Running Water:

Balancing Water Supply and Flow in the Hunt River

By

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B.A., Brandeis University, 1999

Thesis

Submitted in partial fulfillment of the requirements for the Degree of Master of Arts in the Program in Environmental Studies at Brown University

PROVIDENCE, RHODE ISLAND

MAY 2005

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EXECUTIVE SUMMARY

This thesis addresses the question: How can a balance be struck between supply and flow in the Hunt River?

The Hunt borders three towns in central Rhode Island. It is connected through groundwater to its neighboring basins, the Annaquatucket and Pettaquamscutt. However, according to the United States Geological Survey (USGS) withdrawals from wells in the Hunt have a negligible effect on the streamflow of the other two rivers. Since I am examining the relationship between supply and flow I will be looking solely at the Hunt River.

Several pieces of evidence suggest that flows in the Hunt are already compromised. In a 2001 study, USGS found that withdrawals from the Hunt River wells caused significant depletion in the summer months. The wells also caused the normal groundwater discharge from the aquifer to the river to reverse, with a further loss of water to the river. I conducted a 7Q10 analysis (the seven consecutive day low flow that occurs once in ten years) to characterize the river's flows during the dry summer months. The Hunt's measured 7Q10 is 1.63 cfs from 1940 – 2003, the period of record of the USGS streamgage on the lower reaches of the river. I used an equation developed by USGS to calculate 8.2 cfs as the potential 7Q10, i.e. what the 7Q10 would be without withdrawals. The difference, 6.57 cfs, is close to the average amount withdrawn in July 6.43 cfs (4.15 MGD). Flows are below the potential 7Q10 48% of the time in August and September when by definition the flow should be at the 7Q10 for seven continuous days once every ten years. I compared the Hunt's flows to the Rhode Island Aquatic Base Flow (RIABF) numbers for unregulated coastal lowlands, a median figure. An unregulated stream is one that has no withdrawals, while wells have pumped from the Hunt since 1943. The Hunt's flows were below the ABF 49% of the time, as expected statistically. However, in the summer months the Hunt was below the ABF 66% of the time. This indicates that the river can maintain normal flow patterns during the wet fall, winter, and spring, when people use less water and streamflows are higher. The drier summer climate with full evapotranspiration from trees creates lower flows naturally. At the same time more water is demanded from the communities causing the flow in the river to be severely reduced.

The Rhode Island Department of Environmental Management (RIDEM) conducted a fish survey in the Hunt in the summers of 1997 and 2004. The survey found minimal representation of fluvial dependent species in the lower Hunt and concluded that the habitat degradation is due to groundwater withdrawals.

Three public suppliers maintain seven wells adjacent to the Hunt River. North Kingstown's Water Department has three wells which withdraw an average of 1.2 MGD in the fall, winter, and spring and an average of 2 MGD in the summer. These wells provide an average of 50% of the town's water. The Rhode Island Economic Development Corporation (RIEDC) has three wells which supply an average of 0.7 MGD to the Quonset Davisville Port and Commerce Park. Kent County Water Authority (KCWA) has a single well which provides an average of 0.65 MGD, about 5% of total company supply.

The neighboring communities of the Hunt Aquifer have attempted to find regional solutions to protect their shared water supply, but thus far efforts have not been successful. The Hunt Wellhead Protection Committee, comprised of representatives from the suppliers and the major towns within the basin, disbanded in 2002. The Town Councils of Warwick and East Greenwich did not pass zoning legislation to protect the water supply wells. North Kingstown adopted protective zoning prior to the formation of the committee.

Residents of North Kingstown use almost double the amount of water in the summer than in the winter, and summertime use is increasing without further development. The Water Department and Town Council have tried to reduce demand through implementation of an odd/even day watering schedule every summer and through an educational campaign, but these efforts have had no noticeable effects.

RIEDC plans to further develop Quonset and projects a demand of almost 3.6 MGD at full buildout. Within the pumping capacity of their wells, RIEDC believes that this amount is available for their use, primarily due to a consultant's error in estimating the safe yield from the Hunt basin.

In 1968 USGS reported on the sustained yield of the wells in the Hunt Aquifer. They found that the wells can withdraw 8 MGD without drying out, but note that withdrawals at this rate would cause large portions of the river to run dry for up to 160 days of the year in drier years. In 1995 the Hunt River stakeholders commissioned a project to detail all aspects of the basin. This study reported that 8 MGD was the safe yield of the Hunt and could be withdrawn without harm to streamflow, citing the 1968 USGS report. North Kingstown and RIEDC have relied on the 1995 report and believe that 8 MGD is the safe yield of the Hunt. They use this figure, citing the 1968 study, in their Water Supply System Management Plans and in the Quonset Master Plan.

From my research and analysis, I believe that the Hunt is already stressed. Flows are already low in the summer and, according to the DEM, the lower Hunt does not support fluvial species. Withdrawals are high in relation to USGS's estimation of safe yield and two out of three suppliers are projecting increases in water use. To complicate matters, the suppliers believe that more water exists in the Hunt than can be withdrawn without further decreasing river flow.

North Kingstown, RIEDC, and the state agencies of Rhode Island should take measures to ensure that withdrawals not increase from existing wells in the Hunt. If possible, summer flow should be restored to support fluvial species in the lower reaches of the river.

The RIEDC should upgrade conservation measures and use treated wastewater at least to irrigate their golf course and possibly in other ways. If growth continues at Quonset as projected a new supply source will be required. Water may exist for purchase from neighboring communities, but RIEDC will likely need a new well. USGS suggests that the lower Annaquatucket basin may be a good place for this new source.

North Kingstown should implement demand management strategies to reduce summertime use in the Hunt. Many alternatives could accomplish this goal; possibilities include placing an absolute cap of water use on residents per person per day, offering tax breaks for low water-use lawns, and raising water rates to financially support the supplier in these endeavors.

The DEM and the Water Resources Board (WRB) should set watershed specific streamflow standards. The DEM should take regulatory action to protect the Hunt regardless of when flow standards are set through their capacity to protect water quality. The WRB should allocate the Hunt River water and work with North Kingstown to reduce summer demand and the RIEDC to find an alternative supply. The WRB also approves the Water Supply System Management Plans and should require amendment of North Kingstown and RIEDC's plans to reflect an accurate safe yield estimate. According to USGS the Hunt safe yield is in the range of 2.34 – 4.81 MGD. The Rivers Council should support efforts by the DEM and WRB and engage the community in activism directed towards protecting the Hunt with the eventual goal of establishing a Watershed Council.

The combination of efforts from all stakeholders will guarantee that adequate supply exists for human needs and for the aquatic community in the Hunt.

ACKNOWLEDGEMENTS

This thesis could never have been completed without assistance from many people. I especially wish to thank my advisor, Harold Ward, for helping to conceive of this project, pushing it in the right direction, talking me down from every crisis, and sharing your wisdom.

Endless thanks to Kathy Crawley and Alisa Richardson, my committee. Kathy, I am grateful to you for sharing your knowledge of everything water, for your patience, and for your willingness to confront the challenges inherent in the process of water allocation. Alisa, this report would never have been written without your technical support, constant enthusiasm, good will and spirit, and innovative explanations.

Thank you to the faculty at the Center for Environmental Studies. I feel honored to have learned from you for the past two years. I especially wish to thank Caroline Karp and Don Pryor who helped me to develop this project and to look at ideas in new ways.

This thesis could never have been completed without help from many individuals working on water supply in Rhode Island. Particular thanks to Susan Licardi, Dale Grogan, and Marilyn Cohen, from North Kingstown, Bill Harritos and Geoff Grout, from RIEDC, Meg Kerr, from Rhode Island Rivers Council, Beverly O'Keefe, from the Water Resources Board, Jim Campbell, from USGS, Veronica Masson, from U.S. Fish and Wildlife, all the members of the Streamflow Working Group, and our Water Working Group.

Thank you to my family and friends. This program would have been a lot harder if I didn't have all of you to complain to. Mom and Dad, I am forever grateful for all your love and support and am always proud to be your daughter. Jason and Lizzie, you are both light and grounded and it keeps me going. To Mica. To my rocks, Jessica, Carrie, Shirley, Amy, Kristine, and Shane you are the world. CES crew, what a ride, Erin, Ben, Nick, Karen, and Chris, maybe I could have pulled this off without you, but I would not want to try.

I dedicate this thesis to my fellow environmental soldiers striving to find a way to coexist in peace with the natural world.

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In this world there is nothing softer
or thinner than water
But to compel the hard and unyielding,
It has no equal.
That the weak overcomes the strong,
That the hard gives way to the gentle–
This everyone knows,
Yet no one acts accordingly.

—Lao Tzu,
6th c. B.C.E.

I: INTRODUCTION

This thesis explores the question: How can a balance be struck between water supply and flow in the Hunt River? Located in central Rhode Island, three public water supply companies maintain wells within the Hunt watershed. State agencies have expressed concern over health of the aquatic community in the river due to low flows resulting from high withdrawals during the summer. The Hunt is a finite resource and human needs are increasing in the region. Throughout this thesis I examine current flow conditions, human needs, the politically charged nature of this water supply, how these issues relate to each other, and finally recommend solutions. I believe that the suppliers, municipalities, and state should act now to ensure that adequate flows exist to support a more diverse and natural riverine community in the lower Hunt.

State of the Hunt River

Geography

This project focuses on water supply in the Hunt River watershed in central Rhode Island. The Hunt aquifer has a groundwater connection to the neighboring basins of the Annaquatucket and Pettaquamscutt. Together the Hunt-Annaquatucket-Pettaquamscutt basin is known as the HAP. In recent times, the United States Geological Survey (USGS) classified the HAP as a single entity due to an interchange of groundwater.[1] However they found that withdrawals in one basin have negligible effects on the streamflow in the other two basins. Because of this, for my purposes in examining the effects of withdrawals on Hunt River flows, I will discuss the Hunt as a separate entity.

The Hunt River comprises the boundary between North Kingstown and East Greenwich and, further downstream, the border between North Kingstown and the Potowomut section of Warwick. Several large tributaries contribute to the Hunt's flow, including the Fry Brook, the Mawney Brook, the Frenchtown Brook, the Scrabbletown Brook, and the Sandhill Brook. There are also some unnamed tributaries.

Most of the Hunt's 22.9 square mile watershed covers East Greenwich and the northern portion of North Kingstown. Portions of the drainage basin also cover Potowomut, Warwick, and touch West Warwick, West Greenwich, Coventry, and Exeter, in central Rhode Island.

The river and the aquifer flow from the west to the east and drain into Narragansett Bay just south of Greenwich Bay.[2] When the Hunt becomes tidal, it is known as the Potowomut River.

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[1] Barlow, Paul M. and David C. Dickerman. 2001. Numerical-Simulation and Conjunctive Management Models of the Hunt-Annaquatucket-Pettaquamscutt Stream-Aquifer System, Rhode Island. U.S. Geological Survey Professional Paper 1636, 88 p. Online: (http://water.usgs.gov/pubs/pp/pp1636/)

[2] Ibid.

Figure 1: The Hunt Watershed in Rhode Island

Figure 2: The Towns of the Hunt Watershed

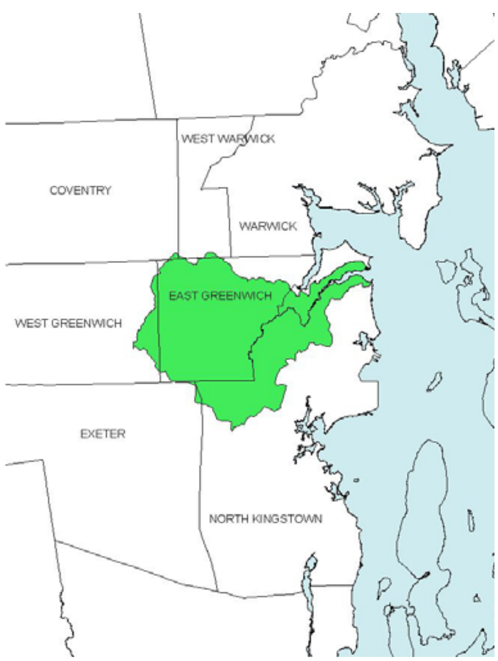

Figure 3: The Hunt River and its Tributaries

The region surrounding the headwaters of the Hunt is suburban residential, but the mid-course of the river passes through a more commercial district. The Hunt flows under Routes 4 and 2, two major roadways in the area, and passes by strip-malls and other commercial buildings. In the lower reaches the surrounding areas are appropriately classified as suburban residential again.

The majority of the Hunt watershed consists of forest (37.9%) and residential (26.9 %) land use. Wetlands (16.1%), agricultural (5.1 %), transportation (2.3%), and industrial (2.3%) components contribute to the subbasin land use.[3]

The Rhode Island Department of Environmental Management (RIDEM) classifies the Hunt as Class B[4], suffering from pathogen impairments[5]—and considers it Group 1, which is the highest priority for attention from the agency. The TMDL study, a plan to reduce pathogen loads, was completed in February, 2001.[6]

The United States Environmental Protection Agency (USEPA) has designated the HAP as a "Sole Source Aquifer," since there is no alternative supply available to the region.[7]

Withdrawals

There are three different water supply companies with seven wells adjacent to the Hunt River. The Rhode Island Economic Development Corporation (RIEDC) withdraws

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[3] Nimiroski, Mark T. and Emily Wild. 2004. Water Use and Availability in the West Narragansett Bay Study Area, Coastal Rhode Island. DRAFT. USGS.

[4] Class B- These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquaculture uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.
From: Rhode Island Department of Environmental Management (RIDEM). August 6, 1997 (promulgated). Water Quality Regulations. Online: (http://204.139.0.230/pubs/regs/regs/water/h20qlty.pdf)

[5] RIDEM. Office of Water Resources (OWR). February, 2005. State of Rhode Island, 2004 303(d) List, List of Impaired Waters. Draft. Online: (http://www.state.ri.us/dem/pubs/303d/303d04.pdf)

[6] RIDEM. OWR. February, 2001. Fecal Coliform TMDL Development for Hunt River, Rhode Island. Final Report.

[7] North Kingstown Department of Water Supply. Online: (http://www.northkingstown.org/waterdept/default.htm)

an average of 0.7 MGD from its three wells to supply 100% of the water for Quonset Davisville Port and Commerce Park, an industrial and commercial park in North Kingstown.

Kent County Water Authority (KCWA) withdraws an average of 0.65 MGD from its single well on the Hunt River. This supply represents about 5% of total company needs. KCWA provides water to residential and commercial users throughout Kent County.

North Kingstown's Department of Water Supply withdraws an average of 1.2 MGD during September through May and an average of 2 MGD in the summer from its three wells along the Hunt. This water, along with supply from the town's eight other wells in the Annaquatucket and Pettaquamscutt basins, serves approximately 9,000 customers in North Kingstown.[8] The Hunt wells provide an average of 50% of the Town's water (44 - 59%) each month.

Demand is projected to increase in North Kingstown due to increasing summertime use and at Quonset Point to 3.6 MGD due to development.

Withdrawal versus consumption

The majority of customers in the North Kingstown and Kent County service areas maintain on-site septic systems for waste disposal. Septic systems return 85 – 90% of

[8] Ibid.

water back to the system[9] and if the homes overlay the Hunt basin the water is returned to the aquifer. This water was withdrawn from the wells, but not consumed.

All clients serviced by RIEDC and the remainder of KWCA and NK residents are sewered and discharge to the Quonset Point Wastewater Treatment Facility. This water is consumed since it is transferred out of the basin. Also, water is consumed when used by residents with septic systems that don't overlay the Hunt. North Kingstown uses the majority of Hunt water, but most of the Town does not overlay the Hunt. All of RIEDC's withdrawals and some of KCWA's withdrawals are returned outside the Hunt basin. Therefore, most of the Hunt water withdrawn is also consumed.

The Hunt is delicious!

On March 18, 2005 The Providence Journal reported that North Kingstown well 10, adjacent to the Hunt River, was named the best tasting water in the sixth-annual Rhode Island taste-test. As of writing this, the Hunt River water will soon compete in Washington D.C. in the national water taste-test competition.[10]

Streamflow

USGS has maintained a streamgage in the lower reaches of the Hunt since 1940 which records average daily flow in the river. A recent USGS study showed ways to

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[9] Alisa Richardson, Principal Sanitary Engineer, OWR, RIDEM, April 12, 2005. Personal communication (email).

[10] Gedan, Benjamin N. 2005. "North Kingstown water worth raising a glass for." The Providence Journal, Providence. Online: (http://www.projo.com/westbay/content/projo_20050318_w16water.14dd87919.html)

increase withdrawals to the Annaquatucket and Pettaquamscutt Rivers to relieve pressure on the Hunt, due to concerns that withdrawals were depleting the Hunt's flow by the Rhode Island Department of Environmental Management and the Rhode Island Water Resources Board.[11] Though many have spoken of their concern off the record, in meetings or other informal means, there has been only one official document attesting to degraded conditions of the aquatic community in the Hunt.

RIDEM's Division of Fish and Wildlife conducted a survey of the fish in the Hunt in 1997 and 2004.[12] The study concludes that the condition of the fish community in the lower reaches of the Hunt is degraded, but because of an impoundment creating Potowomut Pond, more research is needed to demonstrate what portion of degradation is caused by public supply withdrawals and what portion is caused by the dam or other outside effects.

I conducted analyses of the USGS gage data and found that flows were much lower than they would be if the stream was unregulated during the times of highest stress and lower than average during the summer months.

Thesis Question

In this thesis I examine the question: How can a balance be struck between water supply and flow in the Hunt River? Several communities rely on the Hunt Aquifer for

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[11] Barlow and Dickerman. 2001.

[12] Masson, Veronica J. 2004. Hunt River Watershed Preliminary Target Fish Community Survey. RIDEM Division of Fish and Wildlife.

supply, North Kingstown, Quonset Point, Kent County, and the fish and other aquatic life in the river. The Hunt is a finite resource, human needs are increasing, and there is evidence that the lower reaches cannot support fluvial species. By taking action now the suppliers, municipalities, and state can ensure that enough water will be available to provide for health, safety, welfare, business, and the riverine community.

Methodology

Research

In the process of answering my question I reviewed previous studies and documents regarding Rhode Island's water supply in general and, specifically, the Hunt watershed. I read several studies from USGS and studies commissioned from private engineering firms, and documents generated by other state and federal agencies. I reviewed state laws and regulations with regard to water supply and state-mandated documents such as Water Supply System Management Plans and the Quonset Master Plan. I looked at documents and policies generated from other states for comparison and alternative ideas.

The Rhode Island office of the USGS was commissioned by the Water Resources Board to study the water availability and use in each watershed in the state to fulfill the

Board's statutory requirement to inventory and allocate the state's water resources.[13] I attended presentations about their methods and findings in regard to various watersheds.

Data Analysis

I gathered three different data sets to supplement my research. I obtained all available withdrawal records from each well within the bounds of the Hunt watershed. There were periods of missing data from two of North Kingstown and Rhode Island Economic Development Corporation's wells so I estimated the missing data using monthly withdrawal averages from the appropriate years before and after the gaps. A detailed description of this process can be found in Appendix 1.

I utilized daily flow data recorded by the USGS streamgage that has been in place in the lower Hunt since 1940. From these data I generated a 7Q10 and ABF analysis as well as compared flows to withdrawals. I also obtained precipitation records to compare with the flow and withdrawal data.

I created every map depicted within this thesis using Arc View, a geographic information system program, from RIGIS data. I used Kaleidagraph to generate the graphs presented.

Interviews

In the process of developing and exploring this project I conversed with local and state officials concerned with the Hunt Aquifer and Rhode Island's water in general. The

[13] Rhode Island General Laws § 46-15.7.3 Online: (http://www.rilin.state.ri.us/Statutes/TITLE46/46-15.7/46-15.7-3.HTM)

discussions were conducted as formal interviews, over the phone, and via email through the course of my project. These meetings proved valuable to understanding not only the history of water supply in the region, but also the sensitive politics involved, since some of the more politicized issues are not documented in any official capacity. I believe that it was only through speaking with the community that my understanding of the complexity of the watershed issues developed.

Statewide Water Allocation Process

Through the course of this project I had the great privilege to sit in on Rhode Island water allocation meetings. When I began exploring topics for this thesis Rhode Island was in the thick of stakeholder meetings intended to develop a system to manage the state's water supply, known as the Water Allocation Program Advisory Committee (WAPAC), and led by the RI Water Resources Board (WRB). I began attending these monthly meetings and was immediately immersed in the topic of Rhode Island water supply. The WAPAC process continued through the spring of 2004, when each subcommittee presented a final report and the stakeholders, over two meetings, met to discuss and finalize recommendations.

After the completion of WAPAC, the WRB began to initiate the process of allocating water through the Rhode Island Water Management System Implementation Team, which met from June through December 2004. The Implementation Team was also comprised of stakeholders, though a more technical group and including local planners. I had the benefit of attending these meetings as well. The team focused on allocating the water in the Blackstone River basin, to create a system applicable to every watershed in the state.

I also attended meetings of WAPAC's Streamflow Subcommittee. This committee examined flow standards and identified data gaps, such as streams that needed gaging. The group continued to meet, though sporadically, after WAPAC concluded with the long term goal of setting specific flow standards for each watershed in Rhode Island. The group is a collaboration of the DEM, WRB, and USGS with input from other stakeholders.

Water Working Group

In the fall of 2004, five members of the Center for Environmental Studies community formed a water working group. The group included two master's students, Erin Bray and myself, and an undergraduate, Alexandra Coria. Professors Harold Ward and Caroline Karp completed the group and served as our advisors. Each student wrote a thesis concerning water supply in Rhode Island.

In this capacity we were able to discuss our projects with people focused on similar issues, explore new ideas as a group, and get feedback and suggestions on our work. These meetings proved very helpful especially by ensuring that nothing was missed—that all elements of research were covered. They also enriched my understanding of Rhode Island's water supply overall as I was able to learn about two other projects in detail.

Our projects had some overlap, which allowed for collaboration and a better understanding of the region as a whole. Alexandra Coria examined supply in South Kingstown and Narragansett from the Mink and Chipuxet aquifers to the south of the HAP aquifer. Erin Bray addressed future needs in Coventry and West Greenwich supplied by KWCA, to the west of the HAP aquifer.

Next Communities Initiative

In the fall of 2004 I attended a five part workshop series in Rhode Island, the Next Communities Initiative. Sponsored by Grow Smart Rhode Island and the University of Southern Maine's Edmund S. Muskie School of Public Service, the course taught the concept of "smart growth" and was specifically aimed at community and planning officials in the Blackstone Valley of Massachusetts and Rhode Island. This course helped me to better understand the local governance process and the variety of ways that local communities try to deal with environmental issues. The course particularly focused on land-use, however water availability was discussed as well. There was also a section on conflict resolution that I found interesting and relatable to my thesis topic.

Water for a Sustainable and Secure Future

On January 29-30, 2004 I attended a conference sponsored by the National Council for Science and the Environment, *Water for a Sustainable and Secure Future*, in Washington, D.C.[14] This conference covered a multitude of water issues and I was able

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[14] Conference information online: (http://www.ncseonline.org/NCSEconference/2004conference/)

to attend breakout sections dealing with allocation and supply. Focusing on the national and international perspective of water supply was helpful to develop my thesis project by putting my research in a broader context.

Organization

In Chapter II. I examine the flows of the Hunt through different methodologies and research. I discuss the USGS HAP study and the DEM Fish Survey as well as explain my 7Q10 and ABF analyses.

Following the flow discussion I describe withdrawals in the basin, and show both current and historical trends. I also discuss the operations of the water supply companies.

In Chapter IV. I explain aspects of the politics in the watershed. There is unresolved conflict over water quality protection in the Hunt among the stakeholders, which suggests that future problems may be difficult to solve. In addition, the individual suppliers face difficult situations. RIEDC projects significant future growth and increased withdrawals in the Hunt. Despite experiencing negligible growth, North Kingstown uses more and more water every summer.

In addition, I demonstrate how information was incorrectly passed down to the present day through an error in a report over-representing the amount of water available in the Hunt. This error caused the three water supply companies to believe that much more water is available in the basin than exists.

Chapter V. will pull the variety of issues together to show why conflict over water supply in the Hunt can be expected unless problems are dealt with today.

In Chapter VI. I propose recommendations for RIEDC, North Kingstown, and state-wide agencies respectively.

Finally, this paper will show that by coordinating efforts to protect streamflow Rhode Island stakeholders can ensure adequate water supply for human consumption and aquatic needs.

II: THE HUNT RIVER'S FLOW

Several indicators point to flows low enough to potentially harm the aquatic community in the Hunt River. The United States Geological Survey has studied the Hunt and connecting basins and found that flows are depleted due to withdrawals. They have recorded average daily streamflow since 1940, so ample data exist to allow us to assess the flow conditions. DEM has also reported their findings regarding the health of the aquatic community in the Hunt. These components together indicate that the Hunt experiences degraded conditions from low flows in the summer months resulting from groundwater pumping by the public water supply wells along the river's banks.

United States Geological Survey Report

In 2001, USGS published *Numerical-Simulation and Conjunctive-Management Models of the Hunt-Annaquatucket-Pettaquamscutt Stream-Aquifer System, Rhode Island*, which reports the results of modeling conducted by USGS staffers.[15] The study was prepared in cooperation with the watershed stakeholders, the Town of North Kingstown, Rhode Island Department of Environmental Management, Rhode Island Water Resources Board, and the Rhode Island Economic Development Corporation. Throughout this thesis the report will be referred to as the HAP study.

[15] Barlow and Dickerman, 2001.

The report was commissioned to address concerns about low flow in the HAP system and the Hunt in particular.

> Concerns by the Rhode Island Department of Environmental Management (RIDEM) regarding the effects of ground-water withdrawals on streamflow depletions in the HAP stream-aquifer system prompted an investigation to better understand the water resources of the system and to evaluate alternatives for the conjunctive management of the ground- and surface-water resources of the system.

A scientific organization, USGS does not decide whether flows are too low but their scenarios present approaches to increase flow in the Hunt River.

The models in the HAP study demonstrate the effects that various groundwater withdrawal scenarios have on streamflow within the aquifer. The paper reports that the wells along the Hunt River deplete significant quantities of groundwater that would normally contribute to streamflow as well as cause abnormal infiltration from the river to the aquifer. Similar effects are found to a much lesser degree in the Annaquatucket and Pettaquamscutt Rivers.

In the absence of withdrawals, the Hunt should be a gaining stream—as it travels along its course it should gain water from the aquifer, but withdrawals from the supply wells were found to cause an average infiltration of 0.7 cfs each year. Therefore, the river instead loses water from its flows to the aquifer. The HAP study notes that infiltration does not occur in the wet spring and winter months meaning that since 0.7 cfs is an annual average much more than 0.7 cfs is lost through infiltration in the summer and fall.[16]

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[16] cfs – cubic feet per second. A rate of the flow of water; it is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second.

USGS found that the Hunt experiences significant streamflow depletion, meaning that much less groundwater feeds the river than would in natural conditions because of the withdrawals. In the HAP report, the transient model was used to calculate monthly depletion rates which range from 3.7 cfs to 5.2 cfs with an annual average of 4.2 cfs. The conjunctive-management model found depletion rates at the end of July, August, and September to range from 4.3 cfs to 4.75 cfs. USGS determined that these depletion rates represent 22 – 28 percent of the pre-withdrawal streamflow for the Hunt River. For comparison, the depletion rates in the Annaquatucket and Pettaquamscutt were much lower, 16 – 21 percent and 5 – 9 percent of pre-withdrawal streamflow respectively.

The scenarios are designed to maximize overall withdrawals in the HAP system during July, August, and September, without increasing depletion rates to the Hunt. The first scenario aims to increase withdrawals but maintain current rates of depletion in all three rivers. Scenario two decreases depletion rates in the Hunt and maintains current rates in the Annaquatucket and Pettaquamscutt. In set three current depletion rates are maintained in the Hunt and depletion rates to streamflow are allowed to increase in the other two rivers, and in four depletion rates are decreased in the Hunt and increased in the other two rivers.

In all cases, total withdrawals were increased though the amounts differed in each scenario. USGS staffers found that overall withdrawals could increase by 8-18% in July, August, and September while depletions to the Hunt could decrease from 5-15% in those same months. The USGS also found that downstream wells were better situated geologically to handle higher withdrawal rates than upstream wells.

The USGS study lists the safe-yield for the entire HAP system as 8 MGD. Safe Yield is defined in *Water Supply Analysis for the State of Rhode Island* as the quantity of water that can be obtained from a source on a continuous basis during the worst drought of record.[17] Though the USGS report does not state what the individual safe yields are for the Hunt, Annaquatucket, and Pettaquamscutt, I can estimate them based on the July withdrawals scenarios put forth in the study. The safe yield for the Hunt is likely in the range of 2.34 – 4.81 MGD, the Annaquatucket ranges from 2.68 – 4.07 MGD, and the Pettaquamscutt ranges from 0.41 – 1.24 MGD. Safe yield is reached when withdrawals approach these ranges from each sub-basin.

The USGS HAP study tells us how much water is withdrawn throughout the system. We learn that significantly less flow reaches the river today than would under natural conditions due to depletion and river water unnaturally is drawn into the aquifer due to infiltration. Then the study tells us ways to better optimize the system through careful management practices allowing withdrawals to increase through the system as a whole and restore flows to the Hunt. While it proposes higher pumping capacity, the study does not address the issue of whether increased withdrawals from the Annaquatucket and Pettaquamscutt would cause degradation to those rivers.

[17] Little, Arthur D., Inc. et al. October, 1990. Water Supply Analysis for the State of Rhode Island: Final Report to Rhode Island Water Resources Coordinating Council. Reference 63851.

The Hunt's Flow

A USGS streamgage has been recording average daily flows in the lower reaches of the Hunt since 1940. However, it is important to note that four out of the seven withdrawal wells became operational in 1943-1944 so although we have extensive flow data, almost the entire period of record reflects times of significant withdrawals. There is no available data of the Hunt's flows under unregulated conditions.

The flows fluctuate greatly between the winter and summer months and between wet and dry years. Analyses of the 7Q10 and Rhode Island Aquatic Base Flow (RIABF) show that the Hunt will not likely meet streamflow standards when set by the DEM and WRB.

Listed below are the monthly average flows of the Hunt River since 1940. Averages don't recognize the highs and lows of the flow in the Hunt, but are useful to understand how the hydrograph changes through the seasons. To protect the aquatic community we need to consider the low flows, and determine whether or not they are too low, I will present low-flow analyses in the next section. The averages should not be considered representative of usual or common flows.

Table 1: Average Monthly Flow in the Hunt River

	Average flow (cfs) 1940-2002[18]
January	62.6
February	70.7
March	89.2
April	83.8
May	61.5
June	38.6
July	19.7
August	15.3
September	14
October	17.2
November	37.7
December	52.7

Complete average daily flow figures are available on-line at the USGS website.[19] Using the USGS data I was able to more closely examine the flow conditions of the Hunt River during the past 62 years.

[18] USGS Monthly Streamflow Statistics for Rhode Island. Online: (http://nwis.waterdata.usgs.gov/ri/nwis/monthly/?site_no=01117000)

[19] USGS Daily Streamflow Statistics for Rhode Island. Online: (http://nwis.waterdata.usgs.gov/ri/nwis/discharge/?site_no=01117000&agency_cd=USGS)

7Q10 Analysis

One way to approach the question of whether or not low flows are a problem in the Hunt is to conduct a 7Q10 analysis. Defined by USGS as:

> The 7-day, 10-year flow (7Q10) is the discharge at the 10-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days (the 7-day low flow). For low flow, the recurrence interval is the average interval of time between occurrences of a flow less than a given magnitude. A 10-year low-flow discharge is a value that, on the average, will be less than, once every 10 years.[20]

I determined the lowest mean stream flow for seven consecutive days that occurred once in ten years for the Hunt. The 7Q10 is not a flow standard, but a water quality measurement, representing the amount of flow necessary in a stream to "meet point discharge water quality thresholds."[21] The standard is used for water quality protection and is not deemed appropriate for use as a flow standard by scientists. Often the 7Q10 represents less than 10% of average annual flow and will likely result in destruction of the aquatic community if it is adopted as a protective streamflow standard.[22] However, this measurement is valuable to show what the flows of a river look like at the times of greatest stress—for the Hunt in August and September. The 7Q10 gives us a glimpse into the Hunt's most flow-stressed periods.

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[20] Cervione, Jr., Michael A., Alisa R. Richardson, and Lawrence A. Weiss. 1993. Low-Flow Characteristics of Selected Streams in Rhode Island. U.S. Geological Survey. Water Resources Investigations Report 93-4046. Providence, Rhode Island.

[21] Annear, T., I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. Instream flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

[22] Tennant, D. L. 1976. "Instream Flow Regimens for Fish, Wildlife, Recreation, and Related Environmental Resources." Fisheries 1(4):6-10.

The 7Q10 for the Hunt is 1.63 cfs for the period of record of the streamgage, 1940 to 2003. However, for almost the entire record of the gage, the wells by the Hunt River have withdrawn substantial amounts of groundwater, which the HAP study showed results in depletions to streamflow. Two out of three RIEDC wells have been in place since 1943 and two of the three North Kingstown wells were installed in 1944. The HAP study shows that the rate Hunt's flows would be much higher without the groundwater withdrawals, so we can assume that the 7Q10 would be different, most likely higher if there were no withdrawals in the system. A river with regulated flows yields a regulated 7Q10.

In 1993 the USGS published *Low-Flow Characteristics of Selected Streams in Rhode Island*,[23] a water-resources investigations report detailing a regression equation to determine the potential 7Q10, what the 7Q10 would be if no depleted streamflow occurred in the Hunt River.

The equation given is:

$$7Q10 = 0.67\ (\text{area of stratified drift}) + 0.03\ (\text{area of till})$$

The correlation coefficient works out to be 0.97 for the local coastal areas of Rhode Island. The equation was tested in gaged rivers with no withdrawals and was found to be an accurate assessment tool. The equation determines the 7Q10 for rivers with no gages in place or with significant groundwater withdrawals, such as the Hunt. According to this equation the potential 7Q10 for the Hunt River is 8.2 cfs, with a range of +/-20% (6.6 - 9.8 cfs). The Hunt's actual 7Q10 is approximately 80% lower than the potential 7Q10.

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[23] Cervione, Richardson, and Weiss. 1993.

There is a large discrepancy, about 6.6 cfs, between the actual 7Q10 and the potential 7Q10. The difference is most likely attributable to public supply withdrawals. From 1990-2004 the average quantity pumped for July, the month with the highest withdrawals, is 4.15 MGD or 6.43 cfs, which is close to the difference between the measured and the potential 7Q10. Of course, 4.15 MGD is the higher-end of withdrawals from the Hunt River occurring during the period of record. The summertime average is 3.8 MGD and the year round average is 2.4 MGD.

The potential 7Q10—8.2 cfs—shows what the Hunt's flows should look like under natural dry conditions. *Average monthly* flows in the Hunt are lower than the potential 7Q10 11% of the time in the period of record of the USGS streamgage at the lower reach of the river, primarily in the summer months. *Average daily* Hunt flows in August and September from 1940 to 2003 are below the potential 7Q10, 8.2 cfs, 48% of the time. By definition, the flows should only be below the 7Q10 for seven continuous days every ten years. During the times of greatest stress to riverine flora and fauna the river is running much lower than it would be under normal dry conditions almost half of the time.

The 7Q10 analysis shows that during the times of lowest flows, demand is the highest and therefore the Hunt runs 80% lower than it would in a natural state—if groundwater was not withdrawn.

Rhode Island Aquatic Base Flow

I also analyzed the USGS stream gage data against the Rhode Island Aquatic Base Flow (RIABF) figures for the Hunt. The RIABF has been developed by the DEM as a flow assessment tool, to replace the U. S. Fish & Wildlife ABF for wetlands permitting until watershed specific flow standards are in place. The RIABF applies to unregulated streams with a drainage area greater than 5 square miles.[24] The Hunt, as a regulated stream does not meet the conditions of this standard. However, I used the RIABF as a tool to see how the Hunt measures up to a statistic that represents the river's median flows in a natural state.

The RIABF is a modification of the U.S. Fish and Wildlife ABF adapted for Rhode Island's smaller basins and is described in a recent paper by the DEM, *Modified Aquatic Base Flow (RI-ABF) for Rhode Island*.[25] "The standard consists of monthly medians of unregulated streams organized by physiographic regions." The RIABF has a set of monthly data in cfs/m2 for the eastern highlands and one for the coastal lowlands region. The figures are multiplied with each basin's drainage area to get a monthly ABF specific to each river.

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[24] RIDEM, OWR. March, 2005. Modified Aquatic Base Flow (RI-ABF) for Rhode Island.

[25] Ibid.

Table 2: The Hunt's monthly ABF levels:

	Hunt ABF (cfs)
October	13.51
November	27.48
December	38.93
January	45.8
February	52.67
March	66.41
April	64.12
May	43.51
June	25.19
July	13.05
August	11.22
September	10.99

I compared the ABF figures to the Hunt's actual flows. Since these are median points, an unregulated river's flows should be above the monthly figure 50% of the time and below the figure 50% of the time.

I looked at average daily flows from the USGS streamgage from 1992-2002 and found that overall the Hunt's daily flows were below the RIABF figures 49% of the time—in line with the natural hydrograph of the river. However, in July, August, and September the Hunt's flows were below the ABF 66% of the time.

The ABF analysis indicates that the river can experience a certain amount of withdrawals and maintain natural flow patterns but at a certain threshold of withdrawals the river can no longer sustain normal flows.[26] [27] In the winter flows are high, withdrawals are low, and the river is able to maintain its natural hydrograph. However, in the summer withdrawal rates double while flows are naturally much lower due to drier conditions and higher natural demands. The ABF analysis shows that the under this period of stress the flows meet natural patterns only about 1/3 of the time. When the Hunt does meet the ABF level, it is primarily due to precipitation events and not because of baseflow levels. Though rainfall adds significant flow to the Hunt, the water is high in nutrients, and possibly other contaminants, washed in from the land surface. The rainwater is also warmer than the river's baseflow from the aquifer.

The Hunt's flows are below the RIABF 66% of the time in the summer, rather than 50% of the time as it would if the river was unregulated. In the summer, the ABF is met 34% of the time because of rainstorms. The 7Q10 analysis shows that the river flows significantly below what it should be at times of greatest stress, when there are no precipitation events. Together these data analyses demonstrate that often when the Hunt runs below median flows (which it does about 2/3 of the time) it runs really low, lower than the potential 7Q10 48% of the time in September and August. By definition flows should only be below the potential 7Q10 for seven continuous days every ten years. The drier summer climate with full evapotranspiration from trees creates lower flows

[26] Alisa Richardson, Principal Sanitary Engineer, OWR, DEM, April 11, 2005. Personal communication.

[27] Average withdrawals in the fall, winter, and spring equal 2.4 MGD. July average withdrawals equal 4.2 MGD, but have reached 5 MGD.

naturally. At the same time more water is demanded from the communities and well pumping increases, resulting in severely reduced flow in the Hunt. These frequent really low flows are of concern to the DEM, as they have the greatest potential to harm the aquatic community.

Fish Survey

A recent fish survey conducted by the DEM's department of U.S. Fish and Wildlife indicates some ill health in the Hunt River fish populations downstream of withdrawals. Completed in the fall of 2004, the *Hunt River Preliminary Target Fish Community Survey*[28] sampled fish from nine stations in the Hunt watershed in 1997 and 2004. Two data points are not enough to make any definitive conclusions of the abundance of fish species and flow related problems, but from these surveys we can get a sense of conditions in the Hunt up and downstream of the water-supply wells. This work should yield further benefits in the future as the agency plans to sample the same stations more regularly and compare the data.

The most important criterion missing from the study is an estimation of what fish populations should look like in an unregulated stream that is otherwise comparable to the Hunt. That component would present a framework for conclusions to be drawn regarding the health of the system and should be included in future reports.

[28] Masson. 2004.

The sampling was done by a Fish and Wildlife biologist, Alan Libby, shocking the water with a backpack shocker with two to three netters to collect the fish that rose to the surface. Species were recorded and released back to the river, ostensibly unharmed. The fish were characterized into three categories, fluvial dependents, that require flowing water for a specific part of their life, fluvial specialists, that "live the majority of their lives in flowing streams and require flowing water to complete their life cycle," and macrohabitat generalists, which includes species found in ponds, lakes, and streams that are able to complete their life cycle in any of these systems. Generally in rivers with altered flow we expect to find that macrohabitat species are dominant.[29]

By comparing the breakdown of species found in the upper reaches of the Hunt to the species found in the lower Hunt—primarily at the station directly downstream of the cluster of six water supply wells, we can see the effects that withdrawals might be having on the aquatic community.

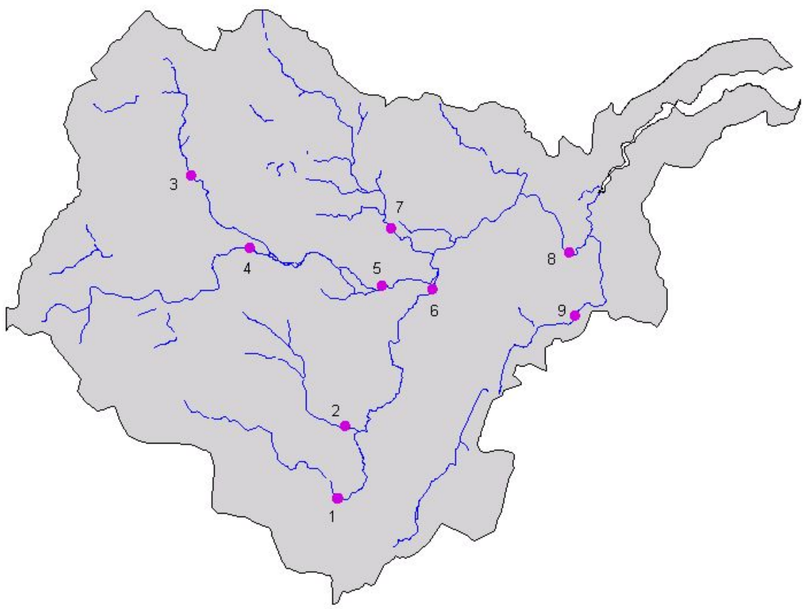
Since this analysis is focused on the possible effects of low flows I will compare other stations to Potowomut Road, which is downstream of the cluster of public water supply wells. In 2004, at Potowomut Road 94% of the catch was macrohabitat generalists. In 1997, at the same station, 60% was macrohabitat specialists, but almost all fluvial specialists caught were Atlantic Salmon which were stocked to the Hunt River that year. No salmon were stocked to the Hunt in 2004. Therefore, discounting the

[29] Bain, M. B. and Meixler, M. S. 2000. "Defining a target fish community for planning and evaluating enhancement of the Quinebaug River in Massachusetts and Connecticut." Fish and Wildlife Research Unit, Cornell University, Ithaca, NY.

stocked salmon, the percentages of categorical catchings is comparable. An equivalent amount of water was being withdrawn in 1997 and 2004.

Perhaps more appropriate is to compare the samples from Potowomut Road, downstream of the wells, to the fish caught upstream of the wells in the same year.

Figure 4: Hunt River Fish Survey Sampling Sites



The breakdown of fish recorded at each site is displayed in Table 3. Site 8, Potowomut Road is the primary comparison point for our purposes as it is downstream of the seven public supply wells. It is important to note that the vast majority of macrohabitat generalists caught were eels, showing a lack of species diversity.

Table 3: Percentage Species Breakdown at Sampling Sites in 2004

	Stations	% Fluvial Dependent	% Fluvial Specialist	% Macrohabitat Generalist
1	Scrabbletown Brook	0	98	2
2	South County Trail	0	92	8
3	Mawney Brook	0	83	17
4	Frenchtown Brook	0	93	7
5	Frenchtown Brook Davisville	22.5	37.5	40
6	Hunt River Davisville	32	3	65
7	Fry Brook	31	47	22
8	Potowomut Road	3	3	94
9	Sandhill Brook	0	0	100

These data demonstrate that heading downstream to the areas impacted by withdrawals the dominant species are macrohabitat generalists, the fish that do not rely on flow to survive at any part of their lifecycle. The data suggests (but does not prove) that fish species are impacted by low flows resulting from withdrawals. The species that rely on steady flows are represented in much smaller numbers in the area impacted by human activity, although some changes are expected due to a river's natural variations of flow characteristics in the higher and lower reaches. However, the composition of species, primarily eels, in the lower reaches also suggests a problem with oxygen supply.[30]

By looking at the percent of species found from upstream to downstream a strong relationship emerges between the dominance of macrohabitat specialist species and the distance the samples were taken from the mouth. We can speculate that this breakdown is due to the fluvial-requiring fish simply not having enough flows due to groundwater withdrawals, but the survey does not prove that is the case. High amounts of red algae were present at the Potowomut Road station during the sampling. This alga is an indication of low flows in the river, as it results from little to no flushing. The habitat could be assessed as poor based on the red algae alone, without examining other factors.[31] Therefore, flows likely play a large part in the lower Hunt's degradation. Another possibility is that the temperature of the water effects the species composition.

The fish survey data found that the Hunt's water was warmer downstream than upstream. At Scrabbletown Brook the temperature was 15° C, 15.7° C at South County

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[30] Harold Ward, Professor Emeritus, Environmental Studies and Chemistry, Brown University, April 6, 2005. Personal communication.

[31] Alisa Richardson, Principal Sanitary Engineer, OWR, RIDEM, April 12, 2005. Personal communication (email).

Trail while at Potowomut Pond the temperature was 18.2°C. Increased temperatures are an indirect result of low flows, since less cold groundwater enters the system, as explained in the USGS HAP study.

The man-made impoundment, Potowomut Dam exacerbates the situation in the lower Hunt. The dam has been in place for over 100 years and formed Potowomut Pond. Site 8 is downstream of the dam and the pond. Though the dam does have a fish ladder, this impoundment could be hindering the fish population in the lower reaches of the Hunt by creating higher temperatures in combination with little to no flows. The more sensitive fluvial fish cannot tolerate the warmer water.

There are other reasons that we could speculate cause a degradation of the downstream portion of the Hunt—there is no way to tell for sure at this point. There has been on-going construction near the Davisville site since 1997. It's also possible that changes in land-use and development, and other outside forces may be impacting the river.

The survey concludes that low flows are impacting the fish populations at the Potowomut Road station. "The exclusion of fluvial specialists and dependents means a degradation of habitat which is the direct result of reduced flow, caused by water withdrawals and/or drought conditions." This statement marks the first and, as of writing this, only time a state agency has made an official statement attesting to the degraded quality of the lower Hunt.[32] It is significant, because if the DEM views the Hunt habitat as impaired they are legally required to work to improve conditions. The survey

[32] The USGS HAP study was undertaken in response to concerns of low flows in the watershed, but never directly states that the Hunt is in a degraded condition.

concludes that the evidence supports the idea that withdrawals are negatively impacting the environment of the Hunt.

Other Studies

Despite extensive research I have found no other existing studies looking at impacts of low flows on the health of the aquatic community in the Hunt River. I especially searched for reports that examined influxes to Narragansett Bay and Greenwich Bay, to determine whether or not there was any information regarding potential effects on estuarine ecology of decreased freshwater flows from the Hunt River or other comparable river. I found no studies that looked into these issues.

Conclusions: What the flow information tells us

The RIDEM report suggests that lessened flow from groundwater withdrawals is degrading the natural habitat in the Hunt River. There is some debate between local officials over whether the current conditions of the Hunt are acceptable or whether withdrawals should be reduced. Several state officials I spoke to believe that the lower reaches of the Hunt are impaired. However, there is disagreement over whether or not these impairments are acceptable since they only affect the lower reaches while the majority of the river remains in good shape and since the water is needed for public supply.[33]

It is the standard opinion from DEM that any impairment to the river is unacceptable.[34] Current growth projections and a lack of alternate supply, suggest that, absent action by a state agency or suppliers, withdrawals from the Hunt wells will likely increase over the next few years. Before withdrawals increase any further, measures need to be taken to ensure the protection of the river's habitat.

[33] Kathleen Crawley, Acting General Manager, WRB, September 22, 2004, James Campbell, Subdistrict Chief, Water Resources Division, USGS, September 2, 2004, and Alisa Richardson, Principal Sanitary Engineer, OWR, RIDEM, September 17, 2004. Personal communications.

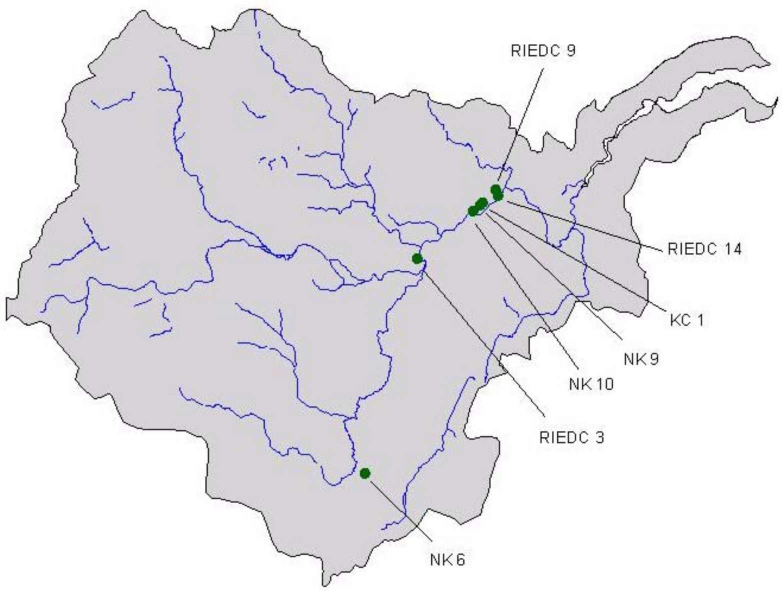
[34] Alisa Richardson, Principal Sanitary Engineer, OWR, RIDEM, September 17, 2004. Personal communication.

III: PUBLIC WATER SUPPLY WITHDRAWALS IN THE HUNT AQUIFER

Three public water supply companies withdraw water from seven wells adjacent to the Hunt River. Kent County Water Authority, North Kingstown Department of Water Supply, and Rhode Island Economic Development Corporation maintain the wells and provide water to their customers, Kent County, the Town of North Kingstown, and corporations at Quonset Point respectively. There is also an industrial well along the river.

I obtained recent pumping records (from 1998-2004) from each supplier and historical pumping records from the USGS HAP study. Data are missing for several years from the historical records of most of the supply wells, from which I had to construct withdrawals based on monthly averages from the years before and after. The methodology used to construct this missing data is explained in Appendix 1.

Figure 5: Public Supply Wells in the Hunt Basin



Kent County Water Authority

Kent County Water Authority (KCWA) has a single well in the Hunt River watershed which is located in a cluster with four other wells towards the lower reaches of the Hunt upstream of Potowomut Pond and the dam. Each day KCWA pulls an average of 0.65 MGD from the Hunt River well (KC1). Summertime withdrawals occasionally are higher than this figure, but in general the rate is fairly constant throughout the year.

The Hunt well represents roughly 5% of the total company water supply.

According to KCWA's Water Supply System Management Plan[35] there are no plans to increase withdrawals from well KC1, despite significantly increased projected demands over the next five and twenty year periods. Because they have no plans to increase withdrawals, I have not considered KCWA a major factor in planning for the future. Since the Hunt well produces such a small percentage of their total supply it is possible that KCWA may be persuaded to give up the well entirely.

Kent County Water Authority is a large private public water supplier to residential, commercial, and industrial water users in central Rhode Island. They have well fields in other basins, but approximately 70% of their water comes from the Scituate Reservoir, via purchase from the Providence Water Supply Board. All water is directed to central distribution towers and then redistributed to clients. Some residents within the Kent County supply area have private wells on their own property.

Most customers have on-site septic systems, but some areas are sewered, such as the residential units in the Potowomut section of Warwick. These sewers discharge to the Quonset Point Wastewater Treatment Facility. Unless the on-site treatment lies within the Hunt basin, the water withdrawn from the Hunt well is consumed.

North Kingstown Department of Water Supply

The Town of North Kingstown has three wells along the Hunt River. NK6 is adjacent to the Hunt towards the middle of its course, while NK9 and NK10 are

[35] Kent County Water Authority. October, 2001. Water Supply System Management Plan for Kent County Water Authority, Volume 1. West Warwick, Rhode Island.

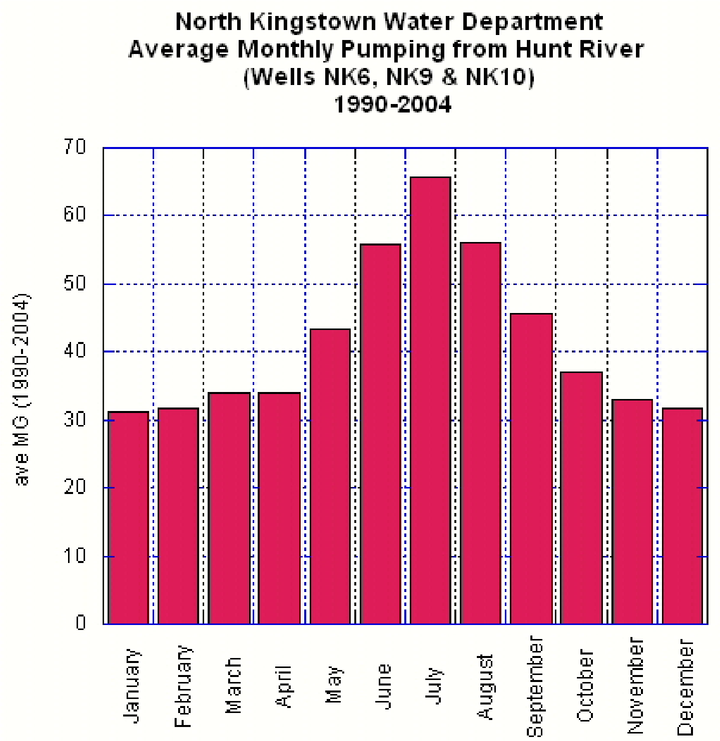
downstream in the cluster of 5 wells. These wells supply an average of 50% of the town's total water needs, though month to month it ranges from 44% to 59%.

In September through May the town withdraws an average of 1.2 MGD while in the summer it pulls almost double—an average of 2 MGD.[36] Average July withdrawals are 2.2 MGD. The extra summertime water represents about 25% of the total withdrawn from the Hunt.

North Kingstown has eight other wells located in the Hunt's adjacent basins, the Annaquatucket and Pettaquamscutt. However, since the three Hunt wells withdraw half of the water supply, the Hunt is a primary water source for the town.

[36] Autumn average withdrawals = 1.3 MGD, winter average withdrawals = 1.1 MGD, spring average withdrawal = 1.2 MGD

Figure 6: North Kingstown Average Monthly Pumping

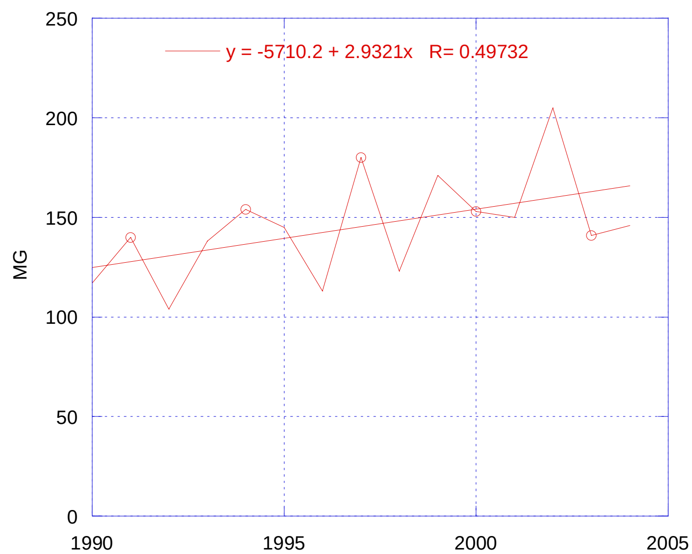


North Kingstown is almost fully built-out and has been for some time. There have been minimal developments within the water supply area of the town during the past decade or so, and that trend will continue into the future.[37] However, despite the lack of growth, water usage is increasing each year, primarily in the summer. These days the North Kingstown community is comprised of year-round residents and does not experience an influx of summer vacationers as it did in the past. The usage trend is due to increased lawn watering in the summer months, exacerbated by the increasing

[37] The Town of North Kingstown. November, 2000 (submitted). November, 2001 (revised). Water Supply System Management Plan for North Kingstown Water Supply Department, Volume 1. Rhode Island.

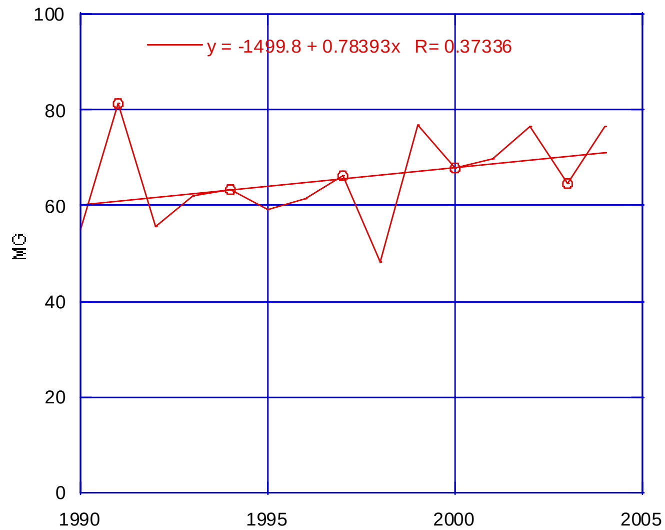
popularity of automatic, in-ground sprinkler systems. These sprinklers are generally programmed to run automatically despite cooler or rainy conditions and often excess water is used.

Figure 7: North Kingstown Total July Withdrawals[38]



[38] In Figures 7 & 8 yearly variations are due to precipitation levels.

Figure 8: North Kingstown July Withdrawals from Hunt River Wells



North Kingstown officials believe that the increasing water use is a problem threatening the water supply for the region.[39] The public officials I spoke with consistently recognized that the Hunt Aquifer is a finite resource that should be protected. An additional concern for North Kingstown officials is public safety, specifically fire prevention. In order to properly provide adequate supply there must be enough water and water pressure in the storage tanks to put out fires, even on nights following summertime peak use days. Traditionally, the town has installed additional supply wells to cope with increased demand.

The water department is a town-run public water supply company. Water withdrawn from any of North Kingstown's 11 wells is piped to towers and then

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[39] Susan Licardi, Water Director, NK Department of Water Supply, September 21, 2004, Marilyn Cohen, Town Planner, NK, August 24, 2004, and Dale Grogan, Town Council, NK, June 22, 2004. Personal communications.

distributed to clients. There are more than 9,000 connections which supply about 94% of the town.[40] The remaining residents maintain private wells. The vast majority of residents have on-site septic systems, but some residential units have sewer lines connected to the Quonset Point Wastewater Treatment Facility. Since most of North Kingstown is outside the Hunt Basin, a large portion of the water withdrawn by NK wells is consumed.[41]

Rhode Island Economic Development Corporation

The Rhode Island Economic Development Corporation (RIEDC) owns and operates three wells along the Hunt River which supply 100% of the water to Quonset Point, a commercial and industrial park along Narragansett Bay within the borders of North Kingstown. Two wells are located within the cluster of five wells on the lower reaches of the Hunt, while the third is adjacent to the river towards the middle of its course. These wells withdraw an average of 0.7 MGD at fairly constant rate throughout the year.

RIEDC, in keeping with the priorities of the state government, plans to further develop Quonset in the immediate and longer-term future. According to the 2003 Master

[40] North Kingstown Department of Water Supply. Online: (http://www.northkingstown.org/waterdept/default.htm)

[41] Some water from the Annaquatucket and Pettaquamscutt basins is released to the Hunt.

Plan,[42] estimated peak demand at full build-out is 3.595 MGD. It notes that this is within what they understand to be the well pumping capacity of 4.6 MGD. I was led to believe through conversations with RIEDC officials that it would be possible to withdraw 4.6 MGD if necessary.[43] RIEDC believes they can withdraw 3.6 - 4.6 MGD from the Hunt for a couple of reasons. The Master Plan states "All these operating parameters are consistent with the…USGS safe yield of the Hunt Aquifer of 8 MGD." This is incorrect as I will discuss in Chapter VI. Quonset Point was originally a Navy Base which was heavily utilized during World War II. In September 1943, the Hunt Navy wells were pumped at an average of 4.78 MGD, above the level of full capacity listed today. However, claims of prior use have no legal bearing in Rhode Island as riparian rights are based upon reasonable use not prior appropriation.[44]

RIEDC is a quasi-public state governmental organization dedicated to expanding and developing business, commerce, and industry in Rhode Island.[45] RIEDC assumed control of Quonset Point from the Rhode Island Port Authority (RIPA) in the early 1990s, and have since been developing the site. RIEDC pumps, distributes, and sells water to its clients at Quonset Point and Davisville Port. Wastewater is channeled to the Quonset

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[42] RIEDC, Quonset Davisville Division. December, 2003. Quonset Davisville Port and Commerce Park Master Plan. 2003 Revision of 2001 Update. North Kingstown, Rhode Island.

[43] Vasilios Harritos, Facility Engineer, RIEDC, October 28, 2004, and W. Geoffrey Grout, Managing Director, Quonset Point, RIEDC. November 8, 2004. Personal communications.

[44] RI WRB. 2003. Preliminary Findings of the Subcommittee on Water Rights and Regulatory Authorities. December 5, 2003. Online: (http://www.wrb.state.ri.us/programs/wa/wapac/waterrights/FindingsDec03.pdf)

[45] RIEDC. Online: (www.riedc.com)

Point Wastewater Treatment Facility where it undergoes secondary treatment and is released to Narragansett Bay. Therefore, all water withdrawn from RIEDC wells is transferred out of basin and consumed.

Other Withdrawals

There is an industrial well along the Hunt River that withdraws an average of 0.26 MGD in a fairly constant rate throughout the year.[46] Many residents in the Hunt watershed have private wells. Most residences with private wells also have septic systems which return 85-90% of the water to the aquifer. Therefore, these small-scale private withdrawals are not a concern. USGS leaves these wells out of their models and I have not considered them in my study.

Historical Pumping Trends in the Hunt

At its height in the early 1940's the Quonset Naval Air Station at Quonset Point employed approximately 20,000 people. In 1942, the Navy built and established the Construction Battalion Center at Davisville as a training center to complement the airport. Over 100,000 people were trained at Davisville in its 3 years of operations.[47] To support this massive increased activity Quonset needed more water. In February 1943,

[46] Barlow and Dickerman. 2001.

[47] RIEDC, Quonset Davisville Division. 2003.

the Navy sank 2 wells in Hunt watershed, now known as RIEDC wells 9 & 14. These wells immediately began running at peak capacity. In September 1943 143.3 million gallons[48] were withdrawn and due to low rainfall[49] the Hunt streamflow reached its lowest rate during the entire period of streamgage record, 0.1 cfs. The Hunt's flow remained at 0.1 cfs from September 13, 1943 to September 19, 1943.

In June and August 1944 North Kingstown installed wells NK 9 & NK 10 for public supply drinking water for a growing town and centralized fire protection.[50] Thus, by August 1944 four large capacity supply wells were in operation in the Hunt River basin. That month the largest rate of water was withdrawn in the entire period of record. In August 1944 195.2 million gallons were withdrawn from the Hunt River wells, which is equivalent to 6.51 MGD. In this month the Hunt's flows were well under the potential 7Q10 mark (8.2 cfs) for the entire time. Average monthly streamflow was recorded at 3.18 cfs, but 61% of the time the Hunt's flows were below 3 cfs. The 7 day consecutive low flow for that year, also recorded in August was 1.1 cfs.

KC 1 began supplying water in February 1965, NK 6 began pumping in March 1978, and RIEDC 3A began pumping in July 1993.

From 1943 through the mid 1970's the Hunt River wells generally were pumped at 100 to 140 million gallons each month, about 3.33 to 4.6 MGD. In 1975 the Navy began to reduce operations at the Quonset and Davisville bases, passing authority over

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[48] 143.3 million gallons = 4.78 MGD, 0.18 MGD more than is listed today as peak capacity of all three wells.

[49] 0.82 inches in 8/43 and 1.24 inches in 9/43—from the National Weather Service, T.F. Green Weather Station.

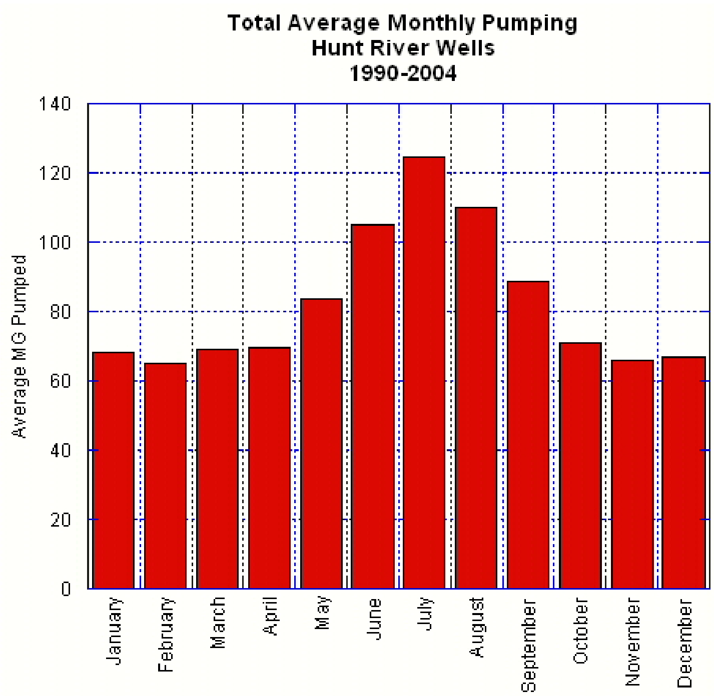
[50] Well NK 1 in the Annaquatucket basin was installed in December of the same year.

much of Quonset Point to the Rhode Island Port Authority. From 1975 until 1993 overall withdrawals from the Hunt decreased due to less supply needed at Quonset. From 1975 until 1993 total monthly withdrawals from all suppliers generally ranged from approximately 60 to 90 million gallons, about 2 to 3 MGD.

From 1992-1996 full control of Quonset and Davisville was transferred to the Rhode Island Economic Development Corporation. At this time, businesses and industry began to move into the office park and to old naval buildings on the site.

Since 1990 average monthly withdrawals from Hunt River wells are 82.4 million gallons, about 2.8 MGD. However, there is significant seasonal variation. In the fall, winter, and spring the rate of withdrawals is mostly constant at 72.2 million gallons, 2.4 MGD. In the summer average monthly withdrawals are 113.1 million gallons, or 3.8 MGD.

Figure 9: Total Average Hunt Withdrawals



Conclusions

Both North Kingstown and RIEDC expect to increase withdrawals from the Hunt River in the future—North Kingstown to satisfy increasing demand from existing customers in the summer, and RIEDC to support new growth and development on-site. In the next chapter I explore the political ramifications implicit in this discussion. Will the towns and supply companies be able to work together to provide adequate supply for both people and the aquatic community in future times of drought? RIEDC expects to use more water in the future, and believes that they will not harm the Hunt—why? North Kingstown expects to use more water in the future even though they are aware of low flows in the river. In Chapter II. I discussed stressed streamflow levels. What has happened that causes North Kingstown and RIEDC to believe that more water is available for use than is actually there?

IV: THE POLITICS OF WATER SUPPLY IN THE HUNT BASIN

Record of Disagreement over Water Supply

Upstream the Hunt serves as the boundary between North Kingstown and East Greenwich. Then, closer to Narragansett Bay, it borders North Kingstown and the Potowomut section of Warwick. The majority of the Hunt watershed lies within the boundaries of East Greenwich, but parts of northern North Kingstown, southern Warwick, and other towns are also encompassed. Although, most of the water withdrawn from the Hunt River wells supplies areas in North Kingstown including Quonset Point, the Kent County well supplies customers in the other regions of the watershed. Because of all this, the Hunt is a transboundary resource, shared between municipalities.

In 2001 the major Hunt River stakeholders formed the Hunt Wellhead Protection Committee. The group was comprised of two members each from North Kingstown, East Greenwich, Warwick, Kent County Water Authority, and the Rhode Island Economic Development Corporation, with oversight from the Water Resources Board.[51] The objective of this committee was to shield wells from contamination by each town enacting protective zoning legislation.

The committee was partly a response to a pollution event—in September 1992 NK10 was taken offline due to the presence of fecal coliform. Around the same time, there was a gasoline spill in East Greenwich which luckily did not contaminate the water

[51] Dale Grogan, Town Council, NK, June 22, 2004. 6/22/04. Personal communication.

supply. In reaction to these events North Kingstown's Town Council passed wellhead protection zoning to protect the aquifer within their boundaries. North Kingstown officials hoped that their neighbors would adopt similar legislation. A report from 1995 commissioned by the stakeholders recommended forming a Protection Committee to safeguard the Hunt.[52]

The representatives from East Greenwich drafted the protective zoning legislation, but it was ultimately vetoed by the town council. East Greenwich has not revisited the issue. Warwick never drafted legislation. North Kingstown, RIEDC, and KCWA supported the proposed zoning changes. According to committee members from North Kingstown, the councils from the other towns felt bullied by North Kingstown's government to protect North Kingstown's water, even though the supply reached their own residents too. They also worried that it might inhibit economic development.[53]

The Hunt Wellhead Protection Committee disintegrated in 2002 and the members haven't met as stakeholders since. Feelings of ill-will towards the other towns linger with officials of North Kingstown. They also harbor some resentment of the Water Resources Board for not being a stronger presence and not stepping in to facilitate a solution upon the committee's failure.[54]

[52] GZA GeoEnvironmental, Inc. 1995. Hunt Aquifer Wellhead Protection Plan. Prepared for The Hunt Aquifer Committee: Town of North Kingstown, Town of East Greenwich, City of Warwick, Kent County, Water Authority, Rhode Island Port Authority. File No. 30930. 1 & 3. February 1995.

[53] Dale Grogan, Town Council, NK, June 22, 2004. Personal communication.

[54] Ibid. and Susan Licardi, Water Director, NK Department of Water Supply. June 25, 2004. Personal communication.

This story of the failure of the Hunt Wellhead Protection Committee is relevant to the future. The stakeholders may have to meet again to discuss an issue or problem with the Hunt water supply. The negative feelings remain and may make any debate and resolution difficult.

North Kingstown Water Supply

As discussed in Chapter III., North Kingstown uses almost double the amount of water in the summertime than they do in the rest of the year. In the fall, winter and spring they withdraw a constant average of 1.2 MGD, while in the summer they withdraw from the Hunt an average of 2 MGD with a July average of around 2.2 MGD from 1990 - 2004. This increase is due to lawn watering and other outdoor summer uses. Though historically there was an influx of summertime-only residents, this is no longer the case.[55] Many in the suburban community have large lawns and have embraced the popular trend of installing in-ground sprinkler systems.

Not only do residents use a lot of extra water in the summer, but, to make matters worse, North Kingstown summertime water use is increasing over time, as shown in Chapter III.[56] This increase is not due to population growth or development, but rather to existing users using more and more water. If current trends continue, more water will be

[55] Susan Licardi, Water Director, NK Department of Water Supply. March 7, 2005. Personal communication (email).

[56] Figures 7 & 8.

withdrawn in the already stressed summer months, despite the absence of significant growth.

The NK water department recognizes that this increase in usage is a problem, both environmentally and for public safety.[57] In the past few summers, on high-use days the water towers were nearly emptied and only filled up overnight. Should a fire occur on a high-use day water pressure may be too low to adequately suppress it.

To address this crisis, the town has instituted an odd/even day lawn watering schedule from Memorial Day to Labor Day. The policy applies to all residents, whether they are on the town supply or not. Odd mailing addresses are permitted to water on odd dates and vice versa. So far this strategy has proved ineffective at lowering overall summer time usage because residents believe that they *should* be watering their lawns every other day, rather than once a week, which is recommended to maintain a healthy lawn.[58] Many residents oppose the policy, some hostily—the Water Department gets numerous complaints every summer in the form of angry calls and letters. Complaints tend to peak at times of two odd days in a row, such as July 31 to August 1. While the odd/even policy has not managed to decrease overall use and benefit the environment, it has been effective at cutting usage at very peak demand times, allowing for adequate fire protection. [59]

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[57] Susan Licardi, Water Director, NK Department of Water Supply. June 25, 2004. Personal communication.

[58] Healthy Landscapes Initiative. Online: (www.healthylandscapes.org)

[59] Susan Licardi, Water Director, NK Department of Water Supply. June 25, 2004. Personal communication.

In addition to the watering schedule the town has launched an educational campaign for proper lawn care directed at all residents. In conjunction with University of Rhode Island's Cooperative Extension program, North Kingstown created the Healthy Landscapes Initiative.[60] This program provides information through brochures sent out to residents, free seminars held at public events, and demonstration sites at private homes. Healthy Landscapes teaches proper watering techniques, home water conservation methods, and the benefits of landscape plants that are native to coastal Rhode Island and require less water than lawns. Despite best intentions and a high level of effort the town has not seen a noticeable effect on water use from this initiative.

Water Supply to Quonset Point

Quonset Point and Davisville are focal points for industrial and commercial growth in Rhode Island. In their 2003 Master Plan, RIEDC's Primary Objective is stated as: "To continue the development of a world class multi-modal industrial park at Quonset Davisville and to provide jobs and other economic benefits to the residents of Rhode Island."[61] By developing Quonset the RIEDC hopes to attract businesses to Rhode Island. In the Master Plan, 752 acres are slated for new development. "The…Master Plan provides space for approximately 22,000 employees at the site. New jobs will be in the office, research and development, manufacturing, distribution, retail and services

[60] Healthy Landscapes Initiative. Online: (www.healthylandscapes.org)

[61] RIEDC, Quonset Davisville Division. 2003.

employment categories." With this increased development Quonset will require more water in the future. Currently, 100% of their supply comes from wells in the Hunt basin.

In 1999, Grow Smart Rhode Island published a report from a planning perspective detailing problems and limitations with Quonset that, if left unaddressed, will constrain development.[62] One of the constraints discussed was the limits to water supply.

> The projected average daily demand for water generated by the North Kingstown and Kent County Water Authorities plus the projected demand generated by Quonset Davisville Port and Commerce Park at full buildout may exceed the quantity of groundwater available in the Hunt-Annaquatucket-Pettaquamscutt stream-aquifer system.

The study notes that USGS is studying the region and that more information would be available upon the HAP report's completion.

In 2002, Grow Smart published its follow-up report which concluded that water supply was no longer a constraining factor to development of Quonset.[63] The conclusion was based partly on smaller growth projections than had been predicted in 1999 for the park and because of the anticipated availability of groundwater from the state's Big River groundwater development project, which Grow Smart expected to produce "6 to 10 MGD" within "one to two years." Reading this report three years later, with Big River supply still undeveloped, it is clear that the Grow Smart report was optimistic in

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[62] Grow Smart Rhode Island. 1999. Quonset Point Davisville, North Kingstown, Rhode Island. Planning for the Proposed Port and Commerce Park: An Overview.

[63] Grow Smart Rhode Island. 2002. Quonset Point Davisville, North Kingstown, Rhode Island. Planning for the Proposed Port and Commerce Park: An Update.

predicting the timeline for additional supply. Also, the potential water available from Big River will likely be needed by the adjacent communities, which are growing rapidly.[64]

Big River supply is not yet developed. Depending on the needs of surrounding communities there may be enough water generated from the project to alleviate pressures on the Hunt and allow for some additional supply to Quonset. However, this has not been fully explored and Grow Smart's 2002 Update simply assumes that Big River water development will address all future demand. The report fails to prove that development of Big River supply will provide for enough water for Quonset. They do note that even if the Big River supply were available, only average daily demands will be met over a 20 year period, not peak demand. Thus, we must conclude that water *is* a constraint for growth at Quonset.

As discussed in Chapter III., RIEDC currently withdraws about 0.7 MGD. Anticipated future peak demand is listed as 3.595 in the 2003 Master Plan. Officials at RIEDC believe that they have the right to withdraw up to 4.6 MGD if necessary, the capacity of their wells. Part of the reason that RIEDC believes that they can use this much water is because of prior use, during Navy World War II operations.[65] However, there is currently no legal basis for prior use claims nor is there currently a process for allocation in Rhode Island.[66]

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[64] Bray, Erin N. 2005. Is it necessary to augment existing water supply to meet increasing demands of suburban sprawl?: A Case Study of Coventry and West Greenwich. M.A. thesis, Brown University. Providence, Rhode Island.

[65] In September 1943 the Hunt's flow dropped to 0.1 cfs for a whole week.

[66] Kathleen Crawley, Acting General Manager, RI WRB. September 22, 2004. Personal communication.

The Master Plan says that there is ample water available for the RIEDC wells to withdraw the necessary 3.595 MGD for future water needs. "All of these operating parameters are consistent with the…(USGS) estimated safe yield of the Hunt Aquifer of 8 MGD."[67] *This statement is incorrect.* RIEDC does not include a citation to say where they acquired this information, and I found no record of USGS stating that the safe yield of the Hunt Aquifer is 8 MGD. The recent HAP study states that the safe yield of the *Hunt-Annaquatucket-Pettaquamscutt Aquifer* is 8 MGD.[68] It follows that the safe yield of the Hunt Aquifer must be well lower than 8 MGD.[69] In July 2004 public supply withdrawals from the Hunt equaled 4.3 MGD with 0.77 MGD going to Quonset Point. If the RIEDC had used 3.595, the amount projected for peak demand at full buildout, withdrawals would have been 7.125 MGD, close to the safe yield of the total HAP system and much higher than the safe yield of the Hunt.

In the Water Supply System Management Plan for Quonset, RIEDC also lists safe yield at 8 MGD.[70] Here they cite the USGS Water Supply Paper #1775. Unfortunately this information is wrong.

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[67] RIEDC, Quonset Davisville Division. 2003.

[68] Barlow and Dickerman. 2001.

[69] In July, 2004 HAP withdrawals from public supply wells, state fisheries wells, and the private industrial well equaled 7.48 MGD—only 0.52MGD away from safe yield limits. Since this total does not include private withdrawals it is likely that summer withdrawals are equal to or exceed USGS's safe yield of 8 MGD.

[70] RIEDC. October, 1999 (submitted). September, 2000 (revised). Water Supply System Management Plan for Rhode Island Economic Development Corporation, Quonset Point Industrial Park Water Supply System, Volume 1. North Kingstown, Rhode Island.

Information through the ages….

In 1968 USGS published *Hydrologic Characteristics and Sustained Yield of Principal Ground-Water Units Potowomut-Wickford Area Rhode Island*.[71] This report, water-supply paper 1775, discusses water availability in the area that is now referred to as the HAP aquifer. In 1968 five out of the seven existing wells were in place and pumping water from the Hunt Aquifer. The paper reports the *sustained yield* of 8 MGD for the Hunt wells, the amount that the wells can withdraw without ever running dry. However, clearly noted in paper 1775 is that withdrawals of this magnitude would sometimes result in zero flows in portions of the Hunt River.

> A withdrawal of 8 mgd from the [Hunt] reservoir will have negligible effects on streamflow and on marsh and pond storage during a wet year, such as 1958. However, in exceptionally dry years, such as 1949, 1957, and 1963, this withdrawal will result in no streamflow for as much as 160 days of the year in a sizable reach of the Hunt and Potowomut Rivers. An undetermined decrease in marsh and pond storage should also result.

Therefore it is clear that this paper does not consider 8 MGD the *safe* yield of the Hunt. In 1968, streamflow and environmental impacts in general were less of a concern for our society. The USGS reported on the well yields as assigned, streamflow was not an issue for this report. The safe yield of the aquifer is not discussed.

In 1995, North Kingstown, East Greenwich, Warwick, Kent County Water Authority, and Rhode Island Port Authority commissioned the *Hunt Aquifer Wellhead*

[71] Rosenshein, J. S., Joseph B. Gonthier, and William B. Allen. 1968. Hydrologic Characteristics and Sustained Ground-Water Units Potowomut-Wickford Area Rhode Island. Geological Survey Water-Supply Paper 1775. United States Government Printing Office, Washington.

Protection Plan from GZA GeoEnvironmental, a private consulting firm.[72] The primary purpose of this report was protection of water quality and it resulted in the formation of the Hunt Wellhead Protection Committee that disbanded in 2002.

However, along with water quality the report examines the water supply quantity as well. The GZA paper incorrectly reports that the safe yield of the Hunt Aquifer is at least 8 MGD (and possibly as much as 13.3 MGD) and cites the 1968 USGS study. “The USGS reported in their water supply paper 1775 that the safe yield of the Hunt Aquifer is 8 MGD.” This is wrong. As discussed, 1775 reported that the *sustained* yield of the Hunt wells, not that the safe yield of the aquifer, was 8 MGD.

This is not simply a case of different terminology. The GZA paper explicitly states that safe yield would be protective of streamflow.

> Determining the future ‘safe-yield’ of an aquifer depends on how the requirements for ‘in-stream’ water use is defined and valued….In-stream use is the water necessary to maintain the existing flora and fauna of the stream (Hunt River & its tributaries) and adjacent wetland systems.

To restate for emphasis, the GZA report says that the safe yield (which protects flora and fauna of the river) of the Hunt Aquifer is 8 MGD. GZA cites Paper 1775 as the source of this information, while the USGS paper clearly discusses well sustainable yields and demonstrates that withdrawals of 8 MGD would cause much of the river to run completely dry for up to 160 days of the year in drier years. This is obviously not protective of streamflow and not the safe yield. The fact that GZA erroneously claims

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[72] GZA GeoEnvironmental, Inc. 1995.

that the safe yield may be as much as 13.3 MGD, an amount for which they offer no proof, has had highly unfortunate consequences.

By issuing this report, GZA has misled the public and the agencies that commissioned it. They have implied that much more water is available in the Hunt than is there, according to any scientific assessment. Mistakes like this can cause significant difficulty for the people who rely on the Hunt for water supply and for the aquatic community of the Hunt.

This is problematic for the future since the GZA report is used for planning purposes in the Hunt watershed today. Officials from North Kingstown and from the RIEDC pointed me towards the GZA report, and implied that this report told them everything they needed to know about water supply in the Hunt.[73]

RIEDC's Master Plan[74] and Water Supply System Management Plan[75] list 8 MGD as the safe yield of the Hunt. The supply plan incorrectly cites USGS paper 1775. I believe that RIEDC has not read the USGS report and that they take this information from the GZA report. Though the Master Plan has no citation for their estimate of water availability from the Hunt, it likely comes from the same source

RIEDC is not the only supplier that has been misled by the GZA error. The North Kingstown Water Supply System Management Plan also lists 8 MGD as the safe yield of

[73] Susan Licardi, Water Director, NK Department of Water Supply, June 25, 2004, Dale Grogan, Town Council, NK, June 22, 2004, and Vasilios Harritos, Facility Engineer, RIEDC, October 28, 2004. Personal communications.

[74] RIEDC, Quonset Davisville Division. 2003.

[75] RIEDC. October, 1999 (submitted). September, 2000 (revised).

the Hunt and incorrectly cites the USGS Water Supply Paper 1775.[76] I believe that they also took this information from the GZA report.

The Water Resources Board was also misled by the GZA report since they are charged with approving both Water Supply System Management Plans.

Actual Hunt Safe Yield

As discussed earlier, USGS no longer separates the Hunt, Annaquatucket, and Pettaquamscutt subbasins in their work. The 2001 study reports that the safe yield of the *total* HAP basin is 8 MGD, but USGS does not list safe yields for the individual subbasins. I estimated each subbasin's safe yield from the July withdrawal scenarios put forth in the study. Safe yield for the Hunt ranges from 2.34 – 4.81 MGD, for the Annaquatucket from 2.68 – 4.07 MGD, and for the Pettaquamscutt from 0.41 – 1.24 MGD.[77]

The Water Resources Board also commissioned a comprehensive analysis of total state water supply by Arthur D. Little, Inc. which was published in 1990.[78] This report lists safe yields of each watershed. They differentiate between safe yield and average year yield, safe yield being "the quantity of water that can be obtained from a source on a

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[76] The Town of North Kingstown. November, 2000 (submitted). November, 2001 (revised).

[77] Barlow and Dickerman. 2001.

[78] Little, Arthur D., Inc. et al. October, 1990.

continuous basis during the worst drought on record." The average year yield is the amount that can be obtained during a year of average rainfall.

Table 4: Yields from *Water Supply Analysis for the State of Rhode Island*

	Safe Yield (MGD)	Average Year Yield (MGD
Hunt	2.0 – 3.5	3.5- 6.5
Annaquatucket	1.0 – 1.5	1.5 – 2.5
Pettaquamscutt	0.2 – 0.4	0.4 – 0.8

The Little report has been used as a reference during the Water Resources Board WAPAC process. These numbers differ from the USGS study, but are not far out of the range. In particular, the Hunt safe yields are pretty close to the USGS HAP study figures and in line with USGS Water Supply Paper 1775, significantly less than 8 MGD.[79]

Conclusions

Many issues envelop water supply in the Hunt basin and each community relies on their needed water to be there. Officials in North Kingstown expressed concern about

[79] Hunt withdrawals reached 4.25 MGD in July 2004.

how much water RIEDC will use in the future. It is possible that a large water-using industry will move in to Quonset Point which could threaten the Town's water supply.[80]

On the other hand, RIEDC officials believe that North Kingstown residents are irresponsible with their water use in the summertime, when the water could be used to support a business which would benefit the entire state. RIEDC believes that they have a conservation-oriented approach to water demand and that North Kingstown residents use water frivolously in the summer.[81] Water is a necessity to the future of the Town and the business park and both parties have issues to address.

[80] Dale Grogan, Town Council, NK, June 22, 2004, and Susan Licardi, Water Director, NK Department of Water Supply. June 25, 2004. Personal communications.

[81] Vasilios Harritos, Facility Engineer, RIEDC, October, 28, 2004, and W. Geoffrey Grout, Managing Director, Quonset Point, RIEDC, November 8, 2004. Personal communications.

V: SYNTHESIS OF THE HUNT WATER ISSUES

In the previous chapters I examined the current conditions of the Hunt Aquifer. Streamflow levels were analyzed, using the RIABF and 7Q10 methods. I have detailed a DEM Fish Survey report which looks at the health of the species composition in the Hunt River and its tributaries. In Chapter III., I discussed withdrawals in the system today and historically. Then I explained the politics revolving around the Hunt Aquifer, first the past conflict between the three Hunt border towns, and second, issues with the major suppliers; namely that North Kingstown is increasing withdrawals every summer due to lawn watering and that RIEDC predicts significant increased water usage to support growth and development at Quonset Point. I also showed why local stakeholders believe that more water exists in the Hunt than is actually available. The suppliers have been misled by their commissioned GZA study which incorrectly cites a USGS report and erroneously claims that 8 MGD can be withdrawn from the Hunt River without harm to streamflow.

This information already paints a troubling picture of the situation in the Hunt watershed, but next I consider how each of these points relate to each other by addressing my central question: How can a balance be struck between supply and flow in the Hunt River?

Flow versus Withdrawals

It is important to compare several high pumping periods to flow to see if correlations exist. In August 1998 151.7 million gallons (4.9 MGD) were pumped from Hunt River wells. Additional high withdrawals occurred in July 2001 and 2002 when 130.9 and 146.1 million gallons were taken from Hunt River wells. (4.2 and 4.7 MGD)

I compared flows during periods of high withdrawals to the potential 7Q10 level. However, as discussed in Chapter II., reaching the 7Q10 should be avoided as it represents less than 10% of the average annual flow for most rivers and occurs only once in ten years for a week in unregulated conditions. According to experts, most aquatic life can only survive under 7Q10 conditions for a short time.[82] The Hunt generally experiences the lowest flows in August and September, but occasionally in July or October.

In August 1998 the Hunt River average flows were 11.8 cfs. Flows were above the potential 7Q10 (8.2 cfs) for the entire month. In September 1998 average daily flows were below the potential 7Q10 twelve times, but never were lower than 6.1 cfs. There were 2.39 and 2.3 inches of rainfall in August and September of 1998.

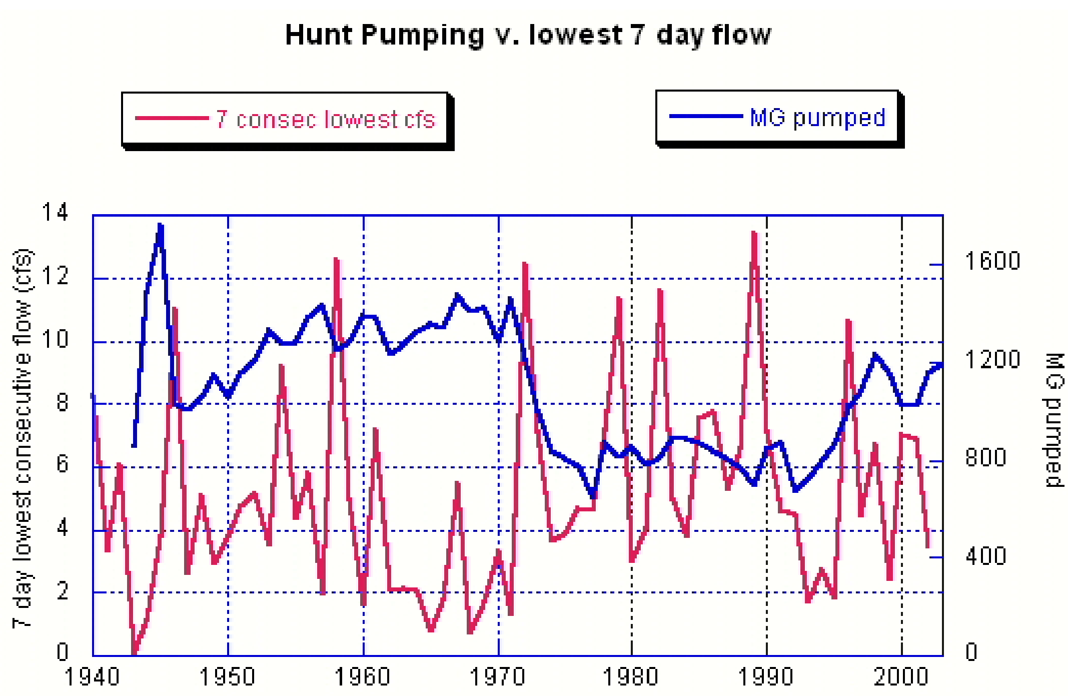
In July 2001, with 4.2 MGD being pumped from the Hunt River, average flow (without much variation) was 26.5 cfs, well above any streamflow standard. In August all flows were above the potential 7Q10, and flows reached a low of 9.6 cfs. The August average flow was 18 cfs. In September average flow was recorded at 16.9 cfs, but

[82] Annear, Chisholm, Beecher, & Locke. 2004.

average daily flows were lower than the potential 7Q10 on twelve days. Rainfall was 1.92, 4.5, and 4.4 inches in July, August, and September.

In July 2002, about 4.7 MGD were pumped from the Hunt wells and average streamflow was 10.6 cfs. Daily flows were below the potential 7Q10 on 5 days. In June drought conditions set in which began to effect flows in August. In August average flow was recorded at 5.52 cfs. Flow reached the potential 7Q10 mark (8.2 cfs) on one day, but the rest of the month was below that level. In September flows were below 8.2 cfs for 26 out of 30 days. Average September flow was 5.35 cfs.

Figure 10: Low flow Versus Withdrawals Over Time



To create this graph I used the average seven day low flow for each year, which was utilized in the 7Q10 analysis. The data are useful to show the river at its most stressed point in each year. It is important to note that this is not representative of the river's flows the majority of the time, the average amount of time, or even as typical summer flows. The withdrawal data are listed in million gallons pumped per month.

This graph demonstrates the relationship that withdrawals have on the river during times of stress. There is a direct correlation between pumping and flow in this graph. In the forties though the seventies we can see that withdrawals were relatively high and low flows were mostly below the potential 7Q10 figure of 8.2 cfs.

In the 1970's, Navy operations at Quonset significantly declined as did their water use, which is apparent in Figure 10. Withdrawals declined and flow recovered somewhat. Variations are due to precipitation levels, but the overall trend from the mid 70's to the early 90's is that flow levels are close to the potential 7Q10. Starting in the early 1990's RIEDC assumed control over Quonset and withdrawals increased. The trend shows that in recent times low flows are declining.

Safe Yield

As discussed in Chapter IV., I estimated the safe yield of the Hunt from the USGS HAP study and found it to be in the range of 2.34 – 4.81 MGD. Withdrawals in recent summers have approached the upward limit of this safe yield range, and breached it in

1999. I believe that no further withdrawals should be allowed from the Hunt, and that future July withdrawals continue at a lower rate than in the recent past.

Table 5: Average Recent July Withdrawals

July	Average withdrawals (MGD)
2004	4.3
2003	4.2
2002	4.7
2001	4.2
2000	3.8
1999	5
1998	4.8

Conclusions: Summary of Problems

The Hunt River is the border of three towns, which have a prior record of conflict over their shared water resource. The Hunt aquifer supplies three different public water supply companies—serving as the sole source for RIEDC and the primary source for North Kingstown. Summertime demand is both high and increasing in North Kingstown. Significant growth is projected for Quonset Point and RIEDC believes that more water is available in the Hunt than is actually the case. The DEM’s fish survey concludes that the lower reaches of the Hunt are in degraded conditions. Current July withdrawals come close or exceed the upward limit of the safe yield range estimated from the USGS HAP study. At the same time, the DEM and WRB are in the process of establishing watershed specific flow standards and based on my calculations of the 7Q10 and ABF, the Hunt is likely to be in violation of any flow standard that is set, at least in the summer months.[83]

Based on all these points, I conclude that it will be impossible to increase withdrawals from the Hunt in the summertime without completely destroying the natural hydrograph. Thresholds will most likely be reached in July with current levels of withdrawals when the Hunt's flow standards are set by the DEM and WRB. Once standards are set, suppliers and communities will legally have to ease withdrawals and use.[84] While, standards might affect current usage amounts, they will certainly curb future expectations of supply.

Therefore, it would be prudent for suppliers and municipalities to act now to ensure that enough water is available for all users including the fluvial species residing in the Hunt. The suppliers need to accept that they have been operating under incorrect assumptions as to water availability in the Hunt. If measures are taken now to reduce demand and conserve supply the Town and RIEDC will stave off major economic and

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[83] It is likely that flow standards will be set to the 25% probability rate. Once flows reach the lowest point that has a one-in-four-year likelihood of occurring, withdrawals will have to be eased. Ideally, once flows reach this level the RI Drought Management Plan will take effect.
From: Water Resources Board. 2002. Rhode Island Drought Management Plan. State Guide Plan Element 724. Report Number 104. Statewide Planning Program, Providence, Rhode Island.
Online: (http://www.planning.ri.gov/landuse/dmp.htm)

[84] The DEM has decided that new flow standard regulations will apply to existing users.
From: Alisa Richardson, Principal Sanitary Engineer, RIDEM, OWR, April, 21, 2005. Written communication (email)

environmental hardships in the near future. The remainder of this paper will focus on measures that should be implemented to avert large-scale problems facing the Hunt watershed in the near future. I will try to answer my central question and determine how a balance can be struck between supply and flow.

VI: RECOMMENDATIONS

Based on my research laid out in the previous chapters I believe that the Hunt is over-pumped and that withdrawals should not increase from any well in the basin. I propose that the Rhode Island Economic Development Corporation, North Kingstown Water Department, and certain Rhode Island agencies modify current policies or behavior to address water scarcity in the Hunt basin. Enough water will be available for future human needs and enough flow will remain in the river to support the aquatic community if each stakeholder undertakes the following actions. Ideally, these recommendations will be enacted and some flow will be restored to the Hunt River. I present recommendations in order of importance.

I have chosen not to propose any changes for KCWA, since their Water Supply System Management Plan states that they do not intend to increase withdrawals from the Hunt River well.[85]

Rhode Island Economic Development Corporation:

I recommend four actions for the RIEDC, listed in order, to balance supply demands with flow criteria. For an adequate future supply, a combination of these mechanisms should be adopted. It is vital to the health of the Hunt that the RIEDC enact measures to ensure that additional water is not withdrawn from their wells.

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[85] KCWA. October, 2001.

1. Conservation

As a state-sponsored semi-public agency, the Rhode Island Economic Development Corporation should set an example to business and industry and act in an environmentally sound manner. Indeed, the Quonset Davisville Port and Commerce Park Vision Statement of November 20, 2000 on page one of the Master Plan expressly purports to maintain environmental values.

> It is the vision of the Boards of Directors of the Rhode Island Economic Development Corporation that, with responsible stewardship of existing resources, we can foster and encourage the development of the Quonset Davisville Port and Commerce Park through the integration of transportation and land planning in a way that balance local, state, and regional economic benefits with respect for the environment.[86]

If the Hunt is found to be in violation of a standard set by the DEM, then RIEDC may legally have to limit withdrawals to current use levels at Quonset. However, given the evidence presented in this paper, especially including the fact that all projections for future availability are based on the erroneous water data, a sensible action for the RIEDC would be to develop an alternative supply plan on their own accord.

The agency already recognizes both the value and limitations of their water supply to some degree. In interviews with officials I learned that RIEDC works closely with each new business to make certain that they conserve water using reasonably

[86] RIEDC, Quonset Davisville Division. 2003.

available methods.[87] The 2003 Master Plan specifically states that water conservation is a priority at Quonset Point.

> RIEDC is a long-term member of the Hunt Wellhead Protection Committee…. The purpose of the Committee is to protect the Hunt aquifer, as it is an important water supply source for the area. Water conservation is a main priority of this Committee and RIEDC.

Further:

> The RIEDC promotes practical water conservation through a Major Users Technical Assistance Program tailored to each major user. This process starts with new users during initial site development reviews so that conservation measures can be integrated into the users' initial construction. The RIEDC has also been an active participant in the development of a Drought Management Plan by the RI Water Resources Board, which will serve as a future guide to water suppliers, municipalities, state agencies and consumers throughout the state including the proposed park.

RIEDC works to reduce demand from each user within the office park and appears to recognize the value of the Hunt Aquifer. However, despite these efforts the projected demand needed for Quonset at full buildout will burden the already overtaxed Hunt. All efforts to conserve water at Quonset should be continued and updated with new technology. Costs will vary depending on the technology used. Conservation is the easiest thing Quonset businesses can do to preserve the integrity of the Hunt.

2. Wastewater Reuse

In the future, wastewater reuse should play a role at Quonset Point. Reuse is feasible since Quonset operates its own Wastewater Treatment Facility (WWTF) on-site,

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[87] Vasilios Harritos, Facility Engineer, RIEDC, October 28, 2004, and W. Geoffrey Grout, Managing Director, Quonset Point, RIEDC, November 8, 2004. Personal communications.

with the potential of providing ample supply at a minimum distance from a potential user. The issue was explored in detail in a Brown University Master's Thesis from 2004 by Kathleen Esposito.[88] She found that the North Kingstown Municipal Golf Course at Quonset is an ideal candidate for reuse for irrigation purposes. The golf course with minimal infrastructure changes could replace drinking water with treated wastewater for irrigation, thus saving approximately 0.15 MGD in the summer months. The report did not include cost estimates for this project, but notes that pipeline costs $60/foot for 18 inch diameter and $80/foot for 24 inch diameter. The golf course is approximately one mile from the WWTF.

Currently the WWTF uses secondary treatment before discharging into the Bay. This treatment is sufficient for irrigation or toilet flushing purposes. If the scope of wastewater reuse were to be expanded, then there would be an additional cost to upgrade the WWTF to tertiary treatment.[89]

Reuse of wastewater would reduce peak demands on the Hunt and ease future needs for RIEDC. Irrigation could lead to wastewater reuse at Quonset in other areas which will become an eventual necessity if current projections hold. In the future, due to supply constraints, RIEDC may have no choice but to reuse wastewater in other capacities.

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[88] Esposito, Kathleen. 2004. Connecting the Drops: Exploring the Role of Wastewater Reuse in the Future of Water Resources Management in Rhode Island. M.A. thesis. Brown University, Providence, Rhode Island.

[89] Cech, Thomas V. 2003. Principles of Water Resources: History Development, Management, and Policy. John Wiley & Sons, Inc. Hoboken, New Jersey.

3. Purchase, if possible

It may be necessary for Quonset to augment their Hunt supply with another source depending on the streamflow standards set and the level of success the agency has with conservation methods and wastewater reuse. During interviews with Quonset officials I discussed the possibility of purchase from other suppliers.[90] Consistently mentioned is the possibility of purchase from Kent County Water Authority. However, Kent County's Water Supply System Management Plan forecasts shortages both in the immediate (5 years) and long term (20 years) future.[91] This forecast does not include any sale of water to RIEDC. This option would be much more feasible should Big River Management Area be developed for water supply, as suggested by Grow Smart Rhode Island's 2002 report.[92] However, as discussed in Chapter IV., it seems probable that most if not all of Big River water will be needed by the communities in the immediate vicinity.[93]

Another possibility is to purchase water from the Providence Water Supply Board (PWSB), which gets its supply from the Scituate Reservoir. While this resource is not currently stressed, it is limited based on rainfall.[94] The PWSB currently supplies about 70% of Kent County's water along with their own and several other districts. It is

[90] Vasilios Harritos, Facility Engineer, RIEDC, October 28, 2004, and W. Geoffrey Grout, Managing Director, Quonset Point, RIEDC, November 8, 2004.

[91] KCWA. October, 2001.

[92] Grow Smart Rhode Island. 2002.

[93] Bray, 2005.

[94] Providence Water Supply Board. Online: (www.provwater.com)

unclear as to whether further supply will be available from Providence Water particularly with Kent County Water Authority's predicted shortfalls.

The infrastructure connecting Quonset water supply to KCWA and through them PWSB is already in place.[95] Connections were established to provide water in an emergency in case of extreme drought, contamination, or other unforeseen catastrophe. The costs for purchase would be set by the suppliers.

4. New Supply Source, if needed

Should conservation, wastewater reuse, and purchase from other major suppliers prove insufficient to meet future demands at Quonset, RIEDC may need to develop a new supply source of its own. The USGS HAP study suggests that further withdrawals may be possible in the lower reaches of the Annaquatucket and Pettaquamscutt basins, south of the Hunt. If this option is explored by RIEDC, they should work with the DEM, WRB, and USGS to prove that a new well would not degrade conditions in the other rivers substantially. It would be unfortunate to the sacrifice the health of one river to help another. However, with careful management and input from government agencies, RIEDC should find an appropriate location for a new supply well for Quonset.

In 2004 North Kingstown installed a new well in the lower Annaquatucket. According to Water Director Susan Licardi, the total project cost was $243,401, "which included identifying ten potential well sites, test well drilling at a number of sites, test

[95] RIEDC. October, 1999 (submitted). September, 2000 (revised).

well and monitoring well installation, production well installation, and pump testing."[96] The final, operational production well is 18' x 12" and 150 feet deep. A new RIEDC well in the same region would likely cost a comparable amount in 2004 dollars. An additional cost of piping to Quonset would be needed and would fall in the general range discussed for wastewater infrastructure of $60/foot for 18 inch diameter piping and $80/foot for 24 inch diameter piping.[97] Quonset Point is approximately two and a half miles from the lower Annaquatucket.

Summary

As a state agency the RIEDC has an ethical responsibility to protect the resources and environment of Rhode Island. The RIEDC also has the economic means to make alternative arrangements for their water supply. Any new costs for infrastructure development for conservation, wastewater reuse, or a new supply source, could be split evenly through the corporations in residence at Quonset through an increase in water rates. Because of these circumstances RIEDC should begin to confront the scarcity issues facing their water supply now.

[96] Susan Licardi, Water Director, NK Department of Water Supply. April 28, 2005. Written Communication (email).

[97] Esposito. 2004.

Demand Management Strategies for North Kingstown:

Despite the limited availability of water from the Hunt Aquifer, North Kingstown is relatively lucky for a town planning for future need. The community is almost built-out so, theoretically, the rate of water use in the town can stabilize. The water supply is high quality, delicious, and ample to suit their needs if carefully managed. In order to guarantee that the town uses water sustainably and that the Hunt River remains healthy, it is critical that the North Kingstown government enact demand management strategies to curtail increasing summertime use.

This report does not present a definitive plan to reduce summertime use. Unfortunately, I was limited by time constraints and unable to fully flesh out a specific plan for North Kingstown, but I have researched several ideas. It is my hope that the North Kingstown Town Council considers these ideas, studies the feasibility of their application, and enacts one or more of these recommendations as soon as possible. By planning for adequate future supply the Council will act in the long term best interest of the town and community as a whole.

1. Adopt comparable polices to Massachusetts

The Massachusetts Department of Environmental Protection recently adopted a new water management policy for stressed basins.[98] [99] The policy only applies to new users and includes the following regulations:

- [A] cap on per capita per day residential water use…(no more than 65 gallons per capita for high and medium stressed basins, no more than 80 gallons per capita for low stress and unassessed basins).
- Limits on unaccounted for water (no more than 10% for high and medium stress basins, no more than 15% for low stress and unassessed basins).
- Summer limits on withdrawals (limit varies based on prior use).
- Streamflow thresholds that trigger mandatory limits on nonessential outdoor water use, including but not limited to lawn and landscape irrigation.

The Town could implement policies similar to those adopted in Massachusetts but apply them to every user in the town, even to users with private wells. The last point may overlap with state practices if limits are imposed by the WRB and DEM.

Some of the Massachusetts policies are similar to the steps laid out in the Rhode Island Drought Management Plan.[100] An alternative for North Kingstown would be to follow drought procedures during dry summers, without waiting for a drought to be declared by the WRB. Perhaps the drought plan could take effect when a specific streamflow threshold is reached in the Hunt.

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[98] Commonwealth of Massachusetts Executive Office of Environmental Protection. 2004. Water Management Policy For Permit and Permit Amendment Applications and 5-Year Reviews. Water Management Act Program (310 CMR 36.00) WMA Policy #: BRP/DWM/DW/P04-1. Online: (http://www.mass.gov/dep/brp/wtrm/files/wmafinpol.doc)

[99] Commonwealth of Massachusetts Executive Office of Environmental Protection. 2004. Guidance Document for Water Management Act Permitting Policy. Guidance #: BRP/DWM/DW/G04-1 Online: (http://www.mass.gov/dep/brp/wtrm/files/wmafinguid.doc)

[100] RI WRB. 2002.

North Kingstown should impose a fine for exceeding the set limits for residential summertime use. All water meters can be read outside the house and the Town is in the process of updating their system to allow for more efficient meter reading. As explained by Water Director Sue Licardi, "Currently most meters are Schlumberger (Neptune) with an ARB encoder located on the outside of the house that the meter reader plugs into to get the reading." The town is in the process of transferring over to radio-read meters—they update 300-400 meters per year to Hersey meters with a wired ERT. These are read by walking or driving by the front of the house with the meter reading equipment. They are also able to retrofit the newer Neptune meters with the ERT and transform them to radio read.[101] The accessibility of meters allows the Town to have many options from which to proceed since they are able to easily monitoring residential water use.

Enforcement could be handled through spot check techniques. An enforcement officer or water department supervisor could read the meters in various neighborhoods a few nights in one week, and assess charges to users in breach of regulations. Checks would not have to be consistent or regularly performed. If fines are high enough spot enforcement should be effective.

Either of these plans would be effective to reduce demand, but would require significant regulation by officials and likely incite public criticism, if the response to

[101] Susan Licardi, Water Director, NK Department of Water Supply, March 7, 2005 and March 10, 2005. Written communication (email).

odd/even day watering is any guide. Other techniques may also curb usage but invite less bureaucracy and more public support.[102]

2. Property tax deduction for "Healthy Landscapes" certified residences

North Kingstown has an advantage over many small communities in the state to promote water conservation since the water department is a division of the town government. All of their neighbors rely on private suppliers or have no centralized system in place. I propose that North Kingstown offer property tax deductions for any residence or business certified as having adopted a "Healthy Landscape."

The Healthy Landscapes Initiative is a project developed by University of Rhode Island's Cooperative Extension and North Kingstown. Healthy Landscapes currently provides information to the public regarding natural landscape plants that require less water than standard turf. They also teach the proper amounts needed to water lawns and ways to conserve water, such as using rain barrels. Healthy Landscapes provides generalized and site-specific methods for efficient lawn care.[103]

So far, North Kingstown Water Department has been working closely with Healthy Landscapes Initiative in an educational basis. They hold regular free seminars and are a presence at many town events. The North Kingstown Town Council sends out informational brochures from Healthy Landscapes promoting water conservation and

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[102] The USGS, working in conjunction with the RIWRB, is set to begin a project around May 1, 2005 to study drought triggers in the HAP. This study will examine year-round precipitation records to determine whether correlations for drought with the hope of providing information to the water suppliers to allow them to better manage the system.

[103] Healthy Landscapes Initiative. Online: (www.healthylandscapes.org)

natural landscaping to every resident of the town. Despite the aggressive educational campaign over the last few years, the Water Department has noticed no reductions in use. I think the program is impressive in the level of detail of the information provided and that current efforts should be continued since education should always be a priority. The program likely has benefited the watershed though in immeasurable ways. However, the program could be more effective if financial incentives were offered to residents for following these practices.

I suggest that upon certification of a “Healthy Landscape” by a member of the Initiative, a property tax deduction be rewarded to residences or businesses. I foresee the following process to be tweaked as necessary. Residents would fill out an application provided by Healthy Landscapes, which includes a copy of their water bill, information as to size of their household, and the reasons that their lawn should qualify for certification. Then, a member of the Initiative would visit the residence and meet with the applicant. Healthy Landscapes could confirm or deny the application as they see fit. If approved, the applicant would be rewarded a certificate and qualify for a property tax deduction through the town. A new application would be required for each year, but subsequent years would not require a visit by a member of the initiative, following an initial approval and submission of an appropriately low water bill.

The certification of “Healthy Landscape” would apply to a variety of circumstances. Examples include a lawn that is never watered, a drip or conservation oriented lawn irrigation system, a rain barrel to irrigate gardens, or a landscape consisting of natural plants that do not require irrigation. Essentially, the experts at Healthy

Landscapes have complete discretion for approval or denial of an application, but the residents have many options as to how to qualify for “Healthy Landscape” certification.

Most workers currently at Healthy Landscapes are volunteers. This process could be conducted primarily through volunteer efforts with official oversight. The official would have the charge of approving applications but visits and reviews of information could be entrusted to volunteers. As this program gains visibility through the Town’s further involvement more volunteers will be attracted to participate.

To be effective the tax break should be significant enough to act as an incentive to reduce lawn watering. I propose that the Healthy Landscapes tax deduction range from 5 – 10% of the total property tax.

Incorporating the Healthy Landscapes Initiative further into town policies would encourage water conservation primarily in the summer. This plan would help to curb the popular and growing trend of installing automatic sprinklers. If enacted and encouraged by the Town Council this program could reduce summertime demand.

3. Water rate increase

To support efforts to reduce demand, North Kingstown should increase rates. Last May the Town Council voted to increase rates for their approximately 9000 users. Rates will increase incrementally over the next 5 years from $1.93 per 1,000 gallons to eventually reach $2.60 per 1,000 gallons. Quarterly water flat fees will also increase incrementally from $12.41 to eventually reach $13.96 in five years.[104] While this small increase is not likely to effect usage it represents a big step for North Kingstown since, for the first time, discounts for large users have been abolished. However, to encourage users to conserve water and financially support the supplier while use declines, North Kingstown should raise water rates even more, abolishing flat fees and putting the full bill on a consumption basis, and perhaps adopt an inclining block rate.

The Water Resources Board water allocation program included a rate committee charged with exploring the role of costs of water in Rhode Island. Their recommendations include:

1. Fair and reasonable rates
    - Eliminate flat or fixed water and sewer rates and tie rates to volume of water used; use preferred (lower) rates for those using less water or reusing water; use seasonal (higher) rates or temporary drought surcharges during periods of water scarcity;
    - Establish a "consumption per capita" standard which considers household size; consider an excess use rate over the standard rate.[105]

To complement higher rates, the committee proposes an increased frequency of billing cycles. Typically, residents receive their water bills several months after they have consumed the water. Because of this, even high rates do not impact use during the dry summer. Residents would have more of an opportunity to link behavior to fees if bills came more regularly.

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[104] Bottis, Beth. 2004. "NK council approves five year water plan." NKStandardTimes.com. June 7, 2004. Online: (http://www.northkingstown.org/waterdept/WArates.htm)

[105] RI WRB. 2003. WAPAC Fees/ Water Rates/ Alternatives Subcommittee Recommendations. Online: (http://www.wrb.state.ri.us/programs/wa/wapac/pdf/waterratesrec.pdf)

In 2002, a Brown University Masters thesis project from Megan Terebus examined water rates in Rhode Island.[106] The project ultimately recommends that "An inclining rate system should be used to reduce excessive water use." An optimal inclining structure to encourage conservation would set thresholds just below average annual consumption levels for each category and include a significant rate increase at each level.

The Water Resources Board believes that consumption will not be curbed by an increase of water rates alone.[107] Residents are disconnected from their water bills since they currently come months after the water was used and amounts in the bills are often expressed in units that are somewhat incomprehensible to the general public, such as cubic feet per second as opposed to gallons. Also, many people will pay the amount charged and not even question whether a modification of behavior could lower costs. Bills should be distributed monthly, amounts expressed in gallons, and a high inclining block rate should be adopted at least on a seasonal basis as proposed by the Water Rates Committee. Together these actions may effect water use, but the Water Department will need sufficient staff to implement monthly billing cycles and the North Kingstown Town Council (along with most local governments in Rhode Island) needs the political will to approve a meaningful rate increases necessary to curb water consumption.

A substantial seasonal rate increase would have benefits and should be adopted regardless of whether use will be impacted enough to restore flows to the Hunt. The

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[106] Terebus, Megan J. 2002. Preparing for the calm or relying on the storm?: The Rhode Island Water Supply System Management Plan. M.A. thesis, Brown University. Providence, Rhode Island.

[107] Kathleen Crawley, Acting General Manager, RI WRB, April 25, 2005. Personal Communication.

North Kingstown Town Council has the authority to set rates as needed and should be encouraged to continue the trend they started last summer. The funds generated would offset revenue losses to the Water Department due to decreased use and finance staff to allow more frequent billing. Extra funds could be used to support the property tax deductions for "Healthy Landscape" certifications. Any additional revenue could benefit the town as needed.

Summary

North Kingstown has a significant advantage over most of their neighbors in that their water supply is linked to the town government. This allows the Town to act in concert with their water department to address the growing problem of excessive summertime usage. They do not have to plan for many new users, but must deal with the users already in place. The town has many options to reduce demand; they just need the political will to go forward. I urge the town to act soon and adopt one or more of these recommendations. The town has all the potable water it could ever need, while allowing for adequate flow in the Hunt so long as steps are taken now to protect the resource. The Hunt can be managed in a sustainable manner—but North Kingstown needs to take action. The more water used each summer, the harder it will be for residents to cut back.

Actions for the State of Rhode Island:

Rhode Island state agencies can do much to help mitigate the impending supply crisis in the Hunt aquifer. The Water Resources Board will need to intervene should a conflict arise between the suppliers with wells in the basin. Ideally, any conflict could be avoided through actions taken now to mitigate the impending water shortage. As discussed through this paper, streamflow, and thereby aquatic life, will be in jeopardy if withdrawals in the Hunt even begin to approach 8 MGD, which the suppliers erroneously consider the safe yield. Based on the USGS HAP study the true safe yield is significantly lower than 8 MGD, 2.34 – 4.81 MGD and reached in recent summers. If North Kingstown and RIEDC can not manage their supply sustainably state agencies will inevitably have to step in. The agencies can act now to reduce the chances of a crisis later.

Watershed Specific Flow Standards

For the past few years the DEM and the WRB have been in the process of developing a streamflow standard system for the state. A streamflow subcommittee has been meeting on a semi-regular basis since 2003 as a spin-off from the Water Resources Board's WAPAC[108] process. The subcommittee is in the process of developing a system to set general watershed standards and more specific site standards, which will look at

[108] Water Allocation Process Advisory Committee. Formed by the WRB to research and inform the process for allocating Rhode Island's waters and to present recommendations.

flow in regards to particular projects.[109] However, the committee is still a long way from determining watershed flow standards. They have completed significant background research and are now beginning this part of the process. The group is using Big River as a model and plans to apply their findings to the rest of the state. I recognize the need for careful methodologies that will hold up over time, but urge the committee to prioritize this process and to set reasonable goals aimed at developing streamflow standards for each watershed in Rhode Island.

The DEM has adopted the RIABF to use in place of the U.S. Fish and Wildlife ABF standard as a tool for wetlands permitting applications.[110] The RIABF only applies to unregulated streams however, so it does not apply to the Hunt for any regulatory purpose at this point.

Actions for the Agencies

Regardless of when streamflow standards are set, agencies have an important role to play in the Hunt watershed. Based on my 7Q10 and ABF analyses, I believe that the Hunt River's flows are in trouble in the summertime during drier years and possibly more often than that. If they agree with my assessments, agencies such as the DEM, the Rivers Council, and the Water Resources Board should officially state that the Hunt is in trouble, that withdrawals to the River should not increase, and potentially be eased in the summer months.

[109] Streamflow Working Group meeting. RI DEM, RI WRB, USGS, March 30, 2005.

[110] RIDEM, OWR. March, 2005.

If a river is in trouble, it should be a priority to restrict future and, if possible, ease current withdrawals. The DEM, WRB, and the Rivers Council ought to advocate for the Hunt. This may include asking North Kingstown to enact demand management policies and the RIEDC to conserve, reuse, and possibly find an alternative supply. In addition they should advise the RIEDC to amend their Master Plan to more accurately reflect the available quantity of water. An official statement can be used to support advocacy.

Department of Environmental Management

Streamflow protection falls under the DEM's jurisdiction through the Water Quality Regulations Rule 8:

> A. Purpose. A water quality standard defines the water quality goals of a surface waterbody, or portion thereof, by designating the use or uses of the water and by setting criteria necessary to protect the uses. Water quality standards are intended to protect public health, safety and welfare, enhance the quality of water and serve the purposes of the Clean Water Act and Chapter 46-12 of the General Laws of Rhode Island. "Serve the purposes of the Act" (as defined in Section 101(a)(2) and 303(c) of the Clean Water) means that water quality standards should, whenever attainable, provide water quality, including quantity, for the protection and propagation of fish and wildlife and for recreation in and on the water and take into consideration their use and value as public water supplies, propagation of fish and wildlife, recreation in and on the water, agricultural, industrial, and other purposes including navigation.[111]

It is the DEM's responsibility to preserve sufficient quantity in a waterbody in order to maintain the appropriate quality. Through this jurisdiction the DEM is empowered to set minimum flow standards. In this capacity the agency can make an official statement

[111] State of Rhode Island and Providence Plantations. Department of Environmental Management Water Resources. 2001. Water Quality Regulations. Regulation EVM112-88.97-1 Online: (http://www.state.ri.us/dem/pubs/regs/regs/water/h20qlty.pdf)

attesting to the poor quality of the Hunt whether or not watershed specific flow standards are in place. The agency has discretion to decide whether the Hunt is degraded or not.

Water Resources Board

The Water Resources Board is charged with protection of the state's waters. Their duty is to allocate water to users and to protect the resource. In the Rhode Island General Laws:

> 46-15-1 (2) In recent years it has become increasingly apparent that water supply management, protection, development, and use must be fully integrated into all statewide planning, and rivers and watershed planning and management processes, and that the allocation of the state's water resources to all users, purposes, and functions, including water to sustain our natural river and stream systems and natural biotic communities, must be equitably decided and implemented under a process which emphasizes efficiency of use and management, minimization of waste, protection of existing supplies, demand management, drought management, conservation, and all other techniques to ensure that our water resources serve the people of Rhode Island for the longest time, in the most efficient use, and in an environmentally sound manner;
>
> (6) It shall be the duty of the water resources board to regulate the proper development, protection, conservation and use of the water resources of the state.[112]

Further:

> § 46-15.7-1 (b) (3) This requirement shall be carried out by management of fresh water resources of the state based on long-range planning for and conservation of these resources; fairness, equitable distribution, and consideration for all human uses; matching the use of water with the quality of water necessary for each use, giving priority to those uses that require the highest quality water; maintenance of

[112] RI General Laws §46.15.1, Waters and Navigation, Water Resources Board. Online: (http://www.rilin.state.ri.us/Statutes/TITLE46/46-15/46-15-1.HTM)

> native aquatic and terrestrial animal and plant species, populations, and communities and statewide diversity; continued upholding of and improvement in the quality of the environment and especially of the water resources itself; and careful integration with all other social, economic, and environmental objectives, programs, and plans of the state.
>
> (4) The water resources board is the state agency which manages the withdrawal and use of the waters of the state of Rhode Island.[113]

This legislation charges the Board with protection of rivers and streams and to advocate for demand management solutions and overall conservation. Under the authority of this statute the Water Resources Board can go on record and officially declare that the Hunt is in degraded condition. They can step in to help North Kingstown implement demand management strategies as discussed earlier in this chapter. The Board can decree that the RIEDC must protect the Hunt resource through reuse, conservation, and if necessary, alternative supply to meet future demands. I recommend that the Water Resources Board mandate that withdrawals not increase from any well in the Hunt basin.

The Water Resources Board also approves the Water Supply System Management Plans. I recommend that the Board no longer approve the plans for RIEDC and North Kingstown while they contain the incorrect safe yield amount and incorrect citation of the USGS Water Supply Paper 1775. If possible, the Board should require revision of existing plans.

I propose using the safe yield range discussed in the USGS HAP study, which I estimated from their pumping scenarios as 2.34 – 4.81 MGD for the Hunt.[114] In July

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[113] RI General Laws. § 46-15.7-1 Waters and Navigation. Management of the Withdrawal and Use of the Waters of the State. Online: (http://www.rilin.state.ri.us/Statutes/TITLE46/46-15.7/46-15.7-1.HTM)

2004 Hunt withdrawals totaled 4.3 MGD, in July 2002 withdrawals totaled 4.7 MGD, and in July 1999 withdrawals totaled 5 MGD. To me these data suggest that the Board should mandate that no further withdrawals occur from the Hunt wells.

The WRB should require that North Kingstown and RIEDC stop using the 1995 GZA report for reference, at the very least for water availability information and perhaps completely.

Rhode Island Rivers Council

The Rhode Island Rivers Council is also charged with ensuring the health of the Hunt River, though not in a regulatory capacity. According to its website:

> The RI Rivers Council was created by statute to coordinate, oversee, and review efforts to improve and preserve the quality of the state's rivers and other water bodies and to develop plans to increase river use. The General Assembly created the Council because "state jurisdiction over rivers, environmentally, culturally and economically, is scattered among state agencies and in some instances, state policies and plans [concerning rivers] are conflicting.

Duties of the Council regarding the protection of the Hunt include:

> 2) to advise State Agencies and municipalities concerning programs and measures to improve and protect river and watershed quality and to promote river use consistent with the Rivers Plan
>
> 3) to foster public involvement in river planning and decision-making through public education and promotional activities[115]

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[114] Barlow and Dickerman. 2001.

[115] RI Statewide Planning Program. Rivers Council. Online: (http://www.planning.state.ri.us/rivers/default.htm)

The Council can play an important role by supporting the Water Resources Board and the DEM since they are charged to coordinate and review efforts to improve the quality of the state's rivers. They are also entitled to advise state agencies. In this regard they can urge the RIEDC to confront the scarcity issues.

There is currently no citizens group concerned about the state of the Hunt. Should citizens come forward, the Council can facilitate approval to become a watershed council. The Council could also encourage development of such a watershed group. Residents concerned about the Hunt are more likely to conserve water in the summer and encourage their neighbors to do the same.

If the Council agrees with my research I urge them to make an official statement decreeing that the Hunt wells are over-pumped and that no supplier should increase withdrawals. This statement would help to gain recognition and awareness of the Hunt's problems and allow the suppliers to begin to deal with the inevitable problems of supply shortages should current trends hold.

General Assembly

The Subdivision Enabling Act, Chapter 45-23 in Rhode Island General Laws discusses the process by which major land developments and major subdivisions are approved. While "preliminary suitability for…public water systems" determinations are required in the preliminary plan stage, the second stage of the process, there is no explicit requirement to check for water availability in the initial stage which requires comments on a Master Plan.

Chapter 45-23-40 of the Rhode Island General Laws says:

> (3) Initial comments will be solicited from (i) local agencies including, but not limited to, the planning department, the department of public works, fire and police departments, the conservation and recreation commissions; (ii) adjacent communities; (iii) state agencies, as appropriate, including the departments of environmental management and transportation, and the coastal resources management council; and (iv) federal agencies, as appropriate. The administrative officer shall coordinate review and comments by local officials, adjacent communities, and state and federal agencies.[116]

The DEM comments at this stage and in this capacity they can express concerns about water supply based on streamflow. RI WRB might fall under the category of an appropriate state agency, however they are not specified. This statute does recommend soliciting comments from local agencies; however, it does not specify water departments. In many instances throughout Rhode Island the water supplier is a private company and would not fall under the category of local agency. In order for the initial comment phase to be most effective, the Subdivision Enabling Act should require initial comments from all public water suppliers within the watershed where the development is proposed. I see no point to go beyond an initial comment stage if adequate supply is unavailable. The developer should be able to demonstrate that adequate supply exists early in the process.

Research

To complement all the other recommendations research efforts should continue. I found no studies that examined whether low flows in the Hunt were harming Narragansett Bay. The Hunt discharges directly south of Greenwich Bay, which suffered

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[116] RI General Laws § 45.23.40. Towns and Cities. Subdivision of Land. Online: (http://www.rilin.state.ri.us/Statutes/TITLE45/45-23/45-23-40.HTM)

a large fishkill in the summer of 2003 and faces on-going quality issues. Given the fragility of the area additional research is justified.

I urge the DEM's U. S. Fish and Wildlife division to continue surveying the fish in the Hunt, if possible every summer. The 1997 and 2004 Surveys are a good starting place but annual data will be valuable in the near future when it comes to making decisions regarding increased withdrawals. I believe that they do plan to continue gathering these data. More importantly, the survey report should present an approximation of what a healthy fish population should look like in the lower Hunt. This information would allow readers to better understand any damage due to human impacts.

Any additional research in the Hunt Basin will be valuable to state agencies and the local suppliers when decisions have to be made regarding future withdrawals.

USGS Streamgages

I further recommend that USGS install streamgages to the lower Annaquatucket and Pettaquamscutt Rivers. If withdrawals increase from either of these basins it will be important to monitor the flows to make sure that these Rivers are not degraded to the level of the Hunt.

Summary

The agencies and legislators of Rhode Island can take many steps to ensure the health of the Hunt River and aquifer today and in the future, as well as the other rivers in the state. State government may have an important role to play in the future of the Hunt watershed by helping to avert conflict. Potential conflict may arise between the suppliers due to water scarcity if usage trends hold. By working with the suppliers, the agencies can ensure that the Hunt remain the high quality drinking source that it is today while allowing for sufficient streamflow for the aquatic community who call the Hunt home.

VII: CONCLUSIONS

A Plan for Action

After intensive study of the Hunt Watershed I believe that there is enough water available in the aquifer for a healthy aquatic community and for current human needs, if my recommendations are followed and summer demand is reduced. All further water needs should be met from alternative sources. I believe that if all three suppliers work together a plan can be developed to protect the Hunt. Growth at Quonset will benefit the entire state of Rhode Island and should be considered a priority as high as, but not higher than, protecting streamflow. Any plan will require substantial conservation efforts by all stakeholders. In particular, residents and businesses in North Kingstown need to reduce summertime demand significantly. RIEDC should embrace wastewater reuse for their golf course and work to implement reusing water in other capacities along with conservation efforts.

Current pressures on the Hunt in the summer could be reduced if North Kingstown successfully reduces summertime demand, though I have conducted no research on how much comprehensive water conservation measures will save.

RIEDC predicts a need of 3.595 MGD at peak demand at full build-out. In July 2004 they used an average of 0.77 MGD. This means that they need about 2.825 MGD to meet future peak demands. Reuse at the golf course would immediately free up 0.15 MGD in the high stress summer months.

Development of the Big River wells could potentially ease pressures on Kent County Water Authority, perhaps to the extent that they would consider abandoning their Hunt well. In July 2004 KC1 withdrew 0.77 MGD which could be allocated to the RIEDC for additional development.

These measures would provide an extra 0.92 MGD, for a total of 1.69 MGD, to Quonset. That is a good start for RIEDC to develop the park. It still leaves the Corporation with the need to find the additional 1.905 MGD predicted in the Master Plan for peak demand. For this water RIEDC will need to find an alternative supply unless considerable reuse[117] and conservation are employed.

Of course, this still leaves a lot of questions. For instance, it is not clear that Big River will ease supply to the Hunt by freeing up Kent County's need of the resource. RIEDC has been extremely hesitant to reuse wastewater due to cost restrictions. And, so far, North Kingstown has had no luck reducing demand in the summertime.

The Hunt River stakeholders are at a critical point. The aquatic community is degraded and if changes are not implemented now the fluvial species in the Hunt River will suffer further problems. The Hunt withdrawals jeopardize the life in the stream and agencies and suppliers need to begin an honest discussion about how to address this issue. I hope that solutions will be found and demands will be met. Most importantly,

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[117] At Foxboro stadium in Massachusetts, water needs have been reduced by 80% by treating wastewater and using it to flush the toilets. RIEDC could take similar measures at their industrial park. Perhaps all buildings, but especially new buildings could include the separate plumbing system needed for wastewater reuse, which would greatly reduce the overall demand.
From: Alisa Richardson, Principal Sanitary Engineer, Office of Water Resources, RIDEM, 4/12/05, Written communication (email) and Esposito, 2004.

the suppliers and communities should begin dialogue and planning now to ensure that everyone operates with accurate information.

My original question was: How can a balance be struck between supply and flow in the Hunt River? I believe that if each stakeholder makes good faith efforts to reduce their need for additional water, enough will be available for all. Rhode Island agencies and local municipalities and suppliers must work together to ensure the health of the aquatic community in the Hunt and provide for adequate supply for human consumption with careful management practices and firm streamflow standards.

Regional Supply Problem

The Hunt's problems are amplified when scrutinized in a regional context. Two of my colleagues wrote complementary theses on water supply in neighboring basins to the HAP. Erin Bray looked at water supply in two rapidly developing Rhode Island towns, Coventry and West Greenwich in Kent County, Rhode Island, directly to the west of the HAP basin.[118] She found that there is insufficient water in the watersheds overlaying the towns to support the projected full buildout without causing severe stress to the North Branch Pawtuxet, South Branch Pawtuxet, and Usquepaug-Queen subbasins. Withdrawals at the levels predicted would most likely result in low summer flows in these rivers and possible devastation to the aquatic community.

Alexandra Coria examined water supply to South Kingstown and Narragansett from the Mink and Chipuxet aquifers to the south of North Kingstown and the HAP

[118] Bray. 2005.

basin.[119] Though more research is needed, she demonstrates that the lowest flows in the Chipuxet River are getting lower due to withdrawals and that estimated safe yield has been breached in the Mink River. Coria recommends that no more water be pumped out of either aquifer until availability is better understood. However, current evidence suggests that both streams are being depleted due at least in part to withdrawals, particularly in the Mink.

Together the three theses illustrate that water scarcity is a regional issue facing southern Rhode Island. They demonstrate that when these communities face shortages, they cannot simply look to their neighbors to bail them out. Each community will have to learn to live with the available local supply.

Water Scarcity is a Global Problem—Rhode Island is not Alone

One of the most interesting aspects of this project for me is the knowledge that comparable issues are faced by communities all over the country and all over the world. The Hunt River basin is a small neighborhood resource and yet there are conflicts between the local suppliers. Many states and countries face similar controversies over transboundary waterways. It was fascinating to examine the Hunt as a case study with the knowledge that though each watershed is individual in its geography and supply needs, the same issues face millions throughout the world. Some regions struggle to maintain quality standards, some with serious shortages, and some with both. Worldwide

[119] Coria, Alexandra. 2005. Is there enough? Communication in water resource management in South Kingstown and Narragansett, Rhode Island. B.A. thesis, Brown University. Providence, Rhode Island.

communities confront water supply as a life or death issue and the mechanisms used to allocate and control that supply are comparable to those I examined for the Hunt.

Numerous communities across the globe will face serious decisions involving water supply in the future. I have learned that accurate information, comprehensive understanding of the issues, and careful planning are necessary to ensure that enough water is available for all users. However, in order to achieve future stability of supply we need to work now to conserve and properly maintain our resources. The world will be a bleak place if all our rivers are dammed or dried out and our aquifers are polluted. Every community must act to preserve water resources, protect the environment, and ensure adequate and sustainable future supply.

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APPENDIX 1: Withdrawal Data for Hunt River Wells

Methodology

The first wells were installed in the Hunt basin in 1943. I used the withdrawal data listed in the USGS HAP study for all of my analysis. USGS provides information from installation of each well until December 1998. I acquired withdrawal information from January 1999 – August 2004 directly from each supplier. Though amounts withdrawn were recorded for the most part, several data gaps exist for most of the wells. In order to determine the total withdrawals for each year, I filled in the gaps with the monthly averages from the appropriate years before and after the missing data. The data I generated from this method in are displayed in blue, while recorded data are listed in black.

RIEDC 9 & 14

Withdrawal data from RIEDC wells 9 and 14 are missing from January 1962 – December 1969. For each well I found a single average withdrawal figure from the installation point in 1943 – December 1961 and from January 1970 – December 1975. A single figure was used because withdrawals were fairly constant from month to month over these two time periods.

Withdrawal data are also missing from January 1976 – December 1992 for these two wells. For each well I determined monthly averages from 1973, 1974, 1975, 1993, and 1994 and used these figures to fill in the gaps. The Navy started to leave Quonset in 1973 and the RIEDC assumed control in 1993 – 1994, so I assume that the years I used best reflect the usage while Rhode Island Port Authority (RIPA) ran Quonset.

RIEDC 3

No missing data.

KCWA 1

No missing data from installation – July 2004. I used the amount pumped in August 2003 to estimate withdrawals in August 2004.

NK 9 & NK 10

Withdrawal data are missing from January 1983 – December 1989. For NK 9, I used monthly averages from the nine years before and after the missing data to fill in the gaps (January 1974 – December 1982 and January 1988 – December 1998). For NK 10, I used monthly averages for the nine years before the missing data, but only could use three and a half years after the data gaps due to the well taken off line from fecal coliform contamination (January 1974 – December 1982 and from January 1988 to August 1992, and September, October, November, and December 1991).

NK 6

Withdrawal data are missing from installation and initial pumping, March 1978, though December 1989. To fill in the missing data I used monthly averages of all years listed in the USGS HAP study, from January 1990 – December 1998.

Industrial Well

I generated a constant monthly withdrawal rate for the industrial well from an annual figure provided by the USGS HAP study.

Using the measured and constructed data I determined total million gallons (MG) pumped from Hunt River wells by month and annually. I also divided the monthly MG total by 30 to get an estimate of MGD. I used this spreadsheet as the basis for all withdrawal calculations for this thesis.

Since most withdrawal data are available from 1990 onwards, many analyses and charts presented in this these only utilize data from 1990 – 2004.

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1943	January	0	0						7.8	0		0.00
1943	February	29.4	7.2						7.8	44.4		1.48
1943	March	35.7	17.5						7.8	61		2.03
1943	April	24.5	20.5						7.8	52.8		1.76
1943	May	39.4	24						7.8	71.2		2.37
1943	June	35.8	26.1						7.8	69.7		2.32
1943	July	35.7	32.8						7.8	76.3		2.54
1943	August	44.6	45.4						7.8	97.8		3.26
1943	September	62.5	73						7.8	143.3		4.78
1943	October	35.4	40.1						7.8	83.3		2.78
1943	November	28	37.1						7.8	72.9		2.43
1943	December	33	37.9						7.8	78.7	851.4	2.62
1944	January	32.5	64.6						7.8	104.9		3.50
1944	February	30.6	38.5						7.8	76.9		2.56
1944	March	58.8	68.9						7.8	135.5		4.52
1944	April	36.8	37.6						7.8	82.2		2.74
1944	May	39.5	40.1						7.8	87.4		2.91
1944	June	40.1	39.9				18.4		7.8	106.2		3.54
1944	July	40.9	40.5				42.8		7.8	132		4.40
1944	August	38.4	59			57.8	32.2		7.8	195.2		6.51
1944	September	34.3	36			51.6	17.1		7.8	146.8		4.89
1944	October	36.1	37.5			29.8	30.6		7.8	141.8		4.73
1944	November	38	38.8			18.7	35.7		7.8	139		4.63
1944	December	36.9	43.7			40.5	10.1		7.8	139	1486.9	4.63
1945	January	38	44.2			46.5	15.3		7.8	151.8		5.06
1945	February	33.3	36.9			29.7	26.1		7.8	133.8		4.46
1945	March	41.8	46.2			26.7	28.3		7.8	150.8		5.03

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1945	April	39.4	43.8			18.7	37.6		7.8	147.3		4.91
1945	May	40.8	45.5			22.8	32.1		7.8	149		4.97
1945	June	39.8	44.5			28.7	35.6		7.8	156.4		5.21
1945	July	41.8	63.5			32.3	43.2		7.8	188.6		6.29
1945	August	43.4	46.7			35.7	37.5		7.8	171.1		5.70
1945	September	41.6	45.2			33.6	21.4		7.8	149.6		4.99
1945	October	50.8	58.6			30.4	10.5		7.8	158.1		5.27
1945	November	13.4	44.4			5.7	33.4		7.8	104.7		3.49
1945	December	19.3	28.2			15.1	24.9		7.8	95.3	1756.5	3.18
1946	January	37.9	6.9			34.8	6		7.8	93.4		3.11
1946	February	29.1	9.7			35.4	1.8		7.8	83.8		2.79
1946	March	32	13.2			30	11.4		7.8	94.4		3.15
1946	April	21.9	9.2			36	4.6		7.8	79.5		2.65
1946	May	24.4	6.3			36.6	5.4		7.8	80.5		2.68
1946	June	26.3	7.1			18.7	25.8		7.8	85.7		2.86
1946	July	25.6	24.7			12.3	35.5		7.8	105.9		3.53
1946	August	31.9	7.1			14.9	22.1		7.8	83.8		2.79
1946	September	28.1	12.2			13	20.8		7.8	81.9		2.73
1946	October	36.5	5.9			13.3	20.1		7.8	83.6		2.79
1946	November	23	4			25.2	19.4		7.8	79.4		2.65
1946	December	21	4.1			30.1	18.3		7.8	81.3	1033.2	2.71
1947	January	25.1	3.4			29.2	19.7		7.8	85.2		2.84
1947	February	20.8	2.9			25.3	18.3		7.8	75.1		2.50
1947	March	25.3	3.9			26.9	19.7		7.8	83.6		2.79
1947	April	13.6	10.4			26.5	18.8		7.8	77.1		2.57
1947	May	16.7	11.4			25.6	15.8		7.8	77.3		2.58
1947	June	18.9	12.2			22.4	19.4		7.8	80.7		2.69

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1947	July	23.6	18.5			28.1	14.9		7.8	92.9		3.10
1947	August	22.4	22.1			37.5	5.9		7.8	95.7		3.19
1947	September	22.7	19.4			30.7	11.1		7.8	91.7		3.06
1947	October	20	16.9			28	16		7.8	88.7		2.96
1947	November	13.6	15.9			29	10.1		7.8	76.4		2.55
1947	December	15.3	17.7			26.9	15.1		7.8	82.8	1007.2	2.76
1948	January	14.5	13.7			29.9	10.5		7.8	76.4		2.55
1948	February	12.2	14.9			32.4	7.8		7.8	75.1		2.50
1948	March	12.3	15.6			28.5	14.1		7.8	78.3		2.61
1948	April	12.1	15.5			24.7	17		7.8	77.1		2.57
1948	May	18.6	20.5			27.8	5.7		7.8	80.4		2.68
1948	June	20.6	26.2			22.6	6.6		7.8	83.8		2.79
1948	July	23.6	34.8			30.9	2.9		7.8	100		3.33
1948	August	29.9	39.7			34.1	0.5		7.8	112		3.73
1948	September	33.8	25			20.1	13.9		7.8	100.6		3.35
1948	October	32.2	18.6			18.4	13.4		7.8	90.4		3.01
1948	November	25.1	20.7			15.1	14.1		7.8	82.8		2.76
1948	December	30.9	30.1			19.5	8.2		7.8	96.5	1053.4	3.22
1949	January	25.1	28.5			18.4	8.8		7.8	88.6		2.95
1949	February	6.5	41.4			18.8	7.2		7.8	81.7		2.72
1949	March	21.2	33.5			18.3	10.6		7.8	91.4		3.05
1949	April	18.1	32.2			16.1	12.7		7.8	86.9		2.90
1949	May	23.6	21.9			17	15.7		7.8	86		2.87
1949	June	29.4	37.9			23.1	26.6		7.8	124.8		4.16
1949	July	23.2	44.1			19.8	28.5		7.8	123.4		4.11
1949	August	18.2	48			14.8	24.1		7.8	112.9		3.76
1949	September	22.6	29.4			12.5	18.5		7.8	90.8		3.03

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1949	October	35.6	9.7			16.6	18.3		7.8	88		2.93
1949	November	33.3	9.4			15.5	18.7		7.8	84.7		2.82
1949	December	34.3	10			16.5	16.4		7.8	85	1144.2	2.83
1950	January	35.4	8.5			17.5	13.7		7.8	82.9		2.76
1950	February	29.1	12.9			15.2	13.8		7.8	78.8		2.63
1950	March	35.2	7.2			16.7	18.4		7.8	85.3		2.84
1950	April	28.5	13.9			14.5	19.4		7.8	84.1		2.80
1950	May	2.7	38.5			15.8	21.4		7.8	86.2		2.87
1950	June	9.6	37.4			17.9	22.9		7.8	95.6		3.19
1950	July	9.8	46.2			21.3	21.6		7.8	106.7		3.56
1950	August	11.2	47.8			19.8	16.8		7.8	103.4		3.45
1950	September	4.8	44.5			16.5	16.5		7.8	90.1		3.00
1950	October	2.8	40.1			18.4	15.6		7.8	84.7		2.82
1950	November	2.9	40.6			17.8	12.9		7.8	82		2.73
1950	December	2.1	40.8			18.6	9.9		7.8	79.2	1059	2.64
1951	January	2.4	41.5			19.4	7.7		7.8	78.8		2.63
1951	February	1.5	37.3			17.7	7.7		7.8	72		2.40
1951	March	3.6	41.6			19.9	8.5		7.8	81.4		2.71
1951	April	4.9	40.9			8.6	10.1		7.8	72.3		2.41
1951	May	6.5	44.4			19.3	16.8		7.8	94.8		3.16
1951	June	9.7	45.9			19	18.2		7.8	100.6		3.35
1951	July	21.5	47.7			18.2	30.3		7.8	125.5		4.18
1951	August	16.8	48.8			19.9	23.4		7.8	116.7		3.89
1951	September	9.6	43.8			16.7	24.8		7.8	102.7		3.42
1951	October	9.6	44.7			22	20.3		7.8	104.4		3.48
1951	November	7.1	39.6			23.7	25.2		7.8	103.4		3.45
1951	December	6.6	44.3			22.6	23.2		7.8	104.5	1157.1	3.48

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1952	January	6.9	45			21.3	14.2		7.8	95.2		3.17
1952	February	8.1	40			16.6	12.1		7.8	84.6		2.82
1952	March	7.1	47			17.6	13.6		7.8	93.1		3.10
1952	April	8.4	40.9			17.9	13.6		7.8	88.6		2.95
1952	May	8.5	44			19.1	15.3		7.8	94.7		3.16
1952	June	17.7	45.2			20.1	19.4		7.8	110.2		3.67
1952	July	29.8	46.6			23.1	38.5		7.8	145.8		4.86
1952	August	17.4	43.6			19.5	20.1		7.8	108.4		3.61
1952	September	14.3	42			17.3	19		7.8	100.4		3.35
1952	October	10	44			19.5	15.4		7.8	96.7		3.22
1952	November	7.5	41.8			18.8	14		7.8	89.9		3.00
1952	December	9.9	45.4			18.5	15		7.8	96.6	1204.2	3.22
1953	January	10	46.2			19.3	14.7		7.8	98		3.27
1953	February	9.4	41.3			16.9	14.3		7.8	89.7		2.99
1953	March	7.7	43.5			18.1	14.6		7.8	91.7		3.06
1953	April	11.1	44.9			17.9	14.7		7.8	96.4		3.21
1953	May	13.5	48.1			18.6	19.1		7.8	107.1		3.57
1953	June	29.4	47.2			23.6	38.8		7.8	146.8		4.89
1953	July	24.7	48.7			20.3	34.6		7.8	136.1		4.54
1953	August	24.5	49.2			16.5	29.3		7.8	127.3		4.24
1953	September	22.9	47.1			16.7	28.5		7.8	123		4.10
1953	October	17.3	45.3			17.5	22.7		7.8	110.6		3.69
1953	November	44	15.3			17.6	18.6		7.8	103.3		3.44
1953	December	47.9	14.7			16.7	17.7		7.8	104.8	1334.8	3.49
1954	January	48.3	16			16.9	17		7.8	106		3.53
1954	February	43.4	15.2			15.2	15.8		7.8	97.4		3.25
1954	March	16.7	45.1			16.4	18		7.8	104		3.47

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1954	April	14	42.9			16	17.8		7.8	98.5		3.28
1954	May	11.6	45.2			17	19		7.8	100.6		3.35
1954	June	21.3	40.1			20.6	27.9		7.8	117.7		3.92
1954	July	20.8	46.2			20.9	29.4		7.8	125.1		4.17
1954	August	18.8	43.5			16.3	24.1		7.8	110.5		3.68
1954	September	12.7	40.8			14.8	24.3		7.8	100.4		3.35
1954	October	19.5	37.6			14.1	25.2		7.8	104.2		3.47
1954	November	11.1	44.6			14.4	19.2		7.8	97.1		3.24
1954	December	17.9	49.4			15.1	19.5		7.8	109.7	1271.2	3.66
1955	January	10.9	46.2			15.9	20.1		7.8	100.9		3.36
1955	February	7	41.7			15	17.4		7.8	88.9		2.96
1955	March	9.3	42.5			14.9	18.8		7.8	93.3		3.11
1955	April	8.8	42.2			15.5	16.8		7.8	91.1		3.04
1955	May	13.3	44.7			15.2	29		7.8	110		3.67
1955	June	19	44.5			16.6	25.3		7.8	113.2		3.77
1955	July	24.9	48.6			21.6	33.5		7.8	136.4		4.55
1955	August	20.9	51.1			17.6	33.6		7.8	131		4.37
1955	September	33.2	24			15.4	25		7.8	105.4		3.51
1955	October	42.8	14.7			16.9	22.2		7.8	104.4		3.48
1955	November	15.5	40.7			15.7	20.4		7.8	100.1		3.34
1955	December	16.9	45.2			17.7	21.3		7.8	108.9	1283.6	3.63
1956	January	17	48.1			17.4	20.6		7.8	110.9		3.70
1956	February	15.5	48.7			21.3	8.8		7.8	102.1		3.40
1956	March	11.7	52.9			25.7	4.5		7.8	102.6		3.42
1956	April	14.2	50			16.5	13.5		7.8	102		3.40
1956	May	18.5	49.2			18.7	16.9		7.8	111.1		3.70
1956	June	22.1	50.9			21.7	29.2		7.8	131.7		4.39

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1956	July	27.8	52.8			23.4	20.1		7.8	131.9		4.40
1956	August	32.9	52.6			24.7	18.9		7.8	136.9		4.56
1956	September	25.4	49.2			15.5	19.8		7.8	117.7		3.92
1956	October	19.7	50			16.8	14.3		7.8	108.6		3.62
1956	November	14.1	49.2			22	22.7		7.8	115.8		3.86
1956	December	23.2	43			19.7	20.4		7.8	114.1	1385.4	3.80
1957	January	21.5	52.1			18.6	12.3		7.8	112.3		3.74
1957	February	21.9	44.8			16.6	9.6		7.8	100.7		3.36
1957	March	36.3	31.7			17.4	9.7		7.8	102.9		3.43
1957	April	44.7	25.7			18.6	12		7.8	108.8		3.63
1957	May	43.4	40.4			18.5	27.3		7.8	137.4		4.58
1957	June	41	42.1			26.5	34.9		7.8	152.3		5.08
1957	July	31.9	50.2			17.7	37.2		7.8	144.8		4.83
1957	August	32.8	49.8			9.2	29.4		7.8	129		4.30
1957	September	25.8	48.1			6.1	26.8		7.8	114.6		3.82
1957	October	24.8	47			16.2	15.3		7.8	111.1		3.70
1957	November	18.8	47.4			16.1	11.1		7.8	101.2		3.37
1957	December	23.9	49.8			16.6	15.8		7.8	113.9	1429	3.80
1958	January	21	50.1			15.4	11		7.8	105.3		3.51
1958	February	22.7	46.3			17	6.4		7.8	100.2		3.34
1958	March	21.6	49.5			19.1	8.4		7.8	106.4		3.55
1958	April	21.3	47.2			19	8.5		7.8	103.8		3.46
1958	May	26	38.5			19.6	12.2		7.8	104.1		3.47
1958	June	25.9	34.9			15.3	19.5		7.8	103.4		3.45
1958	July	33.9	26.7			21.6	16.9		7.8	106.9		3.56
1958	August	26.7	34.7			15.7	21.7		7.8	106.6		3.55
1958	September	27.3	38			16.9	17.4		7.8	107.4		3.58

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1958	October	16.5	50.2			16.8	16.7		7.8	108		3.60
1958	November	9.8	44.7			16.2	14.3		7.8	92.8		3.09
1958	December	11.8	49.4			18.1	13.7		7.8	100.8	1245.7	3.36
1959	January	14.4	50.2			20.1	11.7		7.8	104.2		3.47
1959	February	17.1	45.2			16.9	11.4		7.8	98.4		3.28
1959	March	12.4	47.4			9.8	24.1		7.8	101.5		3.38
1959	April	18.3	41.7			12.1	21		7.8	100.9		3.36
1959	May	27.5	34.6			17.9	21.7		7.8	109.5		3.65
1959	June	30.4	32.4			17.1	19.7		7.8	107.4		3.58
1959	July	33.1	39.9			15.5	24.8		7.8	121.1		4.04
1959	August	22	45.5			24.6	21.7		7.8	121.6		4.05
1959	September	23.6	40.1			14.5	24.4		7.8	110.4		3.68
1959	October	26.8	37.3			20.7	21.3		7.8	113.9		3.80
1959	November	27	33			14.4	17.4		7.8	99.6		3.32
1959	December	27.2	30			16.5	15.4		7.8	96.9	1285.4	3.23
1960	January	24.8	32.3			19.4	13.6		7.8	97.9		3.26
1960	February	27.3	26.1			158	16.5		7.8	235.7		7.86
1960	March	26.5	23.9			18.8	15.9		7.8	92.9		3.10
1960	April	20.2	26.6			15.4	21.2		7.8	91.2		3.04
1960	May	27.9	30.8			21.7	19.6		7.8	107.8		3.59
1960	June	26.3	30.1			23.3	25.3		7.8	112.8		3.76
1960	July	19.2	42.5			22.7	27.1		7.8	119.3		3.98
1960	August	20.7	50.2			29.2	21.6		7.8	129.5		4.32
1960	September	20.5	40			23.9	17.8		7.8	110		3.67
1960	October	19.7	34.6			18.6	17.1		7.8	97.8		3.26
1960	November	23.3	27.3			20	13.6		7.8	92		3.07
1960	December	23.4	38.1			22.7	13.6		7.8	105.6	1392.5	3.52

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1961	January	20.2	47.9			23	13.4		7.8	112.3		3.74
1961	February	27	31.5			22.3	12.8		7.8	101.4		3.38
1961	March	27.3	41.8			20.1	16.2		7.8	113.2		3.77
1961	April	21.8	35			20.6	13.4		7.8	98.6		3.29
1961	May	16.5	46.9			21.3	14.2		7.8	106.7		3.56
1961	June	25.7	43.4			24.5	20.1		7.8	121.5		4.05
1961	July	37	38.7			23.9	27.9		7.8	135.3		4.51
1961	August	30.4	48.6			22.2	25.8		7.8	134.8		4.49
1961	September	31.3	42.5			16.1	24.2		7.8	121.9		4.06
1961	October	30.3	41.9			17	18.8		7.8	115.8		3.86
1961	November	25.8	44.4			19.8	14.1		7.8	111.9		3.73
1961	December	22.6	43.5			20.5	13.3		7.8	107.7	1381.1	3.59
1962	January	21.8	31.9			21	14.8		7.8	97.3		3.24
1962	February	21.8	31.9			18.5	13.4		7.8	93.4		3.11
1962	March	21.8	31.9			15.3	20.9		7.8	97.7		3.26
1962	April	21.8	31.9			14	23.4		7.8	98.9		3.30
1962	May	21.8	31.9			17.4	27.3		7.8	106.2		3.54
1962	June	21.8	31.9			19.4	28.6		7.8	109.5		3.65
1962	July	21.8	31.9			21	35.4		7.8	117.9		3.93
1962	August	21.8	31.9			24.3	30.9		7.8	116.7		3.89
1962	September	21.8	31.9			15.2	25.1		7.8	101.8		3.39
1962	October	21.8	31.9			21.3	15.3		7.8	98.1		3.27
1962	November	21.8	31.9			17.1	16.9		7.8	95.5		3.18
1962	December	21.8	31.9			22.3	13.7		7.8	97.5	1230.5	3.25
1963	January	21.8	31.9			21.6	15.7		7.8	98.8		3.29
1963	February	21.8	31.9			20.5	14.1		7.8	96.1		3.20
1963	March	21.8	31.9			23.6	14.9		7.8	100		3.33

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1963	April	21.8	31.9			21.2	20.3		7.8	103		3.43
1963	May	21.8	31.9			17.9	27.7		7.8	107.1		3.57
1963	June	21.8	31.9			24.2	29.7		7.8	115.4		3.85
1963	July	21.8	31.9			28.4	38.6		7.8	128.5		4.28
1963	August	21.8	31.9			24.5	32.5		7.8	118.5		3.95
1963	September	21.8	31.9			22.1	21.9		7.8	105.5		3.52
1963	October	21.8	31.9			37.7	6.2		7.8	105.4		3.51
1963	November	21.8	31.9			12	24.6		7.8	98.1		3.27
1963	December	21.8	31.9			20.7	17.5		7.8	99.7	1276.1	3.32
1964	January	21.8	31.9			20.6	16.9		7.8	99		3.30
1964	February	21.8	31.9			21.5	12.7		7.8	95.7		3.19
1964	March	21.8	31.9			16.3	20.7		7.8	98.5		3.28
1964	April	21.8	31.9			18.1	19.2		7.8	98.8		3.29
1964	May	21.8	31.9			26.5	37.5		7.8	125.5		4.18
1964	June	21.8	31.9			31.3	43.6		7.8	136.4		4.55
1964	July	21.8	31.9			28	33.4		7.8	122.9		4.10
1964	August	21.8	31.9			25.1	29.1		7.8	115.7		3.86
1964	September	21.8	31.9			25.1	27.6		7.8	114.2		3.81
1964	October	21.8	31.9			17.1	27.7		7.8	106.3		3.54
1964	November	21.8	31.9			19.4	23.8		7.8	104.7		3.49
1964	December	21.8	31.9			21.8	19.2		7.8	102.5	1320.2	3.42
1965	January	21.8	31.9			22.9	18.7		7.8	103.1		3.44
1965	February	21.8	31.9			19.5	18.1		7.8	99.1		3.30
1965	March	21.8	31.9			23.1	17.2		7.8	101.8		3.39
1965	April	21.8	31.9		10.3	9	19.5		7.8	100.3		3.34
1965	May	21.8	31.9		33.1	13.2	8.5		7.8	116.3		3.88
1965	June	21.8	31.9		34.9	13.2	18.3		7.8	127.9		4.26

Hunt Pumping Data (Million Gallons)

Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1965	July	21.8	31.9		46	15.5	22		7.8	145		4.83
1965	August	21.8	31.9		37.7	25.3	14		7.8	138.5		4.62
1965	September	21.8	31.9		9.9	30.4	14.3		7.8	116.1		3.87
1965	October	21.8	31.9		3.2	25.1	17.4		7.8	107.2		3.57
1965	November	21.8	31.9		0.2	25.5	17.5		7.8	104.7		3.49
1965	December	21.8	31.9		16.3	16.2	7.4		7.8	101.4	1361.4	3.38
1966	January	21.8	31.9		16.1	20.3	6.6		7.8	104.5		3.48
1966	February	21.8	31.9		13.5	19.5	5.9		7.8	100.4		3.35
1966	March	21.8	31.9		11.8	18.9	7.3		7.8	99.5		3.32
1966	April	21.8	31.9		15.3	17.1	8.7		7.8	102.6		3.42
1966	May	21.8	31.9		22.4	17.9	8.5		7.8	110.3		3.68
1966	June	21.8	31.9		37.8	15.6	9.1		7.8	124		4.13
1966	July	21.8	31.9		44.2	29	21.9		7.8	156.6		5.22
1966	August	21.8	31.9		44.3	11	14.3		7.8	131.1		4.37
1966	September	21.8	31.9		22.4	19	3.3		7.8	106.2		3.54
1966	October	21.8	31.9		16.4	16.2	3.7		7.8	97.8		3.26
1966	November	21.8	31.9		19.1	16.9	4.1		7.8	101.6		3.39
1966	December	21.8	31.9		17.4	18	9.3		7.8	106.2	1340.8	3.54
1967	January	21.8	31.9		19.9	18.1	6.9		7.8	106.4		3.55
1967	February	21.8	31.9		16.3	13	12.3		7.8	103.1		3.44
1967	March	21.8	31.9		9.1	16.1	5.5		7.8	92.2		3.07
1967	April	21.8	31.9		25.3	16.4	6.1		7.8	109.3		3.64
1967	May	21.8	31.9		11.1	29.1	6.3		7.8	108		3.60
1967	June	21.8	31.9		41.4	12.1	10.9		7.8	125.9		4.20
1967	July	21.8	31.9		39.3	14.2	3.4		7.8	118.4		3.95
1967	August	21.8	31.9		33.3	12.5	3.3		7.8	110.6		3.69
1967	September	21.8	31.9		38.6	14.6	5.9		7.8	120.6		4.02

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1967	October	21.8	31.9		25.5	23.5	4.1		7.8	114.6		3.82
1967	November	21.8	31.9		11.7	24.7	6.4		7.8	104.3		3.48
1967	December	21.8	31.9		22.4	19.6	7.6		7.8	111.1	1324.5	3.70
1968	January	21.8	31.9		18.3	18.3	22.6		7.8	120.7		4.02
1968	February	21.8	31.9		15.4	22.2	4.9		7.8	104		3.47
1968	March	21.8	31.9		14.3	23.4	4.9		7.8	104.1		3.47
1968	April	21.8	31.9		18.1	18.6	1		7.8	99.2		3.31
1968	May	21.8	31.9		35.6	17.8	2		7.8	116.9		3.90
1968	June	21.8	31.9		42.8	16.8	3.1		7.8	124.2		4.14
1968	July	21.8	31.9		44.9	17.4	14.2		7.8	138		4.60
1968	August	21.8	31.9		46.9	11.7	10.3		7.8	130.4		4.35
1968	September	21.8	31.9		58.7	10	10.5		7.8	140.7		4.69
1968	October	21.8	31.9		33.8	16.2	0.7		7.8	112.2		3.74
1968	November	21.8	31.9		21.3	21.6	3.1		7.8	107.5		3.58
1968	December	21.8	31.9		25.5	21.3	4.7		7.8	113	1410.9	3.77
1969	January	21.8	31.9		22.4	20.4	3.9		7.8	108.2		3.61
1969	February	21.8	31.9		24.7	17.7	2.5		7.8	106.4		3.55
1969	March	21.8	31.9		32.2	20.2	1.1		7.8	115		3.83
1969	April	21.8	31.9		29.8	18.1	0		7.8	109.4		3.65
1969	May	21.8	31.9		36.1	21.1	0		7.8	118.7		3.96
1969	June	21.8	31.9		55.2	28.2	0		7.8	144.9		4.83
1969	July	21.8	31.9		44.1	23.3	11.4		7.8	140.3		4.68
1969	August	21.8	31.9		53.3	14.2	2.6		7.8	131.6		4.39
1969	September	21.8	31.9		38.4	18.3	8.4		7.8	126.6		4.22
1969	October	21.8	31.9		23.7	18.8	6.7		7.8	110.7		3.69
1969	November	21.8	31.9		18.5	24.7	3.8		7.8	108.5		3.62
1969	December	21.8	31.9		0	39	0		7.8	100.5	1420.8	3.35

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1970	January	24.8	18.6		0	38.8	0		7.8	90		3.00
1970	February	23.8	15.4		0	33	0		7.8	80		2.67
1970	March	32.6	14		0	36.4	0		7.8	90.8		3.03
1970	April	31.5	24		20.1	19.6	0.6		7.8	103.6		3.45
1970	May	26.4	15.5		25.5	28	1.8		7.8	105		3.50
1970	June	21	28.5		25	37.1	5.1		7.8	124.5		4.15
1970	July	26.4	34.1		54.9	20.1	8		7.8	151.3		5.04
1970	August	24.8	38.8		54.1	18	0		7.8	143.5		4.78
1970	September	24	33		48.3	0	0		7.8	113.1		3.77
1970	October	24.8	24.8		35.1	11.8	0		7.8	104.3		3.48
1970	November	25.5	12		18	16.7	0		7.8	80		2.67
1970	December	34.1	6.2		37.7	6.4	0		7.8	92.2	1278.3	3.07
1971	January	29.5	21.7		35.4	4.7	0		7.8	99.1		3.30
1971	February	25.2	19.6		31.6	8.4	0		7.8	92.6		3.09
1971	March	37.2	31		30.9	9.7	0		7.8	116.6		3.89
1971	April	25.5	21		37.4	7.9	0.1		7.8	99.7		3.32
1971	May	29.5	20.2		36.8	10.2	0		7.8	104.5		3.48
1971	June	33	27		62.1	34.1	10.5		7.8	174.5		5.82
1971	July	34.1	38.8		58.2	31.4	10.7		7.8	181		6.03
1971	August	24.8	38.8		49.8	19.3	3		7.8	143.5		4.78
1971	September	21	37.5		58.4	6.9	1.5		7.8	133.1		4.44
1971	October	12.4	37.2		38.7	6.2	0.9		7.8	103.2		3.44
1971	November	12.4	40.5		30.3	8.8	0.8		7.8	100.6		3.35
1971	December	15.5	38.8		39.6	8.6	1.4		7.8	111.7	1460.1	3.72
1972	January	24.8	37.2		31.8	5.9	0.7		7.8	108.2		3.61
1972	February	25.2	30.8		27.3	10.5	1.2		7.8	102.8		3.43
1972	March	32.6	37.2		36.2	8.2	0.7		7.8	122.7		4.09

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1972	April	22.5	25.5		33.2	3.2	0		7.8	92.2		3.07
1972	May	15.5	34.1		43.6	1.3	0.4		7.8	102.7		3.42
1972	June	9	37.5		43.9	0	0.3		7.8	98.5		3.28
1972	July	18.6	37.2		44.2	0	9		7.8	116.8		3.89
1972	August	21	34.5		47.4	0	9.6		7.8	120.3		4.01
1972	September	9	37.5		12.9	0	30		7.8	97.2		3.24
1972	October	12.4	23.3		8.2	0	33.4		7.8	85.1		2.84
1972	November	9	25.5		44.7	0	0		7.8	87		2.90
1972	December	10.9	21.7		42	0	0		7.8	82.4	1215.9	2.75
1973	January	12.4	21.7		49.7	0	0.9		7.8	92.5		3.08
1973	February	9.8	18.2		54.5	0	0		7.8	90.3		3.01
1973	March	14	24.8		55	0	0		7.8	101.6		3.39
1973	April	16.5	24		44.6	0	0.9		7.8	93.8		3.13
1973	May	14	24.8		57	0	0.9		7.8	104.5		3.48
1973	June	12	25.5		58.9	0.4	16.6		7.8	121.2		4.04
1973	July	10.9	26.4		56.2	0	8.1		7.8	109.4		3.65
1973	August	0	0		67.1	0	21.5		7.8	96.4		3.21
1973	September	0	0		47.4	0	3.7		7.8	58.9		1.96
1973	October	0	0		43.6	0	0		7.8	51.4		1.71
1973	November	0	0		34.9	0	0		7.8	42.7		1.42
1973	December	0	0		34.2	3	0		7.8	45	1007.7	1.50
1974	January	0	0		40.8	0.2	0		7.8	48.8		1.63
1974	February	0	0		33.1	0	0.4		7.8	41.3		1.38
1974	March	0	0		35.8	0	0.8		7.8	44.4		1.48
1974	April	0	0		45.7	0	0		7.8	53.5		1.78
1974	May	0	0		52.1	0.3	0.3		7.8	60.5		2.02
1974	June	0	0		53.1	1.8	18.1		7.8	80.8		2.69

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1974	July	1.6	3.1		60.2	1.5	28.6		7.8	102.8		3.43
1974	August	3.1	6.2		59.5	9.7	37.8		7.8	124.1		4.14
1974	September	6.2	19.5		42	0	0.2		7.8	75.7		2.52
1974	October	4.7	23.3		38.2	0	0.4		7.8	74.4		2.48
1974	November	4.5	22.5		30.6	1	0		7.8	66.4		2.21
1974	December	6.2	20.2		31.9	1	0		7.8	67.1	839.8	2.24
1975	January	7.8	18.6		32	0	0		7.8	66.2		2.21
1975	February	15.4	16.8		30.2	0	0		7.8	70.2		2.34
1975	March	20.2	7.8		31.1	0	0		7.8	66.9		2.23
1975	April	21	1.5		31.6	0	0		7.8	61.9		2.06
1975	May	17.1	6.2		43.5	0.7	5.2		7.8	80.5		2.68
1975	June	12	4.5		43.2	1.8	11.9		7.8	81.2		2.71
1975	July	15.5	6.2		49.5	4	29.8		7.8	112.8		3.76
1975	August	0	0		68.7	12	10.4		7.8	98.9		3.30
1975	September	0	0		36.3	2.4	0		7.8	46.5		1.55
1975	October	0	0		33.8	0	0.1		7.8	41.7		1.39
1975	November	0	0		29	1.2	0		7.8	38		1.27
1975	December	0	0		28.2	0.2	0		7.8	36.2	801	1.21
1976	January	4	8.1		27.4	0.1	0		7.8	47.4		1.58
1976	February	5	7		23.9	0	0		7.8	43.7		1.46
1976	March	6.8	6.5		29.8	0	0		7.8	50.9		1.70
1976	April	7.5	5.1		37.1	0.7	1		7.8	59.2		1.97
1976	May	6.2	6.2		40	0	2.7		7.8	62.9		2.10
1976	June	4.8	6		46.5	11.6	35.4		7.8	112.1		3.74
1976	July	6.8	9.2		50.3	6.1	30.9		7.8	111.1		3.70
1976	August	4.4	5.9		51.2	0	12.9		7.8	82.2		2.74
1976	September	7.3	6.2		46.8	0	1.8		7.8	69.9		2.33

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1976	October	3.2	7.6		38	0.5	0.3		7.8	57.4		1.91
1976	November	2	9.1		25	0	0		7.8	43.9		1.46
1976	December	2.4	7.2		18.8	0	0.5		7.8	36.7	777.4	1.22
1977	January	4	8.1		14.1	0	0		7.8	34		1.13
1977	February	5	7		11.7	0	0		7.8	31.5		1.05
1977	March	6.8	6.5		12.8	0	0		7.8	33.9		1.13
1977	April	7.5	5.1		17.2	0.3	1.8		7.8	39.7		1.32
1977	May	6.2	6.2		43.1	4.2	24.1		7.8	91.6		3.05
1977	June	4.8	6		33.7	2.8	24.4		7.8	79.5		2.65
1977	July	6.8	9.2		23.7	17	40.2		7.8	104.7		3.49
1977	August	4.4	5.9		20.2	0.9	21.2		7.8	60.4		2.01
1977	September	7.3	6.2		15.9	0	8.6		7.8	45.8		1.53
1977	October	3.2	7.6		12.7	0	1		7.8	32.3		1.08
1977	November	2	9.1		12.3	0	0		7.8	31.2		1.04
1977	December	2.4	7.2		40	0	0		7.8	57.4	642	1.91
1978	January	4	8.1		44.6	0	0.4		7.8	64.9		2.16
1978	February	5	7		38.7	0	0.04		7.8	58.54		1.95
1978	March	6.8	6.5		46.1	0	0	8.8	7.8	76		2.53
1978	April	7.5	5.1		42.9	2.6	0	10.5	7.8	76.4		2.55
1978	May	6.2	6.2		41	0.8	5.9	12.6	7.8	80.5		2.68
1978	June	4.8	6		32	11.7	22.2	13.1	7.8	97.6		3.25
1978	July	6.8	9.2		27.8	14.3	38.3	15.7	7.8	119.9		4.00
1978	August	4.4	5.9		38.7	0.1	11.4	12.4	7.8	80.7		2.69
1978	September	7.3	6.2		35.5	0	0.2	10.6	7.8	67.6		2.25
1978	October	3.2	7.6		29.6	0	0	10	7.8	58.2		1.94
1978	November	2	9.1		20.9	0	0	6.5	7.8	46.3		1.54
1978	December	2.4	7.2		18.7	1.4	0	5.9	7.8	43.4	870.04	1.45

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1979	January	4	8.1		25.4	0	0	8.6	7.8	53.9		1.80
1979	February	5	7		30.7	0	3.6	8.3	7.8	62.4		2.08
1979	March	6.8	6.5		31	0	0.2	8.8	7.8	61.1		2.04
1979	April	7.5	5.1		32.7	0	0.8	10.5	7.8	64.4		2.15
1979	May	6.2	6.2		32.7	0	5.2	12.6	7.8	70.7		2.36
1979	June	4.8	6		32.5	6.6	20.4	13.1	7.8	91.2		3.04
1979	July	6.8	9.2		30.1	14.8	38.1	15.7	7.8	122.5		4.08
1979	August	4.4	5.9		26.3	1.8	9.9	12.4	7.8	68.5		2.28
1979	September	7.3	6.2		29.3	0.2	3.6	10.6	7.8	65		2.17
1979	October	3.2	7.6		29.8	0	0.6	10	7.8	59		1.97
1979	November	2	9.1		21.8	0	0	6.5	7.8	47.2		1.57
1979	December	2.4	7.2		11.1	17	0	5.9	7.8	51.4	817.3	1.71
1980	January	4	8.1		3.8	30.7	0.4	8.6	7.8	63.4		2.11
1980	February	5	7		28.4	1	1.1	8.3	7.8	58.6		1.95
1980	March	6.8	6.5		19.6	0	0	8.8	7.8	49.5		1.65
1980	April	7.5	5.1		19.1	19.1	5.5	10.5	7.8	74.6		2.49
1980	May	6.2	6.2		29.8	6.4	2	12.6	7.8	71		2.37
1980	June	4.8	6		28.2	18.1	10.4	13.1	7.8	88.4		2.95
1980	July	6.8	9.2		29.2	28.7	30.7	15.7	7.8	128.1		4.27
1980	August	4.4	5.9		32.4	22.1	2.6	12.4	7.8	87.6		2.92
1980	September	7.3	6.2		30.7	26.9	3.6	10.6	7.8	93.1		3.10
1980	October	3.2	7.6		27.2	2.9	0	10	7.8	58.7		1.96
1980	November	2	9.1		18.6	0	0	6.5	7.8	44		1.47
1980	December	2.4	7.2		14.6	0	0	5.9	7.8	37.9	854.9	1.26
1981	January	4	8.1		13.6	0	0	8.6	7.8	42.1		1.40
1981	February	5	7		11.6	2.3	0	8.3	7.8	42		1.40
1981	March	6.8	6.5		14.4	1.9	1.1	8.8	7.8	47.3		1.58

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1981	April	7.5	5.1		20.7	1.1	0	10.5	7.8	52.7		1.76
1981	May	6.2	6.2		28.8	2.8	12.9	12.6	7.8	77.3		2.58
1981	June	4.8	6		38.6	7.1	29.2	13.1	7.8	106.6		3.55
1981	July	6.8	9.2		35.2	12.7	29.7	15.7	7.8	117.1		3.90
1981	August	4.4	5.9		35	0	18	12.4	7.8	83.5		2.78
1981	September	7.3	6.2		32.1	0	6.3	10.6	7.8	70.3		2.34
1981	October	3.2	7.6		25.4	0	0.3	10	7.8	54.3		1.81
1981	November	2	9.1		19.3	0	0	6.5	7.8	44.7		1.49
1981	December	2.4	7.2		20.3	0	0	5.9	7.8	43.6	781.5	1.45
1982	January	4	8.1		17.6	0	0	8.6	7.8	46.1		1.54
1982	February	5	7		18.7	0	0	8.3	7.8	46.8		1.56
1982	March	6.8	6.5		25.3	0	0	8.8	7.8	55.2		1.84
1982	April	7.5	5.1		26.3	0	0	10.5	7.8	57.2		1.91
1982	May	6.2	6.2		39.1	0	12.4	12.6	7.8	84.3		2.81
1982	June	4.8	6		29.9	0	2.5	13.1	7.8	64.1		2.14
1982	July	6.8	9.2		34	16.2	30.3	15.7	7.8	120		4.00
1982	August	4.4	5.9		38.2	0	8.7	12.4	7.8	77.4		2.58
1982	September	7.3	6.2		37.3	0	4.8	10.6	7.8	74		2.47
1982	October	3.2	7.6		39	0	0	10	7.8	67.6		2.25
1982	November	2	9.1		37	0	0	6.5	7.8	62.4		2.08
1982	December	2.4	7.2		38.2	0	0	5.9	7.8	61.5	816.6	2.05
1983	January	4	8.1		35.5	5.1	8.1	8.6	7.8	77.2		2.57
1983	February	5	7		31.6	3	8.1	8.3	7.8	70.8		2.36
1983	March	6.8	6.5		33.4	2.7	8.8	8.8	7.8	74.8		2.49
1983	April	7.5	5.1		36.3	2	9.3	10.5	7.8	78.5		2.62
1983	May	6.2	6.2		24.7	2.5	16.2	12.6	7.8	76.2		2.54
1983	June	4.8	6		7.4	12.8	27	13.1	7.8	78.9		2.63

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1983	July	6.8	9.2		18.7	20.1	37.1	15.7	7.8	115.4		3.85
1983	August	4.4	5.9		13	13.3	20.3	12.4	7.8	77.1		2.57
1983	September	7.3	6.2		13.4	13	7.4	10.6	7.8	65.7		2.19
1983	October	3.2	7.6		24.4	8.9	2.2	10	7.8	64.1		2.14
1983	November	2	9.1		18.3	6.3	5.2	6.5	7.8	55.2		1.84
1983	December	2.4	7.2		20.9	6.1	6.6	5.9	7.8	56.9	890.8	1.90
1984	January	4	8.1		21.2	5.1	8.1	8.6	7.8	62.9		2.10
1984	February	5	7		15.2	3	8.1	8.3	7.8	54.4		1.81
1984	March	6.8	6.5		25.6	2.7	8.8	8.8	7.8	67		2.23
1984	April	7.5	5.1		23.9	2	9.3	10.5	7.8	66.1		2.20
1984	May	6.2	6.2		28.4	2.5	16.2	12.6	7.8	79.9		2.66
1984	June	4.8	6		27.7	12.8	27	13.1	7.8	99.2		3.31
1984	July	6.8	9.2		30.4	20.1	37.1	15.7	7.8	127.1		4.24
1984	August	4.4	5.9		30.7	13.3	20.3	12.4	7.8	94.8		3.16
1984	September	7.3	6.2		26.1	13	7.4	10.6	7.8	78.4		2.61
1984	October	3.2	7.6		19	8.9	2.2	10	7.8	58.7		1.96
1984	November	2	9.1		13.3	6.3	5.2	6.5	7.8	50.2		1.67
1984	December	2.4	7.2		14.3	6.1	6.6	5.9	7.8	50.3	889	1.68
1985	January	4	8.1		8.6	5.1	8.1	8.6	7.8	50.3		1.68
1985	February	5	7		23.3	3	8.1	8.3	7.8	62.5		2.08
1985	March	6.8	6.5		29.4	2.7	8.8	8.8	7.8	70.8		2.36
1985	April	7.5	5.1		26.9	2	9.3	10.5	7.8	69.1		2.30
1985	May	6.2	6.2		31.1	2.5	16.2	12.6	7.8	82.6		2.75
1985	June	4.8	6		31	12.8	27	13.1	7.8	102.5		3.42
1985	July	6.8	9.2		33	20.1	37.1	15.7	7.8	129.7		4.32
1985	August	4.4	5.9		30	13.3	20.3	12.4	7.8	94.1		3.14
1985	September	7.3	6.2		28.4	13	7.4	10.6	7.8	80.7		2.69

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1985	October	3.2	7.6		14.3	8.9	2.2	10	7.8	54		1.80
1985	November	2	9.1		0	6.3	5.2	6.5	7.8	36.9		1.23
1985	December	2.4	7.2		0	6.1	6.6	5.9	7.8	36	869.2	1.20
1986	January	4	8.1		2.2	5.1	8.1	8.6	7.8	43.9		1.46
1986	February	5	7		17.5	3	8.1	8.3	7.8	56.7		1.89
1986	March	6.8	6.5		18.6	2.7	8.8	8.8	7.8	60		2.00
1986	April	7.5	5.1		19.7	2	9.3	10.5	7.8	61.9		2.06
1986	May	6.2	6.2		24.1	2.5	16.2	12.6	7.8	75.6		2.52
1986	June	4.8	6		26.4	12.8	27	13.1	7.8	97.9		3.26
1986	July	6.8	9.2		28.1	20.1	37.1	15.7	7.8	124.8		4.16
1986	August	4.4	5.9		21.7	13.3	20.3	12.4	7.8	85.8		2.86
1986	September	7.3	6.2		17.8	13	7.4	10.6	7.8	70.1		2.34
1986	October	3.2	7.6		16.3	8.9	2.2	10	7.8	56		1.87
1986	November	2	9.1		16.5	6.3	5.2	6.5	7.8	53.4		1.78
1986	December	2.4	7.2		12	6.1	6.6	5.9	7.8	48	834.1	1.60
1987	January	4	8.1		13.4	5.1	8.1	8.6	7.8	55.1		1.84
1987	February	5	7		9.9	3	8.1	8.3	7.8	49.1		1.64
1987	March	6.8	6.5		13.2	2.7	8.8	8.8	7.8	54.6		1.82
1987	April	7.5	5.1		10.6	2	9.3	10.5	7.8	52.8		1.76
1987	May	6.2	6.2		12.2	2.5	16.2	12.6	7.8	63.7		2.12
1987	June	4.8	6		23.7	12.8	27	13.1	7.8	95.2		3.17
1987	July	6.8	9.2		34.3	20.1	37.1	15.7	7.8	131		4.37
1987	August	4.4	5.9		24.3	13.3	20.3	12.4	7.8	88.4		2.95
1987	September	7.3	6.2		11.4	13	7.4	10.6	7.8	63.7		2.12
1987	October	3.2	7.6		13.4	8.9	2.2	10	7.8	53.1		1.77
1987	November	2	9.1		11.9	6.3	5.2	6.5	7.8	48.8		1.63
1987	December	2.4	7.2		13.7	6.1	6.6	5.9	7.8	49.7	805.2	1.66

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1988	January	4	8.1		11	5.1	8.1	8.6	7.8	52.7		1.76
1988	February	5	7		10.2	3	8.1	8.3	7.8	49.4		1.65
1988	March	6.8	6.5		9.9	2.7	8.8	8.8	7.8	51.3		1.71
1988	April	7.5	5.1		10	2	9.3	10.5	7.8	52.2		1.74
1988	May	6.2	6.2		14.3	2.5	16.2	12.6	7.8	65.8		2.19
1988	June	4.8	6		26	12.8	27	13.1	7.8	97.5		3.25
1988	July	6.8	9.2		24.3	20.1	37.1	15.7	7.8	121		4.03
1988	August	4.4	5.9		28	13.3	20.3	12.4	7.8	92.1		3.07
1988	September	7.3	6.2		6.8	13	7.4	10.6	7.8	59.1		1.97
1988	October	3.2	7.6		0	8.9	2.2	10	7.8	39.7		1.32
1988	November	2	9.1		7.9	6.3	5.2	6.5	7.8	44.8		1.49
1988	December	2.4	7.2		6.3	6.1	6.6	5.9	7.8	42.3	767.9	1.41
1989	January	4	8.1		7.7	5.1	8.1	8.6	7.8	49.4		1.65
1989	February	5	7		7.6	3	8.1	8.3	7.8	46.8		1.56
1989	March	6.8	6.5		7	2.7	8.8	8.8	7.8	48.4		1.61
1989	April	7.5	5.1		4.9	2	9.3	10.5	7.8	47.1		1.57
1989	May	6.2	6.2		10.9	2.5	16.2	12.6	7.8	62.4		2.08
1989	June	4.8	6		10.2	12.8	27	13.1	7.8	81.7		2.72
1989	July	6.8	9.2		14.7	20.1	37.1	15.7	7.8	111.4		3.71
1989	August	4.4	5.9		12.7	13.3	20.3	12.4	7.8	76.8		2.56
1989	September	7.3	6.2		7.6	13	7.4	10.6	7.8	59.9		2.00
1989	October	3.2	7.6		0.19	8.9	2.2	10	7.8	39.89		1.33
1989	November	2	9.1		0.18	6.3	5.2	6.5	7.8	37.08		1.24
1989	December	2.4	7.2		0.34	6.1	6.6	5.9	7.8	36.34	697.21	1.21
1990	January	4	8.1		0.32	0	25.9	19.2	7.8	65.32		2.18
1990	February	5	7		0.55	0	25.7	16.8	7.8	62.85		2.10
1990	March	6.8	6.5		0.27	0	28.9	15.5	7.8	65.77		2.19

Hunt Pumping Data (Million Gallons)													
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1990	April	7.5	5.1		0.73	0	29	19.3	7.8	69.43		2.31
1990	May	6.2	6.2		0.73	0	34.4	20.3	7.8	75.63		2.52
1990	June	4.8	6		13.4	0.3	41.9	19.1	7.8	93.3		3.11
1990	July	6.8	9.2		11.2	1	34.6	19.4	7.8	90		3.00
1990	August	4.4	5.9		9.6	1.5	40.4	18.2	7.8	87.8		2.93
1990	September	7.3	6.2		5.6	0	29.2	17.2	7.8	73.3		2.44
1990	October	3.2	7.6		0.23	0	21.8	17.3	7.8	57.93		1.93
1990	November	2	9.1		0	0	30.7	4.5	7.8	54.1		1.80
1990	December	2.4	7.2		0	0	35.1	0	7.8	52.5	847.93	1.75
1991	January	4	8.1		0.26	0	34.8	0	7.8	54.96		1.83
1991	February	5	7		0	0	32.1	2.7	7.8	54.6		1.82
1991	March	6.8	6.5		0.16	0	36.7	5.9	7.8	63.86		2.13
1991	April	7.5	5.1		0	0	39	2.1	7.8	61.5		2.05
1991	May	6.2	6.2		9.6	0	45.7	8.5	7.8	84		2.80
1991	June	4.8	6		23.7	0	62.1	10.5	7.8	114.9		3.83
1991	July	6.8	9.2		18.8	2.9	65.5	13.1	7.8	124.1		4.14
1991	August	4.4	5.9		9.3	0.7	49.9	5.4	7.8	83.4		2.78
1991	September	7.3	6.2		2.8	13.6	22.6	6.1	7.8	66.4		2.21
1991	October	3.2	7.6		0.2	22.3	0	11.1	7.8	52.2		1.74
1991	November	2	9.1		0	5.2	26.7	5.1	7.8	55.9		1.86
1991	December	2.4	7.2		0	0	37.1	3.1	7.8	57.6	873.42	1.92
1992	January	4	8.1		0	0	35.1	1.1	7.8	56.1		1.87
1992	February	5	7		0.08	0	34.1	1.6	7.8	55.58		1.85
1992	March	6.8	6.5		0	0	37.8	1.5	7.8	60.4		2.01
1992	April	7.5	5.1		0	0.6	34.7	0.3	7.8	56		1.87
1992	May	6.2	6.2		4.1	0	43.6	4.1	7.8	72		2.40
1992	June	4.8	6		8.4	0	45.8	10.4	7.8	83.2		2.77

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1992	July	6.8	9.2		8.1	0	48.4	7.2	7.8	87.5		2.92
1992	August	4.4	5.9		2.3	0	20	16	7.8	56.4		1.88
1992	September	7.3	6.2		0	0	0	20.3	7.8	41.6		1.39
1992	October	3.2	7.6		0	0	0	18.5	7.8	37.1		1.24
1992	November	2	9.1		0	0	0	15.4	7.8	34.3		1.14
1992	December	2.4	7.2		0	0	0	16.4	7.8	33.8	673.98	1.13
1993	January	0	0		0	0	0	17.9	7.8	25.7		0.86
1993	February	0	0		0	0	0	15.5	7.8	23.3		0.78
1993	March	0	0		0	0	0	18.3	7.8	26.1		0.87
1993	April	0	0		0	0	0	18.1	7.8	25.9		0.86
1993	May	0	0		10.8	4.1	0	24.5	7.8	47.2		1.57
1993	June	0	0		26	36.6	0	18.3	7.8	88.7		2.96
1993	July	5.8	10	9.3	20.9	47.3	0	14.9	7.8	116		3.87
1993	August	6	12.1	9	19.6	51.4	0	8.9	7.8	114.8		3.83
1993	September	6.3	9.7	7.5	3.1	42.6	0	5	7.8	82		2.73
1993	October	5.3	5.8	7.9	0.5	36.3	0	0.1	7.8	63.7		2.12
1993	November	5.3	8.8	5.9	0	31.2	0	0	7.8	59		1.97
1993	December	5.7	4.5	1.6	0	23.1	0	3.5	7.8	46.2	718.6	1.54
1994	January	0	0	19.6	0	0	0	16.9	7.8	44.3		1.48
1994	February	0	0	17.8	0	0	0	15.2	7.8	40.8		1.36
1994	March	0	0	18.5	0	0	0	17	7.8	43.3		1.44
1994	April	0	0	16.6	0	0	0	15.7	7.8	40.1		1.34
1994	May	0	0	19.1	0.7	0	0	18.7	7.8	46.3		1.54
1994	June	0	0	23	22.7	33.6	0	20.8	7.8	107.9		3.60
1994	July	0.1	0.1	24.8	18.5	44.8	0	18.5	7.8	114.6		3.82
1994	August	12.5	11.3	6	2.8	38.1	0	8.8	7.8	87.3		2.91
1994	September	23.9	1.8	0.1	0.6	38.7	0	7.2	7.8	80.1		2.67

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1994	October	6.2	9	5.4	0	38.9	0	1.7	7.8	69		2.30
1994	November	0	14	6.3	0	34.7	0	0.4	7.8	63.2		2.11
1994	December	0	11.2	9.1	0.3	31.6	0	2	7.8	62	798.9	2.07
1995	January	0	11.9	10.8	0.3	31	0	2.7	7.8	64.5		2.15
1995	February	4.6	12.1	4.7	0	32.1	0	0.02	7.8	61.32		2.04
1995	March	5.8	10	5.8	0	30.4	0	1.8	7.8	61.6		2.05
1995	April	3.2	5.8	9.4	0	0	0	15.4	7.8	41.6		1.39
1995	May	5.2	11.2	6.3	0	12.2	0	11.1	7.8	53.8		1.79
1995	June	7	10.9	7.3	3.4	36.8	0	8.1	7.8	81.3		2.71
1995	July	3.8	18.9	6.1	34.1	41.8	0	17.4	7.8	129.9		4.33
1995	August	7.3	16.3	4.6	42.2	42.9	0	17.9	7.8	139		4.63
1995	September	7	12	3.5	17.2	33.5	0	11.1	7.8	92.1		3.07
1995	October	7.5	12	0.6	0	6	0	16	7.8	49.9		1.66
1995	November	2.8	9.2	6.5	0	3.9	0	13.8	7.8	44		1.47
1995	December	7.4	6.6	6	0	0	0	16.8	7.8	44.6	863.62	1.49
1996	January	3.2	11.5	8	1.8	20	0	10.1	7.8	62.4		2.08
1996	February	5.8	10.2	5.2	2.8	26.5	0	5.9	7.8	64.2		2.14
1996	March	4.5	9.8	5.5	1.4	28	0	4.6	7.8	61.6		2.05
1996	April	6.4	10.1	5	1	23.8	0	6.7	7.8	60.8		2.03
1996	May	6	9.6	5.7	1.6	34.4	0	9.5	7.8	74.6		2.49
1996	June	5.7	11.5	6.1	12.5	44.2	0	10.8	7.8	98.6		3.29
1996	July	5.7	12.4	7.4	1.1	49.8	0	11.7	7.8	95.9		3.20
1996	August	4.2	17.2	7.3	3.2	58.7	0	10.2	7.8	108.6		3.62
1996	September	5.2	10.8	8.7	0	44	0	4.9	7.8	81.4		2.71
1996	October	5	12	7	0	34.6	0	6.4	7.8	72.8		2.43
1996	November	4.5	11.3	6.5	26	33	0	4	7.8	93.1		3.10
1996	December	4.9	9.4	7.1	67.5	34.2	0	6.1	7.8	137	1011	4.57

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1997	January	5.2	8.9	8.5	46.6	3.7	0	6.9	7.8	87.6		2.92
1997	February	12.9	23	9.8	0.5	27	0	8.4	7.8	89.4		2.98
1997	March	4.4	9.5	6.5	0.4	32	0	7.9	7.8	68.5		2.28
1997	April	5.2	8	6.5	0.3	33.8	0	7.5	7.8	69.1		2.30
1997	May	2.1	11.1	6.6	4.8	38.9	0	0.3	7.8	71.6		2.39
1997	June	0	14	11.8	28.4	49.1	0	0	7.8	111.1		3.70
1997	July	0	15.6	16.3	43.9	47.8	0	18.6	7.8	150		5.00
1997	August	4.5	12.2	11.1	27.8	39.7	0	11.7	7.8	114.8		3.83
1997	September	8.3	12.7	6.4	23.6	32.5	0	13.6	7.8	104.9		3.50
1997	October	6.5	6.9	10	14.7	28.8	0	14.2	7.8	88.9		2.96
1997	November	6.2	9.6	6.2	1.9	26.9	0	9	7.8	67.6		2.25
1997	December	5.3	10.5	6.8	0.6	23.3	0	1.2	7.8	55.5	1079	1.85
1998	January	4.9	9.4	6.3	1.2	23.5	0	3	7.8	56.1		1.87
1998	February	4.5	8.5	5.8	9.8	21.3	0	8.2	7.8	65.9		2.20
1998	March	4.9	10.4	7	13.3	31	0	6.9	7.8	81.3		2.71
1998	April	6.2	12	5.8	27.7	27.6	0	9.1	7.8	96.2		3.21
1998	May	5.7	13.9	5.7	41	12.1	0	16.6	7.8	102.8		3.43
1998	June	6.6	16.4	4.4	51.2	0	0	19.8	7.8	106.2		3.54
1998	July	19.4	16.3	1.2	56.4	27.6	0	20.5	7.8	149.2		4.97
1998	August	19.3	13.1	0.2	52.9	43.5	0	14.9	7.8	151.7		5.06
1998	September	8.3	12.7	6.9	50.9	37.2	0	9.9	7.8	133.7		4.46
1998	October	7.9	13.6	3	36.9	35.7	0	5	7.8	109.9		3.66
1998	November	5.2	14.2	4.2	30.2	29.5	0	6.6	7.8	97.7		3.26
1998	December	5.8	11.3	5.6	31.3	17.6	0	3.7	7.8	83.1	1233.8	2.77
1999	January	9.4	9.1	3.6	34	29.4	0	6.6	7.8	99.9		3.33
1999	February	6.9	4.3	7.3	29.3	17.5	0	9.3	7.8	82.4		2.75
1999	March	8.5	2.5	5.2	31	20	0	11.3	7.8	86.3		2.88

Hunt Pumping Data (Million Gallons)

Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
1999	April	7.9	5.4	7.5	7.1	19.8	0	11.6	7.8	67.1		2.24
1999	May	5.8	5.7	5.1	26.8	33	0	15.4	7.8	99.6		3.32
1999	June	5.1	7.3	6.9	34.2	52.6	0	28.9	7.8	142.8		4.76
1999	July	7.2	9.9	11	42.2	53.7	0	23.2	7.8	155		5.17
1999	August	9.2	9.9	9.4	35.8	45.8	0	16	7.8	133.9		4.46
1999	September	6.4	6.7	8.5	13.4	37.3	0	12.1	7.8	92.2		3.07
1999	October	8.8	2.9	7.2	3.5	33.2	0	6.5	7.8	69.9		2.33
1999	November	9.6	9.6	0	3.5	17.8	0	11.2	7.8	59.5		1.98
1999	December	9.7	4.8	5.9	2.3	31.1	0	5.6	7.8	67.2	1155.8	2.24
2000	January	8.9	0	10.3	27.1	32.2	0	3.6	7.8	89.9		3.00
2000	February	4.9	0	15	27.9	29.9	0	3.1	7.8	88.6		2.95
2000	March	5.9	9.1	6	28.6	30.3	0	6.1	7.8	93.8		3.13
2000	April	4	9.4	6.3	31	29	0	8	7.8	95.5		3.18
2000	May	5.5	4	4.4	17.2	41.3	0	5.8	7.8	86		2.87
2000	June	2.6	9.3	6.7	14.4	41.4	0	15.9	7.8	98.1		3.27
2000	July	0	22.6	7.4	10.7	46.4	0	21.4	7.8	116.3		3.88
2000	August	0	11.9	12	3	33	0	13.4	7.8	81.1		2.70
2000	September	0	13.9	7.3	1.7	36.4	0	10.4	7.8	77.5		2.58
2000	October	0	16	4.3	0.4	33.6	0	10	7.8	72.1		2.40
2000	November	0	11.4	7	0.8	26.2	0	9	7.8	62.2		2.07
2000	December	0	13.3	8.1	0.4	23.9	0	9.8	7.8	63.3	1024.4	2.11
2001	January	0.8	14.7	6.2	0.8	18.6	0	11.9	7.8	60.8		2.03
2001	February	5.8	5.6	5.4	0.7	24.6	0	6.6	7.8	56.5		1.88
2001	March	7.1	5.1	6	14.8	20.4	0	11.7	7.8	72.9		2.43
2001	April	7.1	4.7	5.4	24.1	12.6	0	14.9	7.8	76.6		2.55
2001	May	9.6	6.1	7.3	24	34.9	0	21.6	7.8	111.3		3.71
2001	June	4.9	10.3	8.8	19.3	42.2	0	17.5	7.8	110.8		3.69

Hunt Pumping Data (Million Gallons)												
Year	Month	EDC #9A	EDC #14A	EDC #3A	Kent #1	NK #9	NK #10	NK #6	Industrial Well	Total (MG)	Total for year (MG)	Ave. by month (MGD)
2001	July	10.5	3.9	9.7	29.3	47.9	0	21.8	7.8	130.9		4.36
2001	August	11.6	7.4	8	21.3	37.6	0	21.5	7.8	115.2		3.84
2001	September	9.3	9.5	6.3	19.1	37.6	0	19	7.8	108.6		3.62
2001	October	11.3	0.2	8.2	18.6	0	0	20.5	7.8	66.6		2.22
2001	November	0	10.3	8.6	11.3	0	0	18.5	7.8	56.5		1.88
2001	December	6.4	6.4	5.4	13.8	0	0	18.7	7.8	58.5	1025.2	1.95
2002	January	8.9	4.5	6.1	18.1	0	0	22.1	7.8	67.5		2.25
2002	February	7.4	2.5	6.4	13.2	0	0	21.4	7.8	58.7		1.96
2002	March	8.5	3.7	5.9	23.8	3.4	0	23.6	7.8	76.7		2.56
2002	April	10.5	3	6.4	29.4	8.1	0	24.2	7.8	89.4		2.98
2002	May	10	3.5	5.2	29.6	12.8	0	28.6	7.8	97.5		3.25
2002	June	9.6	4.4	7.1	22.5	22.4	0	24.7	7.8	98.5		3.28
2002	July	9.5	10.7	9.3	32.2	45.4	0	31.2	7.8	146.1		4.87
2002	August	5.8	10.9	10.1	34.3	24.9	0	28.6	7.8	122.4		4.08
2002	September	7	8.6	5.9	32.7	12.4	0	25.4	7.8	99.8		3.33
2002	October	5.9	7.4	5.5	33.7	18	0	23.8	7.8	102.1		3.40
2002	November	4.7	6.2	4.3	26.6	31.2	0	17.7	7.8	98.5		3.28
2002	December	5.4	5.5	3.9	23.1	35.4	0	15.1	7.8	96.2	1153.4	3.21
2003	January	6.1	6.1	5.1	24	29.5	0	16.8	7.8	95.4		3.18
2003	February	3.4	5.3	4.9	21.8	28	0	15.7	7.8	86.9		2.90
2003	March	6.8	8.3	7	25.7	17.6	0	20.9	7.8	94.1		3.14
2003	April	5.6	8.2	9.5	25.1	31.1	0	18.1	7.8	105.4		3.51
2003	May	7.4	7.7	8.5	27.8	37.6	0	19.4	7.8	116.2		3.87
2003	June	5.2	8.6	7.7	25.7	35.3	0	19.9	7.8	110.2		3.67
2003	July	4.8	12	9.2	31.4	40.7	0	24	7.8	129.9		4.33
2003	August	4	10.8	9.9	32.5	36.5	0	21.7	7.8	123.2		4.11
2003	September	12.5	1.9	5.9	21.1	37.3	0	20.6	7.8	107.1		3.57

Hunt Pumping Data (Million Gallons)												
Year	**Month**	**EDC #9A**	**EDC #14A**	**EDC #3A**	**Kent #1**	**NK #9**	**NK #10**	**NK #6**	**Industrial Well**	**Total (MG)**	**Total for year (MG)**	**Ave. by month (MGD)**
2003	October	8.4	5.3	3.2	0	35.2	0	22	7.8	81.9		2.73
2003	November	6.1	3.8	8.3	0	32	0	17.9	7.8	75.9		2.53
2003	December	6.8	8.1	1.8	0	34.2	0	16.9	7.8	75.6	1201.8	2.52
2004	January	7.2	8.2	6.2	14.8	30.9	0	15.5	7.8	90.6		3.02
2004	February	6	5.4	5.5	10.1	28.2	1.9	17.3	7.8	82.2		2.74
2004	March	6.3	7.1	4.9	11.1	32.8	1.7	7.7	7.8	79.4		2.65
2004	April	6.8	7.5	4.1	11.3	28.3	7.4	12.5	7.8	85.7		2.86
2004	May	7.1	6.8	6.6	24.2	29.4	7.5	23.3	7.8	112.7		3.76
2004	June	7.2	7.9	7.8	31.1	31.6	9.7	25.2	7.8	128.3		4.28
2004	July	7.2	7.6	8.9	23.8	6.4	50.7	19.3	7.8	131.7		4.39
2004	August	9.3	9.7	4.7	32.5	37.1	4.3	22	7.8	127.4		4.25
2004	September								7.8	7.8		0.26
2004	October								7.8	7.8		0.26
2004	November								7.8	7.8		0.26
2004	December								7.8	7.8	869.2	0.26