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SKM

NVIRP Landscape Scale Regional Assessments

CONDITION 4 ASSESSMENT

- Final
- 10 May 2012

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Executive Summary

The Northern Victoria Irrigation Renewal Project (NVIRP) aims to modernise the irrigation delivery infrastructure within the Goulburn Murray Irrigation District (GMID). In doing so, it will generate water savings through improved efficiency in water delivery that will be split between the environment, irrigators and Melbourne (NVIRP 2010).

In undertaking the modernisation works there will be changes in the water regimes of wetlands and waterways and also changes in groundwater levels and salinity. These changes will occur as a result of reductions in gross water diversions, irrigation channel outfalls, evaporation, bank leakage and seepage, and changes to lateral groundwater flows. The potential environmental impacts associated with these changes have been considered as required under Victorian and Commonwealth legislation.

This report presents the results of assessments of the River Murray, Goulburn River and Barmah Forest Ramsar Site to satisfy the requirements of Condition 4 of the Minister for Planning's decision that an Environmental Effects Statement was not required. This report is part of a suite of responses to the Minister's decision including preparation of a Construction Environmental Management Framework, appointment of an Expert Review Panel, preparation of a Water Change Management Framework, preparation of Environmental Watering Plans for "at risk" waterways and wetlands and making advice from the Expert Review Panel publicly available.

Condition 4 states:
Before December 2010 or such later time as determined by the Minister for Planning, NVIRP must prepare an assessment report on the ecological consequences of hydrological changes arising from the implementation of NVIRP for the River Murray, the Goulburn River and the Barmah Forest Ramsar Site for review and written advice by the Expert Review Panel.

This Condition 4 assessment focused on specific hydrological changes (surface and groundwater) in the River Murray, Goulburn River and Barmah Forest and used conceptual models that describe the relationship between hydrology and biota to determine what, if any, ecological values could be affected by NVIRP.

It is concluded that changes in river levels will be small and that no impact on significant ecological values associated with the River Murray or Goulburn River systems are likely. Moreover, there is unlikely to be any change in the frequency, timing, magnitude or duration of flooding and wetland inundation events that would negatively impact on the Barmah or Gunbower Forests or Hattah Lakes Ramsar sites. Changes in groundwater levels and flows at Barmah and Gunbower Forests are considered too small to be detectable. Changes in river salinities would be too small to have any effect on ecological values.

It is also concluded that the groundwater impacts of NVIRP are modest in the context of recent rain induced rises in groundwater levels.

These conclusions and the development and implementation of environmental watering plans for at risk wetlands and waterways confirm that the assessments and actions in response to the Minister's requirements under the EES decision are sound and reasonable.

The following table summarises the specific responses to the Condition 4 requirements and indicates the sections of the report where more detailed information can be found to support the conclusions of the assessment.

- **Summary of response to Condition 4 requirements.**

Condition 4 requirements	Summary	Response	Where addressed in the report for more detailed information
Identify the ecological values present, including any matters of national environmental significance (MNES) protected under the Environment Protection and Biodiversity Conservation Act 1999.	Values were assessed in the River Murray, Goulburn River and Barmah Forest Ramsar sites. All sites support a diverse range of habitats and plant and animal species that are of national, state and regional significance. Important habitats include river channels, permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forests. These habitats provide sites for breeding, foraging and refuge for waterbirds, fish and frogs. Significant plant communities include River Red Gum Forest and Woodland, Black Box Woodland, Buloke Woodlands and grasslands. When flooded, the Barmah Forest provides one of Victoria's most extensive waterbird breeding sites for colonial nesting waterbirds. Wetlands also provide habitat for several migratory waders that are listed under international conventions. Rivers and wetlands provide habitat for native fish of national and state conservation significance, including Trout Cod, Murray Cod and Freshwater Catfish.	This report did not identify any site or matter of National Environmental Significance not addressed in the NVIRP's Public Environment Report, and associated documents.	Section 3.1 (River Murray) Section 4.1 (Goulburn River) Section 5.1 (Barmah Forest)
Assess the potential for reduction of ecological values as a result of the predicted flow changes derived from the implementation of NVIRP, with consideration of the implications of climate change scenarios and cumulative influences within the catchment. Detailed ecological predictions are not required.	The NVIRP process addressed the potential for reduction of ecological values as a result of the predicted flow (surface and groundwater) changes derived from the implementation of NVIRP. Climate change is expected to have a significant impact on river flows across northern Victoria. Dry flow conditions used in the modelling are analogous to conditions expected under a climate change future. Under both average and dry flow conditions NVIRP is predicted to result in only a very small change in river flow and level during the supplying (irrigation) period and in general very little or no change during the spilling and storing period. It is also very unlikely that NVIRP will result in a change in the timing frequency, magnitude or duration of flooding and water events that inundate key floodplain and wetland habitats in the Barmah or Gunbower Forests or Hattah-Kulkyne Lakes. Groundwater levels are unlikely to be affected.	Changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable and that no impact on significant environmental values are expected. Changes in groundwater levels and flows at the sites investigated are negligible. Changes in river salinities would be too small to have any effect on ecological values. The additional impact over and above that predicted due to climate change is considered to be not significant. NVIRP will not affect any of the biological values that currently occur at the assessed sites. The impacts of NVIRP on groundwater levels are modest in the context of recent rain induced rises in	Section 3.5 (River Murray) Section 4.5 (Goulburn River) Section 5.5 (Barmah Forest) Chapter 8 (Effect of recent rains)

Condition 4 requirements	Summary	Response	Where addressed in the report for more detailed information
	NVIRP has taken into account the increase in groundwater levels as a consequence of recent rains and floods in making this assessment.	groundwater levels.	
Identify residual sources of uncertainty.	Uncertainties related to the distribution of values at specific sites, hydrological modelling and the specific ecological response to water level change has been identified. The conceptual models presented in this report that describe the relationship between flow and different groups of biological indicators provide enough supporting information to be confident that the hydrological changes associated with NVIRP will not have any detectable effect on the groups of biota assessed in the three study areas.	The hydrological changes associated with NVIRP are unlikely to have any detectable effect on the groups of biota in the sites assessed. There are no areas of uncertainty that would affect the confidence in the overall conclusions that NVIRP will not have any detectable effect on any groups of biota in the three study areas	Chapter 6
Provide advice to the Minister for Environment and Climate Change, or a delegate, for consideration in future decisions on use of environmental water entitlements.	NVIRP will leave a strong environmental water management legacy. Implementation of NVIRP will provide up to 175 GL (long term annual average) of water for the environment. This water will be converted to an environmental entitlement which will be callable, tradable and able to be used to meet specific environmental needs at a number of sites. Environmental watering plans (EWPs) have been prepared by NVIRP for individual wetlands and waterways identified as at risk from NVIRP. EWP preparation has been guided by the Water Change Management Framework (WCMF). Development of an Environmental Infrastructure and localised groundwater assessments also address the risks associated with NVIRP implementation. NVIRP EWPs provide a sound basis for the development of full wetland management plans and determining watering priorities beyond the extent of a mitigation water obligation during NVIRP implementation. Preparation of WCMF documents has been overseen by a Technical Advisory Committee and an Expert Review Panel. Victoria has well developed processes for assessing and managing the salinity impacts of works and activities in line with the provisions of the Basin Salinity Management Strategy (MDBC 2001). In addition, regional processes involving CMA’s and relevant agencies support these activities.	The Water Change Management Framework and associated practices can provide a rigourous basis for enhanced and adaptive environmental management of wetlands and waterways across northern Victoria. Any potential salinity and groundwater impacts of the use of environmental water entitlements should be managed through existing processes.	Chapter 7

Contents

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1. Introduction

1.1. Background

The Northern Victoria Irrigation Renewal Project (NVIRP) aims to modernise the irrigation delivery infrastructure within the Goulburn Murray Irrigation District (GMID). In doing so, it will generate water savings through improved efficiency in water delivery that will be split between the environment, irrigators and Melbourne (NVIRP 2010).

In undertaking the modernisation works there will be changes in the water regimes of wetlands and waterways and also changes in groundwater levels and salinity. These changes will occur as a result of reductions in gross water diversions, irrigation channel outfalls, evaporation, bank leakage and seepage, and changes to lateral groundwater flows. The potential environmental impacts associated with these changes have been considered as required under Victorian and Commonwealth legislation.

The Victorian Minister for Planning determined that an Environmental Effects Statement was not required for NVIRP, subject to conditions (summarised below):

1. Prior to commencing works NVIRP must prepare a framework for environmental management of works (Construction Environmental Management Framework)

2. Appoint an Expert Review Panel to provide advice on hydrological and related ecological changes due to NVIRP

3. Before operation of works, NVIRP must prepare a framework for protection of aquatic and riparian ecological values (Water Change Management Framework)

4. Prepare an assessment report on the ecological changes arising from implementation of NVIRP for the River Murray, the Goulburn River and the Barmah Ramsar Site

5. Before operation of relevant works commences, an approved Environmental Watering Plan is required for "at risk" waterways and wetlands

6. Final advice from the Expert Review Panel on the environmental framework (#3 above), the assessment report (#4 above) and individual Environmental Watering Plans (#5 above) is to be made publically available.

Conditions 1, 2 3 and 5 have been satisfied and Condition 6 has been satisfied at it relates to Conditions 3 and 5. A Water Change Management Framework has been prepared. Twelve Environmental Watering Plans have also been prepared to better assess and, where required, to mitigate threats in high value waterways and wetlands where NVIRP is most likely to have a significant effect.

NVIRP has also prepared a Public Environment Report (PER) (NVIRP 2010) for the Commonwealth Minister for Environment Protection, Heritage and Arts (DEWHA) for the assessment and approval of an action that may have an impact upon matters of national environmental significance (MNES) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Minister approved NVIRP's application subject to a number of conditions on 10 May 2010. The approved action must be undertaken in accord with the Water Change Management Framework (WCMF) (NVIRP 2009c) which also addresses Condition 3 of the Victorian Minister for Planning's decision that an EES is not required. The WCMF describes the means by which NVIRP will protect aquatic and riparian ecological values through management of water allocations and flows that may be impacted by implementation of NVIRP within the modernised GMID.

This report presents the results of assessments of the River Murray, Goulburn River and Barmah Forest Ramsar Site to satisfy Condition 4 of the Minister for Planning's decision that an EES was not required. Condition 4 states:

Before December 2010 or such later time as determined by the Minister for Planning, NVIRP must prepare an assessment report on the ecological consequences of hydrological changes arising from the implementation of NVIRP for the River Murray, the Goulburn River and the Barmah Forest Ramsar Site for review and written advice by the Expert Review Panel. The assessment report is to be prepared to the satisfaction of the Secretary DSE. It is to:

a) Identify the ecological values present, including any matters of National Environmental Significance (NES) protected under the Environment Protection and Biodiversity Conservation Act 1999;

b) Assess the potential for reduction of ecological values as a result of the predicted flow changes derived from the implementation of NVIRP, with consideration of the implications of climate change scenarios and cumulative influences within the catchment. Detailed ecological predictions are not required.

c) Identify residual sources of uncertainty;

d) Provide advice to the Minister for Environment and Climate Change, or a delegate, for consideration in future decisions on use of environmental water entitlements.

The Minister for Planning also included reasons for the decision (reproduced in part below):

Any impacts of modified hydrological regimes on aquatic and riparian ecosystems are unlikely to be amenable to detailed, predictive studies (such as might form part of an EES), but are instead suited to mitigation through adaptive management of water flows to maintain ecological values.

Refinement of risks to individual waterways and wetlands by the proponent will enable effective targeting of efforts for development and implementation of environmental watering plans, which can then be monitored and refined over time.

The Victorian Government's commitment to allocate a large part of the water savings from the operation of the project to environmental flows provides a high measure of assurance that any potential or actual risk to aquatic and riparian ecosystems from reduced flows (due to more efficient supply infrastructure) can be mitigated through environmental watering plans or otherwise rectified through adaptive management. While the potential implications of reduced seasonal inflows to the Goulburn and Murray Rivers and the Barmah Forest Ramsar site warrant further investigation and clarity of management responses, this can be achieved through a focussed investigation without requiring an EES.

1.2. Report structure

This report presents the outcomes of the Condition 4 assessment. Chapter 2 provides an overview of the assessment approach. Chapters 3, 4 and 5 provide the detailed assessment for the River Murray, Goulburn River and Barmah Forest Ramsar Site respectively, including an assessment of the hydrological changes (surface and groundwater), the identification of environmental values and an assessment of the likely impacts of the hydrological change on those values. Chapter 6 identifies and assesses residual sources of uncertainty associated with the assessment. Chapter 7 considers uses of saved water for environmental purposes and Chapter 8 discusses the increases in groundwater levels due to the recent rainfall events and the potential impacts of NVIRP on groundwater levels. Chapter 9 provides an overall summary and conclusion.

2. Approach

The specific areas considered in this assessment are:

1. The River Murray from the Hume Dam to downstream of Torrumbarry (including Gunbower Forest and Hattah Lakes) including the river channel and associated floodplain;
2. The Goulburn River from Eildon Dam to its confluence with the River Murray, including the river channel and associated floodplain;
3. The Barmah Forest Ramsar site.

Much of the information used to support the assessment has been drawn from the PER[1] (NVIRP 2010) and supporting documents (specifically Ecological Associates 2009, King and Tonkin 2009, SKM 2009a, SKM 2009b and BL&A 2010).

The aforementioned documents are used to provide a description of the types of habitat that occur in each area and the recognised national, state and regional ecological values present. Matters of National Environmental Significance associated with each area and that have been identified in the PER documents are highlighted.

A summary of the surface water, groundwater and salinity changes that are expected to occur as a result of NVIRP are presented. These changes have already been described in the detailed assessments that were used to support the PER (i.e. SKM 2009a and SKM 2009b) and the relevant information has been reproduced here. Hydrological changes are described for an average climate year (using data from 2000/01 to represent an average flow year) and a dry flow year (using data from 2005/06 to represent a dry flow year). Climate change is expected to have a significant impact on river flows and on the frequency and duration of wetland inundation events (Jones and Durack 2005, DSE 2008). The incremental impacts of NVIRP over and above that expected under climate change are considered by using the dry flow scenario as an analogy for flow conditions that might be expected under climate change. Groundwater impacts due to NVIRP are described and potential impacts on relevant features are assessed.

Conceptual models are used to assess the effect that the expected hydrological changes are likely to have on the national, state and regional environmental values in the study area. These values

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[1] The basis for the assessment of potential effects of NVIRP on the Barmah Forest Goulburn and Murray Rivers is derived from the Public Environment Report for the EPBC referral (Chapter 5) and it's supporting documents (SKM 2009a, b). While the assessment for the PER included the effects of NVIRP on Matters of National Environmental Significance, which include sites outside of Victoria, the current assessment reports on the sites within Victoria as required under the Condition 4 of Victorian Environment Effects Act approval.

include species and communities of plants, fish, birds and frogs. All plants, freshwater fish, frogs and waterbirds can be divided into groups based on their particular water and flow requirements. For example, plants can be divided into terrestrial, amphibious or submerged categories depending on their tolerance and requirement for inundation. Fish can also be divided into different groups based on their reliance on high flows to trigger spawning or migration and the particular habitats they prefer. Existing conceptual models that describe the relationship between hydrology and specific ecological processes are used to determine which groups of plants, fish, birds and frogs are likely to be most affected by the hydrological changes predicted to occur under NVIRP. A review of conceptual model and indicators of ecosystem response and justification for the chosen models/indicators can be found in Appendix A

Based on the findings in the PER, NVIRP is most likely to affect low flows and possibly freshes in rivers, and the duration and timing of pooled water in wetlands. Therefore NVIRP is most likely to represent a threat to the values that rely on those hydrological components. The significance of the hydrological changes to environmental values is discussed. Where the analysis shows that no significant impacts are likely conclusions are drawn that there is unlikely to be an impact on environmental values of national, state or regional significance.

Areas of uncertainty in the analysis (for example uncertainty regarding a particular hydrological change or the ecological response to a hydrological change) are flagged. Potential impacts to ecological processes and indicators due to NVIRP are discussed in the context of other hydrological changes in the region such as drought and climate change.

The report concludes with an evaluation of the extent to which Condition 4 has been met.

3. Hydrological changes to the River Murray

The River Murray between Hume Dam and Torrumbarry Weir carries irrigation supply flows and it takes approximately eleven days for water released from Hume Dam to reach the Torrumbarry weir pool (MDBC 2006). These reaches of the River Murray suffer from seasonal flow inversion (i.e. higher than natural flows in summer and lower than natural flows during winter) (SKM 2009b).

The Gunbower Forest Ramsar site is located at the downstream end of the reach. It is bordered to the north by the River Murray and to the south by Gunbower Creek. The area within (Gunbower Island) is dominated by a River Red Gum forest, and is subject to periodic inundation. The forest features a variety of permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forest (Hale 2009). These wetlands provide habitat for a large number of bird species including those listed under international agreements (e.g. Ramsar convention).

The Hattah-Kulkyne Lakes lie more than 270 km further downstream of Torrumbarry Weir in typical Mallee country with extensive low scrub and open native pine woodland. The Hattah Lakes are a system of 17 perennial and intermittent freshwater lakes, most of which are filled from the River Murray via the Chalka Creek anabranch. The lakes only begin to fill when flows in the River Murray exceed the threshold flow rate of 36,700 megalitres/day (ML/day) at Euston Weir. Their hydrological regimes vary widely, ranging from lakes which used to hold some water almost constantly, to those with inflows averaging 1 year in 4 and with dry spells of 4 to 12 years (MDBC 2006). The system also supports a diverse range of migratory bird species.

3.1. Environmental values

3.1.1. Vegetation

A number of plant species and plant communities of national, state and regional significance occur along the River Murray and in association with the Gunbower Forest and Hattah Lakes regions. Ecological Associates (2009) conducted a recent desktop assessment of flora listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 that are likely to occur in the GMID. They identified nine EPBC listed plant species that were likely to occur either on the banks of the River Murray or in the swamps and wetlands on the adjacent floodplain (Table 3-1).

In addition, the Inland Grey Box Woodland Ecological Community (EPBC-nominated) occurs in flood-prone habitat on the floodplain of the River Murray, although it doesn't tolerate frequent inundation. The Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions (Buloke Woodland) community, which is listed as Endangered, also occurs in these areas.

▪ **Table 3-1 List of EPBC listed plant species likely to occur in the River Murray downstream of Hume Reservoir or on the adjacent floodplain (adapted from Ecological Associates 2009).**

Scientific name	Common name	EPBC status	Habitat Description
Maireana cheelii	Chariot Wheels	Vulnerable	Shallow seasonally wet depressions, in heavy red loam or clay soils prone to scalding
Senecio behrianus	Stiff Groundsel	Endangered	Modified freshwater marsh dominated by *Typha* spp. and Lignum (*Muehlenbeckia florulenta*). The wetland still retains its seasonal flooding regime.
Callitriche cyclocarpa	Western Water-starwort	Vulnerable	Aquatic or amphibious plant occurs on river banks
Amphibromus fluitans	River Swamp Wallaby grass	Vulnerable	Requires periodic flooding of its habitat to maintain wet conditions. Mostly found at margins of permanent swamps
Lepidium monoplocoides	Winged Peppercress	Endangered	Occurs in wetlands, chenopod shrublands and samphire communities
Swainsona plagiotropis	Red Swainson-pea	Vulnerable	On red to brown clay loams and clay soils that are usually seasonally waterlogged. Absent from black low-lying soils
Sclerolaena napiformis	Turnip Copperburr	Endangered	On fertile clay loam soils. Probably can tolerate water-logging in the spring and all remaining populations are located close to a water course or swamp.
Pimelea spinescens subsp. *spinescens*	Spiny Rice-flower	Critically endangered	On basalt-derived soils, usually comprising black or grey clays. Topography is generally flat but populations may occur on slight rises or in slightly wettish depressions.
Brachyscome muelleroides	Mueller Daisy		Damp areas at the margins of claypans or lagoons

In the Gunbower Forest a total of 278 indigenous flora species and 205 indigenous fauna species have been recorded on the Victorian Wildlife Atlas (DSE 2005) and the Victorian Flora Information System (2005). The high diversity of species results from the diverse habitats provided by different water regimes in the forest. Nationally threatened plant species include River Swamp Wallaby Grass, Western Water-starwort and Winged Peppercress (

Table 3-2). Gunbower Forest also has approximately 15,000 hectares of River Red Gum open forest / woodland which constitutes 75% of the site (Woodward 1990). The understorey varies but includes areas of aquatic macrophytes in frequently flooded areas and grasslands and chenopods in less frequently inundated locations (Cooling 2006).

- **Table 3-2 List of EPBC listed plant species likely to occur in the Gunbower Forest (adapted from Ecological Associates 2009).**

Scientific name	Common name	EPBC status	Habitat Description
Callitriche cyclocarpa	Western Water-starwort	Vulnerable	Aquatic or amphibious plant occurs on river banks
Amphibromus fluitans	River Swamp Wallabygrass	Vulnerable	Requires periodic flooding of its habitat to maintain wet conditions. Mostly found at margins of permanent swamps
Lepidium monoplocoides	Winged Peppercress	Endangered	Occurs in wetlands, chenopod shrublands and samphire communities

The Hattah-Kulkyne Lakes Ramsar Site is a system of 12 shallow temporary lakes characterised by River Red Gum and Black Box landscape. Ecological Associates (2009) recorded two EPBC listed plant species in a desktop review of flora associated with the Hattah Lakes (Table 3-3).

- **Table 3-3 List of EPBC listed plant species likely to occur in the Hattah Lakes (adapted from Ecological Associates 2009)**

Scientific name	Common name	EPBC status	Habitat Description
Swainsona pyrophila	Yellow Swainson-pea	Vulnerable	Mallee shrublands of far north west Victoria, on calcareous sands or loams most often on heavy red sands and clay loams between sand rises
Lepidium monoplocoides	Winged Peppercress	Endangered	Occurs in wetlands, chenopod shrublands and samphire communities

3.1.2. Fish

The River Murray main channel between Hume Dam and Torrumbarry Weir supports six species of native fish which are considered threatened in Victoria and are listed under the Flora and Fauna Guarantee Act 1988 (FFG Act). Four of these species are also listed under the EPBC Act (Table 3-4). The Trout Cod population in the Murray and Goulburn Rivers is particularly significant at it makes up the majority of the total national population of the species.

- **Table 3-4 Summary of native fish likely to occur in the River Murray (adapted from King and Tonkin 2009).**

Scientific name	Common name	FFG status	EPBC status
Bidyanus bidyanus	Silver perch	Listed	
Craterocephalus fluviatilis	Murray Hardyhead	Listed	Vulnerable
Maccullochella macquariensis	Trout Cod	Listed	Endangered
Maccullochella peelii peelii	Murray Cod	Listed	Vulnerable
*Macquaria australasica**	Macquarie Perch	Listed	Endangered
Tandanus tandanus	Freshwater Catfish	Listed	

*not likely to occur in the GMID area any more

3.1.3. Other Biota

Brett Lane and Associates (2010) identified 75 bird, mammal, reptile, amphibian and invertebrate species of national environmental significance that had some form of dependency (e.g., for foraging, breeding, refuge etc) on aquatic ecosystems in the GMID. Only 21 of those species were considered likely to be affected by NVIRP (Table 3-5). They included 20 bird species and the Growling Grass Frog, which although it has not been specifically recorded in the GMID could occur due to the presence of suitable habitat (BL&A 2010). Most of the bird species likely to be affected by NVIRP rely on wetland habitats and none of them have been specifically linked to the River Murray. Four of the bird species rely on floodplain forests for some part of their lifecycle (Table 3-5). Of those, only the White-Breasted Sea Eagle and the Eastern Great Egret has been recorded at sites near the River Murray (BL&A 2010).

The Gunbower Forest features a variety of permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forest. More than 22 species of waterbirds breed in these wetlands and at least three migratory wading species (Eastern Great Egret, Cattle Egret and Latham's Snipe) visit the site to feed. Gunbower Forest has suitable habitat for the Growling Grass Frog, but there are few records to indicate the abundance and specific location of this species.

Hattah Lakes provides aquatic habitats that range from permanently inundated to episodically flooded. The bird species likely to rely on these floodplain forests are similar to the Gunbower Forest (Table 3-5).

▪ **Table 3-5 EPBC Act listed terrestrial vertebrates expected to occur in the GMID that may be affected by NVIRP. Preferred habitat types are shown (adapted from BL&A 2010).**

Species	Saline wetland	Freshwater (including floodplain wetlands)				Floodplain forest
		Freshwater meadow	Shallow freshwater meadow	Deep water marsh	Permanent open water	
Birds						
Australian Painted Snipe	X	X	X			
Black-winged Stilt	X	X	X			
Caspian Tern	X	X	X	X	X	
Cattle Egret		X				
Common Greenshank	X	X				
Curlew Sandpiper	X	X				
Double-banded Plover	X					
Eastern Great Egret (previously Great Egret)	X	X	X	X	X	X
Glossy Ibis		X	X	X	X	
Latham's Snipe		X	X	X	X	
Marsh Sandpiper	X	X	X			
Red-capped Plover	X					
Red-necked Avocet	X	X	X			
Red-necked Stint	X	X	X			
Sharp-tailed Sandpiper	X	X	X			
Superb Parrot						X
Swift Parrot						X
Whiskered Tern	X	X	X			
White-bellied Sea-Eagle	X			X	X	X
Wood Sandpiper		X	X			
Frogs						
Growling Grass Frog		X	X	X		
Total Listed Species	**14**	**15**	**12**	**6**	**5**	**4**

3.2. Hydrology

The PER (NVIRP 2010) provided a comparison of the difference in flow magnitude (ML/day) and water level (mm) between pre- and post-NVIRP at key sites on the River Murray during supplying and storing or spilling mode periods[2] for two representative years (2000/01, which is representative of an average year and 2005/06, which is representative of a dry year). That information is summarised by river reach in the following section and is used to inform the assessment of potential effect that NVIRP will have on environmental values in the River Murray. Furthermore, comments are made regarding the likely impacts of climate change on river flows and changes in the nature of wetland water regimes.

Figure 3-1 provides Schematic overview of the Goulburn and Murray systems showing the locations of changes in deliveries and outfalls due to NVIRP.

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[2] The operation of the GMID works in two different modes: 'supplying' and 'storing/spilling' modes. Any changes in water management, mitigation water and savings due to NVIRP depend on which mode is operating. These modes are described below:

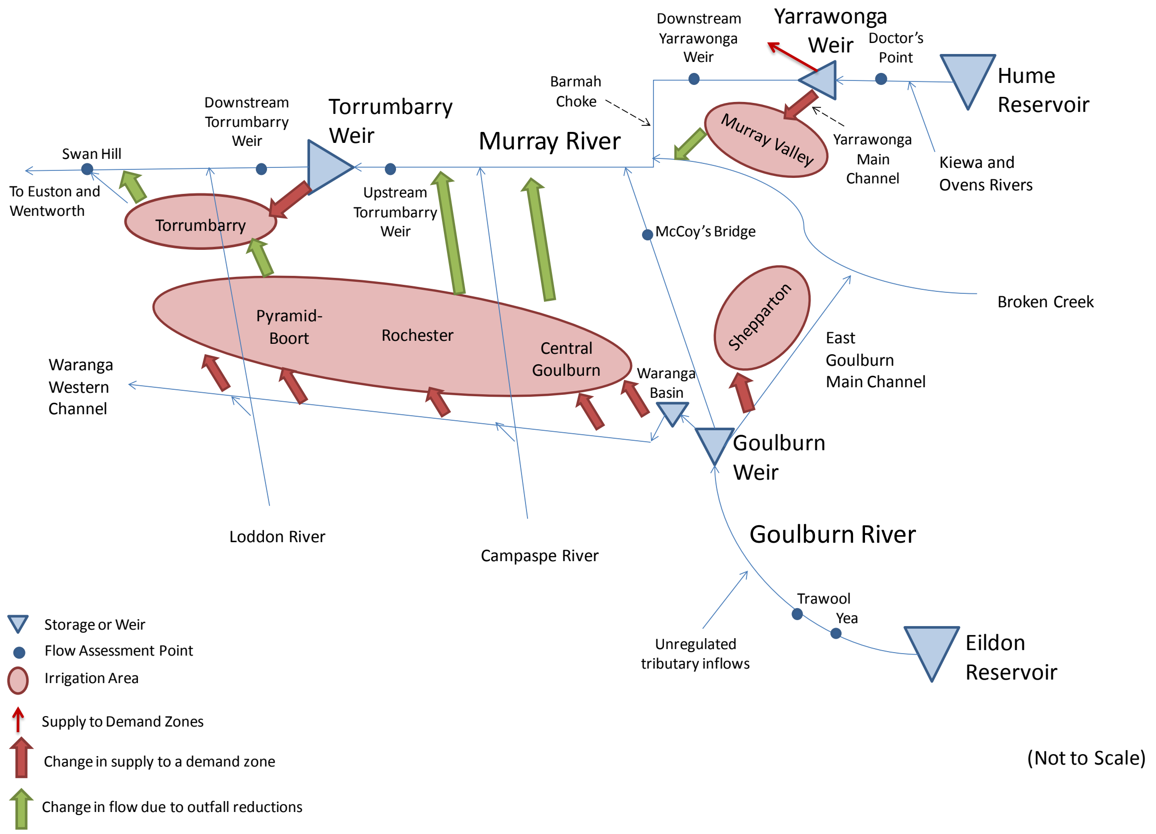
'Supplying' mode

- Supplying mode conditions exist when demands in the system are greater than the volume of tributary inflow available for diversions. System operators are required to release water from storages such as Hume Reservoir and Eildon Reservoir to meet demand. Supplying mode conditions most commonly occur over the summer and autumn irrigation season, but may also occur at times during the May-August (non-irrigation) period to meet minimum passing flow requirements, for environmental watering or for flood pre-releases to protect assets.

'Storing or spilling' modes

The two main occasions when rivers are in storing or spilling mode are:

- When demands in the system from irrigation, for passing flows, for urban water supplies and for environmental watering are less than the volume of tributary inflows. These conditions are most likely to occur outside of the irrigation season (i.e. mid May – mid August) and during traditionally high inflow months of September to November.
- When storages are filled to maximum capacity. In this instance, any inflows originating upstream of storages pass through the storages and flow downstream as the water storages 'spill'. At these times, there are usually high tributary inflows also flowing into the rivers downstream of the storages.



- **Figure 3-1: Schematic diagram of the Goulburn and Murray systems showing the locations of changes in deliveries and outfalls due to NVIRP**

3.2.1. River Murray between Hume Reservoir and Yarrawonga Weir

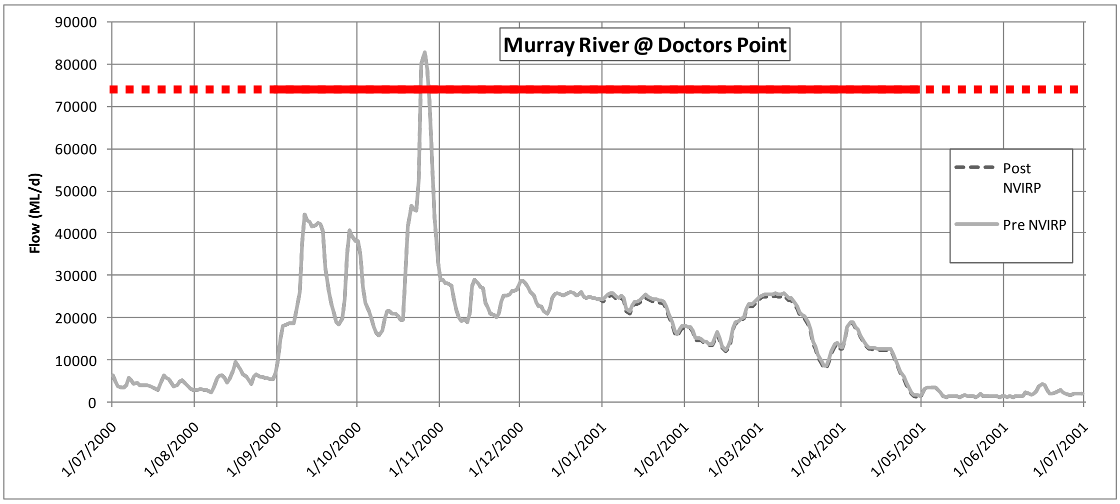
Figure 3-2 to Figure 3-5 show the change in river flow and level due to NVIRP for the River Murray between Hume Reservoir and Yarrawonga Weir (using data from Doctor's Point gauging station), while Table 3-6 summarises the maximum and average difference in water level over the supplying and storing or spilling mode periods.

NVIRP is expected to reduce flow (and level) in the River Murray between Hume Reservoir and Yarrawonga Weir during the irrigation supplying mode (i.e. summer and autumn) because less water will be needed to supply existing irrigation demand.

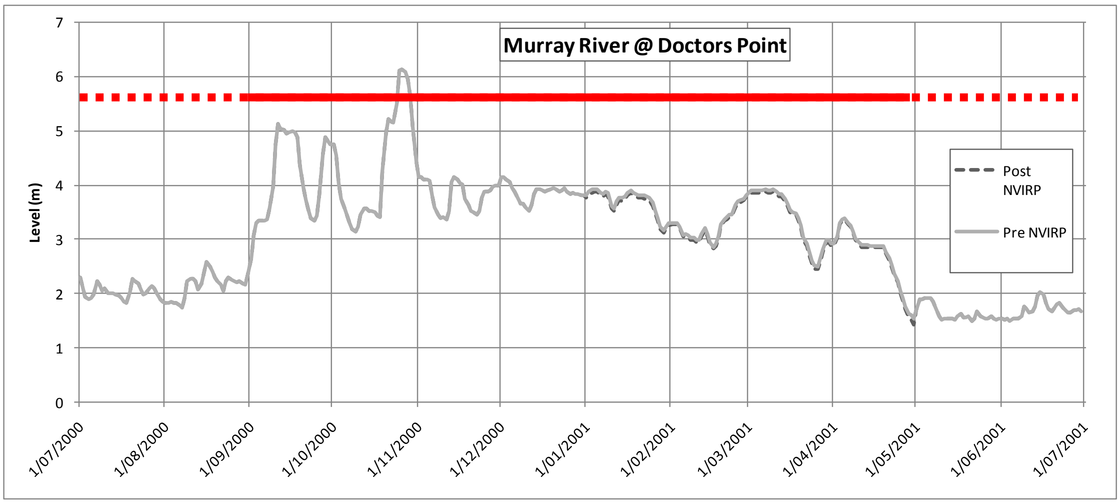
During an average flow year (represented by 2000/01 flow and water level data at the Doctors Point gauge) the average water depth in the channel during the supplying period is approximately 2.53 m. NVIRP is expected to reduce the average water level at this location by approximately 14 mm in the supplying period (equivalent to a 0.6% reduction in water depth). During a dry flow year (represented by 2005/06 flow and water level data at the Doctors Point gauge) the average water depth in the channel during the supplying period is 2.93 m. NVIRP is expected to reduce the average water level at this location by approximately 12 mm in the supplying period (equivalent to a 0.4% reduction in water depth). No change in flow or water level is expected in this reach during the spilling or storing mode (mainly winter and spring).

- **Table 3-6: Comparison of difference in water level (mm) between pre and post NVIRP for the River Murray between Hume Reservoir and Yarrawonga Weir.**

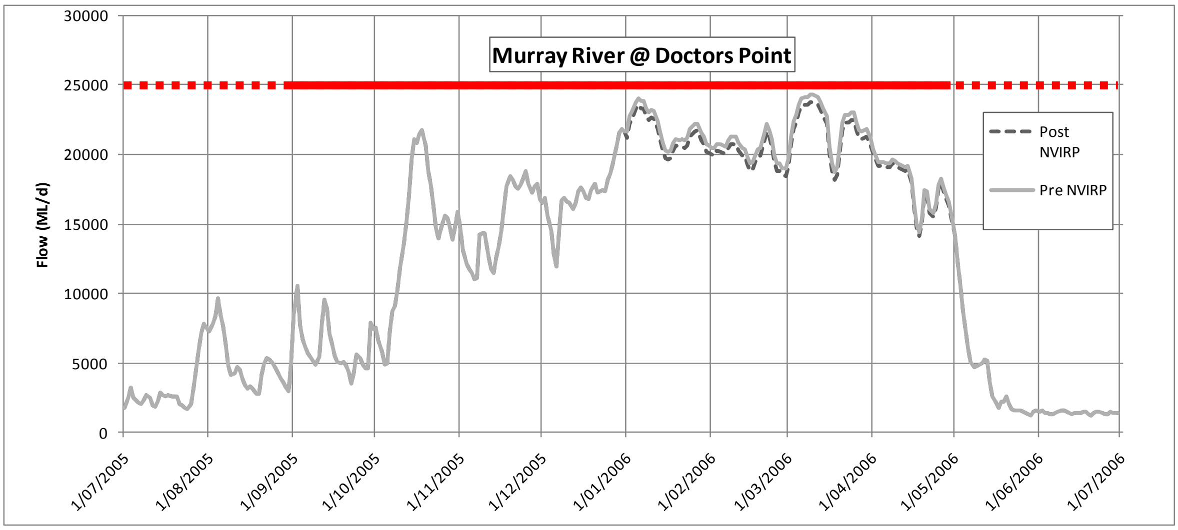
River Channel Site	Year	Level Difference (mm)			
		Storing or Spilling Mode Period		Supplying Mode Period	
		Maximum	Average	Maximum	Average
River Murray between Hume Reservoir & Yarrawonga Weir	Average (2000/01)	0	0	-95	-14
	Dry (2005/06)	0	0	-47	-12



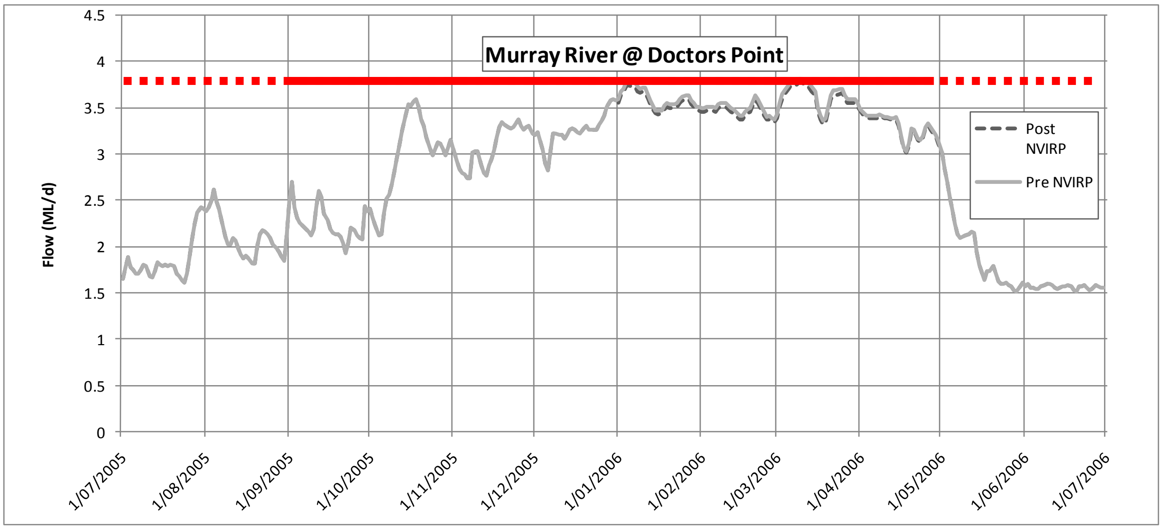
- **Figure 3-2 Difference in flow (ML/d) between pre and post NVIRP at Doctors Point gauging station (409017) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-3 Difference in level (m) between pre and post NVIRP at Doctors Point gauging station (409017) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-4 Difference in flow (ML/d) between pre and post NVIRP at Doctors Point gauging station (409017) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-5 Difference in level (m) between pre and post NVIRP at Doctors Point gauging station (409017) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

3.2.2. River Murray between Yarrawonga Weir and the Broken Creek Confluence

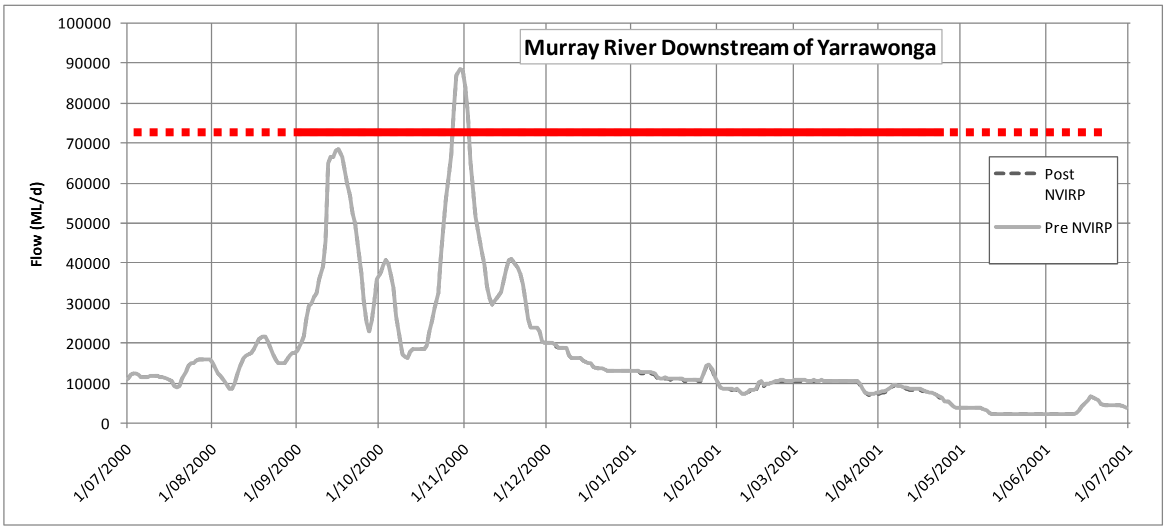
Figure 3-6 to Figure 3-9 show the change in river flow and level due to NVIRP for the River Murray between Yarrawonga Weir and the confluence with Broken Creek (downstream of Yarrawonga Weir gauging station). Table 3-7 summarises the maximum and average difference in water level over the supplying and storing or spilling mode periods.

NVIRP is expected to reduce flow and level in the River Murray between Yarrawonga Weir and Broken Creek during the irrigation supplying period (i.e. summer and autumn) because less water will needed to supply diversions to irrigation areas. During an average flow year (represented by 2000/01 flow and water level data at a gauge downstream of the Yarrawonga Weir) the average water depth in the channel during the supplying period is approximately 1.20 m. NVIRP is expected to reduce the average water level at this location by approximately 7 mm in the supplying period (equivalent to a 0.6% reduction in water depth). During a dry flow year (represented by 2005/06 flow and water level data at a gauge downstream of the Yarrawonga Weir) the average water depth in the channel during the supplying period is 1.49 m. NVIRP is expected to reduce the average water level at this location by approximately7 mm in the supplying period (equivalent to a 0.5% reduction in water depth). During the storing or spilling mode (winter and spring) NVIRP is expected to reduce average water levels in this reach of the River Murray by only 1 mm in both average and dry years (Table 3-7).

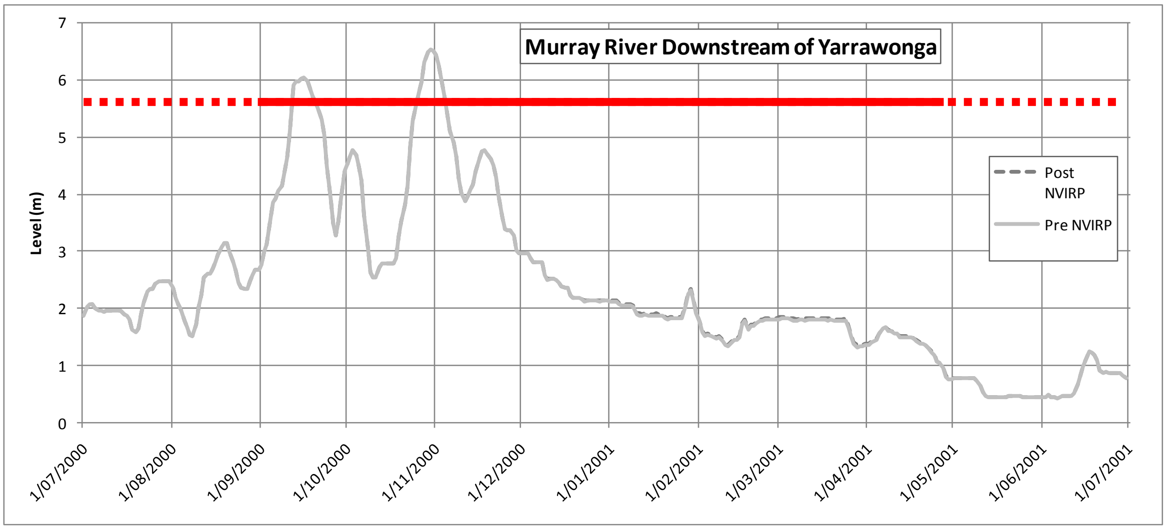
The dry flow year changes in level provide an indication of the potential impacts of NVIRP under climate change. The analysis shows that during dry flow years there is a reduction in river level equivalent to a reduction in average channel depth of is a very small change in river flow and level during the supplying period and no change during the spilling and storing period.

- **Table 3-7: Comparison of difference in water level (mm) between pre and post NVIRP for the River Murray between Yarrawonga Weir and the Broken Creek confluence.**

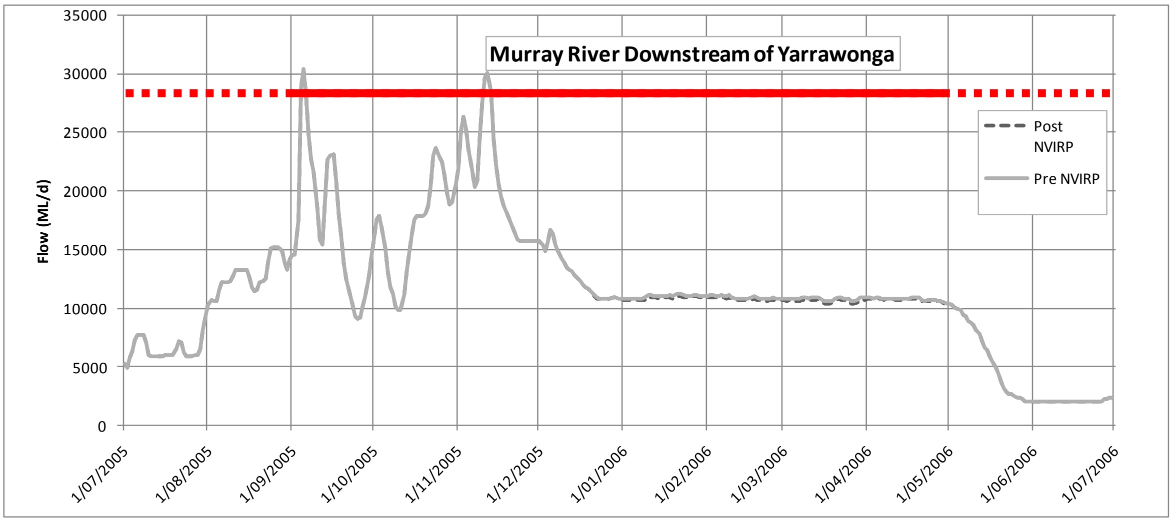
River Channel Site	Year	Level Difference (mm)			
		Storing or Spilling Mode Period		Supplying Mode Period	
		Maximum	Average	Maximum	Average
River Murray between Yarrawonga Weir and the Broken Confluence	Average (2000/01)	-2	<-1	-26	-7
	Dry (2005/06)	-1	>-1	-24	-7



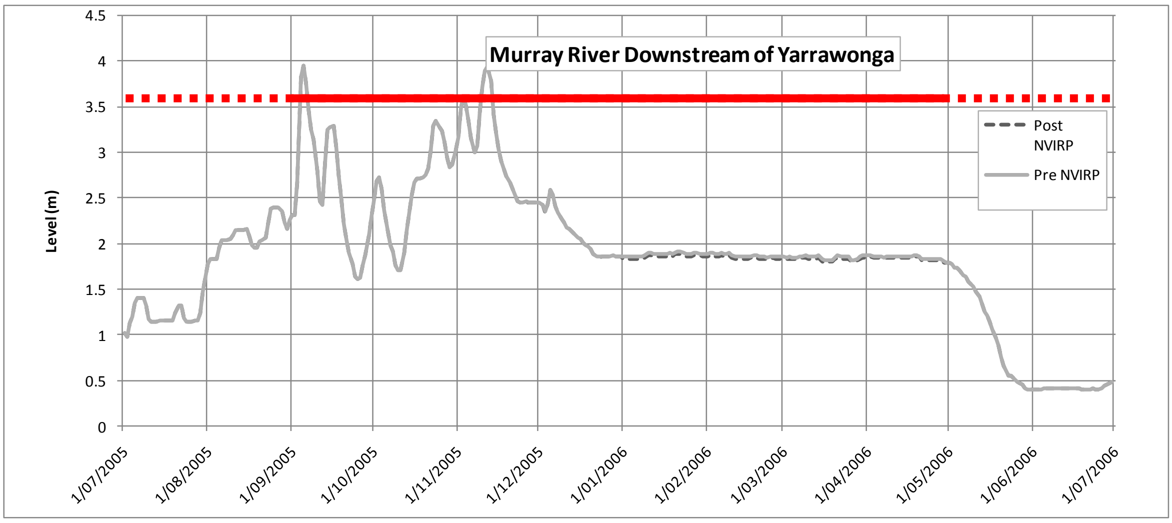
- **Figure 3-6 Difference in flow (ML/d) between pre and post NVIRP downstream of Yarrawonga Weir gauging station (409025) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-7 Difference in level (m) between pre and post NVIRP downstream of Yarrawonga Weir gauging station (409025) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-8 Difference in flow (ML/d) between pre and post NVIRP downstream of Yarrawonga Weir gauging station (409025) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



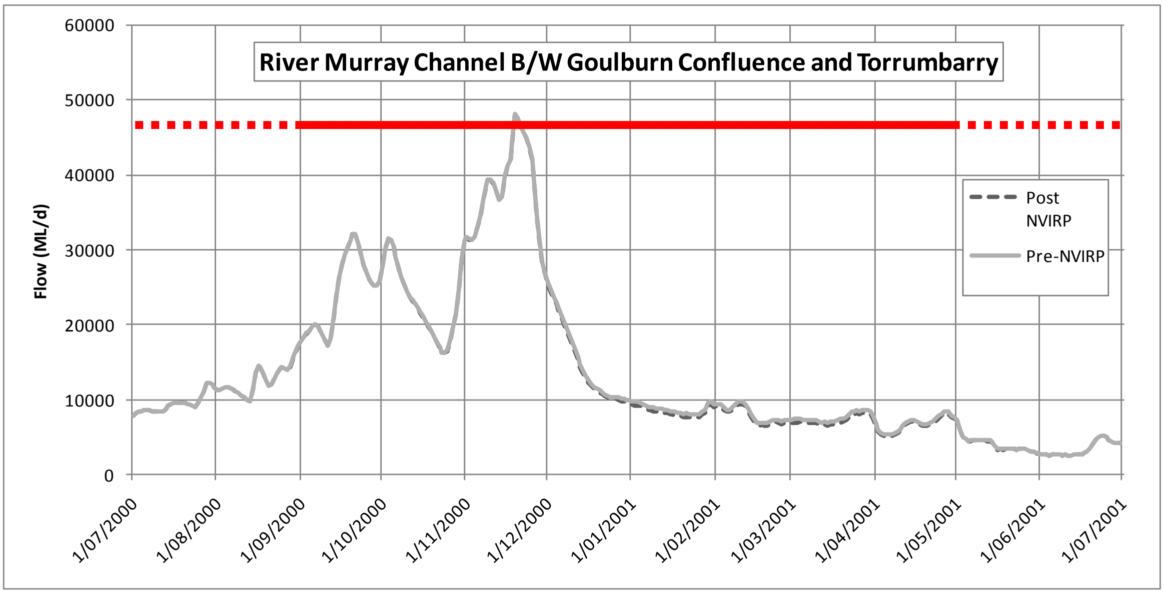
- **Figure 3-9 Difference in level (m) between pre and post NVIRP downstream of Yarrawonga Weir gauging station (409025) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

3.2.3. River Murray upstream of Torrumbarry Weir

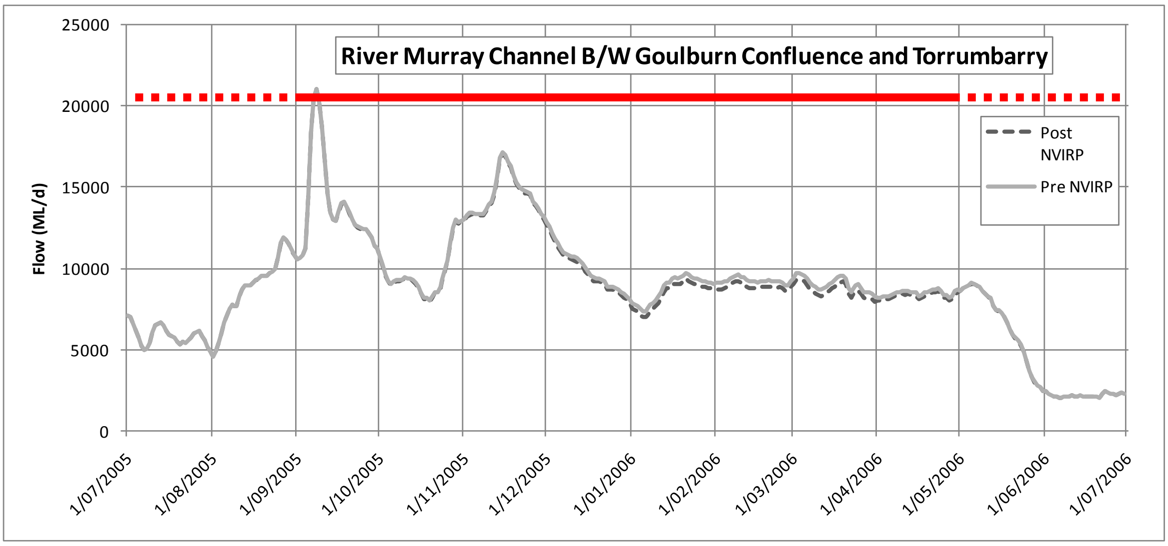
Figure 3-10 and Figure 3-11 show the change in river flow due to NVIRP for the River Murray upstream of Torrumbarry Weir.

Upstream of Torrumbarry Weir, there will generally be a small reduction in river flow due to NVIRP over both the supplying and storing or spilling mode periods. The reduction in flow over the supplying mode period (summer and autumn) is due to the reduced need to supply irrigation diversions to the Torrumbarry irrigation district while the reduction in flow over the storing or spilling mode period (winter and spring) is due to the reduction in outfalls from the Murray Valley, Central Goulburn and Rochester-Campaspe irrigation districts.

The River Murray immediately upstream of Torrumbarry Weir is influenced by the backwater effects of Torrumbarry Weir, thus changes in flow into and out of Torrumbarry Weir due to NVIRP will have no impact on water level at this site.



- **Figure 3-10 Difference in flow (ML/d) between pre and post NVIRP upstream of Torrumbarry Weir (409207+409701) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-11 Difference in flow (ML/d) between pre and post NVIRP upstream of Torrumbarry Weir (409207+409701) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

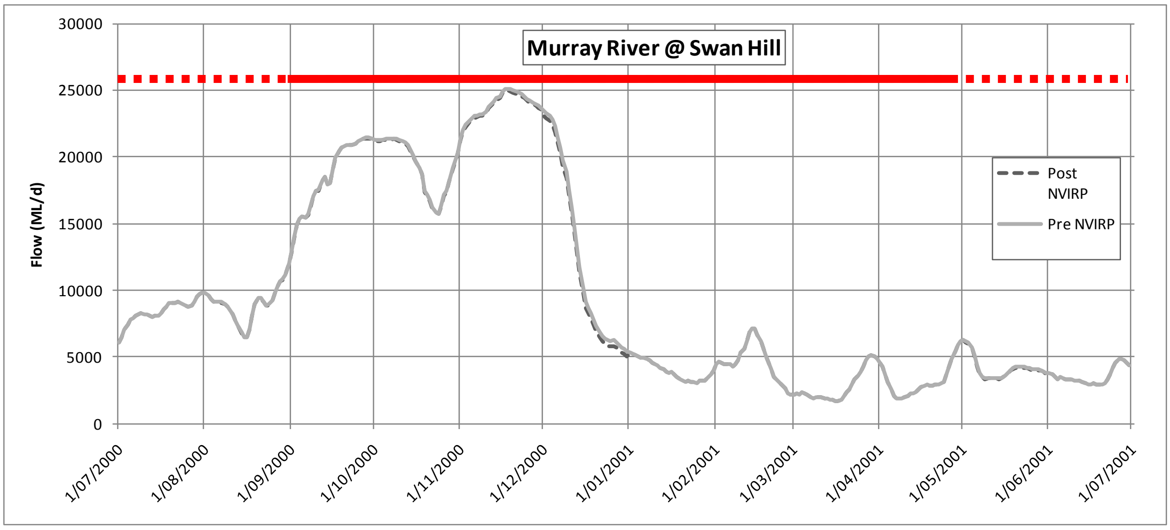
3.2.4. River Murray downstream of Torrumbarry Weir

Figure 3-12 to Figure 3-15 show the change in river flow and level due to NVIRP for the River Murray downstream of Torrumbarry Weir (at the Swan Hill gauging station), while Table 3-8 summarises the maximum and average differences in water level over the supplying and storing or spilling mode periods.

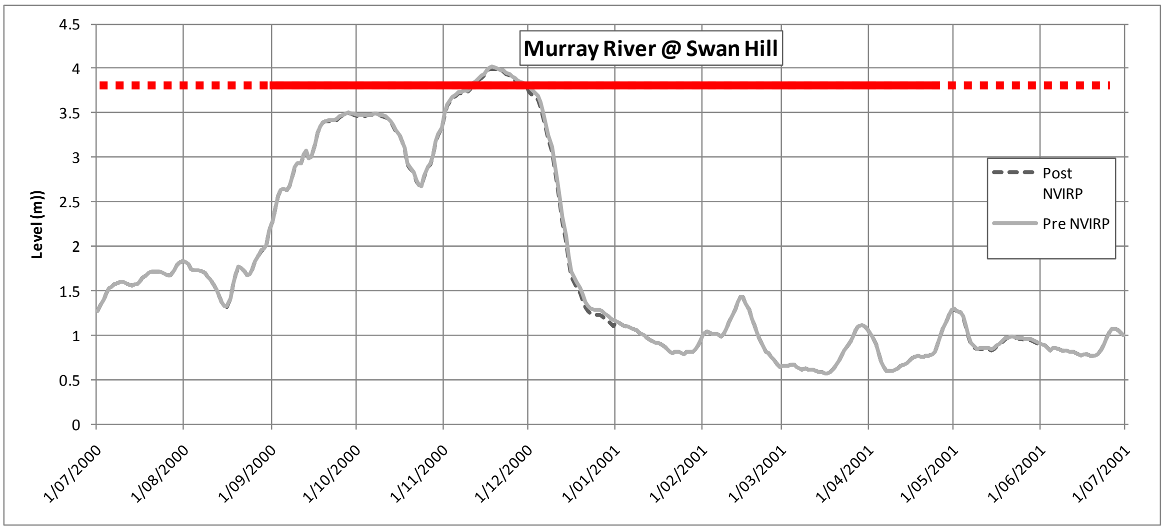
NVIRP will not affect deliveries to irrigation areas downstream of Torrumbarry Weir and therefore it is not expected to alter flow conditions in the River Murray downstream of Torrumbarry Weir during the supplying mode. However, reduced outfalls from the Murray Valley, Central Goulburn, Rochester-Campaspe and Torrumbarry irrigation districts may affect flows in this reach of the River Murray during the storing and spilling mode (i.e. during winter and spring). During an average flow year (represented by 2000/01 flow and water level data at the Swan Hill gauge) the average water depth in the channel during the storing and spilling period is approximately 2.36 m. NVIRP is expected to reduce the average water level at this location by approximately 9 mm in the storing and filling period (equivalent to a 0.4% reduction in water depth). During a dry flow year (represented by 2005/06 flow and water level data at the Swan Hill gauge) the average water depth in the channel during the storing and spilling period is 1.59 m. NVIRP is expected to reduce the average water level at this location by approximately 7 mm in the storing and filling period (equivalent to a 0.4% reduction in water depth).

- **Table 3-8: Comparison of difference in water level (mm) between pre and post NVIRP for the River Murray downstream of Torrumbarry Weir.**

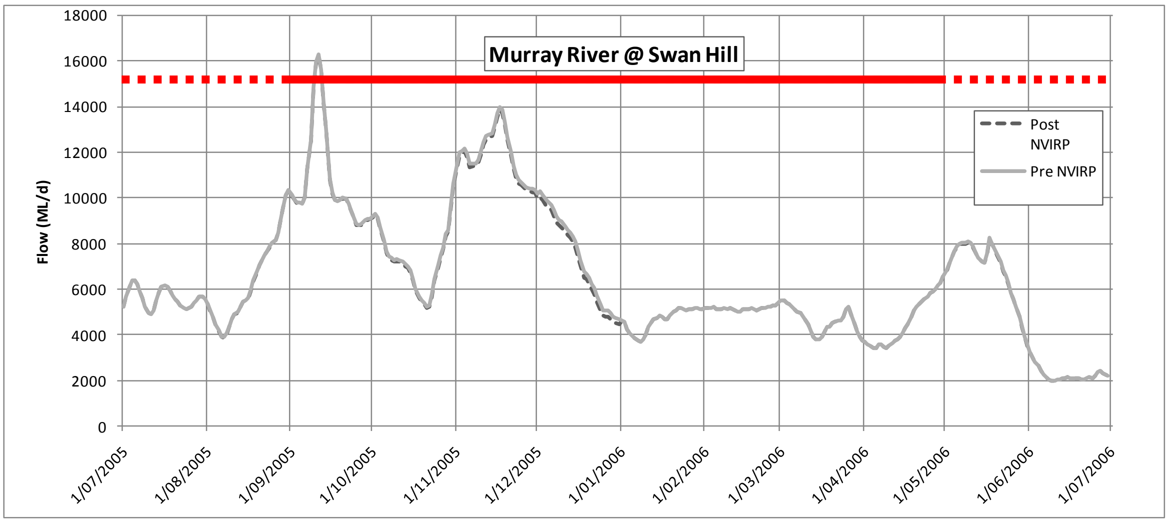
River Channel Site	Year	Level Difference (mm)			
		Storing or Spilling Mode Period		Supplying Mode Period	
		Maximum	Average	Maximum	Average
River Murray downstream of Torrumbarry Weir	Average (2000/01)	-65	-9	0	0
	Dry (2005/06)	-40	-7	0	0



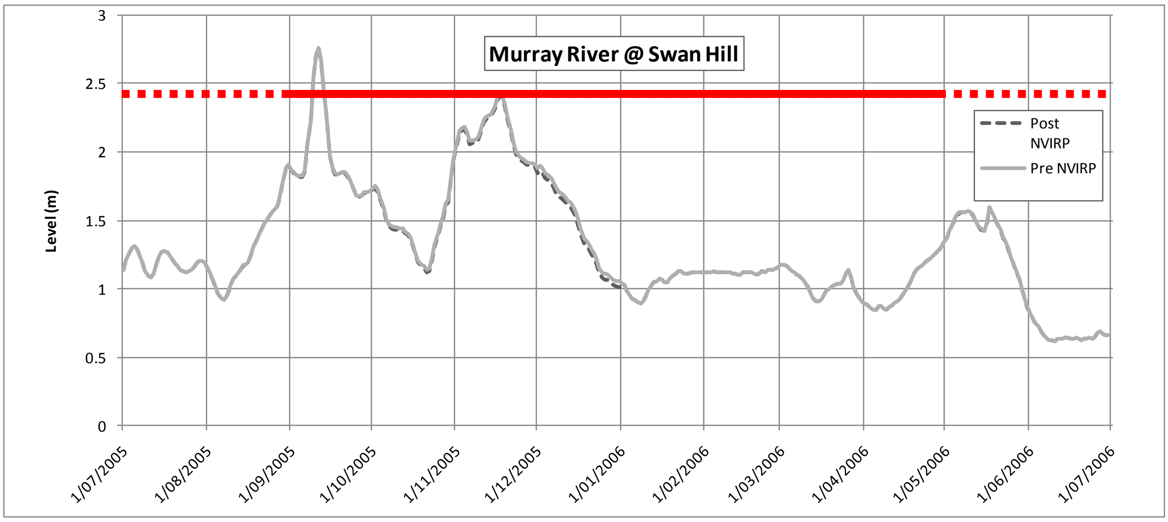
- **Figure 3-12 Difference in flow (ML/d) between pre and post NVIRP at Swan Hill gauging station (409204) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-13 Difference in level (m) between pre and post NVIRP at Swan Hill gauging station (409204) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-14 Difference in flow (ML/d) between pre and post NVIRP at Swan Hill gauging station (409204) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-15 Difference in level (m) between pre and post NVIRP at Swan Hill gauging station (409204) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

3.2.5. Gunbower Forest

The Gunbower Forest is located on the Victorian side of the River Murray downstream of Torrumbarry Weir. This site is adjacent to the project area and therefore hydrological changes due to NVIRP need to be considered. Figure 3-16 to Figure 3-19 show the change in river flow and level due to NVIRP for the Gunbower Forest using flow and level data for the gauge downstream of Torrumbarry Weir (Gunbower Forest gauge). Important commence to flow thresholds are shown on the figures and are labelled with a flow rate only. A key for the vegetation community inundated for each commence to flow threshold is presented in Table 3-9. Table 3-9 also summarises the maximum and average differences in water level and the difference at the peak water level over the storing or spilling mode period (winter and spring). Table 3-10 summarises the change in river level at key commence to flow thresholds while Table 3-11 summarises the change in duration above key commence to flow thresholds.

For the 2000/01 (the year with the largest reduction in river levels during storing or spilling mode periods as modelled with NVIRP in operation), these results show that Gunbower Forest will experience a 3 mm reduction in the flood peak height, with an average reduction in flow level of 3 mm. The reductions in river level at key commence to flow thresholds due to NVIRP are less than 1% of the absolute levels with little (1 or 2 days) or no reduction in the duration of flows above the key commence to flow thresholds.

The maximum reduction in level (60 mm) occurs during the January period at which time flow is well below the minimum commence to flow thresholds. As such this reduction will not affect flow into the forest.

- **Table 3-9: Comparison of difference in level (mm) between pre and post NVIRP for Gunbower Forest.**

Icon Site	Year	Level Difference (mm)			Storing or Spilling Mode Flow Range (ML/day)
		Maximum	Average	At Peak Flow	
Gunbower Forest	2000/01	-60	-3	-3	4,000 – 47,400
	2005/06	-20	<-1	-4	4,300 – 19,900

- **Table 3-10: Change in river level at key commence to flow thresholds due to NVIRP for Gunbower Forest.**

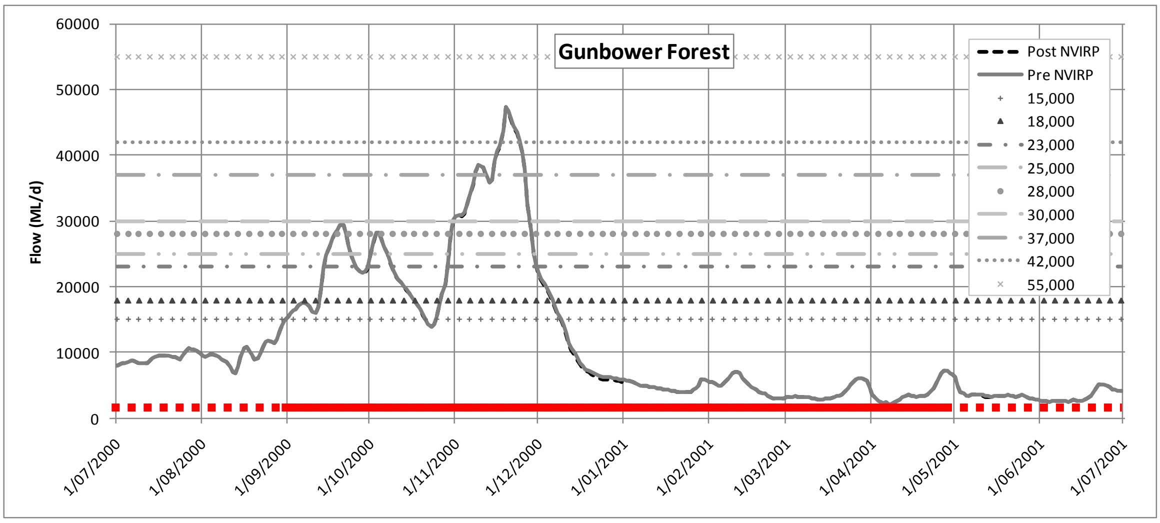
Icon Site	Commence to Flow Threshold			Change in River Level (mm)	
	Flow (ML/day)	Level (m)	Description	2000/01	2005/06
Gunbower Forest	15,000	4.22	Wetlands in lower forest watered with minor inundation of River Red Gums with flood dependent understory	-7	-12
	18,000	4.82	Wetlands in central and lower forest watered, some inundation of River Red Gums with flood dependent understory	-7	-4
	23,000	5.74	Most forest wetlands watered	-6	Not Exceeded*
	25,000	6.04	Wetlands watered and all effluent systems running	-4	Not Exceeded*
	28,000	6.37	Overbank flow commences, flooding of wetlands and surrounding River Red Gums	-4	Not Exceeded*
	30,000	6.56	Widespread flooding, most River Red Gums with flood dependent understory inundated, all semi-permanent and permanent wetlands watered	-4	Not Exceeded*
	37,000	7.06	All River Red Gums inundated, portion of Black Box inundated	-5	Not Exceeded*
	42,000	7.32	Most Black Box inundated	-3	Not Exceeded*
	55,000	7.74	90% of forest flooding, significant impacts on surrounding land	Not Exceeded*	Not Exceeded*

* Flows did not exceed these commence to flow thresholds. As such no change in level has been presented.

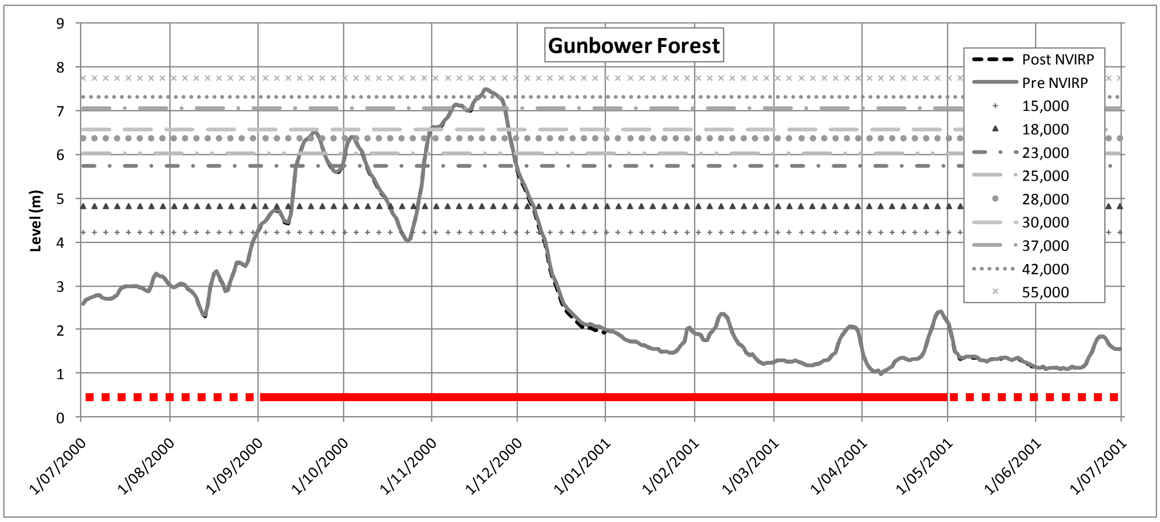
- **Table 3-11: Change in duration above key commence to flow thresholds due to NVIRP for the Gunbower Forest.**

Icon Site	Commence to Flow Threshold				Change in Duration (Days)	
	Flow (ML/d)	Duration Above Threshold (days)		Description	2000/01	2005/06
		2000/01	2005/06			
Gunbower Forest	15,000	97	7	Wetlands in lower forest watered with minor inundation of River Red Gums with flood dependent understory	-2	0
	18,000	75	3	Wetlands in central and lower forest watered, some inundation of River Red Gums with flood dependent understory	-1	0
	23,000	52	Not Exceeded	Most forest wetlands watered	0	Not Exceeded*
	25,000	45	Not Exceeded	Wetlands watered and all effluent systems running	0	Not Exceeded*
	28,000	36	Not Exceeded	Overbank flow commences, flooding of wetlands and surrounding River Red Gums	0	Not Exceeded*
	30,000	28	Not Exceeded	Widespread flooding, most River Red Gums with flood dependent understory inundated, all semi-permanent and permanent wetlands watered	0	Not Exceeded*
	37,000	17	Not Exceeded	All River Red Gums inundated, portion of Black Box inundated	0	Not Exceeded*
	42,000	7	Not Exceeded	Most Black Box inundated	0	Not Exceeded*
	55,000	Not Exceeded	Not Exceeded	90% of forest flooding, significant impacts on surrounding land	Not Exceeded*	Not Exceeded*

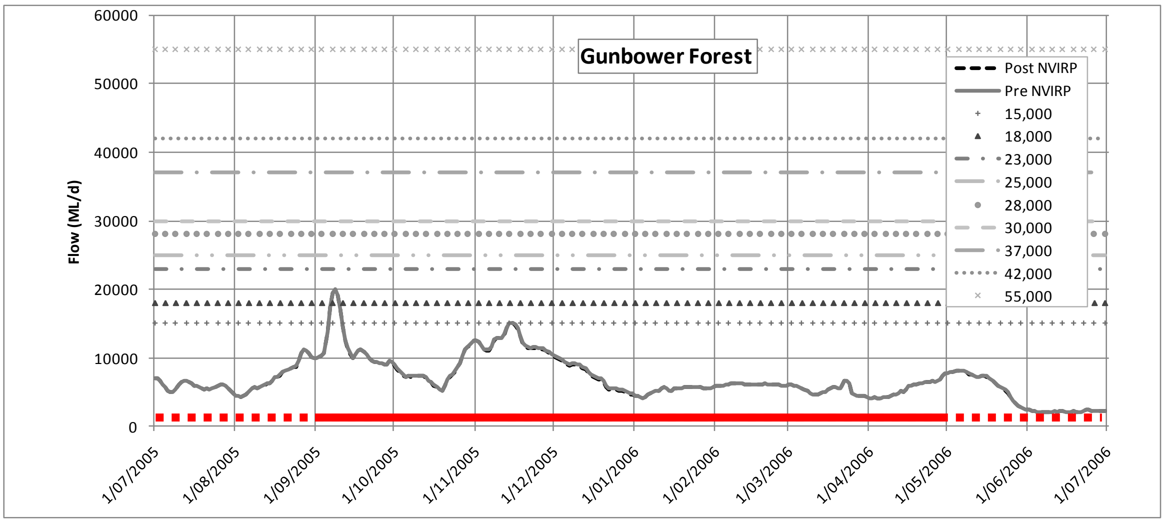
* Flows did not exceed this commence to flow thresholds. As such no change in duration has been presented.



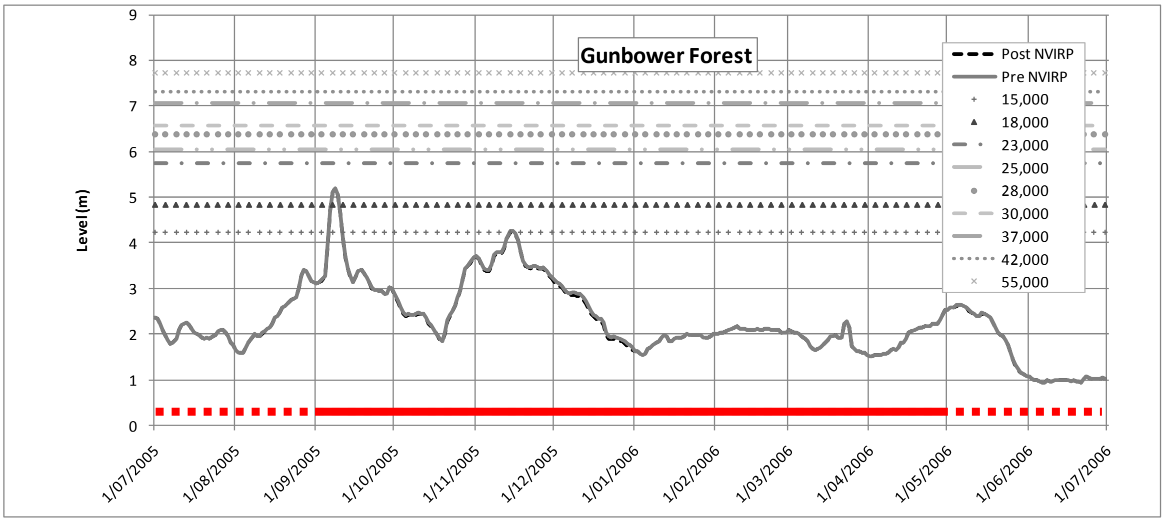
- **Figure 3-16: Difference in flow (ML/d) between pre and post NVIRP at Gunbower Forest (409207) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-17 Difference in level (m) between pre and post NVIRP at Gunbower Forest (409207) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-18 Difference in flow (ML/d) between pre and post NVIRP at Gunbower Forest (409207) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-19 Difference in level (m) between pre and post NVIRP at Gunbower Forest (409207) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

3.2.6. Hattah-Kulkyne Lakes

The Hattah-Kulkyne Lakes are located on the Victorian side of the River Murray downstream of Euston Weir. They are watered by Chalka Creek, which is an anabranch of the River Murray and therefore water levels in the River Murray have a significant effect on the timing, extent and duration of watering in the lakes. Figure 3-20 to Figure 3-23 show the change in river flow and level due to NVIRP at the Euston gauging station. Important commence to flow thresholds for the Hattah-Kulkyne Lakes are shown on the figures below and are labelled with a flow rate only. A key for the vegetation community inundated for each commence to flow threshold is presented in Table 3-12.

Table 3-13 summarises the maximum and average differences in water level and the difference at the peak water level over the storing or spilling mode period (winter and spring). Table 3-14 summarises the change in river level at key commence to flow thresholds while Table 3-15 summarises the change in duration above key commence to flow thresholds.

For 2000/01 (the year with the largest reduction in river levels during storing or spilling mode periods as modelled with NVIRP in operation), these results show that the Hattah-Kulkyne Lakes will experience a 21 mm reduction in the flood peak height, with an average reduction in flow level of 1 mm. The reductions in river level at key commence to flow thresholds due to NVIRP are all less than 12 mm with no change in the duration of flow above the key commence to flow thresholds.

Note the reduction in the flood peak height at this site is greater than the reduction at the upstream sites due to differences in the timing of the flood peak. The flood peaks at the upstream sites (i.e. Barmah Forest) occur during September and November before the main irrigation season when NVIRP will have little impact on river flows and level. The flood peak at Hattah-Kulkyne Lakes occurs during December, during the start of the peak irrigation season when the impacts of NVIRP are greater due to outfall volumes being higher at this time of year.

- **Table 3-12: Key commence to flow thresholds for Hattah-Kulkyne Lakes (personal communications, Andy Wise- Mallee CMA, based on SKM, 2003 and Ecological Associates, 2007).**

Commence to Flow (ML/day)	Description
36,700	Inflows through Chalka Creek to fill the lakes
45,000	Bankful in Chalka Creek, lakes and surrounding floodplain inundated
150,000	Overbank flows from the River Murray, broad scale flooding

- **Table 3-13: Comparison of difference in level (mm) between pre and post NVIRP for Hattah-Kulkyne Lakes.**

Icon Site	Year	Level Difference (mm)			Storing or Spilling Mode Flow Range (ML/day)
		Maximum	Average	At Peak Flow	
Hattah-Kulkyne Lakes	2000/01	-29	-1	-23	2,600 – 50,300
	2005/06	NA*	NA*	NA*	4,800 – 17,100

* During 2005/06 the pre-NVIRP flow at Hattah-Kulkyne Lakes did not exceed the minimum commence to flow thresholds. As such no change in level has been presented for this site.

- **Table 3-14: Change in river level at key commence to flow thresholds due to NVIRP for the Hattah-Kulkyne Lakes.**

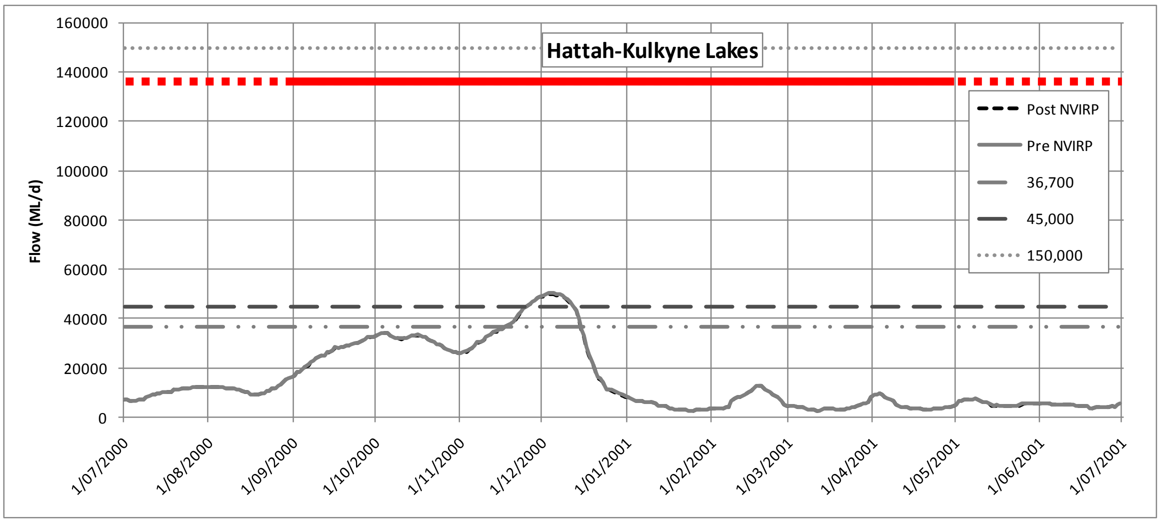
Icon Site	Commence to Flow Threshold			Change in River Level (mm)	
	Flow (ML/day)	Level (m)	Description	2000/01	2005/06
Hattah-Kulkyne Lakes	36,700	4.98	Inflows through Chalka Creek to fill the lakes	-12	Not Exceeded*
	45,000	5.65	Bankfull in Chalka Creek, lakes and surrounding floodplain inundated	-9	Not Exceeded*
	150,000	9.28	Overbank flows from the River Murray, broad scale flooding	Not Exceeded*	Not Exceeded*

* Flows did not exceed these commence to flow thresholds. As such no change in level has been presented.

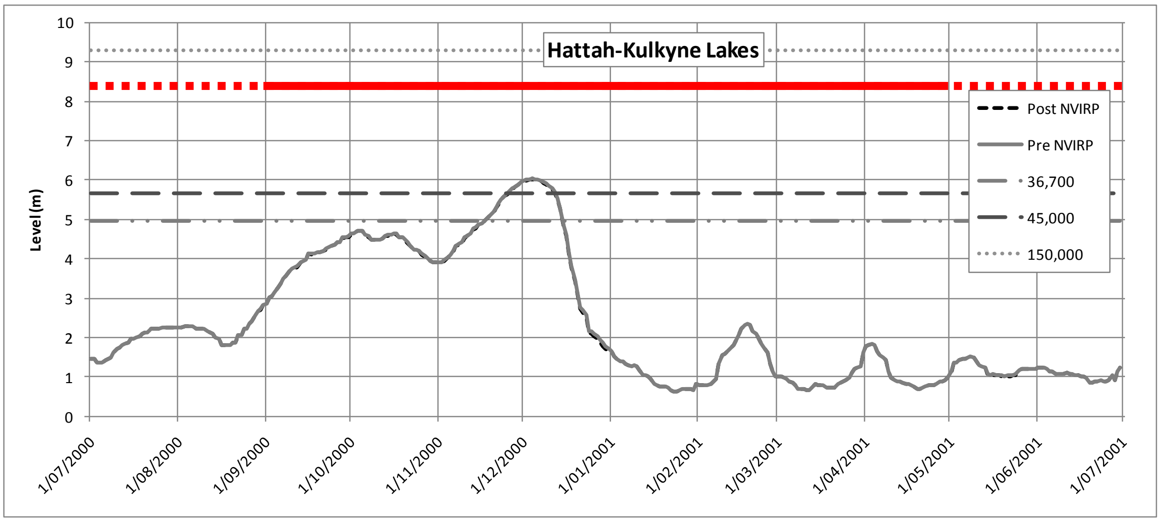
- **Table 3-15: Change in duration above key commence to flow thresholds due to NVIRP for the Hattah-Kulkyne Lakes.**

Icon Site	Commence to Flow Threshold				Change in Duration (Days)	
	Flow (ML/day)	Duration Above Threshold (days)		Description	2000/01	2005/06
		2000/01	2005/06			
Hattah-Kulkyne Lakes	36,700	27	0	Inflows through Chalka Creek to fill the lakes	0	Not Exceeded*
	45,000	18	0	Bankfull in Chalka Creek, lakes and surrounding floodplain inundated	0	Not Exceeded*
	150,000	0	0	Overbank flows from the River Murray, broad scale flooding	Not Exceeded*	Not Exceeded*

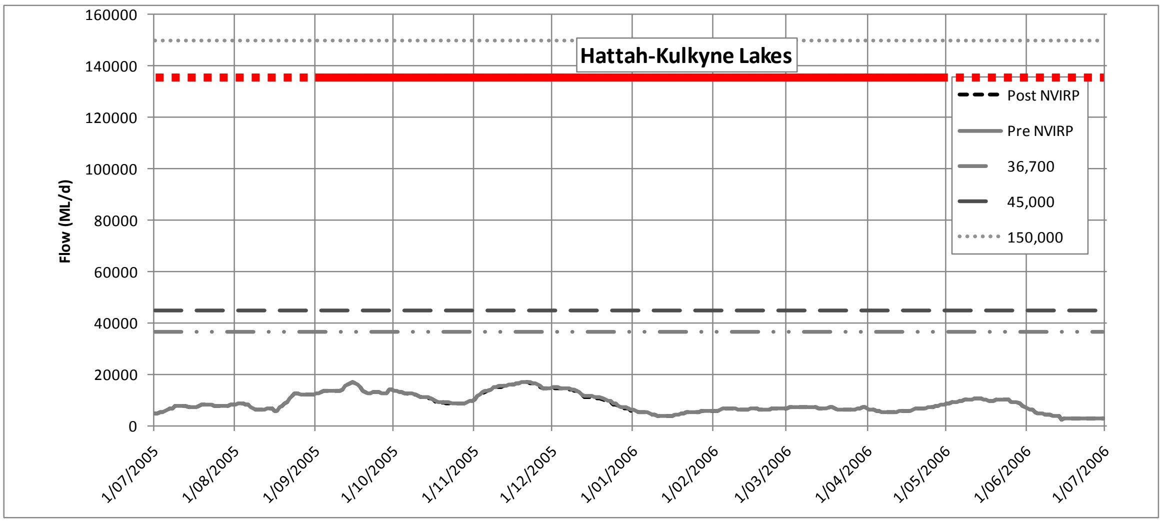
* Flows did not exceed this commence to flow thresholds. As such no change in duration has been presented.



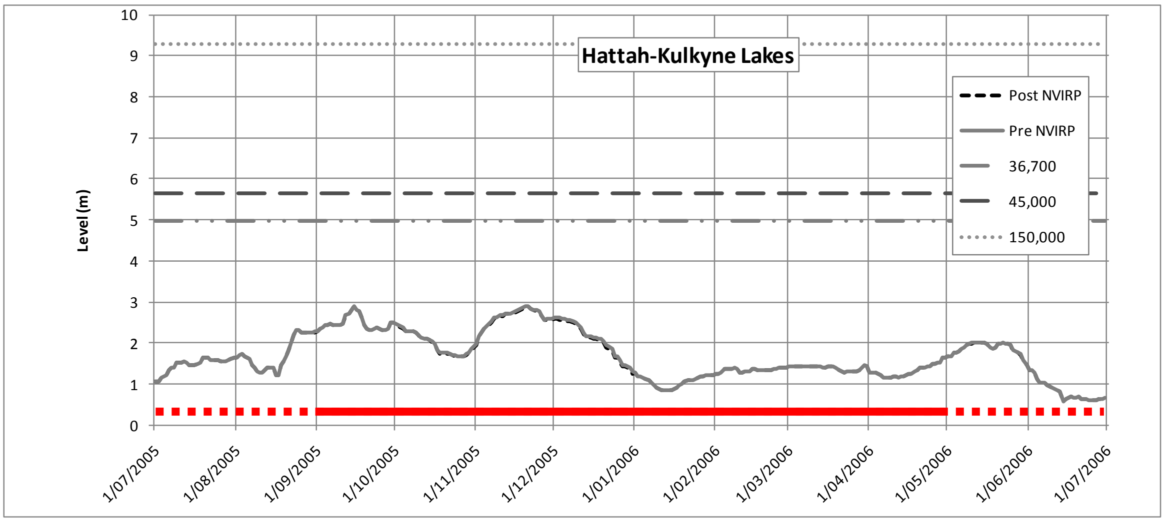
- **Figure 3-20 Difference in flow (ML/d) between pre and post NVIRP at Hattah-Kulkyne Lakes (414203) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-21 Difference in level (m) between pre and post NVIRP at Hattah-Kulkyne Lakes (414203) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-22 Difference in flow (ML/d) between pre and post NVIRP at Hattah-Kulkyne Lakes (414203) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 3-23 Difference in level (m) between pre and post NVIRP at Hattah-Kulkyne Lakes (414203) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

3.2.7. Climate change impacts

Climate change is expected to have a significant impact on river flows and on the frequency and duration of wetland inundation events (Jones and Durack 2005, DSE 2008). Dry flow conditions used in the modelling are analogous to conditions expected under a climate change future.

For the River Murray channel, under both average and dry flow conditions NVIRP is predicted to result in only a very small change in river flow and level during the supplying period and in general no change during the spilling and storing period. Hence the additional impact of NVIRP on river flows over and above that predicted due to climate change is considered insignificant.

For wetlands along the River Murray, NVIRP is predicted to not result in a change in the frequency or duration of wetland inundation events, even under dry flow conditions. Hence the additional impact of NVIRP on wetland inundation events over and above that predicted due to climate change is considered insignificant.

3.3. Groundwater hydrology

One of the aims of NVIRP is to reduce channel seepage and bank leakage. Upgrades to irrigation infrastructure and associated improvements in water use efficiency are expected to reduce recharge to the groundwater system, and as a result regional water tables in the shallow groundwater system (the Shepparton Formation) will fall (SKM 2009b).

Chapter 8 assesses NVIRP's impacts on groundwater levels in light of recent observed increases in groundwater levels.

3.3.1. Predicted regional water table changes

In the documentation prepared for the PER, changes in regional water table levels were estimated by two methods: an Analytical Spreadsheet Model (ASM) and the Southern Riverine Plains Model (SRPM) (NVIRP 2010). Table 3-16 summarises these reductions for areas west of the Terrick Terrick Hills and Table 3-17 summarises the changes for areas east of Terrick Terrick Hills. Predicted watertable depth changes due to NVIRP across the region are also presented graphically in Figure 3-24.

- **Table 3-16 Predicted Water table Drops in GMID West of Terrick Terrick Hills**

Location	High Water-table?	Shepp Formation Pumping?	Deep Aquifer Pumping?	Area	Water table Drop (ASM)	Water table Drop (SRPM)
Pyramid-Boort	Yes	No	No	259,000 ha	0.9 – 1.2 m	Generally less than 1 m
Barr Creek	Yes	No	No	65,000 ha	0.02 m	Less than 0.5 m
Kerang Lakes	Yes	No	No	40,000 ha	n/a	From 0.2 to 1.3 m

- **Table 3-17 Predicted Water table Drops in GMID East of Terrick Terrick Hills (2005/06 case; CG = Central Goulburn; IA = Irrigation Area)**

Location	High Water-table?	Shepp Formation Pumping?	Deep Aquifer Pumping?	Area	Water table Drop (ASM)	Water table Drop (SRPM)
Murray Valley	Yes	Yes	Yes	17,300 ha	0.40 m	From less than 1 to greater than 5 m
Murray Valley	No	Yes	Yes	37,150 ha	0.70 m	
M. Valley	No	No	Yes	73,550 ha	Meth. n/a	
CG 5-9	Yes	Yes	No	56,000 ha	0.2 m	From less than 1 to about 3 m
CG 5-9	Yes	No	No	76,300 ha	0.4 m	
CG 5-9	No	No	No	42,700 ha	0.9 m	
Rochester	Yes	Yes	Yes	19,000 ha	0.4 m	From less than 1 to about 3 m
Rochester	Yes	No	Yes	14,900 ha	0.5 m	
Rochester	No	No	Yes	34,100 ha	Meth. n/a	
Rochester	Yes	Yes	No	7,500 ha	0.4 m	
Rochester	Yes	No	No	6,000 ha	0.5 m	
Rochester	No	No	No	500 ha	1.2 m	
Shepp IA – nth.	Minor	Minor	Minor	65,000 ha	0.9 m	< 1 m
Shepp IA – sth.	Minor	Minor	Minor	16,000 ha	0.3 m	
CG 1-4 – nth.	Minor	Minor	Minor	12,000 ha	0.9 m	
CG 1-4 – sth.	Minor	Minor	Minor	15,000 ha	0.3 m	

Decreases in the depth to water table predicted with the SRPM and ASM were of similar orders of magnitude, although the decreases predicted by the ASM were generally smaller. The PER used the SRPM model results because they:

1) Covered all of GMID whereas the ASM could not cover certain fringe areas, and did not cover the Kerang Lakes area;
2) Provide results for beneath the Barmah and Gunbower forests and represent the variability better across the irrigation areas; and
3) Produce hydrographs that show variation from year to year.

ASM results are still used to estimate reductions in salt loads carried by groundwater towards the major rivers in the GMID and the Barmah and Gunbower Forests.

Water table levels are affected by many factors other than irrigation. A comparison between water table levels in 1991/92 (a wet period prior to the drought with high irrigation water allocations) and 2005/06 (during the recent drought; low rainfall and reduced irrigation water allocations) was used to coarsely estimate changes due to the drought. The conditions observed during 2005/06 are likely to provide an indication of the water table levels that could be expected under the drier climatic conditions that are predicted to occur in the future (CSIRO 2008). Compared to the effect of climatic influences on the water table depth, such as drought and climate change, the changes due to NVIRP are relatively modest (Table 3-18). Other factors, such as groundwater pumping that increases depth to water table, and irrigation intensity that decreases the depth to water table, can also cause significant changes irrespective of NVIRP.

- **Table 3-18 Predicted changes to water table depth with NVIRP compared with inter-annual variability due to factors such as drought/climate change (SKM 2008b)**

Area	Depth to water table 1991/92	Depth to water table 2005/06	Depth to water table 2005/06 with NVIRP
Murray Valley	1.49 m	4.05 m	4.53 m
Central Goulburn (5-9)	0.75 m	1.73 m	1.85 m
Rochester	1.03 m	1.56 m	1.71 m

3.3.2. Groundwater effects on rivers and Ramsar floodplain wetlands

Four groundwater related processes were considered:

- Groundwater flow and salt load towards rivers;
- Actual depths to water-table beneath the Barmah and Gunbower Forests post-modernisation;
- Irrigation-related water-table changes beneath the fringes of the Barmah and Gunbower Forests; and,
- Potential for fresh groundwater to be drained from the Barmah and Gunbower Forests.

These processes are explored further in the following sections. Results of the analysis for Barmah Forest are presented in Chapter 5.

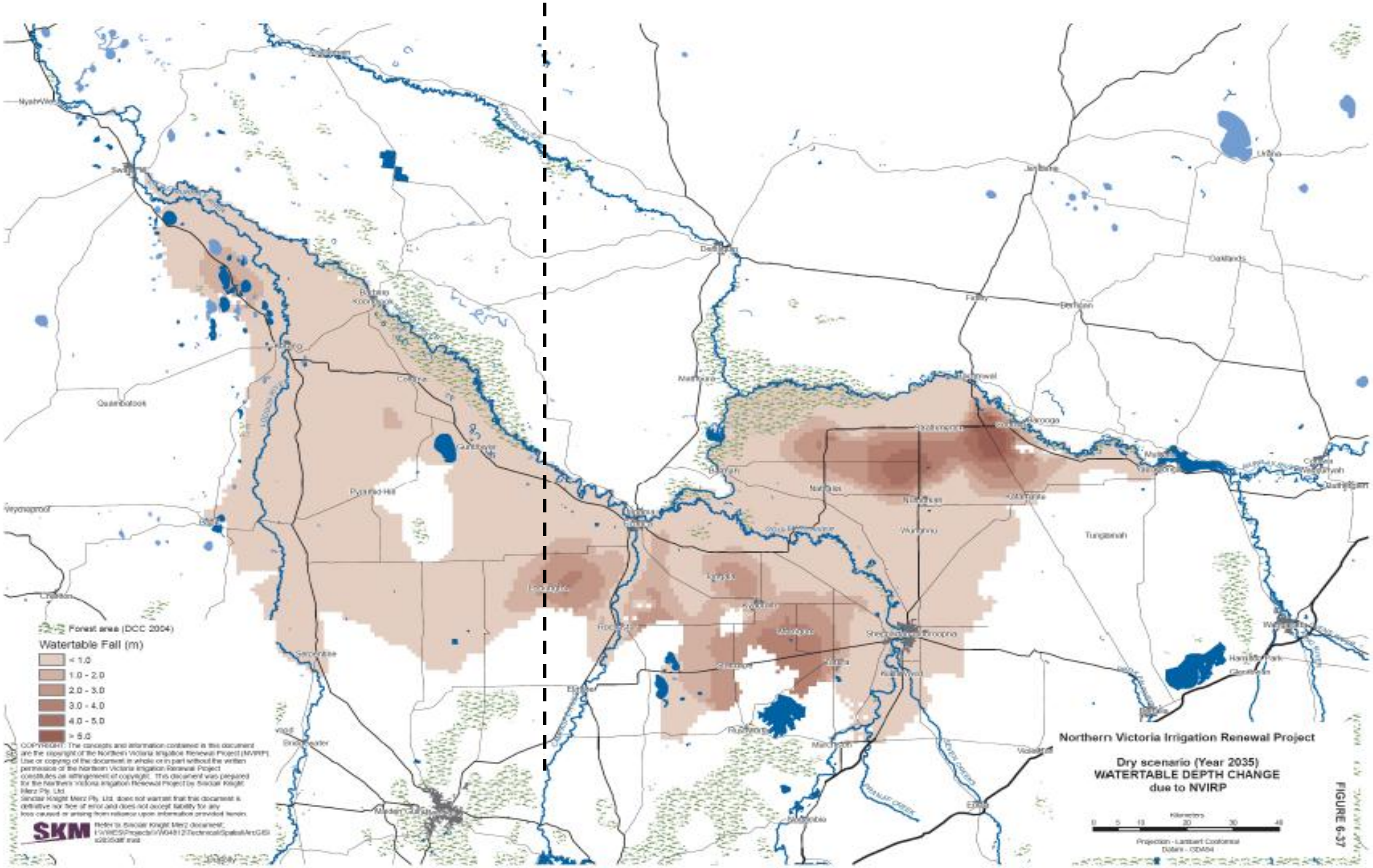


Figure 3-24 Water table depth change due to NVIRP (dry scenario until Year 2035) (NVIRP 2010). The broken line indicates the east-west delineation at Terrick Terrick Hills

3.3.2.1. Groundwater flow and salt load toward rivers and forests

NVIRP works are expected to lead to reduced groundwater levels and hence reductions in groundwater discharge to rivers. Table 3-19 presents the calculated pre- and post- NVIRP groundwater volumes moving towards the River Murray, Goulburn River, Broken Creek, Campaspe River and the Barmah and Gunbower Forests. This impact is very small in terms of flow in the major rivers, but may be significant for Broken Creek and Campaspe River during low flow periods (Table 3-19). Also, it is believed that the pre-and post-NVIRP groundwater volumes, although flowing towards the rivers, are to some extent evaporated within the floodplain (Table 3-19).

- **Table 3-19 Reductions in Groundwater Volumes Flowing Towards Rivers (IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn; NV = NVIRP)**

Asset	Present Head	Head Drop	Factor[(a)]	Vol to River ML/yr		Indicative Difference (ML/yr)
				Pre-NV	Post-NV	
River Murray u/s Barmah Forest	2.5 m	0.40 m	0.84	2,000	1,680	-320
Barmah Forest north of MVIA	12.5 m	0.40 m	0.97	6,773	6,570	-203
Broken Creek – MVIA Bank	2.0 m	0.4 m	0.80	1,883	1,506	-377
Broken Creek – Shepp IA Bank	0.0 m	0.0 m	n/a	0	0	0
Broken River within Shepp IA	2.0 m	0.6 m	0.70	800	560	-240
Goulburn River. b/w Shepp & CGIAs. CG side.	2.6 m	0.24 m	0.91	1,548	1,409	-139
Goulburn River b/w Shepp & CGIAs. Shepp side	0.0 m	0.0 m	n/a	0	0	0
Goulburn River north of CGIA	9.3 m	0.24 m	0.97	6,000	5,820	-180
River Murray north of Rochester IA	1.1 m	0.37 m	0.66	323	213	-110
Campaspe River within Rochester IA	4.0 m	0.5 m	0.88	3,973	3,496	-477
Gunbower Forest north of Barr Ck catchment.	4.0 m	0.02 m	0.995	1,716	1,707	-9
Total				**25,016**	**22,961**	**-2,055**

(a) This factor is (Present Head – Head Drop)/Present Head. It gives the ratio of Post- to Pre-NIVIRP.

Table 3-20 presents the salinities of the groundwater flowing from the irrigation areas towards the major rivers and the floodplain forests in the region, and calculates the corresponding reduction in groundwater-borne salt load. NVIRP is expected to reduce the total salt load flowing towards rivers and floodplain forests by 6 105 tonnes per year. Any reduction in the lateral movement of salt towards the rivers and floodplain forests is likely to be beneficial, because the receiving waterways support high environmental values that may be sensitive to high salinity. However, the overall effect of NVIRP on salt loads is relatively small and represents only a 5% reduction in total annual groundwater salt contributions to these environments. Salt load movements are only understood at a general level and therefore the effect that NVIRP will have at individual sites cannot be determined reliably.

Salinity impacts at Gunbower Forest and Hattah Lakes are being assessed as a component of the Gunbower Forest and Hattah Lakes Living Murray projects. For these two sites the salinity impact of The Living Murray has now been formally submitted to MDBA as required under the Basin Salinity Management Strategy. Living Murray impacts are very much more significant (improvement) than any potentially negative impact of NVIRP (John Cooke, *pers. comm.).*

3.3.2.2. Actual depths to water table beneath Gunbower Forest

The post-modernisation depths to water table have been obtained from the SRPM, and compared with the levels measured beneath the Gunbower Forests. The desirable outcome is a no effect post-NVIRP on depth to water table in either the ‘up’ or the ‘down’ direction of water tables. If a water table rise is predicted, then it could indicate the effects of the irrigation mounds intruding into the Forest. If water tables are predicted to fall then this could indicate that NVIRP would drain useable fresh groundwater away from the Forest.

Modelling results suggest that NVIRP will have no effect on watertable levels beneath the Gunbower Forest and it is highly unlikely there would be transmission of NVIRP effects further to the north into the Koondrook-Perricoota Forest.

3.3.2.3. Irrigation-related water table changes beneath the fringes of the Gunbower Forest

The SRPM results show that NVIRP will not alter the water tables on the fringe of the Gunbower Forest. This is ascribed to the fact that the water table reduction beneath the adjoining irrigation area (Barr Creek Catchment) is relatively small due to only a small amount of channel seepage and bank leakage reduction works under NVIRP.

- **Table 3-20 Reductions in Groundwater-borne Salt Load Moving Towards Rivers (IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn)**

Asset	G'water Salinity (mg/L)	Vol to River (ML/yr)		Salt load to river (t/yr)		Indicative Reduct'n (t/yr)
		Pre-NV	Post-NV	Pre-NV	Post-NV	
River Murray u/s Barmah Forest	900	2,000	1,680	1,800	1,512	288
Barmah Forest north of MVIA	200	6,773	6,570	1,355	1,315	40
Broken Creek – MVIA Bank	1,000	1,883	1,506	1,883	1,506	377
Broken Creek – Shepp IA Bank	2,000	0	0	0	0	0
Broken River within Shepp IA	2,000	800	560	1,600	1,120	480
Goulburn River b/w Shepp & CGIAs. CG side.	2,000	1,548	1,409	3,095	2,820	275
Goulburn River. b/w Shepp & CGIAs. Shepp side	2,000	0	0	0	0	0
Goulburn River north of CGIA	8,500	6,000	5,820	51,000	49,470	1,530
River Murray north of Rochester IA	5,000	323	213	1,615	1,065	550
Campaspe River within Rochester IA	5000	3,973	3,496	19,865	17,480	2,385
Gunbower Forest north of Barr Ck catchment.	20,000	1,716	1,707	34,320	34,140	180
Total		**25,016**	**22,961**	**116,533**	**110,428**	**6,105**

3.3.2.4. Potential for fresh groundwater to be drained from Gunbower Forest

An important consideration for the groundwater assessment is whether water table mounds beneath irrigation areas would be lowered substantially by NVIRP and if so, whether groundwater gradients would flow away from and drain the forests. To investigate this, assessment of the groundwater elevations beneath the irrigation areas were compared to the elevations beneath the forest.

At the Gunbower Forest there is a head difference of about 7.5 metres from the Torrumbarry Irrigation Area into the Forest and the relatively small reduction in this head difference due to NVIRP is unlikely to result in increased rates of fresh groundwater leaving the Forest.

3.3.3. River Salinity

Monthly salinity data was used to undertake an assessment of the effect of NVIRP on the salinities in the River Murray and Goulburn River, as well as in the connected wetlands along the River Murray (including Ramsar sites) by SKM (2009b) as supporting data for the Public Environment Report (NVIRP 2010). In many cases, salinity data were available for threshold flows representing anabranch commence to flow. The assessment was done for an average climate scenario (based on rainfall conditions in 2000/2001) and a dry (10%) climate scenario (based on 2005/2006 rainfalls) (NVIRP 2010).

The results of those assessments indicated that NVIRP will decrease river salinities by up to 5 µS/cm, particularly in the River Murray downstream of Swan Hill during the supplying mode (SKM 2009b). Overall these changes are very small in comparison with background salinity regimes (~ 200 µS/cm) and are not likely to have any effect on biota or other environmental values.

3.3.4. Groundwater effects on Hattah-Kulkyne Lakes

Impacts to the Hattah-Kulkyne Lakes were assessed on the basis of results on Gunbower Forest. Given the results show no significant impacts on Gunbower Forest, and these Lakes are 270 kilometres further down gradient from Gunbower Forest it is not plausible that there would be impacts on the watertable at these Lakes (NVIRP 2010).

3.3.5. Groundwater summary

NVIRP is expected to reduce groundwater discharges to rivers across the whole GMID by approximately 19 ML/day. Such a reduction is too small to have a detectable effect on river flow or water level in the River Murray (NVIRP 2010). In a separate analysis SKM (2009b) concluded that watertables under Gunbower Forest and under the Hattah-Kulkyne Lakes would also be unaffected by NVIRP and that while salinity levels in the River Murray may increase by up to 2 µS/cm or decrease by up to 5 µS/cm, such changes would be too small to have any effect on ecological values.

3.4. Effect of likely flow changes on environmental values

The previous sections demonstrate that NVIRP will have extremely small hydrological changes in the River Murray between Hume Dam and downstream of Torrumbarry Weir, in Gunbower Forest and in the Hattah-Kulkyne Lakes. Effects in the main river channel will be limited to changes in the magnitude of low flows and possibly summer freshes, but average water levels are not expected to fall by more than 14 mm in any reach and the maximum predicted drop at any time is expected to be 95 mm or less. Larger flows in the main river channel will not be affected. Changes in the Gunbower Forest and Hattah-Kulkyne Lakes are also expected to be very small. The timing and duration of flooding is not expected to change in either system and average water levels are expected to fall by no more than 3 mm. The following sections use conceptual models to assess the likely effect that those changes will have on biological values. A review of suitable conceptual models and indicators of ecosystem response and rationale to support the selected models/indicators can be found in Appendix A.

3.4.1. Vegetation

Summer low flows are important for maintaining areas of shallow, slow flowing habitats and backwaters, which support submerged and amphibious species throughout the growing season (Figure 3-25). The predicted fall in average water levels in the River Murray due to NVIRP are too small to affect the availability or quality of shallow habitats and therefore they will not have any effect on any existing vegetation.

Summer freshes are important for watering macrophytes that may otherwise dry out during periods of prolonged low flow and for watering plants on low channel benches (Figure 4-13). Although NVIRP may reduce the magnitude and frequency of some summer freshes in the River Murray, the magnitude of those changes is expected to be extremely small and within the range of flows that are normally experienced by the biota that are currently established in the system. Therefore, NVIRP is not expected to affect the condition or distribution of native plants that rely on summer freshes.

The Hattah-Kulkyne Lakes and Gunbower Forest include a mix of wetlands of varying permanency and support a range of plant communities with different water regime requirements. The distribution of these plant communities within each site is strongly linked to the water regime. Low lying areas support species that require frequent flooding or near permanent inundation, while areas of higher elevation support communities that can only tolerate infrequent and short periods of flooding. Changes to the timing, frequency or magnitude of flooding may have a significant effect on the distribution of established plant communities. The hydrological analysis presented above indicates that NVIRP will not affect the frequency or timing of floods in either Gunbower Forest or the Hattah-Kulkyne Lakes and changes in water levels during floods are expected to be very small. These hydrological changes are too small to affect the established vegetation communities.

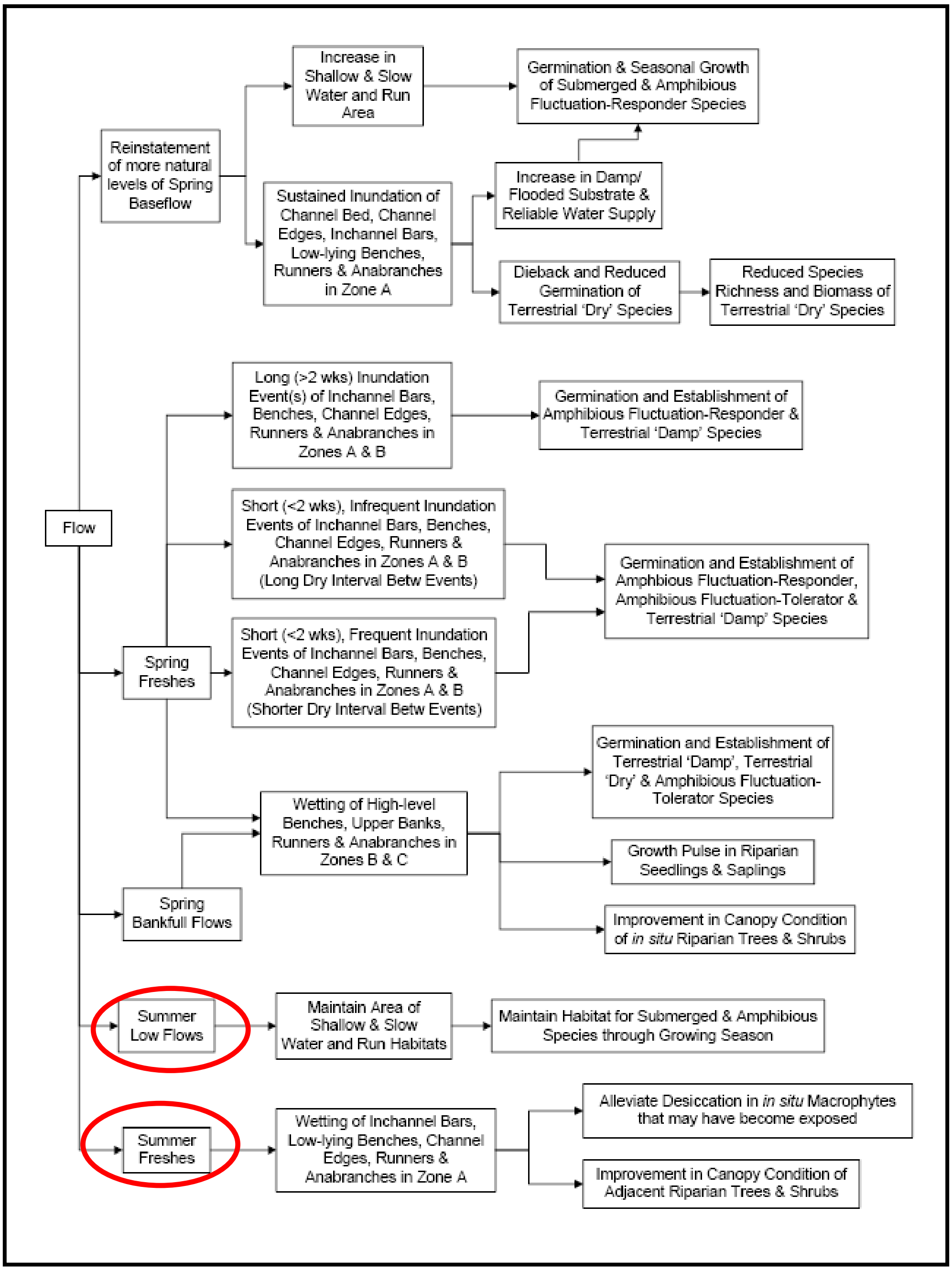
Assessment of groundwater impacts of NVIRP does not indicate any likely impact on vegetation communities.

3.4.2. Fish

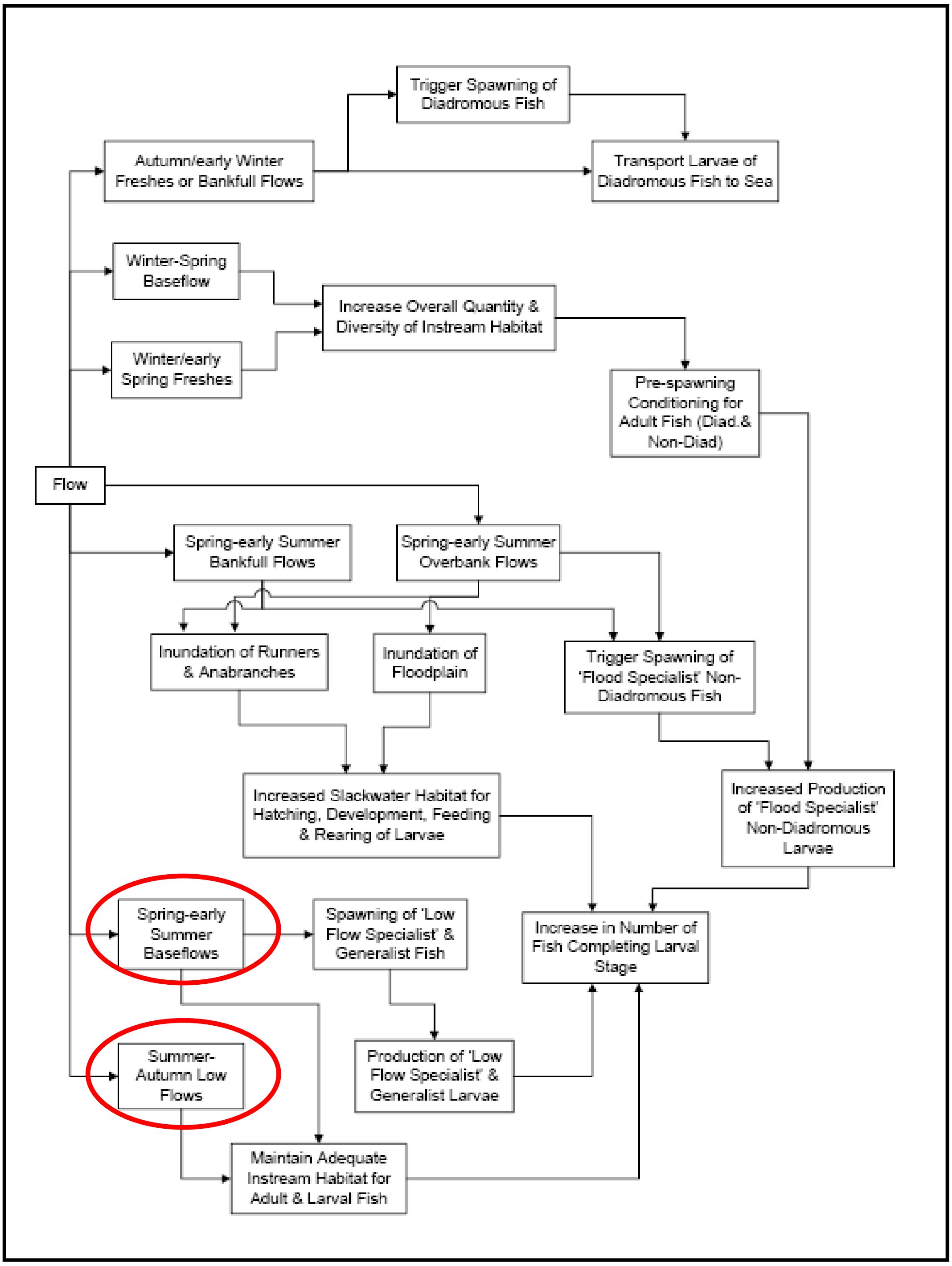
Flows maintained at a minimum level are important for maintaining the quality and quantity of habitat for all fish. In particular low flows maintain depth and water quality in deep pools that are used by large bodied fish such as Murray Cod (Figure 3-26). Low flows are also important for maintaining shallow edge habitats and backwaters that are used by smaller fish and that provide nursery habitats for larvae and juveniles of some native species (Figure 3-26). In a large river such as the River Murray, a substantial change in depth is required before there is likely to be any noticeable change on the availability of deep pool or shallow edge habitats. The hydrological modelling results presented above indicated that average water levels in either average or dry years in the main channel of the River Murray between Hume Dam and downstream of Torrumbarry Weir are not likely to drop by more than 14 mm as a result of NVIRP. Even the maximum predicted change in water level is only 95 mm, and that will be for only a short duration. Such changes represent a less than 1% reduction in river depth and are considered too small to affect the quality or quantity of any in-channel habitats used by fish. Moreover, the magnitude of the change is within the range of daily changes in water level that the biota are already adapted to. Therefore NVIRP is not expected to affect any fish communities in these reaches of the River Murray.

Wetlands and creeks in Gunbower Forest and the Hattah-Kulkyne Lakes provide important habitats for small-bodied native fish and are also important nursery habitats for some larger species. Fish obviously need areas of permanent water to persist in these sites or else must be able to move into the areas during floods and then return to the main river channel before floodwaters recede. The timing, frequency and duration of floods and wetland inundation are critical factors that determine quality and quantity of fish habitat, the availability of food and breeding success of fish that use these sites (Figure 3-27). NVIRP is not expected to change the timing, frequency or duration of floods in Gunbower Forest or the Hattah-Kulkyne Lakes and therefore is not expected to affect the health or composition of any fish communities at these sites.

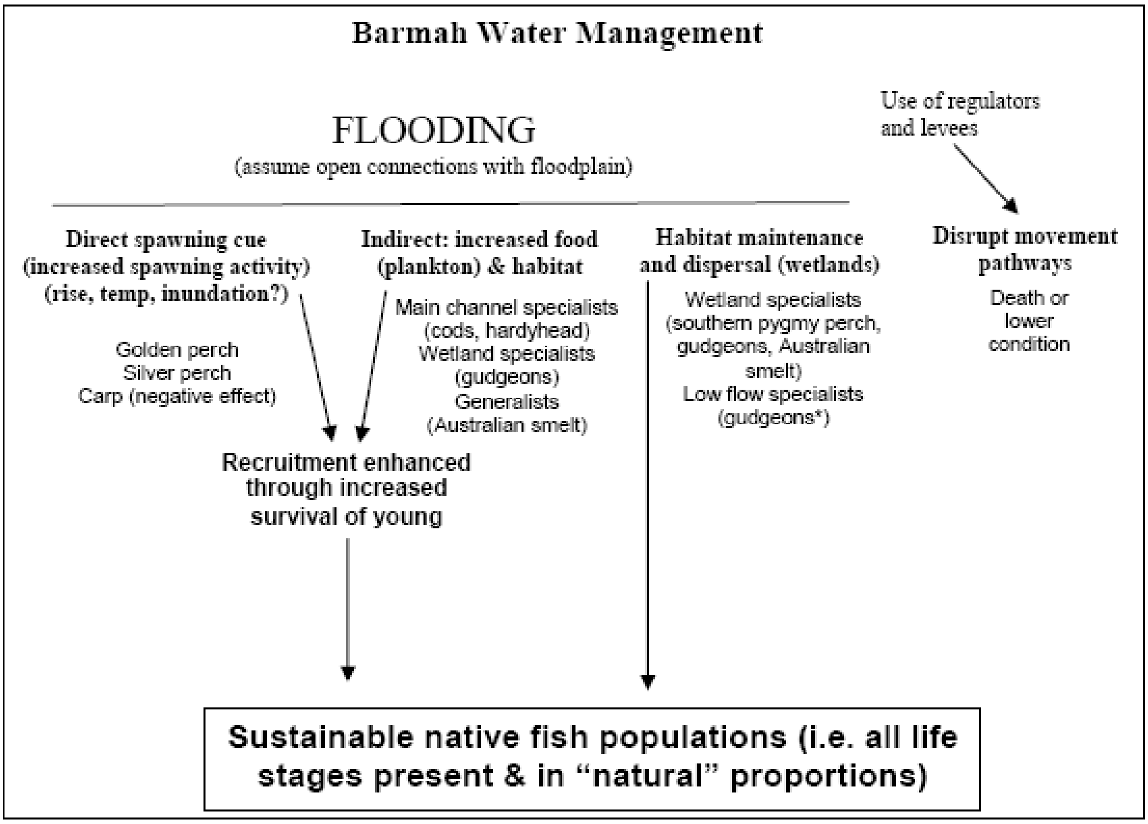
Assessment of salinity levels in the River Murray suggests they may increase by up to 2 μS/cm or decrease by up to 5 μS/cm. Such changes would be too small to have any effect on fish or their habitat.



- **Figure 3-25: Conceptual model of detailed response of different Plant Functional Groups to altered water regime (Source: Chee *et al.* 2006, page 29). Red ovals highlight flow components that are potentially to be affected by NVIRP in the River Murray.**



- **Figure 3-26: Conceptual model for effect of flow on fish spawning and recruitment (Source: Chee *et al.* 2006, page 34). Red ovals highlight the flow components that are likely to be affected by NVIRP in the River Murray.**



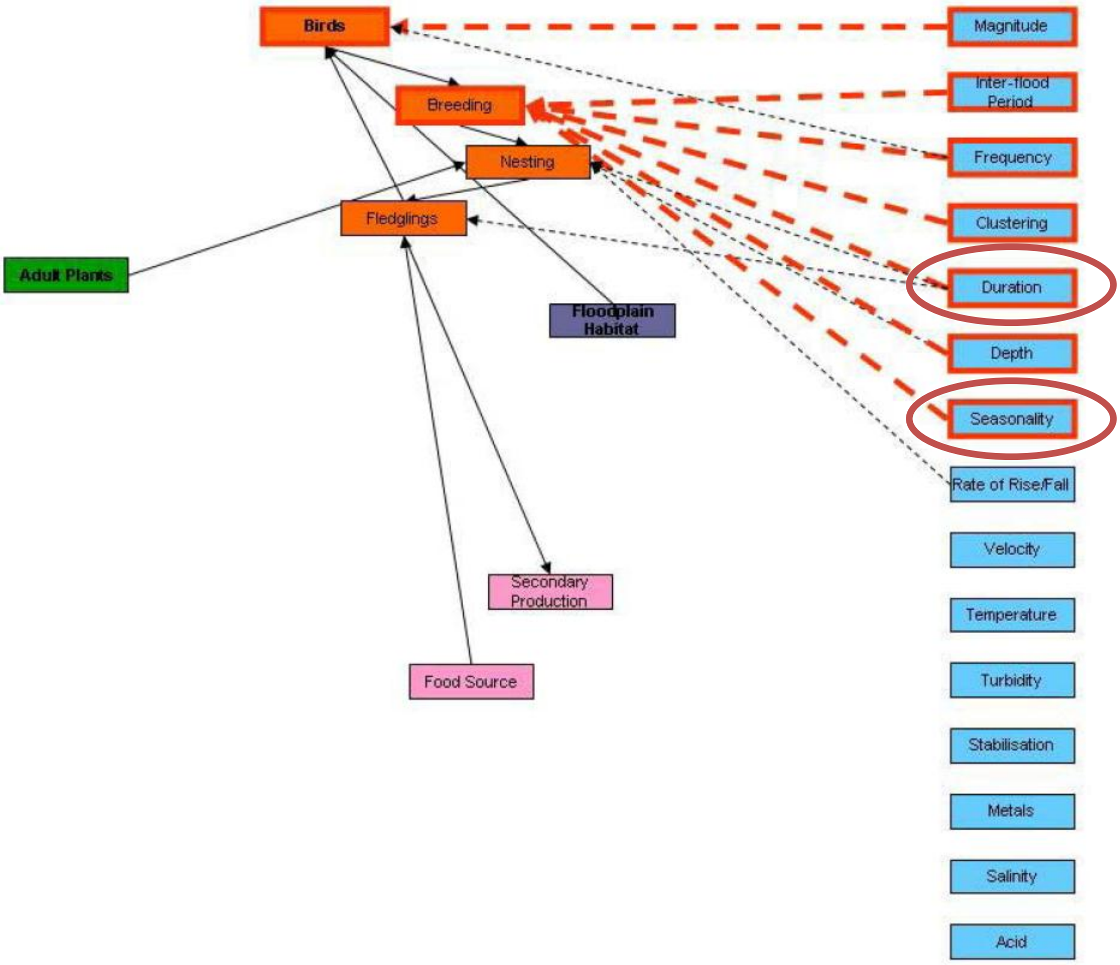
- **Figure 3-27: Conceptual model of impact of flow on fish communities in floodplain river systems using the Barmah Forest as a template (Source: McCarthy *et al.* 2006, page 16).**

3.4.3. Waterbirds and frogs

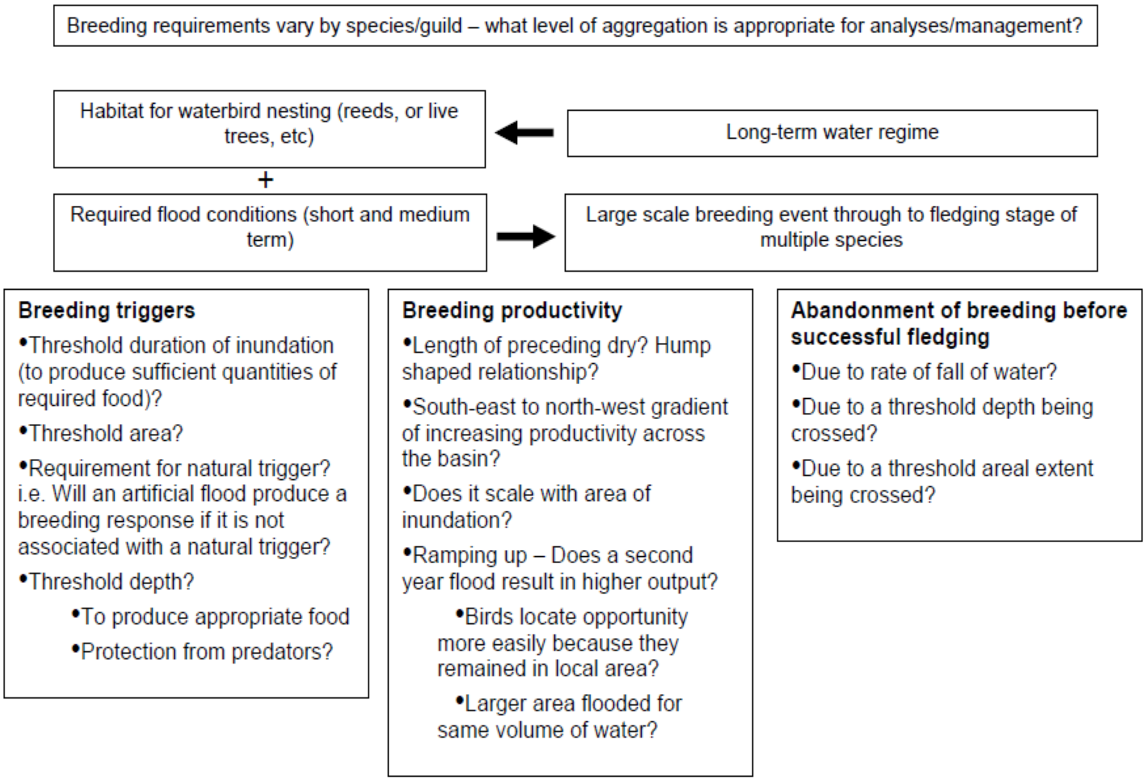
All of the significant bird and frog species that have been recorded in the vicinity of the River Murray rely on floodplain wetlands or riparian forests rather than the main river channel. Therefore this assessment focuses primarily on the effect that NVIRP is likely to have on the water regimes in Gunbower Forest and the Hattah-Kulkyne Lakes.

The main factors that influence the breeding success and health of waterbird populations on the floodplain of lowland rivers are the seasonality and duration of flood events (see Figure 3-28 and Figure 3-29). NVIRP is not expected to affect either of these factors in Gunbower Forest or the Hattah-Kulkyne Lakes and therefore is not expected to affect any of the waterbird populations.

The preferred habitat for frogs that inhabit floodplains and wetlands are vegetated areas that are variably inundated to shallow depths (Cogger 2000). Small reductions in water level of the magnitude predicted may result in some local changes in the distribution of preferred habitat (at the scale of metres), but is not expected to alter the overall quantum of available habitat or the optimal timing or duration of its availability.



- **Figure 3-28: Conceptual model of the major components of waterbirds that relate to aspects of flow regime (Source: Overton et al. 2009, page 403). Red ovals highlight flow components that are most likely to be affected by NVIRP.**



- **Figure 3-29: Hypothetical relationships between breeding responses and flow regimes for colonial nesting waterbirds (Source: Reid *et al.* 2009, page 126).**

3.5. Conclusion

The River Murray between Hume Dam and Torrumbarry Weir carries irrigation supply flows during the summer period. These reaches of the River Murray suffer from seasonal flow inversion (i.e. higher than natural flows in summer and lower than natural flows during winter). The Gunbower Forest Ramsar site, located at the downstream end of the reach, is a River Red Gum forest subject to periodic inundation via Gunbower Creek. The Hattah-Kulkyne Lakes lie further downstream of Torrumbarry Weir in typical Mallee country with extensive low scrub and open native pine woodland. The lakes are connected to the River Murray by Chalka Creek, which leaves the River Murray just downstream of Euston Weir. These systems support a mix of permanently flowing river channels, temporary and permanent wetlands, including lakes, swamps, lagoons and flooded forest which provide habitat for a large number of plant and animal species of national, state and regional significance.

Under NVIRP there will be a reduction in river levels during the irrigation supply period (summer and autumn) as a consequence of needing to release less water from upstream storages to supply diversions to irrigation. This is predicted to result in a small reduction in river levels (<15 mm on average) along the River Murray. This is equivalent to a reduction in river level of less than 1% of channel depth. The reduction in river levels is predicted to have minimal impact on the frequency and duration of events that inundate the Gunbower Forest or the Hattah-Kulkyne Lakes Ramsar sites. Furthermore, the largest reduction in river levels occur at a time of year when levels are well below the minimum commence to flow threshold for the wetland systems. As such river level reductions at this time will not affect flows into the wetland systems.

In addition to the minor impacts on water levels, NVIRP is expected to reduce groundwater discharges to rivers across the whole GMID by approximately 19 ML/day. Such a reduction is too small to have a detectable effect on river flow or water level in the River Murray. Salinity levels in the River Murray may increase by up to 2 µS/cm or decrease by up to 5 µS/cm, but such changes would be too small to have any effect on ecological values. NVIRP is not expected to affect watertable levels beneath Gunbower Forest and therefore impacts on ecological values are not expected to occur.

The hydrological analysis presented above indicates that NVIRP will not significantly affect the river levels in the River Murray or the frequency or timing of floods in either Gunbower Forest or the Hattah-Kulkyne Lakes under current or climate change conditions. On the basis of conceptual models of ecological response to hydrological change it is considered that any hydrological changes are too small to affect the quality or quantity of any in-channel habitats used by fish or other aquatic biota. Changes in the hydrological regime of the wetland systems are also considered too small to affect the established vegetation communities and other biota such as water birds or frogs. Hence, there is unlikely to be any impact on environmental values of national, state or regional conservation significance in the River Murray between Lake Hume and Torrumbarry Weir, or in the Gunbower Forest or Hattah-Kulkyne Lakes Ramsar sites.

4. Hydrological changes to the Goulburn River

The Goulburn River between Eildon Dam and Goulburn Weir flows through a confined floodplain that is 2-4 km wide and has more than 400 small billabongs and wetlands (Cottingham *et al.* 2003). The reach is used as an irrigation supply delivery system. Most of the irrigation water that is released from Eildon Reservoir is diverted at Goulburn Weir, while the rest is passed further downstream to supply demand in the River Murray. These latter flows are called Inter-Valley Transfers (IVTs). The existing operating system means that flows in the Goulburn River between Eildon Dam and Goulburn Weir are higher than natural during the irrigation season but are less than natural at other times. These high irrigation flows inundate many benches and riffles that would normally be exposed during summer and maintain water in some wetlands that are connected to the main river channel.

The Goulburn River floodplain downstream of Goulburn Weir is unconfined and supports more than 1300 wetlands of varying size, including more than 200 wetlands greater than 26 ha. Flow in this reach is maintained to meet passing flow and other environmental requirements, and also to supply demand in the River Murray system (through IVTs). The reach also receives outfall contributions from the Shepparton and Central Goulburn Irrigation areas. Under the existing operating system, summer flows are close to the natural median summer low flow, but the magnitude of winter flows is much lower than natural and the magnitude and frequency of high flows and freshes has reduced (Cottingham *et al.* 2003).

Upgrades to the Shepparton Irrigation Area and the Central Goulburn 1-4 Irrigation Area are not part of NVIRP and therefore reduced outfalls from those areas are not considered as part of the current assessment.

4.1. Environmental values

4.1.1. Vegetation

The Goulburn-Broken Catchment supports 188 native plant species that depend on aquatic environments and 39 of these are considered threatened and listed under the Flora and Fauna Guarantee Act 1988 (see Cottingham et al. 2003). Ecological Associates (2009) conducted a more recent desktop assessment of flora listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 that are likely to occur in the GMID. They identified four EPBC listed plant species that were likely to occur either on the banks of the Goulburn River or in swamps and wetlands on the adjacent floodplain (Table 4-1).

The four EPBC listed species are generally associated with permanently inundated or permanently damp habitats, but they can tolerate periodic drying (Ecological Associates 2009). Cottingham *et* *al*. (2003) also reported that most of the plant species considered threatened at state and regional levels in the Goulburn and Broken River catchments are riparian or amphibious species that can tolerate a range of wetting and drying regimes. However, they did observed that the Goulburn River channel itself had a relatively simple morphology with few shallow backwaters or other microhabitats that are likely to support diverse or abundant macrophyte communities (Cottingham *et al*. 2003).

- **Table 4-1: List of EPBC listed plant species likely to occur in the Goulburn River downstream of Lake Eildon or on the adjacent floodplain (adapted from Ecological Associates 2009).**

Species name	Common name	EPBC status	Habitat description
Amphibromus fluitans	River Swamp Wallaby-grass	Vulnerable	Requires periodic flooding of its habitat to maintain wet conditions. Mostly found at margins of permanent swamps
Brachyscome muelleroides	Mueller Daisy	Vulnerable	Damp areas at the margins of claypans or lagoons
Callitriche cyclocarpa	Western Water-starwort	Vulnerable	Aquatic of amphibious plant occurs on river banks
Myriophyllum porcatum	Ridged Water-milfoil	Vulnerable	Annual aquatic herb found in shallow, temporary wetlands

4.1.2. Fish

The Goulburn River between Lake Eildon and Goulburn Weir supports 10 species of native fish. Four of those species are listed under the Flora and Fauna Guarantee Act and two are listed under the Environment Protection Biodiversity and Conservation Act (Table 4-2). The reach would have historically supported a more diverse and more abundant fish community, but these have declined due to cold water releases from Lake Eildon, higher than natural summer flows and the migration barrier at Goulburn Weir. Anabranches and billabongs between Alexandra and Goulburn Weir provide important habitat for wetland specialist species such as Flat-headed Galaxias, Western Carp Gudgeon and Freshwater Catfish (Cottingham *et al*. 2003).

The Goulburn River downstream of Goulburn Weir supports a diverse native fish community comprising 11 native species (Cottingham *et al* 2003), including six species listed under the FFG Act and three species listed under the EPBC Act (Table 4-2). The reach immediately downstream of Goulburn Weir supports a particularly important population of Trout Cod, but it is doubtful whether Macquarie Perch still occur in that reach (King and Tonkin 2009).

▪ **Table 4-2: Summary of native fish likely to occur in the Goulburn River and associated floodplain wetlands (adapted from Cottingham *et al.* 2003)**

Scientific name	Common name	Reach	group	FFG status	EPBC status
Bidyanus bidyanus	Silver Perch	Both	Flood spec	CEn	
Craterocephalus fluviatilis	Murray Hardyhead	US	Wetland spec	End	Vul
Galaxias rostratus	Flat-headed Galaxias	Both	Wetland spec		
Hypseleotris klunzingeri	Western Carp-gudgeon	Both	Wetland spec		
Maccullochella macquariensis	Trout Cod	DS	Main channel	CEn	End
Maccullochella peelii peelii	Murray Cod	Both	Main channel	Vul	Vul
Macquaria ambigua	Golden Perch	Both	Flood spec		
Macquaria australasica *	Macquarie Perch	DS		End	End
Melanotaenia fluviatilis	Murray Rainbowfish	DS	Generalist	DD	
Nannoperca australis	Southern Pygmy Perch	US	Generalist		
Philypnodon grandiceps	Flat-headed Gudgeon	Both	Generalist		
Retropinna semoni	Australian Smelt	Both	Generalist		
Tandanus tandanus	Freshwater Catfish	Both	Wetland spec	Vul	

Status abbreviations CEn = Critically Endangered, DD = Data Deficient, End = Endangered, Vul = Vulnerable

Reach abbreviations US = Goulburn River between Lake Eildon and Goulburn Weir, DS = Goulburn River downstream of Goulburn Weir.

* Not likely to occur in the GMID area any more.

4.1.3. Other biota

Brett Lane and Associates (2010) identified 75 bird, mammal, reptile, amphibian and invertebrate species of national environmental significance that are dependent on aquatic ecosystems in the GMID. Only 21 of those species were considered likely to be affected by NVIRP. They included 20 bird species and the Growling Grass Frog, which although it has not been specifically recorded in the GMID could occur due to the presence of suitable habitat (BL&A 2010). Most of the bird species likely to be affected by NVIRP rely on wetland habitats and none of them have been specifically linked to the Goulburn River or wetlands that have direct connections to the Goulburn River. Four of the birds rely on floodplain forests for some part of their lifecycle (Table 3-5). Of those, only the White-Breasted Sea Eagle has been recorded at sites near the Goulburn River (BL&A 2010).

4.2. Hydrology

The PER (NVIRP, 2010) provided a comparison of the difference in flow magnitude (ML/day) and water level (mm) between pre- and post-NVIRP using flow and level date from a number of gauge locations on the Goulburn River during supplying and storing or spilling mode periods for two representative years (an average year- 2000/01 and a dry year- 2005/06). That information is summarised by river reach in the following section and is used to inform the assessment of potential effect that NVIRP will have on environmental values in the Goulburn River. Furthermore, comments are made regarding the likely impacts of climate change on river flows and changes in the nature of wetland water regimes

4.2.1. Goulburn River upstream of Goulburn Weir

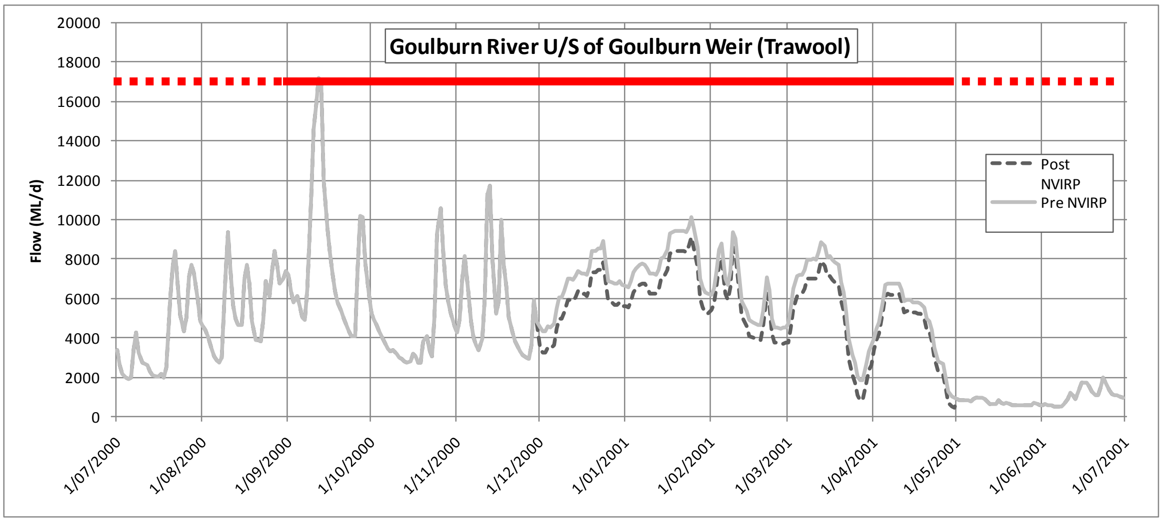
Figure 4-1 to Figure 4-4 show the change in river flow and level due to NVIRP for the Goulburn River upstream of Goulburn Weir (at the Trawool gauging station), while Table 4-3 summarises the maximum and average difference in water level over the supplying and storing or spilling mode periods.

During an average flow year (represented by 2000/01 flow and water level data at the Trawool gauge) the average water depth in the channel during the supplying period is approximately 1.42 m. NVIRP is expected to reduce the average water level at this location by approximately 67 mm in the supply period (equivalent to a 5% reduction in water depth). During a dry flow year (represented by 2005/06 flow and water level data at the Trawool gauge) the average water depth in the channel during the supply period is 1.57 m. NVIRP is expected to reduce the average water level at this location by approximately 57 mm in the supply period (equivalent to a 3.6% reduction in water depth). These reductions mean that summer flows in the Goulburn River between Eildon Dam and Goulburn Weir, will be closer to the flows that would have naturally occurred and that recommended in environmental flow studies (Cottingham *et al*. 2003), but the magnitude of the change is very small and the flows will still be significantly higher than natural during the irrigation supplying period. This is not expected to affect hydrological connectivity with the wetlands (SKM 2009a).

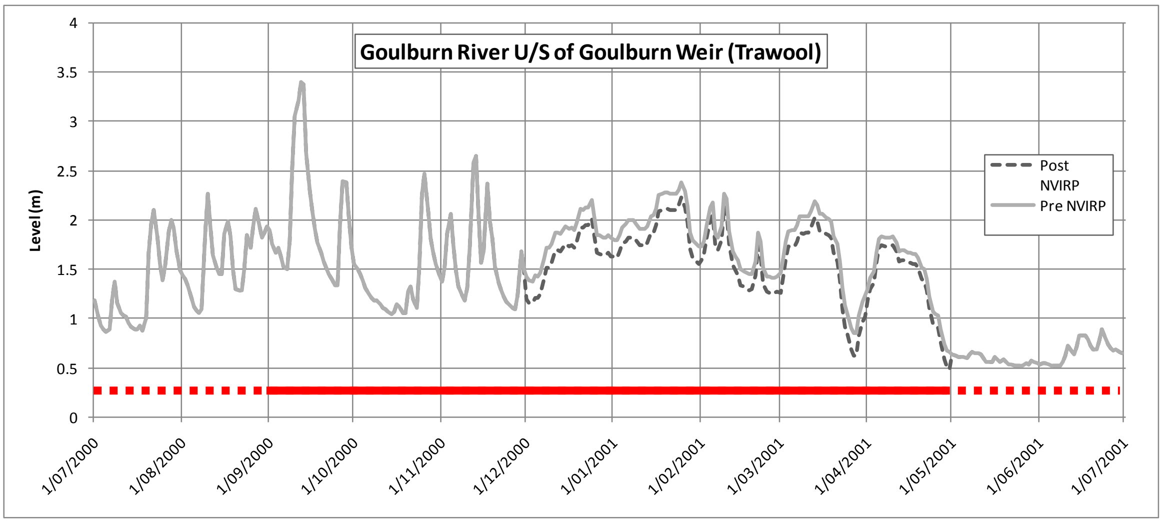
NVIRP is not expected to have any effect on flow in the Goulburn River between Eildon Dam and Goulburn Weir during the irrigation storing or spilling mode period (i.e. during winter and spring).

- **Table 4-3: Comparison of difference in water level (mm) between pre and post NVIRP for the Goulburn River upstream of Goulburn Weir.**

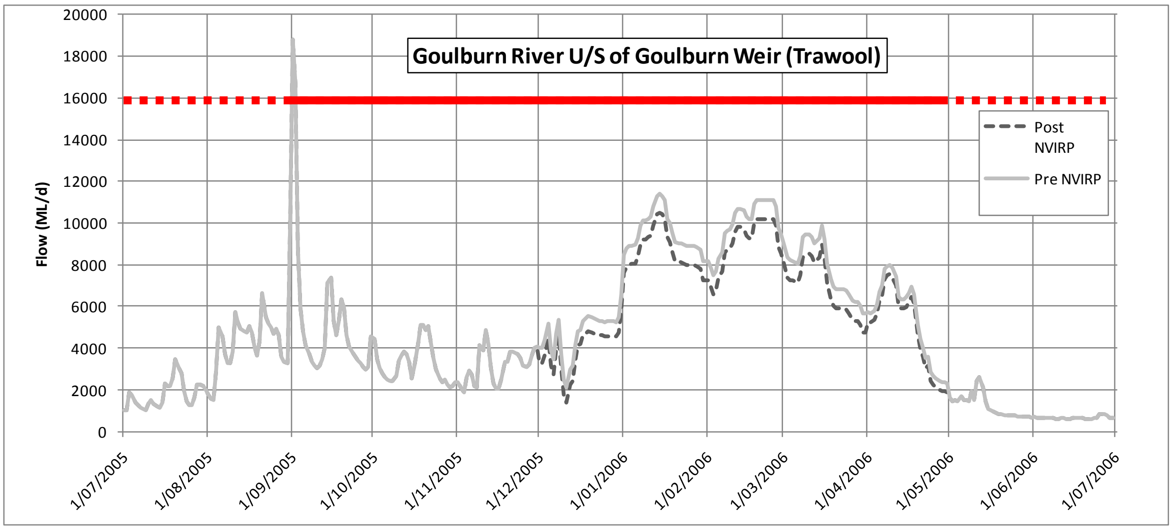
River Channel Site	Year	Level Difference (mm)			
		Storing or Spilling Mode Period		Supplying Mode Period	
		Maximum	Average	Maximum	Average
Goulburn River upstream of Goulburn Weir	Average (2000/01)	0	0	-234	-67
	Dry (2005/06)	0	0	-171	-57



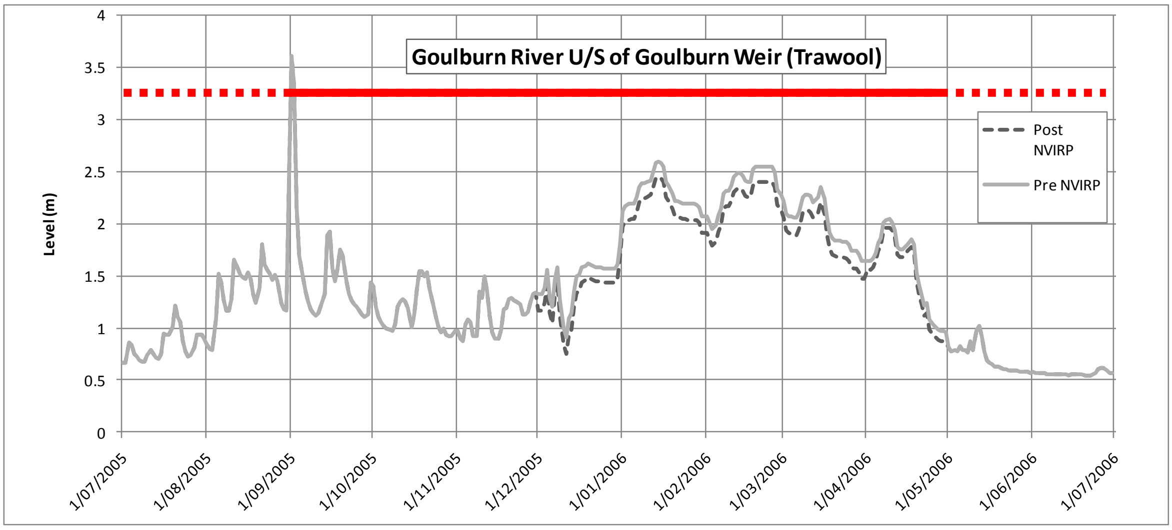
- **Figure 4-1 Difference in flow (ML/d) between pre and post NVIRP at Trawool gauging station (405201) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-2 Difference in water level (m) between pre and post NVIRP at Trawool gauging station (405201) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-3 Difference in flow (ML/d) between pre and post NVIRP at Trawool gauging station (405201) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-4 Difference in water level (m) between pre and post NVIRP at Trawool gauging station (405201) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

4.2.2. Goulburn River between Goulburn Weir and McCoys Bridge

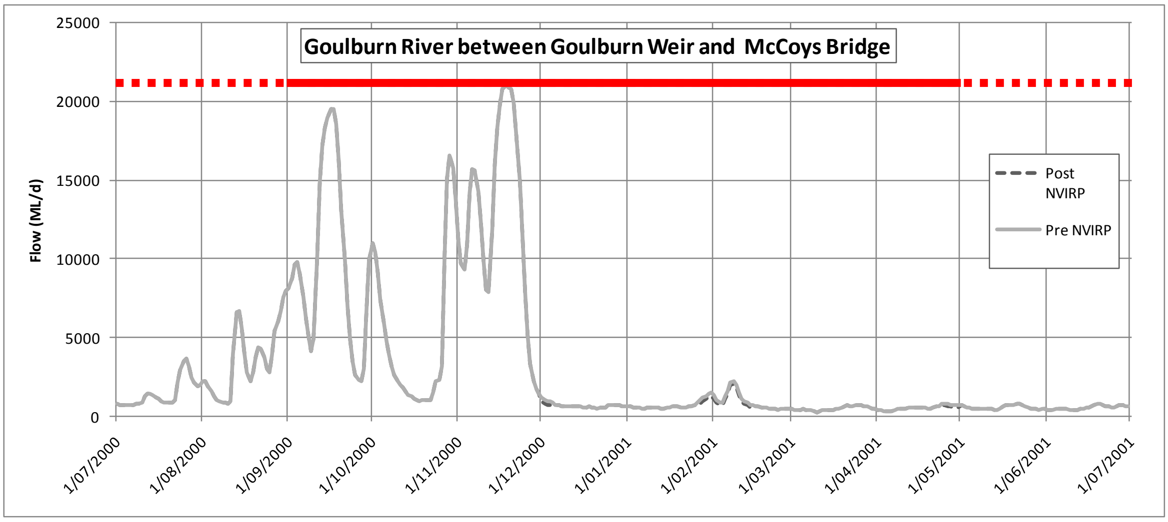
Figure 4-5 to Figure 4-8 show the change in river flow and level due to NVIRP for the Goulburn River between Goulburn Weir and McCoys Bridge (at McCoys Bridge gauging station), while Table 4-4 summarises the maximum and average difference in water level over the supplying and storing or spilling mode periods.

NVIRP is expected to reduce flow and level in the Goulburn River between Goulburn Weir and McCoys Bridge during the irrigation supplying period (i.e. summer and autumn due to water savings). During an average flow year (e.g. 2000/01), NVIRP is expected to reduce the average water level in this reach by approximately 10 mm, which represents a less than 1% reduction from the pre-NVIRP average level of 1.31 m. During a dry flow year (e.g. 2005/06), NVIRP is expected to reduce the average water level by 31 mm, which represents a 2% reduction compared to pre-NVIRP levels of 1.57 m.

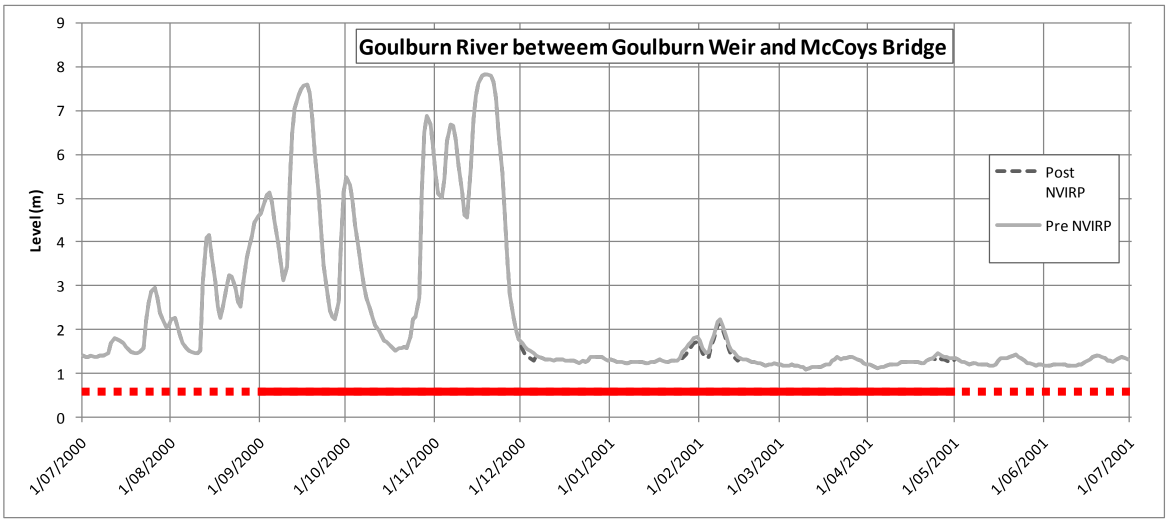
NVIRP is not expected to have any effect on flow in the Goulburn River between Goulburn Weir and McCoys Bridge during the irrigation storing or spilling mode period (i.e. during winter and spring).

- **Table 4-4: Comparison of difference in water level (mm) between pre and post NVIRP for the Goulburn River between Goulburn Weir and McCoys Bridge.**

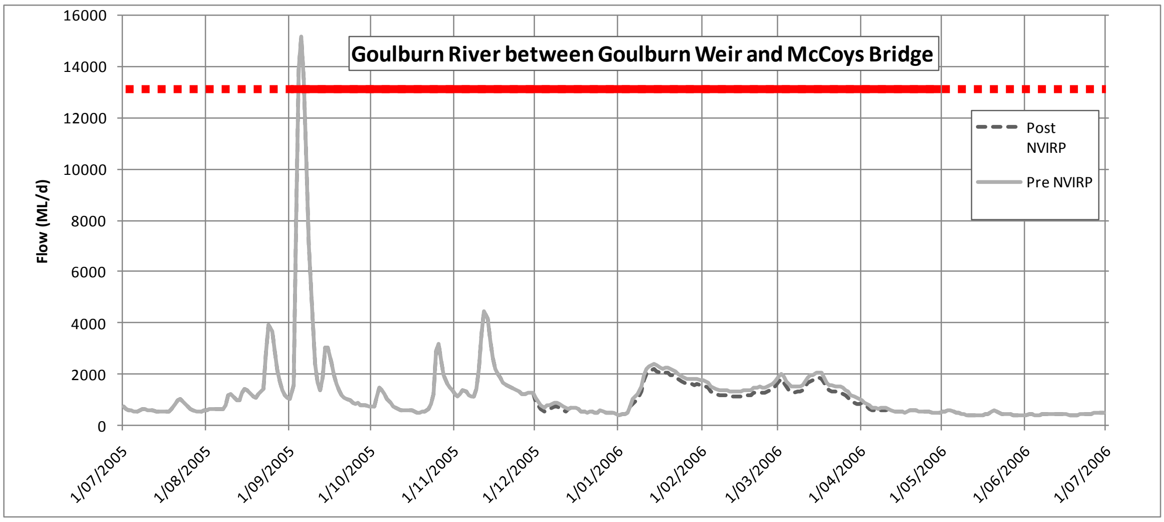
River Channel Site	Year	Level Difference (mm)			
		Storing or Spilling Mode Period		Supplying Mode Period	
		Maximum	Average	Maximum	Average
Goulburn River between Goulburn Weir and McCoys Bridge	Average (2000/01)	0	0	-162	-10
	Dry (2005/06)	0	0	-134	-31



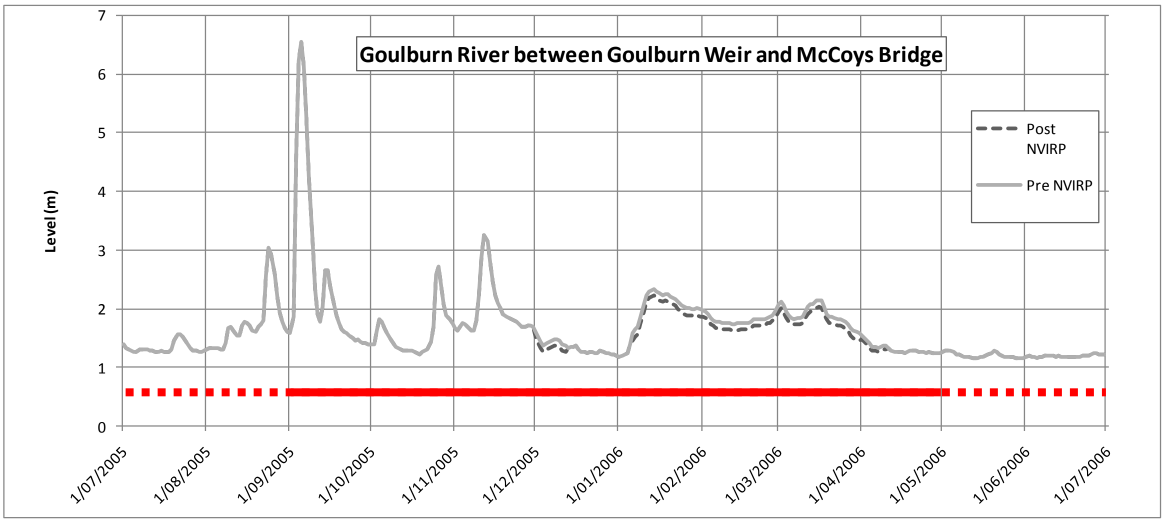
- **Figure 4-5 Difference in flow (ML/d) between pre and post NVIRP for the Goulburn River between Goulburn Weir and McCoys Bridge during an average year (2000/01) Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-6 Difference in level (m) between pre and post NVIRP for the Goulburn River between Goulburn Weir and McCoys Bridge during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-7 Difference in flow (ML/d) between pre and post NVIRP between Goulburn Weir and McCoys Bridge during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-8 Difference in level (m) between pre and post NVIRP between Goulburn Weir and McCoys Bridge during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

4.2.3. Goulburn River downstream of McCoys Bridge

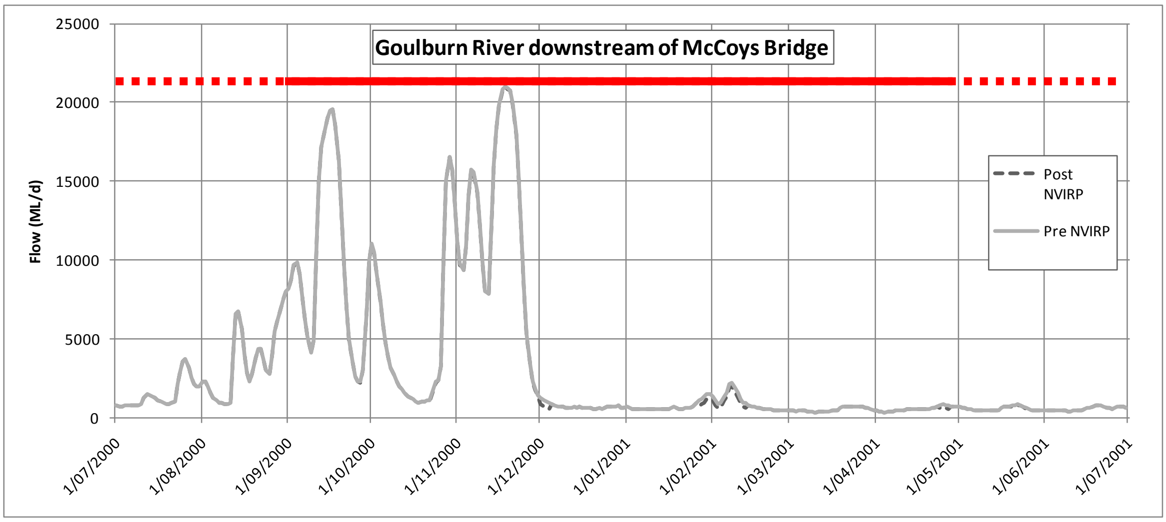
Figure 4-9 to Figure 4-12 show the change in river flow and level due to NVIRP for the Goulburn River downstream of McCoys Bridge (at the McCoy's Bridge gauging station), while Table 4-5 summarises the maximum and average difference in water level over the supplying and storing or spilling mode periods.

During an average flow year (represented by 2000/01 flow and water level data at the McCoy's Bridge gauging station) the average water depth in the channel during the supplying period is approximately 1.31 m. NVIRP is expected to reduce the average water level at this location by approximately 12 mm in the supply period (equivalent to a 1% reduction in water depth). During a dry flow year (represented by 2005/06 flow and water level data at the McCoy's Bridge gauge) the average water depth in the channel during the supply period is 1.56 m. NVIRP is expected to reduce the average water level at this location by approximately 45 mm in the supplying period (equivalent to a 3% reduction in water depth). The reduction in flow and hence river levels over the supplying period (summer and autumn) are due to the back-trade (reduction) of inter-valley transfers that will be held in storage from savings on the River Murray, and a reduction in outfalls to the river. In the reach downstream of McCoy's Bridge these outfalls are not compensated for (i.e. by increased releases from upstream) as it is below the final flow (bulk entitlement) compliance point for the Goulburn River.

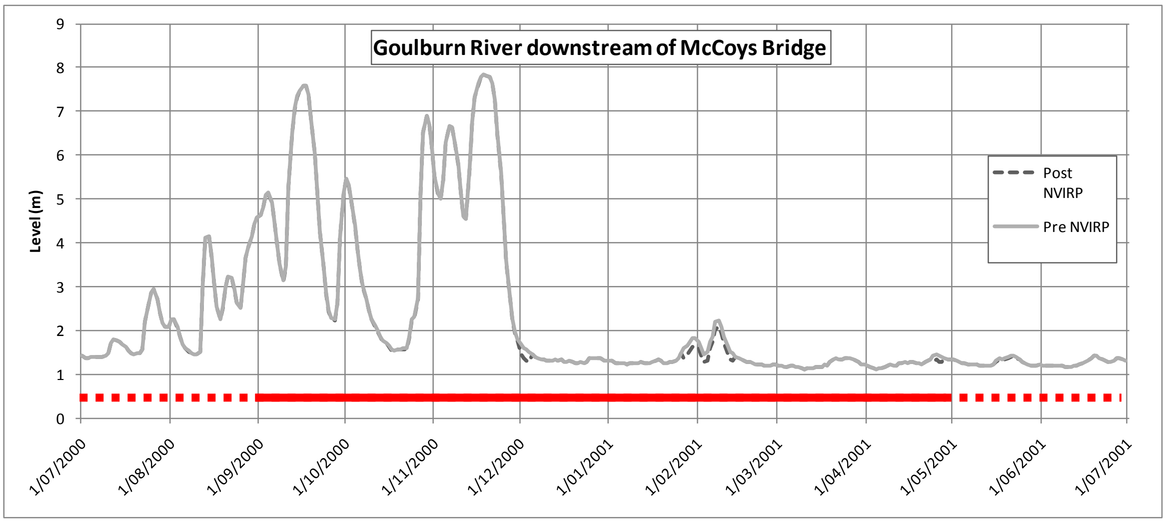
In contrast to upstream reaches, NVIRP is predicted to also result in a reduction in river level during the storing or spilling mode period (winter and spring). This is because the storing and spilling period overlaps slightly with the main irrigation season and therefore some channel outfalls do occur during that period. NVIRP is likely to reduce the magnitude of those channel outfalls and therefore is expected to reduce flows in the Goulburn River downstream of McCoys Bridge for part of the storing and spilling period. That effect is expected to be relatively small and during both average and dry years, the average water level is estimated to drop by only 3 mm (Table 4-5).

- **Table 4-5: Comparison of difference in water level (mm) between pre and post NVIRP for the Goulburn River downstream of McCoys Bridge.**

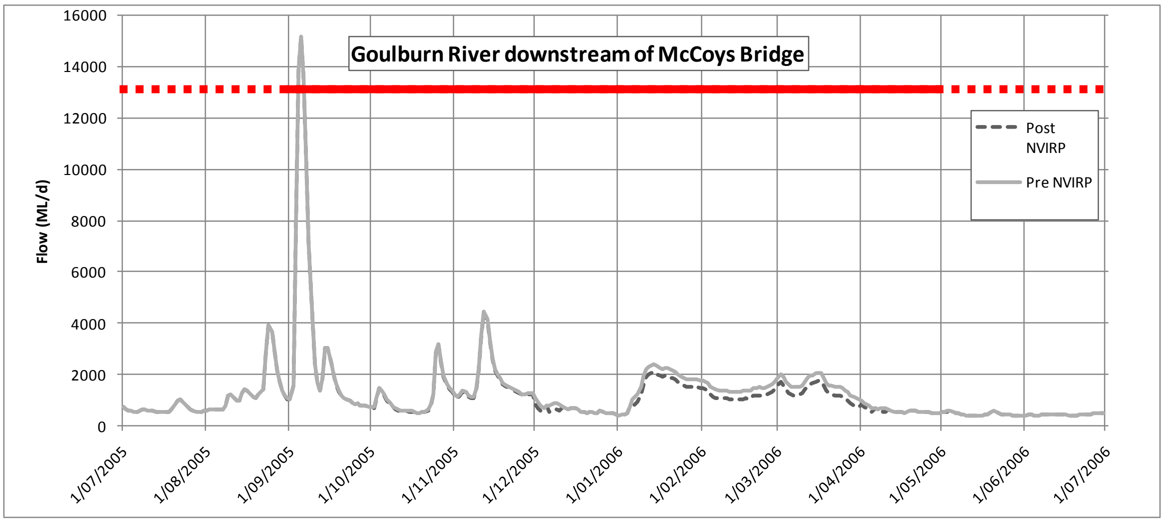
River Channel Site	Year	Level Difference (mm)			
		Storing or Spilling Mode Period		Supplying Mode Period	
		Maximum	Average	Maximum	Average
Goulburn River downstream of McCoys Bridge	Average (2000/01)	-24	-3	-243	-12
	Dry (2005/06)	-23	-3	-204	-45



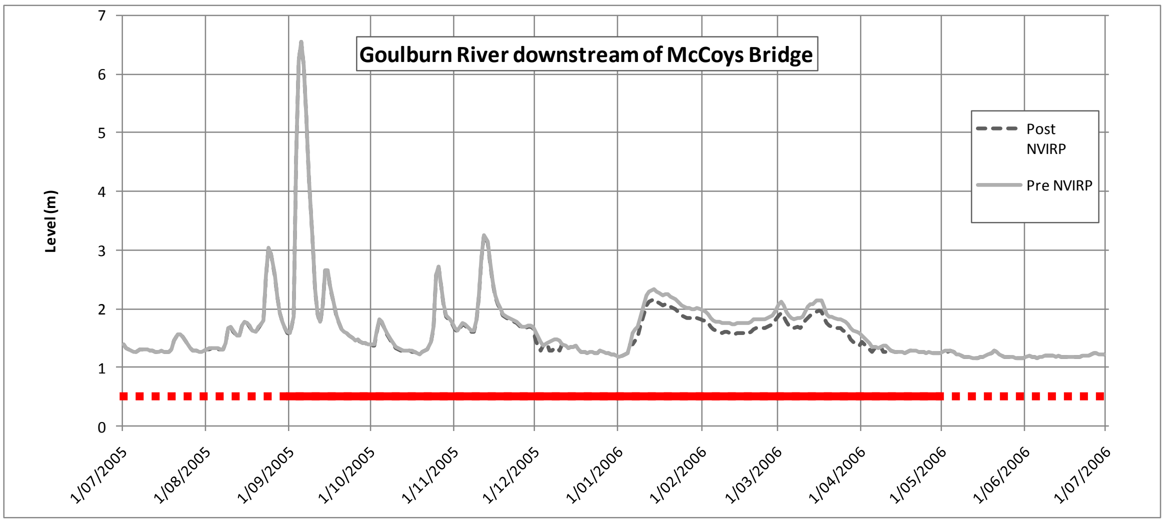
- **Figure 4-9 Difference in flow (ML/d) between pre and post NVIRP for the Goulburn River downstream of McCoys Bridge during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-10 Difference in level (m) between pre and post NVIRP for the Goulburn River downstream of McCoys Bridge during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-11 Difference in flow (ML/d) between pre and post NVIRP downstream of McCoys Bridge during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 4-12 Difference in level (m) between pre and post NVIRP downstream of McCoys Bridge during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

4.2.4. Climate change impacts

Climate change is expected to have a significant impact on river flows and on the frequency and duration of wetland inundation events (Jones and Durack 2005, DSE 2008). Dry flow conditions used in the modelling are analogous to conditions expected under a climate change future.

For the Goulburn River under both average and dry flow conditions NVIRP is predicted to result in only a very small change in river flow and level during the supplying period and in general no change during the spilling and storing period. Furthermore, NVIRP is predicted to not result in a change in the frequency or duration of wetland inundation events, even under dry flow conditions Hence the additional impact of NVIRP on river flows over and above that predicted due to climate change is considered insignificant.

4.3. Groundwater hydrology

One of the aims of NVIRP is to reduce channel seepage and bank leakage. Upgrades to irrigation infrastructure are expected to reduce recharge to the groundwater system, and as a result regional water tables in the shallow groundwater system (the Shepparton Formation) will fall (NVIRP 2010).

Chapter 8 assesses NVIRP's impacts on groundwater levels in light of recent observed increases in groundwater levels.

4.3.1. Predicted regional water table changes

In the documentation prepared for the PER, changes in regional water table levels were estimated by two methods: an Analytical Spreadsheet Model (ASM) and the Southern Riverine Plains Model (SRPM) (NVIRP 2010).Table 4-6 summarises these reductions for areas west of the Terrick Terrick Hills and

Table 4-7 summarises the changes for areas east of Terrick Terrick Hills. (Although not relevant to the Goulburn River, information about the GMID west of Terrick Terrick Hills is included here for completeness). Predicted watertable depth changes due to NVIRP across the region are also presented graphically in Figure 3-24.

- **Table 4-6 Predicted Water table Drops in GMID West of Terrick Terrick Hills**

Location	High Water-table?	Shepp Formation Pumping?	Deep Aquifer Pumping?	Area	Water table Drop (ASM)	Water table Drop (SRPM)
Pyramid-Boort	Yes	No	No	259,000 ha	0.9 – 1.2 m	Generally less than 1 m
Barr Creek	Yes	No	No	65,000 ha	0.02 m	Less than 0.5 m
Kerang Lakes	Yes	No	No	40,000 ha	n/a	From 0.2 to 1.3 m

- **Table 4-7 Predicted Water table Drops in GMID East of Terrick Terrick Hills (2005/06 case)**

Location	High Water-table?	Shepp Formation Pumping?	Deep Aquifer Pumping?	Area	Water table Drop (ASM)	Water table Drop (SRPM)
M. Valley	Yes	Yes	Yes	17,300 ha	0.40 m	From less than 1 to greater than 5 m
M. Valley	No	Yes	Yes	37,150 ha	0.70 m	
M. Valley	No	No	Yes	73,550 ha	Method n/a	
CG 5-9	Yes	Yes	No	56,000 ha	0.2 m	From less than 1 to about 3 m
CG 5-9	Yes	No	No	76,300 ha	0.4 m	
CG 5-9	No	No	No	42,700 ha	0.9 m	
Rochester	Yes	Yes	Yes	19,000 ha	0.4 m	From less than 1 to about 3 m
Rochester	Yes	No	Yes	14,900 ha	0.5 m	
Rochester	No	No	Yes	34,100 ha	Method n/a	
Rochester	Yes	Yes	No	7,500 ha	0.4 m	
Rochester	Yes	No	No	6,000 ha	0.5 m	
Rochester	No	No	No	500 ha	1.2 m	
Shepp IA – nth.	Minor	Minor	Minor	65,000 ha	0.9 m	< 1 m
Shepp IA – sth.	Minor	Minor	Minor	16,000 ha	0.3 m	
CG 1-4 – nth.	Minor	Minor	Minor	12,000 ha	0.9 m	
CG 1-4 – sth.	Minor	Minor	Minor	15,000 ha	0.3 m	

Decreases in the depth to water table predicted with the SRPM and ASM were of similar orders of magnitude, although the decreases predicted by the ASM were generally smaller. The PER used the SRPM results because they:

1) Covered all of GMID whereas the ASM could not cover certain fringe areas, and did not cover the Kerang Lakes area;

2) Provide results for beneath the Barmah and Gunbower forests and represent the variability better across the irrigation areas; and

3) Produce hydrographs that show variation from year to year.

ASM results are still used to estimate reductions in salt loads carried by groundwater towards the major rivers in the GMID and the Barmah and Gunbower Forests.

Water table levels are affected by many factors other than irrigation. A comparison between water table levels in 1991/92 (a wet period prior to the drought) and 2005/06 (during the recent drought) was used to coarsely estimate changes due to the drought. The conditions observed during 2005/06 are likely to provide an indication of the water table levels that could be expected under the drier climatic conditions that are predicted to occur in the future (CSIRO 2008). Compared to the effect of climatic influences on the water table depth, such as drought and climate change, the changes due to NVIRP are relatively modest (Table 4-8). Other factors, such as groundwater pumping that decreases depth to water table, and irrigation intensity that increases the depth to water table, can also cause significant changes irrespective of NVIRP.

- **Table 4-8 Predicted changes to water table depth with NVIRP compared with inter-annual variability due to factors such as drought/climate change (SKM 2008b)**

Area	Depth to water table 1991/92	Depth to water table 2005/06	Depth to water table 2005/06 with NVIRP
Murray Valley	1.49 m	4.05 m	4.53 m
Central Goulburn (5-9)	0.75 m	1.73 m	1.85 m
Rochester	1.03 m	1.56 m	1.71 m

4.3.2. Groundwater effects on rivers and Ramsar floodplain wetlands

The PER (NVIRP 2010) considered four groundwater related processes:

- Groundwater flow and salt load towards rivers;
- Actual depths to water-table beneath the Barmah and Gunbower Forests post-modernisation;
- Irrigation-related water-table changes beneath the fringes of the Barmah and Gunbower Forests; and,
- Potential for fresh groundwater to be drained from the Barmah and Gunbower Forests.

However, for this assessment for the Goulburn River, only information of groundwater flow and salt load toward rivers is discussed in the following sections. Information about Barmah and Gunbower Forests is discussed elsewhere in this report.

4.3.2.1. Groundwater flow and salt load toward rivers and forests

NVIRP works are expected to lead to reduced groundwater levels and hence reductions in groundwater discharge to rivers. Table 4-9 presents the calculated pre- and post- NVIRP groundwater volumes moving towards the River Murray, Goulburn River, Broken Creek, Campaspe River and the Barmah and Gunbower Forests. This impact is very small in terms of flow in the major rivers, but may be significant for Broken Creek and Campaspe River during low flow periods (Table 4-9). Also, it is believed that the pre-and post-NVIRP groundwater volumes, although flowing towards the rivers, are to some extent evaporated within the floodplain (Table 4-9).

- **Table 4-9 Reductions in Groundwater Volumes Flowing Towards Rivers (IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn; NV = NVIRP)**

Asset	Present Head	Head Drop	Factor[(a)]	Vol to River ML/yr		Indicative Difference (ML/yr)
				Pre-NV	Post-NV	
River Murray u/s Barmah Forest	2.5 m	0.40 m	0.84	2,000	1,680	-320
Barmah Forest north of MVIA	12.5 m	0.40 m	0.97	6,773	6,570	-203
Broken Creek – MVIA Bank	2.0 m	0.4 m	0.80	1,883	1,506	-377
Broken Creek – Shepp IA Bank	0.0 m	0.0 m	n/a	0	0	0
Broken River within Shepp IA	2.0 m	0.6 m	0.70	800	560	-240
Goulburn R. b/w Shepp & CGIAs. CG side.	2.6 m	0.24 m	0.91	1,548	1,409	-139
Goulb R. b/w Shepp & CGIAs. Shepp side	0.0 m	0.0 m	n/a	0	0	0
Goulburn River north of CGIA	9.3 m	0.24 m	0.97	6,000	5,820	-180
River Murray north of Rochester IA	1.1 m	0.37 m	0.66	323	213	-110
Campaspe River within Rochester IA	4.0 m	0.5 m	0.88	3,973	3,496	-477
Gunbower Forest north of Barr Catch.	4.0 m	0.02 m	0.995	1,716	1,707	-9
Total				**25,016**	**22,961**	**-2,055**

(a) This factor is (Present Head – Head Drop)/Present Head. It gives the ratio of Post- to Pre-NIVIRP.

Table 4-10 presents the salinities of the groundwater flowing from the irrigation areas towards the major rivers and the floodplain forests in the region, and calculates the corresponding reduction in groundwater-borne salt load. NVIRP is expected to reduce the total salt load flowing towards rivers and floodplain forests by 6 105 tonnes per year. Any reduction in the lateral movement of salt towards the rivers and floodplain forests is likely to be beneficial, because the receiving waterways support high environmental values that may be sensitive to high salinity. However, the overall effect of NVIRP on salt loads is relatively small and represents only a 5% reduction in total annual groundwater salt contributions to these environments. Salt load movements are only understood at a general level and therefore the effect that NVIRP will have at individual sites cannot be determined reliably.

- **Table 4-10 Reductions in Groundwater-borne Salt Load Moving Towards Rivers (IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn; NV = NVIRP)**

Asset	G'water Salinity (mg/L)	Vol to River (ML/yr)		Salt load to river (t/yr)		Indicative Reduct'n (t/yr)
		Pre-NV	Post-NV	Pre-NV	Post-NV	
River Murray u/s Barmah Forest	900	2,000	1,680	1,800	1,512	288
Barmah Forest north of MVIA	200	6,773	6,570	1,355	1,315	40
Broken Creek – MVIA Bank	1,000	1,883	1,506	1,883	1,506	377
Broken Creek – Shepp IA Bank	2,000	0	0	0	0	0
Broken River within Shepp IA	2,000	800	560	1,600	1,120	480
Goulburn R. b/w Shepp & CGIAs. CG side.	2,000	1,548	1,409	3,095	2,820	275
Goulburn River b/w Shepp & CGIAs. Shepp side	2,000	0	0	0	0	0
Goulburn River north of CGIA	8,500	6,000	5,820	51,000	49,470	1,530
River Murray north of Rochester IA	5,000	323	213	1,615	1,065	550
Campaspe River within Rochester IA	5000	3,973	3,496	19,865	17,480	2,385
Gunbower Forest north of Barr Ck catchment.	20,000	1,716	1,707	34,320	34,140	180
Total		**25,016**	**22,961**	**116,533**	**110,428**	**6,105**

4.3.3. River Salinity

Monthly salinity data was used to undertake an assessment of the effect of NVIRP on the salinities in the River Murray and Goulburn River, as well as in the connected wetlands along the River Murray (including Ramsar sites) by SKM (2009b) as supporting data for the Public Environment Report (NVIRP 2010). In many cases, salinity data were available for threshold flows representing anabranch commence to flow. The assessment was done for an average climate scenario (based on rainfall conditions in 2000/2001) and a Dry (10%) climate scenario (based on 2005/2006 rainfalls) (SKM 2009b).

The results of those assessments indicated that NVIRP will decrease river salinities by up to 5 µS/cm, particularly in the River Murray downstream of Swan Hill during the supplying mode (SKM 2009b). Salinity in the Goulburn River at McCoys Bridge was also predicted to fall by up to 5 µS/cm during the supplying mode, but either remain unchanged or increase by up to 2 µS/cm during the storing/spilling mode (SKM 2009b). Overall these changes are very small in comparison with background salinity regimes (~ 200 µS/cm) and are not likely to have any effect on biota or other environmental values.

4.3.4. Groundwater summary

NVIRP is expected to reduce groundwater discharges to rivers across the whole GMID by approximately 19 ML/day. Such a reduction is too small to have a detectable effect on river flow or water level in the Goulburn River (NVIRP 2010). Salinity in the Goulburn River at McCoys Bridge was also predicted to fall by up to 5 µS/cm during the supplying mode, but either remain unchanged or increase by up to 2 µS/cm during the storing/spilling mode (NVIRP 2010). Overall these changes are very small in comparison with background salinity regimes (~ 200 µS/cm) and are not likely to have any effect on biota or other environmental values.

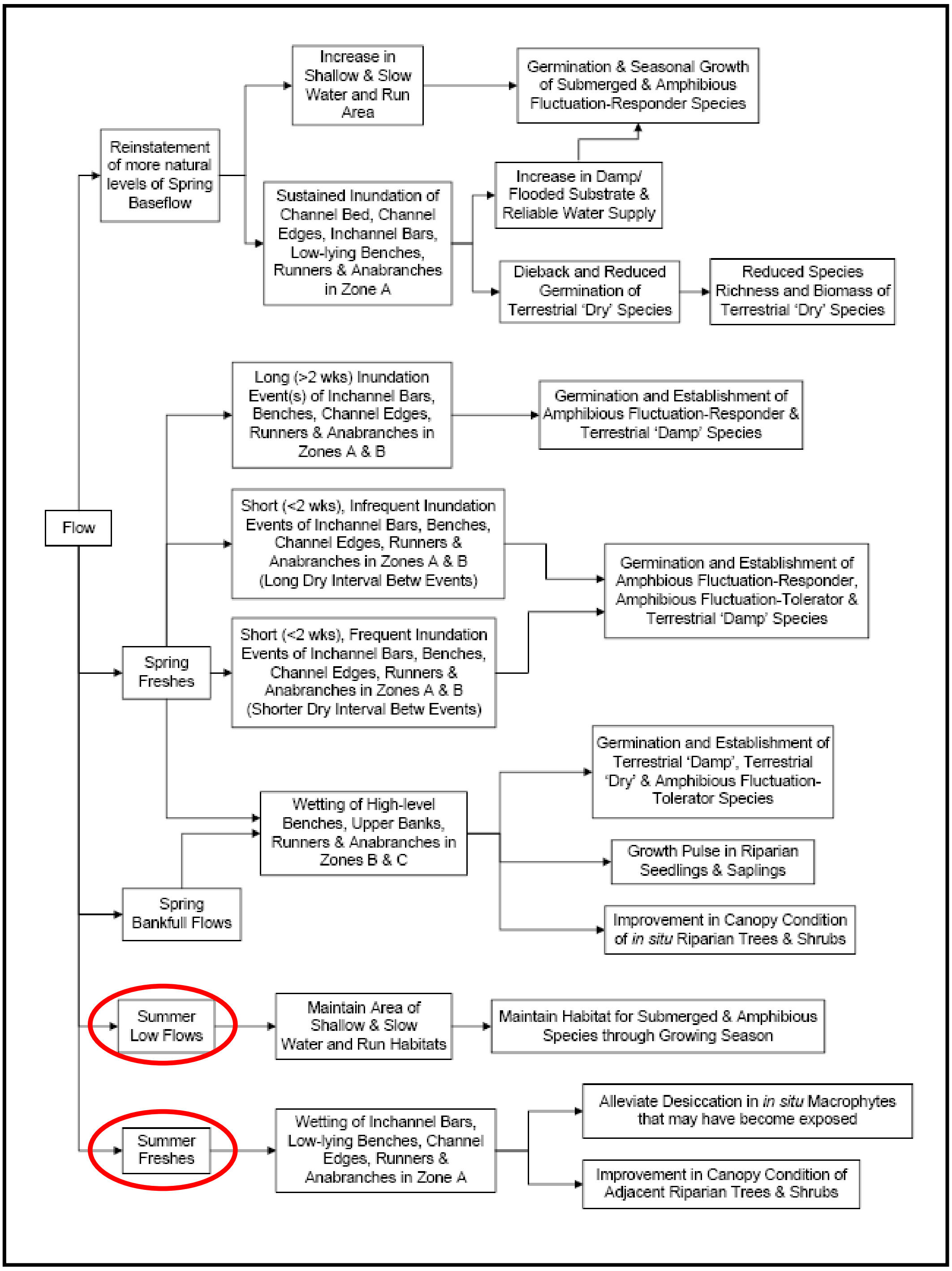
4.4. Effect of likely flow changes on environmental values

Hydrological changes in the Goulburn River as a result of NVIRP will not affect connection to floodplain wetlands (see Section 4.2). Therefore the assessment of likely impacts on environmental values must focus on the main channel. The only flow components in the main channel of the Goulburn River that are likely to be affected by NVIRP are low flows during the supply period (mainly summer and autumn) and to a lesser extent summer freshes. However, as shown in Section 4.2, the magnitude of changes to those flow components is likely to be relatively small. This section uses conceptual models presented in Appendix A to assess the likely effect that those changes will have on biological values.

4.4.1. Vegetation

Summer low flows are important for maintaining areas of shallow, slow flowing habitats and backwaters, which support submerged and amphibious species throughout the growing season (Figure 4-13). As Cottingham *et al.*(2003) described, the Goulburn River, particularly the reaches downstream of Goulburn Weir, have a relatively simple morphology and therefore the slight reductions in water level that are expected to occur as a result of NVIRP, are not likely to alter the quality or quantity of shallow habitats and backwaters. The Goulburn River channel between Eildon Dam and Goulburn Weir is more complex and water level changes in that reach are expected to be greater than in the reach downstream of Goulburn Weir. Changes to summer low flows in the Goulburn River upstream of Goulburn Weir are small and will move the flow regime closer to that which would have naturally occurred and to environmental flow recommendations (Cottingham *et al* 2003). Supply flows currently drown out many shallow water habitats and therefore a return to more natural summer flow levels should increase the abundance and quality of those habitat types and improve conditions for submerged and amphibious plants. In reality, the size of the expected changes are too small to have a significant effect on shallow habitats and so while, the changes are in the right direction, they are not expected to affect the condition or distribution of native plants.

Summer freshes are important for watering macrophytes that may otherwise dry out during periods of prolonged low flow and for watering plants on low channel benches (Figure 4-13). Although NVIRP may reduce the magnitude and frequency of some summer freshes in the Goulburn River, the magnitude of those changes is expected to be very small. Therefore, NVIRP is not expected to affect the condition or distribution of native plants that rely on summer freshes.



- **Figure 4-13: Conceptual model of detailed response of different Plant Functional Groups to altered water regime. (Source: Chee *et al.* 2006, page 29). Red ovals highlight flow components that are likely to be affected by NVIRP in the Goulburn River.**

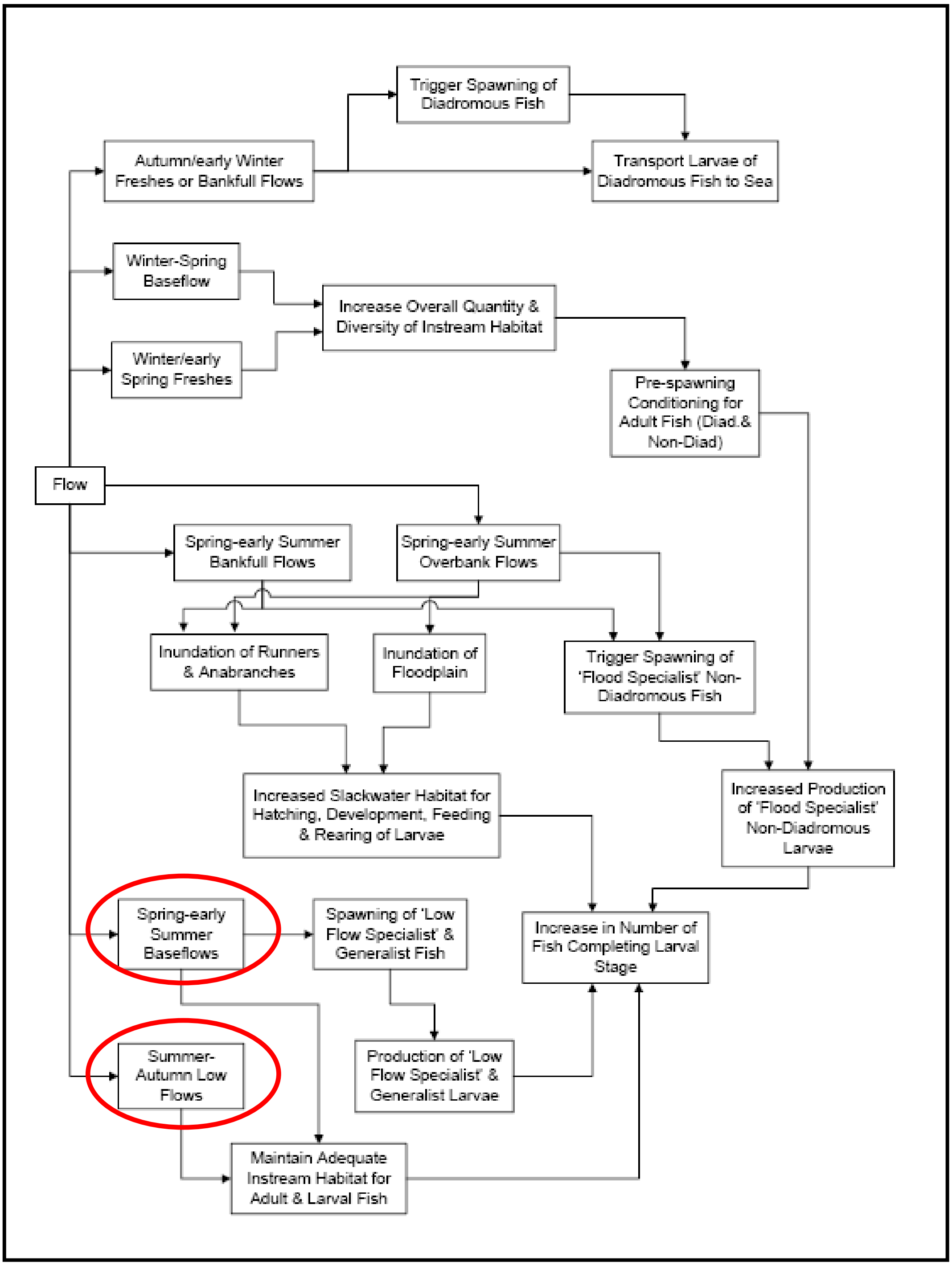
4.4.2. Fish

Flows maintained at a minimum level are important for maintaining the quality and quantity of habitat for all fish. In particular they help to maintain depth and water quality in deep pools that are used by large bodied fish such as Murray Cod (Figure 4-14). They are also important for maintaining shallow edge habitats and backwaters that are used by smaller fish and that provide nursery habitats for larvae and juveniles of some native species (Figure 4-14). Existing flows in the Goulburn River are adequate for maintaining deep pool habitats and the predicted flow reductions are not expected to have any effect on the quality or quantity of those pools. Changes in low flow are more likely to affect the extent and quality of shallow habitats and backwaters.

Flow reductions upstream of Goulburn Weir have the potential to increase the quality and quantity of shallow water habitats, but as described in the vegetation section the magnitude of flow reductions expected as a result of NVIRP is not likely to have a noticeable effect on those habitats or the fish that use them. Flow reductions in the reaches downstream of Goulburn Weir are not expected to be as large as for the upstream reaches and given the simple channel morphology, they are also not expected to affect fish habitats or fish populations.

The conceptual model that describes the relationship between native fish and flow in lowland rivers (Figure 4-14) does not specifically address the role of freshes. Such flows can be important in small or ephemeral streams because they may prevent pools from drying out and help to maintain water quality. These flows are less important to fish in larger rivers such as the Goulburn River. NVIRP is expected to have only a very small effect on the magnitude, timing and frequency of freshes in the Goulburn River and therefore is not likely to have any effect on native fish communities.

Salinity in the Goulburn River at McCoys Bridge was also predicted to fall by up to 5 µS/cm during the supplying mode, but either remain unchanged or increase by up to 2 µS/cm during the storing/spilling mode (SKM 2009b). Overall these changes are very small in comparison with background salinity regimes (~ 200 µS/cm) and are not likely to have any effect on biota or other environmental values.



- **Figure 4-14: Conceptual model for effect of flow on fish spawning and recruitment. (Source: Chee *et al.* 2006, page 34). Red ovals highlight the flow components that are likely to be affected by NVIRP in the Goulburn River.**

4.4.3. Other biota

All of the significant bird and frog species that have been recorded in the vicinity of the Goulburn River rely on floodplain wetlands or riparian forests. Such habitats are affected by the frequency and magnitude of high flows and floods that either fill the wetlands or water the riparian zone. Those habitats and the biota that use them are not likely to be affected at all by the small changes in low flows, freshes and salinity that are expected to occur in the Goulburn River as a result of NVIRP.

4.5. Conclusion

The Goulburn River between Eildon Dam and Goulburn Weir is used as an irrigation supply delivery system. Most of the irrigation water that is released from Eildon Reservoir is diverted at Goulburn Weir, while the rest is passed further downstream to supply demand in the River Murray. The existing operating system means that flows in the Goulburn River between Eildon Dam and Goulburn Weir are higher than natural during the irrigation season but are less than natural at other times. These high irrigation flows inundate many benches and riffles that would normally be exposed during summer and maintain water in some wetlands that are connected to the main river channel. Downstream of Goulburn Weir flow is maintained to meet passing flow and other environmental requirements, and also to supply demand in the River Murray system (through IVTs). The reach also receives outfall contributions from the Shepparton and Central Goulburn Irrigation areas. However, overall flow is lower than natural due to the large volume of upstream diversions, but still retains a natural seasonal pattern.

Despite the altered flow regime, the Goulburn River supports a wide diversity of habitat types and plant and animal species, including species of conservation significance at the national, state and regional levels. Between Eildon and Goulburn Weir the floodplain is 2-4 km wide and has more than 400 small billabongs and wetlands. Downstream of Goulburn Weir the river is unconfined and supports more than 1300 wetlands of varying size, including more than 200 wetlands greater than 26 ha. A significant native fish community is present in the Goulburn River, including the nationally threatened Trout Cod and possibly Macquarie Perch. Other species of conservation significance include Freshwater Catfish and Murray Cod.

Under NVIRP there will be a reduction in river levels during the irrigation supply period (summer and autumn) as a consequence of needing to release less water from upstream storages to supply diversions to irrigation. This is predicted to result in a reduction in river levels (up to 67 mm on average between Eildon and Goulburn Weir, up to 31 mm downstream of the Goulburn Weir and up to 45 mm downstream of McCoy’s Bridge). This is equivalent to a reduction in river level of up to 5% of channel depth between Eildon and Goulburn Weir and 1-2% of channel depth downstream of Goulburn Weir and McCoy’s Bridge. The predicted reduction in river levels mean that summer flows in the Goulburn River between Eildon Dam and Goulburn Weir will be closer to the flows that would have naturally occurred (and closer to the flows recommended in environmental flow studies), but the magnitude of the change is very small and the flows will still be significantly higher than natural during the irrigation supplying period. The reduction is not expected to affect hydrological connectivity with the wetlands. NVIRP is not expected to have any effect on flow during the irrigation storing or spilling mode period (i.e. during winter and spring) upstream or immediately downstream of Goulburn Weir, but may result in a small reduction in level (< 3mm) downstream of McCoy's Bridge due to a reduction in outfall contributions.

In addition to the minor impacts on water levels, NVIRP is expected to reduce groundwater discharges to rivers across the whole GMID by approximately 19 ML/day. Such a reduction is too small to have a detectable effect on river flow or water level in the Goulburn River. Salinity levels in the Goulburn River could decrease by up to 8 µS/cm, which is ecologically insignificant as the background salinity is around 200 to 300 µS/cm.

Compared to the effect of climatic influences on the water table depth, such as drought and climate change, the changes due to NVIRP are relatively modest (Table 4-8). Other factors, such as groundwater pumping that decreases depth to water table, and irrigation intensity that increases the depth to water table, can also cause significant changes irrespective of NVIRP.

Hydrological changes in the Goulburn River as a result of NVIRP under either current or climate change conditions will not affect connection to floodplain wetlands. The only flow components in the main channel of the Goulburn River that are likely to be affected by NVIRP are low flows during the supply period (mainly summer and autumn) and to a lesser extent summer freshes. However, the magnitude of changes to those flow components is likely to be relatively small and also in the direction of recommended environmental flows (in the Goulburn above Goulburn Weir). On the basis of conceptual models of ecological response to hydrological change it is considered that any hydrological changes are too small to affect the quality or quantity of any in-channel habitats used by fish or other aquatic biota. Hence, there is unlikely to be any impact on environmental values of national, state or regional conservation significance in the Goulburn River.

5. Hydrological changes to Barmah Forest Ramsar Site

The Barmah Forest Ramsar site is located on the River Murray floodplain downstream of Yarrawonga Weir. Together with the NSW Millewa Forest it forms the largest River Red Gum forest in Australia. The forest features a variety of permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forest (Hale 2009). These wetlands provide habitat for many environmental values including a large number of waterbird species. The Barmah Forest is not directly connected to the irrigation system. However it is indirectly connected via a number of creeks, particularly Tongalong Creek and the Tullah Creek, and irrigation drains.

Barmah Forest is adjacent to the project area and so could potentially be impacted by hydrological changes as a result of NVIRP operations. The potential impacts of NVIRP on the floodplain wetlands associated with the River Murray arise from two impact pathways (BL&A 2010). First, reduced lateral flow from rivers could decrease the frequency, extent and duration of floodplain inundation. Second, a reduction in irrigation water may cause salinity levels in the river to increase, which may in turn lead to higher salinity in floodplain forests, wetlands and creeks systems.

5.1. Environmental values

5.1.1. Vegetation

The Barmah Forest supports five vegetation categories (River Red Gum Forest, River Red Gum Woodland, Black Box Woodland, Moira Grass (Spiny Mudgrass) and Giant Rushland), which are distributed across the floodplain according to hydrological, soil and salinity gradients (SKM 2009c). Changes in flow regime and flooding have had a significant effect on the distribution of these vegetation categories throughout the Forest and future hydrological changes could affect current distribution patterns.

River Red Gum Forest and River Red Gum Woodland cover approximately 75% of the Barmah Forest site (DSE 2008). The understorey varies but includes areas of Moira Grass, Sedgelands and other grasslands. Moira Grass covers an area of over 4000 hectares; equating to 14% of the site at the time of listing (DSE 2008).

Ecological Associates (2009) identified 11 species of flora listed under the EPBC Act that are likely to occur in the GMID and are associated with periodically flooded or water logged habitats (Table 5-1). Most of these species could potentially occur in the Barmah Forest.

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- **Table 5-1 List of EPBC listed flora species which could potentially occur in the Barmah Forest (adapted from Ecological Associates 2009)**

Species name	Common name	EPBC status	Habitat Description
Amphibromus fluitans	River Swamp Wallabygrass	Vulnerable	Swamp margins in mud, dam and tank beds in hard clay and in semi-dry mud of lagoons. Requires periodic flooding of its habitat to maintain wet conditions.
Brachyscome muelleroides	Mueller Daisy	Vulnerable	Damp areas on the margins of claypans in moist grassland*;* margins of lagoons in mud or water, open positions on the River Murray floodplain and swampy River Red Gum Forest.
Callitriche cyclocarpa	Western Water-starwort	Vulnerable	In River Red Gum open woodland with an open grassy understorey dominated by Moira Grass along river banks, and with wallaby grasses on less-frequently inundated ground. Plains Grassy Wetland
Lepidium monoplocoides	Winged Peppercress	Endangered	Grasslands, wetlands, floodplain woodlands
Maireana cheelii	Chariot Wheels	Vulnerable	Seasonally wet, heavy red loam or clay soils that are prone to scalding. In shallow depressions, often on eroded or scalded surfaces.
Myriophyllum porcatum	Ridged Water-milfoil	Vulnerable	Shallow, temporary wetlands (including lakes, swamps, rock pools in granite outcrops, waterholes in claypans) and highly modified habitats (including farm dams and drainage lines on private land).
Pimelea spinescens subsp. *spinescens*	Spiny Rice-flower	Critically Endangered	Grassland or open shrubland on basalt-derived soils, usually comprising black or grey clays.
Sclerolaena napiformis	Turnip Copperburr	Endangered	Native grassland and Box / Bulloke woodland on fertile clay loam soils. Probably can tolerate water-logging in the spring and all remaining populations are located close to a water course or swamp.
Senecio behrianus	Stiff Groundsel	Endangered	Modified freshwater marsh.
Swainsona murrayans	Slender Darling-pea	Vulnerable	Grassland, herbland, and open Black-box woodland, on level plains, floodplains and depressions. In heavy grey or brown clay, loam, or red cracking clays.
Swainsona plagiotropis	Red Swainson-pea	Vulnerable	On red to brown clay loams and clay soils that are usually seasonally waterlogged.

5.1.2. Fish

The fish communities of Barmah Forest were once diverse and highly abundant, supporting a large commercial fishery and comprising an important food source for local Aboriginals (King 2005). Although catches of native fish have declined substantially and introduced species are common, Barmah Forest remains an important area for native fish as a nursery and feeding area when flooded (King 2005). The native and exotic fish species recorded at Barmah Forest from past surveys are listed in Table 5-2. The fish community comprises of 19 native species, including 9 species listed under the FFG Act and 4 species listed under the EPBC Act.

- **Table 5-2 Summary of native fish species likely to occur in the Barmah Forest floodplain wetlands (Adapted from McCarthy *et al.* 2006).**

Scientific name	Common name	EPBC Status	FFG Status
Maccullochella macquariensis	Trout Cod	Endangered	Listed
Maccullochella peeli peeli	Murray Cod	Vulnerable	Listed
Macquaria ambigua	Golden Perch		
Bidyanus bidyanus	Silver Perch		Listed
Melanotaenia fluviatilis	Crimson-spotted rainbowfish		Listed
Macquaria australasica	Macquarie Perch	Endangered	Listed
Tandanus tandanus	Freshwater Catfish		Listed
Hypseleotris spp.	Carp Gudgeons		
Retropinna semoni	Australian Smelt		
Philypnodon grandiceps	Flathead Gudgeon		
Craterocephalus stercusmuscarum fulvus	Unspecked Hardyhead		Listed
Craterocephalus fluviatilis	Murray Hardyhead	Vulnerable	Listed
Galaxia rostratus	Murray Jollytail		
Nannoperca australis	Southern Pygmy Perch		
Gadopsis marmoratus	River Blackfish		
Mordacia mordax	Shortheaded Lamprey		
Mogurnda adspersa	Southern Purple-spotted Gudgeon		Listed
Nematalosa erebi	Bony Herring		
Galaxias brevipinnis	Climbing Galaxias		

5.1.3. Birds

After flood periods, Barmah Forest is one of Victoria's largest waterfowl breeding areas. Eighteen species of colonial nesting waterbirds have been recorded in the area (Table 5-3). The site supports large breeding colonies of Sacred Ibis and Straw-necked Ibis, with smaller breeding colonies of the Intermediate Egret, Little Egret, Eastern Great Egret, and Yellow-billed Spoonbill (DSE 2003b).

Key breeding habitats for these species include Giant Rush and/or reed beds, emergent living River Red Gum and dead emergent River Red Gum. The Superb Parrot and White-bellied Sea Eagle which are both listed under the EPBC Act have also been recorded in the Barmah Forest.

- **Table 5-3 List of colonial waterbirds known to have bred in the Barmah Forest wetlands and potentially affected by NVIRP (modified from Leslie 2001)**

Scientific name	Common name	EPBC Status	FFG Status
Anhinga melanogaster	Darter		
Phalacrocorax melanoleucos	Little Pied Cormorant		
Phalacrocorax varius	Pied Cormorant	Lower Risk – near Threatened	
Phalacrocorax sulcirostris	Little Black Cormorant		
Phalacrocorax carbo	Great Cormorant		
Egretta garzetta	Little Egret		Listed
Ardea pacifica	White-necked Heron		
Ardea alba	Great Egret	Vulnerable, Migratory (JAMBA, CAMBA)	Listed
Ardea modesta	Eastern Great Egret	Vulnerable, Migratory (JAMBA, CAMBA)	Listed
Ardea intermedia	Intermediate Egret	Critically Endangered	Listed
Ardea ibis	Cattle Egret	Migratory (JAMBA, CAMBA)	
Nycticorax caledonicus	Nankeen Night Heron	Lower Risk – near Threatened	
Threskiornis molucca	Australian White Ibis		
Threskiornis spinicollis	Straw-necked Ibis		
Platalea regia	Royal Spoonbill	Vulnerable	
Platalea flavipes	Yellow-billed Spoonbill		
Chlidonias hybridus	Whiskered Tern	Lower Risk – near Threatened	
Plegadis falcinellus	Glossy Ibis	Lower Risk – near Threatened, Migratory (CAMBA)	

5.1.4. Frogs

Floodplain wetland systems such as Barmah Forest provide important habitats for frog populations. It is not known which frog species persisted at Barmah Forest prior to river regulation. However, frogs identified at Barmah Forest in recent years are listed in Table 5-4.

- **Table 5-4 Summary of frog species likely to occur in the Barmah forest wetlands (adapted from McCarthy *et al.* 2006).**

Scientific name	Common name	FFG status
Litoria peroni	Peron's Tree Frog	
Limnodynastes dumerili	Eastern Banjo Frog	
Limnodynastes tasmaniensis	Spotted Marsh Frog	
Crinia signifera	Common Eastern Froglet	
Limnodynastes fletcheri	Barking Marsh Frog	Data Deficient
Crinia parinsignifera	Eastern Sign-bearing Froglet	
Crinia sloanei	Sloane's Froglet	
Neobatrachus sudelli	Common Spadefoot Toad	
Pseudophryne bibroni	Bibron's Toadlet	Endangered

Additional Notes: The Giant Banjo Frog (*Limnodynastes interioris*) has been recorded in farmland nearby but outside of Barmah Forest (Loyn *et al.* 2002) and was not recorded in the surveys by Ward from 2000-2006. It is listed as Critically Endangered in Victoria (DSE 2003a). The Growling Grass Frog (*Litoria raniformis*) has been listed as being present in Barmah Forest on one occasion but this reporting is now considered erroneous (see Loyn *et al.* 2002).

5.2. Hydrology

5.2.1. Surface water hydrology

The Barmah Forest is located on the Victorian side of the River Murray downstream of Yarrawonga Weir. This site is adjacent to the project area and may be impacted by hydrological changes due to NVIRP. As such, this site requires assessment.

Figure 5-1 to Figure 5-4 show the change in river flow and level due to NVIRP for the Barmah Forest (downstream of Yarrawonga Weir gauging station). Important commence to flow thresholds are shown on the Figures and are labelled with a flow rate only. A key for the vegetation community inundated for each commence to flow threshold is presented in Table 5-5.

Table 5-6 summarises the maximum and average difference in water level and difference at the peak water level over the storing or spilling mode period (winter and spring). Table 5-7 summarises the change in river level at key commence to flow thresholds while Table 5-8 summarises the change in duration above key commence to flow thresholds.

For 2000/01 (the year with the largest reduction in river levels during storing or spilling mode periods as modelled with NVIRP in operation), the results show that the Barmah Forest will experience less than a 1 mm reduction in the flood peak height, with an average reduction in flow level of less than 1 mm. The reductions in river level at key commence to flow thresholds due to NVIRP are also all less than 1 mm with no change in duration (except for low-lying wetlands with a change of 3 days) of flow above most of the key commence to flow thresholds.

As discussed in Section 3.2.7 on the effects of climate change on River Murray flows and wetland inundation events along the River Murray NVIRP is predicted to not result in a change in the frequency or duration of wetland inundation events, even under dry flow conditions analogous to climate change conditions. Hence the additional impact of NVIRP on wetland water regimes over and above that predicted due to climate change is considered insignificant.

- **Table 5-5: Key commence to flow thresholds for Barmah Forest (*personal communications*, Keith Ward- Goulburn Broken CMA, based on observed flooding).**

Commence to Flow (ML/day)	Description
11,000	Low lying wetlands
18,000	Wetlands and Moira grass plains
30,000	Wetlands and River Red Gums
60,000	Broad scale River Red Gum flooding

- **Table 5-6: Comparison of difference in level (mm) between pre and post NVIRP for the Barmah Forest.**

Icon Site	Year	Level Difference (mm)			Storing or Spilling Mode Flow Range (ML/day)
		Maximum	Average	At Peak Flow	
Barmah Forest	2000/01	-26	-1	<-1	8,400 – 88,500
	2005/06	-1	<-1	<-1	5,000 – 30,400

- **Table 5-7: Change in river level at key commence to flow thresholds due to NVIRP for the Barmah Forest.**

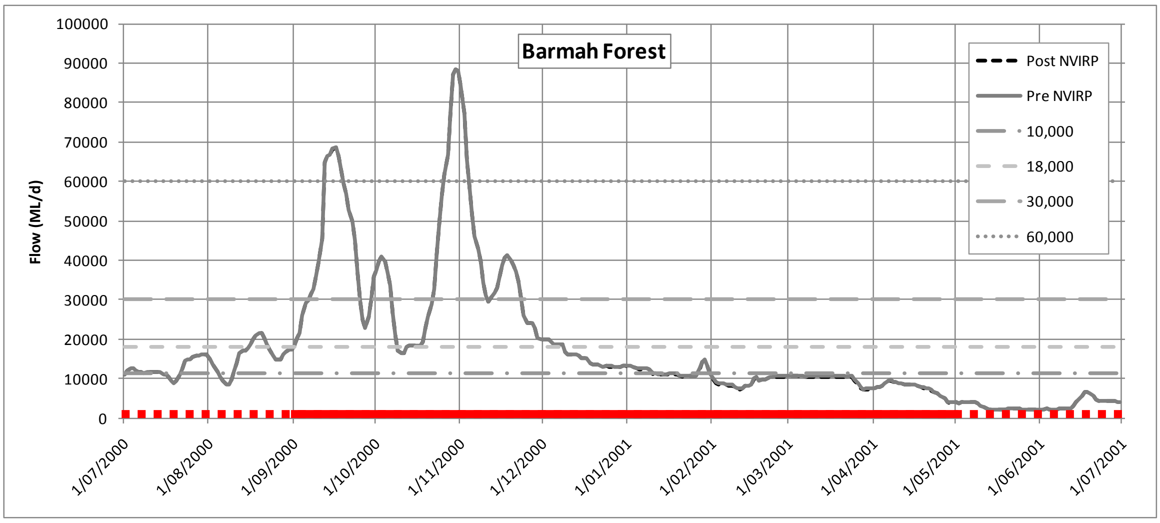
Icon Site	Commence to Flow Threshold			Change in River Level (mm)	
	Flow (ML/day)	Level (m)	Description	2000/01	2005/06
Barmah Forest	11,000	1.91	Low lying wetlands	<-1	<-1
	18,000	2.74	Wetlands and Moira grass plains	<-1	<-1
	30,000	3.92	Wetlands and River Red Gums	<-1	<-1
	60,000	5.74	Broad scale River Red Gum flooding	<-1	Not Exceeded*

* Flows did not exceed this commence to flow threshold. As such no change in level has been presented.

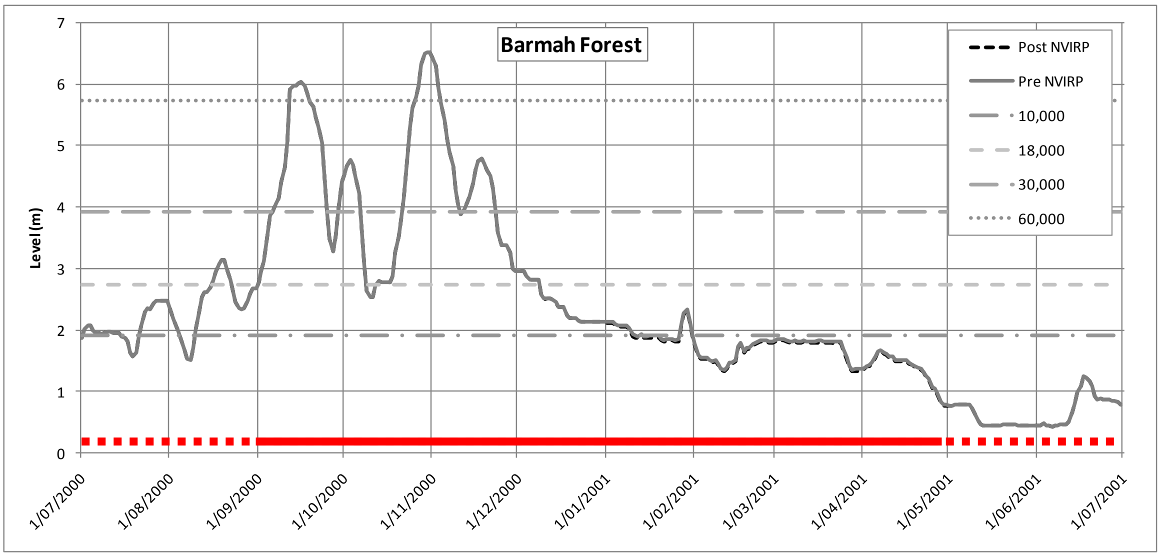
▪ **Table 5-8: Change in duration above key commence to flow thresholds due to NVIRP for the Barmah Forest.**

Icon Site	Commence to Flow Threshold				Change in Duration (Days)	
	Flow (ML/day)	Duration Above Threshold (days)		Description	2000/01	2005/06
		2000/01	2005/06			
Barmah Forest	11,000	187	127	Low lying wetlands	-3	0
	18,000	102	43	Wetlands and Moira grass plains	0	0
	30,000	59	2	Wetlands and River Red Gums	0	0
	60,000	16	0	Broad scale River Red Gum flooding	0	Not Exceeded*

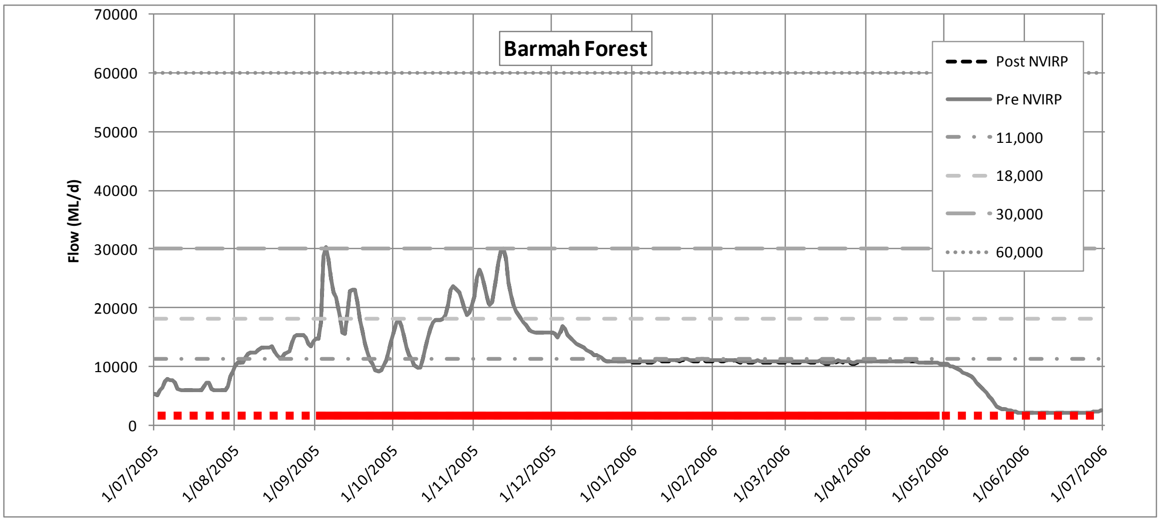
* Flows did not exceed this commence to flow threshold. As such no change in duration has been presented.



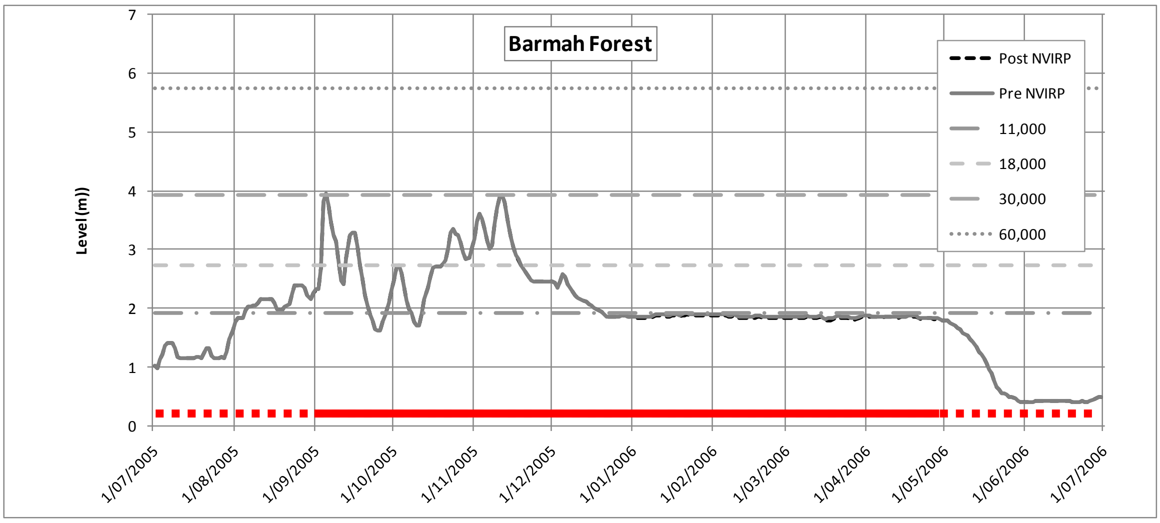
▪ **Figure 5-1 Difference in flow (ML/d) between pre and post NVIRP at Barmah Forest (409025) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 5-2 Difference in level (m) between pre and post NVIRP at Barmah Forest (409025) during an average year (2000/01). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 5-3 Difference in flow (ML/d) between pre and post NVIRP at Barmah Forest (409025) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**



- **Figure 5-4 Difference in level (m) between pre and post NVIRP at Barmah Forest (409025) during a dry year (2005/06). Supply period is solid red line, filling and spilling period is dashed red line.**

5.3. Groundwater hydrology

5.3.1. Groundwater changes

One of the aims of NVIRP is to reduce channel seepage and bank leakage. Upgrades to irrigation infrastructure are expected to reduce recharge to the groundwater system, and as a result regional water tables in the shallow groundwater system (the Shepparton Formation) will fall (NVIRP 2010).

Chapter 8 assesses NVIRP's impacts on groundwater levels in light of recent observed increases in groundwater levels.

5.3.2. Predicted regional water table changes

In the documentation prepared for the PER, changes in regional water table levels were estimated by two methods: an Analytical Spreadsheet Model (ASM) and the Southern Riverine Plains Model (SRPM) (NVIRP 2010). Table 5-9 summarises these reductions for areas west of the Terrick Terrick Hills and Table 5-10 summarises the changes for areas east of Terrick Terrick Hills. (Although not relevant to the Barmah Forest, information about the GMID west of Terrick Terrick Hills is included for completeness). Predicted watertable depth changes due to NVIRP across the region are also presented graphically in Figure 3-24.

▪ **Table 5-9 Predicted Water table Drops in GMID West of Terrick Terrick Hills**

Location	High Water-table?	Shepp Formation Pumping?	Deep Aquifer Pumping?	Area	Water table Drop (ASM)	Water table Drop (SRPM)
Pyramid-Boort	Yes	No	No	259,000 ha	0.9 – 1.2 m	Generally less than 1 m
Barr Creek	Yes	No	No	65,000 ha	0.02 m	Less than 0.5 m
Kerang Lakes	Yes	No	No	40,000 ha	n/a	From 0.2 to 1.3 m

▪ **Table 5-10 Predicted Water table Drops in GMID East of Terrick Terrick Hills (2005/06 case) (IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn)**

Location	High Water-table?	Shepp Formation Pumping?	Deep Aquifer Pumping?	Area	Water table Drop (ASM)	Water table Drop (SRPM)
M. Valley	Yes	Yes	Yes	17,300 ha	0.40 m	From less than 1 to greater than 5 m
M. Valley	No	Yes	Yes	37,150 ha	0.70 m	
M. Valley	No	No	Yes	73,550 ha	Method n/a	
CG 5-9	Yes	Yes	No	56,000 ha	0.2 m	From less than 1 to about 3 m
CG 5-9	Yes	No	No	76,300 ha	0.4 m	
CG 5-9	No	No	No	42,700 ha	0.9 m	
Rochester	Yes	Yes	Yes	19,000 ha	0.4 m	From less than 1 to about 3 m
Rochester	Yes	No	Yes	14,900 ha	0.5 m	
Rochester	No	No	Yes	34,100 ha	Method n/a	
Rochester	Yes	Yes	No	7,500 ha	0.4 m	
Rochester	Yes	No	No	6,000 ha	0.5 m	
Rochester	No	No	No	500 ha	1.2 m	
Shepp IA – nth.	Minor	Minor	Minor	65,000 ha	0.9 m	< 1 m
Shepp IA – sth.	Minor	Minor	Minor	16,000 ha	0.3 m	
CG 1-4 – nth.	Minor	Minor	Minor	12,000 ha	0.9 m	
CG 1-4 – sth.	Minor	Minor	Minor	15,000 ha	0.3 m	

Decreases in the depth to water table predicted with the SRPM and ASM were of similar orders of magnitude, although the decreases predicted by the ASM were generally smaller. The PER used the SRPM results because they:

1) Covered all of GMID whereas the ASM could not cover certain fringe areas, and did not cover the Kerang Lakes area;
2) Provide results for beneath the Barmah and Gunbower forests and represent the variability better across the irrigation areas; and
3) Produce hydrographs that show variation from year to year.

ASM results are still used to estimate reductions in salt loads carried by groundwater towards the major rivers in the GMID and the Barmah and Gunbower Forests.

Water table levels are affected by many factors other than irrigation. A comparison between water table levels in 1991/92 (a wet period prior to the drought) and 2005/06 (during the recent drought) was used to coarsely estimate changes due to the drought. The conditions observed during 2005/06 are likely to provide an indication of the water table levels that could be expected under the drier climatic conditions that are predicted to occur in the future (CSIRO 2008). Compared to the effect of climatic influences on the water table depth, such as drought and climate change, the changes due to NVIRP are relatively modest (Table 5-11). Other factors, such as groundwater pumping that decreases depth to water table, and irrigation intensity that increases the depth to water table, can also cause significant changes irrespective of NVIRP.

- **Table 5-11 Predicted changes to water table depth with NVIRP compared with inter-annual variability due to factors such as drought/climate change (SKM 2008b)**

Area	Depth to water table 1991/92	Depth to water table 2005/06	Depth to water table 2005/06 with NVIRP
Murray Valley	1.49 m	4.05 m	4.53 m
Central Goulburn (5-9)	0.75 m	1.73 m	1.85 m
Rochester	1.03 m	1.56 m	1.71 m

5.3.3. Groundwater effects on rivers and Ramsar floodplain wetlands

Four groundwater related processes were considered:

- Groundwater flow and salt load towards rivers;
- Actual depths to water-table beneath the Barmah and Gunbower Forests post-modernisation;
- Irrigation-related water-table changes beneath the fringes of the Barmah and Gunbower Forests; and,

- Potential for fresh groundwater to be drained from the Barmah and Gunbower Forests.

These processes are explored further in the following sections.

5.3.3.1. Groundwater flow and salt load toward rivers and forests

NVIRP works are expected to lead to reduced groundwater levels and hence reductions in groundwater discharge to rivers. Table 5-12 presents the calculated pre- and post- NVIRP groundwater volumes moving towards the River Murray, Goulburn River, Broken Creek, Campaspe River and the Barmah and Gunbower Forests. This impact is very small in terms of flow in the major rivers, but may be significant for Broken Creek and Campaspe River during low flow periods (Table 5-12). Also, it is believed that the pre-and post-NVIRP groundwater volumes, although flowing towards the rivers, are to some extent evaporated within the floodplain (Table 5-12).

- **Table 5-12 Reductions in Groundwater Volumes Flowing Towards Rivers (IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn; NV = NVIRP)**

Asset	Present Head	Head Drop	Factor[(a)]	Vol to River ML/yr		Indicative Difference (ML/yr)
				Pre-NV	Post-NV	
River Murray u/s Barmah Forest	2.5 m	0.40 m	0.84	2,000	1,680	-320
Barmah Forest north of MVIA	12.5 m	0.40 m	0.97	6,773	6,570	-203
Broken Creek – MVIA Bank	2.0 m	0.4 m	0.80	1,883	1,506	-377
Broken Creek – Shepp IA Bank	0.0 m	0.0 m	n/a	0	0	0
Broken River within Shepp IA	2.0 m	0.6 m	0.70	800	560	-240
Goulburn River b/w Shepp & CGIAs. CG side	2.6 m	0.24 m	0.91	1,548	1,409	-139
Goulburn River b/w Shepp & CGIAs. Shepp side	0.0 m	0.0 m	n/a	0	0	0
Goulburn River north of CGIA	9.3 m	0.24 m	0.97	6,000	5,820	-180
River Murray north of Rochester IA	1.1 m	0.37 m	0.66	323	213	-110
Campaspe River within Rochester IA	4.0 m	0.5 m	0.88	3,973	3,496	-477
Gunbower Forest north of Barr Ck catchment	4.0 m	0.02 m	0.995	1,716	1,707	-9
Total				**25,016**	**22,961**	**-2,055**

(a) This factor is (Present Head – Head Drop)/Present Head. It gives the ratio of Post- to Pre-NIVIRP.

Table 5-13 presents the salinities of the groundwater flowing from the irrigation areas towards the major rivers and the floodplain forests in the region, and calculates the corresponding reduction in groundwater-borne salt load. NVIRP is expected to reduce the total salt load flowing towards rivers and floodplain forests by 6 105 tonnes per year. Any reduction in the lateral movement of salt towards the rivers and floodplain forests is likely to be beneficial, because the receiving waterways support high environmental values that may be sensitive to high salinity. However, the overall effect of NVIRP on salt loads is relatively small and represents only a 5% reduction in total annual groundwater salt contributions to these environments. Salt load movements are only understood at a general level and therefore the effect that NVIRP will have at individual sites cannot be determined reliably.

- **Table 5-13 Reductions in Groundwater-borne Salt Load Moving Towards Rivers(IA = Irrigation Area; MV = Murray Valley; CG = Central Goulburn; NV = NVIRP)**

Asset	G'water Salinity (mg/L)	Vol to River (ML/yr)		Salt load to river (t/yr)		Indicative Reduct'n (t/yr)
		Pre-NV	Post-NV	Pre-NV	Post-NV	
River Murray u/s Barmah Forest	900	2,000	1,680	1,800	1,512	288
Barmah Forest north of MVIA	200	6,773	6,570	1,355	1,315	40
Broken Creek – MVIA Bank	1,000	1,883	1,506	1,883	1,506	377
Broken Creek – Shepp IA Bank	2,000	0	0	0	0	0
Broken River within Shepp IA	2,000	800	560	1,600	1,120	480
Goulburn R. b/w Shepp & CGIAs. CG side.	2,000	1,548	1,409	3,095	2,820	275
Goulburn River b/w Shepp & CGIAs. Shepp side	2,000	0	0	0	0	0
Goulburn River north of CGIA	8,500	6,000	5,820	51,000	49,470	1,530
River Murray north of Rochester IA	5,000	323	213	1,615	1,065	550
Campaspe River within Rochester IA	5000	3,973	3,496	19,865	17,480	2,385
Gunbower Forest north of Barr Ck catchment	20,000	1,716	1,707	34,320	34,140	180
Total		**25,016**	**22,961**	**116,533**	**110,428**	**6,105**

5.3.3.2. Actual depths to water table beneath Barmah Forest

The post-modernisation depths to water table have been obtained from the SRPM, and compared with the levels measured beneath the Barmah Forest. The desirable outcome is a no effect post-NVIRP on depth to water table in either the 'up' or the 'down' direction of water tables. If a water table rise is predicted, then it could indicate the effects of the irrigation mounds intruding into the

Forest. If water tables are predicted to fall then this could indicate that NVIRP would drain useable fresh groundwater away from the Forest.

The modelling results indicate that NVIRP will not alter the watertable levels beneath the Barmah Forest. Given this, it is highly unlikely that there would be any transmission of NVIRP effects further north into the Millewa Forest on the NSW side of the River Murray.

5.3.3.3. Irrigation-related water table changes beneath the fringes of the Barmah Forest

The SRPM results indicate that at the margin of the Barmah Forest the water table will be reduced over time by 0.8 m in the Upper Shepparton formation. This is a desirable outcome given the threat of a high water table altering soil salinities and affecting the forest.

5.3.3.4. Potential for fresh groundwater to be drained from Barmah Forest

An important consideration for the groundwater assessment is whether water table mounds beneath irrigation areas would be lowered substantially by NVIRP and if so, whether groundwater gradients would flow away from and drain the forests. To investigate this, assessment of the groundwater elevations beneath the irrigation areas were compared to the elevations beneath the forests.

It was found that even with the changes due to NVIRP there would still be overall gradients of groundwater flow towards the Barmah Forest from nearby irrigation areas. This is because the water table elevations in the irrigation areas are much higher than the forest, for instance, the water table elevations in the Murray Valley Irrigation Area are 100 metres AHD (Australian Height Datum), which compares to an elevation of about 90 metres AHD at the boundary of the Forest. In the Forest itself, there are hydrographs that go down to an elevation of 83.5 metres. Therefore it is not plausible that fresh groundwater could be drawn out from under the forest by the actions of NVIRP.

5.3.4. River Salinity

Monthly salinity data was used to undertake an assessment of the effect of NVIRP on the salinities in the River Murray and Goulburn River (these are adjacent to the Barmah Forest), as well as in the connected wetlands along the River Murray (including Ramsar sites) by SKM (2009b) as supporting data for the Public Environment Report (NVIRP 2010). In many cases, salinity data were available for threshold flows representing anabranch commence to flow. The assessment was done for an average climate scenario (based on rainfall conditions in 2000/2001) and a dry (10%) climate scenario (based on 2005/2006 rainfalls) (SKM 2009b).

The results of those assessments indicated that NVIRP will decrease river salinities by up to 5 µS/cm, particularly in the River Murray downstream of Swan Hill during the supplying mode

(SKM 2009b). Salinity in the Goulburn River at McCoys Bridge was also predicted to fall by up to 5 µS/cm during the supplying mode, but either remain unchanged or increase by up to 2 µS/cm during the storing/spilling mode (NVIRP 2010). Overall these changes are very small in comparison with background salinity regimes (~ 200 µS/cm) and are not likely to have any effect on biota or other environmental values.

5.3.5. Groundwater summary

NVIRP is expected to reduce groundwater levels at the margin of the Barmah Forest by up to 0.8 m over time, but the gradient of groundwater flows in the region will not change and therefore groundwater levels immediately beneath Barmah Forest will not be affected (NVIRP 2010. The net effect of these changes may be a slight reduction in salinity levels, but such changes are expected to be negligible and have no ecological effects (NVIRP 2010).

5.4. Effect of likely flow changes on environmental values

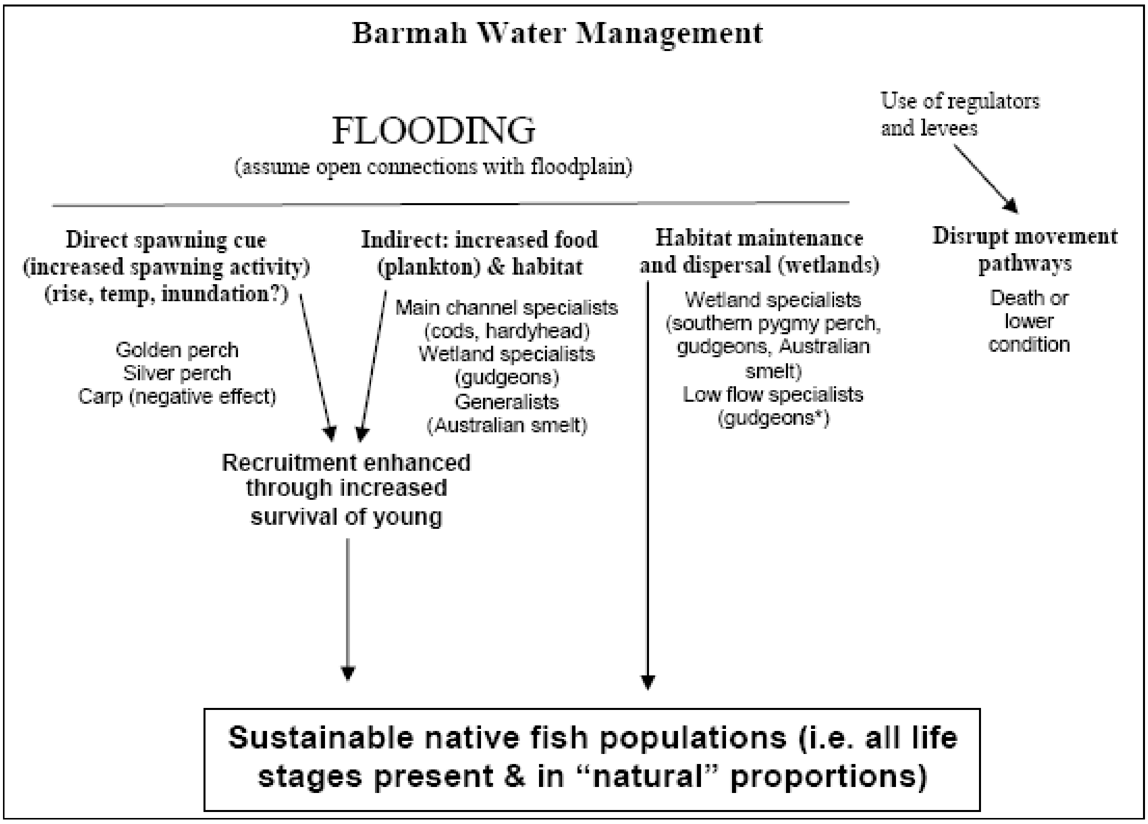
The hydrological processes that are likely to influence the health and abundance of vegetation, fish, bird and frog communities in the Barmah Forest are very similar to those that have already been described for Gunbower Forest and the Hattah-Kulkyne Lakes in Section 3.4 but for the sake of completeness are reiterated briefly in the following sections.

5.4.1. Vegetation

The Barmah Forest contains a mix of wetlands of varying permanency and support a range of plant communities with different water regime requirements. The distribution of these plant communities across the forest is strongly linked to the water regime. Low lying areas support species that require frequent flooding or near permanent inundation, while higher elevation areas support communities that can only tolerate infrequent and short periods of flooding. Changes to the timing, frequency or magnitude of flooding may have a significant effect on the distribution of established plant communities. The hydrological analysis presented above indicates that NVIRP will not affect the frequency or timing of events that inundate the Barmah Forest and changes in water levels during these flood events are expected to be very small. These hydrological changes are too small to affect the established vegetation communities.

5.4.2. Fish

Wetlands and creeks in Barmah Forest provide important habitats for small-bodied native fish and are also important nursery habitats for some larger species. Fish obviously need areas of permanent water to persist in these sites or else they must be able to move into the areas during floods and then return to the main river channel before floodwaters recede. The timing, frequency and duration of floods and wetland inundation are critical factors that determine quality and quantity of fish habitat, the availability of food and breeding success of fish that use these sites (Figure 5-5). NVIRP is not expected to change the timing, frequency or duration of floods in Barmah Forest and therefore is not expected to affect the health or composition of any fish communities at these sites. Small changes in river salinity are not expected to affect fish habitats or fish populations.



- **Figure 5-5: Conceptual model of impact of flow on fish communities in the Barmah Forest (Source: McCarthy *et al.* 2006, page 16).**

5.4.3. Waterbirds and frogs

The main factors that influence the breeding success and health of waterbird populations on the floodplain of lowland rivers are the seasonality and duration of flood events (see Appendix A.1.2). NVIRP is not expected to affect either of these factors in Barmah Forest and therefore is not expected to affect any of the waterbird populations. The availability of frog habitat (vegetated areas that are variably inundated to shallow depths) is also not expected to change. Small changes in river salinities are not expected to have any effect on these biota.

5.5. Conclusion

The Barmah Forest Ramsar site is located on the River Murray floodplain downstream of Yarrawonga Weir. The forest features a variety of permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forest. These wetlands provide habitat for many environmental values including a large number of waterbird species, particularly after floods when the forest provides significant breeding habitat. The forest also provides important habitat for native fish, including species of national, state and regional conservation significance, such as Trout Cod, Freshwater Catfish and Southern Pygmy Perch. The Barmah Forest is not directly connected to the irrigation system. However it is indirectly connected via a number of creeks, particularly Tongalong Creek and the Tullah Creek, and irrigation drains.

Barmah Forest is adjacent to the project area and so could potentially be impacted by hydrological changes as a result of NVIRP operations. The potential impacts of NVIRP on the floodplain wetlands associated with the River Murray arise from two impact pathways. First, reduced lateral flow from rivers could decrease the frequency, extent and duration of floodplain inundation. Second, a reduction in irrigation water may cause salinity levels in the river to increase, which may in turn lead to higher salinity in floodplain forests, wetlands and creeks systems.

For 2000/01 (the year with the largest reduction in river levels during storing or spilling mode periods as modelled with NVIRP in operation), the results show that the Barmah Forest will experience less than a 1 mm reduction in the flood peak height, with an average reduction in flow level of less than 1 mm. The reductions in river level at key commence to flow thresholds due to NVIRP are also all less than 1 mm with no change in duration (except for low-lying wetlands with a change of 3 days) of flow above most of the key commence to flow thresholds.

NVIRP is expected to reduce groundwater levels at the margin of the Barmah Forest by up to 0.8 m over time, but the gradient of groundwater flows in the region will not change and therefore groundwater levels immediately beneath Barmah Forest will not be affected. The net effect of these changes may be a slight reduction in salinity levels, but such changes are expected to be negligible and have no ecological effects.

The hydrological analysis presented above indicates that NVIRP will not significantly affect the magnitude, frequency or timing of floods in the Barmah Forest under either current or climate change conditions. On the basis of conceptual models of ecological response to hydrological change it is considered that any hydrological changes are too small to affect the quality or quantity of any in-channel habitats used by fish or other aquatic biota. Changes in the hydrological regime of the wetland systems are also considered too small to affect the established vegetation communities and other biota such as waterbirds or frogs. Hence, there is unlikely to be any impact on environmental values of national, state or regional conservation significance in the Barmah Forest Ramsar site.

6. Residual uncertainty

Condition 4 c) calls for the identification of residual sources of uncertainty. Areas of uncertainty associated with this assessment are presented below.

6.1. Distribution of species

There is some uncertainty regarding the distribution of some species with high conservation value in the Goulburn River, River Murray and Barmah Forest. For example, there are no specific records of Growling Grass Frogs at these sites despite the presence of suitable habitats. Furthermore, the specific presence or absence of various species, particularly mobile species doesn't infer that existing habitat is or is not critical for survival.

6.2. Hydrological and hydrogeological modelling

There is also uncertainty around the modelling of hydrological and hydrogeological impacts. Data from specific gauge locations are used to infer a hydrological response across a river reach, which could be tens to hundreds of kilometres long. The impact of NVIRP, as modelled at gauge locations, is assumed to be representative of the impacts across the broader reach that is represented by that gauge. Other assumptions around the volumes of outfalls, patterns of water distribution and operational complexity also exist. Uncertainty in the hydrogeological analysis exists regarding the assumptions made for seepage and leakage rates, the distribution of and salinity of groundwater across the GMID, flux rates etc. All these areas of uncertainty, and associated implications for the assessment, in the hydrological and hydrogeological analysis are presented in documents supporting the PER (i.e. SKM 2009a and SKM 2009b). These are reproduced in Tables 6-1 to 6-4.

- **Table 6-1 Summary of sources of uncertainty, their treatment and implications for results - hydrology**

Source of Uncertainty	Treatment of Uncertainty	Implications for results
Volume of outfalls which return to the river	It was assumed 100% of the outfall volume is transferred to the receiving waterway. This ignores losses in drainage lines and diversions from drains	This results in a conservative case in terms of decrease in river level during flood events at sites of significant environmental value
Split of flows distributed to irrigators which will influence changes during the supplying mode times	It was assumed that the distribution to irrigators was in the same proportions to where the savings were made	The outcome of a changed assumption would still result in a change towards reducing Summer and Autumn high flows as recommended by environmental flow studies, with no impact on storing or spilling mode which generally occur in Winter and Spring

Source of Uncertainty	Treatment of Uncertainty	Implications for results
Water distributed to the environment	Use of water by the environment not considered as part of the analysis due to uncertainty about the likely pattern of use in the particularly case study years.	The distribution of water to the environment will provide up to 175 GL (LTCE) of water which can be released (on call) to meet environmental needs. This will provide significant environmental benefits which have not been assessed for this study
The analysis does not represent some of the complexities of changed operations, such as impact of operations in one year affecting subsequent years, channel capacity constraints, harvesting of storing or spilling mode flows and within river losses	Method was developed which utilised the concepts of the major impacts on system operation	The adopted method is judged to be fit for purpose without assessing such changes which may be second order effects
Application of a monthly pattern for flow and level changes due to reduced deliveries and reduced outfalls	Only a monthly pattern of outfalls was deemed to be within the scope of this study. Daily patterns of outfalls for the NVIRP area for the two years analysed are not available and would require substantial data analysis to estimate.	Some variability in outfall reduction on a daily basis is not represented, however given the conservative assumption of assuming the full impact of the change in the outfalls affects the rivers, this is expected to be a reasonable representation.
Identification of periods of supplying and storing or spilling modes	Three gauging stations were used on both the Goulburn and Murray systems to analyse timing of releases for irrigation. These are on a monthly basis to be consistent with flow changes associated reduced outfalls and deliveries	There may be times when during a month, the flow regime changes from one mode to another. At the times when the change occurs there may be up to 15 days when the flow regime is in the opposite mode. Given the requirements to use a monthly time series this limitation is considered minor.

- **Table 6-2 Summary of sources of uncertainty, their treatment and implications for results - Within GMID Hydrogeology Results**

Source of Uncertainty	Treatment of Uncertainty	Implications for Results
In the ASM certain parameters have been assumed to be spread uniformly across the area to which they apply	This source of uncertainty is addressed by applying the model in a range of formulations. These formulations represent the recognised geographic and management variation across the GMID. In the case of fringe areas it was apparent that the models assumptions invalidated the results. The Method was designated as "not applicable" in these areas.	The situations where the model was not applicable is shown clearly and reasons provided.
The ASM does not take account of lateral flow	This could cause errors in fringe areas.	Results with excessive uncertainty (in fringe areas) are not quoted.
In the ASM the method has been to do water balances based on average annual parameters.	The results have only been quoted as changes from "Without NVIRP" to "With NVIRP". Absolute values have not been quoted.	Provided only "with/without" differences are used, the model should be indicative of the relative magnitude of changes.
In the ASM an assumption was made that a fall in watertable of 5 metres would mean that all groundwater pumping from the Upper Shepparton Formation would have to cease (through screens becoming dry).	Consideration was given to the possibility that the fall might be 10 metres before pumping had to cease. If this were the case watertables (with NVIRP implemented) would fall further than would be the case at 5 m cut off depth.	Results based on the cut-off at 5 metres have been quoted. This means that they might be under-estimates. Given that falls in watertables in the GMID are expected to be beneficial, it is conservative to quote the smaller falls.
In the SRPM the extinction depth for groundwater evapo-transpiration in the irrigated plains is set at 2 metres.	The extinction depth could be too shallow.	It needs to be recognised that when a "without/without" scenario is being tested, the case that has the greater drawdown of the watertable might diverge more than would otherwise be the case (due to not having evapo-transpiration to help absorb the effect of the change)
The SRPM in its current form it is not possible to adjust groundwater pumping rates during a run in order to try simulate actual management decisions.	This could have the effect of creating simulated drawdowns greater than would actually be the case in the field.	It needs to be recognised that this over-drawdown could be embedded in the hydrographs

- **Table 6-3 Summary of sources of uncertainty, their treatment and implications for results - Regarding Floodplain Wetland Results**

Source of Uncertainty	Treatment of Uncertainty	Implications for Results
The groundwater salinities used in the calculation of salt load moving in the direction of the Floodplain Wetlands, and rivers within and adjoining GMID, are approximate	An attempt was made to obtain groundwater salinities in an area near the ecological features, not just one or two points. However, given that groundwater salinities can change markedly in a short distance in these locations, the adopted salinities might still be approximate.	The quoted results are intended to be indicative only, and should be taken as such.

- **Table 6-4 Summary of sources of uncertainty, their treatment and implications for results - Regarding River Salinities Results**

Source of Uncertainty	Treatment of Uncertainty	Implications for Results
No lag time for the time of travel downstream was assumed	A monthly time step was adopted to try to “bracket” the travel time.	Quoted results might be "ahead" of the actual time of arrival. Given that the salinity increments or decrements in the River do not change dramatically from one month to another, this does not introduce unacceptable uncertainty
It was assumed that 100% of the volume of outfalls captured by NVIRP transmitted to the rivers concerned.	The 100% assumption was accepted as reasonable.	The 100% assumption means that adverse effects (increases in salinity) will be over-stated, and beneficial effects will also be over-stated. Given that the effects are very small, this is not considered to be a significant source of error.

6.3. Ecosystem response

Finally there is a certain level of uncertainty in the expected ecosystem response to changes in flow and water level and also uncertainty in what constitutes a significant change in water level (i.e. threshold change) from an ecological response perspective.

6.4. Conclusion

The models used for the hydrological assessments and the analyses of ecological impacts do provide a good indication of the likely changes, but may not accurately predict outcomes at individual locations. However, they are based on the best information available at the time of assessment and are considered fit for purpose. They are adequate for the purposes of assessing potential impacts at the scale of this assessment. In future, it will be important to monitor hydrological and ecological changes throughout the GMID and adaptively manage any threats that are identified.

On balance, because the hydrological changes associated with NVIRP are predicted to be so small there are no areas of uncertainty that would affect confidence in the overall conclusions that NVIRP will not have any detectable effect on any groups of biota in the three study areas.

7. Future use of Environmental Water Entitlements

This Chapter addresses the Condition 4 requirement d) to provide advice to the Minister for Environment and Climate Change, or a delegate, for consideration in future decisions on use of environmental water entitlements. (It is assumed that this advice will be focussed on the future use of Victorian environmental water entitlements). The environmental water entitlements generated by implementation of NVIRP will be held by the Victorian Environmental Water holder (VEWH) and the Commonwealth Environmental Water holder (CEWH).

Amongst other things, the roles of the VEWH include:

- holding and managing environmental water entitlements and allocations
- coordinating the delivery of Victorian-held entitlements with those held by the Commonwealth Government to maximise ecological outcomes
- making adaptive, responsive and timely decisions about where and when environmental water is delivered.

The VEWH will focus on Victorian environmental water priorities.

The CEWH is required to use its holdings to protect or restore environmental assets of the Murray-Darling Basin, and other areas outside the Basin where the Commonwealth holds water, so as to give effect to relevant international agreements.

Water that is held in the Murray-Darling Basin is required to be managed in accordance with the environmental watering plan, part of the Basin Plan being developed by the MDBA in consultation with state governments and stakeholders.

7.1. Attributes and use of environmental water

Implementation of NVIRP will generate up to 425 GL (long-term annual average) water savings. Water savings generated will be used to:

- provide water for the environment (up to 175 GL long-term annual average)
- enhance water availability to support improved productivity in Victoria's Food Bowl region (up to 175 GL long-term annual average)
- provide water to Melbourne (up to 75 GL long-term annual average).

As a consequence of NVIRP, up to 75 GL (long-term annual average) of savings will be converted to Victorian environmental water entitlements and up to 100 GL (long-term annual average) of savings will be held by the Commonwealth Environmental Water Holder. These will be callable (or held), tradable environmental entitlements and will be in addition to existing Victorian Government environmental entitlements and water recovery commitments to the Living Murray and Snowy River initiatives.

Experience in managing rivers and wetlands through the current drought has shown clearly the value of callable, tradable environmental entitlements as environmental management tools.

The environmental entitlements recovered through NVIRP will have the same characteristics as water provided to irrigators and towns i.e. a callable (or held) volume in storage can accrue allocations, temporary trade, carry over provisions and be able to be extracted for use at specific locations. They will also be able to be used at multiple locations as the water travels downstream (provided losses and water quality issues are accounted for). This means that the water can be called out of storage at desired times to meet specific environmental needs at a number of sites.

These callable, tradable environmental entitlements provide the capability for active, efficient and responsive environmental management. It enables environmental water to be deployed:

- according to actual seasonal requirements and antecedent conditions recognising the climatic conditions at the time
- to any river or wetland connected to the northern Victorian regulated system
- in conjunction with consumptive water to achieve environmental outcomes (e.g. underwriting losses when consumptive water is used en route for an environmental purpose)
- according to priorities ensuring the best environmental outcome
- at multiple sites, on its way downstream.

In summary, NVIRP will provide up to 175 GL of new environmental entitlement. Whilst not sufficient to meet all of the environmental water requirements of the rivers and wetlands in northern Victoria, it goes a long way to meeting the targets for environmental water recovery outlined in the *Northern Region Sustainable Water Strategy* and will provide significant high reliability water to provide for the survival requirements of these systems during extended drought. There is an established process in Victoria that will be followed to determine the specific areas and volumes that are allocated to sites that fit the above mentioned area. The Victorian Environmental Water Holder, once established, will continue to follow this process and will work collaboratively with the Commonwealth Environmental Water Holder and the Living Murray to maximise environmental outcomes across northern Victoria.

In addition to new environmental entitlements, NVIRP is committed to retaining and where possible and practical, enhancing infrastructure to deliver environmental water. This is part of the Water Change Management Framework and ensures that current means for delivery of environmental water are recognised and maintained whilst also investigating opportunities for improving delivery.

7.2. Water Change Management Framework (WCMF)

NVIRP has prepared a Water Change Management Framework that describes the means to protect aquatic and riparian ecological values through management of water allocations and flows that may be impacted by implementation of NVIRP within the modernised GMID (NVIRP 2010). The WCMF outlines procedures for monitoring, reporting and auditing changes in hydrological conditions in relevant wetlands or waterways associated with the project's operation. It provides the environmental commitments, processes and methods for the relevant operations of the modified system.

Various documents **Error! Reference source not found.**prepared under the WCMF aim to identify and assess potential impacts associated with NVIRP and recommend suitable mitigating actions. Each of these documents is relevant to the use and management of environmental water. Mitigation actions can include

- Development of environmental watering plans (EWPs)
- Environmental Infrastructure Register
- Localised groundwater assessments.

Each of these can result in the commitment of mitigation water to be used to overcome any adverse impacts of NVIRP implementation.

In addition ,the WCMF requires preparation of regional environment and groundwater assessments of the cumulative impacts of NVIRP. These assessments are in preparation.

Preparation of many of these documents is overseen by NVIRP's Environmental Technical Advisory Committee and the Expert Review Panel.

7.2.1. Environmental Watering Plans (EWPs)

NVIRP has undertaken a rigorous process to identify wetlands and waterways potentially at risk from NVIRP operation and to prepare EWPs for relevant sites (NVIRP 2010).

The development of EWPs for sites considered potentially "at risk" from NVIRP operation is an appropriate mechanism to ensure that management of environmental water entitlements is based on the best information available and agreed management objectives. NVIRP EWPs have been the product of rigorous processes that:

- Documented management objectives based on wetland or waterway ecological needs and community consultation
- Determined water regime requirements to achieve management objectives based on water balance modelling
- Set up an adaptive management process of monitoring and regular review.

NVIRP's WCMF sets out the content and the processes to be followed in development, of EWPs. NVIRP EWPs provide a sound basis for the development of full wetland management plans and determining watering priorities beyond the extent of a mitigation water obligation during NVIRP implementation.

Using the WCMF as guidance, EWPs should be prepared for all wetlands and waterways which may benefit from the allocation of environmental water entitlements. This framework could be applicable across Victoria.

In addition to EWPs, NVIRP is preparing a Mitigation Water Operating Protocol that will guide the decision making processes for allocation of NVIRP mitigation water across wetlands and waterways. This protocol should be considered in decisions concerning the future use of environmental water entitlements.

7.2.2. Environmental Infrastructure Register

An Environmental Infrastructure Register has been developed of irrigation infrastructure which is used, or could be used, to deliver environmental water to wetlands or waterways. This is to address the risk that channels which are not included in the backbone but provide water access to significant environmental assets could be decommissioned without regard to the need to retain capability to undertake environmental watering.

7.2.3. Local Groundwater Assessments

Local groundwater assessments are undertaken by NVIRP to assess the potential impacts of a reduction in channel recharge groundwater where it is likely to significantly impact on high environmental values associated with the wetland. This will include matters of national environmental significance and will recommend Environmental Watering Plans to be prepared where significant impacts on high environmental values associated with a wetland will, or are likely to occur.

7.2.4. Environmental Technical Advisory Committee

NVIRP has convened a Technical Advisory Committee (TAC) to provide advice on assessment approaches and the development of the documents outlined in the WCMF, to ensure that:

- a proper process is being followed
- the information provided is appropriate
- the recommendations are practical and feasible.

The TAC includes agencies which will be responsible for ongoing delivery and review of management and mitigation measures and includes representation from:

- Catchment Management Authorities
- Goulburn – Murray Water
- Department of Primary Industries
- Parks Victoria
- DSE.

There may also be occasional representation from other stakeholders (e.g. the land manager of a particular wetland).

Formal agreements to implement the actions of the WCMF will be coordinated via the TAC.

7.2.5. Expert Review Panel (ERP)

The Minister for Planning required that an Expert Reference Panel (ERP) be appointed by the Victorian Minister for Environment to provide advice to the Minister for Water and the Secretary of DSE on the WCMF and the various stages of its implementation including assessment reports identifying waterways and wetlands requiring EWPs. The ERP's advice is published on the NVIRP web site.

7.3. Other processes

Victoria has well developed processes for assessing and managing the salinity impacts of works and activities in line with the provisions of the Basin Salinity Management Strategy (MDBC 2001). In addition, regional processes involving CMA's and relevant agencies support these activities. For example, both the Goulburn Broken and North Central CMAs are implementing projects assessing the potential impacts of recent rainfall events on groundwater levels.

Any potential salinity and groundwater impacts of the use of environmental water entitlements should be managed via these existing processes.

7.4. Legacy of NVIRP

Apart from the provision of environmental water recovered via NVIRP there are a number of benefits of NVIRP implementation that should be considered as NVIRP's environmental water management legacy. This legacy includes:

- The development of the WCMF and associated practices that can provide the basis for enhanced and adaptive environmental management of wetlands and waterways across northern Victoria
- Higher level understanding of the environment of the GMID via the preparation of WCMF assessments and document and the preparation of the EPBC Public Environment Report. This information will be essential in making future management decisions.
- Enhanced environmental management capability of agency staff involved in wetland and waterway management via involvement in WCMF processes
- Enhanced capacity to undertake environmental watering through a modernised system.

7.5. Summary

- NVIRP will provide up to 175 GL of new environmental water entitlement to be managed by the Victorian and Commonwealth Environmental Water Holders. These entitlements are callable and tradable and provide the capacity for active, efficient and responsive environmental management.

- NVIRP's Water Change Management Framework provides a sound basis to protect aquatic and riparian ecological values through management of water allocations and flows that may be impacted by implementation of NVIRP within the modernised GMID.
- The Water Change Management Framework and associated practices can provide the basis for enhanced and adaptive environmental management of wetlands and waterways across northern Victoria.

8. Groundwater effects of NVIRP

This Chapter assesses NVIRP's impacts on groundwater levels in light of recent observed increases in groundwater levels.

The Secretary of DSE, in responding to NVIRP seeking approval for the report submitted to meet the Environment Effect Statement Condition 4 requirements, requested that NVIRP provide further discussion on the impacts of groundwater on environmental values. (This information is now included earlier in this report). The Secretary also requested that NVIRP take into account the increases in groundwater levels due to the recent rainfall in assessing the potential impacts of NVIRP to groundwater levels.

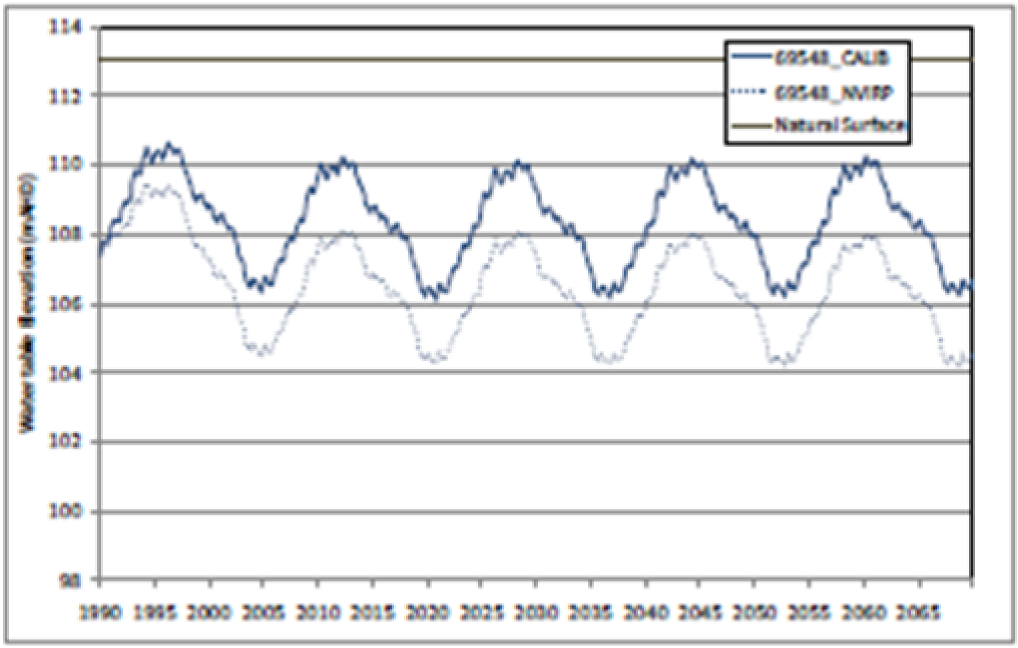
The assessment of NVIRP's groundwater impacts was undertaken for the EPBC PER process (SKM, 2009b) and is briefly summarised below.

The effects of NVIRP on groundwater levels Based on the Groundwater Hydrology Report (SKM 2009b) modelling results, groundwater levels are expected to decrease by a varying amount in different parts of the GMID as a result of NVIRP implementation. The impact of NVIRP on groundwater levels is illustrated through the use of a series of hydrographs showing modelled with and without NVIRP groundwater levels. An example of these hydrographs is shown below (Figure 8-1). Overall, the impact of NVIRP on groundwater levels varies from about 0.3 m to about 3.0 m depending on the distance of monitoring points from irrigation areas and the local depth to water table. The greatest impact on water levels was in areas where the water table is lowest and therefore the risk of impact on the environment is also lowest.

In each Irrigation Area the following approximate declines over an 80 year period (based on five 16 year cycles) were shown (NVIRP 2010):

- 3 m in the Murray Valley Irrigation Area
- 0.5 m in the Shepparton Irrigation Area
- 2-3 m in the Central Goulburn Irrigation Area
- 0.5-1.5 m in the Rochester Irrigation Area
- 0.5 m in the Pyramid Hill – Boort Irrigation Area
- less than 0.5 m in the Torrumbarry Irrigation Area
- 1.3 m in the Kerang Wetlands locality.

The impact at a particular monitoring bore appears constant irrespective of whether or not groundwater levels were rising (wet phase) or falling (dry phase). There is sufficient spread of monitoring bores across GMID to be confident that the response is consistent across the geographic spread and landforms that make up the GMID.



Hydrograph for Bore 69548 in Murray Valley Irrigation Area

- **Figure 8-1 Example hydrograph illustrating NVIRP impact on groundwater levels (from SKM, 2009b)**

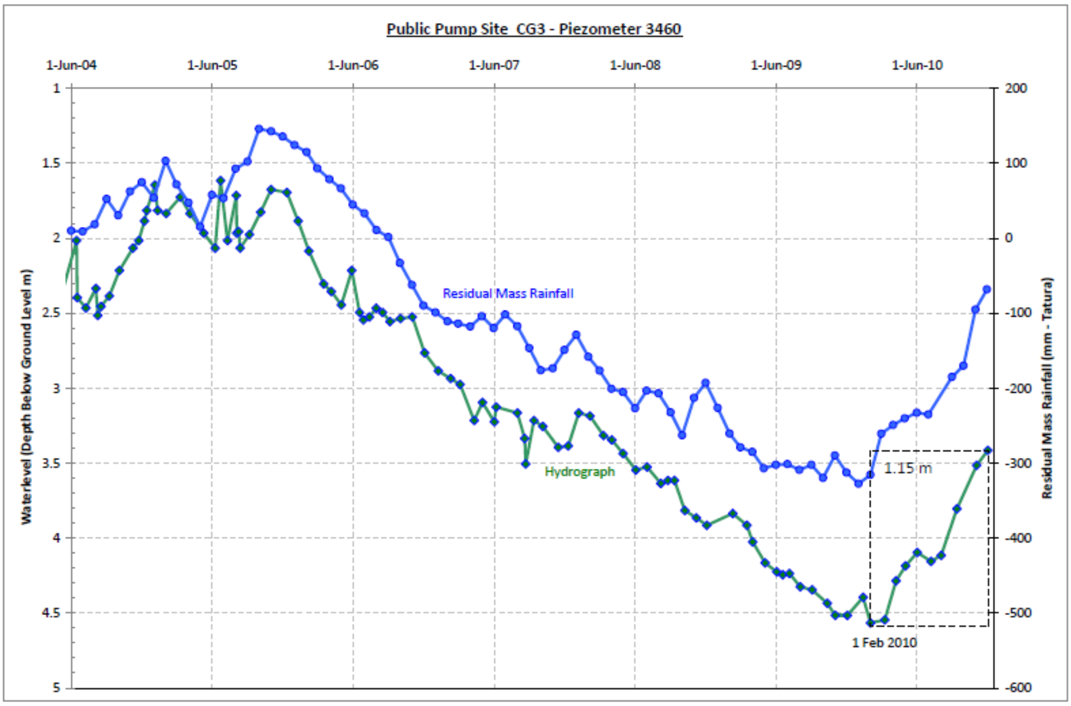
8.1. Recent trends in groundwater levels

Groundwater levels, which have been trending downwards since 2005, have responded quickly and sharply to rainfall events since mid 2010.

Figure 8-2 shows a representative hydrograph from the Central Goulburn Irrigation Area (data supplied by G-MW) for the period June 2004 to late 2010 (note that it does not take into account the December 2010-January 2011 rainfall and flood events). It shows an approximately one meter rise on groundwater levels. Figure 8-3 shows some longer term hydrographs from bores in the shallow Shepparton Formation (bore locations shown in Figure 8-4) which indicate that groundwater levels have been trending downward since the mid 1990s. Figure 8-3 also indicates increases in groundwater levels since 2010.

Figure 8-5 shows a hydrograph from the Barr Creek catchment, representative of bores from the western part of the region. This also shows roughly a one metre rise in groundwater levels over the past year.

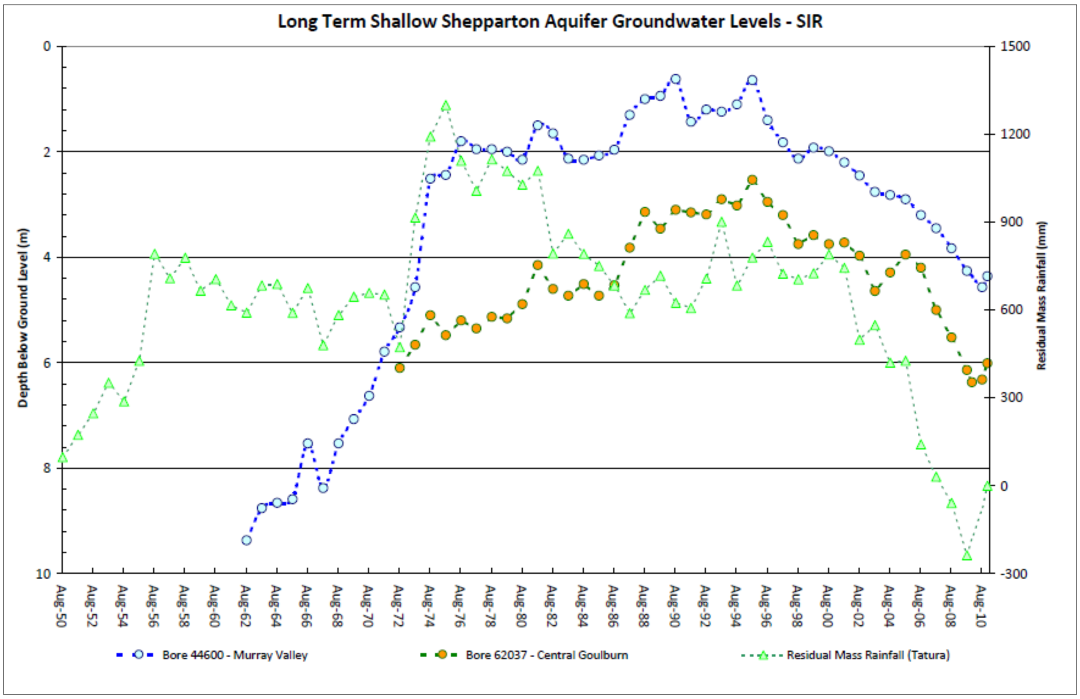
These hydrographs suggest that a possible return to average or wetter conditions could lead to rises in groundwater levels, although this depends on the continued occurrence of rainfall events.



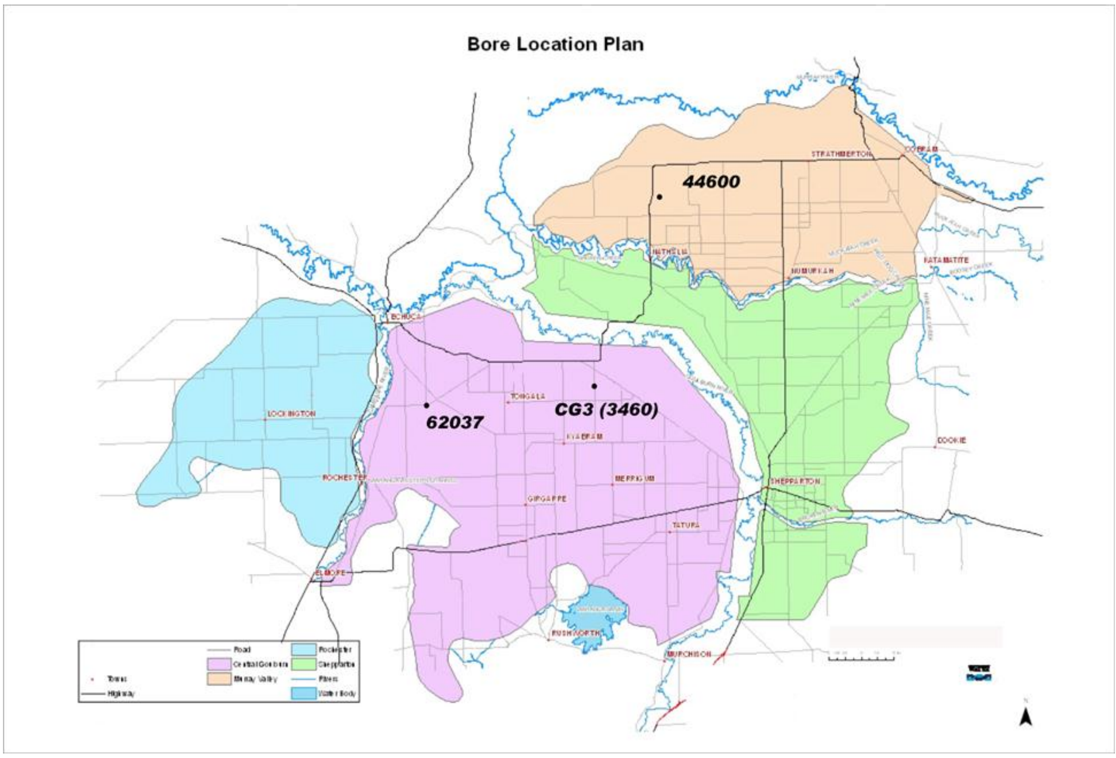
- **Figure 8-2: Recent groundwater levels from a representative hydrograph**

![SKM logo]

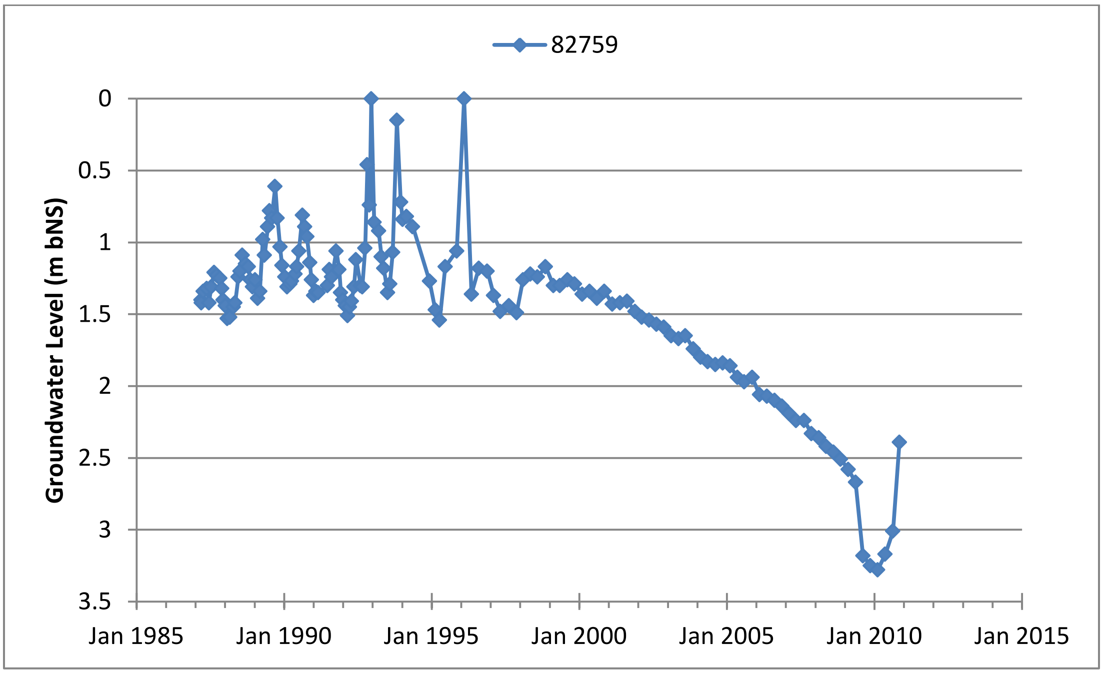
SINCLAIR KNIGHT MERZ



- **Figure 8-3 Long term shallow Shepparton aquifer levels**



- **Figure 8-4 Bore location plan (colours indicate G-MW Irrigation Areas)**



- **Figure 8-5 – Long term groundwater trends – Bore 82759 Barr Creek catchment**

8.2. Summary

The PER assessed the impact of NVIRP on groundwater levels as varying from about 0.5 m to about 3.0 m in an 80 year modelled period (based on five 16 year cycles). This equates to a fall of 0.03 – 0.19 m per year. There is sufficient spread of monitoring bores across GMID to be confident that the response is consistent across the geographic spread and landforms that make up the GMID. The impact appears constant irrespective of whether or not groundwater levels were high (wet phase) or low (dry phase). The period during 2010 saw a rise in groundwater levels of around one meter. This rise is consistent with rises observed at multiple sites across the GMID. Hence the impacts of NVIRP on groundwater levels are modest in the context of recent rain induced rises in groundwater levels.

Groundwater response during the drought and the recent period of high rainfall demonstrates the ongoing risk of high watertables and associated salinity impacts for irrigated areas within the Shepparton Irrigation Region. The Goulburn Broken CMA and DSE Sustainable Irrigation Program are funding the Shepparton Irrigation Region Salt and Water Balance Project to develop adaptive management arrangements for salinity mitigation across the range of wet and dry conditions experienced in the region (T. Hunter 2011, pers comm.). A similar project is commencing in the North Central CMA.

9. Summary

The hydrological analyses conducted as part of the PER (NVIRP 2010) clearly demonstrates that NVIRP will have negligible effects on the hydrology of the Goulburn River and the River Murray and will have almost no effect on the water regime in the Barmah Forest, Gunbower Forest, the Hattah-Kulkyne Lakes and other floodplain wetlands.

Climate change is expected to have a significant impact on river flows across northern Victoria. Dry flow conditions used in the modelling are analogous to conditions expected under a climate change future. Under both average and dry flow conditions NVIRP is predicted to result in only a very small change in river flow and level during the supplying period and in general no change during the spilling and storing period. Hence the additional impact of NVIRP over and above that predicted due to climate change is considered insignificant.

Similarly, NVIRP is expected to have minimal impact of groundwater levels and flows and river salinity levels across the GMID and the ecological effects are expected to be negligible.

All identified hydrological changes are expected to be very small and are unlikely to affect the established biota. The conceptual models presented in this report that describe the relationship between flow and different groups of biological indicators provide enough supporting information to be confident that the hydrological changes associated with NVIRP will not have any detectable effect on any groups of biota in the three study areas.

It is also concluded that the impacts of NVIRP are modest in the context of recent rain induced rises in groundwater levels.

These conclusions and the development and implementation of environmental watering plans for at risk wetlands and waterways confirm that the assessments and actions in response to the Minister's requirements under the EES decision are sound and reasonable.

9.1. Summary of response to the Minister's decision

This assessment report has been prepared to address the requirements of the Minister's decisions that an EES for NVIRP is not required. In particular, the report was required to assess the potential for a reduction of ecological values as a result of predicted flow changes derived from the implementation of NVIRP, with consideration of implications of climate change and cumulative influences within the catchment. Table 9-1 summarises the specific responses to the Condition 4 requirements and indicates the sections of the report where more detailed information can be found to support the conclusions of the assessment.

■ **Table 9-1 Summary of response to Condition 4 requirements.**

Condition 4 requirements	Summary	Response	Where addressed in the report for more detailed information
Identify the ecological values present, including any matters of national environmental significance (MNES) protected under the Environment Protection and Biodiversity Conservation Act 1999.	Values were assessed in the River Murray, Goulburn River and Barmah Forest Ramsar sites. All sites support a diverse range of habitats and plant and animal species that are of national, state and regional significance. Important habitats include river channels, permanent and temporary wetlands, including lakes, swamps, lagoons and flooded forests. These habitats provide sites for breeding, foraging and refuge for waterbirds, fish and frogs. Significant plant communities include River Red Gum Forest and Woodland, Black Box Woodland, Buloke Woodlands and grasslands. When flooded, the Barmah Forest provides one of Victoria's most extensive waterbird breeding sites for colonial nesting waterbirds. Wetlands also provide habitat for several migratory waders that are listed under international conventions. Rivers and wetlands provide habitat for native fish of national and state conservation significance, including Trout Cod, Murray Cod and Freshwater Catfish.	This report did not identify any site or matter of National Environmental Significance not addressed in the NVIRP's Public Environment Report, and associated documents.	Section 3.1 (River Murray) Section 4.1 (Goulburn River) Section 5.1 (Barmah Forest)
Assess the potential for reduction of ecological values as a result of the predicted flow changes derived from the implementation of NVIRP, with consideration of the implications of climate change scenarios and cumulative influences within the catchment. Detailed ecological	The NVIRP process addressed the potential for reduction of ecological values as a result of the predicted flow (surface and groundwater) changes derived from the implementation of NVIRP. Climate change is expected to have a significant impact on river flows across northern Victoria. Dry flow conditions used in the modelling are analogous to conditions expected under a climate change future. Under both average and dry flow conditions NVIRP is predicted to result in only a very small change in river flow and level during the supplying (irrigation) period and in general very little or no change during the spilling and storing period. It is also very unlikely that NVIRP will result in a change in the timing frequency, magnitude or duration of flooding and water events that inundate key floodplain and wetland habitats in the Barmah or Gunbower Forests or Hattah-Kulkyne Lakes. Groundwater levels are unlikely to be affected. NVIRP has taken into account the increase in groundwater levels as a consequence of recent rains and floods in making this assessment.	Changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable and that no impact on significant environmental values are expected. Changes in groundwater levels and flows at the sites investigated are negligible. Changes in river salinities would be too small to have any effect on ecological values. The additional impact over and above that predicted due to climate change is considered to be not significant. NVIRP will not affect any of the biological values that currently occur at the assessed sites. The impacts of NVIRP on groundwater levels are modest in the context of recent rain induced rises in groundwater levels.	Section 3.5 (River Murray) Section 4.5 (Goulburn River) Section 5.5 (Barmah Forest) Chapter 8 (Effect of recent rains)

Condition 4 requirements	Summary	Response	Where addressed in the report for more detailed information
predictions are not required.			
Identify residual sources of uncertainty.	Uncertainties related to the distribution of values at specific sites, hydrological modelling and the specific ecological response to water level change has been identified. The conceptual models presented in this report that describe the relationship between flow and different groups of biological indicators provide enough supporting information to be confident that the hydrological changes associated with NVIRP will not have any detectable effect on the groups of biota assessed in the three study areas.	The hydrological changes associated with NVIRP are unlikely to have any detectable effect on the groups of biota in the sites assessed. There are no areas of uncertainty that would affect the confidence in the overall conclusions that NVIRP will not have any detectable effect on any groups of biota in the three study areas	Chapter 6
Provide advice to the Minister for Environment and Climate Change, or a delegate, for consideration in future decisions on use of environmental water entitlements.	NVIRP will leave a strong environmental water management legacy. Implementation of NVIRP will provide up to 175 GL (long term annual average) of water for the environment. This water will be converted to an environmental entitlement which will be callable, tradable and able to be used to meet specific environmental needs at a number of sites. Environmental watering plans (EWPs) have been prepared by NVIRP for individual wetlands and waterways identified as at risk from NVIRP. EWP preparation has been guided by the Water Change Management Framework (WCMF). Development of an Environmental Infrastructure and localised groundwater assessments also address the risks associated with NVIRP implementation. NVIRP EWPs provide a sound basis for the development of full wetland management plans and determining watering priorities beyond the extent of a mitigation water obligation during NVIRP implementation. Preparation of WCMF documents has been overseen by a Technical Advisory Committee and an Expert Review Panel. Victoria has well developed processes for assessing and managing the salinity impacts of works and activities in line with the provisions of the Basin Salinity Management Strategy (MDBC 2001). In addition, regional processes involving CMA's and relevant agencies support these activities.	The Water Change Management Framework and associated practices can provide a rigourous basis for enhanced and adaptive environmental management of wetlands and waterways across northern Victoria. Any potential salinity and groundwater impacts of the use of environmental water entitlements should be managed through existing processes.	Chapter 7

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Appendix A Biological indicators and conceptual models

The Public Environment Report (NVIRP 2010) has considered the impacts of NVIRP at site specific locations and developed mitigation actions through the implementation of the Water Change Management Framework (NVIRP 2090) for areas identified at risk. The changes in surface-water hydrology and groundwater levels and salinity can be considered at a broader regional scale by relating the predicted changes to a likely ecological response.

We have reviewed a range of ecological indicators to determine whether they were suitable for assessing regional impacts of NVIRP operations on ecological processes and beneficial uses of aquatic systems in the study area and recommend a number of indicators which can be suitably used in the regional assessment. Details of the approach and justification for indicator selection have been provided in an earlier report for this project (SKM 2010). In summary, to be useful, an indicator had to meet most (preferably all) of the following criteria:

- Refer to an important ecological process or component, rather than merely ecological structure (i.e. not be based on taxonomic grounds alone);
- Be supported by a conceptual model with explicit links to altered hydrology, which could be used guide the prediction of likely impacts arising from NVIRP operations. If there was also a robust and readily available literature on ecological responses to a given hydrological perturbation, so much the better;
- Be able to be applied across a range of spatial scales, but especially at the regional scale required for this investigation, and via a desk-top risk analysis able to be undertaken with currently existing information;
- Where possible, complement prior investigations undertaken in NVIRP studies, as well as be linked with and inform on other components of the current investigation; and
- Be consistent with general approaches or specific methods commonly used in ecological studies, and with existing inventories and classification systems.

Our review of indicators and conceptual models has identified biotic and ecosystem/habitat indictors suitable for assessment where changes in hydrology can be related to changes in ecological condition. These indicators and the conceptual models that describe how each indicator is likely to be affected by hydrological changes are summarised below. Most of the conceptual models presented in this report describe links between a range of flow components and indicators. NVIRP will not necessarily affect all of the flow components described in those models and the regional assessment will only focus on the specific flow components and processes that are likely to be affected by NVIRP. More details about the selection of individual indicators and conceptual models are presented in the *Preparation of NVIRP regional assessments – method report* (SKM 2010).

A.1 Biotic Indicators

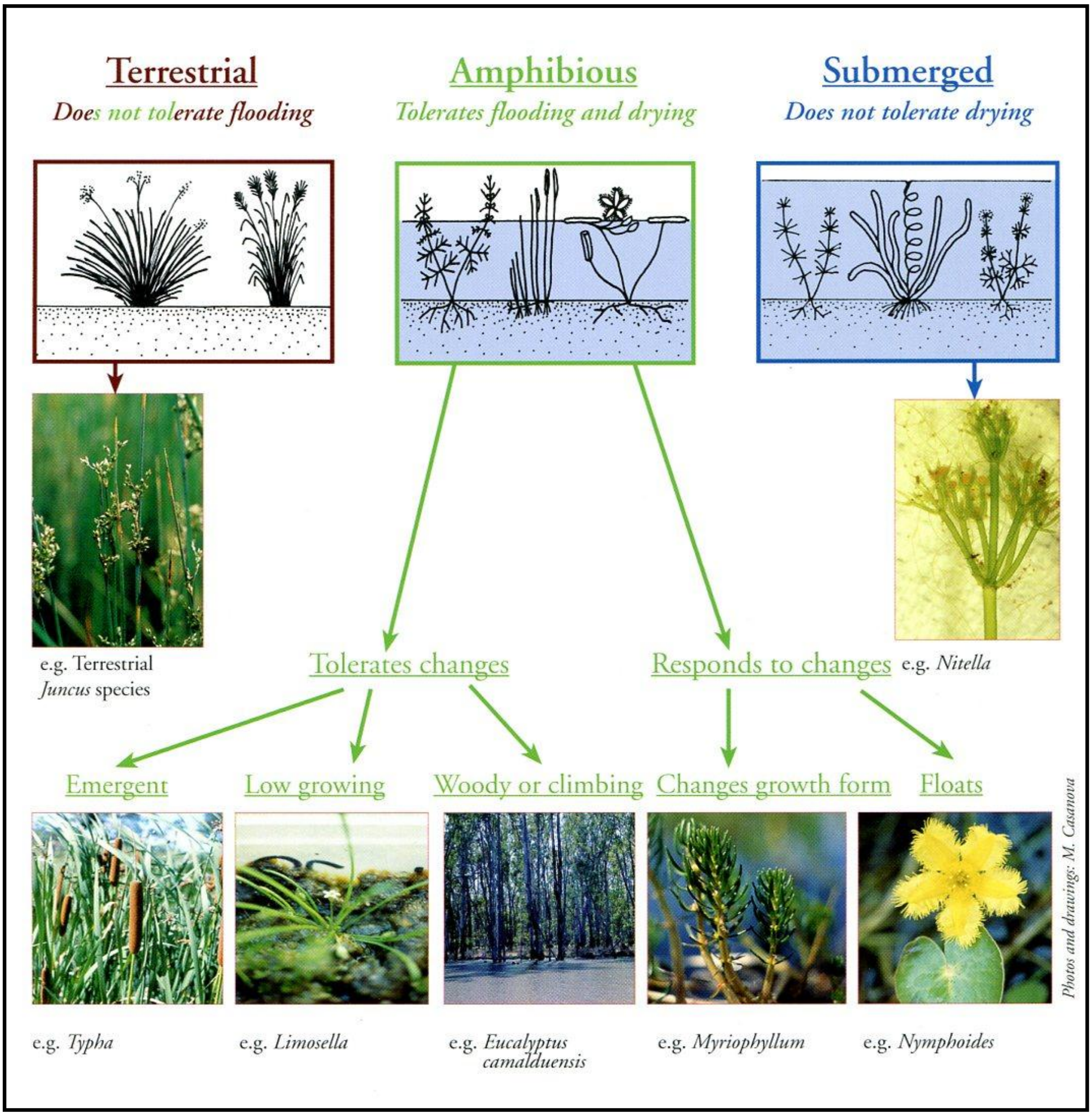
A.1.1 Vegetation as Plant Functional Groups (PFGs).

The method proposed for the current project is to analyse possible effects of NVIRP operations on vegetation in the study region in terms of large-scale vegetation groups that closely reflect ecological processes rather than the discrete taxonomic categories used in the earlier investigations. The recommended typology for the establishment of these broad vegetation units is the Plant Functional Group classification initially proposed by Brock and Casanova (1997) and revised by Leck and Brock (2000). Table 10-1 shows the range of Plant Functional Groups (PFG) in the Leck and Brock schema. For the purposes of this project, the three broadest groups are considered, which include Terrestrial, Amphibious and Submerged plants.

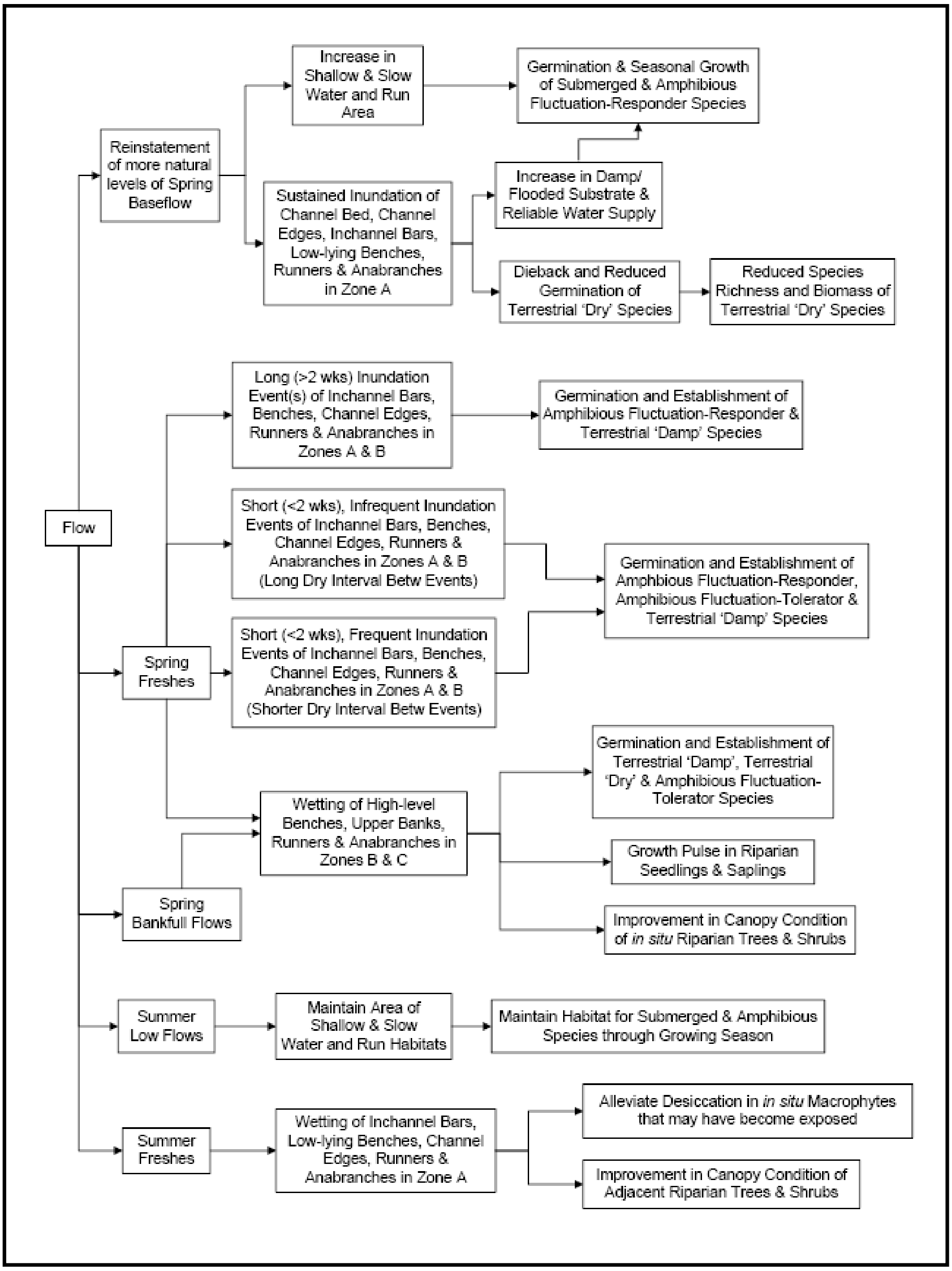
- **Table 10-1 Description of Plant Functional Groups according to Leck and Brock (2000).**

Functional group and abbreviation	Description
Terrestrial	**Species that do not tolerate flooding**
Dry species	Germination, growth and reproduction occur in the absence of surface water and where the water table is below the surface.
Damp species	Germination, growth and reproduction occur on saturated soil.
Amphibious	**Species that tolerate flooding and drying**
Fluctuation tolerator	Germination under damp or flooded conditions
Emergent	Basal portions under water and reproduction out of water
Low growing	Low growing and tolerate complete submersion
Vines	Vines
Trees and shrubs	Woody plants
Fluctuation responders	Germination under flooded conditions, growth in flooded and damp conditions, and reproduction out of water
Morphologically plastic	Heterophylly in response to water level variation
Floating leaves	Floating leaves when plant inundated
Submerged	**Species that do not tolerate drying**

There are two conceptual models that describe the relationships between hydrology and each of the three broad PFGs and are suitable for use in the proposed risk assessments. Figure 10-1 shows a generalised model to inform the basics of the subsequent risk analysis, and Figure 10-2 the detailed assessment. Note that Figure 10-2 is taken from the Victorian Environmental Flow Monitoring Assessment Program (VEFMAP) report for the Campaspe River (Chee *et al.* 2006). Only parts of the conceptual model shown in Figure 10-2 are relevant to NVIRP operations (e.g. for those hydrological components expected to change), but the whole model is shown for completeness.



- **Figure 10-1: Generalised response of different Plant Functional Groups to altered water regime (Source: Brock and Casanova 2000, page 4).**



- **Figure 10-2: Conceptual model of detailed response of different Plant Functional Groups to altered water regime (Source: Chee *et al*. 2006, page 29).**

The risk assessment will use the conceptual models to consider whether the expected hydrological changes associated with NVIRP are likely to adversely affect or benefit terrestrial, amphibious or submerged plant groups in any of the waterways, wetlands or complexes of interest. The assessment can be conducted at any spatial scale that is relevant to the project (e.g. individual wetland, river reach or wetland complex) and can consider whether NVIRP operations are likely to result in a shift across PFGs at a given spatial scale.

The use of these conceptual models allows predictions, which may be used as a foundation for future monitoring. For example, if NVIRP operations were predicted to decrease fluctuations in water level, the PFG approach would predict a decrease in the relative abundance of Amphibious *Fluctuation Responder* plants. If a permanently inundated wetland was expected to dry out for some of the time as a result of NVIRP, then we would predict Submerged plants to disappear or contract to small areas that remain damp.

A.1.2 Birds

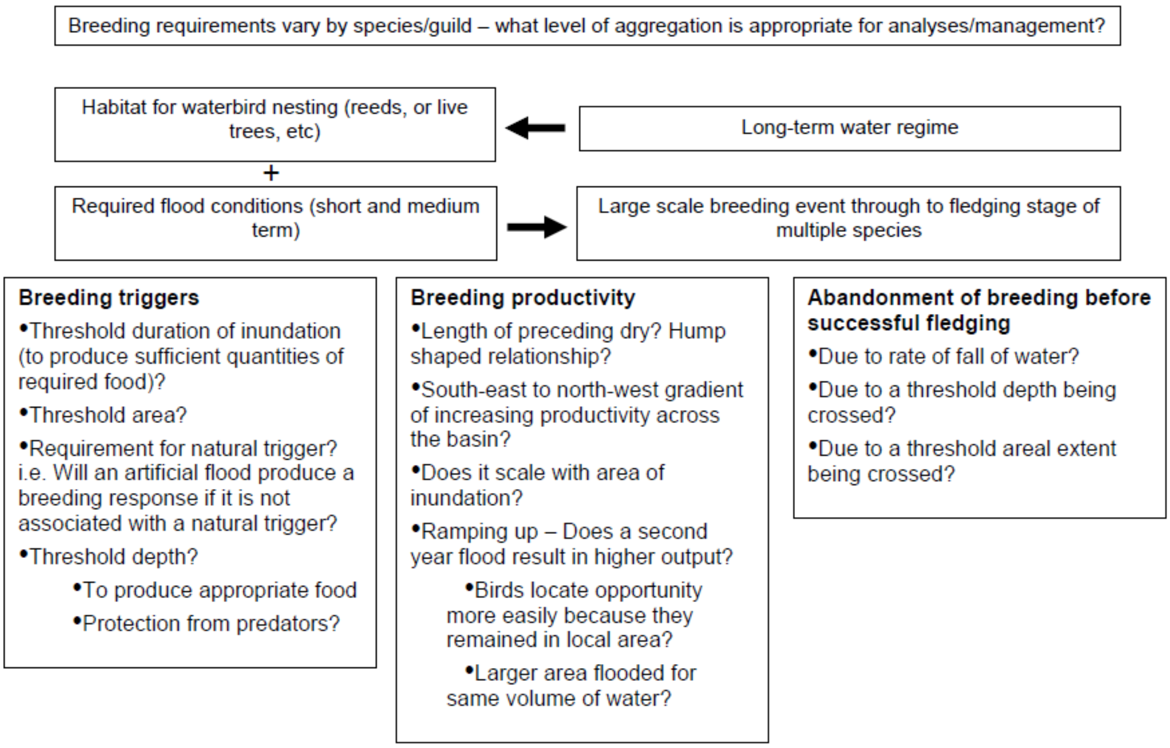
There are a number of ways to group bird taxa into broad groups that could be used in the current investigation. For the purposes of the current project, it is recommended that the simple two-way classification employed in The Murray Flow Assessment Tool (MFAT) be used. In this schema, the two groups of interest are i) colonial nesting waterbirds; and ii) waterfowl and grebes. Colonial nesting waterbirds include taxa such as ibis, egrets, herons and spoonbills. They are common throughout south-east Australia and are an important component of the Ramsar listing of many wetlands sites. Waterfowl and Grebes include teal, duck, shoveler and grebe. Many respond rapidly to flooding. In both cases, there is good information on their responses to altered water regimes (e.g. see Young et al. 2003).

Detailed conceptual models that explicitly describe the relationship between these two groups of waterbirds and hydrology have not been developed and empirically tested, but Reid *et al.* (2009) described six main links between sustainable waterbird communities and water regimes:

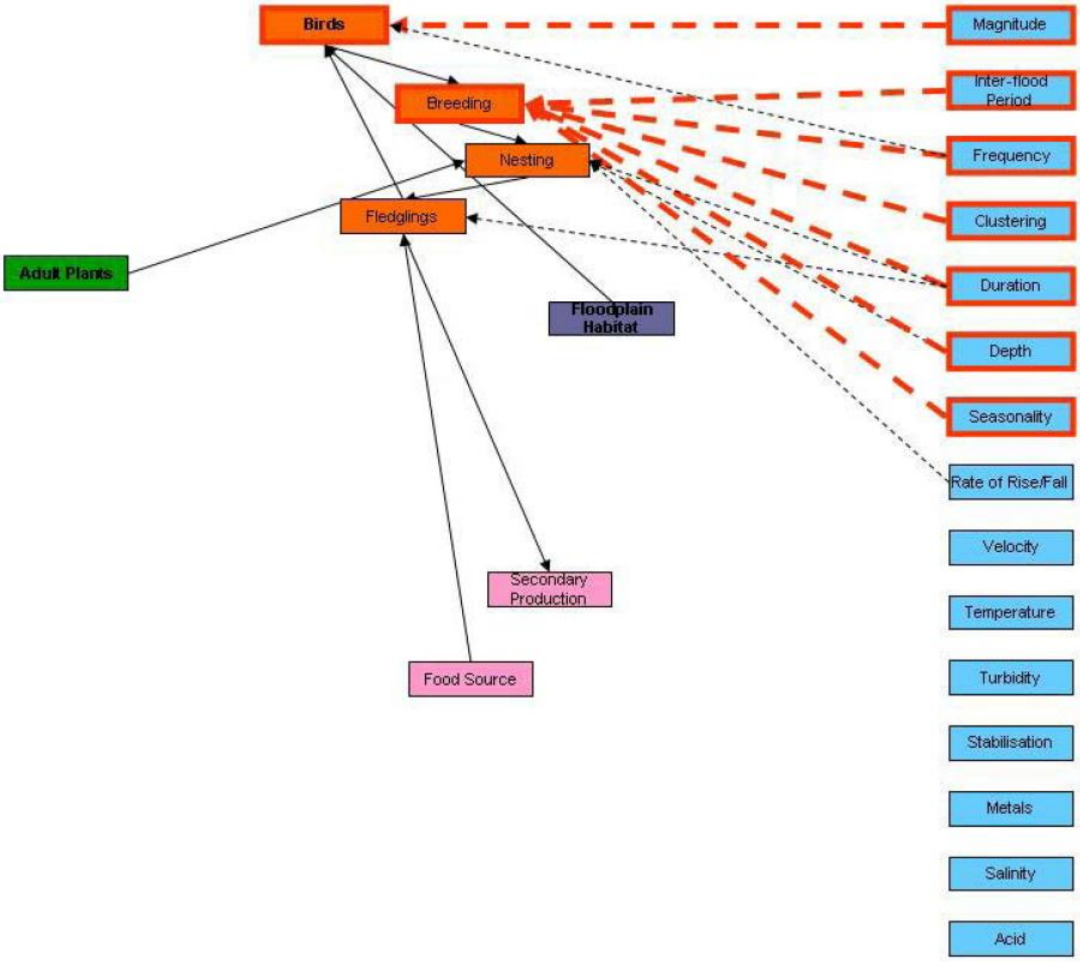
- Waterbird assemblages are dynamic due to individual's (varying) mobility – hence they are open systems;
- Lateral connectivity is important – there are numerous connections (flow paths) between the river and its floodplains and wetlands;
- The most productive (feeding) wetlands are shallow and recently dry – fluctuating water levels increase productivity;
- A broad range of physical wetland and vegetation types is required to maximise assemblage diversity and provide nesting habitat for most species;

- For successful fledgling of most nesting waterbird species to occur, a shifting spatiotemporal mosaic of wetland inundation patterns needs to occur over a lengthy period, e.g. 4-5 months (and occur at the appropriate time of year, i.e. spring for wetlands in the Southern MDB);
- These wetland mosaics need to be sufficiently large to a) support populations of a diverse range of waterbirds and b) sustain successful recruitment of most species in large floods.

These relationships are summarised in Figure 10-4 and Figure 10-5. There is also some excellent quantitative information on the likely response of both groups of waterbirds to changes in water regime (see http://www2.mdbc.gov.au/subs/information.mfat.waterbirds/zb_waterfowl.htm, internet resource viewed 9 March 2010) and McCarthy *et al*. (2006) provide useful and spatially relevant information on water-regime requirements of colonial nesting waterbirds for the Barmah forest.



- **Figure 10-3: Hypothetical relationships between breeding responses and flow regimes for colonial nesting waterbirds (source: Reid *et al*. 2009, page 126).**



- **Figure 10-4: Conceptual model of the major components of waterbirds that relate to aspects of flow regime (source: Overton *et al*. 2009, page 403).**

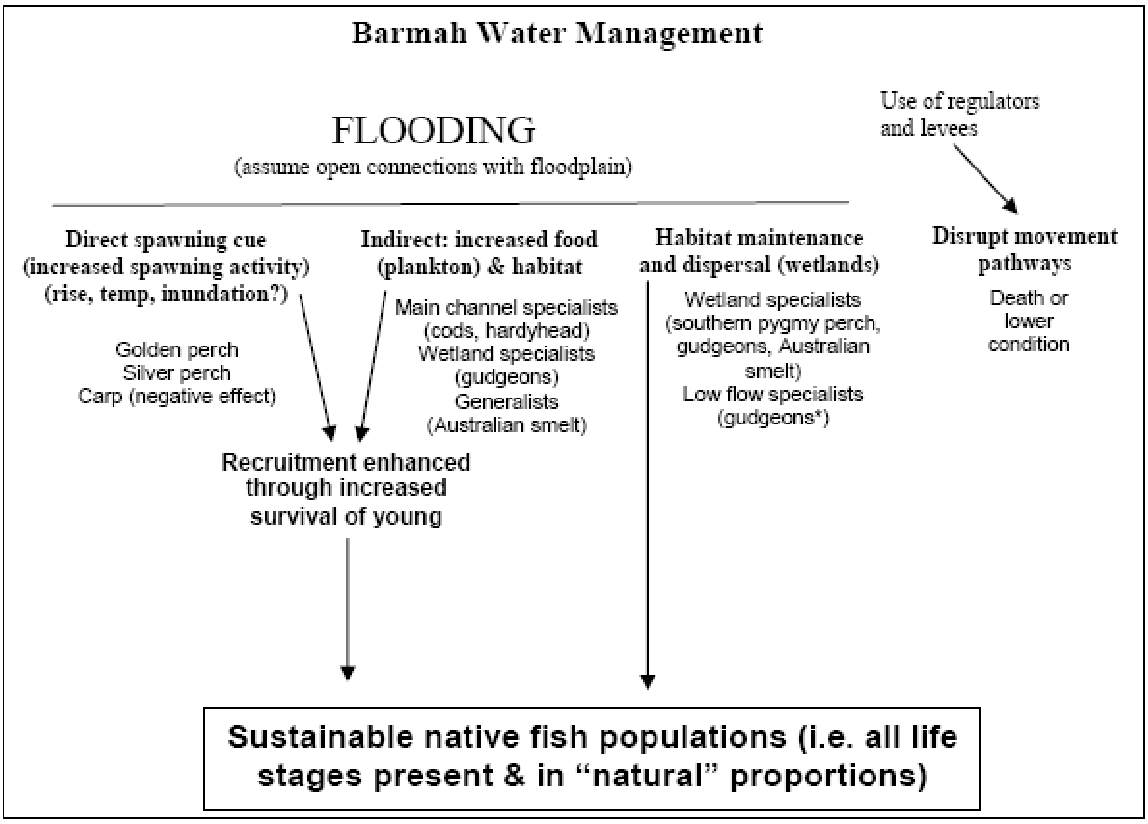
A.1.3 Fish

As with vegetation and birds, it is inappropriate to undertake the regional analysis of the effect that NVIRP is likely to have on fish on a species-by-species basis. Instead, fish will need to be categorised into a manageable number of groups, and likely impacts on those groups examined. King (2002) recognized six broad categories of fish in the Murray-Darling Basin:

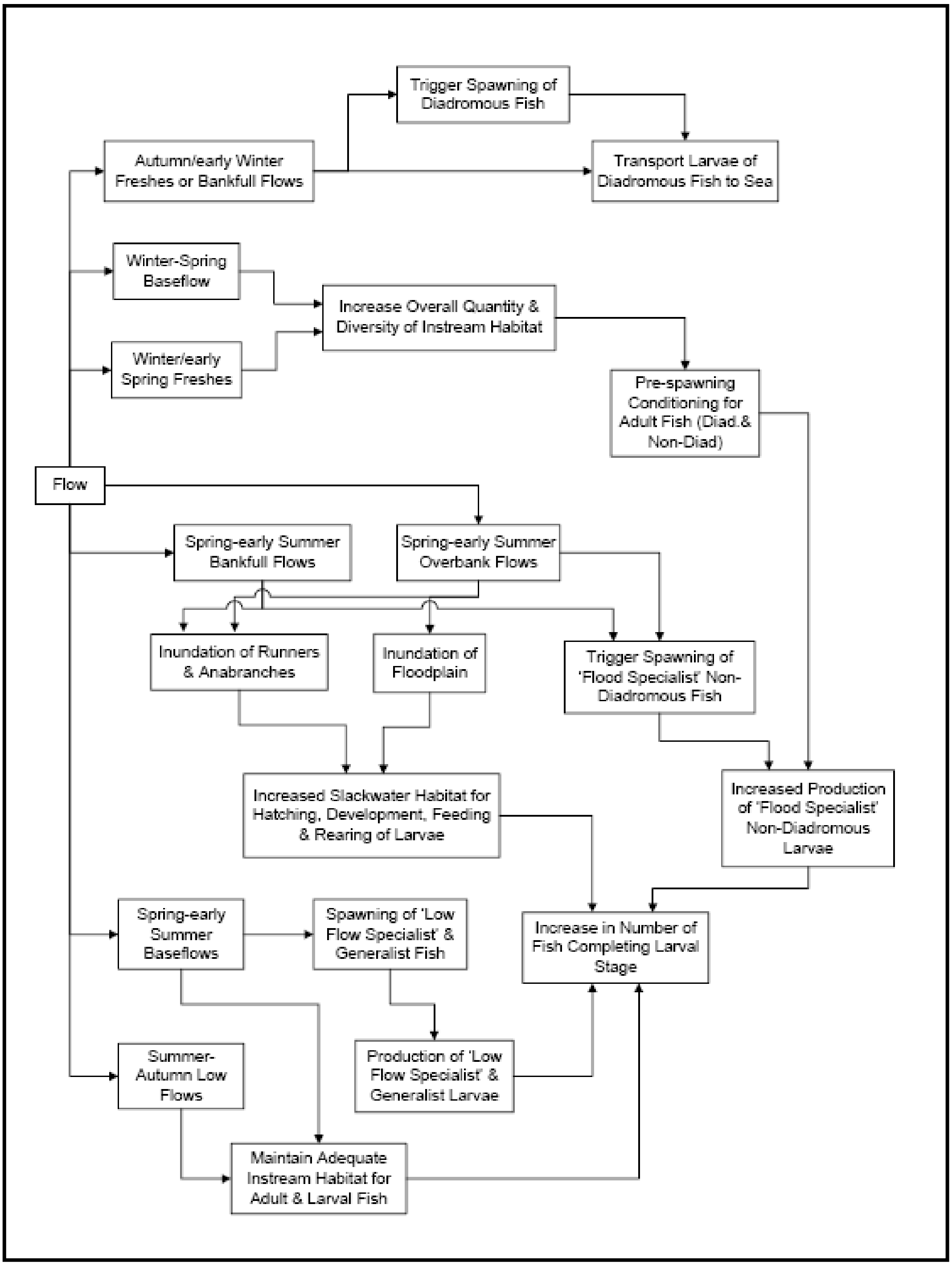
- Flood specialists (e.g. Golden Perch, Silver Perch);
- Flood opportunists (e.g. Carp);
- Low-flow specialists (e.g. Carp Gudgeons, Mosquito Fish);

- Generalists (e.g. Australian Smelt, Flathead Gudgeon);
- Main-channel specialists (e.g. Murray Cod, Trout Cod, River Blackfish); and
- Wetland specialists (e.g. Carp Gudgeons, Australian Smelt, Southern Pygmy Perch).

McCarthy *et al.* (2006) presented a simple conceptual model that describes potential hydrological impacts on these six categories of fish (Figure 10-5). Chee *et al.* (2006) developed a more detailed conceptual model that describes the response of some of these fish categories to changes in specific flow components (Figure 10-6).



- **Figure 10-5: Conceptual model of impact of flow on fish communities in the Barmah Forest (source: McCarthy *et al*. 2006, page 16).**



- **Figure 10-6: Conceptual model for effect of flow on fish spawning and recruitment (source: Chee *et al*. 2006, page 34).**