Koondrook-Perricoota Forest Flood Enhancement Works

Appendix D
Hydrology Assessment

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NSW Office of Water

Forests NSW

Report for Koondrook-Perricoota Forest Flood Enhancement Works

Hydrology Desktop Review

February 2010

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Introduction

1.1 Purpose of this Report

The NSW Office of Water and Forests NSW propose to undertake the Koondrook-Perricoota Forest Flood Enhancement Works Project (referred to in this report as 'the project'). This report has been prepared to provide an assessment of the potential impacts of the project on hydrology, as an input to the environmental impact assessment being prepared in accordance with the requirements of Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

The report addresses the requirements of the Director-General of the NSW Department of Planning (the Director-General's Requirements) dated 22 May 2009 relating to assessment of potential impacts on hydrology. These requirements include the following:

- Outline how the proposed works, operating under the proposed operating regime would affect the natural physical, chemical and biological processes of the Koondrook Perricoota Forest Wetland;
- Include a comparison between the hydrograph of natural floods that reach 78.5 mAHD on the floodplain and the hydrograph of the inundation to be generated by the proposed works (in terms of frequency and duration), so as to provide a clear description of the flooding regimes that will be introduced by the project and how they compare with the conditions experienced during the natural flood; and
- Assess the impact of changed flooding regime on surrounding land use.

1.2 Project Overview

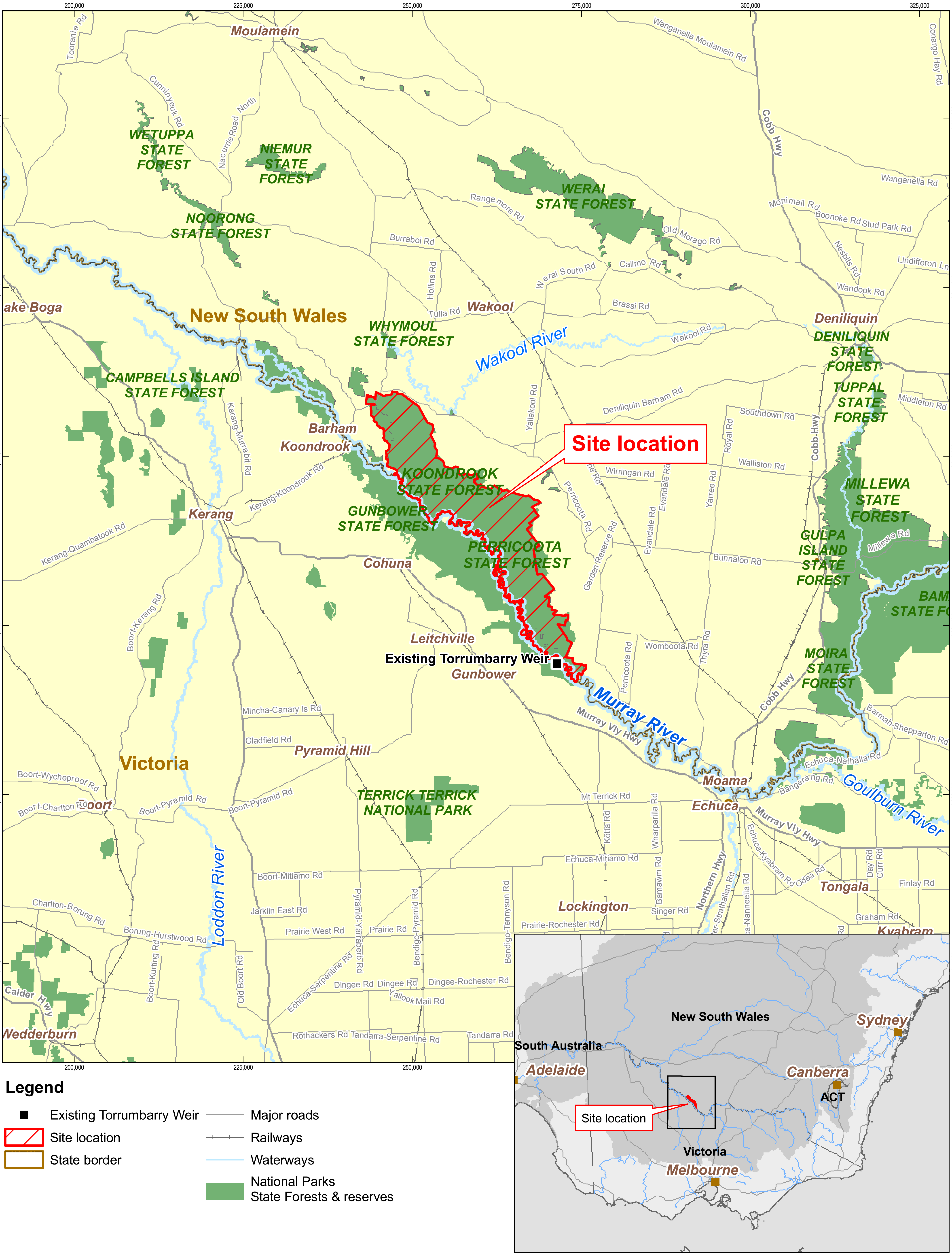
1.2.1 Project Inception

The Living Murray Environmental Works and Measures Program aims to design and build infrastructure works at Icon sites that enhance the environmental outcomes achieved from the use of environmental water. These works include regulating structures, water delivery channels and fishways. The program represents approximately $270 million of investment and is due to be completed in 2012.

1.2.2 Location

The Gunbower-Koondrook-Perricoota Forest covers an area of around 50 000 ha and is located downstream of Torrumbarry Weir on the Murray River, between Moama and Barham. The project is to be located within the Koondrook-Perricoota Forest which forms the component of the forest located on the northern or NSW side of the Murray River. The Koondrook-Perricoota component of the forest (the Forest) covers an area of approximately 32 000 ha.

The project location is shown in Figure 1.



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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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NSW Office of Water
Koondrook-Perricoota Flood Enhancement Works

Job Number 21-18573
Revision B
Date 09 DEC 2009

Figure 1 Location of the project

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Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Data source: StreetMap - Navegate, Drawn: Cwilson

1.2.3 Key Features of the Project

The flow regime of the Murray River in the vicinity of the Forest has been significantly altered as a consequence of construction of a number of large reservoirs upstream of the Forest and utilisation of stored water for irrigation and other purposes over the past 150 years. Compared to natural conditions, there has been a significant reduction in the frequency, duration and extent of flood events in the Forest. The proposed Koondrook-Perricoota Forest Flood Enhancement Works have been designed to reinstate a more natural flood regime to Koondrook-Perricoota Forest, as this is critical to improving forest health. Watering objectives are described in Section 4.1.

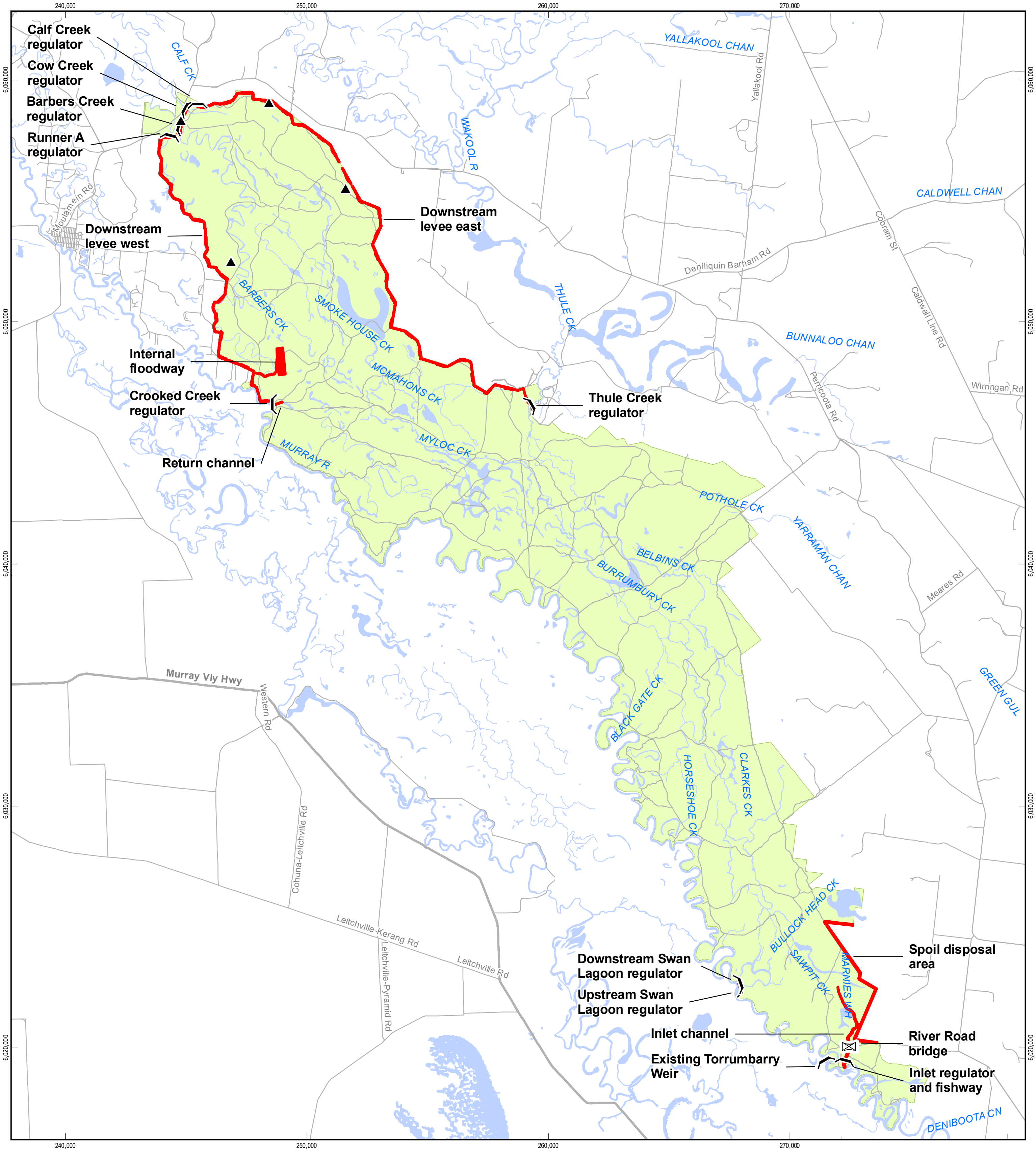
The project involves the construction of a diversion channel and engineering structures to divert environmental flows from the Murray River to the Koondrook-Perricoota Forest. The scheme would be operated so as to mimic a natural flood regime and, as such, has been designed to allow regular flooding of the Forest.

The project is described in Section 4.2 and is summarised as:

- Upstream structures to allow diversion of water into the forest from the Torrumbarry Weir pool, and regulators at Swan Lagoon to prevent flows re-entering the Murray River; and
- Downstream structures to control water leaving the Forest and to maximise return flows back to the Murray River. These structures include a return channel to discharge flow back to the Murray River and a floodway to increase water returns to the Murray River. Regulator structures are required to control the flow of the water from the downstream end of the Forest to existing waterways. A levee generally located around the downstream perimeter of the Forest would connect the regulators and will retain water within the Forest and protect adjoining land from flooding.

The locations of engineering works and other relevant points of interest are shown in Figure 2.

The new works will enable water to be diverted from the Torrumbarry Weir pool for a range of Murray River flows from flows less than the exiting bankfull discharge to discharges slightly above bankfull. The works would not be operated to increase flows through the Forest during moderate to large overbank flooding events. Details of the proposed operating regime are provided in Section 4.3.



Legend

- ▲ Turkey's nest dam
- River Road bridge
- Regulator
- Construction features
- Roads
- Waterway
- Koondrook Perricoota Forest Site

0 1 2 4
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Koondrook-Perricoota Flood Enhancement Works

Figure 2 Location of the main structures

Job Number	21-18573
Revision	C
Date	01 FEB 2010

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Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Data source: Dept of Commerce, Street Map- Navtec, Drawn: Cwilson, cwilson

1.3 Basis of Assessments

This report is intended to provide technical support for the Environmental Assessment (EA) prepared for the Koondrook-Perricoota Flood Enhancement Works under Part 3A of the NSW EP&A Act. All assessments undertaken have been based on the available information provided in the following key background investigations and studies:

- Koondrook-Perricoota Forest Flood Enhancement Project – Hydraulic Modelling, NSW Department of Environment and Climate Change, 2008;
- Hydraulic Capacity of Barbers Creek Downstream of Koondrook-Perricoota Forest, NSW Department of Commerce, 2008;
- Koondrook-Perricoota MIKE Flood Modelling, DHI Water and Environment, 2008;
- Koondrook-Perricoota Forest Flood Enhancement Works – Preliminary Environmental Assessment, Part 3A Application, NSW Department of Water and Energy, 2009;
- Koondrook-Perricoota Forest Flood Enhancement Works – Investment Proposal, NSW Department of Water and Energy, 2008;
- Koondrook-Perricoota Forest Flood Enhancement Works – Preliminary Operating Plan, NSW Public Works, 2009; and
- The Living Murray Works and Water Modelling – Stage 2 Draft Report, MDBA, 2008.

The analyses and interpretations prepared by GHD in this report have also been supported, where relevant, by other literature as referenced throughout the report.

1.4 Report structure

The report structure is set out as follows:

- Section 1 – Introduction;
- Section 2 – Background Information and Context;
- Section 3 – Development of the Project;
- Section 4 – The Project;
- Section 5 – Impact Assessments; and
- Section 6 - References.

2. Background Information and Context

2.1 Murray-Darling Basin

2.1.1 Basin Description

The Murray-Darling Basin (MDB) comprises the catchment of the Murray and Darling Rivers and their many tributaries, extending from north of Roma in Queensland to Goolwa in South Australia. The MDB covers more than 1 million km^2 (one-seventh) of mainland Australia, including parts of Queensland, New South Wales, South Australia, Victoria and all of the Australian Capital Territory. The MDB is bounded by the Great Dividing Range in the south and east. The Darling River (and its tributaries) drains southern Queensland and northern New South Wales, crosses the Darling Plain and joins the Murray River at Wentworth. The Murray River and its tributaries harvest water from inland areas of southern New South Wales and northern Victoria. The Murray River dissects the Riverine Plain from east to west and flows to the Southern Ocean via the Lower Lakes system in South Australia. The Darling (2,740 km), the Murray (2,530 km) and the Murrumbidgee (1,690 km) are Australia's three longest rivers (CSIRO, 2008).

The Murray–Darling Basin Authority (MDBA) manages the Murray River system in close cooperation with state authorities to ensure reliable water supplies for all users. To regulate the River system, the MDBA has responsibility for the operation of a number of major structures, including Dartmouth and Hume reservoirs, Lake Victoria, Lake Mulwala, and Menindee Lakes, 13 locks and weirs, and five barrages.

2.1.2 Murray River System Description

The Murray River rises in the Australian Alps, between Mt. Pilot and Forest Hill on the New South Wales/Victorian border and flows 2,530 km to enter the Southern Ocean through Lake Alexandrina in South Australia. The southern bank of the Murray River forms the border between New South Wales and Victoria for 1,880 km of its length. Near its headwaters, the Murray River is augmented by waters diverted by the Snowy Mountains Scheme and is joined on the Victorian side by the Mitta Mitta River above the Hume Reservoir.

While the Snowy Scheme was designed to produce electrical energy, one of the objectives of the scheme was to mitigate the effects of drought on irrigated agriculture in NSW and Victoria. The Snowy Scheme collects and stores water, diverting it through trans-mountain tunnels and power stations and then releasing it west of the Snowy Mountains into the catchments of the Murray River (the southern Snowy-Murray Development) and the Murrumbidgee River (Snowy-Tumut Development), where it can be used for water supply, irrigation and environmental uses.

The Hume storage is the primary regulating storage operated by MDBA and is typically drawn down in the summer and autumn of every year (MDBC, 1998). Dartmouth Dam, located on the Mitta Mitta River, is the largest regulating storage in the Murray River system with a capacity of approximately 3,900 GL. The Dartmouth Dam storage is primarily used as a reserve storage to supplement the Hume storage in dry years or sequences of years (MDBC, 1998).

Between Lake Hume and Yarrawonga the major tributaries joining the Murray River are the Kiewa River near Albury and the Ovens River upstream of Yarrawonga Weir, which are both unregulated streams.

Yarrawonga Weir is the point of greatest diversion of water from the Murray River. The two main irrigation channels are the Mulwala Canal and Yarrawonga Main Channel. The Mulwala Canal, on the New South Wales side, has a discharge capacity of about 10,000 ML/d. The Yarrawonga Main Channel, on the Victorian side, has a discharge capacity of 3,200 ML/d. These two channels serve a total area of over 8,000 km^2 in New South Wales and Victoria (MDBC, 2009a).

The next major tributary joining the Murray River downstream of Yarrawonga Weir is the Goulburn River, upstream of Echuca. In the low lying areas of the Barmah-Millewa Forest to the east of Echuca, the river has developed a number of anabranches and distributaries, with those in the south returning to the river in a comparatively short distance, while those to the north flowing into the Edward River system and returning to the main system via the Edward and Wakool Rivers some 200 km downstream. During large floods, the majority of river flow will flow north at the Barmah-Millewa Forest into the Edward–Wakool systems, with the remainder of flood waters flowing south along the Murray River.

The Barmah Choke in the Murray River upstream of the Goulburn River confluence limits how much water can pass via the Murray River channel and is a major operational constraint for water deliveries during peak supply periods. Current investigations being undertaken by MDBC (2009b) are considering options to improve the targeted delivery of water to environmentally significant areas downstream of the Choke. The first phase of the study will assess the magnitude of the challenges associated with the Barmah Choke under current conditions and a range of possible future scenarios (MDBC, 2009b).

The next major reach of River is between Echuca and Swan Hill. In this reach, the Murray River is also joined by the Campaspe River below Echuca and further downstream by the Loddon River at Benjeroop and Avoca River at Swan Hill. The Koondrook-Perricoota Forest is located within the reach of the Murray River between the Campaspe and Loddon River confluences.

Torrumbarry Weir is located approximately 74 km downstream of Echuca and 133 km upstream of Swan Hill. The purpose of Torrumbarry Weir is to allow the diversion of flows for irrigation, particularly into the Cohuna, Kerang and Swan Hill areas of Victoria. The National Channel, which diverts into Victoria, carries water from the Torrumbarry Weir pool to farms in the adjacent areas (MDBC, 2009c).

Two major streams enter the Murray River between Swan Hill and Mildura, these being the return of the Wakool-Edward River anabranch and entry of the Murrumbidgee River. The Murrumbidgee River catchment is a major sub-catchment of the Murray-Darling Basin and covers an area of 73,400 km^2. The Murrumbidgee catchment is bounded on the east by the Great Dividing Range, and lies between the Lachlan Catchment to the north and the Murray Catchment to the south. The Murrumbidgee River flows for 1 600 km and includes 14 major dams and 8 large weirs. The Snowy Mountains Hydro Electric Scheme assists with regulating water flow and supplying the 10 000 km of irrigation channels (CRC, 2009).

Euston Weir is located downstream of Swan Hill near the townships of Euston (NSW) and Robinvale (Victoria). Euston Weir raises the water in the River Murray to a level so that it permanently inundates the Euston lakes; Dry Lake and Lake Benanee. Water is also pumped from the Euston Weir pool to supply the Robinvale Irrigation District in Victoria, private diverters in NSW and urban supplies (MDBC, 2009d). The Weir can also maintain adequately high water levels in the river for navigation and operation of the weir pool can be varied to regulate flows between Hume Dam and the South Australian Border.

The last significant reach of the river extends from Mildura to Goolwa in South Australia. There are eleven weirs/locks located in this reach of the River. The purpose of these weirs (and the associated locks) is to provide permanent navigation between the Murray Mouth and Mildura, provide a relatively constant pool level to facilitate pumping for irrigation and water supply; and at Weir 9, water levels are raised to allow gravity diversion to Lake Victoria. Lake Victoria is operated as part of South Australia's water supply. Lake Victoria plays a key role in managing the flows in the entire Murray River. During periods of peak demand, water is re-regulated through Lake Victoria for later release to supply flows to South Australia. Without Lake Victoria it would be necessary to restrict demands upstream of Lake Victoria to ensure South Australia receives its entitlement.

The Darling River, which includes the Menindee Lakes system, is the last major tributary of the Murray River system. The Menindee Lakes storages consist of four large natural lakes (Wetherell, Pamamaroo, Menindee and Cawndilla) and several smaller interconnecting lakes. The purpose of the storages, was to secure water for the townships of Broken Hill, Menindee and Pooncarie, provide water for irrigation and farm supplies in the Lower Darling River downstream to Wentworth, meet stock and domestic requirements along the Great Darling Anabranch as well as supplementing resources of the Murray River system, including the supply of water to South Australia (State Water, 2009). The Menindee storage holds approximately 2 000 GL.

The Lower Lakes, Coorong and Murray Mouth Icon Site extends over approximately 140,000 ha, covering 23 different wetlands types, from very fresh to saltier than the sea. The Coorong is 140 km long and ranked among the top six waterbird sites in Australia, based on the diversity and number of species found there.

2.2 Water Resource Management

2.2.1 Basin Plan

The Basin Plan currently under development by the MDBA will be a strategic plan for the integrated and sustainable management of water resources in the Murray–Darling Basin. The first Plan is due for completion by mid 2010 (MDBC, 2009d).

The Basin Plan will be based on the best and latest scientific, social, cultural and economic knowledge, evidence and analysis. In preparing the Plan, the MDBA will consult extensively with MDB state and territory governments, key stakeholders, and rural and regional communities across the MDB. In the future, as new information and knowledge becomes available, the plan will be reviewed and revised, and will continue to evolve as it is implemented.

The plan will seek to protect and restore key environmental assets, such as rivers, streams, wetlands, forests, floodplains and billabongs, and key ecosystem functions. These are essential to the life of the rivers and their surrounding landscapes, as well as to human activities and cultural values. The Basin Plan must also take into account the impact of this protection and restoration on individual communities, industries, regions and the wider economy.

The Basin Plan will be complemented by water resource plans prepared by MDB states and provided to the Commonwealth Minister for accreditation. It will also play an important role in identifying responsibilities for managing risks related to reduced water availability and changes in reliability of supply.

2.2.2 The Living Murray Initiative

The Living Murray Initiative (TLM) was established in 2002 in response to concerns about the declining health of the Murray River system. It is a partnership of the Australian, NSW, Victorian, South Australian and ACT governments. TLM is Australia's most significant river restoration program and it aims to achieve a healthy working Murray River system for the benefit of all Australians. This includes returning water to the River's environment.

The program focuses on recovering 500 GL of water for the Murray River along with improving the environment at six icon sites. The icon sites, chosen for their high ecological, cultural, recreational, heritage and economic value, are:

- Barmah-Millewa Forest;
- Gunbower-Koondrook-Perricoota Forest;
- Hattah Lakes;
- Chowilla Floodplain and Lindsay-Wallpolla Islands;
- Lower Lakes, Coorong and Murray Mouth; and
- River Murray Channel.

2.2.3 Water Availability

It is proposed that water for the Project will be sourced from a portfolio of water accounts comprising Commonwealth Water, NSW Environmental Water, TLM Water and Unregulated Flows.

Commonwealth Water will comprise water entitlements that the Commonwealth is currently acquiring through the *Restoring the Balance in the Basin Program* (DEWHA, 2009a) and *Sustainable Rural Water Use and Infrastructure Program* (DEWHA, 2009b). The role of the Commonwealth Environmental Water Holder is to protect and restore the environmental assets of the Murray-Darling Basin for which the Commonwealth is currently developing a long-term framework for prioritising environmental watering actions (NSW Public Works, 2009).

Water Sharing Plans are currently used in NSW for managing NSW's water resources. The environmental rules within the water sharing plans are designed to limit total extractions on water use and provide for flow regimes in river systems which replicate natural flow patterns.

The TLM water is based around returning an average annual volume of 500 GL of water to the Murray River system, based on historical climate conditions. The TLM water will include a range of different entitlements with different use provisions, including the ability to call upon regulated water from storages and carry un-used water over from one year to the next.

2.2.4 Environmental Management Plans

For each Icon site, environmental management plans (EMP) have been developed to identify the water needs and to provide a framework for the delivery and management of environmental flows. The wetlands and floodplains of the Icon sites were watered naturally when significant rainfall in the tributary catchments increased flows in the Murray River system, and the river overtopped its banks. River regulation, water resource use and more recently, severe drought have all acted to significantly reduce the frequency of overbank flooding and most of the icon sites are now severely stressed.

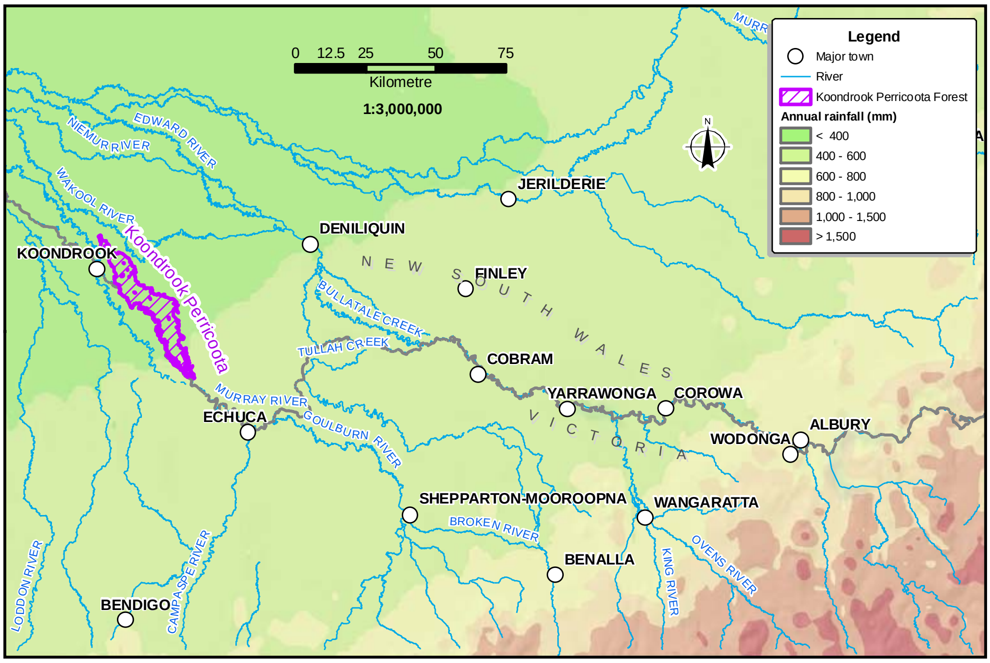
The Living Murray Environmental Works and Measures Program is developing and implementing projects that will direct water to the wetland and forest ecosystems without the dependency on natural high flows or floods. This will enable watering of the ecosystems at the scale, frequency, timing and duration required to achieve environmental objectives (DWE, 2009). As part of the planning process various works and measures have been identified to meet the varying ecological needs and unique characteristics of each site.

2.3 Description of Koondrook-Perricoota Forest Icon Site

2.3.1 Climate

Rainfall varies considerably across the Murray River catchment. While the mean annual rainfall in the mountainous eastern upper reaches is as high as 2,000 mm, the rainfall reduces to between 300 and 400 mm/year along the middle and lower reaches of the Murray River catchment. Figure 3 shows the mean annual rainfall variation of the upper and middle Murray River catchments.

Figure 3 Mean annual rainfall

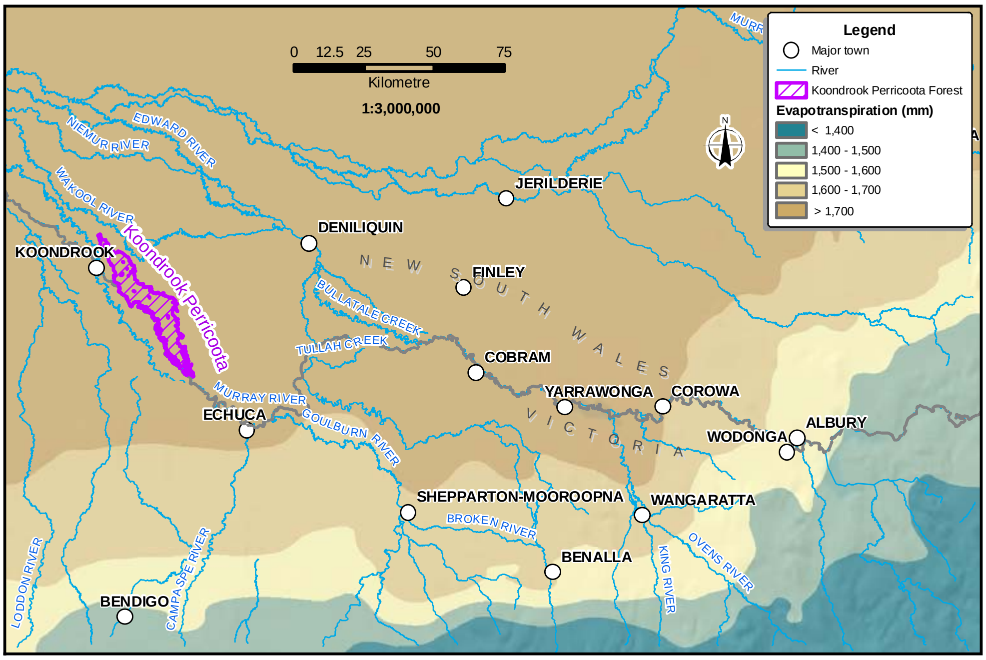


Source: Bureau of Meteorology (data period 1961 to 1990)

The average annual rainfall for the Gunbower-Koondrook-Perricoota site is approximately 390 mm. The highest average monthly rainfall is in October (40 mm) and lowest in December (20 mm) (MDBC et al, 2007).

Potential point evapotranspiration varies from around 1,200 mm/year in the eastern upper reaches of the Murray River catchment to more than 2 000 mm along the lower reaches and towards South Australia. Figure 4 shows the variation in mean annual evapotranspiration of the upper and middle Murray River catchments.

Figure 4 Mean annual evapotranspiration



Source: Bureau of Meteorology (data period 1961 to 1990)

It is clear that the Koondrook-Perricoota Forest is located in an area with relatively low rainfall and high evapotranspiration.

With regards to climate change impacts, CSIRO (2008) noted that there is considerable uncertainty in the potential changes in rainfall by 2030 and hence uncertainty in the resultant impact on runoff. Under the median 2030 climate scenario average annual rainfall is estimated to reduce by about 3% across the MDB and 5% in the southern MDB.

As a result of catchment processes, changes in rainfall would translate into proportionally greater changes to runoff. CSIRO (2008) indicated that the average annual runoff across the MDB would reduce by 9%, runoff in the north-east and southern parts of the MDB would be reduced by 5 to 10 % and by about 15 % in the southern-most areas of the MDB.

CSIRO (2008) did not consider climate projections beyond 2030. However, based on estimates for 2050 derived by extrapolation and for the median global warming scenario, an average annual reduction in runoff of 15% was adopted by CSIRO for the entire MDB and 17% for southern MDB.

CSIRO (2008) further indicated that the median climate becomes increasingly drier further into the future and by 2070 the median climate under high global warming is expected to be broadly similar to the dry extreme 2030 climate. This highlights the need for greater flexibility and adaptive capability in water resources management in the MDB.

2.3.2 Murray River Hydrology

The Gunbower- Koondrook- Perricoota Forest is subject to the influence of flooding from Murray River flood waters that leave and return to the river over the reach from a location in the vicinity of Torrumbarry (near Catfish Lagoon) to a location downstream of Barham/Koondrook. These flood waters are essentially uncontrolled or “out of control” waters and are not intentionally impacted by the Project. Accordingly, the Project will comply with relevant floodplain management legislation with respect to this uncontrolled flooding.

Upstream of Torrumbarry township, floodwaters are mostly contained within the natural banks of the Murray River. Smaller floods first leave the river channel over the right bank just downstream of Torrumbarry Weir at a location known as Swan Lagoon and possibly at other downstream locations near Horeshoe Lagoon, Black Gate Lagoon and Crooked Creek. At similar flow magnitudes, flows occur over the right bank into Gunbower Creek (regulated) and over the levee systems upstream and downstream of Torrumbarry Weir including near Baggotts Creek. With increasing flows, flood waters leave the river in other locations on both banks upstream of Torrumbarry weir. The frequency of overflows and the volume of water leaving the river in this reach are related closely to the combined flow of the Murray, Goulburn and Campaspe Rivers downstream of the confluence of these rivers. Although levee bank systems located on both sides of the river in this reach have existed for some time, no published information is available on their impacts on flooding magnitudes and frequencies in the Forest.

Floodwaters that leave the river over the right (north) bank create flooding in the Koondrook-Perricoota Forest and the larger floods inundate private lands upstream and to the north of the Forest. These floodwaters pass in a north westerly direction through the forest being reduced in flow rate by storage effects and in volume by seepage and evaporation. At a locality approximately 15 km upstream of Barham, a proportion of the remaining floodwaters in the Forest re-enter the Murray River depending on the relative heights of water in the River and the Forest.

Figure 5a illustrates the major waterways that operate during large floods such as the 1975 flood (1 in 15 to 1 in 20 years) including those upstream of the Koondrook Perricoota Forest. This Figure records that there are two mechanisms for flooding of the Koondrook-Perricoota Forest, these being a flooding pathway upstream of the Torrumbarry Weir and a flooding pathway downstream of Torrumbarry Weir. Figure 5b provides a more detailed schematic of flow paths in the vicinity of the Forest derived from topographic maps and interpretation of the satellite images. The proportion of flood waters that leave and re-enter the river in the larger reach is likely to vary in a complex way depending on the peak flow rate, duration and volume of Murray River floods. However, the net effects are illustrated by the comparison of Echuca, Torrumbarry and Barham Gauges at the top, middle and bottom of the reach of interest. Peak flows in 1993 in excess of 120,000 ML/d at Echuca were reduced to a total of approximately 73,000 ML/d downstream of the Forest, made up of 33,000 ML/d at the Barham Gauge and approximately 40 000 ML/d leaving the Forest into the Wakool system. The reduction in peak flow arises from a combined effect of attenuation as floodplain storage, losses to seepage and evaporation in the forests on both sides of the River and some net loss into Victoria. A detailed study of the fate of large floods is not available.

**Figure 5	Relationship between the Tributaries of the Murray River during the 1975 flood (Source: MDBC, 2002)**

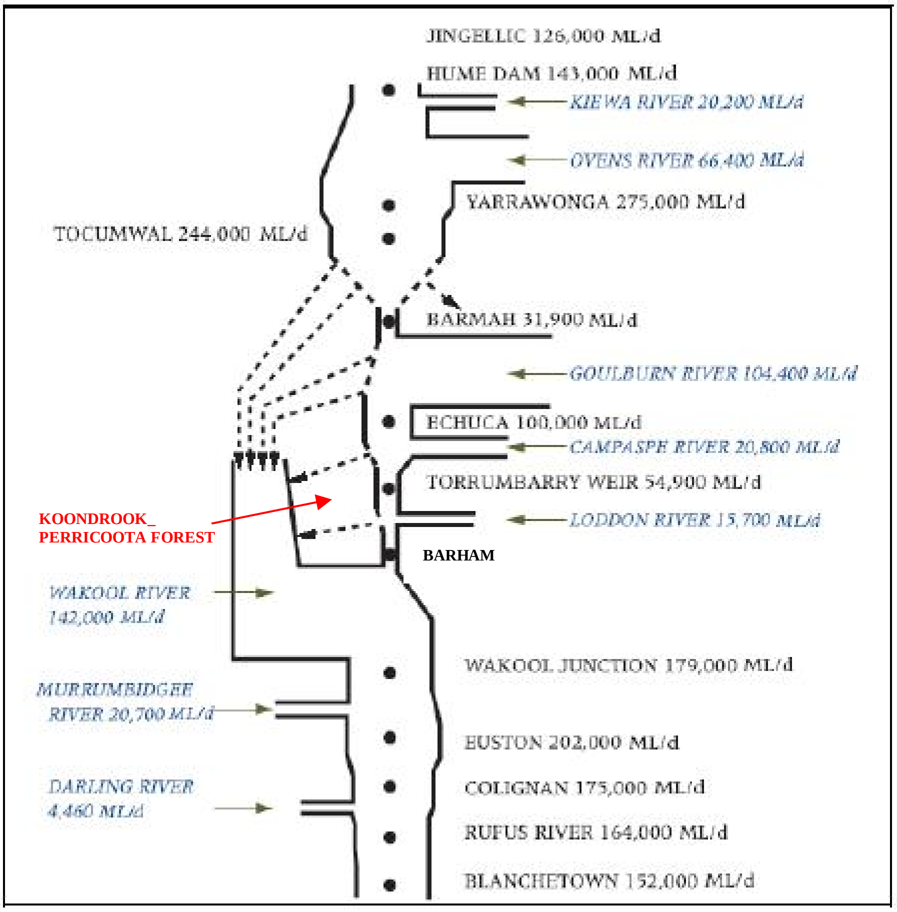
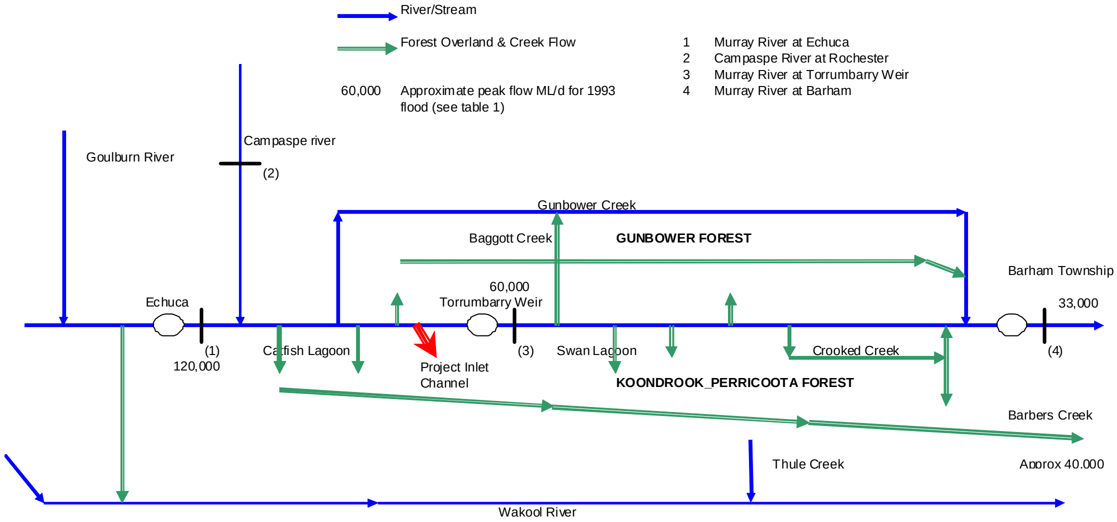


Figure 5b: Major flow paths in large floods



Flood maps such as those provided in WRC-NSW/RWC (1986) and Victorian Flood Data Transfer Project (DSE, 1999) show the extent of historical flooding and potential flooding under large floods within and adjacent to the Forest. This flood mapping shows that Barham Township is protected from large floods by levee systems and road embankments that commence approximately 5 km upstream.

It is important that these flooding systems and mechanisms be recognised in the planning and design of the Project infrastructure and the development of operating schemes. To comply with current floodplain management guidelines and policy the Project will have minimal impact on the historic flood frequency, extent and duration on private lands upstream, downstream and adjacent to the Forest.

There are a number of gauging stations along the Murray River in the general vicinity of the Koondrook-Perricoota Forest. These include the Murray River at Echuca (upstream of the Campaspe River confluence), Torrumbarry Weir (located at the south-eastern end of the Forest) and a flow gauge at Barham (located near the downstream end of the Forest).

Modelled streamflow sequences for these locations, extracted from the MSM-BIDMOD model were obtained from the MDBA which were . The MSM-BIGMOD modelling suite has been developed for simulating flow and salinity in the Murray Lower Darling river system. In this suite MSM and BIGMOD models are run sequentially to simulate water management decisions such as operation of storages, water accounting, resource assessment and irrigation demand computations on a monthly time-step by the MSM model while flow and salinity routing from downstream of Hume Dam to Murray Mouth is carried out by the BIGMOD model on a daily time-step. This flow data has formed the basis for this assessment. Although the derived flows are subject to modelling errors, they do represent a stationary record of flows without the trends caused by floodplain works, river regulation and water use.

Table 1 details the peak flood flows of historic floods at Echuca, Torrumbarry and Barham. It is evident from these peak flows that during moderate flood flows, similar to the 1991 event, a large proportion of the inflow into the Forest is derived from spilling downstream of Torrumbarry Weir. However, for large flood events on the Murray River, the floodwaters entering the Forest are significantly influenced by inflows that occur upstream of Torrumbarry Weir.

Table 1 Historic Flood Peaks in Murray River at Echuca, Torrumbarry and Barham

Year	River Murray at Echuca, u/s of Campaspe River Confluence[1]	River Murray at Torrumbarry[2] 409207	River Murray at Barham[2] 409005
1956	125 000	66 000	34 820
1974	91 500	59 300	32 200
1975	99 000	60 000	34 220
1981	109 500	57 500	33 700
1991		43 100	27 500
1993	121 000	60 000	33 100

Notes 1. at Gauge location 409200 but derived from modelled flow data from MSM-BIDMOD. 2 Based on gauged flow data.

Flood peak frequency analyses were undertaken for a number of sites. Table 2 details the flows for various recurrence intervals at Echuca, Torrumbarry and Barham.

Table 2 Average recurrence Interval of flood flows in Murray River at Echuca, Torrumbarry and Barham

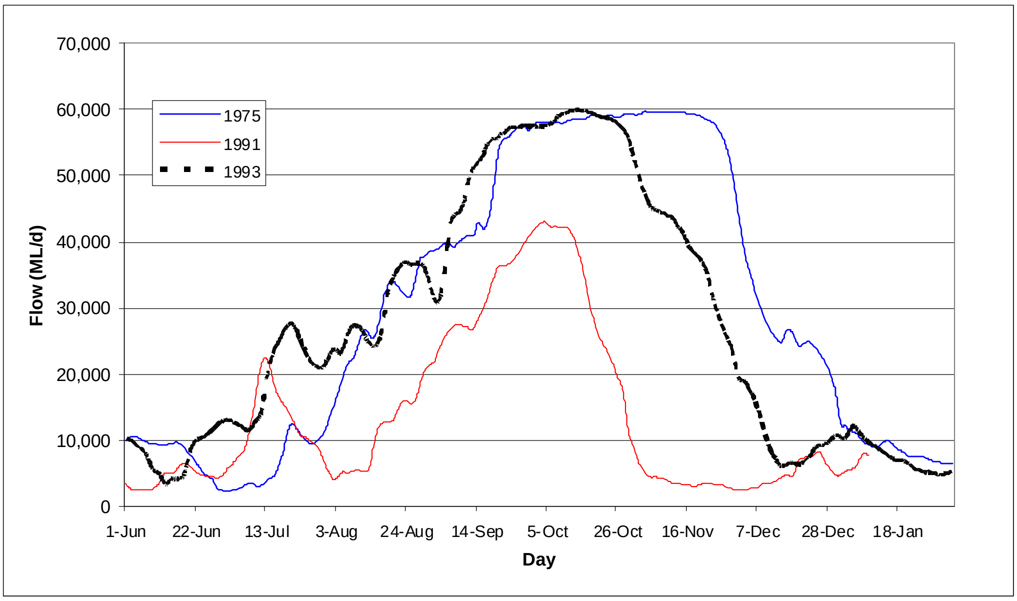
Annual Exceedence Probability	Average Recurrence Interval	River Murray at Echuca, u/s of Campaspe River Confluence[1]	River Murray at Torrumbarry[2] 409207	River Murray at Barham[2] 409005
AEP %	ARI	Flow (ML/d)	Flow (ML/d)	
50	1 in 2 years	33 000	45 000	25 000
20	1 in 5 years	58 000	55 000	32 000
10	1 in 10 years	79 000	60 000	35 000
5	1 in 20 years	102 000	61 000	37 000
2	1 in 50 years	135 000	63 000	38 000
1	1 in 100 years	163 000	65 000	39 000

Notes 1. Based on modelled flow data from MSM-BIDMOD. 2 Based on gauged flow data.

When comparing the recorded flood flows at Echuca and Torrumbarry (from Table 1) to the average recurrence interval (from Table 2) at these locations, it is evident that the flooding frequency of the upper Forest area is related to the frequency of flood flows at Echuca, whereas the flooding frequency of the lower forest area is related to the frequency of flood flows at Torrumbarry.

Furthermore, flooding extents of the Koondrook-Perricoota Forest are significantly impacted by flood volume. Figure 6 illustrates the flood hydrographs of three events on the Murray River.

Figure 6 Recorded Flood Hydrographs – Murray River at Torrumbarry Weir



In 1975, the flood hydrograph was characterised by the duration of the peak, which resulted in flows being sustained above 50 000 ML/d for a period of almost 3 months. For this event, flooding of the Forest occurred via inflow points both upstream and downstream of Torrumbarry Weir for extended periods.

In 1991, the peak flow at Torrumbarry was about 43 000 ML/d, therefore no flooding occurred via the Forest inflow point upstream of the Weir. The flow at Torrumbarry did exceed 18 000 ML/d, which is the threshold for inflows via Swan Lagoon, for a period of about 2 months.

2.3.3 Changes in Murray River Hydrology

The changes in the Murray River flow regime near Torrumbarry have significantly reduced water availability and hence the frequency, duration and magnitude of flooding of flood dependent communities like the Koondrook- Perricoota Forest.

Tables 3 to 5 illustrate the significant reduction in the frequency of flood events exceeding a range of threshold flows leading into the Koondrook-Perricoota Forest. For a flow of 20,000 ML/d, the frequency has reduced from 90% for modelled natural flows to 51% for modelled current day flows, a reduction of approximately 43%. A 50% reduction in flood frequency is estimated to occur under the 2030 median climate change scenario.

Table 3 Frequency of floods under different flow scenarios at Torrumbarry Weir

River Flow (ML/day)	Flood Count (% of years flow peaks above thresholds)		
	Natural	Current	Median Climate Change
18 000	95	66	61
20 000	90	51	45
25 000	87	44	34
30 000	76	35	28
35 000	65	28	18
40 000	55	23	12
50 000	45	16	9
57 000	23	5	3

Note flows at this location are affected by upstream effluents over the right and left banks of the Murray River

Table 4 Maximum period (years) between Murray River flows exceeding threshold flows d/s Torrumbarry Weir

River Flow (ML/day)	Years between floods above threshold flows		
	Natural	Current	Median Climate Change
18 000	4	4	6
20 000	4	4	9
25 000	4	9	9
30 000	4	9	10
35 000	4	10	10
40 000	4	10	13
50 000	4	13	13
57 000	13	38	38

Table 5 Average Annual Duration (Days) of Murray River flows exceeding threshold flows d/s Torrumbarry Weir

River Flow (ML/day)	Average Annual Duration (Days) flows exceeding threshold flows		
	Natural	Current	Median Climate Change
18 000	70	27	24
20 000	63	28	19
25 000	47	21	14
30 000	38	17	10
35 000	29	11	7
40 000	23	8	6
50 000	14	5	3
57 000	4	1	0

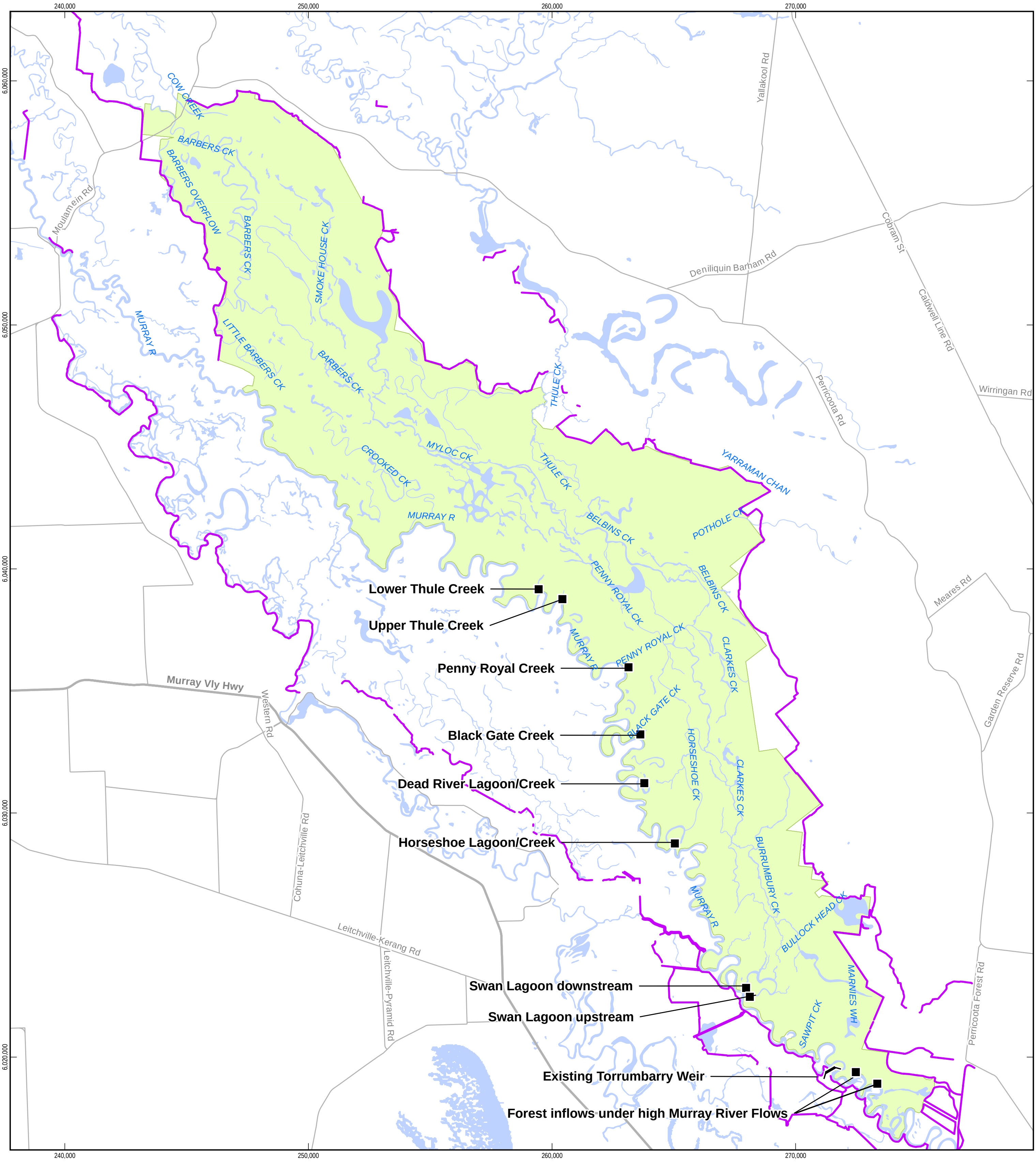
From the information provided in the tables above, it is evident that under current conditions, there has been a significant change in the frequency and duration of flooding compared to natural conditions, and that further negative impacts can be expected under the forecast climate change scenario.

2.3.4 Torrumbarry Weir

Torrumbarry Weir is located at the south-eastern most end of the Koondrook-Perricoota Forest and is a key structure in the design of a watering system for the Forest. Although not studied in detail, it is expected that the Weir has not had a significant impact on flooding of the Forest (GHD, 2006). However, Torrumbarry Weir does have significant potential to assist in Forest inundation due to its ability to raise River operating levels and due to its location at the highest point of the Forest.

2.3.5 Koondrook-Perricoota Forest Hydrology

The flow of floodwater through Koondrook-Perricoota Forest is dominated by the Burrumbarry-Barbers Creek system, sourced naturally from the Swan Lagoon on the Murray River just downstream of the Torrumbarry Weir. For the first 15 km the Forest system comprises well defined channels, which then break down into a myriad of smaller, interlinked runners. These runners cover an area of about 4 500 ha, before eventually joining together into several defined streams, the largest of which is the Myloc Creek. Myloc Creek, together with subsidiary runners, become the Barbers Creek. Figure 7 shows the main hydrologic features of the Forest.



Legend

- Regulator
- Inflow locations
- Existing levees
- Waterway
- Koondrook Perricoota Forest Site

1:150,000 (at A3)

0 1 2 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

GHD

CLIENTS | PEOPLE | PERFORMANCE

NSW Office of Water

Koondrook-Perricoota Flood Enhancement Works

Job Number 21-18573
Revision A
Date 10 DEC 2009

Figure 7 Main hydrology features in the forest

G:\21\18573\GIS\Arcview\Map_Documents\21.18573.Z040_Main_hydrology_features_in_the_forest.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Dept of Commerce, Street Map- Navtec, Drawn: Cwilson

During high Murray River flows (in excess of 50 000 ML/d upstream of Torrumbarry Weir) inflow into the Forest also occurs from the south-east boundary of the Forest, upstream of Torrumbarry Weir (Tuteja et al, 2008).

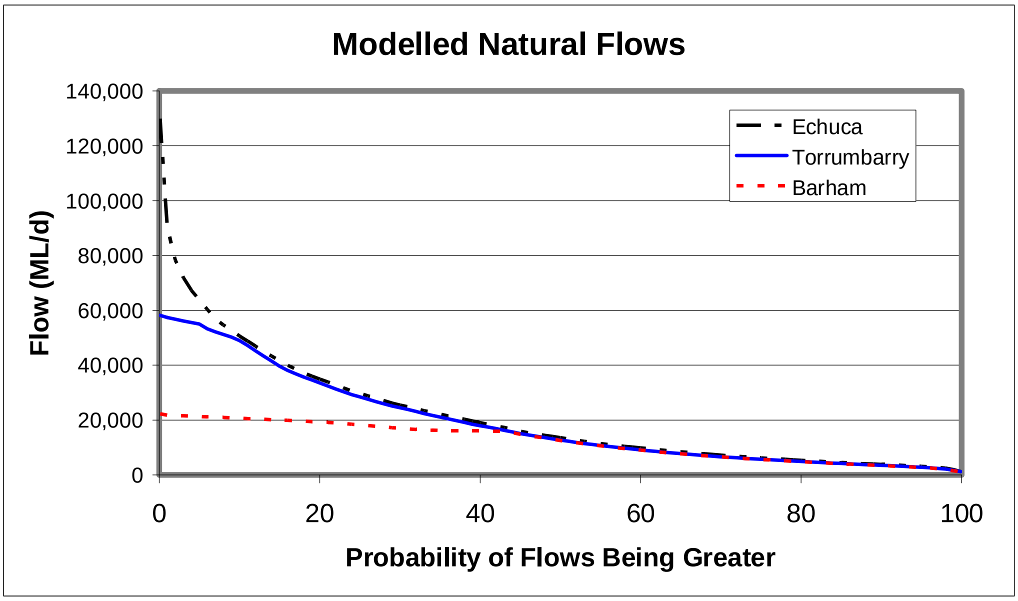
There are eight inflow locations where water can enter the Forest from the Murray River between Torrumbarry Weir and Barham and there are five inflow locations on the left bank of the Murray River that allows floodwater to enter the Gunbower Forest.

The primary flow points from the Murray River downstream of Torrumbarry Weir are located at Swan Lagoon. Swan Lagoon starts to flow when the flow in the Murray River is about 18,000 ML/d whilst the Borrumbury Creek system starts to flow when the flow in the Murray River is about 20,000 ML/d. There are a number of other small inflow points aside from Swan Lagoon.

Analysis of historic flow records shows that up to 46% of the peak flow at Torrumbarry Weir spills into the combined Gunbower-Koondrook Perricoota Forest (for flows of about 60,000 ML/d). Hydraulic Modelling (DECC, 2008) showed that for flows up to 40,000 ML/d, the flow split between the Gunbower and Koondrook Perricoota Forests was approximately 50%:50%.

The thresholds for flood flows entering the Forest are evident in flow duration curves of daily Murray River flows at Echuca, Torrumbarry and Barham for (modelled) natural conditions, refer Figure 8. This highlights the two key thresholds affecting flood flows into the Forest, by comparing the point at which the hydrographs depart from one another. A threshold at 50,000 ML/d is observed when comparing flows at Echuca and Torrumbarry and a threshold at approximately 18,000 ML/d is evident when comparing flows between Torrumbarry Weir and Barham.

Figure 8 Flow Duration – Murray River Natural Daily Flows



Flood extents for the 1991 and 1993 flood events have been provided in Appendix A. The peak flow at Torrumbarry Weir for these events were 43 000 ML/d and 60 000 ML/d, respectively. It is clear from the 1991 flood extent that there was no inflow to the Forest from the Murray River in the upper part of the Forest upstream of Burrumburry Creek (ie inflows from the River upstream of Torrumbarry Weir). However, the 1993 flood extent clearly shows significant inundation in the upper Forest upstream of the Torrumbarry Weir.

2.3.6 Existing Levees Around the Koondrook-Perricoota Forest

The existing levee systems of relevance to this Project can be described in three geographic areas as:

- Upstream of Torrumbarry Weir and the Forest;
- From the middle to upper Forest, north side; and
- Lower Forest, south sides.

Figure 7 shows the approximate alignment of these banks.

Upstream of Torrumbarry Weir

The upstream levees appear to be located on private land and are therefore private banks. Otherwise, nothing is recorded as to their construction date, dimensions and structural integrity. These banks are located in a floodplain zone that provides a pathway for floodwaters into the upper reaches of the Forest in moderate to large floods, for example the 1993 flood.

The imagery of the 1993 flood (Appendix A) does not indicate any influence of these banks and it might be concluded that they are minor or have been built since 1993.

Although a quantitative study of the effect of these banks on flooding has not been located, these banks have the potential to reduce the flow rate and volume of floodwaters entering the forest in moderate to large floods (1 in 10 years and larger). However, the Project does not provide for any modifications to these banks nor does it rely for its efficacy on the continued existence of these private banks.

Middle to upper Forest - North Side

The known levees in this location are shown on Figure 7. They are mostly on private land and are therefore private works and their purpose is to prevent the escape of flood waters from the forest onto private farmlands. We have been advised (pers com Mike Erny) that these banks have heights varying from 0.2 to 0.8 m high. Because the Forest boundary does not follow high ground (along their entire alignment), there are locations where drainage of private lands into the forest occurs. The occurrence of cross drainage works for the banks is minimised by on-farm drainage runoff collection and reuse systems.

Flood mapping referred to above indicate that moderate to large floods will outflank or breach these banks causing inundation of private farm lands adjacent to the forest. Satellite imagery indicates that the banks were effective for the 1993 flood (1 in 20 year). This imagery also shows that flows into Thule Lagoon may have been restricted by these banks when otherwise a significant flow would have been expected under natural flood plain conditions.

Lower Forest – Western Side

An existing bank is located on the historic Forest Boundary and passes to the north of the Barham Township. In conjunction with other smaller banks, this has protected the Township from moderate to large historic floods such as the 1975 and 1993 floods (1 in 20 year).

Additional land has been acquired as part of the project to allow the downstream levee to be constructed on the same site as the existing levee that passes to the north of Barham.

3. Development of the Project

3.1 Introduction

3.1.1 Assessment of Management Options

The key ecological objective of the Koondrook-Perricoota Forest Flood Enhancement Project is to provide an adequate water regime to a representative area of River Red Gum Forest. As part of the Blueprint process a number of management options were identified and assessed for their effectiveness in meeting the objectives. The options considered included:

- Do nothing;
- Delivery of Water to Simulate a Natural Flood;
- Minor works to effluents;
- Cutting from Torrumbarry Weir pool and installation of upstream structures;
- Cutting from Torrumbarry Weir pool and installation of upstream and downstream structures (the proposed option); and
- Weir across the Murray River; and pumping water into the forest.

The Investment Proposal (DWE, 2008) provides a summary of the evaluations for each of these options. The Investment Proposal states that the conclusion derived from the investigations and concept designs undertaken provides overwhelming support for the proposed option detailed in this report. A summary of the options and the conclusions of the evaluation process are provided in Table 3-1. The preferred option is shown as a shaded row.

Table 3-1 Summary of the management options considered to meet the ecological objectives for the Forest (shaded option is the preferred option)

Management options considered		
Option	Description Of works	Evaluation conclusions
Do nothing	No physical works proposed	Comparison of the modelled Current flows against Recorded (Actual) flows suggests further decline in water availability is likely, hence further decline in ecological condition is expected.
Delivery of water to simulate a natural event	No structural works, relying on delivering large volumes of water to simulate a natural flood	Huge volume of water required (in excess of 30,000 ML/day) Channel capacity constraints Significant downstream flooding and landholder compensation issues High delivery losses

Management options considered

Minor works to effluents	Effluent management at creek mouths, de-silting and minor flow limiters and control banks	Minimal effect on broad scale health of the forest Only moderate enhancement to moderate to major floods both spatially and temporally Only minor benefits provided without enhanced delivery
Cutting from Torrumbarry Weir pool and upstream structures	Cutting from Torrumbarry Weir pool and installation of upstream control structures	Downstream flooding and compensation issues Capacity constraints in Barbers Creek High water use requirement compared to the proposed option (additional 194 GL) Higher net water use (56 GL) Only half as efficient (ML per hectare of forest watered) as the proposed option (15 ML/ha as opposed to 31 ML/ha)
Cutting from Torrumbarry Weir Pool, and upstream structures, and downstream structures	Cutting from Torrumbarry Weir pool and installation of upstream and downstream control structures	Provides flexibility to maximise environmental benefits and mitigate risks to private or public land that would arise from uncontrolled releases under a ‘no downstream structures’ option. Substantially lower water use requirement compared to the ‘no downstream structures’ option (saving of 194GL) Lower net water use relative to ‘no downstream structures’ option (56GL) Delivers greater environmental return per megalitre and affords significantly greater operational flexibility over a range of flow conditions.
Weir across the Murray River	New regulator (Weir) across the Murray River to facilitate flooding to both Koondrook-Perricoota and Gunbower Forests	Cost prohibitive (total project costs in excess of $70M) Not supported by Victoria in relation to the Gunbower Icon Site initiatives Detrimental hydrological and hydrogeological impacts Contravenes current NSW policy of no new weirs
Pumping Water into the Forest	Long and Short term pumping from the Murray River	High cost to achieve minimal flooding and limited ecological outcomes Even less effective without downstream control structures 1 000Ml/day over 100 days is likely to only water 10% -15% of the Forest Short term pumping may provide some benefits to discrete areas

3.1.2 Proposed Management Option

The original concept developed for enhancing water regimes in the Koondrook-Perricoota Forest comprised the diversion of water upstream of Torrumbarry Weir, enabling inundation of the Forest to occur in a relatively natural manner.

Preliminary hydraulic modelling (DECC, 2008) demonstrated that River diversions would need to be made at flow rates of up 6,000 ML/d to achieve the required extent of flooding to meet the ecological objectives. The threat of significant downstream impacts to private and public lands and infrastructure, resulting in significant costs in easement attainment, structural works and compensation were the drivers behind the need for consideration of alternative options.

For the preliminary concept, water resource modelling determined that approximately 660 GL of inflow would be required which would inundate approximately 9,600 ha of the Forest (30%). Flood water that passes through the Forest would flow through into Barbers Creek and the Wakool River and discharge into the Murray River some 360 km downstream of Barham. After allowing for transmission losses, it was estimated that approximately 360 GL of water would be returned, resulting in a gross water requirement of 31 ML/ha of forest watered.

The concept comprising downstream structures that enabled the ponding of water in the lower part of the Forest to increase the effective watered area and controlled the discharge into Barbers Creek and Wakool River was developed to mitigate a range of potential impacts identified in the original concept and to improve water use efficiency.

The current proposal for flood enhancement works broadly fall into two categories of key infrastructure as follows:

Upper Forest Regulating Structures

The upstream structures allow diversion of water into the forest from Torrumbarry Weir and escape regulators prevent flow re-entering the Murray River.

Lower Forest Regulating Structures (Downstream Structures)

The downstream structures have been designed to regulate water leaving which maximises the inundation extent of the lower forest area and provides the most efficient use of water.

Further details on the basis for these works are provided below.

3.2 Basis for Upstream Structures

The proximity of Torrumbarry Weir in relation to the highest point of the Forest provides significant operational flexibility to firstly; access water for the forest, and secondly to enable controlled delivery of watering events.

Preliminary studies examined options of works for an upstream regulator and an excavated channel to Bullock Head Creek. These studies revealed that the flows would disperse and be retained in the Forest, provided an escape regulator was constructed at each of the two arms of Swan Lagoon to prevent short circuiting of flow back to the Murray River (NSW Department of Commerce, 2008).

This has largely been adopted however has been subsequently refined to provide a more effective distribution of water into the Forest as well as reducing construction costs associated with the excavation of the proposed cutting.

Extensive hydraulic modelling has been undertaken on the upstream regulator structure and inlet channel to optimise the design capacity of the diversion works.

Further details on each of the proposed structures located in the upper forest area are provided in Section 4.2.1.

3.3 Basis for Downstream Structures

With no downstream structures in place to control the outflow, flows leaving the Forest during a watering event were found to be high and well in excess of the reported capacity of the block bank structures within Barbers Creek downstream of Moulamein Road, this being 200-250 ML/d. This led to the development of a concept comprising:

- A levee around the perimeter of the lower Forest boundary to contain floodwaters, create a pool which increased the effective area of inundation of the Forest, and enable water to be circulated directly back to the Murray River via the return channel;
- Downstream regulators to control the flow rate of water leaving the Forest during a watering event;
- A return channel and regulator structure to increase the rate of discharge directly to the Murray River and to improve water use efficiency for watering events.

The height of the levee has been adopted to maximise the area of inundation achieved in the Forest and to assist with the heading of water to improve the return of flows via the return channel and regulator. The levee structure provides several significant secondary benefits in mitigating potential flood risks in areas downstream of the works. In particular, the township of Barham is located immediately downstream of the works. Existing levees located around the perimeter of the Forest currently provide protection for the township of Barham. The proposed upgrade of the levees as part of this project provides significant improvement to the protection of the Barham township from future flooding.

The downstream structures will enable the release of floodwater into the Barbers Creek and Wakool River systems in a controlled manner at a rate which mitigates the potential for flooding of private property located along the flow path. Significant work has been undertaken to improve the understanding of the hydraulic capacity of Barbers Creek. Structural works are proposed at several locations along the Creek to mitigate isolated capacity constraints and mitigate local flood impacts.

The primary function of the return channel is to maximise the discharge of water back into the Murray River to reduce the volume of water lost through transmission, that would otherwise occur through the Wakool system.

Water resource modelling has determined that approximately 466 GL of inflow would be required which would inundate approximately 16 000 ha of the Forest (about 50%).

By maximising the return of flood water directly to the Murray River it is estimated that approximately 222 GL of water would be returned, resulting in a gross water requirement of 15 ML/ha of forest watered. This is approximately half the water requirement of the preliminary options that were investigated for the scheme.

Further details on each of the proposed structures located in the lower forest area are provided in Section 4.2.2.

4. The Project

4.1 Forest Watering Objectives

The Preliminary Operating Plan (NSW Public Works, 2009) states that the key ecological objective of the project is *"to provide an adequate water regime to a representative area of River Redgum forest that has, or historically supported, a flood dependent understory".* A water regime that achieves this ecological objective for relevant vegetation classes and key species is detailed in the (MDBC *et al*, 2007).

The project has been specifically designed to provide the flexibility to operate within a range of flows to ensure that effective and measurable environmental outcomes are delivered across a broad range of available water. The structures have been designed to create a major flood event; however they can also control small or medium flows of variable volume and duration. It is intended that large flood events would occur every three to four years and that smaller events would occur more frequently.

The Investment Proposal (DWE, 2008) has defined the objectives in the following hydrologic terms:

Inundation Extent

- The proportion of redgum forest inundated is the principal measure with a 30% coverage selected as the minimum extent target (for a regulated event).

Timing and Duration

- Between August and December for at least 3 consecutive months.

Frequency

- 50% of Natural; and
- Maximum period between inundation of 4 years.

DWE (2008) provides the ecologic basis for these hydrologic objectives which is being assessed as part of another study for this EIS.

The Investment Proposal (DWE, 2008) states that the required frequency of inundation for River Red Gum Forest areas is 3 to 9 years in 10, which is 30% to 90%.

On this basis, the hydrologic modelling undertaken for the Project (ie MDBA, 2008) has adopted a frequency on the upper bounds of this range being 1 in 3 years or 33%.

4.2 Description and Purpose of Project Works

The Flood Enhancement works have been designed to provide flexibility to operate within a ranges of flows. This ensures that it can deliver effective and measurable outcomes across a range of available water (NSW Public Works, 2009). The Scheme broadly falls into two categories of key infrastructure as follows:

Upper Forest Regulating Structures - The upstream structures allow diversion of water into the forest from the Torrumbarry Weir pool and escape regulators at Swan Lagoon prevent flow re-entering the Murray River.

Lower Forest Regulating Structures (Downstream Structures) - The downstream structures have been designed to regulate water leaving which maximises the inundation extent of the lower forest area and provides the most efficient use of water.

Further detail on the specific structures in these categories is provided below.

4.2.1 Upper Forest Regulating Structures

The proposed flood enhancement works in the upper Forest area includes:

- Construction of an earth-lined inlet channel extending north from the Torrumbarry Weir pool on the Murray River to Bullock Head Creek. The inlet channel has been designed to mimic natural flow patterns into the Forest. Key elements of the inlet channel:
  - 3.8 km length channel;
  - Trapezoidal cross-section, with a channel bed width of 37 m from the Murray River to the River Road Bridge (900 m), reducing to 10 m between the River Road Bridge and the natural gully (3 800 m);
  - The section of channel downstream of the Road Bridge has a reducing capacity, created by a reverse slope, to move flows out of the excavated section into the floodplain;
  - Flows of 6 000 ML/d will be fully contained within the channel for the first 900 m up to the River Road Bridge, dispersing into the floodplain beyond that; and
  - The channel design capacity of 6 000 ML/d was assessed based on hydraulic modelling undertaken by Commerce MHL, using MIKE 11 software.
- Construction of a gated regulator structure within the inlet channel approximately 200 m from the Murray River. The design of the regulator was aimed at diverting 6 000 ML/d into the channel during watering events, as well as isolation of Torrumbarry Weir up to a weir pool level of 86.55 mAHD (equal to 1956 maximum flood of record). During the design analysis, safety margins were assessed by allowing for increases in Manning's "n". Key elements of the gated regulator structure are:
  - Reinforced concrete structure with five 3.9 m high by 3.65 m wide electrically operated tilting overshot gates;
  - Dual fishway to allow for large and small bodied fish to enter during both filling and emptying phases; and
  - A turtle ramp was included in the concept design to allow fresh water turtles to escape from the main channel and return to the Murray River after a watering event.
- Construction of an access bridge across the inlet channel at River Road. The main design objective was to allow heavy timber vehicles to cross the inlet channel at

any time, while providing the best possible unobstructed waterway for fish and fresh water turtle movement.

- Construction of two regulators at Swan Lagoon. The purpose of the Swan Lagoon regulators is threefold:
  - to prevent flows diverted at the Torrumbarry regulator to return to the Murray River at the upstream end of the Forest during managed events,
  - to allow for the passage of natural flood flows from the Murray River to the Forest; and
  - allow fish to escape the Forest during the recession phase of a managed watering event.

  The Swan Lagoon regulators were designed to a minimum level of 84.0 mAHD to allow for 0.5 m freeboard for wave action and variations in water level. The regulator design allowed for a minimum bankfull waterway area of 75% of the natural waterway cross section to allow for movement of flood water into the Forest. Key elements of the regulator structures include:
  - Three 2 m wide by 2.5 m high vertical undershot lift gates on the upstream arm of the lagoon;
  - Three 2 m wide by 2 m high vertical lift gates on the downstream arm of the lagoon; and
  - Design flow velocities of less than 2.5 m/s to allow for fish passage evacuation purposes.

4.2.2 Lower Forest Regulating Structures

The proposed regulator structures and waterway management works in the lower Forest area include:

- Crooked Creek Regulator, Return Channel and Floodway;
- Thule Creek Regulator; and
- Four downstream regulators located on Runner A (Barbers Overflow), Barbers Creek, Cow Creek and Calf Creek.

The proposed works at Crooked Creek include:

- Construction of a return channel from Crooked Creek to allow return flow back to the Murray River. The main purposes of the return channel are to:
  - Allow water to circulate within the Forest;
  - Provide water savings via the direct return of flows to the Murray River during a watering event; and
  - Provide an outflow or spillway system to protect the flood safety of the downstream structures, particularly the levee system.

  Key elements of the return channel:
  - 300 m long standard trapezoidal cross-section with a channel bed width of 20 m;

- Flow capacity of 1 850 ML/d, with maximum design flow velocities of less than 0.6 m/s; and
- At the junction with the Murray River (right bank), the return channel bed level will be 2.15 m above the main river bed level. A reinforced concrete chute with sheet pile cutoffs at the upstream and downstream ends are proposed for protection against erosion and undermining.

- A gated regulator structure within the return channel from Crooked Creek to the Murray River. The main purposes of the regulator structure are to:
  - Provide operational flexibility via the capability to control the flow returning to the Murray River along the return channel;
  - Provide an outflow or spillway system to protect the flood safety of the downstream structures, particularly the levee system; and
  - Contain the downstream pool to the design level of 78.5 mAHD.

  Key elements of the regulator structure include:
  - Three 1.4 m high and 3.65 m wide electronically operated tilting gates; and
  - A design capacity of 1 850 ML/d, with flow velocities of 1.43 m/s.
- A floodway to enhance return flows to the Murray River. Preliminary flood modelling assessments found that due to some higher terrain there could be restrictions in the hydraulic connectivity between the main pool and the return channel. A floodway was proposed to improve hydraulic connectivity between the main pool and the return channel. The proposed floodway has a length of 1 km and constant bed width of 245 m with an average excavation depth of 0.5 m.

The design concepts for Thule Creek Regulator and the four downstream regulators have been developed on a similar same basis. The purpose of these regulators is to prevent flows escaping (under managed flow events) and provide control over outflows from the Forest. Sizing of the downstream regulators included the capability to pass a natural flood with low impact, while also resulting in minimum environmental impact.

All structures comprise stop-log regulators, with stop logs being lifted with a wheeled crane which is capable of being driven between regulator sites. The regulator sites will each comprise a number of stop log bays and a number of stop logs as summarised in the table below.

Table 2 Design Details – Downstream Regulation Structures

Structure	Height – Pool to bed level (m)	No. of stoplog bays	1956 Flood Discharge (ML/d)	Velocity at Structure (m/s)	No. of stoplogs
Runner A	3.5	7	5 100	0.76	84
Barbers Creek	6.5	5	9 700	0.85	110
Cow Creek	7.0	9	17 100	0.83	207

Structure	Height – Pool to bed level (m)	No. of stoplog bays	1956 Flood Discharge (ML/d)	Velocity at Structure (m/s)	No. of stoplogs
Calf Creek	3.5	9	8 000	0.94	108
Thule Creek	3.5	9	8 000	0.94	108

In addition, the Barbers Creek regulator has been designed to enable it to be retrofitted if required to provide fish passage.

4.2.3 Forest Levees

Provision of a levee is proposed to be provided around the north-western perimeter of the Forest and connecting four of the above regulators (Barbers Creek, Runner A, Cow Creek, Calf Creek, and Thule Creek). The main purposes of the levee are to:

- prevent uncontrolled flows leaving the Forest basin;
- contain the design pool level of 78.5 mAHD; and
- back the design pool up to the location of the return flow channel with sufficient hydraulic head to allow outflows (when WL is above 77.3 mAHD).

Key elements of the levee include:

- total length of about 43 km;
- nominal crest level of 78.8 mAHD, providing a nominal freeboard of 0.3 m freeboard to the design pool;
- 4m wide crest and 1V:2H slopes; and
- levee height above general flood plain level will vary from zero at the upstream end to approximately 4 m at the downstream regulator structures;

The western alignment of the levee has been changed from the initially proposed alignment to the new “western alignment”, including an additional extent of the forest between the proposed levee and the Murray River. It should be noted that the flood modelling was based on the initial alignment.

4.3 Scheme Operation

4.3.1 Watering Principles

The Operating Plan (NSW Public Works, 2009) describes the proposed watering principles that will be used to base decisions to initiate watering events and have detailed these principles in terms of initiation of a watering event and management of a watering event.

The decision to initiate watering will be based on considerations and constraints of the operating environment. The watering principles include:

- Water availability and water requirement are the foundations for the decision to initiate a watering event;
- Clear ecological targets will be defined before initiating a watering event;
- Watering events will aim to maximise net environmental benefits;
- Early watering events will not commence beyond October;
- Overbank flows will be favoured as a cue for initiating watering;
- Unregulated water will be used when beneficial; and
- Autumn watering will be considered if the environment water is not made available until late in the season.

The management of a watering event will be based around the following principles:

- The initial ecological target will be pursed for as long as practicable;
- Modelled natural hydrographs will be used as a guide during the management of an event;
- Where beneficial, managed watering will prolong or enhance overbank flow;
- Downstream regulators will only be used to the extent needed to achieve the required objectives;
- Watering operations will aim to minimise impacts on third party property;
- The protection of watering infrastructure overrides meeting environmental targets;
- Inflows through the Swan Lagoon will be favoured over equivalent inflows through the inlet channel;
- Use of Barbers Creek will be maximised where possible.

4.3.2 Proposed Operating Regimes

Implementing this type of intervention in a regulated river system that is operated for multiple outcomes brings with it some risks and trade-offs that will need to be managed. Early awareness of this issue has led to the Project being designed to enable highly varied and flexible operations. This flexibility enables adaptive management in response to:

- Time varying water availability and river conditions;
- Risk management requirements; and
- Targeting specific environmental outcomes (eg vegetation response, bird breeding events) that may be required from time-to-time to achieve long term objectives.

The overarching objective for the Gunbower-Koondrook-Perricoota Forest is to maintain and restore a mosaic of healthy floodplain communities (DWE, 2008).

The project will be operated in accordance with an Operating Plan developed specifically for the project (NSW Public Works, 2009). The purpose of the Operating Plan is to provide a framework for the operation of the structures to meet key ecological objectives within the broader context of The Living Murray Program and Scheme’s governance.

The Operating Plan will not prescribe particular watering events, however it will provide an effective platform for operational decision making based on knowledge development and a strong understanding of what the Project should aim to achieve.

With reference to hydrologic conditions in the Murray River downstream of Torrumbarry Weir, the operation of the project will occur in one of three general ways:

- For flow events <18 000 ML/d, water can be delivered to the Forest through the inlet channel as a complete “managed” flood event;
- For flow events >18 000 ML/d, water can enter the Forest through natural watercourses/effluents, and potentially be supplemented with water delivered through the inlet channel; and
- There will also be larger flood events within the Forest when the flood enhancement project is not operated.

The natural flow regime at the site provides a guide to the water requirements of the ecological processes and communities that exist there. This regime is highly variable, and comprises floods of various magnitudes and durations, occurring at a range of frequencies. In general, small floods occur more frequently, and larger floods less frequently. It is highly desirable that the project provide a very flexible delivery mechanism that is capable of delivering a range of flood events able to sustain a range of ecological processes and elements, for example:

- Frequent, low flows (but exceeding the commence-to-flow levels) to maintain the wetland habitats occurring in lagoons, depressions and flood runners;
- Less frequent floods of medium magnitude to maintain the extent of the Red Gum communities, with larger floods maintaining the extremities, and smaller floods supporting the core areas with flood dependent understorey communities; and
- Flood events of long duration and in appropriate seasons to facilitate bird breeding.

Opportunities for water utilisation efficiencies will be maximised by a provision to returning water directly to the Murray River via the return channel and to pass water into downstream creeks.

While predictive models provide some guidance, the exact ecological outcomes arising from operation of the project will be unknown until they have been operated in real time under a range of antecedent conditions. In line with adaptive management principles, it will be important to be able to alter the operation of the structures, both during a watering operation and from one operation to the next, in order to react to the ecological response observed. Furthermore, the availability of both unregulated and regulated river flows, and the quantum of environmental water available, is variable from season to season and it is important that provision be made in the design of the structures for flexible operation and the ability to capitalise on a variety of flow events.

Reference should be made to the Environmental Assessment for a description of the operation of the project, including aspects such as:

- The planning and institutional framework;
- Water availability, including regulated water, unregulated flows, Commonwealth water, NSW environmental water, and The Living Murray water;
- Operational constraints; and
- Water operations, including governance, watering principles, decision making, and predicted operations.

4.3.3 Possible Operational Scenario

The approach to preparation of the Environmental Assessment was developed following consideration of the unique characteristics of the project. The project has been designed to have a high level of flexibility to respond to factors such as water availability and the environmental objectives of each event. As such, each flood event will be different, and the location, extent and significance of impacts will vary temporally and spatially.

The project would be operated in accordance with an Annual Environmental Watering Plan prepared each year to set the environmental watering priorities under The Living Murray program. The magnitude and duration of impacts arising from the project would vary with individual flood events. These characteristics mean that it is not practical to assess potential impacts of all possible operational scenarios undertaken over the full length of time the project would function.

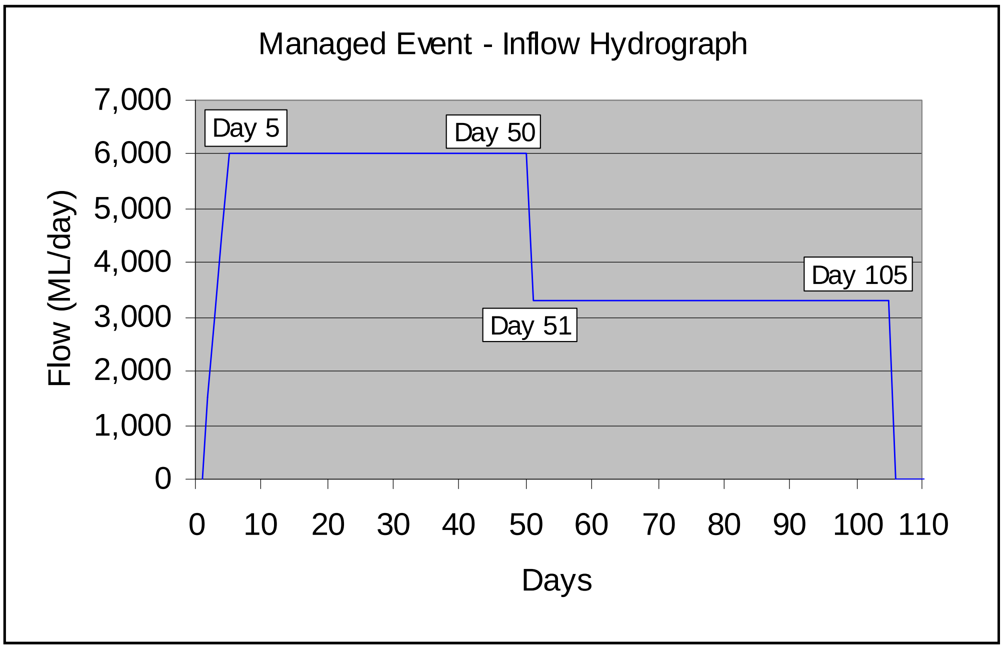
Given the project's high degree of operational flexibility, it is not considered feasible to assess all possible operational scenarios. As such, the environmental assessment and this hydrology assessment focus on one possible operating scenario which is described in the Preliminary Environmental Assessment (DWE, 2009). This operating scenario relates to an entirely managed flood event, involving the maximum possible in-flows of 6000 ML/day via the inlet channel and inundating the maximum possible area.

This possible operating scenario is aimed at achieving a maximum water level of 78.5 mAHD, as well as maintaining forest inundation duration of at least 100 days. This has been referred to as the preferred "managed" event and is in fact the "upper limit" watering event. Refer later for discussion on design watering events. A preliminary possible operating sequence has been developed for the proposed works. Figure 9 shows the simple inflow hydrograph for the proposed operating scenario with further explanation provided below (sourced from Investment Proposal).

This event would have a total cycle of flooding and recession of approximately 235 days, however the full flooding objective would only occur for approximately 100 days of the cycle. The remainder of the time would be required for the water to enter and flow to the lower end of the forest and then the time taken for the water to recede out of the forest. This event is expected to require approximately 466 GL, of which 225 GL would be used by the forest (evaporation and infiltration), and 222 GL would be returned to the Murray River.

This possible operating scenario is outlined below.

Figure 9 Managed event inflow hydrograph to achieve water level of 78.5 mAHD



Phase 1 - Commence diversion

The initial phase will include opening the off-take regulator over a period of five days to achieve 6 000 ML/d diversion capacity. In this phase:

- The return regulator will be fully open; and
- Swan Lagoon structures will be fully closed;
- Downstream stop-log regulator structures will be closed (stop-logs will be in place to deliver 50 ML/d per structure or 200 to 250 ML/d through one structure at Design Pool 78.5 mAHD).

Phase 2 - Rising flood

The off-take regulator will discharge at 6 000 ML/d, with the downstream Forest section to be filled to the design operating level of 78.5 mAHD. Theoretical modelling runs indicate that this process will take 45 days.

Phase 3 - Steady flood

The gates of the off-take regulator will be raised to reduce flow (to 3 400 ML/d) while maintaining the design pool operating level 78.5 mAHD. This diversion flow of 3 400 ML/d will be maintained for 55 days. Modelling has indicated that other surface flows may include:

- Return channel at a flow of 1 850 ML/d or higher; and
- Downstream stop-log structures at a flow of 250 ML/d (combined flow).

Phase 4 - Commence recession

The off-take regulator will be shut down, nominally for a two week period, and flows ramped up and down (if required) to facilitate fish exit. The stop-logs will gradually be removed from one downstream structure bay, possibly Cow Creek, being the deepest structure, to maintain the 250 ML/d flow.

Phase 5 - Flood recession

Stop-logs will continue to be removed from the downstream structure bay to empty the pool. The emptying could theoretically take 110 days. A total of 542 stop-logs from all downstream structures will be stripped and stored. Stop-log removal will initially be slow; however this will gain momentum as the pool drops.

4.4 Hydraulic and Hydrologic Analyses

4.4.1 Hydraulic Modelling

Hydraulic modelling has been used to quantify the extent of inundation of the Forest under natural "un-controlled" flooding and the proposed managed inflow event for comparison against ecological targets for the Forest.

Model development has been undertaken in several stages, moving progressively from simple to more complex forms with the primary aim being to improve the knowledge of the Forest flood inundation processes.

The three hydraulic models developed provided similar results up to flows of about 28,000 ML/d. As flow increases, discrepancies between the model results increase. The MIKE FLOOD model, which is the most sophisticated model developed, provides the most accurate representation of Forest inundation compared to remote sensing analysis. However, run times for this model can be up to 50 days in duration (DECC, 2008).

The latest modelling undertaken by DHI (2008) aimed to provide improved representation of floodplain inundation and overbank flows, compared to earlier modelling, and to assess the structural and operational options associated with the proposed flood enhancement works.

During model development, a number of development scenarios and sensitivity analyses were considered. These included:

- Extensive assessment of soil infiltration rates;
- Inflows required to achieve and maintain a downstream water level of 78.5 mAHD;
- Inflows required to achieve 30% inundation of the forest;
- Flood works without and with downstream levee or regulators, as well as variations on the downstream levee; and
- Refinement of the Murray River return flow channel (floodway).

Historical flood events of 1991, 1993 and 2000 were used for the 1D and 2D model development and validation. It should be noted that due to long simulation run-times only the 1991 event was analysed using MIKE FLOOD to compare the modelled results with the actual remote sensing flood data this event.

The validated MIKE FLOOD model was then used to model a number of operating scenarios assuming inflows to Koondrook-Perricoota Forest from the Torrumbarry Weir cutting.

The modelling was used to qualitatively assess a number of conceptual operating scenarios to enable ecological benefits of various options to be assessed and compared. It should be noted that modelling focussed on a managed watering event, assuming flows in the Murray River were less than the required threshold for natural inundation. The operating scenario aimed at being able to achieve a maximum water level of 78.5 mAHD as well as a forest inundation duration of at least 100 days.

Based on the preliminary results, the preferred option for further analysis comprised the following configuration:

- Torrumbarry Weir cutting inflow to a maximum capacity of 6 000 ML/d;
- Return flow channel of 1 km in length linking the Barbers Lagoon with the Murray River. The floodway would have a constant bed level of 77.32 mAHD with a design discharge of 1 850 ML/d;
- Revised infiltration rates varying temporally and spatially;
- Downstream levee at 78.5 mAHD encompassing the Forest upstream of Moulamein Road; and
- Downstream regulators for use during dewatering of the forest.

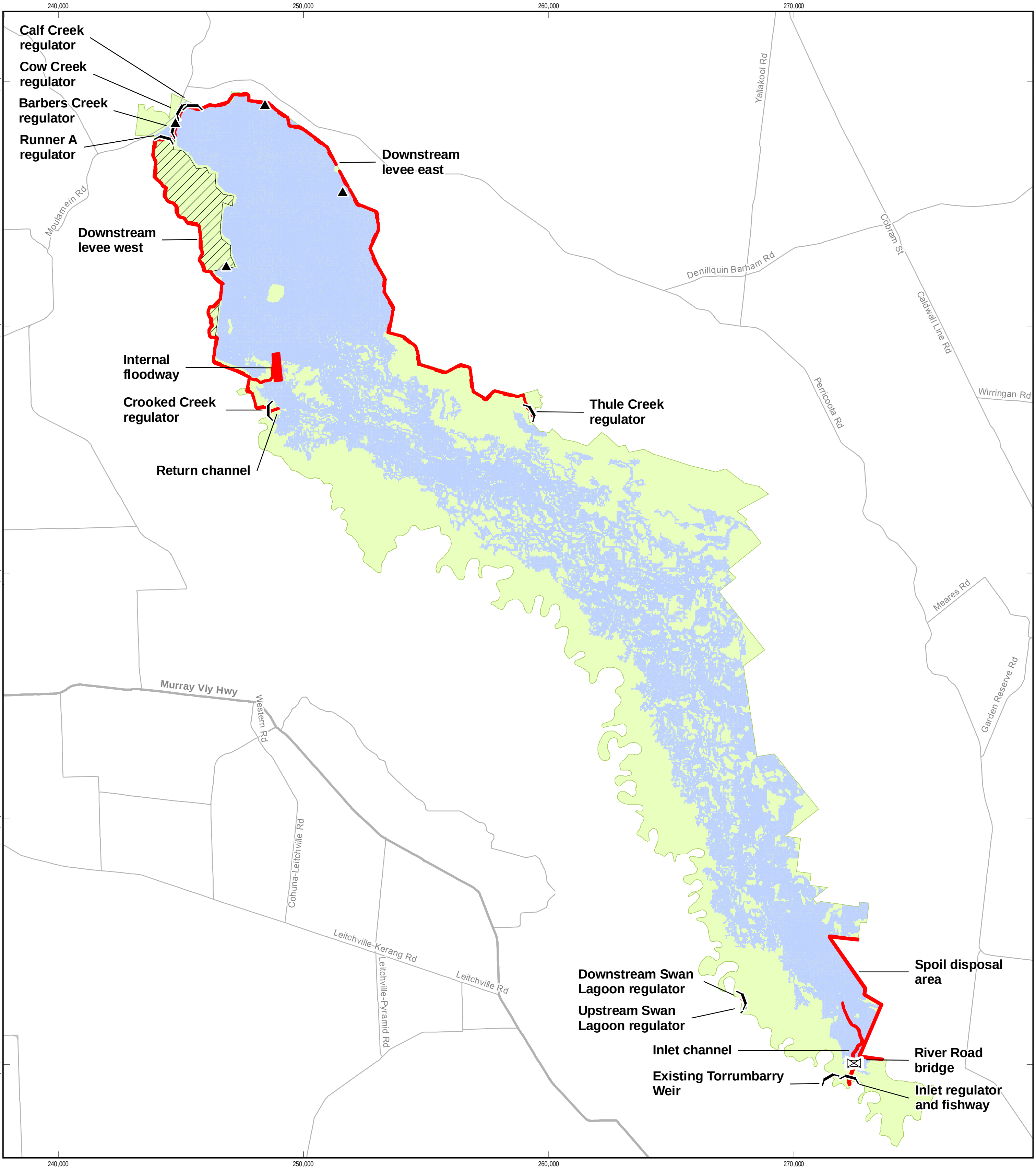
Figure 10 illustrates the extent of flooding to be achieved by the Project.

4.4.2 Hydrological Modelling

Hydrological modelling has been undertaken by MDBA (2008) to quantify to what degree the Icon Sites 500 GL entitlement can be met under historic climate conditions and potential climate change conditions.

Modelling by MDBA (2008) of water allocation and delivery concluded that “the water requirements of the [Icon Sites] can be fully provided by the 500 GL TLM water account”. An operational rostering method was developed for the modelling to allocate water delivery for all Icon Sites along the Murray River whilst retaining water entitlements for existing users.

Results from MDBA modelling are summarised Table 4 providing the outcomes for two key parameters of frequency of (complete) inundation and the maximum duration between events. Further discussion on the water availability for the Forest is provided in Section 5.2.1.



Legend

- Turkey's nest dam
- River Road bridge
- Regulator
- Construction features
- Major roads
- Koondrook Perricoota Forest Site
- Area not included in modelling
- Managed event flooding extent

1:150,000 (at A3)

0 1 2 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

GHD

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NSW Office of Water

Koondrook-Perricoota Flood Enhancement Works

Job Number	21-18573
Revision	B
Date	10 FEB 2010

Figure 10 Managed event flooding extent

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Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Data source: Dept of Commerce, Street Map- Navtec, Drawn: Cwilson, cwilson

5. Impact Assessments

5.1 Summary of Potential Impacts

Potential impacts from the Project related to changes to the hydrology include:

- Impacts on the Murray River water allocation and supply security conditions in context of the Project's water requirements from the system;
- Impacts on the Murray River flows and levels downstream of the Forest due to the diversion of water into the forest and return of water directly to the Murray River;
- Impacts on the Forest itself and surrounding land use due to the proposed flooding regime and the extent of inundation; and
- Impacts on the Barbers Creek system and the hydrological regime outside the forest due to the operation of the downstream regulators;

5.2 Murray River Water Allocation and Supply Security

5.2.1 Water Availability

As a result of the complexity of the Murray System both in terms of water accounting and system operation (water delivery), the regulated delivery of water to the Koondrook-Perricoota Forest cannot be undertaken in isolation and therefore, needs to based on a whole of system approach. To this extent, the delivery of water to all Icon Sites has been considered concurrently by the MDBA.

System wide hydrological modelling has been undertaken by MDBA (2008) to quantify the degree to which the water demand at all Icon Sites can be met with the water available as environmental entitlements under historic climate and potential climate change conditions. This work also assesses the competing actions in regards to system operation and the tradeoffs that need to be considered between the Icon Sites in meeting their respective ecological (and hydrological) targets.

The water available for environmental purposes will be obtained from a range of different entitlements including Commonwealth water accounts and NSW Environmental Water accounts. A large proportion of the water will be accessed from the 500 GL entitlement available for the environment under the TLM Initiative. This water will be obtained from water savings generated throughout the Murray River system as well as a range of other water recovery measures (such as buy back of entitlements). The delivery of this water therefore does not represent a net increase in outflows or diversions from the System, and can largely be considered a substitution of demands.

MDBA (2008) modelling shows that water requirements of all Icon sites can be fully met by the 500 GL of recovered water, with the exception of the Lower Murray Lakes. A practical water rostering method has been developed by the MDBA and demonstrates that system operation can be structured to negate impacts on other system users (in terms of reliability of supply) and maximise water availability at each of the Icon Sites. The modelling has shown that in practice there is a need for some refinement of the allocation protocol developed to maximise the efficiency of the managed events delivered to the Forest.

5.2.2 Water Accounting

A key objective of the National Water Initiative is to ensure that adequate measurement, monitoring and reporting systems are in place, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recovered and managed for environmental and other public benefit outcomes (NWC, 2009). A national water accounting system is currently being established and includes the development of national standards for environmental water accounting as well as standards for water accounting information systems.

The location of structures which form part of the Koondrook-Perricoota Forest Project enables accurate measurement of regulated flows which enter and exit the Forest for water accounting purposes, as well as allowing for the progressive monitoring of flow regimes and volumes and the ecological responses that have been achieved. Therefore, it is expected that the Project can accurately account for water diversions and will therefore comply with the proposed National Metering Standards.

5.3 Impacts on Murray River Flow Regimes

5.3.1 Impacts from Diversions

The project aims to minimise the impacts on the Murray River flow conditions downstream of the Forest boundary as a result of the changed flow regimes during the delivery of managed events and to minimise impacts during large flood events.

During managed flow event's, water will be diverted from the Murray River via the inlet channel and regulator, up to a design flow of 6,000 ML/d. Water will be ponded in the lower Forest area to a design level of 78.5 mAHD and design maximum duration of about 100 days.

Water will be released to Barbers Creek via the lower regulator structures which discharge into the Wakool River. This water is eventually returned to the Murray River some 360 km downstream of the Forest. Under managed flow events, up to 10% of the water diverted from the Murray would be returned (via the Wakool River), after allowing for transmission losses.

To improve system efficiency and provide greater flexibility in control of the inundation level and duration of the Forest area without having to pass large flows into Barbers Creek, water will also be returned directly to the Murray River via the Return Channel from Crooked Creek. The proposed return channel and regulator structures have been designed to discharge up to 1,850 ML/d. Up to 38% of the volume diverted from the Murray River will be returned at this location (upstream of Barham).

5.3.2 River Flow and Level Fluctuations

MDBA modelling (pers com Mike Erny) has shown that during a regulated managed forest watering event, flows in the Murray downstream of Torrumbarry Weir could be as low as 5,000 ML/d to 6,000 ML/d (pers com Mike Erny) and as high as 18,000 ML/d to 35,000 ML/d. The dilution effects and the water quality impacts on the Murray River due to discharges from the Forest (via the Return Channel) are being examined in a separate study.

Rapid changes in flows in the Murray River upstream and downstream of Torrumbarry Weir, following the commencement and completion of diversions into the Forest via the inlet channel, has the potential to impact on river bank stability . The design inflow hydrograph of the managed event allows for the gradual ramping up and ramping down of diversions to account for a range of operational issues such as supply rate availability, the targeted ecological response in the Forest and to accommodate the migration of fish into and out of the Forest.

The Torrumbarry Weir pool provides substantial operational flexibility in regulating water deliveries to enable rates of rise and fall in Murray River flows to be managed within current MDBA river operating guidelines and therefore it is not expected that the project will result in rapid changes to flows in the Murray River.

5.3.3 Impacts on the Murray River during Large Floods

During moderate to large Murray River floods it is proposed that all Forest watering structures are de-activated (either fully opened or fully closed) to enable floodwaters to enter and exit the Forest area in an un-controlled manner, similar to what occurs at present. Thus, it is intended that the Project will not impact on large flood flows in the Murray River, relative to existing conditions.

5.4 Impact of Koondrook-Perricoota Forest Flooding

5.4.1 Flooding Frequency and Extents

Flood inundation areas derived from satellite imagery together with an assessment of the River flow frequency for the 1991 and 1993 flood events are detailed in Table 8.

Table 8 Summary of flood extent and flood frequency

Event	Approximate area of forest inundated (ha)	Echuca Flow (ML/d) and Approx ARI (years)	Torrumbarry Flow (ML/d) and approx ARI (years)
1991	7,800	49,000 (<1 in 5)	43,000 (< 1 in 2)
1993	23,600	121,000 (> 1 in 20)	60,000 (1 in 10)

During the 1993 event floodwaters entered the Forest in locations both upstream and downstream of Torrumbarry Weir. Accordingly flooding in the upper part of the Forest will be more representative of the Echuca flow frequency (ie 1 in 20 years) and flooding in the lower Forest would be at least 1 in 10 years. Further investigations are underway to improve the understanding of the inflows to the Forest under very high flow conditions.

The estimated flood extent resulting from a managed watering event in the Forest as part of the proposed operation (refer Figure 10), illustrates that the overall level of inundation achieved is somewhere in between the 1991 event and the 1993 flood event. The extent of the 1991 and 1993 flood events are shown in Appendix A.

Therefore, it can be inferred that the managed flow event would result in an inundation extent which is similar to a natural flood with a return interval more frequently than say 1 in 5 years, limited only by the availability of the water. This frequency of flooding is consistent with the project objectives.

Two other criteria of the hydrologic objectives are the frequency of flooding events and the maximum interval between events. Hydrological modelling of the Murray River undertaken by MDBA (2008) has confirmed that these criteria are likely to be satisfied.

MDBA modelling results are summarised in Table 4.

Table 4 MDBA (2008) Hydrological Modelling Results

	Average Flooding Frequency (% of years)	Maximum Interval between Events (Years)
Target frequency for large flood events in the Forest with an inundation extent generally equivalent to the managed event this assessment is based on.	33.0	4
Natural benchmark - Frequency for a natural flood event generally equivalent to the managed event this assessment is based on. This is based on natural conditions, i.e. no river operations, diversions and only natural levels of storage in the system	45.3	7.4
Current benchmark - Frequency of a flood event under the current river operations that is generally equivalent to the managed event this assessment is based on. This is based on current river operations, diversions and storage capacities and historical flow conditions	15.4	21.9
Without works - Frequency of a flood event under the current river operations that is generally equivalent to the managed event this assessment is based on. This is based on there being access to water recovered under The Living Murray Initiative however it does not account for operation of the project.	18.8	20.8

	Average Flooding Frequency (% of years)	Maximum Interval between Events (Years)
With works - Frequency of a flood event under the current river operations that is generally equivalent to the managed event this assessment is based on. This is based on there being access to water recovered under The Living Murray Initiative and includes operation of the project	29.1	11.8

The modelling results confirm that the 'with works' scenario (29.1 % of years) is approximately equal to the target frequency of inundation (33 % of years) when taking in consideration all other key Murray system operational requirements.

Whilst the maximum interval between flood events of the maximum design event exceeds the target interval for the Koondrook-Perricoota Forest, it is expected that further optimisation of water delivery via the TLM water account using more sophisticated rostering methods and the utilisation of alternative watering hydrographs (or partial watering events), will enable watering events to be delivered that satisfy the maximum interval criterion.

The downstream levees will be operated to enable ponding of water in the lower Forest area. These levees will change the distribution of floodwaters that exceed the level of service of the existing Barham levee system in the lower forest area compared to current conditions. However, hydraulic modelling has demonstrated that the re-distribution will be completely contained within the Forest boundary. A major advantage of this redistribution of floodwater is the ability to return outflows from managed events directly to the Murray, thereby significantly improving the water use efficiency of the Project.

5.4.2 Downstream Impacts from Large Flood Events

Results from recent modelling by NSW Water Solutions (2009a) shows that the downstream structures when fully open have little impact on the conveyance of large floods through to the Barbers Creek system. A flood flow equivalent to the 1993 event having an assessed ARI of 1 in 10 to 20 years was evaluated and it was demonstrated that the maximum afflux of 0.16m would occur in Runner A, resulting in an upstream water level of 77.12 mAHD. Furthermore, this modelling demonstrated that the backwater effects of this afflux extend some 4 km upstream of the regulator structures and therefore the increase in flood level as a result of the proposed structures is unlikely to result in increased discharge to the Murray River upstream of the levees.

These results demonstrate that moderate flood flows will be contained within the proposed levees which will be constructed to a design elevation of 78.8 mAHD. It is also concluded that the downstream regulators would be able to pass large floods up to the 100 year ARI with minimal afflux such that it is unlikely flood levels would overtop the proposed levees.

5.4.3 Thule Creek

The Thule Creek waterway is one of the natural outflow creeks from the Koondrook-Perricoota Forest, located about halfway along the Forest and flowing in a northerly direction towards the Wakool River.

Under natural flooding conditions, the Thule Creek effluent becomes active during small to moderate flooding events within the Forest as evident from flood mapping of the 1991 and 1993 flood.

The proposed Thule Creek Regulator structure is required to prevent the loss of floodwater during the initial phases of managed flow events. Under managed flow events, it is not proposed to release water from the Forest area via Thule Creek. Therefore there will be no changes to the downstream hydrology of the Thule Creek system compared to the current flow regime.

During large “natural” flood flows, the Thule Creek Regulator will be fully opened (along with the downstream regulator structures) and floodwaters will be allowed to pass through the structure and enter the Wakool River system, as occurs under current conditions.

5.4.4 Forest Debris Blocks

On smaller gated regulator structures such as the Swan Lagoon Regulators, blockage through the accumulation of Forest debris and debris imported from the River has the potential to impact on the operability of the structures and the hydraulic capacity. For structures with larger openings, up to 4m wide in some cases, the risk of blockage through debris is likely to be less of an issue.

To mitigate the impacts of debris blockage on small gated structures, debris booms are proposed to be installed to reduce the risk of debris impacting on the operation of the gates and blockage of the opening of the structure. Detailed Operating Plans for the structures will describe operational activities leading up to, during and following flooding events to manage the accumulation of debris at the structures.

5.5 Impacts on Surrounding Land Use

5.5.1 Existing Forest Levees

The eastern and northern perimeter of the Forest is bounded by private property which comprises mixed land use including dryland and irrigated agriculture. An existing levee system extends from the southern most point of the Forest adjacent to the Murray River and extends (except for some isolated sections of high Ground) along the entire perimeter to Moulamein Road. These levees have been constructed by private landowners to prevent the uncontrolled distribution of floodwaters beyond the Forest perimeter providing flood protection to the adjacent private property.

Flood inundation extents from the 1993 flood event, as detailed in Appendix A, show that the existing Forest levees contained that flood within the Forest boundary, preventing un-controlled flooding of private property.

Under a managed flow event, modelling has shown that in the upper part of the Forest, the depth and overall extent of flooding will be less than the 1993 flood event. It is therefore expected that the project will not impact on the risk of flooding of private property adjacent to the eastern and northern boundary of the Forest.

In the lower Forest area, existing levees are located on the western perimeter of the Forest which are adjacent to Barbers Creek and the flood runners upstream of Moulamein Road. These levees play an important role for flood protection of the township of Barham.

5.5.2 Proposed Forest Levee Upgrade

The Project involves the relocation and upgrading of the levees downstream of the Forest area, to control outflows down Barbers Creek, enable circulation and discharge to the Murray River, and increase the inundation area within the Forest.

Under uncontrolled flood conditions, the risk of overtopping of these western levees will be significantly less due to the proposed upgrade of the levee. Given that the existing banks have uncertain construction standards and the new banks will be engineered and maintained continuously, the flood frequency of lands immediately downstream of the levee, including the township of Barham, will be reduced.

Under a managed flow event, the proposed levee and downstream regulator structures will create a storage with an embankment height of approximately 4 m relative to the floodplain level. It is proposed that the levee embankment and regulating structures will be designed with consideration of adequate freeboard requirements to mitigate damage from wave action, requirements for bank stability, the levee embankment design with specifications on material selection, compaction requirements and moisture control requirements.

These design processes will enable refinement of the concept design and the potential risks to areas downstream of the levee embankments to be appropriately mitigated.

The recent changes to the alignment of the western boundary enables floodwater to enter the Forest and therefore prevents any adverse ecological impacts associated with this area being disconnected from the floodplain.

5.5.3 Activities within the Forest

With regards to impacts within the Forest boundary, the proposed watering regime will increase the frequency in which the Forest area will be inundated and hence, has the potential to impact on current grazing, logging and recreational activities, which is being assessed in a separate study for this EIA. Whilst it is proposed that the Forest will be inundated more frequently than current conditions, it is expected that the frequency will be less than what would occur under natural conditions.

5.6 Hydrology of the Barbers Creek system

The primary drainage system for the downstream (western) end of the Koondrook-Perricoota Forest comprises the Barbers Creek, Runner A, Cow Creek and Calf Creek.

About 2 km downstream of Moulamein Road these creeks enter a large floodplain, with only the Barbers Creek remaining as a defined carrier. From there, the Barbers Creek flows in a north-westerly direction to the confluence with the Wakool River. The total length of the Barbers Creek from Moulamein Road to the Wakool River is approximately 58 km.

The cross section of Barbers Creek is relatively uniform over its length, with a bed width of around 20 m and steep tree lined banks. Critical bank heights ranged between 3 to 4 m, with the left bank generally higher than the right bank.

There are four block bank structures and one severe blockage due to the natural accumulation of debris in the Barbers Creek. These are located between 27 km and 52 km downstream of Moulamein Road.

There are a number of landholders along the Barbers Creek downstream of the Koondrook-Perricoota Forest. For several landholders, the block bank structures are used to pond water and act as pumping pools for irrigation and stock and domestic water use. Seven landholders have irrigation water licenses with agricultural landuse adjacent to the Barbers Creek comprising a mixture of permanent crops (eg. Avocado orchards) and annual crops (eg. cereals).

NSW Water Solutions (2008) undertook an investigation into the hydraulic capacity of the Barbers Creek downstream of the Koondrook-Perricoota Forest and demonstrated that the natural in-bank capacity of Barbers Creek ranged from 1 270 ML/d to 2 300 ML/d and the capacity of the Creek is reduced by approximately 10% as a result of the existing block bank structures, including overtopping of the block banks. Assuming no overtopping of the block bank structures, the capacity at the block banks ranged between 0 and 160 ML/d for the block bank structures and 490 ML/d at the location of the debris block.

NSW Water Solutions (2008) noted that all of the block bank structures have steep downstream face slopes and no erosion protection works. Accordingly, they are considered incapable of sustaining overtopping flow with significant erosion and wash out. In order to avoid erosion of the existing block banks, flows would need to be maintained so that no overtopping occurs.

Therefore, during managed watering events, it is proposed that the outflows via the four downstream Creeks would be limited to total of 250 ML/d. It is also proposed that “bywashes” or small floodways will be installed on the block banks to control overbank flows and prevent damage to the banks during controlled releases. Concept designs have been developed for these structures (NSW Water Solutions, 2009b).

During larger uncontrolled flood events, flood flows would be un-obstructed through the Forest and allowed to pass along the Creek system at the frequency and at flow rates that are similar to current conditions. Therefore during large uncontrolled flood events, the project is unlikely to impact the risk of flooding along Barbers Creek, compared to current conditions.

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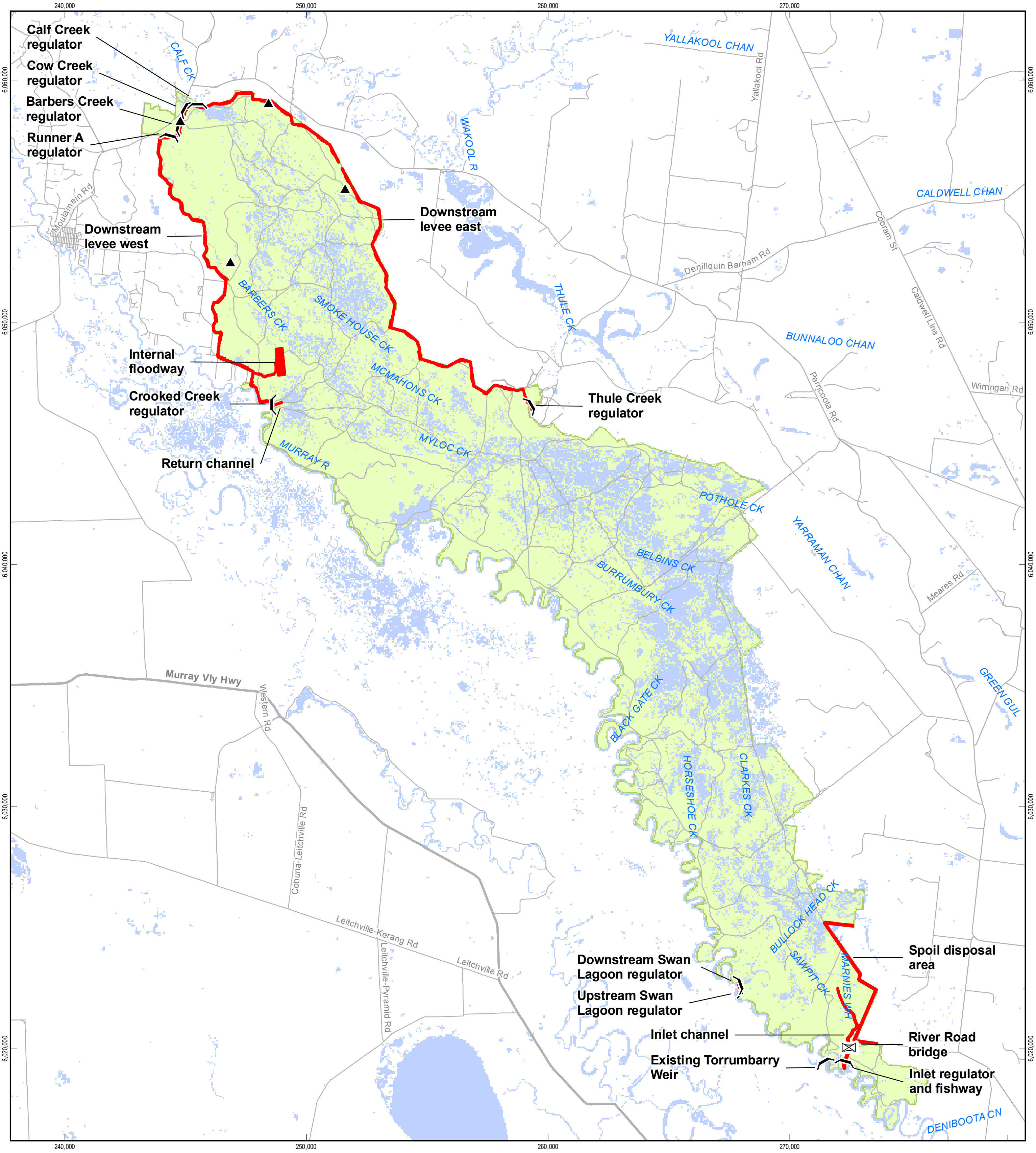
Appendix A

Flood Extents



Legend

- 1991 flood extent
- Turkey's nest dam
- River Road bridge
- Regulator
- Construction features
- Roads
- Koondrook Perricoota Forest Site

0 1 2 4
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Figure 9.4 1991 flood extent

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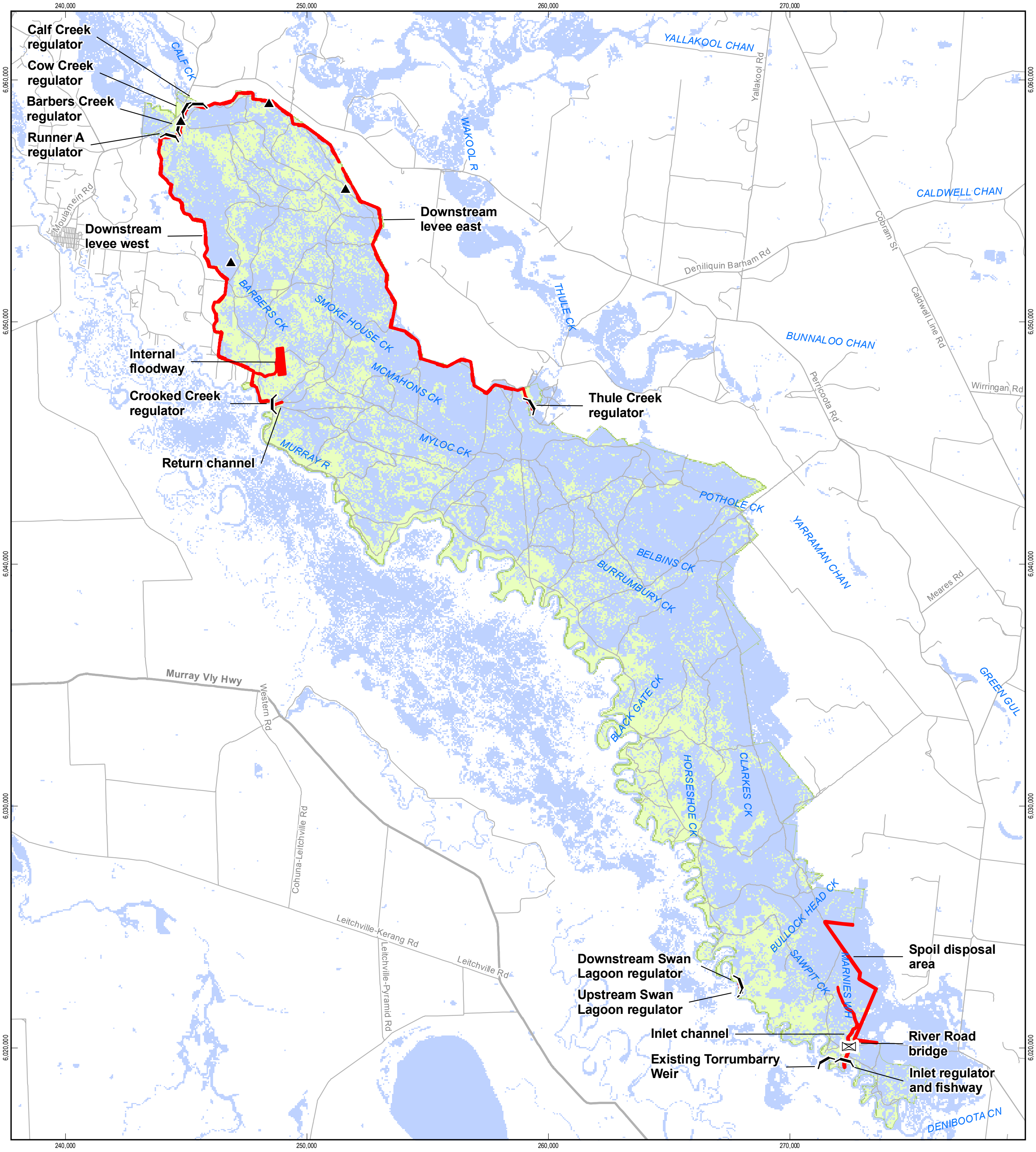
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Dept of Commerce, Street Map- Navtec, Drawn: Cwilson, cwilson



Legend

- 1993 flood extent
- Turkey's nest dam
- River Road bridge
- Regulator
- Construction features
- Roads
- Koondrook Perricoota Forest Site

0 1 2 4
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Figure 9.5 1993 flood extent

Job Number	21-18573
Revision	A
Date	10 FEB 2010

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