APPENDIX F

Groundwater Impact Assessment (SLR Consulting Pty Ltd)

SIX MILE CREEK DAM

Safety Upgrade Project
Groundwater Impact Assessment

Prepared for:

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Fortitude Valley
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1 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by SMEC Australia Pty Ltd (SMEC) on behalf of Seqwater to prepare a Groundwater Impact Assessment associated with the Six Mile Creek Dam (also known as the Lake Macdonald Dam) Upgrade. A Groundwater Impact Assessment is a required component of the Impact Assessment Report (IAR).

The Six Mile Creek Dam is located in Noosa Shire and is owned and operated by Seqwater (see **Figure 1-1**).

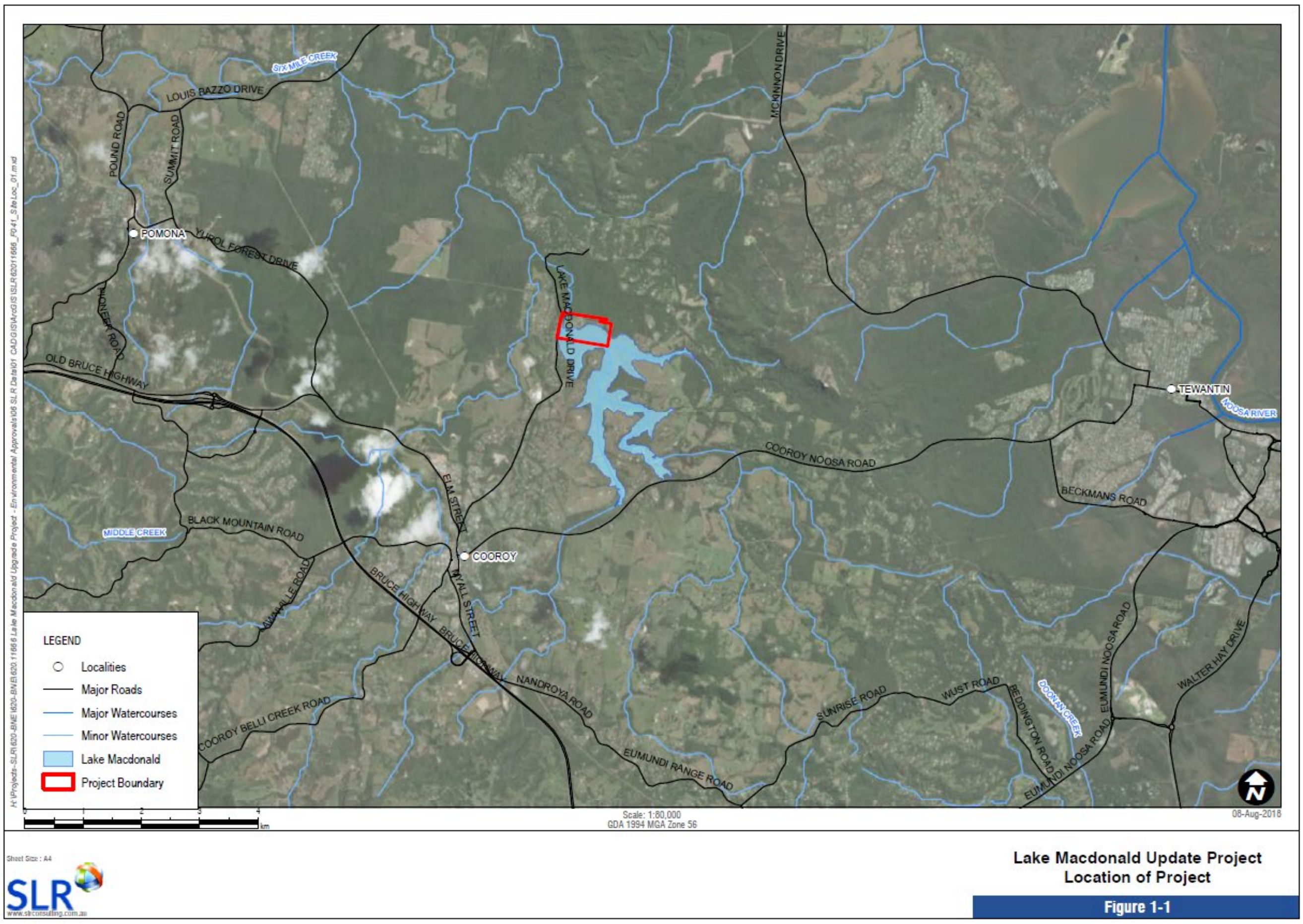


Figure 1-1 Regional Location of Lake Macdonald and the Project Area

1.1 Scope of work

In consultation with relevant regulatory agencies, groundwater was identified as a regulated environmental matter that may potentially be impacted by the Project and requires a description of the expected level of impact, and to identify how impacts can be mitigated and/or managed through established environmental management practices that reflect industry best practice. Specifically, the scope adopted for groundwater are as follows:

To ensure impacts to groundwater, Groundwater Dependent Ecosystems (GDEs) / stygofauna (if present) and aquatic ecology are identified and adequately addressed, the IAR should include an assessment of any potential impacts to groundwater during the project and after its completion. This assessment should identify:

- *current groundwater levels and flows (upstream and downstream of the Project)*
- *whether there is a groundwater connection between Lake Macdonald and groundwater downstream*
- *existing groundwater bores*
- *existing or potential GDEs within the Project area*
- *if there is the potential for changes to groundwater levels and flows:*
  - *a likely groundwater drawdown area and any potentially impacted groundwater bores within that drawdown area*
  - *impacts on groundwater flow regimes*
  - *impacts on GDEs*
  - *impacts to the elevation, flows, quality and connectivity (upstream and downstream) of groundwater within the alluvium aquifer, and the associated potential for impacts to stygofauna (if present)*
  - *the timing and duration of the potential groundwater impacts*
- *mitigation measures to address the potential impacts, noting that these are expected to be typical for a construction project.*

In addition, provide justification for the level of investigation undertaken to assess the potentialimpacts to groundwater resources and GDEs (e.g. assessment indicates that there would be limited impacts /flows regimes are expected to be maintained and therefore impacts unlikely or mitigation measures would address the potential impacts).

2 Project Description

Six Mile Creek Dam requires an upgrade ("the Project") to meet performance requirements of the Queensland dam safety regulations into the future. The upgrade will involve lowering the lake (impoundment) level to facilitate construction, removal of the existing spillway, construction of a new concrete spillway founded on weathered rock, and reconstructing the existing earth embankments.

Aspects of the Project that are relevant to this groundwater impact assessment are as follows:

- Works to prepare for the removal of the existing spillway which include:
  - Lowering the impoundment level to 89.0 m AHD, by way of pumping, to reduce the life safety risk associated with potential failure of the coffer dam.
  - Installation of sheet pile coffer dam into the Alluvium upstream of the existing dam to maintain the reduced impoundment level at 89.0 m AHD during 2 year construction period (2.8% capacity), with the impoundment level lowered a further 0.5 m to 88.5 m for approximately 2 months during the installation of the sheet piles and decommissioning of the existing spillway and embankment (**Figure 2-1**). The sheet piles will remain in situ post construction.
  - Excavation of the existing spillway and embankment structures.
- Installation of secant piles across 9 cells based in the underlying bedrock to a depth of 71.5m AHD (**Figure 2-1**). Excavate pile caissons, and mass concrete backfill to form a mass concrete foundation.
- Construction of a new labyrinth-type spillway structure.
- Potential construction of a saddle dam on Collwood Road (if needed).
- During construction, stormwater flows in Six Mile Creek will pass over the coffer dam through the work area via a diversion channel to discharge downstream. Existing embankment materials excavated from under the spillway slabs and the right embankment will be stockpiled on site for use in embankment reconstruction.

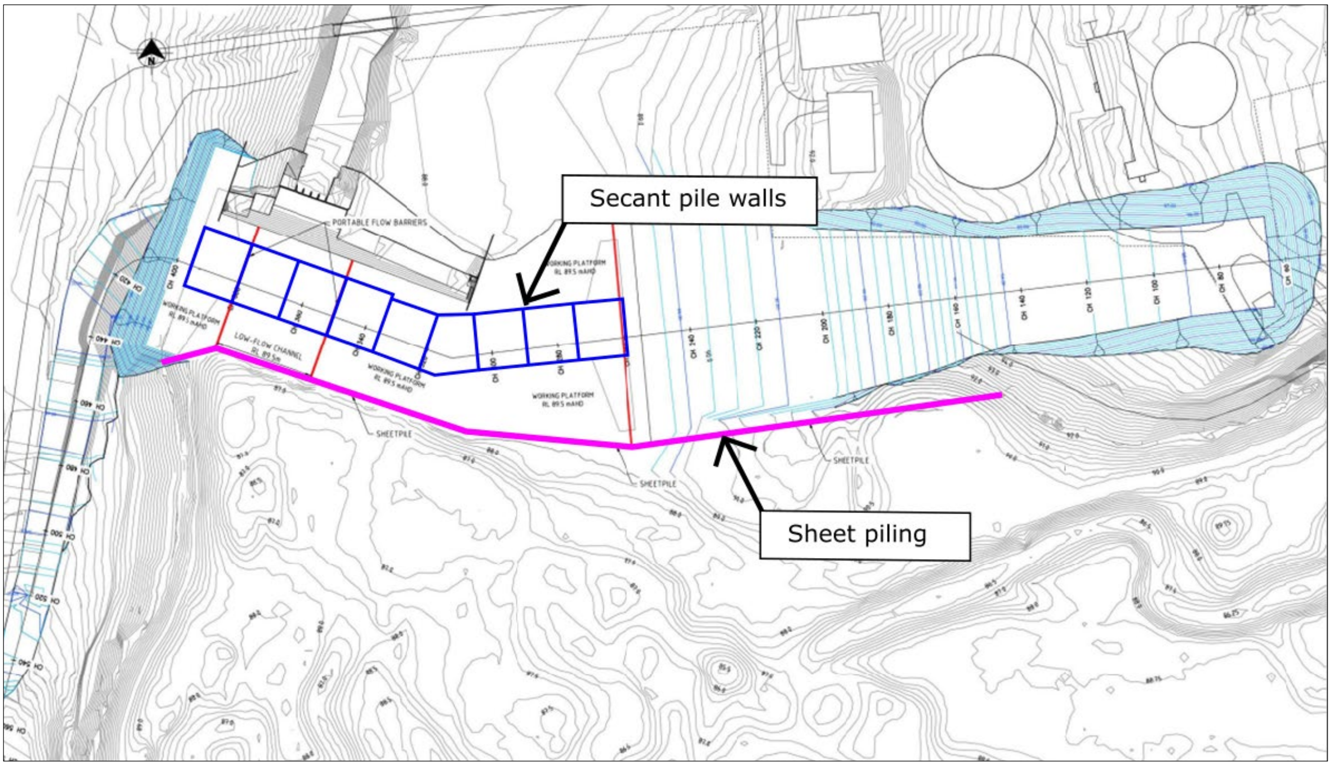


Figure 2-1 Location of Piling Works for Six Mile Creek Dam Upgrade

3 Regulatory Framework

Groundwater use and management in Queensland is regulated under:

- *Water Act 2000* (and subordinate legislation and plans) and
- *Environmental Protection Act 1994* (and subordinate policies).

3.1 Water Act

3.1.1 Water Act 2000

The *Water Act 2000* (Water Act) provides a framework for the sustainable management of water and related resources. The Act regulates the taking, use and allocation of water through (among other things) water resource plans (WRPs) and resource operations plans (ROPs).

The main elements of the Water Act relevant to this Project are:

- WRPs and ROPs can be produced to allow regulation of groundwater
- a system of licensing of water bore drillers prohibits the construction of bores by unlicensed drillers, and
- requirements for the holders of a water bore driller's licence to keep prescribed information for all water bores constructed greater than 6 m deep.

3.1.2 Water Regulation 2002

The *Water Regulation 2002* is subordinate legislation to the Water Act. The main elements of the *Water Regulation 2002* relevant to the Project are:

- delineation of declared subartesian areas
- types of groundwater uses that do not require licences within declared subartesian areas
- licensing requirements of water bore drillers
- requirements that water bores be constructed and decommissioned in accordance with the document Minimum Construction Requirements for Water Bores in Australia (Land and Water Biodiversity Committee, 2003), and
- specification of the information water bores drillers must record.

3.1.3 Mary Basin Resource Operations Plan 2011

The Mary Basin ROP includes operating rules to achieve ecological outcomes in Six Mile Creek downstream of the dam. The stated outcomes are to minimise changes to the low flow regime of the creek, and to minimise changes to the hydraulic habitat requirements of aquatic species.

Seqwater operates Six Mile Creek Dam under a Water Licence to impound and take water as part of the Mary Basin ROP. The Water Licence under the Mary Basin ROP provides for the ecological outcomes through a condition for daily releases from the dam when catchment inflows occur.

3.2 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act), administered by the Queensland Department of Environment and Science (DES), was established "to protect Queensland's environment, while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends". The EP Act utilises a number of mechanisms to achieve its objectives. These include issuing Environmental Protection Policies (EPPs) which are the means by which the State government declares and implements its objectives in relation to environmental protection.

3.2.1 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy 2009* (EPP (Water)) provides a framework for identifying environmental values (EV) for a waterway and deciding water quality objectives (WQO) to protect or enhance those EVs. EVs for water are the qualities of water that make it suitable for supporting aquatic ecosystems and human water uses. These EVs need to be protected from the effects of habitat alteration, waste releases, contaminated runoff and changed flow to ensure healthy aquatic ecosystems and waterways that are safe for community use.

The purpose of this policy is to achieve ecological sustainable development in relation to Queensland waters. It sets a framework for managing environmental impacts on water, the identification of environmental values and the guidelines needed to protect the water environment.

The environmental values and water quality objectives for waters in the Mary River catchment are identified in the *EPP (Water) Mary River environmental values and water quality objectives Basin No. 138, including all tributaries of the Mary River* (DERM, 2010a). Environmental values for surface water in Six Mile Creek and groundwater within the Mary River Catchment are presented in **Table 3-1**.

Table 3-1 Environmental Values of the Project receiving environment (Mary River Catchment)

Environmental value	Six Mile Creek Surface Waters	Groundwater
Aquatic ecosystems	✓	✓
Irrigation	✓	✓
Farm supply/use		✓
Stock water	✓	✓
Aquaculture	✓	
Human consumer	✓	
Primary recreation	✓	
Secondary recreation	✓	
Visual recreation	✓	
Drinking water	✓	✓
Industrial use		
Cultural and spiritual values	✓	

3.3 Water Quality Objectives

The WQO for waters in the Mary River catchment are identified in the EPP (Water) Mary River environmental values and water quality objectives Basin No. 138 (DERM, 2010a). According to the water types shown on Plan WQ1381 (DERM, 2010b), Six Mile Creek is identified as a Lowland freshwater water type and has a moderately disturbed management intent.

Given that more than one EV is identified for surface water in Six Mile Creek and groundwater within the Mary River Catchment, to protect all identified EVs, the most stringent WQO for each water quality indicator applies. The WQOs for physicochemical parameters for surface water in Six Mile Creek are:

- turbidity: <50 NTU
- suspended solids: <6 mg/L
- dissolved oxygen: 85% – 110% saturation
- pH: 6.5 – 8.0

Where groundwater interacts with surface water, groundwater quality should not compromise identified EVs and WQOs for those waters.

4 Existing Environment

4.1 Location and Land Use

The Project area within the local context is shown in **Figure 1-1**. The closest town to Lake Macdonald is Cooroy, with the town centre being approximately 10 km from the proposed construction area. Tewantin and Noosa are the next closest urban centres. 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 semi-rural 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.

4.2 Topography and Drainage

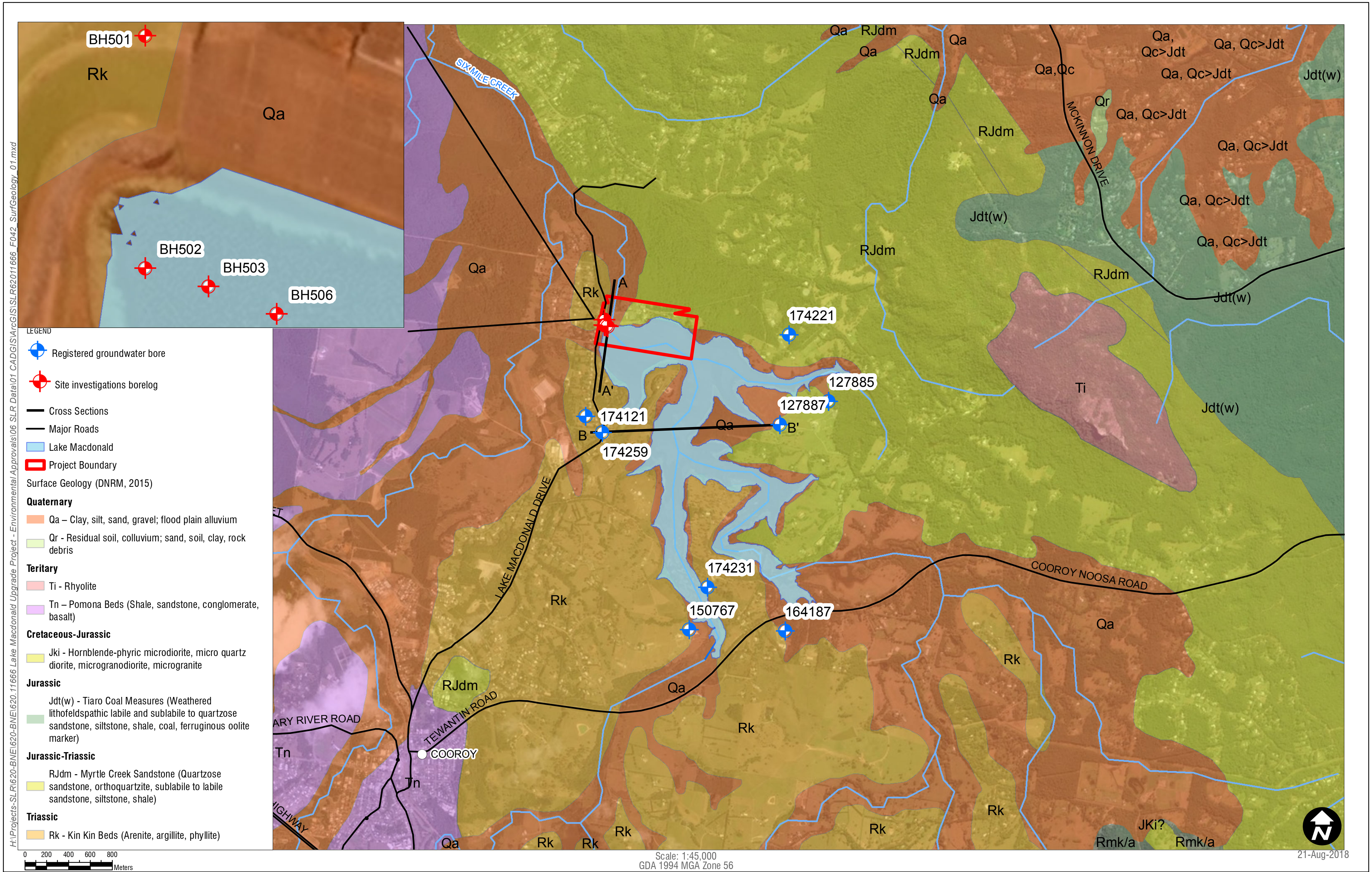
The Six Mile Creek catchment drains an area approximately 49 km^2 and generally flows in a north-westerly direction, joining the Mary River near Gympie approximately 40 km downstream of the dam. The Lake Macdonald catchment headwaters originate in the Blackall Range and are bounded by the Blackall Range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

4.3 Geology

The surface geology map presented in **Figure 4-1** 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 **Table 4-1**.

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).



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Six Mile Creek Dam Safety Upgrade Project
Surface geology

Firgure 4-1

Table 4-1 Stratigraphy for Lake Macdonald Area

Age	Formation	Lithology key *	Lithology
Quaternary	Alluvium	Qa; Qa, Qc; Qa, Qc >Jdt	Clay, silt, sand, gravel; flood plain alluvium
	Residual soil	Qr	Residual soil, colluvium; sand, soil, clay, rock debris
Tertiary	Pomona Beds	Tn	Shale, sandstone, conglomerate, basalt
	Unnamed	Ti	Rhyolite
Cretaceous-Jurassic	Unnamed	Jki	Hornblende-phyric microdiorite, micro quartz diorite, microgranodiorite, microgranite
Jurassic	Tiaro Coal Measures	Jdt(w)	Weathered lithofeldspathic labile and sublabile to quartzose sandstone, siltstone, shale, coal, ferruginous oolite marker
Jurassic-Triassic	Myrtle Creek Sandstone	RJdm	Quartzose sandstone, orthoquartzite, sub-labile to labile sandstone, siltstone and shale
Triassic	Kin Kin Beds	Rk	Arenite, argillite, phyllite, shale, mudstone and sandstone

* Presented on Figure 4-1

4.3.1 Site Geology

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 4-2** from groundwater database bore reports for boreholes surrounding Lake Macdonald and in **Table 4-3** from the latest geotechnical investigations; all locations are shown on **Figure 4-1**. A review of the borelogs (**Table 4-2**) 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 4-1**). 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.

Table 4-2 Lithology of Registered Groundwater Bores

Borehole	Maximum Depth (m)	Depth of Clay from Surface (m)	Lithology	Formation
127885	152.4	5.2	Clay 0-5.2m; brown, grey and pink shale 5.2 -24.4m; grey shale 24.4 - 152.4m.	Myrtle Creek Sandstone*
127887	60.6	7.6	Clay and clay stone 0 - 7.6m; basalt 7.6 - 13.7m; mudstone 13.7 - 60.6m.	Myrtle Creek Sandstone*
150767	30.0	8.0	Topsoil 0 - 1m; brown clay 1 - 8m; brown, white and black shale 8 - 30m.	Kin Kin Beds
164187	30.5	12.2	Soil 0 - 0.6m; white, brown and yellow clay 0.6 - 12.2m; shale 12.2 - 17.4m; mudstone 17.4 - 30.5m.	Kin Kin Beds
174777	30.0	5.5	Clay 0 - 5.5m; weathered red and orange sandstone 5.5 - 9m; sandstone 9 - 30m.	Unknown
174121	37	21.0	Soil 0 - 1m; red, white and brown clay 1 - 21m; sandstone 21 - 37m.	Kin Kin Beds
174221	48.8	3.0	Soil 0 - 0.6m; red clay 0.6 - 3m; grey, dark mudstone 3 - 12.2m; light grey shaley mudstone 12.2 - 32m; dark grey mudstone 32 - 48.8m.	Myrtle Creek Sandstone
174231	37	4.0	Soil 0 - 1m; brown clay 1 - 4m; black shale and quartz 4 - 37m.	Kin Kin Beds
174259	79.2	16.8	Soil 0 – 0.6m; yellow brown white clay 0.6m – 16.8m; grey sandstone 16.8m – 53.3m; sandy mudstone 53.3m – 54m; grey sandstone 54m – 71.6m; sandy mudstone 71.6m – 73.2m; grey sandstone 73.2m – 79.2m.	Kin Kin Beds*

*Interpreted formation

Table 4-3 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

5 Hydrogeology

This desktop study 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.

5.1 Groundwater Resource Units

5.1.1 Quaternary Alluvium

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 4-2** and located on **Figure 4-1** indicate that the alluvium has a minimum depth of 3 m and maximum depth of 21 m surrounding Lake Macdonald.

5.1.2 Tertiary Pomona Beds

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.

5.1.3 Jurassic-Triassic Myrtle Creek Sandstone

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.

5.1.4 Triassic Kin Kin Beds

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 5-1**.

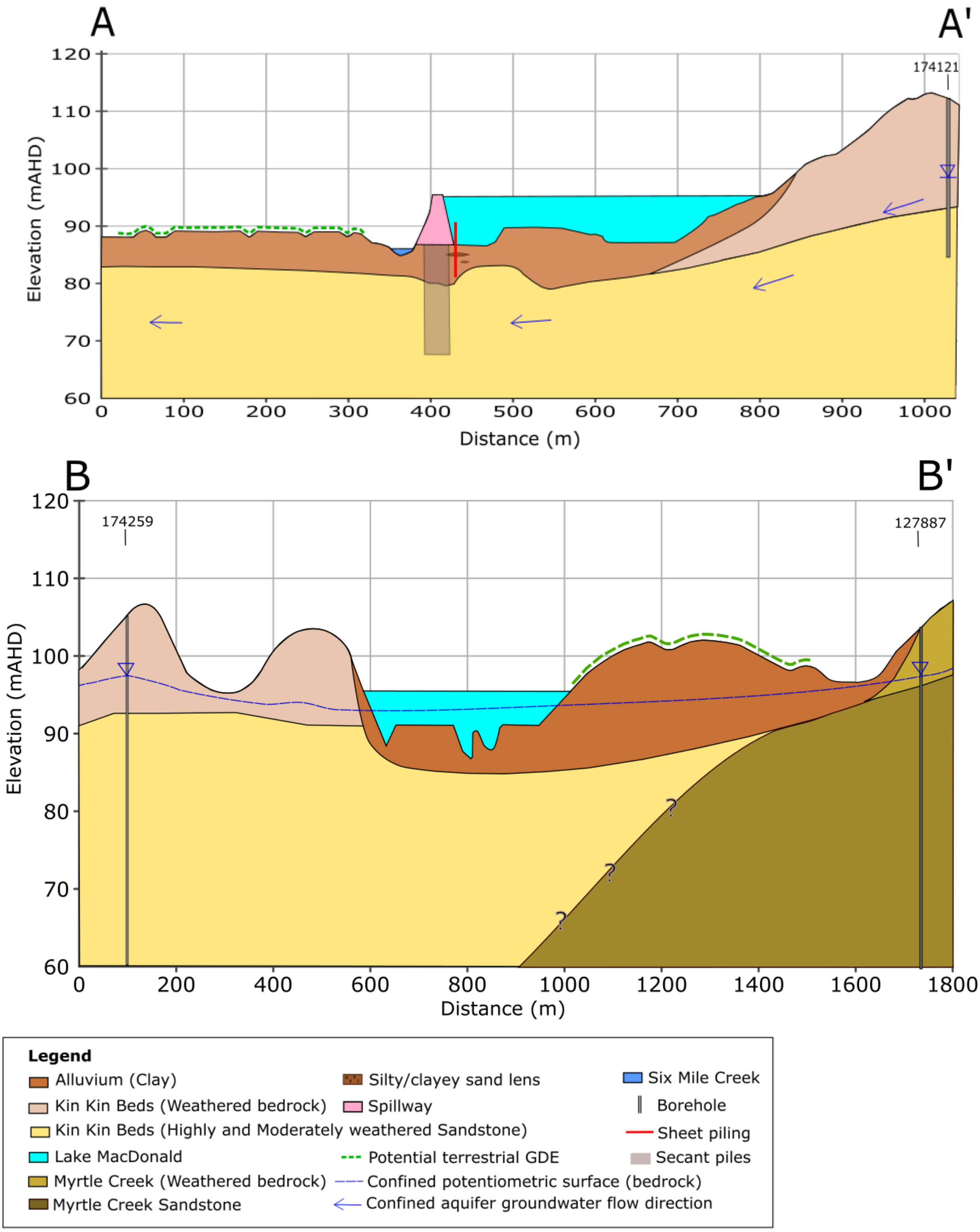


Figure 5-1 Conceptual geological cross sections (locations shown on Figure 4-1)

5.2 Groundwater Levels and Flow Direction

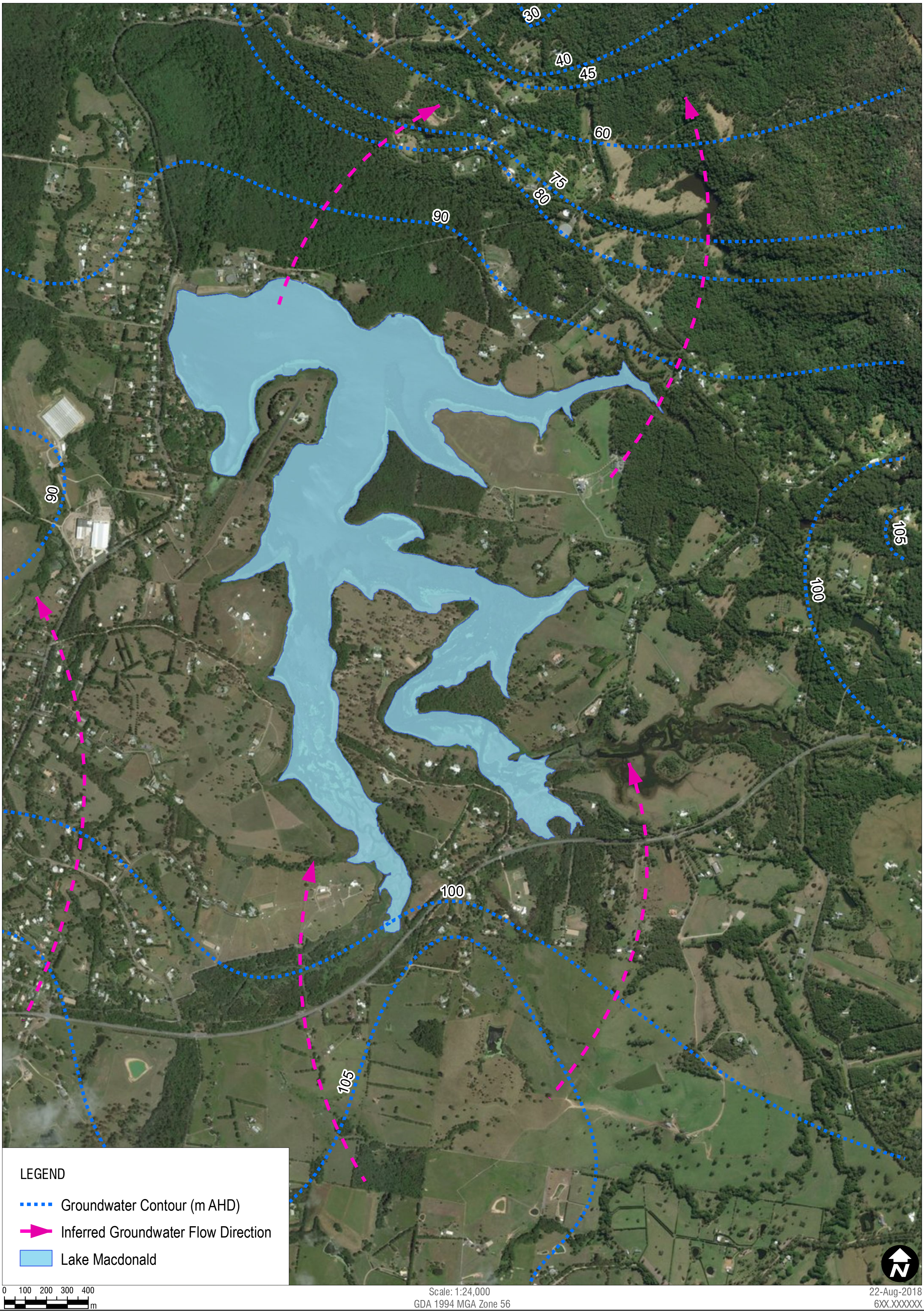
Records of privately owned bores within 2 km of Lake Macdonald were reviewed on the GWDB which provides a water level for when the bore was drilled. Groundwater levels presented by targeted formation are provided in **Table 5-1**; it should be noted that all available water level records are from the 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 5-2**. 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.

Table 5-1 Initial groundwater level for registered groundwater 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	1.0

(Source: DNRME GWDB)

Figure 5-2 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.



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Six Mile Creek Dam Safety Upgrade Project
Groundwater potentiometric contours

Figure 5-2

5.3 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 4-1**). The resulting estimated hydraulic conductivity of the Kin Kin Beds at varying depths based on this testing is presented in **Table 5-2**; as shown, results range from < 8.6×10^{-3} to 1.7×10^{-1} m/d.

The site specific hydraulic conductivity data for the Kin Kin Beds provided in **Table 5-2** 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).

Table 5-2 Estimated hydraulic conductivity ranges for selected bores

Location	Test Depth (m)*	Hydraulic conductivity range (m/d)**	Geology description from borelog
BH502	7.9 - 12.7	< 8.6×10^{-3}	Banded sandstone
BH502	12.7 - 17.1	< 8.6×10^{-3}	Banded sandstone and coarse-grained sandstone
BH502	18.1 - 21.1	8.6×10^{-3} to 5.2×10^{-2}	Banded sandstone and basalt
BH502	22.1 - 26.1	8.6×10^{-3} to 5.2×10^{-2}	Interlayered banded sandstone, coarse grained sandstone, pebbly sandstone
BH502	26.1 – 30.0	< 8.6×10^{-3}	Banded sandstone
BH502	7.9 - 30.6	8.6×10^{-3} to 5.2×10^{-2}	As above (7.9m - 30.6m)
BH503	11.8 - 16.5	5.2×10^{-2} to 1.7×10^{-1}	Banded sandstone, clayey sand and basalt
BH503	18.3 - 21.5	< 8.6×10^{-3}	Banded sandstone
BH503	22.5 - 28.9	< 8.6×10^{-3}	Banded sandstone, massive sandstone, siltstone
BH503	11.8 - 28.9	8.6×10^{-3} to 5.2×10^{-2}	As above (11.8m - 28.9m)
BH506	12.4 - 15.7	< 8.6×10^{-3}	Coarse grained sandstone, siltstone, banded sandstone
BH506	15.7 - 20.7	-	Banded sandstone, massive sandstone
BH506	20.7 - 24.7	8.6×10^{-3} to 5.2×10^{-2}	Massive sandstone, banded sandstone
BH506	12.1 - 24.7	< 8.6×10^{-3}	As above (12.1m - 24.7m)

Source: AECOM, 2018a
* Test depth measured from the reservoir (lake) bed level (excluding height of reservoir above bed level)
** Interpretations based on Quiñones-Rozo (2010)

5.4 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 5-2**.

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. Discharge to Six Mile Creek is discussed further in **Section 5.5**.

5.5 Groundwater-Surface Water Interaction

The information presented in **Table 5-1** 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 5-1**, 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.

5.6 Beneficial Uses of Groundwater

5.6.1 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 2km of Lake Macdonald which are shown on **Figure 5-3**. 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.

5.6.2 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.

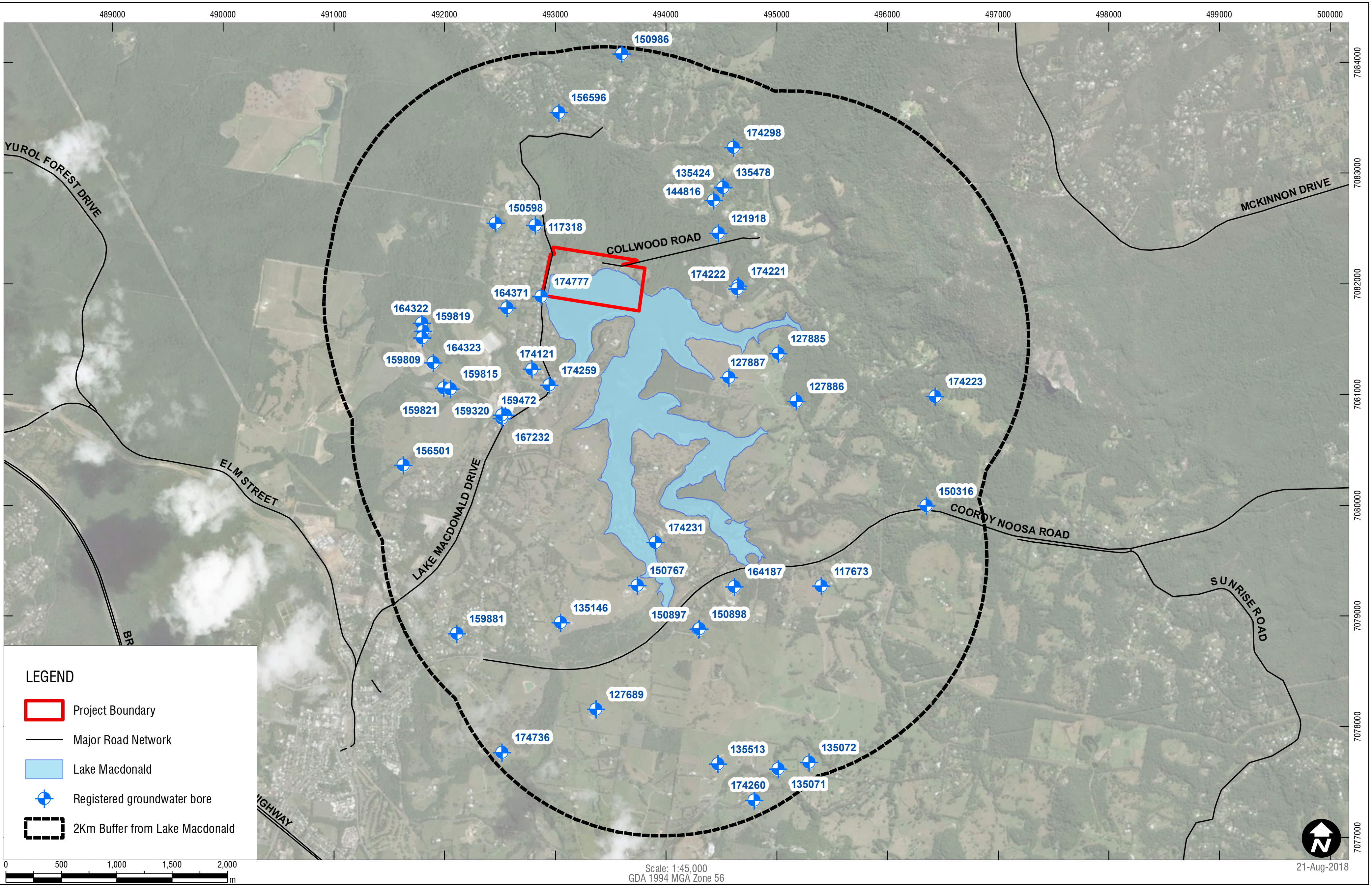
All identified GDEs within the vicinity of the Project are identified on **Figure 5-4**. Within 2 km of Lake Macdonald, three classes of aquatic ecosystems have been identified by WetlandInfo (2013) that rely on the surface presence of groundwater, these being:

- 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; and
- 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.



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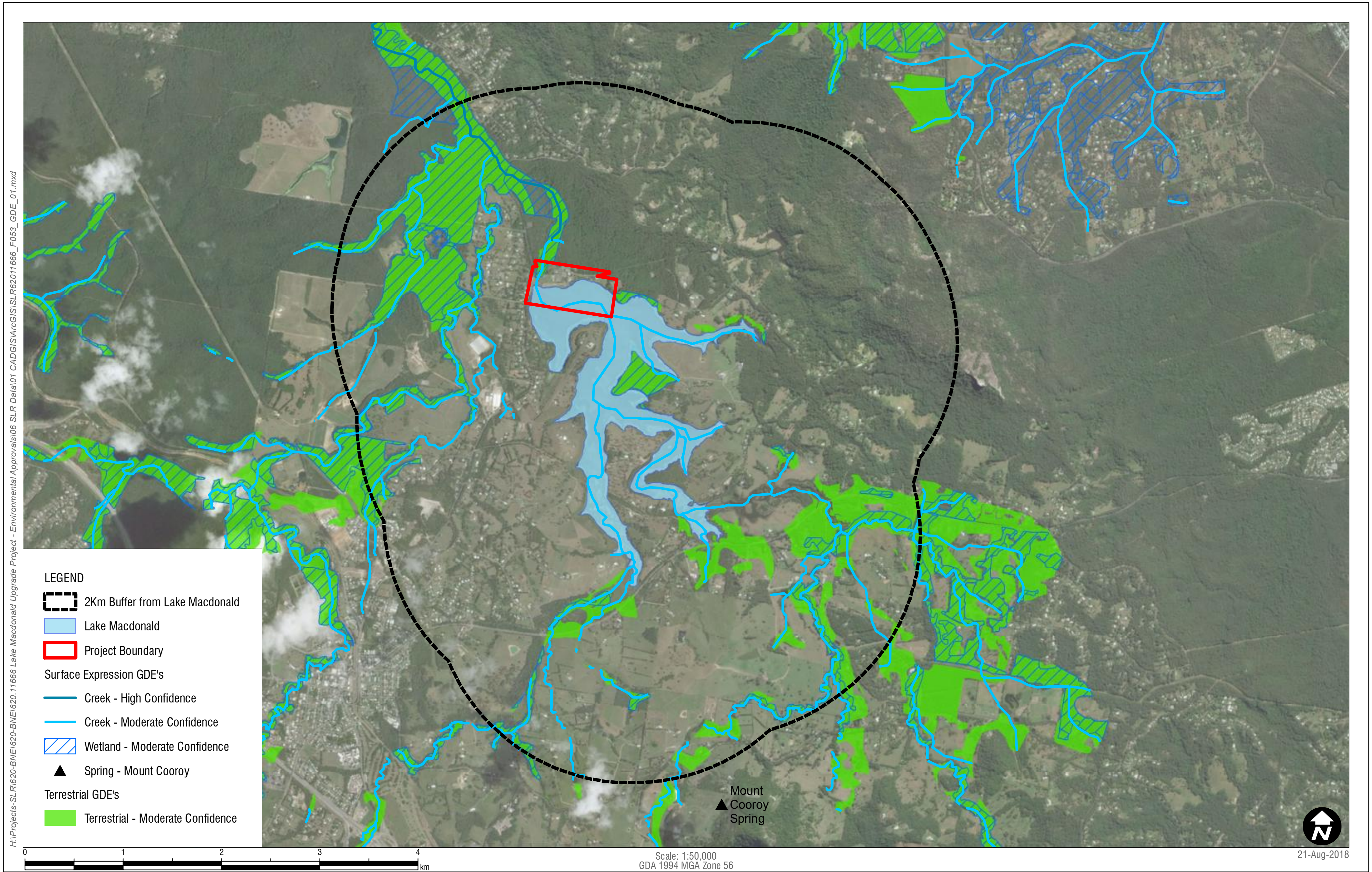
Six Mile Creek Dam Safety Upgrade Project
Registered groundwater bores

FIGURE 5-3



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Lake Macdonald Update Project
Groundwater Dependent Ecosystems

FIGURE 5-4

6 Potential Impacts

6.1 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 89.0 m AHD during the construction period (18 to 24 months), including the further lowering to a level of 88.5m 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.

6.2 Groundwater Drawdown

6.2.1 Method of calculation

Existing bore water users and possible 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; Sy = specific yield.

Calculation assumptions are:

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 6-1**).

6.2.2 Model Parameters

The parameters used for the groundwater drawdown assessment for Lake Macdonald are described in the following.

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.

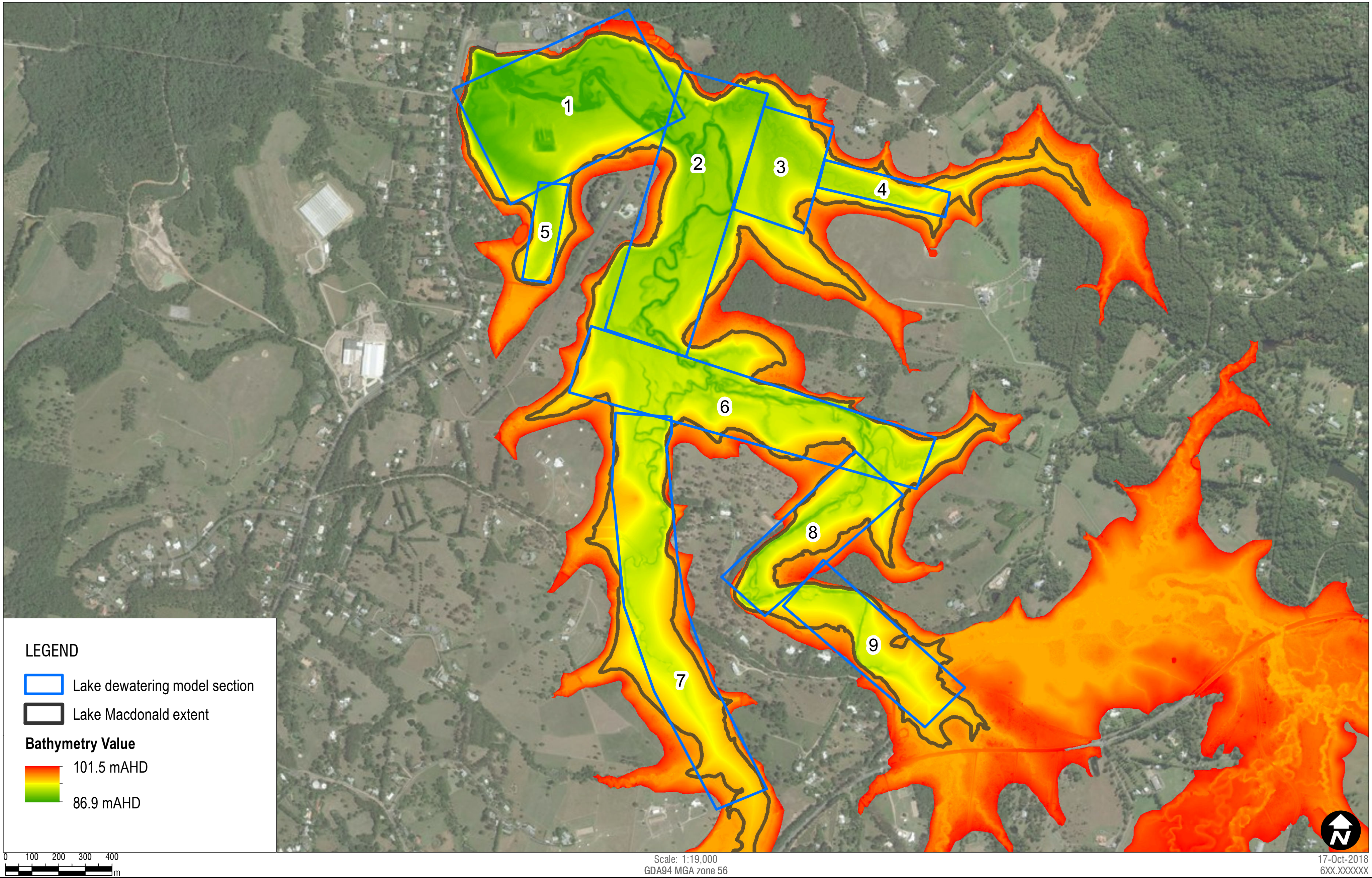
Groundwater level: for the purpose of this assessment, a conservative approach was taken where the initial groundwater level adjacent the lake was assumed to be in equilibrium with the surface water level in Lake Macdonald at the full storage limit (i.e. 95.32 m AHD).

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 5-3**), and
- geotechnical boreholes completed as part of the lake upgrade assessment (AECOM, 2018b).

A review of borelogs (**Table 4-2**) 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 6-1**. Heath (1983) estimates a specific yield value for clay to be in the order of 2%, this value was adopted for the assessment.



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Six Mile Creek Dam Safety Upgrade Project
Dewatered sections used for assessment

Figure 6-1

Table 6-1 Hydraulic Parameters Used in the 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	%

6.2.3 Estimation of Groundwater Drawdown Extent

The dewatering of Lake Macdonald is likely to induce a localised drawdown effect. The estimation of drawdown extent over the 2 year assessment period due to dewatering of each section of Lake Macdonald is presented in **Table 6-2**.

Table 6-2 Estimated drawdown extent over a 2 year period for differed 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

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.

6.2.4 Impacts on Groundwater Users

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 2 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.

6.3 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.

6.4 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.

6.5 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 (**Section 5.1.1**). In the case that water were 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 construction design informs that the 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 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.

6.6 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.

7 Mitigation Measures

Mitigation measures for the potential impacts identified in Section 6.1 are provided in **Table 7-1**.

Table 7-1 Summary of potential impacts and proposed mitigation measures

Potential impacts	Proposed mitigation measures
Groundwater drawdown	▪ No impacts to registered groundwater bores or GDEs were identified.
Reduction of environmental flows	▪ Maintain a low flow 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 shall 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.
Groundwater quality impacts from accidental spills of hazardous materials used and stored within the Project area	▪ The project Environmental Management Plan shall 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.
Groundwater flow barrier	▪ No impacts to registered groundwater bores or GDEs were identified.

Potential impacts	Proposed mitigation measures
Discharge of groundwater	▪ The project Environmental Management Plan shall 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 for the environmental values described in **Table 3-1**. ▪ Discharge to stormwater drainage or sewerage infrastructure in compliance with Queensland Government State Planning Policy Code. ▪ Disposal at a licensed facility.

8 Conclusions

The key conclusions drawn from this groundwater impact assessment report are:

- The local groundwater resources have been identified and characterised.
- Groundwater users within a 2 km buffer of Lake Macdonald were identified, these being:
    - 45 registered groundwater bores.
    - Three classes of aquatic GDEs with a moderate to high confidence level that rely on the surface expression of groundwater.
    - There are six types of terrestrial GDEs with a moderate confidence level that rely on the subsurface presence of groundwater.
- Potential impacts to groundwater resulting from the Project were assessed, and mitigation measures are proposed to address these impacts, these being:
    - Groundwater drawdown resulting from the spillway excavation and the dewatering of Lake Macdonald.
        - Analytical methods showed that groundwater drawdown around Lake Macdonald is both limited in magnitude and highly localised for the 2 year assessed Project 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.
    - 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.
        - Environmental flow regimes shall be maintained in compliance with the operating rules of the Mary Basin Resource Operation Plan and therefore impacts are unlikely.
    - Accidental spills of hazardous materials used and stored within the Project area.
        - Mitigation measures are proposed to address the potential.
    - Groundwater flow barrier resulting from the installation of impermeable structures at the spillway.
        - This spillway construction will not impact groundwater flow as the design will permit groundwater to flow beneath the structure and around either side. No mitigation measures are required.
    - Discharge of groundwater dewatered from secant pile cells.
        - Produce a dewatering management plan 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 shall be tested and must comply with the conditions prescribed under EPP (Water) Mary River environmental values and water quality objectives 2010. 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.

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