existing and future infrastructure in Alaska's Arctic.
3. Model development for watershed behavior in Alaska's rainforests; the outcome of this research could be used by planners to help manage SE Alaska ecosystems.

In 2016, the NCCWSC and the AK CSC, in collaboration with three Alaska LCCs, plans to finish the development of an ecosystem model for Alaska and Northwest Canada that is capable of forecasting how landscape structure and function might change in response to how climate change influences interactions among disturbance regimes, permafrost integrity, hydrology, vegetation succession and migration. This tool would provide scenarios of changes in landscape structure and function that could be used by resource-specific impact models to assess the effects of climate change on natural resources.



Mean annual ground temperatures at 1 m depth in the Alaska Yukon River Basin by a permafrost regime model. Simulated ground temperatures are driven by historical (2000-2009) and projected climate change scenarios (2090-2099). Blues depict temperatures <0°C and reds depict temperatures >0°C, indicating areas most likely to experience permafrost degradation over the next century (modified from IEM factsheet).

In 2017, the NCCWSC and AK CSC would use funds to estimate total glacier loss and its effects on freshwater, as well as undertake research on ecological drought. More details are provided in the box below.

2017 Program Change
<p>Critical Landscapes: Arctic (+\$500,000) for a total of \$500,000: The NCCWSC /AK Climate Science Center would use the requested funding increase to develop a process to estimate total glacier loss in Alaska and potential changes in freshwater input. These estimates would be used along with projections of future changes in climate, fire regimes, vegetation, and water flows, produced by the program’s recently completed Alaska Integrated Ecosystem Model (AIEM). Glacier loss can have a significant effect on river systems and ecosystem dynamics, affecting economically and culturally important species such as salmon and caribou. The funding would also build on existing research investments in interior Alaska to better understand the potential for larger scale and more frequent effects of ecological drought in the region. The tool is capable of providing scenarios that depict changes in landscape structure and function, thereby allowing resource managers to assess the effects of climate change on natural resources.</p>

Science Collaboration

The NCCWSC and CSCs are committed to a partnership-driven model. At the national and regional level, major guidance on priorities and activities is provided by ongoing interactions with stakeholders from the management, science, and public communities. Work is conducted in partnership with Interior bureaus, including FWS and BIA, other Federal agencies, States, and tribal and indigenous partners, and the Department of Interior Landscape Conservation Cooperatives (LCCs). Interior established the Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS) to provide advice on the operations, partnerships, and science conducted by the NCCWSC and the CSCs. ACCCNRS includes representatives of other Federal agencies, States, tribal and indigenous partners, local governments; nongovernmental organizations; private sector entities; and academic institutions. In accordance with the recommendations of the ACCCNRS, the CSCs are continuing to focus efforts on the co-production of actionable science, whereby researchers work closely with the end users of the science information (e.g., natural resource managers), from developing the research question through the analysis and production of the research output. In this way, the CSCs can provide information that directly meets the needs of decision makers.

Activity: Climate and Land Use Change**Subactivity: Climate Variability****Program Element: Climate Research and Development Program**

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Climate and Land Use Change	\$135,975	\$139,975	\$304	\$31,165	\$171,444	\$31,469
<i>FTE</i>	<i>388</i>	<i>388</i>		<i>29</i>	<i>417</i>	<i>29</i>
Climate Variability	\$57,589	\$57,289	\$148	\$5,566	\$63,003	\$5,714
<i>FTE</i>	<i>190</i>	<i>190</i>		<i>14</i>	<i>204</i>	<i>14</i>
Climate Research and Development Program	\$21,495	\$21,495	\$94	\$1,125	\$22,714	\$1,219
<i>FTE</i>	<i>110</i>	<i>110</i>		<i>5</i>	<i>115</i>	<i>5</i>
Patterns and Impacts of Climate Variability	\$6,613	\$6,613		\$0	\$6,613	\$0
Land-use and Climate Interactions	\$3,627	\$3,627		\$0	\$3,627	\$0
Patterns and Impacts of Drought on to Regional to National Scales	\$3,600	\$3,600		\$1,125	\$4,725	\$1,125
<i>WaterSMART: Drought</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,125]</i>	<i>[\$1,125]</i>	<i>[\$1,125]</i>
Arctic Response to Climate Change	\$1,977	\$1,977		\$0	\$1,977	\$0
Coastal Response to Climate Change	\$3,092	\$3,092		\$0	\$3,092	\$0
Impacts of Climate and Land Use Change on the Carbon Cycle	\$2,586	\$2,586		\$0	\$2,586	\$0

Justification of Program Change

The 2017 Budget Request for the Climate Research and Development Program is \$22,714,000 and 115 FTE, a net change of +\$1,219,000 and +5 FTE from the 2016 Enacted level.

Overview

The Climate Research and Development Program (Climate R&D) provides the core data needed to understand and forecast how the Earth system responds to a range of climate and environmental changes. The program conducts research to advance the understanding of the physical, chemical and biological components of the Earth system, the rates, causes and consequences of climate and land-use change, and the vulnerability and resilience of the Earth system to such changes. Program researchers draw on expertise in past and present climate, geology, hydrology, geography, and biology to document patterns of climate and land use change on daily to millennial timescales and to assess and model the impacts of changes on local, regional, and national spatial scales. By coupling data generation with modeling efforts, Climate R&D Program researchers are improving the understanding of mechanisms that influence

climate and land-use change and their impacts on critical habitats and ecosystems. These efforts provide managers and policy makers with real-world data on the response of critical ecosystems to climate and land-use change.

Climate R&D Program activities are planned and conducted over five-year increments to address specific research questions. This strategy provides sufficient time and stability for projects to accomplish their stated goals and produce products and outcomes. It also provides the Climate R&D Program with the flexibility to address emerging critical issues (such as hydrologic extremes of drought and flooding) by coordinating among existing areas of expertise to establish appropriate research teams. Climate R&D enhances USGS capabilities by collaborating with scientists in other Federal agencies (National Park Service, Fish and Wildlife Service, Forest Service, Bureau of Indian Affairs, National Oceanic and Atmospheric Administration, and the Smithsonian Institution) and academic institutions across the globe. Climate R&D Program research supports national and international efforts to understand climate change, such as the U.S. Global Change Research Program Strategic Plan, U.S. National Climate Assessment, and the Intergovernmental Panel on Climate Change.

In 2017, the Climate R&D Program is requesting an increase of \$1,125,000 for work to improve understanding of long-term and medium-term patterns and impacts of drought in the Western and Southeastern United States, and help develop sustainable plans for use of limited water resources by management agencies.

Climate R&D Science Fact:

Climate R&D research is helping the Federal Bureau of Investigation Laboratory to improve their capability to identify the source areas for forensic soil samples. Climate R&D provides the expertise and facilities for pollen analysis to support development and testing of new FBI interpretation tools. Recent analysis of pollen from digging tools recovered from a murder suspect narrowed the search window for the burial site, ultimately leading to recovery of the victims.

Program Performance

The Climate R&D Program is comprised of the six program components: Patterns and Impacts of Climate Variability, Land-use and Climate Interactions, Patterns and Impacts of Drought on Regional to National Scales, Arctic Response to Climate Change, Coastal Response to Climate Change, Impacts of Climate and Land Use Change on the Carbon Cycle

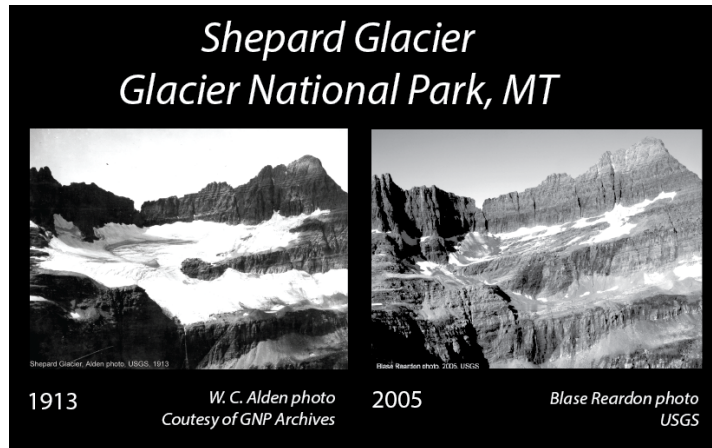
Patterns and Impacts of Climate Variability

(2015 Actual, \$6.6 million; 2016 Enacted, \$6.6 million; 2017 Request, \$6.6 million)

Variability in the Earth's climate affects the distribution and health of terrestrial and marine ecosystems; the distribution, quantity, and quality of water resources; and the sustainability of human societies. Over long-time scales (centuries to millennia), climate variability is influenced by external factors such as changes in the Earth's orbit, tilt of the planetary axis, and solar variability. On shorter time scales (years to centuries), internal processes in the ocean-atmosphere system (such as El Niño) have caused major shifts in the locations and amounts of precipitation. Such variability can alter the composition and distribution of ecosystems, cause droughts and floods, and impact agriculture and natural hazards.

Climate R&D research aims to improve the understanding of the regional, national, and global impacts of different patterns of climate variability and improve our capabilities to model and forecast patterns and impacts of different scenarios.

Climate R&D generates and synthesizes instrumental and paleoclimate reconstructions of temperature and precipitation globally with a focus on different regions of the Nation to understand and more accurately predict impacts of different modes of climate variability on critical habitats and infrastructure. Scientists documenting long-term changes in North American benchmark glaciers are developing standard methodologies to compare regional patterns of mass balance ice loss or gain. Such data are needed to determine the impact of climate fluctuations on glacier dynamics, downstream ecosystems, water supply, and sea level rise. Climate R&D scientists also develop and apply a variety of numerical models and visualization techniques to quantify, explain, and understand interactions between the atmosphere, oceans, glaciers and ice sheets, and ecosystems. Comparisons between paleoclimate data and models are designed to improve computer models that are being used to understand potential future climatic changes and their environmental consequences.



USGS researchers are documenting the sensitivity of alpine glaciers, such as Shepard Glacier in Glacier National Park, Montana, to climate variability during the past century. The principal socioeconomic impact of glacier loss would be sea level rise, but surface water hydrology, ecology, resource management, tourism, and recreation would also be affected by glacier changes.

In 2015, the Climate R&D Program continued its long history of research on long-term patterns of climate variability and began a new initiative to establish historical North American climate baselines based on paleoclimate and instrumental records. Scientists generated evidence on long-term patterns of drought and snowpack variability in the Western United States to evaluate whether recent changes fall within the bounds of natural variability. Climate R&D scientists also developed and instituted standardized field and remote sensing techniques to measure the amount of water contained in alpine glaciers.

In 2016, the Climate R&D Program plans to continue research on long-term patterns of climate variability, generating new data to fill data gaps in 2015. Synthesis of regional patterns of temperature, precipitation, and water availability in the western and Southeastern United States will be used to improve models designed to forecast impacts of different climate phenomena. Climate R&D scientists will expand the number of glaciers analyzed and compare established records glacier recession along a climatic gradient with instrumental records of ENSO (El Niño and La Niña) and other climate parameters.

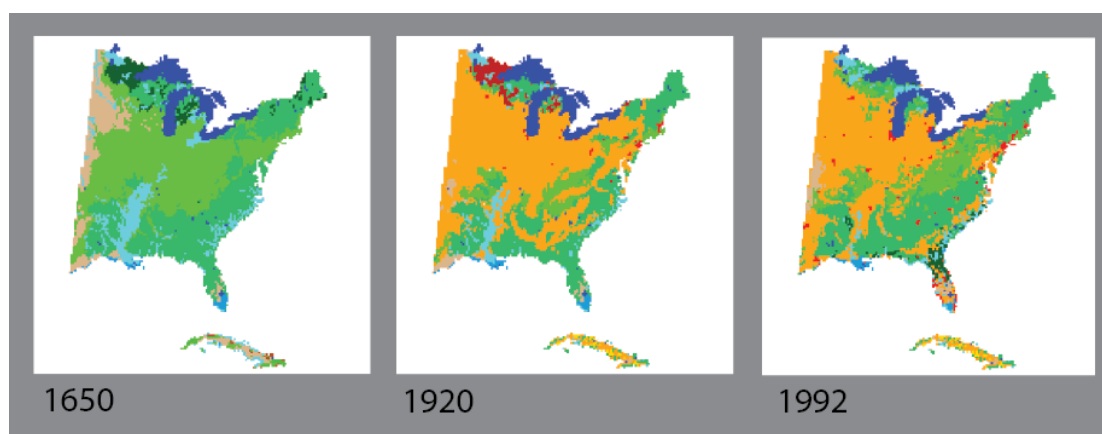
In 2017, the Climate R&D Program would use new data generated in 2016 to synthesize long-term climate variability in additional regions, leading to a national, high-resolution synthesis of climate variability over the last few millennia. Climate R&D research on alpine glaciers will document glacier-hydrology interactions on benchmark glaciers and begin incorporating glaciological data into projections of sea level rise.

Land-use and Climate Interactions

(2015 Actual, \$3.6 million; 2016 Enacted, \$3.6 million; 2017 Request, \$3.6 million)

The land surface of the Earth is covered by various combinations of natural and planted vegetation, water bodies, agricultural fields, and urban areas, collectively are referred to as “land cover.” Changes in land cover have occurred as a result of both human modifications (such as urbanization, deforestation, agriculture, water management) and from natural climate and geomorphic processes (such as flooding, landslides, ice sheet growth and melting). Land use and land cover change (LULCC) affect the full range of terrestrial and marine ecosystems, as well as the economic, public health, and social benefits provided by ecosystems. Climate R&D research on land-cover change uses a combination of remotely sensed data from satellites, ground-based observations, maps, historical accounts, and geologically-based reconstructions to document long-term patterns of LULCC and their consequences for water quantity and quality, carbon sequestration, and other ecosystem services. The studies also provide a means to better understand how LULCC affects, and is affected by, climatic variability and change.

Climate R&D research on land-use and climate interactions includes long-term studies of the land use and disturbance histories of the United States to improve understanding of geographic processes and to report on the status and trends in our Nation’s land surface. Climate R&D scientists also examine how changes in land cover influence regional climate by compiling a time series of high-resolution datasets of land cover and testing their feedbacks to the climate system using climate model simulations. Such information will inform resource managers on potential impacts of different land management scenarios.



Land use and land cover in the United States has been modified extensively since pre-Colonial times, as shown by land cover reconstructions above (modified from Steyaert and Knox, 2008 and Reker et al., 2015). Colors in the figures are coded to specific land-cover categories, such as Crop/Mixed Farming and Mixed Woodland. USGS researchers are examining the potential influence of historical land cover change on local to regional climate by reconstructing historic land cover and running a series of climate simulations to understand and forecast how land cover change alone can

In 2015, the Climate R&D Program conducted research to identify the relevant indicators of land surface change, quantify rates of land surface change, identify key driving forces of land cover change, and project future trends under a range of climate scenarios. Climate R&D scientists also initiated new research to improve understanding of how feedbacks between land use change and climate affect climate and hydrology in the Southeastern United States. Initial results indicate that land cover changes over the past century likely contributed substantially to climate change in the region, particularly over Florida, where deforestation, urbanization and a shift to agriculture increased air temperatures and decreased summer precipitation.



Climate R&D research uses hydrologic proxies in sediment cores to reconstruct the duration and magnitude of past intervals of drought. By integrating these data with instrumental records of the last century, scientists generate baselines for hydrologic variability and document the response of biotic communities to extreme drought. Photo courtesy of J. Duberstein (USGS).

In 2016, the Climate R&D Program plans to continue development of capabilities to model and analyze changes in land use, land cover, and disturbance under a range of future scenarios. Continued research on land-use change and climate in Florida will expand historic range of land-cover datasets to improve model capabilities and initiate collaboration with resource managers to integrate land-cover/climate impacts into water and ecosystem model capabilities. Climate R&D scientists also will expand that work into the Upper Colorado River basin or other relevant regions during 2016.

In 2017, the Climate R&D Program would continue collaboration with resource managers in Florida to improve model capabilities and forecast how different land management strategies would affect climate and the sustainability of those strategies. Research also would continue to document the rates and drivers of land surface change, project future trends under different scenarios, and improve understanding of the feedbacks between land surface and climate change. Incorporation of land-cover impacts on Florida climate into hydrologic and ecosystem models should lead to development of predictive tools for resource managers, and regional datasets will be prepared for initial model runs for the Upper Colorado River basin.

Patterns and Impacts of Drought on Regional to National Scales

(2015 Actual, \$3.6 million; 2016 Enacted, \$3.6 million; 2017 Request, \$4.7 million)

The amount of freshwater on the land surface and in the ground at any given location and time is determined by geology, climate, land use, habitat type, and human management of water resources. The

hydrologic cycle and its related processes have strong and complex interactions with the carbon cycle, sediment and nutrient transport, and the structure, function and health of terrestrial, estuarine, and marine ecosystems. The Climate R&D Program conducts multidisciplinary research to advance our understanding of the mechanisms and sources of climatic variability and their effect on freshwater availability, including extreme events such as floods and drought. Climate R&D researchers reconstruct long-term records of local to regional precipitation and hydrology, monitor and analyze forests and watersheds and use this information in conjunction with modeling to identify impacts of hydrologic variability. These activities aim to improve capabilities to model hydrologic variability under different climate scenarios and forecast potential impacts on ecosystems and societies. Through collaboration with stakeholders and resource managers, these efforts contribute substantially to the development of sound water management strategies.

In 2015, the Climate R&D Program continued to develop long-term records of hydroclimate from a national network of sites. Researchers identified regional data gaps that impede efforts to understand how atmospheric and oceanic processes interact to influence North American hydroclimate. Climate R&D scientists began synthesizing local and regional data to improve understanding of long-term patterns of drought on a national scale. Research on Western U.S. forests affected by the current severe drought was expanded to evaluate the progression and impacts of the drought on Western forests. These data are helping forest and park managers determine the most vulnerable sites to target forest treatments.

In 2016, the Climate R&D Program plans to begin generating new records from data-sparse regions to fill gaps identified in 2015. Results from research on regional trends in hydroclimate over the last 2,000 years will be synthesized to provide much needed information on how hydrology varies on a broad-spatial and temporal scales. Research on the impacts of drought on giant sequoias in California that began in 2015 will continue, providing new evidence on the vulnerability of the forests to extended periods of drought.

In 2017, the Climate R&D Program would expand the network of sites with long-term records of hydroclimate from a regional to a national scale. Synthesis efforts would include new sites and longer timescales, thereby enhancing the understanding of hydrologic responses from regional to a national scale. Research on the impacts of drought on Western U.S. forests would continue and integrate research from multiple regions (northern, central, and southern Rockies, Sierra Nevada) to improve understanding of regional impacts of the recent and ongoing extended drought.

2017 Program Change
<p>WaterSMART: Drought (+\$1,125,000) for a total of \$1,125,000: The Climate Research and Development (R&D) Program would use the requested funding increase to understand long-term and medium-term patterns and impacts of drought in the Western and Southeastern United States. Understanding patterns of drought is critical to develop sustainable plans for use of limited water resources by management agencies. These efforts would focus on generating new records needed to fully understand long-term patterns of United States hydroclimate in the two regions, including amount of precipitation, seasonality of precipitation (rain vs. snow), and variability in water availability over annual, decadal, and longer time scales. This research would provide a context to assess the magnitude and regional impacts of current and future droughts, and provide information on how ecosystems of the</p>

2017 Program Change

Western and Southeastern United States have responded to past intervals of drought. These studies would provide resource managers with real-world results that could be used to test results from a range of climate and ecosystem models.

In the Pacific Northwest and Alaska, water availability and water quality are influenced by glacier dynamics. Increased funding would be used to expand ongoing research on alpine glaciers. Development of new and improved techniques to measure changes in the amount of water contained in alpine glaciers would improve the understanding of long-term patterns of glacier change and their influence on water availability and the transport of carbon and nutrients to streams, estuaries, and oceans. Such evidence would provide data needed by resource managers to better forecast changes in streamflow and ecosystem function in watersheds fed by alpine glaciers. The data and information collected by the Climate R&D Program can be compared to the current data that is collected and served through the National Water Census. This type of comparison would allow resource managers to use past examples to help understand current conditions in their area.

Arctic Response to Climate Change

(2015 Actual, \$1.9 million; 2016 Enacted, \$1.9 million; 2017 Request, \$1.9 million)

During the past few decades, Arctic temperatures have increased while annual and seasonal Arctic Ocean sea ice cover has decreased, leading to greater coastal erosion, changes in marine ecosystems, habitats, and productivity, and greater export of freshwater, among other trends. Changes in permafrost landscapes have the potential to alter the structure and function of northern ecosystems, and changing fluxes of carbon to the

atmosphere could represent a significant biosphere feedback to climate warming.

Climate R&D research aims to understand the processes that influence the presence and extent of Arctic sea ice, document the extent and stability of permafrost, characterize climate variations over a range of time scales, and to identify the impacts of climate variability and change on Arctic habitats.



Climate R&D research on climate change in the Arctic includes research to understand the origin and variability of Arctic sea ice. Sediment cores, such as the one being collected from the Chukchi Sea above, contain biotic and chemical proxies for sea ice. These records span centuries, millennia and longer time intervals and provide data on the variability of sea-ice cover under climates that were warmer and cooler than today.

Photo courtesy of K. Dunton (University of Texas at Austin).

In 2015, the Climate R&D Program conducted research to evaluate the natural sea ice, ocean circulation and climate variability in the Arctic using sediment core proxy records. These data document how climate variability over different time scales affects species diversity, primary productivity, species' geographic range shifts into and out of the Arctic, and community restructuring. Such evidence informs policy makers as they devise management strategies under different climate scenarios. Climate R&D researchers also documented long-term rates and patterns of permafrost thaw and its impact on hydrology and associated ecosystems. New results on formation of permafrost lakes after thawing has provided new information on the role of these Arctic lakes in sequestering carbon and affecting climate change.

In 2016, the Climate R&D Program plans to continue research to understand regional patterns of sea-ice variability and begin development of proxies for Arctic Ocean productivity. Research on long-term variability in permafrost and hydrology will be expanded into new regions in the Arctic to improve understanding of regional variability in this extremely large area.

In 2017, the Climate R&D Program would apply new proxies for Arctic Ocean productivity to quantify past patterns of productivity and evaluate their relations to sea ice. These data would be integrated into model experiments to better understand potential changes in Arctic marine ecosystems under different climate scenarios. Research on long-term patterns of permafrost stability and hydrology would continue and expand to fill data gaps identified in 2015 and 2016. The resulting data would provide critical information on latitudinal patterns of thaw and impacts on hydrology and carbon cycling on regional to global scales.

Coastal Response to Climate Change

(2015 Actual, \$3.1 million; 2016 Enacted, \$3.1 million; 2017 Request, \$3.1 million)

Nearly 40 percent of the United States population lives in a county that is directly on a shoreline; changes in climate and sea level could have severe impacts on coastal habitats, communities, and infrastructure. To fully understand the potential rates, magnitudes, and impacts of sea level rise, the Climate R&D Program conducts research that integrates geologic records of sea level rise with process-based research that examines how sea level rise and other climate factors affect coastal habitats and the ecosystem services that they provide. Geologic records of sea level rise, spanning the last three million years, provide evidence for how high sea level rose when temperatures were warmer than today and polar ice sheets were reduced. These records also indicate how rapidly sea level rose and are helping to understand how melting ice sheets and other factors influence regional sea level patterns. Loss of coastal marshes and wetlands can result from combined effects of sea level rise and reductions in sediment supply from the land. Loss of coastal marshes and wetlands can result from combined effects of sea level rise and reductions in sediment supply from the land. These losses reduce habitat for commercial fisheries and water fowl and decrease the capability of marshes to buffer the coastline from storm surges and sea level rise.

Climate R&D scientists are investigating sites along the Nation's coasts to improve understanding of how rapidly coastal wetland communities can be altered and evaluate the factors that cause those changes. In collaboration with Federal and academic partners, Climate R&D research aims to improve understanding

of the factors that influence wetland sustainability, which has direct implications for management of critical wetland resources by Federal and State agencies, and natural resource conservation groups.

In 2015, the Climate R&D Program initiated research to document ages and elevations of past sea level highstands on the east coast of the United States, complementing ongoing research on the California coastline. Climate R&D scientists also conducted multidisciplinary research to document the impact of changing sea level and climate on coastal marshes in the southeastern and mid-Atlantic coasts. In collaboration with academic institutions and Interior sister agencies (FWS, NPS), a series of models were designed to forecast impacts of sea level rise on marsh elevation, hydrology, and soil salinity.

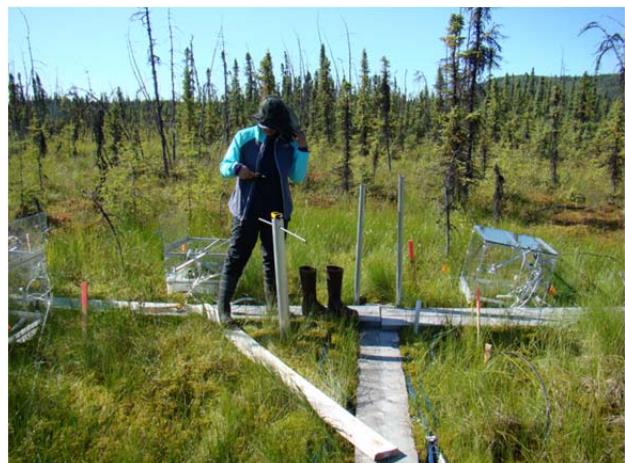
In 2016, the Climate R&D Program will continue research on ages and elevations of sea level highstands on the east and west coasts of the United States, expanding field work to fill in data gaps identified in 2015. Researchers will continue and expand research on the processes that influence southeastern U.S. coastal ecosystem response to sea level rise and will continue refining ecosystem and salinity models.

In 2017, the Climate R&D Program plans to begin synthesizing data from the east and west coasts of the United States to determine the controls on regional sea level and improve capabilities to model impacts of changing ice sheets and glaciers on sea level. Climate R&D scientists also would develop a fully coupled hydrologic and vegetation model to predict wetland responses to predict ecosystem responses to sea level rise along eastern United States coastal rivers.

Impacts of Climate and Land Use Change on the Carbon Cycle

(2015 Actual, \$2.6 million; 2016 Enacted, \$2.6 million; 2017 Request, \$2.6 million)

The carbon cycle is intimately linked to two very important atmospheric greenhouse gases, carbon dioxide (CO₂) and methane (CH₄). Levels of atmospheric CO₂ and CH₄ have varied in the geologic past due to changes in the natural cycling of carbon. Levels of both gases have increased rapidly over the last century due to human activities that include the consumption of fossil fuels and the harvesting of crops and timber. Because changes in CO₂ and CH₄ are known to affect global climate, an understanding of climate change requires knowledge about the carbon cycle and its responses to human activities and natural processes. Conversely, one of the most significant uncertainties in projecting future change in the carbon cycle is its potential response to future climate change. Thus, the changing carbon cycle is both a primary driver of climate change and a primary source of



A USGS researcher prepares to extract a freeze core collected in the thawed permafrost bog in Alaska. Climate R&D scientists are quantifying carbon stocks in thawed bogs and in frozen plateaus to determine whether carbon is lost following permafrost thaw. Automated chambers near the boardwalk are measuring gas fluxes from the bog.

Photo courtesy of M. Jones (USGS)

uncertainty in projecting future climate trends. The Climate R&D Program conducts research on the relationship between changes in climate and land use and the cycling of carbon among the atmosphere, oceans, terrestrial ecosystems, and sediments over a range of temporal scales. This research includes efforts to refine our understanding of the processes involved in greenhouse gas flux and carbon cycling in wetland ecosystems, permafrost, and temperate soils over seasonal to millennial time scales.

In 2015, the Climate R&D Program conducted research to document annual and longer-term trends in fluxes of CO₂ and methane in permafrost and wetland systems of North America, including wetlands along the Atlantic and Gulf coasts, as well as the Prairie Pothole Region of the Great Plains. These efforts clarified the role of lakes formed by thawing permafrost in stabilizing carbon and greenhouse gases, and provides evidence on the impacts of anthropogenic land cover change on capabilities of wetlands to store carbon in eastern U.S. watersheds.

In 2016, the Climate R&D Program will initiate research to understand the rates, forms, causes, and consequences of -losses following permafrost thaw across a landscape gradient of permafrost vulnerability. In wetland habitats, Climate R&D researchers will continue research designed to improve understanding of impacts of changing climate, hydrology, and sea level on wetland carbon cycling.

In 2017, the Climate R&D Program would increase the spatial and temporal sampling resolution on ongoing measurement and research on carbon cycling in wetlands, permafrost, and other soils. The dynamic response of the global carbon cycle to historical effects of changing U.S. land use would be calculated. By documenting the impacts of a range of climate and land cover changes on carbon cycling across the Nation, these efforts would improve model capabilities to forecast the response of the global carbon cycle to a range of climate scenarios and management options.

Science Collaboration

The Climate R&D Program collaborates with scientists in other Interior bureaus (such as National Park Service, Fish and Wildlife Service, Bureau of Indian Affairs) and various Federal agencies (such as Forest Service, the National Oceanic and Atmospheric Administration, Smithsonian Institution, and the Federal Bureau of Investigation) and academic institutions across the globe. Climate R&D Program research supports national and international efforts to understand climate change, such as the U.S. Global Change Research Program Strategic Plan, U.S. National Climate Assessment, and the Intergovernmental Panel on Climate Change. The Climate R&D Program provides these partners with the unbiased, objective, and impartial scientific information that is needed to be able to mitigate the effects of climate change.

Activity: Climate and Land Use Change

Subactivity: Climate Variability

Program Element: Carbon Sequestration

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Climate and Land Use Change	\$135,975	\$139,975	\$304	\$31,165	\$171,444	\$31,469
<i>FTE</i>	<i>388</i>	<i>388</i>		<i>29</i>	<i>417</i>	<i>29</i>
Climate Variability	\$57,589	\$57,289	\$148	\$5,566	\$63,003	\$5,714
<i>FTE</i>	<i>190</i>	<i>190</i>		<i>14</i>	<i>204</i>	<i>14</i>
Carbon Sequestration	\$9,359	\$9,359	\$22	\$0	\$9,381	\$22
<i>FTE</i>	<i>31</i>	<i>31</i>		<i>0</i>	<i>31</i>	<i>0</i>
Biological Carbon Sequestration	\$5,237	\$5,237		\$0	\$5,237	\$0
Geologic Carbon Sequestration	\$4,122	\$4,122		\$0	\$4,122	\$0

Justification of Program Change

The 2017 Budget Request for the Carbon Sequestration Program is \$9,381,000 and 31 FTE, a net change of +\$22,000 and 0 FTE from the 2016 Enacted level.

Carbon sequestration is a process in which carbon dioxide (CO₂) is captured from the atmosphere or from point sources (such as power plants) and stored in biological materials (such as vegetation or soils) or geological formations, thereby reducing greenhouse gas concentrations in the atmosphere. It is a vital step in mitigating the effects of climate change. The effects of climate change are profoundly felt in the frequency and intensity of extreme weather, which can pose significant economic, health and safety challenges with events like devastating floods, longer and more intense droughts, and heat waves. According to a report by the World Meteorological Organization (WMO), the period of 2001-2010 brought unprecedented climate extremes, and the organization's most recent five year analysis, covering 2011-2015 identifies continued extreme weather and that five-year period as the warmest on record. Recognizing the dangers of extreme weather events, sea level rise and other consequences of climate change, on December 12, 2015, 195 nations signed a historic agreement to take steps that will help keep the global temperature rise this century below two degrees Celsius. The work conducted by the Carbon Sequestration Program provides the scientific information needed to achieve that goal.

The USGS Carbon Sequestration Program focuses on two aspects of carbon sequestration: biologic carbon sequestration and geologic carbon sequestration. The biologic carbon sequestration project focuses on the science behind removing carbon from the atmosphere and storing it in vegetation

(particularly forests and wetlands), soil and sediments, and aquatic environments. The geologic carbon sequestration project is researching the effects and capacity of pumping CO₂ deep underground: Will it induce seismic activity; what are the potential benefits in terms of enhanced oil recovery; how much CO₂ can be stored underground and where is it most feasible; and will the CO₂ storage affect drinking water? The U.S. Geological Survey is the only Federal non-regulatory agency working on a national scale to address these issues. The Energy Independence and Security Act (EISA) of 2007 (P.L. 110-140) calls for the USGS to develop a methodology for, and then complete a national assessment of, the geologic storage capacity for CO₂. It also directed Interior to conduct a national assessment to quantify the amount of carbon stored in ecosystems, the capacity of ecosystems to sequester additional carbon, and the rate of greenhouse gases fluxes in and out of the ecosystems (biologic carbon sequestration). The USGS Carbon Sequestration Program has completed the requisite methodologies and regional baseline “LandCarbon” assessments for the contiguous United States. To determine the capacity of ecosystems to store carbon, USGS scientists are working closely with the land managers in the Department of the Interior to understand processes (such as surface water management and fire) that affect carbon stored in various ecosystem types. The geological carbon sequestration team is collaborating with utility companies and the oil and gas industry to explore the feasibility of carbon capture and storage, as well as the potential environmental effects.

Biologic Carbon Sequestration Science Fact:

Biological carbon sequestration counter-balances 15-20 percent of greenhouse gas emissions in the 48 adjoining States of the United States.

Geologic Carbon Sequestration Science Fact:

According to the Intergovernmental Panel on Climate Change, and the International Energy Agency, geologic storage of about 14 percent of the world’s annual energy-related CO₂ emissions is essential to meet future greenhouse gas emission reduction scenarios.

Program Performance

Biologic Carbon Sequestration

(2015 Actual, \$5.2 million; 2016 Enacted, \$5.2 million; 2017 Request, \$5.2 million)

Section 712 of the EISA legislation mandates Interior to develop a methodology and conduct an assessment of carbon storage, carbon sequestration, and fluxes of three principal greenhouse gases for the Nation's ecosystems. The three principal greenhouse gases are carbon dioxide, methane, and nitrous oxide. An assessment methodology was developed to fulfill the first part of the EISA requirements and three regional assessments for biological carbon sequestration have been released, beginning in 2010. A wide range of stakeholders view this assessment as a major advance in the scientific understanding of the relationships between ecosystem capacities to store carbon (or ecosystem vulnerability to release carbon into the atmosphere) and natural and anthropogenic processes, particularly land use change, ecosystem disturbances, management practices and climate change. All major ecosystems are included in the assessment, including forests, agricultural lands, grasslands, wetlands, rivers, lakes, and estuaries. By design, the biological assessment is conducted on a regional basis: Great Plains, Western United States,

Eastern United States, Alaska, and Hawaii. The USGS has already completed and delivered the Great Plains (December 2011), the Western United States (November 2012), and the Eastern United States (June 2014) regional assessments.



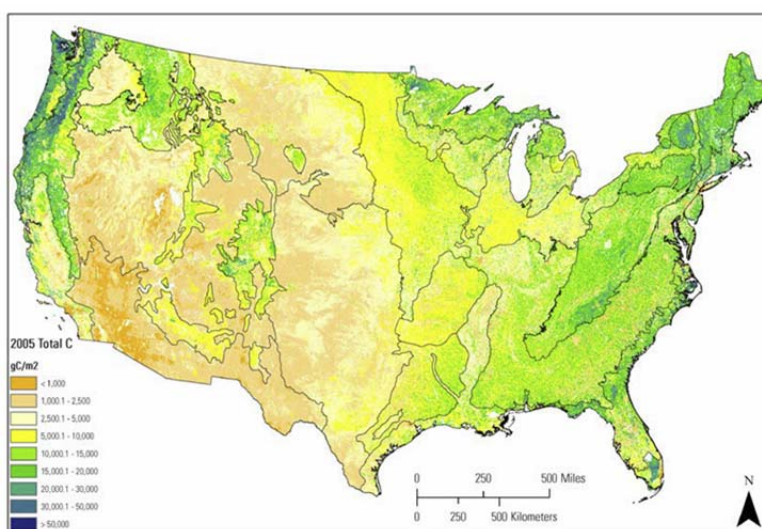
The covers of the assessment methodology, *A Method for Assessing Carbon Stocks, Carbon Sequestration and Greenhouse-Gas Fluxes in Ecosystems of the United States Under Present Conditions and Future Scenarios* (2010), and three regional assessments, the Great Plains (2011), the Western United States (2012) and the Eastern United States (2014)
Source USGS

The Great Plains, Western United States, and Eastern United States assessments confirmed that all three regions are “carbon sinks,” meaning their ecosystems take up more carbon than they emit. Eastern ecosystems are the strongest regional carbon sink in the conterminous United States, sequestering more carbon than the Great Plains and Western United States combined. On a national scale, the amount of carbon that is currently stored per year in the ecosystems of the conterminous United States is around 20 percent of the Nation’s total greenhouse gas emissions.

The assessments of Alaska and Hawaii are currently being conducted, with initial results analyzed and being prepared for peer review; the reports are expected for release by the end of March 2016.

The biological carbon sequestration project developed the “LandCarbon Atlas” online tool, enabling managers and the public to view, analyze, and download carbon sequestration data via the Internet.

This tool is a significant step forward in supporting ecological



Density of carbon stocks of the conterminous United States. These results are derived from the Great Plains, Western, and Eastern U.S. biological carbon sequestration assessments.

carbon sequestration management. Further development of this and other mapping tools in 2015 and 2016 will allow land managers to ask “what-if” questions regarding the impacts of potential land management activities on carbon stocks and sequestration capacity, as well as on other ecosystem services (such as biodiversity, water quality, etc.). Data products (including carbon stock and sequestration estimates, emissions and fluxes in and out of ecosystems, land use change, and wildland fire) for the conterminous United States are now available for analysis and download via the Internet (http://www.usgs.gov/climate_landuse/land_carbon/)

In 2015, the biological carbon sequestration project completed the assessment for Alaska, which has been peer reviewed and is currently in the final editing stage at the USGS. The report is expected for public release by the end of March 2016. Project personnel published over 20 peer reviewed papers during 2015, including high impact papers on the extent, characteristics, and projected loss of Alaskan permafrost (*Remote Sensing of Environment*), carbon characteristics of Federal lands in the United States (*Proceedings of the National Academies of Science*), and carbon losses through the aquatic environment (*Proceedings of the National Academies of Science*).

In an effort to use the USGS carbon assessment to support land management, the USGS and the Fish and Wildlife Service (FWS) have undertaken a series of projects that are investigating the carbon cycle on National Wildlife Refuges (NWR) across the Country. The refuges were selected on the basis of representing environments that are experiencing different types of stresses, such as sea level rise, land conversion/restoration, water management, and ecological stress. The following NWRs are currently under study:

- Great Dismal Swamp, VA/NC – water management, peat accumulation, fire
- Neal Smith, IA – conversion from agricultural land use
- Nisqually, WA – sea level rise
- San Francisco Bay – sea level rise
- Ding Darling, FL – mangrove stress

The Great Dismal Swamp project commenced in 2014, and is investigating science-based observations on the effects of water management on peat accretion, vegetation, water quality, and other ecosystem services into a decision support framework.

Research on biological carbon sequestration processes will continue to be an important component of this project. A number of research projects are underway to support improved *Assessments, Applications, and Interagency Cooperation*. Research is being conducted on improving the efficiency and flexibility of carbon modeling and monitoring using a set of innovative approaches. Carbon modeling, via a state-and-transition simulation (STSim) model combined with a stock and flow model into a system called the Land Use and Carbon Scenario Simulator (LUCAS), is a key component of the proposed ongoing assessments, as well as several of the FWS applications. The model is being adapted to handle annual input from the Land Change Monitoring Assessment and Projection (LCMAP) project that is being developed by the USGS and Boston University. This innovative research examines each observation of each 30m pixel throughout the history of Landsat and identifies land use/land cover and land transitions that have taken

place. The power of LCMAP is its ability to establish when and where land conversions have taken place and continue to monitor the land surface as each new Landsat observation is collected.

In 2016, the biological carbon sequestration project plans to complete the national assessment of biological carbon sequestration with the publication of the assessment reports for Alaska and Hawaii. This will complete the first national assessment of all ecosystems over all land areas of the United States.

One of the objectives of the project in 2016 is to further prepare methodology to commence annual inventories of biological carbon resources on Department of Interior lands in the United States. This functionality requires the operational capability of the USGS LCMAP (land change monitoring, assessment, and projection) model and LUCAS (land use and carbon scenario simulator) model, which are under development.

As a result of work that has contributed to the Alaska assessment, new knowledge has been gained on the release of methane as a result of thawing permafrost (Nature, 2015). This work will continue based on both in situ observations of permafrost and remote sensing data to provide estimates of changes in the active layer and carbon and methane release consequences of thawing.

The pilot projects with FWS will continue and will be further built up with increased operations and studies. The J.N. Ding Darling NWR project will examine the degradation of mangrove forests along the Florida coast and their response to rising sea levels. The Great Dismal Swamp project is producing an ecosystem services decision support tool that will be in the testing phase during 2016. Other projects, including work in Phonpei Island in Micronesia, will be initiated.

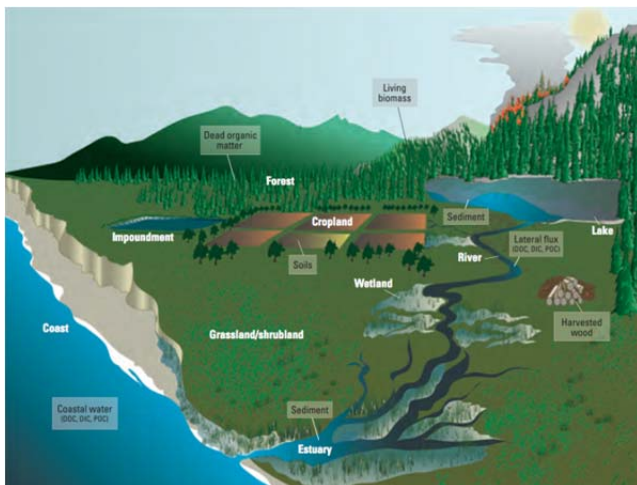


Diagram of the terrestrial and aquatic ecosystems and major carbon pools covered in the assessment

The biologic carbon sequestration project is putting new emphasis on blue carbon mapping activities in the coastal zone. Blue carbon refers to carbon pools and fluxes in coastal intertidal ecosystems, such as salt marshes, mangrove forests, seagrass beds and mudflats. Coastal ecosystems in equilibrium with sea level maintain the highest carbon stock and sequestration potential per unit area. Ongoing research in blue carbon includes the integration of remote sensing, field data collection and carbon balance analysis, and ecosystem service modeling for blue carbon. Cooperative work with FWS and the National Oceanic and Atmospheric Administration (NOAA) will

include a gap analysis of current blue carbon inventory resources and a strategy for filling information gaps that are required for GHG reporting.

The nationwide carbon stock and flux assessment carried out by the USGS biologic carbon sequestration project is only a first step toward contributing to improved carbon stewardship. In 2017, the biological

carbon sequestration project would work with several Federal agencies to better understand carbon cycle science, contribute to science-based decision making, and conduct improved inventories of land sector carbon. The USGS would work with other Federal agencies, including the U.S. Forest Service, NOAA, and others to support the EPA GHG inventories. Areas of emphasis for the USGS will be improving the land representation of inventory land use/land cover types by further incorporating remote sensing products, investigating improved carbon tracking of grasslands (including Federal grasslands, which are not currently represented in the GHG inventory, researching methods for including all of Alaska into the GHG inventory, and further work on blue carbon.

Implementing the methodology for annual inventories of biological carbon sequestration on Department of Interior lands: this will be an important step for an operational assessment of our Nation's carbon resources. In addition, work on the FWS National Wildlife Refuges would be expanded, with the work on ecosystem services decision support tools being extended to neighboring refuges of the pilot sites. Other refuges would be added to the pilot studies to represent other environments that are not currently being studied. Lessons learned from these pilot projects will enable practical applications for enhancing carbon sequestration in a wide range of habitats across the Country.

Geologic Carbon Sequestration

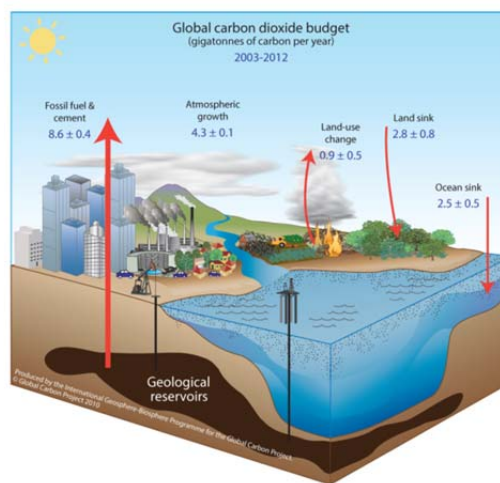
(2015 Actual, \$4.1 million; 2016 Enacted, \$4.1 million; 2017 Request, \$4.1 million)

The geologic carbon sequestration project conducts science to answer vital questions about what happens when CO₂ is pumped deep underground: will it cause earthquakes; what is the potential for CO₂ leakage; what are the environmental risks of storing CO₂ in underground reservoirs; will the CO₂ storage affect drinking water? It also researches how much CO₂ can be stored underground nationwide and how much oil can be produced by injecting CO₂ into reservoirs for enhanced oil recovery.



A carbon dioxide injection well in Mississippi.

Photo courtesy of Peter Warwick (USGS)

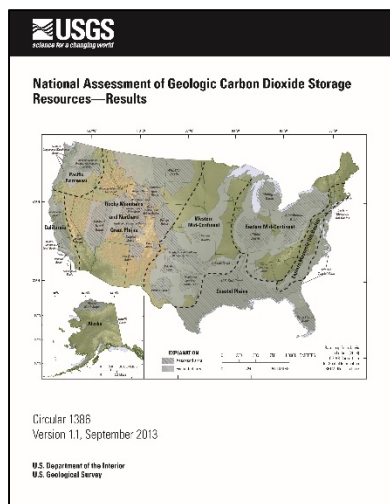


The arrows in the figure above represent global emissions from fossil-fuel burning and cement production, deforestation and other land-use change, and the growth of carbon in the atmosphere, the ocean, and land reservoirs from 2003 to 2012. The units for fluxes are in gigatonnes of carbon per year. (Le Quéré and others, 2014, *Earth Syst. Sci. Data*, 6, 235–263)

The Energy Independence and Security Act (EISA) requests that the USGS, the U.S. Department of Energy (DOE), and other agencies coordinate efforts to conduct research related to geologic carbon sequestration. The USGS has unique expertise needed to understand the injection of CO₂ into saline

formations, as well as provide baseline information in order to understand potential seismicity induced by sequestration activities. As geologic carbon sequestration implementation begins, Interior land and resource managers will need this research and subsequent assessments to plan for future leasing activity and the Environmental Protection Agency (EPA) will use it to better predict and inform the permitting process. The DOE uses products from this USGS research in their Annual Energy Outlook predictions and as a foundation to plan future CO₂ storage projects. All of this work aligns with a 2012 National Research Council Report (http://www.nap.edu/catalog.php?record_id=13355) that recommended that the USGS work with other government and private agencies to collect new data to better understand the risks associated with injection of CO₂ into deep saline formations.

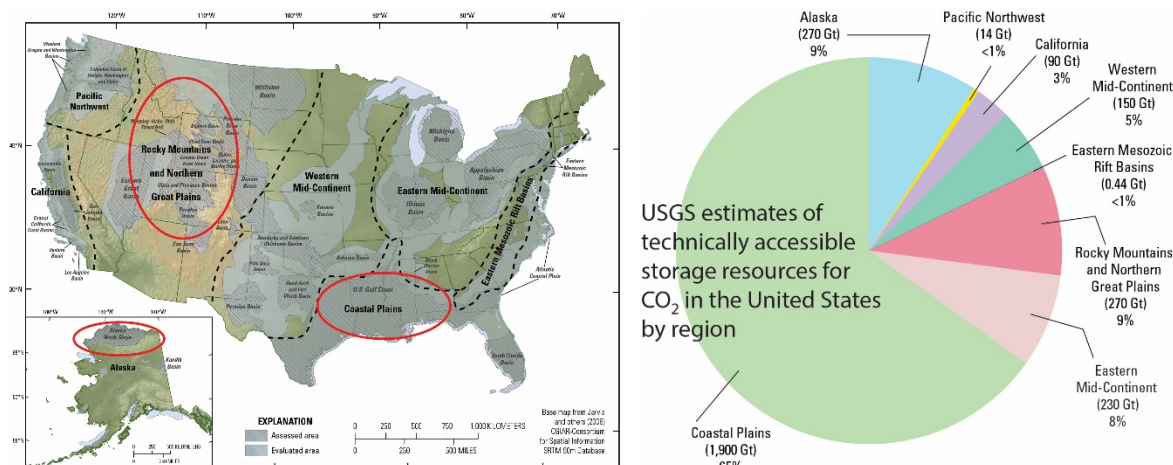
The EISA also requested the USGS to evaluate the national technically recoverable hydrocarbon resources resulting from underground injection and storage through CO₂-enhanced oil recovery (CO₂-EOR). Anthropogenic CO₂ captured from industrial sources is currently being used to recover oil from some reservoirs. The utilization and storage of captured CO₂ helps to decrease the carbon footprint of the produced oil. In 2014, the geological carbon sequestration project developed an assessment methodology and plans to conduct a national assessment of the volumes of recoverable soil and resulting in CO₂ storage associated with CO₂-EOR in the next three years. The project also conducts research to better define the geologic controls on CO₂ storage in geologic reservoirs.



Cover of the National Assessment of Geologic Carbon Dioxide Storage Resources-Results, Circular 1386, Version 1.1, September 2013
Source: USGS

In 2010, the USGS published an assessment methodology (<http://pubs.usgs.gov/of/2010/1127/>) to estimate carbon sequestration-storage potential suitable for uniform application to geologic formations throughout the United States. The USGS methodology, a unique, robust approach to assessing the CO₂ storage potential of individual storage assessment units in sedimentary basins, is a geology-based, probabilistic methodology. The International Energy Agency and representatives from multiple international geological surveys endorsed the methodology and recommend that regional-scale assessment of geologic CO₂ storage capacities should follow the USGS methodology. The results of the USGS national CO₂ storage assessment, which were released in 2013 (<http://pubs.usgs.gov/circ/1386/>), reported that the United States has 36 underground basins that could store 3,000 metric gigatons of CO₂. Those resources could be used by carbon-capture technology applied to coal-fired power plants and other industrial CO₂ sources to reduce carbon emissions. For comparison, the U.S. Energy Information Administration reports that the United States

emitted 5.4 metric gigatons of energy-related CO₂ in 2014. Although the potential for sequestration described in this assessment is unprecedented, injecting CO₂ into geologic formations is not a new process or technology. CO₂ injection has been one method used in enhanced oil recovery since the 1980s. This study provides new information needed for the potential management of CO₂ by various means. Project activities in 2015 focused on the completion and publication of scientific reports that (1) describe the geologic models that formed the basis of the national CO₂ storage assessment, and (2) provide a summary of general land ownership and Federal lands overlying assessed storage areas.



The regions with the largest technically accessible storage resources (circled) are the Coastal Plains (mostly in the U.S. Gulf Coast), Rocky Mountains and Northern Great Plains, and Alaska (mostly North Slope).

In 2015, the geologic carbon sequestration project published 17 USGS reports and journal articles that describe various aspects of geological storage of CO₂. Significant among these reports include a USGS report that delineates CO₂ storage resources underlying Federal lands (<http://dx.doi.org/10.3133/sir20155021>). The report identifies about 130 million acres (or about 200,000 square miles) of Federal lands that overlie potential geologic CO₂ storage resources. Other significant journal articles were published that describe the results of USGS surface monitoring of microseismicity at the largest CO₂ sequestration demonstration site in the United States, located at Decatur, IL, (<http://dx.doi.org/10.1785/0220150062>) and CO₂ retention values associated with enhanced oil recovery (<http://dx.doi.org/10.1016/j.petrol.2015.03.012>). In addition, the geologic carbon sequestration project completed a national geologic and engineering database of oil reservoirs that are amenable to CO₂-EOR and a methodology to estimate the volume of technically recoverable oil from these reservoirs by injecting CO₂ for enhanced oil recovery. The Helium Stewardship Act of 2013 (P.L. 113-40) requested that the USGS work with the BLM to assess the availability of technically recoverable natural helium and CO₂ found in many natural gas reservoirs. In collaboration with the BLM, project scientists worked to build a combined natural gas geochemistry database that can be used to assess the occurrence and distribution of naturally occurring helium and CO₂ in natural gas reservoirs in the United States. Naturally occurring helium is used in industrial, research, military and national security applications, and natural CO₂ is primarily used in enhanced oil recovery operations. Likely, a mix of CO₂ from both anthropogenic and natural sources will be used to recover remaining hydrocarbons. Estimates of the remaining subsurface accumulations of natural CO₂, and their geographic distribution, will aid in determining how much anthropogenic CO₂ will need to be captured for ongoing and future enhanced oil recovery operations. The national resources of recoverable natural helium and CO₂ in the United States are poorly defined and estimations are planned to coincide with industrial CO₂ evaluations. Cooperative data industry sharing agreements were developed in 2014 and 2015 to allow project and industry scientists to evaluate gas geochemical data that can be used to evaluate natural helium and CO₂ resources in the United States.

In 2016, the geologic carbon sequestration project initiated a three-year national assessment of recoverable hydrocarbons resulting from CO₂-EOR in potential storage reservoirs in the United States. Reports describing the database and the methodology used during the assessment are planned for publication during 2016. Research reports are planned on the U.S. midcontinent region that characterizes variations in reservoir temperature and pressures and how these would relate to CO₂ injectivity and storage. In addition, a database and report on the Nation's natural helium and associated CO₂ resources is planned for 2016. The USGS continues to develop economic assessment methodologies in 2016 to evaluate the results of both the 2013 national geologic carbon sequestration assessment and the national assessment of recoverable hydrocarbons resulting from carbon sequestration associated with CO₂-EOR. Research activities continued on the potential impacts of induced seismicity on storage of CO₂ and the identification of the controls on geologic CO₂ storage, and issues related to storage of CO₂ in unconventional reservoirs (primarily coal).

In 2017, the geologic carbon sequestration project would continue efforts on assessing the volume of oil that will be produced during CO₂-EOR operations, as well as the amount of CO₂ that will be stored as a result. In addition, focused detailed geologic studies of reservoirs and seals in selected basins with high potential for carbon sequestration or that have demonstrated capacity to trap naturally occurring CO₂ are planned as more information is needed on geological formations to ensure safe and long-term storage of CO₂. Other research activities would continue on the potential impacts of induced seismicity on storage of CO₂ and the identification of the controls on geologic CO₂ storage, and issues related to storage of CO₂ in unconventional reservoirs (primarily shale). The USGS would also work with government and industry partners to investigate the effects of subsurface CO₂ injection on water and rock chemistry in the process of enhanced oil and gas recovery or geologic carbon sequestration, as well as in CO₂ that occurs naturally in subsurface reservoirs, as very little is known about the chemical effects of injecting high pressure, liquid CO₂ into the subsurface.

Science Collaboration

The Carbon Sequestration Program collaborates with other Interior bureaus (such as Fish and Wildlife, Bureau of Land Management, National Park Service) and Federal agencies (such as Department of Energy, the National Oceanic and Atmospheric Administration, Forest Service) and numerous State, academic, non-governmental organizations, and industrial partners. The Carbon Sequestration Program provides these partners with the unbiased, objective, and impartial scientific information required to make informed decisions on carbon sequestration options. These partners choose to work with the USGS and, in particular, the Carbon Sequestration Program because of its broad, interdisciplinary expertise; rigorous set of protocols (USGS Fundamental Science Practices); innovative monitoring technology, models, and research tools; and robust data management and delivery systems and the programs diligent efforts towards improved carbon stewardship.

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Activity: Climate and Land Use Change

Subactivity: Land Use Change

Program Element: Land Remote Sensing Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Climate and Land Use Change	\$135,975	\$139,975	\$304	\$31,165	\$171,444	\$31,469
<i>FTE</i>	<i>388</i>	<i>388</i>		<i>29</i>	<i>417</i>	<i>29</i>
Land Use Change	\$78,386	\$82,686	\$156	\$25,599	\$108,441	\$25,755
<i>FTE</i>	<i>198</i>	<i>198</i>		<i>15</i>	<i>213</i>	<i>15</i>
Land Remote Sensing Program	\$67,894	\$72,194	\$113	\$24,199	\$96,506	\$24,312
<i>FTE</i>	<i>145</i>	<i>145</i>		<i>9</i>	<i>154</i>	<i>9</i>
Science Research and Investigations	\$14,557	\$14,557		\$6,599	\$21,156	\$6,599
<i>Big Earth Data: Data Cube</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$600]</i>	<i>[\$600]</i>	<i>[\$600]</i>
<i>Critical Landscapes: Arctic</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,857]</i>	<i>[\$1,857]</i>	<i>[\$1,857]</i>
<i>Landsat Science Products for Climate and Natural Resources Assessments</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$2,992]</i>	<i>[\$2,992]</i>	<i>[\$2,992]</i>
<i>Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$500]</i>	<i>[\$500]</i>	<i>[\$500]</i>
<i>WaterSMART: Drought</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$250]</i>	<i>[\$250]</i>	<i>[\$250]</i>
<i>WaterSMART: Remote Sensing</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$400]</i>	<i>[\$400]</i>	<i>[\$400]</i>
Satellite Missions	\$53,337	\$57,637		\$17,600	\$75,237	\$17,600
<i>Landsat 9</i>	<i>[\$0]</i>	<i>[\$4,300]</i>		<i>[\$15,400]</i>	<i>[\$19,700]</i>	<i>[\$15,400]</i>
<i>Sentinel-2</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$2,200]</i>	<i>[\$2,200]</i>	<i>[\$2,200]</i>

Justification of Program Change

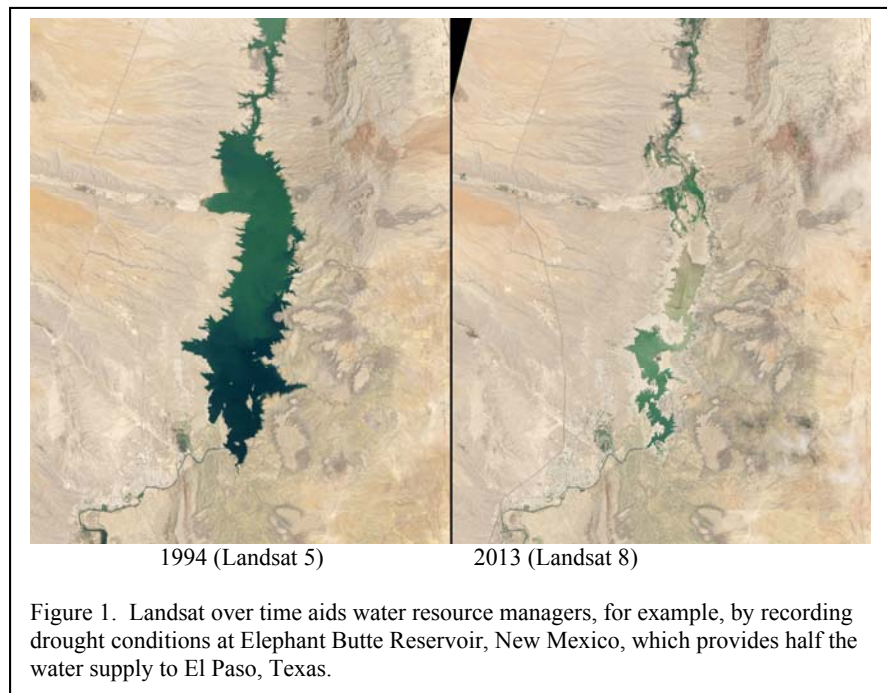
The 2017 Budget Request for Land Remote Sensing is \$96,506,000 and 154 FTE, a net change of +\$24,312,000 and +9 FTE from the 2016 Enacted level.

Overview

The fundamental goals of the Land Remote Sensing (LRS) Program are to provide a comprehensive, impartial record of conditions across the planet's land surface, to support Earth science studies, and to be a leader in defining the future of land remote sensing (<http://remotesensing.usgs.gov/>). The LRS Program collects, processes, and provides the Nation with digital land-surface images acquired by satellite and airborne sensors. All USGS-owned images and derived information products are available via the Internet under a free and open data-access policy (<http://eros.usgs.gov/find-data>). USGS-provided image

products are used in all 50 States and 185 foreign countries for scientific research and natural resource monitoring and management, such as: forest health, wildfire recovery, effects of drought on water supply (Figure 1), flood and other disaster recovery, education, agricultural production, and creating commercial geospatial products and services. Operational elements of the LRS program, including satellite operations and image data collection, archiving, processing, and distribution are performed by the USGS Earth Resources Observation and Science (EROS) Center near Sioux Falls, SD. In its National Satellite Land Remote Sensing Data Archive, EROS houses more than 6 million Landsat satellite scenes acquired globally since 1972. In its Long Term Archive for aerial photos and geospatial data, EROS houses over 6 million high-definition aerial mapping photos of U.S. sites, some dating to 1939.

The LRS Program also provides Federal civil agencies with access to classified Earth observation images and supports the development of unclassified information products derived from such imagery through the National Civil Applications Program (NCAP)/Civil Applications Committee (CAC). Under USGS's Science Research and Investigations component, the LRS Program continues to lead the operational testing and evaluation of unmanned aircraft systems



(UAS) technology in support of many of Interior's activities. Other LRS Program science includes research in improving accessibility to land cover data through the Land Change Monitoring, Assessment, and Projection (LCMAP) initiative; and development and release of provisional climate data records for land surface temperature, burned area, and dynamic surface water extent for stakeholder evaluation.

Finally, the LRS Program is substantially engaged in advancing international policy on Earth Observations. This includes dedicated staff involvement with:

- *The International Charter for Space & Major Disasters*, whose members manage a large constellation of earth-observing satellites that can respond quickly when called upon by emergency management authorities (<https://www.disasterscharter.org>).
- *Group on Earth Observations (GEO)*, a voluntary partnership of 99 nations and the European Commission that envisions “a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations and information” (<http://www.earthobservations.org>).

- *Committee on Earth Observation Satellites (CEOS)*, which ensures international coordination of civil space-based Earth observation programs and promotes exchange of data to optimize societal benefit and inform decision making for securing a prosperous and sustainable future for humankind. The USGS will chair CEOS in 2016-2017 (<http://ceos.org/>).

In 2017, the LRS Program is requesting an increase of \$17,600,000 to continue working on the Landsat 9 mission with the National Aeronautics and Space Administration (NASA); and acquire, store, and disseminate the information from the European Space Agency’s (ESA) Sentinel-2 satellite. Additional increases support WaterSMART activities, including collaborative work that will use remote sensing data to help the National Climate Change and Wildlife Science Center Program to investigate the relationship between drought and climate change on wildlife populations and their food sources; Arctic activities, including the development of predictive models, which support the evaluation of changes to the environment resulting from the conversion of permanently sequestered ice and snow to liquid and gaseous water; and collaborative work with the Land Change Science program to develop new datasets to support coastal land change analysis for improved coastal resource management and resilience planning.

Program Performance

The LRS Program has three components: (1) Satellite Operations, (2) Science Research and Investigations, and (3) National Civil Applications Projects.

Satellite Operations

(2015 Actual, \$53.3 million; 2016 Enacted, \$57.6 million; 2017 Request, \$75.2 million)

End-to-end satellite operations conducted by the USGS/EROS Center involve many space- and ground-based subsystems and processes. For example, ground controllers send commands to Landsat satellites to perform orbit-keeping functions, such as brief thruster burns to maintain orbital altitude and direction. The EROS ground system crew operates 20 hours each day, seven days a week monitoring data recorder and downlink-transmitter performance; checking battery current strength; calibrating sensors; repositioning solar panels, as necessary; and commanding remote-sensing instruments to collect and record or transmit images. The EROS ground receiving station captures raw image data downlinked from satellites, then pre-processes, quality checks, and posts satellite images (or “scenes”) for user preview and retrieval via the Internet.

“...at Planet Labs [developer of CubeSats] we consider ourselves to be in partnership with the civil government earth observation community every day. For example, we use Landsat 8 data for many critical purposes...NASA [USGS] and NOAA provide a critical foundation for our activities, and without their publically available data, we would be significantly challenged to accomplish our goals. Moreover, the longitudinal history and reliability of these systems are key for industry to prosper, and for scientists to discover greater understanding of our planet.” **Mr. Robbie Schingler (co-founder Planet Labs)** Congressional Testimony for Subcommittee on Space and Subcommittee on Environment Hearing - Exploring Commercial Opportunities to Maximize Earth Science Investments, November 17, 2015.

Once the USGS opened its entire Landsat collection, with more than 40 years of continuous data, to free and open access in late 2008, user volumes increased exponentially, from approximately 21,000 scenes distributed per year to over 13 million in fiscal year 2015. Free Landsat data, used in combination with

today's advanced Geographic Information System processing software and powerful desktop computers, enables individual users to download dozens or even hundreds of scenes for a single land management or research project. For example, many historical images of a single site can now be obtained and analyzed for land-surface change over time, or a user can simultaneously see and analyze current land-cover or land-use conditions across an entire State or larger region. Moreover, the burgeoning "small sat" (e.g., CubeSat) industry, e.g., Planet Labs, relies on civil satellites for calibration of their own assets, as well as recognizing the value of a long-term (longitudinal) archive over time to augment their collections (see box insert).

Since 1972, Landsat satellites have provided the only continuous, authoritative global record of changes to the Earth's land surface at a scale allowing the differentiation between natural and human-induced change. Under the Land Remote Sensing Policy Act of 1992, and associated Presidential Decision Directives, Interior and the USGS share responsibility for Landsat program management with NASA. Within this successful partnership, NASA develops and launches Landsat satellites while the USGS develops the associated ground systems and, following launch and on-orbit checkout by NASA, assumes ownership and operation of the satellites. Further, the USGS manages and maintains the data stream produced by the Landsat satellites and makes data products available to support decision makers (<http://landsat.usgs.gov/>).

In 2014, the National Science and Technology Council released a "National Plan for Civil Earth Observations" (http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/national_plan_for_civil_earth_observations_-_july_2014.pdf). In preparation for the plan, a government-wide task force conducted a comprehensive assessment of 362 space, airborne, terrestrial (including fresh water), and marine Earth observation systems. Each was ranked for its impact on 13 societal benefit themes. Landsat ranked third highest overall and second among all satellite systems, behind only GPS. The report also stated, "The NASA Administrator, together with the Secretary of the Interior and through the Director of USGS, will implement a 25-year program of sustained land-imaging for routine monitoring of land-cover characteristics, naturally occurring and human-induced land-cover change, and water resources, among other uses. They will also ensure that future land-imaging data will be fully compatible with the 42-year record of Landsat observations." An updated Earth observation assessment is currently underway, with a new National Plan slated for completion and release in 2017.

Landsat 7 and 8 Operations

The USGS continues to conduct flight operations for Landsat 7 and Landsat 8, typically collecting over 1,000 scenes (each over 12,000 square miles) per day. These scenes include spectral data ranging from visible to near infrared to shortwave infrared to thermal infrared for any location on the Earth's land surface every eight days. With the recent advent of commercial cloud storage and computing services, vendors such as

Half a Year, Half a Billion Landsat Image Inquiries --

On March 19, 2015, Amazon Web Services (AWS) announced that it was hosting Landsat 8 imagery. AWS started with over 85,000 scenes and has been adding at the rate of 700 per day from USGS. On November 9, 2015, at the #SatSummit meeting in Washington, D.C., AWS's Jed Sundwall stated that in the first 5 months, over 500 million inquiries had been received worldwide. In AWS' March Blog, Mr. Sundwall stated, "Because of Landsat's global purview and long history, it has become a reference point for all Earth observation work and is considered the gold standard of natural resource satellite imagery."

Amazon Web Services Blog, March 2015

Amazon, Google, and ESRI, are offering new access points to Landsat data (see box inset), which greatly extends its use potential.

Landsat 7, launched in 1999, continues to collect valuable data, though with 22 percent data gaps in each scene due to an equipment failure in 2003. Now more than a decade beyond its design life and operating on back-up systems that could fail at any time, Landsat 7 has enough fuel remaining to maintain its precise orbit and imaging functions into 2020. The USGS is exploring options for extending imaging cycles into 2021 before decommissioning the satellite. Landsat 8, launched in 2013 with a five-year design life and ten years of fuel for the satellite and its primary sensor, and a three-year design life for its thermal sensor (a key tool used for water management, especially agricultural irrigation consumption).

Landsat 7 collects roughly 475 new scenes per day and Landsat 8 collects approximately 725 new scenes per day. Combined, the pair enables eight-day revisits for site-specific images. Landsat is the only operational civil satellite with both thermal and shorter-wavelength sensors – which are used extensively in water and agricultural management, enabling users to measure water use and monitor crop results in arid lands; discriminate moisture content of soils and vegetation; and estimate heat units in urban areas, among other emerging applications.

Landsat 9 Development

Landsat 9 is the critical follow-on mission to Landsat 8, and direct replacement for Landsat 7, ensuring the continuation of the four-decade collection of Landsat multi-spectral imagery across the Earth's land surfaces, supporting near-weekly Landsat revisit for hundreds of land cover applications supporting tens of thousands of research and operational users across the Nation. Landsat 9's sensors will have the ability to detect more variation in intensity than previous Landsat 1-7 satellites. Landsat 9's Thermal Infrared Sensor (TIRS) design will be more robust and resilient than the comparable TIRS instrument on Landsat 8. Landsat 9 is being developed and operated through an interagency agreement annex established between NASA and DOI USGS. The responsibilities for Landsat 9 project implementation are largely divided between mission segment areas. NASA is responsible for the development of the space segment and launch segment, and DOI USGS is responsible for the development of the ground segment. DOI USGS is responsible for satellite mission operations after completion of the on-orbit checkout period, including image-data collection, management, and distribution. The Landsat 9 project scope includes overall project management and system engineering for the ground segment development, including coordination with NASA for overall mission development and science coordination. The ground segment activities consist largely of the evolution of the current Landsat ground system capabilities necessary to support Landsat 9. When designing Landsat missions, the USGS and NASA work in close partnership to assess user requirements and advances in technology, review mission need in light of prior performance, and establish scientific objectives and instruments.

Landsat 9 Launch Date. NASA and the USGS are working towards anticipated launch date of 2021 for Landsat 9. The proposed request of an additional \$15.4 million for USGS, for a total of \$19.7 million in 2017 is necessary to meet a 2021 launch date to develop and deliver the Landsat 9 ground system in time. The 2021 launch date is critical for Landsat 9 to replace Landsat 7 *without a break* in near-weekly revisit data collection. The total project cost for the USGS ground systems portion of Landsat 9 is estimated at

\$118 million through the 2021 launch date. This amount is in addition to costs for ongoing satellite operations.

Sentinel-2 Data Acquisitions – To meet the increasing demand for more frequent observations in support of operational applications, including monitoring of global crop production and the mapping of natural resource features, the USGS is developing the capability to acquire, store and disseminate data from the European Space Agency's (ESA's) Sentinel-2 satellites (Sentinel-2A, launched in June 2015 and Sentinel-2B, scheduled for a 2016 launch). The Sentinel-2 data should augment land observations over any one spot on the Earth's surface to just three days, as long as two Sentinel-2s and two Landsats are operating. Also, Sentinel-2 data may partially mitigate any possible loss of eight-day revisit coverage during the potential gap between the decommissioning of Landsat 7 and the launch and operations of Landsat 9.

Requirements Collection to Develop the Best Products and Services for our User Communities – The LRS Program is partnering with Federal agencies to document the uses of and requirements for Earth observation data, and develop an analytical infrastructure to map these requirements to a range of Earth observing systems that can meet them. The purpose of this activity is to assist the USGS and the LRS Program in developing Earth observation (EO) products and services that best meet the needs of its user communities. The information will also be used to help inform the development of future land imaging satellite missions, such as Landsat 10 or a Landsat Next Generation satellite, and will be leveraged by other Federal activities intended to improve the management of the Nation's Earth observation assets. This work is incorporated within the LRS Program's Requirements Capabilities and Analysis for Earth Observations (RCA-EO) project (<http://remotesensing.usgs.gov/rca-eo/>).

In 2015, the LRS Program:

- Continued flight operations for both Landsats 7 and 8; maintaining on-orbit health of both satellites while continuing to acquire, process, and distribute scenes at record levels;
- Continued to efficiently manage fuel reserves for Landsat 7
- For the Landsat 9 mission:
 - Established the Landsat 9 Project & selected the USGS Project Manager.
 - Coordinated initial NASA/USGS project formulation documentation & timeline.
 - Developed initial roadmap to Mission Definition Review.
 - Defined USGS roles, responsibilities, and associated project staffing.
 - Defined Work Breakdown Structure (WBS) of task performance.
 - Established project management processes and tools (Risk, Configuration Management, monthly reporting).
 - Initiated the Risk Management Board and performed initial risk identification.
 - Supported NASA spacecraft and instrument studies.
 - Performed an Enterprise Ground System study.

- Developed Acquisition Strategy to include the USGS Mission Operations Center.
- Updated project cost estimates.
- Identified USGS candidate Review Board members.
- Invested in hardware to support the collection and storage of Sentinel-2A and 2B data, including online image-data storage for product dissemination and tape media for both near-line and backup storage. The USGS worked with ESA to have access to sample Sentinel 2A datasets for evaluation.
- Collaborated with NOAA to jointly develop supporting-information infrastructure – the Earth Observation Requirements Evaluation System (EORES). The LRS Program has collected information about the usage of EO data supporting USGS products, services, and research activities, including space-borne, airborne, surface and subsurface sensors and platforms. The RCA-EO project engaged over 500 subject-matter experts in the USGS to evaluate the impact of EO systems on 345 key USGS products and services. Early analysis of these data focused on the relative comparison of how well key land imaging systems support USGS products and services. The USGS also began working with NOAA and other agencies to support the Administration’s Office of Science and Technology Policy (OSTP) Earth Observation Assessment 2016 (EOA 2016), to support a national assessment of the benefits of Earth observations to 13 societal benefit areas. The RCA-EO EORES is the home of the EOA information and will be used to support current and future Federal EO benefit assessments in accordance with OSTP’s National Plan for Civil Earth Observations.
- Supported the USGS Social and Economic Analysis Branch in Fort Collins, CO, to conduct research on demonstrating the benefits of freely provided Landsat imagery to the private sector, which included:
 - Amazon Web Services
 - MapBox (cloud based mapping)
 - E&J Gallo (largest privately owned winery in the United States)
 - Planet Labs (small satellite imagery provider)
 - Digital Globe (satellite imagery provider)
 - Silvia Terra (forest management start-up)
 - BlackBridge (satellite imagery provider)

For the Landsat 9 mission in 2016, the LRS Program will focus on mission systems engineering support of space segment requirements and design reviews for the operational land imaging and thermal infrared instruments. The USGS will perform ground system formulation activities including refining requirements and system design, and procurement of data processing, ground network, and mission operations center initial software and hardware capabilities. Finally, the USGS will perform project management, systems engineering, and software engineering for initial flight systems and data processing software releases in preparation for the Mission Definition Review.

In 2016, the LRS program will operationalize acquisition and archiving of Sentinel-2 data from the ESA data hubs, extend the product offering to include a full-resolution browse, and disseminate the data through the USGS EarthExplorer user portal. An ESA International Data Hub product-distribution portal will be completed in 2016, and with it, the USGS will have a definitive understanding of Sentinel data access and services, allowing its own system design to be finalized. ESA is expected to begin public dissemination of Sentinel 2B data before the end of the year.

In 2017, for the upcoming Landsat 9 mission, the LRS Program will:

- Lead the Ground System Requirements Review.
- Release the Mission Operations Center Request for Proposal.
- Perform the Landsat 9 Ground Network Element Heritage Review.
- Perform the Landsat 9 Data Processing & Archive System Heritage Review.
- Prepare for Ground System Preliminary Design Review.
- Prepare for Mission Preliminary Design Review.

In 2017, the final Sentinel-2 capability at the USGS will be implemented, moving into an operational footing to continue to acquire, store and disseminate Sentinel-2 data in a manner consistent with Landsat data distribution, enabling Landsat users to more easily use this new data in tandem with Landsat for their applications.

In 2016 and 2017, the LRS Program will be collecting more detailed land imaging requirements associated with USGS and other civil agency products and services. The findings will support refined analyses for product and service portfolio management and related investment decisions and inform the ongoing development of a Sustainable Land Imaging (SLI) capability being established by the NASA and the USGS. The LRS Program will also help OSTP complete the 2016 Earth Observation Assessment and perform other studies to evaluate potential gaps for emerging remote sensing technology and new sensor development.

2017 Program Change

Landsat 9 (+\$15,400,000) for a total of \$19,700,000: The proposed increase is to develop the Landsat 9 ground system and deliver the completed system in time to support accelerating the launch date to 2021, as is currently being planned by both NASA and the USGS. A 2021 launch date for Landsat 9 would replace Landsat 7 in time to prevent a break in the eight-day revisit data collection. In order to meet a 2021 launch target, an additional \$15.4 million for USGS is required in 2017 above the \$4.3 million received in 2016. This increase would be applied to the following areas of Landsat 9 development in 2017:

- (1) Mission Systems Engineering support for Landsat 9 instrument development activities and reviews, supporting the two primary instruments on Landsat 9: the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS).

2017 Program Change

- (2) Landsat 9 instrument calibration and validation engineering activities.
- (3) Support and evaluation of spacecraft competitive studies and spacecraft contract award.

In addition, the USGS would apply the increased funding to Landsat 9 ground system activities in 2017. Landsat 9 is the critical follow-on mission to Landsat 8, and direct replacement for Landsat 7, ensuring the continuation of the four-decade collection of Landsat multi-spectral imagery across the Earth's land surfaces, supporting near-weekly Landsat revisit for hundreds of land cover applications supporting tens of thousands of research and operational users across the Nation.

Sentinel-2 (+\$2,200,000) for a total of \$2,200,000: The proposed increase would allow the USGS to increase earth observation satellite data repositories by acquiring, storing, and disseminating the information from the European Space Agency's (ESA) Sentinel-2 satellites. ESA launched the Sentinel-2A satellite in 2015 and plans to launch the Sentinel-2B satellite in 2016. In addition, making Sentinel-2 data available through the USGS may partially mitigate the risk of a gap in data from the loss of either Landsat 7 or Landsat 8. This investment provides the many governmental, commercial, and other users with the confidence that USGS will continue to provide the data they rely upon, in the formats they use, rather than reliance upon an uncertain European distribution system with accompanying issues of lesser priority, less data throughput, and longer data delay times. Through the summer of 2016, and possibly longer, ESA plans to collect Sentinel-2 data over North America once monthly. In the longer term, however, Sentinel-2 data is expected to substantially augment Landsat data, increasing the possible revisit over any one spot on the Earth's surface to just three days, as long as two Sentinel-2s and two Landsats are in orbit at the same time. This frequency of revisit will help the USGS satisfy the increasing demand for rapid revisit required by operational applications, like global crop monitoring and the monitoring of natural resources and features such as forests, sea ice, snow cover, wildfires, and surface water

Science Research and Investigations

(2015 Actual, \$14.6 million; 2016 Enacted, \$14.6 million; 2017 Request, \$21.1 million)

The LRS program conducts and sponsors research in remotely sensed land data collection, access, distribution, and applications. The program is seeking new ways to make remotely sensed data products more accessible and to enhance the overall use of remotely sensed data and emerging technologies. Below are examples of ongoing remote sensing research that will continue in 2016 and 2017.

Unmanned Aircraft Systems (UAS) Applications – On behalf of Interior and its bureaus, the LRS Program continues to lead the demonstration and implementation of UAS technology to support many of the Interior's activities. UAS technology, typified by relatively small, remotely controlled aircraft capable of carrying various types of miniaturized land-imaging sensors, can enable increased monitoring of Earth surface processes (surface water dynamics, groundwater surveys, agricultural tile line surveys, coastal erosion, coastal cliff morphology, paleo-wetland surveys, fault line surveys, microclimate studies, Asian carp, waterfowl, and sea turtle surveys, etc.) in areas difficult to access, and at lower human risk and at lower cost than traditional methods using piloted aircraft or ground exploration methods. All

Interior UAS missions are flown in full compliance with Federal laws and Interior policies and procedures. Working with Interior and through partnerships with NOAA, NASA, and others, the USGS has completed numerous proof-of-concept missions to determine this technology's utility in meeting Interior's current and future Earth observation requirements (<http://uas.usgs.gov>).

Land Change Monitoring, Assessment, and Projection (LCMAP) – LCMAP represents the next revolution in measuring and projecting land change for decision makers. Newly realized “big data” cloud computing capabilities have sufficiently matured to unlock the time series modeling power of the Landsat data record (going back to 1972) in ways that were simply not feasible only a few years ago. It is designed to provide the foundation for Federal land change monitoring activities and is being conducted in partnership with U.S. Federal agencies and universities. There are several elements to the LCMAP concept: (1) analysis ready data (ARD) that have been processed to the highest level of radiometric and geometric quality, allowing streamlined implementation to the user community; (2) a continuous change detection and classification (CCDC) algorithm to generate annual land cover and land change products, from 1985 (initially) through 2015; (3) assessments of the drivers and consequences of changes in land cover state and conditions; (4) projections on where future landscape change is likely to occur based on scenarios land use change and climate variability; (5) an information warehouse and data store which serves as a central repository for the ARD, land change products, and the results of land change assessments and projections; (6) information access and delivery services; and (7) scientific communication and community outreach. This requires developing and implementing new ways to efficiently store and process Landsat time series data, as well as enabling users to extract desired information without having to move large volumes of data.

Landsat Science Products for Climate and Natural Resource Assessments – The Landsat archive provides a record of global observations from 1972 to the present and will continue doing so into the future. The USGS is capitalizing on this valuable time series to derive science data and information products that can be used to document changes to the Earth's terrestrial environment. These products provide an authoritative basis for regional to continental scale identification of historical change, monitoring current conditions, and helping to predict future scenarios so that the impact of such changes can be understood; this, in turn, provides strategies for adaptation and mitigation that can be developed for implementation. These data sets include climate data records (CDRs) which are long-term, time-series measurements such as surface reflectance and surface temperature that support a variety of essential climate variables (ECVs), which include measures of fire disturbance, snow cover, permafrost, surface water extent, land cover, and biomass. The user communities of these products are varied, including the Interior bureaus, and require reliable reporting and consistent processing of these climate data to generate a 30-year record for inclusion in their scientific analyses and products.

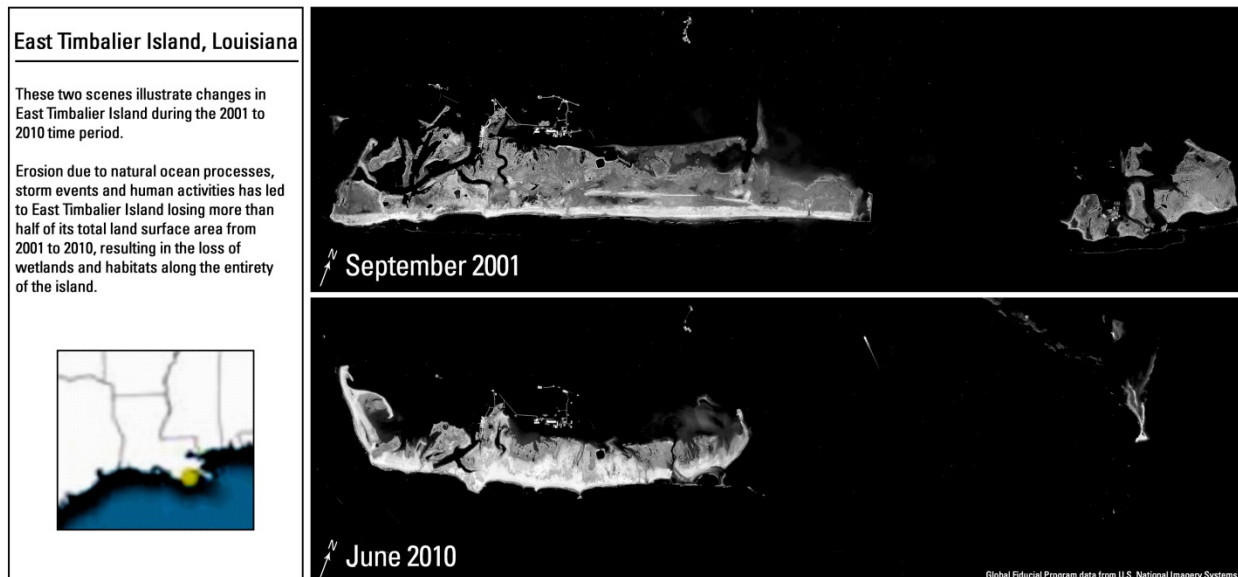
AmericaView – As the recipient of a multi-year competitive award under the LRS Program, AmericaView (www.americaview.org) is a nationwide, university-led consortium of remote sensing scientists who support the use of Landsat and other public domain remote sensing satellite data through applied remote sensing research, K-12 and higher STEM education, workforce development and technology transfer. AmericaView continues to focus on remote sensing high impact projects within the 40 participating States, including activities such as enhancing Landsat data retrieval and delivery through expanded local nodes; expanding undergraduate online remote sensing courses; and introducing students

to remote sensing by showcasing the Landsat mission and the many uses of satellite imagery in addressing some of today's most challenging societal and environmental issues.

Civil Applications Projects – Data from classified geospatial intelligence (GEOINT) systems and commercial satellites are used to investigate climate change and other Earth dynamics, ecosystems, natural hazards, manmade disasters such as wildfires, and improve land and resource management. This activity is managed through the National Civil Applications Project (NCAP).

A Presidential Directive established the Civil Applications Committee (CAC) in 1975. Interior was charged with forming a coordination and oversight committee, and delegated the role of chairing the CAC to the USGS. The 2010 National Space Policy specifies that Interior/USGS has the role to provide environmental and disaster remote sensing information acquired from national security space systems to civil government agencies. For example, U.S. volcano monitoring efforts in Hawaii are significantly enhanced by access to classified imagery. The United States and its territories contain 169 geologically active volcanoes, of which 54 volcanoes are a very high or high threat to public safety. Remote sensing forms a core monitoring dataset at Kīlauea volcano in Hawaii, which is one of the best-monitored volcanoes in the world. Additionally, NCAP in conjunction with the Earth Resources Observation Systems (EROS) Center tasks commercial imagery satellites, under the auspices of the International Charter for Space and Major Disasters, to support disaster relief worldwide, such as the 2015 Ghurka earthquake in Nepal.

Global Fiducials Library – Sponsored by the CAC and executed by the NCAP, Global Fiducials are comprised of declassified National Technical Means imagery dating from the mid-1990's through the present. A fiducial is a precisely located reference point on a map. Global Fiducials are selected locations used for long-term study of Earth change processes. Sites are chosen to study the effects of five Earth Science processes: Ocean, Estuary, and Inland Aquatic Processes; Ice and Snow Dynamics; Atmospheric Processes; Terrestrial and Surface Processes; and Geologic Processes. There are over 150 Global Fiducial sites available to the scientific community and the public (gfl.usgs.gov). The Figure below demonstrates change over time due to erosion using declassified National imagery.



In 2015, the LRS Program:

- Published the UAS Roadmap, which provides operational procedures and lessons learned from completed proof-of-concept UAS missions. This information provides not only an implementation framework but can also help increase the awareness by resource managers, scientists and others of the ability of UAS technology to advance data quality, improve personnel safety, and reduce data acquisition costs.
- Hosted a UAS Workshop involving scientists and leadership from across Federal agencies on current and future opportunities with UAS technology and to introduce them to the challenges and opportunities of UAS technology and the issues surrounding Federal use. The talks covered many topics from coastal mapping using small UAS to measuring shrinking glaciers to UAS applications in resource management to data collection and geospatial data integration. The workshop also provided the over 130 attendees opportunities to discuss possible collaborations. A direct result of the workshop was the selection of proposals from all USGS Mission Areas involving the collection of UAS datasets to support USGS research activities.
- Developed a UAS strategic data management plan and performed a pilot study making UAS datasets available over the Internet. This was the first step toward the goal of integrating these data with other geospatial datasets in order to satisfy Earth science research requirements.
- Purchased several new commercial UAS through an Interior contract. These UAS will take advantage of advances in the design and operation of UAS, which will result in safer, lower risk operations.
- Under LCMAP, completed a science strategy document, a system concept and definition review, and initial project implementation planning activities. Numerous presentations were given to USGS program coordinators, Federal and State agencies, and numerous stakeholder groups.
- Released, for stakeholder evaluation, provisional surface reflectance CDR products derived from Landsat 8 data, and provisional burned area and dynamic surface water extent ECV products from Landsat 4, 5 and 7 data. For submission to peer-reviewed scientific journals, the scientists responsible for these products also prepared manuscripts describing the related science processing algorithms.
- Sponsored the AmericaView activity, a nationwide consortium of remote sensing scientists from 40 States, and hosted their annual conference at the Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD. The scientists shared their remote sensing research, student training techniques, and high impact projects from across the Nation, addressing some of today's most challenging societal and environmental issues.
- Provided support and data for wildfire suppression efforts in the Western United States and Alaska, and damage assessment from natural hazards. The NCAP partnered with the National Geospatial-Intelligence Agency (NGA) to task imagery collection and coordinate post-event scientific analysis of the Gorkha Nepal earthquake. The NCAP sponsored eleven research projects that used classified and commercial GEOINT to address a variety of hazards and climate change issues. The NCAP plans to publish peer-reviewed results in two classified NGA journals.

- Provided support to the Volcano Disaster Assistance Program during the ongoing Sinabung Volcano eruption since 2013. Using National sensors the Volcano Hazards Program provided critical warning information to the Indonesian Government enabling timely evacuations that potentially saved thousands of lives.

In 2016, the LRS Program, under LCMAP, plans to develop the initial base of analysis-ready data for the conterminous U.S. for the years 1985 – 2015, complete annual change analysis and classification for this time period, and compile the necessary reference data with which to characterize the accuracy and uncertainty of the land change products. Development of the information warehouse and data store and data access and delivery services will also commence in 2016, and a workshop will be held with Federal agency and university partners to review the results from land change analyses.

In 2016, the LRS program plans to release provisional land surface temperature CDR products for stakeholder evaluation. The program also plans to release provisional burned area, fraction of snow covered area and dynamic surface water extent ECV products. Several of these products have been selected as indicators of global change and will be released by the US Global Change Research Program at <http://www.globalchange.gov/>. In addition, the LRS Program plans to continue providing exploitation support for the use and integration of fiducial data with multiple data sources to conduct resource assessments, investigation of natural processes and their impacts, and the analysis of natural hazards. LRS will also integrate the Denver Special Applications Science Center (SASC) and the part of the Eastern Geographic Science Center (EGSC) that resides in the Advanced Systems Center (ASC) with the ASC in Reston, Virginia. For the first time, this will consolidate all USGS activities that task and analyze data from classified and commercial satellite systems. This will increase both effectiveness and efficiency through unity of effort.

In 2017, the LRS Program will continue to support UAS applications across the USGS and Interior bureaus through partnerships with NOAA, NASA, and other Federal agencies, universities and commercial UAS service providers. The number and type of applications will continue to increase to support the USGS mission to improve natural hazard forecasting and the analysis of the impacts; improve our understanding of climate change to better plan for likely impacts; develop precipitation and evaporation forecasting to better manage water resources; broaden our abilities to monitor environmental or landscape conditions and changes; and better understand and protect the Nation's ecosystems. The LRS Program will also host the second UAS Workshop, which will continue to introduce scientists and leadership to the challenges and opportunities of UAS technology. Science problems best solved with UAS and emerging opportunities in remote sensing data collection and geospatial data integration will be discussed by USGS scientists and other invited Federal agencies. The LRS Program will investigate new UAS sensors, such as hyperspectral and LiDAR, and working with cooperators like NASA acquire test datasets from small UAS to support scientific investigations. These data, in addition to other UAS data sets, will be archived and made available at the USGS EROS Center where they can be integrated with other remote sensing data.

The LRS Program would expand the LCMAP activities to include Alaska and Hawaii, expand the information warehouse and data store, and extend the development of information access and delivery services. Lessons learned from 2016 activities will be assessed and incorporated into the production of

the next generation of analysis ready data and land change information products. Regional and national scale assessments of land change will be initiated along with scenario-based projections of future land change vulnerabilities and impacts.

In addition, the LRS program would be generating all CDR and ECV products on-demand in routine operations and would begin test and evaluation of these science processing algorithms on sample sites across the globe to determine their robustness for global product development. The scientists responsible for developing these products will have the science processing algorithms documented through peer reviewed journal publications.

Finally, the LRS Program would maintain its civil science leadership of the CAC and assess ways to more effectively use classified assets for hazards, environmental, and natural resources applications, and continue supporting the civil community's requests for releasable GFL data as a sought-after and dependable data source for time series information on sites of interest. The USGS will apply and expand the use of the GFL for the study of global change, environmental health, and other natural processes by building on existing and developing new partnerships that engage a variety of scientists in the integration of fiducials imagery with multiple data sources. In addition, the LRS program would establish an earthquake database for pre- and post-event imagery of earthquake fault changes. The acquisition, archive, and dissemination of classified remotely sensed data to support science programs will be continued. Support for the Volcano Hazard Program and Volcano Disaster Assistance Program will be continued. Finally, under the NCAP Global Fiducials Project, the LRS Program would continue to collect high-resolution images of environmentally sensitive sites for use by cooperating scientists documenting Earth's surface processes and change.

2017 Program Change

Landsat Science Products for Climate and Natural Resources Assessments (+\$2,992,000) for a total of \$2,992,000: The LRS Program would use the requested increase to develop the computing and online storage resources necessary to rapidly produce and widely disseminate a set of Landsat-based information products. The LRS Program has identified and is currently developing a set of Landsat-based science products that will improve applications used by natural resource managers, and will contribute to the international and interagency climate monitoring community's initiative to develop consistent Climate Data Records (CDRs) and related Essential Climate Variables (ECVs). The CDRs are long-term time-series measurements such as surface reflectance and surface temperature that support a variety of ECVs, including measures of fire disturbance, snow cover, permafrost, surface water extent, land cover, biomass estimation, and evapotranspiration modeling. The CDRs and ECVs will provide an authoritative basis for regional- to continental-scale identification of historical change, monitoring of landscape resiliency to changing conditions, and predicting areas that are vulnerable to future changes. The requested increase would enable development of the computing and online storage resources necessary to rapidly generate CDR and ECV products from the historical archive for the conterminous United States and Alaska, to include near-real-time processing of current acquisitions and completion of enhanced data access and delivery services.

Big Earth Data: Data Cube (+\$600,000) for a total of \$600,000: The LRS Program would initiate the development of a pilot study for enhancing Landsat data access and delivery services that would

2017 Program Change

allow the user to define a geographic area of interest, timeframe, and specific parameters derived from the data (e.g., vegetation index) rather than the current scene-based products of prescribed geographic extent and digital numbers provided by the USGS. Today, users are required to perform the framing, subsetting, and extracting information from satellite imagery on their own. The LRS program would prototype these streamlined data access and delivery services to demonstrate the utility and efficiency of direct access to “pixels of interest.” The prototype capability would allow the USGS to demonstrate the ability to extract and create a multi-temporal remote sensing based value-added product(s), or “data cube(s),” which will be “applications ready” for use in support of scientific analysis.

Critical Landscapes: Arctic (+\$1,857,000) for a total of \$1,857,000: The LRS program would use the requested increase for the development of predictive models, which support the evaluation of changes to the environment resulting from the conversion of historically sequestered ice and snow to liquid and gaseous water. Multi-temporal and multi-resolution remote sensing data from satellites and airborne systems (Landsat, Classified Systems, Aircraft, and Unmanned Aerial Systems) would be used in combination with field-based studies and in-situ observations to measure changes of ice and snow volumes and support the development of predictive models describing the impacts from climate-induced changes. Although initial research work to measure the extent of permafrost is currently being conducted, for the first time, this initiative would enable the development of predictive models for permafrost melt, providing the means to prepare local communities across the Arctic for the effects of the thawing land beneath them, while also improving global climate modeling.

Resilient Coastal Landscapes and Communities: Imagery Datasets and Analytical Tools for Coastal Analysis (+\$500,000) for a total of \$500,000: The LRS Program would use the requested funding increase to work with the Land Change Science (LCS) Program and other USGS and interagency partners to develop new datasets to support dynamic coastal land change analyses for improved coastal resource management and resilience planning. The LRS program would support more frequent updates to the National Land Cover Database (NLCD) as the basis for land change information including interim and ongoing monitoring especially after significant storm events. The LRS program would primarily develop datasets that exploit new elevation technologies (to augment 3DEP) and hyperspectral capabilities from various platforms, to include Unmanned Aircraft Systems. The LRS program would provide analytical tools for integrating repeat elevation and spectral data to characterize the impacts of coastal change and severe weather events on terrestrial and aquatic vegetation health, and other features that play a role in coastal resilience and flood inundation. Prototype datasets would be developed for one or two priority areas and made available for peer-review evaluation and for use in sea level rise modeling exercises that will occur within the CMGP and NCCWSC/CSC program. This imagery and the tools described above will provide the most up-to-date assessment of coastal landscapes and communities available, enabling coastal land managers to identify the most vulnerable coastal areas and be better prepared for future storms.

WaterSMART: Drought (+\$250,000) for a total of \$250,000: The LRS program would use the requested increase to work with the NCCWSC and the North Central CSC to investigate the relationship between drought and climate change on wildlife populations and their food sources. Drought-related climate indices and land cover change information would be used to model and predict how drought and climate change are impacting the phenology of animal migration and the forage quality of Western habitats. Current land change datasets and drought products like the Vegetation

2017 Program Change

Drought Response Index (VegDRI) will be evaluated for their adequacy to support management decisions for wide-ranging ungulate (e.g., Mule deer, Big Horn Sheep) populations and key habitats. This collaborative effort would identify gaps in remote sensing data and derivative products, collect new data for model validation, and recommend new methodologies to meet the needs of scientists and decision makers in the conservation and land management communities. VegDRI is an operational drought model and map created weekly and is used by numerous organizations for drought mitigation decision support. VegDRI information will be integrated with the evapotranspiration outputs that the National Water Census is already delivering to the public via the National Water Census Data Portal. The use of these and related capabilities would be extended into the habitat modeling community. This collaborative effort would evaluate current remote sensing data and derivative products such as VegDRI to reliably model land change indicators for projecting drought. Remote sensing data gaps would be identified, and new data sets collected and assembled to enhance model validation. This would allow the development of new methodologies for integrating land change assessment models and drought products with climate driven drought projection models used by NCCWSC to decrease product uncertainties.

Water SMART: Remote Sensing (+\$400,000) for a total of \$400,000: The National Water Census already benefits from the use of remote sensing data and analysis, including Landsat data. In 2017, the USGS would expand work across its land use and water programs to support additional aspects of the National Water Census. The National Water Census is at a place in its development to access operational Landsat products, generated as frequently as every eight days. Several new Landsat-based science products (e.g. dynamic surface water extent) are becoming mature enough to be integrated with the National Water Census.

In the United States, good information on the amount of water in large storage features such as reservoirs and lakes is available. However, there is a significant gap in identifying and quantifying water storage in smaller storage features. These water storage features influence the flow characteristics of streams in each watershed. Understanding and reporting on these features could provide benefit for drought status monitoring, understanding climate variability, and streamflow estimation, particularly in areas without streamgages. Moreover, information on changes in surface water storage is essential in order to accurately estimate the total amount of water in a basin—a central need for the National Water Census.

The increase would support the development of these estimates in a nationally consistent manner, by creating a geo-rectified remote sensing datasets (e.g. dynamic surface water extent) that track changes in the number and size of these surface features within a year and across decades. Detection, documentation and monitoring of temporary water storage features is only feasible through the use of a remote sensing system such as Landsat, which frequently and routinely images the land surface over long periods of time. In a watershed such as the Apalachicola, Chattahoochee, and Flint (ACF) such monitoring would provide an objective and systematic methodology for comprehensively assessing the state of the watershed, allowing multiple political entities to coordinate water usage and management.

Science Collaboration

The LRS Program advances the science and methods for collecting, analyzing, and understanding user needs in order to motivate agility in its product and service portfolio. It establishes and maintains business policies and cooperative support structures that encourage and expand partnerships with Federal, commercial, academic, and foreign cooperators. The program collaborates with many Federal partners, including but not limited to, other Interior bureaus and National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Agriculture (USDA), and the National Geospatial Intelligence Agency (NGA) on remote sensing science; data science business partners; commercial satellite data providers; the Group on Earth Observations (GEO); the Committee on Earth Observing Satellites (CEOS); the European Space Agency (ESA) on data, science, and technology leveraging; Geoscience Australia on Data Cube science; and other foreign remote sensing science cooperators, to expand the understanding of, access to, and value of LRS products and services. Through the Interior Remote Sensing Working Group and other venues, LRS works with various Interior bureaus to better understand their needs for land imaging observations, products and services, and to seek Departmental input on its new products and land imaging initiatives. LRS also leads the development of an annual Interior Remote Sensing Report to highlight and share key remote sensing technology applications that support science and land management across the Department's mission areas <http://eros.usgs.gov/doi-remote-sensing-activities/2015/Home>. Through its various activities and collaborations, the LRS program is helping define the future of land remote sensing.

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Activity: Climate and Land Use Change

Subactivity: Land Use Change

Program Element: Land Change Science

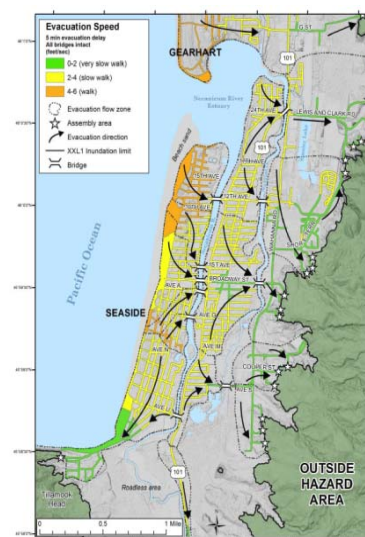
Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Climate and Land Use Change	\$135,975	\$139,975	\$304	\$31,165	\$171,444	\$31,469
<i>FTE</i>	<i>388</i>	<i>388</i>		<i>29</i>	<i>417</i>	<i>29</i>
Land Use Change	\$78,386	\$82,686	\$156	\$25,599	\$108,441	\$25,755
<i>FTE</i>	<i>198</i>	<i>198</i>		<i>15</i>	<i>213</i>	<i>15</i>
Land Change Science	\$10,492	\$10,492	\$43	\$1,400	\$11,935	\$1,443
<i>FTE</i>	<i>53</i>	<i>53</i>		<i>6</i>	<i>59</i>	<i>6</i>
Land Cover Monitoring and Assessments	\$9,184	\$9,184		\$1,400	\$10,584	\$1,400
<i>WaterSMART: Remote Sensing</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$400]</i>	<i>[\$400]</i>	<i>[\$400]</i>
<i>WaterSMART: New Tools and Models to Better Manage Water Nationwide</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,000]</i>	<i>[\$1,000]</i>	<i>[\$1,000]</i>
Risks and Vulnerability Assessments	\$1,308	\$1,308		\$0	\$1,308	\$0

Justification of Program Change

The 2017 Budget Request for the Land Change Science Program is \$11,935,000 and 59 FTE, a net change of +\$1,443,000 and +6 FTE from the 2016 Enacted level.

Overview

The goal of the Land Change Science (LCS) Program is to understand the Nation's most pressing environmental, natural resource, and economic challenges associated with land use and land cover change. The program provides the information and tools necessary for identifying possible solutions to these challenges. It provides a historical record of resource use and indicates trends in the availability and quality of natural resources; assesses the impacts of land cover change; and develops tools for decision makers to use for resource allocation decisions. Comprehensive land cover information is essential in a wide variety of investigations, such as assessing the impacts of climate change, evaluating ecosystem status and health, understanding spatial patterns of biodiversity, and



Potential Tsunami Evacuation Routes for the town of Seaside, Oregon.

informing land use planning. The LCS Program research is also used to reduce risk and vulnerability to natural hazards. The program utilizes models, sensitivity analyses, and geographic distributions of people and infrastructure along with the probability of specific hazard events, to evaluate a community's vulnerability and risk and helps local and State governments develop response plans that minimize loss of life and economic damages. These projects include case studies, interpretative assessments, and science impact studies involving stakeholders and other partners in collaborative processes. One example of these is a Tsunami Evacuation Assessment, which analyzed 73 communities (49 incorporated cities, 7 tribal reservations, and 17 counties from northern California to northern Washington) that are directly threatened by tsunami waves associated with a Cascadia subduction zone earthquake.

Land Change Science Fact:

LCS expertise and tools were used to help the United Nations Education, Scientific and Cultural Organization (UNESCO) in assessing vulnerable world heritage sites, and resulted in the publication of a book: "Sayre, R., Hernandez, M., Spencer, D., Cecere, T., Morganwalp, C., Hamann, S., Fox, C., Benson, L., Cook, S., Bunning, J., Alvarado, S., and Cardenas, M. 2011. *From Space to Place – An Image Atlas of World Heritage Sites on the 'In Danger' List*. UNESCO Publishing, Paris, France." http://www.usgs.gov/blogs/features/usgs_top_story/from-space-to-place-mapping-our-universal-history-through-satellites/

In 2017, the Land Change Science Program is requesting an increase of \$1,400,000 to contribute to WaterSMART activities. The proposed increase would be used to develop automated methods and tools supporting near real-time, satellite-based, drought monitoring, and to help assess soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers identify the onset and severity of drought events and effectively allocate scarce water resources. In addition, the proposed increase would be used to develop digital elevation models (DEM) to monitor height and volumetric storage changes in small water reservoirs that influence the flow characteristics of streams. This would help close a significant gap that currently exists in water volume monitoring and would help provide valuable drought information for areas without streamgages.

Program Performance

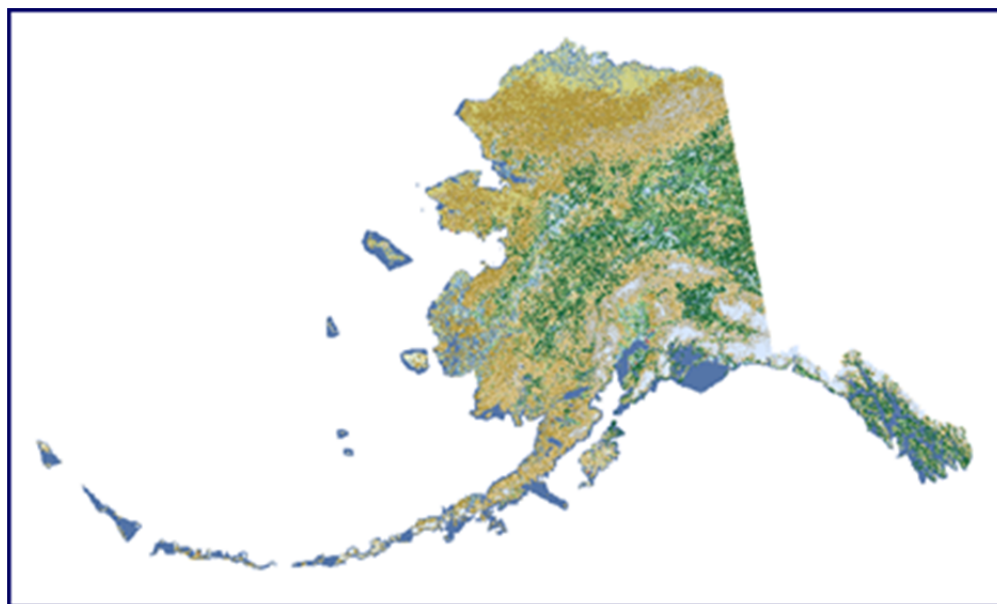
Land Cover Monitoring and Assessments

(2015 Actual, \$9.2 million; 2016 Enacted, \$9.2 million; 2017 Request, \$10.6 million)

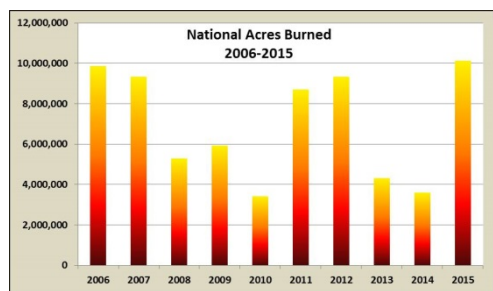
The LCS Program monitors land use and land cover change at multiple scales, documenting the geographic variability of change and defining the environmental, social, technological, and political drivers of change, as well as assessing the impacts of these changes. Current land cover monitoring activities include the National Land Cover Database (NLCD) and regional activities in areas such as the Great Plains, Rocky Mountains and the Chesapeake Bay watershed. The NLCD is a critical component in modeling land cover and forecasting future land cover conditions, which are required for assessing the impacts of climate change on the nation's natural resources. Regional land cover activities are used to assess and model ecosystem extent and functioning, as well as analyzing the services provided by these ecosystems, including carbon sequestration, water availability, and biodiversity conservation. These

activities include assessing the impacts of energy infrastructure development on wildlife in the Western United States, bioenergy intensification on water quality and urbanization in the mid-Atlantic and desert Southwest. International applications of LCS science include supporting the Group on Earth Observations (GEO) efforts to map global ecosystems and applying remote sensing inventory methodologies in assessing forest carbon sequestration, both of which help provide the reliable information decision makers need for policy development and international agreement negotiations

In 2015, in conjunction with the Multi-Resolution Land Characteristics (MRLC) consortium, LCS released the latest edition of the Alaska National Land Cover Database (NLCD). It is the most comprehensive look at land-surface conditions of the State and identifies land cover changes since 2001. By far the greatest change across this decade has been the conversion of forests to shrub and grasslands, primarily as a result of wildland fires. With a decade of change information available, resource managers, researchers, and planners can better understand the trajectory of land cover change patterns and gain insight about land cover change processes. NLCD data can be downloaded free of charge at the MRLC website (www.mrlc.gov).



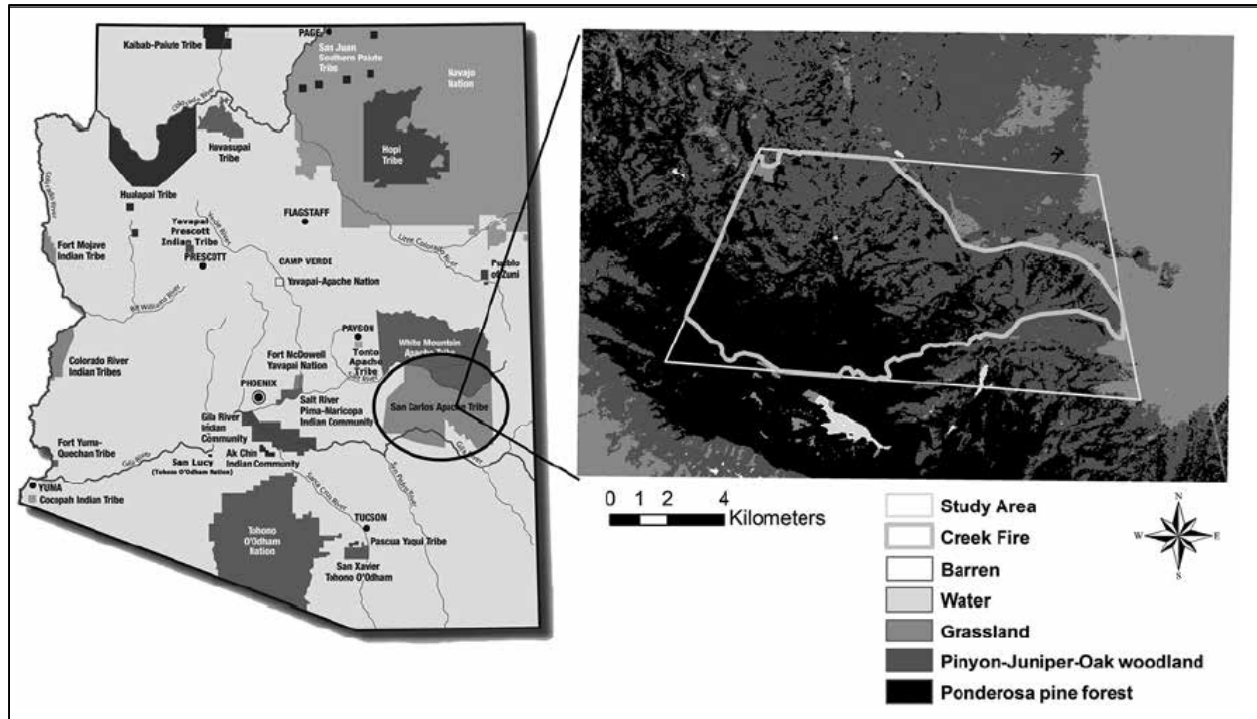
2011 Alaska National Land Cover Database



Source: National Interagency Fire Center, 2016

The year 2015 was the biggest fire year of the past 15 years, with 10,125,149 acres burned in the United States. In addition to monitoring fire trends (within the LRS Program and the Ecosystems Mission Area) LCS researchers conduct in-depth assessments of fire effects on land cover change and post-fire recovery. For example, LRS scientists used remotely sensed data from Landsat and high spatial resolution commercial satellites to assess the impacts of the Creek Fire on the San Carlos Apache Reservation. The study developed

accurate vegetation burn severity mapping techniques that can help guide effective management of forest resources on the San Carlos Apache Reservation, and the broader fire-prone regions of the Southwest.



Assessment of the impacts of the Creek Fire on the San Carlos Apache Reservation

LCS Scientists modeled species distribution maps for 50 North American bird species to determine relative contributions of climate and land use/land cover (LULC) characteristics for contemporary (2001) and future (2075) species distribution maps. Results indicate species-specific responses to climate and LULC variables; however, both are important for modeling contemporary and potential future species ranges. This work represents the first assessment of the effects of climate and LULC for bird species in the conterminous United States using newly available LULC projections of high-spatial and thematic resolution and climate and LULC projections that are consistent with IPCC SRES scenario frameworks. Results of this work will be used to assess the effectiveness of current Refuges and Parks to meet future conservation needs.

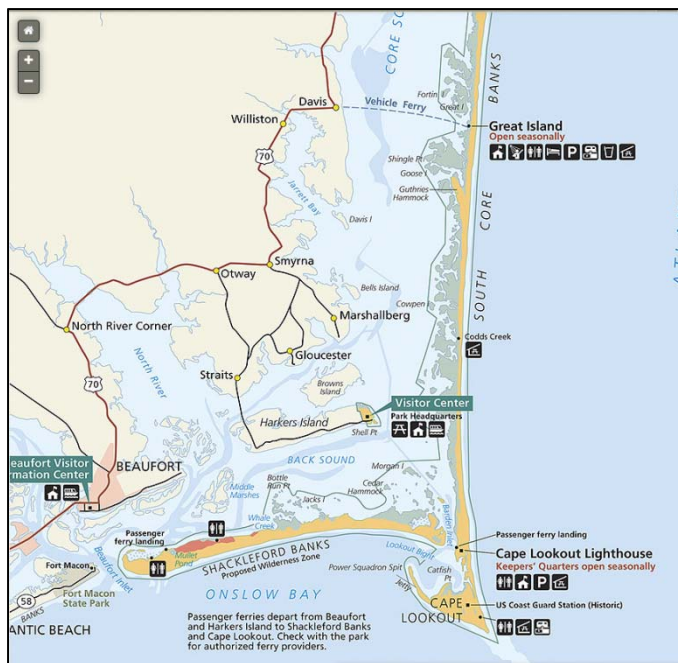
Gaining public support for management actions is important to the success of public land management agencies' efforts to protect threatened and endangered species. This is especially relevant at national parks, where managers balance two aspects of their conservation mission to protect resources and to provide for public enjoyment. LCS researchers examined variables potentially associated with support for management actions at Cape Lookout National Seashore, a unit of the National Park Service. Two visitor surveys were conducted at the park during different seasons, and a resident survey was conducted for households in Carteret County, North Carolina, where the park is located. The results show that perceived values of threatened and endangered species, trust in park managers and the decision-making process, and perceived shared values with park managers were among the strongest indicators of support for management actions.

Understanding the efficacy of revised watershed management methods is important to mitigating the impacts of urbanization on streamflow. LCS researchers evaluated the influence of land use change, primarily as urbanization, and stormwater control measures on the relationship between precipitation and

stream discharge over an eight-year period for five catchments in a suburban county of Washington, D.C. This study developed a methodology to evaluate the actual effectiveness of water management efforts in complex, urbanizing landscapes that could be paired with cost data to conduct cost-benefit analyses of stormwater control measures.

In 2016, the LCS Program plans to implement the next iteration of the NLCD. The NLCD 2016, derived from imagery acquired during the summer of 2016, will continue to improve forest assessments on Native American lands and water management in urban areas. In addition, the LCS Program will collaborate with the ESRI Corporation to develop a marine ecosystem spatial dataset that will be a companion to the terrestrial ecosystem dataset that was completed in 2014. This will be the first dataset of its kind and will serve as a foundation for marine conservation planning.

In 2017, the LCS Program would continue working on the NLCD 2016 and the global marine ecosystem datasets. The LCS would initiate a new project to develop automated methods and tools supporting near-real-time, satellite-based, drought monitoring. Assessed characteristics would include soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers effectively allocate scarce water resources.



Visitors were asked to identify valued area on a map of the Cape Lookout National Seashore.

2017 Program Change
<p>WaterSMART: Remote Sensing (+\$400,000) for a total of \$400,000: The proposed increase would be used to conduct an innovative data integration approach that combines satellite-derived reservoir surface area from the Land Remote Sensing Program’s dynamic surface water extent Landsat dataset and digital elevation models (DEM) to monitor height and volumetric storage changes in water reservoirs. In the United States, good information on the amount of water in large storage features such as documented reservoirs and lakes is available; however, there is a significant gap in identifying and quantifying water storage in undocumented or ephemeral storage features. Despite their smaller size, these water storage features influence the flow characteristics of streams. Understanding and reporting on these features could provide information for drought monitoring, climate variability, and streamflow estimation, particularly in areas without streamgages. Volume information is not currently available for the ungaged reservoirs, and for gaged reservoirs, it is important to express the height information within a form of a standardized index that will express the “fullness” level.</p>

2017 Program Change

Water SMART: New Tools and Models to Better Manage Water Nationwide (+\$1,000,000) for a total of \$1,000,000: The proposed increase would be used to develop automated methods and tools supporting near real-time, satellite-based, drought monitoring. This effort will take advantage of Landsat's data processing and classification system that will provide image data every eight days. Assessed characteristics will include soil moisture, evapotranspiration rates, vegetation drought response, and other metrics of drought impacts on natural and agricultural systems, thus helping water managers identify the onset and severity of drought events and effectively allocate scarce water resources. This information would allow for early detection of drought conditions and extent and enable comprehensive water management by linking water supply sources with its users.

Risks and Vulnerability Assessments

(2015 Actual, \$1.3 million; 2016 Enacted, \$1.3 million; 2017 Request, \$1.3 million)

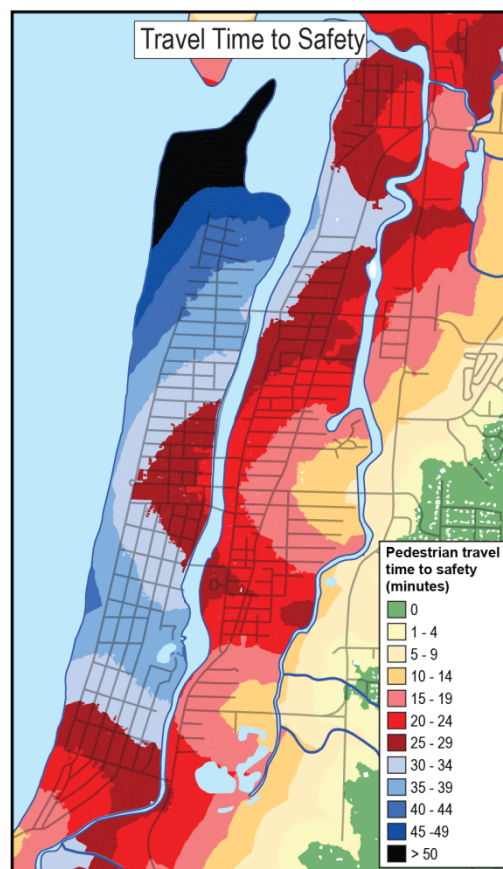
This research utilizes models, sensitivity analyses, and geographic distributions of people and infrastructure, along with the probability of specific disturbance factors, to evaluate a community's vulnerability and risk. The LCS Program helps local and State governments assess their vulnerability by augmenting the USGS's traditional expertise in natural hazards with the ability to assess the exposure, sensitivity, and resilience of a community. These projects include case studies, interpretative assessments, and science impact studies involving stakeholders and other partners in collaborative processes. The Program's research is a critical component of USGS's Science Application for Risk Reduction (SAFRR) project, evaluating the social and economic implications of risk and vulnerability to a wide variety of hazard events, including earthquakes, floods, volcanoes and tsunamis.

In 2015, LCS researchers developed an analytical framework describing variations in community vulnerability to tsunami hazards that integrates: geospatial approaches identifying the number and characteristics of people in hazard zones; models estimating evacuation travel times to safety; and cluster analyses classifying communities with similar vulnerability. This framework was used to analyze 73 communities (49 incorporated cities, seven tribal reservations, and 17 counties) from northern California to northern Washington that are directly threatened by tsunami waves associated with a Cascadia subduction zone earthquake. Results suggest three primary community groupings: (1) relatively low numbers of exposed populations with varied demographic sensitivities; (2) high numbers of exposed populations but sufficient time to evacuate before wave arrival; and (3) moderate numbers of exposed populations with insufficient time to evacuate. These results can be used to enhance general hazard-awareness efforts with targeted interventions, such as education and outreach tailored to local demographics, evacuation training, and/or constructing vertical evacuation refuges.

LCS researchers modeled land cover change from 2011 to 2061 in tsunami-hazard zones associated with Cascadia subduction zone earthquakes in the Pacific Northwest. Results suggest the State of Washington was projected to add the most developed land in the tsunami-hazard zone, with the majority occurring in unincorporated land in Pacific and Grays Harbor Counties. In line with historical change rates, rural coastal areas were projected to grow slowly. The number of residents in Cascadia subduction zone-related tsunami-hazard zones was projected to increase by an average of 22,185 new residents, by 2016, a 23 percent increase in exposed population across Cascadia.

In 2016, the LCS Program plans to continue to support the SAFRR project and expand the Tsunami vulnerability assessments into middle and southern California. In addition, the Program will aid Washington State develop multi-hazard scenario assessments incorporating the threats posed by volcanoes and tsunamis.

In 2017, the LCS Program would continue to support SAFRR and take the methodologies developed for tsunamis and apply them to assessing the risks of sea level rise and storm surges on the east coast of the United States.



Pedestrian Travel Evacuation Time LCS geographers estimated that 21,562 residents in the region would not make it to safety if they walk slowly, at about 2.5 mph. If they walk faster, at about 3.5 mph, the death toll drops to 15,970.

Science Collaboration

The LCS Program works with various domestic and international environmental and resource management partners, including Interior bureaus, Federal agencies, State and non-governmental organizations (such as the Association of Geographers and the World Bank). The LCS Program provides vital land cover information to these partners, as well as integrating their data in environmental and economic risk and vulnerability assessments. These partners choose to work with the USGS and in particular the LCS Program because of its broad, interdisciplinary expertise; rigorous set of protocols (USGS Fundamental Science Practices); innovative monitoring technology, models, and research tools; and robust data management and delivery systems.

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**Energy and Mineral
Resources, and
Environmental Health**

Activity: Energy and Mineral Resources, and Environmental Health

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Energy and Mineral Resources, and Environmental Health	\$92,271	\$94,511	\$453	\$4,519	\$99,483	\$4,972
<i>FTE</i>	<i>553</i>	<i>567</i>		<i>14</i>	<i>581</i>	<i>14</i>
Mineral and Energy Resources	\$70,826	\$73,066	\$361	\$1,496	\$74,923	\$1,857
<i>FTE</i>	<i>434</i>	<i>448</i>		<i>6</i>	<i>454</i>	<i>6</i>
Mineral Resources Program	\$45,931	\$48,371	\$243	\$81	\$48,695	\$324
<i>FTE</i>	<i>294</i>	<i>308</i>		<i>4</i>	<i>312</i>	<i>4</i>
Energy Resources Program	\$24,895	\$24,695	\$118	\$1,415	\$26,228	\$1,533
<i>FTE</i>	<i>140</i>	<i>140</i>		<i>2</i>	<i>142</i>	<i>2</i>
Environmental Health	\$21,445	\$21,445	\$92	\$3,023	\$24,560	\$3,115
<i>FTE</i>	<i>119</i>	<i>119</i>		<i>8</i>	<i>127</i>	<i>8</i>
Contaminant Biology Program	\$10,197	\$10,197	\$45	\$1,223	\$11,465	\$1,268
<i>FTE</i>	<i>60</i>	<i>60</i>		<i>4</i>	<i>64</i>	<i>4</i>
Toxic Substances Hydrology Program	\$11,248	\$11,248	\$47	\$1,800	\$13,095	\$1,847
<i>FTE</i>	<i>59</i>	<i>59</i>		<i>4</i>	<i>63</i>	<i>4</i>

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Mineral and Energy Resources	+ 1,496	+ 6	
Mineral Resources Program	+ 81	+ 4	H-15
Critical Minerals and Materials Flow Initiative	+ 1,022	+ 8	H-19
Geophysical and Remote Sensing Activities	- 1,500	- 8	H-22
R&D to Address Environmental Impacts of Minerals Development	+ 559	+ 4	H-22
Energy Resources Program	+ 1,415	+ 2	H-27
Alternative Energy Permitting on Federal Lands - Geothermal	+ 229	0	H-35
Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment	+ 211	+ 1	H-41
Unconventional Oil and Gas Research	+ 975	+ 1	H-33
Environmental Health	+ 3,023	+ 8	
Contaminant Biology Program	+ 1,223	+ 4	H-47
Critical Landscapes: Columbia River	+ 50	0	H-57
Environmental Impacts of Uranium Mining	+ 273	+ 1	H-60
Unconventional Oil and Gas Research	+ 900	+ 3	H-60
Toxic Substance Hydrology Program	+ 1,800	+ 4	H-65
Critical Landscapes: Columbia River	+ 50	+ 1	H-72
Emerging Contaminants & Chemical Mixtures	- 750	- 4	H-70
Environmental Impacts of Uranium Mining	+ 1,750	+ 8	H-75
Fate and Transport of Contaminants in the Subsurface	- 800	- 5	H-76
Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast	+ 1,300	+ 3	H-68
Unconventional Oil and Gas Research	+ 250	+ 1	H-76
Total Program Change	+ 4,519	+ 14	

Justification of Program Change

The 2017 Budget Request for Energy and Mineral Resources, and Environmental Health is \$99,483,000 and 581 FTE, a net change of +\$4,972,000 and +14 FTE from the 2016 Enacted level.

Overview

The **Energy and Mineral Resources, and Environmental Health (EMEH)** budget activity provides valuable, objective science and information about our Nation's energy and mineral resources, as well as reliable, impartial science critical to understanding the interaction between the physical environment, the living environment, and human health.

In 2016, a technical adjustment was approved for the creation of two subactivities within the EMEH budget activity:

- **Mineral and Energy Resources**, consisting of the following two program elements:
 - Mineral Resources Program (<http://minerals.usgs.gov>)
 - Energy Resources Program (<http://energy.usgs.gov>)
- **Environmental Health**, consisting of the following two program elements:
 - Contaminant Biology Program (<http://www.usgs.gov/envirohealth/cbp/index.html>)
 - Toxic Substances Hydrology Program (<http://toxics.usgs.gov/>)

While EMEH functions as one budget activity, in practice, each subactivity operates autonomously as separate mission areas, each with its own Strategic Science Plan. In 2016, each subactivity will be led by its own Associate Director as well (currently, both subactivities are overseen by a single Associate Director). The Mineral and Energy Resources subactivity is the larger of the two, with a 2016 enacted funding level of \$73,066,000. The Environmental Health subactivity, while significantly smaller, has recently grown and has a 2016 enacted funding level of \$21,445,000.

Mineral and Energy Resources Subactivity

Accurate scientific information about our Nation's mineral and energy resources is critical for policy makers and resource managers to have in order to make responsible decisions about resource development. Our Nation continues to depend on energy to power our homes and businesses, and minerals to manufacture products we rely on every day, from our cell phones and laptops to our hybrid cars. Our policy makers also rely on global mineral commodity data to make informed decisions about national security and international trade policy. The impartial, in-depth science provided by the Mineral Resources Program (MRP) and the Energy Resources Program (ERP) facilitates responsible natural resource development and strategic, evidence-based economic and geopolitical decisions.

The Mineral and Energy Resources subactivity conducts research on the location, quantity, and quality of the Nation's and the world's mineral and energy resources, including the interaction of these resources

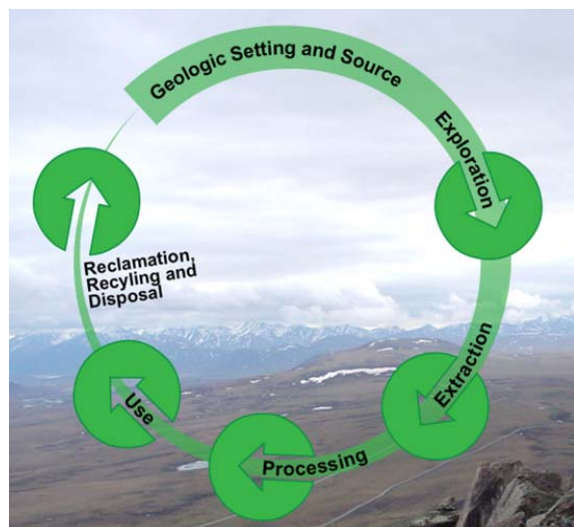


Figure 1: The Mineral and Energy Resources Lifecycle Approach.

with the environment, both naturally and as a result of extraction and use. Both programs provide valuable information to resource managers, policy makers, and the public to support science-based policy development, land and resource management, and decision making on a range of critical resource issues. Utilizing a lifecycle approach (see figure 1), both programs seek to inform our understanding of mineral and energy resources from “cradle to grave.”

In 2017, the Mineral Resources Program is proposing increases in funding for the Critical Minerals and Materials Flow Initiative (+\$1,022,000/+8 FTE) and for R&D to Address the Environmental Impacts of Minerals Development (+\$559,000/+4 FTE), and is proposing to offset much of this proposed increase by

decreasing funding for Geophysical and Remote Sensing Activities (-\$1,500,000/-8 FTE). The Energy Resources Program is proposing increases for the following activities in 2017: Alternative Energy Permitting on Federal Lands – Geothermal (+\$229,000/0 FTE); Ecosystem Services: Enhancing Resilience in Coastal Infrastructure (+\$75,000/0 FTE); Ecosystem Services: Evaluating Green Infrastructure Investment (+\$136,000/+1 FTE); and Unconventional Oil and Gas Research (+\$975,000/+1 FTE).

The MRP and the ERP continue to provide high-quality, value-added science for the most pressing scientific challenges in their areas. Taking into account the impacts to program priorities, the 2017 budget proposes modest increases in a few targeted, critical areas within the Mineral Resources Program and the Energy Resources Program, directing dollars toward projects with high potential to make the most impact.

The **Mineral Resources Program (MRP)** delivers unbiased science and information to understand mineral resource potential, production, consumption, and interaction with the environment. The MRP is the sole Federal provider of this mineral resource-related science and information, which is essential for supporting informed decision making. MRP products facilitate:

- Understanding the origin and distribution of mineral resources.
- Improvement of public land and resource stewardship.
- Formulation of national and international economic and security policy.
- Sustainment of prosperity and improvement of quality of life.
- Protection and improvement of public health, safety, and environmental quality.

The **Energy Resources Program (ERP)** conducts research and assessments (see figure 2) to advance the understanding of energy resources—including the Nation’s energy resource supply and the impacts of its development—in order to provide reliable science for informed decision making to support:

Energy and Mineral Resources, and Environmental Health

- Understanding the fundamental Earth processes that form energy resources.
- Providing inventories and assessments of energy resources.
- Identifying the reliability and availability of energy supplies.
- Characterizing the environmental behavior of energy resources and their waste products.
- Understanding the effects of energy resource development on natural resources and society.



Figure 2: Eastern margin of Upper Cook Inlet, Alaska. The Energy Resources Program conducted an assessment of unconventional gas resources in the region.

Key Accomplishments in 2015: Mineral and Energy Resources

A significant accomplishment for the Mineral Resources Program in 2015 is the special report published by the USGS National Minerals Information Center (NMIC) titled, *The Ebola Virus Disease Outbreak and Mineral Sectors of Guinea, Liberia, and Sierra Leone*. The report concludes that the important mining industries of the aforementioned nations were able to largely maintain their operations during the deadly 2014-15 outbreak of the Ebola virus. The mining industries in these nations are important to their national economies and, in turn, to the global minerals economy. Uncertainty in the status of mining and mineral exploration operations in those three nations following the Ebola outbreak raised questions about the prospects for growth and future foreign investment in the region. The NMIC study provided an accurate, useful account of mining operations in the region that can be used to bolster U.S. economic and geopolitical interests in the region.



Figure 3: Map of the San Joaquin Basin Province.
Source: U.S. National Park Service.

One of the Energy Resources Program's key accomplishments in 2015 was the completion of an assessment of undiscovered continuous oil and gas resources in the Monterey Formation of the San Joaquin Basin in California (figure 3). The results of the assessment showed that the Formation contains technically recoverable resources at an estimated mean volume of: 21 million barrels of oil, 27 billion cubic feet of gas, and 1 million barrels of natural gas liquids. The results of the assessment provide

useful information upon which policy makers can rely in making informed decisions related to U.S. energy policy, leasing of Federal lands, and impacts of energy development on natural resources.

Strategic Science Plan

Each USGS mission area published a Strategic Science Plan in 2013. The Mineral and Energy Resources plan, *U.S. Geological Survey Energy and Minerals Science Strategy—A Resource Lifecycle Approach*, outlines five broad goals for the coming decade:

1. Understand fundamental Earth processes that form energy and mineral resources.
2. Understand the environmental behavior of energy and mineral resources and their waste products.
3. Provide inventories and assessments of energy and mineral resources.
4. Understand the effects of energy and mineral development on natural resources and society.
5. Understand the reliability and availability of energy and mineral supplies.

The Mineral and Energy Resources goals provide a framework for building upon core capabilities while leveraging their application toward new and emerging challenges.

Strategic Actions Planned During 2016

The Mineral Resources Program (MRP) will:

- Continue support for collection, analysis, and dissemination of minerals information and materials flow studies.
- Continue research to better understand the genesis and distribution of the Nation's critical mineral resources, particularly in Alaska and in the midcontinent and southeast regions of the United States.
- Continue geophysical and remote sensing work in different regions of the United States, including Alaska, California, the mid-Continent, and the Eastern United States to support geologic framework studies and mineral potential evaluations. In this regard, the release of a new digital geologic map of Alaska, with a searchable database allowing the identification and evaluation of mineral and energy resources potential, will be one of the important USGS accomplishments in 2016.
- Continue work on environmental impacts of resource extraction and on the understanding of how mineral resources interact with the environment to affect human and ecosystem health. This information is necessary for regulatory agencies such as EPA and BLM to carry out their missions.
- Increase work on new sources of critical minerals and on the lifecycles of critical minerals.

The Energy Resources Program (ERP) will:

- Continue collaborative efforts with the Mineral Resources Program (MRP) to assess domestic uranium resources, including the Texas Coastal Plain.
- Continue collaborative efforts with the MRP and the Toxic Substances Hydrology Program (TSHP) to develop a complementary assessment methodology of the potential environmental impacts associated with uranium occurrence and development. The draft methodology will undergo USGS peer review in 2016.
- Continue efforts to assess unconventional oil and gas resources both domestically and internationally. Domestic assessments in 2016 will include the Barnett Shale.
- Support collaborative studies of groundwater resources and conventional geothermal and Enhanced Geothermal Systems (EGS) energy potential throughout much of eastern Oregon, northeastern California, southwestern Idaho, and northernmost Nevada as part of the Northwest Volcanic Aquifer Study Area (NVASA).

Strategic Actions Planned During 2017

The Mineral Resources Program (MRP) will:

- Build upon 2016 efforts to continue support for collection, analysis, and dissemination of minerals information and materials flow studies.
- Build upon 2016 research to better understand the genesis and distribution of the Nation's critical mineral resources, particularly in Alaska and the midcontinent and southeast regions of the United States.
- Build upon 2016 efforts to conduct work on environmental impacts of resource extraction and understanding how mineral resources interact with the environment to affect human and ecosystem health. This information is necessary for regulatory agencies such as EPA and BLM to carry out their missions.
- Build upon 2016 efforts to conduct work on new sources of critical minerals and on the lifecycles of critical minerals.

The Energy Resources Program (ERP) will:

- Continue collaborative efforts with the Mineral Resources Program to assess domestic uranium resources, including additional U.S. deposit types.
- Submit for external peer review the USGS-reviewed assessment methodology of the potential environmental impacts associated with uranium resource development. The assessment methodology, a collaborative effort supported by ERP, the Mineral Resources Program, and the Toxic Substances Hydrology Program, will be reviewed by a panel of external technical experts.
- Expand unconventional oil and gas research efforts begun in 2016 on the geologic causes of variability in the recovery of petroleum and water, and studies of baseline water quality.

- Continue research into geothermal resources aimed at improving the viability of Enhanced Geothermal Systems (EGS) and studying environmental impacts of geothermal energy development on Federal lands.

Environmental Health Subactivity

Protection and enhancement of human health and the health of our environment are dependent upon sound science to understand the means by which health threats arise from exposures to environmental



Figure 4: The Environmental Health Mission Area works at the intersection of people, the physical environment, and the living environment.

disease agents or contaminants, including chemical, biological, and radiological agents. Whether our aim is to anticipate, detect, or prevent adverse health impacts, USGS Environmental Health (EH) research makes valuable scientific contributions to the well-being of our Nation and the world by focusing environmental health research on health threats from toxins (e.g., mercury) and pathogens (e.g., avian influenza) as well as hidden or poorly understood threats from a range of other contaminants (e.g., pharmaceuticals and pesticides), mixtures of contaminants in the environment, or other biological agents (e.g., parasites). As potential threats from current and newly emerging disease agents continue to increase, public health, the health of our environment, and our economic prosperity may be put at risk. The

Contaminant Biology Program (CBP) and the Toxic Substances Hydrology Program (TSHP) provide indispensable science, tools, and information that comprise the foundation of a national strategy for guarding the health of our people and our environment.

Chiefly through environmental contaminant research, the Environmental Health mission area and budget subactivity contributes critical science needed to understand the relationships linking the quality of the physical environment, the health of the living environment, and human health. The contaminant threats associated with interactions among these three spheres (see figure 4) are driven by human activities, ecological processes, and natural Earth processes. USGS Environmental Health research provides the foundation for managing and protecting our Nation's natural resources and public health from environmental exposures to contaminants or disease agents. Potential exposures, their dynamics, and their interacting effects are mediated by the processes, characteristics, and quality of the physical and living environment.

Energy and Mineral Resources, and Environmental Health

In 2017, the Contaminant Biology Program is proposing increases in funding for Critical Landscapes: Columbia River (+\$50,000/0 FTE), Environmental Impacts of Uranium Mining (+\$273,000/+1 FTE), and Unconventional Oil and Gas Research (+\$900,000/+3 FTE). The Toxic Substances Hydrology Program is proposing increases for the following activities in 2017: Critical Landscapes: Columbia River (+\$50,000/+1 FTE), Environmental Impacts of Uranium Mining (+\$1,750,000/+8 FTE), Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast (+\$1,300,000/+3 FTE), and Unconventional Oil and Gas Research (+\$250,000/+1 FTE). The Toxic Substances Hydrology Program is proposing decreases for the following activities in 2017: Emerging Contaminants and Chemical Mixtures (-\$750,000/-4 FTE), and Fate and Transport of Contaminants in the Subsurface (-\$800,000/-5 FTE).

While both the Contaminant Biology Program and the Toxic Substances Hydrology Program are relatively small (\$10.2 million and \$11.2 million in 2016, for CBP and TSHP, respectively), the scientific contributions they have made toward the improvement of the quality of our Nation's environmental and public health have been indispensable. The CBP and TSHP have made breakthroughs in areas ranging from detection of pesticides potentially harmful to non-targeted organisms such as pollinators in over half of our Nation's streams to the effects of uranium mining on plants and animals in the Grand Canyon. The CBP and TSHP provide objective science critical to making well-informed decisions regarding the protection of our environment and the public health.

The **Contaminant Biology Program (CBP)** conducts research to better understand how environmental drivers (e.g., chemicals, pathogens, natural Earth processes, resource extraction, etc.) can impact the health of living organisms. The CBP serves as the USGS lead for coordinating interagency disaster preparedness and response activities related to chemical and biological threats. The CBP provides objective and reliable science that advances informed decision making by:

- Identifying and assessing risks from exposure to environmental disease agents.
- Developing strategies to prevent and mitigate those risks.
- Collaborating closely with public health and agricultural partners to identify and understand the critical linkages among the health of the environment, fish and wildlife, domesticated animals, and humans.
- Preparing the Nation for, and responding to, impacts and related health threats of natural and man-made disasters.

The **Toxic Substances Hydrology Program (TSHP)** produces dependable, impartial scientific information on the sources, occurrence, behavior, and effects of toxic substances in the natural environment. The TSHP provides a foundation for informed decision making on issues concerning toxic substance contamination of surface water, groundwater, soil, sediment, and the atmosphere by:

- Identifying new and emerging contaminants.
- Examining both point-source and regional/watershed contamination.
- Studying the transport of contaminants through the ecosystem.

- Engaging in discovery and characterization of the complex interactions between, and the combined effects of, exposure to contaminants and pathogens.
- Developing remediation methods that use natural processes;
- Understanding the impacts of toxic substances on living organisms.

Key Accomplishments in 2015: Environmental Health

A significant accomplishment for the Environmental Health subactivity in 2015 is the publication of a recent study on the chemical compound bisphenol-A (BPA) by USGS Environmental Health scientists, in partnership with the University of Missouri. The study showed that fish exposed to the endocrine-disrupting chemicals bisphenol-A (BPA) or 17-ethinylestradiol (EE2) in a laboratory have been found to pass adverse reproductive effects onto their offspring up to three generations later. BPA can be found in some polycarbonate beverage bottles and has been used in food packaging since the 1960s. EE2 is one of the primary ingredients found in many oral birth control pills. USGS Environmental Health research has provided critical science showing the cause-effect relationship between these chemicals and reproductive abnormalities in several generations of fish, which may have important implications for human risk assessments.

Another key accomplishment in the Environmental Health subactivity in 2015 relates to the potential impacts of insecticide use. USGS Toxic Substances Hydrology Program researchers, in partnership with the Georgia Department of Agriculture, USGS Priority Ecosystems Science, and the USGS National Water Quality Program, published a study in the journal *Environmental Chemistry*, finding that neonicotinoid insecticides were present in more than half of water samples collected from streams across the United States (figure 5). Other research has shown that neonicotinoid insecticides can be potentially harmful to non-targeted organisms, including pollinators, and that they may be one of several contributing factors responsible for honeybee declines. The USGS study is the first national-scale reconnaissance of neonicotinoid insecticides in streams across the United States. The study summarizes concentrations of six neonicotinoids in streams across the Nation, including those in both urban and agricultural areas. These findings are important to furthering scientific understanding of the potential unintended impacts that use of neonicotinoid insecticides may have on both aquatic and terrestrial organisms in the environment.



Figure 5: USGS scientist collecting a water quality sample from Zollner Creek, Oregon for a national-scale investigation of the environmental occurrence of neonicotinoid insecticides. Photo credit: Hank Johnson, USGS.

Strategic Science Plan

The Environmental Health Strategic Science Plan, *U.S. Geological Survey Environmental Health Science Strategy—Providing Environmental Health Science for a Changing World*, outlines the following five goals for the 10 years following its publication in 2013:

1. Identify, prioritize, and detect contaminants and pathogens of emerging environmental concern.
2. Reduce the impact of contaminants on the environment, fish and wildlife, domesticated animals, and people.
3. Reduce the impact of pathogens on the environment, fish and wildlife, domesticated animals, and people.
4. Discover the complex interactions between, and combined effects of, exposure to contaminants and pathogens.
5. Prepare for and respond to the environmental impacts and related health threats of natural and anthropogenic disasters.

The Environmental Health mission area goals are intended to provide science to address environmental health threats ranging from informing prevention and preparedness, to supporting systematic management response to environmental health issues.

Strategic Actions Planned During 2016

The USGS Environmental Health subactivity will conduct work in the following areas:

- **Research on Mixtures of Environmental Contaminants:**
 - Compile data and information on mixtures of contaminants in the Nation's streams.
- **Environmental Contaminants Associated with Plant and Animal Agriculture:**
 - Begin research on microbial contaminants in groundwater associated with agricultural feeding operations.
 - Complete and publish a study of the occurrence, fate, and potential ecological health effects of fungicides used in varied agricultural settings across the Nation.
 - Publish research on accidental exposures of native pollinators to pesticides such as neonicotinoids in the environment.
- **Environmental Contaminants Associated with Natural Hazards:**
 - Design and begin installation of a natural hazard response and resilience network to monitor and assess storm-related releases of chemical and pathogenic disease agents along the northeast coast of the United States, including trust resources, sensitive ecosystems, wildlife refuges, and parks.
 - Publish data on human and ecological contaminant exposures associated with Hurricane Sandy.

- **Environmental Contaminants Associated with Energy Development:**
 - Publish results of studies on environmental contaminants associated with wastewater from unconventional oil and gas development activities.
 - As part of an ongoing 15-year multiagency science plan, conduct research on the environmental impacts and potential mobility of contaminants in the environment associated with uranium mining activities. In 2015, the Contaminant Biology Program determined baseline population composition for more than 200 species of plants, invertebrates, amphibians, reptiles, birds and small mammals in and around the inactive Canyon Mine site (AZ). In 2016, these samples will be analyzed for baseline radiation, uranium, and co-occurring elements. Collaboration with the U.S. Department of Energy will provide radiation measures and interpretation of air and dust samples from the Canyon Mine “baseline” site.
- **Environmental Mercury Research:**
 - Publish results of research on the sources and distribution of mercury in the Great Lakes and global ocean environments.
- **Endocrine Disruption Research:**
 - Implement a coordinated five-year plan to study the sources, transport mechanisms, and effects of Endocrine Disrupting Compounds (EDCs) in the Chesapeake Bay Watershed. This research will bring together expertise from across the Nation to evaluate the impacts of EDCs on aquatic and terrestrial organisms, providing new information for resource managers, human health professionals, and policy makers.
 - Initiate synthesis and mapping of over 10 years of historical chemical, biological, and land use data collected from sites throughout the Chesapeake Bay watershed.
 - Initiate studies to determine effects of EDCs on terrestrial wildlife of the Chesapeake Bay watershed with a focus on turtles.
 - Develop methods for tracing the transfer of contaminants through food webs that cross ecosystem boundaries, particularly contaminants within aquatic sediment with the potential to be stored or bioaccumulate in the aquatic nymph stage of flying insects that can then transfer the contaminants to birds and terrestrial wildlife.
- **Avian Influenza Research:**
 - Finalize compliance requirements and user-interface improvements for a Web visualization tool and other tools to improve understanding of the transmission of highly pathogenic avian influenza (HPAI).
 - Expand the scope of North American data for waterfowl species, domestic poultry, and circulating HPAI viruses to predict areas with elevated risk of highly pathogenic avian influenza transmission and novel viral emergence. The data from North America will be applied to models that were developed in 2015.

Strategic Actions Planned During 2017

The USGS Environmental Health subactivity will conduct work in the following areas:

- **Research on Mixtures of Environmental Contaminants:**
 - With data interpretations conducted in 2016, the first characterization of complex chemical mixtures in the Nation's streams will be reported.
- **Environmental Contaminants Associated with Plant and Animal Agriculture:**
 - Based on 2016 results, sampling and field work will be scaled up and conducted for groundwater systems potentially impacted by animal agriculture.
 - Field work will be conducted on pesticides and their adjuvants in the environment.
- **Environmental Contaminants Associated with Natural Hazards:**
 - Continue the natural hazard response and resilience network to monitor and assess storm-related releases of chemical and pathogenic disease agents along the northeast coast of the United States, including trust resources, sensitive ecosystems, wildlife refuges, and parks.
- **Environmental Contaminants Associated with Energy Development:**
 - Based on lessons learned in 2016, design and implement new research on potential ecological impacts of contaminants associated with unconventional oil and gas wastewater.
 - Building upon the assessments of contaminant mobility conducted in 2016, publish baseline chemical data from uranium mining sites.
 - The study of uranium mining effects will be initiated at an active mining operation collecting comparable data to that collected at the Canyon Mine "baseline" site. The second phase of the multi-year study will allow for assessment of relative risk between a site that is not being mined and one that is actively extracting uranium. Future work (2018-2019) will measure similar parameters in areas of cleanup and remediation to determine where the greatest environmental risks lie and to assess impacts and success of remediation.
 - New field methods will be developed to identify biological species that are present at Canyon Mine, the baseline site for the uranium study. These methods will utilize eDNA to identify species using limited water resources in the Grand Canyon watershed. If successful, this method could be an economically viable option (compared to the more extensive and expensive field work required for more traditional methods in remote areas). It is also potentially more precise and less stressful for animals than physical handling.

- **Environmental Mercury Research:**
 - Build upon 2016 findings and tool development to improve understanding regarding sources and distribution of environmental mercury, and begin additional research on environmental exposures.
- **Endocrine Disruption Research:**
 - The synthesized Chesapeake Bay watershed chemical, biological, and land use data from 2016 will be used to build relative risk models that will point to sources of EDCs as well as determine the temporal windows when fish are most vulnerable to exposure. This information will provide natural resource managers with the information to prioritize management efforts related to EDCs.
- **Avian Influenza Research:**
 - Implement Phase II of the avian influenza geospatial analysis project by: (1) including the North American data collected in 2016 on waterfowl species, poultry, and circulating Highly Pathogenic Avian Influenza (HPAI) viruses, and (2) adapting and applying the models for use in North America utilizing data from the 2014-2015 U.S. HPAI outbreak. The models will provide important information to public and animal health professionals for responding to and preventing the spread of the disease in humans and domestic animals.

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Activity: Energy and Mineral Resources, and Environmental Health

Subactivity: Mineral and Energy Resources

Program Element: Mineral Resources Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Energy and Mineral Resources, and Environmental Health	\$92,271	\$94,511	\$453	\$4,519	\$99,483	\$4,972
<i>FTE</i>	<i>553</i>	<i>567</i>		<i>14</i>	<i>581</i>	<i>14</i>
Mineral and Energy Resources	\$70,826	\$73,066	\$361	\$1,496	\$74,923	\$1,857
<i>FTE</i>	<i>434</i>	<i>448</i>		<i>6</i>	<i>454</i>	<i>6</i>
Mineral Resources Program	\$45,931	\$48,371	\$243	\$81	\$48,695	\$324
<i>FTE</i>	<i>294</i>	<i>308</i>		<i>4</i>	<i>312</i>	<i>4</i>
Critical Mineral Resources	\$6,022	\$8,462		\$1,022	\$9,484	\$1,022
<i>Critical Minerals and Materials Flow Initiative</i>	<i>[\$6,022]</i>	<i>[\$8,462]</i>		<i>[\$1,022]</i>	<i>[\$9,484]</i>	<i>[\$1,022]</i>
Research and Assessment	\$24,495	\$24,495		-\$941	\$23,554	-\$941
<i>R&D to Address Environmental Impacts of Minerals Development</i>	<i>[\$5,000]</i>	<i>[\$5,000]</i>		<i>[\$559]</i>	<i>[\$5,559]</i>	<i>[\$559]</i>
<i>Geophysical and Remote Sensing Activities</i>	<i>[\$3,000]</i>	<i>[\$3,000]</i>		<i>[-\$1,500]</i>	<i>[\$1,500]</i>	<i>[-\$1,500]</i>
Minerals Information	\$15,414	\$15,414		\$0	\$15,414	\$0

Justification of Program Change

The 2017 Budget Request for the Mineral Resources Program is \$48,695,000 and 312 FTE, a net change of +\$324,000 and +4 FTE from the 2016 Enacted level.

Overview

The USGS Mineral Resources Program (MRP) is the sole Federal source of scientific information and unbiased research on nonfuel mineral potential, production, and consumption, and on environmental impacts of minerals. The MRP supports data collection and research on a wide variety of nonfuel mineral resources that are important to the economic stability and national security of the United States. The USGS



Figure 1: Powders of six rare element oxides.
Photo credit: Peggy Greb, USDA.

has served as a trusted source of information on mineral resources since it was first established in 1879. In the intervening years, our Nation has evolved significantly, but our need for mineral resources and the science and tools to understand them is greater than ever.

Minerals are a critical part of everyday life and are essential to developing and sustaining a high-tech economy. From smart phones, computers and hybrid cars, to aircraft, new energy technologies and advanced national defense systems—the need for minerals is great and ever increasing. According to a 2008 report by the National Academy of Sciences, every year, we need more than 25,000 pounds of new nonfuel minerals per person to produce items needed for everyday use. Yet, we continue to depend upon other nations for many mineral commodities. Therefore, understanding information about our Nation’s mineral potential, production, and consumption is of paramount geopolitical and economic importance. Furthermore, a detailed scientific understanding of how minerals interact with the environment is essential for improving stewardship of public lands and resources and for protecting and improving public health, safety, and environmental quality.

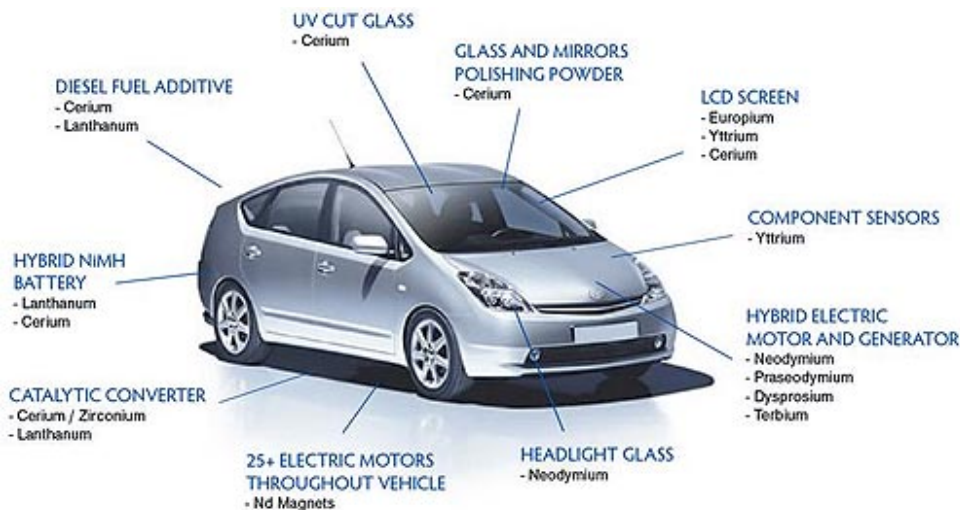


Figure 2: The production of hybrid vehicles is reliant on a number of rare earth minerals and materials. Source: Lee Allison, Arizona Geological Survey.

In 2017, the MRP is requesting increases in funding for the Critical Minerals and Materials Flow Initiative (+\$1,022,000/+8 FTE) and for Research and Development to address the Environmental Impacts of Minerals Development (+\$559,000/+4 FTE). The MRP proposes a decrease for Geophysical and Remote Sensing Activities (-\$1,500,000/ -8 FTE) to offset the increases, maintaining \$1.5 million in base funding.

Program Performance

The MRP is comprised of three program components: Critical Mineral Resources; Research and Assessment; and Minerals Information.

Critical Mineral Resources

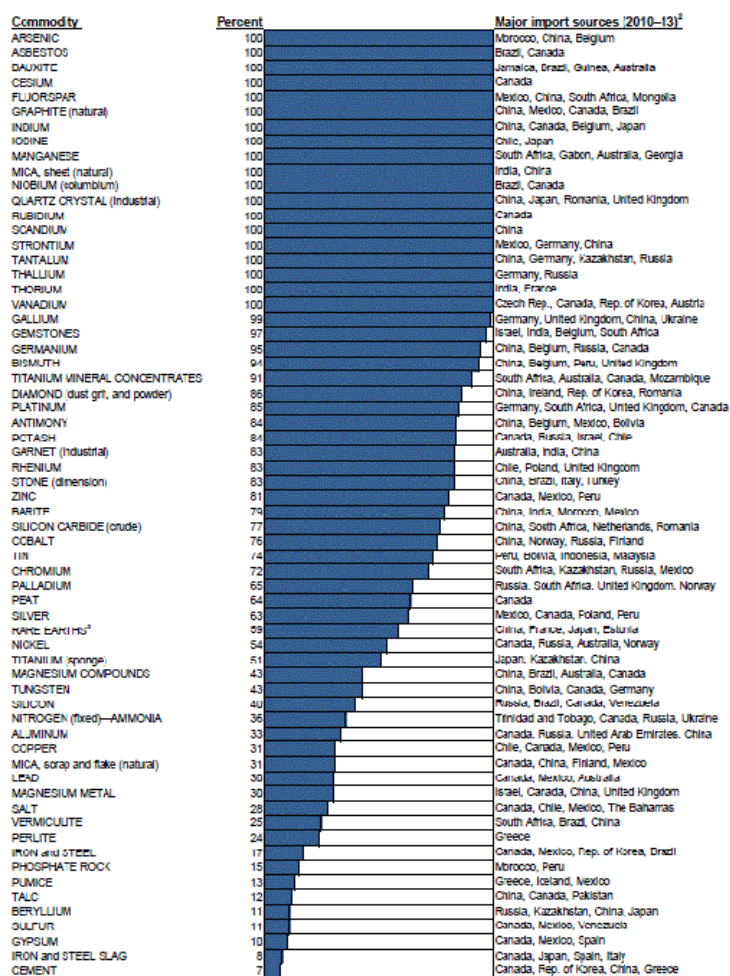
(2015 Actual, \$6.0 million; 2016 Enacted, \$8.5 million; 2017 Request, \$9.5 million)

Global demand for critical mineral commodities is on the rise, with demand mainly being driven by new technologies and consumer products. As a result, there is a growing need for up-to-date information on national and global critical mineral resources. The MRP both characterizes and identifies critical mineral resources important to our Nation’s economy and way of life. Using geologic, geophysical, and remote sensing surveys to comprehensively characterize the unconventional rare earth element (REE) potential of various regions of the United States, MRP information provides an accurate picture of distribution and supply of these critical resources. Understanding our national mineral and REE supply and supply potential is instrumental to both global commodity trade and foreign policy, as well as our domestic economy.

In addition, the MRP examines changes in supply risk and the impact of potential supply disruptions for critical minerals. The USGS National Minerals Information Center (NMIC) has taken a lead role in further development and implementation of a critical minerals initiative by a group comprised of members from a subcommittee of the Office of Science and Technology Policy (OSTP), in collaboration with Federal partners (the Department of Energy, the Department of Defense, the Department of Commerce, among others) and industry stakeholders. The group developed a “criticality matrix” of minerals and mineral products that are essential for industry and emerging technologies, including degrees of criticality based on a number of factors, which can be used to evaluate the impact of supply restrictions.

In 2015, the MRP completed fact sheet studies of five different critical elements: *rhenium*,

2014 U.S. NET IMPORT RELIANCE¹



¹Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (for example, molybdenum) or less than 5% import reliant (for example, lime). For some mineral commodities (for example, hafnium), not enough information is available to calculate the exact percentage of import reliance; for others (for example, tellurium), exact percentages may have been rounded to avoid disclosing company proprietary data.
²In descending order of import share.
³Data include lanthanides and yttrium but exclude most scandium.

Figure 3: A visual representation of U.S. reliance on foreign sources for many significant mineral commodities. Source: USGS Mineral Commodity Summaries (2015)

tellurium, antimony, indium, and germanium. The MRP also completed a resource assessment for critical minerals for which significant potential exists in the State of Alaska, which was jointly funded by the Bureau of Land Management (BLM). The State of Alaska is particularly interested in information about these minerals because resource development is a high priority and significant part of the economy of that State. Moreover, BLM regards this information as essential for their mandated duties to manage Federal land. In addition, the assessment techniques developed for this project are being used as a foundation for the much larger cooperative assessment project that the USGS is doing for BLM in their sage grouse management lands across five Western States.

In 2016, the MRP will release a new study: U.S. Geological Survey Professional Paper 1802 (PP1802), *Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply*, that presents resource and geologic information on the following 23 mineral commodities currently viewed as important to the national economy and national security of the United States (in alphabetical order):

antimony (Sb), barite (barium, Ba), beryllium (Be), cobalt (Co), fluorite or fluorspar (fluorine, F), gallium (Ga), germanium (Ge), graphite (carbon, C), hafnium (Hf), indium (In), lithium (Li), manganese (Mn), niobium (Nb), platinum-group elements (PGE), rare-earth elements (REE), rhenium (Re), selenium (Se), tantalum (Ta), tellurium (Te), tin (Sn), titanium (Ti), vanadium (V), and zirconium (Zr).

For a number of these commodities—for example, graphite, manganese, niobium, and tantalum—the United States is currently wholly dependent on imports to meet its needs. This information is used by a variety of Federal agencies (e.g., the Department of Commerce, the Department of Defense, and the Department of State) and international organizations (e.g., the European Union, the United Nations, and the World Bank) for management and policy development. For example, when the World Trade Organization was considering sanctions against China for manipulation of rare earth element trading, USGS commodity information like PP1802 formed the basis for those decisions.

Other new studies to be initiated in 2016 with the additional \$2.4 million in enacted funding for the Critical Minerals and Materials Flow Initiative include: geophysical projects to characterize rare earth elements and platinum group elements in large layered intrusions; Iron Oxide-Copper-Cobalt-Gold-Rare Earth Element Deposits of southeast Missouri, Tellurium in Alkaline Igneous-Related Deposits in Colorado and New Mexico; rare earth elements in weathered horizons overlying igneous rocks; and studies of individual critical mineral deposits such as Mountain Pass in California, Bokan Mountain in Alaska, and Yellow Pine in Idaho. This information is needed not only for effective land management and trade regulation, but an understanding of the critical mineral commodities available in the United States underlies diplomatic and national security deliberations, such as decisions about whether to impose trade sanctions on other countries.

In 2016, the MRP plans to implement a new early warning and analysis system for critical minerals, which was developed following initial work by an OSTP-led interagency effort. This is based on a two-stage approach, with the first stage involving an indicator-based early warning screening that aims to identify a subset of commodities as “materials of concern.” The second stage will utilize the output of the

early warning screening to prioritize commodities for further in-depth analysis to ensure that the underlying reasons resulting in their inclusion on the list of “materials of concern” are understood and to determine if these represent a significant risk to U.S. economic and national security interests. The early warning screening assesses the criticality potential (*C*) using a uniform methodology that results in a single value for each commodity on a common zero to one scale. Specifically, the assessment is based on the geometric mean of three fundamental indicators: supply risk (*R*), production growth (*G*), and market dynamics (*M*). These indicators were selected because they capture different aspects of criticality and because of their complementary nature: *R* attempts to capture the risk associated with geopolitical production concentration, *G* attempts to capture changes in the commodity’s market size and reliance on geological resources, and *M* attempts to capture the commodity’s price sensitivity to changes in its market.

For 2013, the year for which the most recent data are available, there are 17 commodities that have *C* indicator values of concern. In order to provide some validation of the model and its results, a retrospective analysis was conducted to determine if one could have detected a problem with the rare earths supply prior to 2010, when China decreased its rare earths export quota, which caused concerns of shortages and, in turn, prices to increase dramatically. This methodology would have detected a potential issue with rare earth supplies as early as 2001. Thus, this new MRP capability can contribute directly to national security, economic vitality, and international diplomacy by providing a reliable critical mineral early warning so that decision makers have ample lead-time with which to make geopolitical and economic decisions that are affected by the supply of critical mineral commodities.

In 2017, the following program changes are proposed for MRP in Critical Mineral Resources:

2017 Program Change
<p>Critical Minerals and Materials Flow Initiative (+\$1,022,000, for a total of \$9,484,000): With the proposed increase, the MRP would increase work on identifying and evaluating new sources of critical minerals and would continue lifecycle work on critical minerals. In particular, the MRP would target critical minerals identified in the Critical Minerals Early Warning system currently being implemented by the USGS National Minerals Information Center. The Critical Minerals Early Warning system utilizes a two-stage approach to determine if critical mineral commodities flagged by the system represent a significant risk to U.S. economic and national security interests. The proposed increase would allow for increased criticality analysis of a number of mineral commodities and would support Administration priorities such as developing methodologies to track minerals information.</p>

Research and Assessment

(2015 Actual, \$24.5 million; 2016 Enacted, \$24.5 million; 2017 Request, \$23.6 million)

The MRP supports research on how and where mineral deposits form, and develops methods to detect potential mineral resources. This research facilitates assessments of undiscovered mineral resources, most of which are not easily identified at the Earth’s surface because they are hidden by non-mineral bearing rocks or dense vegetation. Geophysical tools and techniques allow geologic units and structures beneath the Earth’s surface to be seen, and provide three-dimensional models of a particular area to

understand how mineral resources are distributed. Innovative geochemical tools and methods are also being developed by MRP to reduce uncertainty in mineral resource assessments.

MRP assessments support decision makers' interests in ensuring a secure supply of mineral resources by providing reliable, accurate information about the location, quantity, and quality of mineral resources. Assessments at a variety of scales provide valuable information to a range of users, including Federal, State, and local land-use managers. To prepare for a mineral resource assessment, data are collected and compiled. Research studies are conducted to understand the geologic history and characteristics of the area, define what processes formed the mineral deposits, and identify keys to predicting undiscovered deposits. Teams of experts analyze available information, identify characteristics that suggest the presence of undiscovered mineral deposits, and evaluate the quality and quantity of potential mineral deposits.

In addition, MRP supports development of tools and techniques designed to understand what happens when mineral deposits are weathered or mined. Mineral environmental assessments use understandings of mineral deposits to anticipate environmental challenges associated with abandoned mines and the effects of developing new mineral deposits, providing specific information on the potential release of contaminants into the environment. This information is critical for making informed land management decisions. Results of this research—including the techniques developed to identify the sources of contamination and the processes that interact to create

biogeochemical cycles—are applicable beyond the boundaries of Federal lands and are of use to land managers in the United States and around the world.

In 2015, the MRP completed and published an assessment of global copper resources. This first ever geologically-based global assessment of undiscovered copper resources estimates that 3.5 billion metric tons of copper may exist worldwide. The study outlined 225 areas for undiscovered copper in 11 regions of the world, in cooperation with international collaborators from national geological surveys, industry, and academia. Copper is one of the building blocks of civilization and is used in almost every aspect of modern life such as plumbing, electrical wiring, cars, cell phones, and energy systems such as wind turbines. According to the MRP 2015 *Mineral Commodities Summary*, U.S. consumption is currently 2 million metric tons of copper per year, whereas global consumption is 20 million metric tons per year.



Figure 4: USGS MRP laboratory in Denver, Colorado. Geochemists and other scientists in this and other MRP labs provide analytical support and method development for MRP-funded research studies, as well as collaborative studies with other USGS scientific mission areas, other Federal agencies, and academia.

Photo credit: USGS

The amount of undiscovered global copper estimated by the USGS assessment would be enough to satisfy current world demand for more than 150 years.

Other 2015 MRP projects included geophysical characterization of buried rock units in the mid-continent area of the United States, in Iowa and Missouri. Both of these projects helped better understand the resource potential of sub-surface rocks that are only known from a few scattered drill holes and mine workings. Another project characterized the deep weathering of granitic rocks in the Appalachian and coastal plain region of the Southeastern United States. These weathering processes are associated with important mineralization in other parts of the world, but have not been well studied in the United States.

Another major investigation in 2015 was the environmental impact of resource development in the Lake Superior region of the United States, an area with abundant historical mining activity as well as newly developed deposits. It is important to understand these environmental impacts in order to help better manage future developments. For example, the Lake Superior Geoenvironmental Assessment data were included in the Great Lakes Mapper (<http://wim.usgs.gov/sigl>), which is the platform chosen by the EPA to be the main compilation source for environmental data for the Great Lakes watersheds. In addition, the Western Upper Peninsula, an area of past and possibly future copper mining, was soil sampled to establish current baseline characteristics. This work proved prescient, as such, a survey has recently been proposed by the Great Lakes Indian Fish and Wildlife Commission. Water quality, soil, bedrock, and streambed sediment were collected for three watersheds that cross the mineralized basal Duluth Complex, with matching funding from the Midwest Mining Initiative, and continued with external funding from the Legislative-Citizen Commission on Minnesota Resources.

In 2016, the MRP plans to publish a new geologic map for the State of Alaska (see figure 5). This update to the Alaskan Geologic Map was nearly 20 years in the making and is the first fully digital map of Alaska. The map provides a foundation for completing mineral, energy, hazard, and other types of scientific and environmental assessments. Reflecting the efforts of many USGS personnel in Alaska, the map provides clearer insight into the geology of Alaska. This first digital geologic map of Alaska has a searchable database to quickly identify and see the distribution of geologic characteristics that, for example, can:

- Show the location of rock units having mineral potential.
- Show basins that are promising for energy potential.
- Show rock units that might help to define ecosystem characteristics.

Additional new mapping is planned in Alaska for the Yukon-Tanana terrane in northeast

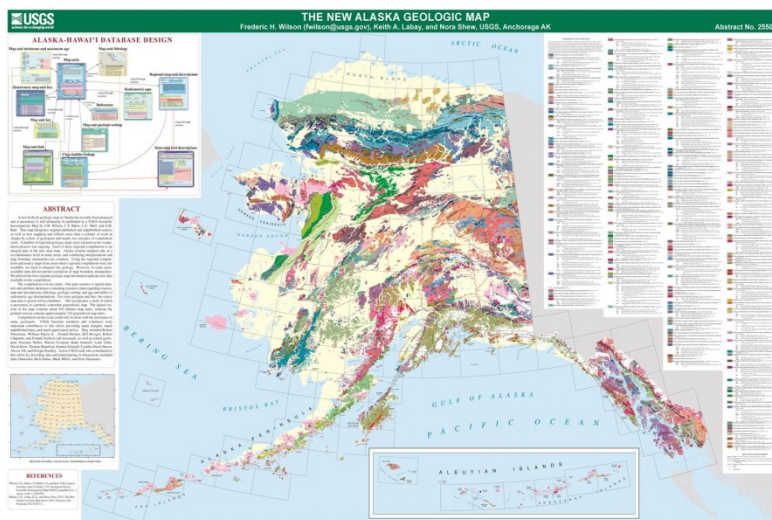


Figure 5: Poster of the updated Alaskan geological map, to be published in 2016. Source: USGS MRP

Energy and Mineral Resources, and Environmental Health

Alaska. In addition to contributing to a better understanding of the bedrock geology, this mapping will allow correlation of Alaskan rock units with the better understood geology across the border in Canada, and will help determine the source of known placer gold deposits in the region.

In 2017, the following program changes are proposed for MRP:

2017 Program Changes
<p>Geophysical and Remote Sensing Activities (-\$1,500,000, for a total of \$1,500,000): With the proposed decrease, the MRP would terminate some geophysical and remote sensing work in different regions of the United States, including Alaska, California, and the mid-continent. Geophysical work includes acquisition of airborne hyperspectral data, aeromagnetic and gravity data, and aero-radiometric survey, as well as techniques to interpret such data. These data are used for the preparation of geologic maps in poorly exposed areas like Alaska. Other projects that the MRP proposes to discontinue in order to fund higher priorities include geophysical characterization of layered plutons in Montana and the Lake Superior region of the mid-continent; identification of buried rock units in Alaska, Michigan, and New York that potentially could host important mineral resources; and spectral investigations of drill core and surface outcrops that are used for mineral assessments such as ongoing work on BLM lands in the Western United States.</p> <p>R&D to Address Environmental Impacts of Minerals Development (+\$559,000 for a total of \$5,559,000): The MRP will focus efforts on the development of new science and tools to reduce the impacts of minerals extraction, production, and recycling on the global environment and human health, including research on supply chain, life cycle, resource sustainability, and minimizing environmental impacts of mineral extraction. This additional funding will allow for enhanced work on toxicity of multiple metals associated with platinum group deposits; trace metal mobility in the Yellow Pine mining district, Idaho; groundwater quality in uranium mining; geoenvironmental health models of mineral deposits; geoenvironmental signatures of rare earth element deposits in Alaska; and refinement of national geoenvironmental models. Other environmental activities include efforts to better understand emerging environmental geochemical challenges for future mining, and the uses, characteristics, and environmental health implications of metal and mineral commodities in the built environment. This work is important for understanding and mitigating the environmental impacts of mineral resource development.</p>

Minerals Information

(2015 Actual, \$15.4 million; 2016 Enacted, \$15.4 million; 2017 Request, \$15.4 million)

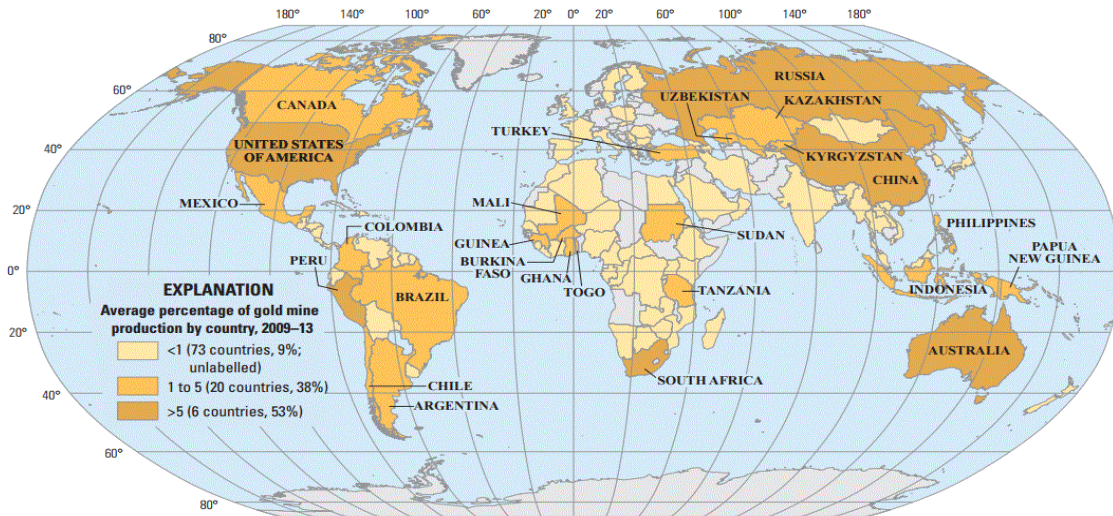
The MRP's Minerals Information function, through the USGS National Minerals Information Center (NMIC), supports collection, analysis and dissemination of data that document production and consumption for about 100 mineral commodities, both domestically and internationally, for 180 countries. The NMIC aims to provide decision makers with the information required to ensure that the Nation has an adequate and dependable supply of minerals and materials to meet its defense and economic needs at acceptable costs related to environment, energy, and economics. The public and private sectors both rely on USGS minerals information to better understand the use and ultimate disposition of materials in the economy; to use natural resources efficiently; and to forecast future supply and demand for minerals.

Domestic and international minerals information is used in policy analysis, in formulating plans to deal with shortages and interruptions in supplies of minerals, and in the development of strategies to maintain a competitive position in the global economy. The NMIC's minerals and materials analysis specialists are experts on mineral industries and markets. Every month, the specialists answer more than 2,000 inquiries from, and interact with, Federal and State agencies, domestic and international organizations, foreign governments, and the public. Program scientists also conduct analyses of and develop information on minerals-related issues, including minerals conservation, sustainability, materials flow, availability, and the economic health of the U.S. minerals industry. Every year, more than 700 reports are prepared by the USGS and added to the minerals information Web pages (<http://minerals.usgs.gov/minerals>).

Information is organized and published by commodity, country, and State and includes:

- *Mineral Commodity Summaries* (annual, by commodity). This annual publication includes statistics on about 90 mineral commodities essential to the U.S. economy and national security, and addresses events, trends, and issues in the domestic and international minerals industries.
- *Minerals Yearbook* (annual)
 - Volume I: Metals and Minerals (by commodity)
 - Volume II: Area Reports—Domestic (by State)
 - Volume III: Area Reports—International (by country)
- *Mineral Industry Surveys* (monthly, quarterly, semiannually, and annually, by commodity).
- *Metal Industry Indicators* (monthly, for primary metals, steel, copper, primary aluminum, and aluminum mill products).
- *Nonmetallic Mineral Products Industry Indexes* (monthly, leading and coincident indexes for the Nonmetallic Mineral Products Industry). Another major emphasis of the MRP and NMIC is on analyzing flows of materials. This allows other agencies, governments, and stakeholders to better understand the changes and importance of mineral resource production, consumption, and use.

In 2015, the MRP produced the annual *Mineral Commodity Summaries*, the most widely used and cited report on both domestic and international mineral resource production, consumption, and materials flow. Specific reports produced included *Recent Trends in Cuba's Mining and Petroleum Industries*, *Conflict Minerals from the Democratic Republic of the Congo—Gold supply chain*, and the *Ebola Virus Disease Outbreak and the Mineral Sectors of Guinea, Liberia, and Sierra Leone*. The latter report concludes that the important mining industries of Guinea, Liberia and Sierra Leone were able to largely maintain their operations during the deadly 2014-2015 Ebola outbreak. The mineral industries of Guinea, Liberia, and Sierra Leone are important sectors to these countries' economies. In 2013 alone, the estimated contribution of the mineral sector to GDP in Guinea, Liberia, and Sierra Leone was about 13, 11, and 23 percent, respectively. Uncertainty regarding the status of mining and mineral exploration operations in the three countries following the onset of the Ebola outbreak and changes in mineral market conditions raised questions regarding the prospects for such growth and future foreign direct investment in the region. An understanding of the global minerals economy, as provided by such MRP information products, is critical to informing U.S. foreign policy and trade relationships.



Average world gold mine production by country, 2009-13.

Figure 6: Map from a USGS National Mineral Information Center publication, showing average world gold mine production by country, 2009-13.

Source: USGS NMIC.

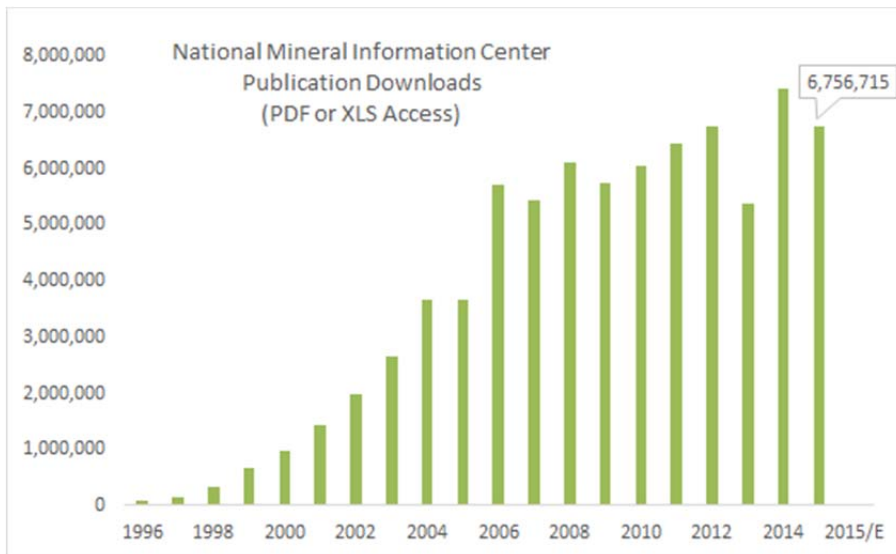


Figure 7: Graph showing number of downloads of USGS National Mineral Information Center publications by year.

Source: USGS.

In 2015, USGS minerals information products continued to be accessed millions of times. There were over 6.7 million downloads from the MRP Web site in 2015 (see figure 7), with a signature product being the annual *Mineral Commodities Summary*.

In 2016, and on a continuing basis, MRP mineral economists and minerals information specialists will provide

minerals information to other Federal agencies, including the U.S. Census Bureau, the Department of Defense, the Federal Reserve Board, and the Office of the U.S. Trade Representative. MRP specialists also chair and contribute to several OSTP-convened working groups that will inform Federal critical minerals policy related to supply chain sustainability, research and development, and mineral information collection, analysis, and dissemination. The global distribution, availability, and security of supply for mineral commodities are essential for the U.S. economic and national security. The ability of the USGS National Minerals Information Center to provide fact-based information to address these issues is unmatched. Events over the past few years have put these issues at the forefront of public policy and

debate. Examples include the crisis over rare earth element supply from China, the requirements for mineral supply chain due diligence mandated by the Dodd-Frank provisions regarding conflict minerals, and economic sanctions on Russia. The National Minerals Information Center is an unrivaled resource in this arena and could be leveraged to support the broader mission of the USGS, the Department of the Interior, and the U.S. Government.

In 2017, the NMIC will continue to provide hundreds of reports such as the *Minerals Commodity Summaries*, the *Minerals Yearbook*, the *Mineral Industry Surveys*, *Metal Industry Indicators*, and the *Nonmetallic Mineral Products Industry Indexes*. These and other MRP information products, along with sound analysis from minerals and materials analysis specialists and program scientists, allow for decision makers and stakeholders to better understand the changes and importance of mineral resource production, consumption, and use. The NMIC will continue to provide high quality information and analysis that informs Federal critical minerals policy and is of paramount importance to U.S. national security and trade interests.

Science Coordination

The MRP collaborates with a number of external organizations, including Federal agencies and multiagency working groups, States, as well as industry stakeholders, to both contribute needed science and minerals information and to leverage the expertise and contributions of partners towards the goal of a more thorough understanding of information about our Nation's mineral potential, production, consumption, and the impacts of mineral resource development on the environment. The MRP has been closely involved with the critical minerals efforts spearheaded by the OSTP, in collaboration with Federal agency partners (including the Department of Energy, the Department of Defense, and the Department of Commerce, among others) and industry stakeholders. Additionally, both the State of Alaska and the BLM derive value from the MRP's critical mineral resource assessments conducted in Alaska, as resource development is an important part of the economy of that State, and BLM considers the MRP's resource assessment information essential for their mandated duties to manage Federal land. The MRP's efforts to assess environmental impacts of resource development in the Great Lakes region have been very useful to both the Environmental Protection Agency and State environmental resource managers in the region. The National Minerals Information Center continues to supply Federal government agencies (including the U.S. Census Bureau, the Department of Defense, the Federal Reserve Board, and the Office of the U.S. Trade Representative) with important information regarding the mineral supply and demand of the United States and other nations, upon which these agencies rely to make strategic economic, trade, and national security decisions.

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Activity: Energy and Mineral Resources, and Environmental Health

Subactivity: Mineral and Energy Resources

Program Element: Energy Resources Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Energy and Mineral Resources, and Environmental Health	\$92,271	\$94,511	\$453	\$4,519	\$99,483	\$4,972
<i>FTE</i>	<i>553</i>	<i>567</i>		<i>14</i>	<i>581</i>	<i>14</i>
Mineral and Energy Resources	\$70,826	\$73,066	\$361	\$1,496	\$74,923	\$1,857
<i>FTE</i>	<i>434</i>	<i>448</i>		<i>6</i>	<i>454</i>	<i>6</i>
Energy Resources Program	\$24,895	\$24,695	\$118	\$1,415	\$26,228	\$1,533
<i>FTE</i>	<i>140</i>	<i>140</i>		<i>2</i>	<i>142</i>	<i>2</i>
Energy Resources: Geological Processes and Characterization	\$6,555	\$6,555		\$0	\$6,555	\$0
Oil, Gas, and Coal Resources	\$8,435	\$8,435		\$975	\$9,410	\$975
<i>Unconventional Oil and Gas Research</i>	<i>[\$5,850]</i>	<i>[\$5,850]</i>		<i>[\$975]</i>	<i>[\$6,825]</i>	<i>[\$975]</i>
Renewable and Alternative Energy	\$1,990	\$1,990		\$229	\$2,219	\$229
<i>Alternative Energy Permitting on Federal Lands - Geothermal</i>	<i>[\$425]</i>	<i>[\$425]</i>		<i>[\$229]</i>	<i>[\$654]</i>	<i>[\$229]</i>
Energy Resources and the Environment	\$1,848	\$1,848		\$0	\$1,848	\$0
Science and Decisions Center	\$910	\$910		\$211	\$1,121	\$211
<i>Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment</i>	<i>[\$75]</i>	<i>[\$75]</i>		<i>[\$211]</i>	<i>[\$286]</i>	<i>[\$211]</i>
Energy Resources on the Landscape: Spatial and Economic Context	\$5,157	\$4,957		\$0	\$4,957	\$0

Justification of Program Change

The 2017 Budget Request for the Energy Resources Program is \$26,228,000 million, and 142 FTE, a net change of +\$1,533,000 million and +2 FTE from the 2016 Enacted level.

Overview

The USGS Energy Resources Program (ERP) is the sole provider of unbiased, publicly available estimates of geological energy resources for the United States*, and provides publicly available estimates

related to global oil and gas resources. The ERP addresses the challenge of increasing demand for energy sources by conducting basic and applied research on geologic energy resources and on the environmental and economic impacts of their use. Among the geologic energy resources the ERP studies are: oil, natural gas, coal, coalbed methane, gas hydrates, geothermal resources, uranium, oil shale, bitumen and heavy oil. The ERP is also involved in studying the impacts of wind development on wildlife. ERP science informs decision making related to domestic and foreign energy resources, as well as the management of energy resources on Federal lands.

As demand for energy resources continues to increase, understanding our Nation's supply and recoverability of energy resources is critical to sustaining a strong national economy. The ERP provides the publicly available data and tools to support energy policy discussions and to support science-based decisions that facilitate sustainable energy development and responsible use of resources.

In 2017, the ERP is requesting increases in funding for Alternative Energy Permitting on Federal Lands – Geothermal (+\$229,000/0 FTE), Ecosystem Services: Enhancing Resilience in Coastal Infrastructure (+\$75,000/0 FTE), Ecosystem Services: Evaluating Green Infrastructure Investment (+\$136,000/+1 FTE), and Unconventional Oil and Gas Research (+\$975,000/+1 FTE).

**Exclusive of the U.S. Outer Continental Shelf.*

Program Performance

The Energy Resources Program is comprised of six major areas of work, described in detail below:

1. Energy Resources: Geological Processes and Characterization
2. Powering Our Future: Oil, Gas, and Coal Resources
3. Powering Our Future: Renewable and Alternative Energy
4. Energy Resources and the Environment
5. Science and Decisions Center
6. Energy Resources on the Landscape: Spatial and Economic Context

Energy Resources: Geological Processes and Characterization
(2015 Actual, \$6.6 million; 2016 Enacted, \$6.6 million; 2017 Request, \$6.6 million)

Accurate and scientifically based assessments of coal, oil, and gas resources of the Nation and world are dependent upon fundamental information on the geologic processes forming energy resources, and an understanding of the geologic setting of these resources. This critical information provides the foundation for informed, evidence-based decision making regarding the energy security and economic welfare of the Nation. The USGS Energy Resources Program's work in geologic process and resource characterization provides a scientific basis from which to evaluate the potential contributions to future energy supplies from currently used energy resources and from emerging resources such as gas hydrates, and for understanding the economic viability and potential environmental factors associated with resource

development and use. For example, geochemical research helps to explain how oil and gas are generated, how they migrate out of source rocks and how they accumulate and are preserved in reservoir rocks. Predictive models for the occurrence, distribution, quality and quantity of energy resources are then developed from this research. These models aid in predicting the type of hydrocarbon generated, the timing of generation in relation to structural movement and trap formation, and the migration pathways and location of oil and gas accumulations. These models are critical in the process of assessing the location and amounts of undiscovered hydrocarbons.

Below are four major areas of ERP work on Geological Processes and Characterization:

Geophysics – The ERP supports efforts to conduct research in reflection seismology with emphasis on (1) determining the type and location of both conventional and unconventional hydrocarbon resources, and (2) making the results and any associated non-proprietary data available to the public.

This project aligns with a number of Office of Science

and Technology Policy (OSTP) priorities and the Administration's 21st Century Grand Challenges, aligning with the objectives to increase domestic energy supplies while protecting the environment and to diversify the Country's sources of traditional and alternative fuels. To address these priorities, geophysics research provides information on types of reservoirs, their location, and the kinds of hydrocarbons that they contain. The effort supports several resource assessment projects within the ERP portfolio, and provides expertise to both the Department of State's Energy Governance and Capacity-Building Initiative (EGCI) Program, and Extended Continental Shelf (ECS) work related to the Law of the Sea project, as well as the Department of Defense's (DoD) Task Force for Business and Stability Operations (TFBSO).

Gas Hydrates – The USGS works extensively on gas hydrates, which are naturally occurring ice-like combinations of natural gas and water that have the potential to provide an immense resource of natural gas from the world's oceans and Polar Regions. Gas hydrates are known to be widespread in permafrost regions and beneath the sea in sediments of outer continental margins. It is generally accepted that the volume of natural gas contained in the world's gas hydrate accumulations greatly exceeds that of known gas reserves. There is also growing evidence that natural gas can be produced from gas hydrates with existing conventional oil and gas production technology. The ERP's gas hydrate work has been conducted most notably on the Alaskan North Slope, the Gulf of Mexico, and internationally on offshore



Figure 6: USGS geologist on outcrop of Nanushuk Formation, Tutku Bluff, Alaska in summer 2004.

Source: Dave Houseknecht, USGS.

eastern India. Lessons learned from these geographically and geologically diverse studies aid in characterizing our domestic gas hydrate resources. The new data provide information about how much gas hydrate exists in a much broader area than can be determined from using standard industry seismic data, which is typically designed to image much deeper geologic units. There is substantial international interest in gas hydrates, and the USGS works closely with the governments of several countries, including the Indian Directorate General of Hydrocarbons (DGH) and the Government of the Republic of Korea, to study, characterize, and explore for hydrates off the coasts of India and the Republic of Korea. In 2016, these collaborative efforts will continue to move forward the collective knowledge of this underexplored resource, and the results are directly applicable to potential resources in the United States. In these efforts, ERP scientists continue to work jointly with those in the USGS Coastal and Marine Geology Program to leverage the diverse expertise and capabilities of scientists in both programs.

Geochemistry of Energy Fuels – Optimizing fuel use and minimizing its impact on the environment are necessary components of 21st century strategies for meeting the power needs of society. Compositional properties of solid fuels have important influences on energy generation efficiency, the impact of fuel use on the environment, and the composition and utility of combustion products generated. One critical aspect of fuel use optimization is an understanding of geologic factors contributing to fuel quality. USGS Energy Resources Program scientists are uniquely qualified to sample solid fuels and related combustion products, and apply a range of analytical procedures to address key questions and evolving trends in the use of solid fuels. Research results will greatly enhance our understanding of the geology and geochemistry of solid fuel resources. These results will be used to improve future energy resource assessments and our understanding of the environmental consequences of solid fuel use. All results will be publicly available and will be provided to land managers and decision makers for use in the formation of science and energy policy.

Petroleum Processes – A thorough understanding of the processes that control petroleum (gas, condensate, oil, and tar) generation, migration, entrapment, and preservation in the Earth's crust is critical to making accurate scientifically sound assessments of the type, quantity, quality, and location of undiscovered petroleum resources on a national and global basis. The ERP supports studies that apply cutting-edge research to critical issues concerning the recognition and assessment of undiscovered petroleum resources, with an emphasis on unconventional resources. As an example, the Energy Policy Act of 2005 recognized the need for updated information on domestic oil shale resources and, in accordance with the legislation, the USGS completed assessments of Green River Formation oil shales—a distinctly different resource type compared to shale oil produced from wells following hydraulic fracturing. Subsequent petroleum processes work in 2016 will focus on (1) advancing techniques for study and characterization of oil shales to inform what might be technically recoverable using various production technology scenarios, and (2) contributing to a better understanding of the origin and geologic controls responsible for unconventional petroleum resources (i.e., tight gas sands, shale gas, and shale oil).

In 2015, the ERP continued to move forward with cutting-edge research on geologic processes and characterization, including playing a major role in India's second National Gas Hydrates Program (NGHP-02). In collaboration with ERP scientists, NGHP-02 completed nearly five months of borehole logging and coring in deepwater gas hydrate areas offshore eastern India aboard the drillship *Chikyu*.

Scientists from the ERP served as advisors to the Indian National Gas Hydrates Program and were onboard experts for the expedition. They determined the locations to be drilled, analyzed the geophysical logs, and supervised the pressure coring process. In doing that, they were able to determine where gas hydrates were present, at what depth and volume. Another significant ERP accomplishment in 2015 was ERP's contribution to the publication of a major USGS study of fossil fuels in the Appalachian Basin region. *U.S. Geological Survey (USGS) Professional Paper 1708* is a modern, in-depth collection of reports, cross sections, and maps that describe the geology of the Appalachian basin and its fossil fuel resources.

In 2016, the ERP plans to continue to provide expertise to India's National Gas Hydrates Program (NGHP-02), and play an extensive role in post-cruise studies and planning for future expeditions. Future expeditions will attempt to go beyond resource analysis to actually producing the gas. If successful, this would be an enormous breakthrough, as it could provide new gas resource opportunities to countries that currently do not have traditional gas resources, and would add to the global gas resources as a whole. Additionally, the USGS ERP will continue its partnership with the BLM in 2016 to conduct a geologic-based analysis of the occurrence of gas hydrates within northern Alaska. This analysis is part of the larger Gas Hydrate Development Lifecycle Assessment Project, designed to determine the role gas hydrates may play as a future domestic energy resource and to characterize the potential environmental and economic impact of gas hydrate exploration and development. Other ERP research in 2016 will examine the variations of mercury in coal in the Illinois Basin to test if they are amenable to mercury reduction by coal preparation. Additionally, studies on the use of cadmium and zinc isotopes as environmental tracers of coal combustion will continue. In 2016, the ERP plans to complete a map and supporting data of metallurgical coal in the United States and conduct field and laboratory experiments on generating natural gas from underground coal seams using special microbes. Metallurgical coal is exceptionally valuable for making steel. In the United States, metallurgical coalmines support domestic steel making and a major export market. Also in 2016, ERP will continue supporting a research partnership with Montana State University to test the use of wastewater from coal gas production to raise algae, which will be converted to biodiesel, and to evaluate the potential for taking the biomass remaining from this conversion and injecting it underground to produce more coal gas. The potential outcome of this effort is a clean coal technology (natural gas production from underground coal) that can also produce renewable biofuels; MSU and USGS researchers are jointly pursuing a patent for the process.

Oil, Gas, and Coal Resources

(2015 Actual, \$8.4 million; 2016 Enacted, \$8.4 million; 2017 Request, \$9.4 million)

Our Nation relies on a steady supply of energy resources to power our homes and businesses. Coal and petroleum resources remain a significant part, constituting over 80 percent of the domestic energy supply (*Source: Energy Information Administration (EIA), 2015*). Through responsible development of these resources, we can transition to a new energy frontier that supports our economy and safeguards our national security and our environment. The Secretary of Interior's Powering Our Future initiative promotes the responsible development of both conventional and renewable resources on public lands—an initiative that the USGS Energy Resources Program supports by providing sound scientific research and assessments of these resources. The Department of Interior manages one-fifth of the Nation's landmass.

Energy resources on public lands, including both onshore and offshore lands, provide 30 percent of our Nation's domestically-produced energy (*Source: Department of Interior, 2015*). Research and assessments conducted by the USGS Energy Resources Program contribute valuable information for decision makers to use in continuing to responsibly develop resources on public lands, and can provide important insight to industry upon which prudent decisions about development can be made.



Figure 7: USGS drillers obtain geologic samples from deep beneath the ground near Waco, Texas to better understand the unconventional oil and gas potential of the region.

Source: USGS ERP

The United States has one of the world's largest coal resource endowments. 2014, almost 40 percent of the electric power generated in the United States was derived from power plants using coal as a fuel source (*Source: EIA, 2015*). In response to the continuing demands for coal and for cleaner electric power generation, USGS ERP research focuses on modern geology-based assessments of the quantity, quality, location, accessibility, and economics of the Nation's coal resources. The USGS recently refined its coal resource assessment methodology to produce a systematic determination of the technically and economically recoverable coal resources on a regional basis. It was applied to the prolific Powder River Basin in Wyoming and is being used to assess all major coal-bearing areas in the Nation successively. In 2015, the ERP also released map data of coal occurrence in China, which provides an understanding of that resource that could be useful in foreign policy.

Understanding the resources available and technically recoverable both in the United States and abroad is an important part of ensuring that development occurs prudently and with the utilization of the best scientific information available in order to safeguard our natural

resources. USGS assessments of oil and gas resources are useful, and are becoming increasingly relevant to energy policy, especially as recovery processes such as directional drilling and hydraulic fracturing become widespread in the United States, accounting for an estimated 70 percent of gas produced domestically (*Source: EIA, 2015*). With respect to unconventional oil and gas activities, the USGS is participating in interagency coordination efforts with other Interior bureaus, the U.S. Department of Energy, and the U.S. Environmental Protection Agency (EPA) aimed at providing research and technologies that support sound policy decisions by Federal, State, and local agencies responsible for ensuring the prudent development of unconventional oil and gas resources while protecting human health and the environment. This effort supports the April 13, 2012, Executive Order and subsequent 2014 report, *Federal Multiagency Collaboration on Unconventional Oil and Gas Research: A Strategy for Research and Development*. Because there is currently no global unconventional oil and gas resource assessment, the ERP has made this a priority and is continuing to publish assessments of conventional and unconventional oil and gas resources from regions around the world, including assessments in China, Indonesia, Mexico, and France that were completed in 2015. In 2015, the ERP initiated two collaborations with the Geological Survey of Canada that will improve the understanding of the geologic framework from eastern Arctic Alaska, the Mackenzie Delta, and the southern passive margin of the Canadian Arctic Islands (including petroleum systems elements). This research is significant because it allows the use of all of the sparse geologic data available in the area and improves the reliability of any oil

and gas assessments performed in the U.S. portion. The regional analysis also supports the development of a U.S. position in Extended Continental Shelf claims under the United Nations Convention on the Law of the Sea.

The ERP assesses oil and gas resource potential through in-depth studies of geology and resources in various petroleum provinces of the United States as well, including regional studies of the Gulf Coast and the North Slope of Alaska. Study of the geologic, geophysical, and geochemical framework of these areas allows for better understanding of the resource potential and potential economic and environmental impacts of oil and gas development in those regions.

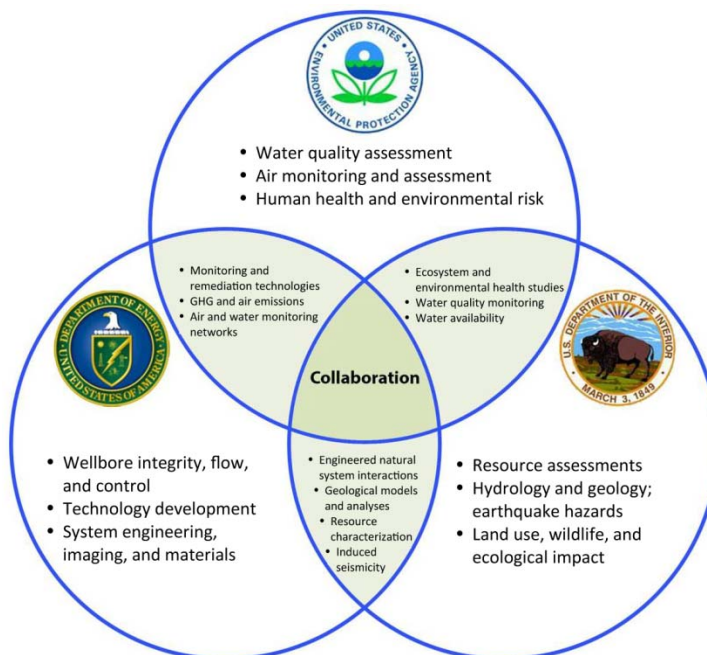


Figure 8: A diagram showing the Department of Interior, the Department of Energy, and the Environmental Protection Agency's roles in the multiagency collaborative effort on unconventional oil and gas research.

Source: Multiagency Collaboration Research Strategy, 2014.

In 2015, the ERP published several reports on coal resource estimates in the Powder River Basin of Wyoming, the Nation’s largest coal-producing area. The ERP also released an unconventional oil assessment of the Monterey Formation of California. This assessment found that the formation contains an estimated mean volume of 21 million barrels of oil, 27 billion cubic feet of gas, and 1 million barrels of natural gas liquids. Other assessments completed by the ERP in 2015 include unconventional oil and gas assessments in the Cherokee Platform in the midcontinent, part of the Uintah Basin in Utah, the Cotton Valley Group along the Gulf Coast, the Cook Inlet of Alaska, and the Michigan Basin. These assessments continue to improve our understanding of domestic oil and gas resources and allow for unbiased science, which informs decisions balancing our Nation’s energy supply needs with environmentally sustainable resource development.

In 2016, the ERP will release an updated unconventional oil and gas assessment for the Barnett Shale in Texas, and will support assessment studies in other areas, including the Monterey Formation in additional California basins, the Chukchi Shelf of Alaska, and several basins in the Appalachians.

In 2017, the following program change is proposed for *Powering Our Future: Oil, Gas, and Coal Resources*:

2017 Program Change
<p>Unconventional Oil and Gas Research (+\$975,000, for a total of \$6,825,000): With the proposed increase, the ERP would expand its work on the evaluation of the nature of brines produced from unconventional oil and gas (UOG) accumulations deep below near-surface aquifers to help predict the quality and quantity of waste fluids associated with energy production. The proposed increase would</p>

2017 Program Change

also allow the ERP to conduct annual field research in Alaska to support the assessment of undiscovered UOG on the North Slope. Domestic assessment of shale and tight oil and gas would expand to increase the number of evaluations performed by about two per year. Furthermore, the Energy Resources Program would increase cooperative efforts with State geologic surveys to acquire fundamental data needed for UOG assessments. Finally, petroleum processes research would expand to improve understanding of the nature of UOG resources and provide needed organic carbon data for UOG assessments. All of this proposed work would support the Energy Resources Program's ongoing contributions to the Federal Multiagency Collaboration on Unconventional Oil and Gas Research, in its *Research Strategy* goal to understand the scale and nature of U.S. UOG resources. The ERP's proposed research will support sound policy decisions by Federal, State, and local agencies responsible for ensuring the prudent, safe, and sustainable development of unconventional oil and gas resources.

Renewable and Alternative Energy

(2015 Actual, \$2.0 million; 2016 Enacted, \$2.0 million; 2017 Request, \$2.2 million)

Renewable and alternative energy sources are sustainable sources for meeting our Nation's energy demand. Geothermal energy in particular represents a largely untapped source of renewable power potential. A 2008 USGS Energy Resources Program assessment of national geothermal resources indicated that enhanced geothermal systems (EGS), if successfully developed, could support an installed geothermal electric power-generating capacity equivalent to about half the U.S. electric power-generating capacity. The ERP's research in alternative and low-carbon energy sources includes uranium resource evaluations, collaboratively funded by the ERP and the USGS Mineral Resources Program to best leverage expertise and capabilities of both programs. U.S. nuclear power plants currently produce 19 percent of the Nation's electricity and represent a potentially growing source of alternative energy (*Source: EIA, 2015*). Domestic sources of uranium may be abundant but have not been comprehensively assessed since 1985. Understanding the potential for further diversifying our energy portfolio by harnessing our Nation's renewable and alternative energy potential is important for informed decision making that takes into account the resulting effects on our economy and environment.

In 2015, the ERP initiated a significant collaboration with the Department of Energy (DOE) to refine methods that would substantially reduce exploration risk associated with efforts seeking to identify geothermal resources underground. Ongoing research with a number of collaborators continued to define geothermal systems in a variety of settings in the Western United States and internationally, including research well drilling, geophysics, and computer modeling. The ERP is also supporting studies of the effects of geothermal development, including the potential for earthquakes (induced seismicity) associated with fluid injection, as well as impacts that expanding production may have on the environment (e.g., groundwater, soil, vegetation, air). For example, the ERP supported substantial research at the Coso Geothermal Field in southern California to better understand the causes of induced seismicity there and to help predict future earthquake activity. This information can be used to inform monitoring and potential mitigation plans to reduce the potential for earthquakes during geothermal resource development, and may be applicable to other geological settings where potential geothermal development could be proposed.

In 2016, the ERP plans to locate potential geothermal heat sources and understand the underlying geology at a number of sites using an array of geophysical field and modeling techniques. In collaboration with the U.S. Department of Energy (DOE), the ERP’s geothermal work will focus on three sites (pending DOE funding) and involve field studies, modeling, and analysis. With partial funding from the Bureau of Land Management, the ERP will start work on regional-scale geothermal favorability maps in Nevada that will help with land and resource management there. The ERP will continue monitoring environmental impacts of increased geothermal development at Long Valley, CA, including the deployment of innovative miniature unmanned aerial vehicles. Planned expansion of a geothermal project to increase power production will also likely result increase in the land surface areas affected by releases of heat (steam) and other gases. Early detection of heat and gas anomalies may help prevent these impacts by indicating the need to change the geothermal production/injection scheme for the area. The ERP is supporting studies to develop, test, and deploy miniature unmanned aerial systems to perform future thermal infrared—or “heat mapping”—studies to monitor changes potentially associated with an expansion in geothermal production.



Figure 9: Coso geothermal plant, Navy One, at Naval Air Weapons Station-- China Lake in southern California.

Source: U.S. Navy

Other ERP work on Renewable and Alternative Energy in 2016 will include the release an updated assessment of uranium resources in one deposit type, a “roll-front” sandstone host, in the Texas Gulf Coast. Work on other deposit types in other regions will continue in 2016. These studies will help inform understanding of the domestic potential for uranium resources that can be used as a fuel source for nuclear power plants to generate electric power. Currently, the United States imports a substantial portion of the uranium used in nuclear power plants. Understanding domestic uranium resources could help the United States reduce this dependence on foreign sources of uranium.

In 2017, the following program change is proposed for *Powering Our Future: Renewable and Alternative Energy*:

2017 Program Change
<p>Alternative Energy Permitting on Federal Lands – Geothermal (+\$229,000, for a total of \$654,000): The majority of domestic geothermal resources are on public lands in the Western United States; hence, the USGS works closely with BLM and USFS. The proposed increase would expand the ERP’s collaborative efforts with BLM to conduct geothermal resource favorability mapping studies, as well as research and technology development to study potential impacts from geothermal development. The ERP will develop, test, and deploy miniature unmanned aerial systems to perform future thermal infrared—or “heat mapping”—studies to monitor changes potentially associated with an expansion in</p>

2017 Program Change

geothermal production. Outcomes from this research could also support science and information needs identified by the BLM, the U.S. Fish and Wildlife Service, and other State partners in the draft Desert Renewable Energy Conservation Plan (DRECP), which is a “landscape-scale plan that uses science to inform the siting of renewable energy development projects and the conservation of species, creating systematic habitat protection and connectivity improvements across the Mojave and Colorado/Sonoran desert regions” (DRECP Executive Summary, September 2014). The BLM and other bureaus can use information from this proposed increase for land use planning and potentially a targeted environmental impact statement for high potential use areas. This is part of the All-of-the-Above Energy Strategy and part of the Secretary of the Interior’s Powering Our Future initiative.

Energy Resources and the Environment

(2015 Actual, \$1.9 million; 2016 Enacted, \$1.9 million; 2017 Request, \$1.9 million)

Understanding how energy resources and their development interact with the environment can lead to progressively better solutions for development with minimal impact, potentially resulting in improved remedies for addressing environmental concerns such as oil spills. ERP research addresses the complete lifecycle of energy resources, from geologic setting and source, to exploration, extraction, processing and use, to reclamation, recycling and disposal. At various points of this lifecycle, there is overlap between human activities and the environment, and ERP research can be leveraged to understand those intersections and improve environmental impacts. The benefits of this science apply to a variety of stakeholders: resource industries can use this research to identify the most cost-effective means to limit adverse environmental impacts while maintaining efficient development of resources; citizens have access to unbiased scientific information about the risks and benefits of resource development; and land use managers and regulators can utilize this research to improve environmental stewardship. Federal resource stewardship, human health, and regulatory agencies such as the Bureau of Land Management,



Figure 10: Western end of Atigun Gorge, Alaska, about 90 miles east of the National Petroleum Reserve – Alaska (NPR).

Source: Dave Houseknecht, USGS

the Bureau of Ocean Energy Management, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the National Institute of Environmental Health Sciences, and the National Institutes of Health, comprise the beneficiaries of ERP energy resource environmental science, and, along with States and local governments, are important partners for mitigating the environmental impacts of resource development.

In addition to science about ongoing energy development activities and their environmental impacts, the ERP also provides research on previous extraction and development activities, which can provide a more complete understanding of long-term biogeochemical processes influencing environmental signatures; insight into complex natural exposure routes to surrounding ecosystems and humans; and information needed for mitigation and remediation as well as informing future responsible resource development. Research on previous development activities can also provide important insights into potential alternative sources of resources through reprocessing of waste waters or beneficial reuse.

Below are a few of the areas in which the ERP provides valuable research on the interaction between energy resources and the environment:

Produced Waters from Hydraulic Fracturing – New technologies have expanded domestic oil and gas production to include low-permeability formations once considered inaccessible. Hydrocarbon production from these formations requires considerable quantities of fresh water to increase fluid conductivity of the reservoir unit through hydraulic fracturing. Hydraulic fracturing fluids generally contain salts and minerals from the formation in addition to the additives used to increase fracking efficiency (“proppants”). Moreover, the large volumes of water involved in hydraulic fracturing could potentially impact the environment. The ERP’s assessments, together with those of the USGS Water Resources Mission Area, provide unbiased information useful to decision makers about water availability and quantities of water and proppant potentially involved with the production of undiscovered, technically recoverable petroleum resources. In 2015, the USGS published a major report and map on water use in hydraulic fracturing activities varying across the United States and the potential associated environmental impacts. This study found water volumes for hydraulic fracturing averaged within watersheds range from 2,600 gallons to as much as 9.7 million gallons per well. This spatial variability in hydraulic fracturing water use relates to the potential for environmental impacts such as water availability, water quality, wastewater disposal, and possible wastewater injection-induced earthquakes. The ERP also developed methodologies to assess quantities of water and proppant injection used in hydraulic fracturing activities, which will also provide valuable information on the same environmental impacts mentioned above. Furthermore, the ERP supports collaborative studies with the USGS Toxic Substances Hydrology Program to study the environmental health impacts of organic substances from unconventional oil and gas production activities to complement other studies focusing on inorganic chemistry (salts) of produced waters.

Wind Energy Impacts – As of 2014, wind turbines in the United States generated approximately four percent of the Nation’s total electricity (*Source: EIA, 2015*). Electricity generation from wind in the United States has increased significantly over the years, from about six billion kilowatt hours (kWh) in 2000,



Figure 11: Screen capture of a USGS interactive map showing wind turbine locations and attributes, as compiled from several publicly available datasets and other Federal, State, and local sources. Source: USGS

to about 182 billion kWh in 2014 (*Source: EIA, 2015*). Wind energy does not produce greenhouse gases and is renewable. However, wind energy production can potentially affect birds, bats, and marine mammals through impact fatalities and disruption and loss of habitat. In response to the Secretary of Interior and Administration priorities, the ERP is supporting efforts to develop a quantitative methodology for assessing the impacts associated with the widespread development of wind energy. This methodology is the first of its kind, evaluating national to regional scale impacts of those bats and birds that breed in and migrate through the United States and focuses primarily on the effects of collisions between wildlife and turbines. The primary objective of the project is to produce a scientifically robust, probabilistic methodology to assess the impacts on wildlife from large-scale wind energy development. To support this objective, the ERP completed a first-of-its-kind national database and interactive map of wind turbine locations. An accurate, complete, and publically available map of wind power infrastructure did not exist until 2014. The interactive map will facilitate planning, assessments, and scientific research on the costs and benefits of wind energy, and provides valuable information relevant to safety, security, and land use planning on Federal lands.

Uranium Resources and the Environment – The sustainability of nuclear energy in the United States relies not only on the occurrence of uranium resources, but also on the ability to produce uranium from those resources in an environmentally responsible manner. Accessible, science-based information describing known environmental implications of modern uranium mining practices is therefore highly valuable to land managers, regulatory entities, and policy makers. To address this need, the ERP jointly supports collaborative research with the USGS Mineral Resources Program and the Toxic Substances Hydrology Program to study the potential environmental effects associated with uranium resource development, and to develop a method to assess these effects to inform future development scenarios. In 2015, the ERP and MRP published findings from a study on the fate of uranium in a sandstone uranium deposit following mining and groundwater restoration. Currently, the primary method of uranium extraction in the United States is *in situ* recovery (ISR), a solution mining technique. The study's findings provide an in-depth understanding of the uranium found in surroundings following ISR. This information is helpful in understanding the limitations of mining and restoration activities, as well as determining potential sources of contamination.

In 2016, the ERP will continue to conduct research in the Energy Resources and the Environment area. The ERP will complete assessments on the quantities of water and hydraulic fracturing proppant required for producing petroleum, and the quantities of water extracted during petroleum production in the Bakken and Three Forks Formations. These water assessments will be based directly on USGS petroleum assessments. For each assessment, the ERP will work with USGS Water Resources scientists to determine water budgets for the area that include water use and production associated with petroleum production. Data on volumes, composition, and impacts of fluids injected into reservoirs is a national priority, particularly in an environment of rapidly changing industry practices. The ERP will also conduct field experiments to obtain baseline produced water geochemistry for the Appalachian, Gulf Coast, and Williston Basin to address connectivity between reservoirs, resulting in a better understanding of the origin and fate of water associated with hydraulic fracturing. This research will provide information to decision makers about water quality prior to production. Additionally, in 2016, following review by an external panel of technical experts, the ERP will finalize the methodology to assess the population level

impacts of onshore wind energy development on birds and bats, which will be critical to making informed decisions regarding placement of wind turbines and related environmental considerations.

In 2016, the ERP will also continue valuable research in collaboration with the USGS Mineral Resources Program and the USGS Toxic Substances Hydrology Program to understand the environmental effects of uranium extraction. A draft methodology will be submitted for review by USGS partners in 2016.

Science and Decisions Center

(2015 Actual, \$0.9 million; 2016 Enacted, \$0.9 million; 2017 Request, \$1.1 million)

The mission of the USGS Science and Decisions Center (SDC) is to advance the use of science in resource management decisions through research and applications on:

1. Ecosystem Services
2. Decision Science (including adaptive management)
3. Resilience and Sustainability
4. Innovation, Information, and Public Participation

These lines of work are interconnected and support improved decision making throughout a variety of natural resource science disciplines. Economists and scientists at the SDC work with partners in Interior and other government agencies, academia, and nongovernmental organizations to develop innovative methods, analytical tools, and institutional structures to integrate science more effectively with resource management.

Valuation of ecosystem services is critical to our Nation's ability to make informed, evidence-based decisions in managing biological, water, and geological natural resources. Since many ecosystem services are public goods, markets do not provide meaningful indications about the value of these services. The SDC applies ecosystem services valuation concepts to natural resource decision making to advance effective planning and conservation. The SDC's complementary focus on decision science provides the analytical structure and tools to support efficient and effective management of resources. The SDC uses concepts like adaptive management (a systematic decision-making approach with an emphasis on learning about management outcomes and incorporating lessons learned into ongoing management) to improve natural resource management outcomes. SDC staff provides leadership, technical expertise, and coordination with external partners on adaptive management, producing guidance and valuable information products that apply adaptive management concepts to tangible resource management situations such as those pertaining to water resources, energy resources, climate change, and the interface between human and natural systems. The SDC's parallel, cross-disciplinary work on resilience and sustainability focuses on finding flexible management approaches that can deliver ecosystem goods and services on a sustained basis. Working with external partners such as the National Research Council, the SDC works to advance the understanding of ecological resilience and sustainability as they pertain to effective natural resource management. The SDC also focuses on innovation and information, addressing issues such as enhancing participation in obtaining and using scientific information and in assessing its societal benefits from use.

In 2015, the SDC continued work with its partners to develop a Multi-Resource Analysis (MRA) that builds on existing natural resource analysis products from across the USGS. The MRA is a next generation suite of analytical products that integrates information and interrelationships among multiple natural resources, including energy, mineral, water, and biological resources and the connection with humans. The MRA utilizes an innovative approach to evaluate biophysical and socioeconomic impacts among various natural resource uses, ecosystem goods and services, and alternative development and conservation strategies to inform resource management decisions. During 2015, the SDC worked with partners in two locations to continue development of an MRA proof-of concept: the Powder River Basin in northeast Wyoming and the Piceance Basin in northwestern Colorado. In addition, the SDC worked with the National Academy of Sciences (NAS) to convene a workshop on the concept of a Multi-Resource Analysis and landscape-scale assessments. The NAS report on this topic will likely be released during 2016. These efforts will advance decision makers' ability to make landscape-level decisions that consider impacts and tradeoffs from multiple natural resources and alternative decisions.

Additionally, in 2015, the USGS continued collaboration with Federal and non-Federal organizations to improve linkages between ecosystem services science and application through leadership in developing the scientific program for ACES (A Community on Ecosystem Services), an international conference on linking science, practice, and decision making. ACES 2014, held in December 2014, brought together leaders in ecosystem services science and practice from over 30 nations to share state-of-the-art knowledge, applications, and tools for applying an ecosystem services framework to resource management decisions.

Also in 2015, the SDC highlighted key issues relating to ecosystem services science, practice, and decision making, by working with partners to guest edit a special edition of *Ecological Economics* (July 2015) on lessons learned from the ACES community. Ecosystem services science and applications have advanced precipitously since the first ACES conference held in 2008. The special edition describes state-of-the art progress and challenges in applying ecosystem service science to societal decisions relating to natural resources management.

The SDC continued work with its partners in 2015 to explore urban ecosystem services and how they connect with green infrastructure. The SDC partnered with the University of Pennsylvania to convene a roundtable entitled, "The Sustainable City: Roundtable on Science, Urban Ecosystem Services, and Green Infrastructure." The roundtable brought together Federal, city, and academic leaders to address the role of science and ecosystem services in decision making on green infrastructure investments.

In 2015, the SDC and its partners continued research efforts on resilience and applications of adaptive management. SDC scientists also continued work with partners to explore ways that an ecosystem services approach can be used to inform climate change adaptation and mitigation decisions. USGS scientists collaborated with partners to complete development of an economic framework for examining ecosystem services impacts on California rangelands from climate change.

Other SDC accomplishments in 2015 include the SDC's collaboration with the U.S. Forest Service to develop a new publication for middle school students on citizen participation in science, and the SDC's work with the USDA Office of Environmental Markets to complete a publication on biodiversity and

habitat market structure, that serves as a primer on market-like and market-based mechanisms designed to conserve biodiversity and habitat. These environmental market approaches rely on incentives to create benefits and provide additional flexibility in achieving biodiversity and habitat conservation outcomes.

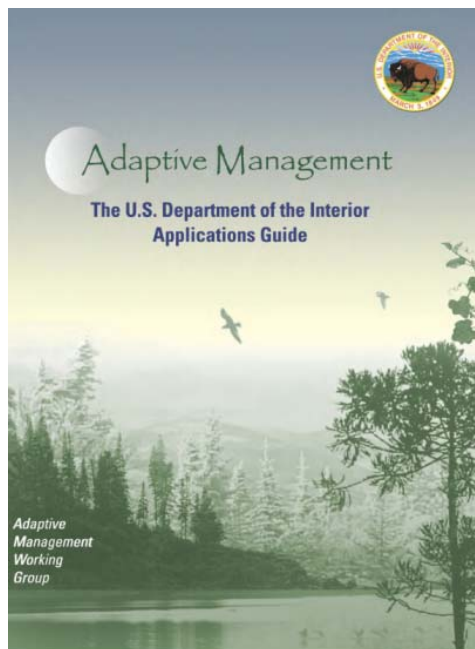


Figure 12: Cover of the *U.S. Department of the Interior Applications Guide to Adaptive Management* (2012). The USGS Science and Decisions Center participated in a DOI working group that wrote this guide.

Source: Department of Interior

on adaptive management issues, including the impacts of administrative law on adaptive management. Furthermore, in 2016, the SDC plans to work with its partners to assess valuation issues related to ecosystem services in the Great Dismal Swamp National Wildlife Refuge and in the Chesapeake Bay region. Finally, in 2016, the SDC plans to collaborate with its partners to assess and apply state-of-the-art methods and practices to determine societal benefits from geospatial scientific information.

In 2016, the SDC will work with partners to meet with diverse stakeholders on the potential structure and applicability of the MRA proof-of-concept in the Powder River Basin and in the Piceance Basin. The SDC will continue to work with partners to explore methods for applying an ecosystem services framework to climate change decisions, including examination of metrics, valuation, and institutional/policy issues. An ecosystem services approach emphasizes the impacts to humans of changes to natural systems and this work advances efforts to consider decisions relating to climate change in this context. Also in 2016, the SDC will continue to work with the USDA Office of Environmental Markets on economic and foundational issues relating to environmental markets. This research is intended to advance understanding of environmental markets methods and applications to a broader community so that these approaches can be more effectively applied. Additionally, the SDC will continue its work with its partners on urban ecosystem services in 2016, and will work with the University of Pennsylvania to examine and highlight on the use of remote sensing data on assessing urban ecosystem services across the landscape.

The SDC will also continue collaboration with its partners

In 2017, the following program change is proposed for the *Science and Decisions Center*:

2017 Program Changes
<p>Ecosystem Services: Enhancing Resilience in Coastal Infrastructure and Evaluating Green Infrastructure Investment (+\$211,000, for a total of \$286,000): Damages from recent storms including Hurricane Sandy have shown the importance of resilience in coastal infrastructure. An important benefit or cost associated with coastal infrastructure investments is the impact to ecosystem services. Part of the requested funds would be used to develop an ecosystem services approach to evaluating enhanced resilience in coastal infrastructure. Included in this approach would be the identification of relevant ecosystem services, assessment of ecosystem services production (which</p>

2017 Program Changes

builds on USGS earth and life science information), and monetary and non-monetary valuation of the services. This work responds to research needs identified in the 2015 National Science and Technology Council study on “Ecosystem-Service Assessment: Research Needs for Coastal Green Infrastructure,” and directly addresses the need to consider ecosystem services in developing plans to enhance coastal infrastructure resilience. Another valuable application of the ecosystems services approach is the evaluation of the impacts of the use of green infrastructure on ecosystem services; understanding these impacts can be extremely beneficial to decisionmakers in evaluations of alternative portfolios of green and traditional infrastructure. The requested increase would therefore also support the development of a framework for implementing an ecosystem services approach to evaluate green infrastructure investments. This work would build upon continuing USGS efforts with partners, including the University of Pennsylvania’s Wharton School, to explore the use of green infrastructure in urban settings in order to assess its effectiveness and its impact on ecosystem services. The framework will include identification of key ecosystem services, assess processes in the production of the services, and provide for monetary and non-monetary evaluation of the services to support evidence-based decision making in green and traditional infrastructure investments.

Energy Resources on the Landscape: Spatial and Economic Context

(2015 Actual, \$5.2 million; 2016 Enacted, \$5.0 million; 2017 Request, \$5.0 million)

Policy makers and resource stewards are increasingly faced with making complex decisions amidst uncertainty, including in emerging areas where data are limited, or in trying to anticipate long-term effects of a decision on society and the environment. In many of these instances, the state of scientific knowledge may be equivocal, or may require data and analysis from multiple scientific disciplines in order to provide a comprehensive foundation to underpin policy analysis and scenario development. The USGS *Science Strategy* (2007) recognized that such synergies among scientific expertise and capabilities within the USGS and through partnerships are essential to support multidisciplinary approaches needed to address the complex issues that society faces regarding energy development, and present and future energy supplies. In keeping with this

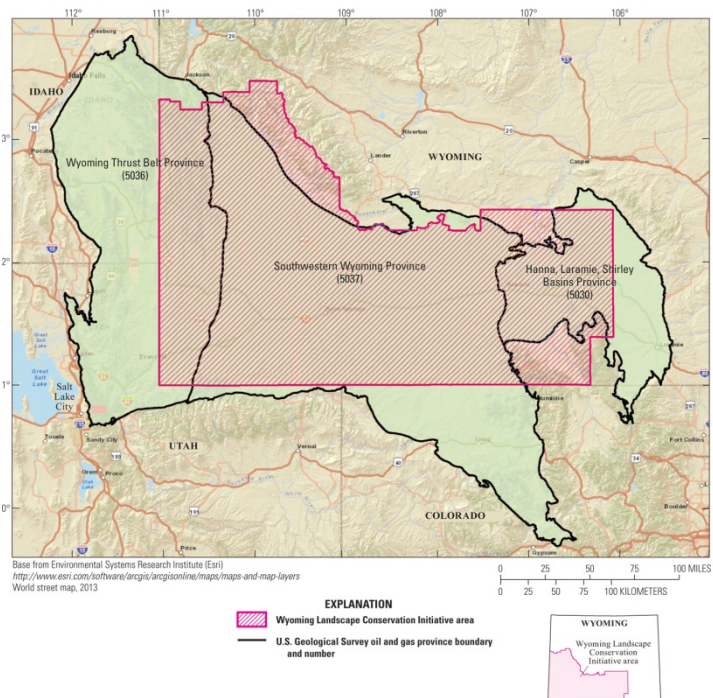


Figure 13: Example of an overlay map of spatial and other energy resource information for southwestern Wyoming and surrounding areas, showing the location of the Wyoming Landscape Conservation Initiative (WLCI) study area in relation to three assessed USGS oil and gas provinces and their assigned province numbers (in parentheses).

Source: USGS Data Series 843: <http://pubs.usgs.gov/ds/843/>

vision, the ERP supports research to address some of the complex energy-related challenges currently facing natural resource management and regulatory agencies, including: increasing domestic energy resource production, anticipating or adapting to emerging use of new technologies and renewable energy development, and mandates to consider the costs, benefits, and cumulative effects of resource development. Outcomes from these ERP-supported research efforts generate large volumes of science-driven research, information, and energy resource assessments on the distribution, quantity, and quality of domestic and international energy resources. These projects require specialized data management expertise and services to assist documentation, data organization, data sharing, and data transformation to web applications and delivery systems. Spatial analyses and other data delivery and analysis tools (e.g., interactive maps), combined with economic analyses of energy resources, facilitate consideration of geologic research and assessments in a broader context, and facilitate data dissemination and synthesis within and among other USGS activities and external USGS collaborators and stakeholders. The information and analyses are used by customers and stakeholders to inform decisions on such issues as energy policy development, natural resource protection, economic vitality and national security, and responsible resource management on Interior and other lands.

Below are several examples of areas in which the ERP promotes user-driven information and analysis through sound science, leveraging partnerships, and expertise in data management and analysis:

State Co-ops and the National Coal Resources Data System (NCRDS) – A long-term partnership of the USGS and State Geological Surveys enables this sustained effort to: collect and analyze basic data about national coal resources, build and verify comprehensive digital databases, and serve these USGS-maintained datasets. The NCRDS contains spatial information on location, quantity, attributes, stratigraphy, and chemical components of U.S. coal deposits and other stratigraphic units. To address other energy resource collaborations, the scope of State Cooperative and NCRDS activity has been increased recently to incorporate conventional and unconventional oil and gas research, along with environmental and geothermal studies. The NCRDS data and supporting geologic framework information facilitate collaborative studies with State and Federal cooperators, and promote strategic decisionmaking about our coal and other energy resources.

Energy Resource Economics – Understanding the economic and technologic factors determining the adequacy of U.S. and global energy supplies is critical to ensuring a stable domestic energy supply and informing foreign policy decisions. Governing economic factors include resource extraction and environmental mitigation technologies and associated costs; transport infrastructure and costs; and the overall interaction between domestic and global energy resource markets. New supplies of oil and gas, driven by new technologies, have introduced complexities into our Nation's energy supply chain. The ERP supports studies to develop economic analyses of energy resources. The application of economics to resource assessments identifies the part of assessed resources that are of high economic value to alert resource managers of potential development pressures. The scaling or conditioning of the resource estimates on prices and other economic variables also allows Federal, State, and industry planners to better project sustainability of oil and gas production, oil and gas supplies, and tax revenues. The resource cost functions that are provided show the estimates of volume of the undiscovered resource that can be developed at specific market prices that will offset the cost of finding, developing, producing, and transporting the produced resource to market. Resource cost functions that are prepared reflect the

uncertainty that characterize the associated geologic assessments. This presentation of economic implications of assessments allows decision makers to more clearly weigh policy alternatives. Furthermore, incorporating an economic dimension into USGS energy resource assessments is important in terms of the Nation's recognition of its potential domestic energy supply and as policy makers formulate a domestic and international energy strategy. Other Federal agencies, such as the BLM, Bureau of Ocean Energy Management, and the Energy Information Administration (EIA), have found ERP methods useful in accomplishing their mission. For example, in 2011, the economic analysis of the updated resource assessment in the National Petroleum Reserve in Alaska (NPRO) was completed, and this analysis was used extensively by the BLM for the development of the 2012 NPRO management plan.

Data Management and User-Driven Information – Data management services are critical for ERP-funded science projects to process and document information, develop products, improve and modernize stewardship, and manage information resources for the long term. The need for modernized approaches to data management has been pushed to the forefront, primarily due to Federal open data policies and initiatives at both the bureau and at the Executive Branch level, including the White House's Open Data Policy (May 2013). In addition, demand for data generated by Federal agencies has never been higher. There is a critical need to expedite information access, improve delivery methods, and provide products in formats that USGS collaborators, other Interior bureaus and Federal agencies, Congress, and the public can readily use for their respective needs. The ERP supports efforts to maintain and expand data delivery infrastructure and support systems, improve, maintain and transition the program's Web presence, and guide the flow of information and products to our clients. This activity also includes participation and engagement with USGS information management working groups, science partners, and the public to increase communication, address their specific information needs, and learn about data management techniques, solutions, and 'best practices'. Participating in these communities enhances ERP visibility, and creates environments where expertise is shared to advance data management, interdisciplinary science, and USGS mission goals to deliver relevant information to the public. The ERP is currently developing a program-wide data management plan for all of its seismic data holdings, and ERP-funded laboratory and data activities are working in concert to develop a program-wide data management plan for all laboratory data to maintain data accessibility.

In 2015, the ERP had several accomplishments in the area of Energy Resources on the Landscape: Spatial and Economic Context. The ERP completed an internal survey of user requirements for the National Assessment of Oil and Gas Web presence redesign, and supported efforts to develop and disseminate geospatial coverages complementing oil and gas resource assessments. In 2015, the State Cooperatives project completed the 2015-2019 round of cooperative agreements and posted these to Grants.gov. This round of agreements will include 21 projects, including projects in two States that had not participated in the previous cycle. Also, in 2015, a technology transfer agreement between the USGS and the West Virginia Geological and Economic Survey was completed. This agreement allowed the latter agency to access USGS databases to develop their own applications. In 2015, the Energy Resource Economics effort published a report in a peer-reviewed journal (*Natural Resources Research*) that included economic analyses of development options for Alaska North Slope viscous and heavy oil. These kinds of analyses are important for State and national energy policy considerations in terms of understanding the potential for additional oil resource supplies in Alaska and the potential impacts on existing (Trans-Alaska Pipeline System) or proposed infrastructure developments.

In 2016, the ERP plans to develop a completely redesigned National Assessment of Oil and Gas (NAGA) Web presence, ensuing from the user information and requirements gathered in 2015. This effort will enhance user access to energy resources assessments and supporting information, and will support new tools and multimedia content that will enable users to select, visualize, and analyze data. Additionally, in 2016, the ERP will finalize the development of an interactive Web-mapping application that displays injected water volume data for oil and gas production over time in the United States. The current produced waters database is seeing high usage, so it is anticipated that regular updates will be valuable to a broad range of users, and the interactive map will complement the produced waters database and present data in a user-friendly format. Additionally, an ERP-wide effort to implement quality management systems is underway for all ERP-funded labs to ensure data quality and accountability, and will continue in 2016.

Science Coordination

The Energy Resources Program participates in valuable scientific collaborations with a number of external partners. The ERP works with Federal government agencies, including the U.S. Department of Energy and the U.S. Environmental Protection Agency, on the Federal Multiagency Collaboration on Unconventional Oil and Gas (UOG) Research, a scientific research collaboration designed to better understand UOG resources and their impacts. Other ERP partners on its UOG projects have included State geologic surveys, industry, academia (including the University of Texas at El Paso, the New Mexico Institute of Mining and Technology, the University of Kentucky, the California Institute of Technology, and Hebrew University), the National Institute of Standards and Technology, the Oak Ridge National Laboratory, and the National Institute of Environmental Health Sciences. Furthermore, the BLM partners with ERP on a variety energy resource projects, including the ERP's work on geothermal energy on Federal lands. The ERP also works with international government partners such as the Indian Directorate General of Hydrocarbons (DGH) and the government of the Republic of Korea to explore for gas hydrate resources off the coasts of those nations, with results from these explorations directly applicable to potential resource assessment and recovery in the United States.

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Activity: Energy and Mineral Resources, and Environmental Health

Subactivity: Environmental Health

Program Element: Contaminant Biology Program

Dollars in Thousands	2015	2016	2017			
	Base	Enacted	Fixed Costs	Program Changes	Request	Change from 2016 Enacted
Energy and Mineral Resources, and Environmental Health	\$92,271	\$94,511	\$453	\$4,519	\$99,483	\$4,972
<i>FTE</i>	<i>553</i>	<i>567</i>		<i>14</i>	<i>581</i>	<i>14</i>
Environmental Health	\$21,445	\$21,445	\$92	\$3,023	\$24,560	\$3,115
<i>FTE</i>	<i>119</i>	<i>119</i>		<i>8</i>	<i>127</i>	<i>8</i>
Contaminant Biology Program	\$10,197	\$10,197	\$45	\$1,223	\$11,465	\$1,268
<i>FTE</i>	<i>60</i>	<i>60</i>		<i>4</i>	<i>64</i>	<i>4</i>
Adverse Health Effects of Disasters: Reducing Risk	\$981	\$981		\$0	\$981	\$0
Emerging Environmental Health Threats: Identifying Hidden Hazards	\$3,501	\$3,501		\$0	\$3,501	\$0
One Health: Disease at the Intersection of Environment, Animals, and People	\$2,239	\$2,239		\$50	\$2,289	\$50
<i>Critical Landscapes: Columbia River</i>	<i>[\$50]</i>	<i>[\$50]</i>		<i>[\$50]</i>	<i>[\$100]</i>	<i>[\$50]</i>
Environmental Lifecycles of Contaminants: Science for Intervention	\$1,400	\$1,400		\$1,173	\$2,573	\$1,173
<i>Environmental Impacts of Uranium Mining</i>	<i>[\$400]</i>	<i>[\$400]</i>		<i>[\$273]</i>	<i>[\$673]</i>	<i>[\$273]</i>
<i>Unconventional Oil and Gas Research</i>	<i>[\$30]</i>	<i>[\$30]</i>		<i>[\$900]</i>	<i>[\$930]</i>	<i>[\$900]</i>
Detecting Future Health Threats in the Environment: Methods, Models, and Tools	\$2,076	\$2,076		\$0	\$2,076	\$0

Justification of Program Change

The 2017 Budget Request for the Contaminant Biology Program is \$11,465,000 and 64 FTE, a net change of +\$1,268,000 and +4 FTE from the 2016 Enacted level.

Overview

The Environmental Health subactivity is comprised of the Contaminant Biology Program (CBP) and the Toxic Substances Hydrology Program (TSHP). Working in close collaboration, both programs provide the science needed to anticipate, detect, and prevent adverse health impacts from existing and emerging

Energy and Mineral Resources, and Environmental Health

contaminants, toxins, and pathogens in the environment. USGS Environmental Health research plays an integral part in protecting the health of our physical environment, our living environment, and public health. The objective, reliable research produced by CBP and TSHP is used by a myriad of Federal partners to support sound decision making.

The CBP's science is a key resource for managing and protecting the health of the environment, fish and wildlife, and people. The CBP provides science to:

- Protect the Nation's natural resources, including Department of the Interior trust species, by identifying and assessing risks from exposure to environmental disease agents and developing strategies to prevent and mitigate those risks.
- Help the Nation prepare for and respond to impacts and related health threats of natural and manmade disasters. The CBP serves as the USGS lead for coordinating interagency preparedness and response activities related to chemical and biological threats.
- Improve the health and economic well-being of the Nation by working in close collaboration with public health and agricultural partners to identify and understand the critical linkages among the health of the environment, fish and wildlife, people, and domesticated animals.

In 2017, the CBP is requesting increases in funding for work on Critical Landscapes: Columbia River (+\$50,000/0 FTE), Environmental Impacts of Uranium Mining (+\$273,000/+1 FTE), and Unconventional Oil and Gas Research (+\$900,000/+3 FTE).

Program Performance

Both programs in the Environmental Health subactivity—the Contaminant Biology Program and the Toxic Substances Hydrology Program—are comprised of five major areas of work:

1. Adverse Health Effects of Disasters: Reducing Risk.
2. Emerging Environmental Health Threats: Identifying Hidden Hazards.
3. One Health: Disease at the Intersection. of Environment, Animals, and People.
4. Environmental Lifecycles of Contaminants: Science for Intervention.
5. Detecting Future Health Threats in the Environment: Methods, Models, and Tools.



Figure 14: Several of the Federal partners that rely on USGS Environmental Health science: CDC, DOD, EPA, DHS, DOI, NIEHS, NIH, and USDA.



Figure 2: A brook trout found in Mount Rainier National Park. USGS and National Park Service scientists collaborated on a study to measure mercury levels in fish in national parks across 10 Western States, including Alaska. Source: Collin Eagles-Smith, USGS.

Adverse Health Effects of Disasters: Reducing Risk

(2015 Actual, \$1.0 million; 2016 Enacted, \$1.0 million; 2017 Request, \$1.0 million)

Both natural disasters and disasters caused by human activity pose a threat to ecological and human health because they often result in the release of environmental disease agents (e.g., toxic chemicals or infectious microbes) into the environment. The unique circumstances surrounding each disaster requires



Figure 3: Parking areas, septic systems, and foundations in South Nags Head, North Carolina, collapsed when the underlying dune was eroded during the September 1999 landfall of Hurricane Dennis.

Source: USGS

environmental health science that can adapt to multiple ecological scales and that can account for a variety of disease agents and interactions. With this science, resource managers and public health professionals can intervene to minimize the health effects associated with disasters, both at the time of the event, when first responders may be at risk, and as the disaster evolves over time in location and character. Mitigating the economic, human health, and environmental health costs associated with disasters requires capabilities to develop disease

models, maps, and diagnostic tools for detecting health threats—expertise that USGS Environmental Health research provides to Federal partners and decision makers responsible for bolstering our Nation’s resilience to disasters of all kinds.

In 2015, the CBP supported activities and accomplishments related to *Adverse Health Effects of Disasters: Reducing Risk* in the following areas:

National Biosecurity

In 2015, the Contaminant Biology Program continued its mission to provide sound science, information, and research toward the goal of protecting our Nation from biological and chemical threats. The CBP, in conducting work on national biosecurity, is responsive to policy directives such as the Presidential Policy Directive 8: National Preparedness (PPD-8), and Executive Orders 12656, 13527, and 13546, which deal with National Security, National Defense Resources Preparedness, Medical Countermeasures Following a Biological Attack, and Optimizing the Security of Biological Select Agents and Toxins, respectively. In 2015, the CBP contributed public health and ecosystem health policy expertise to the Department of Homeland Security’s National Security and Preparedness Response Plans, both within the framework of the Federal Interagency Operating Plans and Federal Emergency Management Agency (FEMA) National Preparedness Goals. In 2015, the CBP also contributed expertise to more incident-specific response preparedness policies such as the White House Homeland Security Council’s National Strategy for Pandemic Influenza; the National Science and Technology Council’s National Biosurveillance Plan; and

the Centers for Disease Control and Prevention’s fact sheet on Biosafety and Biosecurity in the United States. On an ongoing basis, the Contaminant Biology Program also works in close collaboration with and supports the emergency preparedness activities of the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA-APHIS), the U.S. Department of Homeland Security (including the DHS National Biosecurity Information Network), the White House Office of Science and Technology Task Force – Foreign Animal Disease Taskforce, the Federal Animal Emergency Interagency Workgroup, and the Department of Interior Office of Emergency Planning. By participating in an integrated Federal agency response, the CBP’s work optimizes both expertise and resource efficiency toward the goals of increased national security and safety from the disaster threats.

In 2016, the CBP, in conjunction with the Department of Homeland Security (DHS), will release a report identifying currently available data and capabilities related to national biosecurity; gaps in knowledge and biosecurity tools; and the joint communications that are needed to protect human and animal health as well as the economic well-being of the Nation. The information in the report will be used to inform future discussions among Federal agencies as they develop a national framework to prepare for and respond to the potential introduction of high consequence animal diseases into the United States.

In 2016 and 2017, the CBP will work with its Canadian partners (Public Health Canada and Environment Canada) to support the Administration’s and Canada’s shared approach to security entitled *Beyond the Border: A Shared Vision for Perimeter Security and Economic Competitiveness*. *Beyond the Border* describes a bilateral approach to security while expediting lawful trade and travel. The CBP and its partners will:

- Increase awareness and assessment of emerging environmental health threats associated with diseases passed between animals and humans in North America, and improve coordination between the human and animal health communities for responding to those threats.
- Document mechanisms to share disease intelligence on emerging threats—both infectious and toxicological—among wildlife, public health, agriculture and natural resource agencies.
- Provide a summary of strategies for improving detection and management of cross-border environmental disease agents.

National Resource Damage Assessment and Restoration

The mission of the U.S. Department of the Interior's Natural Resource Damage Assessment and Restoration Program (NRDAR) is to restore natural resources as a result of oil spills or hazardous substance releases into the environment. Working in partnership with affected State, tribal and Federal trustee agencies, the USGS, including the Contaminant Biology Program, conducts science that documents



Figure 4: USGS scientists collected environmental data and samples in coastal areas affected by the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. This effort is one of a number of assessments that the CBP conducts where environmental injuries are documented and restoration efforts are implemented.

Source: Lori Lewis, USGS

environmental injuries and implements restoration. These studies are essential to compensating the public for natural resources injuries. In 2015, the USGS CBP was involved in 16 cases representing 20 States in the assessment phase, and led restoration projects in five settled cases. Injury determination studies for assessment cases (oil spills, industrial releases, mining releases) were related to aquatic (fish, mussels) and terrestrial (migratory birds) Interior trust resources. Restoration activities focused on benthic invertebrate and avian communities. The CBP also supported DOI NRDAR by assisting in developing the public Damage Assessment and Restoration Tracking System (DARTS), and is completing an analysis estimating the economic impacts of ecosystem restoration. The CBP plans to continue its environmental assessment work with NRDAR in 2016 and 2017 with base funding.

Emerging Environmental Health Threats: Identifying Hidden Hazards

(2015 Actual, \$3.5 million; 2016 Enacted, \$3.5 million; 2017 Request, \$3.5 million)

The health effects associated with poorly understood disease agents are not always immediately obvious or direct. Exposure to a particular contaminant or pathogen may not result in immediate, life-threatening health impacts, but can compromise reproduction, change behavior, or alter resistance to disease, which can still affect survival or production of offspring. In addition, it may take several subsequent generations for the impacts of a contaminant or pathogen to appear. Moreover, adverse health effects from a contaminant may transfer from aquatic to terrestrial animals via the food chain, making the original cause of the health impact difficult to pinpoint.

USGS Environmental Health research provides the science to identify these hidden health hazards and understand the complex interactions between disease agents and the environment so that resource managers and public health officials can make informed decisions with the best possible understanding of otherwise hidden health hazards.



Figure 5: Typical beak deformity in a black-capped chickadee with avian keratin disorder in Anchorage, AK. USGS researchers have studied the possible relationship between environmental contaminants and chromosomal damage.

Source: Colleen Handel, USGS

In 2015, the CBP supported activities and accomplishments related to *Emerging Environmental Health Threats: Identifying Hidden Hazards* in the following areas:

Hidden Health Effects of Chemicals on Reproduction and Immunity

Endocrine disrupting chemicals (EDCs) are found in many everyday products, and can eventually end up in streams and water sources, coming into contact with aquatic wildlife. In 2015, the CBP conducted research to better understand the impacts that EDCs have on aquatic wildlife, including effects on their reproductive and immune function.

Reproductive Function

In 2015, USGS Environmental Health scientists published a groundbreaking study in partnership with the University of Missouri showing that fish exposed to the chemicals bisphenol-A (BPA) and 17-ethinylestradiol (EE2) were found to pass adverse reproductive effects onto their offspring up to three generations later. BPA can be found in some polycarbonate beverage bottles and has been used in food packaging since the 1960s. EE2 is one of the primary ingredients found in many oral birth control pills. The cause-effect relationship between these chemicals and the reproductive effects in fish not only has implications for the long-term health and sustainability of future generations of fish, but may also have significant implications for human risk assessments.



Figure 6: USGS scientists at the Columbia Environmental Research Center (CERC) conduct contaminant-related research on fathead minnows.

Source: Kit Doyle, Columbia Daily Tribune

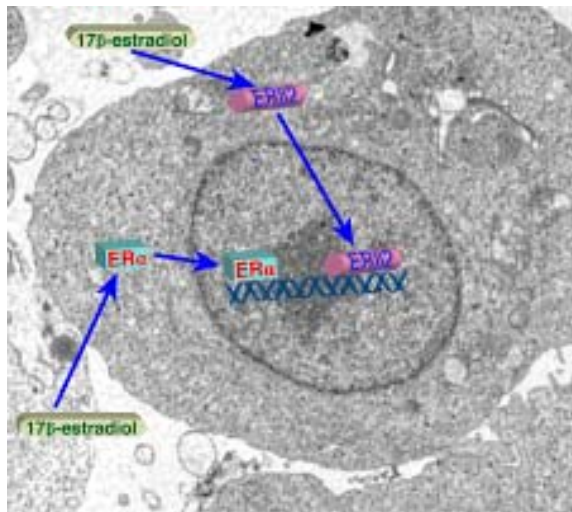


Figure 7: Electron micrograph of channel catfish macrophage. These white blood cells express estrogen receptors ER α and ER β , presenting a pathway for estrogenic chemicals to alter immune function.

Source: Jan Lovy, New Jersey Division of Fish & Wildlife, as modified by David Morganwalp, USGS

In 2016 and 2017, the CBP will use base funding to study the mechanisms by which these chemicals cause the “transgenerational” effects (i.e., effects that are passed to offspring but not seen in parents), which will continue to improve our understanding of EDCs’ interaction with aquatic wildlife.

Immune function

In 2015, the Contaminant Biology Program took a targeted look at how endocrine disrupting chemicals might alter the immune cells of catfish. For the first time, it was shown that white blood cells in fish have receptors for estrogen, and that certain chemicals that act as estrogens may change the function of these immune cells. This research will shed light on the means by which EDCs impact the immune function of aquatic wildlife.

In 2016 and 2017, the CBP plans to utilize base funding to continue studies to determine how estrogenic chemicals in the environment affect fish and wildlife and their susceptibility to infection by bacteria or viruses.

Reproductive Effects of Endocrine Disrupting Chemicals in the Chesapeake Bay Watershed

Aligned with the Executive Order for the protection and restoration of the Chesapeake Bay and its watershed (E.O. 13508), the Contaminant Biology Program studies the presence and effects of endocrine disrupting chemicals (EDC) on fish and wildlife in the Chesapeake Bay watershed. In 2015, USGS

Environmental Health scientists began implementation of the Chesapeake Endocrine Disruption Research Five-Year Plan, examining fish health at over 45 sites in the Chesapeake Bay watershed, including six sites intensively monitored for a robust suite of EDCs in water and sediment samples. These studies identified the presence of female characteristics in male fish, such as testicular oocytes (intersex) and abnormal vitellogenin, a protein made by females for egg production, circulating in the blood of male bass. These changes were shown to correlate with environmental EDCs. This project is closely tied with the broader Chesapeake Bay Watershed Agreement, which includes a consortium of Federal (Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Department of Agriculture, among others), State (Delaware, District of Columbia, Maryland, Pennsylvania, New York, Virginia, and West Virginia) and nongovernmental organizations working to restore the Chesapeake Bay.

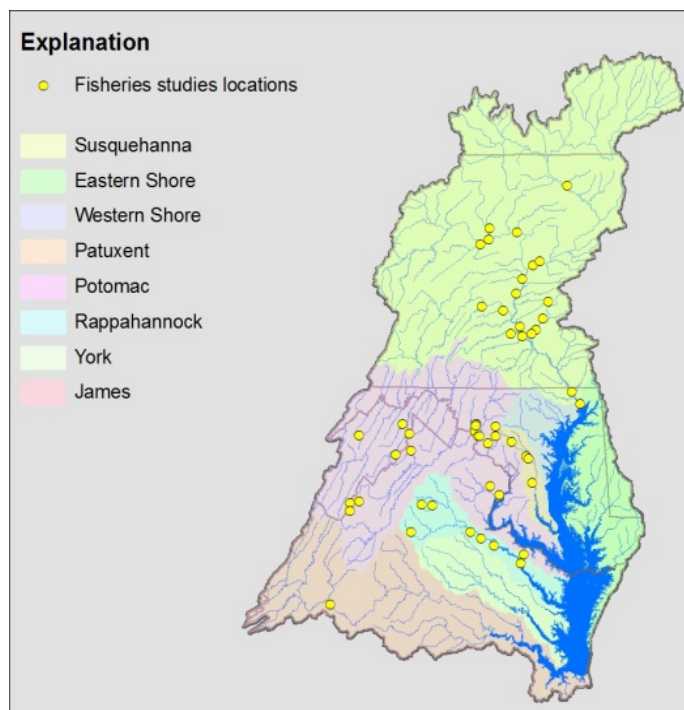


Figure 8: CBP study sites delineate sources, exposure pathways, and effects of endocrine disrupting chemicals in fish and wildlife in the Chesapeake Bay watershed.

Source: Vicki Blazer, USGS.

In 2015, the CBP also supported a joint USGS and U.S. Fish and Wildlife Service study that documented feminization of male smallmouth and largemouth bass at 19 national wildlife refuges (NWRs) in the Northeastern United States. Testicular oocytes (intersex), and vitellogenin were present in bass from all NWR sampled, with up to 100 percent of the fish being affected at some of the refuges, as documented in this first reconnaissance survey of this scope on NWRs. The baseline data collected during this study provides a necessary benchmark for future monitoring and justifies the need for more comprehensive NWR-specific studies to determine potential sources of chemicals contributing to the feminization of fish.



Figure 9: Turtles, such as this eastern painted turtle, will be the focus of a 2016-17 CBP project on the potential effects of endocrine disrupting chemicals (EDCs) on terrestrial wildlife.

Source: Leopoldo Miranda, U.S. Fish and Wildlife Service

In 2016, over 10 years of historical information about chemicals in the water and biological findings in fish at sites throughout the Chesapeake Bay watershed will be synthesized. Using this data, maps will be developed that include chemicals that were found at each site; abnormalities, like feminization, identified in fish from those sites; and how land was managed and used during the year. These maps and data will help scientists locate potential sources of EDCs as well as seasons when fish might be most vulnerable to exposure. This information will provide natural resource managers with the tools necessary to prioritize

for management efforts related to EDCs. In 2016 and 2017, using base funding, the project will also begin looking at potential effects of EDCs on terrestrial wildlife, with a focus on turtles.

One Health: Disease at the Intersection of Environment, Animals, and People
(2015 Actual, \$2.2 million; 2016 Enacted, \$2.2 million; 2017 Request, \$2.3 million)

The linkages between the health of the environment, animals, and people are inextricable. One Health is a cross-disciplinary approach on a local, national, and global scale with the goal of improving public and environmental health. Animals have often served as sentinels for disease caused by both chemical and microbial agents, and can foreshadow potential health impacts in humans. Food chains can serve as a transport mechanism for disease agents from the physical environment to the living environment. Understanding and modeling movements of disease agents and the organisms they affect can provide an early warning system to protect wildlife, domestic animals, and people. Examining the early warning signs in animals can reveal previously unknown routes of exposure and provide public health professionals and environmental managers with possible points of prevention as well as insight into potential health threats.



Figure 10: A USGS scientist takes a blood sample from a blue-winged teal (*Anas discors*) on the Anahuac National Wildlife Refuge in Texas as part of pathogen transmission studies on migratory birds.

Source: U.S. Fish and Wildlife Service.

In 2015, the CBP supported activities and accomplishments related to *One Health: Disease at the Intersection of Environment, Animals, and People* in the following areas:

Modeling Highly Pathogenic Avian Influenza Risk at the Poultry – Wild Bird Interface

According to the U.S. Department of Agriculture’s Foreign Animal Disease Preparedness and Response Plan (FAD PReP) on Highly Pathogenic Avian Influenza (HPAI), the HPAI outbreak of 2014-2015 has been the most costly animal health event in U.S. history. In December 2014, an HPAI virus was detected in wild birds that had the same genetic signature as the HPAI virus that had spread from South Korea to Europe in September 2014. In just 10 months, the virus spread to 21 States, causing the deaths of over 50 million poultry, and resulting in \$3.3 billion in economic losses, as estimated by economist Thomas Elam in his testimony before the U.S.

Senate Committee on Agriculture in June 2015. In 2013 and 2014, the CBP funded studies to develop specialized spatial risk models for highly pathogenic avian influenza movement in China. In 2015, that work focused on building a model of transmission risk for the United States at the interface between wild migratory birds, domestic poultry, and environmental factors. The goal of these models is to predict seasonal distributions for wild birds, match them with census data for poultry, and create a transmission risk models at the interface of wild birds, domestic poultry and the environment in the United States.



Figure 11: A USGS scientist tests a northern pintail duck for avian influenza.

Source: Robert Dusek, USGS

In 2016, the CBP plans to adapt a web visualization tool that could automatically capture and insert U.S. data and chart the ‘real time’ spread of these HPAI viruses in North America. The goal of the project is an early warning system for at-risk populations of wild waterfowl and poultry during a future HPAI epidemic in the United States. These could be particularly important tools for preventing economic losses related to the poultry industry during a potential epidemic of HPAI, and for serving as a sentinel warning if an HPAI virus which is infectious for humans is introduced into North America.

Osprey Nestlings in Delaware Bay Tested for Human Pharmaceuticals

A complex study funded by the CBP in 2015 monitored water, fish, and osprey nestlings for the existence of 24 different pharmaceutical drugs and other compounds at 12 sites in the Delaware Bay watershed to determine the bioaccumulation levels of these compounds in the water-fish-osprey food web. Of these 24 tested pharmaceutical chemicals and compounds, 18 were detected in water samples, and 8 were detected

in fish. Only one compound was found at detectable levels in osprey blood plasma, suggesting that, during the period when ospreys are feeding their chicks, these compounds are not generally being transferred up the food web. The drug diltiazem, which treats hypertension in humans, was detected in blood plasma of all the osprey nestlings sampled and was present at very low concentrations. The threshold of effect for this drug is unknown in ospreys, but the chicks seemed healthy during the sampling period and adverse effects were not detected. This is the first study to look for human pharmaceutical drugs in the blood of osprey chicks. The detection of the human drug diltiazem in osprey chicks is proof of concept that small amounts of pharmaceuticals released from humans after ingestion can make it into the environment and through the food chain into fish-eating birds. The potential effect of these drugs on invertebrates, fish, and birds has yet to be studied. In 2016, the CBP will collaborate with State partners to determine what additional follow-up studies might be needed.



Figure 12: Osprey nestlings on Poplar Island, in Chesapeake Bay, Maryland.

Source: Rebecca Lazarus, USGS

Tracking Mercury in Sport Fish in the Columbia River Watershed

In 2015, the CBP started a new project to study the effects of contaminants on the environmental health of the Columbia River Basin. Diverse urban, agricultural, and industrial land uses throughout the Columbia River Basin interact with its aquatic ecosystems and can ultimately influence the ecological health of the Basin. The Basin is home to about 8 million people, and its economy—including the commercial fishing industry—is inextricably tied with the health of the ecosystems there. The transport and cycling of environmental contaminants, such as current-use pesticides and methylmercury, are strongly linked to various land use, land management, and water management practices. Moreover, the spatial variation in these practices creates a patchwork mosaic of distinct ecological threats across the Basin. Similarly, the ecosystem diversity throughout the region creates a network of key habitats, which are preferentially used



Figure 13: A USGS researcher examines smallmouth bass for abnormalities.

Source: Jo Ellen Hinck, USGS

by sensitive trust resources. When disproportionately high use of these habitats by sensitive fish and wildlife species overlaps with enhanced exposure to contaminants, there is increased likelihood for potentially deleterious impacts to the Columbia River Basin's natural resources, and therefore, its economy. The CBP's work in the Basin will define pathways of contaminant bioaccumulation and risk in key tributaries to the Columbia River and in key main stem wetlands in the estuary to produce a model of risk for the Columbia River Basin. In 2016, the CBP will analyze the contaminant data collected from 2015 studies on the Snake River, a tributary

of the Columbia River. The study will also be expanded to include the Willamette River, and top predator sportfish will be incorporated into the study, which will provide a window into potential human exposure to the mercury and pesticides being measured.

In 2017, the following program changes are proposed for *One Health: Disease at the Intersection of Environment, Animals, and People*:

2017 Program Change
<p>Critical Landscapes: Columbia River (+\$50,000, for a total of \$100,000): The Columbia River Basin, which includes parts of seven States and 13 recognized Tribal reservations, remains a critical part of the Pacific Northwest’s ecosystems, economy, and culture. In 2017, the Contaminant Biology Program would use the proposed increase to expand studies of contaminant exposure and the cycling of mercury and pesticides in food webs to address important Tribal and endangered species of concern in the Columbia River Basin. With the proposed funding increase, new studies focusing on sturgeon will begin. In addition, the proposed funding increase would allow for the collection, archival, and study of samples of small mouth bass for potential exposure to endocrine disrupting chemicals. This work is vital for maintaining the health of this critical ecosystem, which has considerable implications for the region’s economy and the health of the millions of people living in the region.</p>

Environmental Lifecycles of Contaminants: Science for Intervention
(2015 Actual, \$1.4 million; 2016 Enacted, \$1.4 million; 2017 Request, \$2.6 million)

USGS Environmental Health research traces chemical and microbial contaminants from their sources (e.g., pesticides from agricultural runoff), through their modes of transport (e.g., seepage into groundwater), to the initial exposure of an organism (e.g., fish exposed through contaminated water), and finally, through their ultimate health impacts on animals and people (e.g., human consumption of affected fish and resulting negative health effects). The study of this “lifecycle” of contaminants in the environment provides opportunities for environmental managers to reduce exposure to these disease agents at multiple points in their life cycle—from their source in the environment to the changes they make in individual cells—with the ultimate goal of preventing adverse health effects. This science can also be used to evaluate the effectiveness of public health and environmental management actions and to develop more targeted, evidence-based solutions for improving public and environmental health.

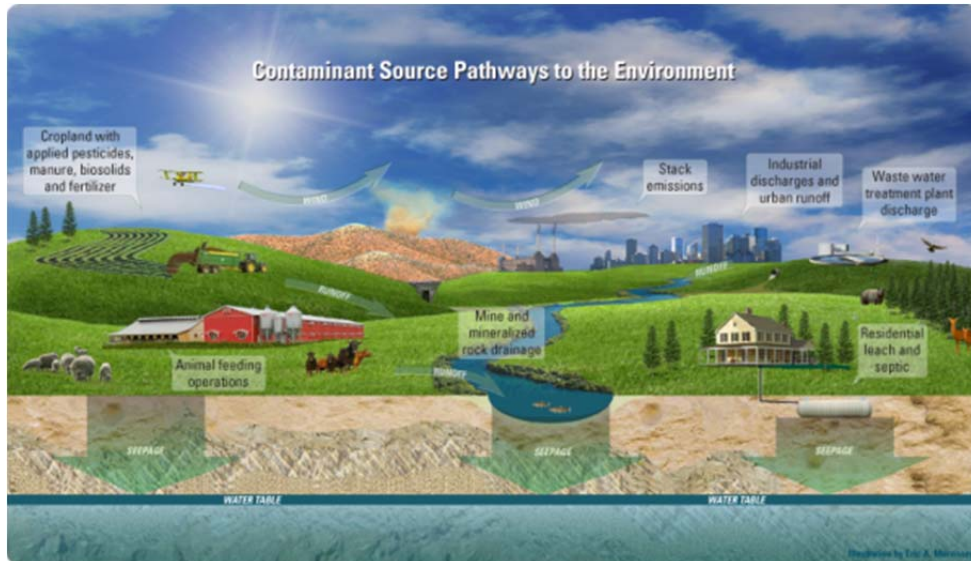


Figure 14: A diagram showing many of the possible pathways of contaminants to the environment. Source: USGS

In 2015, the CBP supported activities and accomplishments related to *Environmental Lifecycles for Contaminants: Science for Intervention* in the following areas:

Unconventional Oil and Gas: Potential Impacts on Human Health

The Contaminant Biology Program, as part of the Multiagency Collaboration on Unconventional Oil and Gas Research, is working with Federal public health agencies (e.g., the National Institutes of Health, the National Institute of Environmental Health Sciences, as well as a number of other partners) toward developing a better scientific understanding of how human health may be impacted by the effects of unconventional oil and gas (UOG) development on air quality, water quality, and water availability, etc. Together with public health partners, the CBP is collaborating to explore new uses of USGS data and to design collaborative studies. In 2015, the CBP published results of a scientific study documenting that waste water from the production of UOG can disrupt the endocrine system in aquatic species. The endocrine system regulates reproductive, immunological, and neurological functions. The potential implications for human health are as yet undetermined. As UOG development in the United States continues to expand at a rapid rate, understanding whether potential public health and environmental health risks exist takes on an added urgency. Successful efforts to mitigate potential risks through safe and prudent development practices increasingly rely on sound, unbiased science.



Figure 15: Contaminant Biology Program research and Federal partner collaborations on the potential impacts of unconventional oil and gas development on human and environmental health can help policy makers and industry mitigate the potential risks associated with development.

Source: USGS

In 2016, the CBP is using \$30,000 to conduct UOG-related research. To keep pace with rapidly evolving technology and development practices, CBP research efforts will need to expand significantly. Proposed research will help to support public health while ensuring the economic interests of the Nation. The proposed increase in 2017 (please see the program change box at the end of this section) will allow the CBP to not only expand its UOG-related research, but also to effectively prioritize those research sites which will provide the greatest amount of data. The CBP is uniquely positioned to collaborate with the environmental and public health communities to conduct timely, critical, and cutting-edge research vital to the development of sound energy and health policy and safe industrial practices related to UOG.

Determining Risk for Uranium Mining in the Grand Canyon Area

In January 2012, then Secretary of the Interior Ken Salazar announced his decision to withdraw one million acres of Federal land from uranium and other hard rock mining in Northern Arizona, including the Grand Canyon, until 2032. This Public Land Order will provide time for research and monitoring of the effects of mining to inform future land use decisions in this critical geographic area.

The USGS continues to lead the multi-agency effort and is evaluating the risk of uranium mining to the Grand Canyon ecosystem. The overall study plan includes four research categories, including: ore genesis, pathways of exposure, characterization of exposure, and biological effects of exposure to uranium and co-occurring elements. CBP efforts in 2015 focused on collected biological data at pre-mining locations to establish baseline exposure (Canyon Mine), active mines (Pinenut Mine), mines under remediation (Arizona 1 – mined and on standby), and non-mineralized reference areas. The results from these collections will be critical to determining whether changes in radiation and chemical concentrations in plants and animals over the course of the mine life cycle result in greater exposure, and thus risk, to the surrounding environment. The results also provide the only chemical and radiation contaminant data in animal and plant life from uranium mining areas in the Grand Canyon watershed.

Furthermore, species composition information of greater than 200 species of plants, invertebrates, amphibians, reptiles, birds and small mammals were identified in and around the mine site. Because currently approved mining operations are allowed to continue under the public land order, and new operations can begin on existing mining claims, this multi-year study will measure similar parameters in areas where mining is occurring, through clean up and remediation to determine where the greatest environmental risks lie, as all phases, from mining to remediation of the



Figure 16: USGS Hydrologist Brad Garner of the Arizona Water Science Center prepares for water quality sampling at Willow Spring, a Bureau of Land Management Wilderness Area in the Kanab Creek drainage of the Grand Canyon.

Source: Fred Tillman, USGS

Energy and Mineral Resources, and Environmental Health

mining site, can contribute to uranium mobilization with exposure to animals and people. The study will also assess the impacts and success of remediation.

The USGS is collaborating with external partners on this project, including the National Park Service, the U.S. Fish and Wildlife Service, the Bureau of Land Management, the U.S. Forest Service, U.S. Department of Energy, Northern Arizona University, Bethel College, Arizona Department of Game and Fish, and the State of Arizona.

In 2016, the CBP will support activities related to Environmental Lifecycles of Contaminants by developing new field methods to identify species presence using environmental DNA detection (eDNA). This test assumes that an aquatic species leaves behind some of its DNA in the water. With a small sample of this water, the test will determine which aquatic species have been present. If successful, this method could be an economically viable option to extensive field work in remote areas, and potentially more precise and less stressful for the animals than physical handling.

In 2017, the following program changes are proposed for *Environmental Lifecycles of Contaminants: Science for Intervention*:

2017 Program Changes

Environmental Impacts of Uranium Mining (+\$273,000, for a total of \$673,000): As part of a 15-year multiagency research plan with the Bureau of Land Management, the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Forest Service, USGS scientists in the Contaminant Biology Program are currently conducting research on baseline radiation levels for natural uranium sites in the Grand Canyon that are not currently being mined. This research is relevant to the Secretary of Interior's 2012 Record of Decision withdrawing about one million acres of Federal land near the Grand Canyon from additional uranium mining development until the year 2032. The 15-year plan was created to address the exact scientific information needed to inform decisions on future mining activities in the region. In 2016, the CBP will begin analyzing the levels of uranium and radiation in dust, water, and biota at the inactive mine sites, and will begin modeling the natural transport and occurrence of uranium and radiation in native animals and plants. With the proposed increase in 2017, the CBP would study the amount of uranium metal and its radiation in birds, mammals, and reptiles, as well as water and dust, near targeted active mines. The 2017 results will then be compared to the baseline data to measure the environmental impacts of uranium mining and its associated release of radiation beyond what is naturally occurring. Biological samples will also be collected at springs near reclaimed mine sites to determine if residual contamination is cause for concern for humans and wildlife. Results will be used to develop a modeling tool to assess ecosystem health before, during, and eventually after uranium extraction. The knowledge gained from these studies will be used for developing prevention and mitigation strategies to ensure that the health and sustainability of natural resources are balanced with economic development. The studies will provide science needed by the Secretary of the Interior for making sound decisions regarding extraction activities on Federal lands.

Unconventional Oil and Gas Research (+\$900,000, for a total of \$930,000): In collaboration with its partners in the Federal Multiagency Collaboration on Unconventional Oil and Gas Research, the CBP would use the proposed increase to assess the potential environmental, wildlife, and human health

2017 Program Changes

impacts associated with unconventional oil and gas (UOG) development. As UOG activities continue to proliferate at a rapid rate in the United States, decision makers rely on unbiased, sound science to understand whether those activities might impact human and environmental health and to inform the prevention or mitigation of those potential impacts. In order to keep pace with rapidly evolving technology and development practices, the proposed increase in 2017 would allow for the CBP to expand testing to help add to a body of collaborative research needed for assessment of potential biological effects of UOG development on living organisms, including humans. The CBP would expand its UOG-related research and effectively prioritize those research sites which will provide the greatest amount of data. Research results would be shared with Federal partners in the Multiagency Collaboration on UOG, and those partnerships would be leveraged to maximize the usability and interoperability of the data. The CBP is uniquely positioned to collaborate with the environmental and public health communities to conduct timely, critical, and cutting-edge research vital to the development of sound energy and health policy and safe industrial practices related to UOG.

Detecting Future Health Threats in the Environment: Methods, Models, and Tools

(2015 Actual, \$2.1 million; 2016 Enacted, \$2.1 million; 2017 Request, \$2.1 million)

Early detection and prediction of potential routes of exposure of disease agents are the foundation of risk reduction and protection of vulnerable populations. Whether it involves an accidental release of toxic chemicals during a natural disaster, or a pathogenic virus that jumps from animals to people, USGS Environmental Health research develops the tools needed to stay ahead of evolving threats. These tools allow for the rapid identification and detection of infectious disease agents and contaminants, continuous tracking of the spread, and measurement of their environmental effects.

In 2015, the CBP supported the following activities and accomplishments related to *Detecting Future Health Threats in the Environment: Methods, Models, and Tools*:

Chronic Wasting Disease of Deer, Elk and Moose

Chronic wasting disease (CWD) is a progressive, fatal, degenerative disease of deer, elk, and moose in North America. This disease has been identified in 20 States and there is no known treatment or vaccine for CWD, which is caused by infectious proteins called prions. While transmission mechanisms of CWD proteins are unknown, they seem to be passed directly from one animal to another through saliva, feces, and urine containing abnormal prions shed in those body fluids and tissues. There are different types of prions and the ones causing chronic wasting disease may become more infectious when they are bound to soil.

For the first time, a CBP study has developed a method that can identify these prions in soil. This shows that the environment is potentially a reservoir for transmission, and provides environmental managers with a tool for surveillance of CWD prions, allowing for CWD outbreak prevention and mitigation.



Figure 17: Healthy male (foreground) and female (background) elk in Anchorage, Alaska. Photo Credit: USGS

Invasive Species Bring Invasive Parasite Causing Encephalitis in Humans

Wildlife, including invasive species, can carry exotic pathogens that infect humans. Detection of these pathogens is of paramount importance to the protection of public health. Some giant African land snails may carry a parasite worm, *Angiostrongylus cantonensis*, that can burrow into the lining of the brain and



Figure 15: A giant African land snail being studied at USGS Leetown Science Center.

Source: U.S. Department of the Interior

cause encephalitis if the snails are consumed. These snails also carry a number of other pathogens responsible for harming wildlife, domestic animals, and humans. More than 150,000 giant African land snails have been collected in Florida since 2011, and they are still overpopulating the region. CBP scientists collaborated with the Centers for Disease Control and Prevention (CDC) to test snails for *A. cantonensis* in Florida. They adapted a sampling method to test for the parasite and were able to increase the sensitivity of the test by 13 percent. The results suggest that many more of the giant African land snails in Florida have the potential to infect humans with the brain worm than was previously thought. By working with public health partners such as the CDC, the CBP is able to leverage the expertise

of scientists from a variety of public and environmental health backgrounds to tackle emerging health challenges at the nexus of human and environmental health.

Science Coordination

The Contaminant Biology Program works closely with a number of external partners. Through CBP work on national biosecurity, the CBP coordinates with the Department of Homeland Security, the Federal Emergency Management Agency (FEMA), the U.S. Department of Agriculture, and the Centers for Disease Control and Prevention (CDC) on national preparedness policies. CBP work in this arena takes into consideration the interactions between animal, plant, and environmental health and the health of humans, either from threats occurring naturally in the environment or from those that are introduced by humans. Other Federal partners such as the National Institutes of Health (NIH), the National Institute of Environmental Health Sciences (NIEHS), the Environmental Protection Agency (EPA), and the Department of Energy (DOE) work with the CBP on a range of issues, including research on the public health impacts of unconventional oil and gas (UOG) development. As part of the multiagency collaboration on UOG, the variety of scientific expertise from these agencies—everything ranging from air quality to human health—is leveraged by the CBP to refine its body of work on UOG; similarly, the other agencies in the collaboration also derive the benefits of unique CBP expertise on the intersection between environmental and human health. State and local governments are often CBP partners on projects that have a particular focus on a specific region, such as the environmental impacts of uranium mining work taking place in the Grand Canyon region. In addition to the Arizona Department of Game and Fish, and the State of Arizona, academic partners have also played a role in the project, including Northern Arizona University and Bethel College. As much of the work is occurring on Federal lands, the

Bureau of Land Management, the National Park Service, the U.S. Forest Service, and the U.S. Fish and Wildlife Service have all been valuable partners on the environmental impacts of uranium mining project with CBP as well.

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Activity: Energy and Mineral Resources, and Environmental Health

Subactivity: Environmental Health

Program Element: Toxic Substances Hydrology Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Energy and Mineral Resources, and Environmental Health	\$92,271	\$94,511	\$453	\$4,519	\$99,483	\$4,972
<i>FTE</i>	<i>553</i>	<i>567</i>		<i>14</i>	<i>581</i>	<i>14</i>
Environmental Health	\$21,445	\$21,445	\$92	\$3,023	\$24,560	\$3,115
<i>FTE</i>	<i>119</i>	<i>119</i>		<i>8</i>	<i>127</i>	<i>8</i>
Toxic Substances Hydrology Program	\$11,248	\$11,248	\$47	\$1,800	\$13,095	\$1,847
<i>FTE</i>	<i>59</i>	<i>59</i>		<i>4</i>	<i>63</i>	<i>4</i>
Adverse Health Effects of Disasters: Reducing Risk	\$234	\$234		\$1,300	\$1,534	\$1,300
<i>Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,300]</i>	<i>[\$1,300]</i>	<i>[\$1,300]</i>
Emerging Environmental Health Threats: Identifying Hidden Hazards	\$2,534	\$2,534		-\$750	\$1,784	-\$750
<i>Emerging Contaminants and Chemical Mixtures</i>	<i>[\$750]</i>	<i>[\$750]</i>		<i>[-\$750]</i>	<i>[\$0]</i>	<i>[-\$750]</i>
One Health: Disease at the Intersection of Environment, Animals, and People	\$1,946	\$1,946		\$50	\$1,996	\$50
<i>Critical Landscapes: Columbia River</i>	<i>[\$50]</i>	<i>[\$50]</i>		<i>[\$50]</i>	<i>[\$100]</i>	<i>[\$50]</i>
Environmental Lifecycles of Contaminants: Science for Intervention	\$5,234	\$5,234		\$1,200	\$6,434	\$1,200
<i>Environmental Impacts of Uranium Mining</i>	<i>[\$750]</i>	<i>[\$750]</i>		<i>[\$1,750]</i>	<i>[\$2,500]</i>	<i>[\$1,750]</i>
<i>Unconventional Oil and Gas Research</i>	<i>[\$770]</i>	<i>[\$770]</i>		<i>[\$250]</i>	<i>[\$1,020]</i>	<i>[\$250]</i>
<i>Fate and Transport of Contaminants in the Subsurface</i>	<i>[\$800]</i>	<i>[\$800]</i>		<i>[-\$800]</i>	<i>[\$0]</i>	<i>[-\$800]</i>
Detecting Future Health Threats in the Environment: Methods, Models, and Tools	\$1,300	\$1,300		\$0	\$1,300	\$0

Summary of Program Changes

The 2017 Budget Request for the Toxic Substances Hydrology Program is \$13,095,000 and 63 FTE, a net change of +\$1,847,000 and +4 FTE from the 2016 Enacted level.

Overview

The Environmental Health subactivity is comprised of the Contaminant Biology Program (CBP) and the Toxic Substances Hydrology Program (TSHP). Working in close collaboration, both programs provide the science needed to anticipate, detect, and prevent adverse health impacts from existing and emerging contaminants, toxins, and pathogens in the environment. USGS Environmental Health research plays an integral part in protecting the health of our physical environment, our living environment, and public health. The objective, reliable research produced by CBP and TSHP is used by myriad Federal partners to support sound decision making.

The TSHP provides sound environmental health science and information on the sources, occurrence, behavior, and effects of toxic substances in the natural and built environments. Industrial, agricultural, mining, and other human activities, as well as natural phenomena such as hurricanes, can significantly affect our environment by the introduction or mobilization of contaminants such as synthetic chemicals (e.g., pesticides and pharmaceuticals), naturally-occurring elements (e.g., arsenic or uranium), and microbes (e.g., viruses and bacteria) in ways that may not be immediately apparent. Contamination of surface water, groundwater, soil, sediment, and the atmosphere can have both short- and long-term health and economic impacts. TSHP research provides the science needed to develop policies and practices for mitigation of environmental deterioration from contaminants, identifying and minimizing potential exposures to environmental contaminants, cost-effective cleanup and waste-disposal strategies, and reduction of future contamination risk.

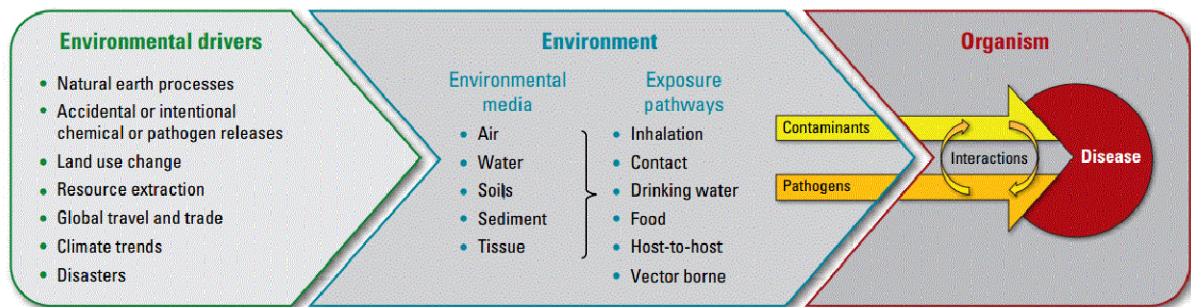


Figure 16: The USGS Environmental Health subactivity addresses the relationships among environmental drivers, exposure to disease agents through various environmental media and exposure pathways, and the complex biological responses to contaminant and pathogen exposure that result in disease in organisms, including fish and wildlife, domesticated animals, and people.

Source: USGS Environmental Health Science Strategy

In 2017, the TSHP is requesting increases in funding for Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast (+\$1,300,000/+3 FTE), Critical Landscapes: Columbia River (+\$50,000/+1 FTE), Environmental Impacts of Uranium Mining (+\$1,750,000/+ 8 FTE), and Unconventional Oil and Gas Research (+\$250,000/+ 1 FTE). Decreases in TSHP funding for 2017 include: Emerging Contaminants and Chemical Mixtures (-\$750,000/-4 FTE), and Fate and Transport of Contaminants in the Subsurface (-\$800,000/-5 FTE).

Program Performance

Both programs in the Environmental Health subactivity—the Contaminant Biology Program and the Toxic Substances Hydrology Program—are comprised of five major areas of work:

1. Adverse Health Effects of Disasters: Reducing Risk
2. Emerging Environmental Health Threats: Identifying Hidden Hazards
3. One Health: Disease at the Intersection of Environment, Animals, and People
4. Environmental Lifecycles of Contaminants: Science for Intervention
5. Detecting Future Health Threats in the Environment: Methods, Models, and Tools

Adverse Health Effects of Disasters: Reducing Risk

(2015 Actual, \$0.2 million; 2016 Enacted, \$0.2 million; 2017 Request, \$1.5 million)

Both natural disasters and disasters caused by human activity pose a threat to ecological and human health because they often result in the release of disease agents (e.g., toxic chemicals or infectious microbes) into the environment. The unique circumstances surrounding each disaster requires environmental health science that can adapt to multiple ecological scales and that can account for a variety of disease agents and interactions. With this science, resource managers and public health professionals can intervene to minimize the health effects associated with disasters, both at the time of the event, when first responders may be at risk, and as the disaster evolves over time in location and character. Mitigating the economic, human health, and environmental health costs associated with disasters requires capabilities to develop disease models, maps, and diagnostic tools for detecting health threats—expertise which USGS Environmental Health research provides to Federal partners and decision makers responsible for bolstering our Nation’s resilience to disasters of all kinds.



Figure 17: U.S. Geological Survey personnel collecting young of year bluefish in Jamaica Bay, NY, to be analyzed for contaminants in the aftermath of Hurricane Sandy.

Source: Daniel Wiczorek, National Oceanic and Atmospheric Administration.

In 2015, the TSHP finalized laboratory and data analyses of contaminants in bluefish, mussels, beach sands and sediment samples collected in areas impacted by Hurricane Sandy along the New York and New Jersey coastlines. These databases, which are now easily accessed online for stakeholder use, are unique information resources that may be used for a variety of purposes, including: (1) to understand the occurrence and distribution of contaminants in a variety of environmental settings; (2) to understand contaminants in the aquatic food chain in

Energy and Mineral Resources, and Environmental Health

the aftermath of Hurricane Sandy; and (3) to assess impacts of future hurricanes using baseline contaminant data.

In 2016, the TSHP plans to conduct field tests of a new prototype process to monitor and assess storm-related releases of contaminants in prioritized areas along the northeast coast of the United States. Field testing the prototype is a necessary step in assessing its performance, which in turn is especially critical when associated with a large natural disaster such as a hurricane. Once tested and validated, the process will form the basis of a contaminant vulnerability network on the East Coast. In addition, in 2016, the TSHP plans to publish a range of scientific papers and related knowledge products on baseline and contaminant occurrence in fish, sediment, and reconstructed beach dunes in selected areas of New York and New Jersey impacted by Hurricane Sandy. This information will address a range of long-term contamination issues potentially associated with natural disasters and inform stakeholder decisions about resiliency planning and mitigation.

In 2017, the following program change is proposed for *Adverse Health Effects of Disasters: Reducing Risk*:

2017 Program Change
<p>Resilient Coastal Landscapes and Communities: Contaminant Network Along the Northeast Coast (+\$1,300,000, for a total of \$1,300,000): As part of the Hurricane Sandy supplemental, the USGS received \$2.0 million for this effort in 2014, and has established a prototype contaminant vulnerability assessment network and standard operating procedures based on a prioritized monitoring and modeling infrastructure supported with extensive landscape-scale assessments of potential contaminant sources. The requested increase would continue that work by: (1) enabling the establishment of real-time water quality monitoring capabilities in key locations associated with the prototype contaminant network along the northeast coast, and (2) supporting the development of standard operating procedures for the rapid deployment and mobilization of field crews to collect environmental samples (including water, soils, fish, and sediment). These capabilities will be developed in close collaboration with local, State, tribal, and other Federal partners, including public health agencies commonly engaged in first response actions. Network monitoring sites will be co-located, where possible, in partnership with a separate USGS effort led by the Water Resources Mission Area, which is establishing a Surge, Wave, and Tide Hydrodynamics (SWaTH) network along the northeast coast. The requested increase will enable real-time water quality sensors to be sited on a subset of SWaTH sites. Interpretation of these data in context with the associated landscape-scale assessments of contaminant sources and modeling will provide supporting information required to mitigate those sources in the short term and minimize their impact for future events. Lessons learned from the establishment and field testing of this prototype network can be applied to other coastal areas of the United States. Ultimately, these data would be used to minimize contaminant threats due to future hurricanes and sea level rise by supporting decisions aimed at creating more resilient coastlines.</p>

Emerging Environmental Health Threats: Identifying Hidden Hazards

(2015 Actual, \$2.5 million; 2016 Enacted, \$2.5 million; 2017 Request, \$1.8 million)

The health effects associated with poorly understood disease agents are not always immediately obvious or direct. Exposure to a particular contaminant may not result in immediate, life-threatening health impacts to be expressed in that individual organism, but might take several subsequent generations for the impacts to appear. Similarly, adverse health effects from a contaminant may transfer from aquatic to terrestrial animals via the food chain, making the original cause of the health impact difficult to pinpoint.

USGS Environmental Health research provides the science to identify these hidden health hazards and understand the complex interactions between disease agents and the environment so that resource managers and public health officials can make informed decisions with the best possible understanding of otherwise hidden health hazards.



Figure 18: Scientists funded by the USGS Toxic Substances Hydrology Program collect water and fish samples to be analyzed for evidence of hidden chemical hazards in urban waterways.

Source: Clifford P. Rice, U.S. Department of Agriculture.

In 2015, the TSHP supported research on Emerging Environmental Health Threats showing that:

- Endocrine disrupting chemicals (EDCs) in water and fish tissue were found in a range of canals and other urban waterways in the Greater Metropolitan Chicago area. Endocrine disruption, which has been documented in a growing body of scientific literature, is an important example of a potential contaminant-related health hazard that is not immediately obvious and therefore its role as a potentially significant environmental health problem is poorly understood. Endocrine disrupting contaminants have been shown to cause reproductive abnormalities in fish in environmental waters such as Boulder Creek, CO, and major tributaries to the Chesapeake Bay; however, further research is needed to understand the sources and mixtures of these contaminants as well as the complex effects these contaminants may have on the long-term health and reproductive success of entire fish populations. Endocrine disruption due to low-level environmental contaminant exposures remains at the forefront of toxicological and environmental health research and spans a range of hypothesized health concerns for all organisms, including humans.
- There is genetic evidence of pathogenic viruses and bacteria in a stream many weeks after a large volume, though not uncommon, spill of swine manure downstream of a large swine operation in Iowa. These types of spills are an often hidden pathway for delivery of liquid livestock manure to streams with potential health consequences to wildlife, livestock and humans. These spills are common in agricultural areas, and TSHP research can help protect public, wildlife and livestock health by providing the science that public health, farmers and environmental managers need to make important prevention and mitigation decisions.

In 2016 and 2017, the TSHP plans to:

- Continue field and laboratory studies on endocrine disrupting contaminants, with the goal of understanding their role, if any, in significant environmental health consequences.
- Continue field and laboratory studies on sources of mercury contamination in the Great Lakes and the global ocean environment. These studies help decision makers assess the efficacy of regulations and policies designed to minimize mercury releases into the environment from a range of potential sources.
- Continue to conduct field and laboratory studies to determine the sources of contaminants and their mixtures that may be responsible for causing previously documented incidences of intersex (a manifestation of endocrine disruption) in smallmouth bass in several rivers in the Chesapeake Bay watershed. Although mixtures of endocrine disrupting contaminants have been shown to induce intersex in fish, the overall long-term health implications of intersex, and therefore exposures to endocrine disrupting contaminants, on populations of fish and other aquatic life continues to be a focus of this research. Understanding the complex interactions of emerging contaminants and their mixtures is important because contaminants are never individually present in water sources. The interactions of individual contaminants in these mixtures can potentially affect the health of the exposed fish and wildlife as well as the health of humans in ways that are not yet clearly understood.

In 2017, the following program change is proposed for *Emerging Environmental Health Threats: Identifying Hidden Hazards*:

2017 Program Change
<p>Emerging Contaminants and Chemical Mixtures (-\$750,000, for a total of \$0): This activity is being decreased to fund higher priority activities. With the proposed decrease, the Toxic Substances Hydrology Program would decrease the scope of its research on environmental contaminants such as mercury, pharmaceuticals, pesticides, contaminants associated with uranium mining, wastes from oil and gas extraction, personal care products, and plastics manufacturing. Ramping down this activity will change the focus of TSHP scientists to conduct research on a more limited list of new and emerging contaminants such as microbeads, nanoparticles, and genetic material such as environmental DNA. Data and information from this research could be used by researchers from other Federal agencies (e.g., the Environmental Protection Agency, the Department of Energy, and the U.S. Fish and Wildlife Service), industry, and academia to better understand the potential for these contaminants and their mixtures to occur in the Nation’s water resources.</p>

One Health: Disease at the Intersection of Environment, Animals, and People
(2015 Actual, \$2.0 million; 2016 Enacted, \$2.0 million; 2017 Request, \$2.0 million)

The linkages between the health of the environment and the health of animals and people are inextricable. Animals have often served as sentinels for disease caused by both chemical and microbial agents, and can foreshadow potential health impacts in humans. Food chains can serve as a transport mechanism for disease agents from the physical environment to the living environment. Understanding and modeling movements of disease agents and the organisms they affect can provide an early warning system to protect wildlife, domestic animals, and people. Examining the early warning signs in animals can reveal previously unknown routes of exposure and provide public health professionals and environmental managers with possible points of prevention as well as insight into potential health threats.



Figure 4: In order to improve knowledge at the intersection of environmental contaminants and livestock raised for human consumption, Toxic Substances Hydrology Program scientists conduct environmental health research in watersheds potentially influenced by animal agricultural activities.

Source: Dana Kolpin, USGS

commercial poultry feeding and manure management operations are associated with the transport of microbial contaminants such as highly pathogenic avian influenza (HPAI) to groundwater or surface water. This research on a variety of animal feeding operations has important implications for agricultural practices, and its findings could potentially be used by agricultural and environmental managers alike to mitigate the potentially devastating effects of diseases like HPAI or other pathogenic diseases on commercial poultry, the release of hormones to environmental waterways, and exposures of these contaminants to fish and wildlife as well as livestock and humans. This research is therefore important to the economy of States that support commercial animal agricultural enterprises as well as to the health of people living in those States.

In 2015, the TSHP contributed to the creation of datasets on the environmental contaminants associated with animal feeding operations, such as biogenic hormones, veterinary pharmaceuticals, and bacterial and viral pathogens. Once interpreted, these data will provide new insights regarding the associations among various livestock (swine, poultry, and beef/dairy cattle) and the mixtures of environmental contaminants released to nearby waterways, with a special focus on the Chesapeake Bay watershed.

In 2016, the TSHP plans to interpret data collected at animal feeding operations in previous years and create new knowledge products such as online databases and scientific journal articles. The TSHP will also begin a study to determine whether

In 2017, the following program change is proposed for *One Health: Disease at the Intersection of Environment, Animals, and People*:

2017 Program Change
<p>Critical Landscapes: Columbia River (+\$50,000, for a total of \$100,000): The Columbia River is the largest river in the Pacific Northwest, and plays an important role in the region’s culture and economy through tribal fisheries, irrigation, power production, and recreation, among other goods and services. This ecosystem has been affected by a number of manmade changes, including the introduction of environmental contaminants. With the proposed increase, the Toxic Substances Hydrology Program would continue to investigate the effects of contaminants such as pesticides and mercury on the fish and wildlife in the Columbia River. This work is essential to the protection of the health of aquatic and terrestrial wildlife in the region, and would also provide the basis for understanding the interactions of these contaminants with fish and wildlife in similar ecosystems in other regions.</p>

Environmental Lifecycles of Contaminants: Science for Intervention

(2015 Actual, \$5.2 million; 2016 Enacted, \$5.2 million; 2017 Request, \$6.4 million)

USGS Environmental Health research traces chemical and microbial contaminants from their sources (e.g., pesticides from agricultural runoff), through their modes of transport (e.g., seepage into groundwater), to the initial exposure of an organism (e.g., fish exposed through contaminated water), and finally, through their ultimate health impacts on animals and people (e.g., human consumption of affected fish and resulting negative health effects). The study of this “lifecycle” of contaminants in the environment provides

opportunities for environmental managers to reduce exposure to these disease agents at multiple points in their life cycle—from their source in the environment to the changes they make in individual cells—with the ultimate goal of preventing adverse health effects. This science can also be used to evaluate the effectiveness of public health and environmental management actions and to develop more targeted, evidence-based solutions for improving public and environmental health.



Figure 5: Toxic Substances Hydrology Program researchers recently developed laboratory methods to detect neonicotinoid insecticides in the environment, leading to the first national scale study to document the occurrence of neonicotinoids in selected streams of the U.S. Neonicotinoid exposures are one of several factors that have been associated with honeybee declines by other researchers.

Source: Mark Vandever, USGS.

In 2015, the TSHP supported research on Environmental Lifecycles of Contaminants that:

- Documented the first study of neonicotinoid insecticide occurrence in the Nation’s streams. The study showed that these insecticides, which along with other factors, in some cases have been linked to the decline of honeybees, are present in more than half of U.S. streams. This has important implications for understanding how to mitigate the occurrence of contaminants that may be associated with the decline of honeybees.
- Demonstrated that, decades after an oil pipeline spill, there were elevated arsenic concentrations (above the Federal drinking water standard) in the subsurface as a result of the natural breakdown of petroleum and interactions with the surrounding hydrogeologic materials naturally present in the area. Arsenic is a known human carcinogen. This study documented a previously unknown source of environmental arsenic that could occur in other similar petroleum spill areas. Because the arsenic release took place very slowly—decades after the petroleum spill—it would not have otherwise been detected. This process would not have been demonstrated without a consistent TSHP research presence at a long-term oil pipeline study site in Bemidji, Minnesota.
- Documented a range of organic, inorganic, and microbial compositions of produced waters from shale gas wells in the Marcellus region of Pennsylvania. Produced waters are a byproduct of hydraulic fracturing, and research on produced and related wastewaters can provide useful context for environmental management of unconventional oil and gas activities. This research provides new tools for assessing environmental risk by “fingerprinting” wastewaters associated with UOG activities that may become environmental contaminants.

Fingerprinting tools provide a mechanism that could be used to associate contaminants found in the environment with UOG activities. The Toxic Substances Hydrology Program’s research on the environmental impacts of UOG informs the Multiagency Collaboration on Unconventional Oil and Gas Research, an effort combining the expertise of the Department of Interior (via USGS), the Department of Energy, and the Environmental Protection Agency to provide sound science informing safe and responsible development of unconventional oil and gas.

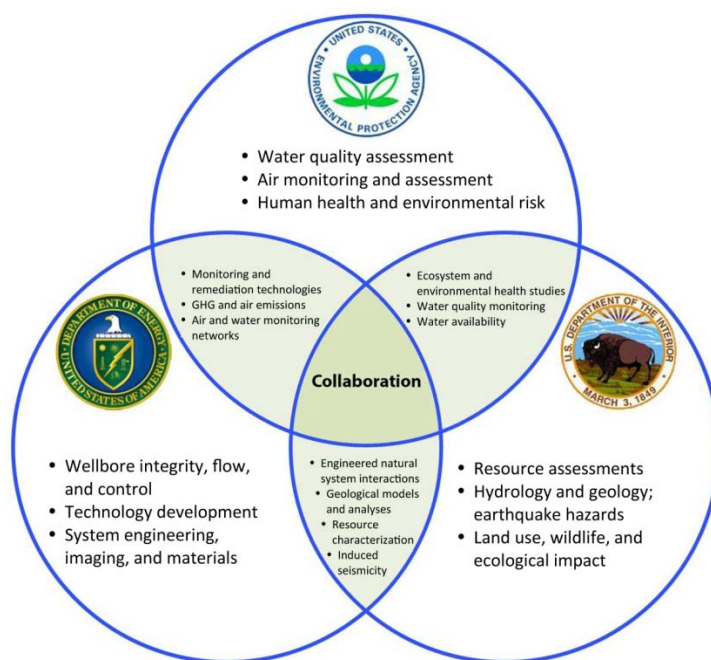


Figure 6: The Toxic Substances Hydrology Program addresses key contamination-related questions posed by the multiagency collaborative effort on unconventional oil and gas research.

Source: Multiagency Collaboration Research Strategy, 2014.

- Depicted the mixtures and concentrations of pharmaceuticals, hormones, and other micropollutants in groundwater impacted by septic systems. Contaminants in septic systems are a poorly understood environmental pathway for emerging contaminants and their mixtures.
- Continued work on developing a baseline for pre-mining levels of contamination in soils in and near uranium mines in the Grand Canyon region for comparison to post-mining soils. In January 2012, then-Secretary of the Interior Ken Salazar announced his decision to withdraw one million acres of Federal land from uranium and other hard rock mining in northern Arizona, including the Grand Canyon, until 2032. This Public Land Order will provide time for research and monitoring of the effects of mining to inform future land use decisions in this critical geographic area. The Toxic Substances Hydrology Program's work will be foundational in conducting before and after mining comparisons of uranium and other associated contaminant levels, which will inform the multiagency 15-year science plan developed in



Figure 6: USGS scientists collect soil samples near a uranium mine (in the background) for contaminant analysis. This work supports science needed to inform decisions related to the Secretary of Interior's withdrawal of public lands in the Grand Canyon area from new mining claims.

Source: Jo Ellen Hinck, USGS

collaboration with the Bureau of Land Management, the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Forest Service. Since contaminants are known to occur naturally in these areas, rigorous, scientifically-designed environmental monitoring of baseline conditions is critical to understanding the potential, if any, for elevated levels and environmental risks that may be associated with mining activities.

In 2016, the TSHP plans to:

- Provide new knowledge and data on neonicotinoids and other pesticides that are used in agricultural settings, including the potential for accidental exposures to native pollinators.
- Provide new knowledge and data on fate and transport of contaminants in the subsurface, including movement of solvents in fractured bedrock. This foundational research continues to provide insights into mitigation and control of movement of carcinogenic solvents in these very complex subsurface environments that are common throughout the East Coast and elsewhere.
- Conduct further field and laboratory studies on the potential contaminant impacts of wastewater spills associated with unconventional oil and gas activities, in support of the Federal multiagency collaboration on unconventional oil and gas.

- Expand upon field and laboratory studies on baseline levels of contaminants and the potential contaminants associated with uranium mining activities, in support of the established scientific collaboration with the National Park Service, the U.S. Fish and Wildlife Service, the Bureau of Land Management, the U.S. Forest Service, and State and local partners in the Grand Canyon region.
- Continue collaborative work with biologists and toxicologists to determine if there are hidden contaminant risks to wildlife and the public in areas associated with uranium mining.
- Continue the scientific collaboration with the National Park Service to identify potential sources and fate of endocrine disrupting chemicals in both heavily visited and less frequented areas of selected National Parks. The living resources (fish and wildlife) that inhabit our national parks are protected from many of the conventional contaminant threats that exist in other areas where urban, industrial, and agricultural land uses are plentiful. However, contaminants in wastes from humans in campgrounds, in less frequented areas, and from wastewater treatment are common in parks, and their associated threats are being assessed through this research.



Figure 7: Scientists supported by the Toxic Substances Hydrology Program, in collaboration with the National Park Service, collect samples to determine the potential for emerging contaminants (such as pharmaceuticals, hormones, personal-care products, and their mixtures) to be transported from septic systems to subsurface water resources.

Source: Chris Schubert

In 2017, the following program changes are proposed for *Environmental Lifecycles of Contaminants: Science for Intervention*:

2017 Program Changes
<p>Environmental Impacts of Uranium Mining (+\$1,750,000, for a total of \$2,500,000): In January 2012, the Secretary of the Interior withdrew over one million acres of public lands in the Grand Canyon region from mining for 20 years. A key factor in the Secretary’s decision to withdraw the land from future mining was lack of scientific information. To address this, the USGS, along with four other Federal partners (the Bureau of Land Management, the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Forest Service) subsequently developed a 15-year science plan to study the environmental impacts of uranium mining in the region. Toxic Substances Hydrology Program</p>

2017 Program Changes

(TSHP) work has thus far focused on developing a baseline for pre-mining levels of contamination in soils for comparison to post-mining contamination in the region, as it is important to understand the levels of naturally-occurring uranium in soils in order to understand what may have been introduced during or following mining activities. With the proposed increase, the TSHP would expand upon this scientific research by including additional sites and environmental settings (e.g., water), and by conducting biological sampling. Additionally, the TSHP would use the proposed increase for interpretation and analysis of the datasets compiled thus far, culminating in the publication of the sources and environmental risks of uranium and other contaminants that may be released to the environment. This research is critical for future decision making on withdrawal of lands from mining in the region, and will help inform the development, mitigation, reclamation, and ecological restoration of mines on valid existing claims, if applicable.

Unconventional Oil and Gas Research (+\$250,000, for a total of \$1,020,000): In support of the existing Federal multiagency collaborative effort between the Department of Energy, the Department of the Interior (via USGS), and the U.S. Environmental Protection Agency to conduct science, research, and development aimed at understanding and mitigating the potential environmental and public health and safety impacts of unconventional oil and gas (UOG) development, the Toxic Substances Hydrology Program (TSHP) would use the proposed increase to study the environmental contamination associated with spills and other releases of liquid and solid wastes from unconventional oil and gas development activities at sites currently under study in West Virginia (Marcellus Shale) and North Dakota (Williston Basin). This research provides valuable, unbiased science and information which decision makers can use to ensure the safe and prudent development of unconventional oil and gas resources.

Fate and Transport of Contaminants in the Subsurface (-\$800,000, for a total of \$0): This decrease is being requested in order to fund higher priority activities. The proposed decrease in funding would shift the focus of TSHP research away from the development of data, information, tools, and knowledge products regarding the movement of contaminants from their point of origin (including industrial, municipal, agricultural, and residential sources), as they are transported or transferred in the environment, and through their pathways of exposure. Instead, TSHP scientists would shift the focus of their research toward studying the environmental exposure of these contaminants to humans and other organisms through scientific collaborations with academia and other Federal scientists with expertise in toxicology and epidemiology.

Detecting Future Health Threats in the Environment: Methods, Models, and Tools
(2015 Actual, \$1.3 million; 2016 Enacted, \$1.3 million; 2017 Request, \$1.3 million)

Early detection and prediction of potential routes of exposure of disease agents are the foundation of risk reduction and protection of vulnerable populations. Whether it involves an accidental release of toxic chemicals during a natural disaster, or a pathogenic virus that jumps from animals to people, USGS Environmental Health research develops the tools needed to stay ahead of evolving threats. These tools allow for the rapid identification and detection of disease agents, continuous tracking of the spread of disease agents, and measurement of their environmental effects.

In 2015, the TSHP developed new and improved methods and conducting field studies of algal toxin occurrence and distribution. Algal toxins can contaminate sources of public drinking water, as well as the treatment facilities that these source waters supply. Recently, the city of Toledo, OH, shut down its municipal drinking water plant when algal toxins were detected. In addition to drinking water contamination, algal toxins are responsible for impacting the health of wildlife, domestic pets, and livestock that may come in contact with affected environmental waters. The extent to which algal blooms and related toxin production is related to land use, nutrient enrichment, and other activities is poorly understood. The TSHP is beginning to answer some of these questions by developing a range of tools and approaches, including laboratory, remote sensing, and field monitoring to detect and quantify the toxins in environmental waters associated with various land-uses. More complete understanding of the underlying causes of toxic algal blooms is necessary to make informed decisions about land management, policy, and regulations that may be useful in minimizing the threat of these toxins.

In 2016 and 2017, the TSHP plans to:

- Continue to develop and refine new remote sensing, field and laboratory methods for algal toxin research. This is important for understanding the relationship between algal toxin occurrence and land use, which can help environmental managers make more informed land use decisions to prevent potential harmful environmental and public health impacts from algal toxins.
- Continue to develop methods for tracing the movement of contaminants from aquatic to terrestrial ecosystems through food chains. This will help scientists understand how contaminants move through ecosystems and ultimately how, or if, they contribute to environmental threats to various predator and prey relationships, as well as the threats they may pose to humans who may exist within those food chains.
- Continue to develop laboratory methods to detect emerging chemical and microbial contaminants in a range of environmental settings, including water, soils, and tissue. These tools will also help scientists understand how contaminants and their mixtures move through ecosystems and contribute to environmental threats. These tools will be applicable to a range of topics, from unconventional oil and gas research, to animal feeding operations, to uranium mining. This research also dovetails with the food chain research noted above.

Science Coordination

In order to provide valuable scientific contributions that take into account stakeholder needs and leverage the diverse expertise of partners, the Toxic Substances Hydrology Program coordinates with a number of partner organizations in conducting its work, including Federal, State, and local agencies, as well as academia and non-governmental organizations. In conducting priority ecosystems research, such as work in the Columbia River Basin or the Chesapeake Bay watershed, the TSHP works with organizations like Idaho Power (Columbia River work), as well as the U.S. Fish and Wildlife Service, the Virginia Department of Environmental Quality and the Pennsylvania Department of Environmental Protection (Chesapeake Bay work). For its research on the environmental impacts of unconventional oil and gas, the TSHP participates in the Multiagency Collaboration via the Department of Interior and in partnership with the Department of Energy and the Environmental Protection Agency. The TSHP's work studying contamination following storms on the northeastern coast of the United States has taken place through a

partnership with the National Oceanic and Atmospheric Administration, and with the States of New Jersey and New York. The TSHP has also partnered with State and local governments on its efforts to study the environmental impacts of uranium mining in the Grand Canyon region. In addition to the Arizona Department of Game and Fish, and the State of Arizona, academic partners have also played a role in the project, including Northern Arizona University and Bethel College. The TSHP, as part of the USGS's effort on the multiagency 15-year science plan in the region, also coordinates with the Bureau of Land Management, the National Park Service, the U.S. Forest Service, and the U.S. Fish and Wildlife Service in sharing scientific research, information, and tools related to the study of environmental impacts of uranium mining in the Grand Canyon region. Through these and many other partnerships, the TSHP is able to leverage cross-organizational efficiencies and expertise to address some of the most pressing environmental health challenges of the 21st century.

Natural Hazards

Activity: Natural Hazards

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
<i>FTE</i>	<i>607</i>	<i>611</i>		<i>20</i>	<i>631</i>	<i>20</i>
Earthquake Hazards	\$59,503	\$60,503	\$193	\$1,500	\$62,196	\$1,693
<i>FTE</i>	<i>239</i>	<i>239</i>		<i>4</i>	<i>243</i>	<i>4</i>
Volcano Hazards	\$25,121	\$26,121	\$117	\$0	\$26,238	\$117
<i>FTE</i>	<i>134</i>	<i>136</i>		<i>0</i>	<i>136</i>	<i>0</i>
Landslide Hazards	\$3,485	\$3,538	\$16	\$500	\$4,054	\$516
<i>FTE</i>	<i>22</i>	<i>22</i>		<i>2</i>	<i>24</i>	<i>2</i>
Global Seismographic Network	\$4,853	\$6,453	\$9	\$860	\$7,322	\$869
<i>FTE</i>	<i>10</i>	<i>11</i>		<i>1</i>	<i>12</i>	<i>1</i>
Geomagnetism	\$1,888	\$1,888	\$10	\$1,700	\$3,598	\$1,710
<i>FTE</i>	<i>12</i>	<i>12</i>		<i>3</i>	<i>15</i>	<i>3</i>
Coastal & Marine Geology	\$40,336	\$40,510	\$174	\$5,609	\$46,293	\$5,783
<i>FTE</i>	<i>190</i>	<i>191</i>		<i>10</i>	<i>201</i>	<i>10</i>

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Earthquake Hazards Program	+ 1,500	+ 4	I-9
Central/Eastern U.S. Seismic Network Adoption	+ 800	+ 2	I-13
Unconventional Oil and Gas Research - Induced Seismicity Earthquake Risk Assessments	+ 700	+ 2	I-18
Landslide Hazards Program	+ 500	+ 2	I-31
Natural Hazard Science for Disaster Response: Landslide Response	+ 500	+ 2	I-36
Global Seismographic Network	+ 860	+ 1	I-39
GSN Primary Sensor Deployment	+ 860	+ 1	I-41
Geomagnetism Program	+ 1,700	+ 3	I-43
Improved Geomagnetic Monitoring to Support Space Weather Nowcasting	+ 1,700	+ 3	I-48
Coastal and Marine Geology Program	+ 5,609	+ 10	I-51
Building Landscape-Level Resilience to Coastal Hazards	+ 2,109	+ 4	I-57
Scenarios for Arctic Actions to Address Imminent Coastal Impacts	+ 3,500	+ 6	I-55
Total Program Change	+ 10,169	+ 20	

Justification of Program Change

The 2017 Budget Request for Natural Hazards is \$149,701,000 and 631 FTE, a net change of +\$10,688,000 and 20 FTE from the 2016 Enacted level.

Overview

The Natural Hazards Activity is comprised of six subactivities:

- Earthquake Hazards Program (EHP; <http://earthquake.usgs.gov>)
- Volcano Hazards Program (VHP; <http://volcanoes.usgs.gov>)
- Landslides Hazards Program (LHP; <http://landslides.usgs.gov>)
- Global Seismographic Network (GSN; <http://earthquake.usgs.gov/monitoring/gsn>)
- Geomagnetism Program (<http://geomag.usgs.gov>)
- Coastal and Marine Geology Program (CMGP; <http://marine.usgs.gov>)



The USGS provides scientific information to emergency responders, policy makers, and the public to reduce losses from a wide range of natural hazards, including earthquakes, floods, hurricanes, landslides, magnetic storms, tsunamis, volcanic eruptions, and wildfires. Working with its partners, cooperators, and customers, the USGS delivers actionable assessments of these hazards and helps to develop effective strategies for achieving more-resilient communities. The USGS is the Federal agency responsible for monitoring and notification of earthquakes, volcanic activity, and landslides in the United States. For many other hazards, the USGS directly supports the warning responsibility of the National Oceanic and Atmospheric Administration.

In addition to direct responsibility for the work supported by the six programs in this Natural Hazards budget activity, the Natural Hazards Mission Area is responsible for overall coordination of USGS hazard activities, which are supported by programs in all mission areas. This broader mission is reflected in the *USGS Natural Hazards Science Strategy—Promoting the Safety, Security, and Economic Well-Being of the Nation* (Circular 1383-F; <http://pubs.usgs.gov/circ/1383f/>)

This Natural Hazards Mission Area also is the primary source of support for USGS activities that characterize and assess coastal and marine processes, conditions, change and vulnerability. USGS expertise in marine geology, geophysics, and oceanographic disciplines provides science and information products essential to support broad ecosystem restoration and protection, adaptation to climate change, and sustainable development and resources use. The USGS actively engages with other Interior bureaus, Federal agencies, and regional ocean alliances to provide data and tools to support better and more cost effective decisions that anticipate changing conditions and the consequences of resource use, management, and restoration.

The mission area's Science Application for Risk Reduction (SAFRR) project works with emergency and business continuity managers to improve warning systems, explore vulnerable interdependencies, enhance emergency response, and speed disaster recovery. SAFRR, created in 2011, builds on the successful Multi-Hazards Demonstration Project that innovated ways of applying USGS hazard science to improve the resilience of southern California. Scenarios developed by that project led to the Great ShakeOut public preparedness drills that have grown to include tens of millions of people worldwide. In 2015, the Mayor of Los Angeles issued the *Resilience by Design* report identifying actions now being taken by the city to address earthquake vulnerabilities identified in the ShakeOut scenario. The same approach of building an end-to-end scenario of catastrophic impacts has been applied to a California-wide winter storm (ARkStorm) and Alaska-generated tsunami impacting port infrastructure in California (SAFRR Tsunami Scenario). The next SAFRR scenario, HayWired, will look at the impact of a large Hayward fault earthquake in the San Francisco Bay area with a focus on impacts to the economy of Silicon Valley. In 2016, the SAFRR project will continue to build alliances and work with communities, businesses, research institutions, and governments to improve the use of existing USGS natural hazards information, identify needs and gaps, and develop new products that increase the effectiveness of USGS science. Scenarios akin to ShakeOut and ARkStorm will remain a cornerstone activity. These science-based scenarios are recognized internationally as a fundamental shift in the way science can serve society.

The Natural Hazards Mission Area implements the Department of the Interior (DOI) Strategic Sciences Group (SSG), created by Secretarial Order in 2012 to provide the Secretary of the Interior with the standing capacity to rapidly assemble trained teams of scientists to construct interdisciplinary scenarios of the cascading consequences of natural disasters and other environmental crises. With co-leaders from the USGS and one other Interior bureau (currently the National Park Service), the SSG complements other USGS hazard responsibilities. During an environmental crisis, the Secretary can direct the SSG to activate a crisis science team composed of experts from government, academia, non-governmental organizations, and the private sector to build scenarios, develop potential interventions to mitigate adverse effects, and deliver information to decision makers and resource managers. In 2013, the SSG was deployed to develop scenarios and actionable interventions in support of the Interior in its role on the Federal Hurricane Sandy Rebuilding Task Force: results informed Interior's selection of projects supported by Hurricane Sandy supplemental funds. Since Sandy, the SSG has focused on capacity building. In 2014-2015, the SSG forged partnerships with 21 professional societies to expand its roster of experts to call on during deployment. This network was successfully tested using a tabletop exercise. In 2015, the SSG explored the applicability of its methods to events associated with climate change, such as long-term drought and severe wildfires: results informed climate adaptation plans in southwestern Colorado. Finally, the SSG continues to explore the science of 'science during crisis' and has been consulted by project teams both within and outside Interior to provide input on developing scenarios for rapid response, project assessment techniques, and mechanisms for science coordination during emergencies. In 2016, the SSG will be preparing for Secretarial deployment in the event of a future crisis affecting Interior-managed resources. During non-crisis times, the SSG will refine scenario development methodology, make necessary preparations for future deployments, and conduct exercises and capacity building activities to maintain staff skills and to build a cadre of deployable experts.

This mission area also houses the bureau's emergency management function, working closely with USGS science centers, the Interior Office of Emergency Management, FEMA and other agencies and

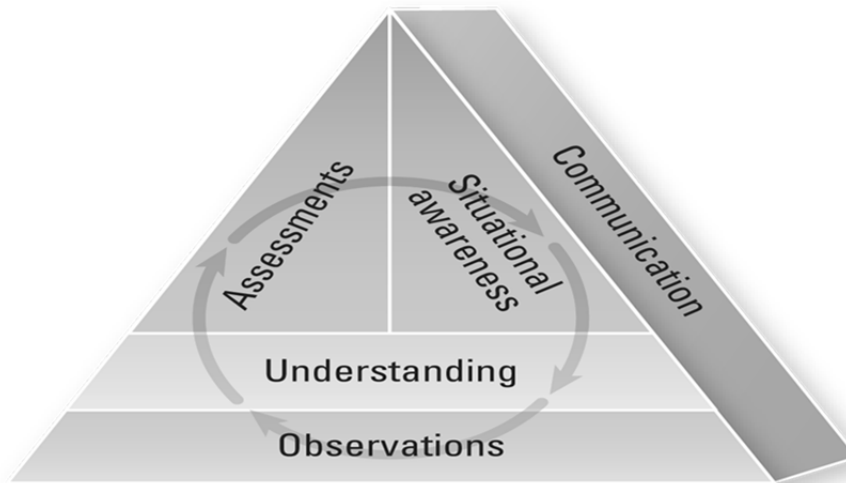
Natural Hazards

organizations. The skills and expertise of many USGS employees are used to respond to a variety of natural hazards and related emergencies. A Hazard Response Executive Committee brings together the executive leadership of the bureau to ensure that necessary resources are brought to bear to plan, prepare, respond, and recover from emergencies.

The 2017 President's Budget Request for the Natural Hazards Activity includes increased funding for activities related to induced seismicity earthquake-risk assessments; the adoption of the Central and Eastern U.S. Seismic Network; improving landslide response; deployment and installation of the new borehole sensors and improvement to GSN sites; improving geomagnetic monitoring; and developing scenarios for Arctic coastal impacts and activities related to building resilience to coastal hazards.

The request maintains support for the core roles and responsibilities of the USGS regarding the delivery of hazards science including:

- Assessments and warnings for earthquakes, volcanic eruptions, and landslides.
- Operation of a global seismic network to support global earthquake reporting and NOAA tsunami warnings.
- Coastal and marine geologic surveys and research to support assessments of earthquake and tsunami hazards, and coastal impacts from storms, hurricanes and sea level rise.
- Geomagnetic observatories to support NOAA geomagnetic storm warnings.
- Evaluation of resource management choices to address coastal change impacts on sensitive ecosystems on Federal and adjacent lands.



Core responsibilities are activities that the USGS must continue in order to uphold its mission. In many cases, these are mandated activities that help to protect lives and assets, or strengths developed as a consequence of long-standing national need. Strategic actions are high-value, priority efforts that go beyond the core responsibilities and will reduce uncertainties about hazards, improve communication, and thus enhance the ability to provide accurate, effective assessments and situational awareness.

Below are key 2017 deliverables that the increases in this budget request would provide to address the four strategic goals required to fulfill the USGS natural hazards mission:

Goal 1: Enhanced observations

- Improved monitoring of geomagnetic fields and induced electric currents.
- Restoration of the Global Seismographic Network to full capability.
- Retaining the enhanced monitoring capability provided by the CEUSN in the Eastern United States.

Goal 2: Fundamental understanding of hazards and impacts

- Delivery of more data and analysis to relate oil and gas field operations to induced seismic events and their associated risks.
- Strengthening the understanding of ocean and coastal geological processes to provide the data and tools for assessments of coastal and marine conditions, change, and vulnerability.

Goal 3: Improved assessment products and services

- Enhance capabilities to respond to landslide crises by investing in new technology to integrate in-situ and remotely sensed observations.

Goal 4: Effective situational awareness

- Expanded NOAA-USGS post-wildfire debris-flow early warning to Colorado, Arizona, and New Mexico.
- Earthquake early warning system implementation for the west coast.

Examples of meeting multiple goals

- Enhance capabilities to respond to landslide crises by investing in new technology to integrate in-situ and remotely sensed observations. (Goals 1, 2, 3)
- Provide underserved Alaskan and Pacific Island Communities with data and tools to enhance resilience and avoid losses. (Goals 1, 2, 3)
- Continued restoration and repair of failed and impaired networks on High-Threat Volcanoes in Alaska. (Goals 1, 3)
- Closure of monitoring gaps in Alaska, California, Hawaii, Oregon, and Washington. (Goals 1, 3)

2015 Natural Hazards Accomplishments

New estimates of Americans' exposure to earthquake risk – The USGS released new estimates of the number of Americans exposed to earthquake damage, and of the economic losses caused by earthquakes in the United States. This new assessment helps to better understand the scale of earthquake hazards,

Natural Hazards

identify critical infrastructure located in high earthquake-hazard areas, and ultimately strengthen the Nation's ability to protect Americans against future events through appropriate building codes.

Partnerships for development of Earthquake Early Warning for the west coast – The USGS expanded funding to the California Institute of Technology, University of California, Berkeley, University of Washington, and University of Oregon to support transitioning the “ShakeAlert” earthquake early warning system toward a production stage.

Completion of Lidar Survey – Glacier Peak and Mt. Baker both rank as Very High-Threat in the Volcano Hazard Program's National Volcano Early Warning System (NVEWS) assessment. Lidar over both volcanoes was completed 2015. This elevation data aided geological mapping on the volcano to refine its eruptive history; assisted in locating new monitoring instrument sites to improve eruption-forecasting capabilities; and modeling lahar (volcanic mudflow) hazards on river drainages.

Continued Repair and Maintenance of Monitoring Systems on Alaska Volcanoes – In 2015, staff from the Alaska Volcano Observatory (AVO) made repairs to seismic monitoring equipment on Aniakchak, Gareloi, Tanaga, Westdahl, and Shishaldin Volcanoes in Alaska. The repairs reduced the backlog of maintenance and restored the monitoring status of each of the volcanoes. As a result, AVO can once again reliably track volcanic unrest at these volcanoes and issue warnings of hazardous eruptive activity.

Post-wildfire debris-flow hazard assessments – Wildfire can significantly change the response of burned watersheds to rainfall such that modest rainstorms can produce flash flooding and debris flows. The USGS produced estimates of debris-flow probability and magnitude for more than 20 large wildfires in the Western United States. The hazard assessments were delivered to Federal and State Burned Area Emergency Response (BAER) teams, local emergency managers, and the general public to help plan for post-wildfire impacts.

Characterizing Marine Geologic Hazards and Resources – During spring 2015, the USGS conducted a seagoing cruise in the North Atlantic to complete the data collection plan for the Extended Continental Shelf program outlined by the U.S. Department of State with NOAA and Interior. The Law of the Sea allows a country to use calculations based on the shape of the seafloor and (or) the thickness of sub-seafloor sediment to determine the edge of its Extended Continental Shelf

Enhancing Delivery of Coastal Change Data, Tools and Knowledge – In 2015, with the advent of Hurricane Joaquin and a large nor'easter, the USGS rolled out new coastal-change forecasts, which integrate information produced by both the USGS and NOAA's National Hurricane Center. Forecasts are updated multiple times daily and are posted to the USGS Coastal Change Hazards Portal. This Web-based portal provides a wealth of information for coastal residents, emergency managers and community leaders about the timing and likelihood that storm waves will erode beaches, damage dunes, overtop the dunes and inundate the land with seawater or open breaches in barrier islands.

Strategic Actions for 2016

- The Earthquake Hazards Program (EHP) will further develop the ShakeAlert system for earthquake early warning, completing a “production prototype” system and expanding coverage through upgrades to existing seismic and geodetic stations and associated communications.
- The Volcano Hazards Program (VHP) will conduct new mapping projects in support of volcanic hazard assessments and real-time monitoring network maintenance and expansion, both prioritizing Very High-Threat and High-Threat Volcanoes.
- The Landslide Hazards Program (LHP) will continue to produce post-wildfire debris-flow hazard assessments for southern California and the Intermountain Western United States. The LHP will also conduct field studies in a selected number of wildland fires to collect data for the development of rainfall thresholds needed for debris-flow early warning.
- The Global Seismographic Network (GSN) will complete testing of a prototype new borehole sensor, will prepare for a large production order of these units, and will begin infrastructure improvements and enhancements in preparation for the arrival of the new borehole sensors.
- The Coastal Marine and Geology Program (CMGP) will continue to support research activities in priority areas, including gas hydrate systems, establishing the U.S. Extended Continental Shelf, and assessment of offshore tsunami source potential. The CMGP will also continue to support a long-term strategy of mapping, research, and model development to provide and enhance assessments and forecasts of coastal change vulnerability to storms, erosion, and sea level rise at regional and national scales, including potential use of Light Detection and Ranging (lidar) mapping.

Strategic Actions for 2017

- The EHP will develop an effort to reduce the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts.
- The EHP, in collaboration with state and local partners, will further develop the ShakeAlert system for earthquake early warning, including: further testing of the system, integrating triggering algorithms, expanding coverage through upgrades to existing seismic and geodetic stations and associated communications, and developing training and education.
- The EHP will assume the long-term operation of an expanded network of seismic stations in the Central and Eastern United States, currently operated with National Science Foundation (NSF) funding.
- The VHP will perform scheduled maintenance on volcano monitoring networks that are easy to access with prioritization on Very High-Threat and High-Threat volcanoes.
- The VHP will continue to improve monitoring networks at Glacier Peak, Mount Baker and Mount Adams in Washington (permit pending).
- The LHP will continue to support research to improve the understanding of landslide initiation and mobility processes. This improved understanding will be used to develop, test, and advance tools for landslide hazard assessment and forecasting.

Natural Hazards

- The LHP will continue to improve post-wildfire debris-flow hazard assessments used by BAER Teams, State Geological Surveys, and Federal, State, and local emergency response to wildfires.
- The LHP will continue to collect data and develop tools to expand the NOAA-USGS post-fire debris-flow warning system.
- The GSN will begin a five-year program for installing replacement borehole sensors and improving vaults at dozens of global seismic stations, improving data quality and thereby the accuracy of earthquake alerts and tsunami warnings, as well as data for basic research.
- The Geomagnetism Program will begin development of a national capability for mapping time-dependent geomagnetic hazards for assessing national space weather vulnerability and risk, with the potential for significantly improving forecasts of space weather and its impacts. These actions are integral to implementation of the National Space Weather Strategy.
- The CMGP will continue to research national and regional coastal change hazards assessment and delivery of forecasts of inundation and overwash for hurricanes, nor'easters, and other extreme storms; evaluation of marine resources including gas hydrates and marine minerals and impacts of extraction or use of energy and mineral resources on seafloor dynamics; development of models and tools for Interior land and resource managers to use to understand and plan for impacts of sea level rise on near shore and estuarine environments; and assessment of offshore tsunami source potential from submarine earthquakes and slope failure.

Activity: Natural Hazards**Subactivity: Earthquake Hazards Program**

Dollars in Thousands	2015	2016	2017			
	Base	Enacted	Fixed Costs	Program Changes	Request	Change from 2016 Enacted
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
FTE	607	611		20	631	20
Earthquake Hazards Program	\$59,503	\$60,503	\$193	\$1,500	\$62,196	\$1,693
FTE	239	239		4	243	4
Research into Earthquake Causes and Effects	\$11,300	\$11,300		\$700	\$12,000	\$700
<i>Unconventional Oil and Gas Research - Induced Seismicity Earthquake Risk Assessments</i>	<i>[\$2,500]</i>	<i>[\$2,500]</i>		<i>[\$700]</i>	<i>[\$3,200]</i>	<i>[\$700]</i>
Hazard and Risk Assessments	\$16,100	\$16,100		\$0	\$16,100	\$0
Monitoring and Reporting	\$29,703	\$30,703		\$800	\$31,503	\$800
<i>Central/Eastern U.S. Seismic Network Adoption</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$800]</i>	<i>[\$800]</i>	<i>[\$800]</i>
Communications and Outreach	\$2,400	\$2,400		\$0	\$2,400	\$0

Justification of Program Change

The 2017 Budget Request for the Earthquake Hazards Program is \$62,196,000 and 243 FTE, a net change of +\$1,693,000 and +4 FTE from the 2016 Enacted level.

Overview

The USGS provides the scientific information and knowledge necessary to reduce deaths, injuries, and economic losses from earthquakes and earthquake-induced tsunamis, landslides and soil liquefaction. The USGS is the only U.S. agency that routinely and continuously reports on current domestic and worldwide earthquake activity. Through the Advanced National Seismic System (ANSS), the USGS and its State and university partners monitor and report on earthquakes nationwide.

The Earthquake Hazards Program (EHP) is the applied Earth science component of the four-Agency National Earthquake Hazards Reduction Program (NEHRP, reauthorized by the Earthquake Hazards Reduction Authorization Act of 2004, P.L. 108–360). Through NEHRP, the USGS partners with the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST) to reduce earthquake losses in the United States.

In 2017, the EHP is requesting two increases: an increase of \$800,000 to significantly improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159

Natural Hazards

stations in the Central and Eastern U.S. Seismic Network; and \$700,000 for reducing the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts.

Program Performance

The EHP includes the following four program components, described in more detail below: Assessment and Characterization of Earthquake Hazards; Monitoring and Reporting Earthquake Activity and Crustal Deformation; Research into Earthquake Causes and Effects; and Earthquake and Safety Information for Loss Reduction.

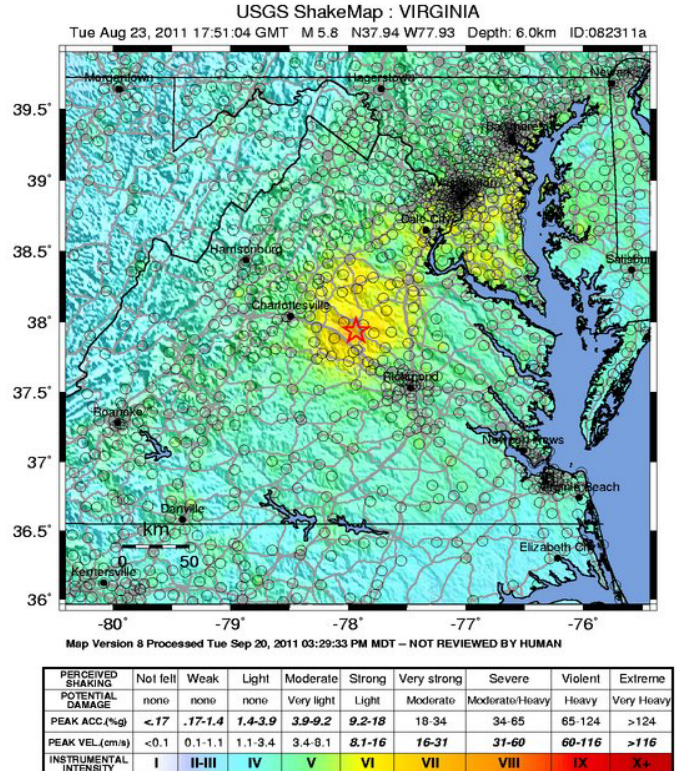
Partnerships are crucial to the program's success. Approximately one-quarter of the total EHP budget is directed toward research grants and cooperative agreements with universities, State agencies, and private technical firms to support research and monitoring activities. This external funding is leveraged by funds from other Federal agencies, States, and the private sector.

The 2017 President's Budget Request includes increases in funding for activities related to induced seismicity earthquake risk assessments and the adoption of the Central and Eastern U.S. Seismic Network.

Monitoring and Reporting

(2015 Actual, \$29.7 million; 2016 Enacted, \$30.7 million; 2017 Request, \$31.5 million)

The Advanced National Seismic System (ANSS) is a cooperative effort to collect and analyze data on earthquakes, issue timely, reliable notifications of their occurrence and impacts, and provide data for earthquake research, hazard, and risk assessment as a foundation for building an earthquake resilient Nation. Deployment of ANSS is focused on expanding and improving the performance and integration of monitoring networks in the United States. The system includes a national backbone seismic network, the National Earthquake Information Center (NEIC), 11 partner-operated regional networks, and the National Engineering Strong Motion Project for monitoring earthquake shaking in structures. The ANSS is capable of detecting almost all felt earthquakes in the United States, except in remote areas of Alaska. Thanks to substantial improvements to station



Above is a USGS ShakeMap of the earthquake that occurred in Virginia in August 2011

coverage and methods for rapid analysis, the ANSS now typically reports on domestic earthquakes within minutes of their occurrence.

The NEIC provides information on potentially damaging earthquakes to the National Command Center; the White House; the Departments of Defense, Homeland Security (including FEMA), Transportation, Energy, and Interior; State offices for emergency services; numerous public and private infrastructure management centers (e.g., highways, railroads and pipelines); the news media; and the public. Rapid earthquake notifications are delivered electronically to about 400,000 subscribers, and a suite of earthquake information products such as *ShakeMaps*, *Did You Feel It?*, rapid *PAGER* estimates of financial and human impacts, and scientific data are available on the EHP’s Web site, which receives more than two million page-views daily.

Earthquake Early Warning (EEW) is the capability to quickly and automatically identify and characterize an earthquake after fault rupture begins; calculate the intensity of ground shaking that is expected to result; and deliver warnings to people and systems that may experience damaging shaking in seconds or minutes. Recent Federal, State, and private investments have resulted in a prototype EEW system called *ShakeAlert*, which has been sending live alerts to selected test users since January of 2012. Before reliable public alerts can be sent, the system requires more ground-motion sensor stations and additional development to maximize its speed, reliability and accuracy.

Regional Earthquake Monitoring – As part of the ANSS, the USGS and cooperating universities operate regional seismic networks in areas of higher seismic risk. Regional data are used to monitor active faults and ground shaking, in much greater detail and accuracy than is possible with the national-scale network. Each region has appropriate local data processing capabilities. ANSS regional networks also serve as State or local distribution points for information about earthquakes to the public, local and State agencies, and other regional interests. To support partner activities in earthquake monitoring, in 2015, approximately \$6.4 million was provided through cooperative agreements for regional seismic and geodetic networks, and structural and geotechnical arrays, operated by the following universities.

Seismic Monitoring Networks supported by the USGS in 2015	
California Institute of Technology	University of Nevada Reno
Columbia University, Lamont-Doherty Earth Observatory	University of Memphis
University of Alaska Fairbanks	University of Oregon
St. Louis University	University of South Carolina
University of California Berkeley	University of Utah
University of Washington	

Geodetic Monitoring Networks supported by the USGS in 2015	
Central Washington University	University of California Berkeley
San Francisco State University	University of Memphis
University of Nevada Reno	

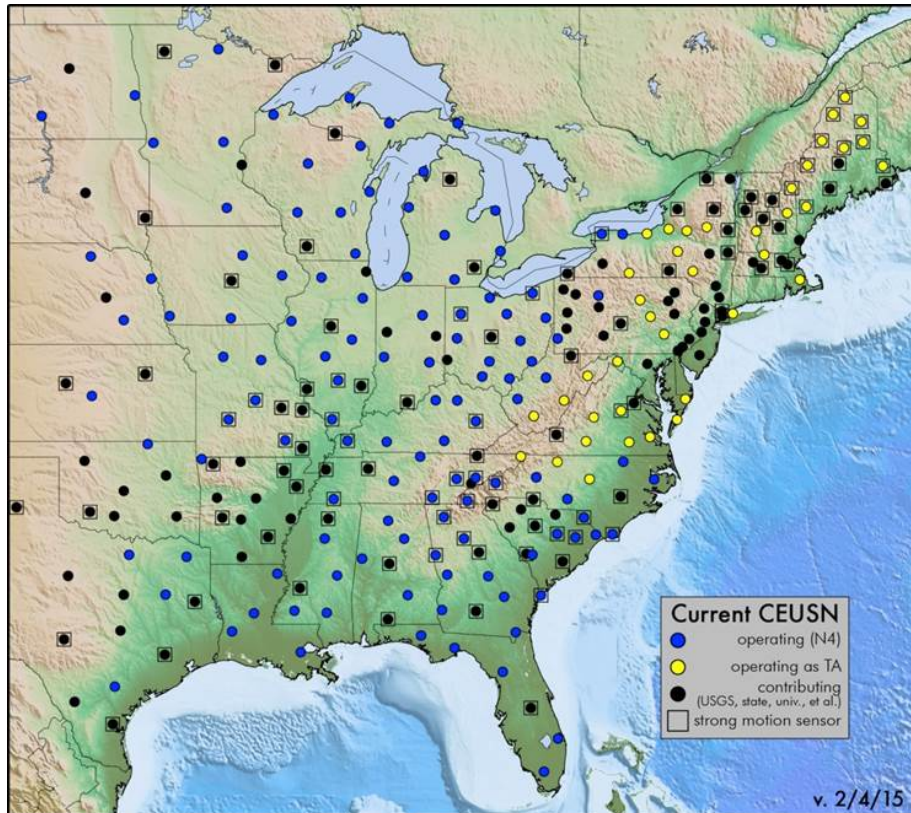
In 2015, in the area of monitoring and reporting, EHP continued to operate and improve the ANSS, and awarded new cooperative agreements to support partner seismic and geodetic networks. Additionally, EHP expanded funding to four universities (California Institute of Technology, University of California,

Natural Hazards

Berkeley, University of Washington and University of Oregon) to support transitioning the “ShakeAlert” earthquake early warning system toward a production stage.

In 2016, in the area of monitoring and reporting, the EHP will continue to operate and improve the ANSS and related geodetic networks. The EHP and its university partners will continue to develop the ShakeAlert EEW system across the west coast of the United States. The EHP will continue development of scientific algorithms, more thoroughly test the system, and improve its performance. In addition, the USGS and university partners will continue work to upgrade and construct approximately 150 seismic sensors to improve the speed and reliability of the warnings. The EHP will also develop user training and education materials and add additional test-system users.

In 2017, in the area of monitoring and reporting, the EHP will continue to operate and improve the ANSS and related geodetic networks and will work with the States of California, Washington, and Oregon to implement a limited earthquake early warning system. Efforts will include expanding seismometer coverage outward around major urban areas, integrating geodetic data into the system, and continued development and testing to improve reliability. In collaboration with State agencies, the USGS will increase end-user education efforts on how to understand and use alerts issued from *ShakeAlert*. In 2017, funding is being requested to significantly and permanently improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159 stations in the Central and Eastern U.S. Seismic Network, which was constructed with NSF funding.



Seismic stations in the Central and Eastern U.S. (CEUSN). NSF support for the CEUSN comprising 159 stations in this region, ends in 2017.

2017 Program Change

Central/Eastern U.S. Seismic Network Adoption (+\$800,000 for a total of +\$800,000): The proposed increase would allow the USGS to significantly improve earthquake monitoring in the Central and Eastern United States by assuming long-term operations of 159 seismic stations in the Central and Eastern U.S. Seismic Network (CEUSN), which was constructed with NSF funding that ends in 2017. If the USGS does not assume operations of these seismic stations, the monitoring equipment will be removed by NSF and added to their inventory of portable equipment that they use for research purposes and the ability to retain this increased the USGS monitoring capability will be lost. In 2012, the USGS and NSF worked with OSTP, NRC, DOE, and OMB to develop a plan for the CEUSN under which the USGS would assume long-term operation of the network; partial funding was provided to the USGS in 2014. This request is for the remaining funds needed for the USGS to assume the long-term operations of the network according to the multiagency agreement.

Hazard and Risk Assessments

(2015 Actual, \$16.1 million; 2016 Enacted, \$16.1 million; 2017 Request, \$16.1 million)

The USGS contributes to earthquake risk-mitigation strategies by developing seismic hazard maps that describe the likelihood and potential effects of earthquakes nationwide, especially in the urban areas of

Natural Hazards

highest risk. Federal, State, tribal, and local government agencies, architects and engineers, insurance companies and other private businesses, land use planners, emergency response officials, and the general public rely on the USGS for earthquake hazard information to refine building codes, develop land-use strategies, safeguard lifelines and critical facilities, develop emergency response plans, and take other precautionary actions to reduce losses from future earthquakes.

The USGS National Seismic Hazard Maps are used to develop new, national building codes for the United States. These digital maps integrate a wide range of geological and geophysical information to estimate the maximum severity of ground shaking that each given location is expected to experience in the coming decades. The USGS works closely with earthquake researchers, engineers, and State and local government representatives across the Nation to ensure the maps represent the most current and accurate information available. USGS science underlies the International Building Code (IBC), the code that has been adopted throughout most of the United States as the standard for building design. The USGS updates National Seismic Hazard Maps on a six-year cycle aligned with the processes that lead to updates to the IBC. The California source model for the 2008 and 2014 updates were derived from Uniform California Earthquake Rupture Forecasts (UCERF), models developed in partnership with the Southern California Earthquake Center (SCEC) and the California Geological Survey.

Because the scale of the national seismic hazard maps precludes taking into account local variations in the size and duration of seismic shaking caused by small-scale geologic structures and soil conditions, the USGS also partners with State and local experts to produce more detailed urban seismic hazard maps for high- to moderate-risk areas. These products make it possible for local officials to make precise and informed zoning and building code decisions. Modeling of ground motion is also provided for engineering applications. In conjunction with release of these targeted products, the USGS conducts workshops to assure the proper transfer of knowledge and to help design effective mitigation strategies.

In 2015 in the area of Hazard and Risk Assessments, USGS experts worked with the building design community to adopt new seismic hazard estimates into engineering design maps and building codes. The 2014 update to the USGS National Seismic Hazard Maps provide improved estimates of the likelihood of ground shaking during the lifespan of buildings, bridges and other structures. The USGS collaborated with FEMA and the Building Seismic Safety Council to publish design maps for the conterminous United States, Guam, American Samoa, and the Northern Mariana Islands in the 2015 NEHRP Recommended Seismic Provisions for New Buildings and Other Structures. Engineering groups are now working to incorporate these maps into the 2016 construction engineering standards of the American Council on Seismic Engineering and the 2018 International Building Code. The USGS co-hosted with the Applied Technology Council a User-Needs Workshop that brought together USGS developers of the National Seismic Hazard Map and a diverse subset of the data user community to provide feedback on the latest (2014) model and associated products and tools. The USGS also released a highly requested Risk-Targeted Ground Motion Calculator that engineers can use to design buildings with appropriate levels of seismic strengthening.

Also in 2015, the USGS released a report titled, *“Earthquake Shaking Hazard Estimates and Exposure Changes in the Conterminous United States,”* which demonstrates that many more U.S. residents may be at risk from damaging earthquakes than previously estimated. The study, published in the journal

Spectra, looked at changes in both the characterization of the earthquake hazard and the total population since 1996. More than 143 million Americans living in the 48 contiguous States are exposed to potentially damaging ground shaking from earthquakes. When the people living in the earthquake-prone areas of Alaska, Hawaii and U.S. territories are added, this number rises to nearly half of all Americans. The new exposure estimate is nearly double the previous 2006 estimate of 75 million Americans in 39 States; that doubling is due to significant growth of populations in areas prone to earthquakes, and to improved scientific methods that allow for more accurate estimates of earthquake hazards and ground shaking.

In 2016, the USGS will produce and update a variety of products derived from the USGS National Seismic Hazard Maps, for use by engineers, city planners and other end-users. USGS scientists will also update seismic design maps currently used in the Department of Defense Unified Facilities Criteria, and by national and State transportation, highway, and railroad associations. In addition, the USGS will partner with FEMA-funded engineering groups in a two-year project to improve methods for development of future building codes, and will continue development of seismic hazard maps for Hawaii in collaboration with earthquake experts in that State.

Several areas of the Country are subject to increased seismic shaking hazard due to rising earthquake rates related to underground industrial activity (see following section for further background). In response to requests from State regulators and the petroleum industry, the USGS is developing a new type of seismic hazard map that forecasts the ground motion hazard in those areas, with the first such map due for public release in March 2016, and planned annual updates as described below.

In 2017, the USGS will institute procedures for creating, maintaining and annually updating earthquake hazard and risk assessment products for areas of the Nation that experience induced seismicity related to underground industrial activity; the updating process will include communication with key users to determine which specific map and numerical information is needed for their decision making. The USGS will also examine associated hazards to critical infrastructure such as petroleum storage facilities, nuclear power plants, and transportation lifelines, in partnership with appropriate Federal and State agencies.

Research into Earthquake Causes and Effects

(2015 Actual, \$11.3 million; 2016 Enacted, \$11.3 million; 2017 Request, \$12.0 million)

The USGS conducts a broad suite of research on the causes, characteristics, and effects of earthquakes. This research has direct application in increasing the accuracy and precision of the agency's earthquake hazards assessments, earthquake forecasts, earthquake monitoring products, and earthquake mitigation practices.

Induced Seismicity – The development of underground oil and gas (UOG) resources has the potential to induce earthquakes, primarily through wastewater disposal. Researchers have long known that human actions can cause seismic activity, from petroleum extraction to water reservoir impoundments and fluid injection into the subsurface. Although very small magnitude (“microseismic”) events are commonly produced by hydraulic fracturing operations, current understanding suggests that the potential risk of felt or damaging earthquakes is greatest from high-volume wastewater disposal.

Although the risk of inducing felt seismic events directly stemming from hydraulic fracturing operations is believed to be low, there is concern that potentially hazardous seismic events can be induced through disposal of wastewater through underground injection control disposal-wells. Extensive sets of empirical observations could demonstrate that operations to date are consistent with predictive models over a range of geologic conditions and operational parameters. There is a need for more data and analysis to relate UOG operations to induced seismic events, to connect these events to specific operational parameters and geologic conditions, and to develop mitigation plans for decision makers, State regulators, and industry experts attempting to minimize seismic risks. The USGS is working with industry on case studies that will illuminate the factors controlling the phenomenon.

In 2013-2015, the USGS has responded to significant increases in earthquake rates in Oklahoma, Kansas and Texas, accompanied by moderate-magnitude, lightly damaging earthquakes. The additional funding for induced seismicity research, appropriated by Congress in 2014 and 2015, is being used to develop methods to forecast which types of injections in which geologic setting would be likely to induce or trigger earthquakes, to perform comprehensive studies at carefully-selected field sites, and to establish procedures to adapt USGS National Seismic Hazard Maps to account for potential hazards from earthquakes induced in association with the production of oil and gas. Of note, USGS research showed that the majority of the seismicity in the Raton Basin since 2001, which straddles the Colorado and New Mexico border, has been induced by wastewater injection, including a damaging magnitude 5.3 (M5.3) earthquake. Satellite radar data (InSAR) was used to image the ground displacement caused by that largest earthquake, introducing a new method to estimate the depth and sense of slip of faults disturbed by deep fluid injection.

In 2016 and 2017, the USGS will continue to work with State and academic partners to monitor and investigate the cause of earthquakes related to underground industrial activity. Models will be developed to estimate earthquake probabilities after fluid injection ends, important in understanding how seismicity may change in response to regulatory actions or changes in industrial practice. USGS scientists will use high-resolution aftershock mapping to image fault structures involved in the damaging 2011 magnitude 5.6 Prague, OK, earthquake to determine whether fault structures differ in the sediment and basement and examine how that complex sequence of earthquakes evolved over time. Seismic data from the Prague sequence will also be used to improve ground-motion prediction equations for the central United States, a key ingredient in seismic hazard assessment.

Forecasting Hazards from Earthquake Sequences – Earthquakes occur in sequences, typically a large event followed by many aftershocks, some of them large and potentially damaging. A large earthquake may also trigger the occurrence of additional earthquakes on nearby faults at a later time. Furthermore, earthquakes related to volcanic, geothermal, or industrial activity may occur in swarms, prolonged series of earthquakes with up to several largest events. The USGS is engaged in research to quantify changes in earthquake likelihoods with time, in response to observations of the earthquake generation process from data such as earthquake catalogs and geodetic deformation.

In 2015, in the area of Forecasting Hazards from Earthquake Sequences, the USGS developed methods and procedures for issuing aftershock forecasts on-demand following large earthquakes anywhere in the United States or abroad. Following the April 2015 M7.8 Gorkha earthquake in Nepal, USGS scientists

responded to a request from the Department of State to issue aftershock advisories based on these new methods, which were communicated to U.S. Embassy staff and to the public through local media sources. In 2016, the USGS will begin the process of integrating the aftershock forecasting methodology within the software systems of the National Earthquake Information Center, and institute procedures for issuing aftershock warning advisories following large earthquakes striking anywhere within the United States. Improved methods will be developed and integrated into the operational system after appropriate testing.

In 2017, the USGS will develop a suite of new earthquake forecast products useful to society, ranging from one-time earthquake forecasts, to new hazard assessment maps, continuously updated online releases, and user-customized estimates for decision support and situational awareness. The USGS will also explore partnership with the Department of State to develop earthquake information and warning products and protocols useful for U.S. Embassies in at-risk countries.

Supporting External Research Partnerships – External collaboration advances targeted research and addresses specific needs of the USGS using the experience and knowledge of world experts. The EHP provides competitive, peer-reviewed, external research support through competitive grants and cooperative agreements that enlist the talents and expertise of the academic community, State government, and the private sector.

External program activities include: mapping seismic hazards in urban areas; developing credible earthquake planning scenarios including loss estimates; defining the prehistoric record of large earthquakes; investigating the origins of earthquakes; improving methods for predicting earthquake effects; and testing the prototype system for an earthquake early warning system (see previous discussion). The USGS also has a cooperative agreement with the Southern California Earthquake Center, a 40-institution research consortium funded by the USGS and the NSF. The following table lists the institutions and agencies that received grants and cooperative agreements in 2015. The USGS anticipates that a similar number and range of partners will receive assistance in 2016.

USGS 2015 Grants for Earthquake Research and Hazard Assessments	
AECOM	San Jose State University
Applied Technology Council	Seafloor Survey
Arizona State University	Sitka Sound Science Center
Association of Bay Area Governments	Stanford University
Boise State University	Temple University
Brown University	University of Texas El Paso
California Institute of Technology	University of Alaska Fairbanks
California State Polytechnic University Pomona	University of California Berkeley
Central Washington University	University of California Davis
Colorado School of Mines	University of California Riverside
Cornell University	University of California San Diego
Desert Research Institute	University of Cincinnati
Elizabeth Hearn	University of Colorado Boulder
Fugro Consultants, Inc.	University of Kentucky
Georgia Institute of Technology	University of Massachusetts Amherst
Indiana University	University of Memphis

Natural Hazards

USGS 2015 Grants for Earthquake Research and Hazard Assessments	
InfraTerra, Inc.	University of Miami
Lehigh University	University of Michigan
Lettis Consultants Int'l, Inc.	University of Missouri Kansas City
Miami University	University of Nevada Reno
Missouri Department of Natural Resources	University of Rochester
New Mexico State University	University of Southern California
New Mexico Institute of Mining and Technology	University of Texas Austin
North Carolina State University	University of Utah
NorthWest Research Associates	URS Group, Inc.
Optim Seismic Data Solutions	Utah Geological Survey
Princeton University	Utah State University
Purdue University	Virginia Polytechnic Institute and State University
San Diego State University	

2017 Program Change
<p>Unconventional Oil and Gas Research – Induced Seismicity Earthquake Risk Assessments (+\$700,000 for a total of \$3,200,000): The proposed increase would fund a project aimed at reducing the risk posed by induced seismicity through the improvement of short-term earthquake hazard forecasts. Currently, areas of induced seismicity have been removed from USGS assessments of national earthquake hazards because they are assumed short-term perturbations of the hazard. A USGS advisory committee has recommended that the USGS issue annual forecasts of earthquake probabilities for these areas in a separate product, which will serve the needs of decision makers (including government regulators, petroleum companies, and communities) seeking to manage earthquake risk, (e.g., incorporating changes into building codes based on hazard forecasts). This product would also further USGS efforts toward short-term earthquake probability forecasts, which would be useful for all earthquake sequences.</p>

Communications and Outreach

(2015 Actual, \$2.4 million; 2016 Enacted, \$2.4 million; 2017 Request, \$2.4 million)

The Earthquake Hazards Program produces a large and growing quantity of data and information on earthquakes and related hazards. For this science information to be effectively used to mitigate risk and limit losses, the USGS takes a proactive role with various user communities in the application and interpretation of program results. Active engagement with users provides opportunities for dialogue on modifications to existing products and advice on new products that make USGS work and results more relevant and applicable. Opportunities for engaging users take place at both national and regional levels.

The Program strives to create and refine a variety of earthquake information products that accurately and effectively communicate earthquake science to key audiences, including decision makers. The EHP supports the USGS SAFRR project to improve sharing of earthquake safety information with the general public, conducting research with social scientists with expertise in risk communication.

In 2015, in the area of Communications and Outreach, the USGS partnered with FEMA to provide earthquake scenarios and seismic hazard and risk information to several cities in the Dallas-Fort Worth metropolitan area, a previously quiet area which has experienced five notable swarms of earthquakes since 2008. Dallas and other cities are incorporating this information into emergency response procedures and improved public messaging about earthquake safety. The USGS also joined several other agencies and groups promoting participation in the annual “Great Shakeout” earthquake response drill that is held each October in nearly every U.S. State. In 2015, a scenario for an earthquake in southern California served as the basis for the Federal Capstone disaster response exercise and annual *Golden Guardian* statewide response exercise.

In 2016, the USGS will release a major earthquake scenario to identify and address the impacts of cascading hazards resulting from large earthquakes. The scenario involves a magnitude-7 (M7) earthquake rupturing the Hayward Fault in the San Francisco Bay Area of California—the EHP estimates there to be a 1-in-3 chance that that fault will produce a major earthquake within the coming three decades. Shaking from the theoretical earthquake is felt throughout the Bay Area, inducing liquefaction and landslides that cause further damage to buildings and lifeline infrastructure. The scenario’s name, *HayWired*, speaks to the potential chaos caused by impacts to an urban environment in which communities, culture and economy are all entwined with the Internet. City, State and Federal agencies will use the scenario to understand the ripple effects of damages and disruption resulting from such an event, and to prioritize mitigation actions to increase resilience. As noted above, partnerships are key, and the *HayWired* scenario in partnership with FEMA, the California Governor’s Office of Emergency Services, the Association of Bay Area Governments, Joint Ventures Silicon Valley, and the California Seismic Safety Commission.

In June 2016, the USGS will participate in the Cascadia Rising Catastrophic Earthquake and Tsunami Functional Exercise, based on a scenario M9.0 earthquake rupturing off the coasts of northern California, Oregon, Washington, and southern British Columbia with accompanying tsunami. Agencies from the States of Washington, Oregon, and Idaho and the Canadian Province of British Columbia, as well as active-duty military, FEMA and local emergency management offices will be involved. The exercise focuses on issues of coordination and integration between all levels of government as well as private sector coordination in an area of some eight million people, and large companies such as Boeing, Microsoft, Starbucks, Amazon, and Nike.

In 2017, the EHP will continue its earthquake risk communications, with a focus on preparing users and the public for effectively using earthquake early warnings. The EHP will also work with the Utah State earthquake program to prepare for an earthquake response exercise in the Salt Lake City area, and will further efforts to communicate the hazards and risks posed by induced earthquakes.

Science Collaboration

Through NEHRP, the USGS partners with the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST) to reduce earthquake losses in the United States. For example, the USGS partners with FEMA in the development and updating of building codes, based on USGS earthquake hazard science. The USGS

Natural Hazards

ShakeMap product, which provides rapid situational awareness of earthquake ground motions, is imported directly into FEMA's HAZUS software for detailed estimation of earthquake impacts. The USGS also participates in FEMA-led national-level earthquake disaster response exercises, in which the USGS contributes directly to two of the Emergency Support Functions within the National Response Framework. Data from USGS-managed seismometers flow directly into the two Tsunami Warning Centers maintained by NOAA. The warning centers use those data to quickly estimate the magnitude, location and depth of large earthquakes and to send rapid warnings of potential tsunami arrivals.

The EHP and NSF's Geoscience Directorate jointly fund national and global seismic and geodetic monitoring, as described above. The USGS and NSF also jointly support the Southern California Earthquake Center, a highly leveraged research consortium, which is making significant advances in the fields of seismic hazards assessment, seismic-resistant engineering, public risk communication, paleoseismology, and modeling of earthquake ground motions via high-performance computing.

Monitoring data from seismic networks supported by EHP's ANSS, as well as EHP supported geodetic networks, are publically available and used by many NSF-supported basic research projects. In a complementary way, NSF supports the ANSS by providing data archiving and distribution through the IRIS Data Management System (see www.iris.edu).

Activity: Natural Hazards

Subactivity: Volcano Hazards Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
<i>FTE</i>	607	611		20	631	20
Volcano Hazards Program	\$25,121	\$26,121	\$117	\$0	\$26,238	\$117
<i>FTE</i>	134	136		0	136	0
Targeted Volcanic Research	\$6,270	\$6,270		\$0	\$6,270	\$0
Hazard and Risk Assessments	\$6,800	\$6,800		\$0	\$6,800	\$0
Monitoring and Reporting	\$11,440	\$12,440		\$0	\$12,440	\$0
Communications and Outreach	\$611	\$611		\$0	\$611	\$0

Justification of Program Change

The 2017 Budget Request for the Volcano Hazards Program (VHP) is \$26,238,000 and 136 FTE, a net change of +\$117,000 and 0 FTE from the 2016 Enacted level.

Overview

Volcanic eruptions are among the most destructive phenomena of nature, and even small events can have a significant social and economic impact. Unlike many other natural disasters, however, volcanic eruptions can be predicted well in advance of their occurrence, providing the time needed to mitigate the worst of their effects. For example, in 2014, VHP scientists at the Alaska Volcano Observatory (AVO) successfully forecast an explosive eruption of the Pavlof Volcano in Alaska and gave FAA and NWS advanced notice of the ensuing airborne volcanic ash. From June 2014 to March 2015, VHP scientists at the Hawaiian



Natural Hazards

Volcano Observatory (HVO) carefully monitored the progress of a 13-mile lava flow emanating from a vent on Kilauea volcano. The flow destroyed property and threatened homes and businesses in the Puna district (population ca. 45,000) on the Big Island of Hawaii. The HVO has worked closely with local, State, and Federal emergency managers to provide these officials the information they need to manage the current crisis.

Despite these successes, the Nation's volcano monitoring infrastructure remains incomplete. Many volcanoes, including some of the most threatening, lack the instrumentation necessary for effective forecasting and have had only rudimentary geologic study. To address this monitoring gap, the VHP is implementing the National Volcano Early Warning System (NVEWS), a comprehensive effort to ensure that all of the Nation's volcanoes possess a level of monitoring commensurate with the threat they pose. In 2015, an authorization bill was introduced by Senator Murkowski for the establishment of a National Volcano and Early Warning and Monitoring System. NVEWS is a proactive and systematic approach to volcano monitoring designed to detect unrest at the earliest stages and built around the idea that effective mitigation of volcanic hazards requires coordinated study and action across a broad front.

The VHP works closely with other Federal agencies including NOAA, NSF, NASA, NGA, FAA, DOE and DOD. In most cases, the information transfer is two way; the VHP provides interpretive products about volcanic activity to these agencies, while also receiving from them an abundance of data useful for volcano monitoring. Interagency cooperation of this sort is critical to success of NVEWS, which emphasizes both external partnerships and the need for data from a wide variety of instrument types.

The VHP is built around a structure of volcano observatories that divide the Nation's volcanoes into distinct areas of responsibility:

- Hawaiian Volcano Observatory (HVO) – Hawaii
- Cascades Volcano Observatory (CVO) – Idaho, Oregon, and Washington
- Alaska Volcano Observatory (AVO) – Alaska and the Commonwealth of the Northern Mariana Islands
- California Volcano Observatory (CalVO) – California and Nevada
- Yellowstone Volcano Observatory (YVO) – Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming

Under the NVEWS model, the observatories retain considerable independence, recognizing the importance of local knowledge and close ties with local officials and emergency managers. NVEWS also places great value on the interoperability among the observatories, ensuring that they all use a common set of tools and standards. Ideally, the observatory structure balances the benefits of centralization against the realities of local differences. Each observatory is responsible for volcano monitoring, community preparedness including development and regular practice of volcano hazard emergency response plans, managing volcanic crises, and coordinating research in their areas of responsibility.

Program Performance

The VHP includes the following four program components, described in more detail below: Targeted Volcanic Research; Hazard and Risk Assessments; Monitoring and Reporting; Communications and Outreach.

Targeted Volcanic Research

2015 Actual, \$6.3 million; 2016 Enacted, \$6.3 million; 2017 Request, \$6.3 million)

The VHP conducts applied research to advance understanding of how volcanoes work, what causes them to erupt, and how to interpret signals that may be precursors to eruption. Better understanding of the physical processes that drive volcanic eruptions forms the scientific basis for improved eruption forecasts and warnings, quantitative hazard assessments, and situational awareness. This applied research includes a variety of key topics including: (1) characterizing erupted products from recent and pre-historical eruptions and their distribution on the landscape, (2) deducing the eruptive histories, recurrence intervals and hazards from past eruptions, (3) analyzing the gases and waters on volcanoes that provide clues of subsurface activity, (4) measuring and interpreting the earthquakes and ground movements at restive and resting volcanoes, (5) surveying the volcanoes from space to detect subtle change, (6) modeling the physical and chemical processes that occur prior to and during eruptions, (7) developing new mathematical tools to forecast eruptions based on growing databases and physical principles, and (8) tracking the changes effected by volcanic eruptions. All lines of applied research fundamentally support and inform the VHP of the nature of precursor signals we may observe on volcanoes as a result of magma ascent. The applied research by the VHP allows for accurate assessment of volcano threat levels, improved analysis and interpretation of observed data, and streamlined design of modern monitoring networks. Results from applied research are fully integrated in an iterative approach to VHP's long-term volcano monitoring efforts to maintain effective, cost efficient, and state-of-the-art volcano monitoring capability.

In 2015, in the area of applied research, VHP published a landmark paper titled, "Landslide mobility and hazards-Implication of the 2014 Oso disaster" in *Earth and Planetary Science Letters* that identified buildup of pore fluid pressure as contributing to the enhanced flow mobility and the capability to model such phenomena with new physics-based computational software called D-CLAW. The VHP also published a paper in *Journal of Volcanology and Geothermal Research* that describes "An automated SO₂ camera system for continuous, real-time monitoring of gas emissions from Kilauea Volcano's summit Overlook." In 2015, VHP published the results of a 12-year study of gas chemistry of the Yellowstone hydrothermal system, providing a background understanding of gas sources and chemistry that will serve as the means for future monitoring and surveillance of the Yellowstone Caldera. The VHP also published a paper in *Geophysical Research Letters* that documents "Renewed inflation of Long Valley Caldera, California (2011 to 2014)."

In 2016, the Yellowstone Volcano Observatory plans a research experiment to use state-of-the-art continuous monitoring to understand gas discharge at Norris Geyser Basin. Multiple complementary monitoring technologies will be co-located at a single location for up to five months with the goal to improve our ability to interpret signs of volcanic unrest at active volcanoes.

Natural Hazards

In 2016, the VHP will publish its 10-year Strategic Science Plan as a USGS Circular that delineates the focus areas as opportunities for improving capabilities and new growth directions that will enhance our capability to fulfill our mission obligations. This VHP Strategic Science Plan will identify topical areas where other Federal agencies such as National Aeronautics and Space Agency (NASA), National Oceanic and Atmospheric Administration (NOAA), Department of Defense (DOD), Air Force Weather Agency (AFWA), cooperative partners of observatories and international counterpart agencies could potentially collaborate with the VHP to advance volcano science.

The VHP anticipates publication of approximately 80 peer reviewed research publications in 2017. In 2017, the VHP also anticipates better access to synthetic aperture radar data for regular checks of volcano deformation achieved through effective partnerships with foreign space agencies that operate satellite-based synthetic aperture radar satellites.

Hazard and Risk Assessments

(2015 Actual, \$6.8 million; 2016 Enacted, \$6.8 million; 2017 Request, \$6.8 million)

The VHP generates, updates, publishes, and disseminates short- and long-term volcanic hazard assessments on specific volcanoes, and for wider volcanic regions. These products are aimed at providing land managers, decision makers, emergency responders, and the public with information on the likely volcanic hazards that can be expected, the probability of their recurrence, and the areas likely to be impacted by similar hazardous activity in the future so as to proactively mitigate adverse consequences from future activity and ultimately to protect lives and property. Volcano hazard assessments serve as critical inputs for informed public policy on land-use planning, emergency response plans, and other preparedness activities that promote community resilience. The VHP also conducts risk and vulnerability assessments by integrating volcanic hazard information with Geographic Information Systems data on population centers, critical infrastructure, and volcano proximity to commercial air routes in partnership with other Federal, State, and local emergency managers for development of effective, coordinated eruption response plans.

In 2015, the VHP published a paper in *Journal of Applied Volcanology* titled, “Variations in community exposure to lahar hazards from multiple volcanoes in Washington State.” This assessment will aid VHP in prioritizing NVEWS implementation.

In 2016, the VHP will begin the process of revising the national volcano threat-level assessment incorporating recent investigations and eruption responses at U.S. volcanoes since 2005. The initial assessment is now out of date as a result of more recent volcano unrest and research findings. This revision will allow new prioritization for instrument siting and installation and more efficient implementation of the NVEWS. The VHP anticipates the publication of a new NVEWS fact sheet that will incorporate updates to volcano threat levels conducted in 2016. The VHP and the California Office of Emergency Services and California Geological Survey have teamed together to publish a statewide Volcanic Hazard Vulnerability Report in 2016 that assesses the exposure and vulnerability of critical infrastructure to volcanic hazards posed by the Very High- and High-Threat volcanoes in the State of California.

In 2016 and 2017, CVO will be revising the Mount Baker hazards assessment to incorporate data from the lidar survey that was just completed in the fall of 2015. Work will not begin in earnest until 2017; however, planning efforts are underway and include the Geological Society of Canada. In 2017, the VHP hopes to augment monitoring networks at Lassen Volcanic Center and at Mt. Shasta (permits pending).

Monitoring and Reporting

(2015 Actual, \$11.4 million; 2016 Enacted, \$12.4 million; 2017 Request, \$12.4 million)

The VHP operates ground-based volcano monitoring networks on 85 of the Nation’s Very High-Threat to Moderate-Threat Volcanoes. The suite of ground-based instruments for most of these volcanoes consists of seismometers within 20 kilometers of the volcano summit, continuous GPS instruments, tilt meters, Web cameras, microbarographs, and in a few cases, MultiGas sensors or UV camera systems for near real-time measurement of volcanic gas emissions. These inground instruments are augmented by airborne and satellite-based remote sensing instruments. Many of these monitoring instrument suites are deployed in remote locations and must be engineered to withstand extreme conditions as in Alaska. Monitoring networks in Alaska must be maintained every three to five years otherwise station and monitoring network failures will likely result.

The VHP also partners with the Water Mission Area to monitor groundwater geochemistry at Western United States and Alaskan volcanoes as part of its overall monitoring effort. At Yellowstone Volcanic Field, there is a real-time stream and hydrothermal pool temperature-monitoring network to detect rapid increases in groundwater temperatures in order to mitigate against hazardous hydrothermal explosions in a national park with large



attendance during the summer season. The VHP, in partnership with the Water Mission Area, also monitors the Mammoth Lakes area of Long Valley Caldera where there were three carbon dioxide asphyxiation fatalities in April of 2006.

Each year the VHP publishes approximately 80– 120 peer-reviewed publications reporting the findings of applied research and analysis and interpretation of monitoring data, and the results of field investigations of individual volcanoes or volcanic regions resulting in publication of a new geologic map and hazard assessment. Another significant component of VHP reporting is the peer-reviewed publications that

Natural Hazards

result from newly developed physical modeling capabilities that can simulate various types of volcanic eruption processes and hazards.

In 2015, in the area of monitoring and reporting, the AVO made significant improvements to the satellite imagery software package VolcView. These improvements included adding various map overlays suggested by the National Weather Service (NWS) making the software more useful to a broader group of government agencies. Also added was the ability to integrate satellite ash alerts from NOAA. The AVO also deployed two air quality monitors on Kodiak Island in 2015, to determine possible health effects from re-suspended ash from the Valley of Ten Thousand Smokes to residents of communities on Kodiak Island and the operation of aircraft in this portion of south-central Alaska. Katmai re-suspension events occur when strong north winds pick up volcanic ash from eruption deposits within Katmai National Park and blow the ash south to Kodiak Island. This re-suspended ash is similar in character to erupted ash and generates the same hazards as ash from current eruptions.

In 2016, the VHP is developing agreements with NWS to expand the available types of satellite data incorporated into VolcView so that volcanic ash clouds can be tracked in the lower 48 States and in key areas overseas. In 2016, the VHP also will also leverage the 24/7 operations of the National Earthquake Information Center to perform routine off-hours seismic checks of frequently active or erupting Alaskan and Hawaiian volcanoes. These checks will augment the daily volcano seismicity checks performed by the AVO and HVO.

In 2016, the VHP will partner with the Core Science Systems Mission Area and the National Geospatial Program to acquire a high-resolution lidar survey over Mt. Adams, a High-Threat Volcano in Washington State. This lidar survey will facilitate mapping of the volcano and also the design and installation of additional monitoring instrumentation that this volcano should have based on its threat level that would likely be installed in 2017, permits pending.

In 2017, permits pending, VHP intends to install three new seismic monitoring stations including a MultiGas sensor in the Wilderness Area on the summit of Mt. Hood, a Very High-Threat Volcano in Oregon in need of additional instrumentation. The VHP also hopes to install four new monitoring stations at Glacier Peak in Washington State, a Very High-Threat Volcano with virtually no monitoring instrumentation, permits pending.

NNEWS Progress

- The AVO installed two seismic stations, two infrasound stations, and a Web camera on Cleveland volcano in the Aleutians, and also conducted reconnaissance-level geologic mapping. The combination of the geologic investigation and the new instrument network helps close the monitoring gap at this persistently active volcano. The VHP worked in collaboration with the NSF Anthropology and Polar Programs project, leveraging resources to reduce costs and enhanced the safety of NSF-funded field investigators excavating a human antiquities site nearby.
- The VHP, in partnership with the other USGS programs and the U.S. Forest Service, completed a lidar survey of Glacier Peak, a Very High-Threat Volcano in Washington in the early summer 2015. Lidar data will greatly accelerate geologic mapping efforts and provide information useful

for enhancing the monitoring network. At present, Glacier Peak has essentially no ground-based instrumentation. This lidar survey is a first step toward closing the largest monitoring gap at this dangerous volcano.

- The VHP, in partnership with other USGS Programs and Missions, completed a high-resolution lidar survey of Mt. Baker, a Very High-Threat level volcano in the State of Washington in September 2015. As at Glacier Peak, the new lidar data will accelerate geologic mapping efforts, generation of a new volcanic hazard assessment and provide critical data for siting and installation of new monitoring instruments at this under monitored volcano.
- Two new seismometers were installed on Mount Hood, a Very High-Threat Volcano about 45 miles east of Portland, OR. Although these new instruments improve monitoring capabilities at Mount Hood markedly, the volcano still remains significantly under-monitored and three additional instruments are needed for the summit region.
- The VHP developed a plan for operating existing monitoring networks on High- and Very High-Threat Volcanoes in Alaska. The plan involves upgrading telemetry at the networks from analog to digital, and replacing analog seismometers with new, more sensitive, digital seismometers, thereby achieving increased performance, reliability, and lower annual maintenance costs. The upgrades will also bring the VHP into compliance with changing Federal Communications Commission regulations over radio frequency spectrum allocation.

Communications and Outreach

(2015 Actual, \$0.6 million; 2016 Enacted, \$0.6 million; 2017 Request, \$0.6 million)

The VHP provides situational awareness and warnings, and forecasts of hazardous volcanic activity to communities at risk. To achieve success in this critically important role, the VHP delivers its warnings and forecasts to the public via the Internet, social media, teleconferences, and other effective means such that all sections of potentially impacted populations are informed. The volcano observatories operated by the USGS each have Communications and Outreach specialists who are trained in effective communication and outreach with land managers, emergency responders, scientists from other Federal agencies and the public. The VHP proactively engages and seeks input from local land managers and emergency responders as to their needs for volcano hazard information, and to delineate our expected roles and responsibilities during volcanic crises and eruptions. The VHP also conducts exercises with land managers and emergency responders to refine and test volcano emergency response plans

The VHP provided timely hazard information in response to a lava flow crisis at Kīlauea Volcano. From June 2014 through March 2015, Kīlauea Volcano’s Pu‘u ‘Ō‘ō vent on the East Rift Zone produced a lava flow that extended 20 kilometers downslope. Within two months of onset, flow trajectory toward populated areas in the Puna District caused much concern for the possibility of lava inundation. The USGS HVO issued a news release of increased hazard and began participating in public meetings organized by Hawai`i County Mayor and Hawaii County Civil Defense. The HVO upgraded the volcano alert level to “WARNING” based on an increased potential for lava to reach homes and infrastructure. The Governor and the President declared official disasters prompting FEMA to engage on the ground in a support role. Ultimately, lava stalled just shy of a major commercial center and roadway. USGS/HVO scientists tracked and reported the advance of lava from the air and the ground, providing key updates of

changing hazard conditions to Hawai‘i County Civil Defense, State Emergency Managers, the media, and others. The HVO employed numerous methods to communicate science and hazard information including daily written updates of the lava activity, flow front locations and advance rates and frequent updates of Web-hosted maps and images

In 2016, the VHP will prepare a new USGS fact sheet about how to obtain and access all USGS information on volcanic activity products and will make this available on the VHP Web site.

The VHP is making greater use of social media in delivery of volcano situational awareness information and has a successful Facebook page, USGS Volcanoes, and YouTube channel. The VHP Technical Information Products Committee will prepare a briefing about possible future use of Twitter and blogs.

In the summer of 2015, Volcano Science Center scientists led a multi-day workshop for Native American youth near Mount Shasta as part of a collaborative effort between the USGS, USFS, the College of the Siskiyous, the Quartz Valley Indian Reservation, and the Karuk Tribe and a similar event is planned again for 2016. Also in 2015, USGS staff were joined by partners in the Mount St. Helens Institute, U.S. Forest Service, NSF, and NASA to conduct the first GeoGirls field camp program. Mount Rainier and Mount St. Helens were the backdrops for two annual, multi-disciplinary workshops designed to promote teaching about volcanoes in U.S. classrooms.

Public Communication and Community Preparedness

The VHP uses an array of Internet-based technologies as the primary tools to inform the public of volcanic activity and to educate about volcano science. The highly-successful Volcano Notification Service (VNS), a free e-mail and text messaging service that sends customized notifications about the status of volcanic activity and other significant events at volcanoes in the United States, has grown to include 10,000 subscribers since its inception in September 2012. To subscribe to this service go to the URL: <https://volcanoes.usgs.gov/vns/index.php> and click the *Subscribe to VNS* link. The VHP also publishes volcano activity information and timely volcano science via several social media channels in order to meet the ever-growing public demand to receive information in their own “news feeds.” Implementation of Common Alerting Protocol (CAP), which will automatically disseminate local and standardized volcanic activity alerts via communication systems (e.g., cellular networks), is in the future plan as well as expansion of the VHP’s social media offerings.

International Efforts

The Volcano Disaster Assistance Program (VDAP), a joint project with USAID Office of Foreign Disaster Assistance (OFDA), continues to build monitoring infrastructure and crisis response capacity and bring important hazard mitigation lessons home for use in the United States, such as utilizing international eruption experience to improve forecasting of eruptions. VDAP activities include crisis responses to activity and eruptions in Indonesia, Guatemala, Colombia and Nicaragua. The VDAP continues to assist the Indonesian government’s Center for Volcanology and Geologic Hazard Mitigation (CVGHM) in responding to the ongoing eruption of Sinabung volcano in northern Sumatra, where thousands of people have been repeatedly evacuated. Similarly, during 2014, VDAP helped the *Instituto Nacional de Sismologia, Vulcanologia, Meteorologia y Hidrologia* (INSIVUMEH) forecast eruptions and

issue warnings at Fuego volcano during its largest eruption in 20 years. The VDAP is also currently assisting the *Servicio Geologico Colombino* deal with a prolonged seismic crisis at Chiles volcano, located along the Colombia-Ecuador border. In December 2015, VDAP deployed a field team to assist the volcano scientists of Nicaragua's Instituto Nicaraguense de Estudios Territoriales scientists with an ongoing volcano crisis and eruption at Momotombo volcano. All VDAP international responses follow requests from foreign governments, which are evaluated by the Department of State and OFDA in terms of humanitarian benefit and U.S. foreign policy.

Science Collaboration

Collaboration with National Science Foundation (NSF) – The USGS is a major participant in the NSF's GeoPRISMS Program, which will study the geology and geophysics of continental margins, focusing on the Cascadia and the Alaskan-Aleutian subduction zones. VHP scientists worked closely with their academic partners to secure GeoPRISMS funding for a “slab-to-surface” geophysical and geochemical imaging effort at Mount St. Helens. The VHP leveraged scientific expertise and logistics experience with three NSF-funded GeoPRISMS research cruises to the Alaskan subduction margin in the summer 2015 field season. Partnership with NSF-funded Principal Investigators in 2015 allowed the VHP scientists and technical engineers' berth on Alaska research cruises to perform much needed network repair and restoration in the Central and Western Aleutians. Network repairs were conducted at Aniakchak, Gareloi, Tanaga, Westdahl, and Shishaldin in 2015. The repairs reduced the backlog of maintenance and restored the monitoring status of each of the volcanoes. As a result, AVO can once again reliably track volcanic unrest at these volcanoes and issue warnings of hazardous eruptive activity.

The USGS participated in a NSF-funded workshop in September 2014 that sought to address the end of the Earthscope initiative in 2018. The VHP and other parts of the USGS depend on hundreds of instruments deployed as part of Earthscope and their disappearance would represent a major step backward for monitoring capabilities at many U.S. volcanoes. Discussions with NSF and other stakeholders in Earthscope instrumentation continued in 2015, and will likely continue in 2016, with the goal of keeping these instruments functional past their 2018 sunset date.

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Activity: Natural Hazards**Subactivity: Landslide Hazards Program**

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
<i>FTE</i>	<i>607</i>	<i>611</i>		<i>20</i>	<i>631</i>	<i>20</i>
Landslide Hazards Program	\$3,485	\$3,538	\$16	\$500	\$4,054	\$516
<i>FTE</i>	<i>22</i>	<i>22</i>		<i>2</i>	<i>24</i>	<i>2</i>
Research on Landslide Processes	\$2,000	\$2,000		\$0	\$2,000	\$0
Hazard Assessment	\$1,100	\$1,100		\$500	\$1,600	\$500
<i>Natural Hazard Science for Disaster Response: Landslide Response</i>	<i>[\$1,100]</i>	<i>[\$1,100]</i>		<i>[\$500]</i>	<i>[\$1,600]</i>	<i>[\$500]</i>
Communication and Outreach	\$385	\$385		\$0	\$385	\$0

Justification of Program Change

The 2017 Budget Request for Landslide Hazards Program is \$4,054,000 and 24 FTE, a net change of +\$516,000 and +2 FTE from the 2016 Enacted level.

Overview

Landslides occur in all 50 States and around the world in mountainous and hilly areas. Where landslides impact human activities, lives may be lost and property and infrastructure damaged. A recent, tragic example is the March 2014 landslide near Oso, WA, which killed 43, destroyed 40 homes, and buried a mile of State highway 530. Landslides triggered by heavy rainfall can also impact broad regions. For example, landslides that occurred over an area of 1,300 square miles in the northern Colorado Front Range as a result of heavy rainfall, in early September 2013, resulted in three fatalities and damaged property and infrastructure throughout the region. The Landslide Hazards Program (LHP) is the only Federal program dedicated to landslide science and conducts targeted research to understand landslide initiation and mobility processes. This understanding is used to develop methods and models for landslide hazard assessment, develop and deploy systems to monitor threatening landslides, and to develop methods and tools for landslide early warning and situational awareness. Program activities are targeted toward the types of landslides that result in human and economic losses in the United States such as those with long travel distances, those initiated by heavy rainfall, and those exacerbated by the effects of wildfire.

USGS scientists respond to landslide emergencies and disasters nationwide. Federal, State, and local agencies are assisted through landslide site evaluations and are provided strategies for reducing ongoing

Natural Hazards

and future impacts from landslides. USGS expertise is called upon when landslide disasters occur abroad. The USGS works with the USAID Office of Foreign Disaster Assistance (OFDA) to respond to appeals for technical assistance from affected countries.

The USGS deploys near-real-time monitoring systems at active landslide sites to gather continuous movement, rainfall, soil-moisture, and pore-pressure data needed to understand the mechanisms of landslide occurrence and mobility. Such understanding can form the scientific underpinnings for early warning of conditions that may trigger landslides. For example, the LHP works in conjunction with the National Weather Service (NWS) to issue advisories regarding the potential for debris-flows (potentially deadly and destructive, fast-moving landslides) in areas of southern California recently burned by wildfire. Data needed to extend these methods to other parts of the United States are being collected.



Residents of Kerauja, Nepal below a large rock slide that killed one person. Landslides triggered by the April 25, 2015 magnitude 7.8 earthquake caused hundreds of deaths and impacted transportation networks hampering relief efforts. The USGS, in cooperation with other governmental and aid agencies, provided critical technical expertise to Nepalese agencies and villages.

Consistent with the Interior goal to protect lives, resources, and property by providing information to assist communities in managing risks from natural hazards, the LHP provides timely information to the public about current emergency responses and provides information to the external user-community through the program website, social media, fact sheets, reports, and press releases.

In 2017, the Landslide Hazards Program is requesting an increase of \$500,000 for improving landslide response by expanding post-wildfire debris flow hazard assessments and growing capability to respond to landslide crises.

Program Performance

The LHP includes the following three program components, described in more detail below: Research on Landslide Processes, Hazard Assessments, and Communications and Outreach.

Research on Landslide Processes

(2015 Actual, \$2.0 million; 2016 Enacted, \$2.0 million; 2017 Request, \$2.0 million)

The LHP conducts research targeted to improve understanding of landslide processes that informs the development and enhancement of tools for hazard assessment and early warning. Activities include surface and subsurface investigation of past and ongoing landslide activity, operation of natural laboratories to monitor landslide processes, and development of tools and methods for landslide hazard assessment. Sustained efforts in landslide monitoring have led to significant advances in understanding slope stability and landslide processes. Capability built by these efforts in cooperation with the USGS Volcano Hazards Program (VHP) provided the expertise and experience needed to deploy and operate the near-real-time hazard assessment system used to support the search, rescue, and recovery operation at the SR530 landslide near Oso, WA.

In 2015, the LHP released a report describing geotechnical characterization of the geologic materials of the SR530 landslide. This report was prepared in cooperation with the University of California at Berkeley and Washington State Department of Transportation. The LHP also published studies applying objective methods to define rainfall thresholds for post-fire flash floods and debris flows in Colorado and demonstrating methods for estimating debris-flow growth using ground vibrations in 2015. The LHP also established a network to monitor soil moisture conditions and landslide potential in cooperation with Sound Transit, along the rail corridor between Seattle and Everett, WA.

In 2016, the LHP will continue to collect data to develop rainfall thresholds for areas burned by wildfire in the intermountain States that will enhance the predictive capabilities of the joint NOAA-NWS/USGS debris-flow early warning system. The LHP will also continue to monitor hydrologic conditions and landslide response to precipitation that will provide the necessary understanding to develop improved hazard assessments, models, and early-warning criteria for landslide-prone areas in western Oregon, the Ferguson landslide near Yosemite National Park, along U.S. Highway 50 in California, in recently burned areas of southern California, and at Chalk Cliffs in Colorado. The LHP will also deliver a report as part of an international consortium on expected impacts of climate change on landslide hazards in the United States.

In 2016, the LHP will publish studies on geologic factors leading to landslides in western Colorado and Washington State, application of inSAR surveys to understand landslide movement, thermal variation as a driver for rockfall activity, and processes that generate post-wildfire debris flows. In addition, in 2016, the LHP will conduct experiments to examine the potential of using ground vibrations to estimate debris-flow magnitude, velocity, and trajectory.

In 2017, the LHP will continue to collect data to develop rainfall thresholds for areas burned by wildfire to enhance predictive capabilities of the joint NOAA-NWS/USGS debris-flow early warning system and will continue to monitor hydrologic conditions and landslide response to precipitation at natural laboratories in landslide prone regions of the United States.

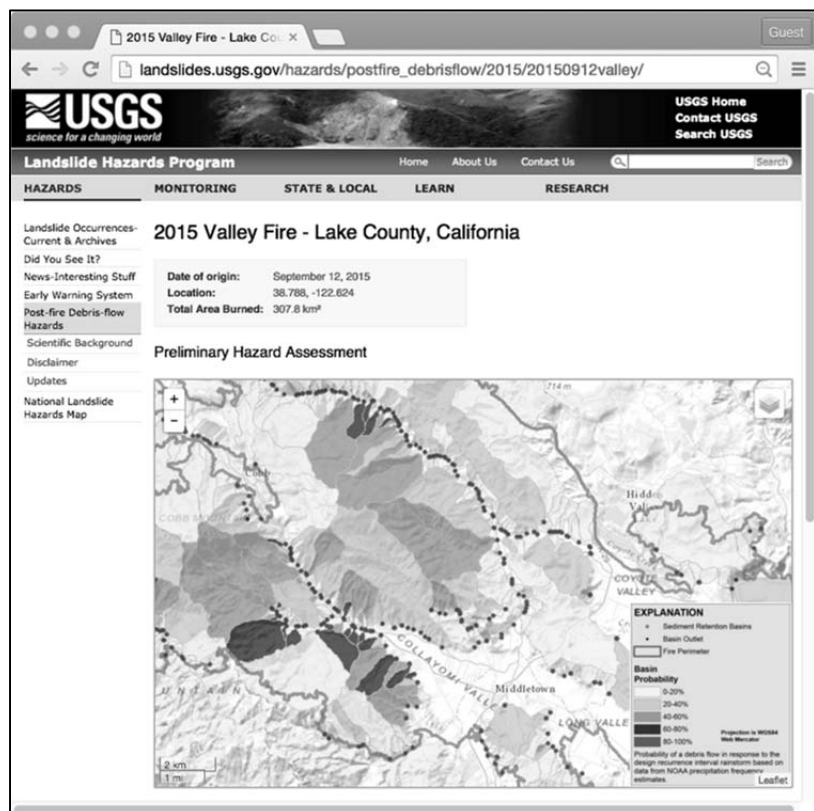
In 2017, LHP will also collect data to inform improved models of post-fire debris-flow generation and conduct studies to determine appropriate methods and data for modeling hydrological response and landslide potential from heavy rainfall.

Hazard Assessment

(2015 Actual, \$1.1 million; 2016 Enacted, \$1.1 million; 2017 Request, \$1.6 million)

The knowledge and improved understanding gained through applied research is used to develop and improve tools and methods for landslide hazard assessment and early warning. The LHP provides susceptibility maps, hazard assessments, and situational awareness to a broad range of Federal and State agencies ranging from the U.S. Forest Service (USFS) to emergency managers of local communities. These jurisdictions use USGS products to mitigate the effects of landslides and debris flows through land use planning, response planning, and warning systems. The LHP produces debris-flow hazard assessments operationally for major wildfires in the Western United States. For other landslide types and in other settings, landslide hazard assessments are typically produced as demonstration projects or in response to a request from Federal or State partners. For example, the LHP partnered with the National Park Service to produce a rockfall risk assessment for Yosemite National Park. The risk assessment, released in 2014, was used to relocate or repurpose park infrastructure to reduce the threat of rockfall impact to park visitors and staff.

Even average rainstorms can initiate debris flows from steep hillsides recently burned by wildfire. In 2014, the LHP moved delivery of post-wildfire hazard assessments to a Web-based system. The shift in delivery method was in response to requests from Burned Area Emergency Response (BAER) teams and emergency managers to deliver information in timely manner in a format that can be readily ingested into data systems they use. In 2015, hazard assessments were conducted for more than 28 major wildfires in the Western United States and results were made available to the public, the USFS, the NWS, and local county emergency response, public works, and flood



Web-based system for delivery of post-wildfire debris-flow hazard assessments. The LHP now delivers hazard assessments using a public-facing Web page. The webpage provides an interactive map viewer to display hazard assessment results along with links to download Geographic Information System (GIS) data for use by emergency managers and BAER teams.

control agencies within a few days after burn severity data became available. Previously, hazard assessments took about one month to complete. This change in delivery procedure represents a 90 percent reduction in the time to produce and deliver a hazard assessment.

In 2015, the LHP produced debris-flow hazard assessments for 28 wildfires in the Western United States. Wildfire can significantly change the response of burned watersheds to rainfall such that modest rainstorms can produce flash flooding and debris flows. The hazard assessments, delivered to Interior, USFS, and CALFIRE Burned Area Emergency Response (BAER) teams, local emergency management, and the general public are used to plan for post-wildfire impacts.

The LHP provided technical assistance and onsite hazard evaluation to Nepalese government and international aid institutions following the April 25, 2015, magnitude 7.8 earthquake. The earthquake and its aftershocks triggered thousands of landslides in the mountains of Nepal causing loss of life and hampering response and recovery efforts. With support of the USAID-OFDA, the USGS conducted aerial and remote-sensing evaluation of valley-blocking landslides with the potential to pose considerable hazard to villages downstream.

In 2015, the LHP sustained and expanded cooperation with the NWS to provide debris-flow early warning in areas burned by wildfire. The LHP also released a computer program—Scoops3D—which can be used to evaluate the stability of many (typically millions) of potential landslides in a digital landscape. The software runs on desktop computers and interfaces with geographic information system or other visualization programs. The LHP continued to apply tools for assessing landslide potential from heavy rainfall to the record-breaking 2013 rainstorm in the Colorado Front Range in 2015.

In 2016, the LHP will continue to provide landslide information to State geological surveys, counties, and other jurisdictions in Oregon, California, Colorado, Pennsylvania, New York, Tennessee, Washington State, and to Interior land management and other Federal agencies and continue to work with the NWS to expand debris-flow early warning beyond recently burned areas in southern California. The LHP will investigate the feasibility of combining quantitative weather forecasts with field-monitoring data and hydrological models to improve predictions of landslide potential in 2016, and will continue to test and verify combined methods for delineating landslide and debris-flow initiation, transport, and inundation. Results will provide a comprehensive approach to mapping landslide hazard.

Also in 2016, the LHP will implement improved models to estimate debris flow potential and magnitude from recently burned basins into operational post-wildfire debris-flow hazard assessments. The LHP will develop and implement a data management system to acquire, ingest, store, and visualize hydrological and displacement information collected at landslide natural laboratories and explore partnerships to expand and improve citizen science-data collection on landslide occurrence in 2016.

In 2017, the LHP will continue to provide landslide information to State geological surveys, counties, and other jurisdictions and to Interior land management and other Federal Agencies, and work with the NWS to expand debris-flow early warning to recently burned areas in Colorado, Arizona, and New Mexico and to selected unburned areas in California and Washington State. Also in 2017, in cooperation with State geological surveys in areas with high-resolution 3DEP topographic data, the LHP will begin

Natural Hazards

demonstration project to apply combined methods for delineating landslide and debris-flow initiation, transport, and inundation and will develop and test an integrated system to monitor landslide movement and processes that can be deployed in response to landslide crises.

2017 Program Change

Landslide Response (+\$500,000 for a total of \$1,600,000) As populations in landslide risk areas increase, the overall exposure to landslide impacts rises. The requested increase would build on investments in 2015 and 2016 to expand post-wildfire debris flow-hazard assessments and grow capability to respond to landslide crises. The USGS product for situational awareness for post-fire debris flows is comprised of two components: debris-flow hazard assessments and debris-flow warnings issued by the NWS, based on rainfall criteria developed by the USGS. Proposed additional funding would be used to monitor rainfall and post-fire debris-flow activity in as many as six wildfires in Arizona, Colorado, and New Mexico. These data would support two systematic studies of rainfall conditions for post-wildfire debris-flow initiation and would be used to develop early-warning criteria for these two States. Additional resources would be used to develop an integrated system to monitor landslide movement and processes combining in-situ and remote-sensing observations with topographic and geologic data. This system would be deployed in response to a landslide crisis in the first year of development. Results and lessons learned would be documented in a systematic study used to improve the system. Partners include the NWS, BAER teams, Federal, State and local emergency management, State geological surveys, and the private sector.

Communication and Outreach

(2015 Actual, \$0.4 million; 2016 Enacted, \$0.4 million; 2017 Request, \$0.4 million)

The LHP will continue to provide scientific information on landslide hazard mitigation and preparedness through the Program Web site and through cooperation with the USGS Office of Communication (OCAP) and the Science Information Service (SIS). In 2012, the LHP launched a new Web application site called “*Did You See It,*” which provides a mechanism for citizens to report landslides. The objective of this citizen-science initiative is to spur awareness of landslide hazards.

In 2015, the LHP continued operation of the National Landslide Information Center (NLIC) responding to inquiries from the general public, educators, and others.

In 2016, the LHP will merge operation of the NLIC and respond to inquiries on landslides and landslide hazards through cooperation with USGS OCAP and SIS. The LHP will also look to partner with other Federal science agencies to increase citizen-science application of “*Did You See It.*”

In 2017, the LHP will work to integrate risk-translation and risk-communication approaches and products into the Applied Research and Hazard Assessment program components.

Science Collaboration

The LHP collaborates with a broad range of international, Federal, State, public, private, and academic partners to understand and address landslide hazards. As the only U.S. Federal agency devoted to landslide science, the LHP often takes the lead in definition of scientific agenda and lines of inquiry.

National Weather Service – The LHP collaborates with the NWS to operationally deliver debris-flow early warning for recently burned areas in southern California. The LHP also coordinates with the NWS to provide debris-flow information during large storms in other parts of the Country. The LHP role in the collaboration is to develop criteria and other information that is used by the NWS to provide debris-flow information as part of other (typically flood) NWS products.

Interior and other public land management agencies – The LHP collaborates with public land management agencies to address landslide hazards on public lands. The LHP operationally produces post-wildfire debris-flow hazard assessments for major fires in the Western United States to support Interior, USFS, and CALFIRE BAER teams. The LHP role in these assessments is data collection, model development, and product delivery. Collaborators provide input and verification data. For specific landslide hazard issues where other agencies have relevant expertise, such as the Yosemite National Park rockfall risk assessment, the LHP cooperates closely with partners on data collection, analysis, and product preparation and publication.

State geological surveys – The LHP collaborates with State geological surveys to address landslide hazards in a number of States. Typically, the LHP provide tools, methods, instrumentation, and data for landslide hazard assessment or study. State geological surveys typically collect data, conduct analyses, and interface with other State agencies and emergency management to implement results. For example, the LHP is working with State surveys in Washington State and California to collect rainfall and geologic data to verify and improve post-fire debris-flow hazard assessments in recently burned areas in those States.

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Activity: Natural Hazards**Subactivity: Global Seismographic Network**

Dollars in Thousands	2015	2016	2017			
	Base	Enacted	Fixed Costs	Program Changes	Request	Change from 2016 Enacted
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
<i>FTE</i>	607	611		20	631	20
Global Seismographic Network	\$4,853	\$6,453	\$9	\$860	\$7,322	\$869
<i>FTE</i>	10	11		1	12	1
Global Monitoring	\$4,853	\$6,453		\$860	\$7,313	\$860
<i>GSN Primary Sensor Deployment</i>	[\$0]	[\$1,600]		[\$860]	[\$2,460]	[\$860]

Justification of Program Change

The 2017 Budget Request for Global Seismographic Network is \$7,322,000 and 12 FTE, a net change of +\$869,000 and +1 FTE from the 2016 Enacted level.

Overview

The Global Seismographic Network (GSN), consisting of more than 150 globally distributed stations, provides high-quality seismic data needed for earthquake alerts and situational awareness products, tsunami warnings, national security (through nuclear test ban treaty monitoring and research), hazard assessments and earthquake loss reduction, as well as research on earthquake sources, and the structure and dynamics of the Earth.

Because of its real-time data delivery, the GSN has become a critical element of USGS hazard alerting activities, as well as supporting activities of other Federal agencies (NOAA tsunami warning, NSF basic research, and DOE and DOD nuclear test treaty monitoring and research). GSN stations transmit real-time data continuously to the USGS National Earthquake Information Center in Golden, CO, where they are used to rapidly determine the locations, depths, magnitudes, and other parameters of earthquakes worldwide, in conjunction with data from other networks. GSN data allows for the rapid determination of the location and orientation of the fault that caused the earthquake, and provides an estimate of the length of the fault that ruptured during the earthquake, which are essential for modeling earthquake effects. An additional important aspect of GSN activities is evaluating, developing, and advancing new technologies for seismic instrumentation, sensor installation, and data acquisition and management.

In 2012, Congress provided \$5.7 million to the DOE's National Nuclear Security Agency for the replacement of aging GSN sensors. The DOE subsequently transferred most of those funds to the USGS for the development and purchase of new borehole seismic sensors. All of the funds were specified for

Natural Hazards

procurement of the new sensors and none for installation or site improvements. Besides needing installation, one-fourth of the GSN's seismic station sites also need vault repairs to improve data quality.

In 2017, the GSN is requesting an increase of \$860,000 to deploy and install the new borehole sensors and to improve the physical infrastructure of select GSN sites.

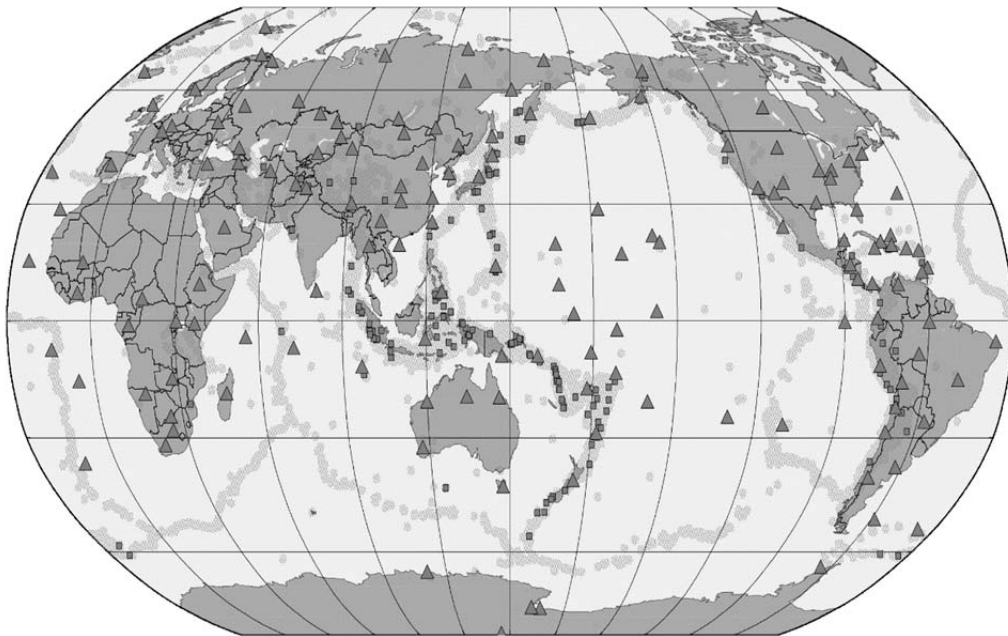
Program Performance

The 2017 President's Budget Request includes a proposal to increase funding needed to install replacement borehole sensors and make repairs to seismic instrument vaults.

Global Monitoring

(2015 Actual, \$4.9 million; 2016 Enacted, \$6.5 million; 2017 Request, \$7.3 million)

In 2015, the USGS continued to operate the 100-station, the USGS portion of the GSN at a high level of data recovery, real-time telemetry performance, and high cost efficiency. The USGS continued to lead a multi-agency effort to develop and procure new borehole sensors, as part of ongoing efforts to maintain and improve the GSN. The GSN data quality has been high in recent years, due to the upgrades of data loggers and the development of software to automatically assess GSN data quality and to identify and diagnose performance issues.



Global Seismic Network stations (triangles) are shown against a backdrop of large earthquakes from 2000–2010 (circles—magnitude 6–6.9, squares—magnitude 7 and larger earthquakes).

In 2016, the USGS will continue to operate the 100-station, the USGS portion of the GSN at a high level of data recovery, real-time telemetry performance, and high cost efficiency. Efforts to refresh, support, and maintain the network at a high level of quality and reliability in future years will be expanded. Increased funding appropriated by Congress in 2016 will allow the GSN to begin a five-year effort to deploy and install the borehole sensors and to improve the physical infrastructure of select GSN sites. Infrastructure improvements and enhancements will be undertaken in preparation for the arrival of the new borehole sensors. Work will be performed testing the prototype very broadband borehole sensor, funded by the Department of Energy, and preparing for a large production order of these units. Data logger upgrades will be completed at the few remaining difficult to reach stations. There will also be further development of the Data Quality Analyzer system to ensure that the outstanding data quality of the GSN is maintained.

In 2017, the USGS will continue expanded efforts to refresh, support, and maintain the network at a high level of quality and reliability in future years. The production order of new borehole seismic sensors will have arrived. The requested increase will allow the GSN to continue a five-year effort to deploy and install the borehole sensors and to improve the physical infrastructure of select GSN sites. Some borehole sites are compromised and need re-drilling and one-fourth of the GSN station sites need vault repairs in order to improve data quality. The needed improvements to the physical infrastructure at the sites are deferred maintenance tasks that have been prioritized by the advisory committee and are necessary to fully benefit from the new instrumentation. The resulting improvements will help ensure that the Global Seismographic Network (GSN) remains the core global system for earthquake and tsunami monitoring, nuclear treaty research and verification, Earth science and research and education.

2017 Program Change

GSN Primary Sensor Deployment (+860,000 for a total of \$2,460,000): The requested increase would allow the GSN to continue a five-year effort to deploy and install over 40 borehole sensors and to improve the physical infrastructure of select GSN sites. Some borehole sites are compromised and need re-drilling and about 20 of the GSN vaults need repairs in order to improve data quality. The needed improvements to the physical infrastructure at the sites are deferred maintenance tasks that have been prioritized by Global Seismographic Network Standing Committee and are necessary to fully benefit from the new instrumentation. The resulting improvements will help ensure that the GSN remains the core global system for earthquake and tsunami monitoring, nuclear treaty research and verification, Earth science and research and education.

Science Collaboration

The GSN is a joint program funded by the USGS and the -NSF, and is implemented by the USGS, the Institute for Geophysics and Planetary Physics (IGPP) of the University of California at San Diego, and the Incorporated Research Institutions for Seismology (IRIS, a consortium of universities). The network currently consists of more than 150 globally distributed seismic stations, installed over two decades by the USGS and the IGPP.

Natural Hazards

GSN operation is accomplished in cooperation with international partners who, in most cases, provide facilities to shelter the instruments and personnel to oversee the security and operation of each station. USGS responsibilities include station maintenance and upgrades, overseeing telecommunications, troubleshooting problems and providing major repairs, conducting routine service visits, training station operators, providing limited financial aid in support of station operations at sites lacking a host organization, and ensuring data quality and completeness.

Other agency programs will continue to be supported by the GSN. GSN data are available to the public and scientists around the world via the IRIS Data Management Center (DMC). GSN data are a critical element of the tsunami warning system operated by the NOAA National Weather Service, and are transmitted in real time to the NOAA Tsunami Warning Centers in Hawaii and Alaska. The NOAA National Tsunami Hazard Reduction Program is also served. GSN data are used by the U.S. Air Force and DOE nuclear test monitoring research programs. NSF projects use GSN data for basic research on Earth structure and dynamics, seismic wave propagation, earthquake source complexity, and climate.



A new GSN borehole sensor that is in development and testing in 2016.

Activity: Natural Hazards

Subactivity: Geomagnetism Program

Dollars in thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
<i>FTE</i>	<i>607</i>	<i>611</i>		<i>20</i>	<i>631</i>	<i>20</i>
Geomagnetism Program	\$1,888	\$1,888	\$10	\$1,700	\$3,598	\$1,710
<i>FTE</i>	<i>12</i>	<i>12</i>		<i>3</i>	<i>15</i>	<i>3</i>
Research on Geomagnetic Hazards	\$579	\$579		\$521	\$1,100	\$521
<i>Improved Geomagnetic Monitoring</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$521]</i>	<i>[\$521]</i>	<i>[\$521]</i>
Monitoring and Reporting	\$965	\$965		\$863	\$1,828	\$863
<i>Improved Geomagnetic Monitoring</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$863]</i>	<i>[\$863]</i>	<i>[\$863]</i>
Data Management and Product Development	\$344	\$344		\$316	\$660	\$316
<i>Improved Geomagnetic Monitoring</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$316]</i>	<i>[\$316]</i>	<i>[\$316]</i>

Justification of Program Change

The 2017 Budget Request for Geomagnetism Program is \$3,598,000 and 15 FTE, a net change of +\$1,710,000 and +3 FTE from the 2016 Enacted level.

Overview

Magnetic storms are caused by the dynamic interaction of the Earth's magnetic field with the Sun. While magnetic storms often produce beautiful auroral lights that can be seen at high latitude, they can also wreak havoc on the infrastructure and activities of our modern, technologically based society. Large storms can induce voltage surges in electric-power grids, causing blackouts, cause the loss of radio communication, reduce GPS accuracy, damage satellite electronics and affect satellite operations, enhance radiation levels for astronauts and high-altitude pilots, and interfere with directional drilling for oil and gas.



USGS Geomagnetic data are integrated into NOAA space weather alerts and warnings. A major goal of the interagency National Space Weather program is to protect the nation's power grid.

Natural Hazards

In order to understand and mitigate geomagnetic hazards, the USGS Geomagnetism Program monitors and analyzes the Earth's dynamic magnetic field. The Program is an integral part of the U.S. National Space Weather Program (NSWP), an interagency collaboration that includes programs in the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF). The Geomagnetism Program provides data to the NSWP agencies, oil drilling services companies, geophysical surveying companies, and several international agencies. USGS data, products, and services are also used by the electric-power industry to evaluate geomagnetic storm risk.

In October 2015, the Administration released a new *National Space Weather Strategy*, identifying high-level priorities and goals for the Nation to protect against space weather hazards. An accompanying *Space Weather Action Plan* (SWAP) outlines how Federal agencies, including the Department of the Interior, will implement the strategy. Interior, through the USGS, plays an important role in implementation, either leading, co-leading, or contributing to 22 actions in the SWAP.

The general categories of USGS involvement in the Space Weather Action Plan are:

- Establish Benchmarks for Space-Weather Events
- Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure
- Improve Space-Weather Services through Advancing Understanding and Forecasting
- Increase International Cooperation

At the requested funding level, the USGS expects to contribute strongly to all its SWAP actions.

In 2017, the Geomagnetism Program requests an increase of \$1,700,000 for improving geomagnetic monitoring and hazard assessment and research in support of the National Space Weather Strategy.

Program Performance

The USGS Geomagnetism Program is composed of the following three program components, each described in more detail below: Research on Geomagnetic Hazards; Monitoring and Reporting; Data Management and Product Development.

Research on Geomagnetic Hazards

(2015 Actual, \$0.6 million; 2016 Enacted, \$0.6 million; 2017 Request, \$1.1 million)

The USGS Geomagnetism Program conducts research to better understand basic physical processes and effects of geomagnetic hazards. In response to recent heightened concern for the security of the Nation's electrical power-grid infrastructure, USGS scientists are developing methods for estimating, in real time, the storm-time induction of electric fields in the Earth's crust and regional electric field estimates.

In 2015, in the area of applied research, the USGS:

- Published research results including analyses and studies on (1) geoelectric fields induced in the lithosphere during magnetic storms, (2) extreme-event geomagnetic disturbance, (3) solid-Earth conductivity of the Midwestern United States, (4) synthetic geoelectric induction across Midwestern United States, and (5) solid-Earth conductivity of Florida. The Program also published outreach articles about induction hazard science.
- Submitted expert-opinion reports to the Federal Energy Regulatory Commission, NASA, and the National Academy of Sciences.
- Continued testing and development of (1) Spherical Elementary Current System (SECS) methods for mapping geomagnetic hazards, and (2) development of ground magnetic disturbance calculator for geospace model validation.
- Began new research on (1) statistics of geomagnetic variation as a function of latitude (for OSTP's Space Weather Operations Response and Mitigation [SWORM] project), (2) numerical simulations of extreme-event geomagnetic disturbance (for SWORM), and (3) the electromagnetic impedance of Florida, at the request of the North American Electric Reliability Corporation (NERC).
- Furthered national and international coordination activities, including through: INTERMAGNET; the National Space Weather Program; Geomagnetic Inter-agency Working Group; NERC Geomagnetic Disturbance Task Force; and the American Meteorological Society (AMS) Scientific and Technological Activities Commission for Space Weather.

In 2016, the USGS is continuing its research efforts in support of the new National Space Weather Strategy, including:

- Completing the analysis of the statistics of geomagnetic variation as a function of latitude (for OSTP's SWORM project).
- Benchmark development and scenario testing: Work in collaboration with the other scientists to develop the technical benchmarks needed to assess geomagnetic hazards for the Nation's infrastructure, and with electric-power companies, oil and gas drilling industry and the U.S. Air Force to compile information on magnetic-storm effects, and assess geomagnetic hazard vulnerability and risks for technological systems and continuity of operations (for SWORM).
- Completing numerical simulations of extreme-event geomagnetic disturbance (for SWORM).
- Furthering national and international coordination activities, including through: INTERMAGNET; the SWORM; the NERC Geomagnetic Disturbance Task Force; and the American Meteorological Society (AMS) Scientific and Technological Activities Commission for Space Weather.
- Complete analysis of empirical impedance tensors for Florida.

Natural Hazards

In 2017, the USGS will begin a multi-year effort to map and model time-dependent geomagnetic hazards in support of the assessment of national space weather vulnerability and risk:

- Construct three-dimensional lithospheric conductivity models for areas of the continental United States covered by magneto-telluric surveys.
- Commence development of numerical tools for estimating electric field from magnetic activity and conductivity model inputs.
- Complete initial release of real-time geomagnetic mapping project for DOC.
- Perform scenario storm analysis of induction hazards at sites where MT surveys have been made.
- Develop a report on the feasibility of providing DOC with a real-time service for geo-electric field maps.
- Evaluate numerical simulations of extreme-event coronal mass ejections for theoretical extreme geomagnetic hazards.
- Construct new three-dimensional lithospheric conductivity models for areas of North America covered by new magneto-telluric surveys.
- Complete development of numerical tools for estimating electric field from magnetic activity and conductivity model inputs.
- Construct geoelectric hazard maps using conductivity models and both synthetic and measured geomagnetic activity.
- Develop real-time operational geoelectric hazard maps.
- Evaluate numerical simulations of full magnetic-storm evolution for theoretical extreme geomagnetic hazards.

2017 Program Change
In 2017, the increase for improving Geomagnetic Monitoring, which is presented under the Geomagnetism – Monitoring and Reporting section, would increase Geomagnetism – Applied Research by \$521,000.

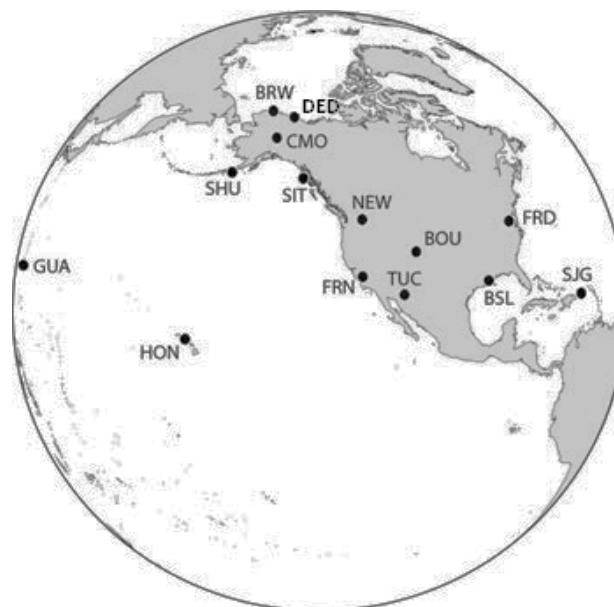
Monitoring and Reporting

(2015 Actual, \$1.0 million; 2016 Enacted, \$1.0 million; 2017 Request, \$1.8 million)

The USGS Geomagnetism Program operates 14 magnetic observatories across the United States and its territories. Data are collected continuously from each observatory by sensor systems that are operated in carefully controlled conditions to ensure long-term measurement accuracy. Data are transmitted in real time to the project's headquarters in Golden, CO, via a set of satellite and internet linkages. Ongoing operational system upgrades will benefit users through improved data quality, availability and timeliness.

In 2015, in the area of Monitoring and Reporting the Geomagnetism Program:

- Deployed four prototype “ObsRIO” data acquisition systems in parallel with current operations. With its low power requirements and high real-time operational reliability, this critical system is expected to replace current acquisition systems in 2017, and beyond.
- Completed a statewide magneto-telluric (MT) survey of the Florida peninsula to better assess hazards for electric power grids.
- E-field monitoring: Tested the application of magneto-telluric sensors to support validation of ground conductivity models used by the North American Electric Reliability Corporation (NERC) and the operators of the bulk power system.
- Completed construction of a new operations building at the Fresno Observatory, which has significantly improved the operational stability of the Fresno data acquisition system.



The locations of the USGS geomagnetic observatories, with three-letter abbreviations of the observatory names.

In 2016, the Geomagnetism Program will continue monitoring operations at much the same level as 2015. The USGS will collaborate with the EarthScope MT Project to install a long-term remote reference MT station at the Fredericksburg observatory, and will design and perform a systematic set of tests to establish how electric field measurements should be made at USGS observatories for long-term monitoring, and will establish permanent electric field monitoring equipment at the Boulder magnetic observatory.

In 2017, the Geomagnetism Program will improve magnetic and electric field monitoring by installing electric-field sensors at five observatories; secure locations for four new variometer sites in the continental United States; provide support for the existing Samoan observatory; initiate planning for a new Wake Island observatory, and eliminate its reliance for operations on transfers from U.S. Air Force.

The Program will also begin a national project for detailed geographic and depth-dependent mapping of U.S.-regional lithospheric electrical conductivity, based upon magneto-telluric (MT) methods that exploit known geological structures, the existing USGS magnetic observatory network, and the network expansion proposed above. The monitoring portion of this project will encompass identifying and filling gaps in MT surveys of the United States, and completing MT surveys of the Northeastern United States.

Natural Hazards

The Geomagnetism Program will lead development of a plan for expansion of the real-time ground-based magnetometer network to improve global geophysical monitoring. This work will include installing four variometer sites in the continental United States; proceeding with a new Wake Island observatory installation; and providing continued support for international observatories to grow and expand the global monitoring network. The national MT survey project will continue its expansion, by concentrating new MT surveys on geographic regions judged to have the highest induction hazards.

2017 Program Change

Improved Geomagnetic Monitoring (+\$1,700,000 for a total of \$1,700,000): Large magnetic storms (solar flares) represent a potential hazard for the activities and infrastructure of our modern, technologically based society, particularly due to impacts to the electrical grid. The long-term monitoring and real-time reporting of geomagnetic storms that is provided by USGS geomagnetic observatories has significant potential to advance space weather impact forecasting and research. The two most needed enhancements are in E-field monitoring; the direct measurement of currents in the Earth's crust; and the gathering and integration of existing global magnetic field data. Electrical currents are induced in the Earth's crust by geomagnetic storms, which can induce currents in the electric power grid that can cause transformers to overheat and fail. Routine collection of E-field measurements are important for modeling hazardous induced currents in the grid, and for assessing compliance by the electrical power industry with a recent ruling by the Federal Energy Regulatory Commission. There is tremendous potential represented in the global magnetic field data collected by other countries, but acquiring and managing these data and modernizing the data collection efforts of many countries has been largely volunteer effort. The interagency National Space Weather Program has given the USGS the mandate to acquire these data, and this proposal would provide the funding needed for this effort. The USGS proposes the following investments to provide enhanced monitoring of geomagnetic- and E-field activity at ground-level:

- Expanded monitoring: Improve magnetic and electrical field monitoring by installing new observatories and variometer stations in the continental United States, adding a Wake Island and South Pole observatory, providing support for the existing Samoan observatory, and monitoring the crustal electric field at every observatory.
- E-field monitoring: Begin a national project for detailed geographic and depth-dependent mapping of U.S.-regional lithospheric electrical conductivity, based upon magneto-telluric (MT) methods that exploit known geological structures, the existing USGS magnetic observatory network, and the network expansion proposed above.
- INTERMAGNET: Work in collaboration with academic and government institutes worldwide to integrate global observatory data with statistical and dynamical models of the magnetosphere and ionosphere to improve regional predictions of hazardous geomagnetic-field activity.
- Scenario testing: Work in collaboration with electric-power companies, the oil and gas drilling industry and the U.S. Air Force to compile information on magnetic-storm effects and make assessments of geomagnetic hazard vulnerability and risk to technological systems and continuity of operations.

2017 Program Change
<p>The result of this investment would be a national capability for mapping time-dependent geomagnetic hazards for assessing national space weather vulnerability and risk, with the potential for significantly improving forecasts of space weather and its impacts. This proposed increase of \$1,700,000 for the Geomagnetism Program would fund activities in Applied Research (+\$521,000), Monitoring and Reporting (+\$863,000), and Data Management and Product Development (+\$316,000).</p>

Data Management and Product Development

(2015 Actual, \$0.3 million; 2016 Enacted, \$0.3 million; 2017 Request, \$0.7 million)

Observatory data are transmitted to the headquarters of the USGS Geomagnetism Program in Golden, CO. From there, they are processed and organized for prompt transmission to the NOAA Space Weather Prediction Center (SWPC), the U.S. Air Force 557th Weather Wing (557th WW), and the NASA Goddard Space Flight Center; data are also transmitted to a number of foreign space weather agencies and to private companies in the United States. Auxiliary calibration measurements are combined with real-time data time series to produce accurate definitive data. These are used for constructing maps of the geomagnetic field and for analysis of long-term changes in geomagnetic activity. USGS data products are available through INTERMAGNET and through the Program's Web site (*geomag.usgs.gov*).

In 2015, in the area of Data Management and Product Development, the Geomagnetism Program:

- Completed upgrades to software components, providing improved methods of Web-based display and calibration and processing of magnetic data.
- Transitioned to a centralized database for all real-time and historical magnetic data, and development of a robust public-facing user-interface for accessing this data.
- Developed, tested, and deployed of an industrialized MXE computer to replace outdated acquisition computers at the observatories.

In 2016, the Geomagnetism Program is continuing data services at much the same level as 2015. The Program will: (1) continue to produce a real-time adjusted data product needed for real-time assessment of induction hazards, directional drilling for oil and gas, and absolute geomagnetic orientation; (2) make improvements to the real-time *Dst* product; (3) continue modernization of data import and export mechanisms to and from customers to streamline operations; (4) archive MT transfer function datasets; and (5) begin populating metadata for current and historical data.

In 2017, the Geomagnetism Program will work in collaboration with academic and government institutes worldwide to integrate global observatory data with statistical and dynamical models of the magnetosphere and ionosphere to improve regional predictions of hazardous geomagnetic-field activity), and will continue development of enhanced visualization and analysis tools for geomagnetic data activity; complete transition of legacy data products to modernized algorithms programming environment; develop and deploy improved real-time data processing algorithms; and continue archiving new MT datasets and populating metadata records for historical data products.

Natural Hazards

The project will add a Data Products Manager to acquire and manage international datasets, merge with existing data sets, manage data products, and expand Web presence for improved customer data access. The Program will also collaborate with INTERMAGNET partners to develop open source data-transmission libraries.

2017 Program Change
In 2017, the increase for improving Geomagnetic Monitoring, which is presented under the Geomagnetism – Monitoring and Reporting section, would increase Geomagnetism – Data Management and Product Development by \$316,000.

Science Collaboration

As noted above, the USGS is a member of the multiagency National Space Weather Program and, since 2014, has worked closely with numerous Federal agencies to develop the National Space Weather Strategy and accompanying Space Weather Action Plan (SWAP). Most actions in the SWAP are collaborative, and the Geomagnetism Program plays an important role in implementation, either leading, co-leading, or contributing to 22 actions therein. Implementation has begun in 2016, with the USGS playing a leading role in the development of space weather benchmarks, for example.

Domestically, the USGS works cooperatively with NOAA, the Air Force 557th Weather Wing, and other agencies. For example, USGS observatory data are used by NOAA's *Space Weather Prediction Center*, and by the U.S. Air Force, for issuing geomagnetic warnings and forecasts. Internationally, the USGS magnetic observatory network is itself part of the global INTERMAGNET network. USGS research is conducted in collaboration with the Colorado School of Mines, the USGS Crustal Geophysics and Geochemistry Science Center, the NOAA/SWPC, and the NASA Community Coordinated Modeling Center.

The USGS also works with private entities that are affected by space weather and geomagnetic activity, including electric-power grid companies and the oil and gas drilling industries. In the oil and gas industry, for example, drill operators need to know which way their drill bits are going to maximize oil production and avoid collisions with other wells. One way to accomplish this important task is to *install a magnetometer*—a sort of modern-day "compass"—in a drill-string instrument package that follows the drill bit. Simultaneous measurements of the magnetic field in the drill hole are combined with those monitored by the USGS to produce a highly accurate estimate of the drill bit position and direction.

Activity: Natural Hazards**Subactivity: Coastal and Marine Geology Program**

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Natural Hazards	\$135,186	\$139,013	\$519	\$10,169	\$149,701	\$10,688
<i>FTE</i>	<i>607</i>	<i>611</i>		<i>20</i>	<i>631</i>	<i>20</i>
Coastal and Marine Geology Program	\$40,336	\$40,510	\$174	\$5,609	\$46,293	\$5,783
<i>FTE</i>	<i>190</i>	<i>191</i>		<i>10</i>	<i>201</i>	<i>10</i>
Characterizing Marine Geologic Hazards and Resources	\$16,000	\$16,000		\$0	\$16,000	\$0
Forecasting Coastal Change Hazards	\$10,500	\$10,674		\$3,500	\$14,174	\$3,500
<i>Scenarios for Arctic Actions to Address Imminent Coastal Impacts</i>	<i>[\$1,425]</i>	<i>[\$1,425]</i>		<i>[\$3,500]</i>	<i>[\$4,925]</i>	<i>[\$3,500]</i>
Assessing Coastal and Marine Ecosystem Health and Sustainability	\$9,736	\$9,736		\$2,109	\$11,845	\$2,109
<i>Building Landscape-Level Resilience to Coastal Hazards</i>	<i>[\$4,126]</i>	<i>[\$4,126]</i>		<i>[\$2,109]</i>	<i>[\$6,235]</i>	<i>[\$2,109]</i>
Enhancing Delivery of Data, Tools, and Knowledge	\$4,100	\$4,100		\$0	\$4,100	\$0

Justification of Program Change

The 2017 Budget Request for the Coastal and Marine Geology Program is \$46,293,000 and 201 FTE, a net change of +\$5,783,000 and +10 FTE from the 2016 Enacted level.

Overview

The Coastal and Marine Geology Program (CMGP) applies capabilities in marine geology, geochemistry and oceanography to provide information and research products on conditions and processes critical to the management of the Nation's ocean, coastal and Great Lakes environments. Program activities include characterizing and understanding ocean and coastal geological settings and processes to provide the data and tools for regional and national assessments of coastal and marine conditions, change, and vulnerability. Integrated mapping and research activities support development of data resources, models and decision-support tools to address policy and management issues at national and regional scales.

In 2017, ongoing priority studies will address coastal resilience and climate adaptation through regional and national studies of coastal change hazards; submarine earthquake/tsunamis hazards associated with the Queen Charlotte-Fairweather Fault in the Gulf of Alaska; and delineation of the Extended Continental Shelf, as an expressed policy of the Administration, consistent with the United Nations Convention on the

Natural Hazards

Law of the Sea. Relevant projects additionally include studies of coral reef health to support Ecosystem-Based Management and Climate Adaptation; integrated research to inform regional restoration of coastal estuaries; cooperative geologic mapping to support State, tribal, and Federal objectives; and improved provision of data, models, and assessments to inform policy and management of coastal and ocean resources. Planning and implementation of this portfolio of activities is the result of cooperative partnerships with many Federal and State agencies and local stakeholders who expect timely project completion and delivery of products.

The CMGP conducts field and interpretive activities to support environmental mapping for management needs within Marine Sanctuaries, National Parks, Fish and Wildlife Refuges, Marine Monuments, and management of fisheries and other living marine resources in State and Federal Waters. In 2017 and beyond, benthic habitat and other seafloor mapping for State and Federal management agencies will only be supported where it enables scientific studies addressing CMGP research priorities and where substantial cost sharing from partnering agencies is available.

In 2017, the CM GP is requesting an increase of \$3,500,000 for Scenarios for Arctic Actions to Address Imminent Coastal Impacts and \$2,109,000 for Building Landscape-Level Resilience to Coastal Hazards.

Program Performance

The CMGP includes the following four program components, described in more detail below: Characterizing Marine Geologic Hazards and Resources, Forecasting Coastal Change Hazards, Assessing Coastal and Marine Ecosystem Health and Sustainability, and Enhancing Delivery of Data, Tools and Knowledge.

The 2017 President's Budget Request includes a proposal to work with communities, the Bureau of Indian Affairs, and the Office of Insular Affairs (OIA), to deliver assessments of coastal vulnerability to storms, erosion, and sea level rise for communities along the Alaskan Arctic and Bering Sea coasts, and throughout U.S. Island Territories and Freely Associated States.

Characterizing Marine Geologic Hazards & Resources

(2015 Actual, \$16.0 million; 2016 Enacted, \$16.0 million; 2017 Request, \$16.0 million)

Ocean hazard events like tsunamis, triggered by earthquakes and landslides, storm surges associated with hurricanes and extreme storms, oil and gas spills, floods and associated watershed contaminants, affect the health and safety of our Nation's ocean and coastal communities and ecosystems. USGS scientists study the causes, distribution and hazard potential of coastal and submarine hazard events including earthquakes and submarine landslides, as well as associated tsunami potential. Additionally, USGS studies focus on geologic mapping, sampling and understanding energy and mineral resources and studies of geologic settings and processes to inform renewable energy development offshore.

In 2015, the CMGP completed and delivered a comprehensive study of tsunamis hazards for the Caribbean region as requested by the Nuclear Regulatory Commission. The USGS completed its final oceangoing cruise to investigate and determine the thickness of sediments in priority regions identified by

the Department of State, as leader of the Extended Continental Shelf Executive Committee. The USGS completed its second survey for studying landslide hazards and identifying the extended continental shelf off the U.S. east coast.

Other 2015 accomplishments include collaborating with the Commonwealth of Massachusetts to map underwater topography and seafloor geology of State waters to support efforts to protect critical habitats while setting standards for sustainable development in the coastal ocean.

To better understand offshore earthquake and tsunami hazards, USGS scientists ran a seismic survey off southern California, which produced detailed images associated with three offshore faults, and large submarine landslides. Results of the survey will contribute to probabilistic hazards models for metropolitan Los Angeles and San Diego.

In 2016, the CMGP will continue collaboration with the California Ocean Protection Council, and the National Oceanic and Atmospheric Administration (NOAA) on a comprehensive California Seafloor and Coastal Mapping Program (CSCMP). The CMGP will also characterize the acoustic properties of sound sources used for routine USGS geophysical surveys (sidescan, chirp, and boomers). The measurements are part of a joint project funded by the Bureau of Ocean Energy Management (BOEM), in cooperation with the Naval Undersea Warfare Center (NUWC). The USGS will obtain accurate measurements of the acoustic properties of various transducers and acoustic sources used in geophysical surveys. These data will then be used to inform permitting guidelines for using these acoustic systems in the marine environment.

In 2017, the CMGP will further collaborate with the USGS Earthquake Hazards Reduction Program on development of a research plan to characterize the geologic setting of the Cascadia Fault System. This field planning effort will build upon understanding the Queen Charlotte-Fairweather Fault, which lies to the north in the Gulf of Alaska. USGS scientists will continue to evaluate potential submarine sources of tsunami damage to large coastal population centers from distant faults and submarine landslides, using data collected during Extended Continental Shelf research cruises. In 2017, the study of gas hydrates will evaluate methane hydrates as a potential energy source; investigate the interaction between methane hydrates and climate change at short and long time scales, particularly in the Arctic; and study the connections between submarine landslides and gas hydrate dynamics.

Forecasting Coastal Change Hazards

(2015 Actual, \$10.5 million; 2016 Enacted, \$10.7 million; 2017 Request, \$14.2 million)

Coastal change poses potential risk to coastal communities across the Nation. Powerful storms generate surge, waves and currents that can move large amounts of sediment, destroy roads, buildings and other critical infrastructure as well as alter natural habitats. The USGS performs a range of studies that document, assess and model coastal change, risk, and vulnerability including historical shoreline change and the geologic structure and history of coastal regions, sediment supply and transport, sea level rise, and how extreme storm events affect rates and impacts of coastal change.

Natural Hazards

In 2015, in the area of applied research, the CMGP did successfully forecast storm damage associated with Hurricane Joaquin. This incorporation of real-time storm wave model data from the National Weather Service into USGS coastal change models resulted in locally accurate forecasts of erosion, overtopping of beach dunes, and cutting of channels. For the first time, emergency managers and first responders could access the forecasts 48 hours before peak impact using hand-held, mobile devices.

In 2015, The USGS and the U.S. Army Corps of Engineers (USACE) collaborated to develop field equipment capable of measuring water levels and changes in beach characteristics during extreme storms. The USGS also compiled a three-dimensional map of how beaches change in northern Monterey Bay. This will be repeated seasonally and annually to provide a detailed picture of how the coastline reacts to changes in waves, currents, and sediment input. Results can be incorporated into future scenarios of sea level rise and climate change, helping Monterey Bay communities determine how and what to protect along their coastlines.



The projected upsurge of severe El Niño and La Niña events will cause an increase in storm events leading to extreme coastal flooding and erosion in populated regions across the Pacific Ocean, according to new research by USGS scientists and their collaborators at institutions in Australia, New Zealand, Canada, Italy, Japan, and the United States. *Nature Geoscience* published the findings on September 21, 2015.

In 2016, the CMGP is focused on expanding the functionality and tools of the Coastal Change Hazards Portal to include Nor'easters. The CMGP will expand the application of mobile apps such as iPlover and iCoast to better engage citizen scientists in identifying and locating fragile coastal environments and local scale changes caused by extreme storms. USGS scientists will build upon Hurricane Sandy supplemental activities to extend forecasts and assessments of coastal change hazards to address specific decision-requirements of Interior and State coastal land and resource managers in the mid-Atlantic Region. Studies to assess the effectiveness and sustainability of existing and alternative strategies for enhancement of natural system resilience, and the associated benefits in terms of reduced vulnerability of coastal infrastructure and communities will be conducted in conjunction with other Federal partners and regional efforts.

In 2017, The CMGP will engage underserved communities in the Arctic and Pacific regions to identify and adapt coastal change hazards forecast tools to meet their needs to understand and thereby plan for near and mid-term changes in sea level and storm impacts to islands and low-lying coastal areas. USGS researchers will focus on development of coastal change assessments and forecasts reflecting processes and conditions unique to vulnerable coastal regions of particular concern to Native communities and

Interior resource managers. Initial development in selected priority communities would establish the framework and requirements for broader development and provision of data, forecasts and decision support tools.

2017 Program Change
<p>Scenarios for Arctic Actions to Address Imminent Coastal Impacts (+\$3,500,000 for a total of \$4,925,000): The proposed increase would allow the USGS to work in the Arctic and selected Pacific Islands where underserved communities are dealing with impacts of sea level rise, severe storms and melting permafrost on their coastal communities and economies. The USGS will use unmanned autonomous vehicles (UAVs) to collect images of coastal areas to deploy structure from motion technology to monitor seasonal coastal land changes in remote areas. This work will build off of pilot studies using UAVs for Flaxman and Barter Islands, AK, and kites for Anahola Valley, HI. The USGS will utilize long-term coastal change models to forecast changing coastal conditions and vulnerability based upon different climate, sea level, and storm scenarios over the next 10–25 years. The resulting science-based scenarios will be shared with local communities to ensure consistency with their specific priorities, whether related to siting of infrastructure, use of natural resources, planning of communities, or other topics. Supported activities will leverage existing USGS tools and delivery mechanisms currently unavailable to these communities outside the open-ocean coastal regions of the coterminous United States.</p>

Assessing Coastal and Marine Ecosystem Health and Sustainability

(2015 Actual, \$9.7 million; 2016 Enacted, \$9.7 million; 2017 Request, \$11.8 million)

Science addresses understanding important ecosystem linkages between watersheds, estuaries, wetlands and offshore ocean regions. Human activities can impact or degrade the health and productivity of these resources by fragmenting habitats, altering drainage or circulation patterns, and introducing contaminants. The USGS brings together multidisciplinary expertise focused on developing tools and models to improve understanding of how healthy ecosystems function as well as how they respond to environmental changes and human impacts including regional ecosystem restoration. Research studies address coral reef, coastal wetland, benthic habitat, and groundwater resources.

In 2015, the CMGP published a major report demonstrating that the remote northern Alaska coast has some of the highest shoreline-erosion rates in the Nation with most of the coast retreating at an average rate of 1.4 meter/year. Extreme erosion in small areas exceeds 18.6 meter/year. The comprehensive assessment will help guide managed response to sea level rise and storm impacts.

The largest dam-removal project in U.S. history, on the Elwha River in Washington State, is the focus of Federal, tribal, and academic scientists collaborating to characterize its effects. In 2015, CMGP published detailed observations about changes in the river’s landforms, waters, and coastal zone during the first two years of dam removal, when massive amounts of sediment were eroded from the former reservoirs and transported downstream through the river and to the coast.

Natural Hazards

The Coastal and Land Use planning program of the New Jersey Department of Environmental Protection organized a 2015 Living Shorelines and Coastal Restoration Summit where CMGP scientists presented coastal change analysis resulting from Hurricane Sandy. The data were collected as part of a multi-year project that sought to characterize the physical estuarine environment of Barnegat Bay, NJ, and its influence on water quality. Discussions are ongoing about how best to tailor USGS products for New Jersey coastal managers.

In 2016, the CMGP will continue work in the San Francisco Bay Delta to add to understanding of impacts of ongoing drought to marsh and wetlands throughout the region. Studies will help forecast sediment movement when normal to strong rains occur. The CMGP will publish reports about the observed resilience of the Assateague-Chincoteague coastal marsh and beach systems as follow up to damage from Hurricane Sandy in 2012. Studies will continue in the Gulf of Mexico to identify and address estuarine changes associated with periods of flooding from the land and from the sea.

In 2017, the CMGP will enhance USGS capacity to work with communities, the Bureau of Indian Affairs, and the Office of Insular Affairs (OIA), to deliver assessments of coastal vulnerability to storms, erosion, and sea level rise for communities along the Alaskan Arctic and Bering Sea coasts, and throughout U.S. Island Territories and Freely Associated States. Resulting data and products will be delivered through the USGS Coastal Change Hazards Portal, which enables access through Federal ocean and climate data and toolkit services that facilitates broad access and application

Additionally, consultation with Tribes, State, and other entities in Alaska and the Arctic, and with Interior resource managers is required to guide systematic prioritization of product development for coastal regions where vulnerable landscapes, ecosystems, and communities face impacts of coastal change caused by sea level rise, changing ice-cover, storms, and shoreline retreat associated with permafrost decline, inundation, and land subsidence. In 2017, the USGS will focus on development of coastal change assessments and forecasts reflecting processes and conditions unique to vulnerable coastal regions of particular concern to Native communities and Interior resource managers.

2017 Program Change
Building Landscape-Level Resilience to Coastal Hazards (+\$2,109,000 for a total of \$6,235,000):

The proposed increase would be used to apply research and modeling findings in the Hurricane Sandy (2012) affected areas to other parts of the U.S. coastline. The funds will be directed in three specific areas:

- Applying research findings and forecast model improvements from the Hurricane Sandy supplemental work to New England, southeast Atlantic, Gulf of Mexico, and contiguous Pacific States. Researchers will extend the availability of high-resolution information that combines trends from historic change data with high-resolution elevation data, National Weather Service surge forecasts, USGS coastal response models, and interagency regionalized sea level rise projections. The new regionally scaled tools and forecasts of coastal vulnerability and change in response to erosion, coastal storms, and sea level rise will be available through the USGS Coastal Change Hazards Portal.
- Offering demonstrations and hands-on workshops to regional planners and emergency managers to increase their abilities to appropriately apply regional storm impact tools to both pre-storm planning to protect lives and livelihood and to longer-term planning to better address vulnerabilities and options for improving resilience to coastal storms.
- Leveraging regional funds and efforts, such as RESTORE in the Gulf of Mexico, to increase use of USGS tools and ensure easy data access and usability through Web-based delivery tools on marine.usgs.gov, data.gov and the climate resilience toolkit.

Enhancing Delivery of Data, Tools and Knowledge

(2015 Actual, \$4.1 million; 2016 Enacted, \$4.1 million; 2017 Request, \$4.1 million)

The CMGP shares a wide range of resources to help explain and illustrate scientific concepts, our scientific activities, expertise, technology, tools, and other educational resources. The CMGP provides coastal and marine resource managers with data, models, and tools for use in planning and managing human activities in the ocean and along the coast. The CMGP is an innovator in mapping and laboratory analyses, whose expertise is sought by other governmental agencies, educational institutions, and private companies. In turn, the USGS seeks collaborative research and development opportunities with similar groups to continually correct and perfect the data collection tools, analytical techniques, and technologies utilized in our coastal and marine studies.

In 2015, the CMGP invested in improving project Web pages to modernize information delivery and to update text, photographs and illustrations. New functionality was added to data and tools pages, augmenting search capabilities. The geospatial feature, COMPASS, was tested, thereby improving search for data using geographic names in addition to shape files and latitude/longitude coordinates. The CMGP worked with data.gov to ensure updated versions of the Coastal Change Hazards Portal were available to the ocean data community as soon as they were available.

Natural Hazards

In 2016, the CMGP will release a new revision of the Coastal and Marine Video and Photography Portal. This portal contains USGS video and photography of the seafloor off of coastal California and Massachusetts, and aerial imagery of the coastline along segments of the Gulf of Mexico and mid-Atlantic coasts. These data were collected as part of several Coastal and Marine Geology Program Seafloor Mapping projects and Hurricane and Extreme Storm research. The CMGP will also release Estuarine Processes, Hazards and Ecosystems Web site. This Web site describes several interdisciplinary projects that aim to quantify and understand estuarine processes through observations and numerical modeling.



The USGS Coastal and Marine Geology Video and Photograph Portal was released in March 2015 (<http://dx.doi.org/10.5066/F7JH3J7N>). The portal makes thousands of photos and videos of the seafloor and coastline (most areas never seen before) available and easily accessible online. This database is the largest of its kind, providing detailed and fine-scale representations of the coast. New video and photographs will be added as they are collected, and archived imagery will also be incorporated over time. The database will help coastal managers to make important decisions, ranging from protecting habitats to understanding hazards and managing land use.

In 2017, the CMGP will add to the Oceanographic Model and Data Portal that serves observational data and model simulations from USGS projects and many others, including the National Data Buoy Center, National Water Information System, the National Estuarine Research Reserve program, and the National Weather Service. The CMGP will evaluate user success with mobile-hand held apps that both deliver USGS information about beach conditions, forecasts of impacts of storms on dunes and communities, and locations of protected species as well as the ability to receive photographs and field notes about beach conditions from science staff and citizen observers who use online training materials to be “certified” to provide observations using a scripted set of functions. The CMGP will modify hand-held applications to meet needs of island communities in the Pacific as well as coastal region.

Science Collaboration

For U.S. Fish and Wildlife Service and National Park Service coastal units in the Northeast, in 2015, CMGP delivered the iPlover, a smartphone application. This new tool helps Interior and local scientists understand how piping plovers use coastal habitat. The USGS analyzed datasets documenting piping plover habitat and developed a plover behavior model that is quantitatively tied to variables including elevation, slope, frequency of inundation and overwash, and amount of vegetation. The USGS also developed a habitat evolution model by relating the datasets documenting changes in the habitat (e.g.,

topography, shoreline position, vegetation) to changes in sea level and storminess. Coupling these two models (plover behavior and habitat evolution) will allow scientists to evaluate historical observations and then model future scenarios to analyze alternative conservation strategies against plausible sea level and other future climate variables.

The USGS collaborated with Oregon State University to map the seafloor in an area off Coos Bay, OR, under consideration for construction of a floating wind-energy facility. Using funds from BOEM and the USGS research vessel *Parke Snavely*, researchers collected data that were used to develop a digital elevation model (DEM), habitat maps, and geologic maps needed by the BOEM for marine spatial planning, ecosystem assessment, environmental reviews, and offshore infrastructure analysis. BOEM will use this information for decisions about the proposed WindFloat Pacific 30-megawatt floating wind farm, the first wind farm proposed offshore of the U.S. west coast.

The CMGP has worked with the USACE to leverage USGS expertise about beach processes and responsibilities for forecasting beach change and USACE role in coordinating beach nourishment projects. During 2015, the USGS and USACE worked with American Shore and Beach Preservation Association (ASBPA) to discuss plans for development of a new Coastal Resiliency Network. The goal is to use the wealth of data that already exists in the Corps, the USGS, and other Federal agencies to quantify coastal resiliency and predict changes through time. Additionally the USGS and USACE collaborated on identifying ways to streamline and improve procedures for transforming raw lidar data into useful data products.

USGS scientists served as subject matter experts in an Inter-Agency Sea Level Rise Panel Discussion hosted by the Federal Emergency Management Agency (FEMA). During the past 10 years, multiple hurricanes have caused billions of dollars in damage and much human suffering. Climate change and sea level rise have received much attention as the Nation strives for improved resiliency. FEMA Risk Mapping, Assessment and Planning (Risk MAP) Federal Coastal Partners are analyzing potential impacts of sea level rise, and supporting disaster planning for coastal States and communities. USGS expertise greatly enhances discussions with FEMA, EPA, NOAA, and USACE about how to incorporate geologic changes into projections of future conditions for America's shorelines.

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Water Resources

Activity: Water Resources

	2015	2016	2017			
	Actual	Enacted	Fixed Costs	Program Changes	Request	Change from 2016 Enacted
Water Resources	\$211,267	\$210,687	\$957	\$16,348	\$227,992	\$17,305
<i>FTE</i>	<i>1,371</i>	<i>1,345</i>		<i>29</i>	<i>1,374</i>	<i>29</i>
Water Availability and Use Science Program	\$40,919	\$42,052	\$236	\$12,100	\$54,388	\$12,336
<i>FTE</i>	<i>277</i>	<i>273</i>		<i>12</i>	<i>285</i>	<i>12</i>
Groundwater and Streamflow Information Program	\$69,707	\$71,535	\$222	\$1,200	\$72,957	\$1,422
<i>FTE</i>	<i>383</i>	<i>384</i>		<i>7</i>	<i>391</i>	<i>7</i>
National Water Quality Program	\$94,141	\$90,600	\$499	\$3,048	\$94,147	\$3,547
<i>FTE</i>	<i>710</i>	<i>687</i>		<i>10</i>	<i>697</i>	<i>10</i>
Water Resources Research Act Program	\$6,500	\$6,500	\$0	\$0	\$6,500	\$0
<i>FTE</i>	<i>1</i>	<i>1</i>		<i>0</i>	<i>1</i>	<i>0</i>

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Water Availability and Use Science Program	12,100	12	J-11
WaterSMART: Water Use Research	1,000	0	J-17
Critical Landscapes: Arctic	1,950	4	J-28
WaterSMART: Drought	1,000	2	J-19
WaterSMART: National Hydrologic Model	750	1	J-26
WaterSMART: Near Real Time Assessment of Water Use During Drought	4,000	0	J-16
WaterSMART: Streamflow Information	400	0	J-24
WaterSMART: Water Use Information	3,000	5	J-16
Groundwater and Streamflow Information Program	1,200	7	J-33
Tribes	500	3	J-40
Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages	700	4	J-44
National Water Quality Program	3,048	10	J-49
Unconventional Oil and Gas Research	450	1	J-68
Enhanced Cooperative Activities and Urban Waters	717	5	J-61
Support NAWQA Cycle Three	1,881	4	J-58
Total Program Change	16,348	29	

Justification of Program Changes

The 2017 Budget Request for the Water Resources Mission Area is \$227,992,000 and 1,374 FTE, a net program change of +\$17,305,000 and +29 FTE from the 2016 Enacted level.

Overview

The Water Resources Mission Area is comprised of four subactivities—

- Water Availability and Use Science Program (WAUSP; <http://water.usgs.gov/wausp/>)
- Groundwater and Streamflow Information Program (GWSIP)
- National Water Quality Program (NWQP)
- Water Resources Research Act Program (WRRRA; <http://water.usgs.gov/wrri/index.php>)

Since 1879, the U.S. Geological Survey (USGS) has addressed issues of water availability and quality, drought, and flood hazards. Today, hydrologic professionals and support staff located in all 50 States, and Puerto Rico, continue this legacy of providing the Nation with critical water information. As the primary Federal science agency for water information, the USGS monitors and assesses the amount and characteristics of the Nation's water resources, assesses sources and behavior of contaminants in the water environment, and develops tools to improve management and understanding of water resources. The USGS is an important source of information during times of drought and floods. Information and tools allow first responders, the public, water managers and planners, and policy makers to—

- Minimize loss of life and property as a result of water-related natural hazards, such as floods, droughts, landslides, and chemical spills.
- Manage freshwater, both above and below the land surface, for domestic, public, agricultural, commercial, industrial, recreational, and ecological uses.
- Protect and enhance water resources for human health, aquatic health, and environmental quality.
- Contribute to wise use, development, and conservation of the Nation's water resources for the benefit of present and future generations.



USGS scientists Chris Rowden, Larry Buschmann and Bob Holmes were on the Mississippi River at St. Louis taking streamflow measurements on New Year's Eve 2015. This information is critical to the National Weather Service, the U.S. Army Corps of Engineers and emergency managers in making flood predictions and response.

The 2017 President's Budget request includes increases in funding for the following activities:

- Arctic research.
- Determining the importance of snowmelt in the hydrologic cycle.
- Developing a near-time assessment of water use during drought.

- Accelerating the collaborative development of a nationwide hydrologic model that accounts for all aspects of the water budget.
- Estimating monthly streamflow statistics through the USGS StreamStats decision support tool.
- Providing comprehensive, high-resolution water use information.
- Working with States, tribal, regional and local cooperators on water use research.
- Expanding the use of flood inundation mapping and rapid deployable streamgages.
- Strengthening technical information needed to support Indian water rights settlement work.
- Enhancing cooperative activities through the Urban Waters Federal Partnership.
- Advancing National Water Quality Assessment Project Cycle 3.
- Conducting unconventional oil and gas (UOG) research focused on water quality and water availability.



In October 2015, a rapid deployable streamgage positioned on a bridge before Hurricane Joaquin makes impact.

In addition, the Water Resources Mission Area is requesting a total of \$60,185,000 in the GWSIP, the NWQP, and the WAUSP for use in matching States, municipalities, and Tribes contributions for cooperative water efforts. This is the matching component of the Water Resources Mission Area.

The *USGS Water Science Strategy: Observing, Understanding, Predicting, and Delivering Water Science to the Nation* (<http://pubs.usgs.gov/circ/1383g/circ1383-G.pdf>) was released in 2013. The USGS Water Science Strategy provides five high-level goals for the Water Resources Mission Area for the coming decade:

1. Providing society the information it needs regarding the amount and quality of water in all components of the water cycle at high temporal and spatial resolution, nationwide.
2. Advancing our understanding of processes that determine water availability.
3. Predicting changes in the quantity and quality of water resources in response to changing climate, population, and land and water management.
4. Anticipating and responding to water-related emergencies and conflicts.
5. Delivering timely hydrologic data, analyses, and decision-support tools seamlessly across the Nation to support water-resource decisions.

The Strategy outlines areas where USGS hydrologic science can make substantial contributions to the Nation and identifies opportunities for the USGS to better use its capabilities to address Administration priorities to ensure healthy watersheds and sustainable, secure water supplies. In doing so, the Strategy informs long-term approaches to USGS program planning, technology investment, partnership development, and workforce and human capital strategies. The choice of strategic water science priority actions, goals and objectives is based on the guiding principles to *observe, understand, predict* and *deliver* water information that allows society to meet the water challenges of the Nation, current and future. While the Strategy does not cover all facets of USGS work in hydrology, it builds on a hierarchy of planning documents and provides a science-based response to the overarching issues of water availability and hydrologic hazards.

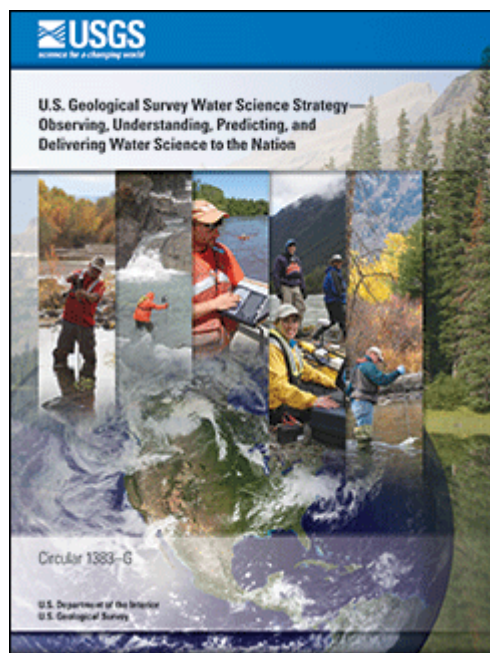
In order to achieve the Strategy vision, it is critical to align funding with the Strategy's goals and objectives. In 2016, the USGS aligned the Water Resources Mission Area budget structure to the Water Science Strategy by consolidating its seven existing programs into four. The GWSIP primarily focuses on *Observing and Delivering*. The other three programs, the NWQP, WAUSP, and WRRRA Program, primarily focus on *Understanding, Predicting, and Delivering*, although observations are an essential component of understanding and predicting. The WRRRA Program remains unchanged in the USGS budget structure and serves as an institutional mechanism for promoting State, regional, and national coordination of water resources research, training and information and technology transfer.

The Water Resources Mission Area carries out its programs through the 35 USGS Water Science Centers covering all 50 States and Puerto Rico, as well as its 3 major research installations located in Reston, VA, Denver, CO, and Menlo Park, CA. The Mission Area encompasses 1,374 scientists, technicians, and support staff and covers all aspects of the hydrologic sciences. In 2015, Mission Area staff published approximately 2,000 publications and supplied monitoring data to its stakeholders through its National Water Information System (<http://waterdata.usgs.gov/nwis>).

Key Accomplishments in 2015: During the past year, the Water Resources Mission Area has achieved the following accomplishments, as they would be tied to the four Mission Area programs. More information about these accomplishments can be found in each program's section:

GWSIP

- Enhanced the stability of the USGS streamgaging network by fully funding 1,138 streamgages with direct Federal funds, which adds an additional 162 fully funded USGS streamgages relative to 2014.
- Initiated the process to provide funds to National Groundwater Monitoring Network (NGWMN) "Data Providers" through competitive cooperative agreements, which starts in 2016. In 2015, six non-competitive, one-year cooperative



agreements were established with State agencies in Utah, Montana, Texas, Illinois, Oregon, and South Carolina to continue groundwater network development and implementation and many more in 2016. A total of 529 groundwater level sites and 69 groundwater quality sites were added to the NGWMN in 2015.

- Collected and analyzed streamflow information, and other hydrologic data at the USGS Water Science Centers in California, Idaho, Nevada, Oregon, Utah, and Washington to document the severity and extent of drought in Water Year 2015 (October 1, 2014, to September 30, 2015) and to assess the vulnerability of water resources in the Western United States to climate change. The USGS regional team assessed how rivers and streams respond to a shift in the dominant form of precipitation from snow to rain at higher elevations and how rivers and streams respond to prolonged drought.
- Supported monitoring at more than 8,100 streamgages and at more than 25,000 wells with more than 850 cooperators. Streamgage data are used for a multitude of purposes, including to protect life and property, manage water supplies, and to plan recreational activities; groundwater data are increasingly important for tracking drought and groundwater depletion from overuse.



At the Lovelady Well in Texas, the USGS is showing the cooperator the equipment in their key reference well. (For more information on that well: http://waterdata.usgs.gov/tx/nwis/uv/?site_no=301237097464801&agency_cd=USGS)

NWQP

- Launched a Web-based, Water-Quality Tracking Tool for stream and river quality data for nutrients and sediment (<http://cida.usgs.gov/quality/river>). This product displays and delivers water-quality information in a more timely and consistent fashion than in the past



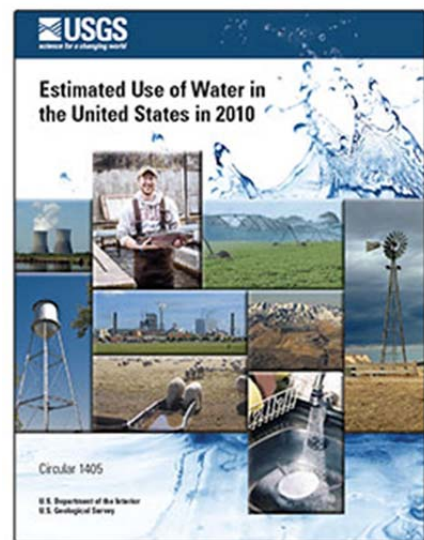
In addition to the large quantities of water that occur during floods, increased amounts of sediment and chemicals are washed from the landscape into rivers and transported downstream. Continuous, real-time USGS water-quality monitoring stations provide scientists, water-resources managers and emergency responders with information to make informed decisions vital for the protection of life, property and the environment. The photo above shows record flooding on the Meramec River near Eureka, Missouri in December 2015. This area is close to a USGS streamgage and water quality monitoring station.

and features comparisons of the most recent year of water-quality data for a stream against data collected in previous years. In 2016, the Water-Quality Tracking tool is expanding to add pesticides and data on all monitoring results will be updated annually. In 2017, the tracking tool will add ecological conditions and begin to expand site coverage for selected data using monitoring results from other programs.

- Improved the ability to provide access to quality-assured data and information from reference (relatively undisturbed) watersheds for use in understanding the effects of land use change, water use, atmospheric deposition, and climate change on freshwater ecosystems. First, water-quality data collection operations at the 17 pristine reference stream sites that were part of the Hydrologic Benchmark Network since 1963 were harmonized and consolidated with those of the National Water Quality Assessment Project. Second, in partnership with the National Water-Quality Monitoring Council, the USGS is leading efforts to develop a collaborative and multipurpose National Network of Reference Watersheds and monitoring sites for freshwaters (<http://my-beta.usgs.gov/nnrw/main/home>).
- Released a new interactive Pesticides Mapping Tool for Streams and Rivers (<http://cida.usgs.gov/warp/home/>) that provides predicted concentrations for 108 pesticides in streams and rivers across the Nation and identifies which streams are most likely to exceed water-quality guidelines for human health or aquatic life.

WAUSP

- Initiated the State Water Use Data and Research (WUDR) Cooperative Agreements in 2015, pursuant to Public Law 111-11 (SECURE Water Act), and 42 States applied for and received \$26,000 each to develop work plans outlining priorities for their use of future funds.
- Advanced the National Brackish Groundwater Assessment which was authorized in Public Law 111-11 (SECURE Water Act). Groundwater chemistry data from about 400,000 sites were compiled from more than 30 national, regional, and State sources for developing updated maps of the distribution of brackish groundwater. In 2015, the USGS released a paper on the chemical considerations for the updated assessment of brackish groundwater resources.
- Released a new model and report for estimating consumptive use of cooling water at thermoelectric generating plants. This report includes the first national estimates of consumptive use for thermoelectric power since 1995, and the model offers a new approach for nationally consistent estimates. Model estimates indicate that withdrawals for thermoelectric power declined 20 percent. Thermoelectric-power water withdrawal is the largest sector of all water withdrawals nationally. However, the consumptive water use associated with thermoelectric power (the amount evaporated into the atmosphere or otherwise lost to the



immediate environment) is relatively small. It is very important to have an accurate understanding of thermoelectric power consumptive use for sound water resources management.

- Supported research to advance methods for documenting permafrost thaw using remote sensing to identify the depth of thaw and numerical modeling to evaluate the formation of water features that would not exist in the absence of thaw. With additional funding, the USGS will support expansion and enhancement of monitoring of permafrost temperature, streamflow, biogeochemical and other materials exported from watersheds, and carbon dioxide and methane exchange between land and water surfaces and the atmosphere.
- Published and released the USGS Water Use Compilation for 2010. The report estimates that about 355 billion gallons of water per day (Bgal/d) were withdrawn for use in the United States during 2010. These are the lowest reported withdrawals since 1970, representing a 13 percent reduction of water use from 2005. Without an adequate description of human water use provided by the water use compilation report, scientists and managers may mistakenly attribute changes to the hydrology caused by water use to other factors such as natural variability, landscape change, and climate change. Numerous Federal agencies, such as the Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), the Bureau of Reclamation (Reclamation), and the U.S. Forest Service (USFS) use the Compilation as the basis for estimating current water demand and projecting water demand into the future.

WRRRA

- Shared best common practices of water resource sustainability issues on tropical islands. The tropical oceanic islands share many of the same water and wastewater problems and issues despite the diverse hydrological and geomorphological factors, climate, and degree of development. With the exchange of knowledge and collaboration with USGS scientists, island research scientists, managers, utility providers, students, and decision makers, there will be an increase of effectiveness with all four Institute programs in addressing common island water issues. (<http://www.wrcc.hawaii.edu/2015conference/index.shtml>)
- Issued 12 new research coordination grants and funded 10 student interns throughout the Nation. The WRRRA Program with the National Institutes for Water Resources is developing a unique Federal-State partnership to use the expertise and capabilities that are available through the network of University Institutes. Coordination grants and student interns are being used by USGS Science Centers and other Federal agencies to collaborate on research to solve water resource problems and issues. Coordination grants and featured student internship projects may be found at (<http://water.usgs.gov/wrri/coordination-grants.php>; <http://water.usgs.gov/wrri/student-internships.php>).

The Water Resources Mission Area supports the following Interior 2014–2018 Strategic Plan goal to “Provide Water and Land Data to Customers.” In particular, the Water Resources Mission Area supports the “Monitor and assess water availability and quality” element in the Strategic Plan. The USGS will continue to monitor and conduct research to generate a more precise estimate of water availability and use, and the influence that water quality has upon it, for meeting current and future human, environmental, and wildlife requirements. These research and monitoring activities will help identify

water resources for use by humans and the environment while also developing tools to forecast likely outcomes for landscape-level planning needs including water use and quality, and aquatic ecosystem health affected by changes in land use and land cover, natural and engineered infrastructure, water use, and climate.

Strategic Actions for 2016

- Support long-term, nationally consistent monitoring of sediment, nutrients, and pesticides at 113 stream monitoring sites, and collect and analyze water-quality samples from about 775 wells in some of the most important aquifers used as a source of water supply. Regional scale modeling for both surface water and groundwater will continue as planned.
- Conduct national and regional assessments, scientific examination of critical groundwater issues, field methods and model development, and improved access to groundwater data.
- Advance efforts in water availability and use by awarding State WUDR Cooperative Agreements; initiate the national implementation for estimating daily flows in ungaged basins; work on geographic Focus Area Studies; and begin to develop methods for estimating water use associated with UOG development.
- Complete the national brackish groundwater assessment and provide valuable insights as to the location and character of an undervalued groundwater resource for the future.
- Collect, manage, and disseminate consistently high-quality and reliable hydrologic information in real time and over the long term. This includes maintaining a unified national streamgaging network of more than 8,100 real-time streamgages as well as a growing network of interdisciplinary “Super Gages.” It also includes the development and application of hazard information and tools to minimize loss of life and property.
- Promote the NGWMN and award cooperative agreements for both new and existing data providers in the NGWMN. Expand work related to water availability issues on tribal lands in order to address such topics as water rights, water use, hydrologic conditions, and water-quality issues. In addition, the USGS will enhance cooperative activities related to energy and water; enhance local cooperative studies related to regional drought, and enhance data collection related to tribal water issues.
- Provide an institutional mechanism for promoting State, regional, and national coordination of water resources research. In addition, the program will continue to support each of the 54 Institutes and coordinate multi-year research, education, and information transfer projects on State and regional water resources issues.

Strategic Actions for 2017

- Synthesize and report information at regional and national scales, with an emphasis on compiling and reporting the information in a way that is useful to States and others responsible for water management and natural resource issues, especially for areas affected by drought.
- Focus on drought research including determining the importance of snowmelt in the hydrologic cycle and developing a near real-time assessment of water use during drought periods that can

provide a regional and national picture of how water use is changing during the drought. This would include effects of human water use, including withdrawals, diversions, and return flows.

- Conduct research on the interactions among water-mediated processes in a warming Arctic, assess system feedbacks (e.g., effects of warming on hydrology and biogeochemical cycling, which subsequently affects climate and hydrology), and better anticipate future system changes, expand monitoring of hydrologic (groundwater, surface water, thermos-karst features) cycles.
- Collect, manage, and disseminate consistently high-quality and reliable hydrologic information in real time and over the long term. This includes maintaining a unified national streamgaging network of more than 8,100 real-time streamgages as well as a growing network of interdisciplinary “Super Gages.” It also includes the collaborative NGWMN as well as the development and application of hazard information and tools to minimize loss of life and property.
- Continue long-term monitoring and modeling studies of nutrients, pesticides, sediment and other important water-quality constituents to provide critical information for water managers, policy makers and the public about current water-quality conditions, how they are changing through time and the major factors that influence observed conditions and trends.
- Continue to promote State, regional, and national coordination of water resources research, by supporting each of the 54 institutes and coordinating multi-year research, education, and information transfer projects on State and regional water resources issues.

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Activity: Water Resources

Subactivity: Water Availability and Use Science Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Actual	Enacted	Fixed Costs	Program Changes	Request	
Water Resources	\$211,267	\$210,687	\$957	\$16,348	\$227,992	\$17,305
<i>FTE</i>	<i>1,371</i>	<i>1,345</i>		<i>29</i>	<i>1,374</i>	<i>29</i>
Water Availability and Use Science Program	\$40,919	\$42,052	\$236	\$12,100	\$54,388	\$12,336
<i>FTE</i>	<i>277</i>	<i>273</i>		<i>12</i>	<i>285</i>	<i>12</i>
Water Use	\$4,104	\$4,104		\$8,000	\$12,104	\$8,000
<i>WaterSMART: Near Real Time Assessment of Water Use During Drought</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$4,000]</i>	<i>[\$4,000]</i>	<i>[\$4,000]</i>
<i>WaterSMART: Water Use Information</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$3,000]</i>	<i>[\$3,000]</i>	<i>[\$3,000]</i>
<i>WaterSMART: Water Use Research</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,000]</i>	<i>[\$1,000]</i>	<i>[\$1,000]</i>
Drought	\$500	\$801		\$1,000	\$1,801	\$1,000
<i>WaterSMART: Drought</i>	<i>[\$500]</i>	<i>[\$801]</i>		<i>[\$1,000]</i>	<i>[\$1,801]</i>	<i>[\$1,000]</i>
Groundwater Studies	\$10,824	\$12,381		\$0	\$12,876	\$0
National and Regional Water Budget Component Studies	\$5,675	\$5,926		\$400	\$6,326	\$400
<i>WaterSMART: Streamflow Information</i>	<i>[\$675]</i>	<i>[\$675]</i>		<i>[\$400]</i>	<i>[\$1,075]</i>	<i>[\$400]</i>
Geographically Focused Water Availability Studies	\$1,280	\$1,685		\$0	\$1,685	\$0
National Research Program	\$8,272	\$6,906		\$750	\$7,656	\$750
<i>WaterSMART: National Hydrologic Model</i>	<i>[\$300]</i>	<i>[\$300]</i>		<i>[\$750]</i>	<i>[\$1,050]</i>	<i>[\$750]</i>
Arctic - Critical Landscapes	\$250	\$250		\$1,950	\$2,200	\$1,950
<i>Critical Landscapes: Arctic</i>	<i>[\$250]</i>	<i>[\$250]</i>		<i>[\$1,950]</i>	<i>[\$2,200]</i>	<i>[\$1,950]</i>
Information Delivery	\$5,616	\$5,601		\$0	\$5,601	\$0
Technical Support	\$4,398	\$4,398		\$0	\$3,903	\$0

Justification of Program Changes

The 2017 Budget Request for the Water Availability and Use Science Program is \$54,388,000 and 285 FTE, a net program change of +\$12,336,000 and +12 FTE from the 2016 Enacted level.

Overview

The Water Availability and Use Science Program (WAUSP) directly support the USGS Science Strategy focus on the Water Census theme; providing scientific information on water availability and use of the United States to inform the public and decision makers about the status of water resources and how they are changing. This program also fulfills the goal stated in the SECURE Water Act (P.L. 111-11), Section 9508, to establish a “national water availability and use assessment program.” The WAUSP will synthesize and report information at regional and national scales, with an emphasis on compiling and

reporting the information in a way that is useful to States and others responsible for water management and natural resource issues.

The WAUSP supports the Department of the Interior WaterSMART initiative and the USGS Water Census Science Strategy through work to estimate flows in ungaged basins, aggregate and analyze water use information, and assess regional groundwater availability. In addition, the WAUSP supports, maintains, and enhances USGS data delivery systems to process and disseminate study results beyond the immediate needs of funding agencies or programs. The WAUSP supports development of cutting edge tools, setting standards of practice for hydrologic activities, training staff for field work as well as complex modeling studies. Finally, activities in the WAUSP also include cooperative science activities with States, localities, and Tribes, as well as the USGS National Research Program's hydrologic sciences.

The WAUSP also supports activities of the Advisory Committee on Water Information (ACWI, a Presidential Federal Advisory Committee) and its subcommittees. The ACWI represents the interests of water-information users and professionals in advising the Federal Government on Federal water-information programs and their effectiveness in meeting the Nation's needs. Member organizations help to foster communications between the Federal and non-Federal sectors on collecting, standardizing, and sharing water information, ultimately resulting in reduced Federal costs for operating resource management and environmental protection programs.

The 2017 President's Budget request includes requested increases in funding for activities related to Arctic research; determining the importance of snowmelt in the hydrologic cycle; developing a near-time assessment of water use during drought; accelerating the collaborative development of a nationwide hydrologic model that accounts for all aspects of the water budget; estimating monthly streamflow statistics through the USGS StreamStats decision support tool; and providing comprehensive, high-resolution water use information; and working with States, tribal, regional and local cooperators on water use research. For more information, on these requested increases, please see the text boxes below.

Program Performance

The WAUSP is made up of nine program components: Water Use, Drought, Groundwater Studies, National and Regional Water Budget Component Studies, Geographically Focused Water Availability Studies, National Research Program, Arctic: Critical Landscapes, Information Delivery, and Technical Support.

Water Use

(2015 Actual, \$4.1 million; 2016 Enacted, \$4.1 million; 2017 Request, \$12.1 million)

The USGS National Water Use Information project estimates total water withdrawals in the United States, every five years, for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric-power generation (Maupin and others, 2014). Thermoelectric power is historically the largest category of water withdrawal, followed by irrigation and public supply; the remaining categories combine for about 10 percent of total water withdrawals. As part of the WAUSP, USGS researchers will focus on improving the information available on the largest water

use categories: thermoelectric, public supply, and irrigation. New methods to estimate water use for thermoelectric sources have been developed that improve the accuracy of location and use information; public supply estimates will be improved by developing a site-specific database for reporting data; and, irrigation estimates will be improved regionally by developing techniques based on local irrigation methods.

In 2015, the USGS released multiple water use reports. The USGS Water Use Compilations (Compilation) are the only consistent effort to periodically document water use for the entire Nation and are one of the most widely cited publications of the USGS. The 2010 national water use compilation (<http://pubs.usgs.gov/circ/1405/>) reported that about 355 Bgal/d were withdrawn for use in the United States during 2010. This is the lowest reported withdrawals since 1970, representing a 13 percent reduction of water use from 2005 (<http://pubs.usgs.gov/circ/1344/>), when about 410 Bgal/d were withdrawn. Between 2005 and 2010, withdrawals for public water supply declined for the first time, despite a four percent increase in the Nation's total population. Public-supply per capita use declined to 89 gallons per day in 2010, from 100 gallons per day in 2005. The Compilation is used by the Congressional Research Service and the Government Accountability Office for their assessments of freshwater supplies and the resulting challenges for meeting expected shortages. Numerous Federal agencies, such as the DOE, EPA, the Reclamation, and the USFS use the Compilation as the basis for estimating current water demand and projecting water demand into the future. The Compilation is used by non-governmental agencies, such as the Electric Power Research Institute and the Natural Resources Defense Council, to assess water use demands. Without an adequate description of human water use provided by the Compilation, scientists and managers may mistakenly attribute changes to the hydrology caused by water use to other factors such as natural variability, landscape change, and climate change. Work to compile data for the 2015 Compilation began in 2016, and will continue into 2017.

The second water use report was the 2010 water use estimates for California (http://ca.water.usgs.gov/water_use/). The estimates showed that, in 2010, Californians withdrew an estimated total of 38 Bgal/day, compared with 46 Bgal/day in 2005. Surface water withdrawals in the State were down, whereas groundwater withdrawals and freshwater withdrawals were up. Most freshwater withdrawals in California are for irrigation. California is the number one State in the Nation in terms of water withdrawals. The current drought in California has increased the need for understanding water use data. Information in this report is critical for managers and planners to understand how factors such as population, industry, crops, energy production and climate affect water withdrawals. There is a lot of interest in this report by water resources managers in California, as 10 percent of the USGS California Water Science Center Web page views between August 2014 and December 2015 were of this report.

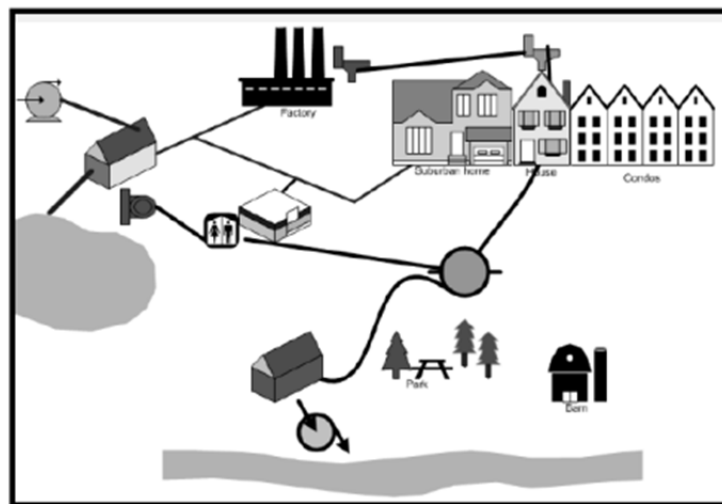
Finally, a third report estimated thermoelectric-power withdrawals and consumptive use of water for 2010 (<http://pubs.er.usgs.gov/publication/sir20145184>). Thermoelectric power water withdrawal is the largest sector of all water withdrawals nationally. However, the consumptive water use associated with thermoelectric power (the amount evaporated into the atmosphere or otherwise lost to the immediate environment) is relatively small. It is very important to have an accurate understanding of thermoelectric power consumptive use for sound water resources management. The report was based on linked heat- and water-budget models that integrated power plant characteristics, cooling system types and data on

heat flows into and out of 1,290 power plants in the United States. These data include the first national estimates of consumptive use for thermoelectric power since 1995, and the models offer a new approach for nationally consistent estimates. Model estimates indicate that withdrawals for thermoelectric power declined 20 percent between 2010 and 2015. A number of factors can be attributed to the decline in thermoelectric-power withdrawals, including an increase in the number of power plants built or converted since the 1970s that use more efficient cooling-system technologies, declines in withdrawals to protect aquatic habitat and environments, power plant closures, and a decline in the use of coal to fuel power plants. The previous national estimates of thermoelectric power consumptive use were conducted in 1995. This new report provides new and up-to-date information on the amount of thermoelectric power consumptive water use and allows comparison with other consumptive water uses for resource management purposes. In 2016, the USGS is publishing a comparison of three national datasets from the USGS, U.S. Energy Information Administration (EIA), and State supplied data for thermoelectric water withdrawals and consumptive use. In 2017, additional information from the USGS, the EIA, and States will be used to determine thermoelectric-water use for the 2015 water use compilation.

USGS Water Science Centers measure and analyze water use information in cooperation with States, localities, and Tribes to determine the amount of water used, where it is used, and how it is used to allow wise management of water resources. Some of these cooperative efforts focus on development of consistent methods of data collection and analyses to improve accuracy in water use estimates and more timely and accessible reporting and delivery of information. Other cooperative efforts focus on assessment of effects from proposed future increases in pumping and population increases, such as the effects of increased irrigation in Georgia and increased population growth in and around Memphis, Tennessee on groundwater level declines.

“We all know we must have water to survive, but water is also necessary to support farming, industry, power generation, aquaculture, recreation and much more. My hope is that these fact sheets provide something for everyone. Water resource stewardship is a community effort and useful, concise knowledge is necessary to that well, especially in the modern world of information overload.” Vincent White, Civil Engineer, LA Department of Transportation and Development

USGS scientists, in cooperation with the Louisiana Department of Transportation (DOT) and Development, passed the halfway point in 2015 with the release of 34 factsheets detailing information about water use and water resources in the State’s 64 parishes. The factsheets provide information on each parish’s water resources, water availability, past and current use, and use trends from groundwater and surface-water sources. The Web page



Schematic for tracking water from the point of withdrawal, to use, to return.

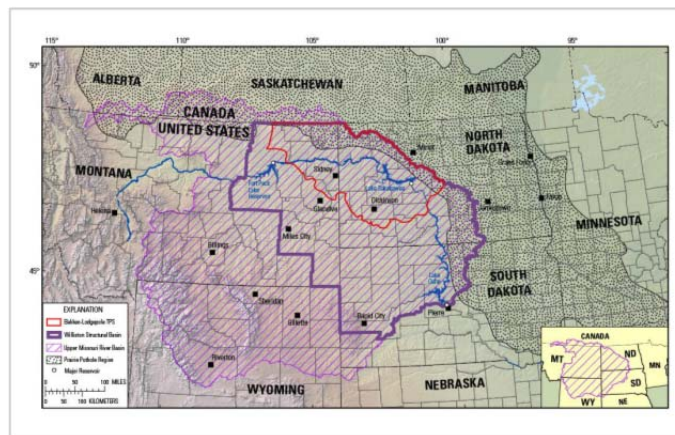
(<http://la.water.usgs.gov/ParishWaterResources.html>) has a publishing schedule for the remaining parishes. This work will continue into 2016 and 2017, with the release of additional factsheets.

In 2016, the WAUSP is developing methods to estimate irrigation consumptive water use at the agricultural field scale. The field scale estimates will be used to develop methods that can be used to estimate the water consumed during irrigation of crops at a national scale for the 2015 water use compilation.

The WAUSP began an effort in 2011 to store site-specific public water supply water use data in the National Water Information System (NWIS) by populating the Site-specific Water-Use Data System (SWUDS). Information stored in the SWUDS will include groundwater and surface-water withdrawal sites, associated distribution system sites, conveyances, and other management structures. The database will include the location and withdrawal information associated with 117,000 wells and 7,000 surface-water intake sites. This work will be completed 2017.

In 2015, the WAUSP received funding to work with States to improve water use data collection, estimation, and reporting. Public Law 111-11 (SECURE Water Act) authorized the USGS to provide financial assistance to State water resource agencies to assist with the development and integration of water use datasets into databases developed or maintained by the USGS. The WAUSP initiated the State WUDR Cooperative Agreements in 2015, and 42 States applied for and received \$26,000 each to develop work plans outlining priorities for their use of future funds. The WAUSP will award additional States in 2016. In addition, a technical committee made up of USGS personnel and stakeholders will develop the competitive Program Announcement for 2016. All States that developed work plans are eligible for the competitive awards in 2016. In 2017, the USGS will continue to develop Program Announcements that will allow States to apply for these assistance awards. The SECURE Water Act limits each State to a maximum of \$250,000 in awards over the life of the program.

In 2016, the WAUSP is beginning a study to quantify water used in the development of UOG resources. The UOG study will be conducted in a series of three phases. The initial phase will focus on quantifying water use associated with UOG in the Williston Basin of North Dakota, South Dakota and Montana, and developing a water use estimation model and accompanying uncertainty methods. Phase 2 will test the model in several other plays within the Nation to evaluate its capabilities. Phase 3 will finalize the water use estimation model and uncertainty methods. Products will include (1) improvements to the USGS SWUDS; (2) a model developed to estimate water use associated with UOG in the Williston basin that is transferable to other ‘plays’ nationally; and (3)



Map of the Williston Basin

tools to estimate uncertainty associated with the UOG water use model. In 2017, phase 1 will continue with phase 2 beginning in late 2017.

2017 Program Change

WaterSMART: Near Real Time Assessment of Water Use During Drought: (+\$4,000,000 for a total of \$4,000,000): Information on past and present water use is needed during drought conditions to allow resource managers to assess vulnerability and determine the effectiveness of conservation measures. The USGS will use the increase to develop methods to assess regional and national water use trends during drought periods. The expected products include delivery of near real-time data on water use during drought periods, the ability to track short-term trends in water use, and monitor effectiveness of conservation measures. These products can be used by resource managers to assess vulnerability of specified basins or water suppliers.

The USGS currently has water use information, by county, for eight sectors of water use, for compilation years 1985, 1990, 1995, 2000, 2005, and 2010, in the Aggregated Water Use Database (<http://water.usgs.gov/watuse/>). This data represents a time series of annual data, for eight sectors of water use, every five years over a 25-year time span. These six sets of data provide an opportunity for estimating water use in drought-stricken areas on a more frequent basis than our traditional “five year compilations.” The USGS would divide the Country into groups of counties that have similar hydroclimatology and water use trends to determine if the county groups can be used as water use monitoring regions. Key questions to answer are: (1) do the county groups respond similarly in their patterns of water use over the 25-year time frame; and (2) is there a subgroup that can be monitored more frequently during a drought that would allow estimation of water use for the entire group of counties. After these subgroups are established, the USGS would monitor the water use condition intensively in the subgroups and use statistical methods to estimate quarterly water use for the entire county group. This effort will require a strategy to build database interoperability, agreement on common data elements, and other water availability supporting information between States and the USGS. The WUDR program will be critical to support States’ efforts to build capacity for providing the necessary data. These steps will allow the USGS to interact effectively with States to obtain a near-real-time picture of water use during the drought. The USGS has been working with the Western States Water Council staff, on WaDE (Water Data Exchange). Under leadership of the Western States Water Council, WaDE brings water use data from 17 States together in a common portal and with common data elements, allowing evaluation of this data across State lines. This type of system is needed nationally to manage water usage on a near-real-time basis.

WaterSMART: Water Use Information (+\$3,000,000 for a total of \$3,000,000): Since 1950, the USGS has been the primary Federal agency responsible for providing a comprehensive understanding of water use across the Nation, with consistent reporting every five years through the USGS series of circulars: Estimated Use of Water in the United States. As required under the SECURE Water Act (P.L. 111-11), and the President’s Climate Action Plan, the USGS is working to expand its efforts and provide comprehensive, high-resolution water use information (on an annual basis and at a location) that will support a host of decision-support systems. This high-resolution water use information will allow resource modelers and managers to understand the influence that human water use has on the hydrologic cycle, the degree to which human consumptive uses influence the sustainability of water supplies, and allows comparison of human water demands to the sustainability of environmental water

2017 Program Change

needs. The USGS has already begun work under the National Science and Technology Council's Committee on the Environment, Natural Resources, and Sustainability to coordinate activities with other Federal and State agencies to scope the effort for providing this high-resolution water use information. The USGS is to begin coordinating an effort with Reclamation, the U.S. Department of Agriculture (USDA), the EPA, the U.S. Army Corps of Engineers (USACE), and the DOE to improve their ability to feed base data into the water use databases.

The 2017 requested increase would allow the USGS to participate in a multiagency, Open Water Data Initiative that will integrate water information that is fragmented among multiple agencies into a national water data framework on a geospatial platform, improving the water use information mentioned above. The Open Water Data Initiative will leverage existing partnerships and infrastructure to allow for greater data accessibility and better tools and solution development.

The requested increase would also allow the USGS to continue to provide grants to State Water Resource Agencies to improve their ability to provide the base data at the necessary resolution for effective decision making. The data would be formatted to allow easy input of water use to the National Hydrologic Model, as well as other models utilized by the USGS and others. The USGS would coordinate these activities with other Federal agency efforts, provide grants to and coordination with State Water Resources Agencies on their data delivery, and maintenance of the comprehensive Site-specific Water Use Data System and Aggregate Water-Use Data System databases. Finally, this funding would support periodic comprehensive analysis of the data to report out on water use trends and provide national water use indicator analysis, and maps of water stress indicators.

Comprehensive water use information would be provided on an annual and ongoing basis for the following sectors of water use: irrigation, public water supplies, thermoelectric cooling water, industrial self-supplied water, and aquaculture.

WaterSMART: Water Use Research (+\$1,000,000 for a total of \$1,000,000): Water use information that identifies the impacts of human water withdrawals and return-flows is critical for the National Water Census's water budget analysis. This information, which is mostly collected at State, tribal, regional, and local governmental levels, must be obtained on a site-specific scale in order to be fully useful in the National Water Census analyses. The WAUSP would work directly with State, tribal, regional, and local cooperators to match this funding and make maximum use of their water use datasets in the water availability and use assessment. Working collaboratively with State, tribal, regional, and local cooperators to determine work that is beneficial to both groups is required to develop better methods of sampling, estimating, aggregating, and presenting water use data. This includes research into new methods that use remote sensing and spatial datasets in water use estimation. The research and networks and analysis functions of the USGS would work together to advance the development of those methods for use within the WaterSMART initiative. The USGS would integrate this information with decision-support tools that facilitate use of that information in a manner that is relevant to water resource management decision making.

USGS monitoring, assessments, and research would continue and expand related to WaterSMART and impacts on water use. Additional focus will be placed on tracking site-specific, public supply and other water use information; developing consumptive use measurements and methodology (particularly associated with irrigated agriculture); assessing watershed water budgets (including developing

2017 Program Change

estimates for streamflow at ungaged sites for more accurate water budgets); developing water use/budget models to track long-term patterns in groundwater and surface water flow; and advancing evapotranspiration measurements and assessment techniques. This funding being requested would be part of the cooperative matching funds.

Drought

(2015 Actual, \$0.5 million; 2016 Enacted, \$0.8 million; 2017 Request, \$1.8 million)

More than 20 Federal agencies have responsibilities in water management. With the number of agencies involved, it is necessary that a coordinated Federal response be a top priority for all agencies. The USGS is viewed as a leader in both drought science and coordination of drought science activities. Some key areas that the USGS provides science leadership and coordination are water use research, regional groundwater assessments, research into the importance of snowmelt in water budgets, and the frequency, duration, and intensity of historical droughts.

In 2015, the WAUSP continued work on estimating hydrologic drought flow frequency, duration, magnitude, and probability to better understand and anticipate drought streamflow conditions. Two methods of hydrologic drought streamflow probability estimation and hydrologic drought streamflow characterization were tested and evaluated, using criteria appropriate for regions of the United States. This study will be completed and the results published in the scientific literature in early calendar year 2016 (including two journal articles and one USGS Scientific Investigations Report).

The USGS and Sonoma County in California continued studies on the Russian River, which provides water for over 650,000 people in Sonoma, Marin, and Mendocino Counties in addition to supporting Sonoma and Mendocino County wineries, one of the most valuable agricultural areas in the United States and a major tourist area. The river also supports three salmonid species listed under the Federal and State Endangered Species Act. The focus of the multi-year study, began in 2015, is to assess sustained drought conditions and predict how climate change may make such extremes even more common. The cooperative effort will help to provide new tools and methods to predict drought conditions, which will be needed for drought preparedness and risk reduction, and to help water managers maintain agriculture, water supplies, endangered species, and tourism in the area.

In 2016, Congress appropriated additional funding to produce science-based information and tools as called for under the President's National Drought Resilience Partnership (NDRP). The NDRP's goal is to make it easier to access Federal drought resources by linking information such as monitoring, forecasts, outlooks, and early warnings with longer-term drought resilience strategies in critical sectors such as agriculture, municipal water systems, energy, recreation, tourism and manufacturing. In addition, the WAUSP will enhance research activities to improve drought forecasting. Groundwater and surface water availability changes would be evaluated by improving internal and external coordination and enhancing monitoring activities and data delivery systems to create a stronger link among the ground-based surface water and groundwater monitoring networks of the USGS, groundwater networks of State agencies and the soil moisture network of Natural Resource Conservation Service (NRCS). Links would then be improved between the well-coordinated ground-based monitoring networks and remote sensing products.

These data and information would be served through the National Water Census Data Portal. Because drought can create an increased demand for groundwater resources, in 2017, the WAUSP will enhance work on land subsidence from groundwater withdrawals.

2017 Program Change
<p>WaterSMART: Drought: (+\$1,000,000 for a total of \$1,801,000): Seasonal snowpack serve as large natural reservoirs that store water through the winter, and release it during spring and summer months, when demand is greatest – often supplying water to meet demands hundreds of miles away. The quantity of water that is stored in the seasonal snowpack and then released as snowmelt is one of the most important inputs used for forecasting annual runoff and water supply in these regions. There is an urgent need to improve our understanding of the role of snow in water budgets at the regional and national scales. Key questions include: (1) What is the contribution of snow to the annual water budget; (2) How much snowfall ends up in streams and rivers; (3) Can models and remotely sensed data be used to accurately estimate snow water content and to simulate snowpack processes across the landscape; (4) How can observations help guide the development of snowpack models and remote sensing techniques, and what temporal and spatial resolution is required for those observations; and (5) How do the dynamics of snow accumulation and snowmelt change in response to changing climate conditions? Given the uncertainties in modeling snow water content and its seasonal evolution, and the importance of snowmelt in the annual water balance, it is essential to conduct a more comprehensive evaluation of data needs and model capabilities for quantifying water budgets across snow-dominated regions of the United States. This increase will allow for the critical evaluation of research on the assimilation of remote sensing observations and ground-based snow measurements into snowmelt runoff models that is needed to provide more accurate forecasts of snowmelt runoff.</p>

Groundwater Studies

(2015 Actual, \$10.8 million; 2016 Enacted, \$12.4 million; 2017 Request, \$12.9 million)

Groundwater is one of the Nation's most important natural resources. It is the primary source of drinking water for approximately 130 million of the Nation's population, provides about 40 percent of the irrigation water necessary for the Nation's agriculture, sustains the flow of most streams and rivers, and helps maintain a variety of aquatic ecosystems. The continued availability of groundwater is essential for current and future populations and the economic health of our Nation. The WAUSP provides objective scientific information and interdisciplinary understanding necessary to assess and quantify availability and sustainability of the Nation’s groundwater resources. Results of these efforts provide information that is used in decision making by resource managers, regulators, other government agencies, and individuals in the public and private sectors.

“...the USGS Scientific Investigation reports and datasets are critical to writing technical reports for water right applications, implementing the DNRC State Water Plan, and groundwater modeling efforts”
-- Attila Fohnagy, Groundwater Hydrologist, Montana DNRC Water Management Bureau

In 2015, regional studies of groundwater availability were conducted to quantify current aquifer resources, evaluate how those resources have changed over time, and provide tools to forecast how much

water will be available in the future. Seven regional water resource assessments and related data collection took place in the following principal aquifer systems:

- Northern Atlantic Coastal Plain Aquifer System (Long Island, New York to North Carolina)
- Williston and Powder River Structural Basins (Montana, North Dakota, South Dakota, and Wyoming)
- Hawaiian Volcanic-Rock Aquifers (Hawaii)
- Ozark Plateaus Aquifer System (Arkansas, Kansas, Missouri, and Oklahoma)
- Glacial Aquifer System (all or parts of 25 northern States from Maine to Washington to Alaska)
- Pacific Northwest Volcanic Aquifer System (Oregon, California, Idaho, and Nevada)
- Appalachian Plateau Groundwater Availability Study (Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Kentucky, Tennessee, Georgia, and Alabama)

In 2015, the WAUSP conducted work on the National Brackish Groundwater Assessment, which was authorized by passage of the SECURE Water Act (P.L. 111-11). Section 9507c of the Act states that the “Secretary of the Interior, in consultation with State and local-water-resource agencies, shall conduct a study of available data and other relevant information to identify significant brackish groundwater resources in the United States.” Groundwater chemistry data from about 400,000 sites have been compiled from over 30 national, regional, and State sources for developing updated maps of the distribution of brackish groundwater. The final report and database will be published in 2016. This will be the first report on a national assessment of brackish groundwater in 50 years. The report will address the four items that the SECURE Water Act outlined as critical information needs to complete an evaluation of the current status of the Nation’s brackish water resources: (1) identify significant brackish groundwater resources; (2) identify data gaps that prohibit full characterize of each brackish aquifer; (3) identify current use of brackish groundwater; and (4) summarize the information available for each brackish aquifer. Reclamation will use the data and report to inform new projects that will develop water supplies from unconventional sources.

The North Atlantic Coastal Plain Aquifer System, Appalachian Plateau Groundwater Availability Study, and National Brackish Groundwater Assessment are scheduled for completion in 2016. In 2017, the Williston and Powder River Structural Basins and the Glacial Aquifer System are scheduled for completion. All these regional assessments are part of an effort to evaluate about 40 regional aquifers across the Nation and, in late 2016, the USGS will begin to compile the information for each of the completed availability studies to prepare a national synthesis of the information that will show trends in groundwater over time.

USGS scientists work with States, localities, and Tribes to assess groundwater availability in principal aquifers across the United States, and interconnections between surface water and groundwater. Often the studies also include assessment of changes in water quality, which can affect groundwater availability.

“Understanding how groundwater moves is critical in order for decisionmakers to protect this finite resource. You can’t manage what you don’t measure.” Darren Thompson, Director of Water Resources at San Antonio Water System

The USGS, in cooperation with the San Antonio Water System (SAWS), developed a groundwater model (<http://pubs.er.usgs.gov/publication/sir20155081>) to better understand how water flows throughout the San Antonio, TX, segment of the Edwards aquifer. The Edwards aquifer is one of the most prolific aquifers in the world and provides more than 50 percent of drinking water consumed in the San Antonio and Austin areas. The aquifer also supplies water to south-central Texas for residential, recreational, industrial, and agricultural uses. Several endangered and threatened species are also sustained by groundwater discharged at Comal, San Marcos and Barton Springs. The focus of the new USGS model is to simulate the interaction between freshwater, saline water, and where the two mix, called the brackish-water transition zone. Model results indicate that effects on fresh water during a severe drought, such as the record drought in the 1950s, would be minor. The USGS continues to work with SAWS in 2016 with new model scenarios.

In 2016, the WAUSP received additional appropriated funding to begin an assessment of the Mississippi Alluvial Aquifer System and reactivate the U.S.-Mexico Transboundary Aquifer Assessment Program (TAAP) that ended in 2010.

The Mississippi Alluvial Plain (MAP) has become one the most important agricultural regions in the United States; it relies heavily on groundwater from a system that is poorly understood and showing signs of substantial alteration. Key to managing water issues in this region is the development of tools and hydrologic understanding that support common assessment and prediction of highly variable interactions among surface- and groundwater systems under stress. This is an essential first step in support of informed public discourse on a range of social, economic, and environmental issues tied to the well-being of this agricultural region.

To facilitate the development of a common context for decision making within the MAP, the USGS is initiating a multi-year program in 2016 to improve the quality of and access to information describing hydrologic conditions and properties of the region and to incorporate improved understanding of system properties into the development of tools that allow the testing and optimization of resource management alternatives for the region. The USGS work includes: (1) gap analysis--establishing and implementing a plan to enhance hydrologic monitoring across the MAP region; (2) information sharing--aggregating and publishing water use and other relevant hydrologic information for open access; (3) tool development--refining and recalibrating an existing USGS groundwater flow model of the region (MERAS) based on an updated analyses of system properties and geologic framework; and (4) analytical support--designing and implementing selected studies to better understand specific drivers and attributes of the system.

Given the size and geologic complexity of the region, construction of a common framework for decision making will require collaboration and support from a range of partner organizations and institutions. As a fundamentally collaborative effort, the work envisioned here should provide both the instrument and the opportunity for public engagement and consensus building around a number of contentious issues involving resource allocation and management. The key objective of this effort is to improve organizational access to reliable information and technical tools for evaluation so to improve transparency in the interpretation of complex technical issues in a way to promote trust and open dialog among partner organizations engaged in a common effort.

The U.S. – Mexico Transboundary Aquifer Assessment Act (TAAP, Public Law 109-448) was signed into law on December 22, 2006, to conduct binational scientific research to systematically assess priority transboundary aquifers and to address water information needs of border communities. The TAAP authorizes the Secretary of the Interior, through the USGS, to collaborate with the States of Arizona, New Mexico, and Texas through their Water Resources Research Institutes (WRRIs) and with the International Boundary and Water Commission (IBWC), stakeholders, and Mexican counterparts to provide new information and a scientific foundation for State and local officials to address pressing water-resource challenges along the U.S. – Mexico border. The USGS produced a report that outlined the work done and identified next steps if funding was available (<http://pubs.usgs.gov/of/2013/1059/>). In 2016, the USGS will convene a meeting with partners to re-evaluate planned work, and decide on a course of action for future years. In 2017, the planned work will begin with the TAAP partners. The TAAP expires in 2016 and requires reauthorization.

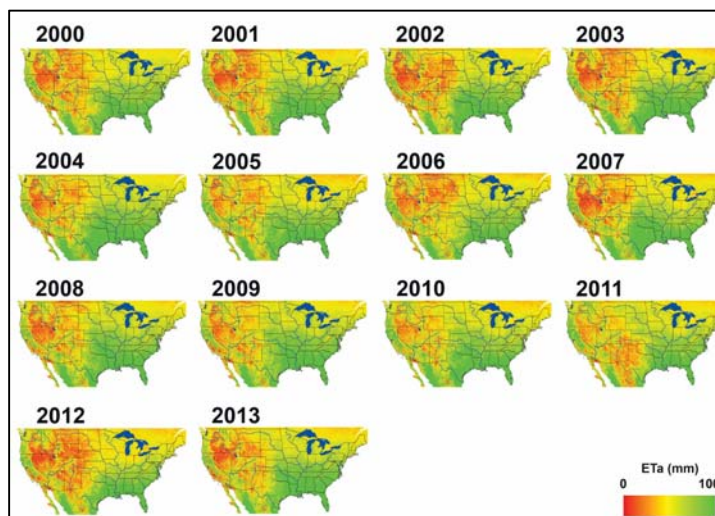
National and Regional Water Budget Component Studies

(2015 Actual, \$5.7 million; 2016 Enacted, 5.9 million; 2017 Request, 6.3 million)

National water-budget component studies provide quantitative information about the amount of water that resides in, or is moving through, individual components of the water budget. In 2015, the WAUSP tested methods to estimate streamflow in ungaged basins at a daily timescale, developed a method to estimate actual evapotranspiration (ET) for the conterminous United States at a monthly timescale, and developed classification tools that allow environmental flow managers to evaluate a region of interest at the scale necessary for management.

Estimates of daily streamflow time series are critical for hydrological investigations and for resource management decisions. Specifically, estimates of daily streamflow for ungaged sub-watersheds will be used to evaluate ecological flow needs; assess the effects of hydrologic alteration on ecological services; and understand the effects of climate and land use change on water resources. The WAUSP is developing methods for estimating daily time series of natural flow at ungaged locations by testing to determine which methods perform best in selected parts of the Country. The project will define and develop metrics for methods comparison; evaluate competing models using established metrics; choose case study areas to apply the chosen methods; and provide a description of a pilot delivery system. Estimates of flow will be generated for small-scale basins in the coterminous United States at a daily time step from 1980 to 2010. In 2016, the selected method (or methods) is being used to begin the implementation of streamflow estimates in the conterminous United States. Final implementation will be completed in 2017.

In order to construct water budgets to determine water availability, actual ET is being estimated across the conterminous United States using the Simplified Surface Energy Balance (SSEBop) model. The SSEBop uses 1-kilometer-resolution Moderate Resolution Imaging Spectroradiometer (MODIS) land-surface temperature imagery from the archive at the USGS Earth Resources Observation Science (EROS) Data Center. ET estimates are being made for monthly and seasonal totals across the continental United States, at small watershed scales, covering the time period 2000-2013.



Annual ET estimates for 2000 to 2013

In Florida, the USGS continues to work cooperatively with eight management districts and other partners to implement a statewide ET network. The *Florida Evapotranspiration Network* is comprised of 15 data-collection sites representing various land cover types, which provide long-term, accurate, and unbiased information needed by Federal, State, and local agencies for planning and operating water-resources projects and regulatory programs. Networks like this also serve as verification data points for the estimates that are derived from remotely sensed data described above.

StreamStats (<http://water.usgs.gov/osw/streamstats/>) is a Web-based Geographic Information System (GIS) application that was created by the USGS, in cooperation with the Environmental Systems Research Institute, Inc., which allows users to easily obtain streamflow statistics and basic characteristics for USGS gaged and ungaged sites. Estimates are based on regression equations or are from data from similar gaged locations on the stream. Streamflow statistics are used by water managers, engineers, scientists, and others to protect people and property during floods and droughts, and to manage, protect, and enhance water resources. Links are provided on the *StreamStats* Web page for individual State applications, instructions for using *StreamStats*, definitions of basin characteristics and streamflow statistics, and other supporting information. In 2015, *StreamStats* was available to the public (fully implemented) for nearly 30 States. Several States were added in 2015, including Georgia in

“StreamStats is the most efficient, user-friendly, and powerful tool I have used in my 30 years with the Colorado Department of Transportation (CO DOT) to delineate drainage basins and calculate peak and minimum flows. In its first year of operation, the Colorado implementation of StreamStats was accessed 300,000 times by CO DOT employees and by other State, county, and city employees, and their consultants, and contractors, and by university researchers and students. CO DOT uses the flood estimates for design and assessment of highway bridges and thousands of culverts. The calculations of minimum flows are critical for fishery, wetland and other environmental requirements during periods of drought. StreamStats has resulted in significant cost savings for our agency; for example, StreamStats calculations of drainage characteristics and peak flows at nearly 250 bridges were completed at about 2 percent of the original cost.” Amanullah Mommandi, M.S., P.E., Colorado Department of Transportation.

cooperation with the Georgia Environmental Protection Division and Georgia DOT, and South Carolina, which resulted in regression equations to estimate flood-frequency flows at rural ungaged locations and at urban and small, rural ungaged locations. The USGS, in cooperation with the Maine DOT, released a factsheet (<http://pubs.er.usgs.gov/publication/fs20153014>) that provides information on regression equations used to estimate the flow statistics in Maine, and describes errors associated with the estimates and methods used to develop the equations and to measure the basin characteristics. Limitations of the methods are also described in the factsheet; for example, all of the equations are appropriate only for ungaged, unregulated, rural streams in Maine. Plans for additional States to be added in 2017 are being developed in 2016.

Historically, water use definitions were limited to the human uses and needs of water. More recently, the focus has expanded to include the ecological water needs. Resource managers must assess ecological uses of water and environmental flows required to maintain habitats and populations and prevent degradation of freshwater ecosystems. Stream classification is an important step in developing an understanding of how natural systems respond to changes associated with resource management actions. In 2015, WAUSP classified streams using a suite of “ecologically-relevant” hydrologic metrics that characterize the five major components of the flow regime – duration, magnitude, frequency, rate of change (rise and fall), and timing and seasonality of flow events. This stream classification is publically available in 2016 for resource managers that need information for instream flow requirements.

2017 Program Change
WaterSMART: Streamflow Information (+\$400,000 for a total of \$1,075,000): Streamflow information is required for water-resources management, and changing streamflow conditions require continuity of information for flood and drought response and routine water allocations. A goal of the National Water Census effort is to provide estimates of streamflow statistics throughout the Nation. The USGS StreamStats decision-support tool allows the USGS and partners to develop these estimates. In 2017, the WAUSP is requesting a funding increase to implement StreamStats in three additional States and to continue to improve methods for providing the estimates. (The States selected will depend on which States supply cooperative funding to help support this work.)

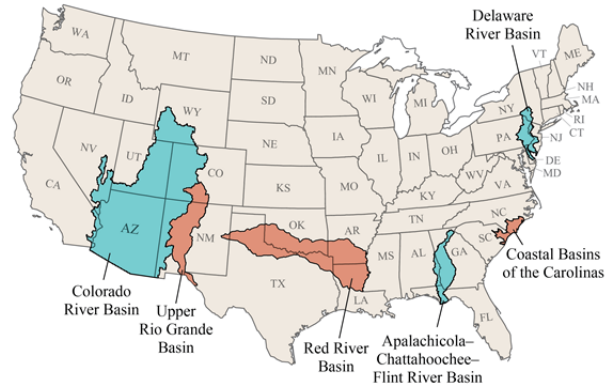
Geographically Focused Water Availability Studies

(2015 Actual, \$1.3 million; 2016 Enacted, \$1.7 million; 2017 Request, \$1.7 million)

In 2011, the USGS began three geographic Focus Area Studies (FASs): Apalachicola-Chattahoochee-Flint (ACF), Colorado, and Delaware River Basins as part of the WaterSMART initiative. A requirement for FASs is substantial involvement by stakeholders in development of the study scope. The USGS’s goal is to provide the information and tools that will allow basin stakeholders to answer the questions that they face about water availability. These three FASs completed most of their work in 2015, and additional products are scheduled for release in 2016. Some examples of the products available to stakeholders from each of these studies include water use data collected and compiled at a small watershed scale (HUC-8 or smaller scale) for at least eight sectors of use; tools that will allow managers to predict changes in streamflow; tools to address endangered species concerns in both the ACF and the Delaware River Basins; and novel approaches to quantifying groundwater contributions to streamflow

and new methods for estimating snowpack contribution to runoff in the Colorado River Basin. Each of the three FASs is planning for final stakeholder meetings in 2016.

Beginning in 2016, three new FASs will begin: the Coastal Carolinas, Red River, and Upper Rio Grande Basins. All three of the new FASs have held well-attended stakeholder meetings to ensure the proposed work provides the data and tools necessary for water managers in the basin. As a result of the meetings, the new FASs work plans were adjusted to meet stakeholder needs. Final products for the new FASs will be completed in 2018 and 2019.



Map of the Focus Area Studies

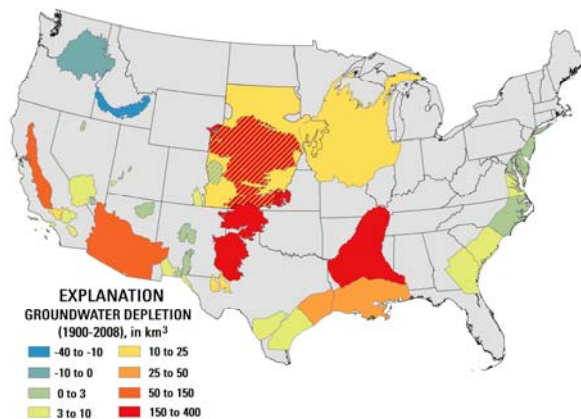
National Research Program

(2015 Actual, \$8.3 million; 2016 Enacted, \$6.9 million; 2017 Request, \$7.7 million)

Research and development are a foundation for the WAUSP. The development and application of new methods, models, tools, and decision support systems allow the USGS to remain in the forefront of water availability and use science. Specific support is provided for models that allow the user to estimate components of the water budget in locations where direct measurements are not available or for time periods when measurements were not taken. The outcome is a consistent set of water budget information across the Nation.

In 2015, USGS researchers completed an update to the Precipitation-Runoff Modeling System (PRMS) with improved processes for simulating streamflow for ungaged basins, land-cover change, climate change scenarios, environmental flows, and other applications. This modeling code is currently being applied throughout the Nation in the National Hydrologic Model, as well as in finer scale applications addressing local and regional water management issues. This model is also used as one of the methods for estimating daily streamflows at ungaged locations. Another product developed from this model code is the USGS software GSFLOW. GSFLOW provides a numerical tool to simulate the groundwater contribution to low flow events. USGS researchers led the development of a new version of GSFLOW, released in 2015, that can be used by the National Weather Service (NWS) for operational forecasting during low-flow conditions.

In a 2015 study ([http://www.ruralwaterresources.com/wp-content/uploads/2015/03/Paper-Long-Term-Groundwater-Depletion-in-the-United-](http://www.ruralwaterresources.com/wp-content/uploads/2015/03/Paper-Long-Term-Groundwater-Depletion-in-the-United-States.pdf)



States.pdf), the USGS documented that the volume of groundwater stored in the subsurface in the United States decreased by almost 1000 km³ during 1900–2008. The aquifer systems with the three largest volumes of storage depletion included the High Plains aquifer, the Mississippi Embayment section of the Gulf Coastal Plain aquifer system, and the Central Valley of California. Depletion rates accelerated during 1945–1960, averaging 13.6 km³/year during the last half of the century, and after 2000 increased again to about 24 km³/year. This information is important for water resource managers as it has important implications for the future of irrigated agriculture in these regions.

Ecosystems around the globe are facing multiple interacting forces of change into the coming decades. Ecosystem services in many cases, such as in San Francisco Bay, already are stretched and degrading, and it is unknown how most ecosystems will function in the future under the influence of drivers like climate change, water management, non-native species invasions, and ecosystem restoration. USGS research is contributing to improved understanding of the synergistic events of these drivers through the Computational Assessments of Scenarios of Change for the Delta Ecosystem (CASCaDE) project. The research is unique in that a series of climate, hydrologic, hydrodynamic, sediment dynamic, and exotic species models are linked and used to assess the cascading effects of possible future climate and management scenarios for the Sacramento-San Joaquin Delta ecosystem in California. In 2015, global climate models were downscaled for the Bay-Delta region, and were incorporated in CASCaDE to evaluate future flow scenarios for the basin, as well as to estimate sea level rise scenarios. Models to evaluate the effects of restored Delta habitats on phytoplankton in the Bay were developed and tested. The work is providing science-based information to support the Delta Stewardship Council in its co-equal goals of sustainable water supply and ecosystem protection. This overall approach of integrating physical, chemical, and biological interactions to new modeling approaches is transferable to other coastal ecosystems (e.g., Puget Sound, Chesapeake Bay, Biscayne Bay, etc.), all of which are facing similar challenges.

Research on and continued development of groundwater-flow models will continue in 2016 and 2017, in order to provide improved assessments of groundwater availability. A key component of this activity will be improving the ability to predict the effects of groundwater on streamflow. The CASCaDE activity will conclude in 2017, and will include final documentation of possible future water-resources and sea level scenarios in the Bay-Delta, including identification of potential mitigation actions to maintain and restore water and ecosystem resources.

2017 Program Change

WaterSMART: National Hydrologic Model (+\$750,000 for a total of \$1,050,000): The Committee on the Environment, Natural Resources, and Sustainability has recognized the need for a National Hydrologic Modeling Framework to advance understanding and forecasting of the water budget, to effectively manage water resources, and to adapt to a changing climate. The USGS currently has a national scale hydrologic model that addresses the major components of the water budget; however, human water use is not addressed explicitly. Moreover, information needed to operate the model must be obtained in a labor-intensive method. There is a need to assemble community modeling resources (i.e., datasets, models, use cases) to economize and enhance model development and verification activities across the community. Model development assumes continued community use of legacy

2017 Program Change

models and datasets rather than proposing a new model framework. Such an activity would improve and modernize access to resources that support development, verification, or model application for specific decision situations.

This work, conducted in collaboration with the EPA and the National Oceanic and Atmospheric Administration (NOAA) on major modeling and data generation activities, would accelerate collaborative development of a nationwide hydrologic model that accounts for all aspects of the water budget. Initially, the USGS would work to incorporate remote sensing, including lidar and geophysical data, to refine landscape-scale topography, landcover, geologic framework, soil moisture, evapotranspiration estimates, and changes in depression storage. The USGS would begin steps to improve linkages between surface and groundwater hydrologic models by accommodating variable grid sizes and time steps, nesting existing fine-scale models within coarse-scale regional models. Finally, initial steps would be taken to refine operation of surface water models in sub-daily mode to better forecast flood response in smaller basins.

Arctic – Critical Landscapes

(2015 Actual, \$0.3 million; 2016 Enacted, \$0.3 million; 2017 Request, \$2.2 million)

The Arctic is warming faster than any other region on Earth, and changes to the cryosphere are resulting in a cascade of hydrologic, biogeochemical, ecologic, and atmospheric consequences. The thawing of permafrost in the Arctic will have important economic consequences on roads and other infrastructure used for resource extraction and other activities that support local economies. The Arctic landscape change could accelerate climate feedbacks, including alterations in surface albedo and temperature, soil moisture, vegetation, carbon gas emissions, and atmospheric water vapor. The most urgent scientific and social questions stemming from a changing Arctic climate require a collaborative, interdisciplinary approach with input from and active involvement of multiple stakeholders.

Water is key to all ecosystem functions, including the carbon cycle. Additionally, rates of carbon processing are commonly much greater in inland waters than terrestrial landscapes, as they collectively store carbon in sediments, export carbon to oceans, and emit carbon dioxide and methane to the atmosphere. Terrestrial ecosystems are a dominant source of carbon to inland waters through surface and subsurface drainage networks. These networks are changing across boreal and arctic regions, as permafrost thaw, climate warming, and fire create new conduits for water movement, change vegetative water use and ET, and alter the distribution of water on the landscape. Understanding the dynamics of these changes in the water cycle is a first step in accurately projecting the effects of climate warming and other environmental drivers on arctic and adjacent ecosystems, and to develop science-based mitigation strategies.

In 2015, the WAUSP supported research to advance methods for documenting permafrost thaw using remote sensing to identify the depth of thaw and numerical modeling to evaluate the formation of water features that would not exist in the absence of thaw. Work will continue in 2016 and 2017.

2017 Program Change

Critical Landscapes: Arctic: (+\$1,950,000 for a total of \$2,200,000): The increase would address interactions among water-mediated processes in a warming Arctic, assess system feedbacks (e.g., effects of warming on hydrology and biogeochemical cycling which subsequently affects climate and hydrology), and better anticipate future system change via these assessments of the cryosphere. The work funded by this increase would expand monitoring of hydrologic (groundwater, surface water, thermos-karst features) and related biogeochemical (particularly carbon, nutrient, and mercury) cycles, and explore opportunities for predictions that allow extrapolation from monitored to unmonitored locations.

The WAUSP would also support the expansion and enhancement of monitoring of sentinels of change including permafrost temperature, streamflow, biogeochemical and other materials exported from watersheds, and carbon dioxide and methane exchange between land and water surfaces and the atmosphere. In particular, increased methane (a powerful greenhouse gas) emissions in high latitudes will be directly mapped to the availability and redistribution of liquid water as a result of permafrost thaw. This emphasizes the need for improved modeling of permafrost thaw. Ponds produced by thaw of ice-rich permafrost will likely be sites of high methane production, which will be supported by the Precipitation Runoff Modeling System model of Alaska will support modeled pond development.

Information Delivery

(2015 Actual, \$5.6 million; 2016 Enacted, \$5.6 million; 2017 Request, \$5.6 million)

The WAUSP supports the development, implementation, and maintenance of reliable systems for real-time and historic information delivery to all stakeholders that include data processing, quality assurance, storage, and readily available access. The funds ensure the operation and maintenance of the NWIS, which is critical to function at peak efficiency and effectiveness, especially during hazard events. NWIS provides current conditions related to streamflow, flood and high flow, drought, and groundwater levels, in addition to water quality and water use data. USGS water data products continued to see increased usage by stakeholders and the public. For NWISWeb, May 2015 was the busiest month on record serving over 73 million requests. That same month, for the first time, NWISWeb was viewed more on mobile devices than on desktops. For perspective, the recent Midwest flooding event resulted in nearly 400,000 views on December 28, 2015. One can compare NWIS Web usage with flooding alerts at (<https://water.usgs.gov/alerts/>).

In 2015, a number of improvements were made for how water information is distributed through USGS Water Web sites (Water Data for the Nation: <http://waterdata.usgs.gov/nwis> and the National Water Census: <http://cida.usgs.gov/nwc/>). The 2010 Water Use compilation dataset was published in addition to summary estimates of precipitation and evapotranspiration for watersheds across the conterminous United States. Public access to water information continued to increase to 1.5 million requests per day on average. Water Year summaries of streamflow are now available online along with open source software tools for analyzing characteristics of streamflow important for understanding water availability. Through a collaboration with NOAA and USACE's (Integrated Water Resources Science and Services, IWRSS), improvements to synchronized data were made including the exchange of streamgage ratings using Web services. A Soil Moisture Data Pilot project (http://cida.usgs.gov/nsmn_pilot/) was completed with

partners from NOAA, National Integrated Drought Information System, the USDA National Resources Conservation Service, and academia that integrate soil moisture measurements from across a number of local, regional and national sensor networks. To better communicate the persistent drought in California, a data visualization was developed within the Open Water Data Initiative:

http://cida.usgs.gov/ca_drought. A reporting tool was developed within the NWIS Modernization project to aid in the compilation and analysis of water data including water use information.

In 2016, plans include improving the Aggregated Water Use Data System software in preparation for the 2015 water use compilation. An improved hydrologic modeling system will be developed that assimilates water budget estimates more directly into software that estimates runoff and streamflow. Major improvements to the NWIS in 2016 include data management of water levels, streamflow, and other sensor data using software from Aquatic Informatics. All 46 USGS Water Science Centers will be migrated onto the new platform resulting in significant data processing and system management efficiencies. USGS Water Science Centers will also be migrating to the BioData system for the storage and distribution of aquatic biological data. Within the Open Water Data Initiative, standardization of water data will continue by using the National Hydrography Dataset for integrating water observations geospatially. Additionally, the release of the Lower Colorado Drought Visualization (<https://www.doi.gov/water/owdi.cr.drought/en/index.html>) in December 2015, with Reclamation and other partners, communicated the complex water-management challenges within the Colorado Basin using USGS water data.

In 2017, new capabilities will include estimates of water use and runoff within watersheds across the United States. This will require a modernization to the USGS water use data management system that includes an ability to exchange water use information with local, State and regional partners (potential partnership with Western States Water Council Water Data Exchange). Progress toward a National Soil Moisture network will also be pursued that integrates observations from in-situ sensors, satellite observations and citizen scientists. Soil moisture is critically important as an early detector of drought onset and as an indication of overall drought severity. Soil moisture data is currently fragmented across a myriad of Federal, State and local agencies and organizations—making regional and national decisionmaking using soil moisture information difficult. A pilot, in collaboration with National Institute for Discovery Science during 2015, has demonstrated the feasibility and value of integrating soil moisture information across several jurisdictions. A modernization of the groundwater and water-quality data management system will also be initiated in 2017, which will allow users to access the data more efficiently.

Technical Support

(2015 Actual, \$4.4 million; 2016 Enacted, \$4.4 million; 2017 Request, \$3.9 million)

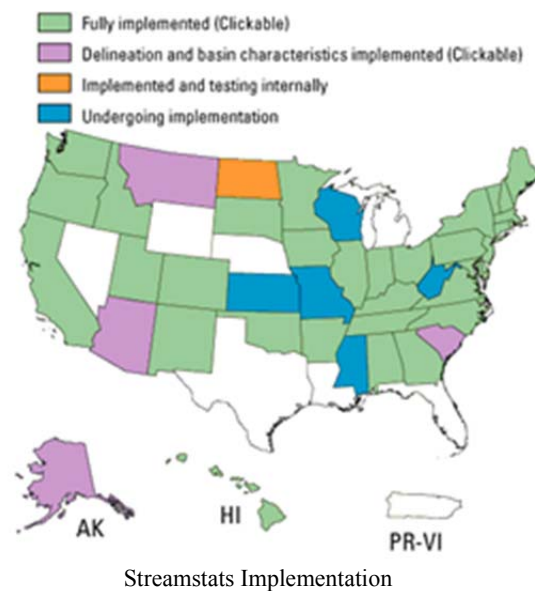
The WAUSP relies on the development and application of new technologies, methods, and models to remain on the cutting edge of hydrologic science. Continued support of resources such as the Groundwater Toolbox, hydrogeophysical tools, MODFLOW, and StreamStats are critical to the success of the WAUSP.

The Groundwater Toolbox, initially released in 2015, is a graphical and mapping interface for analysis of hydrologic data from the NWIS to estimate groundwater recharge from streamflow data. This powerful time-saving tool will be enhanced in 2016, and 2017, to provide similar capability using NWIS groundwater-level data.

Hydrogeophysical tools and techniques provide a view into the subsurface to cost-effectively increase our understanding of aquifer systems. In 2015, the USGS continued development and field testing of a borehole Nuclear Magnetic Resonance logging system; development, and testing of innovative active and passive seismic methods for groundwater investigations; and development, testing, and patenting of the Electrical Resistivity Infiltration Monitoring method for improving estimates of hydraulic conductivity and recharge rates in unsaturated sediments. In 2016 and 2017, the USGS will continue to support development of new tools and technologies to assist in water resource investigations including improving airborne electromagnetic methods for aquifer characterization. In addition, a national borehole geophysical log archive system will be developed.

MODFLOW is the USGS's three-dimensional finite-difference groundwater model and is considered an international standard for simulating and predicting groundwater conditions and groundwater/surface-water interactions (<http://water.usgs.gov/ogw/modflow/>). Originally developed and released solely as a groundwater-flow simulation code when first published in 1984, MODFLOW's modular structure has provided a robust framework for integration of additional simulation capabilities that build on and enhance its original scope. The family of MODFLOW-related programs includes capabilities to simulate coupled groundwater/surface-water systems, solute transport, variable-density flow (including saltwater), aquifer-system compaction and land subsidence, parameter estimation, and groundwater management. In 2015, USGS released MODFLOW-USG, a version of the code designed to improve our ability to simulate complex hydrogeological structures and improve simulation efficiency. During 2015 and 2016, the fundamental structure of the MODFLOW code is being redesigned for the first time since 2005, in order to take advantage of modern computing advancements. This new version of the international standard software for groundwater modeling will be released in 2017.

The USGS operates national databases and information delivery systems that provide base data and statistical information needed by Federal, State, tribal, and local agencies that allocate or permit water use or allocate water rights. Many of these agencies rely extensively on USGS StreamStats, a national, Web-based, GIS program designed to serve flow statistics and basin characteristic data for gaged and ungaged locations. These agencies use StreamStats for a variety of purposes such as estimating the risk of inadequate streamflows, establishing minimum release requirements for dams, determining safe



discharge rates for water treatment plants, and for the design of irrigation works and water treatment plants. StreamStats is also used extensively by many State Departments of Transportations for designing transportation infrastructure. Indeed, thirty-eight States have at least one set of regression equations implemented through StreamStats.

During 2015, the USGS launched a major effort to improve StreamStats. The effort included a new user interface and a Web services framework. In 2016 and 2017, the StreamStats database will take advantage of the new high-resolution National Hydrography Dataset-plus (NHD-plus) as the data become available. In addition, StreamStats will convert some functionality into a cloud-based architecture that will speed service, expand coverage, and provide a more reliable system.

In 2016 and 2017, the USGS will work in partnership with the EPA, to develop new software for statistical analysis of streamflow. The new software, called SWToolbox, delivered via Web services, will permit Federal, State, and local agencies to quickly and consistently characterize flow statistics from USGS streamflow records.

Science to Support Collaboration

The WAUSP works with States, municipalities, and Tribes on cooperative water efforts. Cooperators choose to work with the USGS because of its broad, interdisciplinary expertise; high-quality, nationally consistent procedures and quality-assurance; innovative monitoring technology, models, and research tools; and robust data management and delivery systems that provide readily available public access to national data. In addition, other partners include:

- USACE
- EPA
- Reclamation
- NPS
- FWS
- Bureau of Land Management (BLM)
- Department of Defense (DOD)
- National Aeronautics and Space Administration (NASA)
- Department of Commerce (Commerce)
- Department of State
- Department of Homeland Security(DHS)
- DOT
- USDA
- DOE

The Water Resources Mission Area partners provided \$286,500,000 of reimbursable funding in 2015.

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Activity: Water Resources

Subactivity: Groundwater and Streamflow Information Program

Dollars in Thousands	2015		2016		2017	
	Actual	Enacted	Fixed Costs	Program Changes	Request	Change from 2016 Enacted
Water Resources	\$211,267	\$210,687	\$957	\$16,348	\$227,992	\$17,305
<i>FTE</i>	<i>1,371</i>	<i>1,345</i>		<i>29</i>	<i>1,374</i>	<i>29</i>
Groundwater and Streamflow Information Program	\$69,707	\$71,535	\$222	\$1,200	\$72,957	\$1,422
<i>FTE</i>	<i>383</i>	<i>384</i>		<i>7</i>	<i>391</i>	<i>7</i>
National Streamflow Network Tribes	\$49,378	\$50,180		\$500	\$50,680	\$500
	<i>[\$2,000]</i>	<i>[\$2,000]</i>		<i>[\$500]</i>	<i>[\$2,500]</i>	<i>[\$500]</i>
Groundwater Network and the National Groundwater Monitoring Network	\$6,800	\$7,930		\$0	\$7,930	\$0
Water Hazards	\$2,560	\$2,560		\$700	\$3,260	\$700
<i>Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages</i>	<i>[\$2,560]</i>	<i>[\$2,560]</i>		<i>[\$700]</i>	<i>[\$3,260]</i>	<i>[\$700]</i>
National Research Program and Technical Support	\$8,779	\$8,825		\$0	\$8,825	\$0
Information Delivery	\$2,190	\$2,040		\$0	\$2,040	\$0

Justification of Program Changes

The 2017 Budget Request for the Groundwater and Streamflow Information Program is \$72,957,000 and 391 FTE, a net program change of +\$1,422,000 and +7 FTE from the 2016 Enacted level.

Overview

Monitoring networks that generate hydrologic data are the foundation of understanding the Nation's water resources. The Groundwater and Streamflow Information Program (GWSIP) encompasses the Water Resources Mission Area's objectives to collect, manage, and disseminate consistently high-quality and reliable hydrologic information in real-time and over the long-term, which are both critical for managing our Nation's water resources and anticipating and responding to water hazards that can result in loss of life and property.

The GWSIP serves as the national source of impartial, timely, rigorous, and relevant data for short- and long-term water decisions by local, State, tribal, regional, and national stakeholders. Decisions based on continuous real-time water data are needed for (but not limited to) emergency response, flood forecasting, reservoir releases, water use restrictions, drinking water deliveries, permit compliance, water-quality studies, and recreational safety. Decisions based on long-term data are needed for water-supply planning; aquifer storage and recovery; reservoir, dam, bridge, and transportation infrastructure design; floodplain

and ecosystem management; energy development; resolution of interstate and international water disputes; and forecasting changing water conditions due to land use and climate changes. Access to water information is increasingly more critical as our climate and land use changes and our populations grow, driving an even higher need to sustain water for competing water priorities.

Historically, the collection and dissemination of hydrologic information have been managed through multiple USGS programs, including in large part, the Cooperative Water Program (CWP) and the National Streamflow Information Program (NSIP). Beginning in 2016, the USGS is managing the information and funded in the GWSIP to enhance its comprehensiveness and interdisciplinary value and more effectively represent key components of the hydrologic cycle (including surface water, groundwater, evapotranspiration, and precipitation).

Vital components of the GWSIP include:

- Unified national unified streamgaging network of more than 8,100 real-time streamgages and a growing network of interdisciplinary “Super Gages.”
- Groundwater-level networks, including the collaborative NGWMN.
- Development and application of hazard information and tools to minimize loss of life and property.
- Research, development, and application of innovative techniques and technical oversight for cost-effective monitoring.
- Management and development of instrumentation through the Hydrologic Instrumentation Facility (<http://water.usgs.gov/hif/>).
- Information management and delivery of hydrologic data.

In 2017, the GWSIP is requesting an increase in funding to expand the use of flood inundation mapping and rapid deployable streamgages and to strengthen technical information needed to support Indian water rights settlement work. For more information, on these requested increases, please see the text boxes below.

Program Performance

The GWSIP is made up of the following five program components: National Streamflow Network; Groundwater and the NGWMN; Water Hazards; National Research Program and Technical Support; and Information Delivery.

National Streamflow Network

(2015 Actual, \$49.4 million; 2016 Enacted, \$50.2 million; 2017 Request, \$50.7 million)

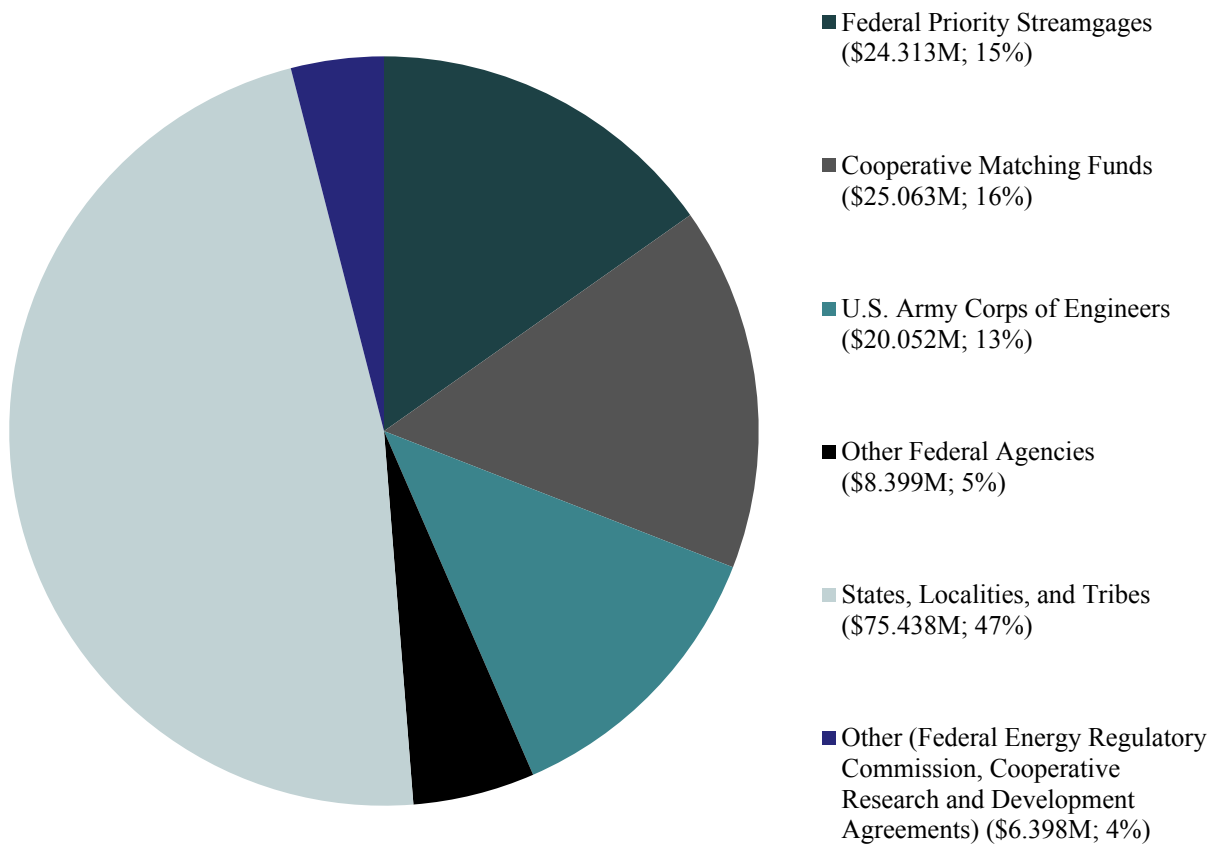
In 2015, the USGS Streamflow Information Network (hereafter referred to as the Network) provided streamflow information at more than 8,100 streamgages (<http://waterwatch.usgs.gov/>) across the Nation. The USGS provides a continuous source of streamflow information (<http://water.usgs.gov/data/>) that is

used in countless ways by governmental organizations, private industries, and the general public. Serving as the largest water data holder in the world, the information provides the scientific basis for decision making related to protection of life and property from water-related hazards, such as floods; cost-effective management of freshwater that is safe and available for drinking, irrigation, energy, industry, recreation, and ecosystem health; and national, State, tribal, and local economic well-being.

To provide reliable streamflow information across the Country—information that is available to every citizen—the USGS works in partnership with more than 850 Federal, regional, State, tribal, and local agencies. The latest streamflow information is available as alerts to users (<http://water.usgs.gov/waternow/>) by email or text message and as real-time stream conditions (<http://waterdata.usgs.gov/nwis/rt>), updated at intervals of one hour or less.

In 2015, the Network funding was approximately \$160 million, including USGS appropriated funding (about 31 percent through the former CWP and NSIP programs); reimbursable funding from local, State, and tribal Cooperators through jointly funded agreements (about 47 percent); reimbursable funding from other Federal agencies (about 18 percent); and various other types of reimbursable funding as indicated in the graphic below (about 4 percent). The breadth of partnerships reflects widespread recognition and support by USGS stakeholders on the agency’s critical role and primary responsibility for collecting, analyzing, managing, and delivering streamflow information.

Support for USGS Streamgages in 2015 - About \$160 million



The USGS places utmost importance on high quality, accessible, and consistent streamflow measurements over the full range of streamflow conditions to reduce uncertainty and to position the United States for a future that may hold unanticipated challenges, such as related to bigger and (or) more frequent floods, more sustained droughts, and changes in snowpack regimes. In addition, the USGS prioritizes *robustness* of the 8,100 streamgauge network in order to cover a broad range of watersheds and streamflow conditions across the Nation. A robust network is vital to support hydrologic research needed to characterize regional streamflow and estimate streamflow at ungaged locations, which is essential because it is not economically feasible to measure all rivers and streams at all the important locations. And yet, streamflow information is needed at ungaged locations; for example, Federal and State transportation agencies annually estimate flood-frequencies for designing and upgrading hundreds of bridges at ungaged locations across the Nation.

One of the highest goals of the USGS is to maintain long-term stability of a “Federal needs backbone network” for long-term tracking and forecasting/modeling of streamflow conditions in response to changes in land use, water use, and climate. Specifically, consistent and systematically-collected information is paramount to meet the full gamut of Federal water priorities and responsibilities over the long term (formerly developed as five goals of the NSIP design) related to:

- Forecasting extreme hydrologic events (floods and droughts).
- Interstate agreements, compacts, court decrees and other legal obligations.
- Streamflow tracking in major river basins and across borders.
- Long-term streamflow forecasts due to population growth and changes in land use, water use, and climate.
- Water-quality assessments on sources, transport, and fate of contaminants in major rivers and estuaries.

In 2015, approximately 3,100 streamgages in the Network were identified as meeting these strategic long-term Federal priorities and responsibilities. These Federal high-priority streamgages were funded by the NSIP, the CWP, and USGS partners. In 2015, a total of 1,138 streamgages were fully funded by the USGS (through NSIP), which increased the number of USGS fully funded streamgages by 162 relative to 2014, and nearly 350 since 2013. In general, these streamgages had been supported by other funding sources that may be less stable over the long term or reactivated after being discontinued because of funding reductions in recent years. An increase of \$1.2 million to NSIP in 2015 helped build upon this investment and continued the expansion and improved stabilization of Federal priority streamgages.

The remaining 5,000 streamgages in the Network also are integral to the USGS mission and national water priorities related to hazard mitigation and water availability for human and ecosystem health. These 5,000 streamgages were supported by the CWP, in concert with Cooperators and other USGS partners. The streamflow information is used to facilitate management decisions, operations, and

"Elwha River streamflow data are invaluable for successful management of the Tribe's fish hatchery and monitoring recovery of the Elwha River ecosystem following dam removal." Doug Morrill, Natural Resources Director, Lower Elwha Klallam Tribe

responsibilities by other Federal agencies, States, localities, Tribes, regional commissions, industry, and non-governmental organizations. Most streamgages provide information to stakeholders serving more than one use, related to, for example:

- Water resource appraisals, allocations, and diversions (water supply/water use/water budgeting).
- Infrastructure planning and design for reservoirs, bridges, roads, culverts, and treatment plants.
- Operation of reservoirs, power plants, flood-control systems, and navigation locks and dams.
- Instream flow requirements for ecosystems and habitat.
- Management of groundwater pumping and depletion.
- Flood plain mapping and planning.
- Tide monitoring and prediction.
- Recreational safety and enjoyment.



USGS streamflow information is widely used for recreational activities, as shown in the photo above of canoeists enjoying the Shenandoah River in western Virginia. Information about how high or low water is in a stream or how fast water is flowing benefits countless outdoor enthusiasts, from canoeists and whitewater rafters, to fisherman and swimmers alike. The USGS continues to expand uses of streamflow information with the recreational community, including with outfitters and other non-governmental organizations, which need streamflow information on a real-time basis for operations and management of natural resources.

In 2015, the USGS continued to work with other Federal, State, local, tribal, regional, and non-governmental partners to minimize streamflow information gaps by adding streamgages in unmonitored watersheds and by collecting needed ancillary watershed information to better estimate streamflow at ungaged locations. For example, other Federal agencies continued to rely on streamflow information to meet their respective obligations, such as the NWS for predicting floods using information from more than 4,000 streamgages; the Federal Emergency Management Agency (FEMA) for identifying flood prone areas; the USACE for operation of locks and dams; the Reclamation for dam and water conveyance systems operations; and the National Park Service (NPS) and the U.S. Fish and Wildlife Service for managing water resources and ecosystems. For example, the USGS and the NPS jointly operated more than 600 streamgages in 2015 within or near national parks; the USACE supported (partially or fully) USGS streamgages at more than 1,965 stream locations.

The USGS responded to flooding across the Nation in 2015. Information was immediately released in timely flood alerts (<http://water.usgs.gov/floods/>) throughout the year and in USGS publications. For example, heavy rainfall occurred across South Carolina during October 2015 as a result of an upper atmospheric low-pressure system that funneled tropical moisture from Hurricane Joaquin into the State. The storm caused major flooding from the central to the coastal areas of South Carolina. USGS streamgages recorded peaks of record at 17 locations, and 15 other locations had peaks that ranked in the

top five for the period of record. During the October 2015 flood event, USGS personnel made about 140 streamflow measurements at 86 locations to verify, update, or extend existing streamflow rating curves, which are used to compute streamflow from monitored river levels. Findings were published in a USGS report (<http://pubs.usgs.gov/of/2015/1201/ofr20151201.pdf>) in November 2015.

At the opposite end of the hydrologic spectrum, 2015 continued drought across large parts of the Nation. Information from over 4,000 long-record streamgages was used by the USGS and partners to determine the extent, duration, and severity of droughts and to allocate water for critical uses. For example, the USGS closely monitors the development and effects of drought through data collection and research, and is studying the current California drought in the context of long-term hydrologic, climatic, and environmental changes. These studies support successful planning and science-based decision making

(<http://ca.water.usgs.gov/data/drought/drought-water-decisions.html>) by water managers who must address complex issues and competing interests in times of drought. They also help decision makers prepare for climate change and possible future drought.

California's 2015 water year (which ended September 30, 2015) was one of the warmest years on record. In April 2015, the California Department of Water Resources (<http://www.water.ca.gov/>) measured the statewide water content of Sierra snowpack (<http://cdec.water.ca.gov/cdecapp/snowapp/sweq.action>) at five percent of average. These levels were lower than any year in records going back to 1950.

Snowpack provides about one-third of the water used by California's cities and farms.

In 2015, USGS Water Science Centers in California, Idaho, Nevada, Oregon, Utah, and Washington collected streamflow information and other hydrologic data, to document the severity and extent of drought in Water Year 2015 (October 1, 2014 to September 30, 2015) and to assess the vulnerability of water resources in the Western United States to climate change. The spring snowpack in 2015 was extremely low compared to normal conditions across the western United States. Moreover, the precipitation that did occur was more often in the form as rain than as snow compared to long-term climate averages. This baseline information will be helpful with the WAUSP's 2017 requested increase to determine the importance of snowmelt in the hydrologic cycle.

The USGS continues to expand the existing streamgage infrastructure to integrate many types of monitoring sensors, which record and transmit hydrologic data at key monitoring locations. (As defined

Flood Forecasting

Dependence on USGS streamflow data is most visible, and USGS streamgaging activities take on the most urgency, during floods. Practical, unbiased streamflow information is used across the Nation to protect and minimize loss of life and property from water-related hazards, such as floods. Because all locations provide information over the full range of streamflow conditions—extreme lows (droughts) to extreme highs (floods)—with a high level of certainty, streamflow information at all 8,100 streamgages is critical during extreme events for forecasting streamflow and emergency response, whether it is at a large river draining a large populated watershed or a small, high impact basin vulnerable to fast, flash flood events.

The NWS is the Federal agency charged by law with the responsibility for issuing river forecasts and flood warnings, but it depends on up-to-date, accurate, and reliable information to provide the service.

The USACE adjusts flood-control reservoir releases; the Coast Guard issues shipping directives and advisories; and States, Tribes, and local communities prepare for floods based on USGS river measurements.

Increasingly, emergency managers with localities and States and the general public use the real-time information and dynamic flood inundation maps (<http://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html>) to see the expected extent of a flood on a street-by-street basis, hours or even days before it occurs, reducing the possible devastating toll of floods on communities.

in the *USGS Water Science Strategy—Observing, Understanding, Predicting, and Delivering Water Science to the Nation*, <http://pubs.usgs.gov/circ/1383g/>, pages 12-13.) Examples of the type of hydrologic data transmitted include meteorological data (precipitation and evapotranspiration) and physical data such as water temperature and water velocity through optical or hydroacoustic technology. The physical infrastructure of a streamgage and the data recording and telemetry instrumentation it contains makes the streamgage an ideal platform for measuring and transmitting a variety of parameters simultaneously in real time and over the long term, which helps to manage water resources during floods and droughts and over long periods due to changes in water use, land use, and climate. Two examples of recent Super Gages include the Illinois River at Florence, Illinois (*USGS streamgage 05586300*, http://waterdata.usgs.gov/nwis/inventory/?site_no=05586300&agency_cd=USGS), which drains 26,870 square miles of agricultural and urban land, and the White River at Hazleton, Indiana (*USGS streamgage 03374100*, http://waterdata.usgs.gov/nwis/inventory/?site_no=03374100&agency_cd=USGS), which drains more than 11,000 square miles of primarily agricultural land. Parameters collected at these Super Gages include water level (stage), streamflow, water velocity, water temperature, nutrients, and suspended sediment. In 2015, nine additional Super Gages were added in Illinois in partnership with the Illinois Environmental Protection Agency and other partners to provide nutrient and sediment loading information as an integral part to the Illinois Nutrient Loss Reduction Strategy. Streamgages are critical for providing flow information needed to determine the total quantity of the nutrients and sediment transported in the streams and rivers.

In 2016, the Congress appropriated additional funding to support streamflow information. The increase supports continued expansion and stabilization of Federal priority streamgages and information over the full range of hydrologic conditions, which is particularly important in managing impacts from floods, drought and climate. It also supports flood hardening and infrastructure enhancements at critical streamgages; expanded use of streamgages for hazard response; increased capabilities in calculating uncertainty in streamflow (particularly during extreme hydrologic events); and for continued expansion of streamgage uses with the recreation community. In addition, the increase is funding tests to determine the potential of estimating streamflow in remote areas, such as in the Alaska frontier and for using remote sensing-based methods of stream discharge estimation for seasonal (“open flow”) streams. A mix of reaches, at least one from within the lower 48 States and in Alaska, will be selected to provide a range of available data and technical challenges. Field data collection will be conducted for model accuracy assessment and as required for some candidate remote sensing techniques. Where required for technique implementation, the benefit of field data collection and requirements for operationalization to USGS standards will also be assessed.

2017 Program Change

Tribes: (+\$500,000 for a total of \$2,500,000): The USGS is not directly involved with Indian Water Rights settlement. The USGS instead provides technical information to support Indian Water Rights settlement work that is then given to decision makers. The increase will enhance streamflow information to support tribal needs and decisions. Monitoring, along with assessments, and research, would help address availability issues on tribal lands including such topics as water rights, water use, hydrologic conditions, and water-quality issues. This will allow tribal river managers to develop effective strategies to maintain water supplies and restore critical habitats and healthy ecosystems. The cooperative funding would be allocated in coordination with the Secretary’s Indian Water Rights Office and other bureaus (including the Bureau of Indian Affairs and Reclamation) that support the Federal trust responsibility for water in Indian Country. This funding being requested would be part of the cooperative matching funds.

There are large costs associated with supporting streamflow information during extreme events that requires around-the-clock USGS work as well as significant equipment investment. The USGS often does not receive financial relief from Congress to address the large unpredicted costs. The USGS in turn has to redirect funding from other areas within the USGS to address these needs. In 2015, the USGS incurred more than \$1.2 million in extraordinary expenses responding to floods, including:

- Extreme flooding in South Carolina (described above) which cost more than \$0.4 million to support equipment losses, travel, and labor.
- Flooding in May 2015 in Oklahoma, Kansas, Texas and Nebraska cost more than \$0.6 million to support expenses.

“The USGS continues to provide long-term and timely assistance to the City of Austin. The improvements and the additions that the USGS made to the gage network after the Halloween 2013 flood greatly enhanced the City’s ability to manage the Halloween 2015 flood. We especially appreciate the technical expertise and professionalism of the USGS staff. The USGS provides superior support throughout the year, but especially during the times of flooding. We appreciate being a cooperative technical partner with them and look forward to continuing this relationship in the future.” Kevin Shunk, P.E., City of Austin, Texas

Supplemental funding post extreme events would help the USGS to: (1) continue to expand and stabilize streamgages and information over the full range of hydrologic conditions, from floods to drought, as well as to support flood hardening and infrastructure enhancements at critical streamgages across the United States; (2) install Super Gages; (3) statistical estimates of streamflow at ungaged sites where it is not feasible or practical to place a streamgage; (4) calculate the uncertainty in streamflow (particularly during extreme hydrologic events) at gaged and ungaged locations; and (5) continue to expand streamgage uses with the recreation community. In 2017, the USGS will continue to leverage the Network and Super Gage network, where possible, in collaboration with local, State, tribal, Federal and non-government partners.

In December 2015 and January 2016, USGS field crews measured record flooding on rivers and streams in 12 States across the United States (<http://water.usgs.gov/floods/events/2016/winter/>). USGS hydrologists and field crews collect this critical flood information for emergency forecasting and response, taking flood measurements, collecting water samples, repairing damaged streamgages and flagging high water marks (<http://water.usgs.gov/edu/highwatermarks.html>). The USGS collected critical streamflow data that were vital for protection of life, property and the environment. These data are used by the NWS to develop flood forecasts, the USACE to manage flood control and local agencies in their flood response activities (http://water.usgs.gov/floods/photo_vid_archive/2016_winter/bob_holmes_twc_12_31.mp4).

Groundwater Network and the National Groundwater Monitoring Network
(2015 Actual, \$6.8 million; 2016 Enacted, \$7.9 million; 2017 Request, \$7.9 million)

The quantity of groundwater in an aquifer is an important factor in determining water availability. In 2015, water levels were monitored in about 25,000 wells; groundwater levels were measured in real-time in about 1,500 wells; and the response of groundwater levels to changes in climate was measured in more than 650 wells.

The USGS works in collaboration with States, Tribes, and localities to monitor groundwater levels that help to increase understanding of groundwater flow (totaling more than \$4.0 million in cooperative matching funds). For example, the USGS, in cooperation with the Colorado Water Conservation Board and Reclamation, established a groundwater monitoring network on the east side of the Uncompahgre River Basin in southwestern Colorado. The network provides the managers with lithologic understanding, well characteristics, and water levels, which will ultimately help understand groundwater connections to surface water.

The USGS, in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey, measured water levels in the Ozark aquifer within Arkansas. The Ozark aquifer is the largest aquifer, both in area of outcrop and thickness, and the most important source of freshwater in the Ozark Plateaus physiographic province, supplying water to northern Arkansas, southeastern Kansas, southern Missouri, and northeastern Oklahoma. The study area includes 16 Arkansas counties lying completely or partially within the Ozark Plateaus of the Interior Highlands major physiographic division.

In 2015, planning and development of the NGWMN design continued (supported by about \$2.7 million). The design was proposed in 2009 by the Advisory Council of Water Information in response to the SECURE Water Act (P.L. 111-11), which authorized a collaborative groundwater network among Federal, tribal, State, and local agency data providers. In 2015, six non-competitive, one-year cooperative agreements were established with State agencies in Utah, Montana, Texas, Illinois, Oregon, and South Carolina to continue groundwater network development and implementation; to set up Web services that link data to the NGWMN portal; and to produce a report. Planning continued for

“USGS crews are working around the clock to make accurate flood measurements available to the Army Corps of Engineers, National Weather Service, and emergency managers for flood forecasting and flood-control operations. Our team is working closely with other agencies, like the U.S. Coast Guard, to assist with the logistics of gaining safe access to rivers for our USGS field crews. This was especially true as we prepared for the Mississippi River crest in St. Louis.”
USGS National Flood Coordinator, Bob Holmes

Water Resources

implementation of non-competitive cooperative agreements in 2016 with North Carolina, Delaware, Kansas, Oklahoma, and Mississippi.

A National Program Board was developed to evaluate NGWMN proposals received in 2016. The USGS continued upgrades to the NGWMN portal (<http://cida.usgs.gov/ngwmn/>) to accommodate additional data providers and increased use. The USGS also continued the refinement of a national network of wells across the Nation that meet design criteria related to quality, accessibility, density, and frequency of measurements and goals of the NGWMN design framework (http://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf). A total of 529 groundwater level sites and 69 groundwater quality sites were added to the NGWMN in 2015.

The USGS restructured the Climate Response Network (CRN) to provide Federal support for a CRN site with continuous, real-time instrumentation, in each Climate Division in each State and U.S. territory as outlined in P.L. 111-11. These data are critical as a measure of groundwater conditions during drought. Instrumentation for 40 new real-time CRN sites was funded. The USGS Water Science Centers provided useful information for the development of the national CRN. For example, a USGS report (<http://pubs.er.usgs.gov/publication/ofr20151062>) released in 2015 describes a framework for hydrologic monitoring in six States in New England, identifying specific inland hydrologic variables that are sensitive to climate variation; geographic regions with similar hydrologic responses; and a proposed fixed-station monitoring network composed of existing streamflow, groundwater, lake ice, snowpack, and meteorological data-collection stations for evaluation of hydrologic response to climate variation.

In 2016, the USGS received an increase of \$1.0 million for the NGWMN. The funding will support cooperative agreements with new and existing data providers and enhance the expansion of the CRN. In 2017, no additional funding was requested for the NGWMN. The USGS will continue to work with local, State, tribal, and other Federal partners to enhance groundwater monitoring in principal aquifers heavily used for water supply, irrigation, energy, and other uses in order to develop a more nationally consistent federally funded backbone of groundwater monitoring stations, and to continue to track effects of climate and drought on groundwater levels over the long term.

Water Hazards

(2015 Actual, \$2.6 million; 2016 Enacted, \$2.6 million;
2017 Request, \$3.3 million)

The GWSIP promotes the development and application of information and tools to minimize the loss of life and property due to hazards, including, for example, support for flood forecasting, storm surge monitoring during hurricanes and floods (through storm tide sensors and Rapidly Deployable Streamgages), drought, debris flows, and fires. The USGS Flood Event Viewer (<https://water.usgs.gov/floods/FEV/>) provides a one-stop application for partners and the public to view all flood data for a particular event, including USGS flood

“America has launched a new era of increased coordination and collection of groundwater data to better inform decision-making by water resource managers. This data will be used to generate a more comprehensive picture of groundwater on a national scale. With increased pressure on water resources, particularly in the West, the implementation of the National Ground Water Monitoring Network will help inform good management of groundwater supplies across the country. This is important to the continued use of water wells as a source of safe drinking water for millions of Americans who rely on either a public water system or on a privately owned household well.” Kevin McCray, CEO, National Ground Water Association

response, streamflow information, and high-water marks. A new USGS Floods Web page (<http://water.usgs.gov/floods/>) now provides access to a range of USGS tools and datasets for current and past events.

USGS enhanced flood inundation mapping (<http://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html>) capabilities in order to provide emergency managers and the public with ready access to flood inundation information. The USGS, in concert with the NOAA, USACE, and local and State agencies, continue to enhance standardized geospatial flood inundation models and maps indexed to real-time streamgages that show floodwater extent and depth on the land surface. These flood forecasting tools are used for flood response and mitigation and enable emergency management officials at local, State, tribal, and Federal levels to assess flood threats and to see, along with the general public, on a street-by-street basis, the expected extent of a flood hours, or even days, before it occurs.

In 2015, 36 flood inundation maps (http://water.usgs.gov/osw/flood_inundation/libraries.html) were made available for stream reaches, contributing to a total of 82 maps spanning 16 different States. Flood inundation maps are done in cooperation with States, localities, and Tribes through support of cooperative matching funds. For example, in 2015, maps were made in cooperation with:

- DeKalb County, Georgia, for South Peachtree Creek.
- Indiana Office of Community and Rural affairs for Tippecanoe River at Winamac, Indiana and White River in Indianapolis.
- City of Lansing for Grand River, Red Cedar River and Sycamore creek near Lansing, Michigan.
- City of Kansas City for the Missouri Blue River and selected tributaries near, Kansas City, Missouri.
- New Jersey Department of Environmental Protection for the Hohokus Brook in Waldwick Borough, Ho-Ho-Kus Borough, and the Village of Ridgewood, New Jersey.

The USGS is working in cooperation with other Cooperators and expects the release of more than 20 flood inundation maps in 2016.

The USGS continues to expand the use of storm tide sensors that measure tidal fluctuations and height of the tide relative to land surface. These sensors are part of a relatively new USGS mobile network of rapidly deployable, experimental instruments that are used to observe and document hurricane-induced storm-surge, waves and tides as they make landfall and interact with coastal features. This network, known as *USGS SWATH* (<http://water.usgs.gov/floods/swath/>), consists of water-level and barometric-pressure monitoring devices that are deployed in the days and hours just prior to a potential widespread storm-surge event, and then retrieved shortly after event occurrence. In fall 2015, the USGS deployed storm tide sensors along the U.S. eastern coast in an effort to

“Flood inundation maps are vital for emergency response planning for the communities. They help guide placement of scarce state resources during a flood event, assist in the delineation of the damage areas and guide preliminary damage assessment teams to document damages for a Federal declaration as well as provide documentation for mitigation grant applications.” Manuela Johnson, State Disaster Relief Fund, Indiana Department of Homeland Security

measure storm-tides associated with Hurricane Joaquin.

The network also includes a smaller number of Rapid Deployment Gages (RDGs), which are temporary water-stage sensors with autonomous data-transmission capacity. The RDGs provide temporary real-time information to flood-threatened communities that lack permanent USGS streamgages. RDGs are set up in advance of an event to provide short-term water-level and meteorological data during the event for areas that are particularly vulnerable to the effects of storm surge. RDGs can be installed, rated, and ready to broadcast data within hours to monitor flood heights and approximate flood flows, especially as the water levels approach elevations requiring careful management of reservoir releases or close scrutiny of levee performance.

2017 Program Change

Expand Use of Flood Inundation Mapping and Rapid Deployable Streamgages: (+\$700,000 for a total of \$3,260,000): The USGS would use the increase to expand the use of flood inundation mapping and RDGs. There is an urgent need to develop the means for providing the same information to flood-threatened communities that lack a permanent USGS streamgage. The increase supports a focused, expansion to further test and operationalizes this RDG technology. Implemented together, the flood-inundation and RDGs systems provide crucial flood data needed to help manage flood response activities.

The increase would be used to expand the present library of flood-inundation maps based on present technologies. Effective flood-damage mitigation and flood response also requires timely, reliable, and real-time information about river levels, flood flows, and geospatial understanding of the extent and timing of potential flood inundation, all of which the USGS is uniquely positioned to provide. The USGS, NOAA, the FEMA, and the USACE engaged in joint efforts to standardize new flood-inundation mapping processes, enabling emergency management officials at the Federal, State, tribal, and local level to assess, in both real time and in advance, the threat that flooding poses to public facilities, businesses, and homes. For the first time, emergency officials and the public can know the forecasted height of floodwaters, and can see on a street-by-street basis, the expected extent of a flood hours or even days before it occurs. However, these maps require extensive field data-collection to develop and calibrate.

National Research Program and Technical Support

(2015 Actual, \$8.8 million; 2016 Enacted, \$ 8.8 million; 2017 Request, \$8.8 million)

The GWSIP promotes research, development and application of new methods, equipment, sensors, platforms, software development, and techniques for monitoring, which results in cost savings and allows the USGS to remain in the forefront of hydrologic observations. The GWSIP also funds technical support to assure high quality, reliable and reproducible measurements with known accuracy and well-tested, documented methods of surface water and groundwater over the full range of hydrologic conditions—at extreme lows and highs. Specific support is provided for quality control, technology transfer, method and technology development and standardization, priority setting, and management of the USGS Hydrologic Instrumentation Facility.

In 2015, enhanced technical support resulted in many advancements, including more timely correction of time-series data displayed on the Internet; improved verification of peak-stage data for streams; improved verification and calibration of groundwater tapes and field methods for measuring ground-water levels (<https://pubs.er.usgs.gov/publication/ofr20151137>); telemetry coordination; verification and calibration of water-velocity meters (<https://pubs.er.usgs.gov/publication/ofr20151139>); continued improvement, evaluation, and verification of hydroacoustic equipment and water-level instruments; and nationwide training on basic electronics and water-monitoring equipment.

A 2015 USGS study (<http://onlinelibrary.wiley.com/doi/10.1002/rra.2939/abstract>) published in the journal *River Research and Applications* presents an extensive analysis of temporary (intermittent) streams across the western plains and southwest regions of the conterminous United States; and describes their sensitivity to past climate. Five distinct types of intermittent streams with record lengths of generally over 40 years and with minimal direct human influence were identified. Processes included the timing of precipitation, antecedent soil-moisture conditions, snowmelt, and evaporation, which were investigated as to their effects. Notably, the duration of wet and dry periods were found to affect the seasonality of streamflow at intermittent streams, but the intensity of precipitation events had little effect. The sensitivity of streamflow to variability in precipitation suggests that potential future drying and wetting patterns in precipitation would impact streamflow at intermittent streams.

Studies involving groundwater/surface water exchange are a major, and growing, part of USGS science investigations. A variety of streamflow (baseflow separation) and groundwater-level (water table fluctuation) approaches often are used to quantify groundwater/surface water exchange. Research has shown that a suite of these approaches—a “tool box”—is the most effective way to apply these approaches. In 2015, USGS scientists released the Groundwater Toolbox, a single software tool that allows users to generate results from multiple groundwater/surface water exchange research methods and easily compare them (<http://pubs.usgs.gov/tm/03/b10/>).

USGS research associated with the GWSIP also has advanced knowledge of debris flow hazards. Hydrologic processes during extreme rainfall events are poorly characterized because of the rarity of measurements. Improved understanding of hydrologic controls on natural hazards is needed because of the potential for substantial risk during extreme precipitation events. A study by the USGS and others helps define landscape characteristics that make slopes most vulnerable to destructive debris flows (<http://geology.gsapubs.org/content/43/8/659>).

Large destructive wildfires have ravaged the Western United States in recent years, and the scarred landscapes they leave behind are subject to catastrophic floods and debris flows. USGS research is being conducted to understand and better prepare communities for these hazards. Recent research demonstrates techniques to measure the initiation of runoff in areas scarred by wildfire (<http://onlinelibrary.wiley.com/doi/10.1002/esp.3704/abstract>) and describes how wildfire burn severity affects runoff and flooding after fires (<http://www.publish.csiro.au/?paper=WF14062>). USGS scientists also identified the importance and methods for preserving geomorphic data records of flood disturbances (<https://doaj.org/article/f08ddc92ed7b45c68b8fc92dd4770df4>).

In 2016 and 2017, the GWSIP would continue to find cost efficiencies in existing monitoring networks and improve capabilities for measuring uncertainties related to the full breadth of hydrologic properties. In addition, the GWSIP would continue to support research needed to measure and understand groundwater, streamflow, velocity, and sediment. This research capability is increasingly important as the USGS tracks impacts of land use and climate change over time.

Information Delivery

(2015 Actual, \$2.2 million; 2016 Enacted, \$2.0 million; 2017 Request, \$2.0 million)

The GWSIP supports the development, implementation, and maintenance of reliable systems for real-time and historic information delivery to all stakeholders that include data processing, quality assurance, storage, and ready available access. The funds ensure the operation and maintenance of the NWIS, which is critical to function at peak efficiency and effectiveness, especially during hazard events. NWIS provides current conditions related to streamflow and groundwater levels during periods of flood, high water levels and drought. The USGS receives, on average, more than 1.5 million requests for information per day, offering data at more than 1.5 million monitoring sites that span multiple media.

In addition, the GWSIP supports: (1) improved field computing applications supporting the digital collection and translation of all field visit data, enhancing consistency, accuracy, and cost savings; (2) new systems that facilitate continuous records processing in a more consistent and streamlined workflow; (3) nationwide implementation of a new time series processing system (referred to as AQUARIUS software) used to analyze and manage streamflow and other time-series data in order to ensure that it remains reliable, reproducible, readily accessible, cost-effective, and of a high quality over the full range of hydrologic conditions; (4) Web portals with increased access to nationwide and interdisciplinary USGS information; and (5) applications for immediate delivery of observations on mobile devices. In 2015, the USGS received nearly a 50 percent increase of information requests from mobile devices. Increased use of applications include *WaterNow* (<http://water.usgs.gov/waternow/>), which allows on-demand current conditions for water data directly to your mobile phone or email; *WaterAlert* (<http://water.usgs.gov/wateralert/>), which is a Web-based, subscriber-customer service used significantly during floods, but also every day for our recreationists who want notification about water levels that have reached an elevation of interest to them; and, finally USGS Water-Watch pages remain one of USGS most visible products, providing current conditions for groundwater levels (<http://groundwaterwatch.usgs.gov/>), springs, and streamflow (<http://waterwatch.usgs.gov/>).

In 2016 and 2017, the GWSIP would continue to enhance data processing, quality assurance, storage, and easy data access for real-time and historic streamflow information. Specifically, funding would be directed to enhance data processing, visualization, quality assurance, and auditing through AQUARIUS software. Activities would include training of the software in USGS Water Science Centers nationwide. In addition, software development would continue to enhance field collection input and user-friendly mobile applications for immediate access to information by USGS stakeholders and society at large.

Science to Support Collaboration

The GWSIP works with States, municipalities, and Tribes contributions for cooperative water efforts. Cooperators choose to work with the USGS because of its broad, interdisciplinary expertise; high-quality,

nationally consistent procedures and quality-assurance; innovative monitoring technology, models, and research tools; and robust data management and delivery systems that provide readily available public access to national data. In addition, other partners include:

- USACE
- EPA
- Reclamation
- NPS
- FWS
- BLM
- DOD
- NASA
- Commerce
- Department of State
- DHS
- DOT
- USDA
- DOE

The Water Resources Mission Area partners provided \$286,500,000 of reimbursable funding in 2015.

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Activity: Water Resources

Subactivity: National Water Quality Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Actual	Enacted	Fixed Costs	Program Changes	Request	
Water Resources	\$211,267	\$210,687	\$957	\$16,348	\$227,992	\$17,305
<i>FTE</i>	<i>1,371</i>	<i>1,345</i>		<i>29</i>	<i>1,374</i>	<i>29</i>
National Water Quality Program	\$94,141	\$90,600	\$499	\$3,048	\$94,147	\$3,547
<i>FTE</i>	<i>710</i>	<i>687</i>		<i>10</i>	<i>697</i>	<i>10</i>
Surface Water Quality Monitoring and Modeling	\$49,803	\$47,925		\$1,977	\$49,902	\$1,977
<i>Support NAWQA Cycle 3</i>	<i>[\$62,000]</i>	<i>[\$62,000]</i>		<i>[\$1,881]</i>	<i>[\$63,881]</i>	<i>[\$1,881]</i>
<i>Enhanced Cooperative Activities and Urban Waters</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$717]</i>	<i>[\$717]</i>	<i>[\$717]</i>
Groundwater Quality Monitoring and Modeling	\$25,147	\$24,502		\$1,071	\$25,573	\$1,071
<i>Unconventional Oil and Gas Research</i>	<i>[\$200]</i>	<i>[\$200]</i>		<i>[\$450]</i>	<i>[\$650]</i>	<i>[\$450]</i>
National Atmospheric Deposition Program	\$1,626	\$1,576		\$0	\$1,576	\$0
National Park Service Cooperative Technical Support	\$1,793	\$1,743		\$0	\$1,743	\$0
	\$15,772	\$14,854		\$0	\$14,854	\$0

Justification of Program Changes

The 2017 Budget Request for the National Water Quality Program is \$94,147,000 and 697 FTE, a net program change of +\$3,547,000 and +10 FTE from the 2016 Enacted level.

Overview

Water-quality issues facing the Nation are growing in number and complexity, and solutions are becoming more challenging and costly. The U.S. Census Bureau projects that our population will increase 25 percent by 2050, to almost 400 million people. Increases in population will be accompanied by development of land for urban and other non-agricultural uses, increased use of fertilizers and pesticides for food production, and greater pressure on existing resources to supply water for irrigation, drinking water, energy development, and ecosystem needs. Investments in monitoring, assessments, and

Every time I see a product come out of the NAWQA program I'm even more impressed in terms of the early thinking that went into the program. A couple things that come to mind in terms of accomplishments that jump right to the forefront when I think about the NAWQA program. One was the MTBE effort in terms of finding that in groundwater and raising awareness, in terms of the challenges associated with that gasoline additive. The other area that really struck me is the development of the SPARROW model. That really allows a predictive capability in terms of ungaged areas of streams and so forth in terms of being able to determine the impacts of changing sources and so forth, in terms of receiving waters like streams and estuaries. A very, very important tool for decision makers as they look at various scenarios in terms of the future. Dr. P. Patrick Leahy, American Geological Institute, introductory remarks at Congressional briefing on Groundwater Quality of Principal Aquifers of the United States, March 6, 2015, Washington, D.C.

research are necessary to provide the science needed to address current and future water-quality challenges.

The NWQP encompasses the water-quality monitoring, assessment, and research activities done by the Water Resources Mission Area that: (1) assess the current quality of the Nation’s freshwater resources and how it is changing over time; (2) explain how human activities and natural factors (e.g., land use, water use and climate change) are affecting the quality of surface water and groundwater; (3) determine the relative effects, mechanisms of activity, and management implications of multiple stressors in aquatic ecosystems; and (4) predict the effects of human activities, climate change, and management strategies on future water-quality and ecosystem conditions.

Prior to 2016, these water-quality goals mentioned above were addressed by several USGS programs including the National Water-Quality Assessment Program (NAWQA); CWP; Hydrologic Research and Development Program; and the Hydrologic Networks and Analysis Program, including the National Stream Quality Accounting Network (NASQAN), the Hydrologic Benchmark Network, National Monitoring Network for U.S. Coastal Waters and Tributaries, National Atmospheric Deposition Program, and the NPS Water-Quality Partnership. On October 1, 2015, the water-quality activities done by these programs were integrated under the NWQP to strengthen and enhance the linkages and opportunities for collaboration with stakeholders at local, State, regional and national levels. The NWQP will continue providing leadership to other Federal, State, and local agencies through the National Water Quality Monitoring Council to develop collaborative, comparable, and cost-effective approaches for monitoring and assessing our Nation’s water quality.

The NAWQA Project is the largest component of the NWQP. In 1991, Congress established NAWQA within the USGS to address a fundamental question: “What is the status of the Nation’s water quality and is it getting better or worse?” Since then, the NAWQA Project has been a primary source of objective and nationally consistent water-quality data and information on the quality of the Nation’s streams and groundwater. NAWQA Project data and models provide answers to where, when, and why the Nation’s water quality is degraded, and what can be done to improve and protect it for human and ecosystem needs (<http://water.usgs.gov/nawqa/xrel.pdf>).

Two decades of the NAWQA Project monitoring and modeling have resulted in a solid foundation of data and scientific understanding and improved capability within the water community to address current and future water-quality issues. During its first decade, (1991-2001 or Cycle 1), the NAWQA Project completed interdisciplinary baseline assessments of the quality of streams, groundwater, and aquatic ecosystems in 51 of the Nation’s largest and most important river basins and aquifers. The assessments were based on sampling at 505 stream sites and more than 5,000 wells. During its second decade, (2001-2012 or Cycle 2), the NAWQA Project built upon the baseline assessments by reporting on how water-quality conditions are changing over time and by developing regional-scale water-quality models to extrapolate findings to unsampled areas.

“NAWQA has evolved from a water-quality program emphasizing data collection and trend assessments to one that has the potential to predict and forecast pollution occurrence and trends under multiple scenarios at nationally significant scales.” National Research Council (2012, p 158)

The NAWQA Project's third decade (2013-2023 or Cycle 3) science plan (<http://pubs.er.usgs.gov/publication/ofr20131160>) continues strategies that have been central to the NAWQA Project's long-term success, but also adjusts approaches, monitoring intensity, and study design to address data and science information needs identified by the NAWQA Project stakeholders and the National Research Council (NRC, 2012), which reviewed the plan in 2012 (http://www.nap.edu/openbook.php?record_id=13464&page=R1). The Cycle 3 plan addresses stakeholder needs for more timely reporting of water-quality information, science, and tools such as: (1) annual Web-based reporting of concentrations, loads, and trends of nutrients, sediment, and other contaminants in rivers draining into important coastal estuaries; (2) maps showing the distribution of nitrate, arsenic and other contaminants in important water-supply aquifers at the depth tapped by domestic and public-supply wells; and (3) model-based decision support tools that allow managers to evaluate how water quality or stream ecosystems may change in response to different scenarios of population growth or climate change.

In 2017, the NWQP is requesting an increase in funding to enhance cooperative activities through the Urban Waters Federal Partnership, advance the NAWQA Project Cycle Three, and conduct UOG research focused on water quality and water availability. For more information, on these requested increases, please see the text boxes below.

Program Performance

The NWQP is made up of the following five program components, described below in more detail: Surface Water Quality Monitoring and Modeling; Groundwater Quality Monitoring and Modeling; National Atmospheric Deposition Program; NPS Cooperative; and Technical Support.

Surface Water Quality Monitoring and Modeling

(2015 Actual, \$49.8 million; 2016 Enacted, \$47.9 million; 2017 Request, \$49.9 million)

Water-quality of streams, lakes and estuaries remains a concern for human use and ecosystem health. Restoring and enhancing water-quality monitoring networks, analysis of long-term trends in water quality, and the development of new regional and national water-quality models are three high priorities for the surface-water component of the NWQP. Regional and national monitoring and assessments will continue to focus on nutrients, sediment, pesticides, and other contaminants and stressor's effects on aquatic ecosystems. The monitoring, as well as trend analysis and modeling, includes major rivers, agricultural and urban streams, and pristine reference streams. Rivers and streams monitored are located in the Mississippi River Basin, which drains into the Gulf of Mexico; in watersheds of other important estuaries, such as the Chesapeake Bay, San Francisco Bay/Delta and Puget Sound; and in major inland drainage basins, including selected tributary streams in agricultural, urban, and undeveloped watersheds.

National Water Quality Network—Streams: During 2015, the USGS continued collecting water-quality samples at 102 of the 313 long-term monitoring sites recommended in the NRC-reviewed NAWQA Project Cycle 3 Science Plan (Figure 1A). The network of 102 sites comprising the USGS National Water Quality Network (NWQN) includes 61 long-term monitoring sites sampled by the NAWQA Project during Cycles 1 and 2 to determine the status and trends in loads and concentrations of nutrients,

pesticides, sediment and other contaminants in the Nation's large rivers, including loads to major estuaries, and a selected set of 20 smaller streams representing urban and agricultural land use in different parts of the Country. In addition, 19 pristine reference streams (increasing to 30 in 2016) were monitored for streamflow, temperature, sediment, major ions, and nutrients. All reference, urban, and agricultural streams are also sampled annually for ecological condition. The NWQN is the only nationally designed monitoring network for tracking the quality of the Nation's rivers and streams with consistent and comparable methods at all sites, and which includes measurements of a wide range of water-quality stressors and ecological condition.

Ten of the NWQN monitoring sites also are instrumented with state-of-the-art water-quality sensors that provide real-time, continuous data for nitrate, turbidity, and other basic properties such as pH. The more frequent measurements afforded by continuous water-quality sensors for nitrate and turbidity are improving the accuracy of estimated stream nutrient and sediment loads, which are the basis for water-quality models used by resource managers. Findings published by the USGS in 2015 showed that continuous sensor data for nitrate levels in the Mississippi River resulted in significantly more accurate estimates of nitrate loads to the Gulf of Mexico and also improved the NWQP's ability to identify sources of nitrate to the river, which is critical to improving water-quality management. The USGS is a part of the coalition of Federal agencies, that launched the Nutrient Sensor Challenge in 2015—an open-innovation competition to accelerate the development and deployment of affordable sensors that can measure nutrients in aquatic environments—which is discussed in more detail below in the Water Quality Technical Support section.

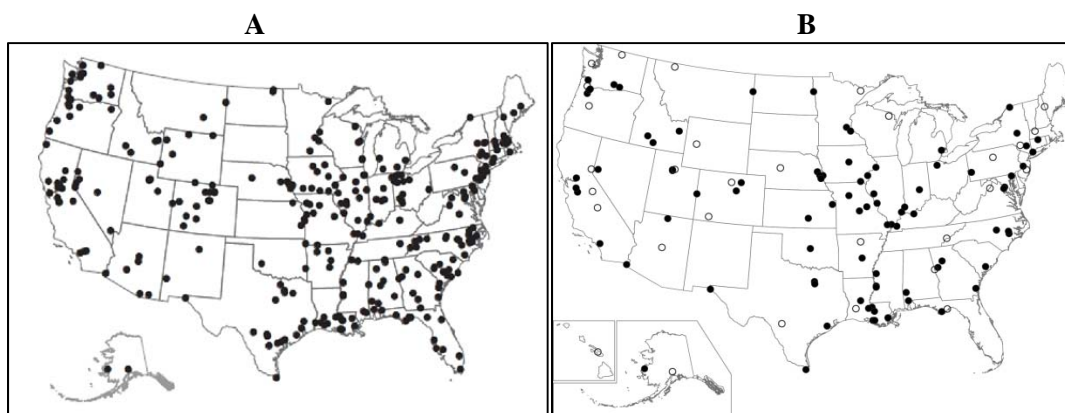


Figure 1. A. Locations of 313 stream and river sites recommended for sampling during NAWQA Cycle 3. B. Locations of 113 stream and river sites sampled in the NWQN in 2016 (increased from 102 in 2015) after merging with the Hydrologic Benchmark Network. A total of 30 reference sites (shown as white circles), are being monitored in 2016; this represents an increase of 19 sites from 2015.

Also in 2015, significant progress was made to provide expanded and improved access to quality-assured data and information from pristine reference watersheds for use in understanding the effects of water use, atmospheric deposition, and climate change on stream water quality. Water-quality data collection operations at pristine reference stream sites that were part of the USGS Hydrologic Benchmark Network since 1963 were harmonized and consolidated with those of the NWQN. The combined operations, commencing in 2016, result in a total of 30 reference sites in the NWQN (Figure 1B).

Reference-watershed monitoring is yielding important information on water-quality trends. For example, USGS reference watersheds during 1970-2010 for streams in the Northeastern United States showed that there were declines in stream sulfate concentrations (acidification), which were statistically significant, but less than two and a half percent per year. Sulfate in reference watershed streams is largely derived from wet and dry deposition of sulfur derived from the burning of coal with observed declines largely attributed to reductions in sulfur emissions associated with implementation of the Clean Air Act in 1970, and subsequent amendments targeting sulfur dioxide emissions in 1990. Observed declines in stream sulfate were less than declines of sulfate observed in wet atmospheric deposition, suggesting that stream quality is improving, but that it is lagging behind changes in sulfate deposition because of depletion of calcium in watershed soils by acid deposition. Results published in October 2015

(<http://pubs.acs.org/doi/abs/10.1021/acs.est.5b02904?journalCode=esthag&>) by the USGS, in collaboration with the USFS and Canadian scientists, used monitoring data for soils in NWQN reference watersheds, combined with other sites in the United States and Canada, to show that the effects of acidic deposition on North American soils have begun to reverse. This reversal in soil conditions should further improve the beneficial response of streams to reductions in atmospheric sulfate deposition.

In partnership with the National Water-Quality Monitoring Council, the USGS is leading efforts to develop a collaborative and multipurpose National Network of Reference Watersheds (NNRW) and monitoring sites for freshwaters. Beginning in 2011, initial work focused on developing a database that will provide users with the ability to identify reference watersheds of interest and download watershed information and water-quality data. In 2015, a Web site (<https://my.usgs.gov/nnrw/main/home>) was released whose purpose is to allow users to search the NNRW database of reference watersheds, to identify watersheds of interest, and download watershed information and water quality data. The Web site includes information on the 30 reference sites in the NWQN, as well as an additional 22 USGS reference sites monitored only for streamflow and temperature. In 2016 and 2017, the USGS will refine tools for users to search and identify reference watersheds suitable for meeting different objectives and add these features to the NNRW Web site while also working with collaborating agencies to identify additional sites that can be added to the NNRW.

In 2016 and 2017, the NWQP will continue to work with other agencies and organizations in the Great Lakes basin to improve long-term water-quality monitoring and reporting for tributaries draining to the Great Lakes. In particular, those tributaries that drain into the western Lake Erie Basin will be monitored as there have been significant increases of harmful algal blooms (HABs) associated with increases in dissolved phosphorus loads. HABs are overgrowths of algae in water that can be triggered by a combination of high dissolved nutrient concentrations, the right weather conditions, and other environmental factors. To reduce the impacts of HABs, a bi-national committee, formed as part of the Great Lakes Water Quality Agreement, has recommended that phosphorus loads to the western Lake Erie Basin be reduced by 40 percent. There is a need to rigorously monitor progress towards achieving the phosphorus reduction target because it will likely take a decade or more to achieve the goal.

Most of the current monitoring of tributaries is done by multiple agencies supported by short-term funding from the Great Lakes Restoration Initiative (in addition to appropriated funding, the NWQP receives reimbursable funding from the EPA to conduct water-quality monitoring of selected Great Lakes tributaries). Monitoring approaches vary among agencies and include both the collection of discrete

water-quality samples and the use of continuous sensor technology. Current timelines necessary to complete laboratory analyses and data interpretation make it difficult to provide drinking water operators and managers of beaches and other recreational areas with the information necessary to forecast the onset of HABs in a timely manner. The NWQP aims to increase the use of new continuous sensor technology to facilitate near real-time tracking of nutrient inputs to Lake Erie and other Great Lakes, to be done in coordination with existing HABS-related monitoring and research by other Federal, State, local, university, and private partners.

For further discussion about NWQP research on understanding why HABs form, and when and where they occur, see the sub-heading titled “Harmful Algal Blooms” below.

Reporting on Water-Quality Conditions: In 2015, the USGS released a new, Web-based Water-Quality Tracking tool for stream and river quality data for nutrients and sediment (<http://cida.usgs.gov/quality/rivers>). This product displays and delivers water-quality information in a more timely and consistent fashion than in the past and features comparisons of the most recent year of water-quality data for a river or stream against data collected in previous years. In 2016, the Water-Quality Tracking tool will be expanded to add pesticides. Data on all monitored parameters, including nutrients, suspended sediment, and pesticides, will be updated annually. In 2017, the tracking tool will add ecological conditions and begin to expand site coverage for selected data using monitoring results from other programs.

Reporting on Water-Quality Trends: Long-term monitoring of water quality is essential to track how changes in land use, climate, and water-quality management actions are impacting streams and rivers and associated commercial and recreational fisheries in estuaries across the Nation. The NWQP is working on a detailed analysis of water-quality trends within the past 50 years in streams and rivers across the Nation to provide a consistent national synthesis of data from the USGS and numerous other agencies.

In 2015, the USGS presented new national findings on historical trends in nitrate levels, a nutrient that can lead to the formation of zones of low oxygen in coastal waters that are harmful to fisheries, recreational use, and ecological habitat and can result in major economic impacts. The study found that there is no widespread evidence of improving conditions during recent decades. During 1945 to 1980, nitrate levels in rivers increased up to five fold in intensively managed agricultural areas of the Midwest (Figure 2). The greatest increases in river nitrate levels coincided with increased nitrogen inputs from livestock and agricultural fertilizer, which grew rapidly from 1945 to 1980. In some urban areas along the U.S. east and west coasts during the same period, river nitrate levels doubled. Since 1980, changes to nitrate levels have been smaller as the increase in fertilizer use has slowed in the Midwest and large amounts of farmland have been converted to forest or urban land along the U.S. east coast. Data from these and other planned trend analyses conducted by the NWQP are used by Federal, State, local, and regional agencies to track progress in meeting water-quality goals, evaluate results of management or regulatory actions taken to improve water quality, and to put recent trends in perspective relative to long-term trends.

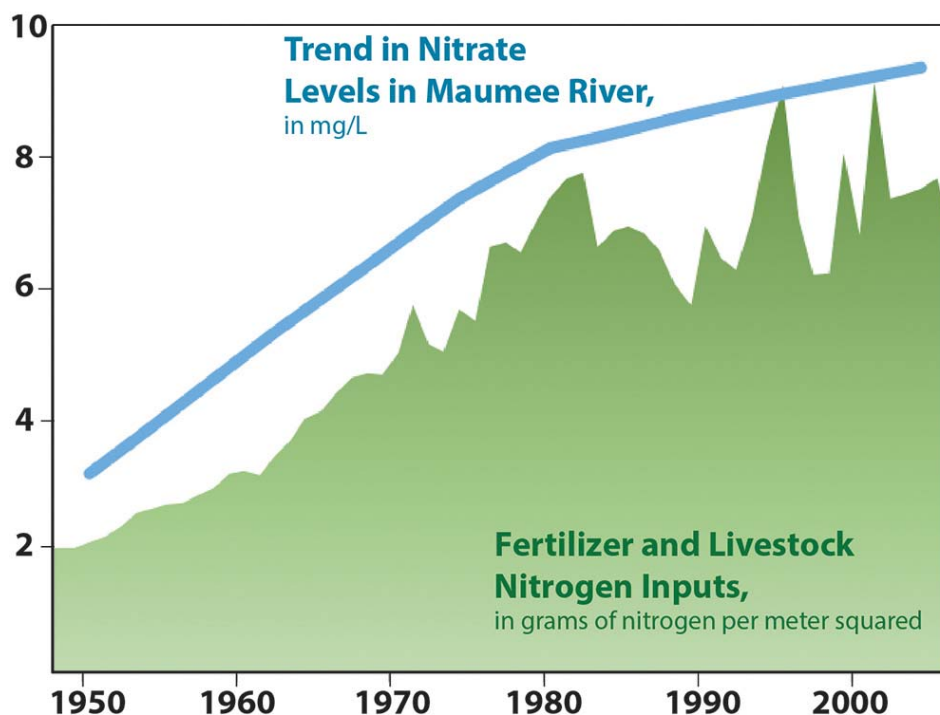


Figure 2. Nitrate concentrations in the Maumee River flowing through northwest Ohio into Lake Erie increased rapidly between 1945 and 1980 as nitrogen inputs from fertilizer and livestock increased. Since 1980, changes in nitrate levels have been much smaller as nitrogen inputs leveled off.

Also in 2015, the USGS reported new findings on trends in use and concentrations for 11 pesticides in 38 streams and rivers nationwide. Trends in pesticide concentration were mostly linked to trends in agricultural use or by regulatory changes for compounds used for urban and other purposes. In most cases where concentration and use trends did not agree, river or stream concentrations increased more than use, which may be caused by unaccounted uses. Trend information is used by EPA and State agencies to inform pesticide registration decisions and related regulatory actions.

Work also continued on the analysis of historical water-quality data compiled from both USGS sources and hundreds of other agencies and organizations nationwide to provide a more comprehensive national analysis of long-term trends, and also for development of improved SPARROW models. The resulting database contains more than 147 million records from more than 500 local, State, and Federal agencies and is the most comprehensive ever assembled in the United States. Unfortunately, only a small fraction of these data are suitable for trend analysis because they were collected for different purposes with widely varying data requirements. Thus, the record at a particular site may only represent a short period of time, lack information on streamflow, or include only sparse sampling over time and for limited parameters. For example, of the thousands of sites represented in the national database, 111 sites met data criteria for analyzing total phosphorus trends for 1982-2012, while 374 sites met the same criteria for the more recent 2002-2012 period. Collectively, however, the data from appropriate subsets of sites with long-term monitoring are expected to provide local, State, Federal, and tribal partners with expanded insight into historical trends and how natural factors and human activities have contributed to water-quality changes over time in Nation's streams and rivers. During 2015, scientists refined data preparation and applied

statistical methods to quantify trends using the data from long-term monitoring sites identified and screened in 2014.

In 2016, trend results are being summarized regionally and nationally for pesticides, nutrients, sediment, salinity and carbon, and compared to historical data on changes in land use, climate, point and nonpoint sources, and other major factors to help explain observed trends. Trend results will also be compared to aquatic-life and human-health benchmarks to evaluate progress towards meeting national water-quality goals. In 2017, trend analyses will focus on evaluating the causes of trends observed in the national analysis, reporting on how these causes vary geographically in different land uses, and the implications for improving water quality management.

Model Analysis and Decision Support Tools: The primary models used by the USGS to develop national and regional assessments of water quality conditions from monitoring data are the SPATIally Referenced Regressions On Watershed attributes (SPARROW) (model for sediment, nutrients, and dissolved solids, and the Watershed Regressions for Pesticides (WARP) model.

In 2015, the new Web-based SPARROW applications, which were released in 2014 for mapping nutrient sources to 115 major estuaries along the Atlantic coast, Gulf of Mexico, and Pacific Northwest, as well as for 160 watersheds draining into the Great Lakes,

were used by a wide variety of stakeholders to evaluate nutrient reduction strategies and to inform nutrient policies across the Nation. During this initial period of use, the functionality of the application has been reviewed with users and a number of upgrades are planned for 2016.

Additionally in 2015, a new national SPARROW model and decision-support system was completed for dissolved solids, a measure of salinity. Excessive dissolved-solids concentrations in some of the Nation's streams and rivers can have adverse effects on human uses, such as drinking-water supply, irrigation of crops, and on the health of aquatic ecosystems. The new model provides a tool for identifying major sources of dissolved solids, including some human sources such as road deicers and urban runoff. The model also provides a means of mapping major sources and identifying those that are most important so that problems can be more effectively managed.

“SPARROW was the key for us to quantify progress achieved towards our nutrient reduction goals thus far, and we anticipate employing the model to estimate accomplishments over the next 25 years. Most models only estimate phosphorus or nitrogen, whereas the SPARROW approach is particularly valuable because it offers insight for both constituents. Consistent with Wisconsin’s Nutrient Reduction Strategy, the Wisconsin Department of Natural Resources uses SPARROW to help prioritize monitoring efforts and target implementation. Finally, during 2015 all states were required to develop a vision and prioritization framework for the restoration of impaired waters. One of 3 key components for Wisconsin’s prioritization relies upon SPARROW results to identify high-loading nutrient areas.” Brian M. Weigel, Ph.D., Chief, Water Evaluation Section, Water Quality Bureau, Wisconsin Department of Natural Resources, January 4, 2016.

In 2015 and 2016, existing SPARROW models are being used to evaluate potential benefits of agricultural management practices on reducing nutrient levels in streams and in downstream receiving waters. Over recent decades, significant expenditures have been made to reduce the amount of agricultural nutrients that ultimately reach streams. However, improving trends related to those expenditures have not yet been detected. Improving water-quality models for national assessment of the

benefits of management strategies increasingly depends on the availability of reliable information on factors that affect water quality, such as fertilizer use, livestock waste, agricultural management practices, and wastewater treatment improvements. For example, information on these and other factors is needed to better understand the sources of nitrate loading to the Gulf of Mexico and other coastal zones of the conterminous United States. The USGS is working with States and other Federal agencies that are part of the Hypoxia Task Force to provide the data and information necessary to develop effective strategies for both groundwater and surface water. In 2014, the USGS and the USDA Natural Resources Conservation Service entered into a five-year Memorandum of Understanding to facilitate the development of uniform regional and national geospatial datasets to represent suites of nutrient and sediment-reduction conservation practices. A USGS-USDA co-authored report is planned for release in 2016 that incorporates USDA information on conservation practice intensity at a large scale (250,000 to 1,250,000 acres) into the USGS SPARROW model to assess the benefits of conservation actions to reduce nutrient transport in the upper Mississippi River basin. These data are critical to improving models and our understanding of the effectiveness of costly management strategies, but the collaboration to obtain similar conservation data nationwide and at smaller scales (10,000 to 40,000 acres) has proceeded very slowly due to policy and procedural obstacles at the USDA.

SPARROW model development in 2016 will focus on completing regional and national sediment models and initiating the development of updated nutrient models. The Web-based portal, completed in 2014, to provide quality-assured, historical USGS suspended sediment data, is the data source for the sediment models. During 2016 and 2017, updated regional SPARROW models for total nitrogen and phosphorus will be completed using the national databases developed during 2013-2015 to reflect changes to land and water management practices. The updated models will provide improved capability to: (1) predict nutrient conditions in streams throughout the United States; (2) identify those areas and sources that contribute the largest amounts of nutrients to downstream receiving water bodies such as the Great Lakes, Chesapeake Bay, and Gulf of Mexico; and (3) identify the most important environmental factors that affect nutrient delivery to streams.

“The USGS pesticide model is a valuable tool that we can use, along with other modeling and analytical tools, to evaluate data as we complete ecological risk assessments for pesticides,” Dr. Donald J. Brady, Director, Environmental Fate and Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency, September 16, 2015

In 2015, the USGS released a new version of the Web-based modeling tool, referred to as WARP, for estimating pesticide concentrations in streams and rivers across the Nation (Figure 3). The updated WARP model enables online predictions for 112 pesticides in most streams and rivers nationwide, including comparisons to water-quality benchmarks. For example, 25 pesticides were predicted to have concentrations exceeding one or more aquatic life benchmarks in one or more stream segments with a 50 percent or greater probability. The EPA has used the WARP model to design monitoring requirements for atrazine and is now using model predictions for other pesticides as screening-level information for initial risk assessments. In 2016, the WARP model Web site will be expanded to include new mapping and graphing capabilities and selected regional models will be developed to support interpretation of regional ecological monitoring results. In 2017, the national WARP model will be updated with new monitoring data.

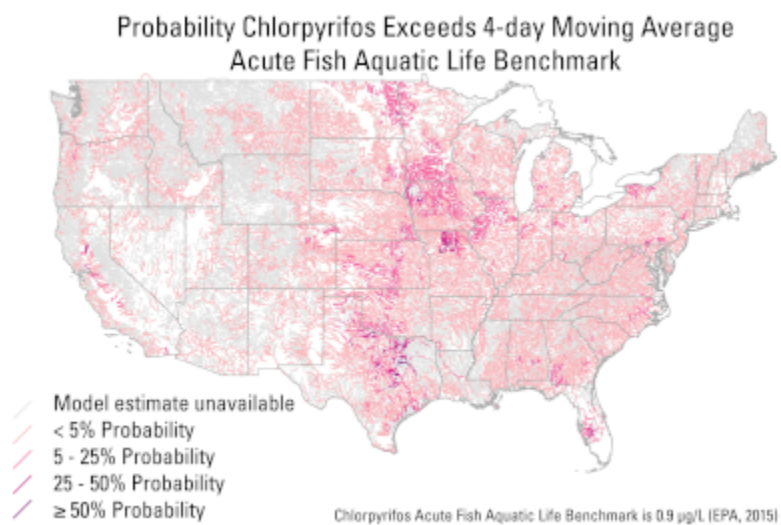


Figure 3. WARP model estimates for Chlorpyrifos, an insecticide used commonly on cotton, corn, citrus, and almond crops along with estimates of the probability that concentrations for streams in 2012, exceed aquatic life benchmarks for fish.

2017 Program Change
<p>Support NAWQA Cycle 3: (+\$1,881,000 for a total of \$63,881,000): In 2017, the NWQP is requesting an increase to Support NAWQA Cycle 3. The increase would be used to restore and enhance long-term surface water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for the Cycle 3 of the NAWQA Project. One of the priorities, for example, is to work with other agencies and organizations in the Great Lakes basin to improve long-term water-quality monitoring and reporting for tributaries draining into the western Lake Erie Basin that has experienced significant increases in Harmful Algae Blooms associated with increases in dissolved phosphorus loads. The increase would also be used to restore and enhance long-term groundwater water-quality monitoring networks and expand development of modeling tools that are a priority of stakeholders for the Cycle 3 of the NAWQA Project. One example for the increase would be to reactivate selected NAWQA Project decadal trend networks in areas where rapid changes in population and land use are affecting the quality of shallow groundwater, such as Colorado, Texas, or the Northeast (Figure 4), and to work with local agencies to better understand how these changes might affect drinking water supplies. This proposed increase of \$1,881,000 for the Support NAWQA Cycle 3 would fund activities in Surface water quality monitoring and modeling activities (+\$1,260,270) and groundwater quality monitoring and modeling (+\$620,730).</p>

Harmful Algal Blooms: HABs gained national attention in August 2014 when a toxic cyanobacterial bloom in Lake Erie caused the City of Toledo, OH, to issue a tap-water ban that left over 500,000 people without drinking water for two days. Lake Erie has experienced chronic HAB issues over the last decade, and the 2015 bloom was among the most severe on record. HAB issues are not unique to Lake Erie. Many water bodies throughout the Nation experience chronic HAB issues, and toxic blooms have occurred in at least 41 States.

The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 (HABHRCA, P.L. 113-124) reaffirms the mandate to advance the scientific understanding and ability to detect, predict, control, mitigate, and respond to HAB and hypoxia events and emphasizes the need for coordinated, collaborative Federal efforts. USGS HAB science is focused on developing analytical laboratory and field methods to detect and quantify blooms and associated toxins and taste-and-odor compounds, understanding causal factors, and developing early warning systems for potentially harmful blooms.

“Algal blooms, especially cyanobacteria, are highly dynamic phenomena in Kansas reservoirs. The high resolution, comprehensive suite of data and analyses on these blooms we get from USGS gives us insight on how they change over time and location within particular reservoirs. This allows us to adjust response policies on cyanobacteria as well as evaluate the efficacy of watershed treatment implemented to abate the nutrient loading supporting those blooms. USGS data and information complement our in-house monitoring efforts to broaden our knowledge base on eutrophication and its manifestations.” Tom Stiles, Chief of the Watershed Planning, Monitoring, and Assessment Section, Kansas Department of Health and Environment.

USGS HAB science is supported by several different sources of funding including appropriations to the Toxic Substances Hydrology Program, and the NWQP. The NWQP focuses on methods development and basic research into the ecological processes affecting HAB formation and studies done in partnership with other local, State, and tribal cooperators through joint funding agreements. Excess nutrients are a key driver of HAB formation. Thus, the long-term water-quality monitoring and sensor networks and updates and enhancements to SPARROW models described previously are integral to understanding changes in nutrient concentrations and loading that may affect the timing, magnitude, and duration of HAB events. Such information, when combined with real-time sensors that monitor changes in chlorophyll and other pigments produced by the algae, along with studies that determine what environmental conditions trigger HABs, can be used by drinking water suppliers and water resource managers to develop short-term (hours to days to weeks) forecasts of when and where toxin-producing blooms will occur and can adjust their treatment and management strategies accordingly to better protect human health.

HAB science is conducted in about 20 USGS Water Science Centers. Studies range in scale from individual water bodies to those that are regional or national in scope, and are conducted in collaboration with a variety of local, State, Federal, and tribal partners.

New methods and technologies are being used to develop early warning systems to help alert decision makers of changing water-quality conditions that may affect public health. For example, in 2015, USGS scientists in Ohio developed a promising system using continuous water-quality monitors to quickly estimate cyanotoxin levels and provide advisories to swimmers and boaters. Also in 2015, scientists with NASA, the EPA, NOAA, and the USGS began a multiagency effort to use ocean color satellite data to develop an early warning indicator for toxic and nuisance algal blooms in freshwater systems and an information distribution system to aid expedient public health advisories.

USGS scientists in Kansas and Oregon are using optical sensors and high-resolution security cameras to quantify the spatial and temporal patterns in cyanobacterial bloom development. Information gained from these studies, which will be completed in 2016, will be used to inform local, State and Federal decisions on recreational beach advisories. Similarly, the USGS is continuing work on developing a real-time water-quality notification system to alert water suppliers that use the Kansas River as a source-water

supply of the potential for occurrence of cyanobacteria and associated compounds so treatment processes can be adjusted before the onset of a HAB event.

Cyanotoxins, along with pesticides and other potentially toxic contaminants, are measured as part of regional-scale assessments of small streams done as part of the NAWQA Project's Cycle 3. During 2015, streams in the Pacific Northwest were sampled and streams in the Northeastern and the Southwestern United States will be sampled in 2016 and 2017, respectively. These assessments are among the first to document that the occurrence of cyanotoxins in fresh waters is not restricted to lakes, reservoirs, and large rivers. Cyanotoxins also occur relatively frequently in smaller streams.

Urban Waters Federal Partnership: The USGS is partnering with other Federal, State and local agencies to reconnect urban communities, particularly those that are economically distressed, with their waterways by improving coordination among Federal agencies and collaborating with community-led revitalization efforts. The Urban Waters Federal Partnership (UWFP) began in 2011 piloting work in seven locations: Anacostia watershed (Washington, DC area), Patapsco watershed (Baltimore, MD), Bronx and Harlem Rivers watershed (New York City, NY), Lake Pontchartrain Area (New Orleans, LA), Northwest Indiana area, (East Chicago, IN) South Platte watershed (Denver, CO), and Los Angeles River watershed (Los Angeles, CA). This work is done in the NWQP through reimbursable funding from partner organizations in several partnership locations.

"The Conservation Fund is working closely with the USGS through the UWFP on a variety of projects--addressing stormwater flooding issues in Atlanta, promoting green infrastructure and climate resiliency planning in Baltimore, and community education about the land and water connections in Los Angeles. Thanks to UWFP, The Conservation Fund has strengthened its relationship and work with the USGS." Erik J. Meyers, Vice President and Stacy Funderburke Assistant Regional Counsel & Real Estate Associate, The Conservation Fund

In 2015, the USGS continued activities in the seven original pilot locations and began new activities in seven newly designated UWFP locations: Mystic River watershed (MA), Greater Philadelphia area/Delaware River Watershed (PA, NJ, DE), Grand River/Grand Rapids (MI), Western Lake Erie Basin (OH), Middle Blue River (MO), Passaic River Basin (NJ), and Proctor Creek watershed (Atlanta, GA).

USGS contributions to the partnership typically include expanding the number of streamgages and water quality monitoring sites, assessing the health of aquatic ecosystems, and providing educational outreach for the general public. For example, in 2016, the USGS plans to publish an analysis of century-scale water quality trends and changes for the Harlem River. Data was provided from a variety of sources including the New York City Department of Environmental Protection, Riverkeeper, Inc., and EPA. With support from NOAA, the Wildlife Conservation Society and the USGS have constructed a kiosk at the Bronx Zoo to educate Zoo visitors on current Bronx River conditions. It is functional and is actively displaying real-time Bronx River conditions. Since 2011, the USGS has participated in the annual Harlem River Festival, an event that has grown into a two-week-long, borough-wide outreach effort that brings the local communities together through educational activities. The USGS and the Bronx Council for Environmental Quality (BCEQ) continue to work with faculty and students from minority serving institutions such as Eugenio Maria de Hostos Community College, Lehman College, and Borough of Manhattan Community College to help collect and interpret water-quality information and sustain green infrastructure projects. For example, the USGS completed work in 2015 with the BCEQ to better understand the types and relative concentrations of roadway contaminants in stormwater runoff that drain

from the Major Deegan Expressway to the Harlem River and the efficacy of an innovative pop-up wetland on reducing contaminants reaching the river.

In east Chicago, the USGS is currently working with partner agencies on a multifaceted strategy involving improvements to the sewerage system, beach management strategies, and monitoring audits to reduce the levels of fecal bacteria at several beaches and increase public access to Lake Michigan. In the Mystic River watershed, the USGS, in partnership with the State of Massachusetts and with the Mystic River Watershed Association, has installed and is operating three new real-time streamgages in the watershed that will provide the flow information necessary to quantify nutrient loads that ultimately reach the Charles River and Boston Harbor. (Go to <http://newengland.water.usgs.gov/> for real-time data from these stations.) Finally, in the Procter Creek watershed, the USGS is partnering with EPA and others to add two new real-time streamgages in 2015, and operate them in 2016 in a highly urbanized section of the watershed in Atlanta, GA, that will be a great asset for potential flood warning for the residents.

2017 Program Change
<p>Enhanced Cooperative Activities and Urban Waters: (+\$717,000 for a total of \$717,000): The USGS is partnering with other Federal, State and local agencies to reconnect urban communities, particularly those that are economically distressed, with their waterways by improving coordination among Federal agencies and collaborating with community-led revitalization efforts. In 2017, the NWQP is requesting a funding increase to support matching agreements with cities and towns that enable similar types of streamflow and water-quality data collection efforts that provide science-based information used by State and local partners to develop plans for economic revitalization, urban water restoration and educational outreach for the general public. This funding being requested would be part of the cooperative matching funds.</p>

Groundwater Quality Monitoring and Modeling

(2015 Actual, \$25.1 million; 2016 Enacted, \$24.5 million; 2017 Request, \$25.6 million)

Currently about 130 million people in the United States rely on groundwater for drinking water and the need for high-quality drinking-water supplies becomes more urgent as our population grows. Although groundwater is a safe, reliable source of drinking water for millions of people nationwide, high concentrations of some chemical constituents can pose potential human-health concerns. Some of the chemical constituents are naturally occurring contaminants that come from the rocks and sediments of the aquifers themselves, and others are chemicals that people use in agriculture, industry, and day-to-day life. When groundwater supplies are contaminated, millions of dollars can be required for treatment so that the supplies can be usable. Groundwater contaminants can also affect the health of streams and valuable coastal waters.

The NAWQA Project is the only Federal program that monitors the status of the Nation’s groundwater quality and reports on how these conditions are changing over time. The EPA uses these data to help identify and prioritize contaminants that are suspected to be present in drinking water and do not have health-based standards set under the Safe Drinking Water Act for monitoring by public water utilities as part of the Unregulated Contaminant Monitoring Rule.

Reporting on Water-Quality Conditions: In 2015, the USGS published a national summary report and eight regional reports describing the quality of groundwater in source (untreated) water from 6,600 relatively shallow wells sampled through 2010 in regionally extensive aquifers from across the United States. The release was followed by briefings on Capitol Hill by USGS scientists for stakeholders, Congressional staff, and the general public on the report's main findings. The comprehensive sampling, along with detailed information on geology, hydrology, geochemistry, and chemical and water use, was used to explain how and why aquifer vulnerability to contamination varies across the Nation. By knowing where contaminants occur in groundwater, what factors control contaminant concentrations, and what kinds of changes in groundwater quality might be expected in the future, water quality managers can ensure the future availability and quality of this vital natural resource. The report's key findings include:

- More than one in five (22 percent) groundwater samples contained at least one contaminant at a concentration of potential concern for human health.
- Most of the contaminants of potential concern for human health that occurred at high concentrations in groundwater are derived from the rocks and minerals that comprise the aquifers. These contaminants include manganese, arsenic, uranium, and radon.
- Differences in contaminant concentrations among aquifers, within an aquifer, and even between two nearby wells, can be explained by large- and local-scale differences in geology, hydrology, geochemistry, and chemical and water use. Understanding how natural features and human activities affect groundwater quality helps to predict how and why aquifer vulnerability to contamination varies across the Nation.
- High-volume pumping and irrigation in many areas have profoundly changed groundwater flow and quality. By moving shallow groundwater deeper, into parts of aquifers used for drinking water, irrigation and pumping have increased the vulnerability of drinking-water supplies to contamination from nitrate, pesticides, and other manmade chemicals from the land surface.
- Irrigation, high-volume pumping, and artificial recharge can cause different types of waters to mix, with the unexpected consequence of causing the aquifer rocks and sediment to release naturally occurring contaminants, such as arsenic, selenium, or radium, into the groundwater.
- Our actions today are determining groundwater quality for decades to come. The effects of human activities on groundwater quality are increasing across the Nation, even over the relatively short periods of a single decade.

In 2015, the USGS also published the results of a comprehensive assessment of the quality of groundwater used for public supply in California supported by the California Water Resources Control Boards that began in 2001. The assessment design was comparable to the design of groundwater studies of the NAWQA Project

"The GAMA studies are an invaluable resource for the public and water managers to improve our understanding of groundwater quality. This comprehensive effort allows for better knowledge and access to information, which leads to informed groundwater management at the local, regional, and statewide levels," John Borkovich of the State Water Resources Control Board, California Environmental Protection Agency, July 15, 2015

and enabled the Water Boards to fulfil their obligations to the California Legislature under Assembly Bill 599 – the Ground-Water Quality Monitoring Act of 2001. Study findings were based on water-quality data from 11,000 wells representing nearly all (greater than 99 percent) of the groundwater used for

public supply in California. The USGS found that about 20 percent of the groundwater used for public supply in California has high concentrations of one or more contaminants that exceed human health benchmarks. Naturally-occurring trace elements are more prevalent at high concentrations than contaminants from known human sources including nitrate, volatile organic compounds (VOCs), and pesticides. The State of California recognizes the importance of groundwater, particularly in light of recent severe drought conditions the State has experienced that has forced increased reliance on existing groundwater resources, and the work conducted by the USGS is important for the protection of groundwater resources.

Water-Quality Conditions in Deeper Parts of Aquifers Used for Public Supply: Beginning in 2013, the NAWQA Project's Cycle 3 began an effort to sample about 1,500 public-supply wells in 20 principal aquifers (large, regional extensive aquifer systems that are major sources of water supply that can underlie multiple States) to provide both regional and national contexts for understanding where and why contaminants occur at concentrations that may be harmful to human health in these deeper systems (Figure 4). The NAWQA Project will also resample about 2,500 relatively shallow observation and domestic-supply wells sampled during Cycles 1 and 2 and during Cycle 3 to assess how groundwater-quality conditions are changing over time. The total number of wells that the NAWQA Project currently samples as a part of Cycle 3 is about two-thirds the recommended number of wells in the Science Plan. The NAWQA Project's use of broad-spectrum laboratory analytical methods that include a wide range of currently used pesticides, hormones, pharmaceuticals, VOCs, and other contaminants provides the EPA, States, and water utilities with critical information about the occurrence of contaminants of emerging concern that would otherwise be unaffordable to most organizations.

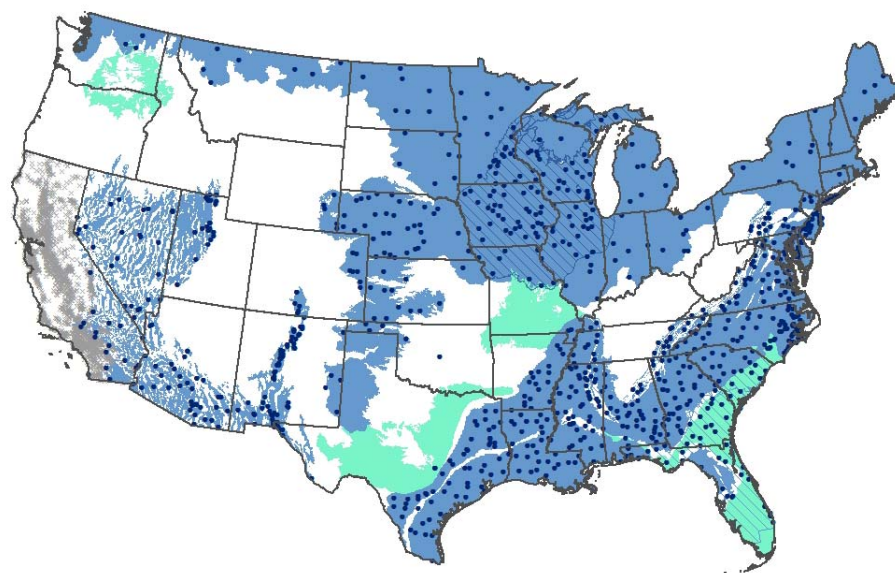


Figure 4. The NAWQA Project is sampling about 1500 public supply wells in 20 Principal aquifers during Cycle 3. Areas in blue show the locations of the wells and Principal Aquifers that were sampled by the NAWQA Project from 2013 to 2015; green areas are Principal Aquifers to be sampled from 2016 to 2022. Cross-hatched areas occur where a Principal Aquifer overlies another Principal Aquifer. Sampling of public-supply wells in the gray areas in California was done in cooperation with State agencies using the same procedures as the NAWQA Project so that the data can be used as part of the assessment of the quality of groundwater in Principal Aquifers.

In 2015, 210 public-supply wells were sampled in the Basin and Range Carbonates (Arizona, Nevada, and Utah), Floridan (Florida, Alabama, and Georgia), Texas Coastal Uplands (Texas), and High Plains (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Wyoming) Principal Aquifers as part of the NAWQA Project's Cycle 3. In 2016, water-quality samples are being collected from 160 public-supply wells in the Biscayne (Florida), Columbia Plateau Basalts (Idaho, Oregon, and Washington), High Plains (Texas), and Ozarks Plateau (Arkansas, Missouri, and Oklahoma) Aquifers. In 2017, water-quality samples will be collected from 180 additional public-supply wells in the Columbia Plateau Basalts (Idaho, Oregon, and Washington), Edwards (Texas), and Stream Valley Aquifers (States to be determined).

In 2016, factsheets summarizing groundwater-quality conditions at the depth zone used for public supply will be completed for six Principal Aquifers: Basin and Range Alluvial Fill (Arizona, California, Nevada, and Utah), Coastal Lowlands (Alabama, Florida, Louisiana, Mississippi, and Texas), Northeastern Coastal Plain (Delaware, Maryland, New Jersey, New York, North Carolina, and Virginia), Southeastern Coastal Plain (Alabama, Georgia, Kentucky, Mississippi, South Carolina, and Tennessee), and the Valley & Ridge, Piedmont, and Blue Ridge Carbonates (Alabama, Georgia, New Jersey, Pennsylvania, Tennessee, and Virginia).

In 2017, factsheets will be published summarizing water-quality conditions in six additional Principal Aquifers: Cambrian-Ordovician (Illinois, Iowa, Michigan, Minnesota, and Missouri), Glacial (21 States), Mississippi Embayment & Texas Coastal Uplands (Alabama, Arkansas, Kentucky, Missouri, Louisiana, Mississippi, and Tennessee), Piedmont and Blue Ridge Crystalline (Alabama, Georgia, Pennsylvania, New Jersey, Maryland, North Carolina, South Carolina, Tennessee, and Virginia), and Rio Grande (Colorado, New Mexico, and Texas).

Groundwater-Quality Trends: During the NAWQA Project's Cycle 3, the NWQP is resampling 79 networks of relatively shallow wells that were previously sampled during Cycles 1 and 2 to provide information on how the quality of water recently recharged to the aquifer is changing through time (Figure 5). Each network typically consists of 20 to 30 wells broadly distributed over an area. The data obtained from these relatively shallow wells, along with the data from the deeper public supply wells, will also be used to develop a three-dimensional perspective on regional groundwater quality conditions. Assessments of how groundwater quality changes with time and with depth can be used by planners and managers to better understand the vulnerability of existing supply wells and guide decisions on the possible placement of new wells.

In 2015, about 285 wells were sampled in ten networks (California, Illinois, Georgia, Maryland, Nebraska, Texas, Washington, and Wisconsin) that were previously sampled during Cycles 1 and 2. National maps showing where contaminant concentrations are changing will be posted on the Web in 2016. In 2016, about 270 wells in nine networks (Idaho, Michigan, Michigan, Minnesota, New Mexico, Nevada, South Carolina, and Washington) will be resampled; and in 2017, about 320 wells will be resampled in eleven networks (Arkansas, California, Connecticut, Iowa, Idaho, Illinois, Mississippi, and New Jersey).

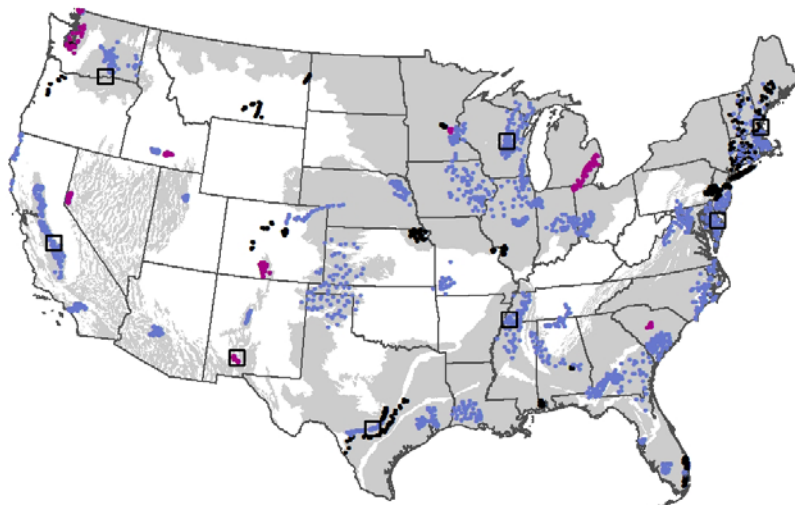


Figure 5. Seventy nine well networks in 20 principal aquifers will be resampled during the NAWQA Project's Cycle 3 to determine how groundwater-quality conditions are changing. Each network consists of 25 to 30 wells in the same principal aquifer spatially distributed (and randomized) across areas ranging from several hundred to several thousand square miles. Nine networks (purple symbols) will be resampled in 2016 with a similar number of networks to be resampled in future years. Resampling of 21 other networks proposed in the Science Plan (black symbols) has been postponed because of funding constraints. More frequent sampling is being done in areas (black squares) to provide information on the relative magnitude of short-term changes to groundwater quality.

Groundwater Quality Modeling and Mapping: Modeling of groundwater quality is an integral component of the NAWQA Project's Cycle 3. These modeling efforts are providing additional insights into the most important factors that affect the vulnerability of domestic and public supply wells to contamination in different aquifer systems, as well as providing capability for extrapolating water-quality findings into areas of sparse data. Water-quality modeling studies are being conducted at local, regional and national scales, and are coordinated with the groundwater flow modeling being done by the USGS Water Availability and Use Program (WAUSP). Groundwater-quality modeling efforts at the regional scale during the NAWQA Project's Cycle 3 are focused on four Principal Aquifer systems: California's Central Valley aquifer system, the Glacial aquifer system that extends across 26 Northern States, the North Atlantic Coastal Plain aquifer system that underlies five Eastern States, and the Mississippi Embayment aquifer system that underlies six Gulf Coast States.

In 2016, the NAWQA Project will complete statistical models of nitrate and arsenic concentrations, two contaminants known to exceed EPA maximum contaminant levels in groundwater pumped from the depths used for domestic and public supply in California's Central Valley aquifer system. Models of aquifer geochemical conditions that affect whether these drinking-water contaminants can persist in California's Central Valley groundwater will also be completed. In 2017, aquifer-wide maps produced with these models will be published and will provide resource managers with information on the sustainability of groundwater as a source of drinking water in California's Central Valley. The models and maps will also provide insight into the length of time needed before water quality changes occur at the depths typically used for domestic and public supply following changes in climate, water use, and (or) land use. Finally, model results at a regional scale will provide estimates of the contribution of contaminants from groundwater to streams that will be useful in calibration of SPARROW models.

For example, defining the parts of aquifers where oxygen concentrations are high (oxic) in the aquifer and where they are low (suboxic) is critical for determining whether nitrate will be transported through groundwater and discharged to streams. In 2015, NAWQA developed a statistical approach (<http://pubs.acs.org/doi/abs/10.1021/acs.est.5b01869>) for mapping the interface between oxic and suboxic groundwater, and provided maps for the Chesapeake Bay watershed (Figure 6). The statistical approach uses geologic, hydrologic, and soils information to predict the occurrence of oxic conditions in the subsurface. In addition to helping assess whether high nitrate concentrations are likely to occur in groundwater used for drinking water, the maps of subsurface conditions provide a basis for assessing the vulnerability of streams to nitrate contamination. Also in 2015, the USGS began work in the Fox-Wolf-Peshtigo watershed in Wisconsin, a tributary to Green Bay, to estimate nitrate flux to the groundwater, subsurface conditions that affect whether nitrate can persist in the groundwater and the time it takes nitrate in groundwater to travel from the water table to streams throughout the watershed.

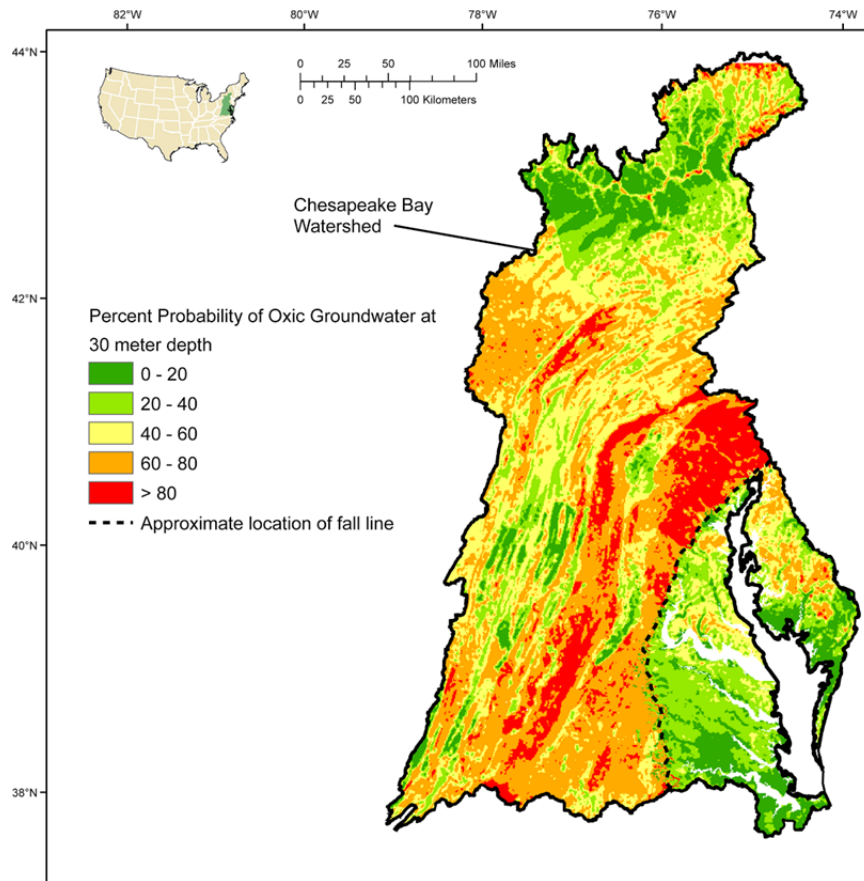


Figure 6. Map illustrating probability of finding oxic groundwater at a 30 meter depth. Areas in red indicate a high probability of oxic groundwater, which in turn, indicates the potential for high concentrations of nitrate, a drinking water contaminant of human health concern, derived from agricultural (fertilizer, manure) and residential (septic leachate, lawn fertilizer) sources.

In 2016, the NAWQA Project will sample 30-40 wells in New York and Maryland to support modeling efforts in the North Atlantic Coastal Plain, with particular emphasis on providing an improved understanding of the loading of nitrate by groundwater to the Chesapeake Bay. In 2017, NAWQA Project

will evaluate the need for sampling a similar number of wells in six-State region (Arkansas, Alabama, Louisiana, Mississippi, Tennessee, and Texas) to support statistical models of groundwater quality in the overlying Mississippi Embayment aquifer system.

2017 Program Change

In 2017, the increase for Support NAWQA Cycle 3, which is presented under the Surface Water Quality Monitoring and Modeling, would increase the Groundwater Quality Monitoring and Modeling by \$620,730.

Unconventional Oil and Gas: Recent technological advances in horizontal drilling and hydraulic fracturing practices have paved the way for significant growth in unconventional oil and natural gas production. More specifically, the Energy Information Administration estimated in its 2014 Annual Energy Outlook that natural gas production could increase by 56 percent in 2040, when compared to production in 2012. The report points out that shale gas alone may account for over half (53 percent) of that increased production in 2040. However, the scale and nature of these technologies have prompted concerns over potential human health and environmental impacts.

One of the widespread public concerns regarding hydraulic fracturing and associated activities is the potential for the impact to water quality of streams and groundwater. Water co-produced with both conventional and UOG production can be highly saline and can contain other naturally occurring contaminants such as radium and arsenic that can contaminate aquifers used as a source of water supply as well as stream ecosystems.

USGS water-quality research, monitoring, and assessments related to UOG extraction is being done at sites across the Country and is supported by several different sources of funding including appropriations to the Toxic Substances Hydrology Program, the WAUSP, and NWQP. The latter includes work done in partnership with other local, State, and tribal cooperators through joint funding agreements.

Cooperative matching funds are supporting water-quality monitoring and assessment activities with State and local partners to help resource managers track the potential effects of oil and gas development. For example, the USGS California Water Science Center began work with the California Water Resources Control Board to design and implement a regional groundwater monitoring program that will help the State to assess and track the potential effects of well stimulation for oil and gas extraction and other oil and gas development activities on groundwater resources that currently, or may in the future, have beneficial uses. Initial implementation of the Regional Monitoring Program during 2015 to 2017 will be primarily focused on Kern County in the southern San Joaquin Valley, which has a long history of oil and gas development, including current extraction by conventional means.

NWQP research is focused on developing and disseminating science based information and tools needed for a fundamental understanding of the processes that affect the occurrence, transport, fate and effects of contaminants in streams and groundwater. For example, in 2015, USGS researchers published findings (<http://www.sciencedirect.com/science/article/pii/S0883292715000955>) from a study examining the inorganic, organic, and microbiological composition produced waters from 13 hydraulically fractured shale gas wells in north-central Pennsylvania that should inform resource managers concerned with the

reuse and handling of produced waters. The study detected a few volatile organic compounds (e.g., benzene) in produced waters that could present potential risks to human health, if the waters were not properly managed. Results indicating that microbial activity is contributing to the degradation of organic compounds present in the produced waters could mitigate potential migration of organic contaminants during disposal or in the case of a surface release of produced waters due to spills or improper handling.

In 2016 and 2017, the NWQP would continue to examine UOG impacts on groundwater and surface water quality including research on the fate and transport of UOG waste in different hydrologic and climatic settings. Studies characterizing the microbial communities associated with produced waters and their potential to degrade different types of organic contaminant will be done. Development of analytical methods to detect a range of chemical additives (i.e., surfactants, corrosion inhibitors, biocides) commonly used in hydraulic fracturing fluid mixtures will also be done. This research and methods development work is needed to understand potential impacts over the entire cycle of UOG operations, and develop best practices and mitigation technologies. In 2017, the NWQP will also develop geochemical methods and models to evaluate contamination of water supplies. This includes applying forensic geochemical approaches for fingerprinting different types of UOG-related contamination to environmental receptors. Cooperative matching funds will be used in 2016 and 2017 to measure fluxes of methane from groundwater to streams and to conduct baseline assessments of groundwater quality in areas undergoing UOG development.

2017 Program Change
Unconventional Oil and Gas Research: (+\$450,000 for a total of \$650,000): The increase to develop and disseminate science-based information and tools needed for a fundamental understanding of the processes that affect the occurrence, transport, fate and effects of contaminants in streams and groundwater affected by UOG extraction activities.

National Atmospheric Deposition Program

(2015 Actual \$1.6 million; 2016 Enacted, \$1.6 million; 2017 Request, \$1.6 million)

Since 1981, the USGS has been the lead Federal agency for the monitoring of wet atmospheric deposition (chemical constituents deposited from the atmosphere via rain, sleet, and snow) in the United States for the interagency National Atmospheric Deposition Program (NADP). The USGS supports about one-third (79 of approximately 250) of the NADP-National Trends Network sites which measure acidity, sulfate, nutrients and other major ions in precipitation (Figure 7). The USGS also supports sites in the 100-site NADP-Mercury Deposition Network and the NADP-Mercury Litterfall Network. These networks provide scientists, resource managers and policy makers worldwide with long-term, high-quality atmospheric deposition data used to support research and decision making in the areas of air quality, water quality, agricultural effects, forest productivity, materials effects, ecosystem studies, watershed studies, and human health.

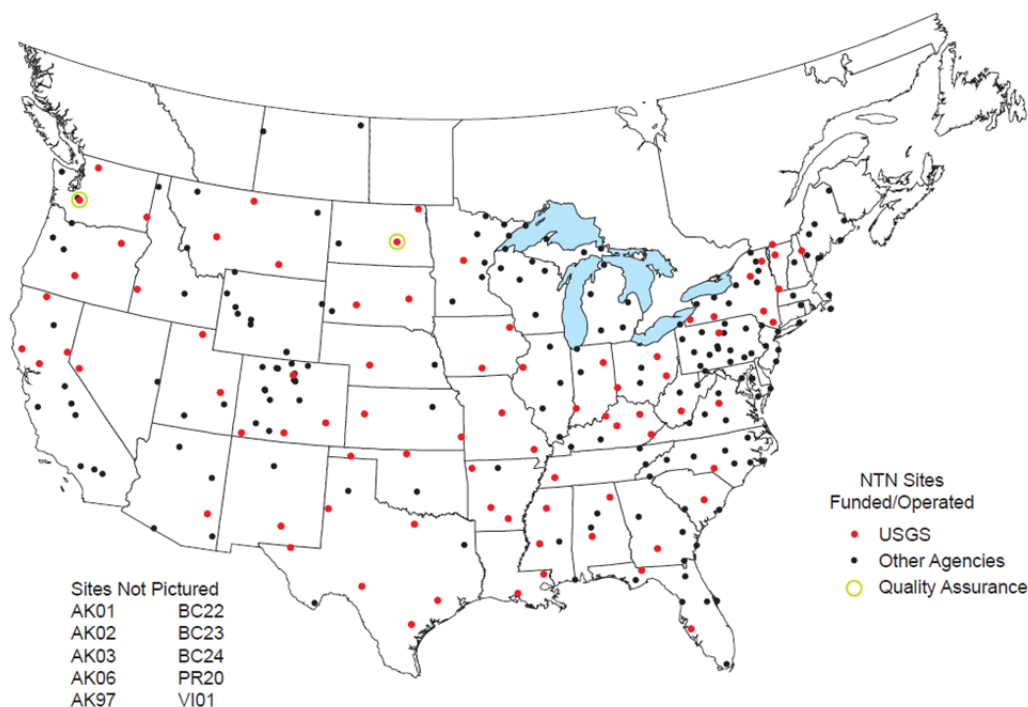


Figure 7. Location of sites in the National Atmospheric Deposition Program Nation Trends Network where acidity, sulfate, nutrients and other major ions in precipitation are measured.

One of the most important purposes of environmental monitoring and assessment is to provide resource managers, policy makers, and the general public with an improved scientific basis for evaluating the effectiveness of environmental management programs. In 2015, research by an American-Canadian collaboration of five institutions led by the USGS showed that the decline in acid rain levels over the past several decades as a result of American and Canadian air-pollution control measures has begun to reverse soil acidification in forests of the Northeastern United States and Eastern Canada leading to partial chemical recovery of streams. Previously published research on soils indicated that soils were becoming more acidic in most areas despite several decades of declining acid rain. As acid rain acidifies soils, it depletes soil calcium reserves, which are important in preventing the formation of aluminum compounds that are toxic to plants and aquatic life. Calcium is also a nutrient essential for healthy ecosystems. Results of this study show that soils are no longer being depleted of calcium and that toxic aluminum levels have substantially decreased. The start of widespread soil recovery is a key step to remedy the long legacy of acid rain impacts on terrestrial and aquatic ecosystems. But the timing and magnitude of ecosystem recovery remains variable and uncertain, and this work is providing valuable information to better understand the expected timing and magnitude of recovery.

Also in 2016, updated, national-scale assessments will be completed and published on: (1) the effects of the recent large declines in sulfur and nitrogen emissions, on atmospheric deposition and (2) multi-decade trends in winter snowpack chemistry at high elevation Rocky Mountain sites ranging from New Mexico to the Canadian border. The assessment of trends in snowpack chemistry is important because these high-elevation mountainous areas, that include many sites in Department of the Interior managed lands, experience some of the highest levels of atmospheric deposition of nitrogen and acidic compounds (due mainly to high precipitation amounts) and ecological impacts in the Western United States.

In 2017, collaborative assessments of the extent and magnitude of ecosystem recovery from acid rain in the Eastern United States will continue using soil chemistry data collected along the entire length of the Appalachian Trail and from USGS reference watersheds in the East, including those near coastal areas. A similar assessment in the Western United States, focusing on observed changes in stream water quality and stream ecology in relation to declines in atmospheric deposition will be conducted.

National Park Service Water-Quality Partnership

(2015 Actual \$1.8 million; 2016 Enacted, \$1.7 million; 2017 Request \$1.7 million)

The NPS manages many of our Nation's most highly valued aquatic systems across the Country, including portions of the Great Lakes, ocean and coastal zones, historic canals, reservoirs, large rivers, high-elevation lakes and streams, geysers, springs and wetlands. Since 1998, the USGS has worked in partnership with the NPS to conduct studies aimed at providing data and information that will assist the NPS in addressing high priority water quality issues of concern. New projects are proposed each year by USGS scientists working in collaboration with NPS staff in specific Parks. Project selection is highly competitive, with an average of only eight new projects funded each year out of approximately 75 proposals submitted.

Researchers have completed more than 200 projects since the beginning of the NPS Partnership and conducted these studies in 115 national parks, extending from Denali in Alaska to the Everglades in Florida and from Acadia in the Northeast to Kaloko-Honokohau National Historical Park in Hawaii in the West. Projects range from monitoring periodic streams for contaminants affecting human health or aquatic life to interpretive studies evaluating the effect(s) or vulnerability of NPS resources to visitor usage and other natural and anthropogenic activities.

“Today, collaboration between NPS and the USGS helps to inform managers and the public about the condition of park resources and the science needed to support informed decision making. The interagency cooperation and sharing of new and state-of-the-art technologies have enabled evaluation and study of parks and their resources that could never be contemplated when NPS was founded in 1916.” Vince Santucci, Senior Geologist, National Park Service, 2014, George Wright Forum vol. 31 no. 2

In 2015, 11 new projects were started in 16 NPS administered units (for example, parks, reserves, monuments, recreation areas, and wild and scenic rivers) (Figure 8). Projects are providing important information on nutrient loading and impacts from agricultural and other upstream land-use development that could degrade water quality in the Buffalo National River (Arkansas) and Big Thicket National Preserve (Texas); the distribution of bacteria indicators that are of concern to bathers and other recreational users within Tumacacori National Historic Park (Arizona); occurrence and significance of endocrine disrupting compounds across the Southeastern United States, including Big South Fork National River and Recreation Area (Kentucky and Tennessee), Chattahoochee River National Recreation Area (Georgia) and Little River Canyon National Preserve (Alabama); understanding the impacts to water quality and stream biology from dam removal in Olympic National Park (Washington); assessing remediation strategies at abandoned mining sites in Saguaro National Park (Arizona) and identifying hotspots for botulism toxin production at Sleeping Bear Dunes National Lakeshore (Michigan).

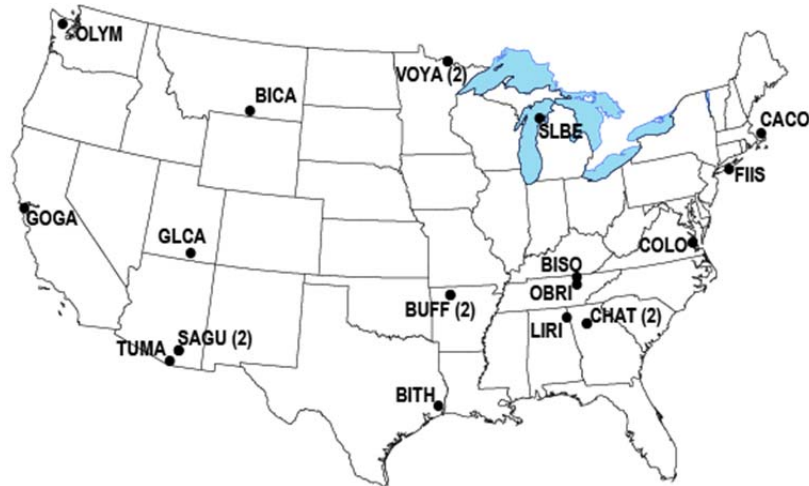


Figure 8. Locations of USGS-NPS Water Quality Partnership Projects initiated in 2015 and 2016.

In 2016, the partnership is initiating eight new projects. One project in the Chattahoochee River National Recreation Area (Georgia) is monitoring potentially harmful bacteria levels and identifying their sources to protect recreational users. At the Jamestown Island Colonial National Historic Park (Virginia), USGS scientists are monitoring network design, protocols and water quality data needed to help the park protect vital archeological, cultural and biological resources threatened by increasing groundwater and groundwater salinity levels. A project at Fire Island National Seashore (New York) will provide the NPS with information on the sources, and movement of nutrients, hormones, and pharmaceutical and other contaminants common to septic systems in shallow groundwater that could impact ponds, wetlands and the Great South Bay estuary located within the Park. At Glen Canyon National Recreation Area (Arizona and Utah) a partnership project is determining the effectiveness of recently implemented personal watercraft regulations intended to reduce hydrocarbon contamination to the waters of Lake Powell. Within Golden Gate National Recreation Area (California), a partnership project is working to identify the specific causes of recent fish kills, including those affecting two federally listed endangered/threatened species and to identify appropriate management actions to ameliorate the problem. Within Saguaro National Park (Arizona), a project is evaluating the impacts to this sensitive ecosystem from aerially applied herbicides used to control damaging invasive species of grasses. At Kabetogama Lake, Voyageurs National Park (Minnesota), USGS scientists are using molecular tools to understand the causes of and to help predict harmful algal blooms and their toxicity levels within the lake.

In 2017, the partnership plans seven new projects following an extensive review and prioritization of proposed projects with the NPS. Projects focus on providing the NPS with critical information needed for management decisions to protect and improve water quality and ecosystem health related to historic land use and reclamation, regional development, nutrient loading impacts, visitor use impacts and contaminants of emerging concern.

Technical Support

(2015 Actual, \$15.8 million; 2016 Enacted, \$14.9 million; 2017 Request, \$14.9 million)

Use of state-of-the-art, high-quality methods for collecting, analyzing, and interpreting water-quality samples and associated data and making these data readily accessible to all are signature strengths of the USGS and the NWQP. A major goal of providing national-level technical support and training is to ensure use of nationally consistent methods and approaches, and consistent quality control so that data from USGS monitoring and assessment activities are comparable across the Country and over time.

New Laboratory Method for Pesticides: The USGS National Water Quality Laboratory (NWQL) is a state-of-the-art, nationally accredited laboratory providing high-quality, reproducible data from the chemical analysis of water, sediment, and tissue samples, and the taxonomic identification of aquatic insects and other invertebrate organisms. The NWQL is a leader in the research and development of new analytical methods to improve detection of contaminants in trace- and ultratrace-levels and in the detection of new and emerging contaminants, such as new pesticide methods, for the NWQP. In 2015, the NWQL completed development of a new analytical method for pesticides that has been approved for the analysis of samples from the NWQN for streams and groundwater. The new method provides capability to analyze for 229 current-use pesticides and pesticide degradates that were included because of their potential for occurrence and persistence in streams and groundwater, and because of their potential toxicity to humans and aquatic organisms. One-third (78) of the compounds are new analytes to be tracked by USGS monitoring networks. The relatively large number of pesticide degradates measured by the method provides the ability to more thoroughly assess the fate of pesticides in the environment, as well as effects of exposure.

In 2016 and 2017, the NWQL will continue to analyze about 30,000 water quality samples collected annually by USGS national programs and science centers, and other Federal, State, and local customers. New analytical methods to analyze VOCs and halogenated organic compounds will be completed.

Nutrient Sensor Challenge: The USGS is part of the coalition of Federal agencies that launched the Nutrient Sensor Challenge in 2014 to accelerate development and deployment of field sensors for nutrients in aquatic systems that will make tracking nitrogen and phosphorus in waterways, which cause HABS and other objectionable conditions, easier, cheaper, and more accurate. In 2015, the Alliance for Coastal Technologies hosted events in the waters of the Great Lakes, Chesapeake Bay, and an ocean setting for participants to test their prototypes. Alliance crews collected water samples throughout the testing events and supplied nutrient data to the teams to give participants some experience deploying their instruments while taking an early look at performance. Verification testing will occur in 2016. Winners of the competition will be announced in December 2016. Sensors that perform well in verification testing, and may be especially well-suited for specific environments/applications, will be eligible to collaborate with piloting partners following conclusion of the Nutrient Sensor Challenge in 2017.

Field Methods and Training: The USGS develops, documents, and mandates the use of scientifically sound, quality-assured field methods, including protocols, procedures, and recommended practices for the collection of water-quality data. These methods are documented in the National Field Manual for the Collection of Water Quality Data. Documenting our methods in a citable reference serves as the basis for

maintaining a highly trained workforce and enables the USGS to: (1) maintain continuity and understanding of the science-based and field tested methods required to accomplish data-collection objectives; (2) support consistency in the implementation of these methods to produce data that are nationally comparable and transferable; and (3) minimize data bias and apply practices that result in data that are reproducible within appropriate limits of variability. Revisions to the National Field Manual are ongoing, incorporating up-to-date technological and scientific advances to keep the manual current with emerging data needs. National training is provided in the use of these field techniques to those responsible for the collection and processing of samples as well as the operation and computation of records of continuous water quality monitors.

Water Quality Portal and Related Tools: Until recently, ready access to current and historical water-quality data and related ancillary information in standardized formats was a major challenge for scientists, resource managers and the public faced with questions about the quality of the Nation's water resources. The Water-Quality Portal, cosponsored by the USGS and the EPA under the auspices of the National Water Quality Monitoring Council and the Advisory Committee for Water Information was specifically designed to address this issue. It integrates publicly available water quality and ecological data from the USGS NWIS, the EPA STORage and RETrieval (STORET) Data Warehouse, and the USDA Agricultural Research Service (ARS) Sustaining The Earth's Watersheds - Agricultural Research Database System (STEWARDS). The Portal currently provides on-line access to more than 275 million water-quality and ecological records collected by more than 450 State, Federal, tribal, and local agencies. Improvements to the data discovery and download features of the Portal in 2014 simplified access to the system resulting in a 45 percent increase in portal visits by the public in 2015. On average, nearly 1.1 million water-quality results are downloaded from the system daily. State agencies are using the Portal to incorporate data from multiple agencies into statewide reporting and assessment efforts. For example, the New Jersey Department of Environmental Protection obtained data through the Portal to automatically generate 305(b) reports for pathogens and the Washington Department of Ecology is starting to incorporate data from the Portal into an integrated reporting tool.

In 2016 and beyond, efforts are focused on encouraging more agencies and organizations to store data in a format recognizable by the Portal; assessing and improving data quality; and designing new simple data exploration tools. Together, the Water Quality Portal and related tools are enabling the USGS to conduct more comprehensive analyses of current water-quality conditions nationally. By making these capabilities available to the public, future innovation is informed from across the water science community.

Science to Support Collaboration

As described above, the NWQP works with States, municipalities, and Tribes in their contributions toward cooperative water efforts. Cooperators choose to work with the USGS because of its broad, interdisciplinary expertise; high-quality, nationally consistent procedures and quality-assurance; innovative monitoring technology, models, and research tools; and robust data management and delivery systems that provide readily available public access to national data. In addition, other partners include:

- USACE

Water Resources

- EPA
- Reclamation
- NPS
- FWS
- BLM
- DOD
- NASA
- Commerce
- Department of State
- DHS
- DOT
- USDA
- DOE

The Water Resources Mission Area partners provided \$286,500,000 of reimbursable funding in 2015.

Activity: Water Resources**Subactivity: Water Resources Research Act Program**

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Actual	Enacted	Fixed Costs	Program Changes	Request	
Water Resources	\$211,267	\$210,687	\$957	\$16,348	\$227,992	\$17,305
FTE	1,371	1,345		29	1,374	29
Water Resources Research Act Program	\$6,500	\$6,500	\$0	\$0	\$6,500	\$0
FTE	1	1		0	1	0
Annual Base Grants	\$5,500	\$5,500		\$0	\$5,500	\$0
Non-Competitive Grants	\$1,000	\$1,000		\$0	\$1,000	\$0
Coordination Grants	\$0	\$0		\$0	\$0	\$0
Student Internships	\$0	\$0		\$0	\$0	\$0

Justification of Program Changes

The 2017 Budget Request for the Water Resources Research Act Program is \$6,500,000 and 1 FTE, with no change from the 2016 Enacted level.

Overview

The Water Resources Research Act (WRRRA) of 1984 established a Federal–State partnership in water resources research, education, and information transfer through a matching grant program. The WRRRA authorized the establishment of State Water Resources Research Institutes (National Institutes for Water Resources) at land grant universities across the Nation. There are 54 Institutes: one in each State, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam. The Guam institute also serves as the Federated States of Micronesia and the Commonwealth of the Northern Mariana Islands. The WRRRA Program provides an institutional mechanism for promoting State, regional, and national coordination of water resources research, promotes student education and training, and is a focal point for research coordination and information and technology transfer. This program will continue to support each Institute and coordinate multi-year research, education, and information transfer projects on State and regional water resources issues. The WRRRA expired in 2011 and requires reauthorization.

Mission: The *WRRRA Program* plans, facilitates, and conducts research to aid in the resolution of State and regional water problems. The program promotes technology transfer and the dissemination of research results while providing for the training of the next generation of scientists and engineers through their participation in research.

In 2016, the WAUSP received \$1.0 million for the U.S. Mexico Transboundary Aquifer Assessment. In the United States – Mexico Transboundary Aquifer Assessment Act (TAAP, Public Law 109-448) that was signed into law by the President of the United States on December 22, 2006, it states for the USGS to

conduct binational scientific research to systematically assess priority transboundary aquifers and to address water information needs of border communities. The TAAP authorizes the Secretary of the Interior, through the USGS, to collaborate with the States of Arizona, New Mexico, and Texas through their Water Resources Research Institutes (WRRIs) and with the International Boundary and Water Commission (IBWC), stakeholders, and Mexican counterparts to provide new information and a scientific foundation for State and local officials to address pressing water-resource challenges along the U.S. – Mexico border. The WAUSP will work closely with the WRRRA Program’s Arizona, New Mexico and Texas Water Resources Research Institutes to develop work plans and implement the project. The TAAP expires in 2016 and requires reauthorization.

In 2017, a comprehensive programmatic Institute evaluation will be conducted on all 54 Institutes to determine their eligibility for continued support under the WRRRA. The programmatic evaluation is conducted at least once every three years with the last evaluation in 2014. The determination of continued support is based on each Institute’s effectiveness in the use of its Federal grant dollars and required matching funds in meeting the mandates of the WRRRA. The evaluation panel will be composed of: (1) a Department of the Interior Employee; (2) a University or other professional with experience in conducting water resources research; (3) a former Director of a Water Resources Research Institute; and (4) a University faculty or other professional with relevant experience in information transfer.

Program Performance

The WRRRA program includes the following four program components, described in more detail below: Annual Base Grants (104b), National Competitive Grants (104g), Coordination Grants, and Student Internships. The Coordination Grants and Student Internships components are funded solely by reimbursable funding.

Annual Base Grants (104b)

(2015 Actual, \$5.5 million; 2016 Enacted, \$5.5 million; 2017 Request, \$5.5 million)

In 2016, the USGS appropriated dollars of \$5.5 million plus an Institute match of \$10.6 million funded 225 research projects to address State and regional water problems. These projects addressed the entire spectrum of water issues and were used by water managers and the public to improve water quality, water treatment technologies, and water supply reliability at the State and regional level. These research projects directly supported student education by training scientists and engineers through their participation in research (<http://water.usgs.gov/wrri/annual-base-grants.php>). All research projects funded by annual base grants are selected at the Institute level through a competitive selection process that is run by each Institute within their respective States. Additional funding beyond the current \$6.5 million of Federal funding would be used to develop a regional competitive grants program that Institutes would use to assist in achieving the USGS Strategic goals and the Administration’s national water science priorities.

Research projects funded in 2016 and 2017 will not only meet the goals of the WRRRA, but will also promote the national mission and objectives of the USGS which are focused on water quality and quantity

information, understanding water availability, addressing the influence of climate on water resources, and responding to water-related emerging needs.

A major effort of the WRRR program in 2016 that will continue into 2017 is to develop and host regional conferences to address significant water resource issues. An example of a successful conference, described below, that was held in 2016.

- Tropical oceanic islands share many of the same water and wastewater problems and issues despite the diverse hydrological and geomorphological factors, climate, and degree of development. By sharing knowledge and developing collaborations with research scientists across many islands, the Water Resources Research Institute Directors (Hawaii, Puerto Rico, Guam, and U.S. Virgin Islands) hosted a conference, in December 2015, to share their Institutes' results, perspectives, and potential solutions to these concerns. Through the exchange of knowledge and collaboration with USGS scientists, island research scientists, managers, utility providers, students, and decision makers, the goal of the conference was to increase the effectiveness of all four Institute programs in addressing common island water issues. (<http://www.wrrc.hawaii.edu/2015conference/index.shtml>)

During 2016 and 2017, the WRRR program will be writing factsheets on national priority topics (harmful algal blooms, hydraulic fracturing, drought, nutrient runoff, and educating the next generation of scientists) related to water resources worked on through the Annual grants. These series of factsheets will be published by the USGS, and will document the collective impact that the Institutes have had in addressing these topics through their research and student education programs.

Annual Base Projects: Below are examples of Annual Base Grant projects in the WRRR Program:

- *Moving Toward a Real-Time Drought Assessment and Forecasting System for Kansas:* This research project by the **Kansas Water Resources Institute** will document and establish the requirements of developing a real-time Kansas drought assessment and forecasting system in order to improve decision-making activities that affect the economic efficiency and sustainability of the Kansas. Project goals are to construct an integrated drought-related dataset that will be used to analyze historic drought episodes, establishing Kansas's benchmark metrics for detecting the onset, duration, severity and frequency of drought.
- *Effect of a Weed Killer (Herbicide Atrazine) on Phytoplankton, Water Quality, and Ecosystem Functions in Louisiana Coastal Wetlands:* The **Louisiana Water Resources Research Institute** is quantifying the amount of Herbicide Atrazine entering into the Breton Sound Estuary as result of freshwater inputs from the Mississippi River under different flow and nutrient regimes. In addition, the Institute is assessing distinct responses of local phytoplankton communities to the Atrazine by determining the toxicity of the herbicide on individual phytoplankton growth and community structure changes. Knowing the natural levels of Atrazine and responses of phytoplankton to such levels can be especially important for higher trophic levels, since their growth and abundance can determine the potential productivity of the entire ecosystem.
- *Development of Soil Moisture Drought Index (SODI) to Characterize Hydrological Droughts in the Northwest:* A new drought index is needed to capture variations of precipitation, temperature, and soil moisture variation over time. This **Idaho Water Resources Research Institute** project

will make improvements to the existing drought indices to also consider local hydrologic variables, such as streamflow, reservoir storage, and groundwater levels. The SODI index may be able to detect and quantify extended drought in the Northwest.

National Competitive Grants (104g)

(2015 Actual, \$1.0 million; 2016 Enacted, \$1.0 million; 2017 Request, \$1.0 million)

This program component supports an annual call for proposals to focus on water problems and issues that are of a regional or interstate nature or relate to a specific program priority identified by the Secretary of the Interior and the Institutes. Total funding in 2015 was approximately \$1.0 million and funded four research projects to study: (1) human and ecological health impacts associated with water reuse; (2) hydrologic life cycle of the mountain pine bark; (3) investigation of trace organic contaminants in urban storm water; and (4) assessing insecticide toxicity in urban sediments. Additional information on these projects may be found at the Web site (<http://water.usgs.gov/wrri/national-competitive-grants.php>). In 2016 and 2017, the WRRRA Program will promote collaborations between the USGS and University scientists in research on significant national and regional water resources issues. USGS appropriated funds will be used to fund USGS scientists to collaborate on University research proposals that are selected through the competitive process.

In 2016 and 2017, the USGS plans to further refine the Request For Proposal to further the goals of the WRRRA and the strategic directions for *USGS Water Science Strategy: Observing, Understanding, Predicting, and Delivering Water Science to the Nation* (<http://pubs.usgs.gov/circ/1383g/circ1383-G.pdf>). Specific areas of research that overlap include: (1) providing society the science it needs regarding the amount and quality of water in all components of the water cycle; (2) advancing our understanding of processes that determine water availability; and (3) predicting changes in the quantity and quality of water resources in response to changing climate, population, land use, and management scenarios.

Annual Base Projects: Below are examples of National Competitive Grant projects in the WRRRA Program:

- **Natural Uranium contamination in major U.S. aquifers are linked to nitrate** – Two scientists from the University of Nebraska-Lincoln were funded by the 2014 National Competitive Grant program to study naturally occurring groundwater uranium (U) in the High Plains and Central Valley aquifers that exceeded the EPA maximum contaminant level (MCL = 30 µg/L). Approximately 1.9 million people live over these two aquifers and many obtain their drinking water from these systems. Analysis of geochemical parameters revealed a moderately strong correlation between U and nitrate, a common groundwater contaminant. Their results indicate that nitrate, a primary contaminant, should be considered as a factor leading to secondary groundwater U contamination in addition to the recognized role of alkalinity and calcium.
- **Impacts to surface water reservoirs from deforestation** – A student at the South Dakota School of Mines and Technology was recently funded by the 2015 National Competitive Grant program to study the impact to municipal water supplies across the Western United States from the mountain pine beetle epidemic. Not only does the massive tree loss change watershed and runoff characteristics, but the decay of dead trees and needles have increased dissolved organic

matter which when incorporated into municipal water supplies are precursors to toxic disinfection by-products.

Coordination Grants

These grants are reimbursable funding and authorized by the WRRRA Program that allows the USGS and other Federal agencies to take advantage of the expertise and capabilities that are available through the network of Institutes. In 2015, the USGS issued 12 new coordination grants in cooperation with other USGS programs, the EPA, Nuclear Regulatory Commission, and USACE. Additional information on these projects may be found at the Web site (<http://water.usgs.gov/wrri/coordination-grants.php>). In 2016 and 2017, the WRRRA Program will continue to award these annual grants based on the availability of reimbursable funding.

Student Internships

In cooperation with the National Institutes for Water Resources, the WRRRA Program coordinates student interns to provide undergraduate and graduate students with career field, laboratory, and research experience through participation in USGS activities as interns. This is done through reimbursable funding. In 2015, 10 students participated in new and ongoing internships throughout the Nation. Featured student internship projects along with a listing of all internships may be found at (<http://water.usgs.gov/wrri/student-internships.php>). In 2016, the WRRRA program initiated a new project entitled “USGS WRRRA-NIWR Education Project” to look at the impact of the internship program, and students funded to research through the Annual Base Grants, to determine if funded students have become USGS scientists or leaders in the hydrologic community after graduation.

Science to Support Collaboration

As described above, the WRRRA Program works closely with land grant universities across the Nation as a Federal–State partnership in water resources to further research, education, and information transfer through a matching grant program. The Water Resources Mission Area partners provided \$286,500,000 of reimbursable funding in 2015.

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Core Science Systems

Activity: Core Science Systems

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Core Science Systems	\$107,228	\$111,550	\$408	\$6,437	\$118,395	\$6,845
<i>FTE</i>	469	472		6	478	6
National Geospatial Program	\$58,532	\$62,854	\$238	\$5,887	\$68,979	\$6,125
<i>FTE</i>	264	267		6	273	6
National Cooperative Geologic Mapping Program	\$24,397	\$24,397	\$89	\$0	\$24,486	\$89
<i>FTE</i>	114	114		0	114	0
Science Synthesis, Analysis, and Research Program	\$24,299	\$24,299	\$81	\$550	\$24,930	\$631
<i>FTE</i>	91	91		0	91	0

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
National Geospatial Program	+ 5,887	+ 6	K-9
3D Elevation: Alaska Mapping and Map Modernization	+ 1,500	+ 0	K-14
3D Elevation: Coastal lidar	+ 500	+ 0	K-15
3D Elevation: National Enhancement	+ 2,387	+ 3	K-14
3D Elevation: NHD/Landscape Level Assessments - Chesapeake Bay	+ 500	+ 0	K-15
WaterSMART: National Hydrography Database	+ 1,000	+ 3	K-15
Science Synthesis, Analysis and Research Program	+ 550	+ 0	K-31
Pollinators	+ 350	+ 0	K-36
WaterSMART: Drought	+ 200	+ 0	K-36
Total Program Change	+ 6,437	+ 6	

Justification of Program Changes

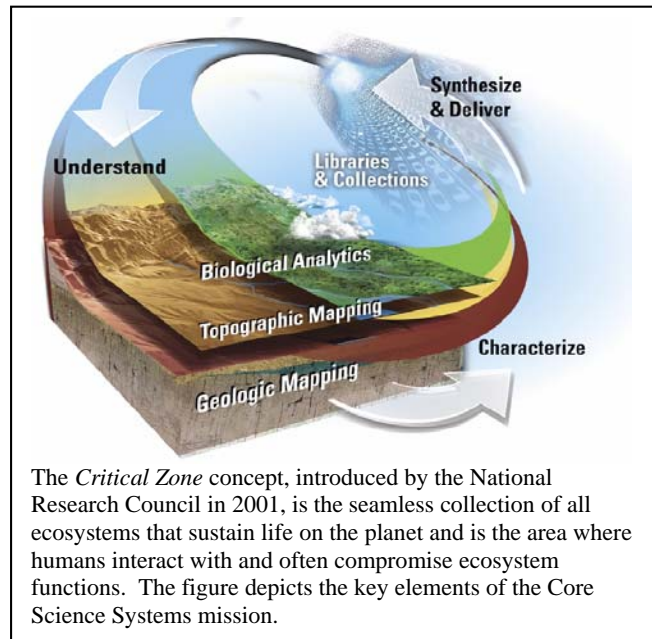
The 2017 Budget Request for Core Science Systems (CSS) is \$118,395,000 and 478 FTE, a net change of +\$6,845,000 and +6 FTE from the 2016 Enacted level.

Overview

As part of the Nation's largest water, Earth, and biological science and civilian mapping agency, the CSS Mission Area conducts national-focused Earth-system science to deliver an understanding of the Earth's complex geologic structure. CSS conducts core sciences across a broad range of fields from structural geology, geomorphology (geomorphologists seek to understand why *landscapes* look the way they do, to understand landform history and dynamics and to predict changes) and geophysics, to geography and remote sensing, evolutionary biology and biogeography (the study of the distribution of *species* and *ecosystems* in geographic *space* and through (*geological*) *time*). Products include scientific publications, three-dimensional geologic models, fundamental geospatial data, geologic and topographic maps, and interpretive studies, all of which are essential for informed public policy decision making and economic development.

Core Science Systems

Modern mapping includes Earth observations from many platforms (such as satellite, airborne, and unmanned aerial vehicles) and uses continuously evolving technologies that can sense and map an expanding list of features, such as gravity, magnetism, and thermal signatures using the latest technologies. Through collaborative efforts with Federal, State, tribal and local partners, CSS delivers nationally consistent, high-quality geologic, topographic, and biogeographic information. Detailed, accurate information about the nature and origin of the geology of an area, portrayed through geologic maps and three-dimensional frameworks, is essential for identifying mineral, oil, and gas resources, finding and protecting groundwater, guiding earthquake damage prediction, identifying landslide and post-wildfire hazards, guiding transportation planning, and generally improving the quality of life and economic vitality of the Nation. For example, highly accurate elevation maps and data are essential for hazards mitigation, conservation, infrastructure development, national security, coastal shoreline erosion, and many other applications. The benefits apply to flood risk management, agriculture and precision farming, water supply, homeland security, renewable energy, aviation safety, and other activities.



CSS's overarching themes include:

- Providing foundational geospatial data throughout the Country
- Upholding long-standing successes and flagship products
- Achieving breakthroughs in research and technology
- Building on a foundation of consultation and collaboration
- Continuing collaborative partnerships with State, local, and tribal entities
- Connecting with a diverse constituent base that relies on these programs

Core Science Systems Objectives

The National Geospatial Program (NGP) provides the digital geospatial foundation for the Nation. These data are accessed through The National Map, a free, interactive application from which customers can download geospatial data and map products directly, or incorporate those products into their own applications through a variety of Web map services. The NGP not only acquires and manages geospatial data, but also conducts quality control and assessment prior to publishing and delivering high quality products to the public characterizing the Nation's topography, natural landscape, and built environment. Federal, State, local, and tribal governments as well as the private sector incorporate these

data and maps into their business activities and applications to make more informed decisions. Data available in The National Map enable a diverse array of applications including understanding seismic and landslide hazards and forecasting floods, analyzing and mitigating coastal erosion and storm surge, improving aviation safety, enabling precision agriculture and conservation, water quality analyses, assessments of water quantity, and improved estimates of water usage. Topographic maps produced by the NGP are essential for scientific fieldwork, and provide a base onto which geologic and other scientific data can be overlain and referenced. The USGS works with several Federal agencies to acquire new geospatial data, which are collected primarily by industry partners via the USGS Geospatial Product & Services Contracts. These partnerships increase the amount of data, lower the contract management burden and overall costs of collecting data, reduce redundancy, and ensure interoperability standards and data availability in the public domain. The USGS also receives new geospatial data from State and local partners through cooperative agreements and directly from donations. For more information, go to:

The National Map site – <http://nationalmap.gov/>

The Federal Geographic Data Committee (FGDC) implements cross-government geospatial initiatives, such as the Geospatial Platform, promotes and endorses consistent data and metadata standards, system interoperability, and cross-government best business practices for geospatial resources, policies, standards, and technology in support of the National Spatial Data Infrastructure. The FGDC Office of the Secretariat, administered by the USGS, supports the Committee and its 32 member agencies to enhance the availability, increase delivery efficiency, and reduce duplication of Federal geospatial data. The FGDC has oversight responsibility for the Geospatial Platform shared service, an Internet-based suite of trusted geospatial data, services, and applications for use by Federal agencies and their State, local, tribal, and regional partners. For more information, go to:

Federal Geographic Data Committee, Office of the Secretariat – <http://www.fgdc.gov/>

Geospatial Platform – <http://www.geoplatform.gov>

The National Cooperative Geologic Mapping Program (NCGMP) surveys and researches the Nation's geological resources, and portrays the findings in maps, models, and databases, through a Federal-State-university partnership. The NCGMP cooperates with State geological surveys to provide publications, digital geologic maps, and multidimensional models and visualizations to sustain and improve the quality of life and economic vitality of the Nation and to mitigate natural hazards. The program makes geologic mapping data, from all of North America, publically and freely available by way of the National Geologic Map Database. Since its inception over 23 years ago, the program has leveraged more than \$118 million in Federal funding matched by the State geological surveys to collaboratively produce modern geologic maps for the Nation and \$9 million matched by universities to train over 1,100 college geoscience students. For more information, go to:

NCGMP main program page – <http://ncgmp.usgs.gov/>

The National Geologic Map Database – http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

FEDMAP component– <http://ncgmp.usgs.gov/about/fedmap.html>

STATEMAP component– <http://ncgmp.usgs.gov/about/statemap.html>

EDMAP component – <http://ncgmp.usgs.gov/about/edmap.html>

Federal Advisory Committee – http://ncgmp.usgs.gov/about/evaluation/faca_intro.html

The Science Synthesis, Analysis, and Research (SSAR) subactivity is comprised of the J.W. Powell Center for Analysis and Synthesis; the National Geological and Geophysical Data Preservation Program; and the Core Science Analytics, Synthesis, and Libraries program. The SSAR provides unique scientific collaborations, employs nationwide biological analytics to enable data-driven science (e.g. developing species distribution and protected areas maps), preserves and makes available rock and ice core samples for scientific research, and advances a framework for geoscience data and information sharing. These programs develop and distribute contemporary compilations of data about land management, biodiversity and species distribution, and subsurface characterization. Using state-of-the-art technologies, SSAR enhances CSS's ability to advance the USGS Science Strategy by developing, identifying, and implementing best practices for accessing, integrating, visualizing, and delivering USGS data and information. For more information, go to:

J.W Powell Center for Analysis and Synthesis – <http://powellcenter.usgs.gov/>

National Geological & Geophysical Data Preservation Program – <http://datapreservation.usgs.gov/>

Core Science Analytics, Synthesis, and Libraries – http://www.usgs.gov/core_science_systems/csas/

The USGS Library – <http://library.usgs.gov/>

The 2017 President's Budget Request for CSS includes increases in funding for activities to further develop the 3D Elevation Program (3DEP), improve the National Hydrography Dataset, and acquire data to support a landscape level understanding of priority areas. The 3DEP funds would be used to increase and facilitate nationwide USGS cooperation and investments with partners proposing to cost share 3DEP data acquisition through a competitive solicitation process (e.g. Broad Agency Announcement). The 3DEP increase would also be dedicated to expanding the acquisition of elevation data in Alaska collected by ifsar (interferometric synthetic aperture radar) as well as improving mapping products that are dependent upon ifsar elevation. Involvement with the Alaska Mapping Executive Committee and coordination with other Federal and State agencies facilitates identification of priority needs and partnering opportunities both in Alaska and across the Nation. The request also includes an increase toward the development and acceleration of a higher-resolution National Hydrography Dataset (1:24,000 scale) over the conterminous 48 States, Hawaii, and Puerto Rico. This effort would enable integration of USGS 3DEP lidar data with high-resolution elevation information, and vastly improving the accuracy and usefulness of surface water data datasets. Increased funding would also support 3DEP data acquisitions and hydrography data development over coastal areas vulnerable to natural disasters and landscape change, as well as the Chesapeake Watershed to better assess impacts of regional agriculture and conserve important natural resources and wildlife. A proposed request for additional funds for the pollinator initiative would address research priorities identified through the 2014 Presidential Memorandum on Pollinator Health, through decision tools for land and resource management agencies. This increase would allow the program to create maps and analyses for habitats of critical concern for pollinators. In addition, a requested funding increase would be used to build on existing capabilities in gap analysis and collaborations with the Land Change Science Program to provide species modeling for specific habitats. These outputs would improve the USGS support to ecosystem conservation planners by providing maps and analyses of species and habitats of critical concern for drought effects.

Key Accomplishments in 2015

- Achieved a fully operational 3D Elevation Program (3DEP).
- Published 18,770 US Topos over the lower 49 States and Puerto Rico and 1,756 Alaska US Topos.
- Acquired 69,000 square miles of ifsar over Alaska (State coverage is now 62 percent). Acquired 151,000 sq mi of QL2 or better lidar data over the lower 49 States; awarded over \$30 million for data acquisition via contracts with the public sector.

- Continued leadership of the 3DEP Executive forum to strengthen Federal interagency coordination and share applications and technology development; held a 3DEP Stakeholders meeting; assisted all 50 States and many Federal agencies via public webinars on how to participate in interagency data acquisition partnerships.
- Chaired the Arctic Spatial Data Infrastructure Board and worked with international stakeholders to make progress on the Arctic SDI Strategic Plan 2015-2020, the Arctic SDI Geoportal, and Pan-Arctic Elevation Model.
- Worked with other Federal agencies and State partners to achieve 62 percent of elevation mapping for the State of Alaska.
- Leveraged every Federal dollar awarded through STATEMAP and EDMAP to attract State and university dollars, and FEDMAP dollars were leveraged to attract contributions from other Interior agencies, State and county water agencies and private industry.
- Published a GSA Special Paper (509) titled *The 2011 Mineral, Virginia, Earthquake, and Its Significance for Seismic Hazards in Eastern North America*.
- Delivered high performance computing to conduct more than 150 science projects, improving model run times, and broadening scientific research capability.
- Nearly doubled the size of Biodiversity Information Serving Our Nation (BISON), now with nearly 244 million records. Disparate species occurrence data, with an emphasis on USGS Ecosystems Science Center data, was integrated into BISON, creating efficiencies in delivering this data from a single system with a national view.
- Produced a synthesized map of resource management concerns in Nevada, showing sage grouse habitat suitability, fire history, pinyon-juniper habitats, cheatgrass coverage and geothermal energy development sites.
- Provided support to States that enabled preservation and digitization of unique and irreplaceable geoscience materials.
- Provided access to 1.7 million feet of rock core samples from 33 States to researchers; benefits include national resource development potential, prosperity, and security.

The American Council for Technology (ACT) – Industry Advisory Council (IAC) recognizes successes in Government via their annual Excellence.gov awards, a benchmark for superior performance in government programs.

In 2015 the USGS Community for Data Integration was chosen for the 2015 Award for Excellence in “Analytics and Big Data” among 70 competitors

This recognition truly represents a USGS-wide award as members of the community come from all regions, all mission areas, and all science and technical disciplines. The Community is richly deserving of this recognition and has demonstrated the power of solutions from the bottom-up. Since its inception, the Community has significantly increased the visibility of USGS science by making its data more discoverable, accessible, and integrated, and has made the Department of the Interior a leader in a variety of data management topics, from Open Data, to Data Visualization, Modeling, High Performance and Mobile Computing, and Citizen Science.

The CSS's Strategic Plan, *U.S. Geological Survey Core Science Systems Strategy – Characterizing, Synthesizing, and Understanding the Critical Zone through a Modular Science Framework*, outlines three broad goals for the coming decade:

1. Provide research and data to characterize and understand the Critical Zone.
2. Expand USGS research applications through scientific services.
3. Conduct scientific analysis and synthesis to improve coverage, scientific quality, usability, and timeliness of information.

The CSS Mission Area uses its information resources to create a more integrated and accessible environment for existing and new USGS data resources and participates in building global integrated science platforms.

CSS leads the USGS in the development and implementation of national standards for use in the creation, management, and dissemination of digital Earth systems information to stakeholders.

Strategic Actions for 2016

- Continue the formal implementation of the 3DEP to systematically collect enhanced elevation data over the conterminous United States, Hawaii, and the U.S. territories using high-quality light detection and ranging (lidar). Emphasize data collection over areas subject to flooding, sea level rise, geologic hazards, wildfires, and threats to critical infrastructure to enhance planning and improve landscape level resilience.
- Implement Web-based services to allow users to easily access elevation data and derivatives for use in landscape-level planning, decision support and scientific modeling applications.
- Continue to partner with Federal, State and local agencies in the Columbia River basin and Puget Sound priority ecosystem areas to develop detailed elevation, hydrography, and other geospatial data needed to support scientific activities, and better plan mitigation and restoration efforts.
- Continue to enhance hydrography (surface water) feature data by adding regional water modeling information to increase the value of this data to hydrologists, water resource managers, and other users in collaboration with other Federal, State, local, and tribal governments as part of the WaterSMART initiative.
- Deliver base geospatial data products and services from a cloud-based platform to maximize ease of use and increase speed and performance of delivery to end users.
- Employ the Geospatial Platform to provide guidance and tools to assist communities in landscape-level decision making, using a shared infrastructure to host, register, and provide data services.
- The Geospatial Platform will begin utilizing cloud infrastructure to support geospatial data and services hosting to expand agencies' opportunities to register and provide data and tools in support of landscape level understanding.

Strategic Actions for 2017

- Continue leadership through the 3DEP Executive Forum to facilitate Federal agency participation in the Broad Agency Announcement process to coordinate the acquisition of elevation data and leverage federal investments.
- Implement an outreach and communication strategy to successfully promote the partnership approach for data acquisition.
- Continue development of improvements to the Lidar Base Specification to insure improved and consistent data quality.
- Continue the three-year cycle of replacing topographic maps for 49 States, Washington, D.C., Puerto Rico, and the Virgin Islands. Use the new enhanced elevation data to improve the quality of the topographic maps.
- For the State of Alaska, continue acquisition of modern elevation data, develop more efficient means of updating hydrography data, and increase the rate of topographic map production and distribution methods.
- The Geospatial Platform will provide a dashboard of tools that report automated metrics on system use, tool use, and data service quality. Federal agencies will have access to these tools to improve data service and data quality reporting to assist with management responsibilities for National Geospatial Data Themes that provide key data for landscape-level management.
- Deliver base geospatial data products and services from a cloud-based platform to maximize ease of use and increase speed and performance of delivery to end users.

Activity: Core Science Systems

Subactivity: National Geospatial Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Core Science Systems	\$107,228	\$111,550	\$408	\$6,437	\$118,395	\$6,845
FTE	469	472		6	478	6
National Geospatial Program	\$58,532	\$62,854	\$238	\$5,887	\$68,979	\$6,125
FTE	264	267		6	273	6
User Engagement	\$9,000	\$9,000		\$0	\$9,000	\$0
Topographic Data Services	\$20,932	\$25,254		\$5,887	\$31,141	\$5,887
<i>3D Elevation: Alaska Mapping and Map Modernization</i>	<i>[\$3,900]</i>	<i>[\$5,222]</i>		<i>[\$1,500]</i>	<i>[\$6,722]</i>	<i>[\$1,500]</i>
<i>3D Elevation: Coastal lidar</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$500]</i>	<i>[\$500]</i>	<i>[\$500]</i>
<i>3D Elevation: National Enhancement</i>	<i>[\$16,500]</i>	<i>[\$19,500]</i>		<i>[\$2,387]</i>	<i>[\$21,887]</i>	<i>[\$2,387]</i>
<i>3D Elevation: NHD/Landscape Level Assessments - Chesapeake Bay</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$500]</i>	<i>[\$500]</i>	<i>[\$500]</i>
<i>WaterSMART: National Hydrography Database</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$1,000]</i>	<i>[\$1,000]</i>	<i>[\$1,000]</i>
Cartographic Data Services	\$19,700	\$19,700		\$0	\$19,700	\$0
Geospatial Research	\$5,100	\$5,100		\$0	\$5,100	\$0
Federal Geographic Data Committee - Office of the Secretariat	\$3,800	\$3,800		\$0	\$3,800	\$0

Justification of Program Change

The 2017 Budget Request for the National Geospatial Program is \$68,979,000 and 273 FTE, a net change of +\$6,125,000 and +6 FTE from the 2016 Enacted level.

Overview

The National Geospatial Program (NGP) organizes, updates, and publishes the geospatial baseline of the Nation's topography, natural landscape and built environment through *The National Map*; and conducts geospatial research to discover new approaches for updating and using geospatial data and for reducing costs of these activities. Users throughout the Federal Government, including those in Interior, the Departments of Agriculture (USDA), Commerce, and Defense; the Environmental

In 2014 and 2015, NGP along with other USGS programs partnered with the U.S. Forest Service to obtain over 480 sq. mi. of high-resolution lidar data over Glacier Peak, WA, a very high-threat volcano that had no real-time monitoring network and a poorly understood eruptive history. The data are now uploaded onto mobile devices and used in the field by USGS volcanologists. A real-time sensor was installed at an optimum site, and more are planned as part of a monitoring network. The nearly 760,000 people residing in Snohomish County, WA, and more in nearby Seattle-Tacoma area are now better protected. The USGS will be conducting new geologic investigations and hazard assessments using these data.

Protection Agency (EPA), the Federal Emergency Management Agency, National Guard Bureau; and States, Tribes, the private sector, and other organizations use NGP geospatial data, derived topographic map products and Web services to support their decision making and operational activities. The NGP focuses on communities of use including the areas of water resource and flood risk management, geologic mapping and hazards, and natural resource management. NGP-sponsored cooperative data acquisition projects reduce duplication of expenditures among Federal agencies and with State and local governments, and result in millions of dollars in contracts for America's geospatial industry. The NGP supports the Interior's responsibilities for national geospatial coordination, and carries out the USGS's government-wide leadership responsibilities for elevation, hydrography and watershed boundaries, and geographic names.

The Federal Geographic Data Committee Office of the Secretariat (FGDC OS) coordinates geospatial activities across Federal agencies and with non-Federal organizations as required by the Office of Management and Budget (OMB) Circular A-16 and Executive Order 12906. The FGDC OS provides support for key Federal geospatial initiatives and priorities, including the Geospatial Platform, the National Spatial Data Infrastructure (NSDI) Strategic Plan, and the OMB Circular A-16 Supplemental Guidance and its associated National Geospatial Data Asset Management Plan. The Geospatial Platform directly supports Interior's Strategic Plan goal to provide shared landscape-level management and planning tools, and supports other Federal mission areas as a shared service and primary community collaboration tool. These activities support and enhance information availability for decision making and science, increase information delivery efficiencies, and minimize duplication of Federal geospatial-data assets through shared services that leverage economies of scale.

Program Performance – The National Geospatial Program is comprised of five program components: User Engagement, Topographic Data Services, Cartographic Data Services, Geospatial Research, and the Federal Geographic Data Committee – Office of the Secretariat

User Engagement

(2015 Actual, \$ 9.0 million; 2016 Enacted, \$9.0 million; 2017 Request, \$9.0 million)

The User Engagement component works within the USGS and with States and other Federal agencies to optimize how the USGS develops The National Map to best meet user needs. The component performs targeted outreach and provides technical and programmatic support to demonstrate the applicability of NGP products and services in meeting users' geospatial data requirements. A distributed network of National Map Liaisons works to gather user requirements for geospatial products and services, actively promotes the products and services of the NGP, and provides critical support related to joint geospatial data acquisition strategies with key partners. Communities of Use (Water Resources, Geologic Mapping and Hazards, and Natural Resources Conservation) are engaged to determine and prioritize geospatial data requirements of USGS scientists, Interior and other Federal resource managers, and State and local decision makers. User Engagement also includes Federal and National Map Liaison activities to develop and maintain relationships with users and sources of authoritative data. Through these efforts, the USGS ensures program capabilities meet current and future requirements and mission needs for 3D elevation and hydrography data and applications across the broadest possible spectrum of users.

The component supports the Alaska Mapping Executive Committee, and coordinates NGP efforts to modernize mapping over the State of Alaska, as well as the broader Arctic region. The NGP supports execution of mandated responsibilities for the Arctic Spatial Data Infrastructure, in accordance with the U.S. Chairmanship of the Arctic Council. The component also coordinates the provision of USGS geospatial products and services related to natural hazards emergency response and recovery and mitigation activities, including support for emergency responders. Oversight and management is provided for the USGS Geospatial Information Response Team charged with acquiring and providing access to satellite and aerial imagery and maps to support response to domestic natural hazard events including tornadoes, snowstorms, wildland fires, and debris flows.

In 2015, User Engagement completed a transition of staff from the USGS regional management structure to the National Geospatial Program headquarters office. This enhanced support for key NGP initiatives in 3DEP through conducting public meetings for data acquisition coordination, staffing the development of joint funding agreements with partners, and updating project status information for the U.S. Interagency Elevation Inventory. User Engagement led the National Hydrography Requirements and Benefits Study, which will define requirements for hydrography data nationwide, and help determine a right-sized NGP hydrography effort that meets user needs in a cost-effective manner. These activities will continue through 2016 and into 2017.

Topographic Data Services

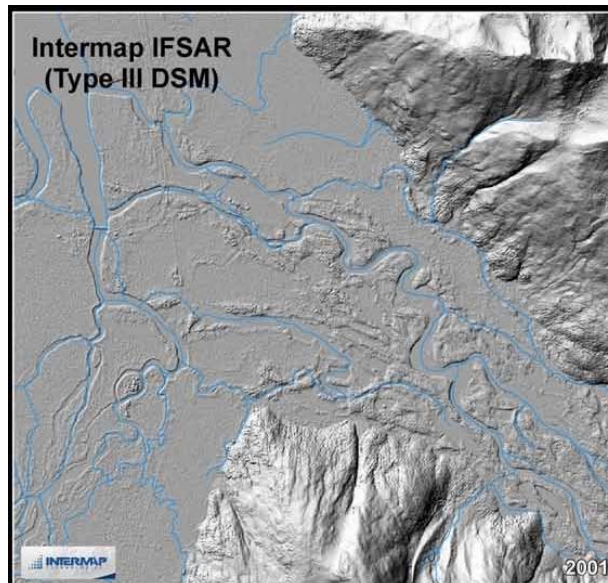
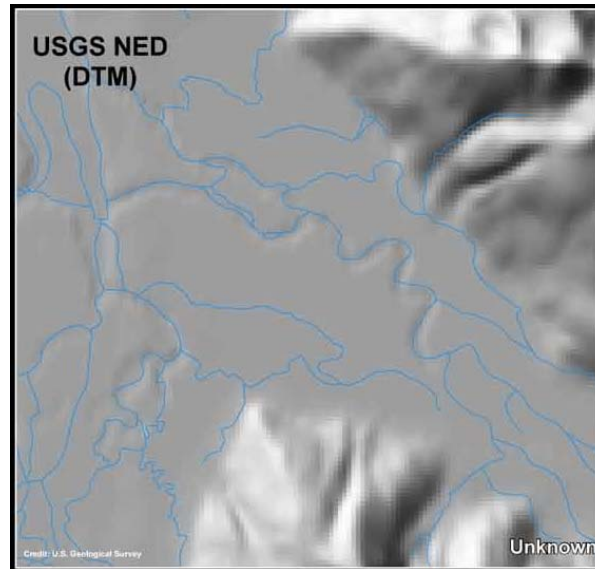
(2015 Actual, \$ 20.9 million; 2016 Enacted \$25.3 million; 2017 Request, \$31.1 million)

The Topographic Data Services component provides strategic direction and funds for the elevation and hydrography themes of The National Map. Elevation and hydrography are the priority data themes of the NGP because they define the Nation's topography which underpins a broad range of applications and serves as the key components of US Topo, the NGP topographic maps. Multiple datasets are managed under the component: 3D Elevation Program (3DEP), National Hydrography Dataset (NHD), National Hydrography Data Plus High Resolution (NHD+HR) and a portion of the Watershed Boundaries Dataset (WBD) in collaboration with the USGS Water Mission Area. Topographic Data Services develops and manages the strategy for products and services development, and data acquisition and stewardship for NGP's priority data themes of elevation and hydrography. Through Topographic Data Services, the USGS provides executive support to several interagency coordination and user groups including the 3DEP Executive Committee and Working Group, the Subcommittee on Spatial Water Data (a Federal Advisory Committee Act-chartered group), National Hydrography Dataset Management Team and the Watershed Boundaries Steering Committee. Topographic Data Services has the additional responsibility to co-lead the OMB Circular A-16 geospatial data theme and data set management responsibilities for elevation and inland water data. Topographic Data Services shares this co-leadership effort with the National Oceanic and Atmospheric Administration (NOAA) and U.S. Fish and Wildlife Service.

The NGP has worked for many years with the National Water Quality Program and StreamStats, to create and continuously improve the National Hydrography Dataset (NHD). Along with the Watershed Boundary Dataset, the NHD is used to portray surface water on The National Map. The NHD represents the drainage network with surface water features such as rivers, streams, canals, lakes, ponds, coastline, dams, and streamgages. Efficiently tracking water use and the relationship between manmade diversions and stream flow, requires that the points of withdrawal and discharge be mapped within the stream

Core Science Systems

network. Currently, hydrography datasets of differing functionality and scales are used by agencies including the USGS, the Environmental Protection Agency, the U.S. Forest Service, and the Bureau of Land Management. The water resource community, including Federal, State, tribal and local water resource managers; and private and non-profit organizations would benefit from using a single, scalable hydrographic referencing system with robust functionalities. Other potential users include the National Fish Passage Program and the State of California Division of Water Rights Electronic Water Rights Information Management System (eWRIMS).



Comparison of older USGS National Elevation Dataset (NED) with newer ifsar elevation data

Elevation: The 3D Elevation Program (3DEP) is a cooperative activity to produce lidar data for the conterminous United States, Hawaii, and U.S. territories, and ifsar data for Alaska. The USGS and partner organizations acquire high quality 3D elevation data for the United States and its territories that support requirements beyond what could be realized if agencies pursued independent lidar and ifsar data collection activities. From 2012 through 2015, program growth, new data collection, product and service development, and technology modernization have been the primary activities. Data collection rates have been increasing as a growing number of State and Federal agencies participate in cooperative data acquisition projects.

In 2015, the first 3DEP products and services were published, including 1-meter digital elevation model and lidar point cloud data. The NGP issued the second Broad Agency Announcement (BAA) that provides detailed information on how stakeholders can partner with the USGS and other Federal agencies to acquire high-quality 3D elevation data (See <http://nationalmap.gov/3dep/BAAReferenceMaterials.html>). Extensive outreach was provided through national and State/regional public meetings to improve awareness and participation in elevation partnerships. The Topographic Data Services component defines and implements annual and multi-year 3D elevation data acquisition plans including project selection and collaborative partnerships. It also defines and supports the quality assurance, processing, and management of a very high volume of elevation data on a national level. In April, the first 3DEP Stakeholder meeting was conducted to explore strategies to implement 3DEP. Over 30 participants and 25 observers attended the meeting. The National Digital Elevation Program (NDEP), chartered in 2000 as an interagency elevation data coordination group, developed a new charter to formalize as the 3DEP Working Group. This working group serves as the operational coordination body for the program. In 2016, the 3DEP Executive Forum and Working Groups are focusing on enhancing the process to initiate a unified Federal plan for funding data investments. By 2017, the BAA will be advanced to provide a more systematic partnering approach to State, local, tribal, and other organizations.

Hydrography and Watershed Boundaries: In 2015, NGP continued developing a high-resolution (1:24,000 scale or higher) version of NHDplus (NHD+HR) that will provide a unified framework composed of the highest available resolution data and generalizable to many different scales. This is a critical first step to integrating surface water information with landscape characteristics derived from elevation data. NHDPlus is a geospatial, hydrologic framework dataset that underpins a range of applications across agencies and levels of government, including EPA Watershed Assessment, Tracking and Environmental Results (WATERS) activities and the USGS National Water Quality Assessment (NAWQA) Program's SPARROW modeling. The effort will continue in 2016, with a goal to complete a first implementation of national coverage by 2018. In 2016, an interagency group is

3D Nation: Building a modern elevation foundation nationwide for stronger, more resilient communities and U.S. economy: The 3D Elevation Program (3DEP) is one component of an interagency **3D Nation** partnership that will ensure access to an accurate, routinely updated, continuous elevation surface from the land to the depths of our waters. **3D Nation** coordinates and unifies the goals of the USGS 3DEP, NOAA's GRAV-D program, and the coastal topographic and bathymetric mapping activities of NOAA, USGS, FEMA, USACE and the States. In some instances, old data will be replaced with data that are accurate to within centimeters of their real-world positions. 3D Nation will provide an authoritative national geospatial foundation to support mapping needs for commerce, agriculture, land and sea navigation, resource management, climate change, hazards response, and a host of other activities. It will result in economic and job growth, and lead to private sector innovations in each of these business areas.

working to determine longer term strategies and goals for elevation-hydrography integration. The results will be more accurate and better maintained data as user stewards migrate to a single framework, and will form the basis for many advances in the hydrologic sciences for years to come.

As the NHD+HR is built, the USGS is seeking community engagement in using and improving the initial release of the data. This supports the National Water Census and hydrologic modeling activities by organizing hydrologic observations with the Nation's river network and watersheds, which is an initial step in delivering the Open Water Data Initiative (OWDI). The Subcommittee on Spatial Water Data was led by NGP to explore several OWDI use cases to integrate various sources of water information to underpin innovation, modeling, data sharing, and solution development.

In 2015, NGP also conducted the National Hydrography Data Requirements and Benefits Study to identify user requirements, and the associated benefits, for improved hydrographic data. In 2016, the results will be analyzed and, by 2017, will provide return on investment documentation to guide development of program directions for the next 3-5 years, by identifying which features and functionality would be of most value to the user community.

In 2015, the NGP matched over \$10 million of program funds with \$32 million of cooperator resources to acquire more than \$42 million of elevation and hydrography data for The National Map.

The following program changes are proposed in 2017 within this component:

2017 Program Changes
<p>3-D Elevation Program – Alaska Mapping and Map Modernization (+\$1,500,000, for a total of \$6,722,000): The NGP would increase collection of ifsar in Alaska, and improve mapping products. These maps and improved data are urgently needed for aircraft navigation, since weather conditions in Alaska deteriorate quickly and pilots frequently need to fly using only their instruments and GPS. The highly improved maps would also become critical tools for investigation as climate change begins to reshape the North. Melting permafrost, land subsidence, and erosion are poised to redefine Alaska's terrain. Involvement with the Alaska Mapping Executive Committee and coordination with other Federal and State agencies would facilitate identification of priority needs and partnering opportunities. This increase would allow for at least 25 percent more data acquisition than in FY15, with the potential to reach 50 percent by leveraging cooperatively funded partnerships to accelerate completion of Statewide data coverage.</p>
<p>3-D Elevation Program – National Enhancement, Landscape-scale 3-D Maps (+\$2,387,000, for a total of \$21,887,000): The NGP would increase acquisition of lidar data to expand publicly available 3DEP holdings. An improved Broad Agency Announcement process and use of interactive tools on the Geospatial Platform will facilitate collaboration with partners. Based on prior experiences, the increase could attract as much as \$10.0 million in additional partner funding resulting in nearly 60,000 square miles of new data. Accelerating the national coverage of lidar would enable decision making in the management of infrastructure and construction, more accurate and cost effective application of chemicals in farming, development of energy projects, and support of aviation safety and vehicle navigation. Science would benefit in numerous ways, including support for habitat change studies,</p>

2017 Program Changes

identification and mitigation of seismic and landslide hazards, improved dynamic flood inundation maps and applications for flood response and mitigation, study of contaminant transport to identify vulnerable environmental settings, and monitoring of land change.

3-D Elevation Program - Coastal Lidar (+\$500,000, for a total of \$500,000): The NGP would use the requested increase to collect enhanced elevation data using lidar in coastal zones over the United States. New and accurate baseline elevation data is required to understand and mitigate the negative effects of coastal erosion and storm surge, to map existing and potential landslide hazards, and to monitor biomass in a changing world. The USGS 3DEP responds to growing needs for high-quality and high resolution topographic data to capture change in the Nation's natural and constructed features and would be used for sea level rise modeling projects in the Coastal and Marine Geology Program.

3-D Elevation Program – NHD/Landscape Level Assessments – Chesapeake Bay (+\$500,000, for a total of \$500,000): With the increase, the NGP would systematically collect and manage high-quality lidar over the eastern shore of the Chesapeake Bay. This 65,000 square mile drainage basin is the largest estuary in the United States and touches six States and the District of Columbia. New and accurate baseline elevation data are required to understand landscape processes at a parcel and local scale and to develop strategies that allow for the Bay's sustainable development and management of natural resources. Ongoing Federal and State lidar acquisition partnerships throughout the Chesapeake Bay watershed would be leveraged and expanded. In 2015, the USGS was able to leverage \$860,000 with \$875,000 from other Federal, State, and university sources to acquire lidar over the Chesapeake watershed, for a 1:2 leveraging ratio.

WaterSMART: National Hydrography Database (+\$1,000,000, for a total of \$1,000,000): With these funds, the USGS would complete national high-resolution National Hydrography Dataset (NHDPlus at 1:24,000 scale or better) coverage for the conterminous 48 States, Hawaii, and Puerto Rico. Taking this step now positions the USGS to be able to fully utilize lidar data as they become available through 3DEP. This achievement would create an integrated elevation-hydrography dataset for water resource managers throughout the Nation. Future lidar-derived integrated elevation-hydrography data would fit into the same structure and use the same utilities. This full integration of elevation and hydrography would simplify hydrography data and streamline the user experience, application development, and stewardship of the data. It would also support the National Water Census and enable an initial step in delivering the Open Water Data Initiative. Developing a single, scalable hydrographic referencing system would integrate currently fragmented water information into a connected, national water data framework to underpin innovation, modeling, data sharing, and solution development.

Cartographic Data Services

(2015 Actual, \$19.7 million; 2016 Enacted, \$19.7 million; 2017 Request, \$19.7 million)

The Cartographic Data Services component guides the planning and use of technology to create and deliver modern topographic maps, deliver National Map products and services, develop and maintain geospatial data to support mapping and geospatial analysis at local, regional, and national scales, and apply The National Map, geographic names, historic topographic scanned maps, and cartographic base maps to support Web mapping applications within the bureau, Interior, other Federal agencies, and State, local, and private entities. Efforts ensure availability of nationally consistent, modernized, scalable, and integrated base geospatial data and technology for use by USGS scientists and researchers as well as external partners and customers. Cartographic Data Services activities include data processing, decision-support systems, and cloud-based storage and delivery services for geospatial information.

The National Map includes national databases of geospatial imagery, transportation, structures, and boundaries, although the USGS relies on partners to acquire and be stewards of these data. The component also funds cartographic products derived from National Map data and other associated geospatial services generated from the databases, such as the US Topo digital topographic maps and National Map visualization services.

Geographic Names: The NGP maintains geographic names data and staffs the Board on Geographic Names (BGN), authorized by P.L. 80-242. In 2015, NGP continued to house and provide access to all of the Geographic Names information that has been collected over the years.

US Topo: To keep pace with an increasing demand for updated map products and data and technological advances, the USGS continues to revise each US Topo map every three years (70 maps each day) and to post new digital topographic maps for download. The quadrangles of US Topo maps are created from geographic datasets in The National Map and allow the user to select among data layers to be displayed; a technology advancement not available on older paper-based topographic maps. The new US Topo maps provide other modern technological advantages that support wider and faster public distribution, and on-screen geographic analysis tools for users. US Topo maps have a new crisper and cleaner design that enhances their readability when viewed online and printed.

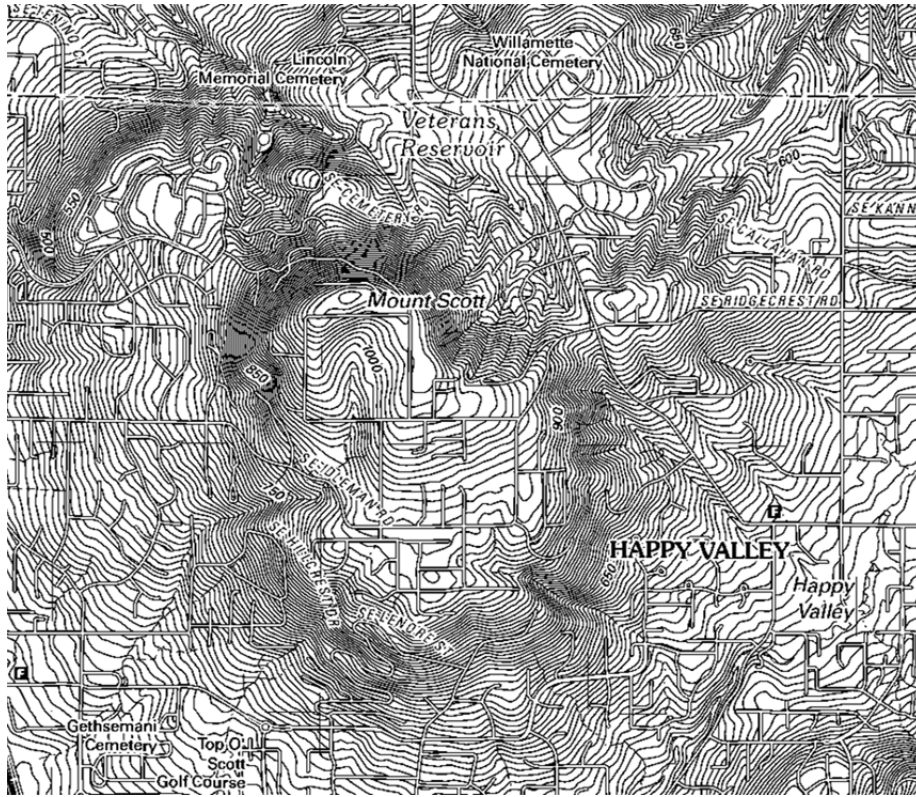


Figure 1. Portion of US Topo design from 2011 (Gladstone, OR)



Figure 2. Portion US Topo from 2014 using the new design (Gladstone, OR)

In 2015, the NGP completed US Topo mapping products for one-third of the conterminous United States as part of a three-year revision cycle. The US Topos will continue to mature and add content in 2016 and 2017, maintaining the three year update cycle. In 2017, NGP will investigate transitioning to a change-driven production cycle. US Topo products are freely downloadable from The National Map Viewer and Download Platform as well as the Geospatial Platform. Through October 2015, more than nine million US Topo Products had been downloaded from USGS sites with a daily average of 6,400 in 2015.

Historical Topographic Map Collection (HTMC): In conjunction with the US Topos, the USGS has released more than 188,000 online high-resolution scans of historical topographic maps of the United States dating back to 1884 (founding of the USGS mapping program). Until 2013, the historic maps were only available in a paper format and by citizens and researchers visiting the Library of Congress and other depository libraries. The HTMC has accurately cataloged and created metadata to accompany the high-resolution, georeferenced digital files that make available the Nation's legacy of printed topographic maps. Through October 2015, more than 11 million HTMC products were downloaded from USGS sites with a daily average of 6,300 in 2015.

The NGP publishes its digital geospatial data and maps through data downloads, Web map services, bulk download requests, Geospatial Platform, Data.gov and a robust National Map viewer.

Geospatial Research

(2015 Actual, \$5.1 million; 2016 Enacted, \$5.1 million; 2017 Request, \$5.1 million)

The Geospatial Research component funds applied research that improves the efficiency and effectiveness of The National Map and its operations, products, and services, and contributes to the Nation's understanding of geospatial science. Components of a digital topographic map design and map generalization research project have been completed, and the NGP is using the results to improve the design of the US Topo maps and to take advantage of detailed hydrography data for maps at regional and national scales.

In 2016, the program will continue to expand its work in high performance computing and Cyber GIS to support processing of the massive amounts of lidar and derivative data and products from 3DEP. Research in geospatial semantics and ontology is internationally recognized and is designed to enable discovery and linkages to The National Map using natural language versus technical GIS-specific terminology. Using USGS research staff in conjunction with academic research grants, NGP continues research to access legacy geospatial data and enhanced elevation data to support integration with other USGS science data and modeling. One research goal is to identify relations between map scale and geomorphological and other characteristics of map features to automate generalization (zooming in and out while still maintaining a legible image) and determine the effects of high-resolution elevation and hydrographic data on science models. The researchers will integrate data from The National Map with selected USGS science datasets to support visualization, analysis, modeling, and decision-making efforts of the USGS, other government agencies, and the public in addition to evaluating how geospatial data can be used to help restore supply chains after a natural disaster.

In 2017, the program will extend the research with high performance computing and lidar focusing on extracting hydrographic networks and conflating these with existing National Hydrography data. Generalization and data integration work will focus on matching legacy data from The National Map with lidar derived elevation and hydrography. Geospatial semantics research will include defining and extracting geomorphic features, such as hills and mountains, as well as integrating semantics for other data layers including hydrography and transportation with legacy data. Researchers will continue work to determine the impacts of high-resolution lidar data on science model results, particularly hydrologic models, and will provide usable models built from data from The National Map for restoration of supply chains after a natural disaster.

Federal Geographic Data Committee – Office of the Secretariat

(2015 Actual, \$3.8 million; 2016 Enacted, \$3.8 million; 2017 Request, \$3.8 million)

The FGDC is an interagency committee focused on improvements in the coordination and effective and economical use and management of spatial data assets in the digital environment for the benefit of the government and the Nation. The FGDC implements cross-government geospatial initiatives, such as the Geospatial Platform Shared Service; coordinates the collection, use, and dissemination of geospatial data and information to develop the National Spatial Data Infrastructure (NSDI); and develops best business practices for the management, delivery, and sharing of geospatial information and services through collaboration with Federal, non-governmental, private sector, and partner organizations and committees. It promulgates standards, system interoperability, geospatial shared services, and best business practices, policies, technology, and partnerships. The Secretary of the Interior chairs the FGDC and the Deputy Director for Management, OMB, serves as the Vice-Chair. The FGDC Office of the Secretariat (OS) provides executive, administrative, and technical support to the FGDC.

In 2015, the FGDC continued to release enhancements to the Geospatial Platform, an Internet-based capability providing shared and trusted geospatial data, services, and applications for use by government agencies, their partners and the public. Enhancements included migration of the integrated shared identity and access management controls to the GeoPlatform from Data.gov to improve operational efficiency; releasing spatial data lifecycle management analysis support tools to improve data management and reporting; and initial implementation planning for Geospatial Platform cloud migration to provide shared infrastructure. As an identified tool supporting the Secretary of the Interior's priority of building a Landscape Level of Understanding, the FGDC, through the Geospatial Platform, released three new collaboration communities focused on improving Federal geospatial data management practices, climate resources, and Worldwide Human Geography analysis, bringing the total number of cross-agency collaboration communities to 20. These communities leverage the Geospatial Platform's shared data, services, and tools to provide information sharing and best-practices, and to support solution development and decision making.

The FGDC continued the implementation of the National Spatial Data Infrastructure (NSDI) Strategic Plan 2014 – 2016, and the National Geospatial Data Asset Management Plan (NGDAMP). These plans were endorsed by Federal agencies and non-Federal partners and provide direction for the Federal Government's role in implementing the NSDI and ensuring increased efficiency, management, and availability of federally funded geospatial data. One of many successful actions included the 100 percent

registration of data records by managing Federal agencies for the 173 National Geospatial Data Asset datasets for improved data discovery, sharing, and use. The FGDC continued to execute the geospatial cloud computing testbed, collaboratively developing cloud-based, geospatial-computing environments that are preapproved for deployment across agencies, reducing individual deployment costs. The FGDC and Office of the President, Information Sharing Environment office jointly released the Geospatial Interoperability Reference Architecture (GIRA). The GIRA is the reference guide for geospatial interoperable architecture governance, design and implementation as shared geospatial investments, to increase information sharing through geospatial interoperability, and establishes the Geospatial Platform as a technology and collaboration environment for unclassified geospatial information sharing for the Federal Government. The Secretariat supported all FGDC activities, including the FGDC committees, the National Geospatial Advisory Committee, development of geospatial standards, and development and management of the Geospatial Platform.

In 2016, the FGDC OS continues to support FGDC activities including the development and expansion of the operational phase and core capabilities of the Geospatial Platform by working with numerous agencies to establish new collaborative communities and new shared tools in support of information sharing for decision making. To increase information accessibility and accountability, the FGDC OS is implementing NSDI Strategic Plan actions, and working with FGDC agencies to further develop their NGDAMP strategies and implement reporting tools. The Geospatial Platform will release its shared, cloud-based, data hosting environment; geospatial services will migrate from the cloud test bed to the shared cloud environment; seamless map service interoperability between GeoPlatform.gov and the leading geospatial technology provider will be implemented; enhanced data visualization and interface tools will be released; and the GIRA will become an online collaboration resource community. The FGDC member agencies will continue to advance current actions and begin development of the next NSDI Strategic Plan, and will continue implementation of the NGDAMP and its actions supporting increased data management, transparency, and Federal geospatial portfolio investment and management.

In 2017, the Geospatial Platform's shared cloud infrastructure will be leveraged to provide agencies with increased options for data hosting and service support and will continue to mature its shared services with guidance from the *Geospatial Platform Business Plan* and Geospatial Platform Oversight Body. The FGDC OS will also continue to support the FGDC agencies in updating the actions of the NSDI Strategic Plan and the NGDAMP in alignment with FGDC, Federal, and national priorities.

Science Collaboration

Some examples of the many collaborative partnerships working with NGP:

The NGP works with States and multiple Federal agencies such as FEMA, the Natural Resources Conservation Service, U.S. Forest Service, U.S. Army Corps of Engineers, through the 3DEP Executive Forum and Working Group to establish a systematic, unified approach toward data acquisition and dissemination. The NGP collaborates with these entities to strengthen Federal interagency coordination and share applications and technology development. In 2015, the NGP held a 3DEP Stakeholders meeting and assisted all 50 States and many Federal agencies with public webinars about the Broad Agency Announcement process and proposal submissions.

The Subcommittee on Spatial Water Data works toward integration of water information from various sources into a connected, national water data framework by leveraging existing systems, infrastructure and tools to underpin innovation, modeling, data sharing, and solution development.

The National Hydrographic Database and Water Boundary Dataset Management Teams define the direction and implementation of national hydrography datasets to meet the needs of Federal and State users.

The NGP and the USDA Forest Service share data for mapping purposes to create more consistent and current products. This collaboration reduces costs for map production and results in more consistent products.

The NGP, in collaboration with the Census Bureau, works to improve the Census TIGER data and facilitate incorporation of the data on USGS topographic maps. This results in improved data geometry and attribution, and a more consistent representation.

Per the OMB Circular A-16, the FGDC OS supports cross-government FGDC initiatives including the Geospatial Platform. The Department of the Interior has included the Geospatial Platform in its Strategic Plan to help develop a landscape-level understanding of natural resources through a shared capability to which other bureaus can register data and services. These efforts increase geospatial data discovery, access, use, and registration of decision support tools for decision making and data sharing. The registry is integrated with solutions supporting the Administration's priorities including the Open Data policy and Data.gov.

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Activity: Core Science Systems

Subactivity: National Cooperative Geologic Mapping Program

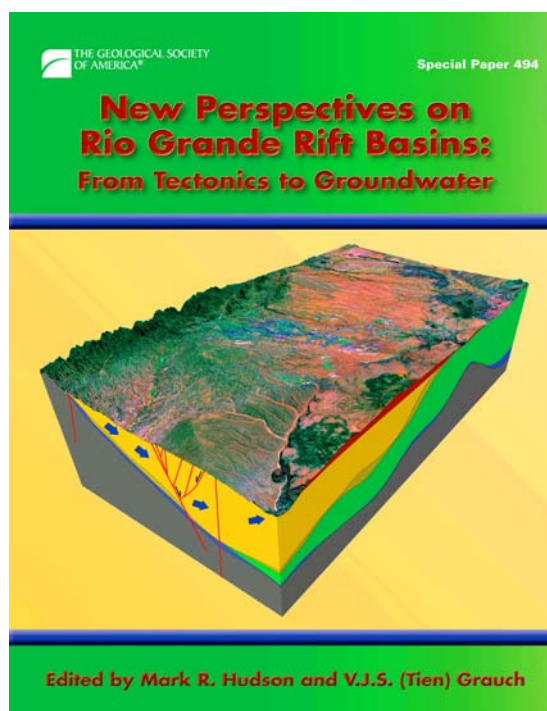
Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Core Science Systems	\$107,228	\$111,550	\$408	\$6,437	\$118,395	\$6,845
<i>FTE</i>	<i>469</i>	<i>472</i>		<i>6</i>	<i>478</i>	<i>6</i>
National Cooperative Geologic Mapping Program	\$24,397	\$24,397	\$89	\$0	\$24,486	\$89
<i>FTE</i>	<i>114</i>	<i>114</i>		<i>0</i>	<i>114</i>	<i>0</i>
FEDMAP - Federal Geologic Mapping Science Applications	\$16,997	\$16,997		\$0	\$16,997	\$0
STATEMAP - Serving State Priorities for National Needs	\$6,900	\$6,900		\$0	\$6,900	\$0
EDMAP - Training the Next Generation of Geoscientists	\$500	\$500		\$0	\$500	\$0

Justification of Program Change

The 2017 Budget Request for National Cooperative Geologic Mapping is \$24,486,000 and 114 FTE, a net change of \$89,000 and 0 FTE from the 2016 Enacted level.

Overview

In a time when the key to so many solutions to the Nation's most pressing problems lie in the ground beneath our feet, the National Cooperative Geologic Mapping Program (NCGMP) advances the understanding of the nature of the materials—rocks, energy resources, water—and processes such as characterization, containment, and flow. This nationwide program of geologic research produces about 100 peer-reviewed journal articles annually on surficial and bedrock geology, mapping, and multidimensional models that provide fundamental research and data that underpin all of the themes of the USGS Science Strategy. These primary findings and data are applied in natural hazards



The 18 journal articles published by USGS scientists and their partners in other Federal and State agencies, as well as academia, tell the complex geologic history of the Rio Grande rift valley and the sedimentary basins that contain the aquifers that supply water to Albuquerque, Santa Fe, and other communities. This research provides the landscape-level understanding for decision makers in New Mexico and southern Colorado, especially about water issues.

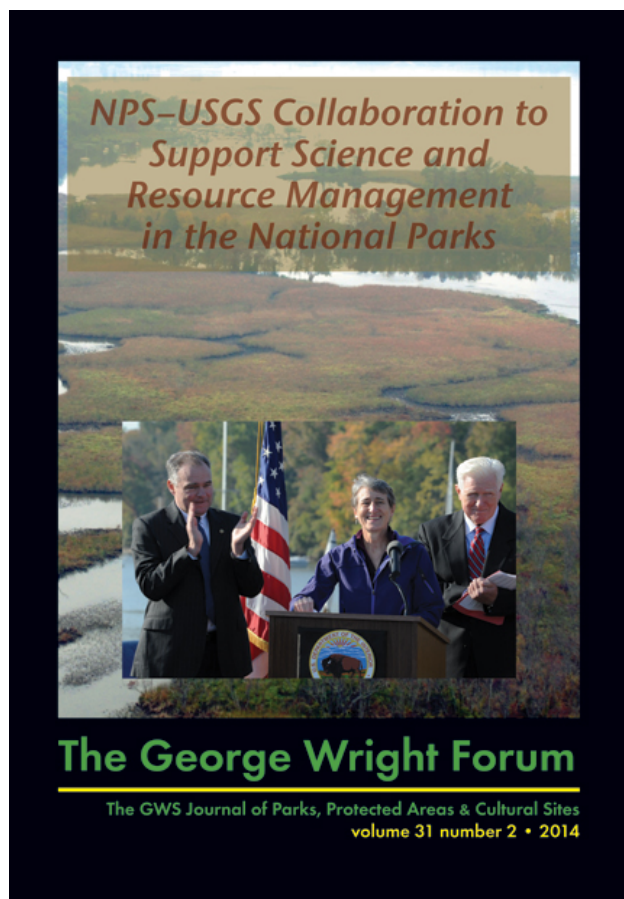
mitigation, water resources delineation, energy and minerals exploration, climate change studies, and ecosystem and environmental health analysis and are readily accessible through the National Geologic Mapping Database.

In 2015, the NCGMP marked the 23rd anniversary of the National Geologic Mapping Act of 1992, by presenting an Award for the Best Student Geologic Map at the Geological Society of America Meeting. This award has now become a tradition within the EDMAP Program of the NCGMP that is training the next generation of geologic mappers. Over its history, the program has leveraged over \$118 million in Federal funding matched by the State geological surveys to collaboratively produce modern geologic maps for the Nation and \$9 million matched by universities to train the next generation of geologic mappers—more than 1,100 college geoscience students to date.

Geologic maps and frameworks define the subsurface shape of aquifers, how much water can be stored in them, and parameters for water movement through the ground. Geologic mapping products also provide critical information for predicting and mitigating natural hazards, such as landslides, earthquakes, and volcanoes. In 2014, geologic maps were critical tools used in emergency response situations such as major landslides that had human casualties in Washington State and western Colorado.

The NCGMP supports a major Federal geologic mapping partnership between the USGS and the National Park Service (NPS). Over the past 16 years, the NCGMP has helped the NPS to inventory the geologic resources of more than 200 parks and to create digital geologic maps for many of them. Park managers require these products to make effective landscape-level decisions.

A hallmark of the NCGMP, the National Geologic Map Database, is a major collaborative effort with the Association of American State Geologists (AASG). This national database provides rapid access for the public, scientists, and decision makers to well-documented and standardized Federal and State geoscience information that can be used to support research, understanding, and decisions on a number of societal needs. Through annual workshops, the NCGMP's National Geologic Map Database leads national-level information exchanges and the development of more efficient methods for digital mapping, cartography, geographic information system analysis, and information management.



The NCGMP works in close collaboration with State geological surveys, and with the Great Lakes Geologic Mapping Coalition. This coalition is a Federal-State partnership created to produce urgent, detailed, three-dimensional surficial-materials maps that provide a foundation for making sound economic and environmental decisions related to ground water resources, land, and other natural resources of the Great Lakes.

Program Performance

The National Cooperative Geologic Mapping program is made up of three program components: FEDMAP, STATEMAP, and EDMAP.

FEDMAP – Federal Geologic Mapping Science and Applications

(2015 Actual, \$17.0 million; 2016 Enacted, \$17.0 million; 2017 Request, \$17.0 million)

The FEDMAP component of the NCGMP supports about 25 regional geologic mapping and synthesis projects that cross jurisdictional boundaries. New and ongoing geologic mapping work plans are evaluated annually by a FEDMAP Review Panel, which includes representatives from State geological surveys, the NPS, and USGS researchers that have diverse scientific backgrounds.

Examples of NCGMP interdisciplinary geologic mapping accomplishments and goals that contribute to answering a breadth of the Nation’s natural resource issues include—

- In 2015, the Geological Society of America (GSA) published a book titled *The 2011 Mineral, Virginia, Earthquake, and Its Significance for Seismic Hazards in Eastern North America* that was co-edited by a USGS NCGMP-sponsored author. Twenty-four USGS scientists authored or co-authored this book intended for geoscientists and policy makers interested in understanding earthquake hazards associated with intra-plate Eastern U.S. seismic events.
- Research on groundwater availability, movement, and contamination across the United States, such as in California, New Mexico, Colorado, the mid-Atlantic Coastal Plain, and New England that will continue through 2017.
- Improved understanding of earthquake hazards in the Seattle-Portland urban corridor, California, the Central United States, and Virginia that enables improved mitigation, research on landslide hazards in Washington State, Colorado, New York, and California; and sinkhole hazards in numerous Eastern States in 2015 that is continuing through 2017.
- In 2015, the National Karst Map was released and is useful in identifying areas with potential for sinkholes.
- Ongoing 2016 geologic mapping along the Columbia River within its gorge and downstream to the Pacific Ocean that builds on earlier work will continue in 2017, and has revealed a rich history of interaction between the ancient Columbia River and sea level changes, glaciation, volcanism, landslides, mega-floods and regional mountain-building.

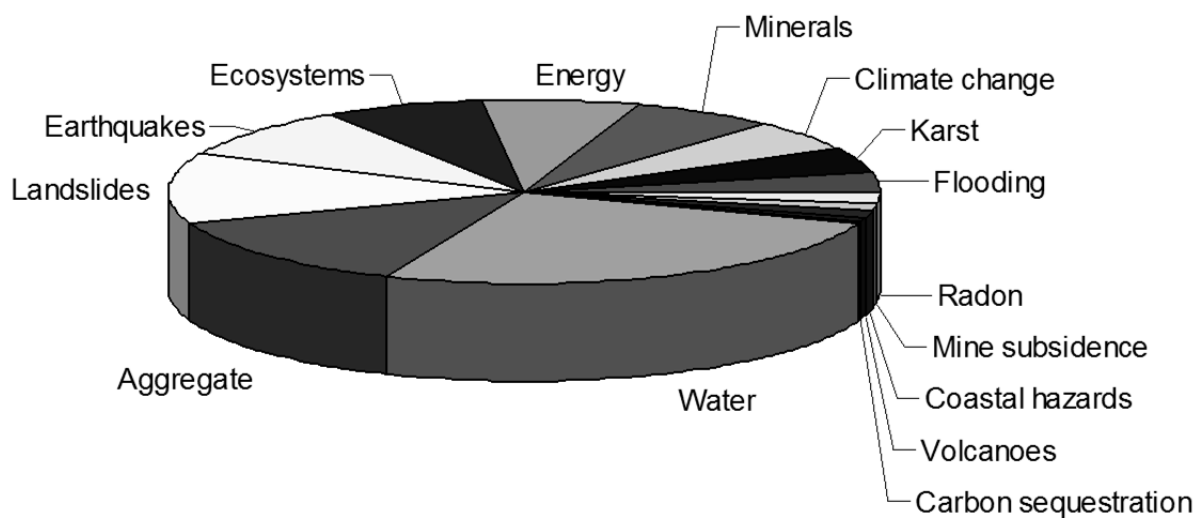
- 2015 analysis of newly acquired aeromagnetic and lidar mapping that resulted in the delineation of the Spokane Fault that is believed to have been responsible for a swarm of small earthquakes and associated land uplift inside Spokane city limits in 2009.
- In 2015, and continuing through 2017, 3D hydrogeologic framework modeling in the Santa Rosa Plain of California has enabled a groundwater flow model, leading to the approval of a broad Petaluma Basin groundwater study aimed at supporting well informed water resource management decisions by Sonoma County.

STATEMAP – Serving State Priorities for National Needs

(2015 Actual, \$6.9 million; 2016 Enacted, \$6.9 million; 2017 Request, \$6.9 million)

The STATEMAP component of the NCGMP currently supports geologic mapping studies conducted by 44 State geological surveys through a competitive cooperative agreement program that matches every Federal dollar with a State dollar. Since STATEMAP's inception in 1993, 48 States have matched more than \$118 million in Federal funds with an equivalent amount of State funds. In each State, geologic mapping priorities are determined with the help of State Mapping Advisory Committees that include representatives from all levels of government, the private sector, academia, and industry. Currently, more than 500 individuals offer their time on these committees to prioritize geologic mapping needs. This group acts as “grass roots” allowing the program to stay in touch with citizens’ greatest needs. States propose mapping projects based on their highest priority societal, economic, and scientific issues.

Societal Applications of Federal and State Geologic Mapping



Many STATEMAP geologic mapping projects provide vital information needed by States and industry. Program outcomes from geologic mapping for the 2015 proposal cycle include mapping that provides information primarily for groundwater quantity and quality projects across the United States. For example, the Washington State Geological Survey mapped the Lake Chaplain 7.5 minute quadrangle that was used by the King County Water and Land Resources Division for river and floodplain management, groundwater protection and infrastructure planning, and to identify landslide hazard areas. Further,

STATEMAP geologic maps have the potential to aid in understanding hydraulic fracturing in the development of unconventional gas production.

During the last two decades, STATEMAP has been highly successful in stimulating geologic mapping at the State level and, in 2016 and 2017, the NCMGP aims to build on this foundation by enhancing the existing fundamental geologic mapping capacities established within the STATEMAP Federal–State partnership. Moreover, the NCGMP will, in 2016 and 2017, work with the States to establish national geologic mapping priorities, and to identify opportunities for high value targeted derivative map products that are highly responsive to societal needs. Building on the foundation provided by STATEMAP fundamental geologic mapping, the NCGMP will work closely with the States to define derivative products that assimilate additional geospatial data collected by State Geological Surveys and other USGS programs. Potential derivative products could be focused on enabling improved knowledge of ground water quality and quantity, or natural hazards such as floods or earthquakes, and could aid the geotechnical analyses needed for infrastructure renewal and development.

EDMAP – Training the Next Generation of Geoscientists

(2015 Actual, \$0.5 million; 2016 Enacted, \$0.5 million; 2017 Request, \$0.5 million)

The EDMAP component of the NCGMP supports the training of a new generation of geoscientists in universities and colleges through a competitive matching-fund cooperative agreement program. Through the EDMAP program, students learn the fundamental principles of geologic mapping and field techniques. Since EDMAP's inception in 1996, more than \$9 million from the NCGMP has supported geologic mapping efforts of more than 1,100 students working with more than 230 professors at 157 universities in 45 States, the District of Columbia, and Puerto Rico. Sponsoring universities match, dollar-for-dollar, the Federal EDMAP funding they are awarded. The NCGMP will continue to support EDMAP's essential training function in 2016 and 2017, and will also seek to more closely align EDMAP-sponsored field investigation with ongoing geologic map production within FEDMAP and STATEMAP. Moreover, the NCGMP will aim to extend the educational benefits of EDMAP to include focused training in the broad proficient use and analysis of regional geospatial data contained in *The National Map* provided by the National Geospatial Program. EDMAP signifies the strong NCGMP commitment to STEM education, and EDMAP engagement of young scientists in important societal problems through targeted and relevant field studies is one of the program's highest priorities. 2015 marked the second annual Best Student Geologic Map Competition co-hosted by the Geological Society of America and sponsored by partner organizations. The competition provides EDMAP students and others a venue to showcase their mapping projects to a wide audience of scientists, professionals, and their peers.



Winners of the 2015 Best Student Geologic Map Competition—Baltimore GSA Meeting

Science Collaboration

Some examples of the many collaborative partnerships working with NCGMP:

The NCGMP works in collaboration with the National Park Service; National Forest Service; National Resource Conservation Service, Virginia Division of Geology and Mineral Resources; Maryland Geological Survey; North Carolina Geological Survey; Virginia Department of Conservation and Recreation’s Natural Heritage Program to develop geologic mapping and geochronology of bedrock in the Appalachian Blue Ridge. Unique capabilities include 35 years of expertise in Blue Ridge geologic investigations and cooperation and state-of-the-art geochronology not available to other agencies. Landscape evolution, ecosystem management, and Earth history defined by project research are sought after by these agencies to provide the framework for numerous applications.

The NCGMP is working with the Virginia Department of Mines Minerals and Energy (VDMME) on geologic mapping and providing staff support in the central Virginia seismic zone (CVSZ). The VDMME is currently mapping three quadrangles in the CVSZ epicenter area (bedrock and surficial). Through a grant process, the VDMME will work along the James River using ground penetrating radar. The NCGMP collaborates with VDMME partners to thoroughly and efficiently map the CVSZ at a scale useable for seismic hazard assessment. Their close collaboration and involvement in mapping allows the

USGS to partition the seismic zone into quadrangles for which they will be responsible for mapping, those the USGS will be solely responsible for, and those that will be a mutual effort.

The NGCMP collaborates with the Washington, D.C., District Department of the Environment, Natural Resources Administration on a geologic mapping project that maps ancient river channels in Washington, D.C. Outcomes include obtaining relatively continuous subsurface river channel cores in Washington D.C., compilation and interpretation of surficial and subsurface Coastal Plain geological core, borehole, and geophysical data; and creation of maps that depict the shape, thickness, and original environmental setting of ancient river channels beneath Washington, D.C. The USGS geological mapping of the Quaternary paleochannels is providing a much greater understanding of their extent and nature, and may identify preferential flow paths for groundwater to discharge to the Anacostia River and the Potomac River, and play a role in localized flooding. USGS mapping clearly indicates structural controls on changes in paleochannel trends. USGS analysis of the rocktypes and fossils within these ancient river channels will provide essential paleoclimate and sea level information.

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Activity: Core Science Systems

Subactivity: Science Synthesis, Analysis, and Research Program

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Core Science Systems	\$107,228	\$111,550	\$408	\$6,437	\$118,395	\$6,845
<i>FTE</i>	<i>469</i>	<i>472</i>		<i>6</i>	<i>478</i>	<i>6</i>
Science Synthesis, Analysis, and Research Program	\$24,299	\$24,299	\$81	\$550	\$24,930	\$631
<i>FTE</i>	<i>91</i>	<i>91</i>		<i>0</i>	<i>91</i>	<i>0</i>
The John Wesley Powell Center for Analysis and Synthesis	\$300	\$300		\$0	\$300	\$0
Data Preservation	\$2,100	\$2,100		\$0	\$2,100	\$0
Core Science Analytics, Synthesis, and Libraries	\$21,899	\$21,899		\$550	\$22,449	\$550
<i>Pollinators</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$350]</i>	<i>[\$350]</i>	<i>[\$350]</i>
<i>WaterSMART: Drought</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$200]</i>	<i>[\$200]</i>	<i>[\$200]</i>

The 2017 Budget Request for Science Synthesis, Analysis, and Research (SSAR) is \$24,930,000 and 91 FTE, a net change of \$631,000 and 0 FTE from the 2016 Enacted level.

Overview

SSAR provides analysis and synthesis of scientific data and information, and long-term preservation of scientific data and library collections. SSAR ensures that data are strategically managed, integrated, and available to decision makers and others as they focus on issues associated with Earth and life science processes. SSAR includes the J.W. Powell Center for Analysis and Synthesis (Powell Center); the National Geological and Geophysical Data Preservation (NGGDP) program; and the Core Science Analytics, Synthesis and Libraries program (CSAS&L).

Program Performance

The Science Synthesis, Analysis & Research program is made up of the following three program components: The John Wesley Powell Center for Analysis and Synthesis, the National Geological and Geophysical Data Preservation Program, and the Core Science Analytics, Synthesis, and Libraries program.

The John Wesley Powell Center for Analysis and Synthesis

(2015 Actual, \$0.3 million; 2016 Enacted, \$0.3 million; 2017 Request, \$0.3 million)

The Powell Center serves as a catalyst for innovative thinking in Earth system science research focusing on multi-faceted issues, funding interdisciplinary working groups to investigate discrete, high-impact scientific challenges. The scientist-driven center provides unique opportunities for collaboration among government, academic, and industry scientists.

In 2015, the Center received 29 proposals for potential funding from which the Powell Center Science Advisory Board, made up of leading scientists from many disciplines both within and outside the USGS, selected four new working groups. The newest working groups focus on major scientific questions, including high-impact insect invasions, coral reef resilience, river water quality, and soil carbon storage. The Powell Center continues to expand its partnership with the National Science Foundation (NSF), adding new NSF representation from their Directorate for Biological Sciences onto the Science Advisory Board. The NSF and the USGS also signed a Letter of Agreement for participation in NSF's Graduate Research Internship Program. Powell Center Working Groups have published over 70 scientific articles since the Center's inception, including publications in the high-profile journals, *Nature Climate Change* and *Science*. These publications have been cited more than 500 times. In 2016 and 2017, the Powell Center will continue to provide opportunities for scientific collaboration through the working groups, continue publishing on the results of working groups investigating hydraulic fracturing, and host workshops to address emerging policy and management needs.

Data Preservation

(2015 Actual, \$2.1 million; 2016 Enacted, \$2.1 million; 2017 Request, \$2.1 million)

The National Geological and Geophysical Data Preservation (NGGDP) program efforts are dedicated to the management, preservation, and exposure of physical geoscience samples, and data. Information about these unique geoscience artifacts and associated data populate the National Digital Catalog, a digital data management infrastructure developed by the USGS using open source methods to preserve, catalog, and dynamically expose scientific data and assets generated by the USGS and partner efforts including State geological surveys and other Interior bureaus.

Preserving endangered and unique geological and geophysical collections is vital for reducing duplicative collection costs and providing information, some of which may no longer be available, to enhance scientific investigations and decision making now and in the future. The USGS works with States and partners to ensure information and data are managed and organized in well-designed repositories using best practices, as defined by standards and a community of users. Many Federal and State geological physical sample repositories are at or near capacity and unable to accept additional geoscience materials. The NGGDP program supports the continued development of national standards, procedures, and protocols for preserving collections and improving their accessibility for current and future researchers. By collaborating to preserve and expose valuable geoscience artifacts, the USGS and its partners are leveraging existing efforts to effectively provide new insights in context with the scientific record.

In 2016, the NGGDP program is working with USGS technologists and other experts to develop and advance geoscientific data exchange methods, including metadata interoperability and Web services to enable data distribution to other applications and virtual tools. The USGS and the Smithsonian National Museum of Natural History (NMNH) are collaborating to preserve and enhance distribution of valuable paleontological assets that continue to inform scientific investigations focusing on paleoclimates and ecology, resource development, geological mapping, and more. In 2017, the USGS will continue to partner with NMNH to perfect a data model and database design, and will collaborate with large-scale efforts to determine efficient data exchange methods to inform the scientific communities.

The NGGDP program continues to collaborate with States and partners in establishing common best practices for preserving, managing, and disseminating geoscientific samples and data for informing the public and research community. Recent data preservation projects funded by the NGGDP program focus on environmental safety and health, historical research and observations to inform today's science, and industry/resource management. Collaboration between the USGS and partners improves the National Digital Catalog, enabling better methods to find, obtain, and use preserved geoscience data. The National Digital Catalog includes over 750 collections, representing nearly three million physical geoscience samples and associated data points, provided by 44 States and USGS projects. These resources contribute to expanding digitization, description, and accessibility of research products in possession of the USGS and its partners for broader availability for integration and discovery in scientific investigations.

Included in Data Preservation are two essential repositories:

Core Research Center (CRC) – Established in 1974, the CRC preserves valuable rock cores for use by scientists and educators from government, industry, and academia. Rock cores and drill core cuttings are permanently stored and available for examination and testing at the CRC, located in Denver, CO. Because of this storage capability, billions of dollars are saved by not re-drilling and replicating collections. The drilling cost to replicate these collections is conservatively estimated to be in excess of \$40 billion. The CRC is one of the largest and most heavily used public core repositories in the United States. The CRC also houses, in volume, the second largest Federal fossil collection in the United States. In 2015, the USGS fossil curation staff digitally located and identified 20,000 fossil localities, vital information for investigating paleo environments, taxonomy, resource availability, and temporal variability. To date, over 55,000 fossil localities have been identified. The CRC also contributed technical assistance to the USGS Central Energy Resources Science Center by preparing subsurface samples to reveal depositional features vital for USGS oil and natural gas assessments. CRC staff worked with industry representatives to preserve and curate core and cuttings materials representing approximately 500,000 feet of the subsurface that would otherwise have been lost. These samples have been integrated into the CRC collections and are readily available to others. In 2016, the CRC continues to provide samples, services, and data to industry, academia, and USGS scientists. Additionally, the CRC routinely collaborates with the USGS Central Energy Resources, Central Mineral and Environmental Resources, and Crustal Geophysics and Geochemistry Science Centers to conduct subsurface investigations to improve understanding of geological controls and identify existence of valuable resources (minerals, oil, gas) to benefit the Nation. These collaborative partnerships will continue into 2017 and beyond.

National Ice Core Laboratory (NICL) – The NICL is the Nation’s repository for storing, curating, and studying approximately 18,000 meters of ice cores, with an approximate value of \$300 million, recovered primarily from ice sheets of Antarctica and Greenland in a safeguarded, temperature-controlled environment. The NICL provides a first class facility for researchers to conduct examinations and measurements on the working scientific collections of ice cores that have been drilled over the past 50 years, including samples obtained by the most recent South Pole Ice Coring project conducted during 2015. The NICL is a National Science Foundation (NSF) funded facility operated and maintained by the USGS through an interagency agreement. Research on the ice cores supports the scientific goals of the NSF, Division of Polar Programs in the fields of paleoclimate reconstruction, and atmospheric change and history of the Earth.

Core Science Analytics, Synthesis and Library

(2015 Actual, \$21.9 million; 2016 Enacted, \$21.9 million; 2017 Request, \$22.4 million)

The CSAS&L program conducts biological occurrence data acquisition, biological taxonomic analysis and interpretation, computational analytics and synthesis, and provides access to broad collections of scientific information (including USGS publications) in paper and digital forms. In doing so, the program drives innovation in biodiversity, computational, and data science to accelerate scientific discovery that anticipates and addresses societal challenges. The CSAS&L program leads the USGS in expanding the capacity for mobilizing data and creating innovative tools and technologies, allowing scientists to collect, access, analyze, integrate, synthesize, and model scientific data.

The USGS Science Strategy emphasizes applied Earth systems information research with a focus on data integration and new methods of investigation. In 2015, CSAS&L worked closely with other mission areas to improve scientific discovery and innovation by using high end computing resources and expertise to reduce model run times and expand scientific analyses for projects such as volcanic ash drift, burn scar detection, and DNA and lidar data processing.

The USGS Library maintains over 1.8 million physical volumes and three million maps, provides access to digital collections, and offers expertise locating and acquiring rare or specialized research products needed by scientists. In 2016, the Library will complete space consolidation efforts in the Denver and Menlo Park branches, resulting in the overall Library footprint being reduced more than 40 percent. The Library continues to implement efficiencies with technology upgrades that will expand resource access and discovery assistance to USGS researchers.

The CSAS&L supports national-scale resources that provide essential information on biodiversity for conservation and management. As a result of strategic science planning in 2015, in 2016 these resources will combine efforts to produce new integrated products (e.g., National Biogeographic Map or National Biodiversity Assessment) that synthesize data and deliver new and more useful visualizations and assessments of the status of biodiversity and threats to it. These national-scale biogeographic characterization and biodiversity products will use a new spatial analytics and synthesis research and development process to produce information for landscape level conservation planning and resource management decision making.

The CSAS&L maintains products and capabilities that make national-level data available through interactive systems that facilitate integration, modeling, and visualization of the data. They include—

- **Applied Research Computing (ARC)** – ARC provides High Performance Computing (HPC) capabilities and expertise to USGS scientists for the acceleration and expansion of scientific discovery. Capabilities such as access to USGS specific HPC computing resources, the ability to perform analysis and synthesis utilizing several of the world’s fastest supercomputers (e.g., DOE Oak Ridge National Laboratory Titan computer) via interagency agreements, expertise to improve modeling performance via software parallelization methods, and shared commercial license purchases are being made available to USGS scientists, data managers, and collaborators.
- **Biodiversity Information Serving Our Nation (BISON)** – The national integrated resource for U.S. Federal and non-Federal biological occurrence data serves more than 243 million records of species occurrences for every State, county, and congressional district in the United States. BISON serves as the U.S. connection to the Global Biodiversity Information Facility and is the biodiversity hub of the EcoINFORMA informatics capability recommended in the July 2011 report on sustaining environmental capital by the President’s Council of Advisors on Science and Technology.
- **Community for Data Integration (CDI)** – The CDI is a collaboration of USGS scientists, data managers, policy experts, and other organizations that promote data management best practices and data integration capabilities. It is an instrumental community of practice for leveraging expertise and resources to test new technologies and institutionalize best practices.
- **Gap Analysis Program (GAP)** – The Gap Analysis Program assesses the status of biodiversity in the United States and provides products from this understanding to better inform resource management decision making at landscape scale. The GAP builds and maintains three unique datasets: land cover, land stewardship, and species distributions. The GAP conducts a research program to use advanced analytics methods to examine specific taxa, or groups of species of interest to identify the most threatened groups and describe potential conservation priorities. The USGS and other Federal agencies, States, local government, and others use GAP as a source for up-to-date, standardized environmental data that help to determine habitat suitability and guide land purchase decisions.
- **Integrated Taxonomic Information System (ITIS)** – With more than 830,000 scientifically vetted entries, the ITIS is the authoritative source for scientific names of species and higher-level groups of organisms in North America and the world. The ITIS is produced in conjunction with eight other Federal partners that use it as the authority for taxonomic information. Its partnership with the European-based Species 2000 yields the global names standard: Catalogue of Life. ITIS data is used in thousands of databases in industry, academia and government.
- **USGS Library** – Authorized by Congress in 1879, the USGS Library program provides services, collections, and expertise that are essential to fulfilling the U.S. Geological Survey’s science mission. The Library is focused on enhancing online resources and services in order to expand access to critical information, consolidate facilities to realize efficiencies, save researchers valuable time, and help further scientific inquiry and discovery.

- **National Fish Habitat Partnership Data System (NFHP-DS)** – The NFHP-DS is a data system that provides Federal and other members of the National Fish Habitat Partnership an integrated data system to upload, interact with, and download data. This reduces data processing workload and increases accessibility needed for national habitat assessments to better inform decision makers. The NFHP-DS provides users with geospatial data visualization, downloadable maps, metadata, and map service capabilities.
- **Ocean Biogeographic Information System of the United States (OBIS-USA)** – The OBIS-USA integrates marine biological data to better define, understand, and address issues that threaten marine ecosystems. OBIS-USA provides marine biological data following international standards and supporting the U.S. Open Data Policy. OBIS-USA serves as an integrated data system for the biological data of the Integrated Ocean Observing System, the Bureau of Ocean Energy Management, and the Marine Biodiversity Observing Network.
- **ScienceBase** – ScienceBase is a data and information management capability that enables data upload, documentation, sharing, and dynamic data services through standards-compliant methods and technological components to provide a foundation for data stewardship, government open data, and scientific discovery.
- **Science Data Management** – This component provides bureauwide leadership in establishing and implementing science data-management practices. It provides access to standards, workflows, training, and tools to help ensure Federal data is properly maintained, described, preserved, and made accessible.

The following program changes are proposed in 2017 within this component:

2017 Program Changes
<p>Pollinators (+\$350,000, for a total of \$350,000): This increase would allow the program to create maps and analyses for habitats of critical concern for pollinators with areas of greatest potential for mitigation and restoration activities and enhance existing only repositories to capture national distributions and ranges for pollinators to inform climate change. The work would be conducted in collaboration with the Ecosystems Mission Area. Conservation and land managers would use these maps and analyses to make more informed decisions on pollinator habitat mitigation and restoration strategies. The Pollinators Initiative would address research priorities identified through the 2014 Presidential Memorandum on Pollinator Health, through decision tools for land and resource management agencies.</p> <p>WaterSMART – Drought (+\$200,000, for a total of \$200,000): The SSAR program would use this funding to build upon existing expertise to synthesize scientific research on species most at risk from the effects of drought, model the effects of drought on the habitat for those species, and create maps that show areas most viable for mitigation activities. These outputs would improve USGS support to ecosystem conservation planners by providing maps and analyses of species at risk and habitats of critical concern for drought effects and those areas most promising for mitigation actions. Resource managers would be able to use climate scenarios to help determine appropriate mitigation strategies to address drought effects on habitats and species at risk.</p>

Science Collaboration

Some examples of the many collaborative partnerships working with SSAR:

Big Earth Data: The Big Earth Data Initiative makes Earth science data more discoverable, accessible and usable. The USGS leads the U.S. Group on Earth Observations data management working group and provides many big Earth data systems allowing smaller datasets to be integrated for delivery, which reduces duplication of effort and makes earth science data more readily available to better inform conservation decisions. The SSAR works in concert with all Interior bureaus, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), United States Department of Agriculture (USDA).



The USGS Community for Data Integration wins the American Council for Technology – Industry Advisory Council Excellence.Gov Award for excellence in analytics and big data.

National Science Foundation (NSF) GRIP: In July 2015, a Letter of Agreement was signed between the USGS and the National Science Foundation (NSF) to provide internship opportunities through their Graduate Research Internship Program (GRIP). The CSAS&L took the lead on establishing this partnership, which extends opportunities for current NSF Graduate Research Fellows to intern with Federal Agencies. The first two USGS GRIP opportunities listed (in high performance computing and earth science informatics) are jointly sponsored by CSAS&L and the Powell Center.

Participation in this program strengthens ties with NSF and provides NSF graduate fellows with opportunities for professional development at Federal facilities. The USGS’s GRIP interns can grow professionally with a rewarding research experience and receive mentoring from USGS scientists, while focusing on the USGS’s mission of providing reliable scientific information to describe and understand the Earth.

The John Wesley Powell Center for Analysis and Synthesis (Powell Center) serves as a catalyst for innovative thinking in Earth system science research focusing on multi-faceted issues. The scientist-driven center provides unique opportunities for scientific collaboration among government, academic, and private sector scientists. Scientists from many paths form working groups that leverage existing research efforts to produce powerful new insights and move scientific understanding forward at an accelerated pace.

The Integrated Taxonomic Information System (ITIS) is an interagency collaboration led by the USGS. It is the authoritative source for the names of biological organisms and leverages the unique expertise and capabilities of CSAS&L in biodiversity informatics and the unique taxonomic expertise of the Biological Survey Unit (BSU) of the USGS Patuxent Wildlife Research Center (PWCR). Both the ITIS content team and the PWCR BSU experts are hosted by the Smithsonian.

ITIS (www.itis.gov) receives more than two million visits a year from professional and citizen scientists all over the world. It is the most taxonomically comprehensive database of its kind on Earth and serves as the basis for scientific species names and hierarchy across many Federal agencies and in thousands of databases in government, industry and academia.

Some of the many partners include the Smithsonian, USDA-Natural Resources Conservation Service; USDA- Agriculture Research Service; and the Department of the Interior – National Park Service (NPS) and U.S. Fish and Wildlife Service (FWS).

Biodiversity Information Serving Our Nation (BISON) supports the mobilization of Federal biological collections occurrence data as the Federal counterpart to iDigBio, the National Science Foundation's hub for the Advancing Digitization of Biological Collections Data (ADBC) program for these data in the non-Federal sector. It is also the primary Federal application and the United States point of presence for the Global Biodiversity Information Facility, funded primarily by NSF through the Smithsonian Institution. The combination of the biodiversity informatics capability of CSAS&L, especially with respect to Big Data, and complimentary taxonomic expertise in ITIS are essential and unique.

BISON serves as the Federal clearinghouse and mapping service for biological occurrence data with more than 250 million records, a large proportion of which were originally generated with Federal funds. Integration of these data allows users to immediately see and download checklists and data for documented species in any area in the United States. The temporal aspect of the records allows users to look back more than a century and compare seasonal movements. Mapping and other Web services provided for other agencies data allows them to provide modern Web services, a geospatial interface, and dramatically increase public use of their data.

Some of the many partners include NSF, Environmental Protection Agency, USDA-Forest Service, Bureau of Land Management, NPS, and FWS.

National Assessment: The USGS provides expertise in species distribution modeling, data management, geographic information systems and conservation assessments to produce a National Assessment of the status of fresh water and coastal aquatic resources in the United States. Central to the assessment are several USGS national datasets (e.g., National Hydrologic Dataset, National Land Cover Database).

Some of the many partners include National Fish Habitat Partnership – FWS, National Oceanic and Atmospheric Administration, State Fish and Wildlife Agencies, and Association of Fish and Wildlife Agencies.

The USGS SSAR provides management and coordination for the Federal Geographic Data Committee Vegetation Subcommittee’s implementation of the U.S. National Vegetation Classification (USNVC). The USGS makes the USNVC accessible to the public and partner agencies. The National Vegetation Classification (NVC) is a central organizing framework for how all vegetation in the United States is inventoried and studied, from broad-scale formations (biomes) to fine-scale plant communities. The purpose of the NVC is to produce uniform statistics about vegetation resources across the Nation, based on vegetation data gathered at local, regional, or national levels. The standard provides the common language across the natural resources agencies. Partners include the U.S. Forest Service, NPS, Bureau of Land Management, and Natural Resource Conservation Service.

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Science Support

Activity: Science Support

Dollars in Thousands	2015	2016*	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Science Support	\$105,611	\$105,611	\$164	\$4,817	\$110,592	\$4,981
<i>FTE – Science Support</i>	467	467		19	486	19
<i>FTE - SPN</i>	0	117		0	117	0
<i>FTE Total</i>	467	584		19	603	19
Administration and Management	\$84,192	\$81,981	\$141	\$4,197	\$86,319	\$4,338
<i>FTE – Science Support</i>	408	394		17	411	17
<i>FTE - SPN</i>	0	117		0	117	0
<i>FTE Total</i>	408	511		17	528	17
Information Services	\$21,419	\$23,630	\$23	\$620	\$24,273	\$643
<i>FTE – Science Support</i>	59	73		2	75	2
<i>FTE - SPN</i>	0	0		0	0	0
<i>FTE Total</i>	59	73		2	75	2

*Includes the 2016 reprogramming of funds from Administration and Management to Information Services that was approved on September 24, 2015.

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Administration and Management	+ 4,197	+ 17	L-7
DOI Science Coordination	+ 200	+ 1	L-17
Mendenhall Program Postdocs	+ 500	+ 1	L-17
Outreach to Underserved Communities	+ 200	+ 0	L-17
Enhance Science Support Capacity to Support Science Mission Goals	+ 1,997	+ 14	L-15
Tribal Science Coordination	+ 300	+ 0	L-15
Youth & Education in Science	+ 1,000	+ 1	L-17
Information Services	+ 620	+ 2	L-19
Enhance Science Support Capacity to Support Science Mission Goals	+ 620	+ 2	L-23
Total Program Change	+ 4,817	+ 19	

Justification of Program Change

The 2017 Budget Request for Science Support is \$110,592,000 and 486 FTE, a net change of +\$4,981,000 and +19 FTE, from the 2016 Enacted level.

Overview

The Science Support Activity provides the functions that make it possible to conduct USGS science. The Science Support Activity provides business and information systems including: acquisitions and grants; finance; internal control; communications; budget; monitoring and evaluation of science quality and

Science Support

integrity; education; information assurance; information management and technology services; and human capital, each of which are crucial to conducting quality science. Science Support includes the executive leadership and management that provide guidance, direction, and oversight for all USGS science activities.

For 2017, the Science Support Activity seeks to sustain the USGS science mission by providing the essential foundation and structure to conduct world-class science and allow implementation of support activities that would advance the USGS science mission. The essential support functions and services provided by the Administration and Management and Information Services subactivities form the foundation for the USGS science mission. The breadth of responsibilities funded include purchasing scientific equipment and field supplies; developing science agreements with partners; contracting for support scientists and researchers; safety training; hazardous waste management; strategic planning; succession planning; hiring and staffing; protecting science data assets; providing reliable and robust Information, Management and Technology (IMT) connectivity; developing applications; and employee development and training. Youth and education programs would contribute to National science, technology, engineering and mathematics (STEM) goals for future workforce capabilities by providing work experiences to students and the opportunity to participate in science projects contributing to improving their world. Science Coordination will contribute to building and maintaining networks of scientists and increased collaboration opportunities.

The 2017 President's Budget request includes increases in funding for activities related to supporting the science mission, and improving infrastructure support to support science; DOI and Tribal science coordination; increasing the number of Mendenhall postdoc scientists; further development of outreach to underserved communities; and increased development and coordination of youth and education in science programs and internships.

Science Support Objectives – The organizations funded by the Science Support Activity are responsible for implementing a wide array of Administration and Departmental priorities. Priorities include the Cross-Agency Priorities (CAP) to benchmark and improve mission support operations; deploy a world-class workforce; provide Open Data; enhance Lab-to-Market initiatives; pursue strategic sourcing and shared services opportunities, enhance customer service; develop smarter Information Technology (IT) delivery; promote STEM education; and focus on cybersecurity. By leading the initiatives on Administration and Departmental priorities, the Science Support Activity organizations free up field resources that can be utilized to conduct and deliver world class science.

Beginning in 2016, the USGS changed a business practice which moved the Science Publishing Network (SPN) from operating out of a working capital fund to operating within a direct funding model for publishing costs. Program dollars previously used to fund publishing will continue to fund publishing in the new business model.

2015 Key Accomplishments

Web Reengineering – The USGS Web reengineering project launched the new USGS Web site, www.usgs.gov, using open source content management software, hosted within Interior's cloud. This

effort creates a more effective and manageable Web presence and provides Web-enabled technology, real-time access, social and collaborative cloud-based tools, and extensive use of mobile and tablet devices. The new site is customer focused, provides science-driven content, is mobile ready, uses industry best practices, improves searching, Web site functionality, navigation, and complies with Federal standards. The new site incorporates insights learned through customer satisfaction data and usability testing. In addition, a new internal Web site was also developed and implemented, which provides ready access to science news and business and workforce management information.

Obtaining Science Resources – The innovative Scientific and Technical Support Services Contract (STSSC), which streamlines obtaining scientific research and technical support, was awarded. This contract will enable a more nimble response to new science project requirements. This contracting vehicle combines similar services across the landscape and will take advantage of competition among 8(a) companies, and reduces the number of sole source awards. This will better serve USGS science in addition to fulfilling acquisition performance goals to improve competition rate for acquisitions and achieves economies of scale to the maximum extent possible. Additionally, in 2015, another innovative contracting strategy, a cooperative agreement with the Southwest Conservation Corps (SCC), was put in place to provide science, technology, engineering and mathematics (STEM) work experiences to youth by providing jobs assisting USGS Science Centers with data collection and ongoing science research activities. These vehicles will be utilized in 2016 and beyond.

Connecting Science Quality Best Practices Together – The Office of Science Quality and Integrity (OSQI) provided internal controls on Fundamental Science Practices (FSP) and the Information Product Data System (IPDS) to demonstrate evidentiary processes for maintaining the quality of USGS science. OSQI is responsible for ensuring science quality best practices are followed for approving and releasing publications; helping the bureau grow the next generation of Federal scientists through high school and College internships and Mendenhall research postdocs; evaluating USGS research, development, and senior scientists; and maintaining scientific knowledge base associations through the scientist emeritus program.

Supporting Native American Needs – The USGS Office of Tribal Relations (OTR) continues to foster relationships with Indian Tribes and Alaska Native Villages that support increased scientific research collaboration with the USGS. The OTR supports annual trainings on a variety of scientific topics designed to increase the capacity of tribal natural resource departments. The OTR also supports USGS scientists who work with Tribal Colleges and Universities (TCUs) such as Salish Kootenai College, Northwest Indian College and Southwestern Indian Polytechnic Institute to provide mentoring and to supplement and improve curriculum offerings in subjects such as hydrology and remote sensing. The OTR also funds internship opportunities for work on USGS research projects conducted on tribal lands and developed the Native Youth in Science – Preserving our Homelands summer camp.

Cloud Hosting Solutions (CHS) – The USGS, in coordination with the Department of the Interior, awarded the first USGS bureau-wide contract for Cloud Hosting Solutions (CHS) that provides public cloud services through a Virtual Data Center (VDC) that can be leveraged as needed by system owners. CHS provided USGS science with a platform that supports on-demand delivery of IT resources and applications via the Internet with pay-as-you-go pricing and enables efficient data-driven science. The

Science Support

CHS Core team worked diligently to complete the build out of the components and services needed to support a VDC such as security, firewalls, networking, monitoring, backups, financial billing and reporting. During the fourth quarter of 2015, the first application was successfully migrated into the cloud environment for the USGS National Geospatial Technical Operations Center. This is the first of many scientific applications that will be moving into the cloud environment over the next several years.

Strategic Actions for 2016

The organizations funded by the Science Support Activity contribute to work that preserves core capabilities providing the framework for the science mission. To that end, the Science Support Activity will ensure that scientific integrity processes are in place so that decision makers have the best available information on hand and share and communicate findings throughout the scientific community. In order to enable high quality science, Science Support will purchase science equipment and field supplies, execute science agreements with partners, contract for support scientists and researchers, conduct safety training and appropriately manage hazardous waste removal. Succession planning is critical to the continued provisioning of high quality science and will be a focus for Science Support. In order to safeguard the quality and integrity of USGS data, Science Support will focus on activities that will protect these important science data assets in addition to providing a reliable and robust connectivity that will enhance the development and exchange of important scientific data. Applications will be developed with the purpose of enhancing science collaboration and information delivery and guarantee that USGS science is quality assured, preserved, and efficiently delivered so that world-class science collaboration will occur now and in the future.

Strategic Actions for 2017

The essential support functions and services provided by the Science Support activity form the foundation for the USGS science mission. Achieving high-quality science research depends on having the required resources, including scientific equipment and supplies, facilities and laboratories, scientists, technicians and researchers; information technology security, infrastructure and information management; partnership agreements and contracts in place; and the management processes to control and best utilize these resources. The organizations funded by the Science Support Activity will contribute to a robust national scientific community and train future scientists through youth work experiences in the USGS scientific mission areas.

As the backbone of the USGS, Science Support must remain vital and effective to support all of mission areas in the delivery of strong science. This request provides the funding necessary to support the USGS science funding in the 2017 budget. With the requested funds in 2017 the following actions would occur:

- Provide additional human capital staff to hire and support essential FTE for new science initiatives.
- Acquire acquisition support to accomplish procurement actions for the proposed 2016 scientific programmatic changes.

- Hire a management analyst to develop automated tracking systems and establish customer service metrics and quality standards for administrative processes for executive leadership and senior management to use in continuous evaluation of service and quality.
- Obtain technology transfer support to review new and modified non-standard agreements and assist scientists with the development of cooperative research and development agreements and technology transfer.
- Expand internal control support in order to evaluate the increased risk associated with program changes and assist science management in developing risk reduction processes.
- Obtain a bureau approving official to apply scientific integrity principals in support of additional science priorities for the USGS and decrease the amount of backlog and time it takes to move through the review process for scientific journals and studies, delivering science products to land-use managers and the public quicker, without risking scientific quality.
- Recruit Mendenhall Fellows to carry out research that covers the entire spectrum of USGS science. Provide opportunities to grow outreach programs to youth in underserved communities.

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Activity: Science Support

Subactivity: Administration and Management

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Science Support	\$105,611	\$105,611	\$164	\$4,817	\$110,592	\$4,981
<i>FTE – Science Support</i>	467	467		19	486	19
<i>FTE – SPN</i>	0	117		0	117	0
<i>FTE Total</i>	467	584	0	19	603	19
Administration and Management	\$84,192	\$81,981	\$141	\$4,197	\$86,319	\$4,338
<i>FTE – Science Support</i>	408	394		17	411	17
<i>FTE - SPN</i>	0	117		0	117	0
<i>FTE Total</i>	408	511		17	528	17
Bureauwide Bills	\$10,641	\$10,641		\$0	\$10,641	\$0
Science Coordination and Services	\$73,551	\$71,340		\$4,197	\$75,537	\$4,197
<i>Support Science Mission, Infrastructure Capacity to Support Science</i>	[\$0]	[\$0]		[\$1,997]	[\$1,997]	[\$1,997]
<i>Tribal Science Coordination</i>	[\$432]	[\$432]		[\$300]	[\$732]	[\$300]
<i>DOI Science Coordination</i>	[\$0]	[\$0]		[\$200]	[\$200]	[\$200]
<i>Youth & Education in Science</i>	[\$1,530]	[\$1,530]		[\$1,000]	[\$2,530]	[\$1,000]
<i>Mendenhall Program Postdocs</i>	[\$0]	[\$0]		[\$500]	[\$500]	[\$500]
<i>Outreach to Underserved Communities</i>	[\$0]	[\$0]		[\$200]	[\$200]	[\$200]

Justification of Program Change

The 2017 Budget Request for the Administration and Management subactivity is \$86,319,000 and 486 FTE, a net change of +\$4,338,000 and +17 FTE from the 2016 Enacted level.

Overview

The Administration and Management Subactivity provides bureauwide leadership and direction; establishes organizational vision, mission, goals and scientific priorities; develops and enforces standards for scientific rigor and integrity; plans, obtains and manages necessary resources including people, budget authority, facilities and equipment; provides resource management systems; implements statutory and regulatory requirements and monitors and enforces compliance; and communicates the USGS mission and science to Congress and the public. Administration and Management is comprised of the following areas:

Science Support

The USGS **Office of the Director** performs chief executive officer and chief operating officer responsibilities.

The science mission area **Associate Directors** establish program direction and goals, and serve as science advisors to the Director in their respective program areas.

The **Regional Directors** exercise line management responsibility for the science centers and implement science projects on the landscape.

The **Office of Budget, Planning, and Integration (BPI)** secures funding resources needed for the USGS to perform its mission goals, facilitates information sharing internally and externally, provides oversight of the internal controls process and the USGS Working Capital Fund, and provides in-depth analysis of USGS goals, strategies, performance and budget data for the USGS to understand, anticipate, and respond to the changing demands resulting from public policy decisions and science needs.

The **Office of Communications and Publishing (OCAP)** guides and conducts public affairs, legislative relations, customer service, external stakeholder, and internal communications and provides publishing and Web development services. The Science Publishing Network (SPN) provides services including technical writing, editing, design, and illustration to prepare scientific reports and maps for publication. This information is widely used across the Nation by members of Congress and their staff, other natural resource planners and managers, recreational hunters and hikers, emergency response officials, and the media.

The **Office of Science Quality and Integrity (OSQI)** establishes and implements bureau-wide standards for scientific integrity and quality and administers offices and programs for ethics; fundamental science practices; youth and education development; research evaluation, review, and recognition; and tribal relations, including the USGS Office of Ethics, the Youth and Education in Science program, the Mendenhall Postdoctoral Fellowships, the Research Grade Evaluation (RGE) and Equipment Development Grade Evaluation (EDGE) program, the Scientist Emeritus program, and the Office of Tribal Relations.

The **Office of International Programs (OIP)** enhances the USGS scientific mission by providing opportunities for USGS scientists to interact with scientific partners abroad and extend research and investigations to other countries. The OIP supports the development and conduct of a broad spectrum of international activities involving scientific cooperation and assistance in geological, hydrological, biological, and geospatial research and scientific investigations. The OIP provides guidance and representation to domestic and international agencies and organizations in matters pertaining to international scientific activities of the USGS.

The **Office of Diversity and Equal Opportunity (DEO)** develops policies and procedures, administers the federally mandated EEO and Diversity related programs, facilitates early resolution of discrimination complaints, and develops guidelines to ensure proper implementation of Equal Opportunity laws and regulations. DEO staff chair the USGS Diversity Council, coordinate outreach and recruitment events

focused on minorities with the various mission areas, and develop and submit required/mandatory reporting on EEO Complaints and Diversity. The office is also responsible for ensuring the USGS provides reasonable accommodations to employees/applicants with disabilities.

The **Office of Administration (OA)** establishes policies, manages, coordinates, provides oversight and conducts operations in the areas of accounting and fiscal services, general services, security, safety and occupational health, acquisitions and grants, internal controls, technology transfer, facilities and property, environmental protection, human capital programs, including human resources and employee development. The Associate Director is the Chief Financial Officer (CFO) and Designated Agency Safety and Health Official (DASHO).

The Administration and Management Subactivity contributes to a robust national scientific community and trains future scientists through youth work experiences in the USGS scientific mission areas; maintains the Mendenhall Research Fellowship Program to a consistent high standard for projects and researchers; manages the Publications Warehouse which provides a comprehensive program to make USGS publications, research results and datasets more accessible; implements Web Reengineering in order to streamline USGS internal and external websites; leads workforce planning and leadership succession planning; and implements process improvement principles to evaluate human capital and acquisitions to increase operational efficiency and improve science mission support.

In 2017, the Administration and Management Program is requesting an increase in funding of \$4,338,000, including fixed costs.

Program Performance

The Administration and Management Subactivity includes the following program components, described in more detail below: Science Coordination and Services and Bureauwide Bills.

Science Coordination and Services

(2015 Actual, \$73.6 million; 2016 Enacted, \$71.3 million; 2017 Request, \$75.5 million)

Science Coordination and Services establishes program direction and goals for the USGS, exercises line management responsibility for science centers, and implements science projects on the landscape; ensures scientific rigor and integrity; and carries out international activities as a complement to domestic science programs. Science Coordination and Services provides bureau leadership with foundational administrative services for the conduct of science by organizing and conducting operational planning and budgeting; providing policy guidance and direction; implementing, monitoring and enforcing statutory requirements; managing and acquiring people, equipment, funds and facilities; and communicating the USGS mission and science to the public and others. These core science support capabilities that provide the framework for the USGS mission must be preserved in order to provide the high quality science for which the USGS is known.

Office of Science Quality and Integrity (OSQI) - The OSQI coordinated the development of four new data related interim policies to facilitate providing our data to the public. This is significant because these data will now be available to the public, enhancing the transparency and accountability of our science products.

The OSQI led efforts to develop the Department's first scientific integrity training module established through the DOI Learn Training Center. The OSQI also coordinated a major revision of the USGS scientific integrity policy—the first update since the policy was established in 2007.

A total of 8,445 interpretive and noninterpretive science information products were approved in compliance with fundamental science practices and tracked using the internal Information Product Data System. Of these, 3,368 were considered new and interpretive science and as such were approved by Bureau Approving Officials in OSQI. The remaining 5,077 products were approved at the USGS science center level.

Office of Diversity and Equal Opportunity (DEO) - In addition to providing mandatory legal programs and services of Equal Employment Opportunity (EEO) processing during 2015, DEO provided a robust training and awareness program to educate the workforce on their rights and responsibilities regarding the EEO process and procedures to include EEO briefings to employees and managers, diversity training events, briefings to executive leadership, Diversity Council presentations and assistance visits in various parts of the country. By providing training and education to USGS employees, they obtained a greater understanding of their rights and responsibilities regarding EEO, raised complaints and successfully mediated those complaints or made the conscious decision to withdraw them, allowing the employees to return to their assignments and continue to passionately engage their science.

Office of International Programs - In Latin America, the Global Seismic Network program participated on an international panel of experts to conduct a technical and procedural review of the Centro Sismológico Nacional - University of Chile (CSN). The USGS participation supported long-standing joint collaboration with the Government of Chile on seismic monitoring. The USGS continued to play an active role with DOI with respect to environmental work related to the Monarch butterfly in Mexico and along the US-Mexico Border region. Current focus with FWS is the establishment of a North American monarch partnership with Mexico and Canada to effectively research and manage the species. Additionally, The Secretary of the Department of the Interior signed a Memorandum of Understanding between the USGS and the National Institute of Statistics and Geography of Mexico for cooperation in the use of Land Remote sensing satellite data. This is the first ground receiving station in Latin America to be able to download Landsat 8 imagery.

In addition, the USGS led regional Central and South Asia Seismic Training Workshops. The workshops brought seismologists together from up to 17 nations in coordination with local government and non-government institutions as well as international organizations. Specifically, the workshops focused on enhancing regional cooperation in weak and strong motion seismology, engineering seismology and earthquake risk management, through training and strengthening of the networking among scientists of South and Central Asian regions and provided the opportunity to discuss problems and exploration of suitable approaches for improved data sharing and collection, and regional cooperation.

A water resources training workshop held in Astana, Kazakhstan, in September 2015, focused on new developments in integrated water-resources analytical techniques and remote sensing applications in support of water resource assessments in Central Asian Countries and Afghanistan. Experts gathered together to discuss and share information on surface-water and groundwater investigations and remote sensing applications for water resources. Problems and exploration of suitable approaches for remote sensing applications in water resources were of major interest to the participants. The training workshop was an important step towards data sharing and cooperative work in the Central Asian region for improved water resources management. This training workshop contributed to sustainable regional development, to the health and safety of all the people in the region, and the building of international trust and cooperation.

Progress has been made in the creation of an Arctic Spatial Data Infrastructure (Arctic SDI), an initiative that brings together the eight national mapping agencies of the Arctic Council member countries in order to facilitate access to geographically related Arctic data, digital maps and tools to facilitate environmental monitoring and natural resources decision-making. The Arctic SDI is a voluntary partnership between the national mapping agencies that seeks to build on the existing and future geospatial infrastructure in each of the eight agencies to develop a complex of spatial information resources, structures, technologies and related supporting tools, standards, operational policies and best practices in order to improve access to and efficient use of spatial data. The decision-making body of the Arctic SDI is the Arctic SDI Board which consists of designated representatives from each of the mapping agencies. The Board generally meets once a year, and its activities are performed by Lead Countries joined by Support Countries. The Lead Country, USA, represented by the USGS, currently serves as chair of the Arctic SDI and rotates according to the rotation cycle of Arctic Council Chairmanship.

As a result, the USGS now has the responsibility for the operation and progress of the activities of the Arctic SDI.

Succession Planning – The USGS is conducting succession planning for the leadership ranks (GS-14 and above), as outlined in the USGS Workforce Plan. Started in 2015 and continuing into 2016, succession planning is initially focused on positions in the Senior Executive Service (SES). This involves identifying the potential pipeline of candidates who could compete for SES positions at the USGS and developmental opportunities to prepare this talent pool. The next phase of succession planning, to begin in 2017, will focus on the pipeline for Center Director positions. The USGS will also conduct additional pilot efforts at different organizational levels. These concurrent efforts will help solidify a succession planning methodology and tools that can be applied more broadly across the USGS and ensure a talent pool of employees with the skills needed to assume key positions. The USGS continued its dedication to effective leadership and management by offering tailored training in specific skills appropriate to various career stages. For new supervisors, four week-long sessions of the USGS Supervisory Challenge course was provided to 100 new supervisors. This course covers the competencies required for supervisors during their first year of supervisory responsibility. A variety of assessment instruments are included in the course to provide supervisors with insights into their own preferences and behaviors. In addition, a multi-rater assessment tool has been implemented as an optional tool available to USGS supervisors to assess their progress in specific supervisory behavioral categories.

Leadership Training – Training was provided to approximately 260 employees across the bureau through Leadership Intensives, a two-day course that introduces leadership concepts, including the USGS guiding principles, to employees at all grade levels. In addition, the two-part series of Leadership 101 and Leadership 201, geared toward employees in grades GS-12 to GS-15, was offered to employees selected by nomination. Two national level Leadership 101 classes were delivered to 52 employees, and two Leadership 201 classes were delivered to 52 USGS employees. For the second time, the Office of Organizational and Employee Development deployed the Leadership 101 course at the regional level, providing comprehensive USGS leadership training to 26 employees in the Midwest Region and 26 employees in the Pacific Region. In addition to Leadership Training, the USGS continues to support a comprehensive Mentoring Program that pairs mentors and protégés for a year-long guided mentoring process. Support is provided through the program to both the mentors and the protégés, culminating in successful partnerships that often last for years.

Ensuring Financial Health – Innovative tools (such as a financial matrix dashboard) for science centers were deployed in 2015. The tools put financial information at the fingertips of USGS executive leadership and senior leadership at our centers in order for them to maintain an awareness of their financial status to maximize science budgets. In 2015, the USGS successfully implemented Treasury’s new Central Accounting and Reporting System (CARS) and continued to implement modifications to the Department’s new financial management tool, the Business Process Consolidation (BPC) module, which replaces financial reporting software that is no longer supported. In addition, the USGS implemented AGILE, a new method of implementing modifications to our Financial and Business Management System (FBMS). The USGS will continue to refine and improve internal processes to ensure strong financial management controls. Financial performance improved as measured by the Interior scorecard metrics, in Prompt Pay, Electronic Funds Transfer (EFT), and Charge Cards.

Leadership in Environmental Stewardship – The USGS has implemented an Environmental Management System (EMS) in order to ensure compliance with environmental policy and regulation; prevent pollution; and achieve Administration goals for reduction of facility energy and greenhouse gas emissions from owned and operated facilities and equipment. The EMS is a comprehensive structure to measure and manage the USGS’s environmental impact and includes an overarching policy, an executive management council, cross-functional teams, bureau-wide training, database tools, metrics and performance goals to measure compliance, and external audits to independently evaluate and verify program effectiveness. In addition to pollution prevention, and environmental compliance, the USGS includes sustainability goals for reducing facility energy, fleet fuel, greenhouse gas emissions, potable water, and solid waste generation.

In 2015, objectives and targets were established for improving energy efficiency in USGS facilities and fleet vehicles, improving solid waste diversion from landfills, conducting internal environmental inspections, and increasing environmental awareness for all employees.

In 2015, the USGS began implementing an alternatively financed Energy Savings Performance Contract (ESPC) worth \$12.7 million. This contract has enabled infrastructure improvements to USGS facilities including energy management control systems; heating, ventilation, and air conditioning (HVAC) improvements; lighting upgrades and controls, and renewable energy systems installation. The ESPC will

reduce the USGS energy consumption by 15 percent and potable water use by 5 percent. The ESPC will also help achieve total energy reduction of over 30 percent, from its 2003 baseline year, and over 26 percent total reduction of water from its 2007 baseline year. Additionally, the ESPC will help reach the USGS GHG Scope 1 and 2 emission-reduction goal of 36 percent from the 2008 baseline. The utility cost savings from the improvements is \$650,000 per year, and this savings will be used to pay for the contract.

Leadership in Environmental Compliance – In 2015, the USGS developed an Environmental Compliance Management and Auditing System. The Web application framework and platform will be used to manage environmental documents and it will also be used to generate workflows to meet science center environmental needs. A tool is integrated to facilitate environmental audits conducted at the science centers and audit findings will be documented and tracked. The workflow generated by the software tool will facilitate development and implementation of corrective actions. Senior Leadership can use this tool to monitor the status of environmental compliance and progress of science centers in meeting environmental goals. Training was provided to the Environmental Protection Specialists (EPSs) and Collateral Duty Environmental Protection Coordinators (CDEPCs) on the use of the Environmental Compliance Management and Auditing System in 2015. Additional training will be provided to the EPSs and the CDEPCs in 2016.

Technology Transfer – The Federal Technology Transfer Act, 15 USC 3710a, as amended, requires each Federal laboratory having 200 or more full-time scientific, engineering and related technical positions to establish a research and technology application function. Within the USGS, this function is housed in the Office of Policy and Analysis where staff service USGS Science Centers and offices throughout the country. USGS science and research contributes to a broad range of valuable collaborative projects in the private and academic sector. In 2015, the USGS continued negotiating and drafting Cooperative Research and Development Agreements (CRADAs), Technical Assistance Agreements (TAA), Facility Service/Use Agreements (FSUA), Material Transfer Agreements (MTA), and Patent Licenses. This office also manages the USGS intellectual property and inventions program; markets USGS technology opportunities and technical assistance to industry, non-profits, academic institutions, and State agencies; and provides training to USGS personnel on technology transfer and intellectual property protection.

During 2015, the USGS increased its technology transfer activity both in terms of number of collaborations and projects and reimbursable funding. The USGS executed 13 new CRADAs and over 200 new TAAs, making for 34 active CRADAs and more than 400 active TAAs. The USGS had more than 30 specialty analytical laboratory services providing unique capabilities to the United States, private sector partners, and academia. New facility use agreements executed during 2015 totaled more than 300. The total partner contributions from these various types of technology transfer agreements exceeded \$9 million. The USGS managed a total of 15 active patent licenses and filed seven patent applications, received two patents, and executed three new patent licenses.

Science Support

The table below summarizes the number of technology transfer projects in 2015.

Active	Total Number	Private	Non-Profits	Academic Institutions	Government Entities	International Entities	Partner Contributions (\$)	USGS In-Kind Contributions (\$)
CRADAs	34	29	1	1	0	3	735	1485
TAA	211	69	49	45	18	30	7,074	863
Patent Licenses	15	15	0	0	0	0	85	0

In 2016, Science Coordination and Services plans to:

Workforce Planning – The USGS Workforce Plan 2015-2020 identifies workforce planning actions to take at the bureau-level to ensure the USGS has the workforce it needs to continue its leadership in Earth science. The Workforce Plan Implementation Team, made up of science and science support employees across the USGS, is working on initiatives particularly in the areas of skill set gaps, workforce flexibility, diversity, and succession planning. Activities in these areas will span 2016 and 2017.

Electronic Award Files – Beginning in 2016, the USGS began supporting award of all acquisition and financial assistance actions with electronic files. While the initiative is led by Interior, the USGS will be implementing across the board in advance (likely by more than two years) of Interior requirements for all actions, including grants and cooperative agreements. The use of electronic files supports Federal initiatives, decreases costs by reducing space required to house paper files, and provides access to files for auditing and review purposes, thereby decreasing postal and travel costs. Electronic files support contingency operations by allowing financial documents to be maintained in backup and offsite locations accessible from anywhere.

International Scientific Solutions – The USGS has a clear opportunity to introduce more effective scientific and technological solutions to help resolve the local, national, and regional water resources issues. International workshops in 2016 and beyond will include the improved presence and use of integrated networks for real-time remote water monitoring systems providing data on water availability and quality, as well as providing early warning of potential risks associated with drought, flooding, desertification, agricultural production, and famine. Such integrated networks in concert with remote sensing applications could overcome issues of incomplete data coverage and lack of timely data dissemination within nations and among nations resulting in the poor quality of current predictive water management tools currently in use. Additional future training in data standardization, data collection, data dissemination techniques, modeling techniques, and remote sensing application would: (1) facilitate remediation of current issues; (2) provide career opportunities for younger scientists, engineers, hydrologists, modelers, remote sensing experts, and water resources managers, and, ultimately; and (3) contribute greatly to improved stability.

The USGS and the EPA recently met in Mexico City with Mexican counterparts on defining next steps for the Gulf of Mexico Large Marine Ecosystem project. In 2016 a workshop will be held to further project work.

Over recent years, Science Support funding has not kept pace with increases in the science programs. To maintain an appropriate level of science support, the USGS proposes the following increases to support the science programs:

2017 Program Changes
<p>Enhancing Science Support Capability to Support Science Mission Goals (+\$1,997,000 for a total of \$1,997,000): Investments in the Administration and Management support functions provides the tools, people and support needed to accomplish the USGS science mission.</p> <p>Strategic reviews and workforce analysis have guided the USGS in preserving core capabilities while adapting to changing requirements and technologies, within a decreasing budget. The USGS is struggling to provide basic support functions, especially in the areas of acquisitions and human capital. These functions are essential in supporting the USGS science, as they provide the equipment, field supplies, and contract support, as well as hire the vital talent, that is needed for executing the mission. In addition, as a science mission grows, additional support is needed in the areas of internal controls and reporting, and science integrity, so that the science can be reviewed, published, and in the hands of decision makers in a timely fashion.</p> <p>A&M supported functions will continue to use workload and workforce analysis to adapt to meet evolving requirements, and ensure that science support appropriately supports the science mission of the USGS. This increase would improve service delivery and support closer collaboration between service providers and scientists. This increase, for example would:</p> <ul style="list-style-type: none"> • Provide additional human capital staff to hire and support essential FTE for new science initiatives. • Acquire acquisition support to accomplish procurement actions for the proposed 2016 scientific programmatic changes. • Hire a management analyst to develop automated tracking systems and establish customer service metrics and quality standards for administrative processes for executive leadership and senior management to use in continuous evaluation of service and quality. • Obtain technology transfer support to review new and modified non-standard agreements and assist scientists with the development of cooperative research and development agreements and technology transfer. • Expand internal control support in order to evaluate the increased risk associated with program changes and assist science management in developing risk reduction processes. • Obtain a bureau approving official to apply scientific integrity principals in support of additional scientific quality. • Recruit Mendenhall Fellows to carry out research that covers the entire spectrum of USGS science. Provide opportunities to grow outreach programs to youth in underserved communities. <p>Tribal Science Coordination (+\$300,000 for a total of \$732,000): This increase in funds for the USGS Office of Tribal Relations (OTR) will increase outreach that helps form relationships with</p>

2017 Program Changes

Indian Tribes , which will assist them in responding to environmental challenges that disproportionately affect Indian communities; expand technical training; provide for the development of a tribal emergency data portal to improve Tribes' ability to design plans for emergency services; and increase partnerships with Tribal Colleges and Universities (TCUs) and tribal communities to help prepare Native youth for scientific careers.

The increase would make existing partnerships more robust by enhancing and expanding outreach coordination efforts with Tribes. For example, OTR would fund five USGS regions to meet directly with Tribes to familiarize them with the many services the USGS can provide to help them address environmental challenges, such as water quality and drought, fisheries health, and invasive species threatening tribal ecosystems. This is essential to fulfilling the Federal Tribal Trust Responsibility. Tribes are typically struggling with small budgets and overburdened staff in their Natural Resource departments and need our help. These communities benefit greatly from partnerships with the USGS on environmental issues that help tribal natural resource departments respond to environmental threats and to plan for meeting future challenges to the health of their homelands. Working with the USGS regional and mission area tribal liaisons, OTR will forge partnerships to connect Tribes to scientists in Interior and Federal agencies.

The funding would also support expanding tribal training through the TEchnical training in Support of Native American Relations (TESNAR) program, which provides for the transfer of information from the USGS to tribal natural resource staff on research techniques and technology for use in management decisions and resiliency planning. This training provides much needed capacity building to Tribes and supports self-determination in their climate adaptation and mitigation activities. This funding will allow OTR to provide six more TASNAR trainings.

Increased funding will also allow for the development of a USGS data portal designed to give Tribes access to historical and projected data for inclusion in FEMA emergency services grants. Since Tribes frequently lack the funding and staff that States and municipalities possess, they are less equipped to access and compile historic scientific data on natural hazards that have affected their communities and scientific predictive studies about new threats. This portal will be designed specifically to provide Tribes with easy access to data. It will be one of the first USGS portals that can be accessed by mobile devices in the field, and will be tailored to provide data specifically required by FEMA for the development of Tribal Mitigation Plans, migration grants and emergency funding.

Increased funding will support the expansion of USGS OTR efforts to partner with tribal colleges and universities (TCUs) to enhance their science programs, so these students are equipped to understand the changing environmental conditions impacting the health of their tribal lands and prepare them for employment within their respective tribal natural resource departments. In addition, this funding will allow for the expansion of the Native Youth and Science program, which brings the USGS and other DOI bureau scientists, along with tribal keepers of traditional ecological knowledge (TEK) together in partnership to teach tribal youth about the ecology of their homelands. This introduces to Native youth how scientific research can determine the health of ecological systems, fostering a new generation of interested in pursuing scientific careers. This will allow OTR to bring the Native Youth and Science program to two additional Tribes.

2017 Program Changes

DOI Science Coordination (+\$200,000 for a total of \$200,000): The funding would support a dedicated scientist to coordinate USGS science efforts with other Interior bureaus and would improve Interior's science integrity process overall. This unified approach strengthens scientific research and application across Interior and aids land management and land use policy development and implementation by ensuring that Interior agencies and bureaus have a known, point of contact to facilitate communication and ensure their science needs and priorities are properly channeled to the relevant mission areas.

Mendenhall Program Postdocs (+\$500,000 for a total of \$500,000): The Mendenhall Research Fellowship Program is the flagship postdoctoral research program for the USGS. Established in 2001, this program is widely accepted as one of the most prestigious and coveted postdoc programs in science. Through the Mendenhall Program, the USGS obtains some of the best available new PhD talent to address the needs of its science mission. This increase will be used to base fund the program, thereby providing program stability, the opportunity for program growth, and the incentive to annually recruit 3 to 5 new Mendenhall Fellows to carry out research that covers the entire spectrum of USGS science.

Outreach to Underserved Communities (+\$200,000 for a total of \$200,000): This additional funding would help the USGS to provide an understanding of the opportunities available through STEM studies and demonstrate a path toward development as future scientists. This funding would supplement the cost of up to 60 interns hired via the Pathways Programs recruited from minority serving institutions and tribal colleges. This funding would also allow for program startups at new minority serving institutions and tribal colleges.

Youth and Education in Science (+\$1,000,000 for a total of \$2,530,000): The requested increase would enable the USGS to build on existing youth hiring and youth outreach activities which contribute directly to STEM capabilities for the Nation, and introduce future scientists to the value of public service in the Earth and biological sciences. In 2015, this program provided supplemental funds in support of nearly 300 youth engaged with USGS science. Requests for support from this program doubled in 2016 and not all needs were met. USGS Centers are actively working to replace a dwindling workforce and are increasingly turning to the Youth and Education in Science program for the needed support to do so.

Bureauwide Bills

(2015 Actual, \$10.6 million; 2016 Enacted, \$10.6 million; 2017 Request, \$10.6 million)

A significant portion of the Administration and Management subactivity goes directly to paying a portion of “must pay” bills, such as bills related to programs and enterprise-wide systems managed in Interior’s Working Capital Fund. The science mission areas also fund these bureauwide support costs through their respective program budgets.

Interior’s Office of the Secretary and the Interior Business Center provides oversight, DOI-wide coordination, and operational and business support services in lieu of duplicative systems in each bureau. Funding from the bureaus maintain programs and systems such as: the infrastructure and support for the

Science Support

Financial and Business Management System (FBMS); the DOI-wide e-Travel system; the Interior Operation Center which serves as the focal point for emergency response activities; the consolidated financial statement audit; operations and maintenance of the Federal Personnel and Payroll System (FPPS); the DOI University and their online learning system; and the Office of Aviation Services which provides policy and oversight on aviation activities. Additionally the Administration and Management Activity manages the mandated costs associated to the Department of Labor's Worker's Compensation (P.L 94-273) and Unemployment Compensation (P.L. 96-499) programs.

In recent years, fixed cost increases have been largely funded within base, reducing the net programmatic funding. Additional information is located in the Sundry Exhibit under Section 403 Compliance in the annual budget justification.

Activity: Science Support

Subactivity: Information Services

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Science Support	\$105,611	\$105,611	\$164	\$4,817	\$110,592	\$4,981
<i>FTE – Science Support</i>	467	467		19	486	19
<i>FTE - SPN</i>	0	117		0	117	0
<i>FTE Total</i>	467	584	0	19	603	19
Information Services	\$21,419	\$23,630	\$23	\$620	\$24,273	\$643
<i>FTE – Science Support</i>	59	73		2	75	2
<i>FTE - SPN</i>	0	0		0	0	0
<i>FTE Total</i>	59	73		2	75	2
DOI Information Management and Technology Bureau Bills	\$7,845	\$7,845		\$0	\$7,845	\$0
Information and Management Technology Services	\$13,574	\$15,785		\$620	\$16,405	\$620
<i>Support Science Mission, Infrastructure Capacity to Support Science</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$620]</i>	<i>[\$620]</i>	<i>[\$620]</i>

Justification of Program Change

The 2017 Budget Request for Information Services is \$24,273,000 and 75 FTE, a net change of +\$643,000 and +2 FTE from the 2016 Enacted level.

Overview

The Information Services subactivity provides the critical information management and technology (IMT) foundation for the USGS science mission by implementing advances in IMT and using them to facilitate research, data gathering, analysis and modeling, scientific collaboration, knowledge management and work processes. This subactivity funds numerous IMT services such as the USGS information assurance program, infrastructure and computing services, applications and end user services, and information and investment management programs. In addition to IMT services, this subactivity also supports the Interior information management and technology bureau bills. Although Information Services has been confronted with competing mission challenges resulting from cyber security incidents, continued austere budgets, and the implementation of the Federal Information and Technology Acquisition Reform Act (FITARA), the subactivity continues to provide critical IMT Services and bureauwide IMT services necessary to support a successful and respected science organization.

In addition, Information Services provides shared services with Interior, and its bureaus, by consolidating numerous software purchases that deliver economies of scale. Information Services also functions as the service provider of fiber optic cabling for offices within Interior and its bureaus, as well as for agencies within the U.S. Forest Service, the Department of Labor, the General Services Administration and other Federal agencies.

In 2017, the Information Services Program is requesting an increase in funding of \$643,000.

Program Performance

The Information Services Program includes the following two program components, described in more detail below: Information and Management Technology Services and DOI Information Management and Technology Bureauwide Bills.

Information and Management Technology (IMT) Services (2015 Actual, \$13.6 million; 2016 Enacted, \$15.8 million; 2017 Request, \$16.4 million)

Information Assurance protects infrastructure and data from improper or malicious access or manipulation; protects the integrity and availability of science information; preserves the confidentiality of privacy and other sensitive information; and ensures compliance with Federal information technology mandates and regulatory requirements. Oversight is applied to security control implementation to ensure well-rounded information system management is used to increase the reliability of the technology supporting science information delivery. The Information Assurance office provides specialized security training to nine major systems and over 100 subcomponents in the appropriate remediation of vulnerabilities, planning, and internal control implementation to ensure risks are managed commensurate with data sensitivity and mission requirements.

Information Technology (IT) Infrastructure delivers telecommunications and hosting infrastructure services throughout the USGS. Telecommunications support timely transmission and sharing of emergency and routine data such as from earthquakes, flooding, volcanic eruptions, and business information system data. This complex network, telephony, and video architecture is used to provide timely access to global environmental, eco-system data to promote, protect, and enhance the Nation's economy, security, environment, and quality of life. To fulfill its responsibilities, the Telecommunications Program ensures that current and future mission-related telecommunications needs are accurately assessed and supported through fully integrated and secure services.

A component of the Telecommunications Program includes the USGS Radio Frequency Spectrum Program which provides strategic and operational support to the science mission including radio frequency spectrum management for approximately 1,000 radio frequency assignments and risk management for over \$85 million of radio-enabled assets. These include maritime mobile, hydrological, ground penetrating radio, weather radar, satellite communications, water metering systems, underwater communications systems, aeronautical mobile and wildlife tracking systems.

Hosting Services provides enterprise-level and local science center support for multiple IMT services including directory services, Google, user provisioning, mobile device management, SharePoint, internet and intranet services (NatWeb), and cloud hosting. The primary services include secure authentication, group policy management, directory services, IMT asset management, and security compliance monitoring. The Bison Connect Google system is the primary avenue of delivering information quickly throughout the USGS, as well as to cooperators and colleagues throughout the world. It allows scientists to receive notifications quickly from automated systems that send information on earthquakes, tsunamis, hurricanes, and flooding around the country and the world.

IT Applications and End User Services supports Interior and USGS automated resource management systems and electronic processes. This includes the analysis, design, development, testing, implementation, documentation, user training, operations, maintenance, and user support for business workflow applications used across the Bureau. Included in these applications are the required security reviews, Privacy Act information evaluations, and Assessment and Authorization activities. As a part of end user services, the USGS Service Desk serves as a single point of contact for support to USGS employees. The Service Desk has primary responsibility for incident resolution, service request tracking, and customer satisfaction. The continuing consolidation of services into the USGS Service Desk creates an integrated environment that improves service excellence and extends the ability to support mobile resources.

Information and Investment Management supports responsible practices for managing and preserving information throughout the data lifecycle as well as ensuring that IMT funds are spent in the most efficient and effective manner to support the science mission of the USGS. Information Management oversees a broad suite of activities that support information delivery and ensures the collection, storage, sharing, preservation and publication of scientific data according to Federal laws and regulations. Information Management also provides policies, guidance, services, and tools that promote appropriate public access to data and enables the effective delivery of USGS science and information products.

The program also works to increase transparency and accountability of IMT spending, supporting solid Capital Planning and Investment Control (CPIC) practices and ensuring that IMT investments are integrated with strategic planning, budgeting, procurement, and solid project management principles in support of the USGS mission. The USGS Investment Portfolio is projected to be \$146 million in 2016 and \$167 million in 2017.

In 2015, IMT resources assessed the effectiveness of more than 85 security controls associated with all USGS IMT systems in support of Annual Assurance Statements. As a result of working closely with science centers, more than 500 weaknesses were remediated. The USGS Computer Security Incident Response Team successfully provided analysis, tracking and closure to 122 reported incidents across the USGS. The Training and Awareness Team continued to successfully administer and track completion of both the Federal Information System Security Awareness and Role Based Security Training to 100 percent completion for all USGS employees. The Security Assurance Team coordinated and tracked the remediation of over 400,000 vulnerabilities. Working in conjunction with other areas of the Office of Enterprise Information, a reduction of 2,000 privileged user accounts occurred along with security software deployment to over 13,500 USGS systems. Successful

implementation of cybersecurity requirements through the deployment of Information Services enhanced bandwidth to USGS science centers, transitioned infrastructure services into the Interior Enterprise Services Network, lead the USGS maturity of cloud hosting services architecture, and provided Radio Frequency Spectrum outreach to USGS science centers and science programs. Over 50,000 service tickets were handled by the USGS Service Desk and several business workflow processes were developed including hiring waivers, privileged access, conference attendance, and ordering of National Parks and Federal Lands Recreational Pass for seniors online. Over 213 new Freedom of Information Act (FOIA) requests, a new bureau record, were handled during 2015 and efforts to digitize important scientific information to preserve USGS knowledge and increase public accessibility continued.

In 2016, Information Services plans to continue protecting the integrity of systems, applications and data and ensuring reliable and continual access to resources. The top priority will be continued compliance with the Federal Information Security Modernization Act (FISMA) requirements as well as Interior security mandates. Inheritable security controls will be provided to mission areas for securing IMT systems from misuse, unauthorized access, and unofficial data modification. Information Services will continue increasing bandwidth in support of scientific cloud initiatives and managing bandwidth utilization throughout the USGS, enabling science mission requirements. Expansion of business workflow application development to science centers will take place beginning with a pilot implementation, automating additional workflow processes, improvements to software that manages development of USGS information products, and tiered service desk operations. Working collaboratively with science centers on the implementation of FITARA will allow for greater accountability of IMT spending and will be a focus for Information Services.

In 2017, Information Services would continue to protect the integrity of systems, applications and data and ensure reliable and continual access to resources. Compliance with the FISMA requirements and Interior security mandates will continue to be the highest priority. Advanced security controls will be provided to the USGS for protecting IMT systems from illegal access and data modification. The USGS will increase its cybersecurity capabilities by expanding network monitoring to identify threats and earmark additional resources to correct system vulnerabilities for reducing the risk of intrusion. Providing high quality and secure telecommunications and hosting services would be essential in supporting the USGS science mission. Expansion of cloud services and business workflow application development would continue in order to improve efficiencies as well as service desk enhancements to meet the dynamic needs of the USGS workforce. Ensuring records management policies are adhered to and enhancing accountability of IMT in accordance with FITARA will also continue.

2017 Program Change

Enhancing Science Support Capability to Support Science Mission Goals (+\$620,000 for a total of \$620,000): The proposed increase to Information Services would provide more robust support for the bureau in the areas of cloud hosting and services as well as continue to advance information and management technology to enable 21st century science. The Office of Enterprise Information (EI) will make high-value assets and technical tools available to the public in support of the Administration's Open Government Initiatives. EI would use the funding to increase efficiency in USGS processes, such as programming and developing tools, to assist with IMT spending and management in support of FITARA as well as for improving existing Web applications that will benefit and impact USGS employees and the advancement of USGS science.

Information Management and Technology Bureau-wide Bills

(2015 Actual, \$7.8 million; 2016 Enacted, \$7.8 million; 2017 Request, \$7.8 million)

A significant portion of the Information Services funding is provided directly to must-pay bills on behalf of the Bureau. These bills include funding necessary to provide and maintain services throughout the USGS that represent key IMT support functions where costs are largely determined by organizations outside the Bureau and funding requirements are less flexible. To ensure the effective performance of the USGS, these costs are managed on a centralized basis.

IMT Bureau-wide Bills are assessed to the USGS from Interior's Working Capital Fund Central Bill and Direct Bill. The services covered under these bills include Interior's IT Transformation, unified messaging, information assurance, hosting, electronic records and other IMT initiatives through contributions to these working capital funds. The IMT Bureauwide Bills have seen increases over the years, yet has not received the necessary fixed costs in the appropriation process to keep up with the increases. When this occurs, overall service levels within the Bureau are impacted.

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Facilities

Activity: Facilities

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Facilities	\$100,421	\$100,421	\$1,223	\$15,614	\$117,258	\$16,837
<i>FTE</i>	<i>58</i>	<i>58</i>		<i>0</i>	<i>58</i>	<i>0</i>
Rental Payments and Operations & Maintenance	\$93,141	\$93,141	\$1,223	\$15,614	\$109,978	\$16,837
<i>FTE</i>	<i>58</i>	<i>58</i>		<i>0</i>	<i>58</i>	<i>0</i>
Deferred Maintenance and Capital Improvement	\$7,280	\$7,280	\$0	\$0	\$7,280	\$0
<i>FTE</i>	<i>0</i>	<i>0</i>		<i>0</i>	<i>0</i>	<i>0</i>

Summary of Program Changes

Request Component	(\$000's)	FTE	Page
Rental Payments and Operations & Maintenance	+ 15,614	0	M-9
Operations and Maintenance Stewardship	+ 2,712	0	M-10
Reducing the Facilities Footprint - Cost Savings and Innovation Plan (RTF/CSIP)	+ 10,902	0	M-12
Sustainability Investments	+ 2,000	0	M-13
Total Program Change	+ 15,614	0	

Justification of Program Changes

The 2017 Budget Request for Facilities is \$117,258,000 and 58 FTE, a net change of +\$16,837,000 and 0 FTE from the 2016 Enacted level.

Overview



*Large Research Vessel Program (R/V) Articus,
USGS Great Lakes Science Center*

Photo by Andrea Miehl, USGS

The U.S. Geological Survey (USGS) Facilities Activity provides safe, functional workspace to accomplish the bureau's scientific mission with an emphasis on the mission driving facility needs. Funds support basic facility operations; security; facility maintenance in compliance with Federal, State, and local standards; and provide a safe working environment for USGS employees, visiting partners, and customers.

Assets include property consisting of land, buildings, or other improvements permanently attached to the land or a structure on it. The Department of the Interior (Interior)

Facilities

defines a facility as an individual building or structure. The USGS defines facilities to include all sites where USGS activities are housed and mission related work is conducted. Facilities typically provide space for offices, laboratories, storage, parking, shared support for cafeterias, conference rooms, and other common space uses. The USGS also classifies its eight large (greater than 45 feet in length) research vessels as laboratory facilities. Owned assets are usually part of a campus, for example, the Leetown Science Center includes all associated land, buildings, and other structures.

The Facilities Activity is comprised of two subactivities: Rental Payments and Operations and Maintenance (RP and O&M), and Deferred Maintenance and Capital Improvements (DMCI).

This Activity supports Interior's goal of facilities improvement by tracking outcomes such as:

- Assessing the overall condition of buildings and structures;
- Reducing energy intensity by three percent annually;
- Assessing the percentage of square footage that meets Executive Order (E.O.) 13514 sustainable building goals; and
- Savings initiatives through space consolidations.

The Facilities program goal is to meet bureau science needs while optimizing facility locations, distributions, and use, to control or reduce costs. Objectives for meeting this goal are to—

- Coordinate facility planning with science planning to provide safe, high-quality workspace aligned with science needs.
- Develop Asset Business Plans to meet asset management goals, continue annual surveys, and cyclic condition assessments.
- Meet performance targets for improving space utilization, controlling rent and operating costs, and releasing unneeded space.
- Reduce deferred maintenance by renovating and constructing buildings and other facilities to replace assets otherwise no longer cost effective to operate.
- Establish an effective maintenance program at each owned facility to meet industry best practices.
- Increase co-location consistent with science program objectives.
- Achieve sustainability goals.

Facility Planning – The USGS utilizes site-specific Asset Business Plans (ABPs) that support the USGS Asset Management Plan (AMP). The ABPs are 5- to 10-year plans developed by Science Center Directors that address specific needs of a field unit, campus, or region including all assets reported in the Federal Real Property Profile (FRPP). The USGS ABPs effectively address the life cycle issues and characteristics of a site's real property assets. For the local facility or program manager, the ABPs help provide a profile of their current facilities, size, staffing, and utilization rate. The plans also anticipate future needs, create an awareness of recurring and one-time space costs, plan mission operations with

facilities in mind, and identify issues that may qualify for additional funding. The ABPs are also used as annual action plans to direct bureau resources where they are most needed to support the USGS mission.

The USGS has been aggressively pursuing actions to reduce its footprint and to achieve an office space utilization-rate of 180 usable square feet (USF) per person. The USGS scrutinizes all space actions, irrespective of how the space is acquired, to work toward set goals in the Office of Management and Budget's (OMB) Reduce the Footprint policy. This broad-based approach allows the bureau to manage all the space in the portfolio holistically. To control the footprint and to administer the space policy, the USGS developed an automated, centralized Space Action Approval and Waiver (SAAW) process for all space actions. This process ensures each space action does not unnecessarily increase the bureau's footprint, works toward the utilization standard, and keeps costs under control. This tool uses alternative analyses to help manage the footprint and allow for a more informed decision making process regarding facilities investments and space actions.

The USGS relies on General Services Administration (GSA) -owned and -leased buildings for about 67 percent of the space it occupies. The USGS has no ability to reduce fixed rental rates at these sites and can only offset the higher facility costs by vacating space. Therefore, the primary emphasis is on improving space utilization; disposal of underutilized assets; consolidating operations within; and relinquishing space back to GSA. This space includes offices, laboratories, data centers, and warehouses at major USGS centers in Reston, VA, Denver, CO, and Menlo Park, CA.

The USGS owns 270 buildings situated on 2,157 acres. These buildings total about 1.3 million SF and have a replacement value of approximately \$396 million. Approximately 60 percent of USGS owned buildings are over 40 years old and many USGS owned assets will require significant investment to modernize the infrastructure in order for the USGS to continue to produce world-class science. The USGS is in the process of developing modernization plans for its aging portfolio.

Additionally, the USGS owns 283 structures with a replacement value of \$117.8 million. The owned inventory includes ten ecological science centers; five ecological field and research stations; one land use science center—the National Center for Earth Resources Observation Science (EROS); and ten geomagnetic, seismic and volcano observatories.

The USGS also owns eight large research vessels that have operations and maintenance costs that are comparable to those of a USGS building. These vessels exceed 45 feet in length and perform overnight research to support biological, water resources, and marine geology research. Five of the vessels operate on the Great Lakes; two operate in California, and one in Alaska.

As part of the Strategic Facilities Master Plan (SFMP), USGS facilities were ranked in terms of their mission dependency using a tool called the Asset Priority Index (API). Although the largest concentrations of employees are in GSA-controlled space in Reston, VA, Denver, CO, and Menlo Park, CA, 15 of the top 20 mission-critical assets are owned assets in other locations. These owned assets have specialized capabilities positioned on the landscape to address specific science issues. One example of this is the EROS Data Center (EDC). The EROS Data Center is centrally located for receiving data as Landsat satellites pass over North America, and is equipped to collect, process, and distribute remotely

Facilities

sensed land data and archive for users worldwide. The EDC's location eliminates the need for ground stations on both the west coast and the east coast.

Another location is the National Wildlife Health Center (NWHC), in Madison, WI, where the USGS is the only Federal agency with a facility dedicated to understanding and safeguarding wildlife and ecosystem health from a natural resources and conservation perspective. Without this facility, the Nation would lose much of its ability to investigate the causes of wildlife diseases and to develop management options to mitigate the devastating impacts of epidemics such as those caused by white-nose syndrome in bats. This center is certified by the Centers for Disease Control and Prevention (CDC) to receive and work with select disease agents and maintains a high-security infectious disease facility that operates at the Biological Safety Level 3 (BSL-3). The U.S. Department of Agriculture (USDA) has also approved the NWHC to import, export, and transport domestic animal infectious agents. In the case of wildlife disease emergencies, the NWHC is the lead for Interior under the Department of Homeland Security's National Response Plan. Institutions that use animals in experiments must maintain, by law, an adequate Animal Care and Use Program, which includes providing appropriate housing and environmental conditions for the species being maintained. This includes appropriate space, temperature and humidity, ventilation and air quality, illumination, noise and vibration control, and sanitation. Unable to maintain these minimum standards, the USGS will no longer be able to conduct critical animal research (reference: 8th Edition of the Guide for the Care and Use of Laboratory Animals, National Research Council), delaying key studies involving agents of National importance. Due to the aging infrastructure of the NWHC, the entire Animal Isolation Wing is temporarily shut down because of faulty plumbing. Alternate plans have been established to continue some live animal studies with lower consequence agents in the Main building and with the University of Wisconsin; however, these alternate facilities are not suitable or approved for BSL-3 work. The USGS is currently evaluating repair costs and evaluating best investment plans.

The USGS's five-year **Space Management Plan (SMP)** supports the Bureau's Asset Management Plan (AMP) and Site-Specific Asset Business Plans (ABPs), providing a framework, strategic vision, and plan of action for effective bureau management of GSA provided space, USGS direct leases, and owned property. It is used by USGS management to implement bureau space goals, including consolidation, co-location, and disposal. Information contained in the SMP focuses on mission dependency and program requirements for space.

Reduce the Footprint (RTF) – Space reductions and cost savings are integral to rent and operations management. The USGS realizes space savings with space consolidations or relocations to space with lower costs. The USGS is actively assisting Interior to meet its Reduce the Footprint (RTF) targets by proceeding with a Real Property Efficiency Plan, formerly known as the Cost Savings and Innovation Plan (CSIP). The USGS's goals under the plan are to reduce its footprint and costs, and move toward a 180 USF per person utilization standard. To focus on meeting these goals, the USGS has a centralized space action approval process and a five-year planning process for CSIP projects. The processes include a ranking, scoring and approval process as well as identifying funding for CSIP/RTF projects. The USGS leveraged existing software for project inventory, status updates, calculating savings and cost avoidances. The USGS is prioritizing RTF projects that have the shortest payback period and significantly reduce the Bureau's footprint.

Since 2012, the USGS has made great accomplishments with reducing its footprint. However, to continue this space reduction, an increase for RTF funding is required to invest in additional projects to allow the USGS to consolidate space, reduce the occupancy footprint, improve utilization and create additional real property cost savings and other efficiencies.

Maintaining America's Heritage (MAH) is Interior's commitment as a steward of priceless and natural resources to preserve and maintain operational facilities and major equipment. The 2017 Facilities budget includes an estimated \$40 million for this effort. Of this funding, \$7.3 million is for Deferred Maintenance and Capital Improvements (DMCI), including facility projects, equipment maintenance, maintenance management, condition assessment and project planning. Estimated costs for operations and maintenance for USGS facilities is about \$33 million.

2015 Key Accomplishments

The USGS has been a leader during the Freeze the Footprint initiative. In response to the Reduce the Footprint initiative, the USGS prepared a Real Property Efficiency Plan (RPEP) which details the Bureau's efforts to reduce the footprint, improve real property data quality, and establish targets for out-year space reductions.

The CSIP has provided the USGS with the ability to reduce its footprint by more than 615,000 rentable square feet (RSF) from 2012 through 2015. These efforts focused on the three major USGS centers in Reston, VA, Denver, CO, and Menlo Park, CA. Each of these centers have successfully taken on major consolidation projects, reduced space requirements, actively sought co-location opportunities and vacated more-expensive space. The results achieved were the direct impact of the Bureau's footprint reduction and CSIP activity.

The USGS reduced its footprint by over 80,000 rentable square feet (RSF) through space reductions and consolidations in 2015 and is on target to reduce its footprint by 730,000 RSF (since 2012) by the end of 2016. This reduction will save the Federal government almost \$13 million a year in annual rent bills. By 2017, the USGS anticipates an additional reduction of 24,500 RSF, bringing the overall footprint reduction to 755,000 RSF. This is a 13 percent decrease of the USGS space portfolio since 2012. The USGS goal is to reduce another 3 percent of office and warehouse space by 2021 under Reduce the Footprint.

The USGS completed a multi-year upgrade initiative to its Facilities Maintenance Management System, enabling all Interior bureaus to be on a common version of the software.

In 2015, with DMCI funds, 10 major cableway projects were completed. These projects provided upgrades to restore the safety of cable operations and the removal of abandoned cableways presenting a potential hazard to public safety. Six additional DMCI projects were started and once completed will provide lab modernization, life safety, energy efficiency, the ability to grow the science mission, and will comply with the Americans With Disabilities Act (ADA).

2016 and 2017 Strategic Actions

In 2016, the USGS Facility Energy Program completes the development of a Multi-Site Energy Savings Performance Project. The project will produce a 15 percent energy reduction for the Bureau and a five percent potable water reduction, which generates over \$600,000 of savings annually.

In 2016 and in 2017, the USGS will make efforts to ensure that energy reporting and Greenhouse Gas (GHG) emissions reporting for fully-serviced building leases over 10,000 rentable square feet are included as requirements for lessors. This is a requirement of E.O. 13693 *Planning for Federal Sustainability in the Next Decade*.



125 KiloWatts Photovoltaic (PV) Array Recently Installed at the USGS National Center, Reston, VA
Photo by Calvin Graves, USGS

The USGS will continue to focus on meeting the sustainable building and energy efficiency goals as outlined in E.O. 13693 *Planning for Federal Sustainability in the Next Decade*.

In 2016 and 2017, the USGS will: Continue to make great strides in the areas of space reduction and sustainability.

- Continue with ongoing program activities, such as historical preservation; the use of the Financial and Business Management System (FBMS) to track costs; and the use of cost modeling to identify appropriate operations and maintenance funding.
- Consolidate and actively seek additional Federal partners to improve the space utilization at the USGS National Center in Reston, VA, and, continue consolidation efforts at the Denver Federal Center, and the Menlo Park Campus.
- Initiate 57 cableway projects, renovating cableways in use, and removing of abandoned cableways for public safety through DMCI funds.
- The USGS will make efforts to ensure that energy reporting and Greenhouse Gas Emissions (GHG) emissions reporting for fully-serviced building leases over 10,000 rentable square feet are included as requirements for lessors.
- The National Strong Motion Program (NSMP) will begin to replace obsolete observation systems and backup power



USGS, National Center, Reston, VA

capabilities at communication hubs that provide centralized data flow for a significant portion of the Northern California Seismic Network.

- The USGS will continue to use industry standard cost modeling to project the appropriate sustainment level for operations and maintenance funding and to identify voids in critical cyclical and preventive maintenance practices and processes.
- In 2017, the USGS will continue utilizing the Interior's Financial and Business Management System (FBMS) to track all of its utility costs and consumption. This action ensures the Interior has a consistent methodology for collecting and reporting purposes.

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Activity: Facilities

Subactivity: Rental Payments and Operations and Maintenance

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Facilities	\$100,421	\$100,421	\$1,223	\$15,614	\$117,258	\$16,837
<i>FTE</i>	<i>58</i>	<i>58</i>		<i>0</i>	<i>58</i>	<i>0</i>
Rental Payments and Operations & Maintenance	\$93,141	\$93,141	\$1,223	\$15,614	\$109,978	\$16,837
<i>FTE</i>	<i>58</i>	<i>58</i>		<i>0</i>	<i>58</i>	<i>0</i>
<i>Operations and Maintenance Stewardship</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$2,712]</i>	<i>[\$2,712]</i>	<i>[\$2,712]</i>
<i>Reducing the Facilities Footprint (RTF) - Cost Savings and Innovation Plan (CSIP)</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$10,902]</i>	<i>[\$10,902]</i>	<i>[\$10,902]</i>
<i>Sustainability Investments</i>	<i>[\$0]</i>	<i>[\$0]</i>		<i>[\$2,000]</i>	<i>[\$2,000]</i>	<i>[\$2,000]</i>

Justification of Program Changes

The 2017 Budget Request for the Rental Payments and Operations and Maintenance is \$109,978,000, a net change of +\$16,837 from the 2016 Presidents Budget.

Overview

The Rental Payments (RP) and Operations and Maintenance (O&M) Subactivity provides the USGS with funding needed to meet asset management goals and carry out Executive Orders (E.O.) related to Federal space.

In 2017, the USGS plans to spend \$136.0 million on rent and operations and maintenance. Of these costs, 73 percent (\$99.1 million) are funded through this subactivity. Reimbursable partners and science programs fund the remaining costs at 23 percent and four percent respectively. In 2017, the total facilities rent cost is estimated to be \$96.3 million. Approximately 25 percent of rent and operations and maintenance funds are spent on USGS owned properties; these assets are unique and mission critical in the USGS portfolio.

Facilities

The Rental Payments cost component provides rental payments for space occupied by the USGS to the GSA, other Federal sources, private lessors, and cooperators. The USGS has unique facility requirements for supporting science functions and relies heavily on General Services Administration (GSA) to meet those needs, including modern laboratory space. The USGS occupies approximately four million square feet of rentable space in about 164 GSA buildings nationwide, making the USGS one of the largest users of GSA space within Interior. Approximately 22 percent of USGS space is owned. The remaining 78 percent of USGS space is provided through the GSA, direct leases with the private sector, and cooperative and interagency agreements with state and local governments, universities, and other Federal agencies.

The Operations and Maintenance cost component provides funding for basic facility operations and security and facility maintenance, providing a safe working environment for USGS employees, visiting partners, and customers. Maintenance involves the upkeep of USGS owned facilities, structures and capitalized equipment, necessary to maintain the useful life of the asset. To protect its important resources, ongoing investments in annual and cyclic maintenance, repair, revitalization, and disposal of assets must be considered as a part of a long-term operations and maintenance program. Operational costs at USGS owned facilities include costs such as utilities, janitorial services, waste management, and salaries for staff responsible for the day-to-day operations of the facility. The USGS also funds the operations and maintenance of its research vessels from this subactivity.

Since 2011, within this subactivity's funding level, USGS has not fully funded the bureau's rent and O&M costs. In 2015, the rent and O&M costs of \$10.6 million were funded by science mission areas. In 2016, the USGS estimates that \$10.6 million of rent and O&M expenses will be borne by the science mission areas. In 2017, the USGS estimates that \$7 million in these costs will be borne by the science mission areas.

2017 Program Change

Operations and Maintenance Stewardship (+\$2,712,000 for a total of \$2,712,000): The requested increase would improve the performance of the USGS real property portfolio by providing the Bureau the ability to complete annual operations and maintenance responsibilities and would decrease the rent and O&M costs paid by science mission areas. A facility cannot operate at peak efficiencies without being properly maintained. The result of this shortfall requires the Bureau science programs to use science funding to pay for facility costs. This impacts the USGS science mission and directly reduces the amount of funding available for science research.

In 2015, the USGS used \$10.6 million in science funding to pay for rent and O&M costs to cover the shortfall within the Facilities subactivity. In 2016, it is estimated that the USGS will need to use \$10 million in science dollars to cover rent and O&M costs. With the proposed increase in 2017, it is estimated that the USGS will have to use \$7 million.

With the increase, the USGS would be able to approach full-funding levels in the Operations and Maintenance component of the Rental Payments and Operations and Maintenance subactivity for USGS owned facilities. The funding will also be used to perform necessary recurring operations and maintenance, which will slow the increase of the deferred maintenance backlog. The requested increase would enable the bureau to realize the full life cycle of its real property assets and help prevent emergency repairs that result in unplanned additional repair costs and unexpected outages

2017 Program Change
<p>compromising the science missions of the USGS. In addition, the USGS will enhance its ability to meet the requirements of statutory energy goals thereby increasing the USGS's efforts of energy reduction, water conservation, and waste reduction. The funding would also provide the USGS with the ability to meet specified environmental requirements, enable more efficient and economical maintenance of its real property assets, and enhance the Bureau's ability to fund Reduce the Footprint (RTF) projects.</p>

The USGS has leveraged its Deferred Maintenance and Capital Improvement funding to support its CSIP footprint reduction projects allowing the USGS to reduce its footprint by more than 615,000 RSF from 2012 through 2015. These efforts focused on three major centers in Reston, VA, Denver, CO, and Menlo Park, CA. Each of these centers have successfully taken on major consolidation projects, reduced space requirements, actively sought co-location opportunities and vacated more-expensive space. The achieved results were the direct impact of the Bureau's footprint reduction and CSIP activity.

At the USGS National Center in Reston, VA, the USGS performs building operations and maintenance under GSA delegated authority and has day-to-day control of most space assignments. Of the approximate 1.1 million SF facility at the National Center, the USGS supports Interior and other agencies by providing more than 278,670 SF or 25 percent of released space to other Federal partners. In 2017, the USGS will continue to consolidate and actively seek additional Federal partners to improve the space utilization at the National Center.

The Denver Federal center consolidation efforts included moving out of older GSA-owned building into newer and more suitable buildings such as Building 25, Building 95, and Building 810. Consolidations in 2017 will further reduce the USGS space requirement by an additional 22,000 SF.

The USGS will continue to fund a co-location project with the Bureau of Reclamation, in Boulder City, NV. This project, with the target completion in 2017, will significantly reduce the rent costs by \$450,000, as well as lessen the Interior's overall footprint by 3,000 SF.

The USGS has made great accomplishments with reducing its footprint. However, these achievements have exhausted available resources, therefore, the funding requested in 2017 for CSIP projects is essential for continued footprint reduction success.

2017 Program Change

Reducing the Facilities Footprint and Cost Savings and Innovation Plan (RTF/CSIP)

(+\$10,902,000 for a total of \$10,902,000): The requested increase will fund prioritized RTF projects with the shortest payback period, significantly reducing the Bureau’s footprint and costs. The USGS relies on the General Services Administration (GSA) owned and leased buildings for about 66.7 percent of the space it occupies, the USGS has fixed rental rates at these sites and can offset the higher facility costs by vacating space. Space savings are integral to rent and operations management. The USGS realizes space savings when locations are able to consolidate space or relocate to spaces with lower cost. Therefore, primary emphasis is placed on improving space utilization, consolidating operations within, and relinquishing space to GSA provided offices, laboratories, data centers, and warehouses. The USGS is proceeding with a Real Property Efficiency Plan, formerly known as the CSIP. The USGS’s goals under the plan are to reduce its footprint and costs, and move toward a 180 USF per person utilization standard. To focus on meeting these goals, the USGS has a centralized space action approval process and a five-year planning process for CSIP projects. The processes include a ranking, scoring and approval process as well as identifying funding for RTF projects. The USGS leveraged existing software for project inventory, status updates, calculating savings and cost avoidances.

Prior to 2017, the USGS has funded its CSIP/RTF projects from the Deferred Maintenance and Capital Improvements (DMCI) subactivity. This management priority cannot be sustained. This investment reduced the USGS footprint by more than 615,000 rentable square feet (RSF) and increased funding will reduce space by an additional 140,000 RSF. This would be a 13 percent decrease of the USGS space portfolio since 2012.

The USGS has made great accomplishments with reducing its footprint. However, these achievements have exhausted available resources, leaving no other recourse but to request CSIP funding that will give the USGS the ability to invest in additional RTF projects which will allow the USGS to consolidate space, reduce the occupancy footprint, improve utilization, and create additional real property cost savings and other efficiencies. The USGS is in the planning stages for large RTF projects at the USGS National Center in Reston and at the Denver Federal Center. At the National Center in Reston, the USGS plans to convert 30,000 RSF formerly used as a data center to office space. The \$5M project will allow other Department of Interior Bureaus or Offices to co-locate at the National Center, saving the Department an estimated \$1million in rent annually.

Energy Sustainability Efforts – The USGS has made great strides in reducing the energy intensity of its owned and leased buildings. The recent E.O. 13693 *Planning for Federal Sustainability in the Next Decade* requires an additional 25 percent decrease from 2015 to 2025. Meeting this requirement will require a \$30 million annual investment, of which only \$2.0 million is factored into the 2017 budget.

2017 Program Change

Sustainability Investments (+\$2,000,000 for a total of \$2,000,000): The requested increase would help the USGS meet the energy and Greenhouse Gas reduction goals of E.O. 13693, and will also allow the USGS to improve its aging energy systems that in many cases are approaching or have already exceeded their useful life. The USGS awarded an Energy Savings Performance Contract (ESPC) in July 2014 for \$12 million. The ESPC will reduce the USGS's energy consumption by 15 percent, potable water use by five percent, and direct and indirect (purchased electricity) Greenhouse Gas (GHG) emissions by nine percent, annually generating over \$650,000 of savings, which will pay for the energy and water improvements. A series of preliminary audits identified an additional \$13.0 million in additional ECMs. The requested increase would allow the USGS to pursue these ECMs to further reduce the bureau's energy consumption. The ECMs would take place at the Earth Resources Observation and Science Center, Leetown Science Center, Patuxent Wildlife Research Center, Northern Appalachian Research Laboratory, Conte Anadromous Fish Laboratory, Northern Prairie Wildlife Research Center, Upper Midwest Environmental Sciences Center, and the National Wetlands Research Center, including a wide range of improvements in boiler systems, chiller plants, building automation, HVAC, building envelope, and electric motors and drives. In addition to improving energy efficiency and GHG emissions, these projects support the strategies outlined in the Department's Climate Change Adaptation Plan by improving the resiliency of the facilities.

Ongoing Program Activities – The National Historic Preservation Act (NHPA) (54 U.S.C. 300101 et. seq.) requires all Federal agencies to consider how their projects will have an effect on historic property. Under the facilities activity and in compliance of this Act, the USGS has continually evaluated its assets inventory to identify and evaluate which properties may be historic as part of its facilities Comprehensive Condition Assessment Program. As part of E.O. 13327 Federal Real Property Asset Management, the results of the historic evaluations are transferred to Federal Real Property Reporting through the Federal Maintenance Management System (FMMS). To date, 188 real property assets have been historically evaluated. The USGS will continue to evaluate all of its properties, which is anticipated to continue through 2021.

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Activity: Facilities**Subactivity: Deferred Maintenance and Capital Improvements**

Dollars in Thousands	2015	2016	2017			Change from 2016 Enacted
	Base	Enacted	Fixed Costs	Program Changes	Request	
Facilities	\$100,421	\$100,421	\$1,223	\$15,614	\$117,258	\$16,837
<i>FTE</i>	<i>58</i>	<i>58</i>	<i>0</i>	<i>0</i>	<i>58</i>	<i>0</i>
Deferred Maintenance and Capital Improvement	\$7,280	\$7,280	\$0	\$0	\$7,280	\$0
<i>FTE</i>	<i>0</i>	<i>0</i>		<i>0</i>	<i>0</i>	<i>0</i>

Justification of Program Changes

The 2017 Budget Request for Deferred Maintenance and Capital Improvements is \$7,280,000, level with the 2016 Presidents Budget.

Overview

Deferred maintenance is maintenance and repair activity that was not performed on owned assets (buildings, structures, and equipment) when it should have been, or was scheduled to be, and was put off or delayed to a future period in order to save costs, meet budget funding levels, or realign available budget monies.

The Deferred Maintenance and Capital Improvements (DMCI) subactivity funds the highest priority USGS facility and equipment requirements in accordance with Interior budget guidance. Unfunded requirements result in a backlog of DMCI needs, which continues to grow. Besides increasing the deferred maintenance backlog, inadequate DMCI funding levels accelerate the rate of facilities deterioration, decreasing the value of the asset, costlier repairs, and in some cases, health and safety implications or asset failure. The current funding level is approximately 7.7 percent of the facilities deferred maintenance and capital improvements backlog of \$95 million. The 2017 USGS DMCI five-year plan includes DMCI projects and other programs and stewardship responsibilities for unique mission equipment that are funded annually through the DMCI Program, such as hazard warning networks, river cableways, and stream gaging stations, all of which require maintenance and capital investments to preserve their functionality.

Annually, the USGS develops a DMCI five-year plan. The plan provides the projects of greatest need in priority order that best support bureau missions, with focus first on critical health and safety and critical resource protection. The bureau has undertaken an extensive effort in developing this plan, identifying projects where the urgency of remediation and science program impact are most viable.

Facilities

The USGS prioritizes critical DMCI needs according to the Interior's guidelines. Five-year plans are updated on an annual basis using the uniform, department-wide process. Plans are subject to adjustments in outyears due to funding changes and revised priorities based on comprehensive facility condition assessments, annual condition surveys, and emergency needs. The goal of the five-year planning process is to focus limited resources on projects that are both mission critical and in the most need of repair or replacement. The ranking equation is designed to accommodate many types and sizes of projects, from simple to complex and places the highest priority on facility buildings based on their Facility Condition Index (FCI) and Asset Priority Index (API) ranking. This emphasizes projects that involve mission critical assets in unacceptable condition with less emphasis on non-mission critical assets. FCI is defined as the ratio of maintenance needs to current replacement value. The lower the number, the better the FCI ratio. The average FCI for USGS owned building is 0.189 and the average FCI for USGS owned structures is 0.154. The USGS determines anything below a 0.15 score on an asset to be in the acceptable range of condition. The Interior's newly defined criteria and methodology for 2016 also takes into account projects that are clearly aligned with Interior, bureau, office and program missions and strategic goals; projects that clearly define a positive return on investment, leverage outside interest, and reduce operation and maintenance liabilities; projects that have unacceptable risk levels should the project not be completed.

The condition assessment (CA) process identifies deferred maintenance needs and determines the current replacement value of constructed assets. The condition assessment program includes annual surveys and a cyclic process for comprehensive onsite inspections to document deferred maintenance. Facilities projects reflect comprehensive evaluations conducted by independent architectural and engineering firms. These installation-wide assessments help establish core data on the condition of USGS constructed assets. Additionally, knowing the estimated cost of deferred maintenance and the replacement value of constructed assets allows the USGS to use the industry standard FCI as a method of measuring facility condition and condition changes. It is an indicator of the depleted value of capital assets. Funds are also available through the condition assessment process to identify, report, and track any asbestos, environmental, and disposal liability sites on departmental lands according to guidelines issued by the Interior's Office of Environmental Policy and Compliance. Through the asset management planning process, the USGS can identify real property assets that are candidates for disposition. Any asset that is no longer critical to the mission, in poor condition, or no longer cost effective to maintain is a candidate for possible disposal.

The Facility Maintenance Management System (FMMS) is the USGS's implementation of the commercial maintenance-management software application Maximo™. The FMMS system supports efficient operation and maintenance of USGS facilities by providing accurate maintenance information to local, regional, and national facility managers. It is used to document maintenance needs and accomplishments, preventive maintenance schedules, and the condition of USGS real property assets. The system is also used in the development of the USGS Deferred Maintenance and Capital Improvement (DMCI) five-year plan. Condition assessments results, which often are the basis for DMCI projects, are automatically imported in FMMS, which provide an automated repository of deficiency findings and the actions taken to address them. Use of the FMMS supports the USGS's Asset Management Plan by establishing an inventory and maintenance history on all constructed assets and associated equipment, standardizing maintenance business practices, facilitating maintenance reporting and data analysis, and

supporting the budget and the DMCI five-year planning processes. The USGS upgraded its Maximo infrastructure as a part of the Interior Maximo Upgrade Project. Separately the USGS fielded a modern, smart device based mobile work order management solution that integrates with Maximo.

The USGS plans to take advantage of recent advances in instrumentation and purchase instrumentation to begin replacing obsolete observation systems, particularly in the National Strong Motion Program. A major vendor in the world of seismological instrumentation recently announced the availability of a modern low-cost strong motion instrumentation package. The USGS can begin to make advances in replacing obsolete instrumentation without compromising the quality of sensors. The USGS also plans to use DMCI funds to replace infrastructure at other communications hubs in Northern California. A major problem at a number of the National California Seismic Network communication hubs is aging infrastructure. Of particular concern are the backup power systems, which provide continued operational capability when standard power is lost. In 2015, the generator at Hog Canyon failed. With funds provided through DMCI, the USGS was able to make an emergency procurement to replace it. The USGS is investigating the backup power situation at other communications hubs with the goal of identifying possible components for replacement. These hubs provide centralized data flow for a significant portion of the Northern California Seismic Network.

Cableways have been used for many decades by the USGS for the measurement of streamflow and collection of water-quality samples. DMCI funds associated with the USGS Streamgaging Network provided the ability to upgrade vital cableways that needed to be restored to safe operation, and to remove abandoned cableways that present a potential hazard to public safety. Properly constructed and maintained cableways are dependable and convenient platforms for obtaining water-resource data. The use of cableways eliminates the need for USGS personnel to work from dangerous highway bridges and allow the selection of sites that offer optimum hydraulic characteristics for measuring stream discharge. Cableways consisting of a main cable, anchors, support structures, backstays, cablecars, and other equipment are subject to damage and deterioration from temperature changes, moisture, and vandalism. The integrity of the structure may also be threatened by erosion as a result of overland runoff, flooding, treefalls or forest fires. Because of this, cableways are carefully monitored on a continuing basis and those that do not meet safety standards are removed from service until all defects are corrected and approved for use by USGS personnel. The Water Resources Mission Area (WRMA) determined that certain cableways might possibly pose a risk to low-flying aircraft and should be retrofitted with aircraft warning markers. To minimize safety hazards, USGS policy states that intact overhead cables are to be removed from inactive cableways as soon as possible. There are 792 active cableways in service with 39 in need of inspections or repairs. These cableways are at locations nationwide. In 2016, the USGS is actively working on repairing 14 inactive cableways and in 2017, and additional 12 projects are planned. Currently, there are 52 additional cableways awaiting removal, 77 inactive but remain in place for possible future use, and 38 are dismantled awaiting remediation. A portion of this work will be funded through the DMCI program with the focus on keeping the active cableways safe and then removing the most dangerous inactive ones.

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USGS Working Capital Fund

Working Capital Fund Overview

The U.S. Geological Survey (USGS) Working Capital Fund (WCF) was established to allow for the efficient financial management of the components listed below. The WCF was made available for expenses necessary for furnishing materials, supplies, equipment, work, and services in support of USGS programs, and as authorized by law (authorization information begins on page 3 of this section), to agencies of the Federal Government and others. The WCF consists of four components:

1. The WCF **Investment** Component provides a mechanism to assist USGS managers in planning for and acquiring goods and services that are too costly to acquire in a single fiscal year or that, due to the nature of services provided must operate in a multi- as opposed to a single-year basis of funding. Investments are supported by documented investment plans that include estimated acquisition/replacement costs, a schedule of deposits, and approval of the plans, deposits and expenditures by designated USGS officials.
 - **Telecommunications Investments** are used for telecommunication hardware, software, facilities, and services. Examples include replacement or expansion of automatic exchange systems and computerized network equipment such as switches, routers, and monitoring systems.
 - **Equipment Investments** are used for the acquisition, replacement, and expansion of equipment for USGS programs. Equipment may include, but is not limited to, hydrologic, geologic, and cartographic instruments, laboratory equipment, and computer hardware and software.
 - **Facilities Investments** support facility and space management investment expenses for USGS real property, including owned and leased space. Authorized investment expenses include nonrecurring and emergency repair, relocation of a facility, and facility modernization. The component does not include annual expenses such as rent, day-to-day operating expenses, recurring maintenance, or utilities.
 - **Publications Investments** are used for the preparation and production of technical publications reporting on the results of scientific data and research. Research projects typically are three to five years in duration, and planning the medium in which to report results occurs over the life of the project. The Publications Investment Component provides a mechanism for establishing an efficient, effective, and economical means of funding publications costs over the duration of the research.
2. The WCF **Fee-for-Service** Component provides a continuous cycle of client services for fees established in a rate-setting process and, in some cases, with funding provided by appropriated funds. Fees are predicated upon both direct and indirect costs associated with providing the services, including amortization of equipment required to provide the services.
 - **The National Water Quality Laboratory (NWQL)** conducts chemical and biological analyses of water, sediments, and aquatic tissue for all USGS science centers and other customers, including other USGS mission areas, other Interior bureaus, and non-USGS

customers. The NWQL also does biological classification for these customers. NWQL analysis services are provided on a reimbursable basis, with the price of services calculated to cover direct and indirect costs.

- **The USGS Hydrologic Instrumentation Facility (HIF)** provides hydrologic instrumentation on a fee-for-service basis. The facility provides its customers with hydrologic instruments that can be rented or purchased, maintains a technical expertise on instrumentation, and tests and evaluates new technologies as they become available in the marketplace.
 - **Bureau Laboratories** – There are currently five laboratories within the Water Resources Mission Area that perform gaseous dissolved chlorofluorocarbon measurements, environmental microbiology analyses and isotope-ratio measurements of water, sediments, rocks, and gases for all USGS mission areas, and for USGS customers.
 - **The National Training Center** conducts USGS training programs. Examples include specialized training for USGS employees, cooperators, and international participants in many facets of earth science, as well as computer applications, management and leadership seminars, and various workshops.
 - **Research Drilling Program** – The Drilling Program is operated out of two locations, Lakewood, CO, and Las Vegas, NV. The Drilling Program provides drilling and drilling related services to research projects across the United States. These services include conducting exploratory drilling and obtaining geologic samples and cores in difficult hydrogeologic environments, installation of sampling devices, monitoring wells and other sub-surface sensors, borehole geophysical logging, and well and aquifer hydraulic testing support.
3. The **GSA Buildings Delegation** Component is used to manage funds received under the delegated authority for the J.W. Powell Building and Advanced Systems Center in Reston, VA, as provided by 40 U.S.C. 121 (d) and (e) (formerly subsections 205 (d) and (e) of the Federal Property and Administrative Services Act of 1949, as amended, and 40 U.S.C. 486 (d) and (e), respectively). Delegated functions include building operations, maintenance, cleaning, overseeing fire and life safety, maintaining high voltage switchgear and fire alarms, recurring repairs, minor alterations, historic preservation, concessions, and energy management. Because of the size of the Reston buildings and the need to expend the facility funds in a manner corresponding to GSA's no-year funding (Federal Buildings Fund) mechanisms and the GSA National Capital Region long-range capital improvement plan, no-year funding is a prerequisite to administering the delegation. Public Law 104–208, Section 611, provides that, for the fiscal year ending September 30, 1997, and thereafter, any department or agency that has delegated authority shall retain that portion of the GSA rental payment available for operation, maintenance, and repair of the building and the funds shall remain available until expended. This WCF component was established in 2004 to provide USGS with this no-year flexibility.
4. The **Enterprise Services** Component has been removed from the Fee-for-Service funding model. Based upon the findings of an executive level team, the USGS Director determined that annual up front funding using a direct funding model would be more efficient for this critical function. This change is effective beginning 2016 and will allow the Science Publishing Network (SPN) to provide USGS scientists with the most efficient and effective publishing support possible. Key metrics are in

place to ensure that the SPN continues to be successful under this new model, and a review of the new model is planned for 2018. Beginning in 2016, the USGS changed a business practice that moved the SPN from operating out of a working capital fund to operating within a direct funding model for publishing costs. Program dollars previously used to fund publishing will continue to fund publishing in the new business model.

Appropriation Language and Citations

Permanent authority:

1. Provided further, That, in fiscal year 1986, and thereafter, all amortization fees resulting from the Geological Survey providing telecommunications services shall be deposited in a special fund to be established on the books of the Treasury and be immediately available for payment of replacement or expansion of telecommunications services, to remain available until expended.
 - **43 U.S.C.50a** established the Telecommunications Amortization Fund, which was displayed as part of the Surveys, Investigations and Research appropriation from 1986 through 1990. Beginning in 1991, the Telecommunications Amortization Fund was merged into the WCF described in the next citation.
2. There is hereby established in the Treasury of the United States a working capital fund to assist in the management of certain support activities of the United States Geological Survey (hereafter referred to as the "Survey"), Department of the Interior. The fund shall be available on and after November 5, 1990, without fiscal year limitation for expenses necessary for furnishing materials, supplies, equipment, work, facilities, and services in support of Survey programs, and, as authorized by law, to agencies of the Federal Government and others. Such expenses may include laboratory modernization and equipment replacement, computer operations, maintenance, and telecommunications services; requirements definition, systems analysis, and design services; acquisition or development of software; systems support services such as implementation assistance, training, and maintenance; acquisition and replacement of computer, publications and scientific instrumentation, telecommunications, and related automatic data processing equipment; and, such other activities as may be approved by the Secretary of the Interior.

There are authorized to be transferred to the fund, at fair and reasonable values at the time of transfer, inventories, equipment, receivables, and other assets, less liabilities, related to the functions to be financed by the fund as determined by the Secretary of the Interior. Provided, That the fund shall be credited with appropriations and other funds of the Survey, and other agencies of the Department of the Interior, other Federal agencies, and other sources, for providing materials, supplies, equipment, work, and other services as authorized by law and such payments may be made in advance or upon performance: Provided further, That charges to users will be at rates approximately equal to the costs of furnishing the materials, supplies, equipment, facilities, and services, including such items as depreciation of equipment and facilities, and accrued annual leave: Provided further, That all existing balances as of November 5, 1990, from amortization fees resulting from the Survey providing telecommunications services and deposited in a special fund established on the books of the Treasury and available for payment of replacement or expansion of telecommunications services as authorized by Public Law 99-190, are hereby transferred to and merged with the working capital fund, to be used for the same purposes as originally authorized. Provided further, That funds that are not necessary to carry out the activities to be financed by the fund, as determined by the Secretary, shall be covered into miscellaneous receipts of the Treasury.

P.L. 101-512 Department of the Interior and Related Agencies Appropriations Act, 1991 This authority established a Working Capital Fund account in 1991. The Telecommunications Amortization Fund was included as part of the WCF and all balances of the Telecommunications Amortization Fund existing at the end of 1990 were transferred to the WCF. These balances were to be used for the same purposes as originally authorized.

P.L. 103-332 Department of the Interior and Related Agencies Appropriations Act, 1995 The amendments that were made in this appropriations act are shown in underline in the second citation shown above. This authority expanded the use of the Working Capital Fund to partially fund laboratory operations and facilities improvements and to acquire and replace publication and scientific instrumentation and laboratory equipment.

Working Capital Fund

United States Geological Survey
Federal Funds

General and special funds:

WORKING CAPITAL FUND
Program and Financing

(In millions of dollars)

Identification Code		2015 Actual	2016 Enacted	2017 Request
14-4556-0-4-306				
	Obligations by program activity:			
08.01	Working Capital Fund	88	93	91
	Budgetary resources:			
	Unobligated balance:			
10.00	Unobligated balance carried forward, start of year	85	89	69
10.21	Recoveries of prior year unpaid obligations	2		
10.50	Unobligated balance total	87	89	69
	Budget Authority:			
	Spending Authority from offsetting collections, disc			
17.00	Collected	90	73	65
19.30	Total budgetary resources available	177	162	134
	Memorandum (non-add) entries:			
19.41	Unexpired unobligated balance, end of year	89	69	43
	Change in obligated balances:			
	Obligated balance, start of year:			
30.00	Unpaid obligations, brought forward, Oct 1	26	29	43
30.10	Obligations incurred, unexpired accounts	88	93	91
30.20	Outlays, Gross	-83	-79	-72
30.40	Recoveries of prior year obligations	-2	0	0
	Obligated balance, end of year:			
30.50	Unpaid Obligations, end of year (gross)	29	43	62
	Budget authority and outlays, net:			
	Discretionary			
40.00	Budget authority, gross	90	73	65
	Outlays, gross:			
40.10	Outlays from new discretionary authority	46	33	29
40.11	Outlays from discretionary balances	37	46	43
40.20	Outlays, gross	83	79	72
	Offsets against gross budget authority and outlays:			
	Offsetting collections (collected) from:			
40.30	Federal Sources	-86	-73	-65
40.70	Budget authority, net (discretionary)			
40.80	Outlays, net (discretionary)	-7	6	7
41.80	Budget authority, net (total)			
41.90	Outlays, net (total)	-7	6	7

WORKING CAPITAL FUND

Balance Sheet

(In millions of dollars)

Identification Code		2014	2015
14-4556-0-4-306		Actual	Actual
	ASSETS:		
	Federal assets:		
1101	Fund balances with Treasury	111	111
	Investments in U.S. securities:		
1106	Receivables, net		
1803	Other Federal assets: Property, plant and equipment, net	34	34
1999	Total assets	145	145
	LIABILITIES:		
2101	Federal liabilities: Accounts payable		
2201	Non-Federal liabilities: Accounts payable	4	4
2999	Total liabilities	4	4
	NET POSITION:		
3300	Cumulative results of operations	141	141
3999	Total net position	141	141
4999	Total liabilities and net position	145	145

Working Capital Fund

WORKING CAPITAL FUND

Object Classification

(In millions of dollars)

Identification Code		2015	2016	2017
14-4556-0-4-306		Actual	Enacted	Request
Reimbursable obligations:				
Personnel compensation:				
11.1	Full-time permanent	17	8	8
11.3	Other than full-time permanent	1	0	0
11.5	Other personnel compensation	1	1	1
11.9	Total personnel compensation	19	9	9
12.1	Civilian personnel benefits	5	3	3
21.0	Travel and transportation of persons	0	1	1
23.1	Rental payments to GSA	2	3	3
23.3	Communications, utilities, and miscellaneous charges	2	2	1
24.0	Printing and reproduction	1	0	0
25.2	Other services	8	11	13
25.3	Other purchases of goods and services from Government	9	10	10
	Accounts			
25.4	Operation and maintenance of facilities	8	9	9
25.7	Operation and maintenance of equipment	1	4	4
26.0	Supplies and materials	5	5	5
31.0	Equipment	27	35	32
32.0	Land and structures	1	1	1
99.9	Total new obligations	88	93	91

WORKING CAPITAL FUND

Employment Summary

Identification Code		2015	2016	2017
14-4556-0-4-306		Actual	Enacted	Request
Reimbursable:				
2001	Civilian full-time equivalent employment	228	111	111

USGS Exhibits

United States Geological Survey

Federal Funds

General and special funds:

SURVEYS, INVESTIGATIONS, AND RESEARCH

For expenses necessary for the United States Geological Survey to perform surveys, investigations, and research covering topography, geology, hydrology, biology, and the mineral and water resources of the United States, its territories and possessions, and other areas as authorized by 43 U.S.C. 31, 1332, and 1340; classify lands as to their mineral and water resources; give engineering supervision to power permittees and Federal Energy Regulatory Commission licensees; administer the minerals exploration program (30 U.S.C. 641); conduct inquiries into the economic conditions affecting mining and materials processing industries (30 U.S.C. 3, 21a, and 1603; 50 U.S.C. 98g(1)) and related purposes as authorized by law; and to publish and disseminate data relative to the foregoing activities; [\$1,062,000,000] \$1,168,803,000, to remain available until September 30, [2017] 2018; of which [\$57,637,189] \$75,237,189 shall remain available until expended for satellite operations; and of which \$7,280,000 shall be available until expended for deferred maintenance and capital improvement projects that exceed \$100,000 in cost: *Provided*, That none of the funds provided for the ecosystem research activity shall be used to conduct new surveys on private property, unless specifically authorized in writing by the property owner: *Provided further*, That no part of this appropriation shall be used to pay more than one-half the cost of topographic mapping or water resources data collection and investigations carried on in cooperation with States and municipalities.

Appropriation Language and Citations

For expenses necessary for the United States Geological Survey to perform surveys, investigations, and research covering topography, geology, hydrology, biology, and the mineral and water resources of the United States,

- **43 U.S.C. 31(a)** provides for establishment of the Office of the Director of the Geological Survey, under the Interior Department, and that this officer shall have direction of the Geological Survey, and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain.

A full listing of USGS appropriation language and citations is available at the USGS Office of Budget, Planning, and Integration Web site, under Resources and Tools.

Web site: http://www.usgs.gov/budget/resources_tools.asp

Expiring Authorization Citation	
Bureau/Office Name	USGS/Energy and Mineral Resources, and Environmental Health
Program Name	Energy Resources Program
Citation	50 U.S.C. 167n, P.L. 113-40
Title of Legislation	Helium Stewardship Act of 2013
Last Year of Authorization	2015
BY Budget Request (\$000)	\$ 400
Explanation of Authorization Requirement for BY	Completion of Helium Gas Resource Assessment
Program Description	<p>Not later than 2 years after October 2, 2013, the Secretary, acting through the Director of the United States Geological Survey, shall-(1) in coordination with appropriate heads of State geological surveys-(A) complete a national helium gas assessment that identifies and quantifies the quantity of helium, including the isotope helium-3, in each reservoir, including assessments of the constituent gases found in each helium resource, such as carbon dioxide, nitrogen, and natural gas; and(B) make available the modern seismic and geophysical log data for characterization of the Bush Dome Reservoir;(2) in coordination with appropriate international agencies and the global geology community, complete a global helium gas assessment that identifies and quantifies the quantity of the helium, including the isotope helium-3, in each reservoir;(3) in coordination with the Secretary of Energy, acting through the Administrator of the Energy Information Administration, complete- (A) an assessment of trends in global demand for helium, including the isotope helium-3; (B) a 10-year forecast of domestic demand for helium across all sectors, including scientific and medical research, commercial, manufacturing, space technologies, cryogenics, and national defense; and (C) an inventory of medical, scientific, industrial, commercial, and other uses of helium in the United States, including Federal uses, that identifies the nature of the helium use, the amounts required, the technical and commercial viability of helium recapture and recycling in that use, and the availability of material substitutes wherever possible; and (4) submit to the Committee on Energy and Natural Resources of the Senate and the Committee on Natural Resources of the House of Representatives a report describing the results of the assessments required under this paragraph.</p>

Expiring Authorization Citation	
Bureau/Office Name	USGS/Natural Hazards
Program Name	Earthquakes Hazards Program
Citation	P.L. 108-360; 42 U.S.C. Sec. 7701-7709
Title of Legislation	National Earthquake Hazards Reduction Program Reauthorization Act of 2004
Last Year of Authorization	2009
BY Budget Request (\$000)	\$62,196
Explanation of Authorization Requirement for BY	No individual programmatic authorization is necessary for the USGS to continue this effort
Program Description	Monitoring, research, assessment and characterization of earthquake hazards

Expiring Authorization Citation	
Bureau/Office Name	USGS/Core Science Systems
Program Name	Science Synthesis, Analysis, and Research
Citation	42 U.S.C. 15908 sec 351, P.L. 109-58
Title of Legislation	National Geologic and Geophysical Data Preservation Program Act of 2005
Last Year of Authorization	2010
BY Budget Request (\$000)	\$24,930
Explanation of Authorization Requirement for BY	No individual programmatic authorization is necessary for the USGS to continue this effort
Program Description	SEC. 351. Preservation of Geological and Geophysical Data Program.—The Secretary (Interior) shall carry out a National Geological and Geophysical Data Preservation Program in accordance with this section—(1) Establishment.—The Secretary shall establish, as a component of the Program, a data archive system to provide for the storage, preservation, and archiving of subsurface, surface, geological, geophysical, and engineering data and samples. The Secretary, in consultation with the Advisory Committee, shall develop guidelines relating to the data archive system, including the types of data and samples to be preserved.

Expiring Authorization Citation

Bureau/Office Name	USGS/Water Resources Mission Area
Program Name	Water Resources Research Act Program
Citation	42 U.S.C. 10301 - 10303, P.L. 109-471
Title of Legislation	Water Resources Research Act Amendments of 2006
Last Year of Authorization	2011
BY Budget Request (\$000)	\$ 6,500
Explanation of Authorization Requirement for BY	No individual programmatic authorization is necessary for the USGS to continue this effort
Program Description	Sec. 2 (a) Scope of Research; Other Activities; Cooperation and Coordination. –Section 104(b)(1) of the Water Resources Research Act of 1984 (42 U.S.C. 10303(b)(1) is amended to read as follows: “plan, conduct, or otherwise arrange for competent applied and peer reviewed research that fosters: improvements in water supply reliability; the exploration of new ideas that address water problems, or expand understanding of water and water related phenomena; the entry of new research scientists, engineers, and technicians into water resources fields; and the dissemination of research results to water managers and the public.

Expiring Authorization Citation

Bureau/Office Name	USGS/Water Resources Mission Area
Program Name	Water Availability and Use Science Program
Citation	Public Law 109-448
Title of Legislation	United States—Mexico Transboundary Aquifer Assessment Act
Last Year of Authorization	2016
BY Budget Request (\$000)	\$1,000
Explanation of Authorization Requirement for BY	No individual programmatic authorization is necessary for the USGS to continue this effort.

<p>Program Description</p>	<p>SEC. 4. ESTABLISHMENT OF PROGRAM. (a) IN GENERAL.—The Secretary, in consultation and cooperation with the Participating States, the water resources research institutes, Sandia National Laboratories, and other appropriate entities in the United States and Mexico, and the IBWC, as appropriate, shall carry out the United States-Mexico transboundary aquifer assessment program to characterize, map, and model priority transboundary aquifers along the United States-Mexico border at a level of detail determined to be appropriate for the particular aquifer. (b) OBJECTIVES.—The objectives of the program are to— (1) develop and implement an integrated scientific approach to identify and assess priority transboundary aquifers, including— (A) for purposes of subsection (c)(2), specifying priority transboundary aquifers for further analysis by assessing— (i) the proximity of a proposed priority transboundary aquifer to areas of high population density; (ii) the extent to which a proposed priority transboundary aquifer would be used; (iii) the susceptibility of a proposed priority transboundary aquifer to contamination; and (iv) any other relevant criteria; (B) evaluating all available data and publications as part of the development of study plans for each priority transboundary aquifer; (C) creating a new, or enhancing an existing, geographic information system database to characterize the spatial and temporal aspects of each priority transboundary aquifer; and (D) using field studies, including support for and expansion of ongoing monitoring and metering efforts, to develop—(i) the additional data necessary to adequately define aquifer characteristics; and (ii) scientifically sound groundwater flow models to assist with State and local water management and administration, including modeling of relevant groundwater and surface water interactions; (2) consider the expansion or modification of existing agreements, as appropriate, between the United States Geological Survey, the Participating States, the water resources research institutes, and appropriate authorities in the United States and Mexico, to— (A) conduct joint scientific investigations; (B) archive and share relevant data; and (C) carry out any other activities consistent with the program; and (3) produce scientific products for each priority transboundary aquifer that— (A) are capable of being broadly distributed; and (B) provide the scientific information needed by water managers and natural resource agencies on both sides of the United States-Mexico border to effectively accomplish the missions of the managers and</p>
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	<p>agencies.</p> <p>Section 8: AUTHORIZATION OF APPROPRIATIONS. (a) IN GENERAL.—There are authorized to be appropriated to carry out this Act \$50,000,000 for the period of fiscal years 2007 through 2016. (b) DISTRIBUTION OF FUNDS.—Of the amounts made available under subsection (a), 50 percent shall be made available to the water resources research institutes to provide funding to appropriate entities in the Participating States (including Sandia National Laboratories, State agencies, universities, the Tri-Regional Planning Group, and other relevant organizations) and to implement cooperative agreements entered into with appropriate entities in Mexico to conduct specific authorized activities in furtherance of the program, including the binational collection and exchange of scientific data. (c) Criteria- Funding provided to an appropriate entity in Mexico pursuant to subsection (b) shall be contingent on that entity providing 50 percent of the necessary resources (including in-kind services) to further assist in carrying out the authorized activity.</p>
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Expiring Authorization Citation	
Bureau/Office Name	USGS/Water Resources Mission Area
Program Name	Water Availability and Use Science Program
Citation	Public Law 111-11
Title of Legislation	Secure Water Act
Last Year of Authorization	2013
BY Budget Request (\$000)	\$1,500
Explanation of Authorization Requirement for BY	No individual programmatic authorization is necessary for the USGS to continue this effort
Program Description	Section 9508 of the SECURE Water Act directs the Secretary of the Interior to administer grants to State water resource agencies to assist in developing water use and availability datasets that are integrated with each appropriate dataset developed or maintained by the Secretary. Responsibility for administration of this Water Use Research and Data program has been delegated to the U.S. Geological Survey. State Water Use assistance awards will be used to improve the collection and reporting of water use categories by State agencies, including the inclusion of categories that have been discontinued in the past due to limited resources. The total authorized funding for State Water Use assistance awards is \$12,500,000 for a period of five years.

Administrative Provisions

From within the amount appropriated for activities of the United States Geological Survey such sums as are necessary shall be available for contracting for the furnishing of topographic maps and for the making of geophysical or other specialized surveys when it is administratively determined that such procedures are in the public interest; construction and maintenance of necessary buildings and appurtenant facilities; acquisition of lands for gauging stations and observation wells; expenses of the United States National Committee for Geological Sciences; and payment of compensation and expenses of persons employed by the Survey duly appointed to represent the United States in the negotiation and administration of interstate compacts: *Provided*, That activities funded by appropriations herein made may be accomplished through the use of contracts, grants, or cooperative agreements as defined in section 6302 of title 31, United States Code: *Provided further*, That the United States Geological Survey may enter into contracts or cooperative agreements directly with individuals or indirectly with institutions or nonprofit organizations, without regard to 41 U.S.C. 6101, for the temporary or intermittent services of students or recent graduates, who shall be considered employees for the purpose of chapters 57 and 81 of title 5, United States Code, relating to compensation for travel and work injuries, and chapter 171 of title 28, United States Code, relating to tort claims, but shall not be considered to be Federal employees for any other purposes.

Administrative Provisions Language and Citations

A full listing of USGS appropriation language and citations is available at the USGS Office of Budget, Planning, and Integration Web site, under Resources and Tools.

Web site: *http://www.usgs.gov/budget/resources_tools.asp*

USGS Exhibits

Activity/Subactivity/ Program Element	2015 Actual	FY 2016 Enacted		Fixed Costs (+/-)	Internal Transfers (+/-)	Program Changes (+/-)		2017 Budget Request		Change from 2016 (+/-)	
	Amount	FTE	Amount			FTE	Amount	FTE	Amount	FTE	Amount
Surveys, Investigations, and Research											
Ecosystems											
Status and Trends Program	20,473	119	20,473	89	0	6	1,705	125	22,267	6	1,794
Fisheries Program	20,886	133	20,886	97	0	5	3,100	138	24,083	5	3,197
Wildlife Program	45,257	282	45,757	218	0	1	150	283	46,125	1	368
Environments Program	36,224	198	38,415	137	0	18	4,800	216	43,352	18	4,937
Invasive Species Program	16,830	75	17,330	47	0	6	2,500	81	19,877	6	2,547
Cooperative Research Units	17,371	143	17,371	113	0	4	750	147	18,234	4	863
Ecosystems Total	157,041	950	160,232	701	0	40	13,005	990	173,938	40	13,706
Climate and Land Use Change											
<i>Climate Variability</i>											
National Climate Change and Wildlife Science Center/ DOI Climate Science Centers	26,735	49	26,435	32	0	9	4,441	58	30,908	9	4,473
Climate Research and Development Program	21,495	110	21,495	94	0	5	1,125	115	22,714	5	1,219
Carbon Sequestration	9,359	31	9,359	22	0	0	0	31	9,381	0	22
Subtotal	57,589	190	57,289	148	0	14	5,566	204	63,003	14	5,714
<i>Land Use Change</i>											
Land Remote Sensing Program	67,894	145	72,194	113	0	9	24,199	154	96,506	9	24,312
Land Change Science	10,492	53	10,492	43	0	6	1,400	59	11,935	6	1,443
Subtotal	78,386	198	82,686	156	0	15	25,599	213	108,441	15	25,755
Climate and Land Use Change Total	135,975	388	139,975	304	0	29	31,165	417	171,444	29	31,469
Energy and Mineral Resources, and Environmental Health											
<i>Mineral and Energy Resources</i>											
Mineral Resources Program	45,931	308	48,371	243	0	4	81	312	48,695	4	324
Energy Resources Program	24,895	140	24,695	118	0	2	1,415	142	26,228	2	1,533
Subtotal	70,826	448	73,066	361	0	6	1,496	454	74,923	6	1,857
<i>Environmental Health</i>											
Contaminant Biology Program	10,197	60	10,197	45	0	4	1,223	64	11,465	4	1,268
Toxic Substance Hydrology Program	11,248	59	11,248	47	0	4	1,800	63	13,095	4	1,847
Subtotal	21,445	119	21,445	92	0	8	3,023	127	24,560	8	3,115
Energy and Mineral Resources, and Environmental Health Total	92,271	567	94,511	453	0	14	4,519	581	99,483	14	4,972

Activity/Subactivity/ Program Element	2015 Actual	FY 2016 Enacted		Fixed Costs (+/-)	Internal Transfers (+/-)	Program Changes (+/-)		2017 Budget Request		Change from 2016 (+/-)	
	Amount	FTE	Amount			FTE	Amount	FTE	Amount	FTE	Amount
Natural Hazards											
Earthquake Hazards Program	59,503	239	60,503	193	0	4	1,500	243	62,196	4	1,693
Volcano Hazards Program	25,121	136	26,121	117	0	0	0	136	26,238	0	117
Landslide Hazards Program	3,485	22	3,538	16	0	2	500	24	4,054	2	516
Global Seismographic Network	4,853	11	6,453	9	0	1	860	12	7,322	1	869
Geomagnetism Program	1,888	12	1,888	10	0	3	1,700	15	3,598	3	1,710
Coastal and Marine Geology Program	40,336	191	40,510	174	0	10	5,609	201	46,293	10	5,783
Natural Hazards Total	135,186	611	139,013	519	0	20	10,169	631	149,701	20	10,688
Water Resources											
Water Availability and Use Science Program	40,919	273	42,052	236	0	12	12,100	285	54,388	12	12,336
Groundwater and Streamflow Information Program	69,707	384	71,535	222	0	7	1,200	391	72,957	7	1,422
National Water Quality Program	94,141	687	90,600	499	0	10	3,048	697	94,147	10	3,547
Water Resources Research Act Program	6,500	1	6,500	0	0	0	0	1	6,500	0	0
Water Resources Total	211,267	1,345	210,687	957	0	29	16,348	1,374	227,992	29	17,305
Core Science Systems											
National Geospatial Program	58,532	267	62,854	238	0	6	5,887	273	68,979	6	6,125
National Cooperative Geologic Mapping Program	24,397	114	24,397	89	0	0	0	114	24,486	0	89
Science Synthesis, Analysis and Research Program	24,299	91	24,299	81	0	0	550	91	24,930	0	631
Core Science Systems Total	107,228	472	111,550	408	0	6	6,437	478	118,395	6	6,845
Science Support											
Administration and Management	84,192	511	81,981	141	0	17	4,197	528	86,319	17	4,338
Information Services	21,419	73	23,630	23	0	2	620	75	24,273	2	643
Science Support Total	105,611	584	105,611	164	0	19	4,817	603	110,592	19	4,981
Facilities											
Rental Payments and Operations & Maintenance	93,141	58	93,141	1,223	0	0	15,614	58	109,978	0	16,837
Deferred Maintenance and Capital Improvement	7,280	0	7,280	0	0	0	0	0	7,280	0	0
Facilities Total	100,421	58	100,421	1,223	0	0	15,614	58	117,258	0	16,837
Total, USGS	1,045,000	4,975	1,062,000	4,729	0	157	102,074	5,132	1,168,803	157	106,803

US Geological Survey
Justification of Fixed Costs and Internal Realignments
(Dollars In Thousands)

Fixed Cost Changes and Projections	2016 Change	2016 to 2017 Change
Change in Number of Paid Days This column reflects changes in pay associated with the change in the number of paid days between the 2016 and 2017.	+2,439	-4,901
Pay Raise The change reflects the salary impact of programmed pay raise increases.	+8,004	+9,652
Departmental Working Capital Fund The change reflects expected changes in the charges for centrally billed Department services and other services through the Working Capital Fund. These charges are detailed in the Budget Justification for Department Management.	+1,046	-1,265
Worker's Compensation Payments The adjustment is for changes in the costs of compensating injured employees and dependents of employees who suffer accidental deaths while on duty. Costs for 2016 will reimburse the Department of Labor, Federal Employees Compensation Fund, pursuant to 5 U.S.C. 8147(b) as amended by Public Law 94-273.	-24	+145
Unemployment Compensation Payments The adjustment is for projected changes in the costs of unemployment compensation claims to be paid to the Department of Labor, Federal Employees Compensation Account, in the Unemployment Trust Fund, pursuant to Public Law 96-499.	+10	-78
Rental Payments The adjustment is for changes in the costs payable to General Services Administration (GSA) and others resulting from changes in rates for office and non-office space as estimated by GSA, as well as the rental costs of other currently occupied space. These costs include building security; in the case of GSA space, these are paid to Department of Homeland Security (DHS). Costs of mandatory office relocations, i.e. relocations in cases where due to external events there is no alternative but to vacate the currently occupied space, are also included.	-2,506	-2,084
O&M Increases from Moves out of GSA-Space into Bureau Space In accordance with space maximization efforts across the Federal Government, this adjustment captures the associated increase to baseline operations and maintenance requirements resulting from movement out of GSA or direct-leased (commercial) space and into Bureau-owned space. While the GSA portion of fixed costs will go down as a result of these moves, Bureaus often encounter an increase to baseline O&M costs not otherwise captured in fixed costs. This category of funding properly adjusts the baseline fixed cost amount to maintain steady-state funding for these requirements.	+0	+3,260

Account Exhibits

SURVEYS, INVESTIGATIONS, AND RESEARCH

Summary of Requirements by Object Class

(Millions of Dollars)

Appropriation: Surveys, Investigations, and Research		2016		Fixed Costs		Program		2017	
		FTE	Enacted Amount	FTE	Amount	FTE	Changes Amount	FTE	Request Amount
Object Class									
Personnel compensation									
11.1	Full-time permanent		419		4		8		431
11.3	Other than full-time permanent		39		0		2		41
11.5	Other personnel compensation		8		0		0		8
Total personnel compensation		4,975	466	0	4	143	10	*5,132	480
12.1	Civilian personnel benefits		146		1		3		150
13.0	Benefits for former personnel		1		0		0		1
21.0	Travel and transportation of persons		21		0		0		21
22.0	Transportation of things		1		0		0		1
23.1	Rental payment to GSA		57		-2		0		55
23.2	Rental payments to others		3		0		0		3
23.3	Communications., utilities, and miscellaneous charges		16		0		0		16
24.0	Printing and reproduction		1		0		0		1
25.1	Advisory and assistance services		17		0		-6		11
25.2	Other services from non-Fed sources		69		-1		55		123
25.3	Other goods and services from Fed sources		77		0		0		77
25.4	Operation and maintenance of facilities		13		3		16		32
25.5	Research and development contracts		3		0		0		3
25.7	Operation and maintenance of equipment		21		0		0		21
26.0	Supplies and materials		22		0		0		22
31.0	Equipment		43		0		24		67
32.0	Land and structures		1		0		0		1
41.0	Grants, subsidies, and contributions		84		0		0		84
Total requirements			1,062		5		102		1,169

This information is displayed in budget authority (not obligations) by object class.

* The 2017 FTE for USGS is updated from the estimate included in the Appendix, Budget of the United States Government, Fiscal Year 2017. The 2017 estimate reflected above is 14 more than reflected in the Appendix, but accurately reflects the FTE associated with the budget.

SURVEYS, INVESTIGATIONS, AND RESEARCH

Summary of Requirements by Object Class

(Millions of Dollars)

Appropriation: Surveys, Investigations, and Research							
Reimbursable Obligations		2016		2017		Increase or Decrease	
		FTE	Enacted Amount	FTE	Request Amount	FTE	Amount
	Personnel compensation						
11.1	Full-time permanent		156		156		0
11.3	Other than full-time permanent		30		30		0
11.5	Other personnel compensation		4		4		0
	Total personnel compensation	2,702	190	2,702	190	0	0
12.1	Civilian personnel benefits		61		61		0
21.0	Travel and transportation of persons		12		12		0
22.0	Transportation of things		1		1		0
23.1	Rental payments to GSA		20		20		0
23.2	Rental payments to others		1		1		0
23.3	Communications, utilities, and miscellaneous charges		8		8		0
25.1	Advisory and assistance services		3		3		0
25.2	Other services		60		60		0
25.3	Other purchases of goods and services from Government accounts		29		29		0
25.4	Operation and maintenance of facilities		12		12		0
25.5	Research and development contracts		1		1		0
25.7	Operation and maintenance of equipment		7		7		0
26.0	Supplies and materials		12		12		0
31.0	Equipment		17		17		0
41.0	Grants, subsidies, and contributions		31		31		0
	Total requirements		465		465		0

United States Geological Survey

Federal Funds

General and special funds:

SURVEYS, INVESTIGATIONS, AND RESEARCH

Program and Financing

(Millions of Dollars)

Identification Code		2015	2016	2017
14-0804-0-1-306		Actual	Enacted	Estimate
	Obligations by program activity:			
00.01	Ecosystems	156	158	173
00.02	Climate and Land Use Change	141	140	171
00.03	Energy and Mineral Resources, and Environmental Health	92	97	99
00.04	Natural Hazards	135	152	158
00.05	Water Resources	208	214	227
00.06	Core Science Systems	107	112	118
00.07	Science Support	106	107	112
00.08	Facilities	103	100	118
07.99	Total direct obligations	1,048	1,080	1,176
08.01	Reimbursable program	465	465	465
09.00	Total new obligations	1,513	1,545	1,641
	Budgetary resources:			
	Unobligated balance:			
10.00	Unobligated balance brought forward, Oct 1	432	483	465
10.01	Discretionary unobligated balance brought fwd, Oct 1	432	447	0
10.11	Unobligated balance transfer from other acct [072-1037]	1	0	0
10.21	Recoveries of prior year unpaid obligations	13	0	0
10.50	Unobligated balance (total)	446	483	465
	Budget authority:			
	Appropriations, discretionary:			
11.00	Appropriation	1,045	1,062	1,169
11.60	Appropriation, discretionary (total)	1,045	1,062	1,169
	Appropriations, mandatory:			
12.21	Appropriations transferred from other accts, Spectrum Relocation Fund [011-5512]	36	0	0
12.60	Appropriation, mandatory (total)	36	0	0
	Spending authority from offsetting collections, discretionary:			
17.00	Collected	441	465	465
17.01	Change in uncollected payments, Federal sources	28	0	0
17.50	Spending auth from offsetting collections, disc (total)	469	465	465
19.00	Budget authority (total)	1,550	1,527	1,634
19.30	Total budgetary resources available	1,996	2,010	2,099

SURVEYS, INVESTIGATIONS, AND RESEARCH

Program and Financing cont'd

(Millions of Dollars)

Identification Code 14-0804-0-1-306	2015 Actual	2016 Enacted	2017 Estimate
Memorandum (non-add) entries:			
19.41			
Unexpired unobligated balance, end of year	483	465	458
Change in obligated balance:			
Unpaid obligations:			
30.00			
Unpaid obligations, brought forward, Oct 1	331	337	290
30.10			
Obligations incurred, unexpired accounts	1,513	1,545	1,641
30.11			
Obligations incurred, expired accounts	2	0	0
30.20			
Outlays (gross)	-1,490	-1,592	-1,670
30.40			
Recoveries of prior year unpaid obligations, unexpired	-13	0	0
30.41			
Recoveries of prior year unpaid obligations, expired	-6	0	0
30.50			
Unpaid obligations, end of year	337	290	261
Uncollected payments:			
30.60			
Uncollected payments, Fed sources, brought forward, Oct 1	-496	-506	-506
30.70			
Change in uncollected payments, Fed sources, unexpired	-28	0	0
30.71			
Change in uncollected payments, Fed sources, expired	18	0	0
30.90			
Uncollected payments, Fed sources, end of year	-506	-506	-506
Memorandum (non-add) entries:			
31.00			
Obligated balance, start of year	-165	-169	-216
32.00			
Obligated balance, end of year	-169	-216	-245
Budget authority and outlays, net:			
Discretionary:			
40.00			
Budget authority, gross	1,514	1,527	1,634
Outlays, gross:			
40.10			
Outlays from new discretionary authority	872	1,344	1,438
40.11			
Outlays from discretionary balances	618	240	218
40.20			
Outlays, gross (total)	1,490	1,584	1,656
Offsets against gross budget authority and outlays:			
Offsetting collections (collected) from:			
40.30			
Federal sources	-246	-251	-251
40.33			
Non-Federal sources	-212	-214	-214
40.40			
Offsets against gross budget authority and outlays (total)	-458	-465	-465

SURVEYS, INVESTIGATIONS, AND RESEARCH

Program and Financing cont'd

(Millions of Dollars)

Identification Code		2015	2016	2017
14-0804-0-1-306		Actual	Enacted	Estimate
	Additional offsets against gross budget authority only:			
40.50	Change in uncollected payments, Fed sources, Unexpired	-28	0	0
40.52	Offsetting collections credited to expired accounts	17	0	0
40.60	Additional offsets against budget authority only (total)	-11	0	0
40.70	Budget authority, net (discretionary)	1,045	1,062	1,169
40.80	Outlays, net (discretionary)	1,032	1,119	1,191
	Mandatory:			
40.90	Budget authority, gross	36	0	0
	Outlays, gross:			
41.01	Outlays from mandatory balances	0	8	14
41.80	Budget authority, net (total)	1,081	1,062	1,169
41.90	Outlays, net (total)	1,032	1,127	1,205

SURVEYS, INVESTIGATIONS, AND RESEARCH

Object Classification

(Millions of Dollars)

Identification Code	2015	2016	2017
14-0804-0-1-306	Actual	Enacted	Estimate
Direct obligations:			
Personnel compensation:			
11.1	399	419	431
11.3	38	39	41
11.5	7	8	8
11.9	444	466	480
12.1	139	146	150
13.0	1	1	1
21.0	21	21	21
22.0	1	1	1
23.1	60	57	55
23.2	3	3	3
23.3	16	16	16
24.0	1	1	1
25.1	11	17	11
25.2	94	87	130
25.3	77	77	77
25.4	13	13	32
25.5	3	3	3
25.7	21	21	21
26.0	22	22	22
31.0	36	43	67
32.0	1	1	1
41.0	84	84	84
99.0	1,048	1,080	1,176

SURVEYS, INVESTIGATIONS, AND RESEARCH

Object Classification cont'd

(Millions of Dollars)

Identification Code		2015	2016	2017
14-0804-0-1-306		Actual	Enacted	Estimate
	Reimbursable obligations:			
	Personnel compensation:			
11.1	Full-time permanent	156	156	156
11.3	Other than full-time permanent	30	30	30
11.5	Other personnel compensation	4	4	4
11.9	Total personnel compensation	190	190	190
12.1	Civilian personnel benefits	61	61	61
21.0	Travel and transportation of persons	12	12	12
22.0	Transportation of things	1	1	1
23.1	Rental payments to GSA	20	20	20
23.2	Rental payments to others	1	1	1
23.3	Communications., utilities, and miscellaneous charges	8	8	8
25.1	Advisory and assistance services	3	3	3
25.2	Other services from non-Fed sources	60	60	60
25.3	Other goods and services from Fed sources	29	29	29
25.4	Operation and maintenance of facilities	12	12	12
25.5	Research and development contracts	1	1	1
25.7	Operation and maintenance of equipment	7	7	7
26.0	Supplies and materials	12	12	12
31.0	Equipment	17	17	17
41.0	Grants, subsidies, and contributions	31	31	31
99.0	Reimbursable obligations	465	465	465
99.9	Total new obligations	1,513	1,545	1,641

SURVEYS, INVESTIGATIONS, AND RESEARCH

Employment Summary

Identification Code		2015	2016	2017
14-0804-0-1-306		Actual	Enacted	Estimate
	Direct:			
1001	Civilian full-time equivalent employment	4,843	4,975	*5,132
	Reimbursable:			
2001	Civilian full-time equivalent employment	2,702	2,702	2,702
	Allocation account:			
3001	Civilian full-time equivalent employment	95	80	38

* The 2017 FTE for USGS is updated from the estimate included in the Appendix, Budget of the United States Government, Fiscal Year 2017. The 2017 estimate reflected above is 14 more than reflected in the Appendix, but accurately reflects the FTE associated with the budget.

Sundry Exhibits

Funding of U.S. Geological Survey Programs
(Obligations)
(Thousands of Dollars)

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Ecosystems			
Appropriated			
Multi-Year appropriation	156,218	158,459	172,984
Total (appropriated)	156,218	158,459	172,984
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Technology Transfer	2,985	2,985	2,985
Miscellaneous	10,841	10,841	10,841
Subtotal (non-Federal domestic sources)	13,826	13,826	13,826
<i>Non-Federal (Foreign) sources</i>			
Miscellaneous	31	31	31
Subtotal (non-Federal Foreign sources)	31	31	31
<i>State and local sources</i>			
States-Coop (unmatched)	165	165	165
Subtotal (state and local sources)	165	165	165
<i>Federal sources</i>			
Department of Agriculture	2,186	2,186	2,186
Department of Commerce	652	652	652
Department of Defense			
Corps of Engineers	19,689	19,689	19,689
National Geospatial-Intelligence Agency	3,178	3,178	3,178
Other	143	143	143
Department of Energy			
Bonneville Power Administration	1,711	1,711	1,711
Other	365	365	365
Department of Homeland Security	121	121	121
Department of Interior			
Bureau of Land Management	4,352	4,352	4,352
Bureau of Ocean Energy Management	1,075	1,075	1,075
Bureau of Reclamation	14,807	14,807	14,807
Fish and Wildlife Service	9,666	9,666	9,666
Office of Secretary			
Interior Business Center	70	70	70
Other	691	691	691
Environmental Protection Agency	94	94	94
Health and Human Services	76	76	76
National Aeronautics & Space Admin	600	600	600
Miscellaneous Federal Agencies	48	48	48
Subtotal (Federal sources)	59,524	59,524	59,524
Total (reimbursements)	73,546	73,546	73,546
Total: Ecosystems	229,764	232,005	246,530

Sundry Exhibits

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Climate and Land Use Change			
Appropriated			
Multi-Year appropriation	85,411	82,388	95,375
No-Year appropriation	55,571	57,750	75,237
Total (appropriated)	140,982	140,138	170,612
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Technology Transfer	86	86	86
Miscellaneous	113	113	113
Subtotal (non-Federal domestic sources)	199	199	199
<i>Non-Federal (Foreign) sources</i>			
Corporacion Andina de Fomento	295	295	295
Saudi Geological Survey	74	74	74
The World Bank Group	21	21	21
Miscellaneous	1,237	1,237	1,237
Subtotal (non-Federal Foreign sources)	1,627	1,627	1,627
<i>Federal sources</i>			
Agency for International Development	6,211	6,211	6,211
Department of Agriculture	805	805	805
Department of Commerce	85	85	85
Department of Defense			
Corps of Engineers	476	476	476
Department of Energy	114	114	114
Department of Homeland Security			
Federal Emergency Management Agency	155	155	155
Other	18	18	18
Department of Interior			
Bureau of Indian Affairs	72	72	72
Bureau of Land Management	1,138	1,138	1,138
Bureau of Reclamation	614	614	614
Fish and Wildlife Service	257	257	257
Office of Secretary	3,753	3,753	3,753
Environmental Protection Agency	1,415	1,415	1,415
Health and Human Services	95	95	95
National Aeronautics & Space Admin	10,827	10,827	10,827
Sale of maps, photos, reproductions, & digital products	311	311	311
Miscellaneous	8	8	8
Subtotal (Federal sources)	26,354	26,354	26,354
Total (reimbursements)	28,180	28,180	28,180
Total: Climate and Land Use Change	169,162	168,318	198,792

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Energy and Mineral Resources, and Environmental Health			
Appropriated			
Multi-Year appropriation	92,293	96,320	99,185
No-Year appropriation	38	229	0
Total (appropriated)	92,331	96,549	99,185
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Technology Transfer	747	747	747
Miscellaneous	585	585	585
Subtotal (non-Federal domestic sources)	1,332	1,332	1,332
<i>Non-Federal (Foreign) sources</i>			
Miscellaneous	15	15	15
Subtotal (non-Federal Foreign sources)	15	15	15
<i>State and local sources</i>			
States-Coop (unmatched)	59	59	59
Subtotal (state and local sources)	59	59	59
<i>Federal sources</i>			
Department of Agriculture	132	132	132
Department of Commerce	48	48	48
Department of Defense			
Corps of Engineers	1,292	1,292	1,292
Department of Energy	53	53	53
Department of Homeland Security	290	290	290
Department of Interior			
Bureau of Land Management	514	514	514
Bureau of Reclamation	207	207	207
Fish and Wildlife Service	400	400	400
Office of Secretary	93	93	93
Office of Surface Mining	28	28	28
Department of Justice	20	20	20
Environmental Protection Agency	340	340	340
Health and Human Services	4	4	4
Housing and Urban Development	349	349	349
Subtotal (Federal sources)	3,770	3,770	3,770
Total (reimbursements)	5,176	5,176	5,176
Total: Energy and Mineral Resources, and Environmental Health	97,507	101,725	104,361

Sundry Exhibits

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Natural Hazards			
Appropriated			
Multi-Year appropriation	134,450	138,352	149,049
Total (appropriated)	134,450	138,352	149,049
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Technology Transfer	1,174	1,174	1,174
Miscellaneous	2,336	2,336	2,336
Subtotal (non-Federal domestic sources)	3,510	3,510	3,510
<i>Non-Federal (Foreign) sources</i>			
Saudi Geological Survey	1,570	1,570	1,570
Miscellaneous	8	8	8
Subtotal (non-Federal Foreign sources)	1,578	1,578	1,578
<i>State and local sources</i>			
States-Coop (unmatched)	1,043	1,043	1,043
Subtotal (state and local sources)	1,043	1,043	1,043
<i>Federal sources</i>			
Agency for International Development	3,775	3,775	3,775
Department of Agriculture	75	75	75
Department of Commerce	114	114	114
Department of Defense			
Corps of Engineers	1,136	1,136	1,136
National Geospatial-Intelligence Agency	78	78	78
Other	645	645	645
Department of Energy	1,848	1,848	1,848
Department of Homeland Security			
Federal Emergency Management Agency	591	591	591
Department of Interior			
Bureau of Ocean Energy Management	146	146	146
Bureau of Reclamation	449	449	449
Bureau of Safety and Environmental Enforcement	25	25	25
Fish and Wildlife Service	155	155	155
Office of Secretary	68	68	68
Department of State	127	127	127
Department of Veterans Affairs	157	157	157
Environmental Protection Agency	82	82	82
Health and Human Services	50	50	50
National Aeronautics & Space Admin	7,532	7,532	7,532
National Science Foundation	98	98	98
Nuclear Regulatory Commission	636	636	636
Subtotal (Federal sources)	17,787	17,787	17,787
Total (reimbursements)	23,918	23,918	23,918
Total: Natural Hazards *	158,368	162,270	172,967

* This table does not include obligations for the Spectrum Relocation Fund, since it is a mandatory fund. MAX obligations do include the Spectrum Relocation Fund. The amounts included in MAX are: FY 2016 \$13,566K, and FY 2017 \$8,773K. This table does not include obligations from the unobligated balance transfer from USAID, which is included in MAX. The amount for FY 2015 is \$170K.

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Water Resources			
Appropriated			
Multi-Year appropriation	207,817	214,209	227,095
Total (appropriated)	207,817	214,209	227,095
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Permittees & licensees- Fed Energy Regulatory Commission	5,922	5,922	5,922
Technology Transfer	3,408	3,408	3,408
Miscellaneous	3,202	3,202	3,202
Subtotal (non-Federal domestic sources)	12,532	12,532	12,532
<i>Non-Federal (Foreign) sources</i>			
The Environment Agency - Abu Dhabi	1,353	1,353	1,353
The World Bank Group	57	57	57
Miscellaneous	383	383	383
Subtotal (non-Federal Foreign sources)	1,793	1,793	1,793
<i>State and local sources</i>			
States-Coop (matched)	57,710	57,710	60,185
States-Coop (matched - In-Kind Services) NON ADD	424	424	424
States-Coop (unmatched)	102,631	102,631	100,156
Subtotal (state and local sources)	160,341	160,341	160,341
<i>Federal sources</i>			
Department of Agriculture	1,097	1,097	1,097
Department of Commerce	155	155	155
Department of Defense			
Corps of Engineers	39,479	39,479	39,479
National Geospatial-Intelligence Agency	1,628	1,628	1,628
Other	3,089	3,089	3,089
Department of Energy			
Bonneville Power Administration	473	473	473
Other	6,774	6,774	6,774
Department of Homeland Security			
Federal Emergency Management Agency	2,224	2,224	2,224
Other	564	564	564
Department of Interior			
Bureau of Indian Affairs	285	285	285
Bureau of Land Management	2,485	2,485	2,485
Bureau of Reclamation	20,013	20,013	20,013
Fish and Wildlife Service	2,573	2,573	2,573
Office of Secretary	250	250	250
Office of Surface Mining	33	33	33
Department of Justice	25	25	25
Department of State	2,199	2,199	2,199
Environmental Protection Agency	26,370	26,370	26,370
Health and Human Services	121	121	121
Millenium Challenge Corporation	88	88	88
National Aeronautics & Space Admin	1,001	1,001	1,001
Nuclear Regulatory Commission	517	517	517
Tennessee Valley Authority	412	412	412
Subtotal (Federal sources)	111,855	111,855	111,855
Total (reimbursements)	286,521	286,521	286,521
Total: Water Resources	494,338	500,730	513,616

Sundry Exhibits

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Core Science Systems			
Appropriated			
Multi-Year appropriation	106,722	112,451	117,984
Total (appropriated)	106,722	112,451	117,984
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Technology Transfer	75	75	75
Miscellaneous	63	63	63
Subtotal (non-Federal domestic sources)	138	138	138
<i>State and local sources</i>			
States-Coop (unmatched)	9,683	9,683	9,683
Subtotal (state and local sources)	9,683	9,683	9,683
<i>Federal sources</i>			
Department of Agriculture	4,647	4,647	4,647
Department of Commerce	335	335	335
Department of Defense			
Corps of Engineers	440	440	440
National Geospatial-Intelligence Agency	20	20	20
Department of Education	25	25	25
Department of Energy	126	126	126
Department of Homeland Security			
Federal Emergency Management Agency	8,453	8,453	8,453
Other	501	501	501
Department of Interior			
Bureau of Land Management	1,967	1,967	1,967
Bureau of Ocean Energy Management	50	50	50
Bureau of Reclamation	1,653	1,653	1,653
Fish and Wildlife Service	263	263	263
Department of Justice	100	100	100
Department of State	50	50	50
Department of Treasury	25	25	25
Department of Veterans Affairs	25	25	25
Environmental Protection Agency	226	226	226
General Services Administration	100	100	100
Health and Human Services	100	100	100
Housing and Urban Development	100	100	100
National Science Foundation	914	914	914
Tennessee Valley Authority	116	116	116
Miscellaneous	75	75	75
Subtotal (Federal sources)	20,311	20,311	20,311
Total (reimbursements)	30,132	30,132	30,132
Total: Core Science Systems *	136,854	142,583	148,116

* This table does not include obligations from the unobligated balance transfer from USAID, which is included in MAX. The amount for FY 2015 is \$395K.

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Science Support			
Appropriated			
Multi-Year appropriation	106,205	105,743	109,745
Total (appropriated)	106,205	105,743	109,745
Reimbursements			
<i>Non-Federal (Domestic) sources</i>			
Map Receipts	1,018	1,018	1,018
Sale of photos, reproductions, and digital products	730	730	730
Technology Transfer	53	53	53
Subtotal (non-Federal domestic sources)	1,801	1,801	1,801
<i>Federal sources</i>			
Department of Agriculture	8	8	8
Department of Commerce	905	905	905
Department of Defense			
Corps of Engineers	2,210	2,210	2,210
Department of Interior			
Bureau of Indian Affairs	106	106	106
Bureau of Reclamation	4,003	4,003	4,003
Bureau of Safety and Environmental Enforcement	221	221	221
Fish and Wildlife Service	118	118	118
Office of Secretary	6,804	6,804	6,804
Office of Surface Mining	5	5	5
Health and Human Services	12	12	12
Sale of maps, photos, reproductions, & digital products	1,082	1,082	1,082
Miscellaneous	21	21	21
Subtotal (Federal sources)	15,495	15,495	15,495
Total (reimbursements)	17,296	17,296	17,296
Total: Science Support *	123,501	123,039	127,041

* This table does not include obligations for the Spectrum Relocation Fund, since it is a mandatory fund. MAX obligations do include the Spectrum Relocation Fund. The amounts included in MAX are: FY 2016 \$1,265K, and FY 2017 \$2,742K.

Sundry Exhibits

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Facilities			
Appropriated			
Multi-Year appropriation	94,904	91,746	109,305
No-Year appropriation	8,395	8,003	8,280
Total (appropriated)	103,299	99,749	117,585
Total: Facilities	103,299	99,749	117,585

SIR Summary:

Appropriated			
Multi-Year appropriation	984,020	999,668	1,080,722
No-Year appropriation	64,004	65,982	83,517
subtotal (appropriated)	1,048,024	1,065,650	1,164,239
Reimbursements			
Non-Federal Sources			
Map Receipts	1,018	1,018	1,018
Domestic	32,320	32,320	32,320
Foreign	5,044	5,044	5,044
State and local sources	171,291	171,291	171,291
Federal Sources	255,096	255,096	255,096
subtotal (reimbursements)	464,769	464,769	464,769
Total: SIR *	1,512,793	1,530,419	1,629,008

* This table does not include obligations for the Spectrum Relocation Fund, since it is a mandatory fund. MAX obligations do include the Spectrum Relocation Fund. The amounts included in MAX are: FY 2016 \$14,831K, and FY 2017 \$11,515K. This table also does not include obligations from the unobligated balance transfer from USAID, which is included in MAX. The amount for FY 2015 is \$565K.

	2015 Actual	2016 Enacted	2017 Estimate
Surveys, Investigations, and Research (SIR)			
Contributed Funds:			
Permanent, indefinite appropriation:			
Ecosystems	1,503	1,076	413
Climate and Land Use Change	5	3	2
Energy, Minerals, and Environmental Health	45	63	60
Natural Hazards	21	48	7
Water Resources	102	265	70
Total: Contributed Funds	1,676	1,455	552
Operation and Maintenance of Quarters:			
Permanent, indefinite appropriation:			
Ecosystems	4	21	15
Natural Hazards	3	63	30
Total: Operation and Maintenance of Quarters	7	84	45
Working Capital Fund:			
National Water Quality Lab	15,389	15,450	15,980
Hydrologic Instrumentation Facility	19,052	20,451	20,461
Other	51,123	56,648	54,671
Total: Working Capital Fund	85,564	92,549	91,112
Allocations from other Federal Agencies: *			
Department of the Interior: Departmental Offices			
Natural Resource Damage Assessment	6,956	5,000	5,000
Central Hazardous Materials Fund	50	0	0
Total: Allocations	7,006	5,000	5,000

* Allocations are shown in the year they are received, not when they are obligated.

United States Geological Survey
Trust Funds
 CONTRIBUTED FUNDS
Special and Trust Fund Receipts
 (Millions of Dollars)

Identification Code		2015	2016	2017
14-8562-0-7-306		Actual	Enacted	Estimate
01.00	Balance, start of year	0	0	0
	Receipts:			
	Current law:			
11.30	Contributed Funds, Geological Survey	1	2	1
20.00	Total: Balances and receipts	1	2	1
	Appropriations:			
	Current law:			
21.01	Contributed Funds	-1	-2	-1
50.99	Balance, end of year	0	0	0

Program and Financing
 (Millions of Dollars)

Identification Code		2015	2016	2017
14-8562-0-7-306		Actual	Enacted	Estimate
	Obligations by program activity:			
08.01	Donations and contributed funds	2	1	1
09.00	Total new obligations	2	1	1
	Budgetary resources:			
	Unobligated balance:			
10.00	Unobligated balance brought forward, Oct 1	2	1	2
	Budget authority:			
	Appropriation, mandatory:			
12.01	Appropriation (trust fund)	1	2	1
12.60	Appropriation, mandatory (total)	1	2	1
19.30	Total budgetary resources available	3	3	3
	Memorandum (non-add) entries:			
19.41	Unexpired unobligated balance, end of year	1	2	2

CONTRIBUTED FUNDS
Program and Financing cont'd
(Millions of Dollars)

Identification Code 14-8562-0-7-306		2015 Actual	2016 Enacted	2017 Estimate
	Change in obligated balance:			
	Unpaid obligations:			
30.10	Obligations incurred, unexpired accounts	2	1	1
30.20	Outlays (gross)	-2	-1	-1
	Budget authority and outlays, net:			
	Mandatory:			
40.90	Budget authority, gross	1	2	1
	Outlays, gross:			
41.00	Outlays from new mandatory authority	0	1	0
41.01	Outlays from mandatory balances	2	0	1
41.10	Outlays, gross (total)	2	1	1
41.80	Budget authority, net (total)	1	2	1
41.90	Outlays, net (total)	2	1	1

Object Classification
(Millions of Dollars)

Identification Code 14-8562-0-7-306		2015 Actual	2016 Enacted	2017 Estimate
	Direct obligations:			
25.3	Other goods and services from Federal Sources	1	0	0
99.5	Adjustment for rounding	1	1	1
99.9	Total new obligations	2	1	1

Employment Summary

Identification Code 14-8562-0-7-306		2015 Actual	2016 Enacted	2017 Estimate
	Direct:			
1001	Civilian full-time equivalent employment	5	5	5

Employee Count by Grade
(Total Employment)

	2015 Actual	2016 Estimate	2017 Estimate
Executive Level V	0	1	1
SES	17	21	21
Subtotal	17	21	21
SL – 00	8	10	11
ST – 00	49	55	60
Subtotal	57	65	71
GS/GM – 15	480	470	476
GS/GM – 14	730	715	724
GS/GM – 13	1,237	1,211	1,227
GS – 12	1,514	1,483	1,502
GS – 11	1,212	1,187	1,202
GS – 10	17	16	17
GS – 9	933	914	926
GS – 8	238	234	237
GS – 7	627	614	622
GS – 6	218	213	216
GS – 5	371	363	368
GS – 4	175	172	174
GS – 3	84	82	83
GS – 2	35	34	34
GS – 1	9	9	9
Subtotal	7,881	7,718	7,816
Other Pay Schedule Systems	304	304	304
Total employment (actual/estimate)	8,259	8,109	8,213

Section 403 Compliance

This section describes details related to any assessments to, or within the USGS to support bureauwide services and functions. Details regarding the USGS's payments to the Department of the Interior's Working Capital Fund, and payments to other Federal Agencies are included in the External Administrative Costs subsection. Additional information on internal assessments and cost allocation methodologies can be found in the Bureau Administrative Costs subsection.

	2017 Estimate (\$000)
External Administrative Costs	
The Department of the Interior's Working Capital Fund	
WCF Centralized Billings	\$16,577
WCF Direct Billings	\$10,271
Payments to Other Federal Agencies	
Worker's Compensation Payments	\$2,482
Unemployment Compensation Payments	\$526
GSA Rental Payments	\$82,421
Bureau Administrative Costs	
Shared Program Costs	\$13,441
Internal Bureau Overhead	\$39,500

External Administrative Costs

The Department of the Interior's Working Capital Fund

The Department's Working Capital Fund was established pursuant to 43 U.S.C. 1467, to provide common administrative and support services efficiently and economically at cost. The Fund is a revolving fund, whereby capital is expended to provide services for customers who pay for the services. Customers consist of the Department's bureaus and offices, as well as other Federal agencies. Through the use of centrally provided services, the Department standardized key administrative areas such as commonly used administrative systems, support services for those located in and around the Main and South Interior building complex, and centrally managed departmental operations that are beneficial to the bureaus and offices.

Centralized billing is used whenever the product or service being provided is not severable or it is inefficient to bill for the exact amount of product or service being procured. Customers are billed each year using a pre-established basis that is adjusted annually to reflect change over time. These bills are paid for by both the Administrative & Management and the Information Services subactivities within Science Support, and payment may be adjusted accordingly between these lines during the year of execution based on the enacted appropriation. The following table provides the actual centralized billing to the USGS for 2015 and estimates for 2016 and 2017.

WORKING CAPITAL FUND REVENUE - Centralized Billing
FY 2017 President's Budget
GEOLOGICAL SURVEY
(\$ in thousands)

Activity/Office	2015 Revised	2016 Pres Budget	2016 Revised	2017 Estimate
FBMS Infrastructure Hosting & Support	1,113.8	1,083.1	1,083.1	1,072.9
FBMS Master Data Management	175.7	0.0	0.0	0.0
FBMS Business Integration Office	1,289.4	1,083.1	1,083.1	1,072.9
Aviation Management	430.3	432.5	432.5	397.5
Office of Aviation Services	430.3	432.5	432.5	397.5
Mail and Messenger Services	0.9	0.9	0.9	1.9
Safety, Environmental, and Health Services	0.5	0.5	0.5	1.0
Shipping/Receiving & Moving Services	0.3	0.3	0.3	0.6
Personal Property Accountability Services (formally Property	0.4	0.4	0.4	0.8
Interior Complex Management & Svcs	0.4	0.3	0.3	0.7
Departmental Library	8.5	7.4	7.4	4.6
Mail Policy	37.2	30.7	30.7	31.3
Conference and Special Events Services (formally Audio Visual	0.7	0.7	0.7	1.4
Space Management Services	0.2	0.2	0.2	0.4
Ofc of Facilities & Admin Services	49.2	41.5	41.5	42.6
Office of Valuation Services				
Subtotal OS Shared Services	1,768.9	1,557.1	1,557.1	1,513.0
Alaska Affairs Office	10.8	11.0	11.0	11.0
Alaska Resources Library & Info Services	153.4	153.4	153.4	153.4
Departmental Museum	117.0	133.8	133.8	136.3
Secretary's Immediate Office	281.2	298.2	298.1	300.6
Document Management Unit	0.0	0.0	0.0	0.5
FOIA Tracking & Reporting System	45.7	46.8	46.8	54.3
Executive Secretariat	45.7	46.8	46.8	54.8
Departmental News and Information	108.4	140.7	140.7	143.3
Office of Communications	108.4	140.7	140.7	143.3
Asbestos-Related Cleanup Cost Liabilities	0.0	0.0	0.0	0.0
FedCenter	1.9	1.9	1.9	1.9
Compliance support ESF-11/ESF-11 Website	2.3	2.3	2.3	2.3
Office of Environmental Policy and Compliance	4.3	4.2	4.2	4.2
Invasive Species Council	214.4	216.4	216.4	216.4
Invasive Species DOI Coordinator	38.8	39.2	39.2	39.2

WORKING CAPITAL FUND REVENUE - Centralized Billing
FY 2017 President's Budget
GEOLOGICAL SURVEY
(\$ in thousands)

Activity/Office	2015 Revised	2016 Pres Budget	2016 Revised	2017 Estimate
Office of Policy Analysis	253.2	255.6	255.5	255.5
International Affairs				
CPIC	28.5	28.5	28.5	28.6
Office of Budget	28.5	28.5	28.5	28.6
Financial Internal Controls & Performance Reporting	59.5	76.3	76.3	77.7
Travel Management Center	31.5	38.9	38.9	36.2
e-Travel (formerly e-Gov Travel)	181.7	211.3	211.3	192.9
Partnerships	0.0		34.6	35.3
Office of Financial Management	272.7	326.5	361.1	342.1
Interior Collections Management System (ICMS)	2.1	2.1	2.1	0.0
Space Management Initiative	42.5	40.9	40.9	41.6
Renewable Energy Certif. & NREL Project Coordination	2.9	33.0	33.0	32.4
Facility Maintenance Management System	4.6	4.6	4.6	4.1
Interior Asset Disposal System O&M	5.1	5.1	5.1	5.1
Office of Property and Acquisition Management	57.0	85.7	85.7	83.2
Planning and Performance Management	140.7	136.4	136.4	139.0
Office of Planning and Performance Management	140.7	136.4	136.4	139.0
Conservation and Educational Partnerships	36.2	34.6	0.0	0.0
Department-wide OWCP Coordination	28.7	22.5	22.5	22.5
OPM Federal Employment Services	44.6	42.6	42.6	43.5
Accessibility and Special Hiring Programs (Formerly ATC)	73.8	70.4	70.4	71.7
Accountability Team	78.3	75.4	75.4	76.8
Employee and Labor Relations Tracking System	3.9	3.8	3.8	3.8
Consolidated Employee Assistance Program	92.3	83.8	83.8	85.3
Office of Human Resources	358.0	333.1	298.4	303.6
EEO Complaints Tracking System	4.5	1.4	1.4	1.6
Special Emphasis Program	4.8	4.6	4.6	4.7
Office of Civil Rights	9.3	6.0	6.0	6.3
Occupational Safety and Health	181.3	174.1	174.1	177.4
Safety Management Information System (SMIS)	145.4	139.4	139.4	142.1
Office of Occupational Safety and Health	326.7	313.6	313.6	319.5
Leadership Development Programs (DOI Executive Forums)	111.9	109.1	109.1	111.2

WORKING CAPITAL FUND REVENUE - Centralized Billing
FY 2017 President's Budget
GEOLOGICAL SURVEY
(\$ in thousands)

Activity/Office	2015 Revised	2016 Pres Budget	2016 Revised	2017 Estimate
Dept-Wide Training Prgms (excluding Learn)	136.3	296.5	134.9	137.4
Learning and Performance Centers Management	78.3	78.5	78.5	71.1
DOIU Management	78.9	75.8	75.8	77.2
Learn	161.6		161.6	164.6
DOI University	567.0	560.0	560.0	561.5
Security (Classified Information Facility)	58.3	59.4	59.4	60.5
Law Enforcement Coordination	82.5	79.7	79.7	81.3
Security (MIB/SIB Complex)	3.6	3.8	3.8	7.5
Victim Witness Coordinator	22.2	21.5	21.5	21.9
OLES Detailees - Training and Compliance	0.0		0.0	93.4
Office of Law Enforcement and Security	166.5	164.4	164.4	264.5
Interior Operations Center	261.5	252.4	252.4	257.1
Emergency Preparedness	112.2	107.7	107.7	109.8
Emergency Response	141.5	136.5	136.5	161.6
MIB Emergency Health and Safety	0.1	0.1	0.1	0.2
Federal Executive Board	31.5	31.5	31.5	32.1
Office of Emergency Management	546.8	528.1	528.1	560.8
Alternative Dispute Resolution Training	6.0	5.7	5.7	5.8
Collaborative Action and Dispute Resolution	6.0	5.7	5.7	5.8
Cooperative Ecosystem Study Units (CESU)	51.4	50.9	50.9	50.8
CFO Financial Statement Audit	728.4	610.0	610.0	523.6
Glen Canyon Adaptive Management Plan	130.4	130.7	130.7	130.7
Department-wide Activities	910.2	791.7	791.7	705.1
Ethics	62.9	60.2	60.2	61.3
FOIA Appeals	26.0	26.0	26.0	8.8
Office of the Solicitor	88.9	86.3	86.3	70.1
Subtotal OS Activities	4,171.0	4,111.2	4,111.2	4,148.6
IT Transformation (ITT)	832.0	832.0	832.0	780.0
Office of the Chief Information Officer	832.0	832.0	832.0	780.0
Enterprise Directory Services (fka Active Directory)	360.8	653.5	653.5	593.1
IT Desktop Software Administration	154.5	173.5	173.5	144.9
IOS Collaboration	100.7	136.4	136.4	137.3
Unified Messaging	113.3	162.0	162.0	239.2

WORKING CAPITAL FUND REVENUE - Centralized Billing
FY 2017 President's Budget
GEOLOGICAL SURVEY
(\$ in thousands)

Activity/Office	2015 Revised	2016 Pres Budget	2016 Revised	2017 Estimate
Office of IT Service Delivery - End User Services	729.2	1,125.5	1,125.5	1,114.5
Privacy and Civil Liberties	101.1	109.3	109.3	136.1
Identity Credential Access Mgmt	132.0	144.6	144.6	125.1
Threat Management	522.1	956.0	956.0	780.6
Information Systems Security Operations (ISSO) (Formerly ITD	373.8	25.0	25.0	31.4
ITD PPCD Privacy Records	8.1	0.0	0.0	0.0
Office of Information Assurance (OIA) (formerly Information	87.4	78.6	78.6	123.1
Assessment & Authorization Services	29.8	29.3	29.3	28.4
IT Security	38.7	34.2	34.2	156.8
Enterprise Continuous Diagnostics and Monitoring	124.2	124.1	124.1	126.6
Enterprise Security Incident and Event Management Solution	268.7	268.4	268.4	269.8
Office of Information Assurance	1,685.9	1,769.5	1,769.5	1,777.9
Hosting Services	63.9	134.7	134.7	76.2
Office of IT Service Delivery - Hosting Services	63.9	134.7	134.7	76.2
Electronic Records Management	311.2	472.5	472.5	509.7
Solutions, Design and Innovation (SDI) (formerly Web &	49.4	127.6	127.6	125.0
Geospatial Services	0.0	27.4	27.4	28.5
E-Forms	0.0		0.0	218.8
Office of Information and Technology Management	360.7	627.5	627.5	882.0
Enterprise Services Network (ESN)	1,054.2	1,160.5	1,160.5	439.8
Frequency Management Support	77.9	69.8	69.8	76.7
NTIA Spectrum Management	135.7	113.1	113.1	108.3
Radio Program Management Office (NRSPMO)	81.4	74.1	74.1	129.7
Federal Relay Service	7.1	28.4	28.4	29.0
MIB Data Networking	1.6	0.3	0.3	0.6
Telecommunication Services	3.7	0.8	0.8	1.5
ITD Integrated Digital Voice Communications System (IDVC)	2.7	0.6	0.6	1.3
Enterprise Services Network - Central Bill Pass Thrus	1,567.2	2,257.7	1,460.4	1,864.9
Office of IT Service Delivery - Telecommunications Services	2,931.4	3,705.3	2,908.0	2,651.8
Enterprise Service Desk	0.0	95.5	95.5	0.0
Office of IT Service Delivery - Customer Support Services	0.0	95.5	95.5	0.0
Enterprise Resource Management	184.2	0.0	0.0	0.0
Office of Business Operations	184.2	0.0	0.0	0.0

WORKING CAPITAL FUND REVENUE - Centralized Billing
FY 2017 President's Budget
GEOLOGICAL SURVEY
(\$ in thousands)

Activity/Office	2015 Revised	2016 Pres Budget	2016 Revised	2017 Estimate
Architecture & IT Portfolio Performance Management (fka Enterprise	451.5	492.0	492.0	402.9
Compliance and Audit Management	259.6	285.7	285.7	309.3
IT Budget Formulation & Portfolio Development (fka Capital Planning)	337.2	305.0	305.0	324.7
Office of Planning and Performance Management	1,048.3	1,082.7	1,082.7	1,037.0
e-Government Initiatives (WCF Contributions Only)	457.8	376.4	376.4	380.4
Volunteer.gov	15.1	15.1	0.0	0.0
Office of Planning and Performance Management	472.9	391.5	376.4	380.4
Subtotal IT Shared Services	8,308.5	9,764.2	8,951.8	8,699.7
FPPS/Employee Express	2,021.6	2,023.9	1,885.9	1,875.4
Drug Testing	8.5	28.5	28.5	18.5
Employee Express (Passthrough)	0.0		62.0	85.3
HR Systems Integration Framework (HRSIF)	0.0		85.3	90.0
IBC Human Resources Directorate	2,030.0	2,052.4	2,061.7	2,069.1
Quarters Program Administration	0.8	1.0	0.7	0.7
Quarters - iQMIS	0.4		0.3	0.3
IBC Financial Management Directorate	1.3	1.0	1.0	1.0
Boise Acquisition Office	348.2	370.7	370.7	145.7
IBC Acquisitions Services Directorate	348.2	370.7	370.7	145.7
Subtotal Interior Business Center	2,379.5	2,424.1	2,433.4	2,215.8
TOTAL	16,627.9	17,856.7	17,053.5	16,577.2

Direct billing is used whenever the product or service provided is again severable, but is sold through a time and materials reimbursable support agreement or similar contractual arrangement. The following tables provide the actual direct and reimbursable collections from the USGS for 2015, and estimated billings and collections for 2016 and 2017.

WORKING CAPITAL FUND REVENUE - Direct Billing				
FY 2017 President's Budget				
GEOLOGICAL SURVEY				
(\$ in thousands)				
Activity/Office	2015 Actual	2016 Pres Budget	2016 Estimate	2017 Estimate
Creative Communications	3.0	6.7	5.5	5.6
Ofc of Facilities & Admin Services	3.0	6.7	5.5	5.6
Office of Valuation Services				
Office of Aviation Services				
Subtotal OS Shared Services	3.0	6.7	5.5	5.6
Secretary's Immediate Office				
Office of Environmental Policy and Compliance				
Ocean Coastal Great Lakes Activities	40.4	40.0	40.0	40.4
Office of Policy Analysis	40.4	40.0	40.0	40.4
Office of Budget				
Single Audit Clearinghouse	0.3	0.2	0.2	0.2
Office of Financial Management	0.3	0.2	0.2	0.2
e-OPF	149.6	133.8	133.8	133.8
Office of Human Resources	149.6	133.8	133.8	133.8
EEO Investigations	0.0	3.9	3.9	3.9
Office of Civil Rights	0.0	3.9	3.9	3.9
EEO Training	1.5	1.5	1.5	1.5
Office of Civil Rights	1.5	1.5	1.5	1.5
SESCDP	0.0		18.2	0.0
DOI University (DOIU)	0.0		18.2	0.0
Online Learning	0.0	61.4	61.4	61.4
DOIU Consolidated Learning Centers	61.3	61.3	61.9	62.5
DOI University (DOIU)	61.3	122.7	123.3	123.9
Office of Law Enforcement, Security, and Emergency Management				
Reimbursable Security Services				
Office of Law Enforcement				
Federal Flexible Savings Account (FSA) Program	13.8	52.6	52.8	52.8
Department-wide Activities	13.8	52.6	52.8	52.8
Subtotal OS Activities	266.8	354.7	373.7	356.5
Office of Information Assurance				
Unified Messaging	1,161.1	1,256.7	1,256.7	1,504.7

WORKING CAPITAL FUND REVENUE - Direct Billing
FY 2017 President's Budget
GEOLOGICAL SURVEY

Activity/Office	2015 Actual	2016 Pres Budget	2016 Estimate	2017 Estimate
ITD Desktop Services	1.3			
Office of IT Service Delivery - End User Services	1,162.5	1,256.7	1,256.7	1,504.7
Anti-Virus Software Licenses	279.9	308.0	308.0	308.0
Identity Credential Access Management (ICAM) (fka INFO)	911.0	1,122.3	1,122.3	1,122.3
Data-at-Rest Initiative	14.5	15.0	15.0	15.5
Information Systems Security Operations (ISSO) (formerly ITD ISSO Information)	0.4	31.4	31.4	31.4
ITD PPCD Security Compliance	3.1			
IT Security	21.5			
Office of Information Assurance	1,230.3	1,476.7	1,476.7	1,477.2
Data Center Consolidation and Cloud Planning, Analysis and	185.0	114.4	114.4	115.8
Core Hosting Services	177.1	377.3	377.3	376.1
Office of IT Service Delivery - Hosting Services	362.1	491.7	491.7	491.9
ESRI Enterprise Licenses	2,153.2	1,141.7	1,141.7	1,172.9
Electronic Records Management	516.4	600.3	600.3	718.7
Imagery for the Nation		950.0	950.0	950.0
Office of Information and Technology Management	2,669.6	2,692.0	2,692.0	2,841.6
Enterprise Services Network - Direct Bill Pass Throughs	3,198.9	2,706.8	2,706.8	2,706.8
ISSO ITD Telecommunications		0.0	0.0	
ISSO ITD Network Support Services	110.2	12.9	12.9	12.9
Office of IT Service Delivery - Telecommunications Services	3,309.1	2,719.7	2,719.7	2,719.7
ITD Customer Support Services Division	5.5	0.3	0.3	0.3
Office of IT Service Delivery - Customer Support Services	5.5	0.3	0.3	0.3
Office of Planning and Performance Management				
Volunteer.gov	15.0		0.0	0.0
Office of Planning and Performance Management	15.0		0.0	0.0
Subtotal IT Shared Services	8,754.1	8,637.1	8,637.1	9,035.4
Director, NBC Office of the Director				
IBC Human Resources Directorate				
Payroll & HR Systems	852.4	855.0	466.3	471.2
Payroll & HR Systems Passthrough			385.2	396.2
IBC Human Resources Directorate	852.4	855.0	851.6	867.4
Indirect Cost Negotiations - DOI Internal SAC DM		6.1	6.1	6.4

WORKING CAPITAL FUND REVENUE - Direct Billing
 FY 2017 President's Budget
 GEOLOGICAL SURVEY
 (\$ in thousands)

Activity/Office	2015 Actual	2016 Pres Budget	2016 Estimate	2017 Estimate
NBC Financial Management Directorate		6.1	6.1	6.4
Acquisition Services	209.4	0.0		
IBC Acquisitions Services Directorate	209.4	0.0		
Subtotal Interior Business Center	1,061.8	861.1	857.7	873.7
Ofc of Facilities & Admin Services				
Subtotal				
TOTAL	10,085.6	9,859.6	9,874.0	10,271.2

Sundry Exhibits

Payments to Other Federal Agencies

	2015 Actual	2016 Change	2017 Change
Worker's Compensation Payments	2,361	-24	145
The adjustment is for the change in costs of compensating injured employees and dependents of employees who suffer accidental deaths while on duty. Costs for the BY will reimburse the Department of Labor, Federal Employees Compensation Fund, pursuant to 5 U.S.C. 8147(b) as amended by Public Law 94-273.			
Unemployment Compensation Payments	594	10	-78
The adjustment is for projected changes in the costs of unemployment compensation claims to be paid to the Department of Labor, Federal Employees Compensation Account, in the Unemployment Trust Fund, pursuant to Public Law 96-499.			
GSA Rental Payments	83,704	-2,506	1,223
The adjustment is for changes in the costs payable to General Services Administration (GSA) and others resulting from changes in rates for office and non-office space estimated by GSA, as well as the rental costs of other currently occupied space. These costs include building security, the case of GSA space, these are paid to DHS. Costs of mandatory office relocations, i.e., relocations in cases where due to external events there is no alternative but to vacate the currently occupied space, are also included.			

Bureau Administrative Costs

Shared Program Costs

The USGS maintains less than one percent of its appropriation for other bureau-wide support and science-related activities. These funds are used for initiatives which may be unfunded mandates, are crosscutting in nature, or respond to new and emerging scientific issues.

The funding for the initiatives in the Shared Program Costs are assessed at the budget activity level, based upon one of two methodologies: proportionately, based on total appropriated funds for the mission area; or proportionately, based on total funds for the mission area, including reimbursable funding sources, and are distributed to the initiatives efficiently. The methodology used is tied to the nature of the initiative. For instance, an initiative that is crosscutting to all the mission areas, but is purely an Interior priority (one in which an external partner is not a stakeholder, nor receives direct benefit of the service) would receive its funding based upon a calculation on appropriated funds only. Conversely, an initiative where all customers of the USGS either directly or indirectly receive benefit, such as the aforementioned information technology compliance and security upgrades, would be calculated to each of the mission areas based upon all funding sources, both appropriated and reimbursable. The initiatives on the Shared Program Cost Chart are vetted each year with the Executive Leadership Team of the USGS, and are decided upon in a voting process to ensure bureauwide concurrence.

The following initiatives are currently planned for the USGS's 2017 Shared Program Costs:

2017 Shared Program Cost Chart (\$000)

Mission Area	Ecosystems	Climate & Land Use Change	Energy, Minerals, and	Natural Hazards	Water Resources	Core Science Systems	Total
Delta Science **	122.3	108.3	73.1	107.4	164.8	86.3	662.1
Grand Canyon Monitoring **	186.0	164.7	111.2	163.4	250.7	131.3	1,007.4
Regional Science **	480.9	426.0	287.6	422.5	648.4	339.5	2,604.8
John Wesley Powell Center **	86.9	76.9	51.9	76.3	117.1	61.3	470.5
International Program **	298.0	263.9	178.2	261.8	401.7	210.3	1,613.8
IT Transformation *	743.2	539.6	319.9	522.3	1,603.1	454.7	4,182.7
Web Re-engineering *	515.3	374.1	221.8	362.1	1,111.5	315.2	2,900.0
Total Program Costs	2,432.4	1,953.5	1,243.8	1,915.8	4,297.3	1,598.5	13,441.4

* Proportionally spread by total funds.

** Proportionally spread by appropriated funds.

Delta Science – The California Bay-Delta is recognized as one of the world's threatened treasures of biodiversity, which supports unique native species and their critical tidal habitats. The USGS participates in the Delta Science Federal-State partnership which coordinates the efforts of 25 State and Federal agencies to improve the quality and reliability of California's water supplies while restoring the Bay-Delta ecosystem. USGS science contributes to restoration challenges such as water supply reliability, water quality, sustainability of native species, and flood risk. This funding is to pay for Program oversight of this crosscut.

Grand Canyon Monitoring – The USGS's Grand Canyon Monitoring and Research Center (GCMRC) is the science provider for the Glen Canyon Dam Adaptive Management Program. In this role, the research center provides the public and decision makers with relevant scientific information about the status and trends of natural, cultural, and recreational resources found in those portions of Grand Canyon National Park and Glen Canyon National Recreation Area affected by Glen Canyon Dam operations.

Regional Science – The implementation of the USGS Science Strategy calls for the integration of the full breadth and depth of USGS capabilities; building on existing strengths and partnerships. To that end, many of the USGS's historical "single-discipline" science centers are now reflections of this science strategy, and perform research and conduct science across many USGS mission areas, and need to respond quickly to new and emerging science issues. This funding brings scientists together to work across teams and across regions, to respond to the Nation's highest and changing priorities, respond to global trends, and conduct the best possible science.

John Wesley Powell Center – The John Wesley Powell Center for Analysis and Synthesis serves as a catalyst for innovative thinking in Earth system science research. Initiated as one means of implementing the USGS Science Strategy, the Powell Center supports scientist-driven interdisciplinary analysis and synthesis of complex natural science problems. USGS scientists are encouraged to propose working groups reflecting a mix of USGS scientists and their colleagues from government and academia focused on major earth science issues. The Powell Center work generates cutting-edge, high-visibility publications.

Sundry Exhibits

International Programs – The Office of International Programs is dedicated to high quality, timely, scientific study that is international in scope and that focuses on the USGS Science Strategy's themes. As one of the world's premier science agencies, the USGS has long recognized the mutual benefits resulting from interaction with scientific partners abroad and extending research and investigations to other countries. By providing reliable scientific information about the Earth and its resources from an international perspective, the USGS Office of International Programs supports US foreign policy and national security; provides a basis for science diplomacy, and improves the scientific basis for managing ecosystems and natural resources.

DOI IT Transformation – This funding will be used to support Interior's efforts in IT Transformation. These funds will support the Department's activities related to data center consolidation, single-source messaging, and cloud-based electronic forms, records, documents and content management solutions.

Web Reengineering – This funding will streamline and organize USGS's web presence to create a more effective and manageable Web presence and to provide Web-enabled technology, real-time access, social and collaborative cloud-based tools, and extensive use of mobile and tablet devices.

Internal Bureau Overhead Cost Allocation Methodology

The USGS manages overhead costs at two levels—the bureau and science center. Bureau level costs include headquarters and area executive, managerial, supervisory, administrative, and financial functions and bureauwide systems. At the bureau level, funding appropriated to the Science Support budget activity pays the bureauwide overhead costs in the same proportion as appropriated funding is to total funding. For this reason, bureauwide overhead costs collected on reimbursable support agreements are deposited within Science Support program areas, as well.

The USGS assesses a bureau overhead rate, estimated to remain at 12 percent, on reimbursable work from non-Interior customers to recoup their share of bureau-level costs. In some cases, the USGS assesses a special or reduced rate when it can be demonstrated that indirect costs are substantially and consistently less than the norm and the amount collected covers the full costs, such as with pass-through funding where the Survey does not perform any of the actual work. The following table shows the funding available to the Science Support program, including the anticipated overhead collections to pay for bureauwide costs.

(Dollars in Thousands)

Source of Funding	2017		2017 Estimated Total
	2017 Budget Request	Estimated Bureau Overhead Distribution	
Science Support			
Administration and Management	86,319	30,810	117,129
Information Services	24,273	8,690	32,963
Total Funding	110,592	39,500	150,092

At the science center level, because there generally is not an appropriated funding source to pay the local overhead (common services) costs, both the appropriated and reimbursable funding are assessed a percentage to cover their share of science center-level costs. Science center common services costs include center costs that are not directly attributable to a specific activity or project, such as managerial, supervisory, administrative, and financial functions and related systems, as well as costs incidental to providing services and products, such as postage, training, miscellaneous supplies and materials. The cost during 2015, for the local overhead, totaled \$205 million from both appropriated and reimbursable funds.

In recognition of the USGS role as the science bureau for the Department of the Interior, the USGS is continuing to give Interior bureaus and offices a "preferred" customer rate on overhead charges for a significant portion of reimbursable work, to the extent that matching funds are available within the USGS budget. The maximum rate that cost centers may charge other Interior bureaus for common services and bureau costs combined remains 15 percent net. In 2015, of the 15 percent, 7.5 percent is applied to bureau costs, and the remaining 7.5 percent is applied to common services costs. Cost centers must fund the common services costs not recovered (e.g., the difference between the cost center's standard common services costs and the 7.5 percent) from USGS appropriated funds. In this way, the USGS is partnering on the science needs of Interior from both the bureau and cost centers.

The Chief Financial Officer establishes the USGS bureau special rate for each fiscal year. The special rate for 2016 is estimated to remain at three percent. Cost centers do not charge more than the bureau special rate for facilities-related costs or their standard common services rate when funding is approved for a bureau-level special rate. Special rates are applied under the following circumstances:

- When the USGS receives funds from a non-USGS organization and awards a grant to a third-party entity.
- When the USGS receives funds from one or more non-USGS organizations to support, under USGS leadership, a strategic science objective that includes the USGS passing through funds to one or more third-party entities.
- When the USGS receives funds from a non-USGS organization for the purpose of the customer acquiring services through the Cartographic Services or the Remotely Sensed Data Contracts. The special rate helps encourage other Federal agencies to use these contracts for cartographic services and remotely sensed data, rather than establishing and managing their own contracts, and ensures greater data consistency through the use of common service providers.
- When the USGS receives funds from a non-USGS organization for the purpose of passing through the customer's funds to State and local governments for the direct purchase of geospatial data.
- Ecosystem's Cooperative Research Units (CRUs) are supported by a three-way partnership including the USGS, a State, and a university. The academic institutions where CRUs are co-located provide significant administrative support. In recognition of the direct services support received from the non-USGS partners, CRUs only recover one-half of the bureau rate (six percent) normally recovered from reimbursable customers or partners.

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Appendix

Alphabetical List of Acronyms

3DEP	3D Elevation Program
AAAS	American Association for the Advancement of Science
AAPG	American Association of Petroleum Geologists
ABC	Activity-Based Costing
ABC/M	Activity-Based Costing/Management
ABP	Asset Business Plan
ACCCNRS	Advisory Committee on Climate Change and Natural Resources Science
ACES	Achieving Cost Efficiencies for Science
ACI	American Competitive Initiative
ACP	Arctic Coastal Plain
ACWI	Advisory Committee on Water Information
ADA	Americans with Disabilities Act
AEI	Administration and Enterprise Information
AFS	American Fisheries Society
AFWA	U.S. Air Force Weather Agency
AMD	Aviation Management Directorate
AMP	Asset Management Plan
AMWG	Adaptive Management Work Group
ANS	Alaska North Slope
ANS	Aquatic Nuisance Species (Ecosystems)
ANSS	Advanced National Seismic System
ANWR	Arctic National Wildlife Refuge
APHIS	Department of Agriculture Animal and Plant Health Inspection Service
API	Asset Priority Index
AR	Accounts Receivable
AR5	5 th Assessment Report
ARMI	Amphibian Research and Monitoring Initiative
ARRA	American Recovery and Reinvestment Act
ASC	Alaska Science Center
ASIWPCA	Association of State and Interstate Water Pollution Control Administrators
AVHRR	Advanced Very High Resolution Radiometer
AVO	Alaska Volcano Observatory
AWiFS	Advanced Wide Field Sensor
BASIS+	Budget and Science Information System
BBL	Bird Banding Laboratory
BBS	Bird Breeding Survey
BEN	Balkan Endemic Nephropathy
BT	Budget Team
BGN	Board of Geographic Names
BIA	Bureau of Indian Affairs
BIMD	Biological Information Management and Delivery
BIP	Biological Informatics Program (Equivalent to BMID)
BIS	Commerce - Bureau of Industry and Security
BLM	Bureau of Land Management
BLT	Business Leaders Team
BMPs	Best Management Practices
BNP	Biscayne National Park
BOR	Bureau of Reclamation

Alphabetical List of Acronyms

BPA	Blank Purchase Agreement
BPC	Bureau Program Council
BPI	USGS Office of Budget, Planning, and Integration
BPXA	BP Exploration (Alaska)
BSR	Business Strategy Review
CA	Condition Assessment
CAC	Civil Applications Committee
CALFED	California Federal (Bay-Delta Authority program)
CAP	Cooperative Agreements Program
CARA	Circum-Arctic Resource Appraisal
C&A	Certification and Accreditation
CC	Cost Center
CBERS	China/Brazil Earth Resources Satellite
CBLCM	Chesapeake Bay Land Cover Management
CBM	Coal bed Methane
CBP	Chesapeake Bay Program
CCI	Collaborative Communications Infrastructure
CCOAT	Coast Chesapeake Online Assessment Tool
CCSP	U.S. Climate Change Science Program
CDC	Centers for Disease Control and Prevention
CDR	Critical Design Review (Climate and Land Use)
CDR	Climate Data Record (Climate and Land Use)
CDI	Council for Data Integration
CEN	Climate Effects Network
CENR	Committee on Environment and Natural Resources
CEAP	Conservation Effects Assessment Project
CEGIS	Center of Excellence for Geographic Information Science
CEOS	Committee on Earth Observation Satellites
CEQ/NSTC	Council on Environmental Quality/National Science and Technology Council
CERC	Columbia Environmental Research Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERP	Comprehensive Everglades Restoration Plan
CESU	Cooperative Ecosystems Study Unit
CFO	Chief Financial Officer
CIO	Chief Information Officer
CISN	California Integrated Seismic Network
CITES	Convention on International Trade in Endangered Species
CLU	Climate and Land Use Change
CMG	Coastal and Marine Geology
CMGP	Coastal and Marine Geology Program
CMSP	Coastal and Marine Spatial Planning
CNS	Central portion of the North Slope
CO ₂	Carbon Dioxide
COAST	Chesapeake Online Adaptive Support Toolkit
CoML	U.S. National Committee for the Census of Marine Life
CORE	Committee on Resource Evaluation
CPIC	Capital Planning and Investment Control
CR	Central Region

Alphabetical List of Acronyms

CRADA	Cooperative Research and Development Agreement
CRSSP	Commercial Remote Sensing Space Policy
CRTF	Coral Reef Task Force
CRU	Cooperative Research Units
CRUISE	Columbia River USGS Integrated Science Explorer
CRV	Current Replacement Value
CRWA	Charles River Watershed Association
CSC	Climate Science Center
CSI	Core Science Informatics
CSIP	Cost Savings and Innovation Plan
CSIRC	Computer Security Incident Response Capability
CSMP	California Seafloor Mapping Program
CSRS	Civil Service Retirement System
CSS	Core Science Systems
CTBTO	Comprehensive Test Ban Treaty Organization
CUES	Comprehensive Urban Ecosystems Studies
CUSEC	Central United States Earthquake Consortium
CVJV	Central Habitat Joint Venture
CVO	Cascades Volcano Observatory
CWD	Chronic Wasting Disease
CWP	Cooperative Water Program
CWS	Canadian Wildlife Service
DCIA	Debt Collection Improvement Act
DEM	Digital Elevation Model
DEP	[State] Department of Environmental Protection
DEQ	[State] Department of Environmental Quality
DFRs	Departmental Functional Reviews
DGH	Indian Directorate General of Hydrocarbons
DHS	Department of Homeland Security
DiGIR	Distributed Generic Information Retrieval
DMC	Data Management Center
DMC	Disaster Monitoring Constellation
DMCI	Deferred Maintenance and Capital Improvements
DNR	Department of Natural Resources
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOGAMI	Oregon Department of Geology and Mineral Industries
DPAS	Data Processing and Archiving
DRAGON	Delta Research and Global Observation Network
DROT	Drift River Oil Terminal
DRTO	Dry Tortugas National Park
DWH	Deepwater Horizon
DSS	Decision Support System
EA	Enterprise Architecture
EAD	Enterprise Active Directory
EAL	Energy Analytical Laboratory
ECMs	Energy Conservation Measures
ECO	Energy Conserving Opportunities

Alphabetical List of Acronyms

ECS	[U.S.] Extended Continental Shelf
ECV	Essential Climate Variable
EDCs	Endocrine Disrupting Chemicals
EDEN	Everglades Depth Estimation Network
EDMAP	Education Mapping Program (in National Cooperative Geologic Mapping Program)
EDRR	Early Detection, Rapid Assessment and Response
EEOC	Equal Employment Opportunity Commission
EFT	Electronic Funds Transfer
EGIM	Enterprise Geographic Information Management
EGS	Enhanced Geothermal Systems
EHP	Earthquake Hazards Program (Hazards Program)
EHP	Enterprise Hosting Platform (AEI)
EI	Enterprise Information
EIR	Enterprise Information Resources
EISA	Energy Independence and Security Act of 2007
EIS&T	Enterprise Information Security and Technology
ELA	Enterprise License Agreement
ELT	Executive Leadership Team
EMEH	Energy and Mineral Resources, and Environmental Health
EMS	Environmental Management System
E.O.	Executive Order
EOL	Encyclopedia of Life
EOP	Executive Office of the President
EOR	Enhanced Oil/Gas Recovery
EPA	U.S. Environmental Protection Agency
EPCA	Energy Policy and Conservation Act of 2000
EPM	Ecosystem Portfolio Model
ER	Eastern Region
ERA	F-Risk Assessment
ERAS	eRemote Access Services
EROS	Earth Resources Observation and Science Center
ERP	Energy Resources Program
ESD	Earth Surface Dynamics
ESI	Environmental Sensitivity Index
ESN	Enterprise Services Network
ESPC	Energy Savings Performance Contract
ESRI	Environmental Systems Research Institute
ET	Evapotranspiration
ETM+	Enhanced Thematic Mapper Plus
EVMS	Earned Value Management System
EWeb	Enterprise Web
FAA	Federal Aviation Administration
FAC	Federal Advisory Committee
FACA	Federal Advisory Committee Act
FAER	Fisheries: Aquatic and Endangered Resources
FASAB	Federal Accounting Standards Advisory Board
FBAT	Facilities Budget Allocation Team
FBMS	Financial Business Management System

Alphabetical List of Acronyms

FBWT	Fund Balance with Treasury
FCI	Facilities Condition Index
FEA	Federal Enterprise Architecture
FECA	Federal Employee Compensation Act
FEDMAP	Federal Lands Mapping Program (in National Cooperative Geologic Mapping Program)
FEGLI	Federal Employees Group Life Insurance
FEHB	Federal Employees Health Benefit
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FERS	Federal Employees Retirement System
FMIA	Federal Financial Management Improvement Act of 1996
FFS	Fire and Fire Surrogate
FGDC	Federal Geographic Data Committee
FICA	Federal Insurance Contributions Act
FICMNEW	Federal Interagency Committee for the Management of Noxious and Exotic Weeds
FISC	Florida Integrated Science Center
FISMA	Federal Information Security Management Act
FMT	Field Managers Team
FMFIA	Federal Managers' Financial Integrity Act of 1982
FMMS	Facilities Maintenance Management System
FOS	Flight Operations Segment
FOT	Flight Operations Team
FRAMES	Fire Research and Management Exchange System
FRB	Federal Reserve Board
FRPC	Federal Real Property Council
FRPP	Federal Real Property Profile
FSA	Farm Service Agency
FSAM	Federal Segment Architecture Methodology
FSP	Fundamental Science Practice
FTE	Full-Time Equivalent
FWS	U.S. Fish and Wildlife Service
GAAP	Generally Accepted Accounting Principles
GAM	Geographic Analysis and Monitoring Program
GAP	Gap Analysis Program
GAO	Government Accountability Office
GBIP	Great Basin Information Project
GBIS	Global Biodiversity Information Facility
GCDAMP	Glen Canyon Dam Adaptive Management Program
GC-IMS	Global Change-Information Management System
GCP	Global Change Program
GCMRC	Grand Canyon Monitoring and Research Center
GEO	Group on Earth Observations
GEODE	GEO-Data Explorer
GeoMAC	Geospatial Multi-Agency Coordination Group
GEOMAG	Geomagnetism Program
GEOSS	Global Earth Observation System of Systems
GFDL	Geophysical Fluid Dynamics Laboratory
GFL	Global Fiducials Library

Alphabetical List of Acronyms

GHG	Greenhouse Gas
GIRT	Geospatial Information Response Team
GIS	Geographic Information System
GLS	Global Land Survey
GLSC	Great Lakes Science Center
GNIS	Geographic Names Information System
GOES	Geostationary Operational Environmental Satellites
GOS	Geospatial One-Stop
GPRA	Government Performance and Results Act
GRB	Green River Basin
GHG	Greenhouse Gas
GPS	Global Positioning System
GPSC	Geospatial Products and Services Contract
GSA	General Services Administration
GS-FLOW	Groundwater and Surface-water flow model
GSN	Global Seismographic Network
GWRP	Ground-Water Resources Program
HAZUS	Federal Emergency Management Agency's Earthquake Loss Estimation Program
HBN	USGS Hydrologic Benchmark Network
HDOA	Hawaii Department of Agriculture
HDR	High-Data Rate Radio
HEDDS	Highly Pathogenic Avian Influenza Early Detection Data System
HDDS	Hazards Data Distribution System
HHS	Department of Health and Human Services
HIF	Hydrologic Instrumentation Facility
HLI	Healthy Lands Initiative
HNA	Hydrologic Networks and Analysis Program
HPO	High Performing Organization
HPPG	High Priority Performance Goal
HR	Human Resources
HR&D	Hydrologic Research and Development Program
HRS	Helibourne electromagnetic Surveys
HSPD-12	Homeland Security Presidential Directive 12
HUB	Historically Underutilized Business
HUD	US Department of Housing and Urban Development
HVO	Hawaii Volcano Observatory
HWATT	Hemlock Woolly Adelgid Action Team
I&M	Inventory and Monitoring – NPS
IAGA	International Association of Geomagnetism and Aeronomy
ICAO	International Civil Aviation Organization
ICL	International Consortium on Landslides
ICRP	Internal Control Review Plan
ICWP	Interstate Council on Water Policy
IDWR	Idaho Department of Water Resources
IEAM	Integrated Environmental Assessment and Management
IGPP	Institute for Geophysics and Planetary Physics
IIE	Integrated Information Environment
ILM	Integrated Landscape Monitoring

Alphabetical List of Acronyms

IOOS	Integrated Ocean and coastal Observing System
IP	Investment Plan
IPCC	Intergovernmental Panel on Climate Change
IPDS	Information Product Data System
IRB	Investment Review Board
IRIS	Incorporated Research Institutions for Seismology
IRS	Indian Remote Sensing Satellite
InSAR	Interferometric Synthetic Aperture Radar
ISO	International Organization for Standardization
ISSP	Information Security Strategic Plan
IT	Information Technology
ITAP	Invasive Terrestrial Animals and Plants
ITILOB	Information Technology Infrastructure Line of Business
ITIS	Integrated Taxonomic Information System
ITSOT	IT Security Operations Team
ITSSC	IT Security Steering Committee
ITT	Information Technology Transformation
IUCN	International Union for the Conservation of Nature
IUCN	International Union of Conservation Nations
JFA	Joint Funding Agreement
JV	Joint Venture Partnerships
KSF	Thousand Square Feet
LAS	Local Action Strategy
LCAT	Land Cover Analysis Tool
LCC	Landscape Conservation Cooperatives
LCS	Land Change Science Program
LDCM	Landsat Data Continuity Mission
LDGST	Landsat Data GAP Study Team
LEAG	Long-term Estuary Assessment Group
LHP	Landslide Hazards Program
LiDAR	Light Detecting and Ranging
LIFE	NBII Library of Images from the Environment
LIMA	Landsat Image Mosaic of Antarctica
LMV	Lower Mississippi Valley
LMVJV	Lower Mississippi Valley Joint Venture Office
LOA	Level of Authentication
LRS	Land Remote Sensing
LSC	Leetown Science Center
LST	Landsat Science Team
LTRMP	Long-Term Resource Monitoring Program
LTWG	Landsat Technical Working Group
LUPM	Land Use Portfolio Model
MARCO	Mid-Atlantic Research Consortium for Oceanography
MBTU	Million British thermal units
MD	Management Directive
MEO	Most Effective Organization
METRIC	Mapping EvapoTranspiration with high Resolution and Internalized Calibration
MHDP	Multi-Hazards Demonstration Project

Alphabetical List of Acronyms

MMS	Minerals Management Service
MOA	Memorandum of Agreement
MOC	Mission Operations Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MODFLOW	Modular Ground-Water Flow Model
MOU	Memorandum of Understanding
MRBI	Mississippi River Basin Healthy Watersheds Initiative
MRDS	Mineral Resources Data System
MRERP	Mineral Resources External Research Program
MRLC	Multi-Resolution Land Characteristics Consortium
MRP	Mineral Resources Program
MSCP	Multi-Species Conservation Program
MSH	Mount St. Helens
MSS	Multi Spectral Scanner
MTBE	Methyl Tert-Butyl Ether
MTBS	Monitoring Trends in Burn Severity
MUSIC	MIT-USGS Science Impact Collaborative
MW	Megawatt
MWE	Megawatt electric
NABCI	North American Bird Conservation Initiative
NACO	National Association of Counties
NADP	National Atmospheric Deposition Program
NAGT	National Association of Geoscience Teachers
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act
NARA	National Archives and Records Administration
NAS	National Academy of Sciences (Core Science)
NAS	USGS National Non-indigenous Aquatic Species Database (Ecosystems)
NASA	National Aeronautics and Space Administration
NASQAN	National Stream Quality Accounting Network
NatWeb	National Web Server System
NAWQA	National Water-Quality Assessment
NBC	Department of the Interior – National Business Center
NBII	National Biological Information Infrastructure
NCA	National Climate Assessment
NCAR	National Center for Atmospheric Research
NCAP	National Civil Applications Program
NCCWSC	National Climate Change and Wildlife Science Center
NCDE	Northern Continental Divide Ecosystem
NCEP/NOAA	National Centers for Environmental Prediction
NCGMP	National Cooperative Geologic Mapping Program
NCIA	National Competitiveness Investment Act
NCPP	USGS National Coastal Program Plan
NCRDS	National Coal Resources Data System
NDMC	National Drought Mitigation Center
NDOP	National Digital Orthoimagery Program
NED	National Elevation Dataset
NEHRP	National Earthquake Hazards Reduction Program
NEIC	National Earthquake Information Center

Alphabetical List of Acronyms

NEON	National Ecological Observatory Network
NEPA	National Environmental Policy Act
NEST	National Environmental Status and Trends
NETL	National Energy Technology Laboratory
NFHAP	National Fish Habitat Action Plan
NGA	National Geospatial-Intelligence Agency
NGAC	National Geospatial Advisory Committee
NGGDPP	National Geological and Geophysical Data Preservation Program
NGIC	National Geomagnetic Information Center
NGMA	National Geologic Mapping Act
NGMDP	National Geologic Map Database Project
NGO	Nongovernmental organization
NGP	National Geospatial Program
NGWMN	National Ground Water Monitoring Network
NHD	National Hydrography Dataset
NHWC	National Hydrologic Warning Council
NIEHS	National Institute of Environmental Health Sciences
NIFC	National Interagency Fire Center
NIH	National Institute of Health
NISC	National Invasive Species Council
NISS	National Institute for Invasive Species Science
NISMP	National Invasive Species Management Plan
NIST	National Institute of Standards and Technology
NIWR	National Institutes for Water Resources
NLC	National League of Cities
NLCD	National Land Cover Database
NLIC	National Landslide Information Center
NLIP	National Land Imaging Program
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NORTHCOM	U.S. Northern Command
NOSC	National Operations and Security Center
NPN	National Phenology Network
NPRA	National Petroleum Reserve Alaska
NPS	National Park Service
NRDA	Natural Resource Damage Assessment
NRIS	Natural Resource Information System
NRC	National Research Council (United States National Academies)
NRC	Nuclear Regulatory Commission (United States NRC)
NRCS	Natural Resources Conservation Service
NRMP	National Resource Monitoring Partnership
NROC	Northeast Regional Ocean Council
NRP	National Research Program (research organization in USGS Water Resources)
NRPP	National Resource Preservation Program
NSDI	National Spatial Data Infrastructure
NSF	National Science Foundation
NSGIC	National States Geographic Information Council
NSIP	National Streamflow Information Program

Alphabetical List of Acronyms

NSLRSDA	National Satellite Land Remote Sensing Data Archive
NSMP	National Strong Motion Program
NSPD	National Space Policy
NSTC	National Science and Technology Council
NSVRC	Northern Shenandoah Valley Regional Commission
NTN	National Trends Network
NVCS	National Vegetation Classification Standard
NVEWS	National Volcano Early Warning System
NWAVU	National Water Availability and Use Assessment
NWHC	National Wildlife Health Center
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
NWQMN	National Water Quality Monitoring Network
NWRC	National Wetlands Research Center
NWS	National Weather Service
O&M	Operations and Maintenance
OAEI	Office of Administration and Enterprise Information
OAFM	USGS Office of Accounting and Financial Management
OAG	USGS Office of Acquisition and Grants
OAP	Ocean Action Plan
OBIS	Ocean Biogeographic Information System
OBIS	USGS Office of Business Information Systems, (AEI)
OCAP	USGS Office of Communication and Publications
OED	Office of Employee Development
OEPC	Office of Environmental Policy and Compliance
OES	Office of Emergency Services
OFDA	Office of Foreign Disaster Assistance
OFEE	Office of the Federal Environmental Executive
OFR	Open-File Report
OGC	Open Geospatial Consortium
OHC	USGS Office of Human Capital
OIA	Office of Insular Affairs
OICR	USGS Office of Internal Control and Reporting
OIG	Office of the Inspector General
OGDB	Organic Geochemistry Database
OLI	Operational Land Imager
OMB	Office of Management and Budget
OMS	USGS Office of Management Services
OPA	USGS Office of Policy and Analysis
OPM	Office of Personnel Management
ORPP	Ocean Research Priority Plan
ORPPIS	Ocean Research and Priorities Plan and Implementation Strategy
OSHA	Occupational Safety and Health Administration
OSM	Office of Surface Mining
OSQI	Office of Science Quality and Integrity
OSTP	Office of Science and Technology Policy
OWRS	Office of Western Regional Services
PAGER	Prompt Assessment of Global Earthquakes for Response

Alphabetical List of Acronyms

PBO	Plate Boundary Observatory
PBX	Private Branch Exchange
PCR	Polymerase Chain Reaction
PDA	Personal Digital Assistant
PDF	Portable Document Format
PDR	Preliminary Design Review
PES	Priority Ecosystem Science
PFM	(Department) Office of Financial Management
PI	Principal Investigator
PII	Personally Identifiable Information
PIP	Performance Improvement Plan
PIP	Program Improvement Plan
PMO	Project Management Office
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
POA&M	Plan of Action and Milestone
PP&E	Property, Plant, and Equipment
PRB	Powder River Basin
PSNER	Puget Sound Near Shore Ecosystem Restoration
PSS	Perimeter Security Standard
PTWC	Pacific Tsunami Warning Center
PWRC	Patuxent Wildlife Research Center
QOL	Quality of Life
R&D	Research and Development
RASA	Regional Aquifer-System Analysis
RCM	Regional Climate Models
RCOOS	Regional Coastal Ocean Observing Systems
REE	Rare Earth Elements
REMS	River Ecosystem and Modeling Science
RFP	Request for Proposal
RGIO	Regional Geospatial Information Office®
RIF	Reduction in Force
RIM	River Input Monitoring Program
RISA	Regional Integrated Science and Assessments – NOAA
RPM	Real Property Management System
RSAC	Remote Sensing Application Center
RSSI	Required Supplementary Stewardship Information
RTS	Reports Tracking System (Water Resources)
R/V	Research Vessel
RWRPC	Regional Water Resources Policy Committee
S&T	USGS Status and Trends Program
SAC	Stakeholder advisory Committee (Climate and Land use)
SAC	USGS Science Advisory Council
SAFOD	San Andreas Fault Observatory at Depth
SAFRR	Science Application for Risk Reduction
SAIN	Southern Appalachian Information Node
SAP	Synthesis and Assessment Product
SAR	Synthetic Aperture Radar
SAUS	Storage Assessment Units

Alphabetical List of Acronyms

SBFD	San Francisco Bay and freshwater delta
SBSP	South Bay Salt Pond Restoration Project
SCEC	Southern California Earthquake Center
SCR	System Concept Review
SDI	Spatial Data Infrastructures
SDR	Subcommittee for Disaster Reductions
SDRT	Supervisory Development Review Team
SES	Senior Executive Service
SETAC	Society of Environmental Toxicology and Chemistry
SFBD	San Francisco Bay Delta
SFMP	Strategic Facilities Master Plan
SFWMD	South Florida Water Management District
SHC	Strategic Habitat Conservation
SLC	Scan Line Corrector
SGL	Standard General Ledger
SIR	Surveys, Investigations, and Research
SOGW	Subcommittee of Ground Water
SoIVES	Social Values for Ecosystem Services
SOW	Statement of Work
SPARROW	Spatially Referenced Regressions on Watershed Attributes
SPN	Scientific Publishing Network
SPOC	Security Point of Contact
SPOT	Satellite Pour L'Observation de la Terre
SPRESO	South Pole Remote Earth Science Observatory
SRR	Systems Requirement Review
SRTM	Shuttle Radar Topographic Mission
SSRIs	Selective Serotonin Reuptake Inhibitors
STATEMAP	State Mapping Program (in Cooperative Geologic Mapping Program)
STEM	Science, Technology, Engineering and Mathematics
STIG	Security Technical Implementation Guides
SWPC	Space Weather Prediction Center
TAA	Technical Assistance Agreements
TANC	Transport of Anthropogenic and Natural Contaminants
TCOM	Tahoe Constrained Optimization Model
TDWG	Biodiversity Information Standards
TIC	Trusted Internet Connection
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TMDL	Total Maximum Daily Loads (Clean Water Act requirement)
TRIGRS	Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability Analysis
TRIP	The Road Indicator Project
TROR	Treasury Report on Receivables
TRPA	Tahoe Regional Planning Agency
TSP	Thrift Savings Plan
UAS	Unmanned Aircraft Systems
UHM	University of Hawaii-Manoa
UIC	Underground Injection Control
URISA	Urban and Regional Information System Association

Alphabetical List of Acronyms

U.S.	United States
USACE	U.S. Army Corps of Engineers
USAID	U.S. Agency for International Development
U.S.C.	United States Code
USDA	U.S. Department of Agriculture
USDOE	U.S. Department of Energy
USFS	U.S. Forest Service
USGCRP	U.S. Global Change Research Program
USGEO	U.S. Group on Earth Observations
USGS	U.S. Geological Survey
UMESC	Upper Midwest Environmental Services Center
USNG	United States Nation Grid
VANS	Volcano Activity Notices
VBNS	Very Broadband Network Services
VCP	Vegetation Characterization Program
VDAP	Volcano Disaster Assistance Program
Veg	Vegetation Characterization
VegDRI	Vegetation Drought Response Index
VHP	Volcano Hazards Program
VHSV	Viral Hemorrhagic Septicemia Virus
VOIP	Voice over IP Systems
VONA	Volcano Observatory Notifications for Aviation
VSIP/VERA	Voluntary Separation Incentive Payment/Voluntary Early Retirement Authority
VTC	Video Teleconferencing
WAN	Wide Area Network
WCCI	Wyoming Cooperative Conservation Initiative
WCF	Working Capital Fund
WCMC	UNEP-World Conservation Monitoring Center
WERC	Western Ecological Research Center
WFRC	Western Fisheries Research Center
WLAN	Wide Local Area Network
WLCI	Wyoming Landscape Conservation Initiative
WNS	White-Nose Syndrome
WNV	West Nile Virus
WPA	World Petroleum Assessment 2000
WR	Western Region
WRIR	Water Resources Investigation Report
WRRRA	Water Resources Research Act
WRRIs	[State] Water Resources Research Institutes
WSC	[USGS State] Water Science Center
WSWC	Western States Water Council
WTER	Wildlife: Terrestrial and Endangered Resources
WUI	Wildland-Urban Interface
YMP	Yucca Mountain Program
YVO	Yellowstone Volcano Observatory

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