South-east Queensland
Water Supply Strategy

Environmental Assessment of Logan/Albert and Mary Catchment Development Scenarios
FINAL DRAFT

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Executive Summary

Scope and Objectives

The Department of Natural Resources and Water (NRW) has requested environmental assessments of the following water resource development scenarios in the Logan/Albert and Mary catchments:

- Logan/Albert catchment:
  - **Large Tilleys Dam** – large dam (30 m) on the Logan River near Tilleys Bridge, plus Cedar Grove Weir;
  - **Small Tilleys Dam + Wyaralong Dam** – small dam (20.9 m) on the Logan River near Tilleys Bridge and Wyaralong Dam on Teviot Brook, plus Cedar Grove Weir;
  - **Wyaralong Dam + Glendower Dam** – Wyaralong Dam on Teviot Brook and Glendower Dam on the Albert River, plus Cedar Grove Weir and the Albert River Barrage;
- Mary catchment:
  - **Traveston Dam** – large dam (30 m) on the Mary River at Traveston Crossing;
  - **Four Dams** – Kidaman Dam, Amamoor Dam, Cambroon Dam and raising of Borumba Dam, plus Coles Crossing Weir.

The objectives of this study are to:

- Identify environmental issues associated with each development scenario, including effects on ecosystems upstream and downstream of the new dam(s) and within the ponded area(s); and
- Provide advice on potential measures that could be undertaken to mitigate key environmental issues associated with each development scenario.

The purpose of this study is to assemble information regarding environmental issues and mitigation measures associated with a range of potential development options as required for planning purposes. Formal environmental impact analysis for the preferred option(s) would need to be undertaken as a separate study as part of the project implementation process.

This study does not consider social and economic issues related to the development scenarios.

The study was undertaken by a scientific panel comprising members of the Logan Basin and Mary Basin Water Resource Plan (WRP) Technical Advisory Panels (TAPs). The study drew on baseline information compiled in the course of the WRP environmental investigations, and was undertaken primarily as a desktop investigation.

General Overview of Key Issues and Mitigation Options

It is widely recognised that the installation of any new dam will cause significant environmental changes within the pondage area, and upstream and downstream of the dam, including:

- Conversion of riverine, floodplain and upslope habitats to dam pondage habitat within the impounded area, with significant implications for flora and fauna;
- Changes in water quality resulting from water retention in the dam pondage, with implications for ecosystems within the pondage area and downstream water quality regimes;
- Reduced connectivity between upstream and downstream reaches (including estuarine and nearshore marine environments); and
- Changes in downstream flow regimes, with effects on the geomorphology and ecology of flow-dependent ecosystems (including riverine ecosystems and, potentially, estuarine and nearshore marine ecosystems, depending on the location and scale of development).

There is an extensive body of literature, from Australia and internationally, which discusses these effects. A range of mitigation measures has been developed in Australia and internationally to respond to key issues arising from environmental changes associated with dams. They include measures that would mitigate the severity of ecological impacts arising from dams, as well as measures that could provide compensation for ecological impacts that cannot be directly mitigated.

Mitigation and compensation measures relevant to the one or more of the dam scenarios under consideration in this report are outlined with reference to geomorphological and ecological changes in/upstream of the dam pondage area, downstream impacts on non-tidal reaches and downstream impacts on estuarine reaches. They range from measures that are well-proven and have been adopted as industry-standard best practice to measures that have had limited application in Australia or elsewhere and need to be regarded as experimental. Mitigation options relevant to weirs are not specifically identified or discussed, but many of the options relevant to dams would also be relevant to weirs. Monitoring and adaptive management is integral to the success of many of the mitigation and compensation measures.

Logan/Albert Catchment Development Scenarios

All three scenarios identified for the Logan/Albert catchment have environmental risks and concerns. Large Tilleys Dam is expected to have lesser overall environmental impacts than the other two scenarios. It is more difficult to rank the other two scenarios, as the relative level of impact varies depending on the criterion under consideration. The Wyaralong Dam + Glendower Dam scenario is likely to have the greatest level of overall environmental impact because, in addition to impacts in the Logan catchment, it would have significant effects on the Albert River system, including major impacts on the Logan/Albert estuary resulting from installation of the Albert River Barrage.

The Large Tilleys Dam scenario has the smallest pondage “footprint” in terms of total ponded area and mainstream length impounded, and also the smallest percentage of catchment area isolated by dams from downstream reaches and Moreton Bay. It has a smaller length of supplemented stream than Small Tilleys Dam + Wyaralong Dam scenario (though greater than the Wyaralong Dam + Glendower Dam scenario).

In the Small Tilleys Dam + Wyaralong Dam scenario, installation of two dams in different parts of the Logan catchment would cause more widespread impacts than installation of a single dam in the Large Tilleys Dam scenario. The Small Tilleys Dam + Wyaralong Dam scenario would result in a similar total ponded area as the Wyaralong Dam + Glendower Dam scenario, but greater ponded mainstream length.

The Wyaralong Dam + Glendower Dam scenario would cause significant impacts in both the Logan and Albert catchments, unlike the other two scenarios, where additional development occurs only in the Logan catchment. Fish passage impedance by dams would greater than for the Large Tilleys Dam scenario (but slightly less than for the Small Tilleys Dam + Wyaralong Dam scenario) in terms of percentage of the total Logan/Albert catchment area upstream of large dams. Glendower Dam would isolate 41% of the Albert River catchment from downstream reaches. Fish passage impedance by new weirs (i.e. Cedar Grove Weir and Albert River Barrage) is much greater than for the other two scenarios, which each only require one weir (i.e. Cedar Grove Weir). The length of stream affected by new/additional supplementation is less than for the Large Tilleys Dam or Small Tilleys Dam + Wyaralong Dam scenarios, but a greater length of stream would be affected by new weir pondages.

Impacts of the Wyaralong Dam + Glendower Dam scenario on the Logan/Albert estuary would be much greater than for the other two scenarios because of impacts of the installation of Albert River Barrage (via direct habitat loss and hydrodynamic effects) as well as reduced inflows from the Albert River catchment. Estuarine impacts could be significantly mitigated by not installing a tidal barrage downstream of Luscombe Weir (e.g. redeveloping Luscombe Weir rather than installing the Albert River barrage).

All of the scenarios under consideration involve impoundment of areas that have been extensively cleared for grazing or agriculture but retain remnants of indigenous vegetation including “endangered” RE 12.3.3 (*E. tereticornis* woodland to open forest on alluvial plains). The Small Tilleys Dam + Wyaralong Dam and Wyaralong Dam + Glendower Dam scenarios also involve submergence of remnants of some “of concern” REs. All three scenarios would affect EVR fauna species, including the “endangered” (EPBC[1]) Mary River cod *Macculochella peelii mariensis* and EVR other vertebrates. Existing vertebrate records are too patchy to provide comprehensive lists of EVR fauna for each proposed dam; however, connectivity to headwater forests (Tilleys Dam site) and adjacent forests and upstream wetlands (Wyaralong Dam site) suggest that these two dam sites may be particularly likely to support larger numbers of EVR fauna species.

Well-documented correlations indicate that catches of fisheries species from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 5% (mudcrabs) and 10% (prawns and flathead) compared to present levels as a result of reductions in summer flow in all three scenarios under consideration. Many more fish and invertebrate species are expected to be similarly affected.

[1] Conservation significance of flora and fauna is indicated as per the following legislation:
- Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC); and
- Queensland *Nature Conservation Act* 1992 (NCA).

As the Large Tilleys Dam and Small Tilleys Dam + Wyaralong Dam scenarios involve development in the Logan catchment only, they leave open the opportunity for extensive (catchment-scale) rehabilitation of the Albert River. With removal of Luscombe Weir, it would be possible to provide habitat connectivity between the Albert River headwaters and Moreton Bay. Currently the South Pine River is the only major tributary of Moreton Bay where connectivity between the bay and headwaters is not impeded by a dam or weir.

Mary Catchment Development Scenarios

Both of the scenarios identified for the Mary catchment would cause substantial environmental change. It is difficult to rank them in terms of likely overall environmental impacts, for the following reasons:

- If the water in the Traveston Dam pondage becomes highly turbid (either as a result of erosion and resuspension of soils within the dam pondage or storage and slow release of turbid peak flows), then this scenario would clearly have greater environmental impacts. However, if Traveston Dam is not significantly affected by turbidity or if Cambroon Dam is also significantly affected by turbidity, then levels of environmental impact would be of a similar order.
- Traveston Dam would have a greater impact than the Four Dams scenario on the movement of migratory fish (including potamodromous and diadromous species). Coles Crossing Weir in the Four Dams scenario commands only a slightly lesser percentage of the total catchment area of the Mary River than Traveston Dam, but Traveston Dam would have greater impacts on fish passage than a weir, even if appropriate fish passage devices were installed in both instances.
- Traveston Dam would pond a greater area of land than the new/expanded storages in the Four Dams scenario (7,700 ha versus 6,551 ha), but ponded mainstream length is similar for both scenarios.
- Both scenarios would inundate remnants of “endangered” RE 12.3.1 (Gallery rainforest [notophyll vine forest] on alluvial plains), with Traveston Dam flooding a greater extent of this RE. Both scenarios would also inundate REs “of concern”. A larger number of REs “of concern” would be affected by inundation in the Four Dams scenario because of the wider geographical spread of the four dam pondages.
- The Four Dams scenario would affect a greater number of flora and fauna species of conservation significance (as listed under EPBC and NCA).
- Two “endangered” riparian plant species and five “endangered” upslope plant species would be affected by inundation in the Four Dams scenario, while no “endangered” plant species are known to occur in the area that would be inundated by Traveston Dam (the distribution of rare/threatened plant species is currently a knowledge gap, as the Mary has not been systematically surveyed at the species level).
- Traveston Dam would have a greater impact on reducing landscape connectivity between headwaters and lowlands. However, Amamoor and Kidaman Dams would disrupt State Wildlife Corridors at the subcatchment scale.
- Both scenarios would affect the following EPBC-listed stream-dependent fauna species: the “endangered” Mary River cod (*Maccullochella peelii mariensis*), “vulnerable” lungfish (*Neoceratodus forsteri*), “endangered” giant barred frog (*Mixophyes iteratus*), “endangered” Mary River turtle (*Elusor macrurus*) and “vulnerable/endangered” red goshawk (*Erythrotriorchis radiatus*). The Four Dams

would also potentially affect another three EPBC-listed stream-dependent fauna species – the “endangered” Fleay’s barred frog (*Mixophyes fleayi*) and two frog species “presumed extinct” but possibly still present (the southern gastric brooding frog, *Rheobatrachus silus* and the southern day frog, *Taudactylus diurnus*).

- Both scenarios would impact on the habitat and breeding grounds of four stream-dependent frog species listed under NCA as EVR species (the “endangered” cascade treefrog [*Litoria pearsoniana*], “vulnerable” tusked frog [*Adelotus brevis*], “rare” pouched frog [*Assa darlingtoni*] and “rare” green-thighed frog [*Litoria brevipalmata*]).
- Depending on the distribution of the Mary River turtle throughout the Mary River system (currently not well known as existing datasets are biased by differences in survey effort), Traveston Dam may potentially have greater impacts on the Mary River turtle, particularly if the majority of the population exists downstream of Yabba Creek (greater impact can be expected if the dam water is turbid). Traveston Dam wall is highly likely to isolate upstream and downstream populations of Mary River turtles and reduce potential for exchange of genetic material.
- The Four Dams scenario would cause greater lengths of river/stream channel to be affected by major flow regime change and other downstream effects of dam impoundments than Traveston Dam.
- Traveston Dam would have slightly greater impacts on freshwater inflows to the Mary River estuary and outflows to the Great Sandy Strait than the Four Dams scenario, but there is not expected to be any significant difference with regard to impacts on the medium to large flood flows that discharge freshwater plumes into the Great Sandy Strait.

There are key knowledge gaps with regard to:

- Soil properties and their implications for the turbidity of the dam pondages and downstream river flows, particularly with regard to Traveston Dam and Cambroon Dam;
- The presence and location of individual EVR species, including the Mary River turtle, rare/threatened frog species, rare/threatened plant species, for all impoundments under consideration;
- Nesting and spawning sites for the Mary River turtle and Australian lungfish (Traveston, Cambroon and Kidaman Dams); and
- Indirect impacts of the dam scenarios on EVR species arising from habitat reduction and fragmentation, including isolation of populations, effects on gene transfer and reduced connectivity between lowland alluvial habitat and upper ridge habitat.

1 Introduction

1.1 Background, Scope and Objectives

The Department of Natural Resources and Water (NRW) has requested environmental assessments of the following water resource development scenarios in the Logan/Albert and Mary catchments:

- Logan/Albert catchment:
  - **Large Tilleys Dam** – large dam (30 m) on the Logan River near Tilleys Bridge, plus Cedar Grove Weir;
  - **Small Tilleys Dam + Wyaralong Dam** – small dam (20.9 m) on the Logan River near Tilleys Bridge and Wyaralong Dam on Teviot Brook, plus Cedar Grove Weir;
  - **Wyaralong Dam + Glendower Dam** – Wyaralong Dam on Teviot Brook and Glendower Dam on the Albert River, plus Cedar Grove Weir and the Albert River Barrage;
- Mary catchment:
  - **Traveston Dam** – large dam (30 m) on the Mary River at Traveston Crossing;
  - **Four Dams** – Kidaman Dam, Amamoor Dam, Cambroon Dam and raising of Borumba Dam, plus Coles Crossing Weir.

Key characteristics of the new dams and weirs under consideration in these scenarios are outlined in Table 1.1. Storage curves are presented in Appendix A. All of the scenarios except Traveston Dam also include at least one new weir (as specified above). The weirs are integral components of the development scenarios and are necessary for obtaining the specified yields. For the purposes of this assessment it was assumed that Coles Crossing Weir would be sized and located as recommended by State Water Projects (SWP) (2000) and that Cedar Grove Weir and the Albert River Barrage would be sized and located as specified in the scenarios examined in the environmental investigations for the Logan Basin WRP (Brizga et al. 2006a). The information regarding the new weirs is less detailed than the information regarding the new dams. In the case of Coles Crossing Weir, two size options were identified by SWP (2000) – the larger option (3,897 ML storage) forms part of the Four Dams scenario.

Descriptions of operational scenarios used for hydrological modelling by NRW are provided in Tables 1.2 (Logan/Albert) and Table 1.3 (Mary). In the Mary River, initial assessments by the study team indicated that the environmental flow rules used in the simulation of the hydrologic effects of Traveston Dam in case LR15 (Table 1.3) led to much greater reductions in high flows (particularly minor floods) than the “large reserve” case examined in the Mary Basin WRP environmental investigations (Brizga et al. 2005). Hence, the study team requested that an additional model run be carried out with modified environmental flow rules (LR74). In particular, the team requested that low flow environmental releases be capped at 100 ML/d (compared to 250 ML/d in LR15) so as to enable larger medium/high flow environmental releases to be made (10,000–20,000 ML/d compared to 5,000–10,000 ML/d in case LR15). Comparison of cases LR15 and LR74 provides information on the “sensitivity” of the impacts of the Traveston Dam scenario to environmental flow rules. Case LR74 forms the basis of the assessments of the Traveston Dam scenario presented in this report.

The operating assumptions for each scenario include indicative environmental flow rules, which are intended to test the sensitivity of water yield relative to the provision of environmental flows (and *vice-versa*). They define the types of environmental

Table 1.1 Key characteristics of new dams and weirs in the Logan/Albert and Mary catchment development scenarios

Dam/ Weir	AMTD[2] (km)	Catchment Area (km^2)	Capacity (ML)	Full Supply Level (FSL) (m)	Structure Height (m)	Ponded Area (ha)	Mean Depth at FSL (m)
Logan/Albert catchment							
Large Tilleys Dam	153.4	527	230,000	120.0	30.0	1620	14.2
Small Tilleys Dam	153.4	527	110,000	110.9	20.9	1060	10.4
Wyaralong Dam	14.8	546	104,000	63.6	23.6	1277	8.1
Glendower Dam	60.2	304	86,000	77.0	17.0	1072	8.0
Cedar Grove Weir	81.8	2,386	1,039	n.a.	~5	n.a.	n.a.
Albert River Barrage	22	715	390	n.a.	~6	n.a.	n.a.
Mary Catchment							
Traveston Dam	206.7	2,110	666,000	80.0	30.0	7700	8.6
Cambroon Dam	274.2	290	500,000	145.5	45.5	3335	15.0
Borumba Dam	31.1	466	260,000	158.0	53.0	1455	17.9
Kidaman Dam	6.3	178	100,000	123.2	23.2	938	10.7
Amamoor Dam	19.2	130	200,000	143.5	43.5	1203	16.6
Coles Crossing Weir	212.4	~2000	3,897	60.0	10.4	~100	n.a.

The characteristics of the new dams shown in this table are based on information provided by NRW for the purposes of the present study. Information on the new weirs is based on SWP (2000), Brizga et al. (2006a) and additional information from NRW.

flows (i.e. low, medium or high flow provisions) that could be provided whilst still maintaining viable yields. It is assumed that optimisation of environmental flow rules (e.g. fine-tuning of release rules, including measures to minimise unnatural variability in releases), would be undertaken as part of the design process for a preferred dam option.

The objectives of this study are to:

- Identify environmental issues associated with each development scenario, including effects on ecosystems upstream and downstream of the new dam(s) and within the ponded area(s); and
- Provide advice on potential measures that could be undertaken to mitigate key environmental issues associated with each development scenario.

[2] Adopted middle thread distance

The purpose of this study is to assemble information regarding environmental issues and mitigation measures associated with a range of potential development options as required for planning purposes. Formal environmental impact analysis for the preferred option(s) would need to be undertaken as a separate study as part of the project implementation process.

This study does not consider social and economic issues related to the development scenarios.

The advice provided in this report focuses on the long-term effects of the development scenarios, once the new dam(s) have become established. Additional issues would arise during construction (e.g. construction of access roads, land disturbance and stream disturbance by coffer dams) and in the short term during and after initial filling. For example, new dams often go through a cycle of increasing nutrients, algal blooms and fish recruitment as nutrients are released, then a decay phase and finally settling to some sort of equilibrium between nutrient levels, primary and secondary productivity[3]. The boom phase can last years. Such issues are not discussed further here as it is assumed that they would be dealt with in project-level environmental impact assessment. Assessment of environmental implications of any interbasin transfers that might occur in conjunction with the development scenarios is beyond the scope of this report.

[3] Anecdotal accounts indicate that in the Burnett River, an extensive fish kill (~15 km) occurred in May 2006 due to deoxygenation of the river water caused by rotting trees killed by the Paradise Dam impoundment.

Table 1.2 Hydrologic modelling scenarios for the Logan/Albert catchment

Case Number	Case Description	Environmental Flow Releases	Extraction Point	Additional HNFY (ML/a)
147c	**Large Tilleys Dam** • Tilleys Bridge Dam (230,000ML including 10% dead storage) • Cedar Grove Weir (1,039 ML), • Waterharvesting from Canungra Creek to Hinze Dam (as per case 141g/N026N).	Environmental flow release from Cedar Grove Weir to maintain some low to very low flows downstream of South MacLean Weir (based on case s140c). Based on half the flow at Running Creek's Deickman Bridge GS up to 10 ML/d.	Cedar Grove Weir Hinze Dam Total	47000 8000 55000
144c	**Small Tilleys Dam + Wyaralong Dam** • Wyaralong (104,000 ML including 10% dead storage) • Tilleys Bridge Dam (110,000 ML including 10% dead storage) • Cedar Grove Weir (1,039 ML)	Environmental flow release from Cedar Grove Weir to maintain some low to very low flows downstream of South MacLean Weir (based on case s140c). Based on half the flow at Running Creek's Deickman Bridge GS up to 10 ML/d.	Cedar Grove Weir Total	57000 57000
148a	**Wyaralong Dam + Glendower Dam** • Wyaralong (104,000 ML including 10% dead storage) • Glendower (86,000 ML including 10% dead storage) • Cedar Grove Weir and Albert River Barrage	Environmental flow release from Cedar Grove Weir to maintain some low to very low flows downstream of South MacLean Weir (based on case s140c). Albert R: environmental flow release to maintain some low to very low flows downstream of Albert River Barrage (based on half the flow that is the sum of the flow coming into Glendower Dam and out of Canungra Creek up to 10 ML/d).	Cedar Grove Weir Albert River Barrage Total	21000 25000 46000

(Based on information provided by NRW)

Table 1.3 Hydrologic modelling scenarios for the Mary catchment

Case Number	Case Description	Environmental Flow Releases	Extraction Point	Additional HNFY (ML/a)
LR15	**Traveston Dam** (660,000 ML)	Baseflow releases up to 250 ML/d EFO Release 5–10 K ARI release rule (one release per year)	Traveston	150,000
			Total	150,000[4]
LR74	**Traveston Dam** (660,000 ML)	Baseflow releases up to 100 ML/d EFO Release 10–20K ARI release rule (one release per year)	Traveston	150,000
			Total	150,000[5]
CA34[6]	**Four Dams**			
	• Cambroon (Capacity 500,000 ML, FSL 145.5 m)	Baseflow releases up to 40 ML/d; ARI release 4–8k ML/d	Cambroon	61,000
	• Kidaman (Capacity 100,000 ML, FSL 123.2 m)	Baseflow releases up to 8 ML/d	Kidaman	26,000
	• Borumba Dam (Capacity 260,000 ML, FSL 158 m) + Coles Crossing Weir	Nil	Coles Crossing Weir	48,000
	• Amamoor (Capacity 200,000 ML, FSL 143.5)	Baseflow releases up to 5 ML/d	Amamoor	11,500
			Total	146,500

(Based on information provided by NRW)

4 The yield used in this scenario is slightly less than the historical no-failure yield (HNFY) but is suitable to use in comparison to the other development options proposed.

5 The yield used in this scenario is slightly less than HNFY but is suitable to use in comparison to the other development options proposed.

6 This is a new case developed to provide a comparable yield to the 660,000 ML Traveston Dam, using a combination of the other proposed storages within the Mary catchment. Note that much of the additional storage provided by the Amamoor Dam is used to deliver water to downstream irrigators in order to make more water available for supply from the Borumba Dam - Coles Crossing Weir storages. This has been identified as the most likely operation of Amamoor Dam, and results in an increased yield from Coles Crossing Weir.

1.2 Methodology

1.2.1 Study Process

The study was led by Dr Sandra Brizga, who was responsible for reporting and team coordination. She was assisted by members of the Logan Basin and Mary Basin WRP TAPs, who undertook literature and data reviews and preparation of species lists, participated in workshops, provided advice on specialist matters and reviewed draft versions of this report.

A multidisciplinary team approach was adopted as this provides access to expert knowledge across a broad range of ecological disciplines. The study was undertaken as a desktop study (including reviews of existing information and interrogation of aerial photography) in combination with existing on-ground knowledge of TAP members and limited ground-truthing. No new field survey or sampling has been undertaken for this study.

1.2.2 Ecological Conservation Values (ECVs) of Proposed Dam Pondages

Regional ecosystems (REs) of conservation significance were identified based on mapping data supplied by NRW at a scale of 1:100,000, with outlines of the dam pondage areas overlaid. There are limitations with regard to mapping at this scale as it may not give accurate data on small areas of remnant vegetation and, particularly in the upper reaches of the Mary catchment, there could be significant isolated small scrub remnants.

Flora of conservation significance were identified from information compiled for the Mary Basin and Logan Basin WRP environmental investigations (Brizga et al. 2004, 2005, 2006a), the Environmental Protection Agency's (EPA's) "Wildlife Online" database and the Queensland Herbarium's "HERBRECS" database.

Fauna of conservation significance were identified based on information compiled for the Mary Basin and Logan Basin WRP environmental investigations (Brizga et al. 2204, 2005, 2006a), searches of EPA's "Wildlife Online" database, the Mary catchment Association database, Cooloola Shire Council records and Queensland Museum records.

Conservation significance of flora and fauna is indicated as per the following legislation:

- Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC); and
- Queensland *Nature Conservation Act* 1992 (NCA).

1.2.3 Scenario Assessment Methodology

Environmental impacts of the scenarios in the dam pondage areas were assessed by:

- Compilation of lists of REs, flora and fauna of conservation significance, and other key species (e.g. migratory fish) that have been recorded in the databases described above or are likely to be found in each of the dam pondage areas; and

- Review of existing relevant data and professional judgement with regard to the effects of impoundment on the abovementioned flora and fauna, and other impacts associated with dam pondages.

Downstream environmental impacts of the development scenarios were assessed using a similar process as was used in determining the implications of future water resource management scenarios in the Mary Basin and Logan Basin WRP environmental investigations (Brizga et al. 2005, Brizga et al. 2006a) (see outline of condition rating methodology in Section 1.2.4 below). Baseline data for the scenario assessments in this report were drawn from assessments of current condition and ECVs undertaken as part of the WRP environmental investigations. Simulations of the implications of the development scenarios for downstream flow regimes were undertaken by NRW using the Integrated Quantity Quality Model (IQQM) system.

Implications for environmental condition and ECVs were assessed for two versions of each water resource development scenario:
- Development scenario with no mitigation measures other than installation of fishways on new weirs; and
- Development scenario with implementation of the full complement of feasible mitigation measures.

Comparison of the assessments of the two versions of the scenarios provides an indication of the extent to which mitigation measures can feasibly reduce environmental impacts arising from the scenarios.

Consideration of issues pertaining to groundwater was outside of the brief for the present study. Groundwater is an important source of water supply in some parts of the Mary and Logan/Albert catchments. For the purposes of the scenario assessments, it was assumed that groundwater usage would remain the same as at present. However, changes to flow patterns can directly affect groundwater recharge. Weirs constructed within alluvial areas usually cause mounding of the groundwater and are often constructed to improve recharge in heavily utilised areas. Similarly, dams would also cause groundwater mounding. Groundwater mounding may or may not be desirable, depending on groundwater quality and usage patterns in the vicinity.

There has been little research in the Mary catchment to quantify the biodiversity of freshwater wetlands associated with the floodplain of the Mary River at either an ecosystem level or species level outside the protected area estates[7]. Due to reliance on existing data, limited information on wetlands has been included in this report.

The spatial reference framework used for the scenario assessment is based on the Mary Basin and Logan Basin WRP environmental investigations, for which the major rivers and streams in the study area were divided into relatively homogeneous reaches (Brizga et al. 2004, 2005, 2006a). The criteria used for reach delimitation included major tributary confluences, channel and valley morphology, geology, land use, existing major water infrastructure (dams, weirs, major diversions) and extent of tidal influence. Several of the WRP reaches were further subdivided for this study to enable spatial differentiation of scenario implications (e.g. upstream and downstream

[7] As discussed in the Burnett–Mary Freshwater Biodiversity Report, p. 11.

of a proposed dam site). Flow simulations were examined for all available IQQM reporting node(s) applicable to relevant reaches.

Only changes in environmental condition directly related to the nominated development scenarios have been assessed. River/stream condition reflects a wider range of influences than just water resource management, including catchment land use, riparian zone management and instream modifications. Additional water resource development may lead to increases in the extent and/or intensity of land use pressures, but the location, nature and extent of such impacts are at this stage undefined for the scenarios under consideration. Hence, for the purpose of this exercise, pressures on riverine and estuarine ecosystems arising from factors other than surface water resource development (e.g. land use and other infrastructure) are assumed to remain constant.

1.2.4 Condition Rating Methodology

The implications of each scenario for stream/river and estuary condition were considered in relation to living and non-living components of the ecosystems, in particular, geomorphology, hydraulic habitat, estuarine hydrodynamics, water quality, riparian vegetation (including mangroves and tidal wetlands in estuarine areas), aquatic vegetation, aquatic macroinvertebrates, fish and other vertebrates. Environmental condition was determined in terms of change from reference condition, which was defined as the inferred pre-European or natural condition.

Assessments of scenario implications were undertaken at a reach-scale. Five assessments were undertaken for each ecosystem component (except other vertebrates in freshwater reaches), reach and case (Figure 1.1, Table 1.4). The rating for each aspect of condition represents a discrete assessment and these assessments are not additive. For example, a major change from reference condition can be due to major water resource development impacts (such as flow regime change, ponding and fish passage barriers), or major impacts of other factors (such as riparian zone clearing, alien species invasions and sand/gravel extraction), or both. The condition rating process is the same as was applied in the Mary Basin and Logan Basin WRP environmental investigations. The WRP environmental investigation reports provide further details about the condition rating methodology; including rating criteria for specific ecosystem components (see Brizga et al. 2004, 2006a).

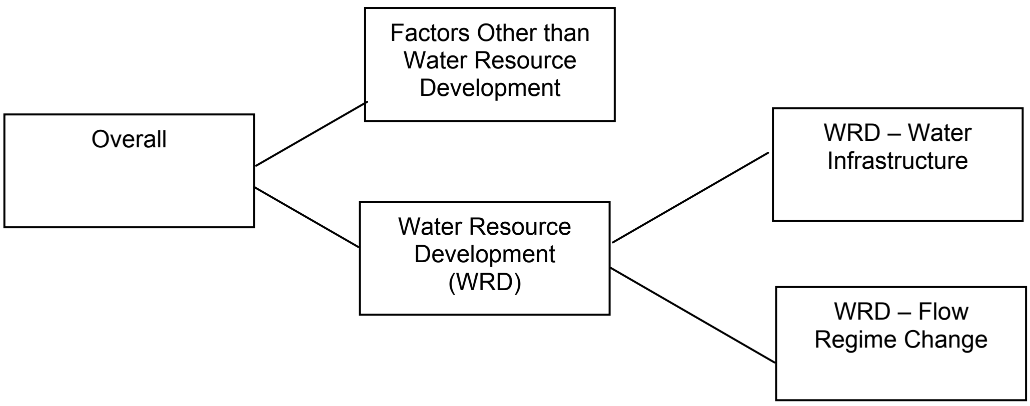

Figure 1.1 Condition assessment categories
(All refer to causes of change from reference condition)

Table 1.4 Definition of condition assessment categories

Category	Definition
Overall Condition	encompasses impacts resulting from water resource development and all other human factors
Factors Other than Water Resource Development	encompasses impacts arising from all human factors other than water extraction and supplementation, including catchment land use, riparian zone management and instream modifications
Water Resource Development (WRD)	encompasses impacts resulting from all aspects of water extraction and supplementation, including infrastructure and flow regime change
WRD Infrastructure	encompasses impacts resulting from infrastructure used for water extraction and supplementation, including barrier and pondage effects of dams and weirs
WRD Flow Regime	encompasses impacts resulting from flow regime changes caused by water extraction and supplementation, including changes in magnitude, frequency, duration, timing and variability

Each of the condition ratings is reported by use of the following five-point scale:
1. **indiscernible** change from reference condition;
2. **minor** change from reference condition;
3. **moderate** change from reference condition;
4. **major** change from reference condition;
5. **very major** change from reference condition.

The study team determined the likely geomorphological and ecological implications of each development scenario for the assessment reaches based on professional judgement, supported by risk assessment models, conceptual models relating flow to ecological functions, research information and literature. Risk assessment models were applied to 'benchmark' the hydrological changes arising from the scenarios against changes that have occurred elsewhere, and for which geomorphological and ecological responses have been assessed and documented (e.g. Brizga et al. 2004, 2006a, 2006b).

The conclusions drawn from the condition assessments are reported in the discussions of specific scenarios in Chapters 3 and 4. Full tabulations of condition ratings and reach-by-reach comments are not presented due to time and resourcing constraints.

1.2.5 Identification of Mitigation Measures

Potential mitigation and compensation measures for addressing impacts of the development scenarios on environmental condition and ECVs were identified based on the experience of study team members, consultation with international colleagues and limited reviews of relevant literature. However, comprehensive literature reviews were beyond the scope of this study.

The investigations into mitigation measures undertaken for the present study are considered to be sufficient for identifying the range and scope of options that may be suitable for these catchments. More detailed investigation of specific measures identified to be relevant would need to be undertaken at the design stage of any infrastructure project.

1.3 Report Outline

Chapter 2 provides a general overview of the types of issues that may arise from the construction of a new dam and general discussion of relevant mitigation options. Chapters 3 and 4 provide assessments of key issues and applicable mitigation measures for the development scenarios for the Logan/Albert catchment (Chapter 3) and Mary catchment (Chapter 4). The Appendices provide supporting information:

2 General Overview of Issues and Mitigation Options

It is widely recognised that the installation of any new dam will cause significant environmental changes within the pondage area, and upstream and downstream of the dam, including:

- Conversion of riverine, floodplain and upslope habitats to dam pondage habitat within the impounded area – at the very least, this would lead to changes in the structure of native flora and fauna communities as the altered habitat conditions within impoundments would not be able to sustain natural populations of all native riverine species and there is significant potential for alien species of plants and fish (e.g. plague minnow [gambusia], carp and tilapia) to establish in pondages, posing threats to native species;
- Changes in water quality resulting from water retention in the dam pondage (as a result of water quality changes due physical and biological processes within a dam pondage, such as sedimentation, resuspension, mineralization, plant and algal nutrient uptake; and also as a result of the effect of a dam in capturing flood peak water quality and then discharging over a long period water that would have naturally passed through the system in one or two days), with implications for ecosystems within the pondage area and downstream water quality regimes;
- Reduced connectivity between upstream and downstream reaches (including estuarine and nearshore marine environments), with implications for downstream transport of sediment and dissolved and particulate organic matter (POM), and upstream/downstream movement of fauna (particularly migratory fish and crustaceans, but also potential disruption of movement corridors for terrestrial species); and
- Changes in downstream flow regimes, with effects on the geomorphology and ecology of flow-dependent ecosystems (including riverine ecosystems and, potentially, estuarine and nearshore marine ecosystems, depending on the location and scale of development).

There is an extensive body of literature, from Australia and internationally, which discusses these effects. Summaries are presented in recent reviews (Baron et al. 2002, Bunn and Arthington 2002, Poff et al. 2003, Postel and Richter 2003, Vorosmarty et al 2004, Nilsson et al. 2005, World Commission on Dams 2000). Local information regarding environmental effects of existing water resource development in south-east Queensland has been compiled in environmental reports prepared as inputs to the development of WRPs (Mary Basin WRP – Brizga et al. 2004; Logan Basin WRP – Brizga et al. 2006a; Moreton and Gold Coast WRPs – Brizga et al. 2006b).

A range of mitigation measures has been developed in Australia and internationally to respond to key issues arising from environmental changes associated with dams. They include measures that would mitigate the severity of ecological impacts arising from dams, as well as measures that could provide compensation for ecological impacts that cannot be directly mitigated.

Mitigation and compensation measures relevant to the geomorphological and ecological changes that may arise from one or more of the dam scenarios under consideration in this report are outlined in Tables 2.1 to 2.3. They range from measures that are well-proven and have been adopted as industry-standard best practice (e.g. multilevel offtakes for dams) to measures that have had limited application in Australia or elsewhere and need to be regarded as experimental. The measures also vary considerably with regard to ease or difficulty of implementation. The relevance of particular mitigation measures to specific dam scenarios is discussed in Sections 3 and 4. The analyses in Chapters 3 and 4 indicate that even with full application of all international best-practice measures, it is not feasible to fully counteract, mitigate or compensate for all environmental impacts of the dam scenarios under consideration.

Mitigation options relevant to weirs are not specifically identified or discussed, but many of the options relevant to dams would also be relevant to weirs.

Some options that are suitable for non-tidal reaches are not suitable for estuaries. For example, sediment renourishment may be used in non-tidal areas to restore substrate characteristics and net downstream transport in sediment-starved reaches downstream of dams. In estuaries, sediment transport is bi-directional (inputs from fluvial and coastal sources). Sediment dynamics need to be well understood before any sediment management/ replenishment is undertaken, as estuaries are often zones of net aggradation. From an international perspective, mitigation measures for estuaries have rarely been implemented and an experimental approach would need to be applied to manage their introduction to estuarine systems.

Monitoring and adaptive management is integral to the success of many of the mitigation and compensation measures identified here. Vegetation management measures (e.g. weed control) require ongoing maintenance.

Table 2.1 Mitigation and compensation options for geomorphological and ecological changes in and upstream of dam pondage areas

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Change to lake habitat and processes (from riverine, floodplain and slope habitats and processes)	• Major habitat change is an inevitable consequence of the creation of a dam pondage • Likely to cause a change in native species composition and may favour alien species, including several that are listed as "noxious" in Queensland	• "No net loss of habitat" – rehabilitation of equivalent habitat elsewhere in lieu of habitats lost due to drowning by the dam pondage	• There is a Canadian policy	• Financial compensation packages would provide resources to protect, restore or rehabilitate selected examples of one or more types of habitats to a high condition	• Inability to locate and restore "equivalent" habitat because of uniqueness. • The costs of rehabilitating/restoring habitat usually far exceed the costs of protecting existing high integrity habitat (as discussed by Rutherfurd et al. 1999, 2004)
Lack of permanent edge and shallow water vegetation communities (between FSL and operating level, and between operating level and the base of the photic zone)	• Caused by variations in water levels resulting from dam operation and evaporation. Water level regimes generally cannot be altered without significantly altering storage operation and yield	• Detention dams along pondage margins to maintain relatively stable aquatic habitat	• Proposed for the Bonnie Doon Arm of Lake Eildon, Victoria (shallow water pondage area) for amenity, boat recreation, habitat and water supply, but not yet implemented	• Provides relatively stable edge habitat that would otherwise not be present within the dam pondage area	• Potential water quality deterioration, particularly blue–green algal blooms, within the detention dams due to high residence times, but this can be avoided by appropriate siting, design and operating measures (e.g. siting detention dams so that they are flushed by local catchment inflows, using outlet valves for draining detention dams if residence times become excessive, avoiding locations with high inputs of pollutants, and introducing appropriate emergent and submerged aquatic plants).

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
	• Failure of lungfish fish to breed successfully due to impacts of variable water levels on aquatic macrophyte beds used as spawning habitats (desiccation or drowning)	• Provision of artificial spawning sites in the form of floating mats of aquatic vegetation maintained at an appropriate depth in the water column (suggested by Professor Jean Joss – lungfish expert).	• None known, but floating platforms have been used overseas to provide nesting sites for waterbirds	• May provide relatively stable habitat for lungfish spawning. • Also likely to be used by other fish species that spawn in aquatic macrophyte beds	• High risk that artificial spawning sites will not be utilised as the precise spawning requirements of lungfish are currently not well understood. Possible problems with security of tethering in floods.
	• Loss of movement corridors for terrestrial species	• Protect, enhance or create a vegetated buffer zone above FSL to maintain corridors for movement of terrestrial species	• Several water supply reservoirs in South Gippsland have wide, heavily vegetated corridors around the pondages, but mainly for water quality management rather than biodiversity (e.g. Lance Creek Reservoir)	• Provides habitat, shelter and food for terrestrial vertebrates • Provides a storage for genetic plant material	• Will consist of upslope species rather than true riparian zone species. Vegetated corridor would be adjacent to the water's edge at FSL but a significant distance from the water's edge when the operating level falls. Weed management required. • Communities on either side of the impoundment will remain disjunct.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Shoreline erosion	• Can occur as a result of wave action (wind, boat traffic), subaerial processes (surface runoff) or through desiccation/dispersion processes when submerged in water. • Limitations to vegetation growth resulting from variable water levels mean that shorelines are often bare soil • Risk levels vary depending on geology, soil type, fetch and local catchment area for any particular part of the dam pondage shoreline	• Structural works to protect key assets where threatened	• Routinely used for asset protection along rivers and coasts	• Mitigates risk of asset loss	• Expensive and increase unnaturalness – measures generally undertaken only where key high value assets are threatened (e.g. roads)
		• Buffer zone between assets and erosion risk zone	• Buffer zones have been widely advocated as a non-structural measure for managing erosion threats to assets along rivers and coastlines	• Mitigation of erosion threats to assets by reducing conflict • Reduces or eliminates the need for structural works	• Does not halt erosion processes and associated mobilisation of sediment
		• Drainage management of surface runoff to avoid concentration of flows onto exposed shorelines and hence mitigate risks of subaerial erosion	• Remedial works have been carried out around Pykes Creek Reservoir (west of Melbourne, Victoria).	• Reduced shoreline erosion by subaerial processes	• Does not stop shoreline erosion due to wave action

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Sediment accumulation in dam pondage	• Loss of dam pondage capacity due to sedimentation (rarely an issue with major dams in Australia)	• Soil conservation and sediment management measures in catchment	• Eppalock Catchment Project (Victoria)	• Reduced sediment input from catchment, hence reduced rates of infill	• Unlikely to be feasible to restore sediment inputs to natural background rates. • Constructed works require ongoing maintenance. Eppalock catchment project has been reported as suffering more than 50% failure rates for constructed works over the longer term due to lack of ongoing maintenance.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Sediment extraction from dam	• Common overseas in areas with high sediment yields, rarely yet found to be necessary for large dams in Australia due to the relatively low rates of sediment supply characteristic of Australian rivers	• Restoration of dam capacity	• Disturbance to dam pondage ecosystems by extraction works

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Stratification of dam pondage	• Commonly occurs in deep waterbodies, as near-surface waters warm up and deeper water remains cooler. The resulting density difference creates an effective barrier to mixing and transfer of oxygen from surface water to deeper water. • Creates conditions conducive to proliferation of blue–green algae • Reduces available aquatic habitat in the dam pondage (most species commonly use the epilimnion – surface waters) • Release of nutrients and toxicants from sediments due to anoxic conditions in the hypolimnion • Potentially significant downstream effects on water quality and ecology if hypolimnetic or turnover releases are made	• Destratifiers in dam pondage (e.g. bubblers, impellers)	• Industry-standard method for “improving” water quality in stratified pondages • In south-east Queensland, destratifiers are used in a number of dams including • North Pine Dam	• Reduction/elimination of stratification • Reduced risks of hypolimnetic and cold-water releases • Reduced risks of blue–green algal blooms •	• Easier to destratify “basin” shaped pondages than dendritic pondages • Risk of mobilising dissolved nutrients and toxicants through the water column • Limited effectiveness in large storages, or where water quality issues other than temperature are important • May not necessarily reduce blue–green algal growth (e.g. see Littlejohn 2004 and the Caffey Dam Project[8])

[8] Caffey Dam Project, CRC for Freshwater Ecology (www.ewatercrc.com.au)

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Accumulation of nutrients and other contaminants in the dam pondage	• Results from accumulation of water, sediment, catchment-derived nutrients and organic matter in the dam pondage. • Exacerbated by clearing, point sources, urban/rural–residential areas and agriculture. • Dam pondages can reduce pollutant levels through processes such as sedimentation and biological uptake but this usually results in the storage of pollutants in sediments. Phosphate, iron, manganese, and hydrogen sulphide can be released from sediments under anoxic conditions[8]	• Catchment land use controls to minimise inputs of nutrients and other contaminants (e.g. buffer zones, water sensitive urban design (WSUD), stock management, controls on land clearing and controls on fertilisers, including replacement of gypsum fertiliser)	• "Closed catchments" (e.g. Upper Yarra Dam and Maroondah Dam in Melbourne's water supply). • Best practice catchment management measures in rural catchments – e.g. in the Tarago Reservoir catchment (Victoria), Melbourne Water have implemented a Stream Frontage Program which provides grants to landowners to fence off and revegetate all tributaries flowing into the reservoir.	• Mitigates unnaturally elevated inputs of nutrients • Undesirable impacts of blue–green algae on pondage and receiving waters are reduced.	• Requires extensive community cooperation • In developed catchments, it is not feasible to restore inputs to natural background levels (very difficult to deal with diffuse sources of pollution in a rural agricultural environment). Any constructed works require ongoing monitoring and maintenance. Stores in existing soils and plant debris within dam pondage will be capable of releasing nutrients for some time - e.g. the Tarago Reservoir catchment measures proved ineffective due to residual nutrient levels and stratification of the reservoir.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
	• Unrestricted access of stock to stream banks has been shown to result in elevated nutrient levels in the waterway. While this may be of limited significance in flowing water, any elevation in nutrient levels is of critical concern in dam impoundments where the high residence time may result in algal blooms	• Vegetated buffer zones along streams and on drainage lines. May include water quality treatment wetlands to mitigate nutrient loads in input waterways and drains.	• Revegetation and fencing programs to re-establish protective corridors, e.g. Melbourne Water frontage programs in the Western Port and other catchments have resulted in the construction of hundreds of kilometres of fencing at a minimum distance of 10 m from the top of the stream bank and complete revegetation of the fenced zones • Grass buffer systems in intensive agricultural areas (e.g. Toolangi Research Farm, Victoria)	• Wetland systems mitigate unnaturally elevated (mostly point source) inputs of nutrients in waterways • Buffer systems can deal with more diffuse runoff provided that discrete point sources are treated as well. • Undesirable impacts of blue–green algae on pondage and receiving waters are reduced.	• Requires extensive community cooperation • In developed catchments, it is not feasible to restore inputs to natural background levels • High intensity rainfall events and very high seasonal variability of rainfall in south-east Queensland limit the effectiveness of wetlands for water quality treatment for nutrients (substantial residence times are required for nutrient processing). • Stream frontage programs have a proven success record but in some situations weeds have spread within fenced area once stock were excluded.

Geomorphological or Ecological Issue	**Process of Impact and Potential Consequences**	**Potential Mitigation or Compensation Option**	**Previous Applications**	**Benefits**	**Risks/Drawbacks**
	• Any catchment will have a range of point sources (e.g. dairy sheds, urban stormwater pipe inputs) all leading to water quality deterioration	• Improve water quality from point sources (or reduce/eliminate point source inputs) • Controls on effluent including industry, mining (past and present), STPs stormwater, and intensive agriculture (e.g. feedlots, piggeries, poultry farms and dairies)	• In the Western Port catchment, incentives are available to farmers for treatment and on-site disposal of dairy shed effluents via storage and irrigation. • In Melbourne, best-practice stormwater management and WSUD measures (e.g. sediment traps, wetlands, vegetated swales, bioretention swales) have substantially reduced total pollutant loads and concentrations in urban runoff	• Mitigates unnaturally elevated inputs of nutrients	• Requires extensive community cooperation including local government and farmers. • Stormwater treatment costly unless implemented for greenfields sites • Contractual obligations may need to be altered.
Elevated turbidity in dam pondage	• May occur due to storage of turbid flood waters, input of sediment from shoreline erosion, turbulent resuspension processes or dispersive soils. Relatively low salinity of floodwater-dominated pondage would reduce tendency to settle.	• Cover area of dispersive soils within dam pondage area with non-dispersive fill	• None known to the study team	• Isolates dispersive soils from the water column, hence mitigates suspension of sediment from this source	• Unsuitable for large areas of dispersive soils on cost and disturbance grounds
		• Measures to mitigate shoreline erosion, as discussed above	• See above	• See above	• See above

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Cyanobacterial blooms	• Accumulation of nutrients in dam pondage and stratification create conditions conducive for cyanobacterial blooms	• Destratification	• See above	• See above	• See above
		• Measures to reduce nutrient accumulation in dam pondage, including catchment land use controls, vegetated buffer zones along streams and drainage lines, and improve water quality from point sources (or reduce/eliminate point source inputs)	• See above	• See above	• See above

Geomorphological or Ecological Issue	**Process of Impact and Potential Consequences**	**Potential Mitigation or Compensation Option**	**Previous Applications**	**Benefits**	**Risks/Drawbacks**
Excessive aquatic macrophyte growth	• May occur due to still water conditions, particularly if the dam pondage is warm and shallow and turbidity is low • Can affect habitat and create deleterious water quality conditions (e.g. low dissolved oxygen [DO]) for aquatic biota including macroinvertebrates and fish	• Mechanical harvesting, hand removal	• Wappa Dam, Lake MacDonald	• Immediate reduction in macrophyte biomass, removal of nutrients (stored in plant tissues) • No instream/in situ decomposition • Improved water quality • Harvested biomass could potentially be used as compost (depending on the extent of bioaccumulation of heavy metals in plant tissues) • Hand removal more selective than mechanical removal (i.e. native species can be retained if required)	• Ongoing efforts required as causes of excessive growth not directly addressed • Can be time consuming; harvested biomass can be replaced quickly (in weeks), hence ongoing control is required • May not remove tubers, turions (young shoots) that are dormant in the substrate, or roots/rhizomes that can form new plants • Plant fragments created during removal can infest new areas • Mechanical harvesting may injure or kill fauna • Mechanical harvesters are limited by depth • Hand removal is laborious but may be feasible for small areas where a mechanical harvester cannot manoeuvre
		• Booms		• Restrict the spread of floating vegetation	• Vegetation accumulating against booms may eventually pass over or under booms • Not applicable to large areas • Maintenance requirements
		• Dredging		• Immediate removal of above- and below-ground plant biomass	• Disposal of spoil • Expensive • Would require ongoing effort • Short term water quality impacts (e.g. elevated turbidity)

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Herbicides	• Widespread use in channels and drains	• Effective at killing aquatic plants	• Unsuitable for domestic water supplies • Ongoing control required • May kill beneficial native species • Decomposition of plant material may lead to low oxygen levels and associated impacts on oxygen-dependent species and other water quality problems
		• Salt spray	• Salt water has been used to kill off salvinia in the Canning River, W.A.	• Inexpensive	• Decomposition of plant material may lead to low oxygen levels and associated impacts on oxygen-dependent species and other water quality problems
		• Drawdown		• Does not require expensive equipment	• May not be effective in killing plants (or below ground parts) that remain moist or protected by overlying vegetation • Undesirable during droughts (and costly to use water for this purpose; could perhaps be implemented in conjunction with environmental flows) • Response of plants to drawdown unpredictable • Potential infestation of exposed margins by emergent vegetation or terrestrial weeds
		• Bottom barriers		• Prevent establishment and growth of aquatic vegetation	• Expensive, requires maintenance of barriers, probably not feasible for large areas

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Dyes		• Reduce light availability therefore preventing or inhibiting growth (note that non-toxic dyes are used for this)	• May only be feasible for small areas with little throughflow • Reduced amenity value for storages used for recreational purposes • Desirable species may be negatively impacted
		• Biological control (e.g. grass carps, insects)	• Grass carps are used in some North American Dams • Insects are used for biological control of some pest aquatic plants in Australia (e.g. salvinia weevil)	• Potential for long-term ongoing control	• Use of alien species (e.g. grass carps) extremely undesirable due to potential impacts on native aquatic communities • Time required to develop test suitable biocontrol agents for specific pest plants

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Proliferation of alien species of macrophytes	• Risk of spread by boat usage of storage (e.g. cabomba is present in Lake MacDonald; salvinia and water hyacinth are present throughout the Mary River system) • Release of unwanted aquarium specimens or deliberate seeding	• Education, signage and boat washing facilities at storages with pest species	• Burnett River	• Mitigates risk of spread of alien species that may displace native species and interfere with human requirements (e.g. cabomba may taint water, increasing cost of treatment) • Prevention of establishment of alien species is cheaper than controlling or removing established populations • Reduced risk of downstream impacts of large floating rafts of water weeds	• Requires ongoing community cooperation and financial support • Does not guarantee that pest species of macrophytes will not be transferred by accident or other means

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Fish passage impedance by dam	• Prevention of large-scale movements of potamodromous fish (e.g. Mary River cod and lungfish) for foraging, spawning and/or dispersal of juveniles • Prevention of large-scale movements of diadromous fish (e.g. Australian bass, jungle perch, bullrout, eels, mullet)[9] • Large numbers of upstream migrating fish may accumulate immediately downstream of barriers and consequently be subject to increased levels of predation and competition potentially resulting in loss of condition and fish death.	• Fish lock / Fish lift	• Generally suitable for structures > ~6 metres wall height • Relatively few examples in Australia (Ned Churchward Weir [formerly Walla Weir], Paradise Dam, Dumbleton Weir). • More common overseas.	• May enable larger-bodied species to migrate past dam (compared with fishway) • Less susceptible to elevated water temperature than a fishway	• Limits to effectiveness (in terms of size and number of fish able to pass) – does not enable passage of all fish that desire to do so. • The fish movement process (by fish lift/lock) is intermittent, and electrical or mechanical failures of any lift or lock system can be detrimental to the condition of migrating fish. • Requires ongoing monitoring to gauge effectiveness for fish passage as there are frequently design issues that require ongoing modifications on a case-by-case basis • Poor efficacy in allowing fish movement downstream • May not be used by small-bodied species • Predation in dam pondage • Lack of cues re. upstream direction in dam pondage. • Requires dedicated flow allocation for effective operation • Paradise Dam experience indicates that turtles may use fish locks; however, in flood times, they tend to get washed down over dams and weirs and get killed

[9] Impacts on diadromous species include (1) trapping downstream spawning migrations of adult fish in dam/weir impoundments thereby preventing access to estuarine and brackish-water spawning habitat, and (2) preventing upstream dispersal of juveniles into freshwater habitats for foraging development and growth.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Fishway	• Generally suitable for structures < ~6 metres wall height. • No Australian examples on large dams (common on weirs – industry standard) • Have been used overseas for large dams	• May be more suitable for small-bodied species and crustaceans than a fish lock	• In Queensland, fishways are generally considered to be unsuitable for large dams because of steep gradients and potentially high costs • Does not enable passage of all fish that desire to do so. • Requires ongoing monitoring to gauge effectiveness for fish passage as there are frequently design issues that require ongoing modifications on case-by-case basis • Requires dedicated flow allocation for effective operation
		• Manual transport of fish over barrier (by truck or barge)	• North America – used for salmon • No recent Australian precedents (historically, transport of mullet in tanks past Mt Crosby Weir on the Brisbane River was attempted in the late 1920s, according to Gregory 1996)	• Enables fish to be shifted upstream past dam and pondage (to avoid problems with passage through the dam pondage)	• Requires ongoing commitment (in terms of financial and human resources) • Potentially only a very small proportion of fish that want to move will be able to be manually transported • Difficulty in gathering fish for downstream transport • Potential bias in selection of fish species to be transported (e.g. recreationally desirable and/or iconic species rather than small-bodied fish)

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Net decline in species distribution and abundance due to dam impoundment	• Decline in abundance of rare/threatened fish species (e.g. lungfish and Mary River cod) and other vertebrates including turtles (e.g. Mary River turtle) and frogs	• Use of hatcheries and/or artificial spawning/rearing habitats to artificially breed juveniles for reintroduction	• Mary River cod hatchery and restocking program. • QPWS Mon Repos laboratory • Green and golden bell frog bred in captivity for two generations before its remaining habitat within the Sydney Olympic Games site at Homebush Bay could be modified.	• May be necessary or the only way to prevent demise of critically endangered species	• Difficult to artificially breed some species (e.g. lungfish) • Difficulty in obtaining broodstock (e.g. Mary River cod) • Long-term efficacy of reintroduction programs not guaranteed for all species, but this approach has been applied successfully for some species (e.g. the Mary River Cod Recovery Program) • Potential impact on genetic integrity of wild populations • Requires ongoing funding
		• Mitigate other pressures on frog populations[10] • Including: • control of feral pigs • control of terrestrial alien plants including mistflower and crofton weed) • control populations of alien fish • alert government agencies and community to potential effects of introduction of alien species and translocation of native species outside their natural geographic range in Australia	• In NSW, the alien plague minnow *Gambusia holbrooki* is listed as a "key threatening process" for frogs	• Control of feral pigs reduces direct predation, impacts of silt deposition on embryos and tadpoles, and spread of weeds such as mistflower and crofton weed. • Decreased negative impacts on habitat would lead to an increase in sites suitable for egg laying • Reduced predation on eggs and tadpoles of stream breeding frogs by alien fish	• May not fully counterbalance habitat loss due to impoundment

[10] Based on "Recovery Plan for stream frogs of south-east Queensland 2001-2005", Harry Hines, Qld Parks & Wildlife Service and South-east Qld Threatened Frogs Recovery Team

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Develop captive husbandry techniques[11]	• Lone Pine Koala Sanctuary has initiated a captive husbandry project for Fleay's barred-frog *Mixophyes fleayi*	• Establishment of populations in zoological institutions outside natural range of the species, may place some breeding populations beyond the causes of population decline.	• Outcomes unknown and may not ensure survival of species
		• Translocation experiments[12]	• Used in Queensland's Wet Tropics, for species that have declined at higher elevation but persist in the lowlands (Northern Queensland Threatened Frogs Recovery Team 2001).	• Not yet known. Await results of monitoring of the Northern Queensland experiment .	• Outcomes unknown and may not ensure survival of species • May have adverse impacts on resident flora/fauna

[11] Based on "Recovery Plan for stream frogs of south-east Queensland 2001-2005", Harry Hines, Qld Parks & Wildlife Service and South-east Qld Threatened Frogs Recovery Team
[12] Based on "Recovery Plan for stream frogs of south-east Queensland 2001-2005", Harry Hines, Qld Parks & Wildlife Service and South-east Qld Threatened Frogs Recovery Team

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Development/review of restoration plan for species	• Relevant management measures will vary depending on the species in question – may include mitigation measures for dam pondage area or compensatory measures that address other threats to species survival	• Review of existing Recovery Plans or development of a Recovery Plan where one does not presently exist is important for all species listed as rare, threatened or endangered. Benefits should arise from addressing all threats to species related to new dams and associated habitat and resource changes, as well as threats arising from other factors • Identification of key outcomes, restoration methodologies and knowledge gaps by all stakeholders	• Recovery Plans are only useful if they are actually implemented. It is expected that such plans would address all mitigation options listed herein, and all other factors affecting each species. • Long-term resource commitment is required by all stakeholders to achieve all Recovery Plan outcomes
Effects of power boating within dam impoundment	• Increased wave action along pondage shoreline, damage to aquatic vegetation and habitat structure, release of toxicants (from outboard fuel/exhausts), boat strikes on large fish (e.g. lungfish, Mary River cod), noise disturbance can affect waterbirds	• Boat traffic restrictions (e.g. speed limits, ban on powerboats in part or whole of dam pondage)	• Speed limits are commonly applied in estuarine areas to reduce boat wake • Power boating is restricted or banned in some dam pondages	• Mitigates an aggravating factor for bank erosion, water pollution, potential damage to habitat, and disturbance of aquatic fauna and other wildlife	• Reduction/loss of recreational amenity

Table 2.2 Mitigation and compensation options for geomorphological and ecological changes downstream of dams (non-tidal reaches)

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Major geomorphological and ecological changes in river system downstream of dam	• Major changes may occur as a result of substantial changes in flow regime and water quality as well as barrier effects of dams. Likely to cause a change in native species composition and may favour alien species.	• "No net loss of habitat" – rehabilitation of equivalent habitat elsewhere in lieu of habitats lost or significantly altered due to downstream effects of dams	• See Table 2.1	• See Table 2.1	• See Table 2.1

Geomorphological or Ecological Issue	**Process of Impact and Potential Consequences**	**Potential Mitigation or Compensation Option**	**Previous Applications**	**Benefits**	**Risks/Drawbacks**
Channel contraction	• In the Australian context, this commonly involves accommodation adjustment (vegetation encroachment) rather than reforming of the channel, due to limited sediment supply. • It results in net loss of aquatic habitat. • Greater reductions in small floods than large floods lead to increased variability in geomorphological processes – extended periods of contraction, punctuated by “catastrophic” stripping by floods. • In the riparian community, reduced flows can induce shifts in zonations and drought symptoms, including moisture stress and potentially higher salt levels if groundwater baseflows dominate, with increased dieback during droughts.	• Vegetation management (trimming, removal from bars to maintain channel capacity)	• Undertaken in the lower Burdekin River to counteract increased vegetation growth on instream bars in response to hydrologic changes resulting from Burdekin Falls Dam. Also undertaken in other north Queensland rivers in response to vegetation encroachment resulting from natural flow regime variability (e.g. GHD et al. 1996). • Willow removal from the Yarra River (Victoria) has been undertaken to counteract channel contraction in response to flow regime changes resulting from Upper Yarra Dam. • Vegetation trimming from inside banks of bends is a standard river management measure to mitigate erosive forces on outer banks.	• Mitigates shift to more episodic channel processes. • Reduces risks of accelerated bank erosion resulting from flow confinement	• Ongoing maintenance required, as underlying cause of channel contraction (reduced flow) is not altered • Loss of natural transition in riparian vegetation zonations • Disturbance to stream environment if machinery is used • Does not mitigate changes in riparian communities; particularly if salt levels increase and/or the vegetation community becomes fire-prone, vegetation diversity may be permanently altered

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Undertake measures to mitigate any unnaturally elevated sediment inputs to reaches below dams (catchment land use measures, stabilisation of erosion)	• Previously undertaken in a number of areas to mitigate risks of loss of storage capacity due to sedimentation (e.g. Eppalock Catchment Project in Victoria); equally relevant to mitigation of channel contraction processes downstream of dams	• Reduced rate of channel contraction (and associated loss of habitat and flow conveyance capacity) as sediment supply is required for physical contraction to occur	• Slows rather than prevents long-term contraction, as a key underlying cause of contraction (reduction in flow) is not altered. Does not prevent accommodation adjustment (vegetation encroachment). •
		• Scarification of bars to maintain bare sand/gravel surface and maintain sediment availability for transport by river	• North American examples (as discussed by M. Kondolf, University of California – Berkeley) • In Australia, some of the north Queensland river improvement trusts undertake clearing of bar vegetation within the high flow channel to maintain high flow channel capacity (e.g. Upper Pioneer River Improvement Trust, Burdekin River Improvement Trust). In Victoria, the Goulburn–Broken CMA has undertaken vegetation removal and bar trimming on the Goulburn bars at Thornton to mitigate erosion of the opposite bank	• Maintain exposed sand/gravel habitat	• Disturbance to stream environment caused by machinery • Depending on sediment supply from upstream, bar surface may be draped in mud after floods

Geomorphological or Ecological Issue	**Process of Impact and Potential Consequences**	**Potential Mitigation or Compensation Option**	**Previous Applications**	**Benefits**	**Risks/Drawbacks**
Clearwater erosion and substrate change (bed armouring and mud deposition)	• Bed armouring, increased deposition of mud and potentially bed and bank erosion can occur below a dam due to trapping of sediment in the dam pondage (sorting processes mean that sediment outputs are limited to finer fractions). • Particularly likely in situations were high flows are maintained but sediment inputs reduced by dam impoundment (e.g. high flow releases to maintain downstream environmental flows). • Risks of bed and bank erosion are particularly significant if the downstream river channel flows through erodible materials (e.g. alluvium). • Substrate changes would be likely to lead to shifts in aquatic flora and fauna.	• Cessation of all instream sand/gravel extraction	• Sand/gravel extraction is not permitted in Victorian streams unless there is a demonstrated need from a river management viewpoint (e.g. aggradation)	• Cessation of sand/gravel extraction is generally beneficial to stream system	• None. (In rare instances, a river/stream may be affected excess sediment and extraction may be beneficial. This is not the case in the Logan/Albert or Mary). However, cessation of sand/gravel extraction may not be sufficient to counter clearwater erosion processes as a stand-alone option.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Sediment renourishment/ augmentation (methods include sediment injection and artificial riffle construction)	• Undertaken in North America and Europe, but mainly gravel (for salmon spawning) rather than sand (as discussed by Merz et al. [2006] and M. Kondolf, University of California – Berkeley)	• Mitigates substrate changes and associated habitat change	• Impacts at extraction site for sediment source (sand/gravel in dam pondage area likely to be "contaminated" with fine sediment and organic matter and may need washing prior to introduction to downstream reaches • Works not self-sustaining – need for ongoing replenishment due to downstream transport (Merz et al 2006) • Installation of larger materials reduces frequency of replenishment required, but lack of abrasion has been observed to result in increased growth of periphyton, degrading habitat values of the gravel beds[13] • Risk of accelerated channel contraction (including infill of pools or more widespread aggradation) if sediment augmentation rates exceed transport capacity

[13] D. Ahern, Herrera Environmental Consultants, Seattle USA (formerly University of California, Davis) pers. comm.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Sediment pass-though and sluicing	• Examples reported from Europe and the USA (Kondolf 1995)	• Potentially relevant to weirs where velocities are sufficient to transport coarser sediment through the pondage area	• Elevated concentrations of suspended sediment and organic matter released from dam, resulting in potential fish kills • Potential aggradation below dam and acceleration of channel contraction processes • Risk of hypolimnetic water release from low level outlets required for sediment sluicing • In the Australian context, with low reservoir sedimentation rates, material accumulated in the proximity of the dam wall is likely to consist of finer particles, the coarser material being deposited in delta deposits at the upstream end of the storage

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Weed invasion of riparian zone	• Changes in flow regime downstream of dams (including reductions in disturbance and scour due to flood flow reductions and elevated and more persistent low flows if supplementation occurs) increase the susceptibility of riparian zones to weed invasion • Severe weed infestations are commonly seen in riparian zones downstream of dams	• Riparian zone weed management programs downstream of dams to compensate for reduction in natural checks on weed growth resulting from floods (scour, drowning). Combined with revegetation where necessary to improve robustness of riparian zone.	• Many examples of riparian zone weed management and revegetation programs, although generally not specifically targeted towards mitigating downstream impacts of dams. • Landcare riparian restoration projects. • Mary catchment Committee riparian restoration projects throughout the Mary catchment.	• Use human effort to compensate for work that would have been carried out by floods in the natural flow regime • May assist in mitigating excessive growth of instream vegetation through shading • Improvement to instream habitat where associated with riparian restoration	• Requires ongoing commitment to maintenance • Ongoing community and landholder support required • Changes to ephemeral habitat for some wildlife (i.e. species that use weeds as habitat)
Hypolimnetic releases from stratified dam	• Releases can have "poor" water quality – e.g. low temperature, low DO, low pH, high concentrations of dissolved metals and foul odours. • Can impact on aquatic flora and fauna.	• Multilevel offtakes for downstream releases from dams [14]	• Industry-standard best practice for new dams that are expected to be subject to stratification	• Mitigates impacts on downstream water quality and effects on instream ecosystems. • Multilevel offtakes could also be operated to mimic some aspects of natural variability in water quality (e.g. seasonal variability in water temperature)	• Monitoring and adaptive operation is essential to effective mitigation of dam impacts on water quality

[14] Other less common methods for mitigating impacts of hypolimnetic or coldwater discharges from dams include surface pumps, floating intakes (trunnions), submerged weirs or suspended curtains, stilling basins and modified guide or rule curves (see Sherman [2000] for further discussion).

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Major change in seasonal patterns of water quality downstream of dam	• In the natural situation, water quality varies seasonally as well as between low flow conditions and high flow/storm events. • The presence of a dam will tend to smooth out this natural water quality regime. Seasonal temperature patterns can be completely disrupted, particularly if stratification occurs.	• Operate multilevel offtakes to simulate natural seasonal variability in water temperature.		• Simulate natural variability in water temperature. • Maintain temperate-related cues for aquatic biota	• Monitoring and adaptive operation is essential to effective mitigation of dam impacts on water quality • The smoothing effect of a dam on water chemistry cannot be mitigated. For example, in an unimpounded waterways flood flows often have very high levels of suspended solids, turbidity, TN and TP but will travel quickly through and within a day or two levels will be back to normal. A dam will store these peaks and release over long periods such that for most of the time pollutant levels are above natural low flow levels.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Factor reinforcement between impacts of water resource development and other factors amplifies water resource development impacts	• Riparian zone vegetation is often impacted by disturbances related to land use (e.g. vegetation loss, weed invasion), which interact with effects of altered flow regime (e.g. loss of low flows that maintain wetted rooting depths, loss of small channel flows that distribute propagules, and loss of high flows that wet upslopes and allow colonisation by propagules after floods). Overall loss of spatial and temporal flow variability reduces habitat variability and hence plant diversity. Stock access may exacerbate these effects via trampling, addition of nutrients, and increased erosion. Competitive alien plant species can add to the pressures within riparian zones.	• Rehabilitate affected ecosystems to increase resilience to impacts of water resource development – e.g. example, replant riparian vegetation appropriate to the particular river reach, remove or control alien species that may outcompete native species and manage stock access	• Many examples of stream rehabilitation works, although generally not specifically targeted towards mitigating downstream impacts of dams. Discussed in Land and Water Australia publications	• Increased resilience of river/stream to effects of water resource development	• Requires ongoing commitment to maintenance • Question of whether stream rehabilitation funds would be more usefully spent to improve areas in good condition and not threatened by water resource development (i.e. maintain/protect natural ecosystem) rather that in areas where water resource development impacts mean that only a modified ecosystem can be sustained

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Barrier effect of dam to downstream movement of biota	• High mortality of fish that are washed over spillway during overtopping flows. • Mortality may be influenced by the size of fish and the height of the dam wall, particularly when combined with other factors such as abrasion from contact with the spillway, rapid pressure changes and shearing effects. • Large fish such as adult lungfish, Mary River cod and mullet can come in contact with the spillway face and suffer high mortalities. • Fish deaths (including lungfish) associated with being washed over spillways have been observed in the Burnett River (Berghuis & Broadfoot 2004; see also Kennard 2000, 2005).	• Provision of fish locks that are effective in allowing downstream fish passage	• Relatively few examples of fish locks in Australia (Ned Churchward Weir [formerly Walla Weir], Paradise Dam, Dumbleton Weir). More common overseas. • However, existing fish lock designs have poor efficacy in allowing fish movement downstream. • No examples are known that have high efficacy in allowing downstream fish movement.	• Will decrease fish mortality	• Very little research has been conducted in Australia on effective fish lock designs for downstream fish passage (see Berghuis & Broadfoot 2004). • Existing fish lock designs have poor efficacy in allowing fish movement downstream

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Net decline in species distribution and abundance due to impacts of water infrastructure and flow regime changes	• Decline in abundance of rare/threatened species of fish (e.g. lungfish and Mary River cod) and other vertebrates, including turtles (e.g. Mary River turtle) and frogs	• Use of hatcheries and/or artificial spawning/rearing habitats to artificially breed juveniles for reintroduction	• See Table 2.1	• See Table 2.1	• See Table 2.1
		• Mitigate other pressures on frog populations (as discussed in Table 2.1)	• See Table 2.1	• See Table 2.1	• See Table 2.1
		• Develop captive husbandry techniques (as discussed in Table 2.1)	• See Table 2.1	• See Table 2.1	• See Table 2.1
		• Translocation experiments (as discussed in Table 2.1)	• See Table 2.1	• See Table 2.1	• See Table 2.1
		• Development/review of restoration plan for species (as discussed in Table 2.1)	• See Table 2.1	• See Table 2.1	• See Table 2.1

Geomorphological or Ecological Issue	**Process of Impact and Potential Consequences**	**Potential Mitigation or Compensation Option**	**Previous Applications**	**Benefits**	**Risks/Drawbacks**
Impacts of flow reductions on downstream ecosystems • reductions in low, medium and high flows • weakening of seasonality by reductions in medium/high flows in the wet season	• Reduction of longitudinal connectivity, may affect access to spawning habitats and juvenile dispersal, and cause a loss of shallow riffle/run habitats • Increased duration of isolation in refuge habitats may increase effects of biotic interactions such as predation, competition, disease transmission • Habitat changes due to changes in physical processes, riparian vegetation and water quality	• Environmental flow provisions: • low flow releases • medium/high flow releases	• Low flow environmental releases are industry-standard best practice for new developments • Medium/high flow releases are less common (primarily due to outlet work constraints and implications for yield) but are becoming more widely adopted	• Mitigation of effects on reduction of aquatic habitat and connectivity • Mitigation of effects on instream processes	• May impact on water yield • Erosion risks associated with medium/high flow releases (including clearwater erosion). • Higher costs for larger capacity outlet controls

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Impacts of flow supplementation on downstream ecosystems • Changed seasonality, including loss of seasonal variation in water quality	• Potential reduction in cues for spawning and movement/dispersal, including potential desynchronisation of elevated spring temperature and low, stable flows, which provide important conditions for spawning and recruitment of many fish species. • Elevated water velocities through pools due to supplemented flows may minimise conditions suitable for fish spawning and larval development (e.g. flushing of eggs and larvae). • Supplemented flows may also alter habitat availability (increased wetted perimeter and extent of submerged marginal areas) to favour a subset of species	• Use of offstream conduits (channels, pipelines) rather than natural stream channels for water delivery	• Has been suggested for the Brisbane River downstream of Wivenhoe Dam (Arthington et al. 2000)	• Mitigates impacts as outlined under “Process of Impact and Potential Consequences”	• Expensive • Reduces total volume of water available to riverine ecosystem • Impacts of a major dam on seasonal patterns of water quality cannot be fully mitigated but ecological significance will vary according to species sensitivity.

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Provision and use of offstream balancing storages to allow instream deliveries in the pattern of a natural hydrograph		• Mitigates the need to maintaining constant elevated flows over extended periods of time within the stream channel – release strategy can be determined by environmental considerations rather than consumptive demand	• Impacts of construction of offstream storage(s), including impoundment effects
Artificial, rapid and/or unseasonal fluctuations in water levels downstream of impoundments due to flow release strategy	• Exposure of previously inundated marginal areas potentially containing fish nesting sites (e.g. aquatic macrophyte beds used by small-bodied species and lungfish, woody debris used by Mary River cod, gravel nests constructed in substrate by eel-tailed catfish), resulting in desiccation of fish eggs and larvae • Loss of spawning and migration cues • Changes to physical habitat quality and quantity, and food availability • (see Bunn and Arthington 2002 for further discussion)	• Development of operating rules that mitigate unnatural variability	• Recommended for Wivenhoe Dam (Arthington et al. 2000). • In New Zealand, the fish faunas of streams below hydrodams have been restored by dampening out unnatural water level fluctuations	• Prevent or mitigate impacts on instream biota resulting from unnatural variability in flows	• Needs to be considered at design stage to ensure that outlet works are capable of delivering suitable release strategies (e.g. cavitation problems with variable releases from cone valves)

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
		• Stilling pondages below dams to mitigate impacts of rapid variations in releases on downstream flow regimes and ecosystems	• Eildon Pondage below Eildon Dam	• Reduce the risk of impact on downstream ecosystems arising from sudden changes in flow	• Additional (minor) barrier to fish passage
Impacts arising from water resource development that pose threats to frogs	• Stream-associated forest dependent frogs (generally found in moister forest types and breed in a range of stream environments) are susceptible to impacts from dam impoundments (as noted in Table 2.1) as well as downstream flow regime changes and associated habitat alterations	• Maintenance of riparian zone vegetation • Reduce stock access to riparian zone • Reduce clearing of riparian zone	• Proposed in south-east Queensland rare/threatened frogs recovery plan (Hines 2001)	• Improves chances of survival for stream-associated forest-dependent frogs	• Requires ongoing commitment to maintenance • Does not guarantee survival of stream-associated forest-dependent frogs

Table 2.3 Mitigation and compensation options for geomorphological and ecological changes downstream of dams (estuarine reaches)

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Major change in estuarine condition as a result of water resource development pressures	• For example, truncation of estuary by tidal barrage, major water quality problems resulting from reduced flushing and increased residence times	• "No net loss of habitat" – rehabilitation of equivalent habitat elsewhere in lieu of habitats lost or significantly altered due to downstream effects of dams	• See Table 2.1	• See Table 2.1	• See Table 2.1
Factor reinforcement between impacts of water resource development and other factors amplifies water resource development impacts	• Impacts of various anthropogenic pressures on estuary condition can be cumulative	• Protection and restoration or rehabilitation of riparian vegetation, mangroves and tidal wetlands in estuarine environments. • Restoration of littoral habitats in estuarine and nearshore locations	• The re-establishment of mangroves is possible (Osunkoya and Creese, 1997; Erftemeijer and Lewis 2000; Lewis 2005) and small-scale plantings have been undertaken by Fisheries Research Consultants in the Brisbane River (R. Kenyon, pers. comm.) • In Victoria, fencing and revegetation of a number of the tidal reaches of streams flowing into Westernport Bay has been successfully undertaken	• Riparian vegetation and, in estuarine environments, mangroves and other tidal wetlands contribute significantly to ecological values, including bank stability, water quality, and food and habitat resources for various biota. Protection and enhancement of such vegetation would assist in retaining functional ecosystems in rivers and estuaries affected by flow regime change.	• Question of whether stream rehabilitation funds would be more usefully spent to improve areas in good condition and not threatened by WRD (maintain natural ecosystem) rather that in areas where WRD impacts mean that only a modified ecosystem can be sustained

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Factor reinforcement between impacts of water resource development and impacts of point and diffuse source inputs on water quality	• Pollution of estuary by point source inputs exacerbated by reduced flushing	• Improve water quality of point sources (e.g. tertiary treatment for sewage effluent) and reuse for land irrigation	• Southeast Queensland – schemes to reduce impact of point source inputs on rivers and estuaries though the Moreton Bay Waterways and Catchment Partnership's (MBW&CP's) initiatives	• Reduced risk of water quality deterioration as a result of reductions in flushing and increased retention times resulting from reduced flows	• High cost of treatment; however, if effluent is disposed by land irrigation, tertiary treatment is not required • Land disposal reduces freshwater input to estuary (in the existing situation, point source inputs may be compensating for reductions in freshwater inputs from upstream catchments)
		• Catchment land use measures to improve water quality (e.g. buffer zones, WSUD, stock management)	• see Tables 2.1 and 2.2	• Mitigate elevated inputs of sediment, nutrients and contaminants from point and diffuse sources (e.g. catchment land use measures, management of stock access to streams in rural areas and treatment of point source inputs) to reduce potential impacts of reductions in flushing flows in estuaries	• See tables 2.1 and 2.2. Requires cooperation from many parties • May be difficult to retrofit existing urban areas to effectively treat stormwater to modern standards. • Particularly different in large catchments due to extensive source areas (particularly if there is significant urbanisation)
Loss of deep-water habitat	• Changes in estuarine sediment transport processes resulting from reductions in high flows can potentially lead to infill of pools, resulting in reduced catches of some fishery species	• Re-create reef and deep pool habitats by installation of artificial reefs (e.g. large rocks – at least 2 m diameter); • the rocks would create diverse reef habitats including rock ledges and crevices, and the hydraulic obstruction caused by the reefs would induce scour and thus create and maintain deep pools	• Habitat rocks in non-tidal reaches of rivers (recommended for some river restoration projects in Victoria) • Overseas, artificial reefs have been used in several countries to enhance fish populations in marine and freshwater habitats (Bombace et al. 1995, Forbis and LaMorte, 1995, Jensen and Collins 1995).	• Provision of deep pool habitats for estuarine fish • Studies of marine reefs show that the spatial arrangement and design of 'reef clusters' affects species richness and abundance. • Experience elsewhere shows improved fishery catches in the vicinity of artificial reefs (particularly of benefit to recreational fisheries)	• The technique remains a focus of experimentation and the use of artificial habitat in estuaries is not well studied. • There is debate about whether these structures actually increase fish biomass, or just increase concentrations of fish in certain areas • Potential liability issues (obstacles to navigation) • Dislodgment threats in floods • Erosion risks, depending on placement

Geomorphological or Ecological Issue	Process of Impact and Potential Consequences	Potential Mitigation or Compensation Option	Previous Applications	Benefits	Risks/Drawbacks
Reductions in biomass of diadromous fish	• Reduced access to upstream catchment due to barrier effects of dam(s) and weir(s)	• Fish passage devices (fish locks, fish lifts, fishways)	• See Tables 2.1 and 2.2	• See Tables 2.1 and 2.2	• See Tables 2.1 and 2.2

3 Logan/Albert Catchment Development Scenarios

Three future water resource development scenarios for the Logan/Albert catchment have been assessed:

- Large Tilleys Dam – large dam (30 m) on the Logan River near Tilleys Bridge, plus Cedar Grove Weir;
- Small Tilleys Dam + Wyaralong Dam – small dam (20.9 m) on the Logan River near Tilleys Bridge and Wyaralong Dam on Teviot Brook, plus Cedar Grove Weir; and
- Wyaralong Dam + Glendower Dam – Wyaralong Dam on Teviot Brook and Glendower Dam on the Albert River, plus Cedar Grove Weir and the Albert River Barrage.

Detailed assessments of environmental issues associated with each of these scenarios are presented in Sections 3.1 (Large Tilleys Dam), 3.2 (Small Tilleys Dam + Wyaralong Dam) and 3.3 (Wyaralong Dam + Glendower Dam). In each instance, consideration is given to dam pondage and upstream barrier effects as well as downstream effects on non-tidal reaches, the Logan River estuary and Southern Moreton Bay. Impacts on condition and values are discussed, as well as relevant mitigation and compensation options and their likely benefits.

All three scenarios identified for the Logan/Albert catchment have environmental risks and concerns. Information regarding environmental issues associated with the scenarios is summarised in Table 3.1. Large Tilleys Dam is expected to have lesser overall environmental impacts than the other two scenarios. It is more difficult to rank the other two scenarios, as the relative level of impact varies depending on the criterion under consideration. The Wyaralong Dam + Glendower Dam scenario is likely to have the greatest level of overall environmental impact because, in addition to impacts in the Logan catchment, it would have significant effects on the Albert River system, including major impacts on the Logan/Albert estuary resulting from installation of the Albert River Barrage.

The Large Tilleys Dam scenario has the smallest pondage "footprint" in terms of total ponded area and mainstream length impounded, and also the smallest percentage of catchment area isolated by dams from downstream reaches and Moreton Bay. It has a smaller length of supplemented stream than Small Tilleys Dam + Wyaralong Dam scenario (though greater than the Wyaralong Dam + Glendower Dam scenario).

In the Small Tilleys Dam + Wyaralong Dam scenario, installation of two dams in different parts of the Logan catchment would cause more widespread impacts than installation of a single dam in the Large Tilleys Dam scenario. The Small Tilleys Dam + Wyaralong Dam scenario would result in a similar total ponded area as the Wyaralong Dam + Glendower Dam scenario, but greater ponded mainstream length.

The Wyaralong Dam + Glendower Dam scenario would cause significant impacts in both the Logan and Albert catchments, unlike the other two scenarios, where additional development occurs only in the Logan catchment. Fish passage impedance by dams would greater than for the Large Tilleys Dam scenario (but slightly less than for the Small Tilleys Dam + Wyaralong Dam scenario) in terms of percentage of the total Logan/Albert catchment area upstream of large dams. Glendower Dam would isolate 41% of the Albert River catchment from downstream reaches. Fish passage impedance by new weirs (i.e. Cedar Grove Weir and Albert River Barrage) is much greater than for the other two scenarios, which each only require one weir (i.e. Cedar Grove Weir). The length of stream affected by new/additional supplementation is less than for the Large Tilleys Dam or Small Tilleys Dam + Wyaralong Dam scenarios, but a greater length of stream would be affected by new weir pondages.

Impacts of the Wyaralong Dam + Glendower Dam scenario on the Logan/Albert estuary would be much greater than for the other two scenarios because of impacts of the installation of Albert River Barrage (via direct habitat loss and hydrodynamic effects) as well as reduced inflows from the Albert River catchment. Estuarine impacts could be significantly mitigated by not installing a tidal barrage downstream of Luscombe Weir (e.g. redeveloping Luscombe Weir rather than installing the Albert River barrage).

All of the scenarios under consideration involve impoundment of areas that have been extensively cleared for grazing or agriculture but retain remnants of indigenous vegetation including "endangered" RE 12.3.3 (*E. tereticornis* woodland to open forest on alluvial plains). The Small Tilleys Dam + Wyaralong Dam and Wyaralong Dam + Glendower Dam scenarios also involve submergence of remnants of some "of concern" REs. All three scenarios would affect EVR fauna species, including the "endangered" (EPBC) Mary River cod Macculochella *peelii mariensis* and EVR other vertebrates. Existing vertebrate records are too patchy to provide comprehensive lists of EVR fauna for each proposed dam; however, connectivity to headwater forests (Tilleys Dam site) and adjacent forests and upstream wetlands (Wyaralong Dam site) suggest that these two dam sites may be particularly likely to support larger numbers of EVR fauna species.

Well-documented correlations indicate that catches of fisheries species from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 5% (mudcrabs) and 10% (prawns and flathead) compared to present levels as a result of reductions in summer flow in all three scenarios under consideration. Many more fish and invertebrate species are expected to be similarly affected.

As the Large Tilleys Dam and Small Tilleys Dam + Wyaralong Dam scenarios involve development in the Logan catchment only, they leave open the opportunity for extensive (catchment-scale) rehabilitation of the Albert River. With removal of Luscombe Weir, it would be possible to provide habitat connectivity between the Albert River headwaters and Moreton Bay. Currently the South Pine River is the only major tributary of Moreton Bay where connectivity between the bay and headwaters is not impeded by a dam or weir.

Table 3.1 Comparison of Logan/Albert catchment development scenarios

	Large Tilleys Dam	Small Tilleys Dam + Wyaralong Dam	Wyaralong Dam + Glendower Dam
Catchment Area Upstream of New Dam(s)	• 527 km^2 (14% of Logan/Albert catchment) upstream of Tilleys Dam, but 106 km^2 of this area (3% of Logan/Albert catchment) is already upstream of Maroon Dam, so net increase of 421 km^2 (11% of total Logan/Albert catchment)	• 1073 km^2 (29% of Logan/Albert catchment) upstream of Tilleys and Wyaralong Dams, but 106 km^2 of this area (3% of Logan/Albert catchment) is already upstream of Maroon Dam, so net increase of 967 km^2 (26% of total Logan/Albert catchment area) • More intensive upstream land uses are likely to lead to poorer water quality in Wyaralong Dam than other storages (with regard to turbidity, nutrients and contaminants)	• 850 km^2 (23% of Logan/Albert catchment) upstream of Wyaralong and Glendower Dams • This is additional to the 106 km^2 (3% of Logan/Albert catchment) already upstream of Maroon Dam • More intensive upstream land uses are likely to lead to poorer water quality in Wyaralong Dam than other storages (with regard to turbidity, nutrients and contaminants)
Catchment Area Upstream of New Weir(s)	• 2,386 km^2 (64% of Logan /Albert catchment or 83% of Logan catchment) upstream of Cedar Grove Weir • The catchment area commanded by Cedar Grove Weir is contained within the catchment area of the existing South MacLean Weir, a smaller structure that is situated further downstream • Leaves open the opportunity to remove Luscombe Weir, which currently interrupts access from the sea to all freshwater reaches of the Albert River	• 2,386 km^2 (64% of Logan /Albert catchment or 83% of Logan catchment) upstream of Cedar Grove Weir • The catchment area commanded by Cedar Grove Weir is contained within the catchment area of the existing South MacLean Weir, a smaller structure that is situated further downstream • Leaves open the opportunity to remove Luscombe Weir, which currently interrupts access from the sea to all freshwater reaches of the Albert River	• 3,101 km^2 (83% of Logan /Albert catchment, including 80% of Logan catchment and 95% of Albert catchment upstream of Cedar Grove Weir and Albert River Barrage) • The catchment area commanded by Cedar Grove Weir is contained within the catchment area of the existing South MacLean Weir, a smaller structure that is situated further downstream • The Albert River Barrage would command a slightly greater proportion of the Albert River catchment area than the existing Luscombe Weir
Area Ponded By New Dams	• 1,620 ha	• 2,337 ha	• 2,349 ha
Ponded Mainstream Length	• ~15 km of Logan River, ~9 km of Palen Creek, ~ 3 km of Burnett Creek	• <~15 km of Logan River, <~9 km of Palen Creek, <~3 km of Burnett Creek, 32 km of Teviot Brook	• 32 km of km of Teviot Brook, 12 km of the Albert River

	Large Tilleys Dam	Small Tilleys Dam + Wyaralong Dam	Wyaralong Dam + Glendower Dam
Rare/threatened REs and Plant Species in Ponded Area	• Small remnants of “endangered” RE 12.3.3 • *Vallisneria nana* (ribbonweed) (“rare” NCA)	• Small remnants of “endangered” RE 12.3.3 (Tilleys and Wyaralong) • One small remnant of “of concern” RE 12.9–10.7 (Wyaralong) • *Vallisneria nana* (ribbonweed) (“rare” NCA) (Tilleys)	• Small remnants of “endangered” RE 12.3.3 (Wyaralong and Glendower) • Small remnants of “of concern” RE 12.9-10.7 (Wyaralong) and RE 12.9–10.3 (Glendower) • *Vallisneria nana* (ribbonweed) (“rare” NCA) recorded downstream of Glendower Dam site and may occur in proposed pondage area

	Large Tilleys Dam	Small Tilleys Dam + Wyaralong Dam	Wyaralong Dam + Glendower Dam
Rare/threatened Fauna Affected by Dam Pondage or Barrier Effects	• Mary River cod *Macculochella peelii mariensis* ("endangered" EPBC) and cod restocking sites • The black-necked stork *Ephippiorhynchus asiaticus* ("rare" NCA), *Petrogale penicillata* ("vulnerable" NCA) and koala *Phascolarctos cinereus* ("vulnerable" NCA) have been recorded in the vicinity of the proposed dam pondage. • The position in catchment and proximity and connectivity to headwater forests suggests significant possibility that additional other vertebrate species of conservation significance are present in this area. They include EVR frogs, birds, marsupials and a bat. • Platypus, *Ornithorhynchus anatinus*, a protected and iconic species	• Mary River cod *Macculochella peelii mariensis* ("endangered" EPBC – Tilleys and Wyaralong) and cod restocking sites (Tilleys) • The following EVR species have been recorded in the vicinity of the proposed dam pondages: brush-tailed rock wallaby *Petrogale penicillata* ("vulnerable" NCA) – Tilleys; grey goshawk *Accipiter novaehollandiae* ("rare" NCA), black-breasted button quail *Turnix melanogaster* ("vulnerable" NCA), spotted-tailed quoll *Dasyurus maculatus maculatus* ("vulnerable" NCA) – Wyaralong; and black-necked stork *Ephippiorhynchus asiaticus* ("rare" NCA) and koala *Phascolarctos cinereus* ("vulnerable" NCA) – both pondages. • The position in catchment and proximity and connectivity to headwater forests (Tilleys) and presence of substantial remnants of native vegetation, connectivity to adjacent forests and proximity to significant wetland areas (Wyaralong) suggests significant possibility that additional other vertebrate species of conservation significance are present in the vicinity of both proposed dam pondage areas. They include EVR frogs, birds, marsupials and a bat. • Platypus, *Ornithorhynchus anatinus*, a protected and iconic species (Tilleys).	• Mary River cod *Macculochella peelii* – Wyaralong and Glendower) • The following EVR species have been recorded in the vicinity of the proposed dam pondages: grey goshawk *Accipiter novaehollandiae* ("rare" NCA), black-breasted button quail *Turnix melanogaster* ("vulnerable" NCA), spotted-tailed quoll *Dasyurus maculatus maculatus* ("vulnerable" NCA) and black-necked stork *Ephippiorhynchus asiaticus* ("rare" NCA – Wyaralong; and koala *Phascolarctos cinereus* ("vulnerable" NCA) – both pondages. • The presence of substantial remnants of native vegetation, connectivity to adjacent forests and proximity to significant wetland areas suggests significant possibility that additional other vertebrate species of conservation significance are present in the vicinity of the Wyaralong Dam pondage area. They include EVR frogs, birds, marsupials and a bat. Other EVR vertebrates may possibly also be present in the vicinity of the Glendower Dam pondage site. • Platypus, *Ornithorhynchus anatinus*, a protected and iconic species (Glendower).

	Large Tilleys Dam	Small Tilleys Dam + Wyaralong Dam	Wyaralong Dam + Glendower Dam
Stream Length Supplemented or Impounded by Weirs	• The non-tidal reaches of the Logan River that would be affected by flow regime changes resulting from the Large Tilleys Dam scenario are already supplemented as far downstream as South MacLean Weir (AMTD 70 km). However, this scenario would lead to in much greater flow regime changes with substantial increases in geomorphological and ecological impacts • Parts of the Logan River are already impounded by the Bromelton and South MacLean Weir pondages (5 km and 2 km). Cedar Grove Weir would pond an additional 10 km of the Logan River plus 3.5 km of Teviot Brook (Brizga et al. 2006a).	• Supplementation of the Logan River and construction of Cedar Grove Weir would occur as per the Large Tilleys Dam scenario (see left). • In addition, the reach of Teviot Brook between Wyaralong Dam and Cedar Grove Weir pondage (11.3 km), which is currently unsupplemented, would become supplemented • Parts of the Logan River are already impounded by the Bromelton and South MacLean Weir pondages (5 km and 2 km). Cedar Grove Weir would pond an additional 10 km of the Logan River plus 3.5 km of Teviot Brook (Brizga et al. 2006a).	• Reaches of Teviot Brook between Wyaralong Dam and Cedar Grove Weir pondage (11.3 km) and the Albert River between Glendower Dam and the upstream end of the Albert River barrage pondage (33.2 km), which are currently unsupplemented, would become supplemented • Cedar Grove Weir would pond an additional 10 km of the Logan River plus 3.5 km of Teviot Brook (Brizga et al. 2006a); this would be in addition to 7 km of river already impounded by the existing Bromelton and South MacLean Weir pondages • The Albert River Barrage would pond 5 km of the Albert River (compared to 3 km impounded by existing Luscombe Weir, a net 2 km increase in ponded length). It would also truncate the upper estuary, with significant impacts on estuarine hydrodynamics, water quality and ecology

	Large Tilleys Dam	Small Tilleys Dam + Wyaralong Dam	Wyaralong Dam + Glendower Dam
Summary of Impacts on Non-Tidal Reaches	• Changes to the geomorphology and ecology of non-tidal reaches of the Logan River downstream of Tilleys Dam would occur as a result of reductions in medium and high flows, coupled with changes in low flow regime resulting from supplementation to Cedar Grove Weir and major reductions in low flows downstream of Cedar Grove Weir • Instream flora and fauna in these reaches are expected to be impacted by barriers to movement, impoundment of riverine habitat, and altered flows, habitat and food resources resulting from water resource development • Riparian vegetation has already undergone substantial change from reference condition as a result of land use pressures, but is likely to become more weed-prone as a result of flow regime changes	• Implications of this scenario for the Logan River upstream of Cedar Grove Weir would be very similar to the Large Tilleys Dam scenario, with incrementally lesser magnitudes of some impacts. Downstream of Cedar Grove Weir, this scenario would generally lead to slightly greater reductions in flow than the Large Tilleys Dam scenario, but very similar geomorphological and ecological impacts. • Major geomorphological and ecological changes would occur in Teviot Brook downstream of Wyaralong Dam, in response to dam impacts, flow regime change and ponding of the lower end of Teviot Brook by Cedar Grove Weir	• Major geomorphological and ecological changes would occur in Teviot Brook downstream of Wyaralong Dam, in response to dam impacts, flow regime change and ponding of the lower end of Teviot Brook by Cedar Grove Weir. • Significant change would also occur in the Logan River, within the Cedar Grove Weir pondage and downstream. • Major geomorphological and ecological changes would occur in the Albert River downstream of Glendower Dam, in response to dam impacts and flow regime change • Luscombe Weir would be replaced by the Albert River barrage, which would have a slightly greater pondage area

	Large Tilleys Dam	Small Tilleys Dam + Wyaralong Dam	Wyaralong Dam + Glendower Dam
Summary of Impacts on Estuarine Reaches and Moreton Bay	• This development scenario would mainly affect the Logan River, with minor implications for the Albert River via hydrodynamic interactions that would affect salinity and water quality, and possibly movements of fish and invertebrates • There would be a substantial increase in salinity of the upper reach of the estuary as well as increased residence times and reduced flushing, which would impact other abiotic factors; with a net effect on the habitats, distribution and behaviour of biota in the estuary. • Cedar Grove Weir (and Tilleys Dam much further upstream) would create barriers to the upstream movement of diadromous fish • Water quality is already significantly impacted by inputs of pollutants from point and diffuse sources, and is predicted to further deteriorate. • Estuarine flora and fauna would adjust in response to changes in salinity gradients and other aspects of water quality, and well as habitat changes resulting from alterations to sediment transport processes • Well-documented correlation indicate that catches of fisheries species from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 5% (mudcrabs) and 10% (prawns and flathead) compared to present levels as a result of reductions in summer flow. Many more fish and invertebrate species are expected to be similarly affected.	• Same as for the Large Tilleys Dam Scenario	• This development scenario would affect the estuarine reaches of both the Logan and Albert Rivers, reducing the possibility of maintaining the functionality of the estuary through the continuation of relatively natural flow conditions from one river. • Installation of a tidal barrage in the Albert River estuary would significantly and measurably increase the impact of this development scenario on the Albert River • There would be substantial increase in salinity of the upper parts of the estuary (Logan and Albert arms) as well as increased residence times and reduced flushing, which would impact other abiotic factors; with a net effect on the habitats, distribution and behaviour of biota in the estuary • The new weirs (and dams further upstream) would create significant barriers for the upstream movement of diadromous fish • Water quality (especially in the Albert River) is already significantly impacted by inputs of pollutants from point and diffuse sources, and is predicted to further deteriorate. • Estuarine flora and fauna would adjust in response to changes in salinity gradients and other aspects of water quality, and well as habitat changes resulting from alterations to sediment transport processes • Well-documented correlations indicate that catches of fisheries species from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 5% (mudcrabs) and 10% (prawns and flathead) compared to present levels as a result of reductions in summer. Many more fish and invertebrates species are expected to be similarly affected.

3.1 Large Tilleys Dam

Dam pondage and upstream barrier effects of the Large Tilleys Dam scenario are discussed in Section 3.1.1, downstream effects on the non-tidal reaches of the Logan River are discussed in Section 3.1.2 and effects on the Logan River estuary and Southern Moreton Bay are discussed in Section 3.1.3. In each section, implications for condition and values, and relevant mitigation and compensation options are examined.

3.1.1 Dam Pondage and Upstream Barrier Effects

3.1.1.1 Implications for Condition and Values

Geomorphology and Hydraulic Habitat

- Large Tilleys Dam would submerge ~15 km of the Logan River, ~9 km of Palen Creek and ~ 3 km of Burnett Creek, plus parts of smaller tributaries.
- Habitat types that would be submerged include river/stream channel (including gravel riffles and pools, sand/gravel bars, benches and backwaters), floodplain, river terrace and upslope habitats.
- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes. However, Tilleys Dam pondage would be different from a natural lake due to greater variability in water levels resulting from dam operation.
- The surficial geology of the Tilleys Dam pondage area is mainly Jurassic Marburg Formation (sandstone, siltstone, shale, conglomerate, coal, oolitic ironstone) with alluvium in the major valleys (Logan River, Burnett Creek, Palen Creek). This would influence shoreline character and sediment inputs. The Marburg formation represents an important source of sandy sediments in the Logan catchment and is associated with relatively high rates of soil erosion.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.
- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the dam pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches.

Water Quality

- Water quality in the Tilleys Dam impoundment would exhibit less temporal variability than the water quality of natural stream flows.
- Elevated surface water temperature and thermal stratification are likely – other large dams in this area, including Maroon (G. McGregor, pers. comm.), Moogerah and Hinze (Brizga et al. 2006b), are subject to seasonal thermal and chemical stratification.
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- The catchment of Tilleys Dam includes forested headwaters and cleared areas used for grazing and agriculture, hence inputs of sediment and nutrients would be elevated due to land use factors.

- There would also be nutrient release from former agricultural soils impounded by the dam pondage in the short to medium term (much of the dam pondage area submerges cleared river flats).
- There are two licensed point source inputs within the catchment area of Tilleys Dam (at Maroon Dam and the Palen Creek Correctional Centre).
- The Tilleys Dam pondage would be at risk of blue–green algal blooms, due to stratification processes and elevated nutrient inputs as discussed above. Blue–green algal blooms have been reported in other nearby storages, including Lake Moogerah (Brizga et al. 2006b) and Maroon Dam (G. McGregor, pers. comm.).
- Turbidity would be altered. Information on the composition of suspended load delivered to the dam pondage area and soil properties within the pondage area would be required to determine the likely direction and extent of change[15].
- Unnatural variability in DO is expected, potentially including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Tilleys Dam pondage, resulting in total loss of true riparian zone vegetation except at the upstream limits of the dam impoundment.
- The variable water level regime in the dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime and lack of flood disturbance).
- Much of the dam pondage and buffer zone area for Tilleys Dam has been cleared, but seven small areas of the "endangered" RE 12.3.3 (*E. tereticornis* woodland to open forest on alluvial plains) were mapped by EPA within existing remnants (Table 3.2).
- No terrestrial or riparian plant species of conservation significance have been identified within the dam pondage or buffer zone areas.

[15] Suspended load from turbid floodwaters stored in the dam pondage may settle in the dam pondage, alternatively it may be held in the water column by turbulent resuspension processes and additional inputs of suspended sediment may be generated by shoreline erosion and soil dispersion – Burdekin Falls Dam provides a clear example of how the net effect of such processes in a dam pondage can lead to an increase in ambient turbidity (Brizga et al. 2006c)

Table 3.2 REs of conservation significance recorded or likely to occur within pondage areas or buffer zones of proposed Logan/Albert catchment dams[16]

			Mapped by EPA in Ponded Area or 200 m Buffer Zone			
RE Number	**RE Description**	**Conservation Status[17]**	**Large Tilleys Dam**	**Small Tilleys Dam**	**Wyaralong Dam**	**Glendower Dam**
12.3.3	*E. tereticornis* woodland to open forest on alluvial plains	Endangered	✓	✓	✓	✓
12.9–10.7	*E. crebra* woodland on sedimentary rocks	Of concern			✓	
12.9–10.3	*E. moluccana* on sedimentary rocks	Of concern				✓

[16] Based on EPA Regional Ecosystems mapping and dam pondage and buffer zone outlines provided by NRW
[17] Vegetation Management Act (August 2003)

Aquatic Vegetation

- The extent to which macrophytes can colonise a dam pondage depends on water quality (particularly turbidity), bank gradients and wind fetch. The response of aquatic vegetation to the construction of a dam pondage may therefore vary from pondage to pondage and also spatially within a pondage.
- One aquatic plant species of conservation significance is present in the Tilleys Dam pondage area – *Vallisneria nana* (ribbonweed). Although classified as "rare" in NCA, this species is commonly found in flowing water in south-east Queensland (see Appendix B for further information). It also occurs in still water and would therefore be expected to persist in the dam pondage, particularly in shallow backwaters. It could potentially colonise deep-water habitats (depending on light availability) as this species is recorded as having leaf lengths of up to 6 m.
- There is limited growth of aquatic macrophytes in the upper Logan River possibly due to limiting effects of relatively low water temperature. If the waters in Tilleys Dam become warmer than natural river water, this would make conditions more conducive for macrophyte growth. A small dam (e.g. as proposed in the Small Tilleys Dam + Wyaralong Dam scenario) could therefore be at greater risk of macrophyte infestation than the larger dam proposed in the Large Tilleys Dam scenario.
- Temporary colonisation of shallow areas by emergent and submerged macrophytes is possible (including *Vallisneria* sp. and *Hydrilla* sp.) as observed in shallow arms of Lake Samsonvale (North Pine Dam pondage), but the macrophytes would not be able to establish permanent communities due to water level variability resulting from dam operating regimes.
- Floating macrophytes are likely to increase in abundance, particularly in sheltered arms of the dam pondage with little wind and wave action (observations indicate that weir pondages are often affected by prolific growth of floating macrophytes, but this is more rarely observed in large dam pondages). There is a risk of rampant growth of alien species including salvinia and water hyacinth in such areas, as these species are present in the region. There is increased risk of transmission if the Tilleys Dam pondage is used for boating.
- *Potamogeton crispus* and *P. perfoliatus* (native species) also occur in the vicinity of the Tilleys Dam site. It is likely that these species would also establish in the pondage.

Macroinvertebrates

- Macroinvertebrate communities in Tilleys Dam pondage would be significantly different to natural due to changes in habitat, water quality and food resources.
- Habitats in the dam pondage would be unfavourable to edge zone species (due to variable water levels and lack of stable vegetation communities) and obligate- lotic species would be eliminated (due to lack of running, shallow-water habitat).
- Much of the dam pondage area would also be unfavourable to pool species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.

- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms and chironomid larvae).
- If abundant macrophyte growth occurs in shallow parts of the pondage and backwater arms (as discussed above), species favoured by macrophytes would increase in abundance in these areas (e.g. grazer invertebrates)
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of the dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Freshwater spiny crayfish (including the Lamington spiny cray *Euastacus sulcatus*) occur in the Logan/Albert catchment. The known range of the Lamington spiny cray is limited to altitudes above 300 m (Merrick 1993), hence they are not expected to occur in the reaches that would be impounded by Tilleys Dam.

Fish

- One fish species of conservation significance would be affected by impoundment and barrier effects of Tilleys Dam, the “endangered” (EPBC) Mary River cod *Macculochella peelii mariensis*, which has been restocked in the Logan/Albert catchment.
- The Tilleys Dam impoundment will inundate parts of the Logan River and tributary streams that are known to support Mary River cod restocking sites.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely to favour a subset of fish species capable of surviving in impounded waters (including carp and gambusia, which are already present in this section of the river).
- The reduction in availability of lotic habitat is expected to affect many species that commonly use shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Tilapia (a declared noxious species in Queensland) could potentially colonise the altered habitats of the Tilleys Dam impoundment. It is not currently present in the Logan/Albert catchment but occurs in the Brisbane River system and Tingalpa Creek. The Logan/Albert catchment is close to southern limit of the temperature tolerance of this species, so if the water in the Tilleys Dam pondage is warmer than river water, it would be favourable for tilapia.
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already limited by downstream weirs (South MacLean and Bromelton).
- Access would be further restricted by Cedar Grove Weir, and Tilleys Dam would cause a major barrier to longitudinal fish movements. Without an effective fish passage device it would sever access by diadromous species to 527 km^2 of catchment upstream of the dam, and restrict the movement of several potamodromous species,

including Mary River cod (see Appendix D) High quality fish habitats are present in the Logan River upstream of the site of the Tilleys Dam pondage area.

Other Vertebrates

- EPA's Wildlife Online database shows records of three other vertebrate species of conservation significance in the vicinity of Tilleys Dam pondage – black-necked stork, brush-tailed rock wallaby and koala (Table 3.3). However, many vertebrate species are highly mobile and records are patchy, so this list is not necessarily comprehensive.
- The position in catchment and proximity and connectivity to headwater forests suggests a significant possibility that additional other vertebrate species of conservation significance may be present in this area, such as EVR frogs (Appendix D). *Mixophyes fleayi*, the "endangered" Fleay's barred-frog; *Litoria pearsoniana*, the "vulnerable" cascade treefrog; *Litoria revelata*, the "rare" whirring treefrog; *Litoria brevipalmata*, the "rare" green-thighed frog; *Kyarranus loveridgei*, the "rare" masked mountain frog; and, *Lechriodus fletcheri*, the "rare" black-soled frog are all associated with freshwater habitats in headwater streams, semi-permanent ponds or wet forested areas.
- The Logan/Albert catchment supports many EVR species of birds, some associated with watercourses and riparian vegetation. All could be affected by ponding of rivers, loss of riparian forests and verge vegetation. Several "vulnerable" marsupials and a bat also occur in the catchment and they could also be affected by a new dam.
- The platypus, *Ornithorhynchus anatinus*, occurs in the Logan and Albert catchments (Albert River, Canungra Creek, Cedar Creek, Sandy Creek and Scrubby Creek). It is a protected species, and an Australian icon. Impounded areas, barriers and flow regime modification are thought to affect its movement patterns, feeding and recruitment.
- The dam pondage would reduce habitat suitability for riverine species of other vertebrates. The turtle fauna would be likely to shift from cloacal ventilators to the generalist *Emydura krefftii.* There would be likely to be reductions in riverine-associated frogs due to loss of habitats (inundation of backwaters) and increased predation by fish. Platypus may not be able to forage successfully in ponded river reaches and their movements along vegetated river banks may be impeded by barriers. The wide unvegetated zone along the dam pondage margins that would be exposed when operating level falls below FSL would put many vertebrate species at risk of increased predation.
- Populations of waterbirds would increase (potentially including species of conservation significance such as the black-necked stork and other species as shown in Table 3.3 or listed in the China Australia Migratory Bird Agreement [CAMBA] and Japan Australia Migratory Bird Agreement [JAMBA]).
- Habitat for terrestrial vertebrate species (e.g. brush-tailed rock wallaby, koala) would be reduced and these species would be expected to retreat to upslope habitats.
- The introduced cane toad, *Bufo marinus,* could spread in disturbed areas, ponded areas and downstream from dams. It is a threat to small reptiles, marsupials and ground insects.

Table 3.3 Other vertebrate species of special conservation significance in the Logan/Albert catchment

					Records in Vicinity of Dam Pondage		
Species	**Common Name**	**Status (NCA)**	**Status (EPBC)**	**Comments**	**Tilleys Dam**	**Wyaralong Dam**	**Glendower Dam**
AMPHIBIANS							
Mixophyes fleayi	Fleay's barred-frog	E	E	Recorded from the Sarabah NP, closely associated with freshwater habitats, eggs laid in stream riffles			
Litoria pearsoniana	cascade treefrog	V		Recorded form Mt Barney NP and Lamington NP, strongly associated with streams and riparian zone			
Litoria brevipalmata	green-thighed frog	R		Occurs in south-east QLD and north-east NSW, breeds in vicinity of grassy, semi-permanent ponds			
Litoria revelata	whirring treefrog	R		Recorded from Wilson's Peak and Lamington NP, breeds in still water			
Kyarranus loveridgei	masked mountain-frog	R		Recorded from Lamington NP, predominantly terrestrial			
Lechriodus fletcheri	black-soled frog	R		Recorded from Lamington NP, breeds in streams			
REPTILES							
Acanthophis antarcticus	common death adder	R		Occurs throughout continental Australia except for central arid areas			
Hoplocephalus stephensii	Stephens' banded snake	R		Inhabits rainforest and wet sclerophyll forests of the coastal strip from Gosford, NSW to southern QLD			
Saproscincus rosei	(skink)	R		Inhabits rainforest and wet sclerophyll forests from near Gympie to Barrington Tops region, NSW			
Caretta caretta	loggerhead turtle	E	E	Inhabits tropical and warm temperate waters off the Australian coast. Common in Moreton Bay.			
BIRDS							
Cyclopsitta diophthalma coxeni	Coxen's fig-parrot	E	E	Occurs in isolated populations in QLD and NSW, mostly in areas above 600 m			
Dasyornis brachypterus	eastern bristlebird	E	CE	Terrestrial			
Erythrotriorchis radiatus	red goshawk	E	V	Endemic to Australia, nests in tall trees within 1km of a watercourse, targets for recovery include maintenance of riparian forests and open wetlands			
Sterna albifrons	little tern	E		Coastal species threatened mostly by activities of beach-goers			

					Records in Vicinity of Dam Pondage		
Species	**Common Name**	**Status (NCA)**	**Status (EPBC)**	**Comments**	**Tilleys Dam**	**Wyaralong Dam**	**Glendower Dam**
Xanthomyza phrygia	regent honeyeater	E	E	Endemic to south-eastern Australia with some records in southern QLD, threatened by clearing of habitat which includes riparian forests			
Accipiter novaehollandiae	grey goshawk	R		Known habitats include riparian forests		✓	
Climacteris erythrops	red-browed treecreeper	R		Occurs in mountainous country from southern QLD to Victoria			
Ephippiorhynchus asiaticus	black-necked stork	R		Inhabits freshwater marshes, lakes and pools from northern Australia to south-east and southern Asia	✓	✓	
Haematopus fuliginosus	sooty oystercatcher	R		An off-shore bird distributed throughout coastal Australia, may utilise mud-flats			
Lophoictinia isura	square-tailed kite	R		Occurs throughout coastal and subcoastal Australia, inhabits wooded inland watercourses, threatened by clearing			
Melithreptus gularis	black-chinned honeyeater	R		Known habitats include riparian zone			
Menura alberti	Albert's lyrebird	R		Inhabits rainforest above 300 m between Blackall Range, NSW and Mistake Range, QLD			
Numenius madagascariensis	eastern curlew	R		Non-breeding visitor to Australia, possible threat is status of Australian wetlands visited by females			
Pachycephala olivacea	olive whistler	R		Known habitats include riparian zone			
Rallus pectoralis	Lewin's rail	R		Nests in sedges/rushes over or near water			
Rostratula australis	painted snipe	R	V	Known habitats include riparian zone			
Tyto tenebricosa	sooty owl	R		Terrestrial			
Atrichornis rufescens	rufous scrub-bird	V		Occurs mostly in areas above 600m in isolated populations in QLD and NSW			
Cacatua leadbeateri	Major Mitchell's cockatoo	V		Known habitats include riparian zone			
Calyptorhynchus lathami	glossy black-cockatoo	V		Found in QLD, NSW and Victoria, slow decline attributed to clearing			
Ninox strenua	powerful owl	V		Occurs in open forest and woodlands in eastern Australia, threatened by clearing			
Podargus ocellatus plumiferus	plumed frogmouth	V		Distributed from south of Gladstone, QLD to Lismore, NSW, utilises gallery forests of creeks			
Stipiturus malachurus	southern emu-wren	V		Terrestrial			

					Records in Vicinity of Dam Pondage		
Species	**Common Name**	**Status (NCA)**	**Status (EPBC)**	**Comments**	**Tilleys Dam**	**Wyaralong Dam**	**Glendower Dam**
Turnix melanogaster	black-breasted button-quail	V	V	Isolated populations in rainforest, wet sclerophyll forest and softwood scrub from south-east QLD and north-east NSW, threatened by clearing and predators		✓	
MAMMALS							
Dasyurus maculatus maculatus	spotted-tailed quoll (southern subspecies)	V	E	Largest quoll, inhabits wet and dry sclerophyll forests and rainforest		✓	
Petrogale penicillata	brush-tailed rock-wallaby	V	V	Inhabits cliffs and rock slopes in dry sclerophyll forests and grassy areas	✓		
Pseudomys oralis	Hastings River mouse	V	E	Known from well-watered dry sclerophyll forest			
Potorus tridactylus tridactylus	long-nosed potoroo	V	V	Inhabits cool rainforest and wet sclerophyll forest with dense ground cover			
Kerivoula papuensis	golden-tipped bat	R		Occurs in cool temperate to tropical rainforest.			
Phascolarctos cinereus	koala	V			✓	✓	✓
Dugong dugon	Dugong	V		Coastal areas, associated with seagrass beds			

CE: “critically endangered”, E: “endangered”, V: “vulnerable” and R: “rare”. Some of the birds shown in this table are migratory species listed in CAMBA and/or JAMBA (Based on Arthington and Capon 2006; updated for proposed dam areas from recent searches of Wildlife Online).

3.1.1.2 Mitigation and Compensation Measures

Key mitigation and compensation measures relevant to the impoundment and barrier effects of Tilleys Dam are presented in Table 3.4. The mitigation measures would address a wide range of environmental issues associated with the dam, but would not prevent the occurrence of major/very major changes to existing ecosystems within the dam pondage area. Hence, rehabilitation/restoration of equivalent habitats outside the dam pondage area is identified as being an appropriate compensation measure.

Table 3.4 Key mitigation and compensation measures relevant to impoundment and barrier effects of Large Tilleys Dam

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats outside dam pondage area	• Further investigations are required to identify suitable sites. • Possible options include nearby tributaries (Running Creek and Christmas Creek – close to the proposed impoundment, but different catchment geology) and/or an equivalent section of the Albert River (e.g. Cainabable Creek to Canungra Creek) and/or Canungra Creek	Varies, depends on existing condition and standard of rehabilitation or restoration Likely to be high.
"No net loss of habitat" – replacement of Mary River cod restocking sites	• Investigations would be required to identify other sections of the Logan/Albert River system suitable for cod restocking	Depends on existence of suitable sites – ranges from low if suitable sites exist, to high if habitat restoration is required before cod restocking
Vegetated buffer zone above FSL to maintain corridors for movement of terrestrial species and platypus	• Could be achieved by retention and enhancement of existing native vegetation (where present) and revegetation of 200 m buffer zone around dam pondage with appropriate indigenous species • As with any revegetation works, proper site preparation and ongoing maintenance is necessary for a successful outcome	At least medium due to ongoing maintenance and weed suppression activities required.
Buffer zone between assets and erosion risk zone	• A 200 m buffer zone has already been identified in the SEQ Water Supply Strategy investigations as an integral component of the Large Tilleys Dam project. • It is desirable for this zone to be vegetated/revegetated with native vegetation from the viewpoint of water quality and ecological values.	Low (to reserve a buffer zone). The level of difficulty of maintaining a vegetated buffer zone is at least medium, as indicated above.
Drainage management of surface runoff to avoid concentration of flows onto exposed shorelines and hence mitigate risks of subaerial erosion	• Soil erosion risks and local drainage issues for the dam pondage shorelines would need to be investigated at the design stage.	Low difficulty from technical viewpoint, but long shoreline may present major costs
Destratifiers in dam pondage (e.g. bubblers, impellers) would mitigate risks associated with stratification, such as blue–green algal blooms	• The shape of the Tilleys Dam pondage (two long, narrow arms) means that several destratifiers placed strategically throughout the pondage would be required.	High
Catchment land use controls and buffer zones along streams and on drainage lines to minimise inputs of nutrients and other contaminants	• Catchment land use is rural. A significant proportion of the catchment area consists of forested headwaters.	High

Mitigation or Compensation Measure	Comments	Level of Difficulty
Improve water quality from point sources (or reduce/eliminate point source inputs)	• Investigation of existing point sources in catchment (near Maroon Dam and Palen Creek Correctional Centre) with regard to implications for water quality in dam pondage and opportunities for improvement	Unknown – point source management can be relatively easy if obvious discrete polluting influences are identified.
Measures to control excessive macrophyte growth (e.g. mechanical harvesting)	• Monitoring and adaptive management. • Storage configuration makes rampant macrophyte growth a significant possibility.	Low to medium. Ongoing management required as harvested biomass can be quickly replaced.
Education, signage, boat washing facilities at storages with pest plant species to mitigate risks of transmission of these species into Tilleys Dam pondage	• Salvinia and water hyacinth (both alien species that can blanket ponded areas and severely alter aquatic habitat structure and water quality) are present in the region and could be transmitted to Tilleys Dam pondage by boat traffic.	Medium. Whilst cheap and simple to implement, extensive community support is required for a successful outcome.
Fish lock/lift on Tilleys Dam	• Would mitigate some impacts on fish movement including some size classes of diadromous and potamodromous species, maintaining access to much of the 527 km2 catchment area upstream of Tilleys Dam (some parts are already inaccessible due to natural barriers and Maroon Dam). • Likely to be more effective in enabling upstream movements than downstream movements. • Fish lock/lift would require sufficient flow allocations to render it effective for allowing fish passage.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though large dam pondage is problematic.
Installation and effective operation of fishways on existing/new weirs located downstream (i.e. Bromelton Weir, Cedar Grove Weir, South MacLean Weir) to maintain access by diadromous and potamodromous fish species	• Existing South MacLean Weir is a small structure than frequently drowns out but does not currently have effective fish passage under low flow conditions (as it does not have a fishway) • Bromelton Weir has a fishway, but there are operational issues • Cedar Grove Weir would be a substantial barrier to fish passage, and would require a fishway to maintain connectivity to this part of the river for diadromous fish species • All existing and new fishways would require sufficient flow allocations to render them effective for allowing fish passage	Low
Restocking of Mary River cod	• Existing populations have been stocked. Natural populations of cod had become extinct from the Logan/Albert system.	Low
Boat traffic restrictions to mitigate boating impacts on dam pondage	• Monitoring and adaptive management	Low, but requires community support

3.1.2 Downstream Effects on Non-Tidal Reaches

3.1.2.1 Implications for Condition and Values

Geomorphology

- The geomorphology of the Logan River between the Tilleys Dam site and the tidal limit currently shows **minor** to **moderate** change from reference condition, largely due to land use influences, and impoundment effects in the Bromelton and South MacLean Weir pondages.
- The reaches between Tilleys Dam and Bromelton Weir as well as the Cedar Grove Weir pondage reach would show **major** change from reference condition, while the reaches from Bromelton Weir to upstream end of Cedar Grove Weir pondage, and downstream of Cedar Grove Weir to tidal limit would continue to show **moderate** overall change from reference condition but increased levels of water resource development impacts.
- These changes in condition ratings reflect impacts of reductions in medium and high flows due to Tilleys Dam (which will have much greater impacts on these flows than the existing Maroon Dam), effects of supplemented flows on sand transport processes (from Tilleys Dam to Cedar Grove Weir) and pondage effects of Cedar Grove Weir.
- Fluvial geomorphological processes, including sediment transport, would be significantly altered. Flattening of the river bed with increased sand accumulation in pools is expected due to reworking of sand deposits on the river bed by supplemented releases, combined with reduced frequency of pool-scouring floods.
- Enlargement of the low flow channel by supplemented releases but contraction of the high flow channel is likely. Contraction would involve accommodation adjustment (i.e. changes in flow area and vegetation zonations) and probably also some reduction in channel size by depositional processes, particularly in the vicinity of tributary confluences. Depositional processes would be enabled by ongoing inputs of sediment, particularly sand from Marburg Formation catchments on the western side of the valley as well as sediment inputs from Running Creek and Christmas Creek.
- Coarsening or armouring of the river bed below Tilleys Dam (particularly between the dam and Running Creek) is likely due to truncation of upstream sediment supply.
- Changed hydraulic interactions with tributary streams may possibly lead to increased risk of tributary erosion as a result of steepening of flood gradients due to reductions in tailwater support, particularly in the reaches closest to Tilleys Dam.

Hydraulic Habitat

- Hydraulic habitat in the Logan River between Tilley’s Dam site and the tidal limit currently generally shows **moderate** change from reference condition in the unimpounded reaches (**minor** downstream of South MacLean Weir) and **major** change from reference condition in the weir pondages.
- In the Large Tilleys Dam scenario, all of the reaches between the dam and tidal limit would show **major** change from reference condition.
- Lateral connectivity to floodplain and bench habitats would be reduced, particularly in reaches closest to the dam where the greatest reductions in high flows would occur.

- The natural seasonal variation in low–medium flows would be significantly distorted in the supplemented reaches between Tilleys Dam and Cedar Grove Weir, with supplemented releases up to about 180 ML/d (much deeper than 30 cm over riffle controls) being made throughout the year, except when natural flow events occur that would provide sufficient supply to Cedar Grove Weir to meet consumptive needs (i.e. mainly in the wet season. Flow velocities in pools may become unfavourable for species and life history stages requiring still water conditions.
- Conversion of riverine habitat to weir pondage would lead to **major** change from reference condition in the Cedar Grove Weir pondage.
- Downstream of Cedar Grove Weir, there would be major further reductions in low flows, thus contraction of low flow habitat.

Water Quality

- The water quality in the Logan River between Tilleys Dam site and the tidal limit currently shows **minor/moderate** (reaches above Bromelton Weir/Beaudesert) to **very major** (downstream of Bromelton Weir/Beaudesert) change from reference condition, mainly reflecting land use pressures (including treated sewage effluent and urban/industrial runoff).
- The reaches between Tilleys Dam and Running Creek would show **very major** change from reference condition and the reach from Running Creek to Bromelton Weir would show **major** change from reference condition in the Large Tilleys Dam scenario, due to the influence of dam waters on water quality. The influence of the dam on water quality would persist downstream, particularly during supplemented releases, but effects would become increasingly mitigated by tributary inflows. **Very major** change from reference condition would continue to prevail in the reaches downstream of Bromelton Weir/Beaudesert; land use impacts would remain the key driver of water quality condition, but the contribution of water resource development to overall change from reference condition would increase.
- Supplemented flows would dilute downstream pollutant inputs under low flow conditions, but reductions in flood flows may enable gradual accumulation of organic matter, nutrients and other pollutants in pools, resulting in long-term rising trends in nutrient and pollutant levels.

Riparian Vegetation

- The riparian vegetation in the Logan River between Tilleys Dam site and the tidal limit currently shows **moderate** (above Running Creek) to **major** (downstream of Running Creek to tidal limit) change from reference condition mainly as a result of land use pressures (historical clearing and weed invasion).
- A shift to **major** change from reference condition would occur between Tilleys Dam and Running Creek, while the overall condition for the reaches further downstream would not change due to the significant disturbance that has already occurred, although the contribution of water resource development impacts to overall change from reference condition would increase.
- Impacts of water resource development on riparian vegetation would increase, including encroachment of riparian vegetation in lower bank areas, increased weed invasion of the riparian zone (including terrestrial weeds such as Chinese celtis as

well as smothering creepers, as observed by Brizga et al. 2006b in Reynolds Creek below Moogerah Dam), downslope changes in vegetation zonations, proliferation of river oaks, and a shift from annual and ephemeral species along the river's edge to a more perennial community of herbaceous species (as observed by McCosker 2000 in the middle Brisbane River below Wivenhoe Dam). Effects would diminish with increasing distance downstream of the new dam

- Impoundment effects and variable water level regimes in Cedar Grove Weir pondage would have major implications for riparian vegetation communities in the weir pondage area.

Aquatic Vegetation

- There is limited information on aquatic vegetation in the Logan River between Tilleys Dam site and the tidal limit. Available data indicates **minor** to **moderate** change from reference condition in reaches where sufficient information was available to make condition assessments. Variable abundances of macrophytes were observed in the vicinity of Rathdowney, reflecting differential shading of sites by riparian vegetation, whereas in reaches downstream of Bromelton Weir, macrophytes are "rare" or absent as the mobile sandy substrate limits colonisation and establishment.
- The condition of aquatic vegetation in the reach between the Tilleys Dam site and Running Creek is currently rated as having undergone **moderate** change from reference condition. An increase to **major** change from reference condition is predicted to occur in the Large Tilleys Dam scenario due to reductions in high flows and the stabilisation and elevation of low flows. This may lead to thickening of emergent marginal vegetation such as grasses and sedges. Macrophytes are currently not very abundant in this reach due to shading from remnant riparian vegetation (e.g. downstream of Rathdowney gauging station) and turbidity.
- If discharge is temporarily reduced for periods of weeks there may be some dieback of macrophytes, particularly in shallow habitats such as riffles.
- The declared "rare" plant *Vallisneria nana* occurs in the Logan River downstream of the Tilleys Dam site. It is expected that flow regime changes downstream of Tilleys Dam would not adversely affect this species, as habitat would be maintained by supplemented releases (dependent upon length of periods of flow reduction; *V. nana* is abundant in the supplemented reaches of Yabba Creek downstream of Borumba Dam).
- The influence of flow regime changes on aquatic vegetation would not persist very far downstream (at least for submerged vegetation) due to (a) the influence of downstream tributaries (Running and Christmas Creeks) and (b) the mobile sandy substrates of the Logan River downstream of the Round Mountain area that are unsuitable for establishment of submerged plants.

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in the Logan River between Tilleys Dam site and the tidal limit currently show **minor** to **moderate** change from reference condition, reflecting impacts of flow regime change and land use pressures. Greater changes are likely to have occurred in the weir pondages, but these have not been separately rated.

- Changes in habitat, vegetation and water quality resulting from water resource development in the Large Tilleys Dam scenario would be expected to lead to a shift to **major** change from reference condition (potentially **very major** change immediately below the dam if affected by hypolimnetic releases).

Fish

- The fish fauna of the Logan River between Tilleys Dam site and the tidal limit currently shows **moderate** change from reference condition, reflecting impacts of existing water resource development (flow regime changes and barrier effects) and moderate impacts resulting from land use impacts and invasion by alien fish species (carp and gambusia).
- A shift to **very major** change from reference condition would occur immediately below the dam, decreasing to **major** further downstream.
- Increased barrier effects arising from Cedar Grove Weir and Tilleys Dam would affect diadromous and potamodromous species (including Mary River cod).
- Impacts of flow regime change include: potential reductions in cues for spawning and movement/dispersal, potential desynchronisation of elevated spring temperature and low and stable flows (important conditions for spawning and recruitment of many small-bodied fish species such as rainbowfish, glass perchlets, hardyheads and gudgeons), potential elevated water velocities through pools during naturally low flow periods (which may minimise conditions suitable for spawning and larval development, such as by flushing of fish eggs and larvae and planktonic food resources), and reduction in access to riparian zone and floodplain habitat for foraging, growth and development.
- Immediately below Tilleys Dam, if abrupt increases/decreases in flow occur, this would be likely to lead to flushing or stranding of fish eggs, larvae and adults.

Other Vertebrates

- The other vertebrate fauna would undergo substantial change from its current condition in response to changes in flow regime, habitat and food resources, particularly in the reaches closest to the new dam. Frogs, turtles, birds and platypus would be affected.

3.1.2.2 Relevant Mitigation Options and Implications for Condition

Key mitigation and compensation measures relevant to the downstream effects of the Large Tilleys Dam scenario on non-tidal reaches are presented in Table 3.5. The mitigation measures would address a range of environmental issues associated with this development scenario. However, benefits would generally be incremental and not measurable on the five-point scale used for condition ratings.

Table 3.5 Key mitigation and compensation measures relevant to downstream effects of the Large Tilleys Dam scenario on non-tidal reaches of the Logan River

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat"	• Rehabilitation or restoration of equivalent habitats to compensate for major geomorphological and ecological changes in the Logan River. • Possible options include the Albert River (but different type of stream) and/or nearby tributaries – Christmas Creek, Running Creek (would provide alternative link to headwaters, but not main trunk streams like Logan) • Appropriate measures on the Albert would include removal of Luscombe Weir, audit and removal of other fish passage barriers, reductions in point and diffuse sources of pollution and riparian vegetation restoration. With removal of Luscombe Weir, there would be an opportunity to rehabilitate a whole major river from headwaters to the sea.	Varies, depending on existing condition and standard of rehabilitation or restoration. Likely to be high.
Install multi-level offtake on Tilleys Dam	• Would mitigate impacts of hypolimnetic ecosystems on downstream water quality and ecology, particularly between Tilleys Dam and Running Creek. • Could also be operated to simulate natural seasonal variability in water temperature. • Destratification measures within the Tilleys Dam pondage (as discussed above) would also have benefits downstream of the dam	Low
Riparian vegetation restoration and weed management	• Riparian zones along the Logan River are already significantly disturbed, with many weed species present and lack of overstorey or midstorey vegetation along extensive lengths of the river. • Restoration of overstorey and midstorey vegetation would provide increased shading of the river (and would be assisted by vegetation thickening processes associated with reduced flood disturbance due to dam effects), which, in turn, may assist in mitigating potential proliferation of aquatic vegetation, which may occur if sand transport processes do not sufficiently restrict vegetation establishment. • Weed management would be a significant issue at revegetation sites.	High
Install fish lock/lift on Tilleys Dam	• Discussed above (Table 3.4). Would also affect fish community structure downstream of dam. • As in the case of any fish passage device on a dam or weir, fish movements would be more constrained than under natural conditions. • It is possible that a fish lift/lock may be used by some migratory crustaceans such as macrobrachium.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Installation of a fishway on Cedar Grove Weir	• Would be necessary to maintain access of diadromous species to Logan River. Assumed to be part of scenario under consideration. • Would require sufficient flow allocations for fishway to allow fish passage	Low
Installation and effective operation of a fishway on South MacLean Weir (existing weir) to maintain access by diadromous and potamodromous fish species	• Mitigation of existing impacts of South MacLean Weir on fish passage would provide partial compensation for net reduction in fish passage by Tilleys Dam and Cedar Grove Weir (even with fish passage devices installed) • Would require sufficient flow allocations for fishway to allow fish passage	Low
Provision of sufficient flow allocation to render fishway on Bromelton Weir effective	• Mitigation of existing impacts of Bromelton Weir on fish passage would provide partial compensation for net reduction in fish passage by Tilleys Dam and Cedar Grove Weir (even with fish passage devices installed)	Medium
Environmental compensation flows	• Some environmental flow rules have been built into the hydrologic modelling of the scenario under consideration, but it is not possible to mitigate impacts of elevated low flows resulting from supplementation without providing additional delivery and/or storage infrastructure. • Medium/high flow releases for environmental purposes are unlikely to be a high priority requirement given the short distance between Tilleys Dam and Running Creek • Further analysis and optimisation of the environmental flows would need to be undertaken at the design stage of the project	Additional environmental flow provisions would reduce consumptive yield
Use of alternative conduit for downstream water delivery	• Would enable impacts of unseasonally elevated flows due to supplemented releases to be mitigated. • However, would not mitigate impacts of reductions in medium/high flows and may result in other impacts arising from an overall reduction in water availability in the stream system	High

3.1.3 Downstream Effects on Estuarine Reaches

3.1.3.1 Implications for Condition and Values

- This development scenario would mainly affect the Logan River, with minor implications for the Albert River via hydrodynamic interactions that would affect salinity and water quality, and possibly movements of fish and invertebrates.

Geomorphology

- The geomorphology of the Logan River estuarine reaches currently shows **moderate** (upper estuary) to **minor** (lower estuary) change from reference condition due to factors other than water resource development.

- No change in overall condition is predicted in the Large Tilleys Dam scenario, but water resource development impacts would increase (from **indiscernible** to **moderate** in the upper estuary and **indiscernible** to **minor** in the lower estuary) due to the effects of reductions in small and medium floods on sediment transport.
- Possible implications for erosion in lower section of Albert River if hydrological changes lead to reductions in tailwater support for floods (due to reductions in some flood events and decoupling of floods).

Hydrodynamics

- The hydrodynamics of the Logan River estuarine reaches currently show **minor** (upper estuary) to **indiscernible** (lower estuary) change from reference condition. Condition is influenced by minor flow regime changes resulting from existing water resource development as well as geomorphological changes due to factors other than water resource development.
- In the Large Tilleys Dam scenario, condition ratings are predicted to shift to **major** change from reference condition in the upper estuary and **minor** change from reference condition in the lower estuary.
- Reduced freshwater inflows (low, medium and high) are predicted to result in a substantial increase in salinity of the upper reach of the estuary[18] as well as increased residence times and reduced flushing.

Water Quality

- The Logan River estuarine reaches currently show **major** (upper estuary) to **moderate** (lower estuary) change from reference condition, mainly due to inputs of pollutants from point sources and diffuse sources.
- In the upper estuary, condition ratings are predicted to increase to **very major** change from reference condition in the Large Tilleys Dam scenario due to reduced flushing and upstream shift in the turbidity maximum (by more than 5 km).
- In the lower estuary, no change in overall condition rating is predicted but impacts of water resource development would increase (from **indiscernible** to **minor**). The lesser magnitude of impact in this part of the estuary is due to the influence of tidal flushing
- The Albert River estuary is flushed with estuarine waters of the Logan River, and the increasing salinity of the Logan would therefore result in an increase, probably minor, in the salinity of the estuarine reach of the Albert River.

Vegetation

- Estuarine vegetation in the Logan River currently shows **moderate** change from reference condition, mainly due to land use impacts (mangroves and saltmarsh) and water quality changes (seagrass, phytoplankton).
- No change in overall condition rating is predicted in the Large Tilleys Dam scenario, but impacts of water resource development would increase (from **indiscernible** to **moderate** in the upper estuary and **indiscernible** to **minor** in the lower estuary).

[18] Inferred from modelling by WBM for the Logan Basin WRP (Brizga et al. 2006a, Appendix E)

- Vegetation zonations are predicted to change, with salt-tolerant species penetrating further upstream in response to changes in salinity gradients.
- Increased concentrations of nutrients due to increased residence times and reduced flushing of local inputs could potentially lead to phytoplankton blooms in the upper reach of the estuary if turbidity decreases (e.g. due to upstream shift in turbidity maximum).
- Old growth mangrove forests near the mouth of the Logan River, which potentially support populations of Illidge's ant-blue butterfly (*Acrodipsas illidgei* – "vulnerable" [NCA]) are not expected to be significantly affected by flow regime changes in this scenario.

Aquatic Macroinvertebrates

- Estuarine macroinvertebrate communities of the Logan River currently show **moderate** change from reference condition due to factors other than water resource development, primarily water quality changes, loss of seagrass and fishing pressures.
- No change in overall condition is predicted in the Large Tilleys Dam scenario, but water resource development impacts would increase (from **indiscernible** to **moderate** in the upper estuary and **indiscernible** to **minor** in the lower estuary).
- The distribution of marine species is expected to extend further upstream in the estuary due to changes in salinity gradients and extended distribution of marine flora (mangroves and saltmarsh).
- Well-documented correlations (e.g. as reported by Loneragan and Bunn 1999) indicate that catches of fisheries species from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 5% (mudcrabs) and 10% (prawns) compared to present levels as a result of reductions in summer flows. Similar flow-related impacts would affect the populations of many more fish and invertebrates in the estuary for which there are no data to enable us to understand the changes.
- The estuarine macroinvertebrate fauna of Logan/Albert estuary is not known to include any species of conservation significance, but few invertebrate species are listed under Australian nature conservation legislation (Dunn 2003).

Fish

- Fish communities of the Logan River estuarine reaches currently show **moderate** change from reference condition due to water quality changes, infill of pools in the upper estuary, loss of seagrass, fishing pressures and barrier effects of existing weirs (including South MacLean Weir on the Logan River and Luscombe Weir on the Albert River).
- No change in overall condition is predicted in the Large Tilleys Dam scenario, but water resource development impacts would increase (from **minor** to **moderate**).
- The distribution of marine species is expected to extend further upstream in the estuary due to changes in salinity gradients and extended distribution of marine flora (mangroves and saltmarsh).
- If increased sedimentation leads to infill of deep pools, this would be likely to lead to reductions in larger fish species (such as jewfish).

- Well-documented correlations (e.g. Loneragan and Bunn 1999) indicate that catches of flathead from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 10% compared to present levels as a result of reductions in summer flows that are associated with migration and other behavioural cues. Similar flow-related impacts would affect the populations of many more fish and invertebrates in the estuary for which there are no data to enable us to understand the changes.
- Installation of Cedar Grove Weir would further reduce fish access to the Logan catchment (already impeded by South MacLean Weir, which is downstream of Cedar Grove Weir site), leading to likely reductions in the abundance of diadromous species.
- The fish fauna of the Logan/Albert estuary includes two fish species of conservation significance recorded in the IUCN Red List: Green Sawfish *Pristis zijsron*[19] and Giant Groper *Epinephelus lanceolatus*[20].

Other Vertebrates

- Undisturbed mangroves and adjacent saltmarsh in the lower Logan River estuary potentially provide habitat for the water mouse (*Xeromys myoides* – "vulnerable" EPBC and NCA). These habitats are not expected to be significantly affected by the flow regime changes resulting from the Large Tilleys Dam scenario.
- The dugong (*Dugong dugon*) lives in Moreton Bay and visits the Logan/Albert estuary – its usage of the estuary may potentially be affected by changes in habitat and food resources resulting from the Large Tilleys Dam scenario.
- Waterbirds of conservation significance, including species listed in JAMBA and CAMBA, occur in wetland areas associated with the Logan/Albert estuary.
- Four species of sea snakes are associated with the Logan/Albert estuary and southern Moreton Bay, including the horned sea snake (*Acalyptophis peronii*), stokes sea snake (*Astrotia stokesii*), elegant sea snake (*Hydrophis elegans*) and yellow-bellied sea snake (*Pelamis platurus*).

3.1.3.2 Mitigation Options

- Key mitigation and compensation measures relevant to the downstream effects of the Large Tilleys Dam scenario on the Logan/Albert estuary are presented in Table 3.6. The mitigation measures would address a range of environmental issues associated with this development scenario.
- In most instances, feasible mitigation measures would lead to incremental reductions in impacts, but not prevent the shifts in condition ratings outlined above – key exceptions are water quality (measures to reduce pollutant inputs would make it possible to hold current condition at **major** change from reference condition, rather than shift to **very major)** and fish (a fishway on Cedar Grove Weir is assumed in the condition ratings presented above, otherwise water resource development impacts would be **moderate** rather than **minor**)
- As the Large Tilleys Dam scenario involves development on the Logan River only, it provides the opportunity to rehabilitate the Albert River, including the potential

[19] Historically recorded from the Brisbane River but there have been no recent records
[20] Common in Moreton Bay (Johnson 1999) .

removal of Luscombe Weir. The removal of Luscombe Weir would enable restoration of habitat connectivity between headwater reaches and Moreton Bay. Currently the South Pine River is the only major tributary of Moreton Bay where connectivity between the bay and headwaters is not impeded by a dam or weir. The Albert River has generally undergone less physical disturbance than the Logan River; its natural geomorphology more resistant to change than the Logan River, which is more fragile due to the sandy banks and substrate.

Table 3.6 Key mitigation and compensation measures relevant to downstream effects of the Large Tilleys Dam scenario on the Logan/Albert estuary

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat approach"	• Rehabilitate estuarine reach of the Albert River as compensation for impacts on the Logan • Appropriate actions would include removal of Luscombe Weir, measures to reduce inputs of pollutants from point sources and diffuse sources, and riparian zone revegetation and weed management • The Albert River would also be affected to some degree by the Tilleys Dam, scenario because of hydrodynamic interactions between the Logan and Albert estuarine reaches	Varies, depending on standard of restoration rehabilitation. Likely to be high, particularly if the percentage of catchment area occupied by urban or residential development increases.
Reduce inputs of pollutants to estuary from point and diffuse sources to mitigate "factor reinforcement"	• Impacts on water quality resulting from longer retention times resulting from reductions in flow are exacerbated if there are elevated inputs of pollutants, as is the case in the Logan/Albert estuary. • Appropriate measures include higher standards for point source inputs, • WSUD for urban areas (new areas and retrofit existing areas), and buffer zones and improved stock management in agricultural areas	Unknown. Point sources can be relatively easy to address if obvious polluting influences can be identified. Diffuse sources in large catchments are very difficult to manage.
Rehabilitate "riparian" vegetation (mangroves and saltmarsh) to improve resilience of estuarine ecosystems	• There is scope for rehabilitation/reinstatement of saltmarsh and mangrove vegetation in areas where there has been significant loss or clearing, and to prevent further clearing. • This would improve the resilience of estuarine ecosystems to impacts arising from flow regime change	Medium due to extent of resources and length of time required for successful outcome. Opportunities to build-on and expand from existing remnants.
Installation of a fishway on Cedar Grove Weir	• Would be necessary to allow longstream movements of anadromous and catadromous species (including mullet, eels, bass and mangrove jack). • Assumed to be part of scenario under consideration. • Would require sufficient flow allocations for fishway to allow fish passage • Less fish would be expected to move between estuarine and freshwater reaches than in the absence of any weirs as barriers to migration, hence abundance of diadromous species would be reduced	Low

Mitigation or Compensation Measure	Comments	Level of Difficulty
Install fish lock/lift on Tilleys Dam	• Discussed above (Tables 3.4 and 3.5). • Would be necessary for maintenance of longstream movements of anadromous and catadromous species to the Logan catchment upstream of Tilleys Dam • However, the upper Logan catchment (above the Tilleys Dam site) is already isolated from the estuary by two existing weirs (South MacLean and Bromelton) and would be further isolated by Cedar Grove Weir. These weirs progressively filter out migratory fish. Therefore, only a small proportion of the number of diadromous species that would have accessed the catchment upstream of Tilleys Dam under natural conditions would be able to access the base on the fish lock/lift.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.
Installation of fish habitat structures in upper estuary	• Maintain habitat diversity in the estuary – e.g. deep hole and ledge habitats	Low

3.2 Small Tilleys Dam + Wyaralong Dam

Dam pondage and upstream barrier effects of the Small Tilleys Dam + Wyaralong Dam scenario are discussed in Sections 3.2.1 and 3.2.2, downstream effects on the non-tidal reaches of the Logan River and Teviot Brook are discussed in Section 3.2.3 and effects on the Logan River estuary and Southern Moreton Bay are discussed in Section 3.2.4. In each section, implications for condition and values, and relevant mitigation and compensation options are examined.

3.2.1 Dam Pondage and Upstream Barrier Effects – Small Tilleys Dam

3.2.1.1 Implications for Condition and Values

Issues are generally the same as for Large Tilleys Dam (as discussed in Section 3.1.1.1), although the footprint of the dam pondage would be smaller. A shallower dam may be more susceptible to extensive invasion by aquatic macrophytes, although it would still be a deep storage (average depth of 10.4 m – Table 1.1).

3.2.1.2 Mitigation and Compensation Measures

Relevant mitigation and compensation measures are generally the same as for Large Tilleys Dam, as outlined in Section 3.1.1.2.

3.2.2 Dam Pondage and Upstream Barrier Effects – Wyaralong Dam

3.2.2.1 Implications for Condition and Values

Geomorphology and Hydraulic Habitat

- Wyaralong Dam would submerge 32 km of Teviot Brook, plus parts of smaller tributaries.
- Habitat types that would be submerged include complex instream habitats (sand bars, sandy glides, large woody debris and backwaters, such as described at the Teviot

Brook IFR site for the Logan River Trial of the South African Building Block Methodology [Arthington and Long 1997]), benches, floodplains/river terraces (with overflow channels and wetlands as noted by Brizga et al. 2006a) and upslope habitats.

- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes. However, Wyaralong Dam pondage would be different from a natural lake due to greater variability in water levels resulting from dam operation.
- The surficial geology of the Wyaralong Dam pondage area consists of sedimentary rocks (Jurassic Marburg Formation sedimentary rocks [sandstone, siltstone, shale, conglomerate, coal, oolitic ironstone] and Triassic–Jurassic Woogaroo Subgroup [Sandstone, conglomerate, siltstone, shale, and coal]) with alluvium in the valleys of Teviot Brook and tributaries. The geology of the upstream catchment also includes the Jurassic Walloon Coal Measures (mainly fine-grained sedimentary rocks) and Tertiary volcanic rocks. Dam pondage site and catchment geology would influence shoreline character and sediment inputs. The Marburg formation represents an important source of sandy sediments in the Logan catchment, contributing to the sandy character of this section of Teviot Brook, and is associated with relatively high rates of soil erosion.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.
- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the dam pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches.

Water Quality

- Water quality in the Wyaralong Dam impoundment would exhibit less temporal variability than the water quality of natural stream flows. High turbidity, low salinity floodwaters would become the dominant influence on ambient water quality, contrasting with baseflows, which are relatively clear and characterised by relatively high conductivity due to natural geological effects.
- Elevated surface water temperature and thermal stratification is likely – other large dams in this area, including Maroon, Moogerah and Hinze (Brizga et al. 2006b, G. McGregor, pers. comm.), are subject to seasonal thermal and chemical stratification.
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- There is one licensed point source inputs within the catchment area of Wyaralong Dam (Boonah STP), which discharges small volumes of treated sewage effluent (Finlow et al. 2006).
- The catchment of Wyaralong Dam pondage includes the town of Boonah and extensive areas used for grazing and agriculture (including intensive farming and cropping in the vicinity of Boonah), hence inputs of sediment, nutrients and toxicants into Wyaralong Dam pondage would be elevated due to land use factors.
- There would also be nutrient release from former agricultural soils impounded by the dam pondage in the short to medium term (the dam pondage area submerges mainly cleared/partly cleared grazing land).
- Wyaralong Dam pondage would be at risk of blue–green algal blooms, due to stratification processes and elevated nutrient inputs as discussed above. . Blue–green

algal blooms have been reported in other nearby storages, including Lake Moogerah (Brizga et al. 2006b) and Maroon Dam (G. McGregor, pers. comm.).
- Turbidity would be altered. Information on the composition of suspended load delivered to the dam pondage area and soil properties within the pondage area would be required to determine likely direction and extent of change [21]. However, catchment geology and relatively high turbidity levels indicated by existing water quality data (Finlow et al. 2006) suggest that the turbidity of water in the Wyaralong Dam pondage may be elevated, depending on the settling velocity of the suspended material.
- Unnatural variability in DO is expected, potentially including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes
- Unusually high copper levels have been recorded by NRW in this part of Teviot Brook and would need further investigation in the context of a new dam pondage because of possibly increased release of copper into the water column due to anoxic conditions in a deep impoundment.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Wyaralong Dam pondage, resulting in total loss of true riparian zone vegetation except at the upstream end of the dam impoundment.
- The variable water level regime in the dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, and lack of flood disturbance).
- Much of the dam pondage and buffer zone area for Wyaralong Dam is cleared, but there are some areas of native vegetation that will be inundated. Five small areas of the “endangered” RE 12.3.3 (*E. tereticornis* woodland to open forest on alluvial plains) and one small area of the “of concern” RE 12.9–10.7 (*E. crebra* woodland on sedimentary rocks) were mapped by EPA within the Wyaralong Dam pondage area (Table 3.2).
- No terrestrial or riparian plant species of conservation significance have been identified within the dam pondage or buffer zone areas

Aquatic Vegetation

- The extent to which macrophytes can colonise a dam pondage depends on water quality (particularly turbidity), bank gradients and wind fetch. The response of aquatic vegetation to the construction of a dam pondage may therefore vary from pondage to pondage and also spatially within a pondage.
- No aquatic plant species of conservation significance have been recorded in the vicinity of the Wyaralong Dam pondage.

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[21] Suspended load from turbid floodwaters stored in the dam pondage may settle in the dam pondage, alternatively it may be held in the water column by turbulent resupension processes and additional inputs of suspended sediment may be generated by shoreline erosion and soil dispersion – Burdekin Falls Dam provides a clear example of how the net effect of such processes in a dam pondage can lead to a net increase in turbidity (Brizga et al. 2006c)

- Temporary colonisation of shallow areas in the Wyaralong Dam pondage by emergent and submerged macrophytes is possible but they would not be able to establish permanent communities due to water level variability resulting from dam operating regimes.
- Floating macrophytes are likely to become abundant in Wyaralong Dam pondage, particularly in sheltered arms with little wind and wave action (observations indicate that weir pondages are often affected by prolific growth of floating macrophytes, but this is more rarely observed in large dam pondages).
- Wetlands near Boonah have abundant growths of water hyacinth, placing Wyaralong Dam at high risk of water hyacinth infestation; salvinia is also present in the region and could potentially be spread into Wyaralong Dam pondage, particularly if it is used for boating.

Macroinvertebrates

- Macroinvertebrate communities in the Wyaralong Dam pondage would be significantly different to natural due to changes in habitat, water quality and food resources.
- Habitats in the dam pondage would be unfavourable to edge zone species (due to variable water levels and lack of stable vegetation communities).
- Much of the dam pondage area would also be unfavourable to pool species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.
- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms and chironomid larvae).
- If abundant macrophyte growth occurs in shallow parts of the pondage and backwater arms (as discussed above), species favoured by macrophytes would increase in abundance in these areas (e.g. grazers invertebrates).
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of the dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Freshwater spiny crayfish (including the Lamington spiny cray *Euastacus sulcatus*) occur in the headwater reaches of the Logan/Albert catchment. They are not expected to occur in the section of Teviot Brook that would be impounded by Wyaralong Dam.

Fish

- One fish species of conservation significance would be affected by impoundment and barrier effects of Wyaralong Dam, the “endangered” Mary River cod *Macculochella peelii mariensis*, which has been restocked in the Logan/Albert catchment.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely

to favour a subset of species capable of surviving in impounded waters, including (including carp and gambusia, which are already present in Teviot Brook).

- The reduction in availability of lotic habitat is expected to have impacted on many species that commonly utilise shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Tilapia (a declared noxious species in Queensland) could potentially colonise the altered habitats of the Wyaralong Dam impoundment. It is not currently present in the Logan/Albert catchment but occurs in the Brisbane River system and Tingalpa Creek. The Logan/Albert catchment is close to southern limit of the temperature tolerance of this species, so if the water in the Tilleys Dam pondage is warmer than river water, it would be favourable for tilapia.
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already limited by South MacLean Weir (on the Logan River).
- Access would be further restricted by Cedar Grove Weir, and Wyaralong Dam would cause a major barrier to longitudinal fish movements. Without an effective fish passage device, it would sever access by diadromous species to 546 km^2 of catchment upstream of the dam, and restrict the movement of several potamodromous species, including Mary River cod. Upstream habitats include a “lowland” floodplain reach near Boonah that is significantly disturbed by land use pressures (including extensive riparian vegetation loss) and upstream headwater areas.

Other Vertebrates

- EPA’s Wildlife Online database shows records of five other vertebrate species of conservation significance in the vicinity of Wyaralong Dam pondage – black-necked stork, grey goshawk, koala, black-breasted button quail and spotted-tailed quoll (Table 3.3). However, many vertebrate species are highly mobile and records are patchy, so this list is not necessarily comprehensive.
- The presence of substantial remnants of native vegetation, connectivity to adjacent forests and proximity to significant wetland areas upstream on the floodplain near Boonah suggests a significant possibility that additional other vertebrate species of conservation significance are present in this area. The Logan/Albert catchment supports EVR frogs, many EVR species of birds, several “vulnerable” marsupials and an EVR bat. All could be affected by ponding of rivers, loss of riparian forests and verge vegetation.
- The dam pondage would reduce habitat suitability for riverine species of other vertebrates. The turtle fauna is likely to shift from cloacal ventilators to the generalist *Emydura krefftii.* There are likely to be reductions in riverine-associated frogs due to loss of habitats (inundation of backwaters) and increased predation by fish. The wide unvegetated zone along pondage margins that would be exposed when operating level falls below FSL would put many species at risk of increased predation.
- Drowning of riparian vegetation would have a locally detrimental effect on the grey goshawk, which nests in tall trees within 1 km of watercourses, but would affect only a small part of the total range for this species.
- Populations of waterbirds would increase (potentially including species of conservation significance such as the black-necked stork and other species as shown

in Table 3.3 and/or listed in CAMBA and JAMBA), particularly given the proximity of Wyaralong Dam to floodplain wetlands near Boonah that provide important waterbird habitat. Noteworthy "rare" species recorded from the Minto wetlands (near Boonah) include the cotton pygmy-goose (*Nettapus coromandelianus*), chestnut teal (*Anas castanea*), great-crested grebe (*Podiceps cristatus*), black-necked stork (*Ephippiorhynchus asiaticus*), painted snipe (*Rostratula benghalensis*) and ground cuckoo-shrike (*Coracina maxima*) (Stewart 1997).

- Habitat for terrestrial vertebrate species (e.g. black-breasted button-quail, koala, spotted-tailed quoll) would be reduced and these species would be expected to retreat to upslope habitats.
- The introduced cane toad, *Bufo marinus,* could spread in disturbed areas, ponded areas and downstream from dams. It is a threat to small reptiles, marsupials and ground insects.

3.2.2.2 Mitigation Options

Key mitigation and compensation measures relevant to the impoundment and barrier effects of Wyaralong Dam are presented in Table 3.7. The mitigation measures would address a wide range of environmental issues associated with the dam, but would not prevent the occurrence of major/very major changes to existing ecosystems within the dam pondage area. Hence, rehabilitation/restoration of equivalent habitats outside the dam pondage area is identified as being an appropriate compensation measure.

Table 3.7 Key mitigation and compensation measures relevant to impoundment and barrier effects of Wyaralong Dam

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats outside dam pondage area	• Teviot Brook is quite different to other major streams in the Logan Albert catchment. • Further investigations would be required to identify comparable habitats, and should include consideration of streams in the Bremer River and Lockyer Creek catchments, which also display some similarities with Teviot Brook, although are subject to a greater degree of anthropogenic disturbance.	Varies, depends on existing condition and standard of rehabilitation or restoration. Likely to be high.
Vegetated buffer zone above FSL to maintain corridors for movement of terrestrial species	• Could be achieved by retention and enhancement of existing native vegetation (where present) and revegetation of 200 m buffer zone around dam pondage with appropriate indigenous species • As with any revegetation works, proper site preparation and ongoing maintenance is necessary for a successful outcome	At least medium due to ongoing maintenance and weed suppression activities required.
• Buffer zone between assets and erosion risk zone	• A 200 m buffer zone has already been identified in the SEQ Water Supply Strategy investigations as an integral component of the Wyaralong Dam project. • It is desirable for this zone to be vegetated/revegetated with native vegetation from the viewpoint of water quality and ecological values.	Low (to reserve a buffer zone). The level of difficulty of maintaining a vegetated buffer zone is at least medium, as indicated above.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Drainage management of surface runoff to avoid concentration of flows onto exposed shorelines and hence mitigate risks of subaerial erosion	• Soil erosion risks and local drainage issues for the dam pondage shorelines would need to be investigated at the design stage.	Low difficulty from technical viewpoint, but long shoreline may present major costs
Destratifiers in dam pondage (e.g. bubblers, impellers)	• Would mitigate risks associated with stratification, such as blue–green algal blooms	Medium/high
Catchment land use controls (for rural and urban uses) and buffer zones along streams and on drainage lines to minimise inputs of nutrients and other contaminants	• Catchment land use includes the town of Boonah, grazing and intensive agriculture.	High
Improve water quality from point sources (or reduce/eliminate point source inputs)	• Investigation of existing point sources in catchment (including Boonah STP) with regard to implications for water quality in dam pondage and opportunities for improvement	Unknown – point source management can be relatively easy if obvious discrete polluting influences are identified.
Measures to control excessive macrophyte growth (e.g. mechanical harvesting)	• Monitoring and adaptive management.	Low to medium. Ongoing management required as harvested biomass can be quickly replaced.
Education, signage, boat washing facilities at storages with pest plant species to mitigate risks of transmission of these species into Wyaralong Dam pondage	• Salvinia and water hyacinth (both alien species that can blanket ponded areas and severely alter aquatic habitat structure and water quality) are present in the region and could be transmitted to Wyaralong Dam pondage by boat traffic.	Medium. Whilst cheap and simple to implement, extensive community support is required for a successful outcome.
Fish lock/lift on Wyaralong Dam	• Would mitigate impacts on fish movement including some size classes of diadromous and potamodromous species, maintaining access to 546 km2 of catchment area upstream of Wyaralong Dam. • Likely to be more effective in enabling upstream movements than downstream movements • Fish lock/lift would require sufficient flow allocations to render it effective for allowing fish passage	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though large dam pondage is problematic.
Installation and effective operation of fishways on existing/new weirs located downstream (e.g. Cedar Grove Weir, South MacLean Weir) to maintain access by diadromous and potamodromous fish species	• Existing South MacLean Weir is a small structure than frequently drowns out but does not currently have effective fish passage under low flow conditions. • Cedar Grove Weir would be a substantial barrier to fish passage, and would require a fishway to maintain connectivity to this part of the river for diadromous and potamodromous fish species • Both fishways would require sufficient flow allocations to allow fish passage	Low
Restocking of Mary River cod	• Existing population has been stocked. Natural populations of cod had become extinct from the Logan/Albert system.	Low.
Boat traffic restrictions to mitigate boating impacts on dam pondage	• Monitoring and adaptive management	Low, but requires community support

3.2.3 Downstream Effects on Non-Tidal Reaches

3.2.3.1 Implications for Condition and Values – Logan River

Implications of this scenario on the Logan River between Tilleys Dam and Cedar Grove Weir would be very similar to the Large Tilleys Dam scenario (as outlined in Section 3.1.2), with incrementally lesser magnitudes of some impacts. Downstream of Cedar Grove Weir, this scenario would generally lead to slightly greater reductions in flow than the Large Tilleys Dam Scenario. However, implications for geomorphological and ecological condition would be similar.

3.2.3.2 Implications for Condition and Values – Teviot Brook

In Teviot Brook, the implications of this development scenario would be generally the same as for Scenario Case D in the Logan Basin WRP environmental investigations (see Brizga et al. 2006a for further details regarding scenario implications):

- Geomorphological condition would show **major** change from reference condition (compared to **minor** in the current situation);
- Hydraulic habitat would show **major** change from reference condition (compared to **moderate** in the current situation);
- Riparian vegetation would continue to show **moderate** change from reference condition (same as the current situation);
- Water quality would show **very major** change from reference condition (compared to **moderate** in the current situation);
- Aquatic vegetation is expected to show **moderate** change from reference condition (currently **minor**);
- Aquatic macroinvertebrates would show **major** change from reference condition in response to changes in flow regime, physical habitat, vegetation and water quality (currently **minor**);
- Fish would show **major** change from reference condition (currently **moderate**); and
- Given the extent of changes predicted for other ecosystem components, significant change in the other vertebrate community is also likely.

3.2.3.3 Mitigation Options

Key mitigation and compensation measures relevant to the downstream effects of the Small Tilleys + Wyaralong Dam scenario on non-tidal reaches are presented in Table 3.8. The mitigation measures would address a range of environmental issues associated with this development scenario. Improvements would generally be incremental and not measurable on the five-point scale used for condition ratings.

Table 3.8 Key mitigation and compensation measures relevant to downstream effects of the Small Tilleys Dam + Wyaralong Dam scenario on non-tidal reaches of the Logan River and Teviot Brook

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats in lieu of major geomorphological and ecological changes in the Logan River	• Rehabilitation or restoration of equivalent habitats to compensate for major geomorphological and ecological changes in the Logan River and Teviot Brook. • Possible options include equivalent sections of the Albert River and Canungra Creek (although different stream character) and/or other tributaries of the Logan River – Christmas Creek, Running Creek (would provide alternative links to headwaters). • Suitable analogues for Teviot Brook may need to be found in other catchments (e.g. Bremer and Lockyer).	Varies, depending on existing condition and standard of rehabilitation or restoration. Likely to be high.
Install multi-level offtakes on Tilleys Dam and Wyaralong Dam	• Would mitigate impacts of hypolimnetic ecosystems on downstream water quality and ecology, particularly between Tilleys Dam and Running Creek, and between Wyaralong Dam and the Cedar Grove Weir. • Could also be operated to simulate natural seasonal variability in water temperature. • Destratification measures within the dam pondages (as discussed above) would also have benefits downstream of the dams	Low
Riparian vegetation restoration and weed management	• Riparian zones are already significantly disturbed in the Logan River, with many weed species present. Less disturbance is evident in Teviot Brook, but weeds are present. • Restoration of overstorey and midstorey vegetation would provide increased shading of the Logan River and Teviot Brook (and would be assisted by vegetation thickening processes associated with reduced flood disturbance due to dam effects), which, in turn, may assist in mitigating potential proliferation of aquatic vegetation, which may occur if sand transport processes do not sufficiently restrict vegetation establishment. • Weed management would be a significant issue at revegetation sites.	High
Install fish locks/lifts on Tilleys Dam and Wyaralong Dam	• Discussed above (Table 3.7). Would also affect fish community structure downstream of the dams. • As in the case of any fish passage device on a dam or weir, fish movements would be more constrained than under natural conditions. • It is possible that a fish lift/lock may be used by some migratory crustaceans such as macrobrachium.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Installation of a fishway on Cedar Grove Weir	• Would be necessary to maintain access of diadromous species to Logan River. Assumed to be part of scenario under consideration. • Fishways would require sufficient flow allocations to render it effective for allowing fish passage	Low
Installation and effective operation of a fishway on South MacLean Weir (existing weir) to maintain access by diadromous and potamodromous fish species	• Mitigation of existing impacts of weir on fish passage would provide partial compensation for net reduction in fish passage by Tilleys Dam, Wyaralong Dam and Cedar Grove Weir (even with fish passage devices installed) • Fishway would require sufficient flow allocations to render it effective for allowing fish passage	Low
Provision of sufficient flow allocation to render fishway on Bromelton Weir effective	• Mitigation of existing impacts of Bromelton Weir on fish passage would provide partial compensation for net reduction in fish passage by Tilleys and Wyaralong Dams and Cedar Grove Weir (even with fish passage devices installed)	Medium
Environmental compensation flows	• Some environmental flow rules (low flows) have been built into the hydrologic modelling of the scenario under consideration, but it is not possible to mitigate impacts of elevated low flows resulting from supplementation without providing additional delivery and/or storage infrastructure. • Medium/high flow releases for environmental purposes are unlikely to be a high priority requirement given the short distance between Tilleys Dam and Running Creek • Further analysis and optimisation of the environmental flows would need to be undertaken at the design stage of the project	Additional environmental flow provisions would reduce consumptive yield
Use of alternative conduits for downstream water delivery	• Would enable impacts of unseasonally elevated flows due to supplemented releases to be mitigated. • However, would not mitigate impacts of reductions in medium/high flows and may result in other impacts arising from an overall reduction in water availability in the stream system	High

3.2.4 Downstream Effects on Estuarine Reaches

3.2.4.1 Implications for Condition and Values

The implications of this development scenario for the Logan/Albert estuary would be very similar to the Large Tilleys Dam scenario (see Section 3.1.3).

3.2.4.2 Mitigation Options

Key mitigation and compensation measures relevant to the downstream effects of the Small Tilleys Dam + Wyaralong Dam scenario on the Logan River estuarine reaches are largely the same as for Large Tilleys, with the addition of a fish lift/lock on Wyaralong

Dam. Considerations for a fish lift/lock on Wyaralong Dam are similar to those outlined for Tilleys Dam (Tables 3.4 to 3.6). Wyaralong Dam is closer to the estuary than Tilleys Dam (and would be separated from the estuary by two weirs rather than three), but flow in Teviot Brook is intermittent (even under natural conditions, flows were less than 1 ML/d on 10% of days – Brizga et al. 2006a), whereas the Logan River is essentially perennial.

3.3 Wyaralong Dam + Glendower Dam

Dam pondage and upstream barrier effects of the Wyaralong Dam + Glendower Dam scenario are discussed in Sections 3.3.1 and 3.3.2, downstream effects on the non-tidal reaches of the Logan and Albert Rivers and Teviot Brook are discussed in Section 3.2.3 and effects on the Logan/Albert estuary and Southern Moreton Bay are discussed in Section 3.2.4. In each section, implications for condition and values, and relevant mitigation and compensation options are examined.

3.3.1 Dam Pondage and Upstream Barrier Effects – Wyaralong Dam

3.3.1.1 Implications for Condition and Values

See Section 3.2.2.1.

3.3.1.2 Mitigation and Compensation Measures

See Section 3.2.2.2.

3.3.2 Dam Pondage and Upstream Barrier Effects – Glendower Dam

3.3.2.1 Implications for Condition and Values

Geomorphology and Hydraulic Habitat

- Glendower Dam would submerge ~12 km of the Albert River, , plus parts of smaller tributaries.
- Habitat types that would be submerged include river/stream channels (including riffles and pools, gravel bars), floodplains/river terraces (with flood runners and wetlands – as documented by Brizga et al. 2006a) and upslope habitats.
- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes. However, Glendower Dam pondage would be different from a natural lake due to greater variability in water levels resulting from dam operation.
- The surficial geology of the Glendower Dam pondage area is complex and includes Jurassic sedimentary rocks (Walloon Coal Measures and Marburg Formation) with extensive deposits of alluvium along the Albert River valley. The upstream catchment geology is dominated by Tertiary volcanics (mainly Lamington Group basalt). This would influence shoreline character and sediment inputs
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.

- A large proportion of the sediment and organic matter delivered from the upstream catchment would be stored in the pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches.

Water Quality

- Water quality in the Glendower Dam impoundment would exhibit less temporal variability than the water quality of natural stream flows.
- Elevated surface water temperature and thermal stratification is likely – other large dams in this area, including Maroon (G. McGregor, pers. comm.), Moogerah and Hinze (Brizga et al. 2006b), are subject to seasonal thermal and chemical stratification.
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- There are no license point sources or towns in the Albert River catchment upstream of Glendower Dam. However, there is extensive rural–residential development (lifestyle blocks) as well as agricultural land use including dairying and intensive animal production, hence inputs of sediment and nutrients into Glendower Dam pondage would be elevated due to land use factors.
- There would also be nutrient release from former agricultural soils impounded by the dam pondage in the short to medium term (the dam pondage area submerges mainly cleared floodplain and river terraces).
- The Glendower Dam pondage would be at risk of blue–green algal blooms, due to stratification processes and elevated nutrient inputs as discussed above. Blue–green algal blooms have been reported in other nearby storages, including Lake Moogerah (Brizga et al. 2006b) and Maroon Dam (G. McGregor, pers. comm.).
- Turbidity would be altered. Information on the composition of suspended load delivered to the dam pondage area and soil properties within the pondage area would be required to determine likely direction and extent of change[22]. Based on catchment and pondage geology, there is a significantly possibility that Glendower Dam pondage would be quite turbid due to resuspension of fine clays derived from basaltic lithologies in the catchment and potentially also from soils derived from fine-grained sedimentary rocks in the dam pondage area.
- Unnatural variability in DO is expected, potentially including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Glendower Dam pondage, resulting in total loss of true riparian zone vegetation except at upstream end of the dam impoundment.

[22] Suspended load from turbid floodwaters stored in the dam pondage may settle in the dam pondage, alternatively it may be held in the water column by turbulent resupension processes and additional inputs of suspended sediment may be generated by shoreline erosion and soil dispersion – Burdekin Falls Dam provides a clear example of how the net effect of such processes in a dam pondage can lead to a net increase in turbidity (Brizga et al. 2006c)

- The variable water level regime in the dam pondage will prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, and lack of flood disturbance).
- Much of the dam pondage and buffer zone area for Glendower Dam has been cleared, but one small area of the "endangered" RE 12.3.3 (*E. tereticornis* woodland to open forest on alluvial plains) and one small area of the "of concern" RE 12.9–10.3 (*E. moluccana* on sedimentary rocks) were mapped by EPA within existing remnants (Table 3.2).
- No terrestrial or riparian plant species of conservation significance have been identified within the dam pondage or buffer zone areas.

Aquatic Vegetation

- The extent to which macrophytes can colonise a dam pondage is dependent on water quality (particularly turbidity), bank gradients and wind fetch.
- The dominant submerged species in this region of the Albert River include *Myriophyllum verrucosum*, *Potamogeton perfoliatus*, *P. crispus* and *Hydrilla verticillata*, which are all native. It is expected that, of these species, *H. verticillata* would be the most likely to be weedy in Glendower Dam (e.g. as in Somerset Dam) and to a lesser extent, *Potamogeton* spp. *M. verrucosum* is typically more abundant in flowing water, particularly riffles.
- There are no records of any aquatic plants of conservation significance present in the Glendower Dam pondage area. However, *Vallisneria nana* ("rare" NCA) has been recorded downstream of the proposed pondage area. It may therefore occur in the Glendower Dam pondage area.
- Temporary colonisation of shallow areas by emergent and submerged macrophytes is possible as observed in shallow arms of Lake Samsonvale (North Pine Dam pondage) but they would not be able to establish permanent communities due to water level variability resulting from dam operating regimes.
- Floating macrophytes may potentially increase in abundance, although the shape of the Glendower Dam pondage means that there are few sheltered arms. There is a risk of alien species including salvinina and water hyacinth becoming established. These species are present in the region and there is increased risk of transmission if the dam pondage is used for boating.

Macroinvertebrates

- Macroinvertebrate communities in the Glendower Dam pondage would be significantly different to natural due to changes in habitat, water quality and food sources.
- Habitats in the dam pondage would be unfavourable to edge zone species (due to variable water levels & lack of vegetation) and obligate-lotic species (due to lack of running, shallow-water habitat).
- Much of the dam pondage area would also be unfavourable to pool species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.

- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms and chironomid larvae).
- If abundant macrophyte growth occurs in shallow parts of the pondage (as discussed above), species favoured by macrophytes would increase in abundance in these areas (e.g. grazer invertebrates).
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of the dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Freshwater spiny crayfish (including the Lamington spiny cray *Euastacus sulcatus*) occur in the Logan/Albert catchment. The known range of the Lamington spiny cray is limited to altitudes above 300 m (Short 2000), hence they are not expected to occur in the reaches that would be impounded by Glendower Dam.

Fish

- One fish species of conservation significance would be affected by impoundment and barrier effects of Glendower Dam, the “endangered” (EPBC) Mary River cod *Macculochella peelii mariensis*, which has been restocked in the Albert River catchment.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely to favour a subset of fish species capable of surviving in impounded waters (including carp and gambusia, which are already present in this section of the river).
- The reduction in availability of lotic habitat is expected to affect many species that commonly utilise shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Tilapia (a declared noxious species in Queensland) could potentially colonise the altered habitats of the Glendower Dam impoundment. It is not currently present in the Logan/Albert catchment but occurs in the Brisbane River system and Tingalpa Creek. The Logan/Albert catchment is close to southern limit of the temperature tolerance of this species, so if the water in the Tilleys Dam pondage is warmer than river water, it would be favourable for tilapia.
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already limited by Luscombe Weir.
- Glendower Dam would cause a major barrier to longitudinal fish movements. Without an effective fish passage device, it would sever access by diadromous species to 304 km^2 of catchment upstream of the dam and restrict the movement of several potamodromous species, including Mary River cod (see Appendix C for a list of migratory fish species relevant to Glendower Dam).
- Although Luscombe Weir may be removed under this scenario, the new Albert River Barrage would also impact on fish movement within the Albert River.

- Good fish habitat exists in the Albert River system upstream of the Glendower Dam pondage area.

Other Vertebrates

- EPA's Wildlife Online database shows records of one other vertebrate species of conservation significance in the vicinity of Glendower Dam pondage, the koala (Table 3.3). However, many vertebrate species are highly mobile and records are patchy, so this list is not necessarily comprehensive. The Logan/Albert catchment supports EVR frogs, many EVR species of birds, several "vulnerable" marsupials and an EVR bat. All could be affected by ponding of rivers, loss of riparian forests and verge vegetation.
- The platypus, *Ornithorhynchus anatinus*, occurs in the Logan and Albert catchments (Albert River, Canungra Creek, Cedar Creek, Sandy Creek and Scrubby Creek). It is a protected species, and an Australian icon. Impounded areas, barriers and flow regime modification are thought to affect its movement patterns, feeding and recruitment.
- The Glendower Dam pondage would reduce habitat suitability for riverine species. The turtle fauna would be likely to shift from cloacal ventilators to the generalist *Emydura krefftii.* There would be likely to be reductions in riverine-associated frogs due to loss of habitats (inundation of backwaters) and increased predation by fish. The wide unvegetated zone along the dam pondage margins that would be exposed when operating level falls below FSL would put many vertebrate species at risk of increased predation.
- Populations of waterbirds would increase (potentially including species of conservation significance such as the black-necked stork and other species as shown in Table 3.3 and/or listed in CAMBA and JAMBA).
- Habitat for terrestrial vertebrate species (e.g. koala) would be reduced and these species would be expected to retreat to upslope habitats.
- The introduced cane toad, *Bufo marinus,* could spread in disturbed areas, ponded areas and downstream from dams. It is a threat to small reptiles, marsupials and ground insects.

3.3.2.2 Mitigation Options

Key mitigation and compensation measures relevant to the impoundment and barrier effects of Glendower Dam are presented in Table 3.9. The mitigation measures would address a wide range of environmental issues associated with the dam, but would not prevent the occurrence of major/very major changes to existing ecosystems within the dam pondage area. Hence, rehabilitation/restoration of equivalent habitats outside the dam pondage area is identified as being an appropriate compensation measure.

Table 3.9 Key mitigation and compensation measures relevant to impoundment and barrier effects of Glendower Dam

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats outside dam pondage area	• Further investigations are required to identify suitable sites. • Possible options include Canungra Creek, Christmas Creek and Running Creek, which have a similar continuum from forested uplands to lowlands and similar catchment geologies, and/or the Logan River	Varies, depends on existing condition and standard of rehabilitation or restoration. Likely to be high
Vegetated buffer zone above FSL to maintain corridors for movement of terrestrial species	• Could be achieved by retention and enhancement of existing native vegetation (where present) and revegetation of 200 m buffer zone around dam pondage with appropriate indigenous species • As with any revegetation works, proper site preparation and ongoing maintenance is necessary for a successful outcome	At least medium due to ongoing maintenance and weed suppression activities required.
Buffer zone between assets and erosion risk zone	• A 200 m buffer zone has already been identified in the SEQ Water Supply Investigations as an integral component of the Glendower Dam project. • It is desirable for this zone to be vegetated/revegetated with native vegetation from the viewpoint of water quality and ecological values.	Low (to reserve a buffer zone). The level of difficulty of maintaining a vegetated buffer zone is at least medium, as indicated above.
Drainage management of surface runoff to avoid concentration of flows onto exposed shorelines and hence mitigate risks of subaerial erosion	• Soil erosion risks and local drainage issues for the dam pondage shorelines would need to be investigated at the design stage.	Low difficulty from technical viewpoint, but long shoreline may present major costs
Destratifiers in dam pondage (e.g. bubblers, impellers) would mitigate risks associated with stratification, such as blue–green algal blooms	• The relatively "simple", basin-like shape of Glendower Dam would facilitate establishment of circulation currents	Low/Medium
Catchment land use controls and buffer zones along streams and on drainage lines to minimise inputs of nutrients and other contaminants	• Catchment land use is rural and rural–residential.	High
Measures to control excessive macrophyte growth (e.g. mechanical harvesting)	• Monitoring and adaptive management.	Low to medium. Ongoing management required as harvested biomass can be quickly replaced.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Education, signage, boat washing facilities at storages with pest plant species to mitigate risks of transmission of these species into Glendower Dam pondage	• Salvinia and water hyacinth (both alien species that can blanket ponded areas and severely alter aquatic habitat structure and water quality) are present in the region and could be transmitted to Glendower Dam pondage by boat traffic.	Medium. Whilst cheap and simple to implement, extensive community support is required for a successful outcome.
Fish lock/lift on Glendower Dam	• Would mitigate impacts on fish movement including some size classes of diadromous and potamodromous species, maintaining access to 304 km^2 of catchment area upstream of Glendower Dam. • Likely to be more effective in enabling upstream movements than downstream movements • Fish lock/lift would require sufficient flow allocations to render it effective for allowing fish passage	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though large dam pondage is problematic.
Installation and effective operation of Fishways on existing/new infrastructure located downstream (Luscombe Weir, Albert River Barrage) to maintain access by diadromous fish species	• Existing Luscombe Weir has no fishway and is a major barrier to fish passage. • The Albert River Barrage would be a substantial barrier to fish passage, but installation of an effective fishway would restore connectivity to this part of the river for diadromous fish species (assuming that Luscombe Weir is removed) • Fishways would require sufficient flow allocations to render them effective for allowing fish passage	Low
Restocking of Mary River cod	• Existing populations have been stocked. Natural populations of cod had become extinct from the Logan/Albert system.	Low
Boat traffic restrictions to mitigate boating impacts on dam pondage	• Monitoring and adaptive management	Low, but requires community support

3.3.3 Downstream Effects on Non-Tidal Reaches

3.3.3.1 Implications for Condition and Values – Teviot Brook and Logan River

This scenario would have significant downstream implications for Teviot Brook between Wyaralong Dam and the Logan River confluence, and the Logan River from the Cedar Grove Weir pondage downstream. Substantial geomorphological and ecological changes are predicted for these reaches. In Teviot Brook, the changes would be the same as in the Small Tilleys Dam + Wyaralong Dam scenario (Section 3.2.3.2) and in the Logan River the changes would be very similar (Section 3.2.3.1). Cedar Grove Weir would also have upstream implications for fish passage through the Logan catchment.

3.3.3.2 Implications for Condition and Values – Albert River

In the Albert River, the implications of this development scenario for the non-tidal reaches of the Albert River downstream of Glendower Dam would be generally the same as for Scenario Case D in the Logan Basin WRP environmental investigations (see

Brizga et al. 2006a for further details):

- Geomorphological condition would show **major** change from reference condition above the Canungra Creek confluence and **moderate** change below (compared to **minor** in both reaches in the current situation);
- Hydraulic habitat would show **major** change from reference condition (compared to **moderate** in the current situation);
- Riparian vegetation would continue to show **moderate** change from reference condition (same as the current situation);
- Water quality would show **very major** (above Canungra Creek) or **major** (below Canungra Creek) change from reference condition (compared to **moderate** in the current situation);
- Aquatic vegetation would show **moderate** change from reference condition (currently **minor**);
- Aquatic macroinvertebrates would show **major** change from reference condition in response to changes in flow regime, physical habitat, vegetation and water quality (currently **minor** above Canungra Creek and **moderate** below);
- Fish would show **major** change from reference condition (currently **moderate**) arising from a combination of factors; and
- Given the extent of changes predicted for other ecosystem components, significant change in the other vertebrate community is also likely.

3.3.3.3 Mitigation Options

Key mitigation and compensation measures relevant to the downstream effects of the Wyaralong Dam + Glendower Dam scenario on non-tidal reaches are presented in Table 3.10. The mitigation measures would address a range of environmental issues associated with this development scenario. Improvements would generally be incremental and not measurable on the five-point scale used for condition ratings.

Table 3.10 Key mitigation and compensation measures relevant to downstream effects of the Wyaralong Dam + Glendower Dam scenario on non-tidal reaches of Teviot Brook and the Logan and Albert Rivers

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats in lieu of major geomorphological and ecological changes in Teviot Brook, Logan River and Albert River	• Rehabilitation or restoration of equivalent habitats to compensate for major geomorphological and ecological changes in Teviot Brook and the Logan and Albert Rivers. • Possible options include Canungra Creek, the Logan River upstream of Cedar Grove Weir pondage, Logan River tributaries, and Coomera River. • Requires further investigation to determine streams with relevant habitats with high feasibility for restoration	Varies, depends on existing condition and standard of rehabilitation or restoration. Likely to be high

Mitigation or Compensation Measure	Comments	Level of Difficulty
Install multi-level offtakes on Wyaralong Dam and Glendower Dam	• Would mitigate impacts of hypolimnetic ecosystems on downstream water quality and ecology, particularly immediately downstream of the dams. • Could also be operated to simulate natural seasonal variability in water temperature. Destratification measures within the dam pondages (as discussed above) would also have benefits downstream of the dams	Low
Riparian vegetation restoration and weed management	• Riparian zones are already significantly altered from natural by structural disturbance and weed invasion, particularly along the Logan River. • Restoration of overstorey and midstorey vegetation would provide increased shading of the Logan River and Teviot Brook (and would be assisted by vegetation thickening processes associated with reduced flood disturbance due to dam effects), which, in turn, may assist in mitigating potential proliferation of aquatic vegetation, which may occur if sand transport processes do not sufficiently restrict vegetation establishment. • Weed management would be a significant issue at revegetation sites.	High
Install fish locks/lifts on Wyaralong Dam and Glendower Dam	• Discussed above (Tables 3.7 and 3.9). Would also affect fish community structure downstream of dam . Would also affect fish community structure downstream of the dams. • As in the case of any fish passage device on a dam or weir, fish movements would be more constrained than under natural conditions. • It is possible that a fish lift/lock may be used by some migratory crustaceans such as macrobrachium.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.
Installation of fishways on Cedar Grove Weir and the Albert River Barrage	• Would be necessary to maintain access of diadromous species to Logan River and Albert River. • Assumed to be part of scenario under consideration. • Fishway would require sufficient flow allocations to render them effective for allowing fish passage.	Low
Installation and effective operation of a fishway on South MacLean Weir (existing weir) to maintain access by diadromous and potamodromous fish species	• Mitigation of existing impacts of weir on fish passage would provide partial compensation for net reduction in fish passage by Wyaralong Dam and Cedar Grove Weir (even with fish passage devices installed) • Fishway would require sufficient flow allocations to render it effective for allowing fish passage	Low
Removal of Luscombe Weir	• Would be necessary to maintain/restore access of diadromous species to Albert River. • Assumed to be part of scenario under consideration (in conjunction with installation of Albert River Barrage).	Medium

Mitigation or Compensation Measure	Comments	Level of Difficulty
Environmental compensation flows	• Some environmental flow rules (low flows) have been built into the hydrologic modelling of the scenario under consideration, but it is not possible to mitigate impacts of elevated low flows resulting from supplementation without providing additional delivery and/or storage infrastructure. • Further analysis and optimisation of the environmental flows would need to be undertaken at the design stage of the project	Additional environmental flow provisions would reduce consumptive yield
Use of alternative conduits for downstream water delivery	• Would enable impacts of unseasonally elevated flows due to supplemented releases to be mitigated. • However, would not mitigate impacts of reductions in medium/high flows and may result in other impacts arising from an overall reduction in water availability in the stream system	High

3.3.4 Downstream Effects on Estuarine Reaches and Receiving Waters

3.3.4.1 Implications for Condition and Values

- This development scenario would affect the estuarine reaches of both the Logan and Albert Rivers, reducing the possibility of maintaining the functionality of the estuary through the continuation of relatively natural flow conditions from one river.

Geomorphology

- The geomorphology of the Logan River estuarine reaches currently show **moderate** (upper estuary) to **minor** (lower estuary) change from reference condition due to factors other than water resource development .
- No change in overall condition of the Logan River estuarine reaches is predicted, but water resource development impacts would increase (from **indiscernible** to **minor**) due to effects of reductions in small and medium floods on sediment transport.
- The geomorphology of the estuarine reach of the Albert River currently shows **minor** change from reference condition due to land use factors and alteration of fluvial sediment supply by Luscombe Weir.
- An increase to **major** change from reference condition is predicted, including conversion of the upper estuary to a weir pondage, and changes in sediment transport processes which are likely to result in increased fine sediment deposition in the remaining section of the estuary below the Albert River Barrage.

Hydrodynamics

- The hydrodynamics of the Logan River estuarine reaches currently show **minor** (upper estuary) to **indiscernible** (lower estuary) change from reference condition. Condition is influenced by minor flow regime changes resulting from existing water resource development as well as geomorphological changes due to factors other than water resource development.

- Shifts in ratings to **moderate** change from reference condition in the upper estuary and **minor** change from reference condition in the lower estuary are predicted.
- Reduced freshwater inflows (low, medium and high) are predicted to result in a substantial increase in salinity of the upper reach of the estuary[23] as well as increased residence times and reduced flushing.
- The hydrodynamics of the estuarine reach of the Albert River currently shows **minor** change from reference condition due the effects of Luscombe Weir and reductions in low flows.
- A shift to **major** change from reference condition is predicted, including loss of approximately 5 km of tidal freshwater/brackish water habitat upstream of the Albert River Barrage (due to conversion of the upper estuary to a weir pondage), and changes in estuary hydrodynamics downstream of the barrage (including minor reductions in tidal compartment and tidal prism, potential tidal amplification, a substantial increase in salinity, increased residence times, and reduced flushing by river flows and tides).

Water Quality

- The Logan/Albert estuarine reaches currently show **major** (upper Logan estuary, estuarine reach of Albert River) to **moderate** (lower estuary) change from reference condition, mainly due to inputs of pollutants from point sources and diffuse sources.
- In the upper estuarine reach of the Logan River, no change in overall condition rating is predicted (already **major**) although impacts of water resource development would increased from **minor** to **moderate** due to reduced flushing and upstream shift in the turbidity maximum (by ~5 km).
- In the lower estuary, no change in overall condition rating of **moderate** is predicted but impacts of water resource development would increase (from **indiscernible** to **minor**) – the lesser magnitude of impact in this part of the estuary compared to upstream reaches is due to the mitigating influence of tidal flushing.
- In the estuarine reach of the Albert River, the overall condition rating is predicted to shift to **very major** change from reference condition, due to the conversion of the upper part of the estuary to a freshwater weir pondage and impacts of hydrodynamic changes in the remaining section of the estuary downstream of the Albert River Barrage (including upstream displacement of the turbidity maximum, reduced DO and increased nutrient concentrations).

Vegetation

- Estuarine vegetation in the Logan/Albert estuarine reaches currently shows **moderate** change from reference condition, mainly due to land use impacts (mangroves and saltmarsh) and water quality changes (seagrass, phytoplankton). In the Albert, flow regime changes that have occurred to date (reductions in low flows) may have already led to some upstream extension of halophytic vegetation.

[23] inferred from modelling by WBM for the Logan Basin WRP (Brizga et al. 2006a, Appendix E)

- No change in overall condition rating is predicted, but impacts of water resource development would increase (from **indiscernible** to **minor** in the Logan River and **minor** to **moderate** in the Albert River).
- Vegetation zonations are predicted to change, with salt-tolerant species penetrating further upstream in response to changes in salinity gradients.
- Increased concentrations of nutrients due to increased residence times and reduced flushing of local inputs would lead to phytoplankton blooms in the Albert River if turbidity is reduced upon better flushing with marine waters, and could potentially lead to phytoplankton blooms in the estuarine reach of the Logan upstream of the Logan/Albert confluence, particularly if there is a local reduction in turbidity in part of the reach (e.g. due to upstream shift in the turbidity maximum).
- The Albert River Barrage pondage would support only freshwater species, potentially including the invasive alien para grass, which has already been recorded in this area and would be at a competitive advantage if unnatural variability in water levels makes habitat conditions unsuitable for native species.
- Old growth mangrove forests near the mouth of the Logan River, which potentially support populations of Illidge's ant-blue butterfly(*Acrodipsas illidgei* – "vulnerable" [NCA]) are not expected to be significantly affected by flow regime changes in this scenario

Aquatic Macroinvertebrates

- Estuarine macroinvertebrate communities of the Logan /Albert estuarine reaches currently show **moderate** change from reference condition due to factors other than water resource development, primarily water quality changes, loss of seagrass and fishing pressures.
- No change in overall condition is predicted in the Wyaralong Dam + Glendower Dam scenario, but water resource development impacts would increase (from **indiscernible** to **minor**).
- The distribution of marine species is expected to extend further upstream in the Logan River due to changes in salinity gradients and extended distribution of marine flora (mangroves and saltmarsh).
- Installation of the Albert River Barrage would lead to a reduction in habitat for estuarine invertebrates in the Albert River (but increase habitat for freshwater species within the weir pondage).
- Well-documented correlations (e.g. as reported by Loneragan and Bunn 1999) indicate that catches of fisheries species from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 5% (mudcrabs) and 10% (prawns) compared to present levels as a result of reductions in summer flows.
- The estuarine macroinvertebrate fauna of Logan/Albert estuary is not known to include any fish species of conservation significance, but few invertebrate species are listed under Australian nature conservation legislation (Dunn 2003).

Fish

- Fish communities of the Logan/Albert estuarine reaches currently show **moderate** change from reference condition due to water quality changes, infill of pools in the upper Logan estuary, loss of seagrass, fishing pressures and barrier effects of existing weirs (including South MacLean Weir on the Logan River and Luscombe Weir on the Albert River).

- No change in overall condition is predicted in the Wyaralong Dam + Glendower Dam scenario (based on the assumption that effective fishways are installed at Cedar Grove Weir and Albert River barrage), but impacts of flow regime change would increase from **indiscernible** to **minor**.
- The distribution of marine species is expected to extend further upstream in the Logan River due to changes in salinity gradients and extended distribution of marine flora (mangroves and saltmarsh).
- Installation of the Albert River Barrage would lead to a reduction in estuarine habitat for fish in the Albert River (but increased freshwater habitat within the weir pondage).
- If increased sedimentation leads to infill of deep pools, this would be likely to lead to reductions in larger fish species (such as jewfish).
- Well-documented correlations (e.g. Loneragan and Bunn 1999) indicate that catches of flathead from the Logan/Albert estuary and Southern Moreton Bay would be reduced by about 10% compared to present levels as a result of reductions in summer flows that are associated with migration and other behavioural cues.
- Installation of Cedar Grove Weir would further reduce fish access to the Logan catchment (already impeded by South MacLean Weir, which is downstream of the Cedar Grove Weir site), but the fishway on Luscombe Weir would increase fish access to the Albert River system (currently blocked by Luscombe Weir, which does not have an effective fishway).
- The fish fauna of the Logan/Albert estuary includes two fish species of conservation significance recorded in the IUCN Red List: Green Sawfish *Pristis zijsron*[24] and Giant Groper *Epinephelus lanceolatus*[25].

Other Vertebrates

- Undisturbed mangroves and adjacent saltmarsh of the lower Logan estuary potentially also provide habitat for the water mouse (*Xeromys myoides* – "vulnerable" EPBC and NCA). These habitats are not expected to be significantly affected by the flow regime changes resulting from the Wyaralong Dam + Glendower Dam scenario.
- The dugong (*Dugong dugon*) lives in Moreton Bay and visits the Logan/Albert estuary– its usage of the estuary may potentially be affected by changes in habitat and food resources resulting from the Wyaralong Dam + Glendower Dam scenario.
- Waterbirds of conservation significance, including species listed in JAMBA and CAMBA, occur in wetland areas associated with the Logan/Albert estuary.

3.3.5 Mitigation Options for Downstream Effects on the Logan/Albert Estuary

- Key mitigation and compensation measures relevant to the downstream effects of the Wyaralong Dam + Glendower Dam scenario on the Logan/Albert estuary are

24 Historically recorded from the Brisbane River but there have been no recent records
25 Common in Moreton Bay (Johnson 1999) .

presented in Table 3.11. The mitigation measures would address a range of environmental issues associated with this development scenario.

- Redevelopment of the existing Luscombe Weir rather than installation of the Albert River Barrage would significantly reduce the impact of the Wyaralong Dam + Glendower Dam scenario on the Logan/Albert estuary, particularly the estuarine reach of the Albert River, as it would avoid direct loss of approximately 5 km of the estuary and hydrodynamics changes that would result from the shortening of the estuary.
- In most other instances, feasible mitigation measures would lead to incremental reductions in impacts, but not prevent the shifts in condition ratings outlined above – key exceptions are water quality (measures to reduce pollutant inputs would make it possible to hold current condition at a maximum of **major** change from reference condition, rather than shift to **very major)** and fish (fishways on Cedar Grove Weir and Albert River Barrage are assumed in the condition ratings presented above, otherwise water resource development impacts would be greater than indicated).

Table 3.11 Key mitigation and compensation measures relevant to downstream effects of the Wyaralong Dam + Glendower Dam scenario on the Logan/Albert estuary

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat approach"	• Development in both the Logan and Albert catchments means that the whole Logan/Albert estuary will be affected by this scenario. • Impacts on the Albert would be greater due to truncation and direct loss of estuarine habitat by the Albert River Barrage, and this may justify greater rehabilitation efforts in the estuarine reaches of the Logan to minimise net loss of estuarine habitat. • Because Cedar Grove Weir will be installed some distance above estuary, the full estuarine transition (freshwater–brackish–saline) will not be removed from the Logan River in this scenario. • As the Logan/Albert estuary is in a relatively natural condition compared to many other large river estuaries in south-east Queensland, it may not be possible to find any suitable analogues. In addition, rehabilitation/restoration of an analogue estuary is unlikely to compensate for functional relationships between the Logan/Albert estuary and Southern Moreton Bay.	Varies, depending on existing condition and standard of rehabilitation or restoration. Likely to be high, particularly given a likely increase in pressures from increased urban and residential land use in the Logan/Albert catchment associated with future development (as predicted by the Office of Urban Management).
Redevelop Luscombe Weir in lieu of installation of the Albert River Barrage	• Luscombe Weir is situated approximately 5 km upstream of the proposed Albert River Barrage • Redevelopment of the existing weir for use in conjunction with Glendower Dam would greatly reduce impacts of this scenario on the estuary, as this would avoid direct loss of estuarine habitat due to truncation	Unknown.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Reduce inputs of pollutants to estuary from point and diffuse sources to mitigate "factor reinforcement"	• Impacts on water quality resulting from longer retention times resulting from reductions in flow are exacerbated if there are elevated inputs of pollutants, as is the case in the Logan/Albert estuary. • Appropriate measures include higher standards for point source inputs, • WSUD for urban areas (new areas and retrofit existing areas), and buffer zones and improved stock management in agricultural areas	Unknown. Point sources can be relatively easy to address if obvious polluting influences can be identified. Diffuse sources in large catchments are very difficult to manage.
Rehabilitate "riparian" vegetation (mangroves and saltmarsh) to improve resilience of estuarine ecosystems	• There is scope for rehabilitation/reinstatement of saltmarsh and mangrove vegetation in areas where there has been significant loss or clearing, and to prevent further clearing. • This would improve the resilience of estuarine ecosystems to impacts arising from flow regime change	Medium due to extent of resources and length of time required for successful outcome. Opportunities to build-on and expand from existing remnants.
Installation of fishways on Cedar Grove Weir and the Albert River Barrage	• Would be necessary to allow longstream movements of anadromous and catadromous species (including mullet, eels, bass and mangrove jack). • Assumed to be part of scenario under consideration. • Would require sufficient flow allocations for fishway to allow fish passage • Less fish would be expected to move between estuarine and freshwater reaches than in the absence of any weirs as barriers to migration, hence abundance of diadromous species would be reduced • Not all species that would naturally move between freshwater and estuarine reaches as temporary visitors would use a fishway. For example, sharks naturally move well into freshwater reaches of rivers in south-east Queensland (as temporary visitors to feed but cannot complete any life history processes in freshwater reaches). It is not known if they would use a fishway at the tidal limit to ascend the river, and, if they do successfully ascend the river, whether they would be able to find and successfully use the fishway to descend back to the estuary.	Low
Install fish lock/lifts on Wyaralong Dam and Glendower Dam	• Discussed above (Tables 3.7, 3.9 and 3.10).	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.
Installation of fish habitat structures in upper estuary	• Maintain habitat diversity in the estuary e.g. deep hole and ledge habitats (particularly relevant to the Logan, which is susceptible to bed flattening by sand movement)	Low

4 Mary Catchment Scenarios

Two future water resource development scenarios for the Mary catchment have been assessed:

- Traveston Dam – large dam (30 m) on the Mary River at Traveston Crossing; and
- Four Dams – Kidaman Dam, Amamoor Dam, Cambroon Dam and raising of Borumba Dam, plus Coles Crossing Weir.

Detailed assessments of environmental issues associated with each of these scenarios are presented in Sections 4.1 (Traveston Dam) and 4.2 (Four Dams). In each instance, consideration is given to dam pondage and upstream barrier effects as well as downstream effects on non-tidal reaches, the Mary River estuary and the Great Sandy Strait. Impacts on condition and values are discussed, as well as relevant mitigation and compensation options and their likely benefits.

Environmental issues associated with the Traveston Dam and Four Dams scenarios are summarised in Table 4.1. It is difficult to rank these two options in terms of likely overall environmental impacts, for the following reasons:

- If the water in Traveston Dam becomes highly turbid (either as a result of erosion and resuspension of soils within the dam pondage or storage and slow release of turbid peak flows), then this scenario would clearly have greater environmental impacts. However, if Traveston Dam is not significantly affected by turbidity or if Cambroon Dam is also significantly affected by turbidity, then levels of environmental impact would be of a similar order.
- Traveston Dam would have a greater impact than the Four Dams scenario on the movement of migratory fish (including potamodromous and diadromous species). Coles Crossing Weir in the Four Dams scenario commands only a slightly lesser percentage of the total catchment area of the Mary River than Traveston Dam, but Traveston Dam would have greater impacts on fish passage than a weir, even if appropriate fish passage devices were installed in both instances.
- Traveston Dam would pond a greater area of land than the new/expanded storages in the Four Dams scenario (7,700 ha versus 6,551 ha), but ponded mainstream length is similar for both scenarios (~73 km versus ~78 km, as outlined in Table 4.1).
- Both scenarios would inundate remnants of “endangered” RE 12.3.1 (Gallery rainforest [notophyll vine forest] on alluvial plains), with Traveston Dam flooding a greater extent of this RE. Both scenarios would also inundate REs “of concern”; a larger number of REs “of concern” would be affected by inundation in the Four Dams scenario because of the wider geographical spread of the four dam pondages.
- The Four Dams scenario would affect a greater number of flora and fauna species of conservation significance (as listed under EPBC and NCA).
- Two “endangered” riparian plant species and five “endangered” upslope plant species would be affected by inundation in the Four Dams scenario, while no “endangered” plant species are known to occur in the area that would be inundated by Traveston

Dam (the distribution of rare/threatened plant species is currently a knowledge gap, as the Mary has not been systematically surveyed at the species level).

- Traveston Dam would have a greater impact on reducing landscape connectivity between headwaters and lowlands. However, Amamoor and Kidaman Dams would disrupt State Wildlife Corridors at the subcatchment scale.
- Both scenarios would affect the following EPBC-listed stream-dependent fauna species: the "endangered" Mary River cod (*Maccullochella peelii mariensis*), "vulnerable" lungfish (*Neoceratodus forsteri*), "endangered" giant barred frog (*Mixophyes iteratus*), "endangered" Mary River turtle (*Elusor macrurus*) and "vulnerable/endangered" red goshawk (*Erythrotriorchis radiatus*). The Four Dams would also potentially affect another three EPBC-listed stream-dependent fauna species – the "endangered" Fleay's barred frog (*Mixophyes fleayi*) and two frog species "presumed extinct" but possibly still present (the southern gastric brooding frog, *Rheobatrachus silus* and the southern day frog, *Taudactylus diurnus*).
- Both scenarios would impact on the habitat and breeding grounds of four stream-dependent frog species listed under NCA as EVR species (the "endangered" cascade treefrog [*Litoria pearsoniana*], "vulnerable" tusked frog [*Adelotus brevis*], "rare" pouched frog [*Assa darlingtoni*] and "rare" green-thighed frog [*Litoria brevipalmata*]).
- Depending on the distribution of the Mary River turtle throughout the Mary River system (currently not well known as existing datasets are biased by differences in survey effort), Traveston Dam may potentially have greater impacts on the Mary River turtle, particularly if the majority of the population exists downstream of Yabba Creek (greater impact can be expected if the dam water is turbid). Traveston Dam wall is highly likely to isolate upstream and downstream populations of Mary River turtles and reduce potential for exchange of genetic material.
- The Four Dams scenario would cause greater lengths of river/stream channel to be affected by major flow regime change and other downstream effects of dam impoundments than Traveston Dam.
- Traveston Dam would have slightly greater impacts on freshwater inflows to the Mary River estuary and outflows to the Great Sandy Strait than the Four Dams scenario, but there is not expected to be any significant difference with regard to impacts on the medium to large flood flows that discharge freshwater plumes into the Great Sandy Strait.

There are key knowledge gaps with regard to:

- Soil properties and their implications for the turbidity of the dam pondages and downstream river flows, particularly with regard to Traveston Dam and Cambroon Dam;
- The presence and location of individual EVR species, including the Mary River turtle, rare/threatened frog species, rare/threatened plant species, for all impoundments under consideration;
- Nesting and spawning sites for the Mary River turtle and Australian lungfish (Traveston, Cambroon and Kidaman Dams); and

- Indirect impacts of the dam scenarios on EVR species arising from habitat reduction and fragmentation, including isolation of populations, effects on gene transfer and reduced connectivity between lowland alluvial habitat and upper ridge habitat.

Table 4.1 Comparison of Mary catchment development scenarios

	Traveston Dam	Four Dams (Including Coles Crossing Weir)
DAM PONDAGE AND BARRIER EFFECTS		
Catchment Area Upstream of New Dam(s)	• 22% of Mary catchment (net increase by 16% of Mary catchment – 1,571 km^2 [2,110 km^2 less 465 km^2 already upstream of Borumba Dam and 74 km2 already upstream of Baroon Pocket Dam])	• 11% of Mary catchment (net increase by 5% of Mary catchment – 525 km^2 [1,064 km^2 less 465 km^2 already upstream of Borumba Dam and 74 km^2 already upstream of Baroon Pocket Dam])
Catchment Area Upstream of New Instream Barriers (Dams and Weirs)	• As above. No new weirs.	• ~21% of Mary catchment (~2000 km^2) upstream of Coles Crossing Weir and Amamoor Dam (130 km^2). Contained with the 90% of the total Mary catchment area already upstream of existing weirs (8,651 km^2 , including 7,343 km^2 upstream of the Mary Barrage and 1,308 km^2 upstream of the Tinana Barrage).
Area Ponded By New/Enlarged Dams and Weirs	• 7,700 ha	• 6,551 ha additional area impounded (based on the total area impounded by the four dams plus Coles Crossing Weir of 7,031 ha, less 480 ha already impounded by the existing Borumba Dam)
Ponded Mainstream Length	• 73 km mainstream length of the Mary River, Kandanga Creek and Yabba Creek (46 km of Mary River, 16 km of Kandanga Creek and 11 km of Yabba Creek) plus smaller tributaries, including parts of Coles Creek, Skyring Creek and Belli Creek	• 78 km additional mainstream length of the Mary River, Obi Obi Creek, Yabba Creek and Amamoor Creek (including 40 km of the Mary River, 15 km of Obi Obi Creek, 7 km of Yabba Creek [excluding stream length already impounded by existing Borumba Dam] and 16 km of Amamoor Creek) plus minor tributaries
Rare/threatened REs in Ponded Area(s) of New/Enlarged Dams	• Remnants of one "endangered" RE [RE12.3.1] • Remnants of two "of concern" REs [RE 12.3.11 and RE 12.11.14] •	• Remnants of one "endangered" RE [RE12.3.1] (Kidaman, Amamoor) • Remnants of seven "of concern" REs (12.3.8, 12.3.11, 12.11.9, 12.11.14, 12.11.15, 12.12.1, 12.12.12) Two of the "of concern" REs (12.11.9 and 12.11.15) occur mainly in the buffer zones
Rare/threatened Plant Species in Ponded Area (s) of New/Enlarged Dams	• One aquatic species of conservation significance – *Vallisneria nana* (ribbonweed – "rare" NCA) • Four riparian species and five upslope species of conservation significance (based on current knowledge)	• One aquatic species of conservation significance – *Vallisneria nana* (ribbonweed– "rare" NCA) • 17 riparian species and 12 upslope species of conservation significance (based on current knowledge) (excludes species shown as "recorded in vicinity of pondages")

	Traveston Dam	**Four Dams (Including Coles Crossing Weir)**
Rare/threatened Fish Species Affected by Dam Pondage, Barrier or Downstream Effects	• Mary River cod *Macculochella peelii mariensis* (EPBC ”endangered”) (including deep pool habitats known to support large cod and also cod restocking sites) – significant impacts on existing populations, high quality habitat and restocking sites predicted • Queensland lungfish *Neoceratodus forsteri* (EPBC “vulnerable”) – major impacts on lungfish spawning grounds and movement predicted	• Mary River cod *Macculochella peelii mariensis* (EPBC ”endangered”) (Cambroon, Kidaman [important habitat for naturally reproducing populations and Obi Obi Creek habitat restoration sites], Amamoor, probably Borumba) – significant impacts on existing populations, high quality habitat (including inundation of habitat in Obi Obi Creek that continues to support wild populations) and restocking sites predicted • Queensland lungfish *Neoceratodus forsteri* (EPBC “vulnerable”) (Cambroon, Kidaman, probably Amamoor) – impacts on lungfish spawning grounds and movement predicted
Rare/threatened Stream-dependent Frogs Affected by Dam Pondage, Barrier or Downstream Effects	• Giant barred frog, *Mixophytes iteratus* (”endangered” EPBC & NCA) • Cascade treefrog, *Litoria pearsoniana* (”endangered” NCA) • Tusked frog, *Adelotus brevis* (“vulnerable” NCA) • Green-thighed frog, *Litoria brevipalmata* (“rare” NCA) – dam pondage area not surveyed but habitat suitable	• Southern gastric brooding frog, *Rheobatrachus silus* (“presumed extinct” EPBC, ”endangered” NCA) (Kidaman, Cambroon) • Southern day frog, *Taudactylus diurnus* (“presumed extinct” EPBC, “endangered” NCA) (Kidaman, Cambroon) • Giant barred frog, *Mixophyes iteratus* (“endangered” EPBC & NCA) – recorded in Kidaman and Cambroon, habitat in Amamoor and Borumba suitable • Fleay’s barred-frog, *Mixyophytes fleayi* (“endangered” EPBC & NCA) – Cambroon • Cascade treefrog, *Litoria pearsoniana* (“endangered” NCA) – Cambroon, Kidaman and Borumba, habitat suitable in Amamoor • Tusked frog, *Adelotus brevis* (“vulnerable” NCA) – Cambroon, Kidaman and Borumba, habitat suitable in Amamoor • Pouched frog, *Assa darlingtoni* (“rare” NCA) – Kidaman, Cambroon • Green-thighed frog, *Litoria brevipalmata* (“rare” NCA) – Kidaman, other dam sites (Cambroon, Borumba and Amamoor) not surveyed but habitat suitable

	Traveston Dam	**Four Dams (Including Coles Crossing Weir)**
Other Rare/threatened Stream-dependent Fauna Affected by Dam Pondage, Barrier or Downstream Effects	• Mary River turtle, *Elusor macrurus* ("endangered" EPBC & NCA; monotypic and endemic to Mary River) – significant impacts expected in Traveston Dam pondage and downstream reaches due to changes in geomorphological processes that maintain sand bars providing key nesting habitat (particularly between Traveston Dam and Six Mile Creek and potentially as far downstream as Munna Creek) • White-faced snapping turtle, *Elseya albigula* (currently being classified, expected to be listed as "vulnerable" NCA) – similar type of impacts as for Mary River turtle, but less specialised in breeding requirements • Red goshawk, Erythrotriorchis radiatus ("vulnerable" EPBC, "endangered" NCA) – loss of nesting habitat in dam pondage areas (typically nests in tall trees usually within 1 km of a river) •	• Mary River turtle, *Elusor macrurus* ("endangered" EPBC & NCA; monotypic and endemic to Mary River) – potentially significant impacts expected in Kidaman Dam, Cambroon Dam and Coles Crossing Weir pondages as well as in downstream reaches due to changes in geomorphological processes that maintain sand bars providing key nesting habitat (particularly upstream of Six Mile Creek and potentially as far downstream as Wide Bay Creek) • White-faced snapping turtle, *Elseya albigula* (currently being classified, expected to be "vulnerable" NCA) – Cambroon, Kidaman, Borumba, Amamoor – similar type of impacts as for Mary River turtle, but less specialised in breeding requirements • Red goshawk, *Erythrotriorchis radiatus* ("vulnerable" EPBC, "endangered" NCA) (Borumba, Cambroon) – loss of nesting habitat in dam pondage areas (typically nests in tall trees usually within 1 km of a river)
Other Key Issues in Dam Pondages	• Wide, shallow dam pondage • Greater risk of water quality issues, including turbidity, nutrients, contaminants (larger catchment with diverse uses; more intensive existing land use in dam pondage area; existing background levels of turbidity and nutrients already high, particularly in high flow events; potential occurrence of dispersive soils associated with Gympie Group lithology [soils investigation required to assess and quantify impact]) • Likely to support extensive aquatic plant growth including alien species • Algal blooms, including toxic blue–green algae, likely to occur	• Raising of an existing dam (Borumba) would cause lesser net environmental change than construction of a new dam; however, the area that would be inundated by an enlarged Borumba Dam pondage has significant ecological values • Borumba and Kidaman Dams will fragment a State Wildlife Corridor • Dams are likely to support extensive aquatic plant growth including alien species • Algal blooms, including toxic blue–green algae, likely to occur • Potentially dispersive subsoils in Cambroon Dam pondage associated with Permian lithology (soils investigation required to assess and quantify impact)

	Traveston Dam	Four Dams (Including Coles Crossing Weir)
Fish Passage Barrier Effects	• Traveston Dam would restrict access by migratory fish to a large area of catchment upstream (2,110 km^2), with major impacts on diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater mullet, bullrout, striped gudgeon) and potamodromous species (e.g. Mary River cod and lungfish)	• Cambroon and Amamoor Dam would restrict access by migratory fish (including diadromous and potamodromous species) to a total of 420 km^2upstream catchment areas • Raising of Borumba Dam would cause little change from the current situation with regard to fish passage in Yabba Creek due to the existing major barrier to upstream fish movement already caused by Borumba Dam • Kidaman Dam will restrict access by migratory fish (including potamodromous and diadromous species) to a small proportion of Obi Obi Creek upstream compared due to existing natural and artificial barriers (including Kondalilla Falls and Baroon Pocket Dam) • Coles Crossing Weir will restrict access by migratory fish (including potamodromous and diadromous species) but less so than Traveston Dam due to smaller wall height and likely more efficient fish passage device
Stream Length Affected by Major Flow Regime Change (one or more HF indicators <50%, median ann. Q<50% unsuppl. reaches)	• 70 km of Mary River, from Traveston Dam (AMTD 206.7 to d/s Fishermans Pocket–u/s Miva (say AMTD 136.5 – Wide Bay Ck confluence)	• ~100 km of stream length, including: • 67 km of Mary River (42 km from Cambroon Dam to Coles Crossing Weir pondage + 25 km from Coles Crossing Weir AMTD 212.4 to d/s Dagun Pocket–u/s Fishermans Pocket (say AMTD 187 – Six Mile Ck confluence) • 6.3 km of Obi Obi Creek • 19.2 km of Amamoor Creek • ~5–10 km of Yabba Creek
Downstream Impacts on Non-tidal Reaches	• There is a risk of clearwater erosion in the reach downstream of Traveston Dam, due to the alluvial nature of this part of the Mary River and proposed "high flow" releases to meet downstream environmental flow objectives • If the turbidity of dam releases is not significantly elevated, impacts of this scenario would be greatest in the reach closest to the new development (i.e. between Traveston Dam and Six Mile Creek) and would generally dissipate downstream – few impacts would be evident in the reaches downstream of Munna Creek • If the turbidity of dam releases is elevated (due to resuspension in the dam and the capture and slow release of high turbidity peak flows in low flow periods), significant ecological impacts are likely to persist downstream to the Mary Barrage.	• Significant geomorphological and ecological impacts are predicted in the Mary River system upstream of Coles Crossing Weir, including the Mary River (between Cambroon Dam and Coles Crossing Weir), Obi Obi Creek (between Kidaman Dam and the Mary River), Yabba Creek (particularly between Borumba Dam and Imbil) and Amamoor Creek (between Amamoor Dam and the Mary River). • Impacts on the Mary River would generally dissipate downstream of Coles Crossing Weir – few impacts would be evident in the reaches downstream of Wide Bay Creek •

	Traveston Dam	Four Dams (Including Coles Crossing Weir)
Summary of Impacts on Estuarine Reaches and Moreton Bay	• End of system flow – mean annual flow 86%, median 78% (of predevelopment) • This scenario would lead to incremental increases in water resource development impacts on all ecosystem components, but not of sufficient magnitude to cause a shift in overall condition ratings • Environmental flow provisions and inflows from tributaries downstream of Traveston Dam mean that medium and high flow events would continue to occur (albeit with reduced magnitude), maintaining natural behavioural cues for estuarine fish and invertebrates. • There would generally be relatively little impact on large floods that discharge significant riverine plumes into the Great Sandy Strait • The low flow regime (including flows in the Mary Barrage fishway) would continue to be determined by barrage operation (rather than Traveston Dam)	• End of system flow – mean annual flow 88%, median 82% (of predevelopment) • This scenario would lead to incremental increases in water resource development impacts on all ecosystem components, but not of sufficient magnitude to cause a shift in overall condition ratings • Environmental flow provisions and inflows from tributaries downstream of the new impoundments mean that medium and high flow events will continue to occur (albeit with reduced magnitude), maintaining natural behavioural cues for estuarine fish and invertebrates. • There would generally be relatively little impact on large floods that discharge significant riverine plumes into the Great Sandy Strait • The low flow regime (including flows in the Mary Barrage fishway) would continue to be determined by barrage operation (rather than upstream dams)

4.1 Traveston Dam

Dam pondage and upstream barrier effects of Traveston Dam are discussed in Section 4.1.1, downstream effects on the non-tidal reaches of the Mary River are discussed in Section 4.1.2 and effects on the Mary River estuary and Great Sandy Strait are discussed in Section 4.1.3. In each section, implications for condition and values, and relevant mitigation and compensation options are examined.

4.1.1 Dam Pondage and Upstream Barrier Effects

4.1.1.1 Implications for Condition and Values

Geomorphology and Hydraulic Habitat

- Traveston Dam would submerge 46 km of the Mary River, 16 km of Kandanga Creek and 11 km of Yabba Creek, plus parts of Coles Creek, Skyring Creek, Belli Creek and other smaller tributaries.
- Habitat types that would be submerged include riffles, pools, sand/gravel bars (particularly point and lateral bars), sand splay/low flow channel complexes, backwaters, benches, floodplains, river terraces and upslope habitats. Instream and bench habitats along the Mary River have been significantly modified by sand/gravel extraction in parts of the proposed Traveston Dam pondage area.
- The Traveston Dam pondage would be different from a natural lake due to greater variability in water levels resulting from dam operation.
- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes.
- The geology of the Traveston Dam pondage area is complex. Much of the pondage would cover Quaternary alluvial deposits associated with floodplains and river terraces. Bedrock formations include the Amamoor Beds (Devonian–Carboniferous sedimentary and metamorphic rocks), Kin Kin Beds (Triassic sedimentary rocks) and Gympie Group (Permian sedimentary and volcanic rocks). This will influence shoreline character and sediment inputs. The Gympie Group is associated with acid sodic subsoils (Peter Wilson NRW pers. comm.), with potentially significant implications for water quality, as discussed below under the heading “water quality”.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur. The different soils associated with the various geological formations are likely to vary in terms of their susceptibility to erosion and the nature of the sediment produced. Being a large storage, some parts of the pondage shoreline would be exposed to significant wind fetch.
- The banks of the Mary River are typically sandy and subject to erosion where the river flows through alluvium. Particularly in the middle and upper sections of the Traveston Dam impoundment, alluvial river banks would be exposed when the storage level is below FSL and subject to increased erosion risks due to weakening by prolonged wetting and loss of protective vegetation as a result of variable water levels (e.g. as observed in the Stanley River at the upstream end of Lake Somerset). A similar issue would apply to Yabba and Kandanga Creeks and several of the smaller tributaries, which also have alluvial banks that would be exposed when the Traveston Dam pondage is drawn down below FSL. Bank

erosion is a significant management issue in the Mary Barrage pondage, further downstream.

- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the Traveston Dam pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches. Sediment transport processes in the Mary River have already been significantly altered by instream sand/gravel extraction (Brizga et al. 2003, 2004).

Water Quality

- Elevated surface water temperature and thermal/chemical stratification is very likely, as the Traveston Dam pondage would be relatively shallow and hence subject to a high degree of solar radiation per megalitre of water (as shown by storage curves in Appendix A). Most other large dams in south-east Queensland are subject to stratification unless destratifiers are used.
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- Traveston Dam has a large catchment with extensive agricultural land use and several towns (including Imbil and Kandanga on the pondage shorelines), resulting in elevated inputs of sediment, nutrients and contaminants. NRW water quality monitoring data show that existing background levels of turbidity and nutrients (total P and total N) exceed ANZECC (2000) guidelines.
- There would also be nutrient release from former agricultural soils impounded by the dam pondage in the short to medium term. Most of the Traveston Dam pondage area would submerge cleared river flats currently used for agricultural purposes.
- Pollutants would potentially be released from submergence of contaminated sites, such as stock drenches and arsenic dips. Sites of potential contamination would need to be investigated for any dam option.
- Information provided by NRW indicates that there are three licensed point source inputs to the Mary River system upstream of Traveston Dam. Maleny sewage treatment plant (STP) is upstream of Lake Baroon and would be irrelevant to Traveston Dam because of processing and interception of inputs in Lake Baroon. The others are Kenilworth STP and a licensed point source just below Borumba Dam. These are potentially relevant to water quality in the Traveston Dam pondage.
- The Traveston Dam pondage would be at high risk of blue–green algal blooms, due to stratification processes and elevated nutrient inputs.
- Unnatural variability in DO is expected, including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.
- Water quality is particularly at risk of deterioration in sheltered arms of the dam pondage, due to limited circulation currents and agricultural runoff, particularly in the valleys of Kandanga and Yabba Creeks, which are also affected by local urban inputs.
- Turbidity of the Traveston Dam pondage would be significantly different to the natural or existing turbidity regime. Information on the composition of suspended load delivered to the dam pondage area and soil properties within the pondage area would be required to determine the likely direction and extent of change. Suspended load from turbid floodwaters stored by the dam may settle in the dam

pondage; alternatively it may be held in the water column by turbulent resuspension processes and additional inputs of suspended sediment may be generated by shoreline erosion and soil dispersion. Burdekin Falls Dam provides a clear example of how such processes can lead to a net increase in turbidity in the dam pondage, as well as downstream effects when turbid flow results from dam waters being released or spilled (Brizga et al. 2006c).

- Analysis of existing NRW turbidity data (as provided for the Mary Basin WRP environmental investigations – Brizga et al. 2004) shows a low flow mean of 7 NTU, high flow mean of 90 NTU and overall mean of 26 NTU at Dagun Pocket gauging station. The difference between the low flow and high flow means illustrates the existing flow-related variability in turbidity. The overall mean turbidity gives an indication of the likely averaging effect of the dam with regard to inflows, prior to any other changes associated with erosion, dispersion and settling processes, and microphyte blooms within the dam pondage.
- Some of the geological formations in the Gympie Group are associated with sodic subsoils, which are dispersive and would have implications for turbidity if submerged in the dam pondage area (Peter Wilson, NRW pers. comm.). However, the sodic soils associated with the Gympie Group are acidic so they are less dispersive than the sodic alkaline soils associated with Burdekin Falls Dam (Peter Wilson, NRW, pers. comm).
- From published geologic mapping (1:100,000 scale), the Gympie Group formations appear to occur in only a small proportion of the total pondage area, mainly in the Coles Creek and Belli Creek valleys. A targeted soils survey would be necessary to confirm the occurrence and extent of dispersive soils.
- If the occurrence of dispersive soils in the pondage area is not extensive, their impact on pondage water quality could potentially be mitigated by covering the affected area within the dam pondage, and ensuring that such soils are fully vegetated and/or suitably treated where they occur in the buffer zone. The possibility of avoiding submergence of dispersive soils by varying dam site location or FSL within the same general area should also be considered.
- If large areas of soil are exposed by dam drawdown due to the shallow nature of the storage, this would lead to elevated turbidity within the dam pondage by turbulent resuspension, even if soils are not dispersive. Storage curves indicate that drawdown to 2 m below FSL would expose 1,100 ha of soil and a similar area (to depth 4 m below FSL) would be subject to turbulent resuspension. The effects of turbulent resuspension processes can be observed in other shallow dam pondage areas – e.g. in the Bonnie Doon Arm of Lake Eildon (Victoria), high turbidity is caused by wave action and currents generated by power boats.
- High turbidity of dam waters is undesirable from an ecological viewpoint given that the natural ecosystems have evolved with relatively clear water, and also from a water supply viewpoint, as high turbidity makes microbiological treatment difficult.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Traveston Dam pondage, resulting in total loss of true riparian zone vegetation except at the upstream limits of the dam impoundment.
- The variable water level regime in the dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above

FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, lack of flood disturbance and lack of indigenous riparian propagules).

- Much of the dam pondage and buffer zone area for Traveston Dam is cleared agricultural or grazing land, but EPA mapping shows that remnant native vegetation in this area includes five REs, three of which have high conservation significance (one "endangered" [RE 12.3.1] and two of concern [RE 12.3.11 and RE 2.11.14]) (see Table 4.2, also refer to Appendix E for further details).
- RE 12.3.1 provides habitat for rare/threatened flora and fauna species. It is important for fruit-eating birds, many of which migrate seasonally from upland to lowland rainforest.
- A substantial linear remnant of "endangered" RE 12.3.1 occurs on Belli/Cedar Creeks. The headwaters are protected within the Mapleton Forest Reserve. The lower reach to the confluence of the Mary was rated as Priority 1 (Protecting and restoring reaches of regional conservation significance) in the Mary River Rehabilitation Plan (MRCCC 2001) due to its intactness, EVR species, VMA status, and representativeness of a functioning natural ecosystem. Impoundment of this area by Traveston Dam would lead to loss of riparian connectivity.
- RE 12.11.3 (Tall open forest generally with *Eucalyptus siderophloia*, *E. propinqua* on metamorphics ± interbedded volcanics) has a status of "not of concern" but is associated with plant species of conservation significance, including *Acomis acoma*, *Corchorus cunninghamii*, *Marsdenia coronata* and *Sophora fraseri*).
- Nine riparian and terrestrial plant species of conservation significance would be affected by Traveston Dam pondage, including four riparian species and five upslope species (Tables 4.3 to 4.5) (as per current knowledge).

Table 4.2 REs of conservation significance recorded or likely to occur within pondage areas or buffer zones of proposed Mary catchment dams[26]

			Mapped by EPA in Ponded Area or 200 m Buffer Zone				
RE Number	RE Description	Conservation Status[27]	Traveston Dam	Cambroon Dam	Kidaman Dam	Borumba Dam	Amamoor Dam
12.3.1	Gallery rainforest (notophyll vine forest) on alluvial plains	Endangered	✓		✓		✓
12.3.8	Swamps with Cyperus spp., Schoenoplectus spp. and Eleocharis spp.	Of concern		✓			
12.3.11	Eucalyptus siderophloia, E. tereticornis, Corymbia intermedia open forest on alluvial plains near coast	Of concern	✓	✓			✓
12.11.9	Eucalyptus tereticornis open forest on metamorphics ± interbedded volcanics. Higher altitudes	Of concern			✓28	✓29	✓30
12.11.14	Eucalyptus crebra, E. tereticornis woodland on metamorphic±interbedded volcanics	Of concern	✓	✓	✓	✓	✓
12.11.15	Woodland with Xanthorrhoea sp. on serpentinite	Of concern				✓31	
12.12.1	Simple notophyll vine forest usually with abundant Archontophoenix cunninghamiana (gully vine forest") on Mesozoic to Proterozoic igneous rocks"	Of concern			✓		
12.12.12	Araucarian complex microphyll vine forest on metamorphics ± interbedded volcanics; northern half of bioregion	Of concern		✓	✓	✓	

[26] Based on EPA Regional Ecosystems mapping and dam pondage and buffer zone outlines provided by NRW
[27] Vegetation Management Act (August 2003)
[28] In buffer zone and at edge of inundated area
[29] Small patches mostly in buffer zone
[30] Patches mostly in buffer zone
[31] Small patches in upper reaches, included in buffer

Table 4.3 Riparian[32] flora species of conservation significance listed under EPBC likely to be impacted by proposed Mary catchment dam pondages

Latin Name	Common Name	Status – EPBC	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Cambroon Dam	Kidaman Dam	Comments
Phaius australis		E	E					✓	Terrestrial orchid Creek banks
Plectranthus torrenticola		E	E					✓	Herb Along seasonal watercourses
Arthraxon hispidus		V	V				✓		Grass Found in sandy spits in damp areas
Floydia praealta	ball nut	V	V	✓	✓	✓	✓		Tree Riverine and lowland rainforest
Fontainea rostrata		V	V		✓	✓		✓	Small tree in riparian vineforests
Macadamia integrifolia	Queensland nut	V	V		✓	✓	✓	✓	Tree Vineforest, gullies
Macadamia ternifolia	small fruit macadamia	V	V			✓	✓	✓	Tree Araucarian vineforest
Quassia bidwillii	quassia	V	V		✓	✓		✓	Shrub Lowland rainforest edges
Romnalda strobilacea		V	V					✓	Shrub Riparian rainforest, floodplain
Syzygium hodgkinsoniae	red lilly pilly	V	V				✓	✓	Tree Riparian, fringing rainforest
Xanthostemon oppositifolius	penda	V	V	✓				✓	Tree Riparian rainforests

E: "endangered", V: "vulnerable"

[32] No aquatic flora species relevant to the Mary catchment proposed dam pondages are listed in EPBC

Table 4.4 Aquatic and riparian flora species of conservation significance listed under NCA but not EPBC likely to be impacted by proposed Mary catchment dam pondages

Latin Name	Common Name	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Cambroon Dam	Kidaman Dam	Recorded in Vicinity of Pondages	Comments
Vallisneria nana	ribbonweed	R	✓	✓	✓	✓	✓		Aquatic plant
Alyxia ilicifolia subsp. magnifolia	chain fruit	R		✓	✓		✓		Remnant rainforest or depauperate rainforest
Choricarpia subargentea	giant ironwood	R	✓	✓	✓		✓		Tree Araucarian vineforests and riparian zones
Corynocarpus rupestris subsp. *arborescens*		R	✓		✓				Small tree Microphyll vineforest
Paristolochia praevenosa	Richmond birdwing vine	R					✓		Vine in understorey of closed riparian forest
Senna acclinis		R		✓					Shrub Assoc with Eucalyptus grandis
Symplocos harroldii	hairy hazelwood	R			✓				Small tree Creek banks, wet sclerophyll
Thisma rodwayi		R						✓	Stream bank

R: “rare”

Table 4.5 Other flora species of conservation significance (not likely to occur within the aquatic or riparian zones, but found in affected REs and/or Herbrecs data) listed under EPBC and/or NCA likely to be impacted by proposed Mary catchment dam pondages

Latin Name	Common Name	Status – EPBC	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Cambroon Dam	Kidaman Dam	Recorded in Vicinity of Pondages	Comments
Cosinia australiana	cossinia	E	E						✓	Small tree Araucarian microphyll vineforest
Macrozamia pauli-guilielmi	pineapple zamia	E	E						✓	Cycad Open Eucalypt forest
Plectranthus omissus		E	E		✓					Herb Rocky outcrops
Pouteria eerwah	shiny –leaved coondoo	E	E		✓	✓		✓		Tree
Triunia robusta[33]		E	E					✓		Shrub Notophyll vineforest
Baloghia marmorata	Jointed baloghia	V	V						✓	Small tree Microphyll–notophyll mixed closed forests
Cryptocrya foetida	stinking cryptocarya	V	V						✓	Tree Rainforest
Fontainea venosa	fontainea	V	V						✓	Small tree Araucarian microphyll vineforest
Marsdenia coronata		V	V	✓	✓	✓	✓	✓		Wiry twiner in scrubby Eucalypt forest
Sophora fraseri		V	V	✓	✓	✓	✓	✓		Shrub
Thesium australe	Austral toadflax	V	V			✓				Herb Open forest on hillslopes

[33] Previously believed to be extinct

Latin Name	Common Name	Status – EPBC	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Cambroon Dam	Kidaman Dam	Recorded in Vicinity of Pondages	Comments
Prostanthera palustris			V						✓	Shrub Open eucalypt forest with rainforest elements
Ricinocarpos speciosus			V						✓	Shrub Open and rain forests
Acomis acoma			R	✓	✓	✓	✓	✓		Understorey shrub in open forest & Araucarian notophyll vineforest
Atalaya rigida			R		✓	✓				Tree Araucarian vineforest
Gossia inophloia			R					✓		Small tree Complex notophyll vineforest
Macrozamia longispina			R						✓	Trunkless cycad Open Eucalypt forest
Nothoalsomitra suberosa			R	✓		✓		✓		Tendril climber in notophyll vineforest
Papililabium beckleri			R				✓	✓		Epiphyte
Picris conyzoides			R	✓			✓	✓		Herb

E: "endangered", V: "vulnerable" and R: "rare"

Aquatic Vegetation

- Aquatic macrophytes are abundant in the Mary River upstream of Traveston Crossing. Given the broad shallow form of the pondage (Appendix A – storage curves), “dendritic” configuration with long narrow arms, relatively high nutrient concentrations and warm water temperatures (particularly near the surface), aquatic macrophytes could be expected to thrive in the Traveston Dam pondage, provided that the water does not become excessively turbid. However, high turbidity would not limit the growth of nuisance floating species.
- Potential problematic (native) species include *Hydrilla verticillata*, which is problematic in Somerset Dam, and pondweeds (*Potamogeton* spp.). Alien species that may be problematic include salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornia crassipes*), which can form nuisance populations in water storages. *Cabomba caroliniana* (cabomba), a declared Class 2 weed, is present in the nearby Lake MacDonald (Six Mile Creek catchment) and could therefore become established in Traveston Dam pondage, either through dispersal by waterfowl or anthropogenic activities. Cabomba has been associated with tainting of water which increases the cost of treatment (Mackey 1996).
- *Vallisneria nana* (“rare” NCA), occurs throughout the Mary River. It occurs in greater abundances in the Mary River than in the Logan or Albert Rivers. In south-east Queensland this species is commonly found in flowing water. It also occurs in still water and would therefore be expected to persist in the dam pondage, particularly in shallow backwaters but could potentially colonise deep-water habitats (dependent upon light availability), as this species is recorded as having leaf lengths of up to 6 m. Lungfish are known to spawn in *V. nana* beds.
- Experience in North Pine Dam, which has shallow sheltered arms affected by extensive growths of aquatic vegetation, indicates that when water levels fall and aquatic vegetation dies and rots, releasing nutrients into the dam water, there are sudden switches in food web structure, from a mixed diet of aquatic plant material and invertebrates when macrophytes are abundant, to carnivory (invertebrates and small fish) when macrophytes die off. For example, this has been observed for the omnivorous spangled perch.

Macroinvertebrates

- Macroinvertebrate communities in the Traveston Dam pondage would be significantly different to natural for this part of the river system in terms of diversity and composition due to changes in habitat, water quality and food resources.
- Habitats in the dam pondage would be unfavourable to edge-zone species of macroinvertebrates (due to variable water levels and lack of stable vegetation communities) and obligate-lotic species would be eliminated (due to lack of shallow, running water habitat).
- Much of the dam pondage area would also be unfavourable to pool macroinvertebrate species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.
- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms, chironomid larvae).

- If abundant macrophyte growth occurs in shallow parts of the dam pondage and backwater arms (as discussed above), macroinvertebrate species favoured by macrophytes would increase in abundance in these areas (e.g. grazer invertebrates) as well as fish that use plants for cover and spawning sites.
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of Traveston Dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Several species of freshwater spiny crayfish occur in the Mary catchment (including the giant spiny crayfish *Euastacus urospinosus*, which is listed in the IUCN Redbook); however, their known range is limited to altitudes above 240 m, hence they are not expected to occur in the reaches that would be impounded by Traveston Dam.

Fish

- Two fish species of conservation significance would be affected by impoundment and barrier effects of Traveston Dam (Mary River cod, *Macculochella peelii mariensis* and Queensland lungfish, *Neoceratodus forsteri* – Table 4.6) – both these species are native to the Mary catchment and have very restricted natural ranges in south-east Queensland.
- Mary River cod restocking sites would be inundated by the Traveston Dam impoundment.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely to favour a subset of fish species capable of surviving in impounded waters, including gambusia and swordtail, which are already present in this part of the Mary River. Warm, shallow, well-vegetated water in the sheltered arms of the pondage would be particularly favourable for these alien species.
- The reduction in availability of lotic habitat is expected to affect many species that commonly use shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already restricted by downstream weirs (Mary Barrage and Gympie Weir).
- Traveston Dam (wall height 30 m)would cause a major barrier to longitudinal fish movements. Without an effective fish passage device it would sever access by diadromous species to 2,110 km^2 of catchment upstream of the dam, and restrict the movement of several potamodromous species, including Mary River cod and lungfish (see Appendix C for a list of migratory fish species relevant to Traveston Dam).
- High quality fish habitats are present in the upper Mary River and key tributaries upstream of Traveston Dam (e.g. Little Yabba Creek, Obi Obi Creek and Kandanga Creek). These provide important areas for spawning, development and refuge for Mary River cod and lungfish. In particular, these areas contain important deep pool habitat known to support large cod and lungfish, naturally

reproducing populations of Mary River cod (particularly Obi Obi Creek), many Mary River cod restocking sites and important habitat restorations sites (Obi Obi Creek).

Table 4.6 Stream-dependent fauna species listed under EPBC likely to be impacted by proposed Mary catchment dam/weir pondages

Latin Name	Common Name	Status – EPBC	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Kidaman Dam	Cambroon Dam	Coles Crossing Weir
FISH									
Neoceratodus forsteri	Lungfish	V		✓	likely to be present	possibly present	✓	✓	✓
Maccullochella peelii mariensis	Mary River Cod[34]	E		✓	✓	likely to be present	✓	✓	✓
AMPHIBIANS									
Rheobatrachus silus	Southern gastric brooding frog	PE	E				✓	✓	
Taudactylus diurnus	Southern day frog	PE	E				✓	✓	
Mixophyes iteratus	Giant barred frog	E	E	✓	possibly present[35]	possibly present[36]	✓	✓	possibly present[37]
Mixophyes fleayi	Fleay's barred-frog	E	E					✓	
REPTILES									
Elusor macrurus	Mary River turtle	E	E	✓			✓	✓	✓
BIRDS									
Erythrotriorchis radiatus	Red goshawk	V	E	✓		✓		✓	

PE: "presumed extinct", E: "endangered", V: "vulnerable" and R: "rare"

[34] Also listed in IUCN Red List 2006
[35] Upper rainforest gullies not thoroughly surveyed, habitat suitable
[36] Upper rainforest gullies not thoroughly surveyed, habitat suitable
[37] Upper rainforest gullies not thoroughly surveyed, habitat suitable

Other Vertebrates

- Tables 4.6 to 4.9 identify other vertebrate species of conservation significance that are likely to be affected by the Traveston Dam pondage.
- The Traveston Dam pondage would reduce habitat suitability for riverine species: stream-dependent frogs (including the "endangered" giant barred frog and cascade treefrog, "vulnerable" tusked frog and "rare" green-thighed frog) and turtles (including the "endangered" Mary River turtle and the white-faced snapping turtle) would be particularly affected.
- Turtles being washed over the dam wall during flood events would be seriously injured and/or sustain fatal injuries. This would decrease the turtle population.
- The "vulnerable/endangered" red goshawk would also be adversely affected by conversion of riverine habitat to dam pondage habitat, as it nests in tall trees usually within 1 km of a river.
- Populations of waterbirds would increase (potentially including the "rare" black-necked stork and "rare" cotton pygmy goose as well as species listed in CAMBA and JAMBA). Waders would be favoured by shallow-water habitats and associated algal growth, cladosorans, worms and oligochaetes.
- The migration of landbirds is likely to be impacted by Traveston Dam[38].
- Habitat for terrestrial vertebrate species would be reduced and these species would be expected to retreat to upslope habitats.

4.1.1.2 Mitigation Options

Key mitigation and compensation measures relevant to the impoundment and barrier effects of Traveston Dam are presented in Table 4.10. The mitigation measures would address a wide range of environmental issues associated with the dam, but would not prevent the occurrence of major/very major changes to existing ecosystems within the dam pondage area. Hence, rehabilitation/restoration of equivalent habitats outside the dam pondage area is identified as being an appropriate compensation measure.

[38] Subtropical areas of eastern Australia are host to both winter migrants that breed further south during summer and summer migrants that spend winter in northern Queensland and New Guinea. South-east Queensland supports a high regional diversity of landbird species due in part to a seasonal turnover of different species.

Many of the winter migrants are small-bodied, foliage-feeding species that include honeyeaters, pardalotes, fantails and whistlers and mainly use remnant lowland forests rather than larger tracts of reserved forest at higher elevations on the region's mountain ranges. River courses and large remnants of native vegetation have been identified as significant migration routes or stopover points in the movement patterns of several landbird species.

As the Mary River runs north–south, it would be an important corridor for north–south migrating birds both in terms of navigation and rest stops. The further apart the fragments, the harder to navigate and refuel.

Non-migratory species are known to move between habitats within the region, e.g. silvereye. Any reductions or modifications to remnant vegetation would result in loss of habitat for migratory and sedentary species and associated population reduction.

(Based on Clarke et al. 1999 and Farmer et al. 2004)

Table 4.7 Other fauna species listed under EPBC likely to be impacted by proposed Mary catchment dam/weir pondages

Latin Name	Common Name	Status – EPBC	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Kidaman Dam	Cambroon Dam	Coles Crossing Weir
BIRDS									
Dasyornis brachypterus monoides	Eastern Bristlebird (northern)	CE	E					✓	
Turnix melanogaster	Black-breasted button quail	V	V			✓			
Cyclopsitta diophthalma coxeni	Coxen's Fig Parrot	E	E				✓	✓	
MAMMALS									
Potorous tridactylus tridactylus	Long-nosed potoroo	V	V			✓			
Dasyurus maculatus maculatus	Spotted-tailed quoll (southern species)	E	V	✓					
Petrogale penicillata	Brush-tailed rock-wallaby	V	V						

CE: "critically endangered", E: "endangered", V: "vulnerable"

Table 4.8 Stream-dependent fauna species listed under NCA but not EPBC likely to be impacted by proposed Mary catchment dam/weir pondages

Latin Name	Common Name	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Kidaman Dam	Cambroon Dam	Coles Crossing Weir
AMPHIBIANS								
Litoria pearsoniana	Cascade treefrog	E	✓	area not surveyed, habitat suitable	✓	✓	✓	✓
Adelotus brevis	Tusked frog	V	✓	area not surveyed, habitat suitable	✓	✓	✓	✓
Assa darlingtoni	Pouched frog	R				✓	✓	
Litoria brevipalmata	Green-thighed frog	R	area not surveyed, habitat suitable	area not surveyed, habitat suitable	area not surveyed, habitat suitable	✓	area not surveyed, habitat suitable	area not surveyed, habitat suitable
REPTILES								
Elseya sp. aff. dentata (Elseya albigula)	White-faced snapping turtle	Currently being classified Expected to be ”vulnerable”(C. Limpus, pers. comm.)	✓	✓	✓	✓	✓	✓

E: “endangered”, V: “vulnerable” and R: “rare”

Table 4.9 Other fauna listed under NCA likely to be impacted by proposed Mary catchment dam/weir pondages

Latin Name	Common Name	Status – NCA	Traveston Dam	Amamoor Dam	Borumba Dam	Kidaman Dam	Cambroon Dam	Coles Crossing Weir
BIRDS								
Glossy black cockatoo (eastern)	*Calyptorhynchus lathami lathami*	V			✓		✓	
Plumed frogmouth	*Podargus ocellatus plumiferus*	V			✓	✓	✓	
Black-necked stork	*Ephippiorhynchus asiaticus*	R	✓					
Red-browed treecreeper	*Climacteris erythrops*	R					✓	
Black-chinned honeyeater	*Melithreptus gularis*	R	✓		✓			
Cotton pygmy goose	*Nettapus coromendlianus*	R	✓					
Sooty owl	*Tyto tenebricosa*	R			✓		✓	
Grey goshawk	*Accipiter novaehollandiae*	R			✓		✓	
REPTILES								
Elf skink	*Eroticoscincus graciloides*	R			✓	✓		
Stephens' banded snake	*Hoplocephalus stephensii*	R					✓	
MAMMALS								
Koala	*Phascolarctos cinereus*	V			✓	✓	✓	
BUTTERFLIES								
Richmond birdwing butterfly	*Ornithoptera richmondia*	V				✓		

E: "endangered", V: "vulnerable" and R: "rare"

Table 4.10 Key mitigation and compensation measures relevant to impoundment and barrier effects of Traveston Dam

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats outside dam pondage area	• Further investigations are required to identify suitable sites. • Possible areas include other parts of the Mary River, other adjacent major rivers (i.e. Burnett and Brisbane – modified to a greater degree than the Mary), and other tributaries of the Mary River that share similar characteristics to the ones impounded (e.g. Amamoor Creek is a possibility due to similarities with Kandanga Creek).	Varies, depending on existing condition, standard of rehabilitation/ restoration and level of community commitment. Likely to be high for mainstream reaches comparable to the parts of the Mary River, Yabba Creek and Kandanga Creek that would be impounded by Traveston Dam, as these are generally subject to significant disturbance due to a range of human activities.
"No net loss of habitat" – replacement of Mary River cod restocking sites	• Investigations would be required to identify other sections of the Mary River system suitable for cod restocking	Depends on existence of suitable sites – ranges from low if suitable sites exist, to high if habitat restoration is required before cod restocking
Detention dams along pondage margins to maintain stable aquatic habitat during main storage drawdown	• The wide shallow margins of Traveston Dam make the lack of stable edge habitat particularly significant in this instance.	Low
Vegetated buffer zone above FSL to maintain corridors for movement of terrestrial species	• Could be achieved by retention and enhancement of existing native vegetation (where present) and revegetation of 200 m buffer zone around dam pondage with appropriate indigenous species. • As with any revegetation works, proper site preparation and ongoing maintenance are necessary for a successful outcome.	At least medium due to ongoing maintenance and weed suppression activities required.
Buffer zone between assets and erosion risk zone	• A 200 m buffer zone has already been identified in the SEQ Water Supply Strategy investigations as an integral component of the Traveston Dam scenario. • It is desirable for this zone to be vegetated/revegetated with native vegetation from the viewpoint of water quality and ecological values.	Low (to reserve a buffer zone). The level of difficulty of maintaining a vegetated buffer zone is at least medium, as indicated above.
Drainage management of surface runoff to avoid concentration of flows onto exposed shorelines and hence mitigate risks of subaerial erosion	• Soil erosion risks and local drainage issues for the dam pondage shorelines would need to be investigated at the design stage.	Low difficulty from technical viewpoint, but long shoreline may present major costs
Destratifiers in dam pondage (e.g. bubblers, impellers) would mitigate risks associated with stratification, such as blue–green algal blooms	• Complex "dendritic" shape of pondage, sheltered arms and large surface area would make it difficult to establish effective circulation currents. • Multiple mixing mechanisms would be required.	High

Mitigation or Compensation Measure	Comments	Level of Difficulty
Catchment land use controls (including WSUD in urban areas and rural land use controls) and buffer zones along streams and on drainage lines to minimise inputs of nutrients and other contaminants	• Large catchments with a mix of rural and urban uses. • Towns on lake shoreline (runoff is discharged into sheltered arms that would have longer retention times than the main pondage).	High
Improve water quality from point sources (or reduce/eliminate point source inputs)	• Higher treatment standards for STPs. • Water quality treatment of town drainage lines and main rural drains	Unknown – point source management is relatively easy if obvious discrete polluting influences are identified. More diffuse sources of pollutants in a large catchment are very difficult to manage
Cover areas of dispersive soils within dam pondage area with non-dispersive fill	• Soils surveys would be required to determine the extent of works required. • Unlikely to be feasible for large areas	Depends on the extent of dispersive soils. Low level of difficulty for a small area, may not be feasible if large areas are affected
Measures to control excessive macrophyte growth (e.g. mechanical harvesting)	• Monitoring and adaptive management. • Extensive macrophyte growth is highly likely	Low to medium. Ongoing management required as harvested biomass can be quickly replaced.
Education, signage, boat washing facilities at storages with pest plant species to mitigate risks of transmission of these species into Traveston Dam pondage	• Cambomba is present in Six Mile Creek Dam pondage (Lake MacDonald)	Medium. Whilst cheap and simple to implement, extensive community support is required for a successful outcome.
Install fish lock/lift on Traveston Dam	• Would mitigate some impacts on fish movement including diadromous and potamodromous species, maintaining access to much of the 2,110 km^2 of catchment area upstream of Traveston Dam (some parts are already inaccessible due to natural barriers and existing dams). • Likely to be more effective in enabling upstream movements than downstream movements. • Fish lock/lift would require sufficient flow allocations to render it effective for allowing fish passage.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though large dam pondage is problematic.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Installation and effective operation of fishways on existing infrastructure located downstream (i.e. Mary Barrage, Gympie Weir) to maintain access by diadromous and potamodromous fish species	• Compensation measure for reduction in fish passage due to Traveston Dam • The Mary Barrage has an existing fishway that appears to be operating effectively when sufficient flow allocations to render it effective for allowing fish passage are provided. Further design modifications have been recommended (Berghuis and Pilz 2005), which, if implemented, should further improve fish passage. • Gympie Weir currently does not have a fishway and so forms a barrier to movement during low flow periods.	Low
Provision of artificial lungfish spawning sites (floating mats of aquatic vegetation) if there is limited colonisation of shallow-water habitat in the dam pondage by Vallisneria[39]	• Has not been trialled yet, so uncertain whether this option would be effective for allowing lungfish spawning and successful recruitment. • Monitoring and adaptive management would be required.	Low to install floating mats of vegetation, but effectiveness for lungfish spawning and recruitment unknown.
Boat traffic restrictions to mitigate boating impacts on dam pondage	• Turbulent resuspension processes are likely to be significant if boat traffic uses shallow water areas. • Management options including restricting boat traffic to deep parts of the dam pondage and/or leaving tree spars in shallow zones to discourage high speed boating.	Low, but requires community support
Develop/review and implement species recovery plans for EVR species	• EVR species that would be significantly affected by Traveston Dam include the Mary River turtle, Mary River cod, Queensland lungfish, and “endangered” frogs	Depends on standard of outcome and types of measures required. Usually high.

4.1.2 Downstream Effects on Non-tidal Reaches

4.1.2.1 Implications for Condition and Values

- The Mary River between the Traveston Dam site and the Mary Barrage spans six assessment reaches and the lower part of a seventh assessment reach, as defined for the Mary Basin WRP environmental investigations (Brizga et al. 2004).
- As water would be extracted directly from Traveston Dam, it would lead to reductions in low, medium and high flows downstream. Environmental flow provisions (including baseflow releases and an annual medium/high flow release) will mitigate some of these impacts.
- Flora and fauna of conservation significance supported by these reaches include the “rare” giant ironwood (*Choricarpia subargentea*) and ribbonweed (*Vallisneria nana*), Mary River cod, Queensland lungfish and Mary River turtle (Brizga et al. 2004) (Tables 4.11 to 4.14).

[39] Suggested by Professor Jean Joss

Table 4.11 Riparian[40] flora species listed under EPBC recorded or likely to occur in non-tidal reaches downstream of proposed dams

Latin Name	Common Name	Status – EPBC	Status – NCA	Mary River D/s Traveston Dam to Mary Barrage	Mary River D/s Cambroon Dam to Coles Crossing Weir	Mary River D/s Coles Crossing Weir to Mary Barrage	Obi Obi Ck D/s Kidaman Dam	Yabba Ck D/s Borumba Dam	Amamoor Ck D/s Amamoor Dam
Phaius australis		E	E						
Plectranthus torrenticola		E	E		✓				
Arthraxon hispidus		V	V		✓		✓		
Floydia praealta	ball nut	V	V						
Fontainea rostrata		V	V						
Macadamia integrifolia	Queensland nut	V	V				✓		
Macadamia ternifolia	Small fruit macadamia	V	V				✓		
Quassia bidwillii	Quassia	V	V				✓		
Romnalda strobilacea		V	V				✓		
Syzygium hodgkinsoniae	red lilly pilly	V	V				✓		
Xanthostemon oppositifolius	penda	V	V						

E: "endangered", V: "vulnerable" and R: "rare"
(Based on Brizga et al. 2004 and more recent information)

[40] No aquatic flora species relevant to the reaches downstream of the Mary catchment proposed dam pondages are listed in EPBC

Table 4.12 Aquatic and riparian flora species listed in NCA but not EPBC recorded or likely to occur in non-tidal reaches downstream of proposed Mary catchment dams

Latin Name	Common Name	Status – NCA	Mary River D/s Traveston Dam to Mary Barrage	Mary River D/s Cambroon dam to Coles Crossing Weir	Mary River D/s Coles Crossing Weir to Mary Barrage	Obi Obi Ck D/s Kidaman Dam	Yabba Ck D/s Borumba Dam	Amamoor Ck D/s Amamoor Dam
Vallisneria nana	ribbonweed	R	✓	✓	✓	?	✓	✓
Alyxia ilicifolia subsp. magnifolia	chain fruit	R						
Choricarpia subargentea	giant ironwood	R	✓	?	✓		✓	✓
Corynocarpus rupestris subsp. *arborescens*		R		?				
Paristolochia praevenosa	Richmond birdwing vine	R						
Senna acclinis		R						
Symplocos harroldii	hairy hazelwood	R					✓	
Thisma rodwayi		R						
Austromyrtus inophloia	thread-barked myrtle	R				✓[41]		
Cupaniopsis newmanii	long-leaved tuckeroo	R				✓[42]		

E: "endangered", V: "vulnerable" and R: "rare"

[41] Noted by Werren (in Brizga et al. 2003). No Herbrecs record.
[42] Noted by Werren (in Brizga et al. 2003). Single record 2004 Herbrecs Kin Kin Creek.

Table 4.13 Stream dependent fauna species listed under EPBC recorded or likely to occur in non-tidal reaches downstream of proposed dams

Latin Name	Common Name	Status – EPBC	Status – NCA	Mary River D/s Traveston Dam to Mary Barrage	Mary River D/s Cambroon dam to Coles Crossing Weir	Mary River D/s Coles Crossing Weir to Mary Barrage	Obi Obi Ck D/s Kidaman Dam	Yabba Ck D/s Borumba Dam	Amamoor Ck D/s Amamoor Dam
FISH									
Neoceratodus forsteri	Lungfish	V		✓	✓	✓	✓	✓	? (likely)
Maccullochella peelii mariensis	Mary River Cod	E		✓	✓	✓	✓	✓	✓
AMPHIBIANS									
Rheobatrachus silus	Southern gastric brooding frog	PE	E						
Taudactylus diurnus	southern day frog	PE	E						
Mixophyes iteratus	giant barred frog	E	E		habitat suitable, not yet surveyed				habitat suitable, not yet surveyed
Mixophyes fleayi	Fleay's barred-frog	E	E						
REPTILES									
Elusor macrurus	Mary River turtle	E	E	✓	✓	✓	?	✓	?
BIRDS									
Erythrotriorchis radiatus	red goshawk	V	E		✓				

PE: "presumed extinct", E: "endangered", V: "vulnerable" and R: "rare"

Table 4.14 Stream-dependent fauna species listed under NCA recorded or likely to occur in non-tidal reaches downstream of proposed dams

Latin Name	Common Name	Status – NCA	Mary River D/s Traveston Dam to Mary Barrage	Mary River D/s Cambroon Dam to Coles Crossing Weir	Mary River D/s Coles Crossing Weir to Mary Barrage	Obi Obi Ck D/s Kidaman Dam	Yabba Ck D/s Borumba Dam	Amamoor Ck D/s Amamoor Dam
AMPHIBIANS								
Litoria pearsoniana	cascade treefrog	E		✓				habitat suitable, not yet surveyed
Adelotus brevis	tusked frog	V		✓				habitat suitable, not yet surveyed
Assa darlingtoni	pouched frog	R						
Litoria brevipalmata	green thighed frog	R		habitat suitable, not yet surveyed				habitat suitable, not yet surveyed
REPTILES								
Elseya sp. *aff. dentata (Elseya albigula)*	White-faced snapping turtle	Currently being classified Expected to be "vulnerable" pers. comm. C. Limpus	✓	✓	?	?	✓	?

E: "endangered", V: "vulnerable" and R: "rare"

Geomorphology

- The geomorphology of the Mary River between the Traveston Dam site and the Mary Barrage pondage currently shows **minor** to **moderate** change from reference condition, largely due to land use influences and instream sand/gravel extraction. **Major** change from reference condition has occurred in the Mary Barrage pondage. There is extensive evidence of bank erosion and slumping, particularly upstream of Gympie and in the Mary Barrage pondage.
- In the Traveston Dam scenario, the reach between Traveston Dam and Six Mile Creek would show **very major** change from reference condition (compared to **minor/moderate** at present), reflecting impacts of flow regime change as well as barrier effects of Traveston Dam on sediment supply, which would lead to bed armouring and potentially clearwater erosion. Clearwater erosion is rare downstream of dams in south-east Queensland, which do not usually make high flow releases. The high flow releases from Traveston Dam, combined with the alluvial banks and substrate, would put the downstream river channel at increased risk of clearwater erosion, which would aggravate the erosion and bank slumping processes that are already apparent. It may be possible to limit impacts to **major** (rather than **very major**) change from reference condition with suitable mitigation measures, as discussed below in Section 4.1.2.2.
- Further downstream, impacts would decrease to **major** change from reference condition in the reaches between Six Mile Creek and Glastonbury Creek (compared to **moderate** in the Gympie town reach and **minor** further downstream at present), **moderate** change from reference condition between Glastonbury Creek and Munna Creek (currently **minor**) and would remain at **minor** change from reference condition below Munna Creek to upstream of the Mary Barrage pondage (i.e. same as existing condition)
- Impacts of Traveston Dam would include reductions in fluvial processes and sediment transport, as well as channel contraction, probably mainly by accommodation adjustment involving vegetation encroachment. Channel contraction would have implications for sand bar habitat used for Mary River turtle breeding, particularly in the reaches closest to the dam but discernible impacts may potentially extend as far downstream as Munna Creek confluence. Vegetation establishment on instream islands would be likely to exacerbate bank erosion processes by diversion of flow currents towards the bank zone.
- Changed hydraulic interactions with tributary streams may possibly lead to increased risk of tributary erosion as a result of steepening of flood gradients due to reductions in tailwater support, particularly in the reaches closest to the dam.

Hydraulic Habitat

- Hydraulic habitat in the Mary River between the Traveston Dam site and the Mary Barrage pondage currently shows **moderate** (upstream of Eel Creek) to **minor** (downstream of Eel Creek) change from reference condition, reflecting the impacts of geomorphological changes (as summarised above) and modifications to the low flow regime arising from existing water resource development. **Very major** change from reference condition has occurred in the Mary Barrage pondage due to impoundment effects and truncation of tidal influence.
- In the Traveston Dam scenario, the reach between Traveston Dam and Six Mile Creek would show **major** change from reference condition, reflecting impacts of changes in flow regime due to upstream dams, including reductions in low,

medium and high flows, with resulting reductions in low flow habitat on riffles, pool flushing and lateral connectivity to floodplain, bench and bar habitats.
- Ratings for the reaches between Six Mile Creek and Wide Bay Creek would show **moderate** change from reference condition (compared to present ratings of **moderate** in the Gympie town reach and **minor** downstream), and stay as **minor** change from reference condition below Munna Creek to the upstream of the Mary Barrage pondage.

Water Quality

- The water quality in the Mary River between the Traveston Dam site and the Mary Barrage pondage currently shows **moderate** (upstream of Glastonbury Creek) to **minor** (downstream of Glastonbury Creek) change from reference condition, mainly reflecting influences of rural and urban land use pressures. **Major** change has occurred in the Mary Barrage pondage.
- In the Traveston Dam scenario, the reach from Traveston Dam to Six Mile Creek would show **very major** change from reference condition, due to impacts of the dam pondage on water quality, inputs of blue–green algae and potential hypolimnetic releases. Some of these impacts could be mitigated using devices such as destratifiers and multilevel offtakes, as discussed below, potentially reducing impacts to **major**.
- Implications for reaches further downstream of Six Mile Creek to the Mary Barrage depend on whether or not outflows from Traveston Dam are turbid
- If outflows from Traveston Dam are not turbid, no changes to overall condition ratings would occur as a result of this scenario, but impacts of water resource development would increase. The reaches between Coles Crossing Weir and Glastonbury Creek would continue to show **moderate** change from reference condition, but with increased impacts resulting from water resource development, including long-term trends in nutrients and DO as a result of the build-up of organic matter in pools due to reduced flushing by floods. The reaches between Glastonbury Creek and upstream of the Mary Barrage pondage would continue to show **minor** change from reference condition.
- If outflows from Traveston Dam are significantly turbid, **major** impacts on water quality would persist downstream through all the freshwater reaches to the Mary Barrage outflow, where the salinity of the estuarine waters would cause flocculation of the suspended sediment.

Riparian Vegetation

- The riparian vegetation of the Mary River between the Traveston Dam site and the Mary Barrage pondage currently transitions from **very major** change from reference condition (Traveston Dam site to Six Mile Creek), through **major** (between Six Mile Creek and Wide Bay Creek), to **moderate** (Wide Bay Creek to upstream of Mary Barrage pondage) as a result of structural disruption and weed invasion, mainly due to land use pressures. **Major** change has occurred in the Mary Barrage pondage.
- No changes to overall riparian vegetation condition ratings would occur in the reaches of the Mary River downstream of Traveston Dam as a result of the Traveston Dam scenario, because of the high degree of disturbance that has already occurred in the reaches that would be most greatly affected by flow regime change resulting from the dam.

- However, impacts of water resource development would increase, including invasion of the riparian zone by more xeric species and downslope changes in species distribution within bank zonations, with an associated increase in fire risk. Grasses and woody vegetation would shift instream across sand/gravel bars in response to reduced flood disturbance. These effects would diminish with increasing distance downstream of Traveston Dam.
- “Flexible” bank toe species (such as weeping bottlebrush, *Callistemon viminalis*) are likely to be replaced with “stiff” species that naturally occur on the floodplain and on the top of the high bank to the middle bank zone (such as forest redgum, *Eucalyptus tereticornis*). The change in the structure of the plant, both above and below ground, is likely to increase bank susceptibility to erosion.

Aquatic Vegetation

- Aquatic vegetation in the Mary River between the Traveston Dam site and the Mary Barrage pondage currently shows **moderate** change from reference condition (except in the Gympie town reach, where **major** change is apparent), reflecting influences of land use factors and existing water resource development. **Very major** change has occurred in the Mary Barrage pondage.
- Vegetation response to the effects of Traveston Dam will depend on the turbidity of outflows from the dam.
- If the water in Traveston Dam pondage is not highly turbid, there would be encroachment of emergent species, including terrestrial weeds, in response to reductions in flows. Higher nutrient levels and reduced flood disturbance would promote increased macrophyte growth and biomass. Shallower pools are likely to support increased growth of submerged macrophytes such as *Hydrilla* sp. and *Potomageton crispus*. Dense growths of *Azolla* sp. are currently present in this section of the river (M. Connell, pers. obs.). A shift to **major** change from reference condition is predicted to occur between Traveston Dam and Six Mile Creek. Similar types of changes but of a lesser magnitude are expected to also occur further downstream (diminishing in magnitude with distance from Traveston Dam), but are not expected to lead to shifts in overall condition ratings, which already indicate significant change from reference condition.
- If the water in Traveston Dam pondage (and hence downstream spills and releases) is chronically highly turbid, this would lead to reductions in the growth of submerged macrophytes due to light limitation, potentially leading to a shift to **very major** change from reference condition through all the non-tidal reaches of the Mary River between Traveston Dam and the Mary Barrage.

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in the Mary River between the Traveston Dam site and the Mary Barrage pondage currently show **moderate** (Traveston Dam site to Munna Creek) to **minor** (Munna Creek to upstream of Mary Barrage pondage) change from reference condition, reflecting impacts of land use pressures and existing water resource development. **Major** change has occurred in the Mary Barrage pondage.
- In the Traveston Dam scenario, the overall condition rating for the reach between Traveston Dam and Eel Creek would increase to **major** change from reference condition, reflecting changes in flow regime, instream habitats and water quality (and consequent changes in food resources), and reductions in POM and drift due

to barrier effects of Traveston Dam. Effects would be more significant if the outflows from the dam are turbid.

- If outflows from Traveston Dam are not excessively turbid, overall condition ratings downstream of Eel Creek are not predicted to change from the existing rating of **moderate**, but impacts of water resource development as far downstream as Wide Bay Creek confluence would increase from the current rating of **minor** to **moderate**, reflecting changes in macroinvertebrate communities in response to changes in flow regime and habitat.
- If outflows from Traveston Dam are turbid, water resource development impacts of at least **moderate** level would persist in all reaches to the Mary Barrage pondage, where **major** change from reference condition has already occurred due to the effects of barrage installation.

Fish

- The fish fauna of the Mary River between the Traveston Dam site and the Mary Barrage pondage currently shows **moderate** change from reference condition in most reaches (**major** change in the Gympie town reach), reflecting **minor** impacts of existing water resource development (flow regime changes and barrier effects) and **moderate** impacts resulting from land use pressures. **Very major** change has occurred in the Mary Barrage pondage.
- In the Traveston Dam scenario, a shift to **major** change from reference condition would occur in the reaches between Traveston Dam and Munna Creek.
- Impacts of increased barrier effects arising from Traveston Dam would affect populations of diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater mullet, bullrout and striped gudgeon) and potamodromous species (e.g. Mary River cod and lungfish) downstream of the dam.
- Flow regime changes resulting from Traveston Dam and associated water extraction (including reductions in magnitude/frequency of medium and high flows) would lead to reduced cues for spawning and movement/dispersal and reductions in access to riparian zone and floodplain habitat for foraging, growth and development, particularly in the reaches closest to Traveston Dam but diminishing downstream due to inflows from unimpounded tributaries.
- Downstream of Munna Creek to the upstream end of the Mary Barrage pondage, it is unlikely that the overall condition of the fish fauna would shift from the current rating of **moderate** change from reference condition.

Other Vertebrates

- Impacts of the Traveston Dam scenario on the geomorphological processes that maintain sand bars that provide key nesting habitat for the Mary River turtle would be greatest in the reach closest to Traveston Dam (i.e. Traveston Dam to Six Mile Creek) and may persist to some degree as far downstream as Munna Creek, but are unlikely to be significantly discernible below Munna Creek. Reductions in occurrence of medium and high flows capable of mobilising sand bars would lead to loss of nesting habitat through bar consolidation in the reaches closest to the dam.
- Any reduction in pool size and depth, particularly during dry periods, would increase the exposure of adolescent turtles (including white-faced snapping turtles, *Elseya albigula* and the Mary River turtle, *Elusor macrurus*) to predation from raptors and other predators.

- Any reduction in the extent of functioning riffles would lead to reduced oxygen levels and food supply for turtles.

4.1.2.2 Mitigation Options

Mitigation options have been identified that could feasibly address downstream impacts of Traveston Dam with regard to clearwater erosion, water quality issues (other than elevated turbidity), weed growth in riparian zones, and fish passage barriers (Table 4.15). These mitigation options would assist in reducing impacts, but generally not sufficiently to alter the predicted trends in condition ratings outlined above. Key exceptions are geomorphology and water quality, for which it may be possible to reduce impacts in the Traveston Dam to Six Mile Creek reach from **very major** (without mitigation) to **major** (with mitigation). In the case of water quality, this would only be possible if outflows from Traveston Dam are not turbid.

Table 4.15 Key mitigation and compensation measures relevant to downstream effects of Traveston Dam on non-tidal reaches of the Mary River

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat"	• To compensate for major/very major impacts on the reach of the Mary River from Traveston Dam to Six Mile Creek or, if Traveston Dam becomes turbid, on the whole river downstream to the estuary. • No equivalent areas are obviously apparent, as the Mary River is the last unimpounded major river is south-east Queensland. • Further investigations would be required to identify alternative stream types that would be appropriate to rehabilitate in this context.	High due to lack of unimpounded major rivers in south-east Queensland.
Cease instream sand/gravel extraction in Mary River reaches downstream of Traveston Dam	• Would be a key component of any management strategy to mitigate sediment deficit leading to bed armouring and/or clearwater erosion.	Low, but would require alternative source of sand/gravel supply
Monitor for evidence of clearwater erosion and undertake sediment renourishment and/or bed stabilisation on an "as-needed" basis	• Monitoring of channel stability and substrate characteristics, particularly in the reach immediately downstream of Traveston Dam, would identify the occurrence of clearwater erosion and enable an adaptive management response • Sediment renourishment could potentially be used to address a sediment deficit; however, changes in flow regime put the reaches of the Mary River downstream of Traveston Dam at increased risk of pool infill and general contraction if excess sediment load is supplied • Sediment renourishment has not been previously undertaken in Australia and thus would be experimental • If significant net bed control lowering occurs as a result of sediment deficit, bed stabilisation works could potentially be used to prevent or mitigate further erosion, although this would be difficult and expensive in such a large river channel	Low for monitoring; medium for renourishment and bed stabilisation
Install destratifier(s) in Traveston Dam pondage	• Mitigation of dam stratification effects (see Table 4.10)	High

Mitigation or Compensation Measure	Comments	Level of Difficulty
Install multi-level offtake on Traveston Dam	• Would mitigate impacts of hypolimnetic releases on downstream water quality and ecology, particularly between Traveston Dam and Six Mile Creek. • Could also be operated to simulate natural seasonal variability in water temperature. • Destratification measures within the Traveston Dam pondage (as discussed above) would also have benefits downstream of the dam	Low
Riparian zone revegetation and weed management	• Riparian zones along the Mary River are already significantly disturbed, particularly between Traveston Dam and Gympie, where there has been extensive native vegetation loss and many weeds are present. • Riparian zone management measures (including revegetation, and surveillance for weeds and prompt removal) would assist in counteracting the effects of reductions in flood disturbance on proliferation of weeds. • The high degree of existing disturbance of the riparian vegetation and existence of numerous weed sources in adjacent areas and throughout the catchment makes vegetation management in this part of the Mary River system a difficult and expensive task. A very major ongoing financial and community commitment would be required for vegetation management measures to be successful in even counteracting the effects of reduced flood disturbance on weed proliferation. • Within Gympie township there has been substantial riparian restoration over the past 10 years, with high a level of public support in this relatively populous area	High
Mechanical removal of floating macrophyte vegetation in Traveston Dam pondage	• Would mitigate impacts on downstream water quality of decomposing aquatic vegetation from dam.	Low to medium. Ongoing management required as harvested biomass can be quickly replaced.
Install fish lock/lift on Traveston Dam	• Discussed above (Table 4.10). Would also affect fish community structure downstream of dam. • As in the case of any fish passage device on a dam or weir, fish movements would be more constrained than under natural conditions. • It is possible that a fish lift/lock may be used by some migratory crustaceans such as macrobrachium.	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.
Installation and effective operation of fishways on existing infrastructure (e.g. Gympie Weir, Mary Barrage) to maintain access by diadromous and potamodromous fish species	• Compensation measure for reduction in fish passage due to Traveston Dam • The Mary Barrage has an existing fishway. Design modifications have been recommended to further improve fish passage • Gympie Weir currently does not have a fishway and so forms a barrier to movement during low flow periods • See Table 4.10 for further details	Low
Develop/review and implement species recovery plans for EVR species	• EVR species that would be significantly affected by downstream effects of Traveston Dam include the Mary River turtle, Queensland lungfish and Mary River cod	Depends on standard of outcome and types of measures required. Usually high.
Environmental compensation flows	• Environmental flow rules have been built into the hydrologic modelling of the scenario under consideration. • Two different environmental flow options were modelled for the Traveston Dam scenario, indicating that there is flexibility to vary the environmental flow rules to address a range of issues.	Low, provided that appropriate outlet works are constructed.

Mitigation or Compensation Measure	Comments	Level of Difficulty
	• Further analysis and optimisation of the environmental flows would need to be undertaken at the design stage of the project	

4.1.3 Downstream Effects on Estuarine Reaches and the Great Sandy Strait

4.1.3.1 Implications for Condition and Values

Geomorphology

- The geomorphology of the estuarine reaches of the Mary River currently shows **moderate** change from reference condition, largely due to effects of instream sand/gravel extraction and tidal barrage installation on fluvial sediment inputs and tidal processes. Anecdotal reports suggest there has been increased sedimentation in the river mouth area, accompanied by expansion of mangroves[43].
- No change in the overall condition of the Mary River estuarine reaches is predicted to occur in the Traveston Dam scenario, but impacts of flow regime change due to water resource development would increase from **indiscernible** to **minor** in the lower estuary due to effects of reductions in small and medium floods on fluvial sediment transport (impacts are already **minor** in the upper estuary).

Hydraulic Habitat and Hydrodynamics

- Hydraulic habitat and hydrodynamics of the Mary River estuarine reaches currently show **moderate** (upper estuary) to **minor** (lower estuary) change from reference condition due to reduced freshwater inflows and changes in tidal flows resulting from the installation of the Mary and Tinana Barrages.
- Impacts of flow regime change would incrementally increase in the Traveston scenario, but not sufficiently to change the condition ratings.

Water Quality

- The water quality of the Mary River estuarine reaches currently shows **major** (upper estuary) to **moderate** (lower estuary) change from reference condition, due to increases in salinity and turbidity associated with water resource development (flow reductions and hydrodynamic changes caused by tidal barrages, particularly the Mary Barrage), as well as influences of land use pressures.
- Impacts of flow regime change would incrementally increase in the Traveston Dam scenario, but not sufficiently to change the condition ratings.

[43] Sedimentation has also been reported in the nearby Elliott and Burrum estuaries, due to natural climatic factors, exacerbated by flow regime changes resulting from water resource development in the case of the Burrum. The expansion of mangrove forests due to colonisation of sediments deposited in the vicinity of large rivers in the last 25 years is well documented in Moreton Bay, a barrier estuary similar to Hervey Bay (Manson et al. 2003).

Riparian Vegetation

- The riparian vegetation of the Mary River estuarine reaches currently shows **major** (upper estuary) to **moderate** (lower estuary) change from reference condition, mainly reflecting vegetation loss due to land use pressures and aggravated by bank erosion.
- Impacts of flow regime change would incrementally increase in this scenario, but not sufficiently to change the condition ratings
- A possible increase in the dominance of saline tidal water in the upper estuary would tend to favour salt-tolerant species, including mangroves and *Casuarina glauca*.

Aquatic Vegetation (Including Freshwater Macrophytes, Mangroves and Seagrasses)

- The aquatic vegetation of the Mary River estuarine reaches currently shows **moderate** (upper estuary) to **minor** (lower estuary) change from reference condition, reflecting influx of aquatic weeds (salvinia and water hyacinth) to the upper estuary from the Mary Barrage pondage, upstream shifts in halophytic communities and reductions in seagrass resulting from the combined impacts of land use pressures (particularly impacts on water quality) and hydrodynamic changes associated with water resource development.
- Mangroves in the lower estuary may have expanded over the last 50 years, as indicated by anecdotal accounts. Elsewhere in south-east Queensland, mangroves have expanded in area, colonising the landward edge of existing mangroves, replacing saltmarsh habitat, and also colonising recent sediments deposited due to changes in catchment use (Manson et al. 2003).
- Impacts of flow regime change on aquatic vegetation would incrementally increase in this scenario, but not sufficiently to change the condition ratings
- The flow regime changes resulting from Traveston Dam may reduce flushing of freshwater floating macrophytes from the upper estuary, which are harboured in the Mary Barrage pondage and spill over into the estuary.
- The upper estuary is very turbid due to tidal resuspension of fine sediment and turbid conditions would be expected to persist under the Traveston Dam scenario. Turbidity has little impact on the prolific fringing mangroves in the upper estuary, though it is crucial for seagrasses. The current and continuing high turbidities preclude seagrasses from growing in the upper reach of the Mary River estuary, though it is doubtful they ever would have existed there.
- A possible increase in the dominance of saline tidal water in the upper estuary would tend to favour salt-tolerant species, including mangroves.
- Old growth mangrove and vineforests at River Heads, which would support Illidge's ant-blue butterfly (*Acrodipsas illidgei* – "vulnerable" [NCA]), are not expected to be significantly affected by flow regime changes in the Traveston Dam scenario.

Aquatic/Estuarine Macroinvertebrates

- The aquatic/estuarine macroinvertebrate communities of the Mary River estuarine reaches currently show **moderate** change from reference condition, reflecting probable reductions in biomass due to shortening of the estuary by the Mary and Tinana Barrages and associated loss of the natural transition zones between freshwater and estuarine reaches, and shifts in community composition associated with changes in water quality and reductions in seagrass habitat. Instream

sand/gravel extraction would have had direct impacts on local macroinvertebrate communities. Mangrove-dependent crustacean communities would have remained relatively intact, as their habitats are stable or possibly expanding in the lower estuary.
- Impacts of flow regime change would incrementally increase in the Traveston Dam scenario, but not sufficiently to change the condition ratings

Fish

- The fish communities of the Mary River estuarine reaches currently show **major** (upper estuary) to **moderate** (lower estuary) change from reference condition. Key changes include loss of the tidal freshwater–brackish water ecotone (which is a key nursery habitat for many estuarine fish species) and reductions in abundance of important recreational/commercial species (e.g. mullet, barramundi, mangrove jack and threadfin) due to overfishing, effects of the Mary Barrage and habitat loss.
- A reduction in fisheries productivity is implied by the reductions in total flow volumes and high flows (summer flows) in the Traveston Dam scenario[44]. However, it is not clear if the flow regime changes resulting from this scenario would change the processes that support growth, movement, survival and reproduction sufficiently to alter the condition ratings, which already reflect substantial change from reference condition.

Other Vertebrates

- The water mouse, *Xeromys myoides* (“vulnerable” EPBC and NCA) lives in the mangrove forests and saltmarshes of the lower Mary River estuary.
- The dugong, *Dugong dugon* (“vulnerable” NCA), Indo-Pacific humpback dolphin *Sousa chinensis* (“rare” NCA), loggerhead turtle, *Caretta caretta* (“endangered” EPBC and NCA) and leatherback turtle, *Dermochelys coriacea* (“vulnerable” EPBC, “endangered” NCA) and the green, hawksbill and flatback turtles (*Chelonia mydas*, *Eretmochelys imbricata* and *Natator depressus* – “vulnerable” EPBC and NCA) live in Hervey Bay and the Great Sandy Strait and visit the Mary estuary. However, they are unlikely to be permanent residents of the estuary and have not been observed to breed there.
- Waterbirds of conservation significance, including species listed in JAMBA and CAMBA, occur in wetland areas associated with the Mary River estuary.
- None of these other vertebrate species are expected to be significantly affected by the Traveston Dam scenario.

Great Sandy Strait

- The Great Sandy Strait has very high ECVs (e.g. as outlined by EPA [2002] and discussed by Werren [2004]). It is a Ramsar wetland and supports flora and fauna species of conservation significance, including sharks (eastern angel shark, *Squatina* sp.), sawfish (green sawfish, *Pristis zijsron*), shovelnose rays (giant

44 This inference is based on black-box models that correlate fisheries productivity with flow, emigration and immigration cues provided by freshwater pulses in estuaries, and reduced lateral connectivity of wetland and floodplain habitats. However, the processes that drive these linkages are not well understood and further research is required to clarify them. Recent studies in central Queensland have clearly linked flows with subsequent fishery catch, but have not distinguished between possible drivers (such as those listed above). The use of key estuarine mangrove, seagrass, shallow bank and channel habitats by juvenile crustaceans and fish during this critical phase of their lifecycle contributes to their abundance as adults in other habitats later on.

shovelnose ray, *Rhinobatos typus*), marine turtles (as noted above), marine mammals (dugong, dolphins, whales) and numerous bird species, including migratory shorebirds protected by CAMBA and JAMBA.

- Water resource development in the Mary catchment could potentially affect the Great Sandy Strait via exports of water and associated loads of sediment, nutrients and organic matter and/or via biological linkages resulting from the movement of fauna between riverine, estuarine and marine environments. However, exports of water and associated loads occur mainly in larger flood events[45], which are generally not greatly altered by the Traveston Dam scenario.
- Impacts of the Traveston Dam scenario on estuarine ecology would be incremental and superimposed upon an existing situation that has already undergone greater change, hence implications for biological linkages would also only be incremental and effects are likely to be indiscernible.
- Fraser Island, on the opposite side of the Great Sandy Strait, is a World Heritage Area; however, only the largest floods in the Mary River would have any affect on the Fraser Island shoreline (via inputs of turbid water and fine sediment deposition). Such large events are generally not greatly affected by the Traveston Dam scenario, hence no discernible impacts on Fraser Island are anticipated.

4.1.3.2 Mitigation Options

Key mitigation and compensation measures relevant to the downstream effects of Traveston Dam on the Mary River estuary are presented in Table 4.16.

Table 4.16 Key mitigation and compensation measures relevant to downstream effects of Traveston Dam on the Mary River estuary

Mitigation or Compensation Measure	Comments	Level of Difficulty
Review sand/gravel extraction in estuary and reduce/cease if necessary	• Sand/gravel extraction in the Mary River estuary has significant implications for estuarine sediment dynamics. • The condition of the estuary under the Traveston Dam scenario would reflect interactions between the effects of sand/gravel extraction (part of the current management regime) and flow regime changes resulting from water resource development.	• Low, but would require alternative source of sand/gravel supply
Reduce inputs of pollutants to estuary from point and diffuse sources to mitigate "factor reinforcement"	• Impacts on water quality resulting from longer retention times resulting from reductions in flow are exacerbated if there are elevated inputs of pollutants.	• Unknown. Point sources are relatively easy to address if obvious polluting influences can be identified. Diffuse sources in large catchments are very difficult to manage.

[45] For example, significant plumes were reported in the 1992 (Preen et al. 1995) and February 1999 (Campbell and Mackenzie 2004) flood events

Mitigation or Compensation Measure	Comments	Level of Difficulty
Rehabilitate "riparian" vegetation (mangroves and saltmarsh) to improve resilience of estuarine ecosystems	• There is scope for rehabilitation/reinstatement of "riparian" vegetation in areas where there has been significant loss or clearing (particularly in the lower estuary). • This would improve the resilience of estuarine ecosystems to impacts arising from flow regime change	• Medium due to extent of resources and length of time required for successful outcome. Opportunities to build-on and expand from existing remnants.

4.2 Mary catchment – Cambroon, Kidaman, Amamoor and Borumba (Raising) Dams Scenario

Dam pondage and upstream barrier effects are outlined separately for the four individual dams in Section 4.2.1 – i.e. Cambroon (Section 4.2.1.1), Kidaman (Section 4.2.1.2), Borumba (Raising) (Section 4.2.1.3) and Amamoor (Section 4.2.1.4). Mitigation options for dam pondage and barrier effects for the four new/raised dams are discussed in Section 4.2.2. Downstream effects on non-tidal reaches of the Mary River and key tributaries (including implications of the installation of Coles Crossing Weir) are discussed in Section 4.2.3 and relevant mitigation options are outlined in Section 4.2.4. Downstream effects on estuarine reaches and the Great Sandy Strait are noted in Section 4.2.5.

4.2.1 Dam Pondage and Upstream Barrier Effects – Implications for Condition and Values

4.2.1.1 Cambroon Dam

Geomorphology and Hydraulic Habitat

- Submergence of river/stream channel habitats on the Mary River and tributaries (including riffles, pools, sand/gravel bars, benches and backwaters), floodplains/river terraces (including old courses) and upslope habitats. Parts of this section of the Mary River have already been significantly disturbed by sand/gravel extraction.
- Creation of dam pondage habitat (different from a natural lake due to greater variability in water levels resulting from dam operation).
- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes.
- The surficial geology of the Cambroom Dam pondage area includes extensive deposits of Quaternary alluvium (floodplain and river terraces) in the Mary River and tributary valleys, Tertiary/Quaternary slopewash deposits, Neurum Tonalite, Cambroon Beds (Permian sedimentary rocks) and Booloumba Beds (Carboniferous to Permian sedimentary rocks and mafites). This will influence shoreline character and sediment inputs – e.g. sandy “beaches” may form on shorelines of granitic lithology (Neurum Tonalite). Further information regarding soil properties would be required to determine the likely occurrence of dispersive soils. The occurrence of acid sodic subsoils on the Permian Gympie Group formation further downstream [discussed in Section 4.1] raises the question of a possible association between Permian formations and dispersive soils in the Cambroon Dam pondage area.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.
- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the Cambroon Dam pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches. Sediment supply rates from the upstream catchment appear to be relatively high in this part of the catchment, due to natural factors (e.g. steep topography and high intensity rainfall), exacerbated by historical clearing. Large episodic inputs of sediment have historically occurred in major flood events (Brizga et al. 2003).

Water Quality

- Being a deep storage, Cambroon Dam pondage would be subject to thermal/chemical stratification. Most other large dams in south-east Queensland are subject to stratification unless destratifiers are used.
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- Land uses in the Cambroon Dam catchment area include forestry, grazing and dairying, which would provide nutrient and sediment inputs to the dam pondage, and information provided by NRW indicates that the town of Conondale would be submerged by the dam pondage. However, existing background levels of nutrients are currently low and meet ANZECC guidelines for upland rivers (Condina 2004).
- There would also be nutrient release from former agricultural soils impounded by the dam pondage in the short to medium term. Most of the Cambroon Dam pondage area would submerge cleared river flats and valley slopes currently used for agricultural purposes.
- Pollutants would potentially be released from submergence of contaminated sites, such as stock drenches and arsenic dips. Sites of potential contamination would need to be investigated for any dam option.
- Cambroon Dam pondage would be subject to medium to high risk of blue–green algal blooms, due to stratification processes and nutrient accumulation.
- Unnatural variability in DO is expected, including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.
- Water quality is particularly at risk of deterioration in sheltered arms of the dam pondage, due to limited circulation currents and agricultural runoff.
- Turbidity would be altered compared to the existing turbidity regime of the Mary River. Information on the composition of suspended load delivered to the dam pondage area and soil properties within the pondage area would be required to determine the likely direction and extent of change. Suspended load from turbid floodwaters stored by the dam may settle in the dam pondage; alternatively it may be held in the water column by turbulent resuspension processes and additional inputs of suspended sediment may be generated by shoreline erosion and soil dispersion.
- Analysis of existing NRW turbidity data (as provided for the Mary Basin WRP environmental investigations – Brizga et al. 2004) shows a low flow mean of 1 NTU, high flow mean of 49 NTU and overall mean of 17 NTU at Bellbird Creek gauging station. The difference between low flow and high flow means illustrates the existing flow-related variability in turbidity. The overall mean turbidity gives an indication of the likely averaging effect of the dam with regard to inflows, prior to any other changes associated with erosion, dispersion and settling processes, and microphyte blooms within the dam pondage.
- Some of the Permian geological formations in the Mary catchment are associated with sodic subsoils, which are dispersive and would thus have implications for turbidity if submerged in the dam pondage area (Peter Wilson, NRW pers. comm.).
- From published geologic mapping (1:100,000 scale), Permian formations appear to be present in the lower section of the Cambroon Dam pondage. A targeted soils survey would be necessary to confirm the occurrence and extent of dispersive soils.

- If the occurrence of dispersive soils in the pondage area is not extensive, their impact on pondage water quality could potentially be mitigated by covering the affected area within the dam pondage, and ensuring that such soils are fully vegetated and/or suitable treated where they occur in the buffer zone. The possibility of avoiding submergence of dispersive soils by varying dam site location or FSL within the same general area should also be considered.
- High turbidity of dam waters is undesirable from an ecological viewpoint given that the natural ecosystems have evolved with relatively clear water, and also from a water supply viewpoint, as high turbidity makes microbiological treatment difficult.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Cambroon Dam pondage, resulting in total loss of true riparian zone vegetation except at the upstream limits of the dam impoundment.
- The variable water level regime in the dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, lack of flood disturbance and lack of indigenous riparian propagules).
- Much of the dam pondage and buffer zone area for Cambroon Dam is cleared agricultural or grazing land, but EPA mapping shows that remnant native vegetation in this area includes seven REs, four of which are “of concern” (REs 12.3.8, 12.3.11, 12.11.14 and 12.12.12) (see Table 4.2, also refer to Appendix E for further details).
- Ten riparian and terrestrial plant species of conservation significance would be affected by Cambroon Dam pondage, including five riparian species and five upslope species (Tables 4.3 to 4.5).

Aquatic Vegetation

- Aquatic vegetation in the reaches of the Mary River that would be submerged by Cambroon Dam has already undergone **moderate–major** change from reference condition, due mainly to factors other than water resource development (including riparian vegetation loss, instream sand/gravel and infill of pools).
- Water storages are generally ideal habitats for the growth of aquatic vegetation. The extent to which aquatic macrophytes can colonise and establish nuisance populations is dependent on a variety of factors including bank slope, depth, substrate composition, wind fetch and the species present in the vicinity of the pondage. The responses of macrophytes to construction of a dam pondage may therefore vary from pondage to pondage, and also spatially within the pondage. It is expected that aquatic macrophytes would be abundant in Cambroon Dam pondage, as macrophytes are currently abundant in this part of the Mary River, provided that the water does not become excessively turbid. However, high turbidity would not limit the growth of nuisance floating species.
- Potential problematic (native) species include *Hydrilla verticillata*, which is problematic in Somerset Dam, and pondweeds (*Potamogeton* spp.). Alien species that may be problematic include salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), which can form nuisance populations in water storages. *Cabomba caroliniana* (cabomba), a declared Class 2 weed, is present in the

nearby Lake MacDonald (Six Mile Creek catchment) and could therefore become established in Cambroon Dam pondage, either through dispersal by waterfowl or anthropogenic activities. Cabomba has been associated with tainting of water which increases the cost of treatment (Mackey 1996).

- *Vallisneria nana* ("rare" NCA) occurs throughout the Mary River. It occurs in greater abundances in the Mary River than in the Logan or Albert Rivers. In south-east Queensland this species is commonly found in flowing water. It also occurs in still water and would therefore be expected to persist in the dam pondage, particularly in shallow backwaters but could potentially colonise deep-water habitats (dependent upon light availability) as this species is recorded as having leaf lengths of up to 6 m.
- Lungfish are known to spawn in *V. nana* beds.

Macroinvertebrates

- Macroinvertebrate communities in the Cambroon Dam pondage would be significantly different to natural for this part of the river system in terms of diversity and composition due to changes in habitat, water quality and food resources.
- Habitats in the dam pondage would be unfavourable for edge zone species of macroinvertebrates (due to variable water levels and lack of stable vegetation communities) and obligate-lotic species would be eliminated (due to lack of shallow, running water habitat).
- Much of the dam pondage area would also be unfavourable to pool macroinvertebrate species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.
- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms, chironomid larvae).
- If abundant macrophyte growth occurs in shallow parts of the dam pondage and backwater arms (as discussed above), macroinvertebrate species favoured by macrophytes would increase in abundance in these areas (e.g. grazer invertebrates) as well as fish that use plants for cover and spawning sites.
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of Cambroon Dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Several species of freshwater spiny crayfish occur in the Mary catchment; however, their known range is limited to altitudes above 240 m, hence they are not expected to occur in the reaches that would be impounded by Cambroon Dam.

Fish

- Two fish species of conservation significance would be affected by impoundment and barrier effects of Cambroon Dam (Mary River cod, *Macculochella peelii mariensis* and Queensland lungfish, *Neoceratodus forsteri* – Table 4.6). Both these species are native to the Mary catchment, have restricted natural ranges in south-east Queensland and are known to occur in the reaches that would be impounded by Cambroon Dam.

- Mary River cod restocking sites would be inundated by the Cambroon Dam impoundment.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely to favour a subset of fish species capable of surviving in impounded waters, including gambusia, swordtail and guppies, which are already present in this part of the Mary River.
- The reduction in availability of lotic habitat is expected to affect many species that commonly use shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already restricted by downstream weirs (Mary Barrage and Gympie Weir).
- Cambroon Dam (wall height 45.5 m) would cause a major barrier to longitudinal fish movements. Without an effective fish passage device it would sever access by diadromous species to 290 km^2 of catchment upstream of the dam, and restrict the movement of several potamodromous species, including Mary River cod and lungfish (see Appendix C for a list of migratory fish species relevant to Cambroon Dam).
- Fish movements would be further reduced by Coles Crossing Weir situated downstream.
- High quality fish habitats are present in the upper Mary River and Kilcoy Creek. They support Mary River cod (including restocking sites) and probably lungfish.

Other Vertebrates

- Tables 4.6 to 4.9 identify other vertebrate species of conservation significance that are likely to be affected by the Cambroon Dam pondage.
- The Cambroon Dam pondage would reduce habitat suitability for riverine species: stream-dependent frogs (including two “endangered/presumed extinct”, three “endangered”, one ”vulnerable” and up to 2 “rare/restricted” species) and turtles (including the “endangered” Mary River turtle and the white-faced snapping turtle) would be particularly affected.
- The ”vulnerable/endangered” red goshawk would also be adversely affected by conversion of riverine habitat to dam pondage habitat, as it nests in tall trees usually within 1 km of a river.
- Populations of waterbirds would increase.
- Habitat for terrestrial vertebrate species would be reduced and these species would be expected to retreat to upslope habitats.

4.2.1.2 Kidaman Dam

Geomorphology and Hydraulic Habitat

- Kidaman Dam would submerge parts of Obi Obi Creek and tributaries. Geomorphological features and habitats that would be submerged in the lower and middle sections of Kidaman Dam pondage include gravel riffles/runs, pools, sand/gravel bars, benches, backwaters, floodplains/river terraces and upslope habitats. The upper section of the Kidaman Dam pondage would extend into the

downstream end of the gorge reach of Obi Obi Creek, which is characterised by a narrow valley and rocky channel with long pools.
- Creation of dam pondage habitat (different from a natural lake due to greater variability in water levels resulting from dam operation).
- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes.
- The surficial geology of the Kidaman Dam pondage includes North Arm Volcanics and Amamoor Beds with minor occurrences of granitic rocks and Tertiary/Quaternary slopewash; the valley below the gorge contains floodplains/ river terraces formed of Quaternary alluvium. This will influence shoreline character and sediment inputs.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.
- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the Kidaman Dam pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches. However, Baroon Pocket Dam further upstream has already eliminated input of virtually all sediments (other than potentially very fine silt/clay) from 42% of the upstream catchment.

Water Quality

- Kidaman Dam pondage would be subject to thermal/chemical stratification. Most other large dams in south-east Queensland are subject to stratification unless destratifiers are used.
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- Baroon Pocket Dam isolates Kidaman Dam from upstream catchment land uses (including urban runoff from Maleny and point sources inputs of treated effluent from the Maleny STP). Local catchment land uses are rural and agricultural, but would provide inputs of nutrient and sediment that are elevated above natural levels.
- There would also be nutrient release from former agricultural soils impounded by the dam pondage in the short to medium term. Most of the Kidaman Dam pondage area would submerge cleared river flats and valley slopes currently used for agricultural purposes.
- Potential release of pollutants from submergence of contaminated sites, such as stock drenches and arsenic dips. Sites of potential contamination would need to be investigated for any dam option.
- Kidaman Dam pondage would be subject to very high risk of blue–green algal blooms, due to stratification processes and inputs of blue–green algae from Baroon Pocket Dam, which is subject to blue–green algal blooms.
- Unnatural variability in DO is expected, including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.
- Water quality is particularly at risk of deterioration in sheltered arms, due to limited circulation currents and agricultural runoff.
- Turbidity would be altered compared to the existing turbidity regime of Obi Obi Creek. Information on the composition of suspended load delivered to the dam pondage area and soil properties within the pondage area would be required to

determine likely direction and extent of change. Suspended load from turbid floodwaters stored by the dam may settle in the dam pondage; alternatively it may be held in the water column by turbulent resuspension processes and additional inputs of suspended sediment may be generated by shoreline erosion and soil dispersion. From available information, it appears likely that turbidity levels in Kidaman Dam would not be unusually elevated compared to other similar dams in south-east Queensland. Experience in Baroon Pocket Dam cannot be used to directly infer likely trends in turbidity in Kidman Dam due to differences in local catchment and dam pondage geology.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Kidaman Dam pondage, resulting in total loss of true riparian zone vegetation except at upstream limits of the dam impoundment.
- The variable water level regime in the dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, lack of flood disturbance and lack of indigenous riparian propagules).
- Much of the dam pondage and buffer zone area for Kidaman Dam has been cleared, but EPA mapping shows that remnant native vegetation in this area includes twelve REs, five of which are of conservation significance (one "endangered" [RE12.3.1] and four "of concern" (REs 12.11.9, 12.11.14, 12.12.1 and 12.12.12) (see Table 4.2, also refer to Appendix E for further details). Over 5 km of "endangered" RE 12.3.1 would be drowned.
- RE 12.3.1 is important for fruit-eating birds, many of which migrate seasonally from upland to lowland rainforest.
- 21 riparian and terrestrial plant species of conservation significance would be affected by Kidaman Dam pondage, including 12 riparian species (including *Phaius australis* and *Pectranthus torrenticola* – both listed as "endangered" in EPBC) and 9 upslope species (Tables 4.3 to 4.5).
- Approximately one quarter of the inundated area of the Kidaman Dam pondage is part of a State Wildlife Corridor.

Aquatic Vegetation

- Aquatic vegetation is expected to increase in abundance in Kidaman Dam pondage (provided depths and light availability are suitable).
- Kidaman Dam pondage would be subject to elevated risk of alien floating species infesting the pondage (due to the urbanised upstream areas). Problem species may include salvinia, water hyacinth and dense waterweed (*Egeria densa*) (present upstream and downstream of Baroon Pocket Dam).
- *Cabomba caroliniana* (cabomba), a declared Class 2 weed, is present in the nearby Lake MacDonald (Six Mile Creek catchment) and could therefore become established in Kidaman Dam, either through dispersal by waterfowl or anthropogenic activities. Cabomba has been associated with tainting of water which increases the cost of treatment (Mackey 1996).

Macroinvertebrates

- Macroinvertebrate communities in the Kidaman Dam pondage would be significantly different to natural for this part of the river system in terms of diversity and composition due to changes in habitat, water quality and food resources.
- Habitats in the dam pondage would be unfavourable for edge zone species of macroinvertebrates (due to variable water levels and lack of stable vegetation communities) and obligate-lotic species would be eliminated (due to lack of shallow, running water habitat).
- Much of the dam pondage area would also be unfavourable to pool macroinvertebrate species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.
- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms, chironomid larvae).
- If abundant macrophyte growth occurs in shallow parts of the dam pondage and backwater arms (as discussed above), macroinvertebrate species favoured by macrophytes would increase in abundance in these areas (e.g. grazer invertebrates) as well as fish that use plants for cover and spawning sites.
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of Kidaman Dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Several species of freshwater spiny crayfish occur in the Mary catchment and, indeed, the type locality for the Conondale crayfish *Euastacoides urospinosus* is Obi Obi Creek at Maleny. However, the known range of freshwater spiny crayfish is limited to altitudes above 240 m, hence they are not expected to occur in the reaches that would be impounded by Kidaman Dam.

Fish

- Two fish species of conservation significance would be affected by impoundment and barrier effects of Kidaman Dam (Mary River cod, *Macculochella peelii mariensis* and Queensland lungfish, *Neoceratodus forsteri* – Table 4.6). Both these species are native to the Mary catchment and have restricted natural ranges in south-east Queensland
- Kidaman Dam impoundment would inundate 15 km of Obi Obi Creek known to support excellent habitat for lungfish and naturally reproducing populations of Mary River cod.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely to favour a subset of species capable of surviving in impounded waters. Alien fish species are often at a competitive advantage in this situation, but no alien fish have been recorded in Obi Obi Creek downstream of Kondalilla Falls.

- The reduction in availability of lotic habitat is expected to affect many species that commonly use shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already restricted by downstream weirs (Mary Barrage and Gympie Weir).
- Fish movements would be further reduced by Coles Crossing Weir, which would be situated on the Mary River downstream.
- Kidaman Dam (wall height 23.2 m) would be an insurmountable barrier to upstream movement of all fish species except eels unless an effective fishway is installed. However, the significance of this impact is limited, as migratory fish (including potamodromous and diadromous species) can currently access just a small area of the Obi Obi catchment upstream of Kidaman Dam (due to the presence of Kondalilla Falls and Baroon Pocket Dam further upstream).

Other Vertebrates

- Tables 4.6 to 4.9 identify other vertebrate species of conservation significance that are likely to be affected by the Kidaman Dam pondage.
- The dam pondage would reduce habitat suitability for riverine species: stream – dependent frogs (including two “endangered/presumed extinct”, two “endangered”, one ”vulnerable” and up to two “rare”/restricted species) and turtles (including the “endangered” Mary River turtle and the white-faced snapping turtle) would be particularly affected.
- Populations of waterbirds would increase.
- Terrestrial species would be expected to retreat to upslope habitats, and increase territorial pressure and competition for food and habitat resources.
- There would be loss of linear habitat connectivity from lowland alluvial habitat to the upper ridge habitat
- Kidaman Dam pondage would fragment a State Wildlife Corridor, isolating species populations and increasing territorial pressure.

4.2.1.3 Borumba Dam Raising

Geomorphology and Hydraulic Habitat

- The raising of Borumba Dam differs from the other dam proposals in the Four Dams scenario in that it involves the enlargement of an existing storage, rather than creation of a new storage. The ponded area would increase substantially, from 480 ha to 1,455 ha.
- The raised Borumba Dam would submerge substantial additional lengths of Yabba Creek and a major tributary, as well as parts of smaller tributaries and some upslope habitats. Riverine habitats that would be submerged include gravel/cobble/boulder riffles and probably rock bars, pools, lateral bars, benches and narrow floodplains.
- There would be a shift from fluvial and terrestrial processes to lacustrine processes in the additional ponded area.
- The surficial geology of the additional area to be impounded by dam raising consists of the same formations as are submerged by the existing Borumba Dam pondage – i.e. Devonian to Carboniferous sedimentary and metamorphic rocks (mainly Amamoor Beds with small areas of Mount Mia Serpentine). Therefore,

the shoreline character of the enlarged dam pondage is likely to be similar to the existing Borumba Dam shoreline.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.
- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the enlarged Borumba Dam pondage, causing accumulation of such material in the pondage area. However, the existing Borumba Dam pondage has a high trap efficiency and has already eliminated downstream transmission of all but the finest sediment fractions (Brizga 2004).

Water Quality
- Water quality in the enlarged Borumba Dam pondage would be similar to existing Borumba Dam.
- Borumba Dam is already subject to thermal/chemical stratification – a further increase in depth may intensify stratification and make it more difficult to break down using destratifiers.
- Accumulation of nutrients and contaminants in benthic sediments would continue to occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- Current land use in the extended dam pondage area is native forest and grazing, but sites of potential contamination associated with past and present land uses would need to be investigated, as for any dam option.
- Lake Borumba is already subject to blue–green algal blooms, which would continue to occur in the enlarged dam pondage.
- Unnatural variability in DO is expected, including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.
- Existing water quality in Lake Borumba and information on the geology of the additional areas that would be submerged in the enlarged dam pondage suggests that elevated turbidity is unlikely to be a significant ecological or management issue. Advice from Peter Wilson (NRW pers. comm.) indicates that sodic or dispersive soils are unlikely to be present in this area, based on geological information.

Riparian and Terrestrial Vegetation
- Existing riparian zone, floodplain and upslope vegetation would be drowned by the extended dam pondage, resulting in total loss of true riparian zone vegetation except at upstream limits of the dam impoundment.
- As in the existing dam pondage, the variable water level regime in the enlarged dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, lack of flood disturbance and lack of indigenous riparian propagules). However, temporary vegetation communities are likely to become established during periods when dam water levels are low (e.g. as evident on 2003 aerial photographs of the existing Lake Borumba).
- Land use in the area that would be submerged by raising of Borumba Dam is a mix of native forest and cleared land used for grazing.
- EPA mapping shows that the enlarged pondage area and buffer zone would affect seven REs, four of which are “of concern” (REs 12.11.9, 12.11.14, 12.11.15 and

12.12.12), although two of these REs (12.11.9 and 12.11.15) are mainly in the buffer zone (see Table 4.2, also refer to Appendix E for further details).

- 16 riparian and terrestrial plant species of conservation significance would be affected by the extended dam pondage resulting from the raising of Borumba Dam, including 9 riparian species and 7 upslope species (Tables 4.3 to 4.5).
- The additional inundated area would bisect a State Wildlife Corridor.
- The enlarged Borumba Dam pondage would inundate areas classified as "Essential Habitat" (habitat in which an EVR species has been known to occur, as mapped by EPA) for the following species: Parsonsia lenticellata *(*a slender wiry twiner vine – "rare" NCA), Podargus ocellatus plumiferus (plumed frogmouth– "vulnerable" NCA) and Maccullochella peelii marie*nsis* (Mary River cod – "endangered" EPBC and NCA).

Aquatic Vegetation

- High macrophyte abundances occur in the existing Borumba Dam pondage, particularly in sheltered arms and tributaries. A similar situation is expected to prevail in the enlarged pondage.

Macroinvertebrates

- Similar types of impacts on aquatic macroinvertebrates as have occurred in the existing Borumba Dam pondage would extend further upstream and across a larger pondage area.
- Several species of freshwater spiny crayfish occur in the Mary catchment; however, their known range is limited to altitudes above 240m, hence they are not expected to occur in the reaches that would be impounded by Borumba Dam.

Fish

- Mary River cod (*Macculochella peelii mariensis*) has been record in Lake Borumba and is likely to occur further upstream in the Yabba Creek system.
- The existing Borumba Dam has caused changes in habitat that favour a subset of species that are capable of surviving in impounded waters, including native species (e.g. bony bream, and fork-tailed catfish) and translocated recreational species (e.g. Australian bass, golden perch, saratoga).
- Enlargement of the pondage area by raising of Borumba Dam would further increase the extent of habitat suitable for such species.
- Borumba Dam is a major barrier to fish movements, and has severed access of all diadromous fish species other than eels and those species stocked in the dam (e.g. Australian bass) to the Yabba Creek catchment upstream of the dam
- Barrier effects to upstream movement would be the same with the raised Borumba Dam as with the existing dam, but likelihood of survival of fish in downstream movement over the dam in floods would be reduced by the higher dam.

Other Vertebrates

- Tables 4.6 to 4.9 identify other vertebrate species of conservation significance that are likely to be affected by the increased pondage area resulting from raising of Borumba Dam.
- The dam pondage would reduce habitat suitability for riverine species: stream-dependent frogs (including two "endangered", one "vulnerable" and one

"rare/restricted" species) and turtles (including the white-faced snapping turtle) would be particularly affected.
- The "vulnerable/endangered" red goshawk would also be adversely affected by conversion of riverine habitat to dam pondage habitat, as it nests in tall trees usually within 1 km of a river/stream.
- Populations of waterbirds would increase.
- Terrestrial species would be expected to retreat to upslope habitats, and increase territorial pressure and competition for food and habitat resources
- The enlarged Borumba Dam impoundment would fragment a State Wildlife Corridor, isolating species populations and increasing territorial pressure. Affected species would include the koala.

4.2.1.4 Amamoor Dam

Geomorphology and Hydraulic Habitat

- Amamoor Dam would submerge parts of Amamoor Creek, minor tributaries and upslope habitats. Riverine habitats that would be submerged include riffles, pools, gravel bars, benches and narrow floodplains.
- Creation of dam pondage habitat (different from natural lake due to greater variability in water levels resulting from dam operation).
- Impoundment would be accompanied by a shift from fluvial and terrestrial processes to lacustrine processes.
- The surficial geology of the Amamoor Dam pondage is very similar to that for the existing Lake Borumba (Amamoor Beds with Quaternary alluvium in the valley); hence, shoreline character can be expected to be similar.
- Shoreline erosion by wave action (including on upslope soils that would not naturally be inundated) and subaerial processes would occur.
- A large proportion of the sediment and organic matter delivered from the catchment would be stored in the Amamoor Dam pondage, causing accumulation of such material in the pondage area and reduced supply to downstream reaches. This part of Amamoor Creek is currently actively transporting gravelly bedload, as indicated by gravel accumulation at the gauging station control weir (Brizga et al. 2003).

Water Quality

- Water quality in Amamoor Dam pondage is expected to be similar to present water quality in Lake Borumba (due to similarities in catchment geology and land use).
- Amamoor Dam would be subject to thermal/chemical stratification. Most other large dams in south-east Queensland (including Borumba) are subject to stratification unless destratifiers are used .
- Accumulation of nutrients and contaminants in benthic sediments would occur due to storage of water, sediment, nutrient and organic matter inputs from the catchment.
- Current land use in the Amamoor Dam catchment area includes native forest and agriculture (grazing), which would provide nutrient and sediment inputs to the dam pondage. Sites of potential contamination associated with past and present land uses would need to be investigated (e.g. stock drenches and arsenic dips).

- Blue–green algal blooms are expected to occur. Algal blooms occur in the existing Lake Borumba in nearby Yabba Creek catchment. Nutrients would be elevated by accumulation from catchment runoff plus release of nutrients from impounded former agricultural soils.
- Unnatural variability in DO is expected, including periodic anoxia resulting from algal blooms and abundant growth of aquatic macrophytes.
- Turbidity would be altered, but experience in Lake Borumba suggests that it is unlikely to be a significant ecological or management issue. Advice from Peter Wilson (NRW, pers. comm.) indicates that sodic or dispersive soils are unlikely to be present in this area, based on geological information.

Riparian and Terrestrial Vegetation

- Existing riparian zone, floodplain and upslope vegetation would be drowned by the Amamoor Dam pondage, resulting in total loss of true riparian zone vegetation except at the upstream limits of the dam impoundment.
- The variable water level regime in the dam pondage would prevent establishment of permanent vegetation cover (riparian or aquatic) below FSL. Conditions above FSL are more suited for terrestrial rather than riparian species (non-alluvial soils, drier moisture regime, lack of flood disturbance and lack of indigenous riparian propagules).
- The dam pondage and buffer zone area for Amamoor Dam includes a mix of cleared land and significant area of remnant vegetation. EPA mapping shows that remnant native vegetation in this area includes nine REs, four of which are of conservation significance (one “endangered” [RE12.3.1] and three “of concern” [REs 12.3.11, 12.11.9, 12.11.14]) (RE 12.11.9 occurs mainly in the buffer zone rather than the pondage area) (see Table 4.2; also refer to Appendix E for further details).
- RE 12.3.1 provides habitat for rare/threatened flora and fauna species and is important for fruit-eating birds, many of which migrate seasonally from upland to lowland rainforest.
- 13 riparian and terrestrial plant species of conservation significance would be affected by Amamoor Dam pondage, including 7 riparian species and 6 upslope species (Tables 4.3 to 4.5).
- In addition to effects on native vegetation, Amamoor Dam would also affect a hoop pine plantation situated within the inundation area and buffer zone.

Aquatic Vegetation

- Aquatic macrophytes are abundant in Lake Borumba and are also likely to become abundant in the Amamoor Dam pondage.
- Potential problematic (native) species include *Hydrilla verticillata*, which is problematic in Somerset Dam, and pondweeds (*Potamogeton* spp.).
- Alien species that may be problematic include salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornia crassipes*), which can form nuisance populations on water storages. *Cabomba caroliniana* (cabomba), a declared Class 2 weed, is present in the nearby Lake MacDonald (Six Mile Creek catchment) and could therefore become established in Amamoor Dam, either through dispersal by waterfowl or anthropogenic activities. Cabomba has been associated with tainting of water which increases the cost of treatment (Mackey 1996).

- *Vallisneria nana* (“rare” NCA), occurs downstream of the Amamoor Dam site. It may therefore occur within the proposed dam pondage area. It occurs in still water and would therefore be expected to persist in the dam pondage, particularly in shallow backwaters but could potentially colonise deep-water habitats (dependent upon light availability) as this species is recorded as having leaf lengths of up to 6 m.
- Lungfish are known to spawn in *V. nana* beds.

Macroinvertebrates

- Macroinvertebrate communities in the Amamoor Dam pondage would be significantly different to natural for this part of the river system in terms of diversity and composition due to changes in habitat, water quality and food resources.
- Habitats in the dam pondage would be unfavourable for edge zone species of macroinvertebrates (due to variable water levels and lack of stable vegetation communities) and obligate-lotic species would be eliminated (due to lack of shallow, running water habitat).
- Much of the dam pondage area would also be unfavourable to pool macroinvertebrate species (e.g. molluscs, bivalves) as a result of water quality changes resulting from stratification, but such species may occur in shallower areas.
- There would be a shift to pelagic species (i.e. zooplankton, such as daphnia and copepods) and species tolerant of low oxygen conditions in benthos (e.g. oligochaete worms, chironomid larvae).
- If abundant macrophyte growth occurs in shallow parts of the pondage and backwater arms (as discussed above), macroinvertebrate species favoured by macrophytes would increase in abundance in these areas (e.g. grazer invertebrates) as well as fish that use plants for cover and spawning sites.
- There is likely to be an increase in predation pressure from large-bodied fish (particularly if stocking occurs) and waterbirds.
- The barrier effects of Amamoor Dam may affect freshwater mussel populations as they have may have a downstream drifting dispersal phase and an upstream movement phase as they attach to fish hosts (not well understood which species). If fish (hosts) are prevented from movement due to barriers, this would impact on mussel dispersal (Ponder and Walker 2003).
- Several species of freshwater spiny crayfish occur in the Mary catchment; however, their known range is limited to altitudes above 240 m, hence they are not expected to occur in the reaches that would be impounded by Amamoor Dam.

Fish

- Two fish species of conservation significance would be affected by impoundment and barrier effects of Amamoor Dam (Mary River cod, *Macculochella peelii mariensis* and Queensland lungfish, *Neoceratodus forsteri* – Table 4.6). Both these species are native to the Mary catchment and have restricted natural ranges in south-east Queensland.
- Major change in habitat from lotic to lentic conditions with associated loss of riparian vegetation, water quality changes and potential infestations of aquatic weeds is likely to favour a subset of fish species capable of surviving in

impounded waters. Alien fish species are often at a competitive advantage in this situation, but no alien fish have been recorded in Amamoor Creek.

- The reduction in availability of lotic habitat is expected to affect many species that commonly use shallow, flowing areas for refuge, foraging and spawning (e.g. eels, smelt, juvenile Australian bass, rainbowfish and hardyheads).
- Access to this part of the river system by diadromous fish species (including eels, Australian bass, mullet, bullrout and several gudgeon species – see Appendix C) is already restricted by downstream weirs (Mary Barrage and Gympie Weir).
- Amamoor Dam (wall height 43.5 m) would cause a major barrier to longitudinal fish movements. Without an effective fish passage device it would sever access by diadromous species to 130 km^2 of catchment upstream of the dam, and restrict the movement of several potamodromous species, including Mary River cod and lungfish (see Appendix C for a list of migratory fish species relevant to Amamoor Dam).
- High quality fish habitats are present in Amamoor Creek. They support Mary River cod (including restocking sites) and probably lungfish.

Other Vertebrates

- Tables 4.6 to 4.9 identify other vertebrate species of conservation significance that are likely to be affected by Amamoor Dam pondage.
- The Amamoor Dam pondage would reduce habitat suitability for riverine species: stream-dependent frogs (including potentially two “endangered”, one “vulnerable” and one “rare/restricted” species) and turtles (including the white-faced snapping turtle) would be particularly affected.
- Populations of waterbirds would increase.
- Terrestrial species would be expected to retreat to upslope habitats, and there would be increased pressures for territory, habitat and food resources, particularly surrounding the inundated remnant vegetation.

4.2.2 Mitigation Options for New/Raised Dams

Key mitigation and compensation measures relevant to the impoundment and barrier effects of Cambroon, Kidaman, Amamoor Dams and raising of Borumba Dam are presented in Table 4.17. The mitigation measures would address a wide range of environmental issues associated with the new/enlarged dams, but would not prevent the occurrence of major/very major changes to existing ecosystems within the dam pondage areas. Hence, rehabilitation/restoration of equivalent habitats outside the dam pondage areas is identified as being an appropriate compensation measure.

Table 4.17 Key mitigation and compensation measures relevant to impoundment and barrier effects of the Four Dams scenario (Cambroon, Kidaman, Amamoor and raising of Borumba)

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat" – rehabilitation or restoration of equivalent habitats outside the new/extended dam pondage areas	• Further investigations are required to identify suitable sites. • Local possibilities in the Mary catchment include Little Yabba Creek and Kandanga Creek. • Six Mile Creek is currently in good ecological condition and has high potential to be held at this level, but is a lowland rainforest stream and hence a very different type of stream to the ones that would be affected by the new/enlarged dam pondages. • The western tributaries of the Mary River downstream of Gympie are different to Amamoor and Yabba Creeks due to naturally higher salinities. • Where native terrestrial vegetation is inundated, non-inundated remnants along the boundaries could be expanded to ensure no net loss of habitat	• Varies, depending on existing condition, standard of rehabilitation/restoration and level of community commitment. Likely to be high for mainstream reaches as these are generally subject to significant disturbance due to a range of human activities.
"No net loss of habitat" – replacement of Mary River cod restocking sites	• Investigations would be required to identify other sections of the Mary River system suitable for cod restocking	• Depends on existence of suitable sites – ranges from low if suitable sites exist, to high if habitat restoration is required before cod restocking
Detention dams along pondage margins to maintain stable aquatic habitat during main storage drawdown	• Particularly relevant to Cambroon Dam which has a relatively wide shallow pondage compared to the other three storages in the Four Dams scenario.	• Low
Vegetated buffer zone above FSL to maintain corridors for movement of terrestrial species	• Could be achieved by retention and rehabilitation/enhancement of existing native vegetation (where present) and revegetation of 200 m buffer zone around dam pondages with appropriate indigenous species • As with any revegetation works, proper site preparation and ongoing maintenance is necessary for a successful outcome	• Varies, depending on extent and condition of existing native vegetation communities. Long-term commitment to maintenance required.
Buffer zone between assets and erosion risk zone	• A 200 m buffer zone around each new/enlarged dam pondage has already been identified in the SEQ Water Supply Strategy investigations as an integral component of the Four Dams scenario. • It is desirable for this zone to be vegetated/revegetated with native vegetation from the viewpoint of water quality and ecological values.	• Low (to reserve a buffer zone). The level of difficulty of maintaining a vegetated buffer zone is variable, as indicated above.
Drainage management of surface runoff to avoid concentration of flows onto exposed shorelines and hence mitigate risks of subaerial erosion	• Soil erosion risks and local drainage issues for the dam pondage shorelines would need to be investigated at the design stage.	• Low difficulty from technical viewpoint (particularly if extensive bedrock outcrops or forested areas are present), but long shorelines may present major costs.
Destratifiers in dam pondages (e.g. bubblers, impellers) would mitigate risks associated with stratification, such as blue–green algal blooms	• Relevant to all four dams. • Multiple mixing mechanisms would be required for pondages with dendritic shapes (particularly Borumba)	• Levels of difficulty would vary between dam pondages.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Catchment land use controls for rural land uses (forestry, agriculture, grazing) and buffer zones along streams and on drainage lines to minimise inputs of nutrients and other contaminants	• Catchment land uses (largely rural) vary between the four dam pondages. • The town of Jimna is situated in the headwaters of Yabba Creek.	• High
Cover areas of dispersive soils within dam pondage area with non-dispersive fill	• Possibly relevant to Cambroon Dam. • Soil surveys would be required to determine the extent of works required (if any). • Unlikely to be feasible for large areas	• Depends on the extent of dispersive soils. Low level of difficulty for a small area, may not be feasible if large areas are affected.
Measures to control excessive macrophyte growth (e.g. mechanical harvesting)	• Monitoring and adaptive management. Extensive macrophyte growth is highly likely.	• Low to medium. Ongoing management required as harvested biomass can be quickly replaced.
Education, signage, boat washing facilities at storages with pest plant species to mitigate risks of transmission of these species into dam pondages	• Cambomba is present in Six Mile Creek Dam pondage (Lake MacDonald)	• Medium. Whilst cheap and simple to implement, extensive community support is required for a successful outcome.
Install fish lock/lift on new dams	• Would mitigate some impacts on fish movement including diadromous and potamodromous species. • Likely to be more effective in enabling upstream movements than downstream movements. • Fish lock/lift would require sufficient flow allocations to render it effective for allowing fish passage. • Relevant to Cambroon, Borumba and Amamoor Dams. • Not relevant to Kidaman Dam because of upstream barriers (Kondalilla Falls, Baroon Pocket Dam)	• Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.
Installation and effective operation of fishways on new and existing weir infrastructure located downstream of dams (i.e. Mary Barrage, Gympie Control Weir and Coles Crossing Weir) to maintain access by diadromous and potamodromous fish species	• Improve fish passage past Mary Barrage and Gympie Weir (as outlined in Table 4.10) as compensation measure for reductions in fish passage due to installation of new dams and Coles Crossing Weir • Coles Crossing Weir would be a major strategic barrier to access of migratory fish to the upper section of the Mary catchment unless an effective fish passage device is installed	• Low
Provision of artificial lungfish spawning sites (floating mats of aquatic vegetation) if there is limited colonisation of shallow-water habitat in the dam pondages by Vallisneria	• Has not been trialled yet, so uncertain whether this option would be effective for allowing lungfish spawning and successful recruitment. • Monitoring and adaptive management would be required. • Relevant to Cambroon, Kidaman and possibly Amamoor Dams	• Low to install floating mats of vegetation, but effectiveness for lungfish spawning and recruitment unknown.
Boat traffic restrictions to mitigate boating impacts on dam pondages	• Turbulent resuspension process likely to be significant if boat traffic uses shallow areas. • Management options including restricting boat traffic to deep parts of the dam pondages and/or leaving tree spars in shallow zones to discourage high speed boating.	• Low, but requires community support

Mitigation or Compensation Measure	Comments	Level of Difficulty
Develop/review and implement species recovery plans for EVR species	• EVR stream-dependent species that would be significantly affected by impoundment and/or barrier effects in the Four Dams scenario include the Mary River turtle, Queensland lungfish, Mary River cod and "endangered" frogs	• Depends on standard of outcome and types of measures required. Usually high.

4.2.3 Downstream Effects on Non-tidal Reaches

Downstream effects of the Four Dams scenario on the non-tidal reaches of the Mary River system are discussed with reference to the Mary River upstream (Section 4.2.3.1) and downstream of Coles Crossing Weir (Section 4.2.3.2), Obi Obi Creek (Section 4.2.3.3), Yabba Creek (Section 4.2.3.4) and Amamoor Creek (Section 4.2.3.5).

4.2.3.1 Mary River – Cambroon Dam to Coles Crossing Weir

The Mary River between Cambroon and the Coles Crossing Weir site spans three assessment reaches and the upper part of a fourth assessment reach, as identified in the Mary Basin WRP environmental investigations (Brizga et al. 2004).
Flora and fauna of conservation significance supported by these reaches are listed in Tables 4.11 To 4.14.

Hydrology

- In the Four Dams scenario, Cambroon Dam would be situated at the upstream end of reach M3 (Cambroon to Obi Obi Creek), causing substantial reductions in medium and high flows (particularly small to medium floods) and elevated low flows due to supplemented releases (particularly in the dry season).
- Reaches M4 and M5 (between Obi Obi Creek and Yabba Creek) would be influenced by Cambroon Dam and Kidaman Dam (on Obi Obi Creek). Substantial reductions in medium and high flows (particularly minor to moderate floods) would persist through these reaches as a result of impacts of Cambroon and Kidaman Dams. Supplemented releases from Cambroon Dam to Coles Crossing Weir mean that low flows would be elevated, particularly in the dry season.
- IQQM simulations show considerable unnatural variability in release rates. It is assumed that operating rules could be optimised to minimise such variability and the scenario condition assessments outlined below are based on this assumption.
- The Coles Crossing Weir would be situated at AMTD 212.4 and its pondage area would extend upstream to a short distance above the Yabba Creek confluence.

Geomorphology

- The geomorphology of the reaches of the Mary River between Cambroon and the Coles Crossing Weir site currently shows **minor** to **major** change from reference condition, depending on the extent of sand/gravel extraction in each reach. Sand/gravel extraction is the key disturbance factor and has caused an existing sediment deficit in this part of the river system. Catchment land use and reductions in high flows resulting from existing water resource development in Obi Obi Creek catchment (Baroon Pocket Dam) have had minor impacts on existing geomorphological condition.

- In the Four Dams scenario, a shift to **major** change from reference condition in all three reaches between Cambroon and Yabba Creek is predicted due to the effects of Cambroon and Kidaman Dams (potentially **very major** in the Cambroon to Obi Obi Creek reach).
- Truncation of upstream sediment supply by Cambroon Dam would bring risks of clearwater erosion and substrate change. The Mary River in this area has a mobile sand/gravel bed. Net removal of sand and fine gravel by erosion processes downstream of Cambroon Dam is anticipated, leaving a lag deposit of coarse gravels draped in mud. Sediment replenishment from Obi Obi Creek would also be reduced due to Kidaman Dam and associated flow regime changes.
- Channel contraction is likely, probably mainly by accommodation adjustment involving vegetation encroachment across the high flow channel. This already occurs to some degree in natural dry periods, but instream vegetation communities would become more permanently established. Vegetation encroachment would potentially be accompanied by increased incidence of bank erosion caused by scour around instream obstructions (vegetation growth on instream islands).
- Increased sediment accumulation in pools is expected due to reworking of sand deposits on the river bed by supplemented releases, combined with reduced frequency of pool-scouring floods.
- Changed hydraulic interactions with Obi Obi Creek and other tributaries may possibly lead to increased risk of erosion in the Mary River or tributaries above the confluence zone, as a result of steepening of flood gradients due to reductions in tailwater support due to changes in flood regime.
- The Coles Crossing Weir pondage would extend upstream beyond Yabba Creek confluence, and would result to a shift to **major** change from reference condition in the weir pondage area (currently **moderate**).

Hydraulic Habitat

- Hydraulic habitat in the reaches of the Mary River between Cambroon and the Coles Crossing Weir site currently shows **minor** to **major** change from reference condition, reflecting impacts of geomorphological changes and minor impacts on low flow habitat arising from existing water resource development (unsupplemented extraction).
- Impacts of changes in flow regime resulting from Cambroon and Kidaman Dams (and associated geomorphological and vegetation responses) mean that all reaches between Cambroon and Yabba Creek will show **major** change from reference condition in the Four Dams scenario.
- Lateral connectivity to floodplain, bench and bar habitats would be reduced.
- Seasonality of low flow habitat would be altered, with supplemented releases up to about 140 ML/d (about 30 cm over riffle controls) being made throughout the year but substantially increasing the extent and persistence of low flow habitat in the dry season.
- Flow velocities through shallow pools (up to 1 m deep) in Mary River should show insignificant increases with supplemented releases up to 140 ML/d. Velocities would be less than 0.2 m/s, assuming no change to riffle stability occurs. Ecological implications (e.g. flushing of fish eggs) would depend on local hydraulic conditions and fish species.
- Conversion of riverine habitat to weir pondage would lead to **major** change from reference condition in the Coles Crossing Weir pondage (currently **moderate**).

Water Quality

- The water quality in the three reaches of the Mary River between Cambroon and Yabba Creek currently shows **minor** change from reference condition, reflecting influences of mainly rural land use pressures.
- In the Four Dams scenario, a shift to **moderate** change from reference condition would occur in these reaches due to the effects of dam releases and spills on ambient water quality; natural variability in water quality would be reduced.
- Blue–green algal blooms are very likely occur in Kidaman Dam on Obi Obi Creek (as they already occur in Baroon Pocket Dam upstream, which provides a source of propagules) and are also likely in Cambroon Dam, with implications for water quality in the Mary River.
- Changes in flushing processes due to reductions in medium and high flows would be likely to lead to accumulation of organic matter in pools and thus potentially rising trends and nutrients and falling trends in DO due to benthic respiration.
- Installation of Coles Crossing Weir would affect water quality in the weir pondage, but no change from the current overall condition of water quality in this reach (**moderate** change from reference condition) is predicted. It is assumed that detention time will be short due to ongoing extraction of water (as occurs in the Mt Crosby Weir pondage on the Brisbane River).

Riparian Vegetation

- The riparian vegetation in the three reaches of the Mary River between Cambroon and Yabba Creek currently shows **major** change from reference condition as a result of structural disruption and weed invasion, mainly due to land use pressures.
- In the Four Dams scenario, the overall condition rating for these reaches would remain as **major** change from reference condition, but the contribution of water resource development impacts would increase from **indiscernible–minor** to **major.**
- There would be increased encroachment of riparian vegetation species onto bars and benches – reductions in flood magnitude/ frequency mean that such vegetation would be scoured less frequently, allowing the establishment of more permanent communities that are less adapted to flood disturbance.
- Increased weed growth would be promoted by reductions in flood disturbance and increased moisture availability in the lower riparian zone due to flow supplementation and exposed mineral earth.
- A range of weed species, including Madeira vine, privet and camphor laurel, is present – these would shift closer to the river bed and thus be at greater risk of being dispersed by large floods. With the increased canopy weight, vegetative damage from major floods is likely to increase.
- Vegetation zonations would change. The river banks are likely to become more xeric and hence more fire-prone with increased instability of the toe in large flows due to loss of fringing vegetation with flexible trunks (due to senescence and replacement with less flexible species).
- Riparian vegetation in the reach between Yabba Creek and Six Mile Creek has undergone **very major** change from reference condition due to extensive vegetation loss and weed invasion. Drowning of part of the bank area in the Coles Crossing Weir pondage would result in further loss of remaining lower bank vegetation and increased instability of the bank toe.

Aquatic Vegetation

- Aquatic vegetation in the Mary River between Cambroon and the Coles Crossing Weir site currently shows **moderate** change from reference condition, reflecting influences of land use factors and, to a lesser degree, impacts of existing water resource development on low flow regimes.
- In the Four Dams scenario, a shift to **major** change from reference condition in the three reaches between Cambroon and Yabba Creek is predicted.
- Increases in macrophyte abundance and biomass are expected with the reductions in flood disturbance.
- Riffles are currently dominated by *Myriophyllum verrucosum* but there may be a shift to dominance by *Vallisneria nana*, which grows prolifically in other supplemented streams (e.g. the middle Brisbane River).
- In the Coles Crossing Weir pondage, there would also be a shift to **major** change from reference condition, reflecting the potential invasion of bank zones by robust emergents such as paragrass, guinea grass, arundo and *Persicaria lapithifolia* (IQQM simulations show an operating range of about 1 m), increased growth of submerged macrophytes at the upstream end of the weir pondage, and potential invasion of the water body by floating macrophytes.

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in the Mary River between Cambroon and the Coles Crossing Weir site currently show **minor** to **moderate** change from reference condition, reflecting impacts of land use pressures and, to a lesser degree, impacts of existing water resource development on low flow regimes.
- In the Four Dams scenario, a shift to **major** change from reference condition is predicted in the three reaches between Cambroon and Yabba Creek, in response to barrier effects of the dams on macroinvertebrate drift and inputs of POM, as well as effects of changes in water quality, increased abundance of aquatic macrophytes and habitat changes (including altered hydraulic habitats and shallowing of pools).
- In the Coles Crossing Weir pondage, there would also be a shift to **major** change from reference condition, reflecting macroinvertebrate community changes in response to impoundment.

Fish

- The fish fauna of the Mary River between Cambroon and the Coles Crossing Weir site currently shows **moderate** change from reference condition due to land use impacts on habitat (including riparian zone degradation and changes in instream habitat due to sand/gravel extraction and sedimentation) as well as minor influences arising from existing water resource development (changes in low flow regime and barrier effects of existing water infrastructure, including the Mary Barrage and Gympie Weir on the Mary River).
- A shift to **major** change from reference condition in the three reaches between Cambroon and Yabba Creek is predicted to occur in the Four Dams scenario as a result of further changes in flow regime (with associated changes in habitat and food resources) and increased barrier effects arising from new infrastructure (including Cambroon Dam and Coles Crossing Weir on the Mary River).
- Impacts of flow regime change include: potential reduction in cues for spawning and movement/dispersal, potential desynchronisation of elevated spring

temperature and low and stable flows (important conditions for spawning and recruitment of many fish species such as rainbowfish, hardyheads, glassfish and gudgeons), possible local increases in flow velocities in some parts of the river during natural low flow periods due to flow supplementation with adverse effects on fish spawning and larval development (e.g. flushing of fish eggs, larvae and planktonic food resources), and reduced access to riparian zone and floodplain habitat for foraging, growth and development.

- Further impedance of fish passage to/from downstream sections of the Mary River would occur due to a new weir at Coles Crossing. Affected taxa would include diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater mullet, bullrout, striped gudgeon) and potamodromous species (e.g. Mary River cod and lungfish).
- Altered flow conditions and associated habitat changes (e.g. proliferation of aquatic macrophytes) are likely to favour a subset of fish species. Alien fish species (e.g. gambusia, swordtail, platys and guppies) are likely to be favoured.
- The fish fauna of the Coles Crossing Weir pondage is predicted to show **very major** change from reference condition as a result of barrier and impoundment effects.
- The barrier effect of Coles Crossing Weir restricts fish access to approximately 2,000 km^2 of upstream catchment.

Other Vertebrates

- Mary River turtles may be present in the reaches of the Mary River between Cambroon and Yabba Creek, and have been recorded in the Mary River below Yabba Creek through to the Mary Barrage. Changes in geomorphology and vegetation between Cambroon and Yabba Creek in the Four Dams scenario would lead to loss of turtle nesting habitat on sand bars. Changes to macroinvertebrate communities may also alter their food resources, thus impacting negatively on Mary River turtles if they do occur in this part of the river.
- The Coles Crossing Weir pondage would provide unfavourable habitat conditions for Mary River turtles. Mature turtles are expected to survive in the weir pondage but are considered unlikely to successfully breed if sandbank habitats are drowned.
- The white-faced snapping turtle is also present in the vicinity of Yabba Creek confluence, and would be affected by the Four Dams scenario similarly to the Mary River turtle, although its breeding requirements are less specific than those of the Mary River turtle.
- A number of other rare/threatened vertebrate species may be present in these reaches of the Mary River, including frogs (cascade and tusked frogs, possibly also green-thighed frogs and the giant barred frog – habitat suitable, not yet surveyed) and red and grey goshawks. The Four Dams scenario would have implications for these species via changes in habitat and food resources.

4.2.3.2 Mary River – Downstream of Coles Crossing Weir to Mary Barrage

- The Mary River between Coles Crossing Weir and the Mary Barrage spans six assessment reaches and the lower part of a seventh assessment reach.

- Flora and fauna of conservation significance supported by these reaches are shown in Tables 4.11 to 4.14, and include several plant species as well as the Mary River cod, Queensland lungfish and Mary River turtle.
- Reach M6 (Yabba Creek to Six Mile Creek) would be influenced by Cambroon Dam, Kidaman Dam and the raising of Borumba Dam, as well as Coles Crossing Weir, which would be situated in the upper part of the reach. The lower part of Reach M6 would also be influenced by Amamoor Dam.
- Reaches M7 to M12 (Six Mile Creek to Mary Barrage) would be influenced by all four new dams and Coles Crossing Weir.
- Changes to the flow regime of the Mary River downstream of Coles Crossing Weir arising from the Four Dams scenario would consist of reductions in high, medium and low flows. The relative magnitude of change would decrease downstream, due to inflows from unimpounded tributaries.

Geomorphology

- The geomorphology of the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently shows **minor** to **moderate** change from reference condition, largely due to land use influences and instream sand/gravel extraction. **Major** change has occurred in the Mary Barrage pondage.
- In the Four Dams scenario, the reach between Coles Crossing Weir and Six Mile Creek would show **major** change from reference condition (compared to **minor/moderate** at present), reflecting impacts of reductions in medium and high flows due to upstream dams.
- Impacts would decrease to **moderate** change from reference condition in the reaches between Six Mile Creek and Wide Bay Creek (compared to **moderate** in the Gympie town reach and **minor** further downstream at present), and **minor** change from reference condition below Wide Bay Creek to upstream of the Mary Barrage pondage (i.e. same as existing condition).
- Impacts would include reductions in fluvial processes and sediment transport, as well as channel contraction, probably mainly by accommodation adjustment involving vegetation encroachment. Channel contraction would have implications for sand bar habitat used for Mary River turtle breeding, particularly in the reaches closest to the dams but discernible impacts may potentially extend as far downstream as the Wide Bay Creek confluence.
- Changed hydraulic interactions with tributary streams may possibly lead to increased risk of tributary erosion as a result of steepening of flood gradients due to reductions in tailwater support, particularly in the reaches closest to the dams.

Hydraulic Habitat

- Hydraulic habitat in the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently shows **moderate** (upstream of Eel Creek) to **minor** (downstream of Eel Creek) change from reference condition, reflecting impacts of geomorphological changes (as summarised above) and modifications to the low flow regime arising from existing water resource development. **Very major** change from reference condition has occurred in the Mary Barrage pondage.
- The reach between Coles Crossing Weir and Six Mile Creek would show **major** change from reference condition in the Four Dams scenario, reflecting impacts of changes in flow regime due to upstream dams, including reductions in low,

medium and high flows, with resulting reductions in low flow habitat on riffles, pool flushing and lateral connectivity to floodplain, bench and bar habitats.
- Impacts would decrease to **moderate** change from reference condition in the reaches between Six Mile Creek and Wide Bay Creek, and **minor** change from reference condition below Munna Creek to upstream of the Mary Barrage pondage.

Water Quality

- The water quality in the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently shows **moderate** (upstream of Glastonbury Creek) to **minor** (downstream of Glastonbury Creek) change from reference condition, mainly reflecting influences of rural and urban land use pressures. **Major** change has occurred in the Mary Barrage pondage.
- No changes to overall condition ratings would occur as a result of the Four Dams scenario, but impacts of water resource development would increase.
- The reaches between Coles Crossing Weir and Glastonbury Creek would continue to show **moderate** change from reference condition, but with increased impacts resulting from water resource development, including long-term trends in nutrients and DO as a result of the build-up of organic matter in pools due to reduced flushing by floods.
- The reaches between Glastonbury Creek and upstream of the Mary Barrage pondage would continue to show **minor** change from reference condition.

Riparian Vegetation

- The riparian vegetation of the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently transitions from **very major** change from reference condition (Coles Crossing Weir to Six Mile Creek), through **major** (between Six Mile Creek and Wide Bay Creek), to **moderate** (Wide Bay Creek to upstream of Mary Barrage pondage) as a result of structural disruption and weed invasion, mainly due to land use pressures. **Major** change has occurred in the Mary Barrage pondage.
- No changes to overall riparian vegetation condition ratings would occur in the reaches of the Mary River downstream of Coles Crossing Weir as a result of the Four Dams scenario, due to the significant disturbance that has already occurred in the reaches that would be most greatly affected by dam-related flow regime change.
- However, impacts of water resource development would increase, including invasion of the riparian zone by more xeric species and downslope changes in species distribution within bank zonations, including loss of fringing vegetation and opportunistic establishment in the toe zone of trees/shrubs with stiff trunks, with an associated increased risk of fire and bank erosion. Grasses and woody vegetation would shift instream across sand/gravel bars in response to reduced flood disturbance. These effects would diminish with increasing distance downstream of the new dams.

Aquatic Vegetation

- Aquatic vegetation in the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently shows **moderate** change from reference condition (except in the Gympie town reach, where **major** change is apparent), reflecting influences of land use factors and existing water resource development. **Very major** change has occurred in the Mary Barrage pondage.

- In the Four Dams scenario, a shift to **major** change from reference condition is predicted to occur between Coles Crossing Weir and Six Mile Creek, reflecting encroachment of emergent species, including terrestrial weeds, in response to reductions in flows. Shallower pools are likely to support increase growth of submerged macrophytes such as *Hydrilla* and *Potomageton crispus*.
- Similar changes but of a lesser magnitude are expected to also occur further downstream (diminishing in magnitude with distance from the developments), but would not lead to shifts in condition ratings, which already indicate significant change from reference condition

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently show **moderate** (Coles Crossing Weir site to Munna Creek) to **minor** (Munna Creek to upstream of Mary Barrage pondage) change from reference condition, reflecting impacts of land use pressures and existing water resource development. **Major** change has occurred in the Mary Barrage pondage.
- In the Four Dams scenario, overall condition ratings are not predicted to change, but impacts of water resource development would increase, particularly in the reach between Coles Crossing Weir and Six Mile Creek, reflecting changes in macroinvertebrate communities in response to changes in flow regime and habitat.

Fish

- The fish fauna of the Mary River between the Coles Crossing Weir site and the Mary Barrage pondage currently shows **moderate** change from reference condition in most reaches (**major** change in the Gympie town reach), reflecting **minor** impacts of existing water resource development (flow regime changes and barrier effects) and **moderate** impacts resulting from land use pressures. **Very major** change has occurred in the Mary Barrage pondage.
- In the Four Dams scenario, a shift to **major** change from reference condition would occur in the reaches between Coles Crossing Weir and Wide Bay Creek, reflecting impacts of increased barrier effects arising from Coles Crossing Weir and the new dams affecting diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater mullet, bullrout and striped gudgeon) and potamodromous species (e.g. Mary River cod and lungfish), potential reduction in cues for spawning and movement/dispersal, and reductions in access to riparian zone and floodplain habitat for foraging, growth and development
- In the reaches between Wide Bay Creek and Munna Creek, it is unlikely that overall condition would shift from the current rating of **moderate** change from reference condition, although impacts of water resource development would increase from **minor** to **moderate**.

Other Vertebrates

- Impacts of the Four Dams scenario on the geomorphological processes that maintain sand bars that provide key nesting habitat for the Mary River turtle would be greatest closest to the new developments (i.e. in this part of the Mary River, the Coles Crossing Weir to Six Mile Creek reach would be most greatly

affected) and may persist to some degree as far downstream as Wide Bay Creek, but are unlikely to be significantly discernible below Wide Bay Creek.
- The white-faced snapping turtle occurs in this part of the Mary River and would be affected by the Four Dams scenario similarly to the Mary River turtle, although its breeding requirements are less specific than those of the Mary River turtle.

4.2.3.3 Obi Obi Creek – Downstream of Kidaman Dam

- Obi Obi Creek was divided into four reaches for the WRP current condition assessments, including Lake Baroon (the pondage of existing Baroon Pocket Dam), one reach above Lake Baroon and two reaches below Baroon Pocket Dam (Brizga et al. 2004).
- Kidaman Dam would be situated in the downstream reach of Obi Obi Creek, and partly impound both of the reaches below Baroon Pocket Dam. The discussion here focuses on the lower part of the downstream reach, below Kidaman Dam.
- The lower reach of Obi Obi Creek supports flora and fauna species of conservation significance (see Tables 4.11 to 4.14).

Hydrology

- IQQM simulations show that the flow regime of Obi Obi Creek has already been substantially changed by Baroon Pocket Dam and would be further altered by the installation of Kidaman Dam.
- There would substantial further reductions in medium and high flows, particularly minor and moderate floods (e.g. the 1.5 year average recurrence interval (ARI) daily flow volume (DFV) would be reduced to zero and the 5 year ARI DFV would be reduced to 62% of pre-development).
- It would be possible for environmental compensation releases to mitigate some impacts on low flows (including existing impacts). Further optimisation runs would be necessary to determine the extent to which such mitigation would be feasible (e.g. provision of a minimum baseflow release at most/all times to mimic the natural near-perennial flow regime).

Geomorphology

- The geomorphology of the lower reach of Obi Obi Creek currently shows **moderate** change from reference condition, including **moderate** impacts of changes in fluvial processes and sediment transport resulting from Baroon Pocket Dam (increased flood durations may be exacerbating natural bank erosion processes; there is also anecdotal evidence of infill of pools, attributed by local residents to flow regime changes resulting from Baroon Pocket Dam) and **minor** impacts of land use factors.
- A shift to **major** change from reference condition is predicted in the Four Dams scenario, reflecting further changes in geomorphological processes, which would result in channel contraction, probably by accommodation adjustment rather than sediment accumulation, due to lack of a substantial local sediment supply. Diversion of flow by vegetated islands may locally cause or exacerbate bank erosion.
- Substrate changes would occur downstream of Kidaman Dam due to reductions in sediment supply from upstream, and clearwater erosion is also possible as the reach is alluvial (but may be countered by reductions in medium and high flows).

- Flow regime changes in the Mary River (reductions in high flows due to a new dam upstream at Cambroon) may lead to increased risk of stream erosion at the lower end of Obi Obi Creek as a result of steepening of flood gradients due to reduction in tailwater support.

Hydraulic Habitat

- Hydraulic habitat in the lower reach of Obi Obi Creek currently shows **moderate** change from reference condition, reflecting impacts of the existing Baroon Pocket Dam and minor pressures arising from other human activities.
- A shift to **major** change from reference condition would occur due to further changes in flow regime in the Four Dams scenario.
- Lateral connectivity to floodplain, bench and bar habitats would be reduced.

Water Quality

- The water quality in the lower reach of Obi Obi Creek currently shows **minor** change from reference condition, reflecting influences of local land use pressures.
- In the Four Dams scenario, a shift to **major** change from reference condition would occur due to the effects of Kidaman Dam on the water quality of spills and releases.
- Blue–green algal blooms are very likely occur in Kidaman Dam, and would have implications for water quality in Obi Obi Creek below the dam.
- Reductions in flushing processes due to reductions in medium and high flows would be likely to lead to accumulation of organic matter in pools and thus potentially rising trends in nutrients and falling trends in DO due to benthic respiration.

Riparian Vegetation

- The riparian vegetation of the lower reach of Obi Obi Creek currently shows **moderate** change from reference condition due to structural disruption and weed invasion, reflecting **moderate** impacts of land use pressures and **minor** impacts of existing flow regime changes resulting from Baroon Pocket Dam.
- An increase to **major** change from reference condition is predicted for the Four Dams scenario.
- Increased weed growth would be promoted by reductions in flood disturbance. Camphor laurel[46] and Madeira vine are already present and would be advantaged by flow regime change.
- Riparian vegetation zonations would change, including invasion of more xeric species that would make the riparian zone more fire-prone, and decline in condition and abundance of species that prefer moister conditions. A shift from “flexible” to “stiff” plants is likely to increase the susceptibility of the bank toe zone to erosion.
- Encroachment in the river channel of opportunistic weeds and resilient native vegetation is likely to occur.

[46] Camphor laurel has particularly significant implications due to its toxicity to some instream biota (particularly macroinvertebrates and early life history phases (eggs and larvae) of fish), although it attracts some species of birds and butterflies. Additional scientific studies are required to confirm/deny anecdotal evidence.

Aquatic Vegetation

- Aquatic vegetation in the lower reach of Obi Obi Creek currently shows **moderate** change from reference condition, with high abundances of submerged macrophytes in some parts of the reach but no alien species have been recorded. Key stressors include riparian vegetation loss and flow regime changes associated with existing water resource development.
- A shift to **major** change from reference condition is predicted in the Four Dams scenario.
- Further increases in macrophyte abundances are expected with the greater reductions in flood disturbance and increased light penetration in shallower flows.
- Downslope shifts of emergent macrophytes would occur as part of channel contraction/accommodation adjustment processes.

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in the lower reach of Obi Obi Creek currently show **moderate** change from reference condition, reflecting **moderate** impacts of land use pressures and **minor** impacts of existing flow regime change.
- A shift to **major** change from reference condition is predicted in the Four Dams scenario, in response to barrier effects of the dam on macroinvertebrate drift and inputs of POM, effects of changes in water quality (including hypolimnetic releases from a stratified dam pondage), increased abundance of aquatic macrophytes, alterations in hydraulic habitat and increased accumulation of leaf litter from camphor laurels (thought to be toxic to many species of invertebrates, including shredding insects).

Fish

- The fish fauna of the lower reach of Obi Obi Creek currently shows **moderate** change from reference condition due to barrier effects of existing water infrastructure (including the Mary Barrage and Gympie Weir on the Mary River; Baroon Pocket Dam is of low significance because of the presence of natural waterfalls upstream and downstream of the dam), flow regime changes, increased abundances of aquatic macrophytes and land use pressures.
- A shift to **major** change from reference condition is predicted to occur in the Four Dams scenario as a result of further changes in flow regime.
- Impacts of additional flow regime change include potential reduction in cues for spawning and movement/dispersal, reductions in longitudinal connectivity (particularly for large-bodied fish such as Mary River cod and lungfish), and reduced lateral connectivity of fish habitat to the riparian zone, benches and floodplain (with consequent reduction in access to habitat for foraging, growth and development).
- Increased accumulation of leaf litter from camphor laurels may adversely affect early life history phases (eggs and larvae) of fish.
- Kidaman Dam would impede upstream dispersal of fish, although access to the upstream catchment of Obi Obi Creek is already restricted by natural waterfalls and Baroon Pocket Dam.
- Further impedance of fish passage to/from downstream sections of the Mary River would occur due to the new weir at Coles Crossing. Affected taxa would include diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater

mullet, bullrout, striped gudgeon) and potamodromous species (e.g. Mary River cod and lungfish).

Other Vertebrates

- It is not known if the Mary River turtle occurs in this reach, but it could potentially use this area as refuge in times of flood.

4.2.3.4 Yabba Creek – Downstream of Borumba Dam

- Yabba Creek downstream of Borumba Dam was divided into three reaches for the current condition assessments for the Mary Basin WRP environmental investigations (Brizga et al. 2004).
- Flora and fauna of conservation significance supported by these reaches of Yabba Creek are shown in Tables 4.11 to 4.14 and include the Mary River cod, Mary River turtle and Queensland lungfish.
- There is one RE of conservation significance associated with Yabba Creek downstream of Borumba Dam: RE 12.3.11 (*Eucalyptus siderophloia*, *E. tereticornis*, *Corymbia intermedia* open forest on alluvial plains near coast), conservation status "of concern".

Hydrology

- IQQM simulations indicate that there would be further reductions in medium and high flows as a result of raising Borumba Dam, particularly immediately downstream of the dam, although these impacts decrease rapidly with distance downstream of the dam due to inflows from unimpounded tributaries.
- Increased flow supplementation would occur (up to about 100 ML/d, compared with about 30 ML/d at present).
- IQQM simulations show considerable unnatural variability in release rates – it is understood that this is an artefact of the modelling and would not occur in reality (the scenario condition assessments outlined below are based on this assumption).

Geomorphology

- The geomorphology of Yabba Creek currently shows **major** change from reference condition immediately downstream of Borumba Dam, transitioning through **moderate** change in the Imbil Weir pondage, to **minor** change downstream of Imbil, reflecting impacts of existing water resource development (Borumba Dam and Imbil Weir) as well as minor impacts of land use pressures.
- No changes in overall condition ratings are predicted in the Four Dams scenario, but impacts of flow regime change in the reach between Borumba Dam and Imbil Weir pondage would increase to **major** (currently **moderate**).
- Enlargement of the low flow channel is expected to occur in response to the larger supplemented releases. Flow depths over riffles would increase to about 40 cm (currently less than 30 cm), provided that the riffles remain stable. However, if adjustment of riffle/pool sequences occurs, this could result in shallower pools and longer riffles/runs. Other enlargement processes could potentially include increased bank and bed erosion as well as changes in vegetation zonations.
- Further contraction of the high flow channel by vegetation encroachment in response to reduced flood disturbance is expected.
- Flow regime changes in the Mary River (reductions in high flows due to upstream dams, including new dams at Cambroon and Kidaman) may lead to increased risk

of stream erosion at the lower end of Yabba Creek as a result of steepening of flood gradients due to reduced tailwater support.

Hydraulic Habitat

- Hydraulic habitat in Yabba Creek currently shows **moderate** change from reference condition, reflecting impacts arising from flow supplementation and reductions in medium and high flows, ponding of the middle reach by Imbil Weir, and minor pressures arising from other human activities.
- A shift to **major** change from reference condition is possible in the Four Dams scenario.
- An increase in supplemented flows from 30 ML/d to about 100 ML/d would take the flow over riffle control from about 20 cm to more than 40 cm. Yabba Creek riffles are ~5 m wide with pools about 1 m deep and less than 10 m wide. Assuming riffles stay stable, pool velocities will likely get close to 0.3 m/s. However, if reworking of riffles occurs, this would lead to shallower pools and longer/narrower riffle/runs, resulting in a greater increase in the extent of fastwater habitat and velocities through pools. Advice provided by the Moreton WRP TAP (Brizga et al. 2006d) indicates that a flow velocity as little as 0.3 m/s across a pool can wash away plankton and fish larvae.

Water Quality

- The water quality of Yabba Creek currently shows **moderate** change from reference condition, reflecting impacts of Borumba Dam (including local effects of hypolimnetic releases immediately below the dam and flow regime change) and influences of land use pressures.
- No changes in condition ratings are predicted in the Four Dams scenario, but the influence of dam releases on water quality would increase because of the larger supplemented releases and further reductions in high flows.
- A further increase in flushing and dilution of local pollutant inputs would occur due to larger supplemented releases.

Riparian Vegetation

- Riparian vegetation in Yabba Creek currently shows **minor** change from reference condition between Borumba Dam and Imbil Weir pondage, **major** change from reference condition in Imbil Weir pondage, and **moderate** change from reference condition further downstream, reflecting impacts of variable land use pressures and drowning of part of the former riparian zone by Imbil Weir pondage.
- An increase to **moderate** change from reference condition in the reach between Borumba Dam and Imbil Weir pondage is predicted in the Four Dams scenario, reflecting increased weed growth. Cat’s claw creeper is present and will spread regardless of further flow regime change, but the rate and extent of invasion would be accelerated by a further reduction in flood disturbance.
- No significant changes in the condition of riparian vegetation are predicted in Imbil Weir pondage or the reach downstream, unless the larger supplemented releases increase bank erosion/failures and subsequent loss of vegetation.

Aquatic Vegetation

- Aquatic vegetation in Yabba Creek currently shows **moderate** change from reference condition. Supplemented releases favour the growth of macrophytes in

unimpounded reaches, particularly on riffles, and some alien species are present. Imbil Weir pondage is dominated by emergent and floating taxa.
- No changes in condition ratings are predicted in the Four Dams scenario, provided that increased supplemented releases do not prevent recolonisation of fastwater habitats after scouring flood events or destabilise riffles.

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in Yabba Creek currently show **major** (Borumba Dam to Imbil Weir) to **moderate/major** (downstream of Imbil Weir to Mary River) change from reference condition, reflecting effects of Borumba Dam (including barrier effects on macroinvertebrate drift and inputs of POM, changes in water quality (including hypolimnetic releases), changes in aquatic vegetation and alterations in hydraulic habitat) as well as land use influences.
- No changes in condition ratings are predicted in the Four Dams scenario, as existing ratings already reflect substantial change from reference condition.

Fish

- The fish fauna of Yabba Creek currently shows **moderate** change from reference condition due to barrier effects of existing water infrastructure (including Borumba Dam and Imbil Weir), flow regime change, and presence of alien and translocated fish.
- In the reach between Borumba Dam and upstream of Imbil Weir, a shift to **major** change from reference condition is predicted to occur as a result of further changes in flow regime in the Four Dams scenario (reduced flood disturbance, increased supplementation). These changes would further disadvantage many native fish species (particularly reductions in flow-related cues for spawning and movement/dispersal and reduced recruitment due to flushing of fish eggs and larvae, and planktonic food resources) and further favour alien fish species (e.g. gambusia, swordtail, platys and guppies).
- No further change in overall condition is predicted in the downstream reach, although the contribution of water infrastructure impacts would increase from **minor** to **moderate** due to further impedance of fish passage to/from downstream sections of the Mary River by a new weir at Coles Crossing. Affected species would include diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater mullet, bullrout, striped gudgeon)] and potamodromous species (e.g. Mary River cod and lungfish).

Other Vertebrates

- The Mary River turtle is present in Yabba Creek, particularly the reach downstream of Imbil Weir. Turtles from the Mary River may use Yabba Creek as refuge at times of flood. Flow regime change may cause some alteration of turtle habitats.

4.2.3.5 Amamoor Creek – Downstream of Amamoor Dam

- Amamoor Creek was divided into two reaches for the WRP current condition assessments for the Mary Basin WRP environmental investigations (Brizga et al. 2004).

- Flora and fauna of conservation significance supported by these reaches of Amamoor Creek are shown in Tables 4.11 to 4.14 and include the Mary River cod and probably the Queensland lungfish.
- Amamoor Dam would impound part of the upper reach of Amamoor Creek. Impacts in the dam pondage area have been discussed above; this section discusses downstream impacts on the section of the upper reach below Amamoor Dam and the whole of the lower reach.

Hydrology

- IQQM simulations show that Amamoor Dam will lead to increased persistence of flows up to supplementation thresholds (about 60 ML/d) and reductions in frequency/duration of flows above this level.
- Key changes in flow regime include very major reductions in high flows (1.5 year ARI DFV reduced to 4% of pre-development, 5 year ARI DFV reduced to 2% and 20 year ARI DFV reduced to 58%), plus flow supplementation effects on low flow regime.
- Hydrologic simulation outputs are available for only one node; however, it is inferred from the drainage network that impacts will decrease with distance downstream of the dam due to inflows from unimpounded tributaries.

Geomorphology

- The geomorphology of Amamoor Creek currently shows **minor** change from reference condition due to land use factors in both assessed reaches.
- In the Four Dams scenario, an increase to **very major** (upper reach) to **major** (lower reach) change from reference condition is predicted downstream of Amamoor Dam due to the barrier effects of the dam on sediment supply (there is currently evidence of active transport of significant quantities of sediment up to cobble size in the upper reach, which would be blocked by the dam) and reductions in fluvial processes, including sediment transport, due to major reductions in small, medium and large flood flows.
- Flow regime changes in the Mary River (reductions in high flows due to upstream dams, including new dams at Cambroon and Kidaman and raising of Borumba Dam) may possibly lead to increased risk of stream erosion at the lower end of Amamoor Creek as a result of steepening of flood gradients due to reduced tailwater support.

Hydraulic Habitat

- Hydraulic habitat in Amamoor Creek currently shows **minor** change from reference condition, reflecting **minor** impacts arising from low flow extraction and land use pressures.
- In the Four Dams scenario, an increase to **very major** (upper reach) to **major** (lower reach) change from reference condition is predicted downstream of Amamoor Dam due to greatly increased persistence of flows up to about 60 ML/d (about 20 cm depth over riffle controls) resulting from supplementation and substantial reductions in frequency/duration of all flows larger than supplementation levels, which would greatly reduce lateral connectivity to bar, bench and floodplain habitats.

Water Quality

- The water quality of Amamoor Creek currently shows **minor** change from reference condition due to land use factors in both assessed reaches.
- In the Four Dams scenario, an increase to **moderate** change from reference condition is predicted in both reaches downstream of Amamoor Dam.
- Water quality would be altered by the dam impoundment; natural variability in water quality would be reduced.
- Changes in flushing processes in reaches below the dam (due to reductions in medium and high flows) would be likely to lead to accumulation of organic matter in pools and thus potentially rising trends in nutrients and falling trends in DO due to benthic respiration.

Riparian Vegetation

- Riparian vegetation in Amamoor Creek currently shows **moderate** change from reference condition, reflecting impacts of catchment land use including weed invasion and, in the lower reach, structural disruption.
- In the Four Dams scenario, an increase to **major** change from reference condition would occur in both reaches downstream of Amamoor Dam, reflecting changes in vegetation zonations and encroachment into the creek channel, as well as increased prevalence of weeds due to reduced flood disturbance and increased moisture availability due to supplementation.
- There would be increased encroachment of fringing vegetation, which is likely to become permanently established without the 'clearing' effects of high flow events.
- Linear connectivity along the riparian zone of Amamoor Creek would be reduced by the dam, with consequent reduction in propagules. Reduction in downstream dispersal of water borne propagules would occur as a result of flow regime change.
- Barrier effects of Amamoor Dam and very major reductions in high flows are likely to reduce the volume of large woody debris entering the stream, with implications for instream habitat. The reduction in high flows will also enable accumulation of increased volumes of forest floor biomass, which in dry periods will increase susceptibility to impacts of fire.
- Although hydrologic impacts decrease downstream of the dam, the lower reach flows through a more disturbed landscape with greater prevalence of alien vegetation species and the substrate of the creek is less rocky, so weed invasion risks are potentially higher.

Aquatic Vegetation

- Aquatic vegetation in Amamoor Creek currently shows **minor** change from reference condition. Macrophyte abundances are generally low and patchy (as would be expected under natural conditions), with low abundances of aliens.
- In the Four Dams scenario, an increase to at least **moderate** change from reference condition is predicted for both reaches downstream of Amamoor Dam.
- It is anticipated that similar changes in aquatic vegetation communities will occur in response to flow supplementation and reduced flood disturbance to those that have been observed in Yabba Creek, where the abundance of macrophytes has increased, particularly on unshaded riffles. However, reductions in flood disturbance in Amamoor Creek appear be greater than those that have occurred in

Yabba Creek, potentially leading to greater changes in macrophytes in Amamoor Creek.

- Increased persistence of flows downstream of Amamoor Dam due to supplementation is not considered to impact greatly upon *Vallisneria nana* as this species is tolerant of high water velocities (e.g. Brisbane River downstream of Wivenhoe Dam).
- The distribution of *Myriophyllum variifolium* may be impacted by supplemented flows as this species is associated with pools. While this species is not of conservation significance it is uncommon in south-east Queensland (its range extends as far north as Rockhampton). It forms a unique species association with *Myriophyllum verrucosum* and charophytes in the upper reaches of Amamoor Creek. To date this association has only been recorded from one other tributary of the Mary River (Booloumba Creek).

Aquatic Macroinvertebrates

- Aquatic macroinvertebrate communities in the upper reach of Amamoor Creek currently show **minor** change from reference condition reflecting influences of factors other than water resource development. Insufficient data were available to rate the condition of the lower reach.
- In the Four Dams scenario, an increase to **major** change from reference condition is predicted downstream of Amamoor Dam. This is based on the current assessed condition of the macroinvertebrate community of Yabba Creek below Borumba Dam, which has undergone similar flow regime change.
- Key factors contributing to impacts on macroinvertebrate communities include barrier effects of the dam on macroinvertebrate drift and inputs of POM, effects of changes in water quality (including hypolimnetic releases from a stratified dam pondage), changes in aquatic vegetation and alterations in hydraulic habitat.

Fish

- The fish fauna of Amamoor Creek currently shows **minor** change from reference condition due to land use pressures and riparian degradation; the impact of downstream weirs on access by migratory fish species is probably only minor.
- In the Four Dams scenario, a shift to **major** change from reference condition is predicted in the reaches downstream of Amamoor Dam, due to impacts of flow regime changes and the barrier effect of the dam on fish movement and dispersal including diadromous species (e.g. Australian bass, jungle perch, sea mullet, freshwater mullet, bullrout, striped gudgeon) and potamodromous species (e.g. Mary River cod and potentially the Queensland lungfish).
- Impacts of flow regime change include potential reductions in cues for spawning and movement/dispersal, potential desynchronisation of elevated spring temperature and low and stable flows (important conditions for spawning and recruitment of many fish species such as rainbowfish, hardyheads, glass perchlets and gudgeons), and reduction in access to riparian zone and floodplain habitat for foraging, growth and development. Flow velocities through shallow pools (up to 1 m deep) in Amamoor Creek should not show significant increase with supplemented releases up to 60 Ml/d (about 20 cm riffle depth). Velocities will be about 0.1 m/s, assuming no change to riffle stability occurs. Ecological implications (e.g. flushing of fish eggs) would depend on local hydraulic conditions and fish species.

- Altered flow conditions and associated habitat changes (e.g. proliferation of aquatic macrophytes) are likely to favour a subset of fish species including gambusia, swordtail, platys and guppies.

Other Vertebrates

- No specific information is regarding the other vertebrate fauna of Amamoor Creek. Habitat is suitable for the giant barred frog (“vulnerable” EPBC) and the cascade, tusked and green-thighed frogs (NCA-listed species) – surveys are required to confirm the presence of these species. Mary River turtles are likely to use Amamoor Creek as a refuge during high flows in the main trunk of the Mary River, when they will require large woody debris or log jams.
- Impacts of the Four Dams scenario will include loss of habitat in remnant vegetation within the dam pondage area, which will increase territorial pressure on existing populations.
- There will be loss of linear connectivity for lowland species with upstream habitat.
- Changes in habitat and food resources arising from geomorphological and ecological changes outlined above may potentially have significant implications for other vertebrates.

4.2.4 Mitigation Options for Downstream Impacts of Dams

Mitigation options have been identified that could feasibly address a range of downstream impacts arising from the Four Dams scenario (Table 4.18). These mitigation options would assist in reducing impacts, but generally not sufficiently to alter the predicted trends in overall condition ratings, with the following exceptions:

- Weed management measures could potentially hold riparian vegetation condition in Obi Obi Creek downstream of Kidaman Dam at the current level of **moderate** change from reference condition;
- Weed management measures could potentially hold riparian condition in the Borumba Dam to upstream of Imbil Weir pondage reach of Yabba Creek at the current level of **minor** change from reference condition;
- Although there would be no shifts in reach-scale condition ratings, significant local benefits for water quality and instream ecology would accrue from installation of multilevel offtakes on all new/enlarged dams (there is already an existing problem with hypolimnetic releases from the existing Borumba Dam); and
- In the lower reach of Amamoor Creek, it may be feasible to hold riparian condition at the current level of **moderate** change from reference condition, although an extremely high level of effort would be required. (It is unlikely to be feasible to do this in the upper reach, due to probable encroachment in response to very major changes in flow regime).

Table 4.18 Key mitigation and compensation measures relevant to downstream effects of the Four Dams scenario on non-tidal reaches of the Mary River and tributaries

Mitigation or Compensation Measure	Comments	Level of Difficulty
"No net loss of habitat"	• To compensate for major/very major impacts of new/enlarged dams on downstream reaches of the Mary River, Obi Obi Creek, Yabba Creek and Amamoor Creek. • Difficult to find equivalent habitats in this part of Mary River system due to the large proportion of major streams that would be affected by new dams. • Further investigations would be required, but Little Yabba Creek and Kandanga Creek would be possibilities	Depends on standard of rehabilitation/ restoration, and community commitment
Cease instream sand/gravel extraction in Mary River reaches downstream of Cambroon Dam	• Would be a key component of any management strategy to mitigate sediment deficit leading to bed armouring and/or clearwater erosion.	Low, but would require alternative source of sand/gravel supply
Install destratifier(s) in new dam pondages	• Mitigation of dam stratification effects (see Table 4.17)	Varies between dam pondages
Install multi-level offtakes on new/raised dams	• Would mitigate impacts of hypolimnetic ecosystems on downstream water quality and ecology, particularly in the reaches immediately below the new/enlarged dams. • Would mitigate existing water quality problems below Borumba Dam. • Could also be operated to simulate natural seasonal variability in water temperature. • Destratification measures within the dam pondages (as discussed above) would also have benefits downstream of the dams.	Low
Riparian zone revegetation and weed management	• Riparian zones already significantly disturbed along the Mary River. There is less disturbance along tributaries but still significant presence of weeds. • Riparian zone management measures (including revegetation and surveillance for weeds and prompt removal) would assist in counteracting the effects of reductions in flood disturbance on proliferation of weeds. • The high degree of existing disturbance of the riparian vegetation and existence of numerous weed sources in adjacent areas and throughout the catchment makes vegetation management a difficult and expensive task. A very major ongoing financial and community commitment would be required for vegetation management measures to be successful in even counteracting the effects of reduced flood disturbance on weed proliferation. • Removal of camphor laurels is likely to benefit aquatic communities, as leaf fall from this species is toxic to some species of aquatic macroinvertebrates and may also affect fish eggs and larvae; however, it would not prevent the predicted shift in ratings for fish and macroinvertebrates, which also reflect other impacts arising from the installation of Kidaman Dam •	High
Mechanical removal of excessive floating macrophytes in dam pondages	• To mitigate impacts on downstream water quality of decomposing aquatic vegetation from dam pondages	Low to medium. Ongoing management required as harvested biomass can be quickly replaced.

Mitigation or Compensation Measure	Comments	Level of Difficulty
Install fish locks/lifts on Cambroon, Borumba and Amamoor Dams	• Discussed above (Table 4.17). Would also affect fish community structure downstream of dams. • As in the case of any fish passage device on a dam or weir, fish movements would be more constrained than under natural conditions. • It is possible that a fish lift/lock may be used by some migratory crustaceans such as macrobrachium • There would be little benefit from the installation of a fish passage device on Kidaman Dam, as access to the upstream catchment is already restricted by Kondalilla Falls and the existing Baroon Pocket Dam • In Yabba Creek, natural access to the downstream river system is limited by a small waterfall just below Imbil Weir	Medium level of technical difficulty to construct. However, provision of downstream fish passage and maintenance of successful upstream fish movement though dam pondages is problematic.
Install a fish passage device (fishway or fish lock/lift)[47] on Coles Crossing Weir	• As in the case of any fish passage device on a dam or weir, fish movements would be more constrained than under natural conditions • Sufficient flow allocations need to be provided to allow effective fishway operation	Low/Medium
Installation and effective operation of fishways on existing infrastructure (e.g. Gympie Weir, Mary Barrage) to maintain access by diadromous and potamodromous fish species	• Compensation measure for reduction in fish passage due to new dams & Coles Crossing Weir • The Mary Barrage has an existing fishway. Design modifications have been recommended to further improve fish passage • Gympie Weir currently does not have a fishway and so forms a barrier to movement during low flow periods • See Table 4.17 for further details	Low
Develop/review and implement species recovery plans for EVR species	• EVR species that would be significantly affected by downstream effects of the Four Dams include the Mary River turtle, Queensland lungfish, Mary River cod and "endangered" frogs	Depends on standard of outcome and types of measures required. Likely to be high.
Environmental compensation flows	• Environmental flow rules have been built into the hydrologic modelling of Four Dams scenario, but these do not fully address all environmental concerns. • Further analysis and optimisation of the environmental flows would need to be undertaken at the design stage of the project	Low, provided that appropriate outlet works are constructed. Would lead to a reduction in water available for consumptive yield and/or reliability
Use of alternative conduit (e.g. pipeline) for downstream water delivery (relevant to supplemented reaches)	• Would enable impacts of unseasonally elevated flows due to supplemented releases to be mitigated. • However, would not mitigate impacts of reductions in medium/high flows and may result in other impacts arising from an overall reduction in water availability in the stream system. • May possibly be feasible for delivery of water for urban uses, where there is a single downstream extraction point (e.g. Borumba Dam to Coles Crossing Weir). • Unlikely to be feasible in Amamoor Creek where supplementation is for downstream irrigators (given the spatially extensive distribution of downstream users, costs are likely to be prohibitive)	High

[47] SWP (2000) recommended a fish lock rather than a fishway for Coles Crossing Weir due to the height of the weir (8.4 m plus 2 m fabridam)

4.2.5 Downstream Effects on Estuarine Reaches and the Great Sandy Strait

4.2.5.1 Implications for Condition and Values

The downstream implications of the Four Dams scenario for the geomorphology and ecology of the estuarine reaches of the Mary River and Great Sandy Strait are generally the same as for the Traveston Dam scenario (refer Section 4.1.3.1). The Four Dams scenario would result in slightly lesser reductions in flow than Traveston Dam, but discernible differences in terms of effects on geomorphology and ecology are not anticipated.

4.2.5.2 Mitigation Options

Possible mitigation options are the same as outlined for the Traveston Dam scenario (refer Section 4.1.3.2).

References

Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. National Water Quality Management Strategy.

Arthington, A.H. and Long, G.C. (Eds.) (1997) Logan River Trial of the Building Block Methodology for Assessing Environmental Flow Requirements: Background Papers. Centre for Catchment and Instream Research, Griffith University and Department of Natural Resources, Brisbane, Queensland.

Arthington, A.H., Brizga, S.O., Choy, S.C., Kennard, M.J., Mackay, S.J., McCosker, R.O., Ruffini, J.L. and Zalucki, J.M. 2000. Environmental Flow Requirements of the Brisbane River Downstream From Wivenhoe Dam. South East Queensland Water Corporation and Centre for Catchment and In-stream Research, Griffith University, Brisbane.

Berghuis, A.P. & Broadfoot, C.P. (2004). Downstream Passage of Fish at Ned Churchward Weir. DPI Fisheries Report for the Department of State Development. March 2004.

Berghuis, A.P. & Pilz, S.A. (2005). Assessment of the upgraded fishway on the Mary River Barrage. Department of Primary Industries & Fisheries Report to the Department of Natural Resources, Mines & Energy. October 2005.

Bombace, G., Fabi, G., Fiorentini, L. (1995) Artificial Reefs and Mariculture: the Italian Experience. In. Ecoset '95: International Conference on Ecological System Enhancement Technology for Aquatic Environments (Volume 2). Tokyo, Japan. Ecoset '09 Secretariat, Japan International Marine Science and Technology Federation. P830-835.

Brizga, S.O., Arthington, A.H, Balcombe, S., Condina , P., Connell, M., Connolly, N., Craigie, N.M., Kennard, M., Kenyon, R., Mackay, S. and Schlacher, T. (2005) Mary River Basin Draft Water Resource Plan: Environmental Flow Assessment Framework and Scenario Implications. Report for the Department of Natural Resources and Mines, Queensland.

Brizga, S.O., Arthington, A.H, Bennett, J., Connolly, R., Duke, N., Hadwen, W., Hunter, H., Kapitzke, R, Kenyon, R., McCosker, R., and Mackay, S. (2006d) Moreton and Gold Coast Water Resource Plans: Environmental Flow Assessment Framework and Scenario Implications. Moreton Bay Waterways & Catchments Partnership and Department of Natural Resources, Mines and Water, Queensland. 2 Volumes.

Brizga, S.O., Arthington, A.H, Duke, N., Evans, P., Hadwen, W., Kapitzke, R, Kenyon, R., MacAlister, A., McCosker, R., Mackay, S., Smith, M., Udy, J. and Vance, D. (2006b) Moreton and Gold Coast Water Resource Plans: Current Environmental Condition Report. Moreton Bay Waterways & Catchments Partnership and Department of Natural Resources, Mines and Water, Queensland. 4 Volumes.

Brizga, S.O., Arthington, A.H., Condina, P., Connolly, N., Craigie, N.M., Kennard, M.J., Kenyon, R., Loneragan, N.L., Mackay, S.J., Werren, G.L. 2004. Mary Basin Draft Water Resource Plan. Environmental Conditions Report. (Includes Mary River, Burrum River and Beelbi Creek Catchments). Department of Natural Resources and Mines, Brisbane. 2 Volumes.

Brizga, S.O., Arthington, A.H., Connolly, R., Kennard, M., MacAlister, A., Mackay, S., McCosker, R., McNeill, V. and Udy, J. (2006a) Logan Basin Draft Water Resource Plan. Environmental Investigations Report. Department of Natural Resources, Mines and Water, Brisbane. 2 Volumes.

Brizga, S.O., Craigie, N.M, Condina, P. and Werren, G.L. (2003) Mary catchment: River Process Study. Report for the Department of Natural Resources and Mines, Queensland. S. Brizga & Associates Pty Ltd.

Brizga, S.O., Kapitzke, R., Butler, B., Cappo, M., Connolly, N., Lait, R, Pearson, R.J., Pusey, B., Smithers, S. and Werren, G.L. (2006c) Burdekin Basin Draft Water Resource Plan. Environmental Assessment Report. Phase 1 – Current Environmental Condition. Department of Natural Resources and Mines, Queensland.

Bunn, S.E. and Arthington, A.H. (2002). Basic principles and consequences of altered hydrological regimes for aquatic biodiversity. Environmental Management 30: 492–507.

Condina, P. (2004) Water Quality. In: Brizga, S.O., Arthington, A.H., Condina, P., Craigie, N.M., Kennard, M.J., Kenyon, R., Loneragan, N.L., Mackay, S.J., Werren, G.L. (2003) Mary Basin Water Resource Plan. Current Condition Report, Mary–Burrum Catchments. Department of Natural Resources and Mines, Brisbane. Appendix D.

Dunn, H. (2003) Can conservation assessment criteria developed for terrestrial systems be applied to riverine systems? Aquatic Ecosystem Health and Management 6, 81–95.

Environment Australia (2002) Information Sheet on Ramsar Wetlands (RIS) Great Sandy Strait (including Great Sandy Strait, Tin Can Bay and Tin Can Inlet).

Erftemeijer, P. L. A., and R. R. Lewis. 2000. Planting mangroves on intertidal mudflats: habitat restoration or habitat conversion? Pages 156-165 in Proceedings of the ECOTONE VIII Seminar "Enhancing Coastal Ecosystems Restoration for the 21st Century, Ranong, Thailand, 23-28 May 1999. Royal Forest Department of Thailand, Bangkok, Thailand.

Farmer D. Catterall, C., Piper, S. (2004) Abundance patterns across months and locations, and their differences between migrant and resident landbirds in lowland subtropical eucalypt forest, Emu 2004, 104 pp 283-296 CSIRO publishing.

Forbis, L.A., LaMorte, D.L. (1995) Lake Havasu Fisheries Improvement Program. In. Ecoset '95: International Conference on Ecological System Enhancement Technology for Aquatic Environments (Volume 2). Tokyo, Japan. Ecoset '09 Secretariat, Japan International Marine Science and Technology Federation. P818-823.

Garnett, S.T. and Crowley, G.M. (2000) The Action Plan for Australian Birds 2000. Environment Australia. http://www.deh.gov.au/biodiversity/threatened/publications/action/birds2000/index.html

GHD (Gutteridge, Haskins & Davey Pty. Ltd.), N.M. Craigie & Associates, and S. Brizga & Associates. (1996) Pioneer and Upper Pioneer River Improvement Trusts: Strategic Waterway Management Plan. Report for Pioneer River Improvement Trust and Upper Pioneer River Improvement Trust.

Gregory, H. (1996). The Brisbane River story: meanders through time. Australian Marine Conservation Society, Brisbane.

Hines, H. (2001) Recovery Plan for stream frogs of south-east Queensland 2001-2005. Qld Parks & Wildlife Service and South-east Qld Threatened Frogs Recovery Team.

Jensen, A., Collins, K. (1995) Artificial reef research in the European Union. In. Ecoset '95: International Conference on Ecological System Enhancement Technology for Aquatic Environments (Volume 2). Tokyo, Japan. Ecoset '09 Secretariat, Japan International Marine Science and Technology Federation. P824-829.

Johnson, J.W. (1999) Annotated checklist of the fishes of Moreton Bay, Queensland, Australia. Memoirs of the Queensland Museum 43(2): 709–762).

Kennard, M. J. (2000). Appendix G: Freshwater Fish. In Brizga, S., Arthington, A., Choy, S., Duivenvoorden, L., Kennard, M., Maynard, R. & Poplawski, W. (2000). Burnett Basin WAMP: Current Environmental Conditions and Impacts of Water Resource Development. Volume II(b). Department of Natural Resources, Brisbane.

Kennard, M.J. (2004). Appendix H: Freshwater fish. In Mary Basin Water Resource Plan (WRP) – Environmental Conditions Report. (Eds S. Brizga, A.H. Arthington, S. Choy, L. Duivendoorden, M. Kennard, R. Maynard, and W. Poplawski). Queensland Department of Natural Resources, Brisbane.

Kondolf, G.M. (1995) Managing bedload sediment in regulated rivers: examples from California, U.S.A. American Geophysical Union, Geophysical Monograph 89, 165-76.

Lewis, R.R. (2005). Ecological engineering for successful management and restoration of mangrove forests. Ecological Engineering 24:403-418.

Littlejohn, C. L. (2004) Influence of Artificial Destratification on Limnological Processes in Lake Samsonvale (North Pine Dam), Queensland, Australia. Masters Thesis, Griffith University

Loneragan, N. R. and Bunn, S. E. (1999) River flows and estuarine ecosystems: Implications for coastal fisheries from a review and a case study of the Logan River, southeast Queensland. Australian Journal of Ecology, 24, 431–440.

Manson, F.J., Loneragan, N.R., Phinn, S.R. (2003) Spatial and temporal variation in distribution of mangroves in Moreton Bay, sub-tropical Australia: a comparison of pattern metrics and change detection analyses based on aerial photographs. Estuarine, Coastal and Shelf Science. 57:653-666.

Merz, J.E., Pasternack, G.B. and Wheaton, J.M. (2006) Sediment budget for salmonid spawning habitat rehabilitation in a regulated river. Geomorphology 76: 207–228.

Michael F. Clarke, Peter Griffioen and Richard H. Loyn. Where do all the birds go by. Wingspan, December 1999 issue (Birds Australia: http://www.birdsaustralia.com.au).

MRCCC (2001) Mary River & Tributaries Rehabilitation Plan. Mary catchment Coordinating Committee, Gympie.

Nilsson, C., Reidy, C. A., Dynesius, M. & Revenga, C. (2005). Fragmentation and Flow Regulation of the World’s Large River Systems. Science. 308: 405-408.

Osunkoya, O.O. and Creese, R.G. (1997) Population structure, spatial pattern and seedling establishment of the Grey Mangrove, Avicennia marina var. australasica in New Zealand. Australian Journal of Botany. 45:707-725.

Ponder, W.F., and Walker, K.F., 2003. From mound springs to mighty rivers: The conservation status of freshwater molluscs in Australia. Aquatic Ecosystem Health and Management 6: 19-28.

Postel, S. & Richter, B. (2003). Rivers for Life: Managing Water for People and Nature. Island Press: Washington.

Preen, A.R., Lee-Long, W.J. and Coles, R.G. (1995) Flood and cyclone related loss, and partial recovery, of more than 1000 km^2 of seagrass in Hervey Bay, Queensland, Australia. Aquatic Botany 52, 3-17.

Pusey, B.J., Kennard, M.J. & Arthington, A.H. (2004). Freshwater Fishes of North-Eastern Australia. CSIRO Publishing, Collingwood.

Rutherfurd, I.D., Jerie, K., Walker, M., Marsh, N.A. (1999). Don’t raise the Titanic: How to set priorities for stream rehabilitation. Proceedings of the Second Australian Stream Management Conference, Adelaide, South Australia, Cooperative Research Centre for Catchment Hydrology.

Rutherfurd, I.D., Ladson, A.R. & Stewardson, M.J. (2004). Evaluating stream rehabilitation projects: reasons not to, and approaches if you have to. Australian Journal of Water Resources. 8(1): 57-68.

Sherman, B. (2000) Scoping options for mitigating cold water discharges from dams. CSIRO Land and Water, Canberra, Consultancy Report 00/21 May 2000.

Merrick, J.R. (1993) Freshwater crayfishes of New South Wales. Published by Linnean Society of New South Wales. Milson’s Point: NSW.

State Water Projects (SWP) (2000) Investigation of Moy Pocket Weir Sites. Report for Water Infrastructure Planning and Development, Contract No. RID/MARY/0003.

Stewart, D. (1997) The Vertebrate Fauna of the Minto Wetlands; Boonah Shire, south-eastern Queensland. Report prepared by Department of Environment for the Department of Natural Resources. 15pp.

Vorosmarty, C.J., Lettenmaier, D., Leveque, C., Meybeck, M., Pahl-Wostl, C., Alcamo, J., Cosgrove, H., Grassl, H., Hoff, H., Kabat, P., Lansigan, P., Lawford, R. & Naiman, R. (2004). Humans transforming the global water system. EOS 85: 509–514.

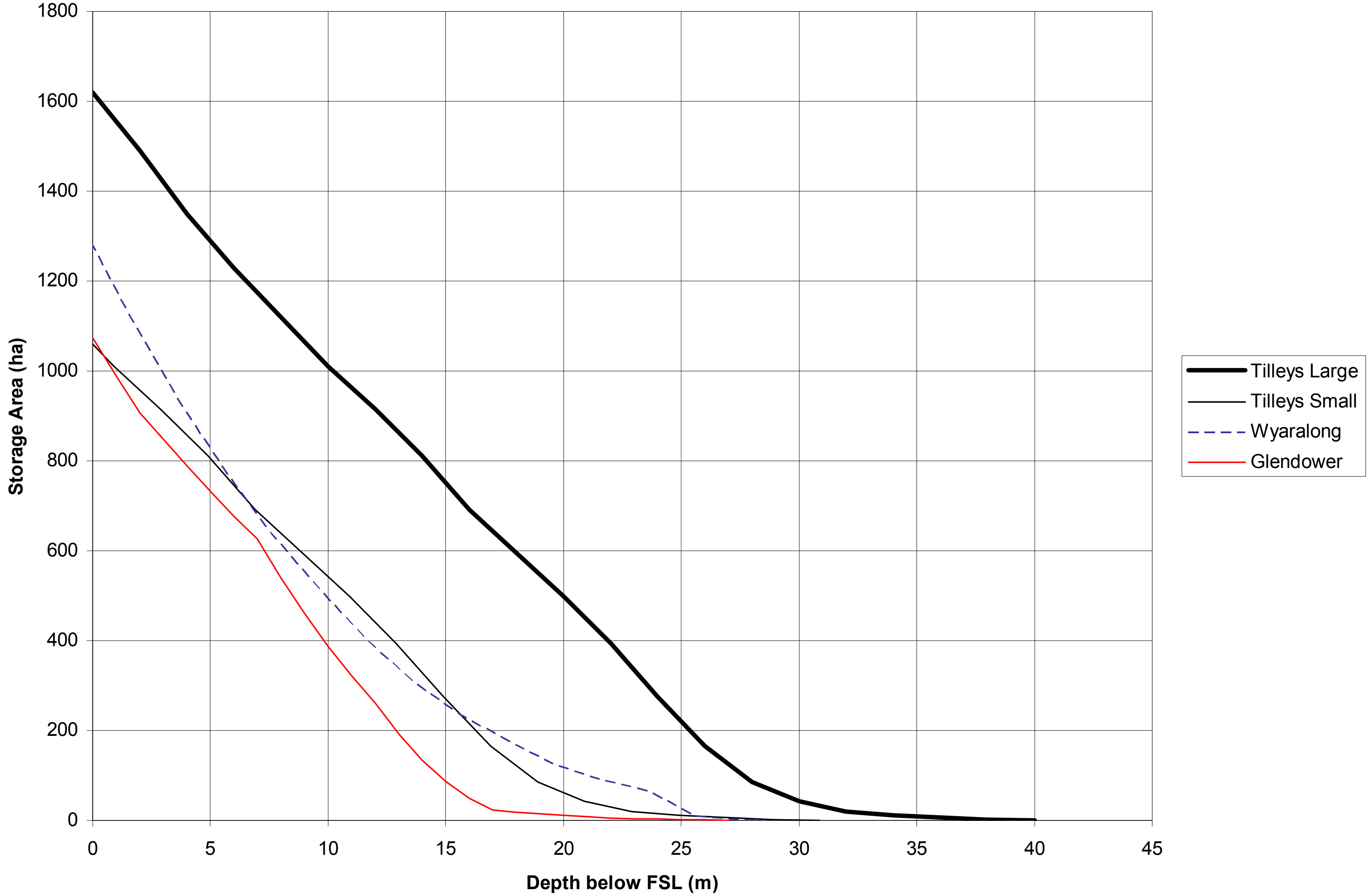
Werren, G.L.. (2004) Other Vertebrates. In: Brizga, S.O., Arthington, A.H., Condina, P., Craigie, N.M., Kennard, M.J., Kenyon, R., Loneragan, N.L., Mackay, S.J., Werren, G.L. (2003) Mary Basin Water Resource Plan. Current Condition Report, Mary–Burrum Catchments. Department of Natural Resources and Mines, Brisbane. Appendix I.

World Commission on Dams (2000) Dams and Development. A New Framework for Decision-making. The Report of the World Commission on Dams. London and Sterling, Earthscan Publications.

Abbreviations

AMTD	Adopted middle thread distance
ARI	Average recurrence interval
CAMBA	China Australia Migratory Bird Agreement
DO	Dissolved oxygen
DFV	Daily flow volume
ECV	Ecological conservation value
EPA	Environmental Protection Agency
EPBC	*Environment Protection and Biodiversity Conservation Act* 1999 (Commonwealth of Australia)
FSL	Full supply level
HNFY	Historical No Failure Yield
IQQM	Integrated Quantity Quality Model
JAMBA	Japan Australia Migratory Bird Agreement
MBW&CP	Moreton Bay Waterways and Catchments Partnership
ML	Megalitre
NCA	*Nature Conservation Act* 1992 (State of Queensland)
NRW	Department of Natural Resources and Water
POM	Particulate organic matter
RE	Regional Ecosystem
STP	Sewage Treatment Plan
SWP	State Water Projects
TAP	Technical Advisory Panel
WRP	Water Resource Plan
WSUD	Water Sensitive Urban Design

Appendix A – Storage Curves



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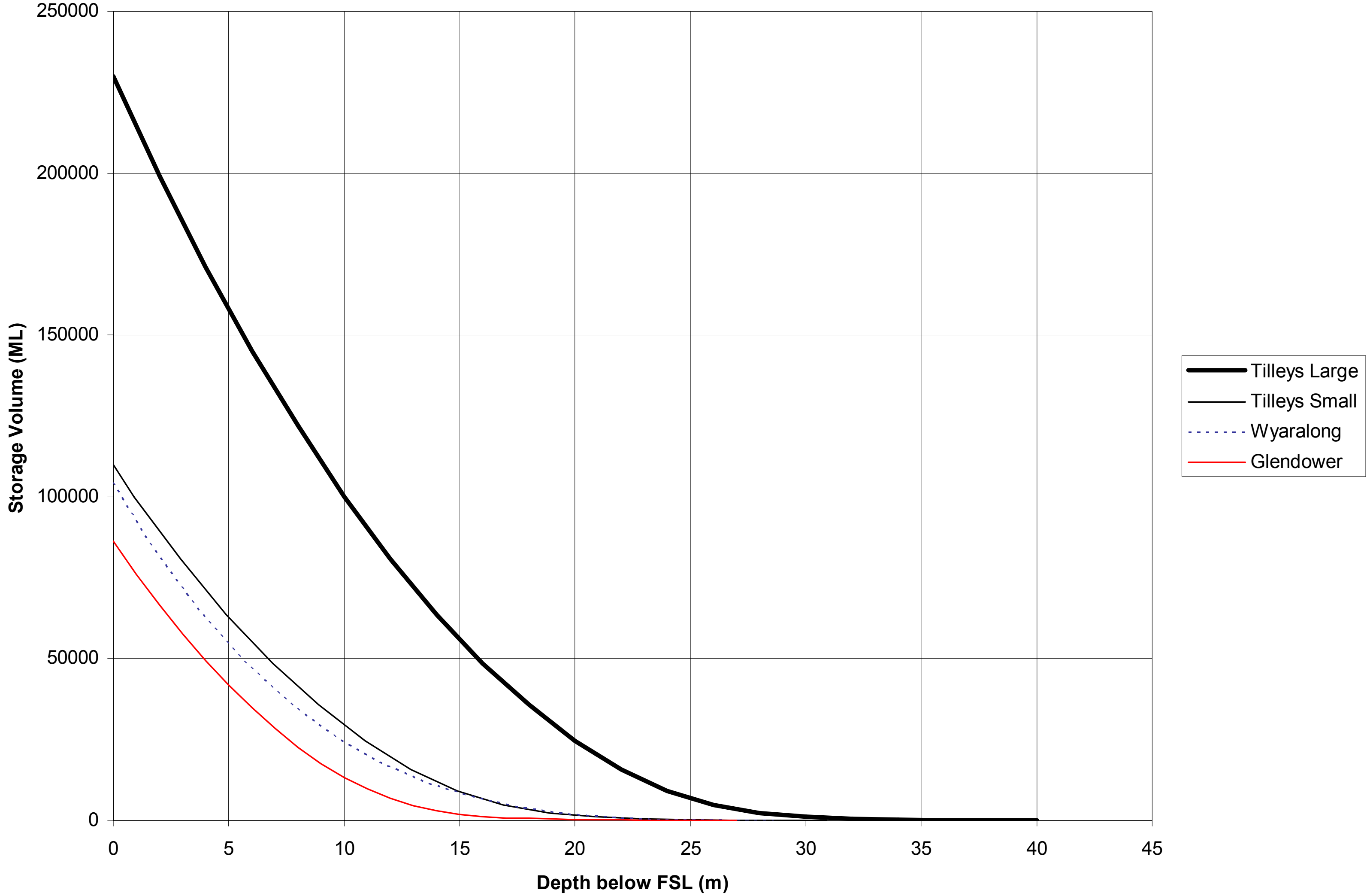
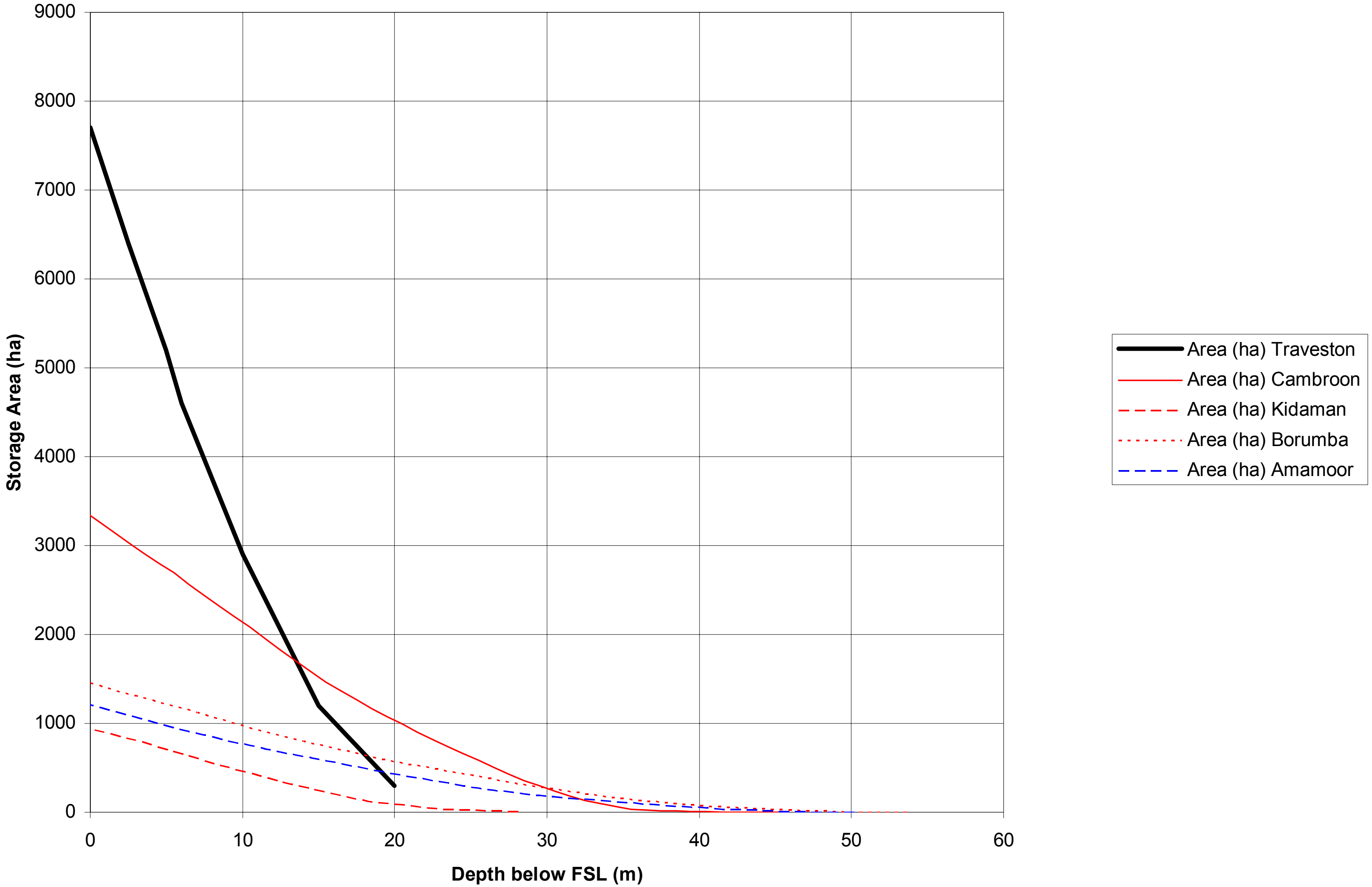
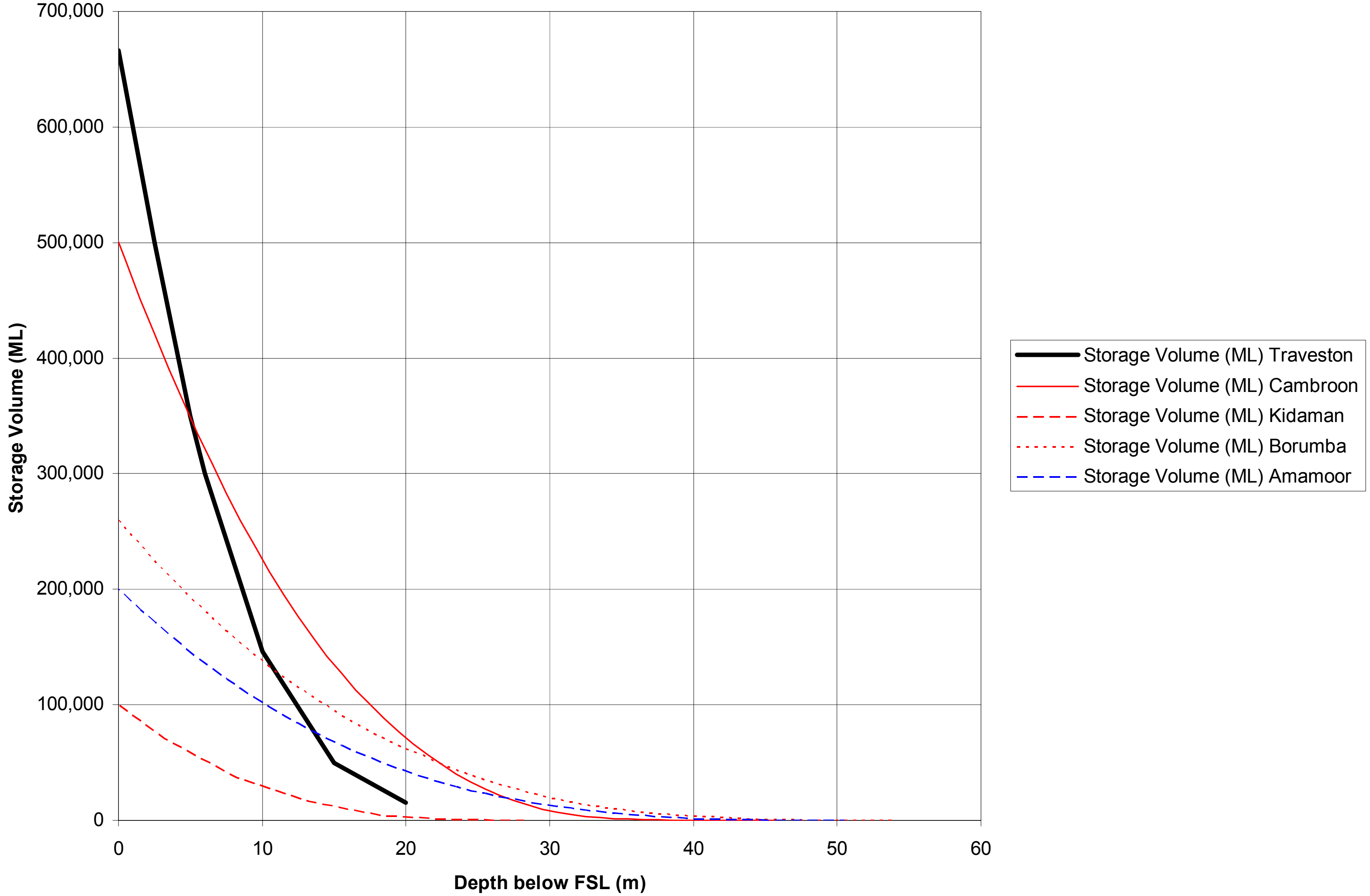
1600
1400
1200
1000
800
600
400
200
0
Storage Area (ha)
0
5
10
15
20
25
30
35
40
45
Depth below FSL (m)
Tilleys Large
Tilleys Small
Wyaralong
Glendower



250000
200000
150000
100000
50000
0
Storage Volume (ML)
0
5
10
15
20
25
30
35
40
45
Depth below FSL (m)
Tilleys Large
Tilleys Small
Wyaralong
Glendower



9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Storage Area (ha)
0
10
20
30
40
50
60
Depth below FSL (m)
Area (ha) Traveston
Area (ha) Cambroon
Area (ha) Kidaman
Area (ha) Borumba
Area (ha) Amamoor



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600,000
500,000
400,000
300,000
200,000
100,000
0
Storage Volume (ML)
0
10
20
30
40
50
60
Depth below FSL (m)
Storage Volume (ML) Traveston
Storage Volume (ML) Cambroon
Storage Volume (ML) Kidaman
Storage Volume (ML) Borumba
Storage Volume (ML) Amamoor

Appendix B – Further Information on *Vallisneria nana*

Table B.1 Further Information on *Vallisneria nana*

Latin Name	Common Name	Status – EPBC	Status – NCA	Comments	References
Vallisneria nana R.Br.	Ribbonweed; Eelgrass	No ranking	Rare	**Habitat** A submerged macrophyte found in a variety of habitats. Does not appear to have any specific water quality requirements. More often associated with variable discharge regimes in the Mary River, as indicated by high coefficient of variation in mean daily discharge (Mackay et al. 2003). However, Blanch et al. (1999) noted the association of *V. americana* with permanently flooded/stable water levels. The growth of *V. americana* has been found to be strongly related to average irradiance in the water column (Blanch et al. 1998). A similar situation may exist for *V. nana* as higher abundances are generally associated with low riparian canopy cover in the Mary River. **Distribution** Found from Sydney to Northern Territory. Widespread in southeast Queensland, particularly in the Mary and Brisbane River catchments, where it often co-occurs with *Myriophyllum verrucosum* on riffles and runs.	Blanch et al. (1998); Blanch et al. (1999); Mackay et al. (2003)

Appendix C – Freshwater Fish Species Relevant to the Logan/Albert and Mary Catchment Development Scenarios

Table C.1 Distribution of freshwater fish species in the streams and rivers of the Logan/Albert catchment. Species occurring upstream, downstream and within each proposed dam/weir impoundment are listed. R = recorded in reach, L = likely to be present in reach, T = recorded in tributary flowing in to reach. Migration pattern codes are D = diadromous (species that migrate between fresh and salt water), P = potamodromous (species capable of extensive movements wholly within freshwaters). Source = Kennard (2006), Pusey et al. (2004) and Kennard (unpublished data).

			Logan River			Teviot Brook			Logan River			Albert River			Albert River		
			Tilleys Dam			Wyaralong Dam			Cedar Grove Weir			Glendower Dam			Albert Barrage		
Species	Common name	Migration pattern	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream
Native species																	
Ambassis agassizii	Olive perchlet	P	L	R	R	L	R	R	R	R	R		R	R	R	R	R
Amb. marianus	Estuary perchlet	D			L						L		R	R	R	R	R
Anguilla australis	Shortfinned eel	D	R	L	R	L	R	R	R	R	R	R	R	R	R	R	R
Ang. reinhardtii	Longfinned eel	D	R	R	R	L	R	R	R	R	R	R	R	R	R	R	R
Arius graeffei	Fork-tailed catfish	P/D			R			L	L	L	R			R		R	R
Arramphus sclerolepis	Snub-nose gar	P/D	R	L	R						R			R		R	R
Craterocephalus marjoriae	Marjorie's hardyhead	D	R	R	L	R	L	L	L	L	L	R	R	R	R	R	R
Cra. stercususcarum fulvus	Flyspecked hardyhead	D			L			L	L	L	L			R	R	R	R
Gobiomorphus australis	Striped gudgeon	D	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Gob. coxii	Cox's gudgeon	D	R			R						R		R	R	R	R
Hypseleotris compressa	Empire gudgeon	D	L	R	R	L	R	R	R	R	R	R	R	R	R	R	R
Hyp. galii	Firetailed gudgeon	P	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Hyp. klunzingeri	Western carp gudgeon	P	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Kuhlia rupeetris	Jungle perch	D												R		R	R
Macquaria novemaculeata	Australian bass	D	R	R	R		L	L	L	R	R	R	R	R	R	R	R
Maccullochella peelii mariensis	Mary River cod	P	R	R	L		L	L	L	L		L	L	L	L		
Megalops cyprinoides	Ox-eye herring	D			R					R	R						
Melanotaenia duboulayi	Duboulay's rainbowfish	D	R	R	R	L	R	R	R	R	R	R	R	R	R	R	R
Mogurnda adspersa	Purple-spotted gudgeon	P	R	L	R						R						
Mugil cephalus	Sea mullet	D	R	R	R	L	R	R	R	R	R			R	L	R	R
Myxus petardi	Freshwater mullet	D	L	R	R			L	L	R	R			R	R	R	R
Nematalosa erebi	Bony bream	P	L	L	R		L	L	L	L	R			R	L	R	R
Notesthes robusta	Bullrout	D	L	L	R		L	L	L	R	R	R	R	R	R	R	R
Philypnodon grandiceps	Flathead gudgeon	P	R	R	R	L	R	R	R	R	R	R	R	R	R	R	R
Philypnodon sp. A	Dwarf flathead gudgeon	P			R		R	R	R	R	R	R	R	R	R	R	R
Pseudomugil signifer	Southern blue-eye		R	R	R	L	R	R	R	R	R	R	R	R	R	R	R
Redigobius bikolanus	Speckled goby	D			R			L	L	L	R			R		R	R
Retropinna semoni	Australian smelt	P	R	R	R	R	L	L	L	L	R	R	R	R	R	R	R
Rhadinocentrus ornatus	Softspined sunfish				T						T						
Tandanus tandanus	Eel-tailed catfish		R	R	R	L	R	R	R	R	R	R	R	R	R	R	R

Species	Common name	Migration pattern	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream
Native species																	
Translocated native species																	
Bidyanus bidyanus	Silver perch	P	R (Maroon)														
Leiopotherapon unicolor	Spangled perch	P	R	R	R		R	R	R	R	R		R	R	R	R	R
Macquaria ambigua	Golden perch	P	R (Maroon)														
Neoceratodus forsteri	Lungfish	P	R (Maroon)														
Scleropages leichardti	Saratoga		R (Maroon)														
Alien species																	
Carrasius auratus	Goldfish		R	R	R	L	R	R	R	R	R	R		R		R	R
Cyprinus carpio	Carp		R	R	R	L	R	R	R	R	R	R	R	R	R	R	R
Gambusia holbrooki	Eastern Gambusia			R	R	L	R	R	R	R	R	R	R	R	R	R	R
Xipophorus helleri	Swordtail				R						R			R		R	R
Xip. maculatus	Platy				R						R						

Table C.2 Distribution of freshwater fish species in the streams and rivers of the Mary catchment. Species occurring upstream, downstream and within each proposed dam/weir impoundment are listed. R = recorded in reach, L = likely to be present in reach, T = recorded in tributary flowing in to reach. Migration pattern codes are D = diadromous (species that migrate between fresh and salt water), P – potamodromous (species capable of extensive movements wholly within freshwaters). Source = Kennard (2003), Pusey et al. (2004) and Kennard (unpublished data).

			Mary River			Mary River			Mary River			Obi Obi Ck.			Yabba Ck			Amamoor Ck		
			Traveston Dam			Cambroon Dam			Coles Crossing Weir			Kidaman Dam			Borumba Dam (enlarged)			Amamoor Dam		
Species	Common name	Migration pattern	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream
Native species																				
Ambasiss agassizii	Olive perchlet	P	R	R	R	R	R	R	R	R	R	R	R	R	R	L	R	R	R	R
Amb. marianus	Estuary perchlet	D			R			R			R									
Anguilla Australis	Shortfinned eel	D			L						L									
Ang. reinhardtii	Longfinned eel	D	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Arius graeffei	Fork-tailed catfish	P/D		R	R			R		R	R					L				
Arramphus sclerolepis	Snub-nose gar	P/D			R			R			R									
Craterocephalus marjoriae	Marjorie's hardyhead	D	R	R	R	R	R	R	R	R	R	R	R	R	L	L	R	R	R	R
Cra. s. fulvus	Flyspecked hardyhead	D	R	R	R	R	R	R	R	R	R	R	R	R	L	L	R	L	L	R
Glossamia aprion	Mouth almighty		R	R	R	R	R	R	R	R	R					L	L		L	R
Gobiomorphus australis	Striped gudgeon	D		R	R			R	L	R	R								L	L
Hypseleotris compressa	Empire gudgeon	D		L	R			R		L	R									
Hyp. galii	Firetailed gudgeon	P	R	R	R	R	R	R	R	R	R	R	R	R	R	L	R	R	R	R
Hyp. klunzingeri	Western carp gudgeon	P	R	R	R	R	R	R	R	R	R	R	R	R	L	L	R	R	R	R
Lates calcarifer	Barramundi	D			R			R			R									
Leiopotherapon unicolor	Spangled perch	P	R	R	R	R	R	R	R	R	R	R	R	R	L	R	R		L	R
Macquaria novemaculeata	Australian bass	D	L	R	R	L	L	R	L	R	R	L	L	L	L	R	L	L	L	L
Maccullochella peelii mariensis	Mary River cod	P	R	R	R	R	R	R	R	R	R	R	R	R	L	R	R	R	R	R
Megalops cyprinoides	Ox-eye herring	D			R			R			R									
Melanotaenia duboulayi	Duboulay's rainbowfish	D	R	R	R	R	R	R	R	R	R	R	R	R	R	L	R	R	R	R
Mogurnda adspersa	Purple-spotted gudgeon	P	R	R	R	R	R	R	R	R	R				R	L	R	R	R	R
Mugil cephalus	Sea mullet	D	R	R	R	R	R	R	R	R	R	R	R	R			R		R	L
Myxus petardi	Freshwater mullet	D	L	L	R	L	L	R	L	L	R	L	L	L						
Nematalosa erebi	Bony bream	P	R	R	R	R	R	R	R	R	R	R	R	R		L	R			R
Neoceratodus forsteri	Lungfish	P	R	R	R	L	R	R	R	R	R	R	R	R		?	R	L	L	L
Neosilurus hyrtlii	Hyrtl's tandan	P	R		R	R	R	R	R		R	R	R	R						
Notesthes robusta	Bullrout	D	L	L	R		L	R	L	L	R		L	L			L			L
Philypnodon grandiceps	Flathead gudgeon	P	R	R	R	R	R	R	R	R	R	R	R	R			R	R	R	R
Philypnodon sp. A	Dwarf flathead gudgeon	P	R	R	R	R	R	R	R	R	R							R	R	R
Pseudomugil signifer	Southern blue-eye		R	R	R	R	R	R	R	R	R	R	R	R			R	R	R	R
Redigobius bikolanus	Speckled goby	D			R			R			R									

Species	Common name	Migration pattern	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream	Upstream	Pondage	Downstream
Retropinna semoni	Australian smelt	P	R	R	R	R	R	R	R	R	R	R	R	R	L	L	R	R	R	R
Rhadinocentrus ornatus	Softspined sunfish		T		R	T	T	R	T		R	R	R	R						
Strongylura krefftii	Freshwater longtom	P/D																		
Tandanus tandanus	Eel-tailed catfish		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Translocated native species																				
Bidyanus bidyanus	Silver perch	P			R			R			R					R				
Hephaestus fuliginosus	Sooty grunter			R				R		R										
Macquaria ambigua	Golden perch	P	T		R	T	T	R	T		R	R	R	R	L	R	R			
Scleropages leichardti	Saratoga															R				
Alien species																				
Cyprinus carpio	Carp				R			R			R									
Gambusia holbrooki	Eastern Gambusia		R	R	R	R	R	R	R	R	R						R			
Xipophorus helleri	Swordtail		R	R		R	R	R	R	L										
Poecilia reticulata	Guppy				R			R			R									

Appendix D – Further Information on Key Fauna Species of Conservation Significance

Table D.1 Stream-dependent fauna species listed under EPBC

Name	Status – EPBC	Status – NCA	Comments	References
FISH				
Queensland Lungfish *Neoceratodus forsteri*	Vulnerable	Not listed	**Habitat** *General*: main river channel and major tributaries in slow- flowing and still waters with deep pools and aquatic vegetation. Closely associated with overhanging vegetation, submerged woody debris, undercut banks and dense beds of aquatic vegetation. *Spawning habitat*: Shallow, still-moderately flowing pools and runs with stable water levels and dense beds of aquatic vegetation over sand and gravel substrates. *Juvenile habitat*: similar to that utilised by adults for spawning – a range of substrates (predominately sand and gravel), water depth 500 mm or less, suitable levels of oxygen and dense macrophyte bed which contains complex variety of algae, protozoa, worms, small molluscs and crustaceans. The dense cover allows juveniles to avoid light, evade predators and provides food resources. **Diet** Juveniles and adults have carnivorous diet. **Movement Requirements** Populations in natural riverine habitats are essentially sedentary with strong site fidelity within a restricted area such that home ranges rarely extend beyond one or two adjacent pools. However, substantial large scale movements may be undertaken by individuals as they actively seek out suitable spawning habitat. Fish in dam and weir impoundments have been documented to move out of these artificially ponded areas and upstream into shallow free-flowing reaches to spawn. **Population Characteristics** The lungfish is a slow-growing and very long-lived species. Sexual maturity may not be achieved until at least 15 years of age and individuals may live as long as 60-100 years. Spawning and recruitment may not occur every year and recruitment into the adult population is probably inherently low. **Distribution** Endemic to the Mary and Burnett River systems and possibly the Brisbane River. Translocated to other nearby rivers and dams. **Other Information** Among the largest of Australia's freshwater fish. Probably the world's oldest living vertebrate species. One of five extant representatives of the ancient and once speciose air-breathing Dipnoan (lungfish) lineage. Sole remaining Australian representative of this group and is most morphologically primitive of the extant Dipnoans. Bimodal respiratory system with only the lungfish having true lungs. Low genetic diversity implying potential susceptibility to anthropogenic impacts (e.g. population fragmentation, population declines, translocations). The taking of lungfish has been prohibited since it was declared a protected species under the *Queensland Fish and Oyster Act 1914*, and it was placed on the CITES list in 1977. It is currently protected from fishing, and collection for educational or research purposes requires a permit in *Queensland under the Fisheries Act 1994*, and from the Commonwealth Government.	Kemp, A. (1986). The biology of the Australian lungfish, *Neoceratodus forsteri* (Krefft 1870). *Journal of Morphology* 1 (Supplement): 181–198. Kemp, A. (1995). Threatened fishes of the world: *Neoceratodus forsteri* (Krefft, 1870) (Neoceratodontidae). *Environmental Biology of Fishes* 43: 310. Frentiu, F.D., Ovenden, J.R. & Street, R. (2001). Australian lungfish (*Neoceratodus forsteri*: Dipnoi) have low genetic variation at allozyme and mitochondrial DNA loci: a conservation alert? *Conservation Genetics* 2: 63–67. Brooks, S.G & Kind, P.K. (2002) *Ecology and demography of the Queensland lungfish (Neoceratodus forsteri) in the Burnett River, Queensland with reference to the impacts of Walla Weir and future water infrastructure development.* Final report May 2004. QO02004. Dept. Primary Industries, Queensland. Agency for Food and Fibre Sciences. Joss, J. (2002). Australian Lungfish, *Neoceratodus forsteri. Fishes of Sahul.* 16: 836–844. Berghuis, A.P. & Broadfoot, C.P. (2004). *Downstream Passage of Fish at Ned Churchward Weir*. DPI Fisheries Report for the Department of State Development. March 2004. 22pp. Berghuis, A.P. & Broadfoot, C.P. (2004). *Upstream Passage of Queensland Lungfish at Ned Churchward Weir Fishlock*. DPI Fisheries Report for the Department of State Development. March 2004. 21pp. Pusey, B.J., Kennard, M.J. & Arthington, A.H. (2004). *Freshwater fishes of north-*

Name	Status – EPBC	Status – NCA	Comments	References
			Key Threats Substantial loss or reduction in the quality of lungfish breeding and nursery habitat has occurred throughout its natural range in the Burnett and Mary Rivers due to water resource development and associated habitat degradation. Impoundments and riverine areas downstream of dams may not provide suitable habitat for spawning, egg development and juvenile recruitment as sudden fluctuations in water levels in these areas may cause exposure and desiccation of macrophyte beds, eggs and larvae. Dams and weirs cause barriers to lungfish movement and affect ability to locate suitable spawning sites, dispersal of juveniles and exchange of genetic material. Lungfish can have difficulty negotiating fishways/fish locks, high mortality of fish that are washed over spillways during overtopping flows can occur and rapid drawdowns can lead to stranding of lungfish downstream of weirs. Lungfish are intolerant of saline conditions if washed/move downstream of tidal barrages and are unable to return upstream. **Knowledge gaps** • Precise spawning, movement and dietary requirements and environmental tolerances. • Environmental cues for movement and purpose of movements. • Factors influencing spawning and recruitment success. • Larval and juvenile habitat requirements • Limited information on age and growth • Precise environmental flow requirements for all life stages	*eastern Australia*. CSIRO Publishing, Collingwood.
Mary River Cod *Maccullochella peelii mariensis*	Endangered	Not listed	**Habitat** *General*: occurs in a variety of types of habitat in the Mary River system including the main channel and tributaries. Habitats range from high-gradient rocky upland streams to large, slow-flowing pools in lowland areas. The ideal habitat appears to be deep, shaded, slow-flowing pools with sand, mud and/or clay substrates, with intact riparian vegetation and abundant in-stream cover such as woody debris and log-jams, rock ledges and boulders. *Spawning habitat*: structures such as hollow logs located in deeper pools are probably used in the wild *Juvenile habitat*: little information available **Diet** Little information available but other cod species are carnivorous. **Movement Requirements** Has been documented to undertake substantial large-scale movements as well as local movements within the home range. Observed patterns of movement of cod in the Mary River were considered to be unrelated to spawning behaviour, as stream depths were generally too low to allow movement in spring when spawning occurs. Large mature cod did not display increased activity or movement immediately before or after the spawning period. However, local activity of cod was relatively high in late summer, autumn and winter in the lead up to spawning, possibly as a consequence of territorial interactions during selection of nest sites prior to spawning. Individual cod may move long distances during periods of high water flow. Movements tend to be upstream in summer and downstream in autumn. Between periods of movement, cod occupy a restricted home range which they maintain for up to several years. Homing to a former home range following extensive movements has been recorded. The movement patterns of juvenile cod are unknown.	Simpson, R. (1994). *An investigation into the habitat preferences and the population status of the endangered Mary River cod (*Maccullochella peeli mariensis*) in the Mary River system, south–eastern Queensland*. QDPI Information Series QI94011. Simpson R. & Jackson, P. (1996) *The Mary River Cod Recovery Plan* Qld Dept of Primary Industries, Fisheries Group. Prepared for Australian Nature Conservation Agency Endangered Species Program. Project Number ESP 505. Simpson, R.R. & Mapleston, A.J. (2002). Movements and habitat use by the endangered Australian freshwater Mary River cod, *Maccullochella peelii mariensis*. *Environmental Biology of Fishes* 65: 401–410. Pusey, B.J., Kennard, M.J. & Arthington, A.H. (2004). *Freshwater fishes of north-eastern Australia*. CSIRO Publishing,

Name	Status – EPBC	Status – NCA	Comments	References
			Population Characteristics Little information on age and growth is available but the Mary River cod is a large-bodied species and is therefore probably long-lived. Sexual maturity probably reached after 4-5years (about 30cm length) and individuals may live as long as 30 years. Little is known on spawning and recruitment patterns in this species. **Distribution** Endemic to the Mary River system. A species of cod (probably very similar to the Mary River cod) was once present in the Brisbane, Logan/Albert and Coomera Rivers, but natural populations are now thought to be extinct. The Mary River cod has since been translocated and stocked widely within these catchments. **Other Information** Mary River cod occupy a high trophic level in the Mary River system. It is therefore likely that they exert a controlling influence over the population size of prey species (particularly decapod crustaceans and other fish species). Restoration of stream habitats to increase their suitability for cod habitation will lead to increased habitat diversity. **Key Threats** Natural populations of the Mary River cod are restricted to only a few tributaries of the Mary River, although re-stocking of cod fingerlings in key parts of the Mary River catchment has been ongoing since 1998. Declines in Mary River cod populations are probably due to a combination of anthropogenic disturbances including habitat degradation, overfishing, the potentially deleterious effects of alien fish species, together with the effects of flow regime modification and barriers to fish movement caused by weirs and impoundments. The overall distribution and abundance of the Mary River cod has undergone significant declines. The known distribution of extends over only some 170 km of stream length, whereas the presumed historical distribution extended over at least 700 km of stream and river length. The total population of cod from the four main areas of remnant populations is estimated to be less than 1000 individuals. In one important focal area, Tinana and Coondoo Creeks, the distribution extends over approximately 70 km of stream length and contains a population of only about 250 individuals. This sub-catchment also contains Queensland lungfish (Neoceratodus forsteri) and the only known populations of the Critically Endangered Oxleyan pygmy perch (*Nannoperca oxleyana*) in the Mary River basin. There has been a significant reduction in the size of cod in this river system since the early 1900s. Cod weighing 5 – 6 kg are now rare, probably as a result of fishing pressure, altered habitat conditions and habitat loss, or a combination of the two. Reduction/loss of fish passage due to dams and weirs is also believed to have impaired the movement and homing behaviour of the cod and disrupted its access to the most suitable habitats and structural features providing cover and resting sites. The presence of tidal barriers (e.g. in the Mary River and Tinana Creek) may further impact on cod by preventing or hindering recolonisation of freshwaters if displaced by floods to brackish estuarine areas downstream of tidal barrages. Simpson and Jackson (1996) have suggested that habitats currently occupied by remnant cod populations in the Mary River system do not represent optimal cod habitats but are simply refuges where small populations have been able to survive. Historical accounts strongly suggest that large deep pools that once occurred along the main channel of the Mary River	Collingwood.

Name	Status – EPBC	Status – NCA	Comments	References
			were probably important habitats producing very large individuals, before erosion and sedimentation caused infilling and loss of habitat heterogeneity. Remnant populations, habitats likely to support natural populations and restocking sites in the Mary River and its tributaries warrant special and ongoing management, protection and/or restoration, given the rarity of Mary River cod and the considerable efforts recently undertaken as part of the recovery plan for this species. Specific recovery actions should include efforts to minimize the impacts of barriers to movement; appropriately designed fishways should be installed on all newly constructed stream storages in the Mary River catchment. Stream crossings should be constructed to conform to guidelines established by the Department of Primary Industries. Large woody debris should be preserved or enhanced throughout the species range in the Mary River catchment. Riparian regeneration should be promoted in areas where riparian cover has been reduced or removed, to foster the production of woody debris and the consolidated structure of stream banks. Mary River cod may not be able to breed successfully in large impoundments and recruitment in impoundment populations is likely to be very low to judge from evidence for other cod species. Nonetheless, Mary River cod breed successfully in large artificial ponds thus successful spawning and recruitment in large dams may potentially lead to self-sustaining populations provided suitable conditions are provided, especially fallen timber and woody debris as cover and spawning sites. The effects on cod of large-bodied translocated species such as yellowbelly (*Macquaria ambigua*) are unknown; however, this ecologically similar species now occurs in several tributaries and main channel areas of Mary River basin. It is possible that negative biotic interactions (e.g. predation and competition for food and space) may be detrimental to remnant and re-stocked cod populations. **Knowledge gaps** • Precise spawning, movement and dietary requirements and environmental tolerances. • Environmental cues for movement and purpose of movements. • Factors influencing spawning and recruitment success. • Larval and juvenile habitat requirements • Precise environmental flow requirements for all life stages	
AMPHIBIANS				
Southern gastric brooding frog *Rheobatrachus silus*	Presumed Extinct	Endangered	**Habitat:** An aquatic species which has never been found more than four metres from water. Restricted to rocky perennial streams, soaks and pools in rainforest and tall open forest with closed understorey. Adults spend extended periods partly submerged and immobile. Habitat is currently threatened by feral pigs, invasion of weeds (especially mistflower *Ageratina riparia*), altered flow and water quality due to upstream disturbances. **Population Characteristics:** Not sighted in the wild since 1981 (however, difficult to observe). If not already extinct, the species is critically endangered. **Distribution:** Records restricted to elevations of 400-800m in Blackall and Conondale Ranges between Coonoon Gibber Creek and Kilcoy Creek.	Hines, H et al (2002) *Recovery Plan for stream frogs of south-east Qld 2001-2005* Qld Environmental Protection Agency Werren (Mary WRP Phase 1 Environmental Investigations, Appendix I) Tyler, M. J. (1984) *There's Frog in my Stomach.* Collins, Sydney. Tyler, M. J. (1989) *Australian Frogs.* Viking O'Neill/Penguin Books Pty Ltd, Ringwood.

Name	Status – EPBC	Status – NCA	Comments	References
			Other Information: One of the only two species known in the world to brood young in the stomach and give birth to living young via the mouth.	McDonald, K.R., Covacevich, J.A., Ingram, G.J. and Couper, P.J. (1991) The status of frogs and reptiles (in) Ingram, G.J. and Raven, R.J. (eds) *An Atlas of Queensland's Frogs, Reptiles, Birds and Mammals*. Board of Trustees of the Queensland Museum, Brisbane: 338–345.
Southern day frog *Taudactylus diurnus*	Presumed Extinct	Endangered	**Habitat** Montane rainforest**,** tall open forest and other riparian vegetation with closed understorey along permanent and temporary streams at elevations between 350 and 800m. Prefers permanent streams with rocky substrate, but will use streams with wide variety of substrates provided the water is not muddy. Active frogs inhabit low vegetation, rocks, leaf litter generally within 10m of water. Habitat threatened by feral pigs, invasion of weeds (mist flower) and altered flow and water quality due to upstream disturbances. **Population Characteristics** Unknown. Not sighted in the wild since 1979. If not already extinct, the species is critically endangered. **Distribution** Disjunct populations in Blackall, Conondale and D'Aguilar Ranges in south east Qld.	Hines, H et al (2002) *Recovery Plan for stream frogs of south-east Qld 2001-2005* Qld Environmental Protection Agency
Giant barred frog *Mixophyes iteratus*	Endangered	Endangered	**Habitat** Shallow rocky streams in rainforest, wet sclerophyll forest and farmland between 100 m and 1000 m or, deep, slow moving streams with steep banks in lowland areas. Knowledge gap – long term studies which include non-breeding times required to adequately assess habitat usage **Population Characteristics** Tadpoles are present throughout the year. Individuals may move up to 100m in a night, but not more than 20m from a stream **Distribution** Belli Creek near Eumundi south to Warrimoo mid-east NSW. Has suffered major declines in southern portion of its range. In south east Qld currently known from scattered locations in Mary River catchment, Maroochy River, Upper Stanley River, Caboolture River, Burpengary Creek and Coomera River. Present in Happy Jack Creek (Traveston Dam pondage area – upper levels of storage will impound part of creek) – MRCCC frog records **Other Information** Chytrid fungus, upstream clearing, changes in water flow regimes, degradation of water quality, feral animals, domestic stock, weed invasion and disturbance to riparian vegetation threaten current population.	Hines, H et al (2002) *Recovery Plan for stream frogs of south-east Qld 2001-2005* Qld Environmental Protection Agency
Fleay's barred-frog *Mixophyes fleayi*	Endangered	Endangered	**Habitat** Adults may be found in leaf litter and along watercourses in rainforest and adjoining wet sclerophyll forests. **Population Characteristics**	Hines, H et al (2002) *Recovery Plan for stream frogs of south-east Qld 2001-2005* Qld Environmental Protection Agency

Name	Status – EPBC	Status – NCA	Comments	References
			Males call from rocks in streams or from pools at the margins of these streams or from forest floor. Females have been located over hundreds of metres from known breeding sites. **Distribution** Disjunct distribution over restricted range from Conondale Range south the Trynney Creek in Richmond Range north-east NSW. **Other Information** Currently in decline in Conondale Ranges. It has disappeared from some sites in Qld and possibly NSW. Large areas of habitat have been and continue to be degraded by feral animals, invasion of weeds, upstream clearing, timber harvesting and urban development.	
REPTILES				
Mary River turtle *Elusor macrurus*	Endangered	Endangered	**Habitat** Main river channel with rocks and logs protruding from the banks or jut from the water. Adults require sparse to dense macrophyte cover, submerged log jams and rock crevices. Riffles provide food source and oxygenate water for all age classes. Suitable sand banks are needed for nesting. Juveniles prefer rocky areas with sand/gravel substrate. **Food** Juveniles feed predominately on aquatic insect larvae and freshwater sponges. As an adult is has predominately an herbivorous diet. **Movement Requirements** Has high site fidelity and females return to specific sites to nest each year. Adults move between 100m to 2km. During flood events they move into gullies. **Population Characteristics** Estimated lifespan of 80 years. Sexual maturity may not be reached until age 15 years Surveys indicate very few juveniles in the population. Populations are thought to have been significantly reduced by predation. **Distribution** Known distribution is main trunk of Mary River between Mary River barrage and confluence of Yabba Creek, extending into Yabba Creek (C. Limpus, pers. comm.). Population is known from Tinana Creek. Existing datasets biased by differences in survey effort. **Other Information** Monotypic species, endemic to Mary River catchment. Described in 1994.	Cann, J.(1998) *Australian Freshwater Turtles* John Cann/Beaumont Publishing Pty Ltd Personal comm. C. Limpus, S. Emerick, M. Connell Flakus, Samatha (2000) *Ontogenetic dietary shifts in an Australian chelid turtle, Elusor macrurus* Tucker, A.D. (ed) (2000) *Cumulative effects of dams and weirs on Freshwater turtles*. EPA Brisbane Van Kampen, T., Emerick, S.P., Parkes, D. (2003) *Increasing survivorship of the Mary River turtle*
BIRDS				
Red goshawk *Erythrotriorchis radiatus*	Vulnerable	Endangered	**Habitat** Tall open forest, woodland, lightly treed savannah and edge of rainforest, forested rivers. **Food** Preys on large birds, mammals, reptiles, insects **Movement Requirements** Home range up to 220 square kilometres. Uses same nest sites each year in top of live tree taller than 20m within 1km of a watercourse or wetland **Population Characteristics**	Garnett, S.T., Crowley, G.M. (2000) *The Action Plan for Australian Birds 2000* Environment Australia

Name	Status – EPBC	Status – NCA	Comments	References
			Population estimate fewer than 1,000 mature individuals; 25-30 pairs in southern Qld **Distribution** Eastern Qld, northern Australia Nesting site known on Mary River	

Table D.2 Other fauna listed under EPBC

Name	Status – EPBC	Status – NCA	Comments	References
BIRDS				
Eastern bristlebird (northern) *Dasyornis brachypterus monoides*	Critically Endangered	Endangered	**Habitat** Usually inhabits grass tussocks in open forest/woodlands near rainforest. Forages and nests in thick ground foliage. **Movement Requirements** Secretive, unable to fly great distances. During fires takes refuge in nearby rainforest **Population Characteristics** Very small population (estimated about 50 birds) **Distribution** Isolated upland areas between Conondale Range and Dorrigo Plateau NSW.	Garnett, S.T., Crowley, G.M. (2000) *The Action Plan for Australian Birds 2000* Environment Australia
Black-breasted button quail *Turnix melanogaster*	Vulnerable	Vulnerable	**Habitat** Vine thicket rainforest, closed canopy and deep litter layer, softwood scrubs, dry sclerophyll forest adjacent to rainforest **Food** Invertebrates from litter on forest floor and possible seeds **Movement Requirements** Adults are sedentary. **Distribution** Previously from Marlborough to Walcha-Yarrowitch NSW. Now reduced density with isolated sub-populations.	Garnett, S.T., Crowley, G.M. (2000) *The Action Plan for Australian Birds 2000* Environment Australia
Coxen's Fig Parrot *Cyclopsitta diophthalma coxeni*	Endangered	Endangered	**Habitat** Occurs wherever fig trees are in lowland and upland subtropical rainforests, riparian corridors, farmland and urban environments. Remaining habitat is fragmented and seasonal food shortages may occur. **Food** Omnivorous, predominately seeds of figs and/or insect larvae and other native fruits **Movement Requirements** Requires adequate undisturbed habitat that is connected to other occupied areas. Movements may occur in response to availability of food. **Population Characteristics** Very small population (estimated about 50 birds) **Distribution** Maryborough to Richmond River NSW. About 60 sightings in Qld since 1990 with nesting sightings in Conondale National Park and Kenilworth State Forest	Coxen's fig parrot recovery team (2001) *Coxen's fig parrot recovery plan 2001-2005* EPA
MAMMALS				
Long-nosed potoroo *Potorous tridactylus tridactylus*	Vulnerable	Vulnerable	**Habitat** Wide range of vegetation types with main requirement being thick groundcover. Prefers light soils that are easy to dig. **Food** Underground fruiting bodies of fungi, roots, fruit, flowers, seeds, insects and their larvae. **Movement Requirements** Spend much time within shelter of understorey vegetation. Patchy distribution, only known from small area of southern Qld and northern NSW	EPA/QPWS (2005) Fact Sheet

Name	Status – EPBC	Status – NCA	Comments	References
Spotted-tailed quoll (southern species)*Dasyurus maculatus maculatus*	Endangered	Vulnerable	**Habitat** Dry and wet sclerophyll forests, riparian forest, rainforest and open pasture. Nest in rock caves, hollow logs or trees. **Food** Small mammals, insects, reptiles and birds **Movement Requirements** Adult males' home range of 875 ha; can travel up to 2.25km per night.	Quoll Seekers Network (2005) *Fact Sheet One*

Table D.3 Stream dependent fauna listed under NCA

Latin Name	Status – NCA	Comments	References
AMPHIBIANS			
Cascade tree frog ***Litoria pearsoniana***	Endangered	**Habitat** Streams in rainforest and adjacent wet sclerophyll forests at elevations of 200-1000m. **Population Characteristics** Males call from low perches up to one metre above water, retreating to humid crevices during the day. During winter, frogs may form large, mixed sex, aggregations in humid crevices with relatively stable temperatures. **Distribution** Kandanga State Forest south to Gibraltar Range north-east NSW. Has disappeared from previously known locations and at other sites is at low densities. **Other Information** Reasons for population decline are unknown. Large areas of habitat have been degraded and continue to be degraded by introduced animals, weeds, timber harvesting, clearing, urban development.	Hines, H et al (2002) *Recovery Plan for stream frogs of south-east Qld 2001-2005* Qld Environmental Protection Agency
Tusked frog *Adelotus brevis*	Vulnerable	**Habitat** Rainforests, wet sclerophyll forests, open grasslands, usually found under logs, stones or leaf litter near puddles, creeks and ponds. **Population Characteristics** Males call from water in spring and summer **Distribution** Eastern Qld and NSW **Other Information** Cooroora Creek Trib, Cedar Ck, Belli Ck, Blackfellow Ck, Cooroora Ck, Six Mile Ck trib, Pinbarren Ck, Coonoon Gibber Ck, Happy Jack Ck, East Cedar Ck, Skyring Ck, Three Mile Ck Kandanga, Happy Jack Ck	Frogs Australia Network (2005) *Australian Frog Database*
REPTILES			
White faced snapping turtle *Elseya sp. aff. dentata (Elseya albigula)*	Currently being classified Expected to be vulnerable pers. comm. C. Limpus	**Habitat** Main river channel with rocks and logs protruding from the banks or jut from the water. Adults require sparse to dense macrophyte cover, submerged log jams and rock crevices. Riffles provide food source and oxygenate water for all age classes. Suitable sand banks are needed for nesting. Juveniles prefer rocky areas with sand/gravel substrate. **Food** Juveniles feed predominately on aquatic insect larvae and freshwater sponges. As an adult is has predominately an herbivorous diet. **Movement Requirements** Adults have high site fidelity and return to specific sites to nest. Adults stay within 0.5-1.5km of preferred riffle or nesting bank. **Population Characteristics** Surveys indicate low juvenile population **Distribution** Endemic to Mary River, Burnett and Fitzroy catchments.	Cann, J.(1998) *Australian Freshwater Turtles* John Cann/Beaumont Publishing Pty Ltd Farley, S. *Conservation Genetics of the snapping turtle* Tucker, A.D. (ed) (2000) *Cumulative effects of dams and weirs on Freshwater turtles*. EPA Brisbane

Appendix E – Regional Ecosystems Within Pondage Areas or Buffer Zones of Proposed Mary Catchment Dams

Table E.1 Regional Ecosystems within Pondage Area or Buffer Zone of Traveston Dam

Note: information gathered from EPA Regional Ecosystems (Version 5.0) & NRM&W DCDB maps produced by NRM&W Maryborough 8 June 2006

Regional Ecosystem	Short Description	Special Values	Veg Mgmt Act Status (Aug 03)	Extent in Dam Site
12.3.1	Gallery rainforest (notophyll vine forest) on alluvial plains	Habitat for rare and threatened flora and fauna species. Important for fruit-eating birds, many of which migrate seasonally from upland to lowland rainforest	Endangered	Coles Ck (upper reaches of dammed area); Kandanga Ck (downstream of township); Skyring Ck; Yabba Ck (excl Imbil) and Mary R. trunk downstream of confluence; Happy Jack Ck (isolated patches); Mary River trunk Carters Ridge to Moy Pocket; Blackfellow & Belli Cks.
12.3.7	Eucalyptus tereticornis, Callistemon viminalis, Casuarina cunninghamiana fringing forest	none listed	Not of concern	Kandanga Ck upstream of township
12.3.11	Eucalyptus siderophloia, E. tereticornis, Corymbia intermedia open forest on alluvial plains near coast	none listed	Of concern	Kandanga Ck upstream of township; Skyring Ck (isolated patches); Yabba Ck (isolated patches); Mary R trunk upstream Moy Pocket; Belli Ck; Blackfellow Ck (isolated patches)
12.11.14	Eucalyptus crebra, E. tereticornis woodland on metamorphic±interbedded volcanics	none listed	Of concern	Mary R trunk (isolated patches near Carters Ridge, downstream Moy Pocket)
12.11.3	Tall open forest generally with Eucalyptus siderophloia, E.propinqua on metamorphics± intebedded volcanics	Habitat for rare and threatened flora species incl Acomis acoma, Corchorus cunninghamii, Marsdenia coronata and Sophora fraseri	Not of concern	Mary R trunk (isolated patch upstream Carters Ridge, upstream of Moy Pocket; Blackfellow Ck (isolated patches)

Table E.2 Regional Ecosystems within Pondage Area or Buffer Zone of Cambroon Dam

Note: information gathered from EPA Regional Ecosystems (Version 5.0) & NRM&W DCDB maps produced by NRM&W Maryborough 8 June 2006

Regional Ecosystem	Short Description	Special Values	Veg Mgmt Act Status (Aug 03)	Extent in Dam Site
12.3.2	Eucalyptus grandis tall open forest on alluvial plains	Habitat for rare and threatened flora species including Acianthus amplexicaulis, Liparis simmondsii, Marsdenia longiloba.	Not of concern	Small patch inundated
12.3.7	Eucalyptus tereticornis, Callistemon viminalis, Casuarina cunninghamiana fringing forest	none listed	Not of concern	Patch fragmented by inundated and dam wall, others inundated
12.3.8	Swamps with Cyperus spp., Schoenoplectus spp. And Eleocharis spp.	none listed	Of concern	Patches inundated
12.3.11	Eucalyptus siderophloia, E. tereticornis, Corymbia intermedia open forest on alluvial plains near coast	none listed	Of concern	Patch inundated
12.11.3	Tall open forest generally with Eucalyptus siderophloia, E. propinqua on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora species incl Acomis acoma, Corchorus cunninghamii, Marsdenia coronata and Sophora fraseri	Not of concern	Patch inundated
12.11.14	Eucalyptus crebra, E. tereticornis woodland on metamorphic ± interbedded volcanics	none listed	Of concern	Patch fragmented by inundated and dam wall & other patches inundated
12.12.12	Araucarian complex microphyll vine forest on metamorphics ± interbedded volcanics; northern half of bioregion	none listed	Of concern	Patches inundated

Table E. 3 Regional Ecosystems within Pondage Area or Buffer Zone of Kidaman Dam

Note: information gathered from EPA Regional Ecosystems (Version 5.0) & NRM&W DCDB maps produced by NRM&W Maryborough 8 June 2006

Regional Ecosystem	Short Description	Special Values	Veg Mgmt Act Status (Aug 03)	Extent in Dam Site
12.3.1	Gallery rainforest (notophyll vine forest) on alluvial plains	Habitat for rare and threatened flora and fauna species including Xanthostemon oppositifolius, Fontainea rostrata, Macadamia integrifolia, M.ternifolia, Ornithoptera richmondia and Cyclopsitia diophthalma coxeni. Important for fruit-eating birds, many of which migrate seasonally from upland to lowland rainforest.	Endangered	Small patches plus 2 remnants several kilometres in length inundated; very small isolated patches will remain in buffer
12.3.2	Eucalyptus grandis tall open forest on alluvial plains	Habitat for rare and threatened flora species including Acianthus amplexicaulis, Liparis simmondsii, Marsdenia longiloba.	Not of concern	Small patch inundated
12.3.7	Eucalyptus tereticornis, Callistemon viminalis, Casuarina cunninghamiana fringing forest	none listed	Not of concern	Patch inundated & in buffer
12.11.1	Simple notophyll vine forest often with abundant Archontophoenix cunninghamiana (gully vine forest") on metamorphics ± interbedded volcanics"	Habitat for rare and threatened flora species including Austromyrtus inophloia	Not of concern	One small patch
12.11.2	Eucalyptus saligna or E. grandis, E. microcorys, E. acmenoides, Lophostemon confertus tall open forest on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora species including Cyperus semifertilis.	Not of concern	Small patch mostly in buffer & edge of inundation
12.11.3	Tall open forest generally with Eucalyptus siderophloia, E. propinqua on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora species incl Acomis acoma, Corchorus cunninghamii, Marsdenia coronata and Sophora fraseri	Not of concern	Small patch mostly in buffer & outside buffer
12.11.9	Eucalyptus tereticornis open forest on metamorphics ± interbedded volcanics. Higher altitudes	none listed	Of concern	patches in buffer & edge of inundation
12.11.10	Notophyll vine forest ± Araucaria cunninghamii on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora including Alyxia magnifolia, Arytera dictyoneura, Choricarpia subargentea, Fontainea rostrata, Graptophyllum reticulatum, Macadamia integrifolia, M. tetraphylla, Pouteria eerwah and Quassia bidwillii.	Not of concern	patches in buffer & edge of inundation
12.11.14	Eucalyptus crebra, E. tereticornis woodland on metamorphic ± interbedded volcanics	none listed	Of concern	patches in buffer & in inundation area
12.12.1	Simple notophyll vine forest usually with abundant Archontophoenix cunninghamiana (gully vine forest") on Mesozoic to Proterozoic igneous rocks"	Habitat for rare and threatened flora species including Argophyllum nullumense	Of concern	Patches mostly in buffer & inundation area

Regional Ecosystem	Short Description	Special Values	Veg Mgmt Act Status (Aug 03)	Extent in Dam Site
12.12.12	Araucarian complex microphyll vine forest on metamorphics ± interbedded volcanics; northern half of bioregion	none listed	Of concern	Mostly in buffer
12.12.15	Eucalyptus siderophloia, E.propinqua, E. acmenoides tall open forest on near coastal hills on Mesozoic to Proterozoic igneous rocks	none listed	Not of concern	Patches mostly in buffer & edge of inundation

Table E.4 Regional Ecosystems within Pondage Area or Buffer Zone of Borumba Dam

Note: information gathered from EPA Regional Ecosystems (Version 5.0) & NRM&W DCDB maps produced by NRM&W Maryborough 8 June 2006

Regional Ecosystem	Short description	Special values	Veg Mgmt Act Status (Aug 03)	Extent in dam site
12.3.7	Eucalyptus tereticornis, Callistemon viminalis, Casuarina cunninghamiana fringing forest	none listed	Not of concern	patches
12.11.3	Tall open forest generally with Eucalyptus siderophloia, E. propinqua on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora species incl Acomis acoma, Corchorus cunninghamii, Marsdenia coronata and Sophora fraseri	Not of concern	extensively impacted - isolating remnants on either side of the inundated area
12.11.9	Eucalyptus tereticornis open forest on metamorphics ± interbedded volcanics. Higher altitudes	none listed	Of concern	
12.11.10	Notophyll vine forest ± Araucaria cunninghamii on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora including Alyxia magnifolia, Arytera dictyoneura, Choricarpia subargentea, Fontainea rostrata, Graptophyllum reticulatum, Macadamia integrifolia, M. tetraphylla, Pouteria eerwah and Quassia bidwillii.	Not of concern	extensively impacted, isolating remnants on either side of the inundated area
12.11.14	Eucalyptus crebra, E. tereticornis woodland on metamorphic ± interbedded volcanics	none listed	Of concern	remnants throughout inundated area
12.11.15	Woodland with Xanthorrhoea sp. on serpentinite	Habitat for rare & threatened flora species including Thesium australe	Of concern	small patches in upper reaches, included in Buffer, so minimal impact
12.12.12	Araucarian complex microphyll vine forest on metamorphics ± interbedded volcanics; northern half of bioregion	none listed	Of concern	patches

Table E.5 **Regional Ecosystems within Pondage Area or Buffer Zone of Amamoor Dam**

Note: information gathered from EPA Regional Ecosystems (Version 5.0) & NRM&W DCDB maps produced by NRM&W Maryborough 8 June 2006

Regional Ecosystem	Short Description	Special Values	Veg Mgmt Act Status (Aug 03)	Extent in Dam Site
12.3.1	Gallery rainforest (notophyll vine forest) on alluvial plains	Habitat for rare and threatened flora and fauna species. Important for fruit-eating birds, many of which migrate seasonally from upland to lowland rainforest	Endangered	Patches throughout inundated area.
12.3.7	Eucalyptus tereticornis, Callistemon viminalis, Casuarina cunninghamiana fringing forest	none listed	Not of concern	Small patches in inundated area & in buffer zone
12.3.11	Eucalyptus siderophloia, E. tereticornis, Corymbia intermedia open forest on alluvial plains near coast	none listed	Of concern	patches throughout inundated area & buffer
12.11.3	Tall open forest generally with Eucalyptus siderophloia, E.propinqua on metamorphics ± intebedded volcanics	Habitat for rare and threatened flora species incl Acomis acoma, Corchorus cunninghamii, Marsdenia coronata and Sophora fraseri	Not of concern	patches throughout inundated area, some remnants in buffer divided by inundation.
12.11.9	Eucalyptus tereticornis open forest on metamorphics ± interbedded volcanics. Higher altitudes	none listed	Of concern	Patches mostly in buffer zone
12.11.10	Notophyll vine forest ± Araucaria cunninghamii on metamorphics ± interbedded volcanics	Habitat for rare and threatened flora including Alyxia magnifolia, Arytera dictyoneura, Choricarpia subargentea, Fontainea rostrata, Graptophyllum reticulatum, Macadamia integrifolia. M. tetraphylla, Pouteria eerwah and Quassia bidwillii	Not of concern	patches throughout inundated area & buffer
12.11.11	Araucarian microphyll vine forest on metamorphics interbedded volcanics; southern half of bioregion	Habitat for rare and threatened flora species including Alyxia magnifolia, Corchorus cunninghamii, Cupaniopsis tomentella, Hernandia bivalvis, Plectranthus omissus, Sarcochilus dilatatus and Sarcochilus weinthalii.	Not of concern	patches throughout inundated area & buffer
12.11.14	Eucalyptus crebra, E. tereticornis woodland on metamorphic ± interbedded volcanics	none listed	Of concern	Patches throughout inundated area.
12.11.18	Eucalyptus moluccana tall open forest on metamorphics ± interbedded volcanics	none listed	Not of concern	Small patches in inundated area & in buffer zone