CHAPTER 6

Water Resources

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6 Water Resources

This chapter assesses the impact of the Six Mile Creek Dam Safety Upgrade Project on surface and groundwater resources in and around the Project area.

6.1 Background

To determine the impact of the Project on surface water resources, Six Mile Creek downstream of Lake Macdonald to the confluence with the Mary River, Lake Macdonald, and Six Mile Creek upstream of Lake Macdonald were assessed (Figure 6-1). The groundwater assessment focused on the Project area and immediate surrounds.

The assessment included identifying and describing:

- The existing environmental values of surface and groundwater resources
- The potential impacts on surface and groundwater from the Project
- Mitigation measures that may be implements to minimise potential impacts on surface and groundwater resources.

The chapter is structured as follows:

- Section 6.2 describes the hydrology of surface water in Six Mile Creek and Lake Macdonald, provides an assessment of potential impacts from the Project, and identifies mitigation measures that can be implemented to minimise impacts
- Section 6.3 describes the surface water quality in Six Mile Creek and Lake Macdonald, provides an assessment of potential impacts from the Project, and identifies mitigation measures that can be implemented to minimise impacts
- Section 6.4 describes groundwater in and around the Project area, provides an assessment of potential impacts from the Project, and identifies mitigation measures that can be implemented to minimise impacts
- Section 6.5 provides an overview of potential impacts to water resources from the Project.

6.1.1 Environmental Values and Objectives

The legislative framework relevant to water resources is discussed in Chapter 2 – Planning and Approvals. Environmental values have been defined for the Mary River Basin, which incorporates Six Mile Creek and Lake Macdonald, in the *Environmental Protection (Water) Policy 2009* Mary River environmental values and water quality objectives Basin No. 138, including all tributaries of the Mary River July 2010. This document applies to fresh and estuarine surface waters and ground waters draining the Mary River Basin.

Environmental values for water are the qualities of water that support a level of aquatic ecosystem function and / or human water uses. These can be impacted by the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use. The environmental values for the Mary River, Six Mile Creek, and groundwater resources are shown in Table 6-1.

Environmental objectives relevant to surface water are also provided in Schedule 5 of the *Environmental Protection Regulation 2008*, as follows:

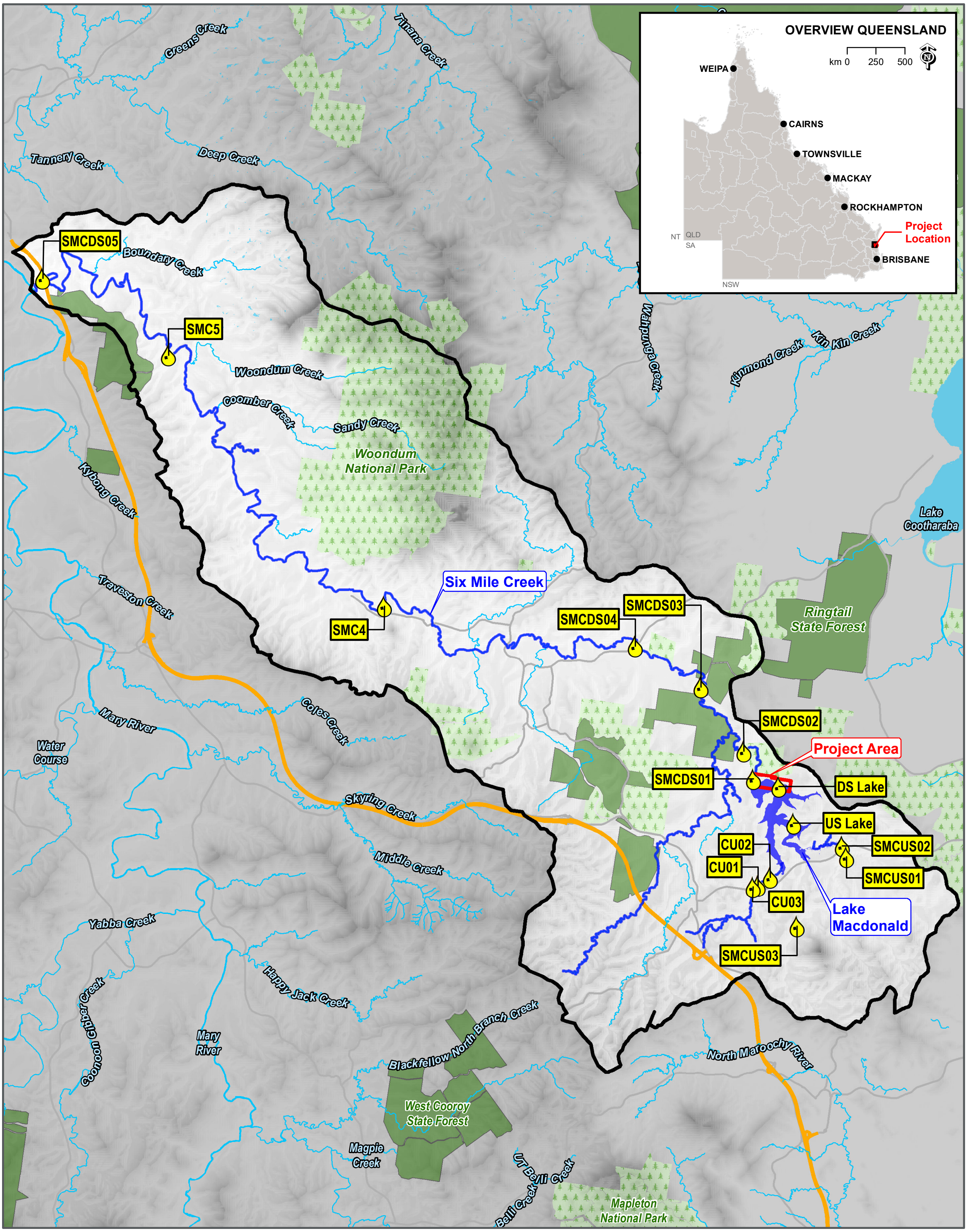
- Water – The activity will be operated in a way that protects environmental values of waters
- Wetlands – The activity will be operated in a way that protects the environmental values of wetlands
- Critical Design Requirements – The design of the facility permits the operation of the site, at which the activity is to be carried out, in accordance with best practice environmental management.

Table 6-1: Environmental Values for Mary River and Six Mile Creek (Freshwater)

ENVIRONMENTAL VALUE	UPPER MARY RIVER	LOWER MARY RIVER	SIX MILE CREEK	GROUNDWATER
Aquatic ecosystems	✓	✓	✓	✓
Irrigation	✓	✓	✓	✓
Farm supply	✓	✓	–	✓
Stock water	✓	✓	✓	✓
Aquaculture	✓	✓	✓	–
Human consumers of fisheries	✓	✓	✓	–
Primary recreation	✓	✓	✓	–
Secondary recreation	✓	✓	✓	–
Visual recreation	✓	✓	✓	–
Drinking water	✓	✓	✓	✓
Industrial use	✓	✓	–	–
Cultural and spiritual values	✓	✓	✓	–

✓ EV applies
– EV does not apply

FIGURE 6-1: SURFACE WATER ASSESSMENT AREA



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seqwater WATER FOR LIFE

LEGEND

- Water Quality Sites
- Bruce Highway
- Secondary Road
- Watercourse
- Six Mile Creek and Upper Tributary
- Lake Macdonald
- Project Area
- Study Area

Protected Areas

- National Parks
- State Forest

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6.2 Surface Water Hydrology

6.2.1 Methodology

Flood Modelling

The Noosa Council flood models and reporting for Six Mile Creek (WMAwater 2018) form the basis of the flood assessment documented in this chapter, the revised modelling of which was performed by WMAwater. The Six Mile Creek catchment was split across three TUFLOW models, namely: Cooroy, Pomona and Six Mile Creek Main Branch (refer to Appendix A).

Seqwater supplied WMAwater a calibrated URBS (Unified River Basin Simulator) hydrologic model of the Lake Macdonald catchment and storage for inclusion in the Six Mile Creek flood study update. It should be noted that although the URBS model was incorporated in the design hydrology by WMAwater, Duration Independent Storm temporal patterns were applied for the WBNM (Watershed Bounded Network Model) hydrologic model adopted for catchments downstream of the Lake Macdonald storage. Genralised Short Duration Method and Generalised Tropical Storm Methods (GTSM-R) were applied to estimating Probable Maximum Precipitation for short and long durations, respectively.

The Noosa Council Flood Study (2018) formed the baseline and was updated in the following ways to assess impacts associated with the Project:

- Revised rating curves (coffer dam and upgraded spillway) were applied to the Seqwater URBS hydrologic model of the Lake Macdonald Dam catchment. The URBS hydrologic model was run for the required Annual Exceedance Probability (AEP) scenarios and the Probable Maximum Flood (PMF).
- In the existing flood study, Probable Maximum Precipitation (PMP) estimates for three areas of interest was derived: Pomona, Cooroy and Cooran. A revision of the PMP for Cooran only was undertaken and the PMF output for the revised spillway design was generated.

The flood modelling scenarios reported herein to measure the flood impact of the Project, in construction phase and future operational phase conditions, against baseline conditions is illustrated in Table 6-2. Please note that all spillway overtopping events modelled are for no dam failure cases.

Table 6-2: Flood Modelling Scenarios

DAM STRUCTURE	MODELLING SCENARIOS
Existing Dam Structure	· 50% (1 in 2 year) AEP · 20% (1 in 5 year) AEP · 10% (1 in 10 year) AEP · 5% (1 in 20 year) AEP · 1% (1 in 100 year) AEP · 0.05% (1 in 2000 year) AEP · Probable Maximum Flood
Coffer dam (construction phase)	· 50% (1 in 2 year) AEP · 20% (1 in 5 year) AEP · 10% (1 in 10 year) AEP · 5% (1 in 20 year) AEP
New Structure (Project)	· 50% (1 in 2 year) AEP · 20% (1 in 5 year) AEP · 10% (1 in 10 year) AEP · 5% (1 in 20 year) AEP · 1% (1 in 100 year) AEP · 0.05% (1 in 2000 year) AEP · Probable Maximum Flood

Dam Water Balance and Flow Releases

Seqwater previously completed a GoldSim water balance model of releases to Six Mile Creek from Lake Macdonald. The simulation dates ranged between the 1 July 1890 to 30 June 2011, based on available data from the Department of Science, Information Technology and Innovation at the time of modelling. Daily rainfall and Moreton Lake evaporation data were obtained from the Scientific Information for Land Owners (SILO) database. Daily catchment inflows were obtained via the Queensland Government. The water balance model was used to assess existing conditions (refer to section 6.2.2 – Flow Releases) and proposed dam upgrade with various release conditions to understand impacts on the storage under various release scenarios.

Qualitative Assessments

A range of qualitative assessments were made relating to impacts to water quality and flow regime and risks to supported ecosystems and licenced water users. The qualitative impacts are based on establishing a baseline environmental values from available data and previous studies; field investigations; and water resource planning documents. Potential impacts associated with the Project are then identified and mitigation measure proposed to reduce residual risk to acceptable levels.

Where the impact is not quantified through modelling or scientific assessment, commitments to meet environmental objectives to achieve performance outcomes are made as stipulated in section 0.

6.2.2 Existing Environment

The Queensland Water Quality Guidelines (QWCG) defines environmental values (EVs) for water as the qualities of water that make it suitable for supporting aquatic ecosystems and human water uses. These EVs need to be protected, by maintaining or enhancing the water quality from the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use. For management purposes, waters are grouped into catchments and sub-catchments and EVs are provided at a catchment level for protection of defined water uses.

This report establishes the existing environmental condition and EVs relevant to the Project.

Climate

Long-term rainfall and evaporation data were collected from the SILO Climate Data[1] at the following coordinate location:

- Latitude: 26.40 degrees south
- Longitude: 152.90 degrees east.

SILO represents a gridded dataset based on records provided by the Bureau of Meteorology (BoM). The data is then processed to fill gaps in data and produce a spatially complete dataset. A summary of monthly averages of the SILO long-term data is provided in Table 6-3 and Figure 6-2.

Some general trends can be observed from the SILO data, such as:

- A distinct wet season during the months of December through April with monthly rainfall averages greater than 100 mm
- A distinct dry season between the months May through November with less than 100 mm mean monthly rainfall between these months
- Evaporation rates that are highest during the summer months, and lowest mid-year. Between the months of July to January, the average evaporation is greater than the average rainfall.

[1] https://legacy.longpaddock.qld.gov.au/silo/

Table 6-3: Data drill average Monthly Rainfall and Evaporation

MONTH	RAINFALL (mm)	EVAPORATION (mm)
January	133	171
February	225	139
March	156	135
April	115	106
May	82	81
June	73	69
July	35	75
August	54	98
September	43	126
October	74	154
November	85	165
December	124	179
Annual Total	**1,199**	**1,498**

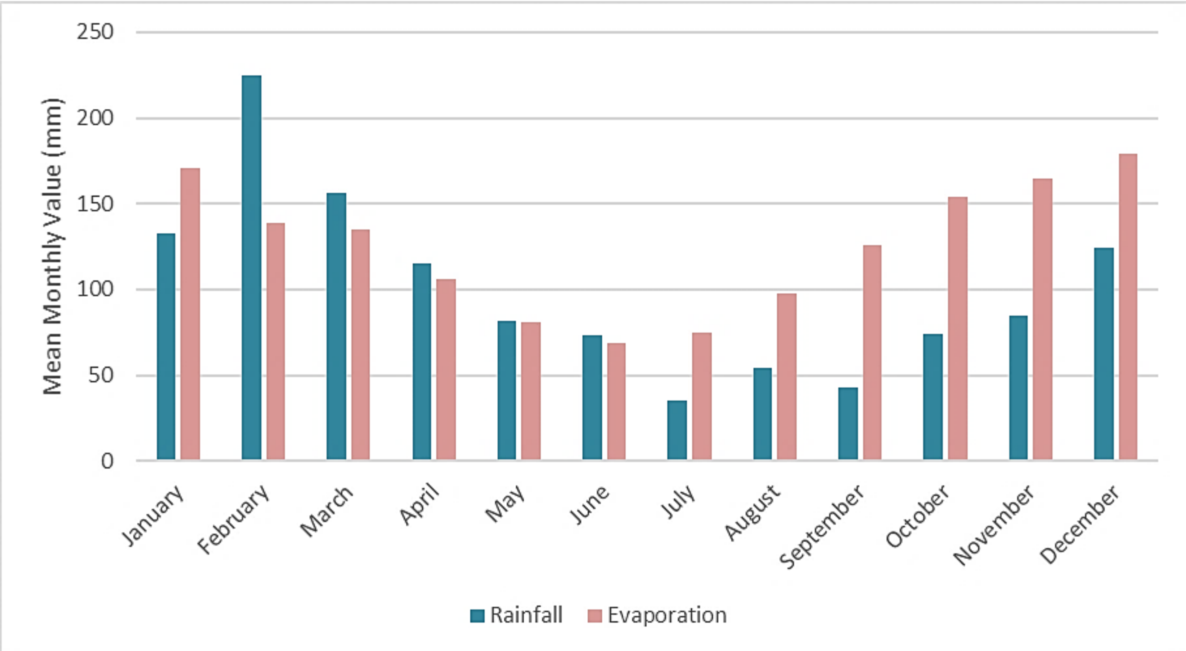


Figure 6-2: Graph of Average Monthly Rainfall and Evaporation from SILO

Catchment Overview

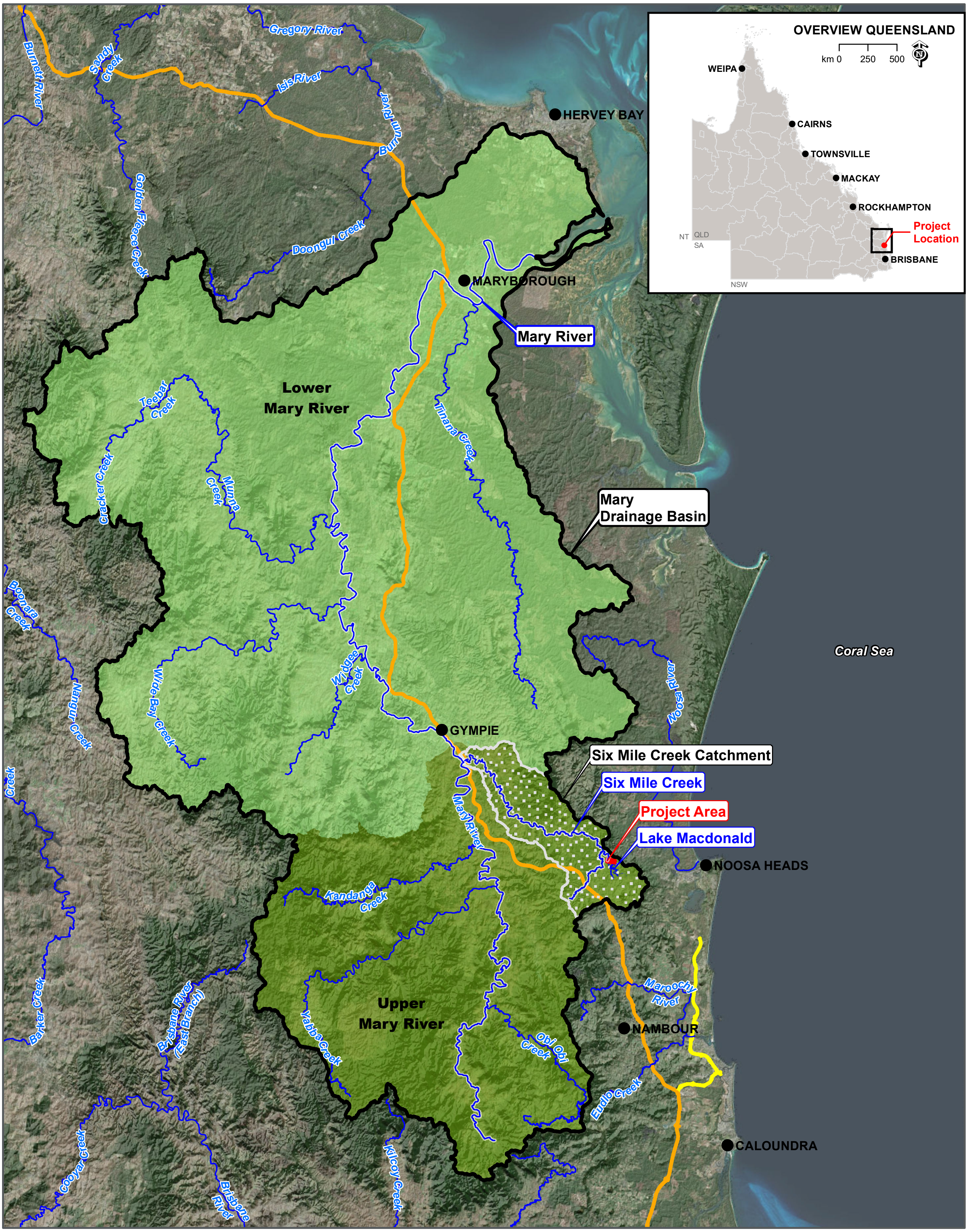
The Project is wholly contained within the Upper Mary River Sub Basin, which in its entirety is comprised of Mary River, Kandanga Creek, Yabba Creek, Obi Obi Creek along with the focused minor system; Six Mile Creek (Figure 6-3). The Project centres on upgrade works to Six Mile Creek Dam (Lake Macdonald), which flows into Six Mile Creek; a watercourse as defined under the Water Act (Figure 6-4). The Six Mile Creek discharges into the Upper Mary River, which is approximately 56 km downstream of Lake Macdonald. The Six Mile Creek catchment is quite steep around the concentrated forested areas, while the rural properties occupy flatter floodplain regions. The total catchment area of Six Mile Creek is 263 km^2, the upper 49 km^2 of which is occupied by the Six Mile Creek dam catchment. The Upper Mary River catchment is 2,713 km^2, inclusive of the Six Mile Creek Catchment.

The Six Mile Creek catchment is predominantly rural, with small towns such as Cooroy and some undisturbed forestry areas. Land upstream of Lake Macdonald is characterised by undulating pasture and a high proportion of rural residential land-uses. Downstream of Lake Macdonald there is a greater proportion of undisturbed forestry areas (both National Park and State Forest). The towns of Cooran, Pinbarren, Pomona, and Glanmire occur downstream of Lake Macdonald in the vicinity of Six Mile Creek. These areas are made up of small towns and rural properties.

There are approximately 165 known wetlands in the Six Mile Creek catchment with the main wetland systems comprised of Lacustrine (353 ha), Palustrine (51 ha) and Riverine (17,510 ha) (refer Figure 6-10 and section 6.2.2 – Wetlands and Farm Dams for more information).

FIGURE 6-3: RIVER BASINS / CATCHMENTS

Six Mile Creek Dam Safety Upgrade Project



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seqwater WATER FOR LIFE

LEGEND

- Locality
- Bruce Highway
- Sunshine Motorway
- Major Watercourse Line
- Lake Macdonald
- Six Mile Creek Catchment Area (Aquatic Study Area)
- Mary Drainage Basin
- Lower Mary River Drainage Sub-Basin
- Upper Mary River Drainage Sub-Basin
- Project Area

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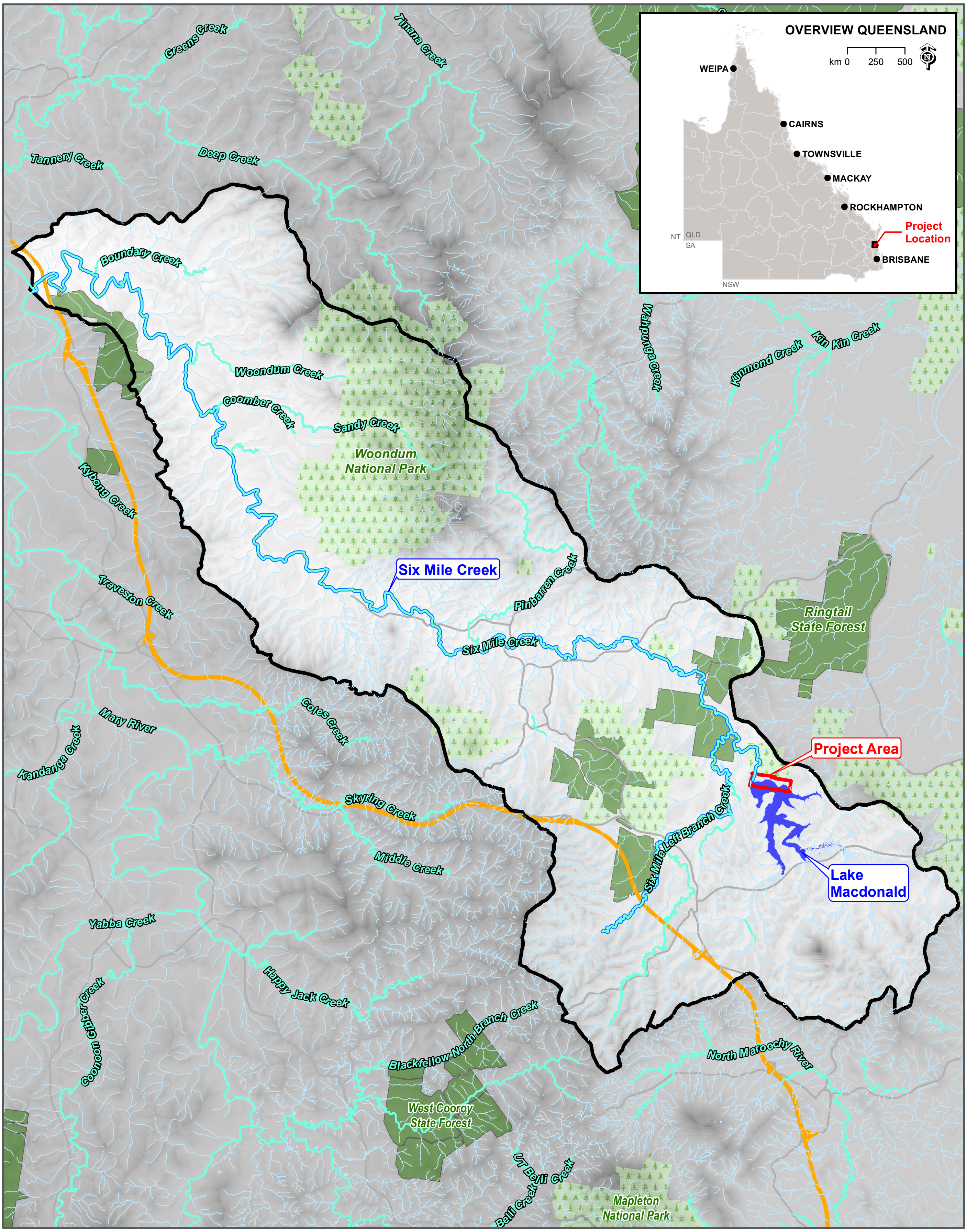
FIGURE 6-4: MATTERS OF STATE ENVIRONMENTAL SIGNIFICANCE - WATERCOURSES

Six Mile Creek Dam Safety Upgrade Project



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2. Matters of state environmental significance - High ecological value waters - waterways - Queensland © State of Queensland (Department of Environment and Science) 2018

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LEGEND

- Bruce Highway
- Secondary Road
- Watercourses under Legislation "Water Act 2000"
- Lake Macdonald
- Project Area
- Study Area

Protected Areas

- National Parks
- State Forest

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Defined Watercourses

Two water features located either in the vicinity or downstream of the Project are defined as watercourses (Figure 6-4) in accordance with the definition of a watercourse provided in the Water Act. These are:

- Six Mile Creek
- Mary River.

Six Mile Creek runs in a north-west direction, is impounded by the Six Mile Creek Dam embankment (Lake Macdonald), and ultimately discharges to the Mary River. Six Mile Creek has a drainage order of five and is classified as non-perennial. The Mary River has a drainage order ranking of eight and is classified as perennial. Perennial streams are those which exhibit a continuous flow of water throughout the year except during extreme drought. On the other hand, non-perennial or semi-perennial streams are those which have no flow for at least a part of the year.

The remainder of low order drainage features surrounding the Project are minor in nature and/or are not directly impacted by the Project by being located upstream to Six Mile Creek and Mary River for which the Project discharges to.

Six Mile Creek

Six Mile Creek was characterised using photos taken at the Six Mile Creek gauge at Cooran (138107B) by the Queensland Government Water Monitoring Information Portal (QGWMIP) hosted by the Department of Natural Resources, Mines and Energy. The below photo is taken at the gauge location. At the time the photo was taken, the creek appears to have a depth of water accumulated within the creek banks greater than 0.5 m. Dense vegetation is present on the banks, consisting of trees and shrubs (Refer to Figure 6-5 and Figure 6-6). The creek appears to have a steady flow at the time, with the water being highly turbid, indicative of the presence of fines (clays and silts) that are not readily settled by the force of gravity. A median electrical conductivity of 181 µs/cm was recorded by the Cooran gauge, indicating the water is fresh and is suitable for irrigation purposes. The channel of Six Mile Creek is estimated to be approximately 10 m in width from the gauging station cross section presented by the QGWMIP.

Figure 6-5: Six Mile Creek Downstream of the Cooran Gauge

Figure 6-6: Six Mile Creek Upstream of the Cooran Gauge

Mary River

The Mary River was characterised using Nearmap imagery (refer Figure 6-7) at the Fisherman's Pocket gauge (138007A). The River is estimated to have a depth of water accumulated within the creek banks greater than 2 m and has distinct low flow and overbank regions. The Mary River main channel is estimated to be on average 50 m wide based on the gauging station cross section provided by the QGWMIP. There is evidence of vegetation establishing along previously cleared sections of the river banks with small trees, grass and shrubs. The substrate appears to have a higher sand content, forming low and high flow regions and islands within the channel. The Mary River at Fisherman's Pocket gauge has recorded a median electrical conductivity of 435 µs/cm, indicating the water is relatively fresh, however more saline than Six Mile Creek.

Figure 6-7: Mary River at Fisherman's Pocket Gauge (Nearmap 2018)

Flow Regime

The temporal patterns of high and low flows are referred to collectively as a river's flow regime. The flow regime plays a key role in regulating geomorphic processes that shape river channels and floodplains, ecological processes that govern the life history of aquatic organisms, and is a major determinant of the biodiversity found in river ecosystems. There are five components that characterise the flow regime:

- Magnitude: the total amount of flow at any given time
- Frequency: how often flow exceeds or is below a given magnitude
- Duration: how long flow exceeds or is below a given magnitude
- Predictability: regularity of occurrence of different flow events
- Rate of change: how quickly flow changes from one magnitude to another.

The following subsections summarise the flow regime of defined watercourses; Mary River and Six Mile Creek.

Six Mile Creek

Summary flow statistics at the Cooran gauge, located on Six Mile Creek downstream of the Project, is provided in Table 6-4. The summary statistics are derived from the period 11/02/1981 to 09/11/2016. The results indicate that the month of February has the greatest monthly mean flow, with the month of October having the least. This distribution of flows corresponds closely with the rainfall statistics summarised in Table 6-3 and attests to the catchment size and ephemeral nature of Six Mile Creek.

Table 6-4: Six Mile Creek Flows at Cooran Gauge (138107B)

MONTH	DAILY FLOW VOLUME (ML)				MONTHLY FLOW VOLUME (ML)
	Max	Min	Mean	Median	Mean
Jan	22,549	0	270	15	8,384
Feb	38,122	0	519	48	14,500
Mar	17,830	0	458	98	14,199
Apr	24,378	0	418	79	12,539
May	10,148	0	227	75	7,022
Jun	18,119	0	215	54	6,461
Jul	19,423	0	144	33	4,462
Aug	23,658	0	92	18	2,866
Sep	4,158	0	56	14	1,685
Oct	4,548	0	49	9	1,507
Nov	4,454	0	57	11	1,672
Dec	12,861	0	147	13	4,552

A flow exceedance probability chart for Six Mile Creek gauge at Cooran is provided in Figure 6-8. The figure shows:

- 95% probability of exceeding 0.0 ML/Day
- 75% probability of exceeding 0.9 ML/Day
- 50% probability of exceeding 20.7 ML/Day
- 25% probability of exceeding 143.7 ML/Day
- 5% probability of exceeding 808.6 ML/Day.

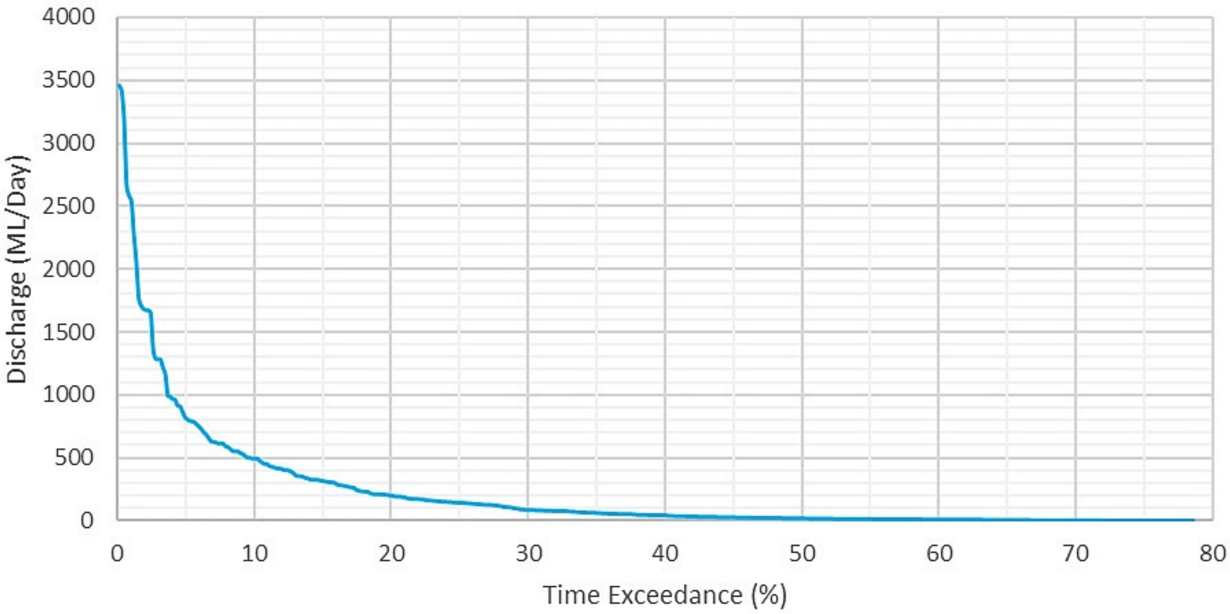


Figure 6-8: Mean Monthly Flow Exceedance for Six Mile Creek at Cooran

Mary River

Summary flow statistics for the Mary River at the Fisherman's Pocket stream gauge is presented in Table 6-5 for the period 01/04/1964 to 23/03/2017. The results indicate that the month of February has the greatest monthly mean flow, with the month of September having the least. The Mary River produces on average 11.5 times greater flows then that of the Six Mile Creek (based on comparison at gauging station locations) and usually has some flow, which attests the perennial nature of the river.

Table 6-5: Mary River Flows at Fisherman's Pocket Gauge (138007A)

MONTH	DAILY FLOW VOLUME (ML)				MONTHLY FLOW VOLUME (ML)
	Max	Min	Mean	Median	Mean
Jan	420,966	2	5,006	352	155,200
Feb	535,609	2	7,500	739	211,876
Mar	193,141	18	4,857	917	150,582
Apr	317,700	5	3,229	679	95,795
May	595,31	13	1,900	569	57,792

MONTH	DAILY FLOW VOLUME (ML)				MONTHLY FLOW VOLUME (ML)
	Max	Min	Mean	Median	Mean
Jun	223,005	20	1,687	392	50,607
Jul	318,497	5	1,730	292	53,249
Aug	100,777	1	699	239	21,667
Sep	282,66	0	512	199	15,355
Oct	67,365	4	620	138	18,619
Nov	37,266	0	908	214	27,231
Dec	106,596	2	1,958	314	60,708

A rainfall and flow exceedance probability chart for the Fisherman's Pocket stream gauge is provided in Figure 6-9. The figure shows:

- 95% probability of exceeding 54.5 ML/Day
- 75% probability of exceeding 155.8 ML/Day
- 50% probability of exceeding 423.4 ML/Day
- 25% probability of exceeding 1,561.2 ML/Day
- 5% probability of exceeding 9,497.1 ML/Day.

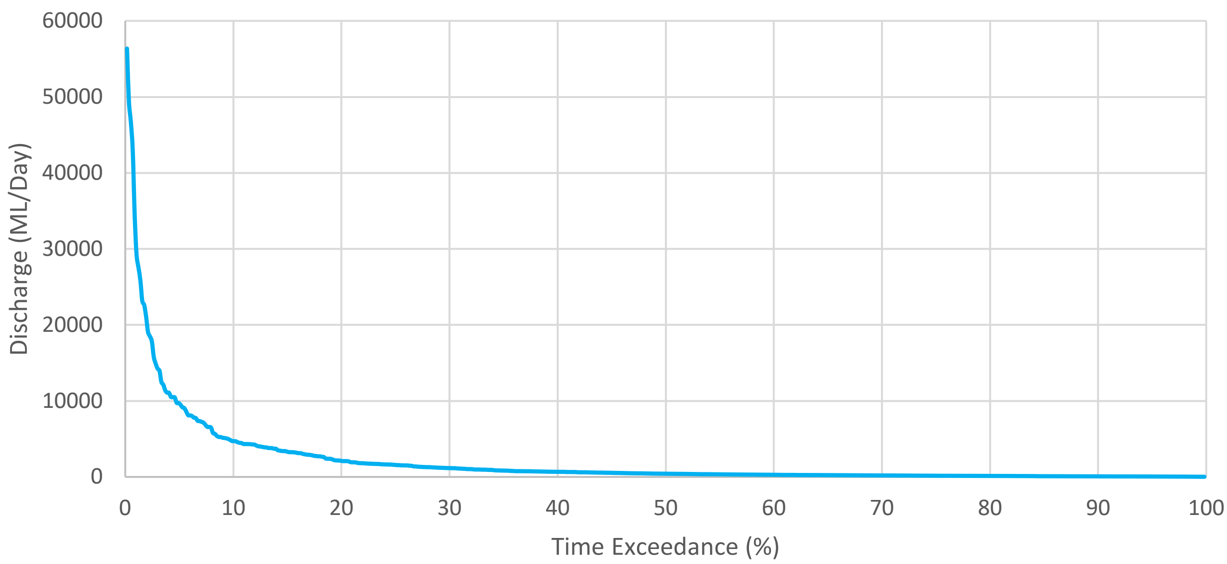


Figure 6-9: Mean Monthly Flow Exceedance for Mary River at Fisherman's Pocket

Wetlands

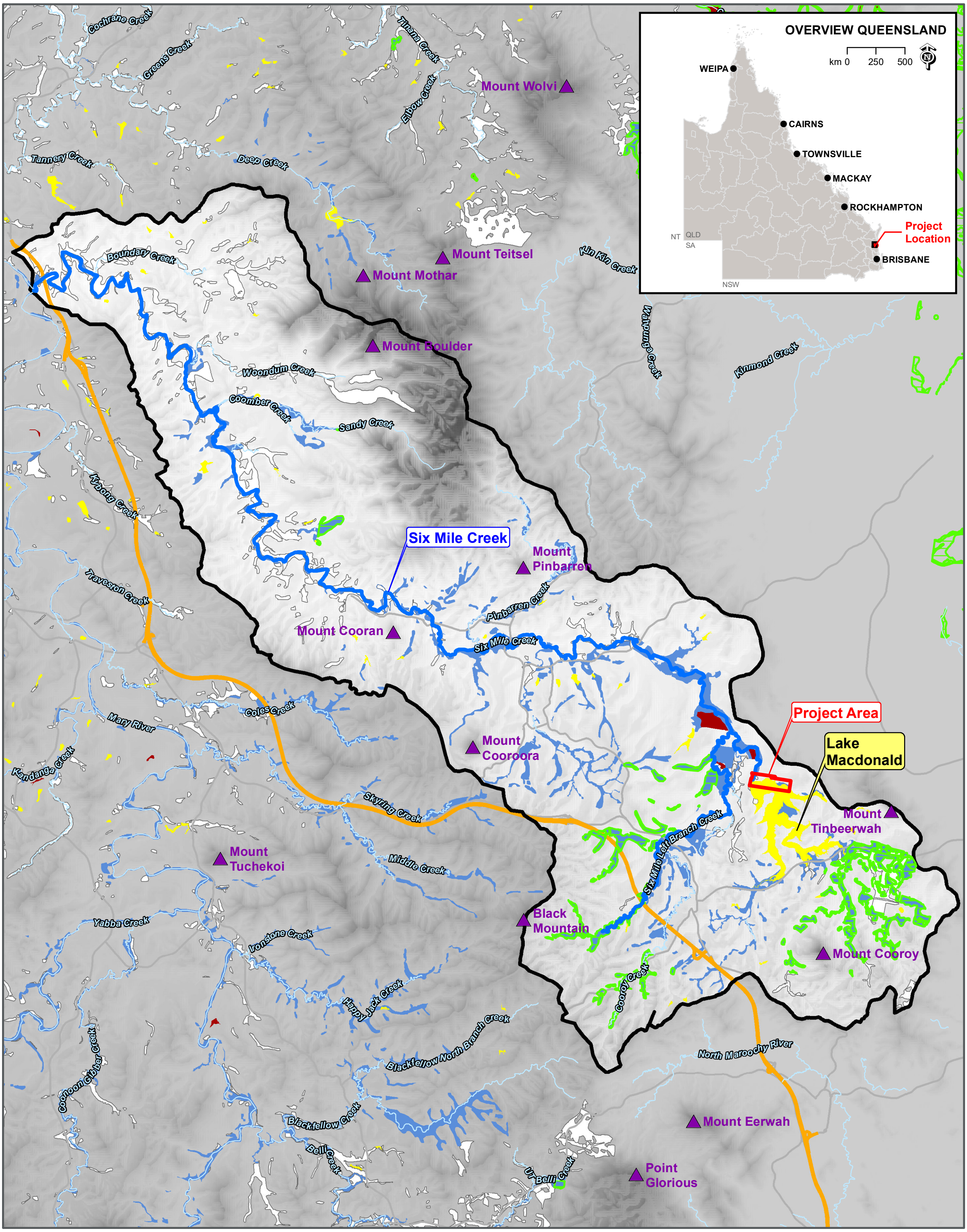
According to the Department of Environment and Heritage Protection (now the Department of Environment and Science), wetlands are defined as 'Areas of permanent or periodic/intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m'. There are three types of wetlands that have been identified within the project area and surrounding areas as shown in Figure 6-10:

- Riverine: wetlands which are systems that are contained within a channel (e.g. river, creek or waterway) and their associated streamside vegetation;
- Lacustrine: wetlands within a topographic depression or dammed river channel that cover an area greater than 8 ha without persistent emergent vegetation and include dams; and
- Palustrine: wetlands dominated by persistent emergent vegetation and include swamps, bogs, and billabongs.

Lake Macdonald is classified as a Lacustrine wetland. Wetlands situated upstream of the lake predominantly consist High Ecological Value Wetlands of State Environmental Significance (MSES wetlands) under the *Environmental Protection (Water) Policy 2009* (EPP Water). Riverine wetlands predominantly reside along the Six Mile Creek and Mary River channel systems.

FIGURE 6-10: MATTERS OF STATE ENVIRONMENTAL SIGNIFICANCE WATERBODIES AND WETLANDS

Six Mile Creek Dam Safety Upgrade Project



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2. Matters of state environmental significance - High ecological value waters - waterways - Queensland © State of Queensland (Department of Environment and Science) 2018

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LEGEND
- Mountain
- Bruce Highway
- Secondary Road
- Watercourses under Legislation "Water Act 2000"
- Project Area
- Study Area
- MSES High Ecological Value Wetlands

Wetland Classifications
- Lacustrine System
- Palustrine System
- Riverine System
- Areas that may include Wetlands

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Existing Water Users

There are numerous surface water allocations within Six Mile Creek which are summarised in Table 6-6 and shown in Figure 6-11. Surface water entitlements are predominantly for irrigation use. The entitlements may be impacted by the Project by being located adjacent to or downstream of the dam site.

Table 6-6: Existing Water Users of Six Mile Creek and Mary River

FIG REF NO.	LAND LOCATION	WRP* / ROP# DESCRIPTION	BASIN	WATER TYPE	WATER SOURCE	AUTHORISATION TYPE	AUTHORISATION PURPOSE
1	32SP285512	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
2	1W39785	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
3	1RP212330	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
4	5SP120729	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Aquaculture; Irrigation
5	40MCH296	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
6	3RP902427	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
7	1RP36949	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
8	1RP172019	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
9	3RP50938	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
10	78MCH546	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
11	2RP184573	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
12	2RP165413	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
13	1RP180666	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
14	4SP215962	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
15	4RP212283	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
16	4RP907513	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
17	334RP860506	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation; Stock
18	1638/RP902161	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Water harvesting
19	118/MCH814	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to interfere by impounding- Embankment or Wall	Impound Water

FIG REF NO.	LAND LOCATION	WRP* / ROP# DESCRIPTION	BASIN	WATER TYPE	WATER SOURCE	AUTHORISATION TYPE	AUTHORISATION PURPOSE
20	5/SP234947	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Any
21	1/RP173437	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Town Water Supply
22	2/RP902427	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
23	118/MCH814	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Town Water Supply
24	1/RP192607	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
25	4/RP825761	Water Plan (Mary Basin) 2006	Mary	Surface Water	Six Mile Creek	Licence to take water	Irrigation
26	224/SP175079	Water Plan (Mary Basin) 2006	Mary	Surface Water	Mary River	Licence to interfere by impounding-Embankment or Wall	Impound Water

* Water Resource Plan

Water Operations Plan

Six Mile Creek Dam – Existing Operation

Six Mile Creek Dam is a zoned earth and rockfill dam that impounds Lake Macdonald. The spillway is an ungated concrete lined chute, meaning that spilling flows passively pass through the spillway structure once the impounded water level exceeds full supply level. The water storage forms part of South East Queensland's drinking water supply, where water is extracted from the storage for the adjacent Noosa Water Treatment Plant, which is connected to and managed under the South-East Queensland water grid. Water extraction from the storage for water treatment is largely dependent on operational strategies to meet water demand, ongoing water security and efficient supply of bulk water as part of the water grid.

As an ungated dam, there are minimal operational requirements related to downstream releases. The current dam also has minimal capacity to make manual releases, other than the daily releases to meet regulatory compliance requirements, as discussed below.

Note also that Six Mile Creek Dam is not part of a water supply scheme and the dam is not operated to make releases for downstream water entitlements.

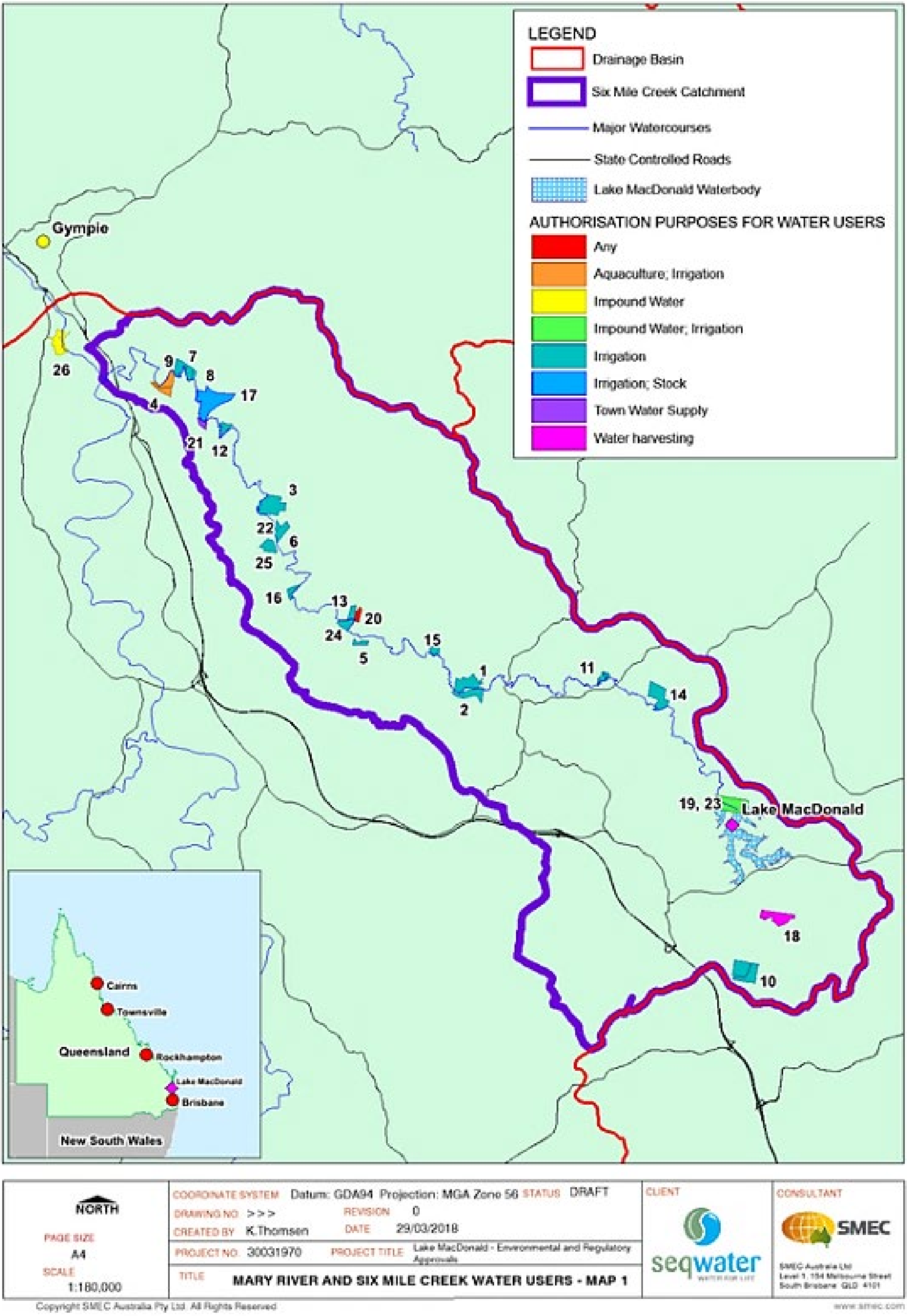


Figure 6-11: Mary River and Six Mile Creek Water Users

Six Mile Creek Dam – Licenses and Conditions

The water licence to interfere with the flow of water in Six Mile Creek, by impounding water (Lake Macdonald), is shown in Table 6-7. The license requires the licence holder to meet environmental flow conditions based on operating levels and inflows to the dam.

Note that Seqwater is the trading name for Queensland Bulk Water Supply Authority, and also incorporates licences previously held by the South-East Queensland Water Grid Manager.

Table 6-7: Water licence to interfere with the flow of water in Six Mile Creek

LICENCES	QUEENSLAND BULK WATER SUPPLY AUTHORITY
Expiry Date	Twenty years from date of grant of licence
Activity	Interfere with the flow of water in Six Mile Creek by impounding water on or adjoining land described as Lot 118 on Plan MCH814. Maximum volume of water stored at full supply level (95.32 metres AHD) not to exceed 8018 megalitres. Maximum height of impounded water at full supply level not to exceed 9.0 metres above the natural bed level at the downstream limit of the impoundment
Purpose	Impound water
Conditions	1. The licensee must not release or supply water from Six Mile Creek Dam when the water level in the dam is at or below the minimum operating level of 87.7 metres AHD. 2. When the storage level in Six Mile Creek Dam is at or above EL 87.7 metres AHD, the licence holder must make daily releases from Six Mile Creek Dam— a. equal to 0.25 megalitres when the inflow to Six Mile Creek dam is equal to or greater than 1 megalitre and less than 10 megalitres; b. equal to 2 megalitres when the inflow to Six Mile Creek Dam is equal to or greater than 10 megalitres and less than 30 megalitres; and c. equal to 5 megalitres when the inflow to Six Mile Creek Dam is equal to or greater than 30 megalitres. 3. The licensee must monitor and record— a. the daily inflow into Six Mile Creek Dam for the purpose of determining the required release rate; b. the rate of release and daily volumes for each release made from Six Mile Creek Dam; c. water quality data in accordance with the Queensland Government's Water Monitoring Data Collection Standards; and d. the storage height for the ponded area of Six Mile Creek Dam on a daily basis in accordance with the Queensland Government's Water Monitoring Data Collection Standards. 4. The license must ensure that quarterly reports are provided to the chief executive in accordance with the Queensland Government's Water Monitoring Data Reporting Standards. Such reports must include all data mentioned in condition 3. The licensee must forward quarterly reports to the chief executive within 3 months after the end of each quarter of every water year. The licensee must forward the data recorded under condition 3 to the chief executive within 10 business days of receiving a request from the chief executive for the data.

Water licenses to take water associated with the impoundment formed by Six Mile Creek Dam are summarised in Table 6-8 and Table 6-9. The major licensee is the South-East Queensland Water Grid Manager (Seqwater) to take an annual volumetric limit of 3,495 ML for the purpose of town water supply. A lesser license to take water is granted to Queensland Bulk Water Supply Authority for an annual volumetric limit of 5 ML/yr. An additional water licence for Seqwater to take water from the impoundment has been granted, but is not documented in the *Mary Basin Resource Operations Plan* (2011). This additional water licence adds 1,500 ML to the annual volumetric limit for town water supply (refer Table 6-10).

Note that no person has a licence to take water from the impoundment of Six Mile Creek Dam, other than the licence for town water supplies held by Seqwater, as described above. At the present time, there is no scope under the Water Act to grant any other person a new water licence to take water from the impoundment.

Table 6-8: Water licence to take water from Six Mile Creek (Licence 1)

LICENCES	QUEENSLAND BULK WATER SUPPLY AUTHORITY
Expiry Date	Ten years from date of grant of licence
Activity	The taking of water from Six Mile Creek on or adjoining land described as Lot 118 on Plan MCH814
Annual Volumetric Limit	5 megalitres per water year
Maximum Extraction Rate	Not to exceed 1 megalitre per day
Purpose	Any
Conditions	1. Water may only be taken from the impoundment of Six Mile Creek Dam. 2. Water must not be taken under this authorisation unless a measuring device of a type approved by the chief executive to measure the volume of water taken, the rate at which water is taken, and the time when water is taken is installed. 3. The volume of water taken under the authority of this water licence must be recorded by the licensee on a daily basis. The records must include the measuring device reading and the time and date that the reading is taken. 4. The licensee must forward the data recorded under condition 3 to the chief executive within 10 business days of receiving a request from the chief executive for the data.

Table 6-9: Water licence to take water from Six Mile Creek (Licence 2)

LICENCES	SOUTH EAST QUEENSLAND WATER GRID MANAGER
Expiry Date	Ten years from date of grant of licence
Activity	The taking of water from Six Mile Creek on or adjoining land described as Lot 118 on Plan MCH814
Annual Volumetric Limit	3,495 megalitres per water year
Maximum Extraction Rate	Not to exceed 45 megalitres per day
Purpose	Town water supply
Conditions	1. Water may only be taken from the impoundment of Six Mile Creek Dam. 2. The licensee must not take water from the ponded area of Six Mile Creek Dam when the water level in the dam is at or below the minimum operating volume of 22 megalitres.

LICENCES	SOUTH EAST QUEENSLAND WATER GRID MANAGER
	3. Water must not be taken under this authorisation unless a measuring device of a type approved by the chief executive to measure the volume of water taken, the rate at which water is taken, and the time when water is taken is installed. 4. The volume of water taken under the authority of this water licence must be recorded by the licensee on a daily basis. The records must include the measuring device reading and the time and date that the reading is taken. 5. The licensee must forward the data recorded under condition 4 to the chief executive within 10 business days of receiving a request from the chief executive for the data.

Table 6-10 Water licence to take water from Six Mile Creek (Licence 3)

LICENCES	QUEENSLAND BULK WATER SUPPLY AUTHORITY
Expiry Date	30/06/2111
Activity	The taking of water from Six Mile Creek on or adjoining land described as Lot 118 on Plan MCH814
Annual Volumetric Limit	1,500 megalitres per water year
Maximum Extraction Rate	Not to exceed 43.5 megalitres per day
Purpose	Town water supply
Conditions	1. Water may only be taken from the impoundment of Six Mile Creek Dam. 2. The licensee must not take water from the ponded area of Six Mile Creek Dam when the water level in the dam is at or below the minimum operating volume of 22 megalitres. 3. Water must not be taken under this authorisation unless a measuring device of a type approved by the chief executive to measure the volume of water taken, the rate at which water is taken, and the time when water is taken is installed. 4. The volume of water taken under the authority of this water licence must be recorded by the licensee on a daily basis. The records must include the measuring device reading and the time and date that the reading is taken. 5. The licensee must forward the data recorded under condition 4 to the chief executive within 10 business days of receiving a request from the chief executive for the data.

Flow Releases

Downstream flow releases from the existing dam location were assessed using hydrologic analysis, as outlined in section 6.2.1, which was based on a daily water balance model (GoldSim platform) to simulate a period of climatic variation between 1st of July 1890 to the 30th of June 2011.

A summary of spillway and environmental flow releases (outflow) under the existing dam conditions is provided in Figure 6-12. The chart shows the percentage of time a given outflow is exceeded over the simulation period, shown per season as well as across all seasons.

The simulation of the existing dam confirmed that the stored water levels greater than 6,000 ML (75% Full Supply Volume) occur around 92% of the time. The dam spillway operates around 23% of the time.

For further context of inflows and outflows, the mean annual water balance for the simulation period yielded the following:

- 33,732 ML/year mean annual inflow and direct rainfall
- -7,166 ML/year mean annual evaporation, extraction and environmental releases
- -26,539 ML/year mean annual spillway overflows

The below chart shows the percentage of time a given overflow is exceeded over the simulation period. The simulation predicts 20 ML/d and 50 ML/d flow exceedances for 17% and 13% of time, compared to the no dam case values of 26% and 16% exceedance for 20 ML/d and 50 ML/d flows, respectively. This indicates that current dam operations slightly decreases flow exceedances to the receiving environment compared to pre-dam construction conditions.

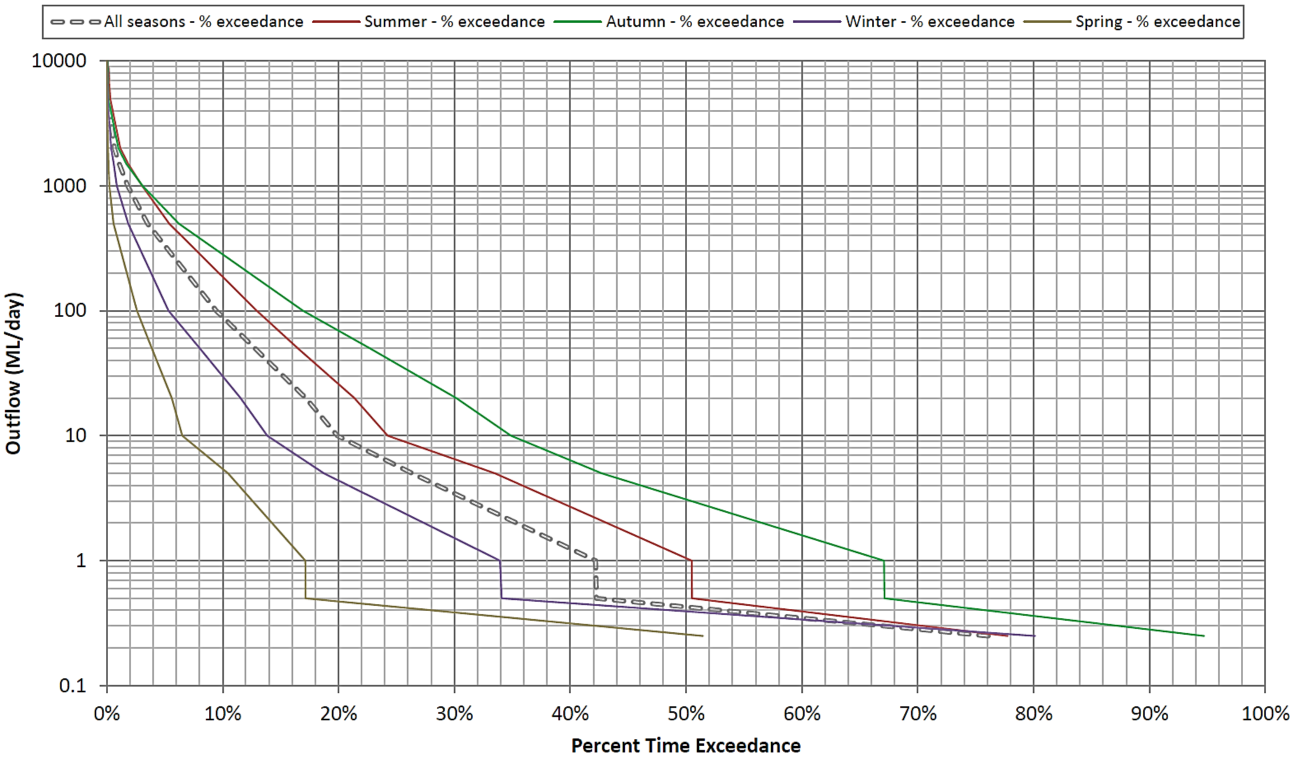


Figure 6-12: Existing Dam scenario - Total Dam Outflow Exceedance Frequency (Spillway Flow + Environmental Release)

Existing Flooding

As discussed in 6.2.1, WMAwater have developed a Six Mile Creek flood model for Noosa Council that covers the floodplain downstream of Lake Macdonald. The model inflows were derived from rainfall runoff hydrologic models (WBNM and URBS) developed by WMAwater (for catchments downstream of the Lake Macdonald Drive). Seqwater supplied dam outflows for the scenarios tested by WMAwater. As per the requirements of Noosa Council, Duration Independent Storms (DIS) were used to simulate rainfall patterns downstream of the lake. To note, the DIS is not a method used by Seqwater for undertaking their hydrologic studies. A suite of AEP design floods were generated for events ranging from the 50% AEP through to the PMF at Cooran.

Existing case peak flood depth maps for the 5% AEP, 1% AEP, 0.05% AEP and the PMF events are shown in Appendix A. The mapping shows that bank full discharge (i.e. flows contained within the main channel) is exceeded in the 5% AEP event, however, there is little breakout flows (i.e. transference flows between creek catchments) occurring for even the PMF. This is likely due to a well-defined and relatively steep channel gradient, thereby reducing floodplain interaction and breakout flows.

6.2.3 Potential Impacts

The key activities and potential impacts arising from the project, which have the potential to influence the environmental values within and around Six Mile Creek, as described in previous sections, are examined in this section of the report. The broad activities and potential impacts from construction and operation of Six Mile Creek Dam and Lake Macdonald identified include:

- Dewatering activities contributing to erosion and sediment runoff
- Construction activities contributing to the suspension of sediment in the water column from disturbance during demolition of the existing dam wall and associated embankments and site establishment
- Post-construction activities influencing water quality conditions from organic material that may accumulate whilst the dam is in a lowered state
- Suspension of sediments from filling of Lake Macdonald
- Construction activities contributing to potential hazardous chemical spills.

Flow Regime

Impacts to the Six Mile Creek flow regime will be most pronounced during construction and due to dam dewatering and flow diversion during the upgrade works. Dewatering and flow diversion during construction will likely:

- Introduce flows during an otherwise dry period during dewatering, thus impacting on the natural wetting and drying cycles of the Six Mile Creek ephemeral system
- Introduce a relatively sudden rate of change in flow during dam dewatering activities with pumping activities designed not to exceed 10 m^3/s. This is much less then what occurs naturally during floods.

Temporary return of Six Mile Creek to a river system (pre-dam condition) during the construction works. Potential increase of the magnitude and frequency of flows due to the removal of the existing dam. It is reasonable to assume that the flow exceedance for Six Mile Creek will approach pre-dam creek conditions during the construction works after the initial drawdown of the dam volume and decommissioning of the existing dam.

In the post construction phase of the new dam, the dam full supply level will remain the same and the spillway is being designed to match the Noosa Council Q100 Flow Rate. Additionally, the existing environmental releases based on water license conditions will be retained post-upgrade.

The potential impact on flow regimes during post-construction operation would occur if environmental release conditions are changed or the new spillway structure outflows differ from the existing dam. The potential outcomes of changing dam releases include:

- A change to the flow frequency curve of the new spillway structure compared to the existing spillway structure
- Potential elongation of discharge events
- Potential decrease in the number of no flow days
- Potential changes to channel geomorphology and supported ecosystems due to the prolonged alteration of the flow regime.

An upstream fishway passage system will not be incorporated into the new dam structure. This is discussed further in Chapter 07 – Aquatic Ecology.

At this stage of the Project, dam releases for environmental flows are proposed to be retained based on water license conditions. Design of environmental release infrastructure will be such that a range of flows can be accommodated in the future.

Seqwater may investigate in the future the potential benefits and impacts of increased environmental releases from the dam, primarily for the purpose of improving aquatic ecology outcomes for the Mary River cod, which is a conservation significant species with a key breeding population downstream of Lake Macdonald. Any such changes would only be made if there was a demonstrable improvement on the existing flow regime on balance of all aspects.

Flow Objectives

Schedule 5 within the *Water Resource (Mary Basin) Plan 2006* (WRP) refers to the conditions regarding Environmental Flow Objectives (EFO) for various locations within the Mary Basin. The nearest reporting node downstream of the Project is Node 3 - Mary River at Fisherman's Pocket. It is unlikely that low, medium, high or seasonal flow objectives be impacted by the Project in part due to; the buffering effect of the contributing catchment at this (node 3) location

(3,068 km^2) compared to the Lake Macdonald catchment (49 km^2); the Six Mile Creek operating conditions replicating existing conditions during future operation; and due the perennial nature of the Mary River. The impact on EFOs under the WRP has not however been quantified within the Resource Operations Plan Integrated Quantity and Quantity Model, which forms the basis for impact assessment on EFOs.

Water Security

During construction of the coffer dam, the dam is to be lowered to RL 88.5-89.0 m AHD, which will impact on existing extraction from Lake Macdonald for town water supply. Seqwater has determined that Lake Macdonald will not be used for water supply during construction and will use alternative water sources, as discussed in Chapter 02 – Project Description.

During construction, the flow frequency exceedance will likely more closely represent no dam conditions, e.g. a natural waterway system (refer section 6.2.2), due to lesser attenuation by the coffer dam compared to the existing dam. This may provide an overall volumetric increase of water discharging to Six Mile Creek for a given rainfall event, however, the duration of flow may be altered due to the absence of flow releases from the dam.

Impact to water security during the future operational phase (post-upgrade) will be unchanged to that currently experienced.

Flooding

The following summarises assessed flood impacts for construction and future operation phases, compared with the existing dam situation. The below Figure 6-13 illustrates result locations that correspond to the hydraulic structures reported herein and to the stage (flood height) and flow hydrographs presented in Appendix A.

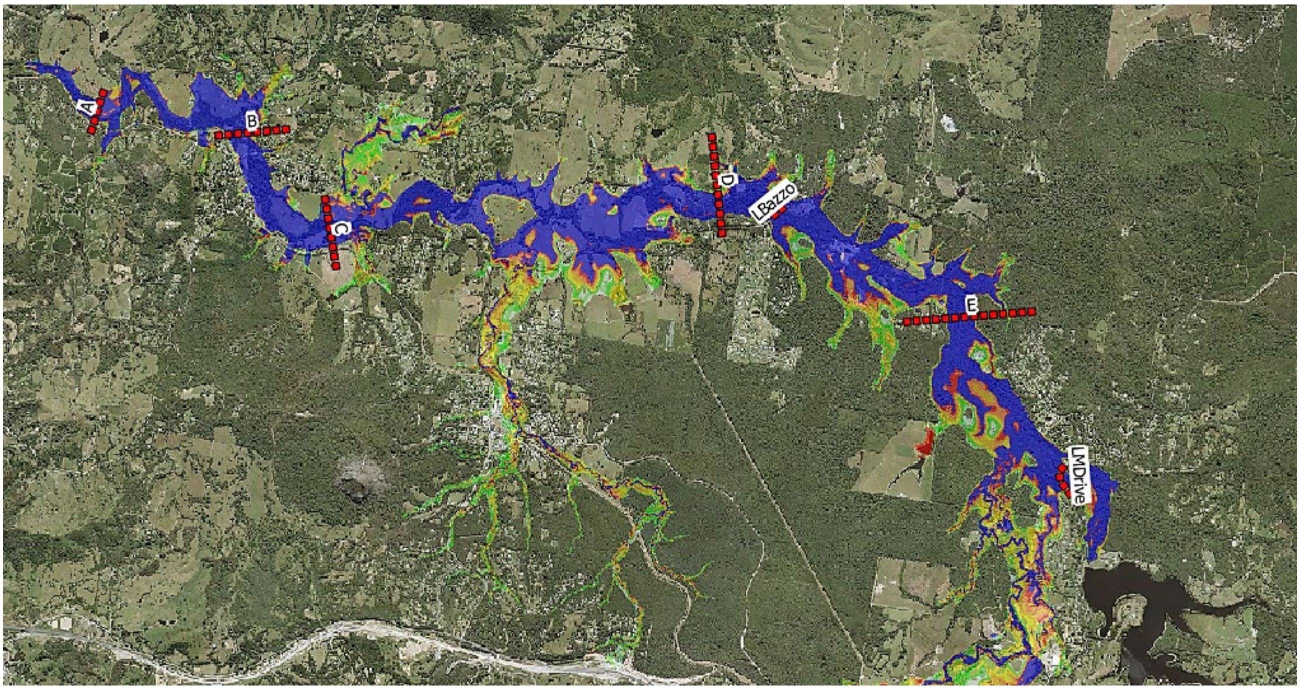


Figure 6-13: Flow Hydrograph Result Locations (WMAwater 2018)

Road Infrastructure

As part of the Noosa Council adopted Six Mile Creek Flood Study, Hydraulic Structure Reference Sheet (HSRS) were produced for waterway crossings across the catchment. Comparison against the Council's HSRS for Lake Macdonald Drive and Louis Bazzo Drive (locations shown in Figure 6-13 as LMDrive and LBazzo, respectively) was undertaken for this impact assessment to understand any changes at these locations due to the change in spillway configuration. The following tables summarises the hydraulic structure output data from the scenario undertaken:

- Lake Macdonald Drive – New Spillway (future operational phase): Table 6-11
- Lake Macdonald Drive – Coffer dam (construction phase): Table 6-12
- Louis Bazzo Drive – New Spillway (future operational phase): Table 6-13
- Louis Bazzo Drive – Coffer dam (construction phase): Table 6-14

Flow and stage hydrographs at these hydraulic structure locations are illustrated in Appendix A (WMAwater 2018). The figures show that whilst the afflux impacts are somewhat pronounced, the immunity and duration of inundation remain largely unaffected. This is with the exception of the 50% AEP construction phase result at Lake Macdonald Drive where the flood level inundates the bridge soffit during existing conditions, however overtops the bridge during the construction phase. The following tables show flow through the bridge and culvert structures (Qstructure) and flow overtopping the structure as weir flow (Qweir). If overtopping (Qweir) values are zero, the road infrastructure is not inundated.

Table 6-11 Modelled structure performance data – Lake Macdonald Drive, New Spillway (future operational phase)

AEP (%)	DISCHARGE		VELOCITY		WATER SURFACE ELEVATION AT UPSTREAM FACE (mAHD)	HEADLOSS (mm)	CHANGE IN WATER ELEVATION FROM EXISTING (m)
	Qstructure (m^3/s)	Qweir (m^3/s)	Vstructure (m/s)	Vweir (m/s)			
PMF	33.5	1263.3	1.57	0.95	91.6	57	n/a
0.05	35.9	625.1	1.7	1.0	90.0	75	+0.2
1	35.0	303.1	1.6	1.1	89.1	80	+0 – 0.1
5	43.0	181.8	2.0	1.6	88.6	116	0
10	51.6	123.4	2.4	1.3	88.5	277	+0.1
20	55.6	74.2	2.6	1.1	88.4	484	+0.1
50	67.7	0.0	3.62	0.0	87.9	600	+0.4
SDDD*	10.0	0.0	1.11	0.0	85.54	85	n/a

*SDDD – Sunny Day Dam Discharge of 10 m^3/s represents maximum dam dewatering flow, significantly lesser than a 50% AEP flood flow.

Table 6-12 Modelled structure performance data – Lake Macdonald Drive, Coffer dam (construction phase)

AEP (%)	DISCHARGE		VELOCITY		WATER SURFACE ELEVATION AT UPSTREAM FACE (mAHD)	HEADLOSS (mm)	CHANGE IN WATER ELEVATION FROM EXISTING (m)
	Qstructure (m^3/s)	Qweir (m^3/s)	Vstructure (m/s)	Vweir (m/s)			
5	40.5	294.1	1.9	1.4	88.9	107	+0.3
10	48.1	231.7	2.3	1.8	88.7	148	+0.3
20	61.3	156.5	2.9	1.4	88.6	410	+0.6
50	65.4	55.3	3.1	0.9	88.3	848	+0.8

Table 6-13 Modelled structure performance data – Louis Bazzo Drive, New Spillway (future operational phase)

AEP (%)	DISCHARGE		VELOCITY		WATER SURFACE ELEVATION AT UPSTREAM FACE (MAHD)	HEADLOSS (mm)	CHANGE IN WATER ELEVATION FROM EXISTING (m)
	Qstructure (m^3/s)	Qweir (m^3/s)	Vstructure (m/s)	Vweir (m/s)			
PMF	68.8	1435.9	1.6	1.2	87.2	44	+0.2
0.05	60.3	724.8	1.4	1.0	84.9	47	+0.1
1	54.6	423.2	1.3	0.8	83.7	49	0
5	51.9	281.7	1.2	0.7	83.1	53	+0.1
10	50.4	215.6	1.3	0.7	82.7	55	+0.1
20	49.1	155.6	1.1	0.6	82.4	59	+0.1
50	47.6	74.6	1.1	0.5	81.8	59	+0.1
SDDD*	9.9	0	0.4	0	79.15	4	n/a

*SDDD – Sunny Day Dam Discharge of 10 m^3/s represents maximum dam dewatering flow, significantly lesser than a 50% AEP flood flow.

Table 6-14 Modelled structure performance data – Louis Bazzo Drive, Coffer dam (construction phase)

AEP (%)	DISCHARGE		VELOCITY		WATER SURFACE ELEVATION AT UPSTREAM FACE (MAHD)	HEADLOSS (mm)	CHANGE IN WATER ELEVATION FROM EXISTING (m)
	Qstructure (m^3/s)	Qweir (m^3/s)	Vstructure (m/s)	Vweir (m/s)			
5	53.2	345.8	1.2	0.8	83.4	51	+0.4
10	51.5	271.7	1.2	0.7	83.0	52	+0.4
20	50.2	198.5	1.2	0.7	82.6	56	+0.3
50	48.2	96.3	1.1	0.6	82.0	68	+0.3

Construction Phase Flood Impacts - Coffer dam

The spillway discharge curves for Lake Macdonald with the existing dam spillway (‘Existing Rating Curve’), new dam spillway (‘New Spillway’) and construction phase coffer dam (‘CofferDam’) arrangements are shown in Figure 6-14. Flood impacts may be pronounced during the construction phase due to the reduced attenuation of inflows to Lake Macdonald through lake lowering and placement of coffer dam. More specifically, reduced attenuation of flood volumes during construction will result in increased flood levels downstream for a given rainfall event.

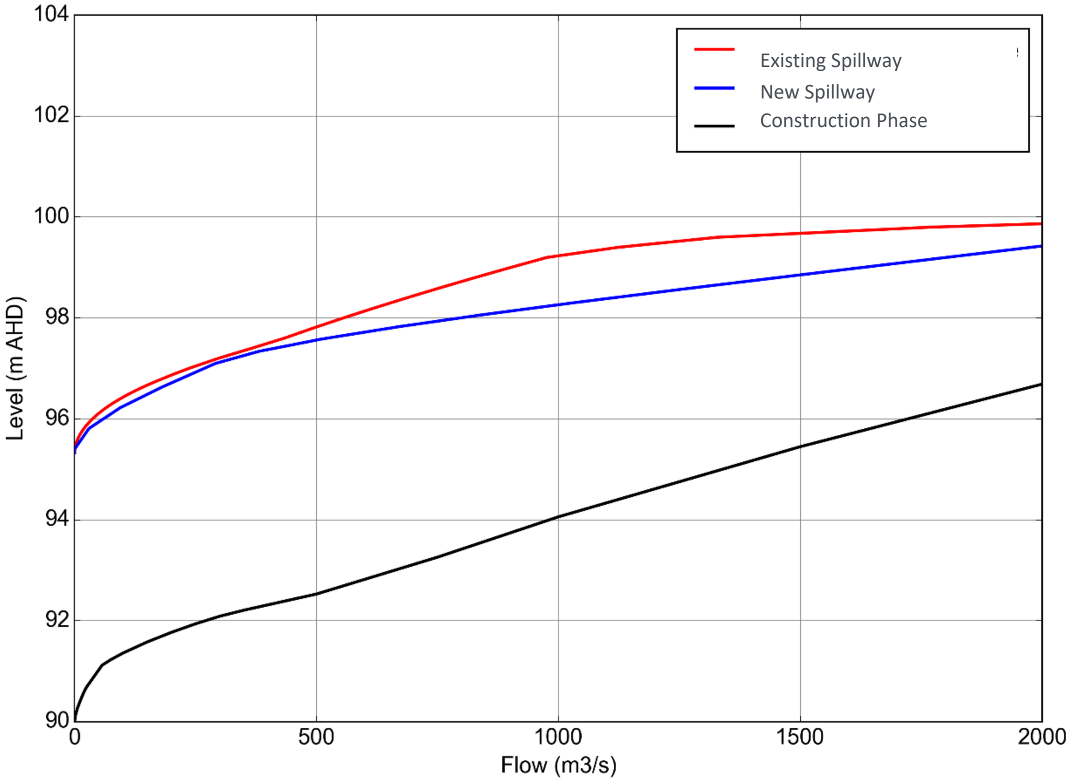


Figure 6-14: Rating curves for Lake Macdonald Spillway arrangements

Construction phase flood afflux (increase in flood levels compared to existing conditions) associated with the coffer dam and diversion works are illustrated in Appendix A for the 50% AEP to 5% AEP.

Construction phase stage and flow hydrographs at various locations along Six Mile Creek are contained in Appendix A (WMAwater 2018).

Operational Phase Flood Impacts

The proposed labyrinth spillway is stepped with two different crest levels. The first crest level accommodates frequent to rare floods up to the 1% AEP with a similar rating to the existing case. The second crest accommodates rare to extreme flood events up to the PMF. The spillway ratings for the existing dam ('Existing Rating Curve') provided by Seqwater and new dam spillway ('Revised Rating Curve') designed and supplied by AECOM are shown in Appendix A.

Spillway overtopping flows for the existing dam spillway ('Lake Macdonald Outflow – Flood Study'), new dam spillway ('Lake Macdonald Outflow – New Spillway') and construction phase coffer dam ('Lake Macdonald Outflow – Coffer Dam') arrangements are shown in Figure 6-15 through to Figure 6-20 for various AEP events.

The figures show:

- The proposed new spillway is more efficient than the existing dam, with the curves diverging for flows above the 1% AEP discharge (325 m^3/s) (refer Figure 6-14)
- The largest increase on peak flow (1.5 times) for the 50% AEP event (refer Figure 6-15)
- Minor differences for the 1% AEP hydrographs on the rising and receding limb, but no changes to the peak flow (refer Figure 6-19)
- A peak discharge increase of approximately 10% for the 0.05% AEP event (refer Figure 6-20).

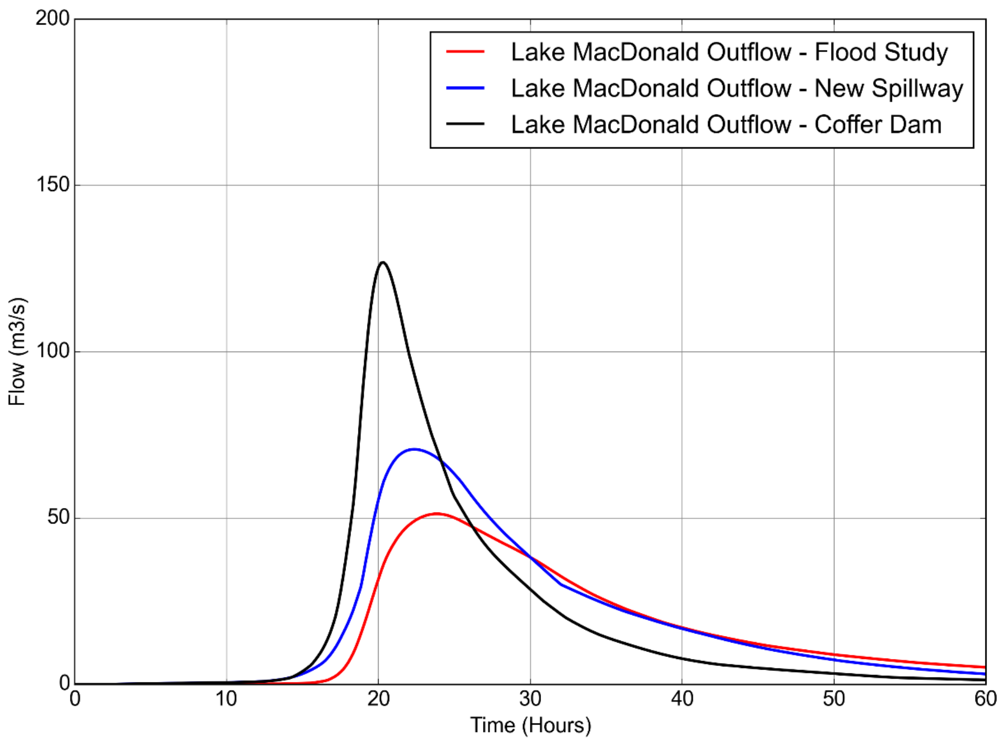


Figure 6-15: Comparison of Design Hydrographs for the 50% AEP Event

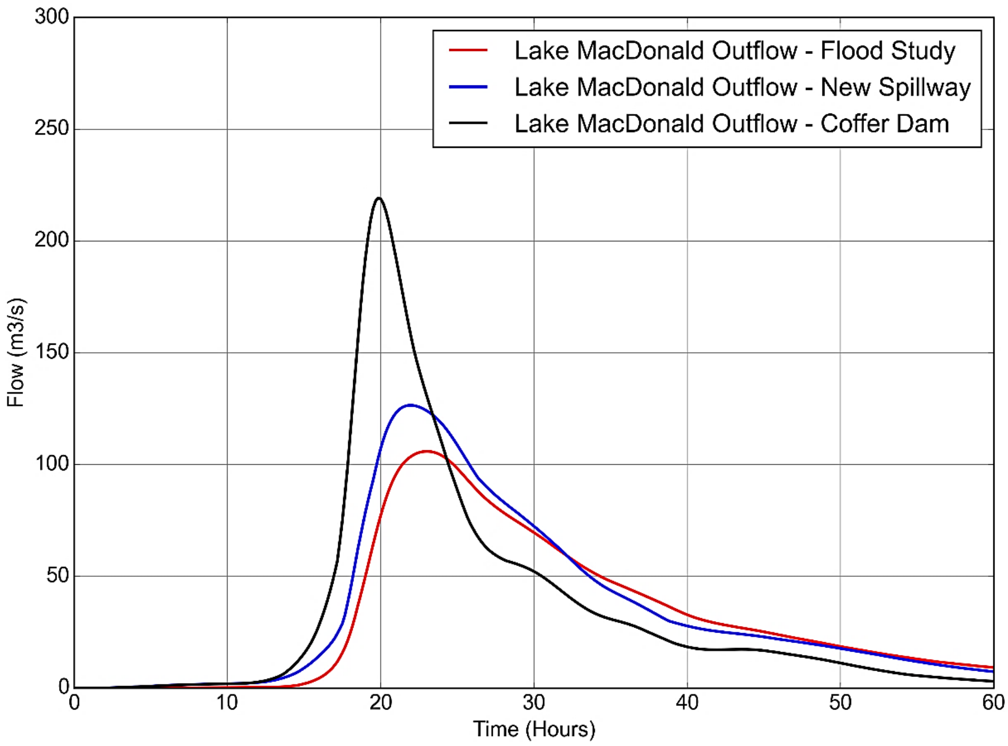


Figure 6-16: Comparison of Design Hydrographs for the 20% AEP Event

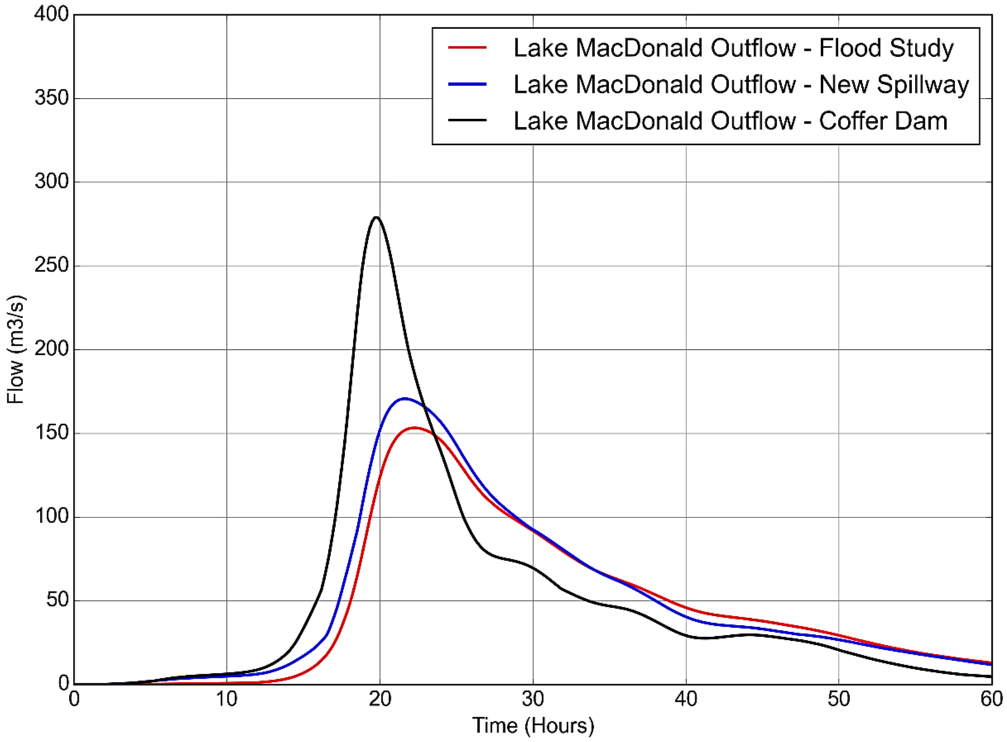


Figure 6-17: Comparison of Design Hydrographs for the 10% AEP Event

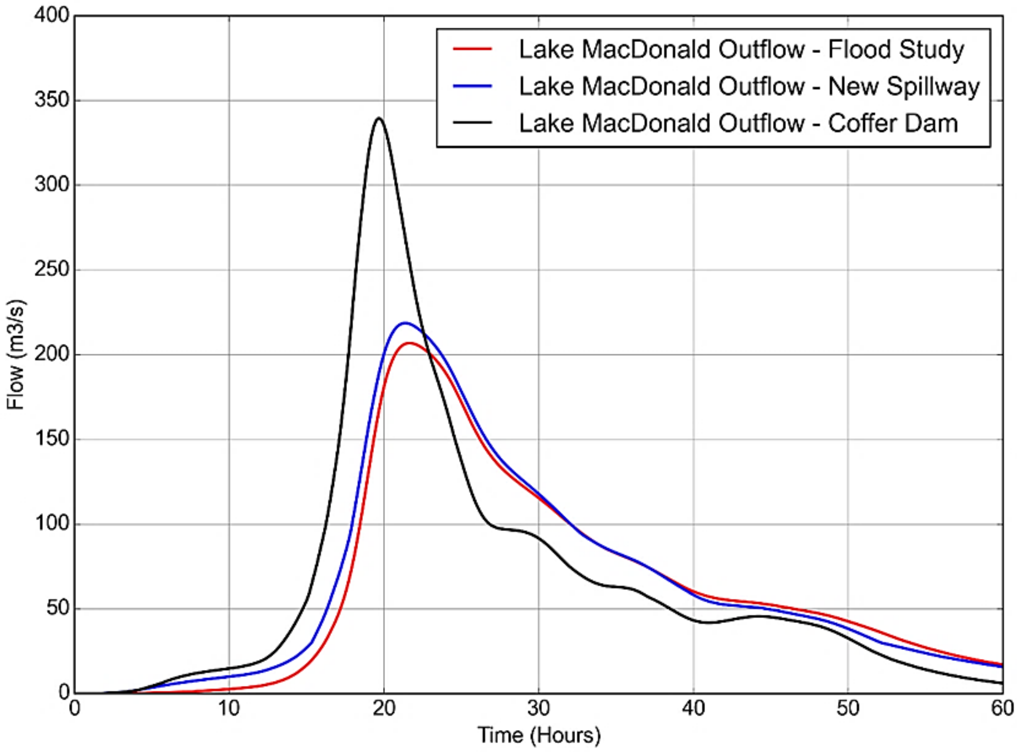


Figure 6-18: Comparison of Design Hydrographs for the 5% AEP Event

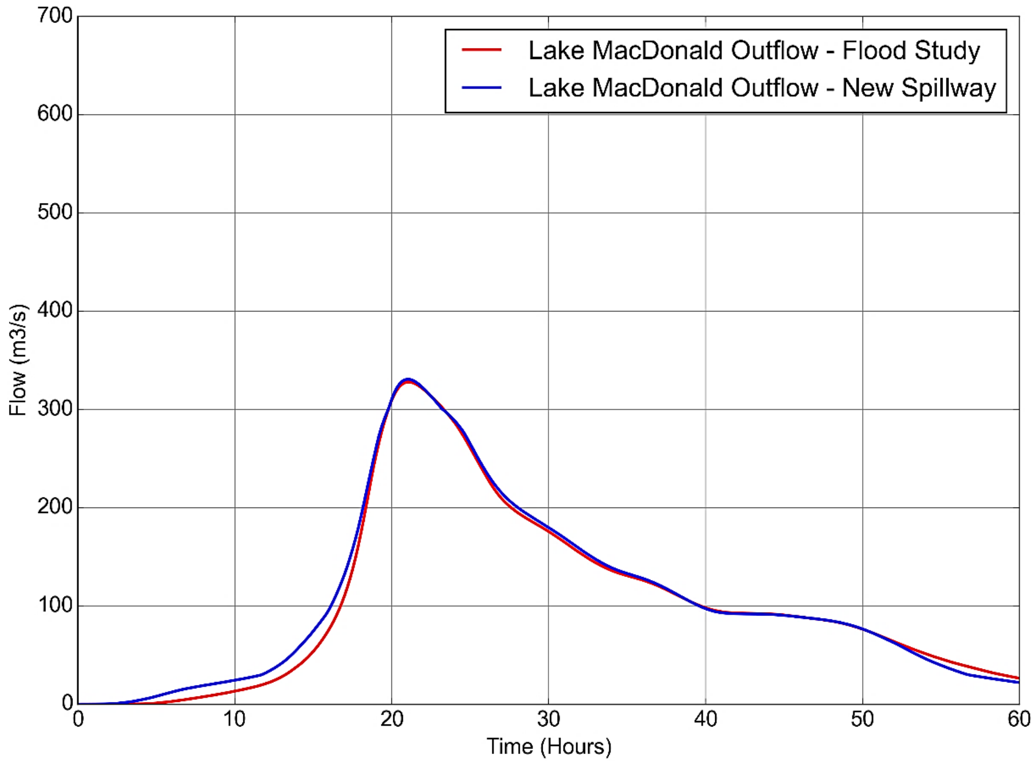


Figure 6-19 Comparison of Design Hydrographs for the 1% AEP Event

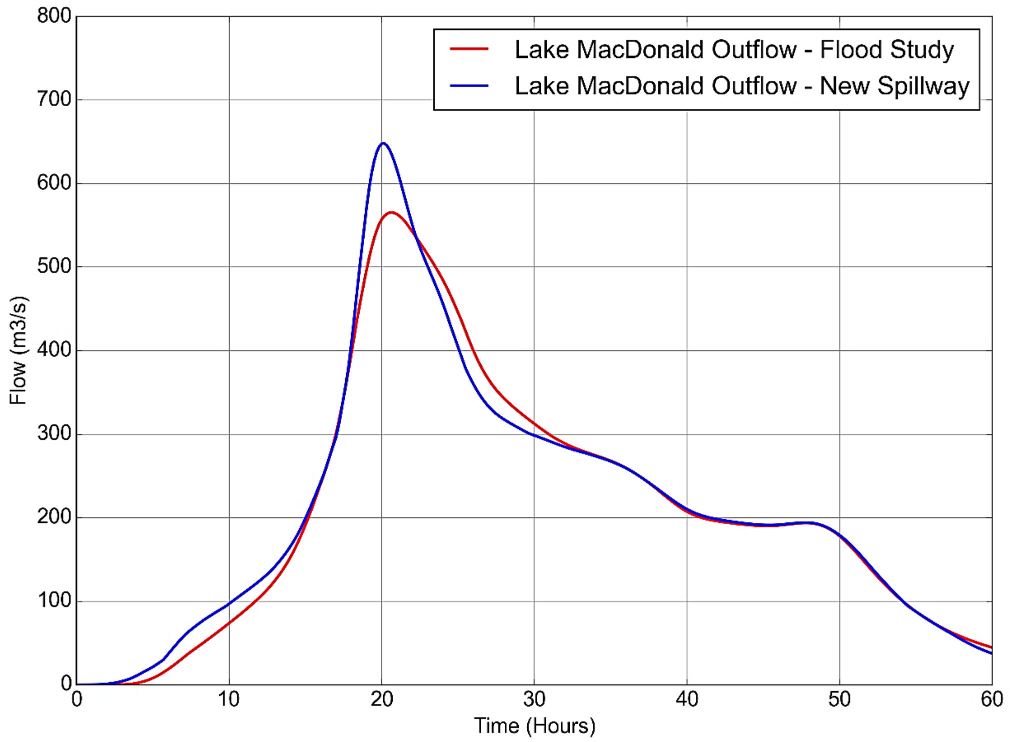


Figure 6-20: Comparison of Design Hydrographs for the 0.05% AEP Event

For the future operational phase, flood afflux associated with the new dam spillway is illustrated in Appendix A for standard design events from the 50% AEP to the PMF. A summary of the flood impacts for each AEP event assessed is presented in Table 6-15. In general, for the future operational phase, flood levels downstream of Lake Macdonald are expected to rise between 50mm to 250mm across the AEP events assessed with no significant increase to newly flooded areas. The predicted flood impacts will be most pronounced during the 50% AEP with minor impacts for the 1% AEP. This is consistent with changes in the spillway rating curve illustrated in Figure 6-14.

Future operational phase stage and flow hydrographs at various locations along Six Mile Creek - refer Figure 6-13 are contained in Appendix A (WMAwater 2018).

Table 6-15: New Spillway Impact Commentary

EVENT	COMMENT
50% AEP (1 in 2 AEP)	The 50% AEP event shows flood afflux across floodplain regions of up to 250 mm as well as some areas where the flood extent has increased (newly flooded areas). The area between the dam wall and Lake Macdonald Drive shows >500 mm flood afflux. This can be attributed to an approximate 50% peak flow increase between the existing spillway and new spillway scenarios. Lake Macdonald Drive acts as a hydraulic control and flood afflux reduces further downstream as a result to generally by <250 mm. The 50% AEP towards Cooran shows significant afflux >500mm, which is not shown in any other design flood event. This area of significant afflux is shown near King Park (downstream of the Cooran township). Flood extents are shown to increase in Chris Kenny Park, which is a known existing flood storage area. The flow width constriction formed by the channel downstream of Cooran drives afflux above 250mm, however does not significantly increase newly flooded areas.
20% AEP (1 in 5 AEP)	The 20% AEP flood afflux areas are similar to that of the 50% AEP, however significantly reduced in terms of level increases. Afflux of between 50 mm to 250 mm is typical along the Six Mile Creek with isolated regions of afflux >250 mm. Increases in flood levels encroach on the very northern properties of Anembo Place (Lake Macdonald residential estate), however, do not appear to increase flooding at the residences. Other sections of the floodplain show +/- 50 mm impacts.
10% AEP (1 in 10 AEP)	The 10% AEP flood afflux is reduced compared to the 20% and 50% AEP event flood afflux results with values typically predicted in the 50 mm to 100 mm range. There are isolated regions of up to 250 mm afflux along Six Mile Creek. Increases in flood levels encroach on the very northern properties of Anembo Place (Lake Macdonald residential estate), however, do not appear to increase flooding at the residences. Other sections of the floodplain show +/- 50 mm impacts.
5% AEP (1 in 20 AEP)	Flood afflux during the 5% AEP is generally shown to be less than 250 mm, with much of the floodplain and residential areas (including Anembo Place properties) reducing to +/- 50 mm afflux. These reduced impacts can be attributed to the new spillway rating approaching that of the existing dam spillway rating for the peak 5% AEP flood flows.
1% AEP (1 in 100 AEP)	Impacts across the floodplain are within +/- 50mm for the 1% AEP. Limited impacts are predicted due to the new spillway and existing spillway ratings reaching near parity for the 1% AEP.
0.05% AEP (1 in 2000 AEP)	There are only minor increases in flood extents predicted during the 0.05% AEP. The increase in flood levels predicted for the 0.05% AEP are generally <250 mm, with the majority of the lower section Six Mile Creek showing increases of up to 100 mm. There are only minor increases in flood extents predicted during the PMF.

EVENT	COMMENT
	Increases in flood levels is expected in Six Mile Creek upstream of the Lake Macdonald inflow tributary in the vicinity of the residential area near Anembo Place. Upstream of Highland Drive (approximately) the impacts associated with the change in spillway rating reduces to +/- 50mm which is consistent with the 1% AEP impacts.
PMF	Flood afflux predicted for the PMF is typically <250 mm with only minor increases in flood extents expected. Increases in flood levels is predicted within the tributary upstream of Lake Macdonald and in the vicinity of the residential area near Highland Drive. Upstream of Liane Drive (approximately) the predicted afflux impacts reduce to +/- 50 mm. The Pomona sub-model was not re-run with revised Six Mile Creek boundary conditions for the PMF event, resulting from the new spillway and increased peak flows overtopping the dam. The Pomona sub-model PMF event afflux results cannot be relied on for this reason.

(WMAwater, 2018)

6.2.4 Impact Mitigation and Management

Performance Outcomes

The main aim for the Project is for no adverse effect on an environmental value from the operation of the activity. The following are the Project's performance outcomes for surface water hydrology:

- Any discharge to water or a watercourse or wetland will be managed so that there will be no adverse effects due to the altering of existing flow regimes for water or a watercourse or wetland
- There will be no potential or actual adverse effect on a wetland as part of carrying out the activity
- The activity will be managed in a way that prevents or minimises adverse effects on wetlands
- The dam upgrade works are in accordance with the *Water Supply (Safety and Reliability) Act 2008* for a Category 2 referrable dam
- Sizing of the temporary coffer dam works that balances flood attenuation capacity vs failure risk and environmental risks
- Design of a low flow / high flow spillway arrangement that minimises changes to flooding downstream for frequent to rare events, whilst allowing efficient and safe passage of extreme flood event flows within the spillway overflow section up to and including the Probable Maximum Precipitation Design Flood (PMPDF) event
- Dam releases, both for dewatering activities and relating to environmental and fish passage releases, minimise impact to environmental flow objectives and water allocation security objectives under the Water Resource (Mary Basin) Plan (2006)
- Regulated structures comply with the 'Manual for assessing consequence categories and hydraulic performance of structures' published by the department
- Provide containers for the storage of hazardous contaminants that are secured to prevent the removal of the containers from the site by a flood event.

Dam Drawdown

Seqwater have developed a dam lowering plan to:

- Understand the scale of proposed drawdown rate vs. rainfall events
- Determine the lowering timeframe, considering the drawdown rate and likely runoff contributing to the dam during lowering
- Optimise the lowering timeframe taking into account downstream impacts
- Consider varying the drawdown flow rate, if feasible within the context of on-ground conditions, to mimic the natural flow regime
- Consider the drawdown rate in the context of geomorphologic impacts and erosion control
- Salvage of aquatic fauna

- Management of water quality during construction period.

The lake lowering plan will also cover water quality, biosecurity and erosion and sediment impacts as outlined in Appendix C.

Flooding

Any flood impact associated with the Project must be considered in the context of the requirement for changing the spillway rating, which is to improve the safety of the dam to meet the current Queensland Dam Safety Regulations. Notwithstanding, it is noted that flood impacts are most pronounced during frequent flooding such as the 50% AEP. This is likely due to the sensitivity of low discharges to relatively large percentage increase due to a small change in the spillway rating (i.e. the impact to discharge is relative to the baseline discharge) and due to the small amount of flood storage at lower flood depths (i.e. any increase in discharge will result in larger afflux where there is limited flood storage).

Residual Impact Assessment

The following Table 6-16 summarises the potential impacts associated with the Project, the proposed mitigation measure and the residual impact that remains after application of the proposed mitigation measure.

Table 6-16: Residual Impact Assessment

POTENTIAL IMPACT	UNMITIGATED IMPACT RATING	MITIGATION MEASURES	RESIDUAL IMPACT RATING
Flow regime changes during dam dewatering leading to adverse effects on stream geomorphology, aquatic ecosystem function and flow objectives.	High	Development of a dam lowering plan to consider, dewatering timeframes and rates. Reassessment of dewatering parameters during dam lowering phase for aquatic fauna relocation (approximately three months)	Low
Mary Basin WRP flow objective breaches – Construction phase	Medium	Meet environmental release requirements throughout construction, either through natural catchment flows or with provision to supplement flows from an alternative source, such as the Mary River raw water offtake.	Low
Mary Basin WRP flow objective breaches – Future operational phase	Low	Include environmental flow release infrastructure in new dam design Maintain compliance with existing environmental flow releases in operation of new dam.	Low
Water availability for water licence holders	Medium	Seqwater does not make manual releases from Lake Macdonald for downstream water licence holders. This will continue to be the case during construction and with the new dam. Develop a communication plan to advise water users of potential impacts and management measures.	Medium
Water Security for town water supply during construction	Medium	Seqwater has carried out a study of the water supply network and determined that there will be no impact to water security with Lake Macdonald being taken offline. Town water supply will be provided from other available sources during construction.	Low

POTENTIAL IMPACT	UNMITIGATED IMPACT RATING	MITIGATION MEASURES	RESIDUAL IMPACT RATING
Flood impacts – Construction phase	High	Undertake core construction activities during the dry season to reduce the likelihood of receiving an extreme flood event during construction.	Medium
Flooding impacts - Future operational phase	Medium	Ensure that the design spillway rating matches the 1% AEP flood and minimises impacts for more frequent events.	Low

6.3 Surface Water Quality

6.3.1 Methodology

The surface water quality of Six Mile Creek and Lake Macdonald was assessed using:

- Literature and database review, including the Mary Basin Draft Water Resource Plan: Environmental Conditions Report including Mary River, Burrum River and Beelbi Creek Catchments (DNRM, 2004)
- Synthesis of existing data collected:
  - Within the scope of the Northern Pipeline Interconnector Stage 2 (NPI2) Aquatic Habitat Monitoring Program
  - Within the scope of baseline studies, including field surveys, completed for the Six Mile Creek Dam Upgrade Project (frc environmental 2016)
  - By Seqwater during routine water quality monitoring programs
  - By the Department of Natural Resources, Mines and Energy's (DNRME's) at gauging station on Six Mile Creek at Cooran (station number 138107B).

Overall water quality data was collected at 13 sites on Six Mile Creek and two sites on Lake Macdonald for the Project (refer to Table 7.1 and Figure 7.1 in Chapter 7). Water quality data collected by Seqwater at an additional four sites was also assessed.

Water quality data that was collected within the scope of the NPI2 AHMP and the baseline studies for the Six Mile Creek project was collected in accordance with the DES' Monitoring and Sampling Manual (DES 2018). Water temperature, pH, dissolved oxygen, and electrical conductivity were measured in situ within 0.3 m of the water surface using a Hydrolab Quanta multi-parameter water quality meter. The meter was calibrated daily according to the manufacturer's instructions. Turbidity was measured in situ within 0.3 m of the water surface using a HACH 2100Q turbidity meter, which was calibrated at the commencement of each field survey.

To protect the waterways and associated environmental values, water quality objectives (WQOs) are established for different indicators such as pH, nutrients and toxicants. The EPP (Water) includes provisions to protect and enhance the suitability of Queensland's waters and has established WQOs for the Mary River Basin. Water quality results were compared to the (WQOs) for lowland streams as presented in the Environmental Protection (Water) Policy 2009 Mary River Environmental Values and Water Quality Objectives Basin No. 138, including all tributaries of the Mary River (DERM 2010) and, where relevant, the Queensland Water Quality Guidelines (DEHP 2013) and National Water Quality Guidelines (ANZECC and ARMCANZ 2000). These WQOs relate to protection of the aquatic ecosystem environmental value. The aquatic ecosystem WQOs were applied as they are generally more stringent than the WQOs for other environmental values except for drinking water, which will not be an applicable value during the Project. The relevant WQOS are shown in Table 6-17 and Table 6-18.

Table 6-17: Published WQOs for protection of aquatic ecosystems for lowland freshwater in the Mary River for selected water quality parameters.

ENVIRONMENTAL VALUE	PARAMETER	WATER QUALITY OBJECTIVE
Aquatic Ecosystem (Lowland Freshwater)	Turbidity	<50 NTU
	Suspended Solids	<6 mg/L
	Chlorophyll a	<5 µg/L
	Total Nitrogen	<500 µg/L
	Oxidised Nitrogen	<60 µg/L
	Ammonia Nitrogen	<20 µg/L
	Organic Nitrogen	<420 µg/L
	Total Phosphorous	<50 µg/L
	Filterable Reactive Phosphorus (FRP)	<20 µg/L
	Dissolved Oxygen	85% - 110% Saturation
	pH	6.5 – 8.0
	Electrical conductivity [a]	626 µS/cm
Aquatic Ecosystem (Freshwater Lakes/Reservoirs)	Turbidity	1 – 20 NTU
	Suspended Solids	n/d
	Median Chlorophyll a	<5 µg/L
	Median Total Nitrogen	<350 µg/L
	Oxidised Nitrogen	<10 µg/L
	Ammonia Nitrogen	<10 µg/L
	Organic Nitrogen	<300 µg/L
	Total Phosphorus	<10 µg/L
	Filterable Reactive Phosphorus (FRP)	<5 µg/L
	Dissolved Oxygen	90% - 110% Saturation
	pH	6.5 – 8.0
	Secchi Depth	n/d

[a] based on the 75th percentile of the Sandy Coastal salinity zone in Appendix G of the Queensland Water Quality Guidelines.

Table 6-18: Water quality objectives for toxicants (ANZECC)

CRITERIA SOURCE (EV)	PARAMETER	WATER QUALITY OBJECTIVE (µg/l)
Aquatic Ecosystem (Freshwater – 95% Species)	Aluminum pH >6.5	0.055
	Arsenic (As III)	0.024
	Arsenic (AsV)	0.013
	Boron	0.37
	Cadmium	0.0002
	Chromium (CrVI)	0.001
	Cooper	0.0014
	Lead	0.0034
	Manganese	1.9
	Nickel	0.011
	Silver	0.00005
	Zinc	0.008

6.3.2 Existing Environment

Water quality in Six Mile Creek is generally good and typically achieves the WQOs for the protection of aquatic ecosystems, although dissolved oxygen levels are often low due to the decomposition of organic matter from the adjacent rainforest canopy (DNRM 2004). DNRM (2004) also report that water quality typically achieves the WQOs for other environmental values identified for Six Mile Creek, including Primary Industry, Recreation, and Drinking Water (assuming disinfection) (DNRM 2004).

Water quality data for water temperature, electrical conductivity and pH were available on the DNRME Water Monitoring Portal, with records commencing in December 1998. Results showed that both electrical conductivity and pH complied with the applicable WQO for aquatic ecosystems (there is no WQO for temperature) (Table 6-19).

Seqwater's water quality monitoring data for Lake Macdonald (Appendix G – Aquatic Ecology technical report) shows:

- Total nitrogen, organic nitrogen, chlorophyll a and dissolved aluminium were commonly higher than the applicable WQO in Lake Macdonald
- Total aluminium, total zinc and total cobalt were sometimes higher than the applicable WQO in Lake Macdonald
- pH, dissolved oxygen, total suspended solids, total nitrogen, organic nitrogen, ammonia, total aluminium, total chromium, total copper, total mercury, total zinc and dissolved aluminium were non-compliant with the applicable WQO at the Lake Macdonald tailwater
- All other parameters (where data was available) complied with the applicable WQO in Lake Macdonald and at the Lake Macdonald tailwater.

Biogeochemical cycling of key elements, including nutrients and metals, in benthic sediments has a significant influence on water quality in reservoirs, with elevated concentrations of these parameters commonly observed in reservoirs (Grinham et al., 2018). Therefore, the above described results are likely typical of water quality conditions for reservoirs.

The Water Monitoring Data Collection Standards (DNRW 2007) define a reservoir as stratified if the temperature difference between surface and basement layers exceeds 5ºC. Depth profile measurements of water temperature through the depth profile in Lake Macdonald (mid-lake) were summarised on a monthly basis between November 2011 and November 2017 (i.e. 70 months), with measurements for 69 of these months indicating no stratification. Stratification was detected in only one month (January 2015). Overall, these results indicate that Lake Macdonald rarely stratifies, and when it does it is only weakly stratified.

Survey data for water quality measured in situ since 2013 was pooled based on reach (i.e. downstream of Six Mile Creek Dam, in the impounded section of Six Mile Creek Dam, or upstream of Six Mile Creek Dam). Results showed that (Table 6-20 to Table 6-22; Appendix G):

- Electrical conductivity, pH and turbidity complied with the WQO in all reaches of Six Mile Creek
- The percent saturation of dissolved oxygen was below the WQO in Six Mile Creek upstream and downstream of Lake Macdonald, but complied with the WQO in Lake Macdonald.

Table 6-19: Summary of mean monthly water quality since December 1989 measured at gauging station 138107B on Six Mile Creek at Cooran

SUMMARY STATISTIC	TEMPERATURE (ºC) [A]	ELECTRICAL CONDUCTIVITY (µS/cm)	pH (UNIT)
Count of mean monthly data points	225	221	93
Minimum	10.0	91	6.4
20th percentile	15.0	145	6.6
Median	19.6	171	6.8
80th percentile	23.2	203	7.1
Maximum	25.3	275	7.8

Dark grey shading indicates if a parameter exceeds the applicable WQO (note median was compared to the WQO).

[a] There is no published WQO for water temperature.

Table 6-20: Summary of water quality since from October 2013 to February 2018 measured at Six Mile Creek downstream of Lake Macdonald

SUMMARY STATISTIC	TEMPERATURE (ºC) [A]	ELECTRICAL CONDUCTIVITY (µS/cm)	pH (UNIT)	DISSOLVED OXYGEN (mg/l)	DISSOLVED OXYGEN (% saturation)	TURBIDITY (NTU)
Count	24	24	24	24	24	24
Minimum	17.7	76	5.55	2.0	24.0	2.5
20th percentile	19.0	114	6.21	3.0	33.5	5.2
Median	20.9	161	6.78	4.5	49.1	7.9
80th percentile	24.5	180	7.18	5.7	65.0	11.0
Maximum	26.6	244	7.43	7.9	93.3	15.6

Dark grey shading indicates where the median value of a parameter does not comply with the WQO

Table 6-21: Summary of water quality since from October 2013 to February 2018 measured at Six Mile Creek in Lake Macdonald

SUMMARY STATISTIC	TEMPERATURE (ºC) A	ELECTRICAL CONDUCTIVITY (µS/cm)	PH (UNIT)	DISSOLVED OXYGEN (mg/l)	DISSOLVED OXYGEN (% saturation)	TURBIDITY (NTU)
count	6	6	6	6	6	6
minimum	22.9	42	6.69	4.2	54.8	3.1
20th percentile	23.2	53	6.77	7.7	99.2	3.5
median	24.5	87	6.99	8.8	105.6	4.5
80th percentile	28.0	92	7.31	9.9	117.1	5.6
maximum	28.8	103	7.46	10.0	119.8	5.8

Dark grey shading indicates where the median value of a parameter does not comply with the WQO

Table 6-22: Summary of water quality since from October 2013 to February 2018 measured at Six Mile Creek upstream of Lake Macdonald

SUMMARY STATISTIC	TEMPERATURE (ºC) A	ELECTRICAL CONDUCTIVITY (µS/cm)	pH (UNIT)	DISSOLVED OXYGEN (mg/l)	DISSOLVED OXYGEN (% saturation)	TURBIDITY (NTU)
count	13	13	13	13	13	13
minimum	17.4	59	5.80	2.1	24.7	4.5
20th percentile	18.9	89	6.25	3.1	34.1	5.8
median	21.2	107	6.67	4.9	51.1	7.4
80th percentile	24.0	142	7.09	7.3	91.6	13.6
maximum	188.0	189	7.61	8.9	110.1	15.4

Dark grey shading indicates where the median value of a parameter does not comply with the WQO

A preliminary assessment of the presence of acid sulphate soils in the Project area was completed in September 2018 and determined that while there is some existing acidity in the soils, it is unlikely to be sulfuric in source. Retained or potential sulfuric acidity was below the laboratory limits of reporting in all representative samples collected. The complete acid sulphate soils assessment report is provided in Appendix H.

6.3.3 Potential Impacts

Drawdown of waterbodies can have adverse impacts on water quality both at, and downstream of, the discharge site(s) and in the lake. Construction earthworks, and runoff from stock piles of soil, during construction can also adversely impact water quality. Submersion of decomposing organic matter can also adversely affect water quality during dam refill phases and lead to eutrophication. The potential impacts to water quality during the drawdown, construction and refill phases include:

- Increased turbidity and total suspended solids via disturbance of bed sediments and / or the erosion of bed and banks during drawdown and construction, and from disturbance of earth and runoff from soil stockpiles during construction.
- Decreased pH associated with exposing or disturbing acidic soils during drawdown and construction and / or where decomposing organic material (e.g. aquatic plants) reduces the pH of water.

- Reduced dissolved oxygen in the lake and in Six Mile Creek downstream if the source waterbody becomes stratified or eutrophied, such as through submersion of decomposing organic matter (e.g. decomposing Cabomba) during the refill phase.
- Increased nutrient concentrations in the lake if drawdown exposes deep sediments below approximately 90 m AHD, which have higher nutrient content than sediments above 90 m AHD (Grinham et al., 2018), and in receiving waters during drawdown if the source water has high nutrient concentrations, or during refill if the lake becomes eutrophied from decomposing organic matter.
- Increased dissolved metal concentrations in the lake and receiving waters during drawdown, construction and refilling phases due to mobilisation and oxidation of lake sediments, lateral transport of sediment pore water and ebullition fluxes during drawdown (Grinham, et al., 2018). Drawdown that exposes deep sediments below approximately 90 m AHD, which have higher metal content than sediments above 90 m AHD, will increase the risk of adverse water quality (Grinham et al., 2018).
- Contamination of water from spills of fuels, oils or other chemicals from pumping equipment or other machinery / vehicles during drawdown and construction.

Increased turbidity (and total suspended solids) may negatively impact aquatic fauna (i.e. fish and macroinvertebrates), because highly turbid water reduces respiratory and feeding efficiency. Increased turbidity may also adversely affect submerged aquatic plants as light penetration (required for photosynthesis) is reduced. Reduced light penetration can also lead to a reduction in temperature throughout the water column. Small and brief increases in turbidity, consistent with increases in turbidity that occur during natural flow events, would be unlikely to have a significant impact on aquatic fauna (Dunlop et al., 2005). However, significant increases in turbidity, especially turbidity caused by fine silt and clay particles, could adversely impact the health, feeding and breeding ecology of aquatic fauna species (Dunlop et al., 2005). However, significant resuspension of sediments is likely to be limited by cohesive properties of the sediment in the Six Mile Creek Dam (Grinham et al., 2018).

Reduced pH can negatively impact fish health by causing diseases (e.g. lesions and ulcers) and impacting metabolism and reproduction in fish, with very low pH (such as from acidic soil exposure) potentially causing fish kills. While many waterways of the lower Mary River Basin are naturally acidic and stained with tannins and organic compounds, Six Mile Creek is not of this acidic water type; similarly, water in Lake Macdonald is tannin stained but is not naturally acidic. Some variation in pH is tolerated by aquatic biota of Six Mile Creek, although significant reductions in pH may have adverse effects on aquatic ecosystem health. Acid sulfate soils were not identified as occurring in the Project area, however the soils were determined to be slightly acidic (Appendix H).

Dissolved oxygen is essential for respiration and metabolism by aquatic biota. Reduced dissolved oxygen can cause stress to fish, and very low dissolved oxygen can cause mass mortality (‘fish kills’). Some waterways of the region can have naturally low dissolved oxygen, especially during low flow periods, and thus much of the aquatic biota of the region can tolerate periods of low dissolved oxygen (i.e. approximately 50% saturation), but sustained periods of low dissolved oxygen and / or very low dissolved oxygen will cause mortality in aquatic fauna.

High nutrient concentrations can cause increased growth of phytoplankton, which in turn can deplete dissolved oxygen concentrations, particularly at night when there is no photosynthesis. Benthic algae, including filamentous algae, and aquatic plant growth may increase under high nutrient conditions, especially under high sunlight conditions. Excessive algae and aquatic plant growth can reduce in-stream habitat quality for some aquatic biota.

Fuels, oils and other chemicals (e.g. lubricants and solvents) that may be required for the operation of pumps and other machinery for lake drawdown, including vehicles, are toxic to aquatic flora and fauna at relatively low concentrations. Spilt fuel is most likely to enter watercourses via an accidental spill when activities are adjacent to waterbodies. A significant fuel spill to waterways (in the order of tens or hundreds of litres) is likely to have a locally significant impact on both flora and fauna, with the size of spill and the volume of water in the creeks being the most significant factors influencing the length of stream impacted.

6.3.4 Impact Mitigation and Management

Performance Outcomes

The main aim for the Project is for no actual or potential discharge to waters of contaminants that may cause an adverse effect on an environmental value. The following are the Project's performance outcomes for surface water quality:

- The storage and handling of contaminants will include effective means of secondary containment to prevent or minimise releases to the environment from spillage or leaks
- Contingency measures will prevent or minimise adverse effects on the environment due to unplanned releases or discharges of contaminants to water
- The activity will be managed so that stormwater contaminated by the activity that may cause an adverse effect on an environmental value will not leave the site without prior treatment
- The disturbance of any acidic soil, or potentially acidic soil, will be managed to prevent or minimise adverse effects on environmental values
- There will be no potential or actual adverse effect on a wetland as part of carrying out the activity
- The activity will be managed in a way that prevents or minimises adverse effects on wetlands.
- Provide containers for the storage of hazardous contaminants that are secured to prevent the removal of the containers from the site by a flood event.

Impact Assessment and Mitigation

Appropriate mitigation measures should be implemented for the Project to achieve the performance outcomes. Suggested mitigation measures are provided in Table 6-23, however alternative measures may also be appropriate to achieve the desired outcomes.

Table 6-23: Mitigation and management measures for surface water quality and residual impact

POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Increased turbidity and total suspended solids via disturbance of bed sediments and / or the erosion of bed and banks during drawdown and construction.	High	Minimise disturbance of unconsolidated bed sediments (e.g. by using pontoon based pump stations). During the drawdown take water from mid-depth, or mix of depths. Allow Cabomba and other exposed aquatic plants to decompose in situ. Avoid or manage areas of potential erosion, for example by implementing an Erosion and Sediment Control Plan in accordance with industry standards, monitoring the efficacy of sediment and erosion control management measures, and/or releasing water to the existing concrete apron during drawdown. Implement real-time water quality monitoring for comparison against suitable objectives for key parameters (i.e. pH, dissolved oxygen, turbidity, TSS, nutrients). The objectives should be consistent with the desired outcomes and trigger corrective action, such as a review and update of existing control measures, if exceeded.	Low
Decreased pH associated with exposing or disturbing acidic soils during drawdown and construction.	Moderate	Implement real-time water quality monitoring for comparison against suitable objectives for key parameters (i.e. pH, dissolved oxygen, turbidity, TSS, nutrients). The objectives should be consistent with the desired outcomes and trigger corrective action, such as a review and update of existing control measures, if exceeded. A precautionary principle should be applied for inland acid sulfate soils and pyritic acid sulphate rock materials in relation to ground and groundwater disturbances. Based on the preliminary acid sulfate soils investigation it is considered that an ASS Management Plan would not be required, but should subsequent geotechnical investigations identify acid sulphate soils or ASR, then all reasonable steps should be taken to implement a plan.	Low
Reduced dissolved oxygen in the lake and in Six Mile Creek downstream if the source waterbody becomes stratified or eutrophied.	Moderate	Minimise disturbance of unconsolidated bed sediments (e.g. by using pontoon based pump stations). During the drawdown take water from mid-depth, or mix of depths, for example with a multi-level intake. Avoid or manage areas of potential erosion, for example by implementing an Erosion and Sediment Control Plan in accordance with industry standards, monitoring the efficacy of sediment and erosion control management	Low

POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
		measures, and/or releasing water to the existing concrete apron during drawdown. Maintain dissolved oxygen concentrations in Lake Macdonald and Six Mile Creek, for example by using aeration units (potentially including the existing destratification unit) within the lake and turbulent release to the existing concrete apron. Where practical, and not being used to manage erosion, remove decomposing Cabomba from exposed lake surfaces, to reduce risk of eutrophication and low dissolved oxygen during refill phase. Implement real-time water quality monitoring for comparison against suitable objectives for key parameters (i.e. pH, dissolved oxygen, turbidity, TSS, nutrients). The objectives should be consistent with the desired outcomes and trigger corrective action, such as a review and update of existing control measures, if exceeded.	
Increased nutrient concentrations in the lake if drawdown exposes deep sediments below approximately 90 m AHD and in receiving waters during drawdown if the source water has high nutrient concentrations.	Moderate	Minimise exposure of deep sediments that have high metal and nutrient concentrations, for example by not lowering water in Lake Macdonald to below 89 m AHD. Implement real-time water quality monitoring for comparison against suitable objectives for key parameters (i.e. pH, dissolved oxygen, turbidity, TSS, nutrients). The objectives should be consistent with the desired outcomes and trigger corrective action, such as a review and update of existing control measures, if exceeded.	Low
Increased dissolved metal concentrations in the lake and Six Mile Creek downstream of the dam during drawdown, construction and refilling phases due to mobilisation and oxidation of lake sediments, lateral transport of sediment pore water and ebullition fluxes during drawdown.	Moderate	Minimise exposure of deep sediments that have high metal and nutrient concentrations, for example by not lowering water in Lake Macdonald to below 89 m AHD. During the drawdown take water from mid-depth, or mix of depths, for example with a multi-level intake. Avoid or manage areas of potential erosion, for example by implementing an Erosion and Sediment Control Plan in accordance with industry standards, monitoring the efficacy of sediment and erosion control management measures, and/or releasing water to the existing concrete apron during drawdown.	Low

POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Contamination of water from spills of fuels, oils or other chemicals from pumping equipment or other machinery / vehicles during drawdown and construction.	Moderate	Implement real-time water quality monitoring for comparison against suitable objectives for key parameters. The objectives should be consistent with the desired outcomes and trigger corrective action, such as a review and update of existing control measures, if exceeded. Reduce the likelihood of chemical spills or leaks, for example through: • Storing fuels, oils and other chemicals in bunded areas in accordance with Australian Standard 1940 (2004) – The storage and handling of flammable and combustible liquids • Establishing bunded areas away from water bodies, preferable above the Q100 level • Only refuelling in bunded areas, and • Making spill kits available to enable a rapid response to a spill if one was to occur.	Low

6.4 Groundwater

6.4.1 Methodology

This groundwater assessment comprises a desktop study that has been carried out based primarily on information sourced from the Department of Natural Resources, Mines and Energy (DNRME) groundwater database (GWDB). Information provided by this database incorporates registered groundwater bore facilities only. The Project area includes boreholes drilled from 2003 to 2017.

Groundwater Drawdown

Method of Calculation

Existing bore water users and possible groundwater dependent ecosystems (GDEs) have the potential to be adversely impacted by a decline in groundwater levels resulting from the temporary lowering of the lake level during construction of the dam spillway, should the regional groundwater system be in direct hydraulic connection with the lake.

Under the assumption of complete hydraulic connection between the groundwater system and Lake Macdonald, to evaluate the potential risk of groundwater drawdown to groundwater users from lake lowering (including to GDEs), an estimation of the likely groundwater drawdown area has been made based on the Bear (1979) analytical equation:

Radius of Influence - $$R = 1.5\sqrt{\frac{KH_r t}{S_y}}$$ Bear (1979)

Where R = radius of groundwater drawdown influence, K = hydraulic conductivity, H = dewatering depth, t =time, and Sy = specific yield.

The calculation assumptions were:

1. Isotropic Homogeneous Material
2. Laminar flow (Darcian flow)
3. Kv:Kh = 0.1 (ratio of vertical hydraulic conductivity to horizontal hydraulic conductivity)
4. Mean Annual Rainfall = 1682 mm/yr, no evaporation.

This analytical method calculates the groundwater drawdown based on inflow to an approximate rectangular excavation. To create rectangular dimensions to suit the analytical model, Lake Macdonald was conceptually divided into nine sections based on the lake bathymetry for the lake dewatering assessment (Figure 6-21).

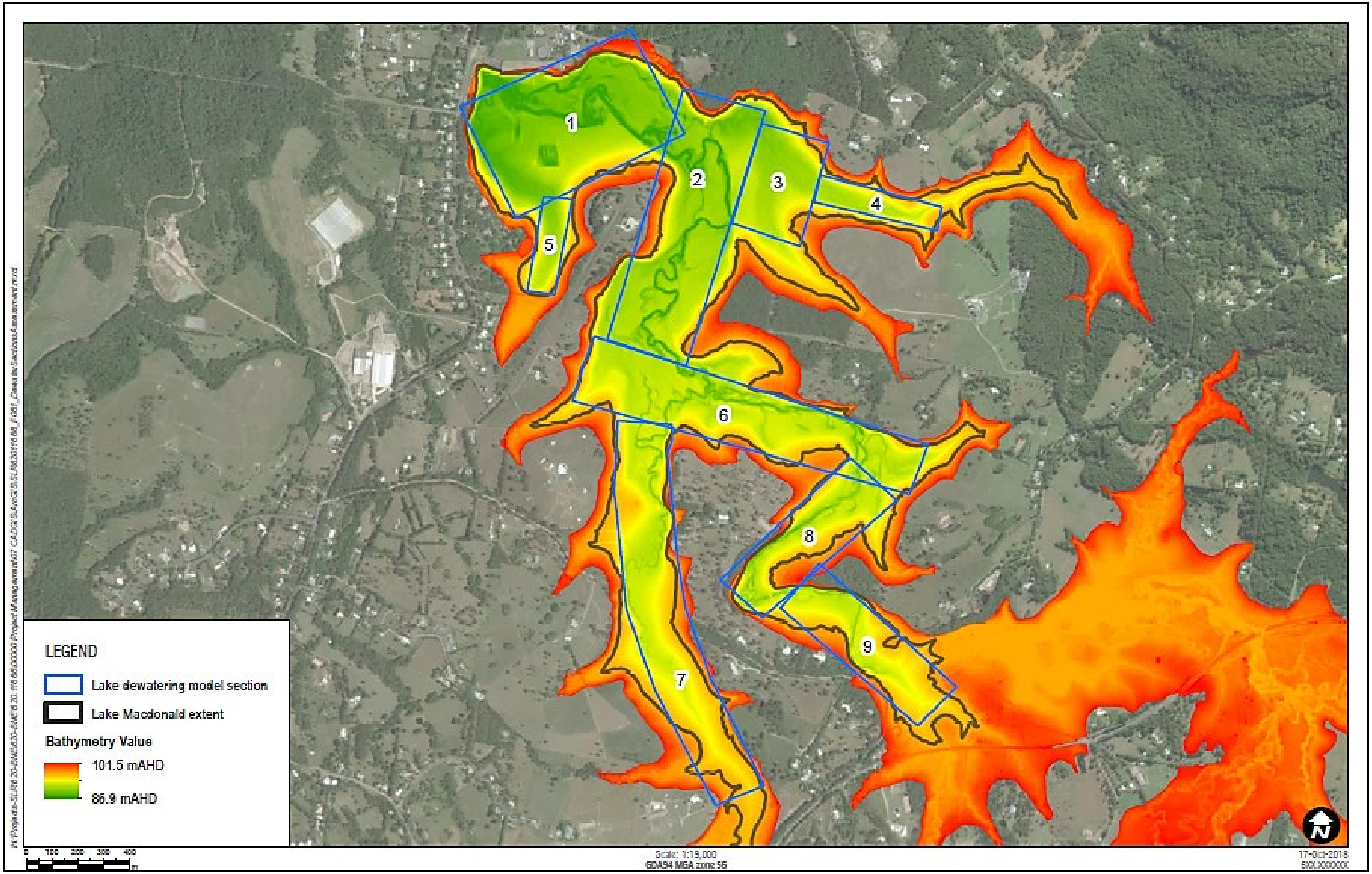


Figure 6-21: Sections of Lake Macdonald used for dewatering assessment (SLR Environmental 2018, Appendix F)

Model Parameters

The parameters used for the groundwater drawdown assessment for Lake Macdonald were as follows:

- Lake dewatered depth – the dewatered depth for each of the nine sections was calculated as the difference between the full storage limit at 95.32 m AHD and the average depth across each section based on bathometry data. Lake Macdonald is a shallow impoundment with an average depth of 3.7 m.
- Duration of dewatering – a period of 2 years was adopted for the assessment and represents the "worst case" scenario.
- Groundwater level – for the purpose of this assessment, a conservative approach was taken where the initial groundwater level adjacent the lake was assumed to be in equilibrium with the surface water level in Lake Macdonald at the full storage limit (i.e. 95.32 m AHD).
- Hydraulic parameters of alluvium hosting the lake – field derived hydraulic conductivity values were not available for the geological materials at shallow depths above bedrock. The hydraulic conductivity values used in this assessment were based on literature values for the geological materials observed in borelogs from:
  - Registered groundwater bores (Figure 6-22)
  - Geotechnical boreholes completed as part of the lake upgrade assessment (AECOM, 2018b).

A review of borelogs (Table 6-24) found that Lake Macdonald sits in clay that reaches a depth between 3 m and 21 m. Localised silty and clayey sand lenses observed in the geotechnical investigation bores were not included in the drawdown assessment due to their lack of connectivity and therefore inability to provide a preferential groundwater flowpath.

Literature values for the hydraulic conductivity of clay were adopted based on Domenico and Schwartz (1990) where the expected case represents the conservative (greatest) value of the literature value range, and the upper bound and lower bounds and one order of magnitude higher and lower respectively. The adopted hydraulic conductivity values for the alluvium hosting Lake Macdonald are presented in Table 6-25. Heath (1983) estimates a specific yield value for clay to be in the order of 2%, this value was adopted for the assessment.

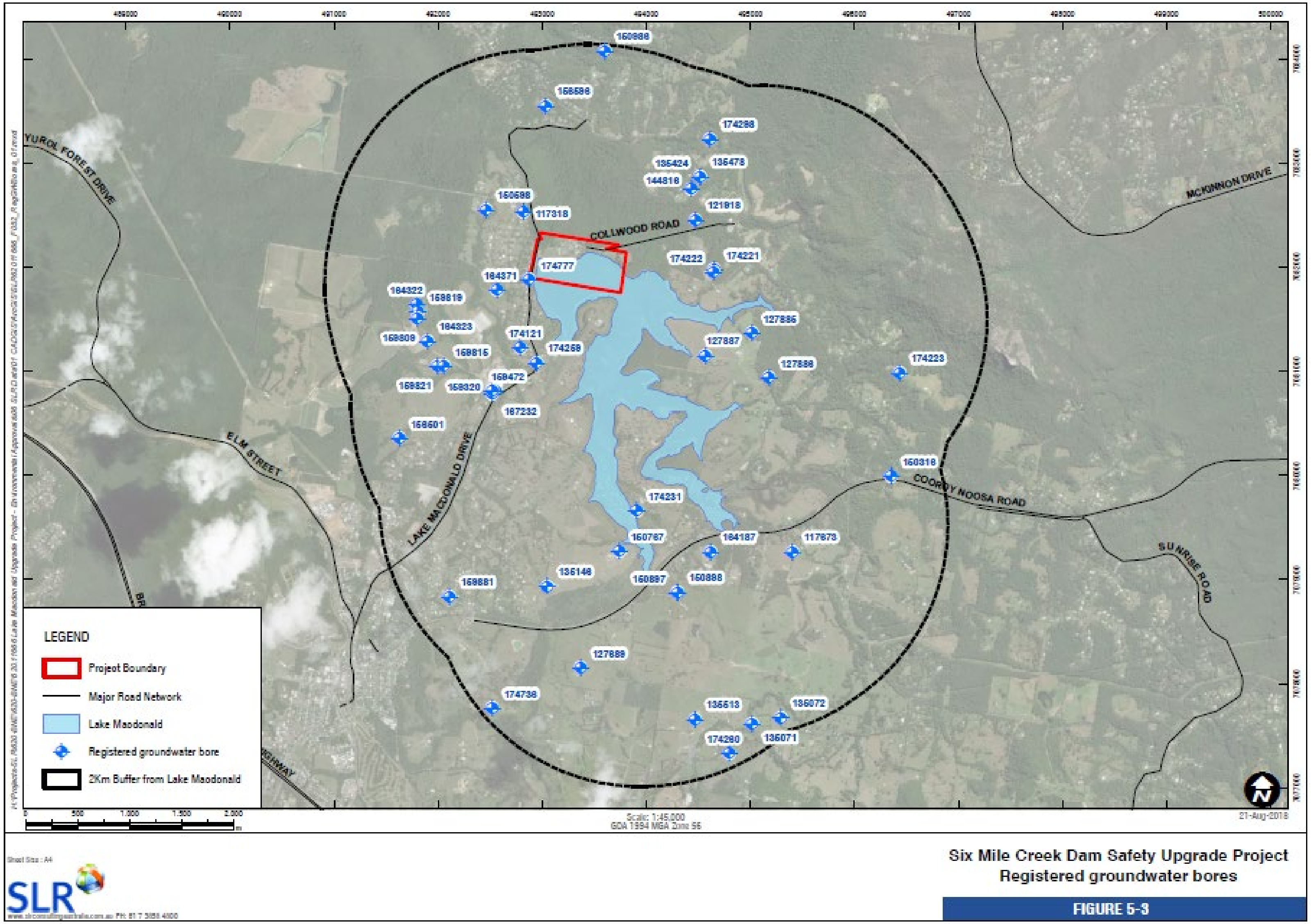


Figure 6-22: Registered groundwater bores in the vicinity of Lake Macdonald

Table 6-24: Lithology of borelogs from geotechnical investigations

BOREHOLE	MAXIMUM DEPTH (M)	DEPTH OF CLAY FROM SURFACE (M)	LITHOLOGY	FORMATION
BH501	30.0	11.2	Residual soil 0 - 10.8m, clayed gravel 10.8 - 11.2m, weathered sandstone 11.2 - 15.6m, banded sandstone 15.6 - 19m, coarse grained sandstone with thin interlayered beds of basalt 19 – 30m. Minor coal laminations in sandstone at 28.5m depth.	Kin Kin Beds*
BH502 (within lake)	30.6	4.4	Alluvium clay 0 - 4.2m; sands (completely weathered sandstone) 4.2 - 4.6m; banded sandstone 4.6 - 12.7m; banded sandstone and coarse-grained sandstone 12.7 - 17.1m; banded sandstone and basalt 17.1 - 21.1m; Interlayered banded sandstone, coarse grained sandstone, pebbly sandstone 21.1 - 26.1m; banded sandstone 26.1 - 30m.	Kin Kin Beds*
BH503 (within lake)	28.9	4.8	Alluvium clay 0 - 4.0m; sands (completely weathered sandstone) 0.4 - 4.8m; banded sandstone, clayey sand and basalt 4.8 - 16.5m; banded sandstone 16.5 - 21.5m; banded sandstone, massive sandstone and siltstone 21.5 - 28.9m.	Kin Kin Beds*
BH506 (within lake)	24.7	7.1	Alluvium sand to 0 - 2.45m; alluvium clay 2.45 - 7.1m; massive sandstone, completely weathered sandstone, clay and siltstone 7.1 - 12.4m; coarse grained sandstone, siltstone, banded sandstone 12.4 - 15.7m; banded sandstone, massive sandstone 15.7 - 24.7m.	Kin Kin Beds*

* Interpreted formation

Table 6-25: Hydraulic parameters used in this assessment

PARAMETER	HYDRAULIC PARAMETERS	DESCRIPTION	VALUE	UNIT
Horizontal hydraulic conductivity	High Hydraulic Conductivity	Upper bound	4.7×10^{-8}	m/s
	Most likely Hydraulic Conductivity	Expected	4.7×10^{-9}	m/s
	Low Hydraulic Conductivity	Lower bound	4.7×10^{-10}	m/s
Vertical hydraulic conductivity	High Hydraulic Conductivity	Upper bound	4.7×10^{-9}	m/s
	Most likely Hydraulic Conductivity	Expected	4.7×10^{-10}	m/s
	Low Hydraulic Conductivity	Lower bound	4.7×10^{-11}	m/s
Specific yield (Sy)			2	%

6.4.2 Existing Environment

Location and Land Use

The Project area within the local context is shown in Figure 6-3. The closest town to Lake Macdonald is Cooroy, with the town centre being approximately 10 km from the proposed construction area. The proposed construction area is adjacent to Lake Macdonald Drive and Collwood Road. Residential properties are present on the western side of Lake Macdonald Drive within approximately 30 m of the proposed construction area, particularly, the left embankment.

Within the dam catchment, there is little urban development and the predominant land uses are rural, rural residential, and forestry/remnant bushland. The land use surrounding the Project area is roughly divided into two areas. Upstream of the dam, land is characterised by undulating pasture and a high proportion of semirural residential land-uses. Downstream land is characterised by minor rural and semi-rural residential properties, and large areas under forest and sections of Tewantin National Park.

Topography and Drainage

The Six Mile Creek catchment drains an area approximately 49 km^2 and generally flows in a north-westerly direction, joining the Mary River near Gympie approximately 40 km downstream of the dam. The Lake Macdonald catchment headwaters originate in the Blackall Range and are bounded by the Blackall Range to the south, Cooroy to the west and Sunrise Road to the east.

Lake Macdonald was created by the construction of the dam on Six Mile Creek in 1965. The lake is a shallow impoundment with an average depth of 3.7 m, and a full storage limit of 95.32 m AHD giving a total surface area of 262 ha.

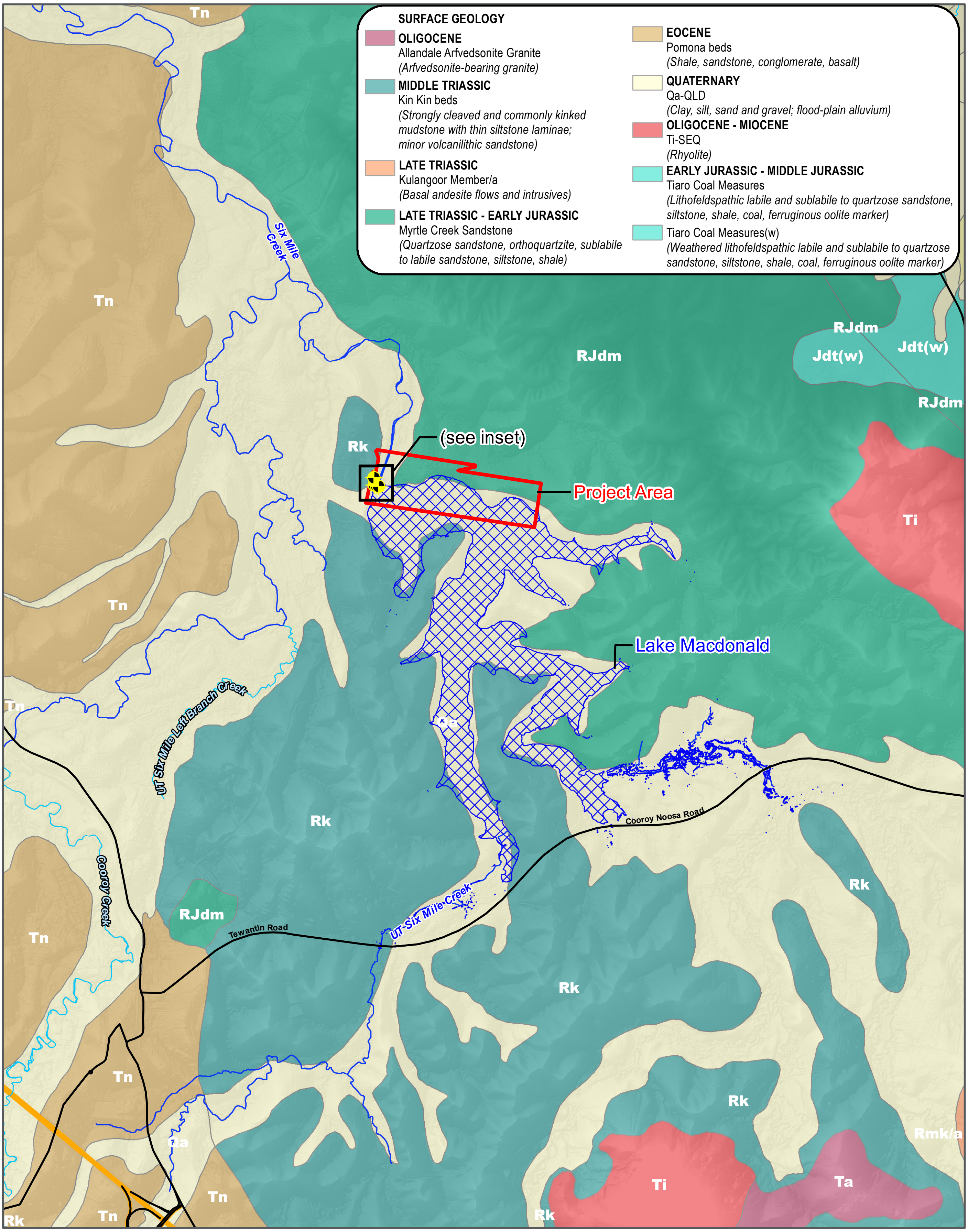
Geology

The surface geology map presented in Figure 6-23 indicates that Lake Macdonald is positioned within a drainage channel composed of Quaternary Alluvium overlying Upper Triassic-Jurassic aged Myrtle Creek Sandstone. Triassic Kin Kin Beds outcrop to the east of Lake Macdonald and host a Tertiary aged rhyolite intrusion, and the Jurassic aged Tiaro Coal Measures outcrop further east. To the west of the Quaternary alluvium hosting Lake Macdonald, the Tertiary aged Pomona Beds outcrop as well as Triassic aged Kin Kin Beds. The stratigraphic relationships between the geological units encountered within and in the vicinity of Lake Macdonald are summarised in Appendix F.

In terms of geological structures, there is an interpreted fault zone across the dam spillway structure which shows a deeper weathering profile compared to the surrounding bedrock (AECOM, 2018a).

As part of geotechnical investigations conducted at the Project site, five series (Series 100 to 500) of boreholes were drilled from 2011 to 2017 by URS and AECOM, to gain a better understanding of the site geology and associated soil and rock physical properties at the spillway location (AECOM, 2018b). Site geological information has been compiled in Table 6-24 from groundwater database bore reports for boreholes surrounding Lake Macdonald and in Table 6-26 from the latest geotechnical investigations; all locations are shown on Figure 6-23. A review of the borelogs (Table 6-24) found that Lake Macdonald is positioned on top of clay that reaches a depth between 3 m and 21 m below ground level, suggesting the alluvium in the area is largely comprised of relatively low permeability and fine grained overbank sediments, typical of a low energy depositional environment, rather than coarser channel deposited materials. Highly localised silty and clayey sand lenses were observed in some of the geotechnical investigation boreholes (BH502, BH503 and BH506, see Figure 6-23). The localised nature of these lenses is indicated by the lack of connectivity over the short distance between the boreholes suggesting a lack of interconnected permeability within the alluvium.

FIGURE 6-23:
SURFACE GEOLOGY IN THE VICINITY OF LAKE MACDONALD



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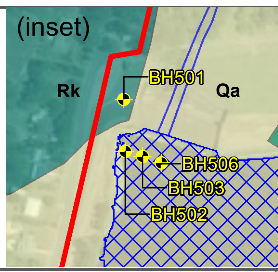
LEGEND
- Site investigation borehole
- Bruce Highway
- Secondary Road
- Watercourse
- Six Mile Creek
- Project Area



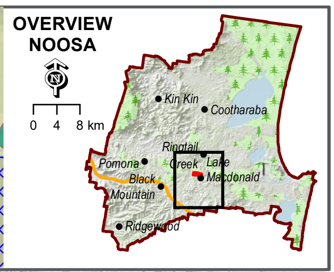


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Table 6-26: Lithology of bore logs from geotechnical investigations

BOREHOLE	MAXIMUM DEPTH (M)	DEPTH OF CLAY FROM SURFACE (M)	LITHOLOGY	FORMATION
BH501	30.0	11.2	Residual soil 0 - 10.8m, clayed gravel 10.8 -11.2m, weathered sandstone 11.2 - 15.6m, banded sandstone 15.6 - 19m, coarse grained sandstone with thin interlayered beds of basalt 19 – 30m. Minor coal laminations in sandstone at 28.5m depth.	Kin Kin Beds*
BH502 (within lake)	30.6	4.4	Alluvium clay 0 - 4.2m; sands (completely weathered sandstone) 4.2 - 4.6m; banded sandstone 4.6 - 12.7m; banded sandstone and coarse-grained sandstone 12.7 - 17.1m; banded sandstone and basalt 17.1 - 21.1m; Interlayered banded sandstone, coarse grained sandstone, pebbly sandstone 21.1 -26.1m; banded sandstone 26.1 - 30m.	Kin Kin Beds*
BH503 (within lake)	28.9	4.8	Alluvium clay 0 - 4.0m; sands (completely weathered sandstone) 0.4 - 4.8m; banded sandstone, clayey sand and basalt 4.8 -16.5m; banded sandstone 16.5 - 21.5m; banded sandstone, massive sandstone and siltstone 21.5 - 28.9m.	Kin Kin Beds*
BH506 (within lake)	24.7	7.1	Alluvium sand to 0 - 2.45m; alluvium clay 2.45 - 7.1m; massive sandstone, completely weathered sandstone, clay and siltstone 7.1- 12.4m; coarse grained sandstone, siltstone, banded sandstone 12.4 - 15.7m; banded sandstone, massive sandstone 15.7- 24.7m.	Kin Kin Beds*

* Interpreted formation

Hydrogeology

Groundwater Resource Units

Local unconsolidated Quaternary alluvium materials, associated with natural flood plain drainage features, occupy topographic depressions in the underlying bedrock surface. Bore logs indicate that the unconsolidated alluvial materials generally have a high clay content and therefore are likely to have a low hydraulic conductivity, and act as an aquitard making them appropriate material to host an overlying surface water body such as Lake Macdonald. Registered groundwater bores located around the circumference of Lake Macdonald do not target the alluvium, confirming that it is likely not a productive aquifer. The selected bores presented in Table 6-24 and located on Figure 6-23 indicate that the alluvium has a minimum depth of 3 m and maximum depth of 21 m surrounding Lake Macdonald.

The Pomona Beds, consisting of shale, sandstone, conglomerate and basalt are the known target formation for six registered bores within 2 km of Lake Macdonald. These bores have an average yield of 4.2 L/s and a ‘potable’ water quality, indicating that groundwater sourced from this unit is likely suitable for domestic purposes.

The Myrtle Creek Sandstone, composed predominately of sandstone with minor siltstone and shale, is the target formation for 17 registered bores within 2 km of Lake Macdonald. These bores have an average yield of 1.8 L/s and a 'potable' to 'brackish' water quality, indicating that groundwater sourced from this unit is likely suitable for agricultural purposes and potentially suitable for domestic purposes.

The Kin Kin Beds, composed shale, mudstone and sandstone, is the target formation for 15 registered bores within 2 km of Lake Macdonald. These bores have an average yield of 2.3 L/s and a 'potable' to 'brackish' water quality, indicating that groundwater sourced from this unit is likely suitable for agricultural purposes and potentially suitable for domestic purposes. The Kin Kin Beds underlie Lake Macdonald in its western section.

A conceptual geological cross sections showing the relationship between these groundwater resource units is presented in Figure 6-24.

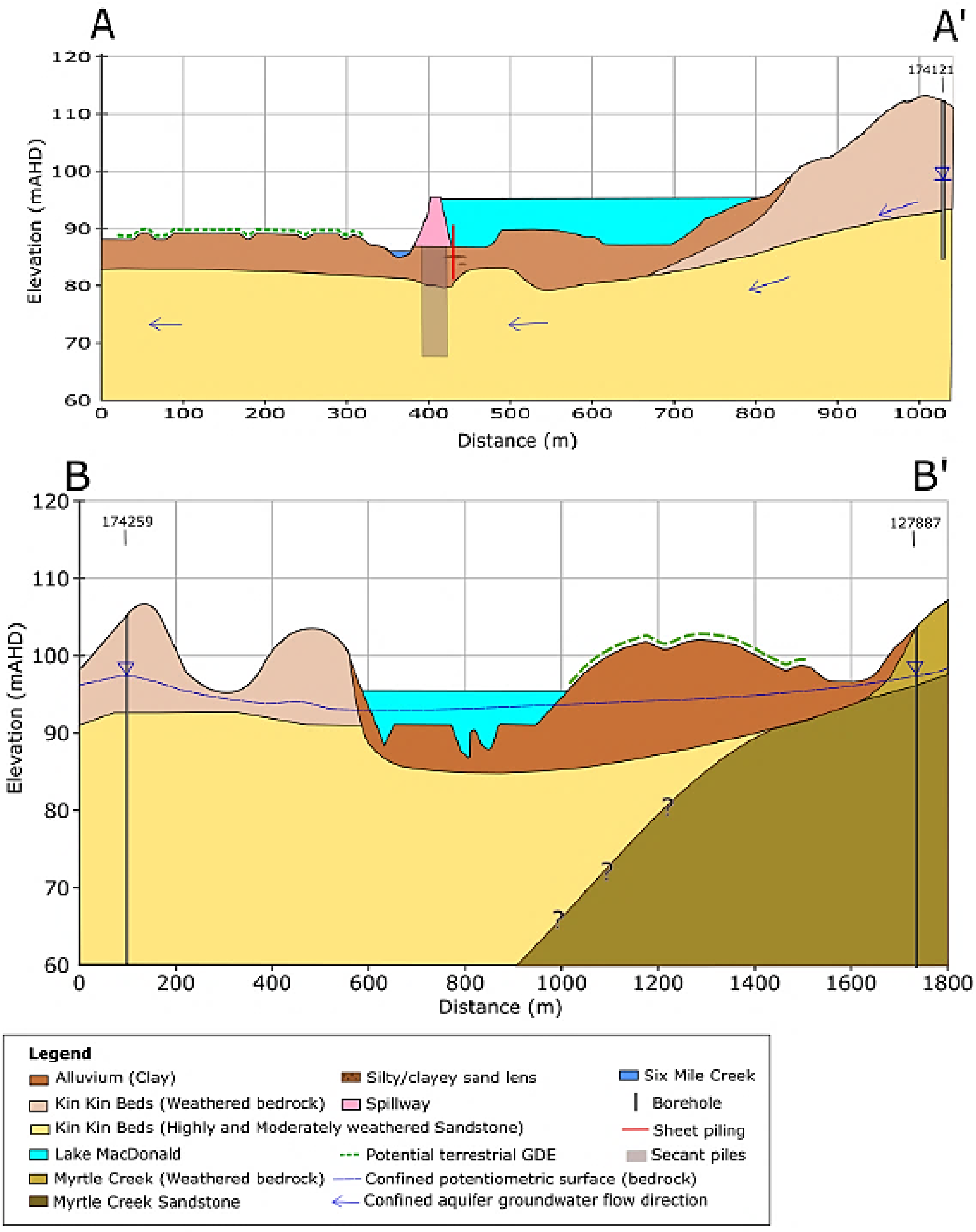


Figure 6-24: Conceptual geological cross sections

Groundwater Levels and Flow Direction

Records of privately owned bores within 2 km of Lake Macdonald were reviewed on the GWDB which provides a water level for when the bore was drilled. Groundwater levels presented by targeted formation are provided in Table 6-27; it should be noted that all available water level records are from the bedrock aquifers. A bedrock aquifer groundwater potentiometric surface contour map based on available records in the GWDB with dates recorded between 2003 and 2017 is presented in Figure 6-25. Available data indicates that groundwater levels reach a minimum depth to groundwater of between 1.0 and 1.5 m bgl, and a maximum of between 12.0 and 26.6 m bgl for all targeted formations.

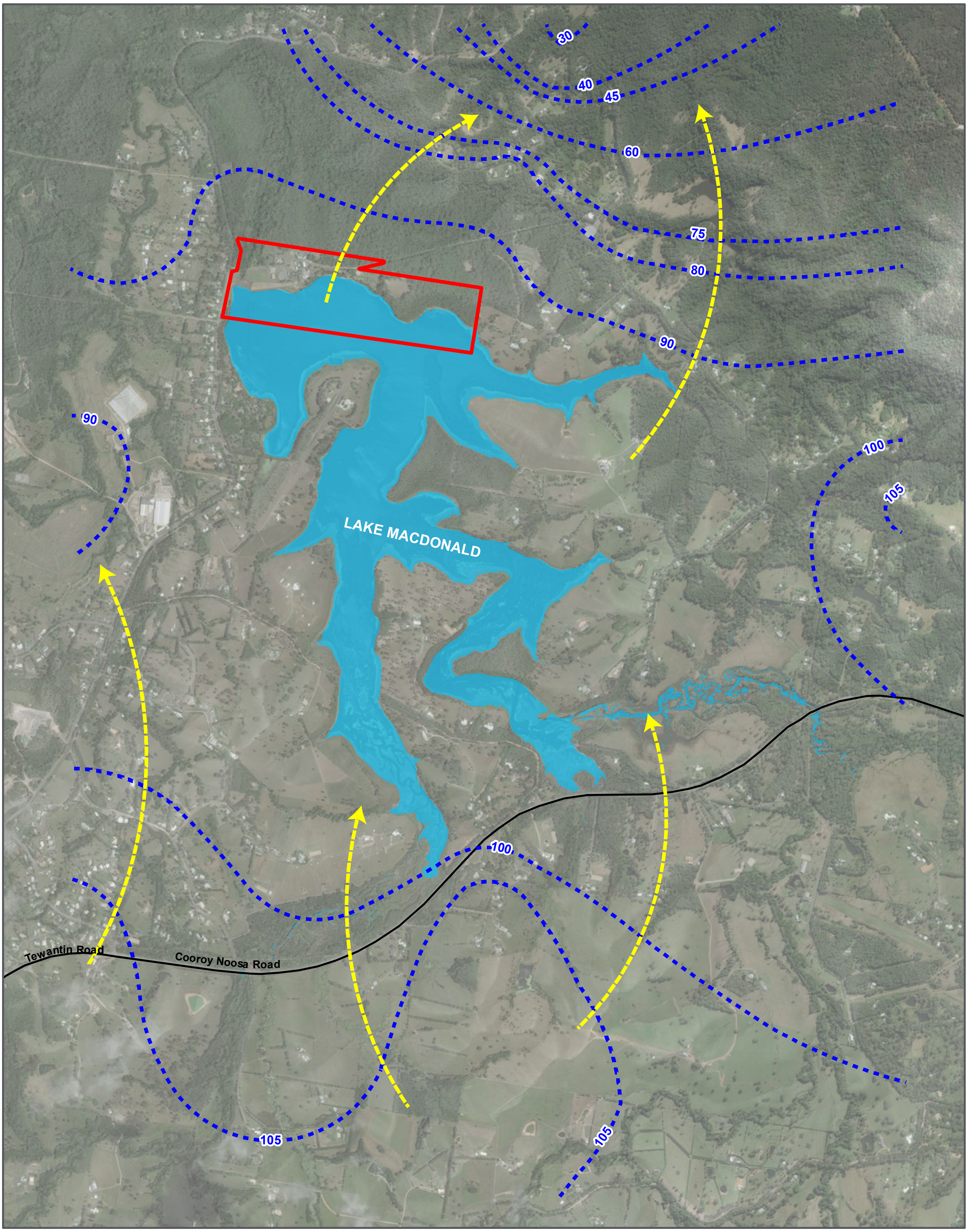
Figure 6-25 shows that the bedrock groundwater flow direction in the Project area is to the north-northwest, from 105 m AHD south of Lake Macdonald to less than 40 m AHD in the north. This is consistent with the expected regional groundwater flow direction, reflecting surface topography and the flow direction of Six Mile Creek and the Mary River Catchment.

Table 6-27: Initial groundwater level for registered bores within 2 km of Lake Macdonald

FORMATION	COUNT	AVERAGE (M BGL)	MAXIMUM (M BGL)	MINIMUM (M BGL)
Kin Kin Beds	15	7.5	17.4	1.5
Myrtle Creek Sandstone	17	11.7	26.5	1.5
Pomona Beds	6	7.5	12.0	1.0

(Source: DNRME GWBD)

FIGURE 6-25: GROUNDWATER POTENTIOMETRIC CONTOURS



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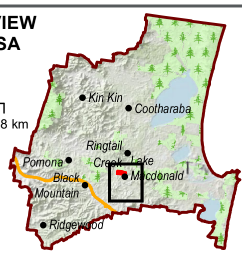
LEGEND

- Groundwater Contour Line (Elevation in m AHD)
- Inferred Groundwater Flow Direction
- Bruce Highway
- Secondary Road
- Lake Macdonald
- Project Area
- Local Governmental Area

OVERVIEW NOOSA



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Hydraulic Properties

Site specific hydraulic properties for the bedrock (Kin Kin Beds) underlying the clay base of Lake Macdonald were determined through packer permeability testing that was carried out by AECOM (2018a) in three boreholes located near to the dam spillway, these being BH502 (6 tests), BH503 (4 tests), and BH506 (4 tests) (Figure 6-23). The resulting estimated hydraulic conductivity of the Kin Kin Beds at varying depths based on this testing ranges from < 8.6×10^{-3} to 1.7×10^{-1} m/d, with detailed results presented in Appendix F.

The site specific hydraulic conductivity data for the Kin Kin Beds generally fall within the broad literature value ranges for the hydraulic conductivity of sandstone (2.6×10^{-5} m/d to 5.2×10^{-1} m/d; Domenico and Schwartz, 1990) and are considered to be indicative of a moderately productive aquifer. By comparison, literature value ranges for the hydraulic conductivity of clay range from 4×10^{-4} to 8.6×10^{-7} m/d (Domenico and Schwartz, 1990).

Recharge and Discharge

The primary recharge mechanism to the regional groundwater system is considered to be direct rainfall infiltration. Additionally, it is likely that Lake Macdonald itself provides a local groundwater recharge source via direct infiltration through the clayey lake base and this is somewhat supported by the potentiometric contours shown on Figure 6-25.

The proportion of net rainfall recharging the groundwater system depends largely on the characteristics of the surface geology, soils, the land use and depth to the water table. Recharge to deeper bedrock aquifers via vertical infiltration is expected to be low, if at all present, in areas where the surface is covered by unconsolidated alluvium composed of clayey soils with a low hydraulic conductivity.

Bedrock aquifers underlying the alluvium are considered to be recharged locally where they outcrop, and by downwards vertical leakage from the overlying unconsolidated sediments in places where it exists and the hydraulic head of the upper aquifer is above that of the lower aquifer.

Extraction of groundwater through the use of existing third-party bores for domestic or agricultural use in the Project area is considered a mechanism of discharge from the groundwater system.

Evapotranspiration from the water table is another mechanism of groundwater discharge likely to be present in the Project area, particularly in the lower lying topographic areas where groundwater elevations are shallower. In areas where the water table is shallow and within the rooting depth of vegetation evapotranspiration can be a significant component of the water balance. Evapotranspiration rates in the Project area would depend on local land use and depth to groundwater.

Groundwater has the potential to discharge into Six Mile Creek, particularly immediately downstream of the dam where the presence of Lake Macdonald is likely to have artificially raised the local shallow water table. This is discussed below.

Groundwater-Surface Water Interaction

The information presented in Table 6-27 shows that groundwater levels in the local stratigraphy are variable, with a minimum of 1 m bgl indicating that hydraulic connection between surface water and groundwater may exist in some locations where groundwater is particularly shallow. This is likely to occur in topographically low lying areas following periods of rainfall where the surface water body (local creeks and Lake Macdonald) is in direct contact with the underlying groundwater system via a zone of saturated material.

As shown on Figure 6-24, the bedrock groundwater potentiometric surface is possibly above ground level in the vicinity of Six Mile Creek immediately downstream of Lake Macdonald, providing the hydraulic potential for discharge of bedrock groundwater to the surface water system of Six Mile Creek. However, the presence of the low permeability unconsolidated clayey alluvial sediments overlying the bedrock in Six Mile Creek likely inhibits such discharge, with shallow groundwater in the unconsolidated sediments maintained by seepage from Lake Macdonald through the existing embankment and dam floor, as well from infiltration from surface water flows in Six Mile Creek.

Where relatively deeper groundwater levels are encountered in the bedrock aquifer, short term fluctuations (rising and falling) in the water table will have little or no correlation with surface water levels in local creeks and Lake Macdonald.

Beneficial Uses of Groundwater

Groundwater Users

Registered groundwater bores located within a 2 km radius of the study area were identified using data sourced from the DNRME GWDB. A total of 45 registered bores are located within 2 km of Lake Macdonald which are shown on Figure 6-22. The specific use of these groundwater bores is unknown, however based on regional land use it has been assumed that they are currently assigned in a beneficial capacity such as for stock and domestic or irrigation purposes.

Groundwater Dependent Ecosystems

Groundwater discharge can be important in maintaining baseflow in rivers and streams, and ecosystems associated with these discharge areas may have a high dependency on groundwater for their water requirements. It should be noted, however, that some of these ecosystems rely on perched aquifer systems that are shallow, surficial and are largely not connected to the deep regional groundwater system. These ecosystems that rely on perched aquifer systems are characteristically sustained by rainfall infiltration.

All identified GDEs within the vicinity of the Project are identified on Figure 6-26. Within 2 km of Lake Macdonald, three classes of aquatic ecosystems have been identified by WetlandInfo (2013) that rely on the surface presence of groundwater, these being:

- Creeks (line type GDE) with a high potential for groundwater interaction, including Six Mile Creek downstream of the spillway and Lake Macdonald
- Creeks (line type GDE) with a moderate potential for groundwater interaction, including Six Mile Creek upstream of Lake Macdonald
- Wetlands (area type GDE) with a moderate potential for groundwater interaction. State mapping of wetlands shows that both riverine and palustrine wetlands associated with Six Mile Creek occur downstream of the spillway.

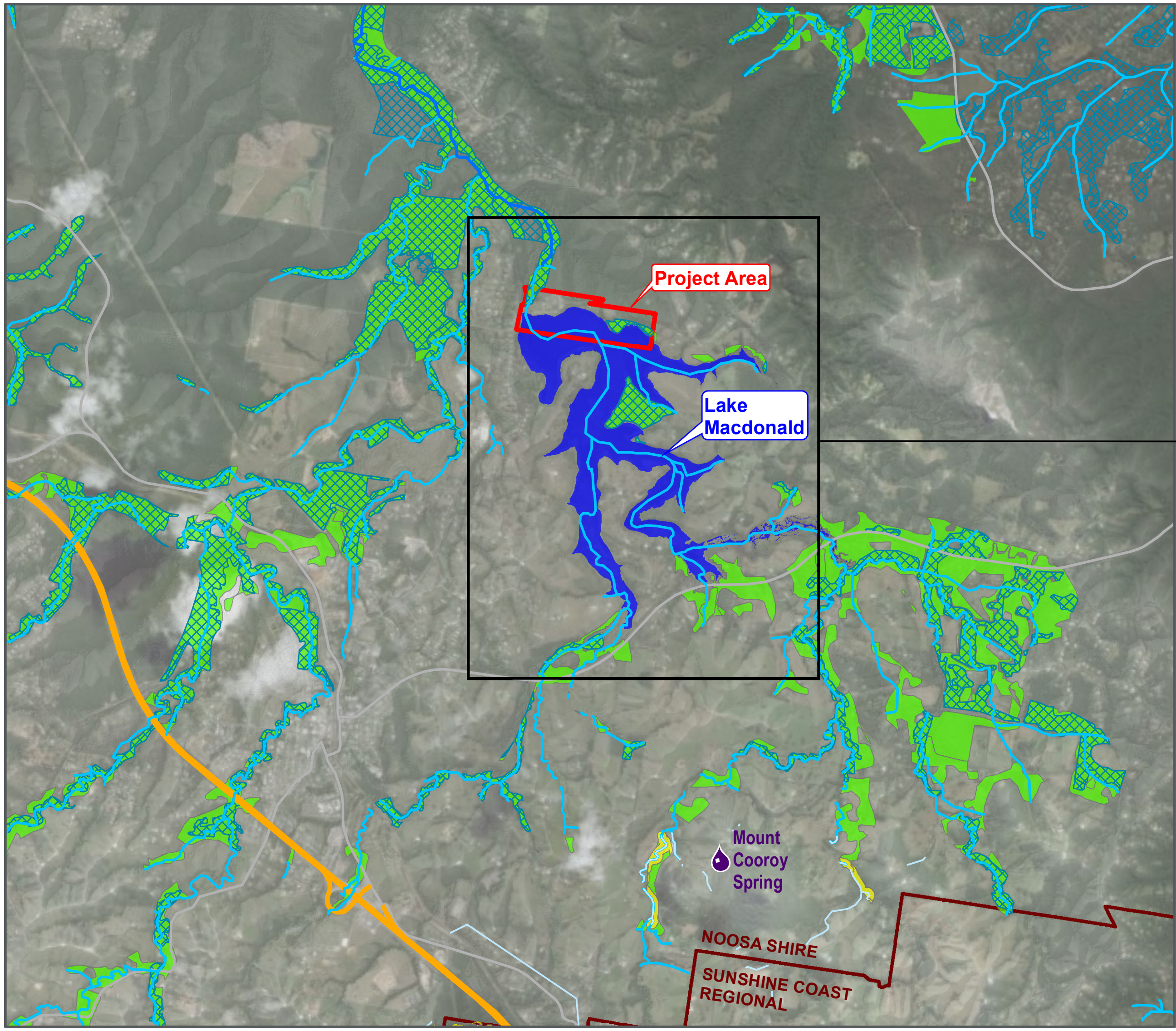
No Ramsar wetlands are mapped within the vicinity of the Project area.

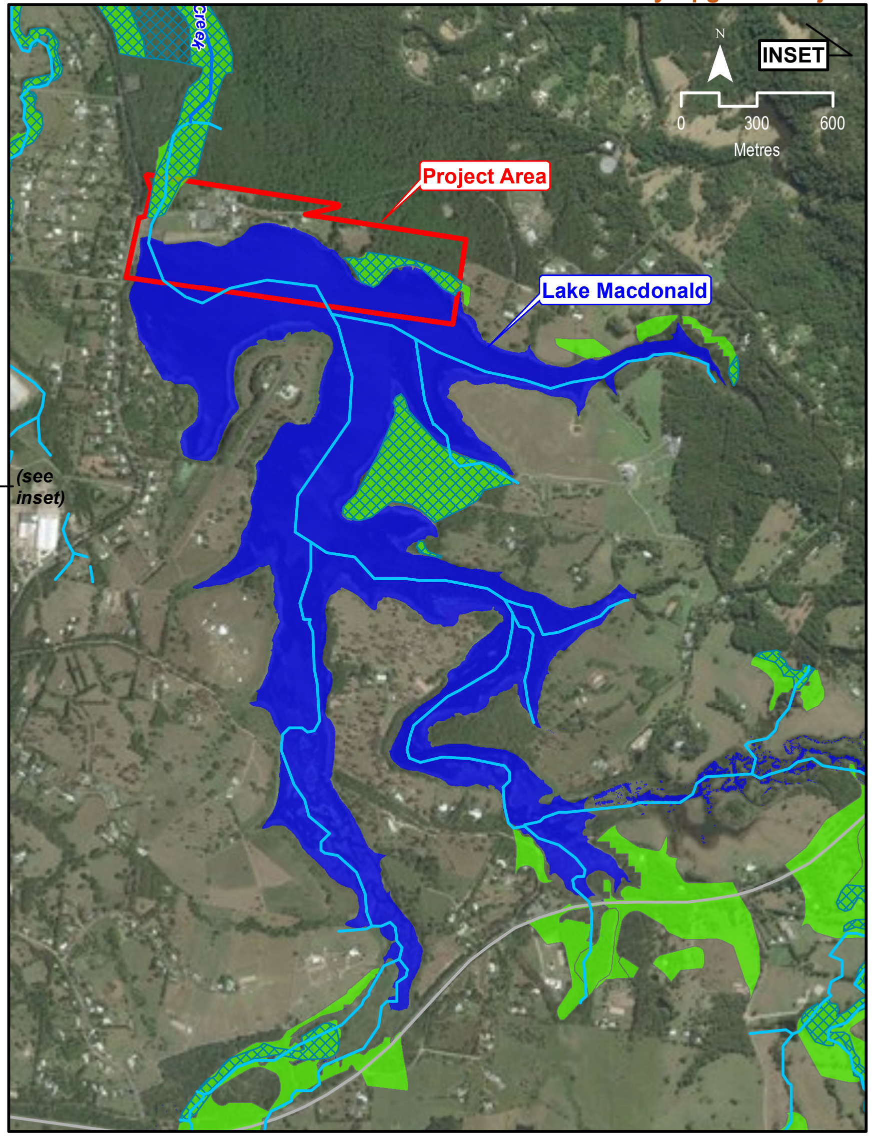
Within 2 km of Lake Macdonald, terrestrial ecosystems were identified that potentially rely on the subsurface presence of groundwater, with a moderate confidence level. WetlandInfo (2013) classifies these terrestrial ecosystems into six regional ecosystems (RE), these being Gallery rainforest (RE ID 12.3.1), *Eucalyptus grandis* (12.3.2) *Melaleuca quinquenervia* and *Eucalyptus robusta* woodland (12.3.4), *Eucalyptus tereticornis* (12.3.11) and *Corymbia intermedia* (12.3.15).

Mount Cooroy Spring (point type GDE), is located 2.4km hydraulically upgradient (southeast) of the Project area. Groundwater in the vicinity of the Project is unlikely to support the presence of this particular GDE due to its location upgradient of Lake Macdonald.

FIGURE 6-26: GROUNDWATER DEPENDENT ECOSYSTEMS

Six Mile Creek Dam Safety Upgrade Project





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1. Localities, Roads, LGA, Waterways, Waterbody, Protected Areas © QLD Spatial Catalogue, State of Queensland (Department of Natural Resources, Mines and Energy) 2018
2. Basemap © Nearmap, 2018
3. GDE version 01_4@ QLD Government (Department of Science, Information Technology, Innovation and the Arts), 2015

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LEGEND

- Bruce Highway
- Secondary Road
- Local Governmental Area
- Project Area

Surface expression GDE (Spring Ecosystems)

- Mount Cooroy Spring

GDE Surface Line

- Derived GDE - high confidence
- Derived GDE - moderate confidence
- Derived GDE - low confidence

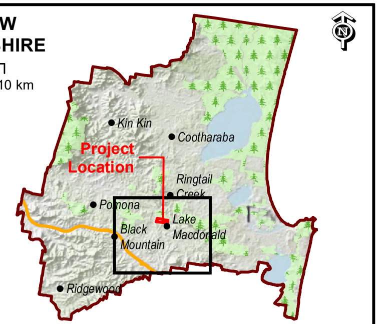
Surface expression GDE

- Derived GDE - moderate confidence

Terrestrial GDE

- Derived GDE - moderate confidence
- Derived GDE - low confidence

OVERVIEW NOOSA SHIRE



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6.4.3 Potential Impacts

Potential for Groundwater Related Impacts

The Project has the potential to result in groundwater related impacts from the following activities and aspects:

- The temporary lowering of Lake Macdonald to a level of 89.5 m AHD during the construction period (18 to 24 months), including the further lowering to a level of 89 m AHD for approximately two months during the demolition of the existing dam structure and installation of sheet pile coffer dam.
- The installation of sheet piling (approximately 300 m in length and up to 10 m depth), and secant piles (135 m in length and 18 m depth) potentially creating a groundwater flow barrier within the unconsolidated alluvial sediments directly below the dam structure.
- A reduction of flows from Lake Macdonald into Six Mile Creek during the refilling of the impoundment.
- Accidental spills of hazardous materials used and stored within the Project area.
- The discharge of groundwater from dewatering the secant pile cells before backfilling with mass concrete.

The dewatering of Lake Macdonald is likely to induce a localised drawdown effect. The estimation of drawdown extent over the two-year assessment period due to dewatering of each section of Lake Macdonald is presented in Table 6-28.

The dewatering of the unconsolidated alluvial materials is likely to induce a minor, highly localised, drawdown affect around Lake Macdonald due to the low permeability of the clay material. Out of all of the dewatered conceptual lake sections, the maximum horizontal extent of drawdown for the expected hydraulic conductivity scenario is 14.1 m and ranges between approximately 2.8 m and 44.7 m for the low and high hydraulic conductivity scenarios respectively.

The potential risk of groundwater drawdown to groundwater users, including groundwater dependent ecosystems resulting from the dewatering of Lake Macdonald is negligible. This is indicated by the estimated groundwater horizontal drawdown extent being less than 14.5 m in all cases for the two-year duration.

The dewatering of Lake Macdonald during the construction phase will not impact groundwater users as environmental flows into Six Mile Creek will be maintained in compliance with the operating rules of the Mary Basin ROP.

Table 6-28: Estimated drawdown extent over a two year period for difference hydraulic conductivity values

DEWATERED AREA	HORIZONTAL DRAWDOWN EXTENT (M)		
	Expected Case	Upper Bound Case	Lower Bound Case
Lake section 1	14.1	44.7	4.5
Lake section 2	13.0	41.2	4.1
Lake section 3	11.8	37.4	3.7
Lake section 4	10.2	32.2	3.2
Lake section 5	11.3	35.6	3.6
Lake section 6	11.0	34.6	3.5
Lake section 7	8.9	28.3	2.8
Lake section 8	10.3	32.7	3.3
Lake section 9	8.8	27.7	2.8

Reduction of Environmental Flows

During the construction phase of the Project, stormwater flows in Six Mile Creek will pass over the coffer dam through the work area via a diversion channel to discharge downstream. Environmental flows into Six Mile Creek will be maintained in compliance with the operating rules of the Mary Basin ROP during construction.

Following construction, there is the potential for flows from Lake Macdonald into Six Mile Creek to be reduced during the natural refilling of the dam from rainfall. A reduction of downstream environmental flows would reduce the amount of surface water available for shallow groundwater recharge in the downstream environment, and therefore potentially reduce the amount of groundwater available to users under the assumption that the surface water and groundwater systems are connected, which may or not be the case. Environmental flows into Six Mile Creek required by the Mary Basin ROP will be maintained during the filling phase.

Groundwater Quality Impacts

The construction phase of the Project has the potential to impact groundwater quality by accidental spills of hazardous materials used and stored within the Project area that may occur and lead to groundwater contamination.

Groundwater Flow Barrier

The installation of impermeable sheet piling and secant piles for the spillway upgrade have the potential to cause a barrier to groundwater flow and hence reduce groundwater flows in the down-gradient ‘shadow’ of the spillway.

The unconsolidated alluvial sediments have been identified to have a low hydraulic conductivity and act as an aquitard. In the case that water was to move through the unconsolidated alluvial sediments, for example through lenses of coarse grained sediments, the alluvium will be covered by lake water following completion of the upgrade and provide a hydraulic connection either side of the sheet piling similar to existing conditions. Based on this, the addition of the sheet piling as an impermeable barrier is not anticipated to have any impact on the local groundwater flow.

The proposed secant pile wall will form a localised mass concrete foundation based in the underlying moderately weathered rock to a depth of 71.5 m AHD, giving the impermeable structure an approximate dimension of 135 m length and 18 m depth. The functional purpose of the secant pile wall is to secure the spillway infrastructure into moderately weathered rock, rather than into the alluvial sediments where the existing spillway is founded. This design will permit groundwater to flow beneath the structure and around either side where it will reach equilibrium within the regional setting and is not anticipated to reduce groundwater flows down-gradient of the spillway.

Discharge of Groundwater

By design, the secant piles should be effective in preventing groundwater ingress, however, where dewatering is required from within the nine secant pile cells, discharge of groundwater to the environment has the potential to impact the receiving environment of Six Mile Creek should there be sediment load, nutrient-rich, low/high pH, salinity or contamination present in the extracted groundwater.

6.4.4 Impact Mitigation and Management

The Project’s performance outcomes for groundwater are:

- No potential or actual adverse effect on groundwater due to Project activities
- The storage and handling of contaminants will include effective means of secondary containment to prevent or minimise releases to the environment from spillage or leaks.

Recommended mitigation measures to achieve the performance outcomes for the Project are provided in

Table 6-29: Mitigation and management measures for groundwater

POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Groundwater drawdown	Low	No impacts to registered groundwater bores or GDEs were identified.	Low
Reduction of environmental flows	Low	Maintain a low flow notch / channel at all times during construction to ensure downstream flows over the coffer dam low flow crest can pass through the dam site with suitable water quality; this should be included in the Project Environmental Management Plan. Incidental high flows will be maintained during spring and summer months when the Mary River cod are more prone to moving upstream to Six Mile Creek from Mary River. Measures must comply the operating rules of the Mary Basin ROP. Reinstate the current conditions during the operational phase.	Low
Groundwater quality impacts from accidental spills of hazardous materials used and stored within the Project area	Low	The Project Environmental Management Plan should include the provision of spill control measures for the duration of the Project. No discharge to the natural environment of contaminated water from the Project works. No visual films or oily residue pooling or ponding around plant or machinery within the Project area. All spill related environmental incidents are closed out in a timely manner. Any servicing and/or repair of plant and equipment should occur off-site. Use drip trays and spill kits when conducting minor repairs. Locate vehicle wash down areas off-site away from drainage lines, Six Mile Creek or any areas that have the potential to release hazardous substances into sensitive areas. Use drip trays under any standing machinery such as generators and compressors. For all works areas on or adjacent to Lake Macdonald and Six Mile Creek, ensure spill kits suitable for working within an aquatic environment are available. Spill kit supplies will be hydrophobic where adjacent to an aquatic environment, as a minimum. Personnel purpose trained.	Low
Groundwater flow barrier	Low	No impacts to registered groundwater bores or GDEs were identified.	Low

POTENTIAL IMPACT	IMPACT RISK BEFORE MITIGATION	MITIGATION AND MANAGEMENT	RESIDUAL IMPACT RISK
Discharge of groundwater	Low	The Project Environmental Management Plan should include the provision of monitoring the quality of the extracted groundwater from the spillway excavation for the duration of the Project, to ensure compliance with the downstream receiving environment water quality targets. Produce a dewatering management plan, detailing: • Discharge to the environment whereby groundwater is transferred to grassy swales for infiltration back into the groundwater source. • If groundwater has a high turbidity, sedimentation basins will be required to capture suspended solids prior to infiltration. Where possible these swales will divert groundwater around the construction area so that groundwater does not further mix with construction runoff. • Where infiltration cannot be achieved through grassy swales then groundwater is to be collected and tested prior to discharge into natural waterways (such as Six Mile Creek) where it must comply with the conditions prescribed under EPP (Water) Mary River environmental values and water quality objectives 2010. • Discharge to stormwater drainage or sewerage infrastructure in compliance with Queensland Government State Planning Policy Code. • Disposal at a licensed facility.	Low

6.5 Summary

6.5.1 Surface Water Hydrology

Six Mile Creek runs in a north-west direction, is impounded by the Six Mile Creek Dam spillway and embankment, and ultimately discharges to the Mary River. It has a drainage order of five and is classified as non-perennial (i.e. has no flow for part of the year) under the Water Act. Other low order drainage features surrounding the Project are minor in nature and/or are not directly impacted by the Project. February has the greatest monthly mean flow, with the month of October having the least, which corresponds closely with the rainfall.

Six Mile Creek Dam is regularly full and spills frequently, with a simulation predicting 20 ML/d and 50 ML/d flow exceedances for 17% and 13% of time, compared to the no dam case values of 26% and 16% exceedance for 20 ML/d and 50 ML/d flows, respectively. This indicates that current dam operations slightly decreases flow exceedances to the receiving environment compared to pre-dam construction conditions.

Potential impacts to hydrology associated with the Project comprise:

- Flow regime changes during dam dewatering leading to adverse effects on stream geomorphology, aquatic ecosystem function and flow objectives
- Flow objective breaches during construction and operation of the Mary Basin WRP
- Water security impacts during construction and impacting on water availability for licensed users
- Flood impacts during construction and operation.

The impact assessment indicates that where appropriate mitigation measures such as those identified below are in place, impacts associated with the Project will be low to medium:

- Development of a lake lowering plan to consider drawdown timeframes and rates that consider the natural flow regime
- Meet ROP environmental release requirements throughout construction, either through natural catchment flows or ability to supplement flows from an alternative source, such as the Mary River raw water offtake.
- Develop a communication plan to advise licensed water users (downstream on Six Mile Creek) of potential impacts of changes in flow characteristics
- Undertake core construction activities during the dry season to reduce the likelihood of receiving an extreme flood event during construction.

6.5.2 Surface Water Quality

Water quality in Six Mile Creek is generally good and typically achieves the WQOs for the protection of identified environmental values. However, a number of water quality parameters in Lake Macdonald and/or the tailwater at times do not comply with the WQOs, including total and organic nitrogen, ammonia, chlorophyll a, some metals, pH, dissolved oxygen, and total suspended solids. Assessment of monitoring data also indicates that Lake Macdonald rarely stratifies and when it does it is only weakly stratified.

Potential impacts to water quality associated with the Project comprise:

- Increased turbidity and total suspended solids
- Decreased pH
- Reduced dissolved oxygen
- Increased nutrient concentrations
- Increased dissolved metal concentrations
- Contamination of water from spills of fuels, oils or other chemicals.

The impact assessment indicates that where appropriate mitigation measures such as those identified below are in place, there is a low risk of impacts to water quality associated with the Project:

- Minimise disturbance of unconsolidated bed sediments (e.g. by using pontoon based pump stations).
- During the drawdown take water from mid-depth, or mix of depths, for example with a multi-level intake.
- Avoid or manage areas of potential erosion, for example by implementing an Erosion and Sediment Control Plan and/or releasing water to the existing concrete apron during drawdown.
- Implement real-time water quality monitoring for key parameters

- Maintain dissolved oxygen concentrations in Lake Macdonald and Six Mile Creek, for example by using aeration units and turbulent release to the existing concrete apron.
- Minimise exposure of deep sediments that have high metal and nutrient concentrations
- Reduce the likelihood of chemical spills or leaks through appropriate storage, handling and spill response.

6.5.3 Groundwater

Within 2 km of Lake Macdonald there are 45 registered groundwater bores, three aquatic GDEs that are likely to rely on the surface expression of groundwater and six terrestrial GDEs that are likely to rely on the subsurface presence of groundwater.

Potential impacts to groundwater resulting from the Project include:

- A reduction of the amount of water available for groundwater recharge in the downstream environment resulting from a reduction of environmental flows to Six Mile Creek
- Accidental spills of hazardous materials used and stored within the Project area
- Discharge of groundwater dewatered from secant pile cells.

Analytical methods showed that groundwater drawdown around Lake Macdonald is both limited in magnitude and highly localised for the two-year construction period. It is not anticipated that groundwater users will be negatively impacted with model predictions indicating that the drawdown extent does not reach any anthropogenic or environmental groundwater users. The spillway construction is also not expected to impact groundwater flow as the design will permit groundwater to flow beneath the structure and around either side.

The impact assessment indicates that where appropriate mitigation measures such as those identified below are in place, there is a low risk of impacts to groundwater quantity and quality:

- Environmental flow regimes should be maintained in compliance with the operating rules of the Mary Basin Resource Operation Plan and therefore impacts are unlikely.
- Management measures should be implemented to address the potential for spills.
- A dewatering management plan should be implemented to safely manage and dispose of groundwater inflows to the spillway excavation. If groundwater is to be discharged to natural waterways (such as Six Mile Creek), it should be tested and comply with the conditions prescribed under EPP (Water). Test groundwater prior to discharge into natural waterways (such as Six Mile Creek) and develop mitigation measures if groundwater quality does not meet environmental thresholds.