

APPENDIX G2

Groundwater Assessment



Groundwater Impact Assessment

Clarrie Hall Dam Raising

Prepared for Tweed Shire Council

August 2024

Groundwater Impact Assessment

Clarrie Hall Dam Raising

Tweed Shire Council

E230039 RP1

August 2024

Version	Date	Prepared by	Approved by	Comments
1	8 January 2024	Nina Baulch	John Ross	Draft
2	30 January 2024	Nina Baulch	John Ross	Addresses client comments
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5	8 August 2024	Nina Baulch	John Ross	Adresses third round of client comments

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Executive summary

A Groundwater Impact Assessment (GIA) has been prepared for the proposed Clarrie Hall Dam raising project (the Proposal) in the far north coast region of NSW. Tweed Shire Council proposes to raise the existing Clarrie Hall Dam by 8.5 metres (m) to a height of 70 metres Australian Height Datum (mAHD) and construct a new enlarged concrete spillway higher on the west abutment. This will increase the dam storage capacity from 16,000 megalitres (ML) to approximately 42,300 ML, and will have an approximate fully supply level (FSL) of 209 hectares (ha). The Proposal will not cause discernible changes to the Tweed River flow regime (EMM 2024a).

ES1.1 Groundwater systems

The groundwater systems comprise:

- minor local, shallow groundwater associated with alluvial deposits
- local, groundwater systems associated with the Tertiary volcanic deposits
- local to regional groundwater systems associated with the porous and fractured rock units within the Clarence-Moreton Basin
- local to regional groundwater systems associated with the fractured rock units of the New England Fold Belt (NEFB).

These groundwater systems have different hydrogeological properties due to their depositional environment. Generally, this is a low yielding resource region with no highly productive aquifer systems.

ES1.2 Potential groundwater impacts

Potential groundwater impacts relate to:

- Groundwater quality impacts from quarrying and project construction. Spills of hazardous materials/chemicals and/or the generation of liquid waste can potentially contaminate groundwater. Similarly, the use of blasting substances may result in residual substances occurring at the face of blasted material, blasting substances leaching from stockpiled material during rain events and/or the introduction of blast material into the groundwater system where blasting occurs. Potential groundwater contamination incidents, if they do occur, are expected to be minor and localised to within the construction impact area.
- Groundwater pressure/level increases in the Clarence Moreton Basin groundwater system up stream of the Dam, owing to increased recharge from a higher FSL. This could occur underlying the FSL inundation area and where there are fractures and rock openings that permit groundwater entry. Potential rises in groundwater levels are not expected to migrate beyond the FSL inundation area as the potentially highly transmissive alluvium is very localised and minor in extent, and the fractured and porous rock units have low transmissivity based on inferred airlift yields.

There are no third party landholder bores within the vicinity of the Proposal, including the FSL inundation area and construction areas. The two closest bores to the FSL inundation area are both deemed to be abandoned. There are no high priority water sharing plan (WSP) listed groundwater dependent ecosystems (GDEs) in the study area. With the exception of a stand of River Oak in the construction footprint, impacts to potential GDEs are not anticipated due to the Proposal.

The risk ranking for all potential groundwater impacts is low. A Water Management Plan will be developed for the Proposal.

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1 Introduction

This Groundwater Impact Assessment (GIA) has been prepared for the proposed Clarrie Hall Dam raising project (the Proposal), in far north coast region of NSW. Due to increasing demand for water as a result of projected population growth and the increasing uncertainty of water supply yield associated with climate change, there is a requirement to augment the Tweed Shire district water supply by 2028. Clarrie Hall Dam is a freshwater reservoir located on Doon Doon Creek, 15 kilometres (km) southwest of Murwillumbah (Figure 1.1).

Clarrie Hall Dam was constructed in 1983 by the NSW Department of Public Works, and is owned and operated by Tweed Shire Council for the primary purpose of providing a drinking water supply to the Tweed Shire region. Tweed Shire Council propose to raise the wall of Clarrie Hall Dam by 8.5 m to a height of 70 m Australian Height Datum (AHD). This will increase the capacity of the dam from 16,000 megalitres (ML) to approximately 42,300 ML. The purpose of the Proposal is to ensure water security for the Tweed Shire region until at least 2065.

The Proposal is State significant infrastructure and is subject to approval by the NSW Minister for Planning and Public Spaces under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act). The Secretary's updated environmental assessment requirements (SEARs) for the Proposal were issued on 31 May 2024. Further information on the location of the Proposal, a description of the Proposal and statutory context is provided in the environmental impact statement (EIS).

1.1 Purpose of this report

This GIA has been prepared to support the EIS, as well as to inform the wider community about the Proposals potential impacts on the local and regional groundwater environments. This GIA documents the existing groundwater environment, methods used to assess changes to the groundwater environment, the initiatives built into the Proposal design to avoid and minimise associated impacts, and the mitigation, and management measures proposed to address any unavoidable residual impacts.

Aspects of the groundwater environment discussed within this report include:

- the existing groundwater baseline conditions within the Proposal and surrounding areas
- the regulatory environment (with respect to groundwater resources) within which the Proposal would operate
- the identification and quantification of the potential impacts of the Proposal on the current groundwater resources, and on water users both environmental and consumptive in accordance with the *Aquifer Interference Policy* (AIP) (DPI 2012)
- mitigation and management measures
- the Secretary's Environmental Assessment Requirements (SEARs) relevant to groundwater impacts.

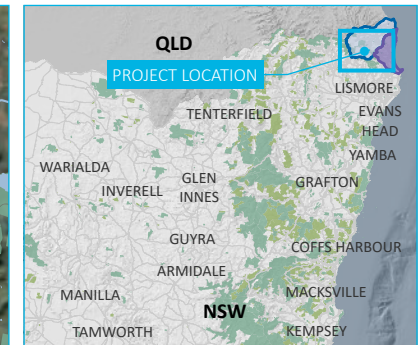
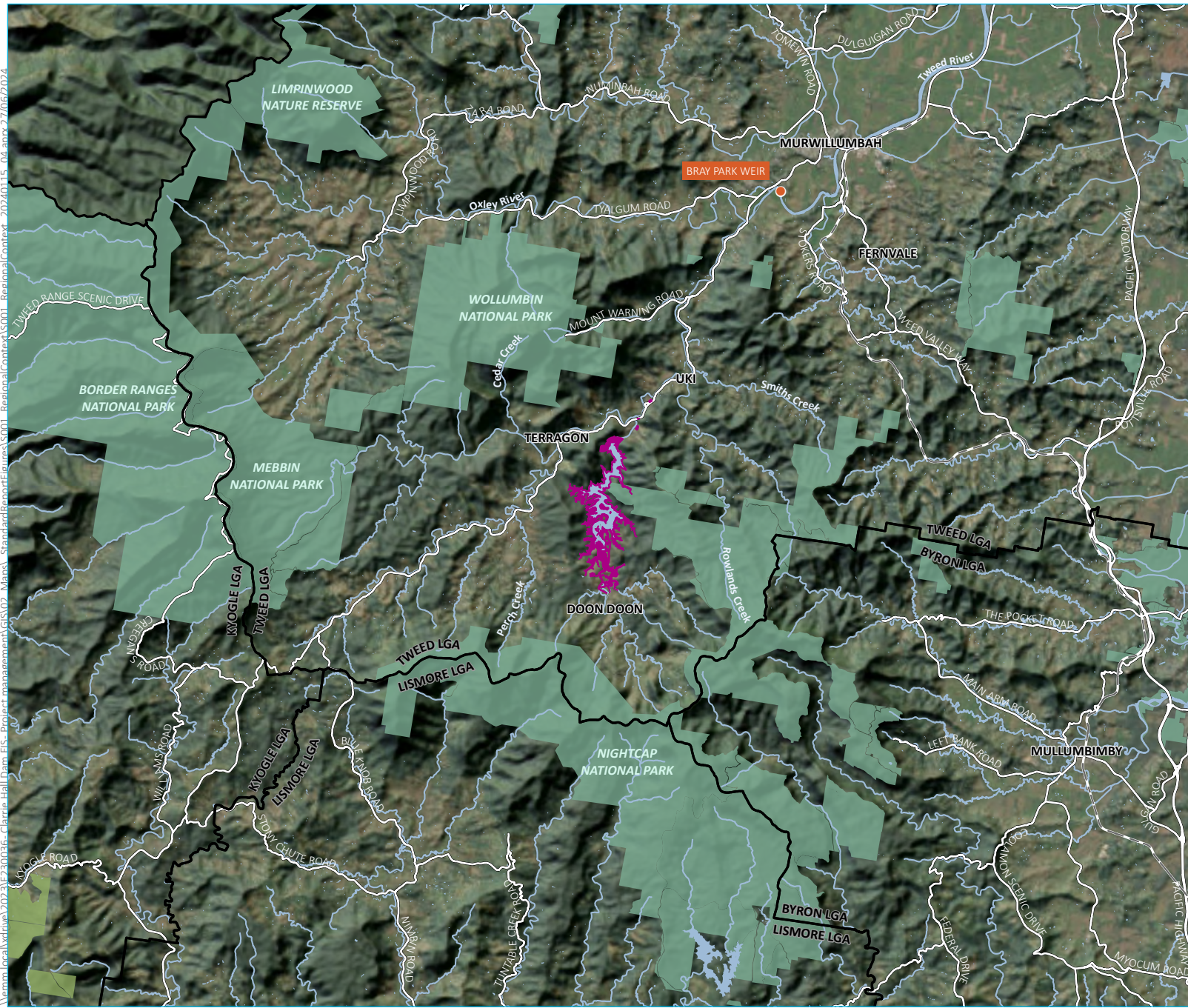
1.2 Assessment guidelines and requirements

This GIA has been prepared in accordance with the SEARs for the Proposal as well as relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies. Table 1.1 lists the SEARs matters relevant to the GIA and where they are addressed in this report.

Table 1.1 **Relevant matters raised in SEARs (dated 31 May 2024)**

SEARs key issue		Actioned
9. Hydrology, flooding and water quality		
1.	The Proponent must describe (and map) the existing hydrological regime for surface and groundwater resources (including reliance by users and for ecological purposes) likely to be impacted by the proposal and identify any requirements for baseline monitoring of hydrological attributes. Mapping must include upstream and downstream tributaries that may potentially be impacted.	Chapters 4 and 5, and <i>Surface Water Assessment</i> (EMM 2024a)
2.	The Proponent must assess and model the impact of the operation of the proposal and any ancillary facilities (both built elements and discharges) on hydrology in accordance with the current guidelines, including: (b) Impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species and groundwater users.	Qualitative assessment undertaken in Chapter 7
6.	The Proponent must describe background conditions for current operations and any water resource likely to be affected by the proposal, including: (a) Existing surface and groundwater quality. (e) Water quality monitoring programs and indicators and trigger values/criteria.	Chapters 5 and 8, and <i>Surface Water Assessment</i> (EMM 2023)
7.	The EIS must assess the impacts of the proposal on water quality, including the nature and degree of impact on receiving waters for both surface and groundwater.	Qualitative assessment undertaken in Chapter 7 and <i>Surface Water Assessment</i> (EMM 2023)

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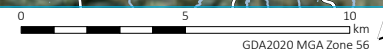
- KEY**
- Construction disturbance footprint
 - Bray Park weir
 - Existing environment
 - Rail line
 - Major road
 - Named watercourse
 - Waterbody
 - NPWS reserve
 - State forest
 - Local government area
- INSET KEY**
- Major road
 - NPWS reserve
 - State forest
 - Brunswick catchment
 - Tweed catchment

Regional setting

Clarrie Hall Dam EIS
Groundwater Impact Assessment
Figure 1.1



Source: EMM (2024); KBR (2024); ABS (2021); DCSSS (2023); ESRI (2024); GA (2009)



2 Proposal description

2.1 Proposal overview

The existing Clarrie Hall Dam consists of a concrete faced rockfill embankment, a concrete lined spillway, intake and outlet works designed by NSW Public Works. The original dam was completed in 1983. Some spillway upgrade works, also designed by NSW Public Works, were completed in 2014.

The Tweed District water supply is currently a run-of-river supply augmented by releases from Clarrie Hall Dam down Doon Doon Creek via an intake tower. Raw water is drawn from upstream of Bray Park Weir, effectively a saltwater barrage, in the Tweed River. In periods of low flow in the river, flows are augmented by releases from Clarrie Hall Dam to ensure availability of water for the Tweed District water supply. The current Clarrie Hall Dam minimum release volume is 1–4 ML/day and dam releases are driven by demands and the volume stored in Bray Park Weir, on the Tweed River. Water is harvested at the Bray Park Weir.

Council proposes to raise the existing Clarrie Hall Dam by 8.5 m from 61.5 mAHD to a height of 70 mAHD (refer to Figure 2.1). This will increase the capacity of the dam from 16,000 ML to approximately 42,300 ML. The changes and upgrades associated with the Proposal include:

- a new spillway channel constructed higher in the left abutment with a flip bucket at the downstream end
- re-establishment of the quarry used to construct the existing dam for the purpose of sourcing rock material to raise the dam wall
- construction of associated haul roads to transport quarry material for the proposed raising of the dam wall
- establishment of a construction area for plant, equipment, storage, material handling and offices
- establishment of stockpile sites associated with construction
- construction of work compounds and site offices
- establishment of materials storage and handling facilities
- construction of workers accommodation
- construction of a concrete batching plant
- realignment of Clarrie Hall Dam Road higher in the right abutment
- raising of the existing intake tower and bridge
- decommissioning of existing recreational facilities at the dam wall area
- construction of new dam operational facilities including signage, car parking, security fences, lighting, monitoring equipment and a boat ramp
- removing or reconstructing impacted recreational infrastructure and facilities at Crams Farm
- upgrading the Kyogle Road and Clarrie Hall Dam Road intersection
- replacing McCabes Bridge and realignment of Commissioners Creek Road

- construction of new recreation facilities including an amenities block, public shelters, viewing areas, interpretation signage, paths, car parks, and landscaping.

A summary of Proposal elements is provided in Table 2.1, with further details provided in Chapter 3 of the EIS. The Proposal features are shown in Figure 2.2.

Table 2.1 Overview of the new Proposal elements

Proposal elements	Summary
Operation	
Description	• Raising the embankment wall of Clarrie Hall Dam by 8.5 m.
Operational footprint	• Approximately 209 ha for the proposed FSL. • Approximately 248 ha for the area between the proposed FSL and the probable maximum flood (PMF), delineating the area where the largest flood that could conceivably be expected would occur.
Dam wall infrastructure	• Increasing the base width of the valley-side abutment and raising the crest of the concrete faced rockfill embankment to 70 mAHD. • Constructing a new concrete lined spillway higher on the west abutment. • Extending the upstream concrete face to the new crest height. • Raising the intake tower and access bridge. • Constructing a new section of the Clarrie Hall Dam Road to provide access to the east abutment of the dam wall. • Establishing new recreation and operational facilities including an amenities block, public shelters, viewing areas, interpretation signage, paths, car parks, landscaping, security fences, lighting, monitoring equipment and a boat ramp.
Ancillary works	• Upgrading the intersection of Clarrie Hall Dam Road and Kyogle Road. • Replacing McCabes Bridge over Doon Doon Creek. • Realigning an approximately 1,000 m section of Commissioners Creek Road. • Removing or reconstructing impacted infrastructure and facilities at Crams Farm. • Realigning overhead power lines and Telstra assets.
Construction	
Construction impact area	• Approximately 58 ha, consisting of 26.2 ha at the dam wall, 6.6 ha of construction compound and workforce accommodation areas, 8.4 ha of quarry area and 16.8 ha of ancillary sites for road realignments and relocating overhead power lines. The removal of the existing overhead power line is not included in the impact area.
Workforce	• Estimated peak of 180 persons at the main dam wall site.
Cut/fill	Re-establishment of the old quarry site used to construct the existing dam, comprising approximately 100,000 m³ deficit of fill material will be derived from the quarry located 400 m southwest from the existing dam. Some blasting may be required to excavate quarry material, and material would be temporarily stored in stockpiles. The quarry design will occur in the detailed design phase of works. Waste rock material from the new spillway construction area would be used to backfill the quarry void and develop the final landform, which would be rehabilitated utilising the stockpiled topsoil. Temporary rockfill stockpiles may be required, noting excess rockfill waste material is expected to be generated and any remaining rock material will be backfilled in the quarry.

Table 2.1 **Overview of the new Proposal elements**

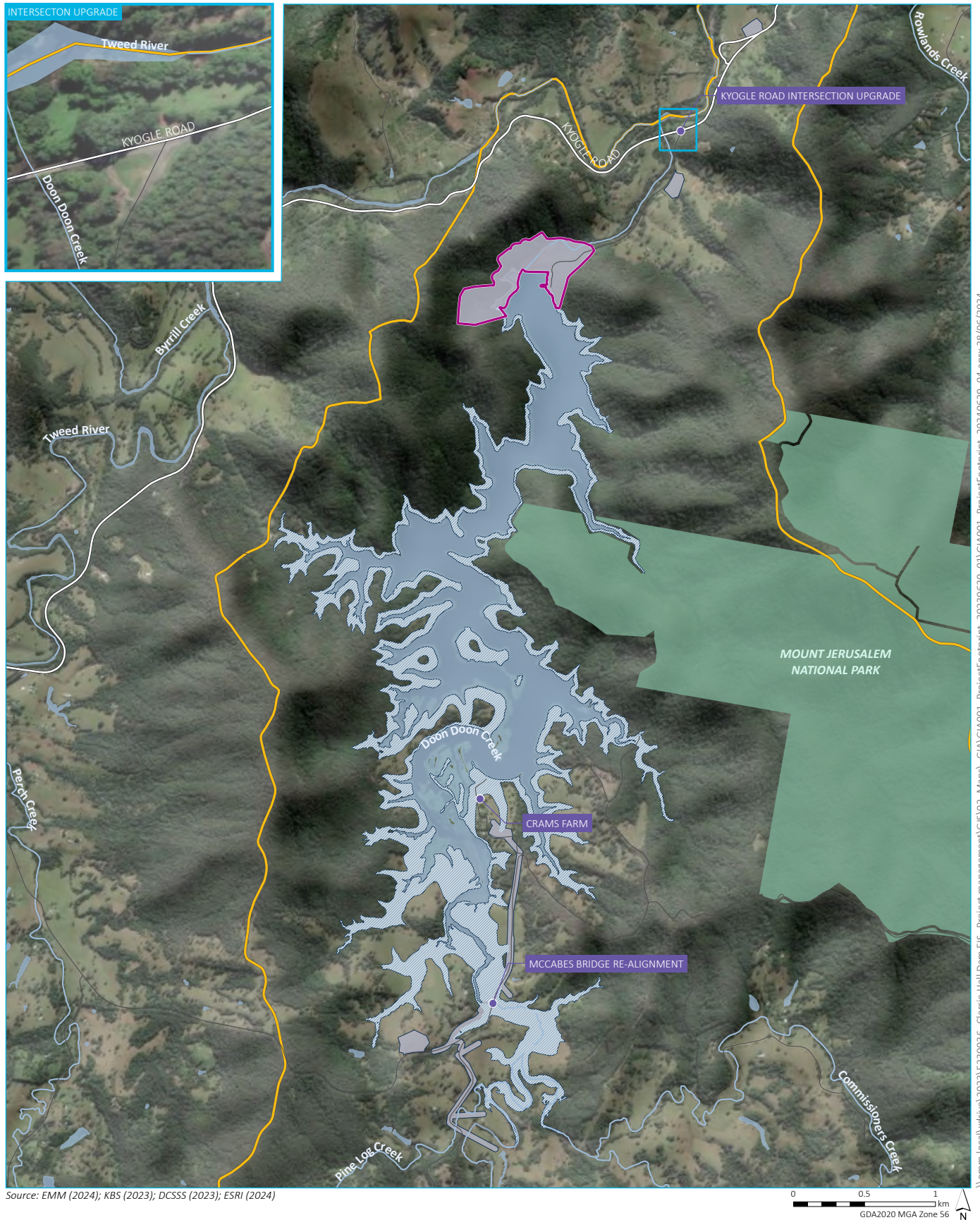
Proposal elements	Summary
Ancillary works	• Constructing access roads to construction areas and establishing the construction site. • Establishing a concrete batching plant and areas for materials stockpiling. • Establishing construction compounds including site offices, compounds and workforce accommodation.
Dewatering	• Lowering dam storage by 300 mm below FSL during construction.
Property	• Permanent and temporary property adjustments and property access refinements.

2.2 Proposal and study areas

The groundwater study area comprises the Doon Doon Creek sub-catchment area, as well as the area immediately downstream of the confluence between Doon Doon Creek with Tweed River, to the confluence between Tweed River and Rowlands Creek. The groundwater study area is shown in Figure 2.3.

The Proposal construction impact area is approximately 58 ha and includes: areas where vegetation clearing and/or ground disturbance is required for the Proposal and construction of ancillary infrastructure (i.e. construction compound, workforce accommodation area, roads etc).

The Proposal operational footprint comprises approximately 248 ha for the area between the proposed FSL and the PMF, as well as areas where there will be permanent operational elements or easements, and Proposal features. This includes infrastructure needed to operate the raised Clarrie Hall Dam and the inundation area, and the new recreation facilities.

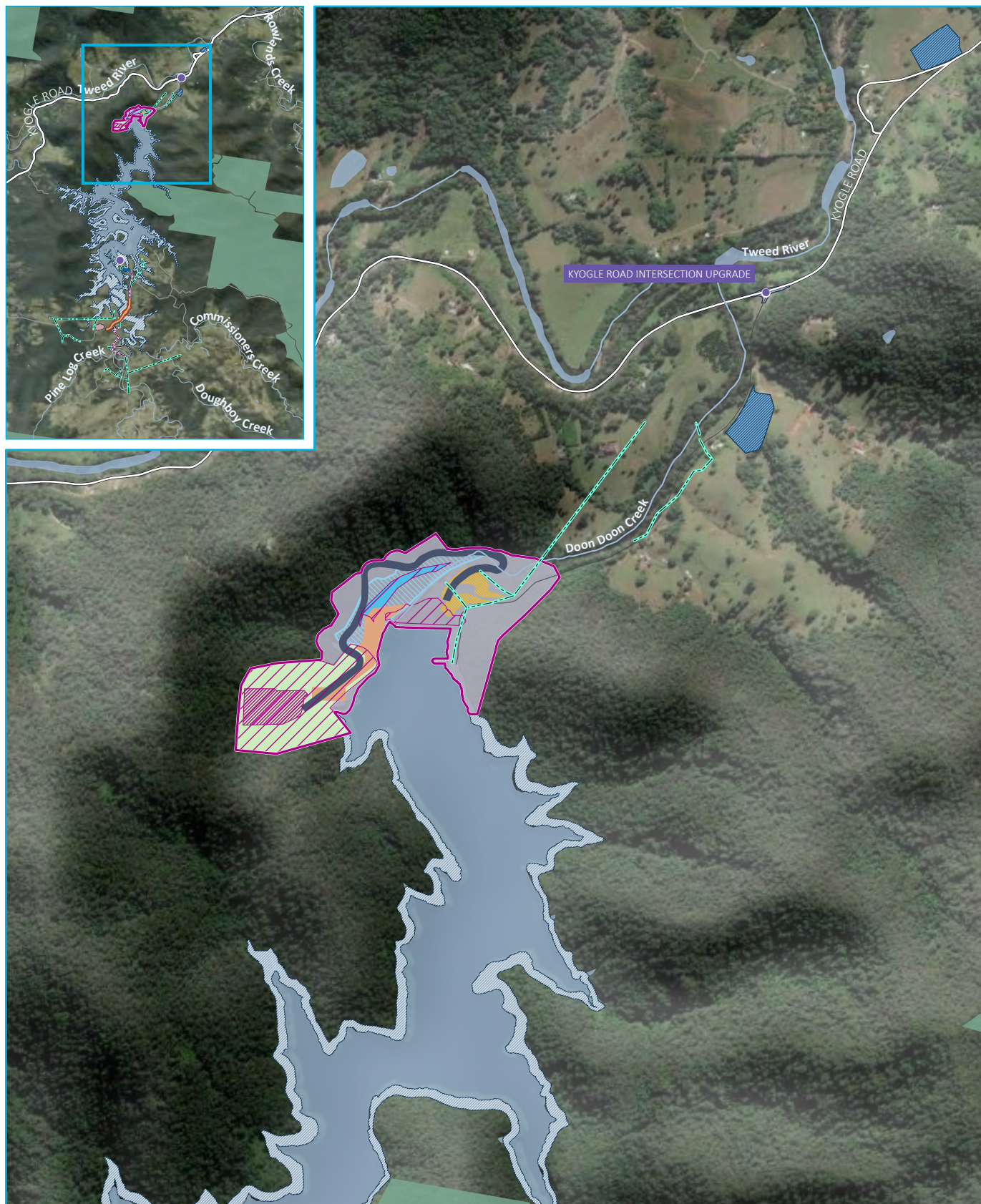


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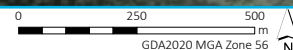
- | | |
|--------------------------------------|----------------------|
| ● Infrastructure upgrade location | Existing environment |
| ■ Construction disturbance footprint | — Rail line |
| ■ Development site | — Major road |
| ■ Full supply level- proposed | — Minor road |
| ■ Study area | — Named watercourse |
| | ■ Waterbody |
| | ■ NPWS reserve |
| | ■ State forest |

Proposal footprint

Clarrrie Hall Dam EIS
Groundwater Impact Assessment
Figure 2.1



Source: EMM (2024); KBS (2024); DCSSS (2023); ESRI (2024)



KEY

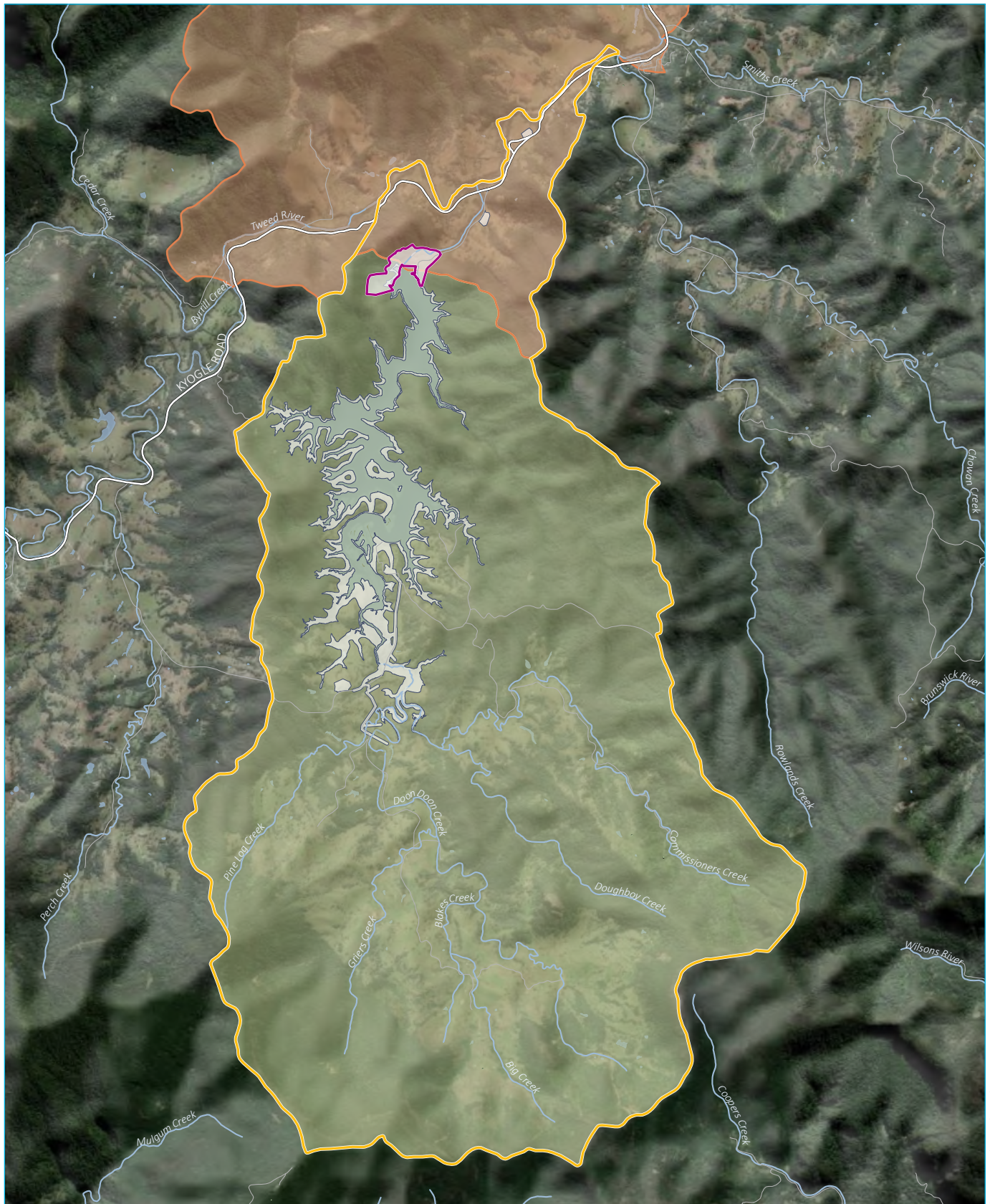
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| ● Infrastructure upgrade location | ■ Quarry site- impact zone | — Existing Transmission line |
| ■ Construction disturbance footprint | ■ Spillway | — New Transmission line |
| ■ Development site | ■ Spillway impact area | — Existing environment |
| ■ Full supply level- proposed | ■ Potential McCabes Bridge stockpile and construction office | --- Rail line |
| ■ Proposed layout | ■ Concrete batching plant or workforce accommodation | — Major road |
| ■ Haul Road- option 1 | ■ Direct disturbance area | — Minor road |
| ■ Haul Road- option 2 | ■ Quarry extraction area | — Named watercourse |
| ■ Office location | ■ McCabes Bridge proposed realignment | ■ Waterbody |
| ■ Potential McCabes Bridge stockpile and construction office complex | | ■ NPWS reserve |

Proposal overview

Clarrie Hall Dam Wall Raising
Groundwater Impact Assessment
Figure 2.2



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Source: EMM (2024); DCSSS (2023); ESRI (2024); DPIE (2021); GA (2009); KBR (2023)

KEY

- Study area
- Construction disturbance footprint
- Development site
- Unregulated water source
- Doon Doon Creek catchment area
- Mid Tweed River catchment area

- Existing environment
- Major road
- Minor road
- Named watercourse
- Waterbody
- Cadastral boundary

Study area

Clarrie Hall Dam EIS
Groundwater Impact Assessment
Figure 2.3



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3 Regulatory and policy context

The primary water related statutes that apply to the Proposal are the NSW *Water Management Act 2000* (WMA), NSW *Water Act 1912* (Water Act), NSW *Protection of the Environment Operations Act 1997* (POEO Act), the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and their attendant regulations (including water sharing plans (WSPs) under the WMA).

Projects that intercept groundwater or exchange water between one water source and another also need to consider the NSW AIP (DPI Water 2012). This policy requires projects to hold licences that account for the volume of water intercepted or exchanged and consider changes in water quality and water levels at sensitive receptors in accordance with prescribed minimal impact criteria.

3.1 Water Act 1912

The Water Act has been largely superseded by the WMA with WSP developed for all water sources across NSW. However, some aspects of the Water Act are still operational such as licences for monitoring bores.

3.2 Water Management Act 2000

The WMA is based on the principles of ecologically sustainable development and the need to share and manage water resources for future generations. The WMA recognises that water management decisions must consider economic, environmental, social, cultural and heritage factors. The WMA provides for water sharing between different water users including environmental, basic rights and all consumptive users including industry. In addition, the WMA provides security to holders of water access licences (WALs). The licensing provisions of the WMA apply to those areas where a WSP has commenced; it has progressively been enacted across NSW since July 2004. The licensing provisions of the WMA become effective for any water source once a WSP for that water source commences.

One of the key components of the WMA is the separation of the water licence from the land; this facilitates opportunities for licence holders to trade water. The WMA outlines the requirements for taking and trading water through WALs, water supply works, and water use approvals.

The WMA is the primary legislation governing water management and licensing relevant to the Proposal. The licensing requirements for industrial use are similar to other consumptive licensing requirements.

3.2.1 Water sharing plans

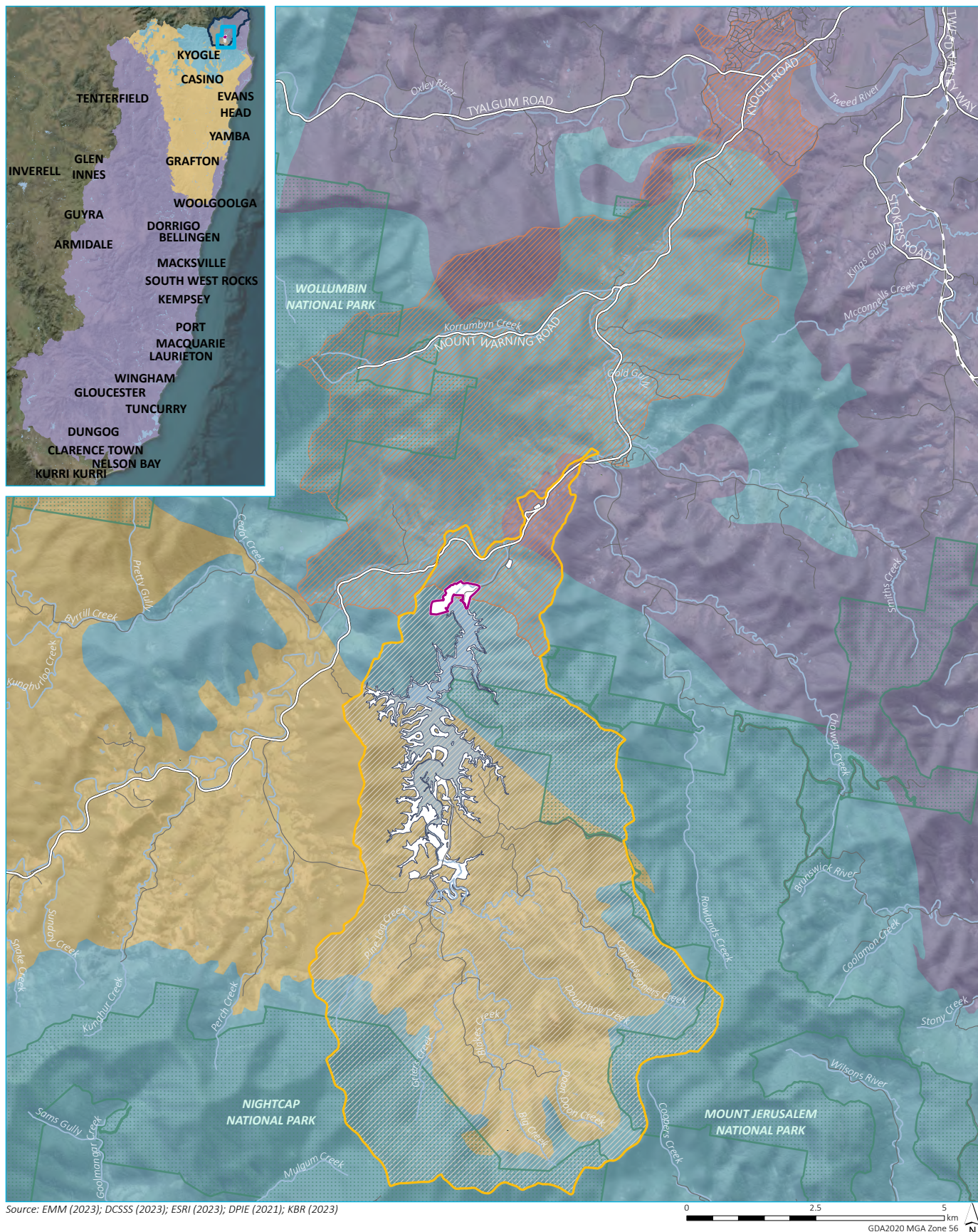
WSPs are statutory documents dictating the management and sharing of water sources. The WSPs set the water management vision and objectives, management rules for WALs, what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals and the extraction of water. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 10 years).

Each WSP documents the water available and how it is shared between environmental, basic rights, and other consumptive uses. The WSPs outline the water availability for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights, and access licences.

The study area overlies two WSP areas that relate to the alluvial and regional fractured rock groundwater units. These areas are shown in Figure 3.1 and are:

- *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016:*
 - Clarence Moreton Basin Groundwater Source
 - North Coast Volcanics Groundwater Source
 - New England Fold Belt Coast Groundwater Source
- *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2023:*
 - Mid Tweed River Water Source
 - Doon Doon Creek Water Source.

Surface water licences required for Proposal construction and operation are discussed in the *Surface Water Assessment* (EMM 2023). The use of groundwater for construction activities is not proposed so groundwater licences are not required.



KEY

Construction disturbance footprint

Study area

Development site

Water sharing plan for the north coast fractured and porous rock groundwater sources 2016

Clarence Moreton Basin Groundwater Source

New England Fold Belt Coast Groundwater Source

North Coast Volcanics Groundwater Source

Water sharing plan for the Tweed River area unregulated and alluvial water sources 2010

Doon Doon Creek water source

Mid Tweed River water source

Existing environment

Major road

Minor road

Named watercourse

Waterbody

NPWS reserve

Groundwater water sharing plan areas

Clarrrie Hall Dam EIS
Groundwater Impact Assessment
Figure 3.1



3.3 NSW Protection of the Environment Operations Act

The POEO Act is the key piece of environment protection legislation administered by the NSW Environment Protection Authority (EPA). The POEO Act enables the government to set protection of the environment policies that provide environmental standards, goals, protocols, and guidelines. The POEO Act also establishes a licensing regime for pollution generating activities in NSW.

3.4 Relevant NSW plans, policies, strategies and guidelines

3.4.1 NSW Aquifer Interference Policy

Aquifer interference activities, which are those that take water intentionally and incidentally for the primary purpose of the activity or those that exchange water between water sources, are assessed against the requirements of the AIP. The AIP clarifies the requirements for obtaining water licences for aquifer interference activities, and defines considerations in assessing and providing advice on whether more than minimal impacts might occur to a key water dependent asset.

The AIP defines the regime for protecting and managing the impacts of aquifer interference activities on NSW's water resources. The AIP requires consideration of the potential impacts of an aquifer interference activity in respect to the watertable, water pressure and water quality.

The AIP states that, unless specifically exempt, a WAL is required under the WMA where any act by a person carrying out an aquifer interference activity causes:

- the removal of water from a water source
- the movement of water from one part of an aquifer to another part of an aquifer
- the movement of water from one water source to another water source, such as:
 - from an aquifer to an adjacent aquifer, or
 - from an aquifer to a river/lake, or
 - from a river/lake to an aquifer.

The Proposal will cause the movement of small volumes of surface water from the reservoir (i.e. the Doon Doon Creek water source) into the underlying groundwater systems (i.e. the alluvium that is part of the Doon Doon Creek water source, and the porous and fractured rock in the Clarence Morton Basin groundwater source and New England Fold Belt Coast groundwater source).

The WMA includes the concept of ensuring “no more than minimal harm” for both the granting of WALs and the granting of project approvals. Minimal impact considerations have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users.

3.4.2 Groundwater Assessment Toolbox for Major Projects in NSW – Overview document

The *Groundwater Assessment Toolbox* (DPE 2022a), aims to create a collaborative, transparent and enabling environment for the preparation and review of groundwater assessments for major projects in NSW. The documents provide a framework to investigate, assess the impacts on, manage and monitor groundwater resources and their interaction with surface water resources within the footprint of a major project. The *Groundwater Assessment Toolbox* references the AIP as the assessment criteria, as well as the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012).

The *Groundwater Assessment Toolbox* is an overview guidance document that comprises the following more detailed guidance documents:

- *Guidelines for Groundwater Documentation for SSD/SSI projects* (DPE 2022b)
- *Minimum Groundwater Modelling Requirements for SSD/SSI Projects* (DPE 2022c)
- *Cumulative Groundwater Impact Assessment Approaches* (DPE 2022d).

These documents denote the DPE Water’s requirements for new groundwater assessments for SSD/SSI projects, and guidance in regard to monitoring and management plans, and compliance reporting.

3.4.3 Risk assessment guidelines for groundwater dependent ecosystems

The risk assessment guidelines for groundwater dependent ecosystems (GDEs) (Serov et al 2012) (*GDE Risk Assessment Guidelines*) are the NSW requirements for assessment and management of GDEs under the WMA. The GDE Risk Assessment Guidelines provide that GDEs:

Explicitly include any ecosystem that uses groundwater at any time or for any duration in order to maintain its composition and condition.

An ecosystem’s dependence on groundwater can be variable, ranging from partial and infrequent dependence, i.e. seasonal or episodic (facultative), to total continual dependence (entire/obligate) (see Figure 3.2). A GDE assessment was made for the Proposal, which considered variations in available water and ecosystem types with assessment methods based on the GDE Risk Assessment guidelines. The relevant sections of this GIA and the Biodiversity Assessment provide further information on the GDE assessment approach and results.

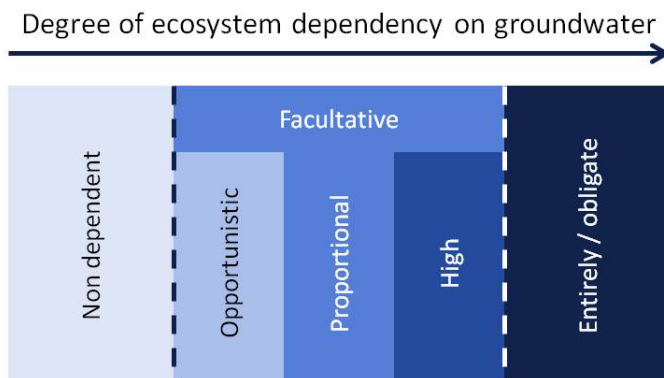


Figure 3.2 Ecosystem level of dependence on groundwater

Any GDEs listed in the WSPs are high priority GDEs, and they are required to be assessed using the minimal impact criteria outlined in the AIP. For this study area, there are no high priority GDE listed in the relevant WSPs.

3.5 Relevant Commonwealth policy and guidelines

3.5.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (*Water Quality Guidelines*) (ANZECC & ARMCANZ 2018) describe the water quality objectives for marine and freshwater environments, aquatic ecosystems, primary industries, and recreational water. These guidelines provide an agreed framework to assess water quality in terms of whether the water is suitable for a range of environmental values.

An environmental and community value is defined in the *Water Quality Guidelines* as a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors. For groundwater systems, the term ‘beneficial use’ is also often used to describe environmental and community values. For each catchment in NSW, the Government has endorsed the community’s environmental values for water, known as ‘Water Quality Objectives’.

Environmental and community values recognised by the *Water Quality Guidelines* are listed in Figure 3.3 below.

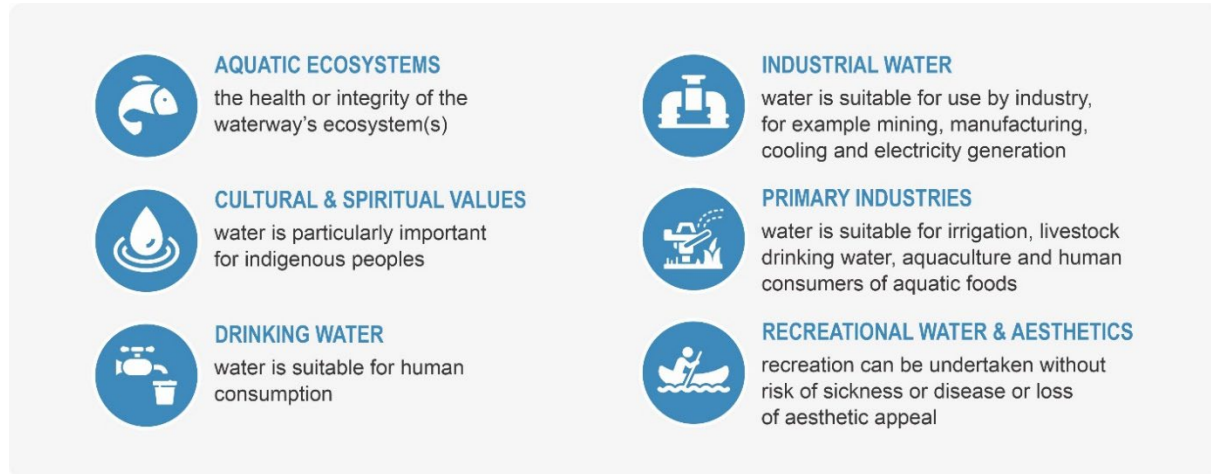


Figure 3.3 Environmental and community values

The groundwater at the Proposal site supports the following values:

- Aquatic ecosystems, where groundwater discharges as baseflow to permanent streams there is the potential for facultative reliance on groundwater.
- Drinking water systems, groundwater discharge into Doon Doon Creek which is part of a drinking water catchment.
- Primary industries, irrigation.

3.5.2 NSW Water Quality Objectives

The *NSW Water Quality Objectives* (WQO) are the agreed environmental values and long-term goals for NSW’s surface waters. They set out:

- The community’s values and uses for our rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water).
- A range of water quality indicators to help us assess whether the current condition of our waterways supports those values and uses.

The WQO have been agreed for fresh and estuarine surface waters and marine waters. The objectives are consistent with the agreed national framework for assessing water quality set out in the *Water Quality Guidelines*. The WQO provide environmental values for NSW waters and the *Water Quality Guidelines* provide the technical guidance to assess the water quality needed to protect those values.

4 Existing environment

4.1 Proposal area and topography

Clarrie Hall Dam is located on Doon Doon Creek in the small rural locality of Doon Doon, approximately 15 km south-west of Murwillumbah in the Far North Coast region of NSW.

The majority of the Doon Doon River sub-catchment consists of rural and agricultural land uses (more than 70% of land is zoned 1a Rural). The catchment incorporates parts of Nightcap National Park in the south-west and Mount Jerusalem National Park in the east and south (partially excised).

The downstream area around Clarrie Hall Dam comprises a narrow, steep valley. Elevations range from approximately 63 mAHD at Doon Doon Creek near the Clarrie Hall Dam to 345 mAHD at the adjacent mountain peaks where the slope gradients are 5% to 30%. Further upstream and downstream the valleys are flatter and wider, and small floodplains exist. Mountain peaks adjacent to the downstream floodplains reach approximately 150 mAHD.

4.2 Climate

The Proposal area's climate is considered as subtropical, characterised by warm humid summers, mild winters, and high rainfall. Summers in the region have average temperatures between 26°C to 32°C and winter temperatures between 19°C to 25°C (BoM station 58158, Murwillumbah, Bray Park).

The rainfall within the region varies significantly, with an average annual rainfall of 2,150 millimetres (mm) (BoM station 58019, Doon Doon McCabes Road, active since 1952). Rainfall is highest in summer, averaging 278 mm per month compared to 100 mm per month in the winter months. The median yearly pan evaporation estimated for the Murwillumbah site by the SILO Australian climate database¹ since 1973 is 1,529 mm per year. Evaporation is generally expected to exceed rainfall at Clarrie Hall Dam from June to January (Surface Water Assessment 2023).

Daily rainfall cumulative deviation from the mean in Figure 4.1, represents the overall rainfall trends from 2000 to present. Downward trends represent below average rainfall conditions and upward trends are indicative of above average conditions. Below average rainfall, drought conditions were observed from 2000 until 2007 and 2017 until 2019. Rainfall trends from December 2020 to December 2022 were above average, and since then have fluctuated between above and below average.

¹ SILO Australian climate database¹: <https://www.longpaddock.qld.gov.au/silo/>

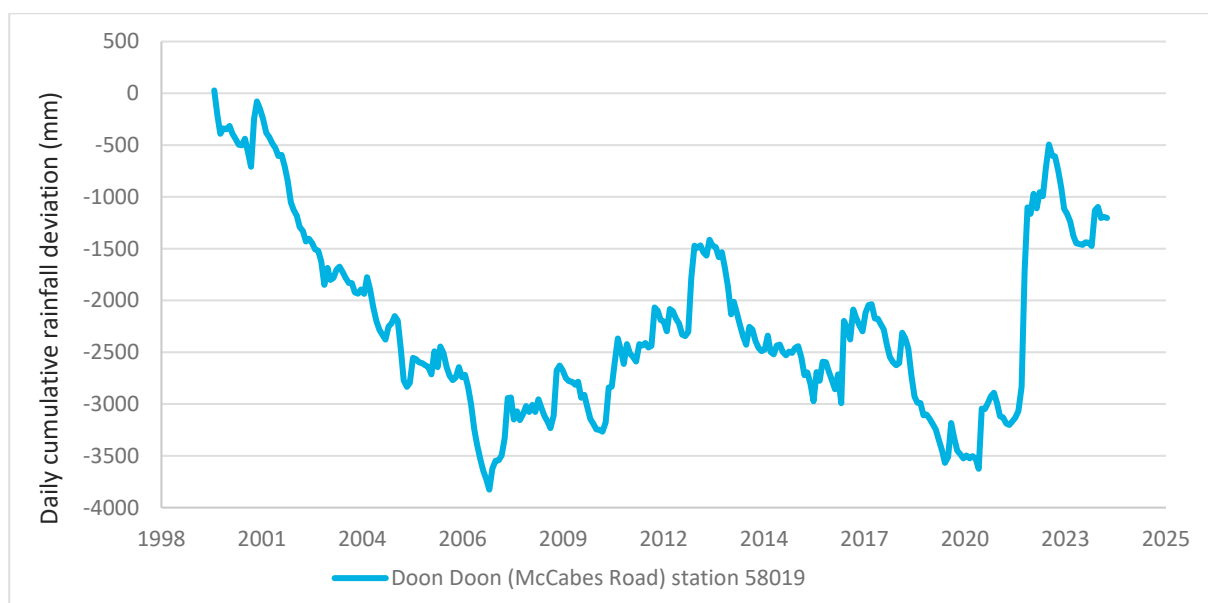


Figure 4.1 Cumulative rainfall deviation, Doon Doon

4.3 Hydrology

Doon Doon Creek is a generally north flowing, fifth-order tributary of the Tweed River, with the confluence approximately 1.5 km downstream of the Clarrie Hall Dam (Figure 2.3). Clarrie Hall Dam is situated in a steep and heavily vegetated valley with a catchment area of 6,000 ha (60 km²). The Tweed River provides water for irrigation and is the primary source of water supply for the Tweed Shire local government area (LGA). Clarrie Hall Dam is operated by Council to provide storage, and during drier months water is released from the dam to augment flows in the Tweed River. The Tweed River has a total catchment area of approximately 1,326 km² and drains the majority of the Tweed Shire LGA (1,340 km²).

The Tweed district water supply is a run of the river supply augmented by releases from Clarrie Hall Dam. Bray Park Weir, located 5 km upstream of Murwillumbah, is the point of abstraction for the district water supply and effectively acts as a tidal barrage. By raising the upstream water level, the weir maintains a pool in the river supplied by the combined flow of the Tweed and Oxley rivers. Raw water is extracted for public water supply from the pool upstream of the weir, and during low-flow periods releases from Clarrie Hall Dam are used to top-up the weir pool.

4.4 Geology

The study area is located in the northern portion of the New England Fold Belt (NEFB) and eastern portion of the overlying Clarence-Moreton Basin. The Palaeozoic NEFB extends from Port Stephens in the south to the NSW–QLD border in the north, and as far east as Moree (DPI Water 2016). The Clarence-Moreton Basin comprises a succession of sedimentary and some volcanic rocks of Mesozoic age (PWA 2018). Tertiary volcanics caps are further north, south and west. Stratigraphic units relevant to the study area and surrounds are shown on Table 4.1 with geology shown in Figure 4.2 (referencing the Seamless Geology layer (NSW Mining, Exploration and Geoscience 2023)).

The study area predominantly overlies Jurassic and Triassic sedimentary and volcanic units, of the Clarence-Moreton Basin, comprising Walloon Coal Measures to the Chillingham Volcanics. The dominant lithology is sandstone with minor shale as recorded in publicly available bore logs in and around the study area. These units have been tilted and eroded, as deduced by the parallel outcrop. The Chillingham Volcanics outcrops where Doon Doon Creek incises the valley upgradient from the dam wall and is described as slightly polyporphritic rhyolite (Hawke 1979). The original and proposed quarry sites target highly weathered rhyolite, to a depth of approximately 10 to 32 m (Public Works Advisory 2018).

In the northern part of the study area, approximately 650 m downstream of the dam wall, the Silurian aged Neranleigh-Fernvale beds outcrops. This formation comprises metamorphosed sedimentary rocks and is part of the NEFB. The dominant geology comprises greywacke and shale. The Neranleigh-Fernvale beds continue to outcrop further north and east, and underlie the Clarence-Moreton Basin.

Quaternary aged alluvium is mapped adjacent to Tweed River and in the upgradient reaches of Doon Doon Creek, comprising unconsolidated gravels, sand and clay. The alluvial deposits are typically narrow, ranging between 50–400 m in width, and are thin, i.e. typically less than 10 m in depth. Gravel deposits on the inside bends of Doon Doon Creek bends are mapped in Hawke 1979 and further minor pockets of alluvium are expected from satellite imagery.

The Alstonville Plateau, to the south of the study area, comprises Tertiary aged extrusive basalt flows known as the Lamington Volcanic Complex. The basalt sequences have been deposited as many overlapping flows and can have clay rich weathered zones between flows (Murray et al 2017). Mount Warning is in the north, a Tertiary aged eroded shield volcano, with a diameter of approximately 40 km.

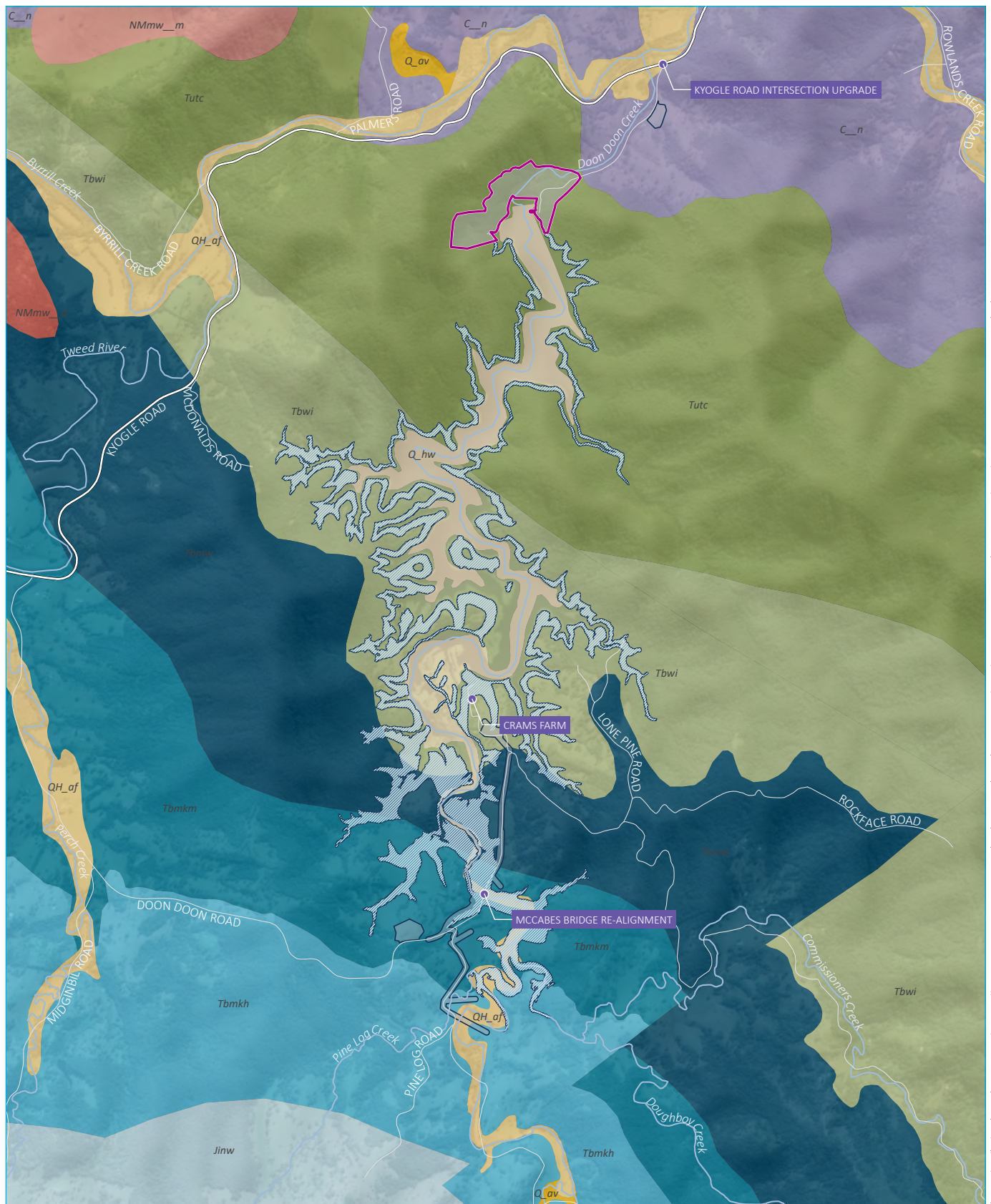
There is a northwest–southeast trending fault through the southern end of the study area, which aligns with the formation boundary between the Chillingham Volcanics and the Ripley Road Sandstone. DPI Water (2016) report the NEFB has undergone regional folding and faulting of the rock formations. Geological investigations undertaken during dam construction report no shear zones, major defects and/or faults around the dam (PWA 2018).

Table 4.1 **Geological units**

Period	Group	Code	Stratigraphic unit	Description
Quaternary		Qa	Alluvium	Quaternary Alluvium, comprising undifferentiated alluvial deposits of sand, clay and gravel
Tertiary	Lamington Volcanics	NMlal	Nimbin Rhyolite	Rhyolite, obsidian, tuff
		NMlan	Lismore Basalt	Basalt, agglomerate
	Mount Warning Volcanics	NMnm	Mount Warning Complex	Basalt, gabbro, trachyte, rhyolite
Jurassic	Koukandowie Formation	Jinw	Walloon Coal Measures	Claystone, shale, siltstone, coal
		Tbmkh	Heifer Creek Sandstone	Sandstone, quartz rich to quartz lithic sandstone
		Tbmkm	Ma Ma Creek Member	Sandstone, shales, siltstones
		Tbmw	Gatton Sandstone	Sandstone, feldspathic to lithic feldspathic sandstone
Triassic	Woogaroo Subgroup	Tbwi	Ripley Road Sandstone	Sandstone and conglomerates, quartz rich
		Tutc	Chillingham Volcanics	Quartzite, rhyolite, rhyolitic tuff, claystone
Silurian		C_n	Neranleigh-Fernvale beds	Sandstone, greywacke, slate, quartzite, metamorphosed

Source: NSW Mining, Exploration and Geoscience (2023) and Geoscience Australia (2023).

Bold text indicates units underlying the study boundary.



Source: EMM (2024); DCSSS (2023); DPIE (2021); ESRI (2024)

KEY

-  Construction disturbance footprint
-  Development site
- Full supply level- proposed
-  Infrastructure upgrade location

Geological u
Quaternary



4.5 Hydrogeology

The groundwater systems comprise:

- minor local, shallow groundwater associated with alluvial deposits
- local, groundwater systems associated with the Tertiary volcanic caps
- local to regional groundwater systems associated with the porous and fractured rock units within the Clarence-Moreton Basin
- local to regional groundwater systems associated with the fractured rock units of the NEFB.

These groundwater systems have different hydrogeological properties due to their depositional environment. Generally, this is a low yielding region with no highly productive aquifer systems.

4.5.1 Alluvial groundwater

Groundwater can be hosted by the alluvial sediments associated with Doon Doon Creek and Tweed River, and other perennial watercourses. These local systems are unconfined with high permeability but low storage owing to the typical narrow and thin extent of the Quaternary aged alluvial deposits, and high clay volumes. Alluvial groundwater receives direct rainfall recharge with water level response likely to be rapid. This local groundwater system is in direct hydraulic connection with the surface watercourses (Murray et al 2017).

4.5.2 Tertiary volcanics groundwater

Local groundwater is stored and moves through the basalt volcanic rocks in fractures, joints and other secondary rock openings. Low bore yields around 1 litre per second (L/s) are expected although a range of permeabilities result from different lava flows affecting the capacity of the basalt to store and transmit groundwater (Murray et al 2016). Groundwater is recharged via rainfall recharge with discharge at geological boundaries or contacts where the underlying permeability is lower. Discharge occurs at springs, particularly at the base of the individual basalt flows, or directly to watercourses. Murray et al (2017) reports the Lamington Volcanics are a major recharge area for the Clarence-Moreton Basin.

4.5.3 Clarence Moreton Basin groundwater

Groundwater in the sedimentary porous rock units, such as the Walloon Coal Measures and Ripley Road Sandstone, flows via primary and secondary flow, i.e. via both the pore spaces and fractures in the rock. Bore yields are typically low, being less than 1 L/s, although can be as high as 10 L/s when highly fractured fault systems are intersected (DPI Water 2016). Flow in the volcanic units, namely the Chillingham Volcanics, is dominated by secondary fracture flow. Hawke's (1979) reports increases in permeability by two orders of magnitude during packer testing at the dam site when fractures are intersected in comparison to unfractured rock mass.

This groundwater system is recharged via direct rainfall recharge at outcrop, and also receives recharge from vertical leakage from overlying Tertiary volcanics in the south (Raiber et al 2016). The porous rock groundwater system is reported as having a low to moderate level of connection with surface water features (DPI Water 2016).

4.5.4 New England Fold Belt groundwater

Like the Tertiary volcanics groundwater system, groundwater in the NEFB is stored and moves through fractures and other secondary rock openings. Yields are typically low, being around 1 L/s, however similar to the porous rock units yields up to 10 L/s may be intersected by highly fractured systems. Groundwater is typically recharged by direct rainfall infiltration at outcrop.

5 Groundwater

5.1 Registered bores

The WaterNSW groundwater database was searched to identify records of private landholder bores located within a 5 km radius from the centre of the study area. The locations of the registered bores are shown in Figure 5.1, with available details included in Table 5.1. This was undertaken to provide a regional perspective of groundwater conditions.

The majority of bores (i.e. 20 bores) target the NEFB groundwater system. The main lithologies targeted were shale, greywacke and sandstone of the porous and fractured rock units, and basalt from the Tertiary volcanics. No bores target the Quaternary alluvium. The average bore depth was 34 m, with bore depths ranging from 8–79 m. Seven bores reported yields greater than 1 L/s, with the maximum yield being 5 L/s. The average standing water level (SWL) was 17 metres below top of casing (mbtoc), with the standing water level (SWL) ranging between 3–45 mbtoc.

Table 5.1 Registered bores in a 5 km radius of the study site

Bore ID	Year drilled	Bore depth (m) ¹	Screen interval (mbgl) ²	Target lithology	SWL ³ (mbgl)	Groundwater system	Yield (L/s) ⁴	Purpose
GW301521	1998	33	27–33	Shale, basalt	20	NEFB	0.5	Water supply
GW070290	1992	30	21–30	Greywacke, shale	-	NEFB	2.3	Water supply
GW302075*	2018		-	-	-	NEFB	-	Abandoned
GW070304	1992	36	12–36	Shale, greywacke	-	NEFB	0.4	Unknown
GW070824	1993	15	-	Clay and rock	-	NEFB	-	Stock and domestic
GW301695	1998	33	-	Basalt	-	NEFB	-	Water supply
GW300530	1996	20	14–20	Clay & gravel, basalt	8	NEFB	0.4	Water supply
GW301314	1995	33	-	Basalt	21	NEFB	0.1	Water supply
GW065593	1988	48	33–42	Fractured rock	26.7	NEFB	0.2	Water supply
GW301388	1995	28	22–28	Shale, basalt	15	NEFB	0.4	Water supply
GW304537	2004		-	-	-	NEFB	-	Irrigation
GW300644	1996	15	12–18	Quartz rock	-	NEFB	2.9	Water supply
GW306456*	2008	79	54–58 63–67 72–76	Slate	45	NEFB	0.5	Water supply
GW303884	2003	12	4.5–7.5	Gravel, shale	-	NEFB	1.2	Water supply
GW071448	1993	36	30–36	Basalt	25	NEFB	0.4	Water supply
GW301145	1995	42	30–42	Shale	-	NEFB	0.6	Water supply
GW300913	1995	42.5	36.5–42.5	Shale, basalt	20	NEFB	0.4	Water supply

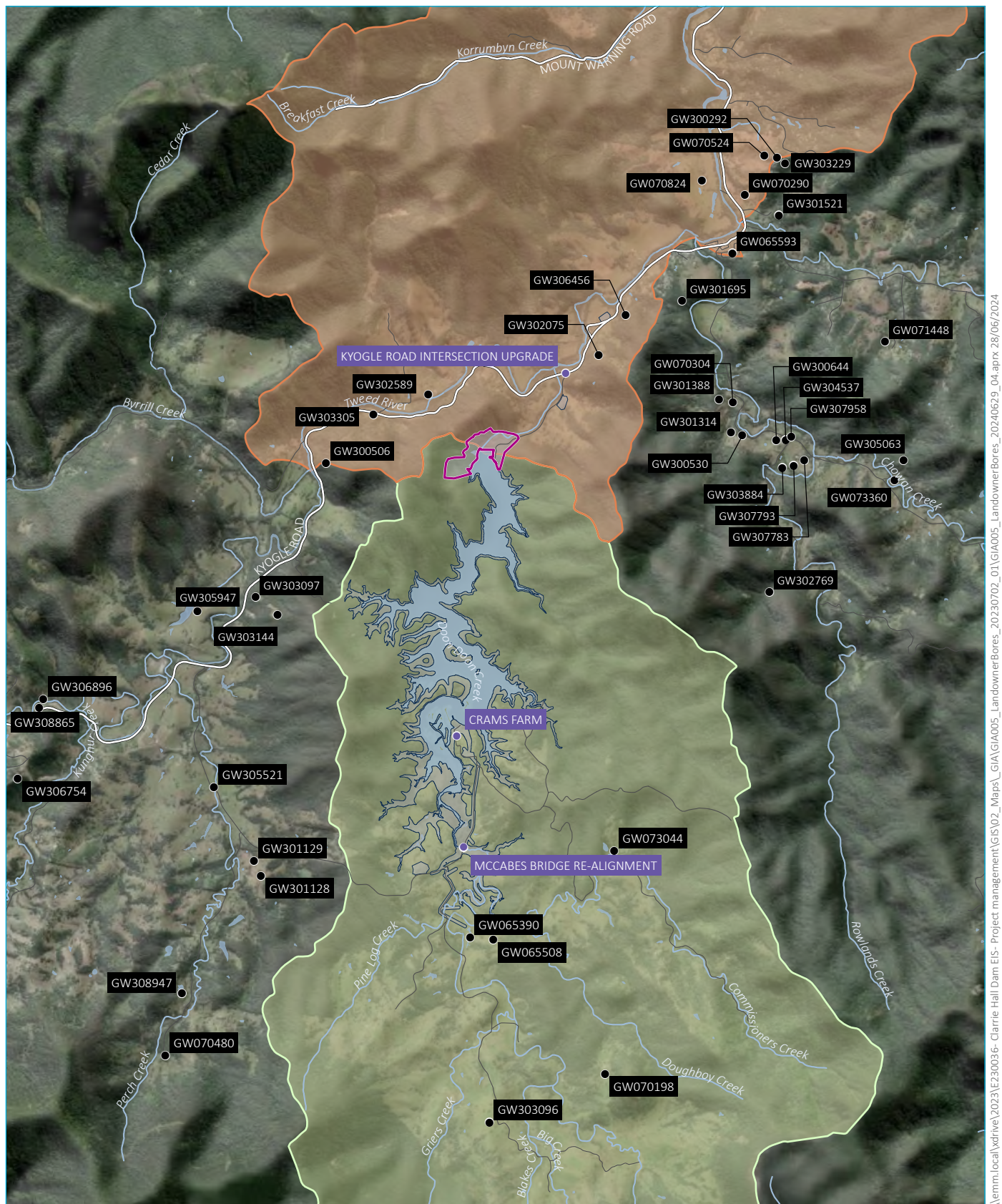
Table 5.1 Registered bores in a 5 km radius of the study site

Bore ID	Year drilled	Bore depth (m) ¹	Screen interval (mbgl) ²	Target lithology	SWL ³ (mbgl)	Groundwater system	Yield (L/s) ⁴	Purpose
GW300439	1996	36	30–36	Shale, weathered	20	NEFB	0.4	Water supply
GW302589	2001	16	10–16	Greywacke	4.9	NEFB	0.6	Exploration
GW303305	2002	51	-	Greywacke	-	NEFB	0.2	Water supply
GW070198	1992	32	26–32	Shale, basalt	18	C-M Basin	0.2	Water supply
GW065390*	1988	30	6–15 21–30	-	3.5	C-M Basin	1.7	Abandoned
GW065508*	1988	8	5–8	-	3.8	C-M Basin	0.5	Abandoned
GW073044	1994	15	8–15	Shale, sandstone	3	C-M Basin	0.2	Stock and domestic
GW301129	1998	59	42–48	Basalt	21	C-M Basin	1.5	Water supply
GW303096*	2002	29.5	23.5–29.5	Sandstone, basalt	15	C-M Basin	0.4	Stock and domestic
GW301128	1998	51	39.0–51.0	Sandstone	-	C-M Basin	1.7	Irrigation
GW305521	2005	25	13.0–25.0	Clay, basalt	20	C-M Basin	0.4	Water supply
GW303144	2002	55	-	Sandstone	-	C-M Basin	-	Water supply
GW300506	1994	36	30–36	Soft shale, basalt	20	C-M Basin	0.4	Water supply
GW303097	2002	26	-	Sandstone	-	C-M Basin	-	Water supply
GW305947	2004	42	18–42	Sandstone	5.7	C-M Basin	5.0	Exploration

Notes: 1. m – metres; 2. mbgl – meters below ground level; 3. SWL - standing water level; 4. L/s – litres per second.

Date of desktop search: 22 February 2023.

Bores with * were visited on 14 March 2023 and details in **BOLD** supersede those reported in the WaterNSW groundwater database.



Source: EMM (2024); ESRI (2024); ABS (2021); DCSSS (2023); DPIE (2021); BOM (2023)

KEY

- Construction disturbance footprint
 Development site
 Infrastructure upgrade location
 NGIS bore
 Unregulated water source
 Doon Doon Creek catchment area
 Mid Tweed River catchment area
- Existing environment
 Major road
 Minor road
 Named watercourse

5.2 Field work

Groundwater related field works were undertaken to:

- determine the status and properties of groundwater bores within the study area
- explore the type and extent of the upgradient floodplain alluvium.

Field work comprised a landholder bore census, and the hand augering of 11 shallow boreholes at 4 locations between 14–15 March 2023. The bore census was undertaken at bores within the study area, comprising the Doon Doon Creek catchment area and at two bores immediately downstream of the confluence between Doon Doon Creek and Tweed River.

5.2.1 Bore census

For the bore census, an EMM Hydrogeologist visited several bores, interviewed landholders about their groundwater use and recorded pertinent bore details. These details are provided in Table 5.2 and include the groundwater quality parameters electrical conductivity (EC) and pH, which were recorded using a calibrated YSI water quality meter. Groundwater quality samples were collected using installed pumps where present, or via a bailer. All bores included in the bore census were visited on 14 March 2023.

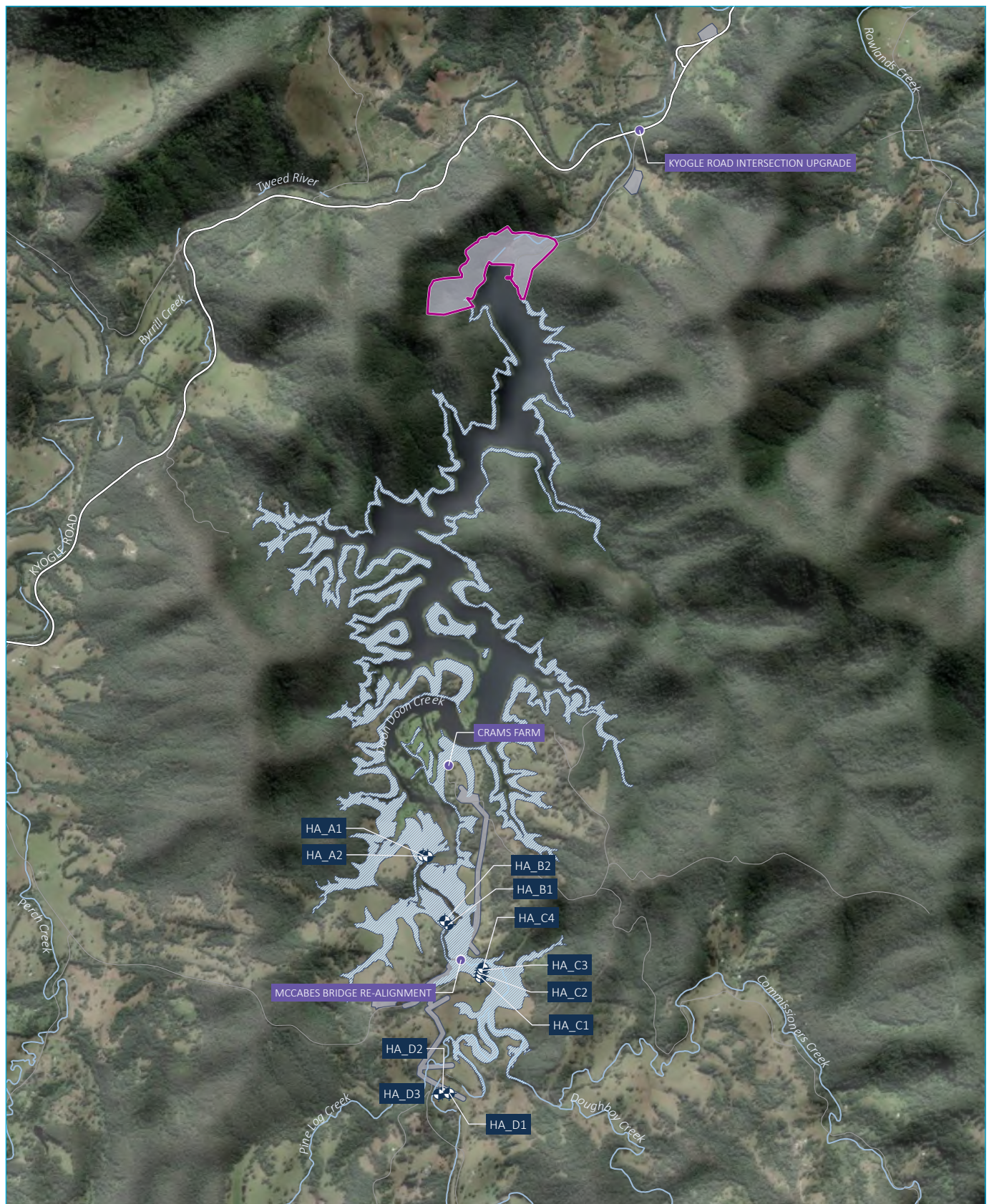
Table 5.2 Bore census results

Bore ID	Landholder comments and bore status	SWL (mbtoc)	Pump installed	EC (µS/cm)	pH
GW065390	Landholder advised bore is not in use, and is deemed abandoned	3.5	no	-	-
GW065508	Landholder advised bore is not in use, and is deemed abandoned	3.8	no	136	5.3
GW070198	Landholder not present, bore not accessed	-	-	-	-
GW302075	Landholder advised that the location of the bore is unknown, therefore bore is deemed abandoned	-	-	-	-
GW303096	Bore used for stock	-	yes	238	6.4
GW306456	Bore used for irrigation and fire fighting	-	yes	943	6.7
GW301695	Landholder not present, bore not accessed	-	-	-	-
GW073044	Landholder not present, bore not accessed	-	-	-	-

5.2.2 Alluvial mapping

Eleven shallow (i.e. less than 2.2 m) boreholes were hand augered at four locations within 100 m of Doon Doon Creek in the southern end of the study area to assess local alluvial/colluvial conditions. Borehole locations are shown in Figure 5.2, and bore logs are included in Appendix A.

The geology intercepted during hand augering was dominated by clay, sand and silt, with bores augered until refusal. Minor lenses of sand and gravel were only identified in a few boreholes, and these were not necessarily water bearing. Groundwater inflows were seen in only two boreholes closest to watercourses at around 1 mbgl. Overall the alluvial/colluvial strata in the southern flood plains was not consistently water bearing and only approximately 2 m in thickness.



Source: EMM (2024); ESRI (2024); ABS (2021); DCSSS (2023); DPIE (2021)

KEY

- Construction disturbance footprint
- Development site
- Full supply level- proposed
- Infrastructure upgrade location
- Hand-augered bore
- Existing environment
- Major road
- Minor road
- Named watercourse

0 0.5 1 km
GDA2020 MGA Zone 56

Hand augered boreholes

Clarrie Hall Dam EIS
Groundwater Impact Assessment
Figure 5.2



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5.3 Groundwater levels

Historic groundwater level data reported for the original dam construction have been reproduced from Hawke's geotechnical site investigations undertaken for the original dam wall (Hawke, 1979). This includes a cross section at the dam wall, showing top water levels, or TWL, presented in Figure 5.3. The original groundwater levels across the site will have been modified by dam storage levels. The current FSL is approximately 61.5 mAHD.

Hawke's (1979) groundwater level measurements indicate groundwater elevations on the left abutment (in the west) were approximately 13 m higher than the FSL, and thus groundwater was most likely discharging to Doon Doon Creek at the dam site. Groundwater elevations on the right abutment (in the east) were only slightly higher than Doon Doon Creek level, by approximately 2–3 m. Public Works Advisory (2018) hypothesis the dam storage may have raised the regional watertable to the storage level on the right abutment.

There is a steeper hydraulic gradient on the left abutment in the west compared to the right, although this is expected to change with topography. On the mountain peaks the depth to groundwater is approximately 20 mbgl, closer to Doon Doon Creek the depth to groundwater is much shallower, closer to 1 mbgl or less (Hawke, 1979).

Upstream of Doon Doon Creek where the valley widens the measured depth to groundwater in the deeper fractured rock is approximately 3.6 mbgl, below the minor local alluvium, recorded from two borehole locations (GW065390 and GW065508). Groundwater depths for the remainder of the boreholes vary considerably, owing to topography.

Groundwater flow follows a muted reflection of topography, however there is insufficient recent information to draw groundwater flow contours around the dam, Doon Doon Creek and downstream areas. Local groundwater flow near the dam wall is expected to be towards the dam on the western flank and flat or away from the dam on the eastern flank.

5.4 Groundwater quality

Physicochemical field parameters collected by EMM indicate groundwater from the Clarence Moreton Basin sandstone units is fresh (average EC of 187 microsiemens per centimetre ($\mu\text{S}/\text{cm}$)) and slightly acidic. The one groundwater sample from the fractured rock NEFB groundwater system was slightly brackish (EC of 943 $\mu\text{S}/\text{cm}$) and neutral (Table 5.2). Review of salinity measurements from boreholes within a 5 km radius from the centre of the study area (and listed in Table 5.1) indicates total dissolved solids range between 74 to 410 ppm (or an EC of 115–640 $\mu\text{S}/\text{cm}$), which is also considered fresh to slightly brackish.

5.5 Sensitive receptors

5.5.1 Overview

This chapter identifies key environmental and third-party receptors of relevance to this assessment that are characterised as having a level of dependence on groundwater. These include:

- third-party groundwater users (i.e. water supply bores operated for stock and domestic, irrigation or other commercial purposes)
- listed high priority GDEs and culturally significant sites listed in the relevant water sharing plans
- potential GDEs, as characterised by publicly available mapping (BoM GDE Atlas) and field mapping and investigations, including:
 - terrestrial GDEs
 - aquatic GDEs
 - subterranean GDEs
- surface water/groundwater connectivity, including discussion around gaining and losing streams.

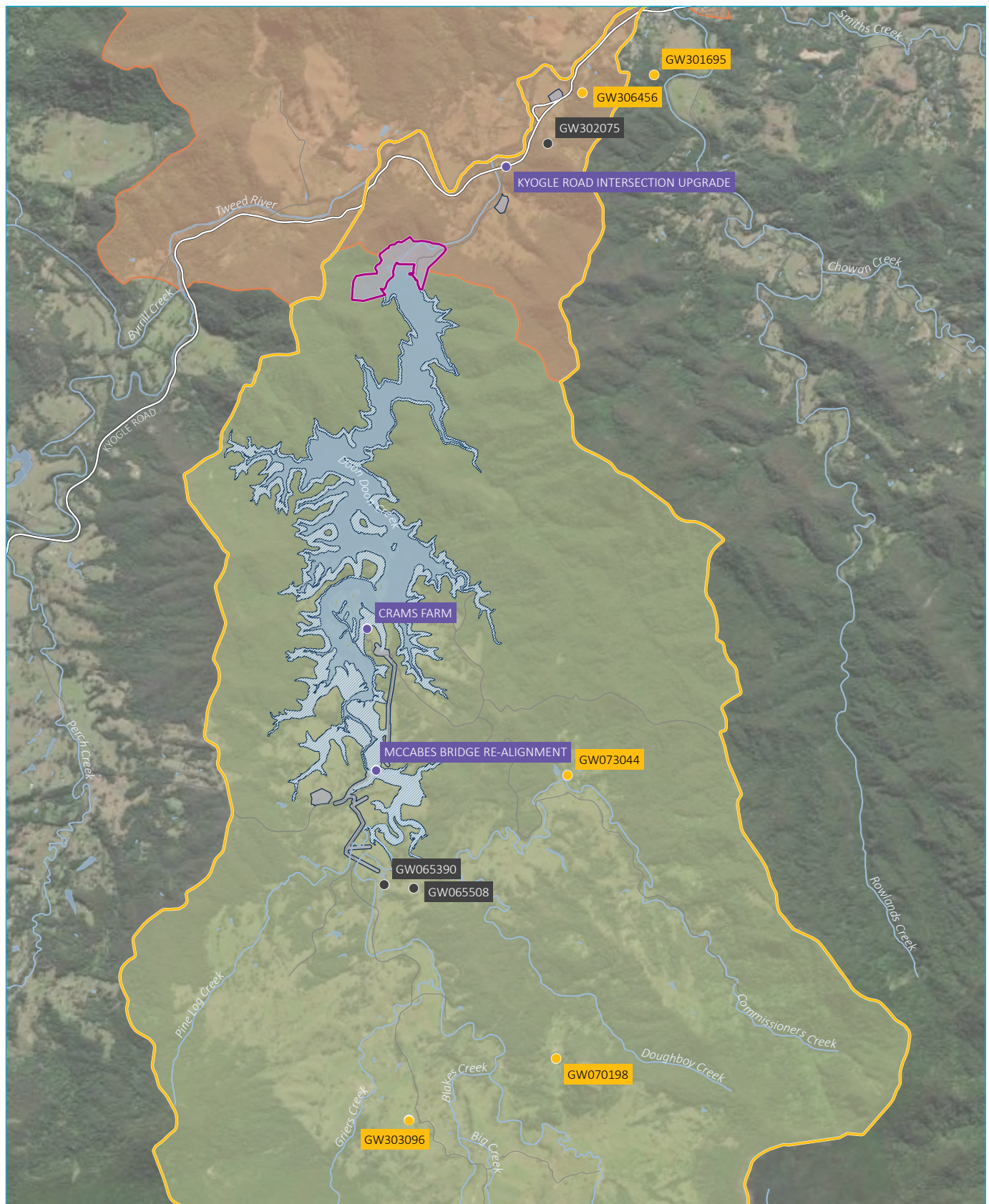
5.5.2 Third party landholder bores

The NSW DPE-Water database was searched to identify records of third party landholder bores located within the study area. Seven landholder bores were identified via the desktop based investigation, however only a possible four bores are considered active following the bore census field work undertaken by EMM. Bore details are included in Table 5.3 and are shown in Figure 5.4. All four licensed bores are conservatively considered to be active bores (and are shown in bold), and are designated as basic rights bores. These bores have a presumed 1 ML annual allocation.

Table 5.3 Study area landholder bores

Bore ID	Groundwater system	Lithology	Approval or status	Approval number	Water source
GW302075	NEFB	-	Abandoned	-	
GW306456	NEFB	Slate	Basic rights	30WA313662	New England Fold Belt Coast GW Source
GW070198	C-M Basin	Shale and basalt	Basic rights	30WA309636	Clarence Moreton Basin GW Source
GW065390	C-M Basin	-	Abandoned	-	
GW065508	C-M Basin	-	Abandoned	-	
GW303096	C-M Basin	Sandstone and basalt	Basic rights	30WA309904	Clarence Moreton Basin GW Source
GW073044*	C-M Basin	Shale and sandstone	Basic rights	30WA309705	Clarence Moreton Basin GW Source

Notes: * = bore presence and condition not verified in the field by EMM.



Source: EMM (2024); ESRI (2024); DCSSS (2023); DPIE (2021); BOM (2023)

KEY

- | | |
|--|---|
| Construction disturbance footprint | Unregulated water source |
| Development site | Doon Doon Creek catchment area |
| Full supply level- proposed | Mid Tweed River catchment area |
| Study area | Existing environment |
| ● Infrastructure upgrade location | — Major road |
| ● Active landowner bore | — Minor road |
| ● Bore within study area | — Named watercourse |

Study area landholder bores

Clarrrie Hall Dam EIS
Groundwater Impact Assessment
Figure 5.4



\\emm.local\drive\2023\E230036- Clarrrie Hall Dam EIS- Project management\GIS\02_Maps\GIA\GIA007_StudyArea_LandownerBores_20230703_01\GIA007_StudyArea_LandownerBores_20240629_02.aprx 28/06/2024

5.5.3 Potential groundwater dependent ecosystems

A desktop assessment was undertaken to identify potential GDEs located within the vicinity of the study area. The desktop assessment involved:

- review of the GDE Atlas (BoM 2022)
- review of the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* 2016
- review of the *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources* 2023
- collation of depth to groundwater information from the NSW DPE-Water database
- review of aerial photographs, topographic and geologic maps.

There are no 'high priority' GDEs listed in the WSPs. However the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* notes high priority GDEs are currently under investigation and some may be identified during the term of this Plan.

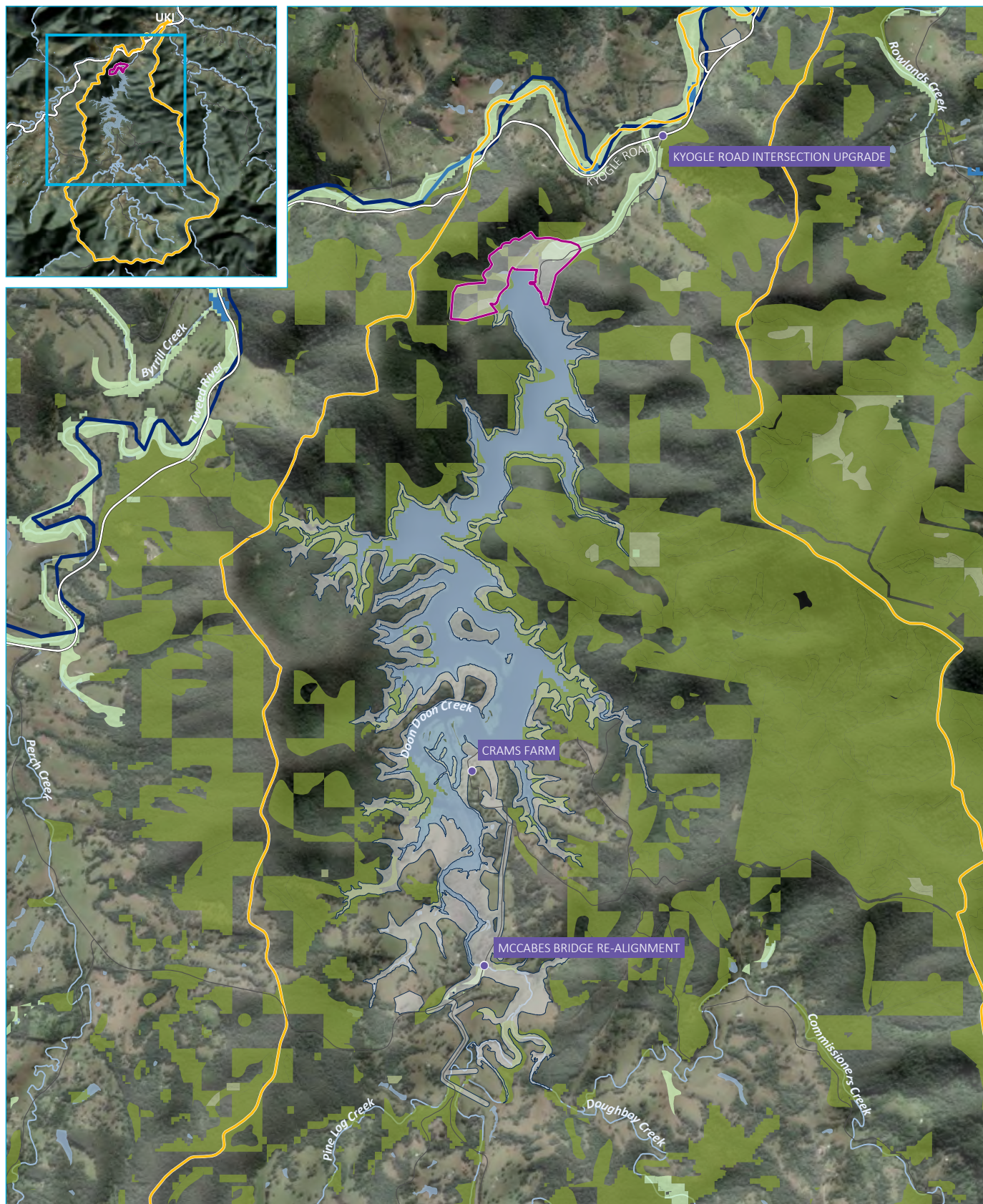
A review of the BoM GDE Atlas (BoM 2022) shows the following potential terrestrial GDEs mapped within the study area, where the potential reliance on groundwater has been inferred from aerial imagery:

- River Oak – high potential GDE
- Wet Bangalow-Brushbox – moderate potential GDE
- Northern Moist Blackbutt – low potential GDE
- Wet Bloodwood-Tallowwood – low potential GDE
- Sub tropical and warm temperate rainforest – low and medium potential GDE.

BoM mapping indicates low potential GDE across the majority of the operational and construction areas, with three small patches of moderate potential GDE, mapped as Wet Bangalow Brushbox Forest, and Subtropical and Warm Temperate Rainforest. Field verification (EMM 2024b) found that these vegetation types are not unique in the context of the construction development site, with no indication of groundwater utilisation in these areas. One 'known' GDE, Wet Heath, is mapped in the south of the development area, however field survey found the area is dominated by wet sclerophyll forest, albeit disturbed and partially cleared.

The Tweed River is considered to support potential aquatic GDEs owing to possible groundwater baseflow contributions according to the BoM GDE Atlas.

EMM 2024b consider it unlikely that groundwater is essential to vegetation communities within the construction area. This is due to the regional high rainfall volumes, the typical depths to groundwater (which averages 17 mbgl in the fractured rock system), and the predominance of groundwater occurrence in fracture networks. There may be some utilisation of groundwater by riparian vegetation upstream of the existing dam where groundwater can be shallower in the alluvium (at approximately 4 mbgl) and is recharged by river flow and rainfall. These areas are largely cleared with native vegetation limited to scattered trees and small patches of forest.



Source: EMM (2024); ESRI (2024); BoM (2023); DCSSS (2023); DPIE (2021)

KEY

- Construction disturbance footprint
- Development site
- Study area
- Infrastructure upgrade location
- Existing environment
 - Major road
 - Minor road
 - Named watercourse
 - Waterbody

- Groundwater dependent ecosystem (GDE)
 - Aquatic
 - High potential GDE
 - Moderate potential GDE
 - Low potential GDE
 - Terrestrial
 - High potential GDE
 - Moderate potential GDE
 - Low potential GDE

High potential groundwater dependent ecosystems (GDEs)

Clarrie Hall Dam EIS
Groundwater Impact Assessment
Figure 5.5



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5.6 Hydrogeological conceptual model

The study area comprises an incised valley system, with two regional groundwater systems, the Clarence Moreton Basin groundwater system in the west and New England Fold Belt groundwater system in the east and to the north. Groundwater is predominantly hosted by these competent, porous and fractured rock units. The bulk of groundwater movement and permeability in the fractured and porous rock groundwater systems is determined by secondary porosity. Groundwater is predominately intercepted at fractures, with permeability decreasing with depth, coinciding with further consolidation of the rock matrix.

Minor alluvium/colluvium occurs in the upstream reaches of Doon Doon Creek, with the potential to host unconfined groundwater, although this was found to be scarce. The alluvial deposit is thin and shallow, and rich in clay which limits storage and permeability. The upstream alluvium overlies the Clarence Moreton Basin and the permeability is via primary porosity.

Potential alluvial groundwater is recharge by rainfall infiltration and flooding events from Doon Doon Creek. Groundwater recharge processes for the fractured and porous rock units is via rainfall infiltration on the upper slopes, ridgelines, and hilltops where there is sub-crops or outcrops, seepage of rainfall run off from valley slopes and potential leakage from the alluvium where water bearing. Groundwater discharge from the geological boundaries between the Tertiary volcanics/Alstonville Plateau in the south can also recharge the underlying Clarence-Moreton Basin and surface water systems.

Groundwater discharge processes for the alluvium include:

- drainage to Doon Doon Creek during/following flooding as a result of bank storage
- leakage from the alluvium to the underlying porous rock units
- transpiration from vegetation intercepting shallow groundwater.

Groundwater discharge processes for the porous and fractured rock groundwater systems include:

- Seepage/springs and evaporation along hill slopes. Historically, permanent springs were located on both the left and right dam abutments (Hawke, 1979) that seeped from below 60 mAHD, however the location and current status of these springs is not known. Public Works Advisory (2018) reported no seepage locations in the gully downstream of the dam.
- Discharge to Doon Doon Creek and Tweed River comprising groundwater baseflow contribution.
- Pumping from landholder bores.

There is a northwest – southeast trending fault through the southern end of the study area, the influence of this structural feature is unknown; it may be a discharge feature for regional groundwater.

Depths to groundwater are variable and are influenced by topography. The regional groundwater flow direction is presumed to be towards the northeast, consistent with topographic gradients, where groundwater flows from catchment highs to valley floors. The localised groundwater flow direction is largely controlled by stratigraphy, dip of the strata, faulting, fractures and topography.

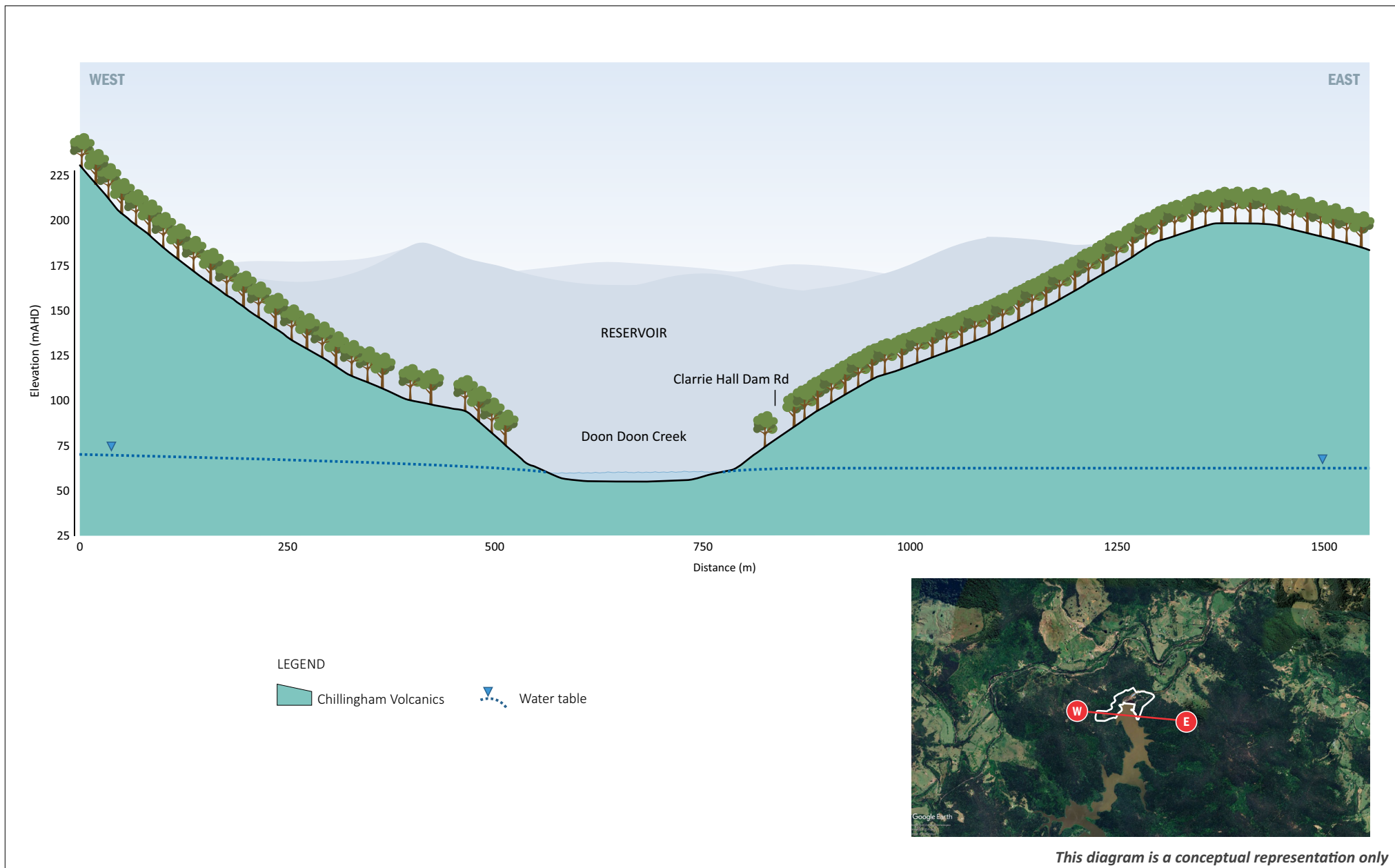
Overall, there is not a high reliance or utilisation of groundwater in the study area and bore yields are approximately 1 L/s. There are five bores licensed for basic rights within the study area, two are upstream and two are downstream, beyond the inundation area. The BoM mapped moderate to high potential GDEs are probably opportunistic groundwater dependent, owing to the regional high rainfall volumes and occurrence of groundwater in fracture networks at depths typically not accessible by plant roots.

5.6.1 Surface water groundwater interaction

In the lower reaches of Doon Doon Creek, immediately behind and downstream of the dam wall, Doon Doon Creek is conceptually a gaining system receiving groundwater discharge as baseflow, controlled by the steep hydraulic gradient created by local topography and the dam reservoir. A conceptual hydrogeological model for the lower reaches of Doon Doon Creek above the dam is presented in Figure 5.6.

Further upstream as the valley widens the groundwater hydraulic gradient flattens, and Doon Doon Creek is probably disconnected from the regional Clarence Moreton Basin groundwater system. A conceptual hydrogeological model for the upper reaches of Doon Doon Creek is presented in Figure 5.7. This shows measurements of the water-table in the porous rock being around 3.6 mbgl, which is below the creek depths of 1–2 mbgl.

The Doon Doon Creek upstream alluvium is presumably hydraulically connected to surface water, with conditions alternating between gaining and losing based on river height. However due to the thin extent and thickness of the alluvium, the alluvium is only partially saturated and in places could be dry for extended periods. The alluvium may act as a temporary storage for overbank flows, with release of water back to surface watercourses once river levels recede.

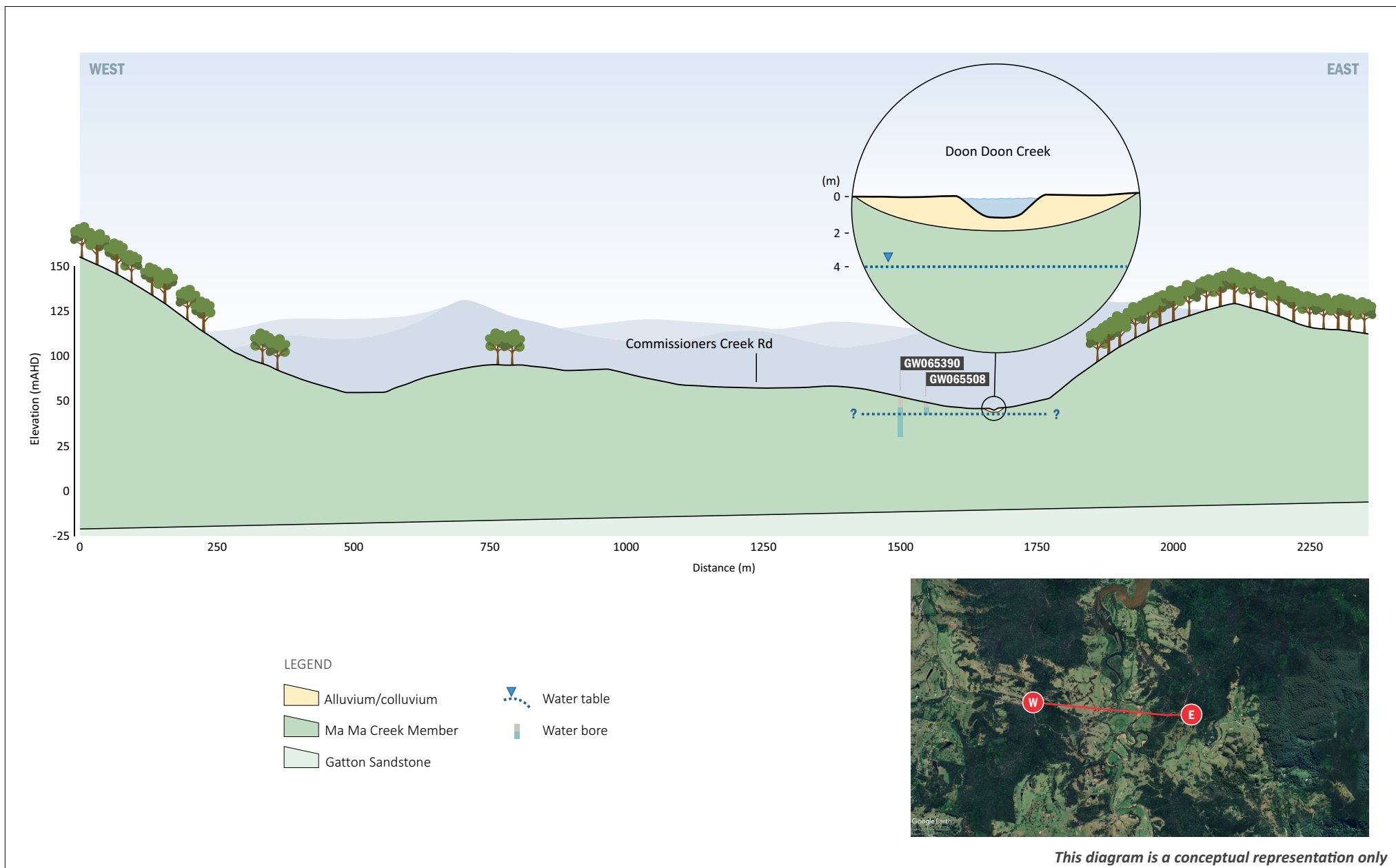


Hydrogeological conceptual model – lower reaches of Doon Doon Creek

Groundwater Impact Assessment – Clarrie Hall Dam Raising

Tweed Shire Council/KBR

Figure 5.6



Hydrogeological conceptual model – upstream Doon Doon Creek

Groundwater Impact Assessment – Clarrie Hall Dam Raising

Tweed Shire Council/KBR

Figure 5.7

6 Assessment methodology

6.1 Assessment approach

The assessment of potential Proposal related impacts on water resources and water users considers the requirements of the WMA, relevant WSPs and the AIP (for some activities). The National Water Commission developed guidelines and a risk framework for assessing local and cumulative effects of mining activities on groundwater systems (Moran et al. 2010). While this is not a mining project, the framework remains applicable and defines the following four possible direct groundwater effects arising from a project:

- Altered groundwater quantity (groundwater levels, pressures and fluxes).
- Altered groundwater quality (concentration of salts and other important water quality constituents).
- Altered surface water – groundwater interaction.
- Physical disruption or removal of aquifers (excavation quarry pits).

Direct effects encompass the changes to physical and/or quality aspects of groundwater due to aquifer interference activities, or the changes to the physical characteristics of aquifers affected by these activities. Direct effects of water affecting activities can result in adverse or beneficial impacts on receptors.

The framework uses a source-pathway-analysis that describes how water affecting activities might impact sensitive groundwater receptors. For an effect to occur to a sensitive water receptor, a pathway must exist between a water affecting activity and a receptor. Risks are characterised by making an informed decision as to the potential for adverse effects to impact sensitive groundwater receptors because of project related activities, while also considering the AIP.

Direct effects encompass the changes to physical and/or quality aspects of groundwater due to water affecting activities, or the changes to the physical characteristics of aquifers affected by these activities. Indirect effects of water affecting activities are those that arise in response to direct effects (Moran et al. 2010). The assessment of potential receptor exposure to adverse changes in the groundwater regime (quantity, quality, groundwater and surface water interactions, and physical disruption of aquifers) requires:

- knowledge of the location of sensitive receptors within the landscape, particularly in relation to the location and area of influence of water affecting activities
- an understanding of the receptor's reliance on groundwater (e.g. depth to watertable, groundwater flux to baseflow-fed streams, groundwater quality to meet beneficial purposes)
- an understanding of the spatial and temporal scale of direct groundwater effects at the location of sensitive receptors.

The potentially sensitive receptors that have been identified include:

- landholder bores used for stock and domestic purposes (four active bores identified)
- ecosystems that potentially rely on groundwater (riparian terrestrial vegetation and aquatic ecosystems), albeit this is considered low likelihood
- watercourses, drainage lines, creeks and springs that receive baseflow.

6.2 Assessment criteria

6.2.1 Aquifer Interference Policy

The AIP defines water sources as being either 'highly productive' or 'less productive' based on levels of salinity and average yields from bores. Specifically, highly productive groundwater sources have a measurement of total dissolved solids less than 1,500 mg/L and can sustain yields greater than 5 L/s; less production groundwater sources have a measurement of total dissolved solids greater than 1,500 mg/L and can not sustain yields greater than 5 L/s. The AIP further defines water sources by their lithological character, being one of alluvium, coastal sand, porous rock, or fractured rock. Based on mapped areas of groundwater productivity in NSW (DPI Water 2012) and the reported yields, the Proposal is considered to be within a 'less productive' fractured and porous rock water source for areas intercepting the North Coast Fractured and Porous Rock groundwater sources, similarly the study area alluvium is also considered to be 'less productive'.

For each category of water source, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the watertable, water pressure and water quality (generally watertable or pressure declines or water quality degradation), and are ranked as being either 'level 1 minimal impact' or 'level 2 exceeding minimal impact'. The definition of 'minimal impact' is outlined in a series of tables which demonstrate how the criteria are applied for different types of water sources and for different sensitive receptors (i.e. other users and ecosystems). The applicable minimal impact considerations are shown in Table 6.1 and Table 6.2 and have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users.

If the impact of an activity is assessed as being level 1 minimal impact, then the project is considered to have impacts that are acceptable. Where the predicted impacts exceed the level 1 thresholds then this is considered as having impacts within the range of acceptability, and extra monitoring or mitigation or remediation would be required during operations. Where impacts are predicted to be 'greater than minimal impact' and the long-term viability of the water-dependent asset is compromised, the impact is subject to make good provisions.

It is considered unlikely this Proposal has even level 1 minimal impacts in accordance with the AIP criteria: there will not be any groundwater decline at landholder bores, there are no high priority listed GDEs and/or cultural sites within the groundwater study area, and groundwater quality changes are not anticipated. The Proposal does not involve the incidental take of groundwater and declining watertables, rather watertables may rise slightly in the vicinity of the dam as the FSL is expected to increase from approximately 61.5 mAHD to approximately 70 mAHD.

Table 6.1 Minimal impact criteria for ‘less productive’ porous and fractured rock water sources

Watertable	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the watertable, allowing for typical climatic ‘post-water sharing plan’ variations, 40 m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site, listed in the schedule of the relevant water sharing plan. c) A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the watertable, allowing for typical climatic ‘post-water sharing plan’ variations, 40 m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site, listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister’s satisfaction that the variation would not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline would not prevent the long-term viability of the affected water supply works unless make good provisions apply.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. If condition 1 is not met then appropriate studies would need to demonstrate to the Minister’s satisfaction that the change in groundwater quality would not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Note: Sourced from NSW Aquifer Interference Policy (DPI Water 2012b).

Table 6.2 Minimal impact criteria for ‘less productive’ alluvial water sources

Watertable	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the watertable, allowing for typical climatic ‘post-water sharing plan’ variations, 40 m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site, listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply. 2. If more than 10% cumulative variation in the watertable, allowing for typical climatic ‘post-water sharing plan’ variations, 40 m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site, listed in the schedule of the relevant water sharing plan then appropriate studies would need to demonstrate to the Minister’s satisfaction that the variation would not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	1. A cumulative pressure head decline of not more than 40% post water sharing plan pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline would not prevent the long-term viability of the affected water supply works unless make good provisions apply.	1(a). Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 1(b). No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a reliable water supply is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. 2. If condition 1(a) is not met then appropriate studies would need to demonstrate to the Minister’s satisfaction that the change in groundwater quality would not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source would not be reduced at the nearest point to the activity.

Note: Sourced from NSW Aquifer Interference Policy (DPI Water 2012), with reference to mining related works removed.

6.2.2 Risk Assessment Guidelines for Groundwater Dependent Ecosystems

Serov et al. (2012) has developed a risk assessment approach, documented in the *Risk Assessment Guidelines for Groundwater Dependent Ecosystems*. The following risk factors that are relevant to the Proposal need to be considered in the assessment:

- Impacts to groundwater quantity: fluctuations in groundwater levels and/or pressure, changes in seasonal baseflow conditions.
- Impacts to water quality: changes in water quality that may impact any beneficial uses of the shallow groundwater and connected ecosystems.
- Impacts to the biodiversity of any GDEs: species diversity or composition, dieback of vegetation, increased exotic species or removal/alteration of habitat.

The risk assessment approach considered the risk of impact (low, medium or high) as well as the ecological value of the GDE (low, medium or high) to determine the overall risk.

7 Groundwater impact assessment

7.1 Potential groundwater impacts

The following Proposal components have the potential to affect groundwater.

Construction:

- Land based construction and laydown areas where there could be potential for groundwater contamination.
- Quarry operation and backfill, and associated material stockpiles: groundwater could be intercepted when quarrying for construction materials.

Operation:

- The applied load from the higher water storage on the alluvial, porous and fractured rock groundwater sources has the potential to enhance recharge and cause the water pressure (or groundwater level) to rise, altering the local groundwater flow regime (hydraulic gradient and flow path) near the inundation area and dam embankment.

Other components of the Proposal that are not considered activities impacting groundwater sources or their dependent ecosystems and are therefore not assessed further include:

- The construction and use of ancillary facilities and roads: works are not anticipated to intercept, penetrate or take water from the local groundwater systems.

Potential groundwater impacts arising through the construction and operation of the Proposal are summarised in Table 7.1 with further discussion below. All the activities potentially impacting groundwater are assessed as being negligible and therefore acceptable level 1 minimal impacts under the AIP.

Table 7.1 **Potential impacts from groundwater affecting activities**

Water affecting activity	Potential impact	Project phase	Receptors potentially impacted
Groundwater quantity			
Project construction – excavation and blasting at the quarry and construction areas (i.e. spillway), with interception of groundwater	Localised drainage of groundwater in the New England Fold Belt rocks at excavations, causing drawdown of the watertable and changes to groundwater flow paths.	Construction	Terrestrial and aquatic GDEs
Project operation	Groundwater pressure/level increase in the Clarence Moreton Basin groundwater system up hydraulic gradient of the Dam, owing to increased recharge from higher FSL capacity, altering the local groundwater flow path.	Operation	Third party landholder bores Terrestrial and aquatic GDEs
Groundwater quality			
Chemical and fuel spills at land based construction, road and laydown areas	Short-term release of contaminants with the potential to interact with the local groundwater.	Construction	Third party landholder bores Terrestrial and aquatic GDEs
Blasting	Introduction of blasting substances that intersect fracture networks resulting in the release of substances beyond the influence of the blasting area. Residual substances occurring on the face of blasted material may leach from stockpiled material during rain events.	Construction	Third party landholder bores Terrestrial and aquatic GDEs
Surface water-groundwater interaction			
Project operation	Potential changes to surface water and groundwater interaction upgradient of the dam wall, where there is more impounded surface water, and down gradient of the dam wall where there is potentially less natural surface water flow.	Operation	Third party landholder bores Terrestrial and aquatic GDEs

7.1.1 Groundwater quantity

The Proposal does not intend to excavate material below the watertable, and consequently there is likely to be negligible groundwater take, incidental or otherwise. Groundwater quantity impacts relate to potential changes in groundwater levels from altered surface water – groundwater relationships. The *Surface Water Assessment* (EMM 2022) concludes the Proposal will:

- Increase the volume of water able to be stored above the FSL, i.e. there will be a greater dam storage capacity.
- Cause an increase in evaporation losses, which will reduce the frequency of spillway flows and increase reliance on managed releases. This will also increase the frequency of minimum flow depth over river riffles within Doon Doon Creek from 38% of the time to 47% of the time.
- Result in a reduction in Doon Doon Creek water depth at some times and an increase in depth at other times, with changes in the order of ± 0.1 m.
- Reduce the duration/severity of water restrictions during drought conditions.
- Not cause discernible changes to the Tweed River flow regime.

i Clarrie Hall Dam operation

The new dam height is 70 mAH, which is approximately 8.5 m higher than the current dam height, and will comprise an additional 140 ha of inundation area. The higher reservoir levels could locally raise groundwater levels in those groundwater systems adjacent to the dam wall and the reservoir. Public Works Advisory (2018) hypothesise that the original dam construction raised the watertable around the dam wall in a very localised area. Furthermore, Public Works Advisory (2018) report that groundwater levels are interpreted to normalise quickly with distance downstream.

Potential rises in groundwater levels are not expected to migrate beyond the FSL inundation area as the potentially highly transmissive alluvium is very localised and minor in extent, and the fractured and porous rock units have relatively low permeability. In a fractured rock mass the upper weathered portion typically has a lower permeability due to infilling of rock mass defects with clay (Public Works Advisory 2018).

The Clarence Moreton Basin and New England Fold Belt groundwater systems are not highly connected to Doon Doon Creek and the Tweed River in the area immediate downstream of the dam wall and the *Surface Water Assessment* notes the changes in surface water flows downstream of the dam will be negligible. This means potential changes to downstream groundwater levels are not expected.

ii Clarrie Hall Dam construction

The re-establishment of a quarry is required to meet construction material demands for the dam embankment; the location of the proposed quarry expansion area is shown on Figure 2.2. Other construction works will also comprise ground excavation works, namely the construction of the spillway (spillway excavation area) and the dam embankment. While the current depth to groundwater at the quarry site is unknown, site inspections in 2018 did not report any surface seepage, or intersection of the watertable by the existing quarry (Public Works Authority 2018). To avoid the interception of the watertable in the fractured rock, it is recommended that quarry expansion occurs laterally, with the current depth of the quarry base maintained if possible.

Construction works around the dam will likely intercept groundwater/surface water given the proximity to surface water and the high watertable near the dam wall. However, construction works will have a short duration and any potential interaction with groundwater during the dam construction will result in very localised, short-term changes to groundwater levels and/or pressure.

7.1.2 Groundwater quality

Spills of hazardous materials/chemicals and/or the generation of liquid waste can potentially contaminate groundwater. Examples of this include spills of hydrocarbons while refuelling or lubricants used by machinery. All scenarios have the potential to impact human and environmental health depending on the type of contaminant if not managed accordingly. However management measures are simple and effective to implement.

Similarly, the use of blasting substances may result in residual substances occurring at the face of blasted material, blasting substances leaching from stockpiled material during rain events and/or the introduction of blast material into the fractured rock groundwater system where blasting occurs. The likelihood of this occurring is low however, if blasting remains above the watertable.

The extent and degree of potential groundwater contamination is dependent on factors such as geology, depth to groundwater, the infiltration capacity/permeability of the geology and the presence, properties and characteristics of a potential pollutant. Potential groundwater contamination incidences, if they even occur, are expected to be minor and localised to within the construction areas with the implementation of management measures.

7.1.3 Surface water – groundwater interaction

The raising of surface water levels immediately upstream of the dam wall may result in less groundwater baseflow contributions to surface water, and more surface water loss to the groundwater system as the hydraulic gradient is altered between surface water and groundwater.

Further upstream, where the valley is broader and there is localised alluvium, the surface water and groundwater interaction is likely to remain unchanged, where surface water is losing to shallow groundwater during periods of high flow and gaining when surface water flows recede and groundwater discharges from the adjacent alluvium.

7.2 Sensitive receptors

7.2.1 Third party landholder bores

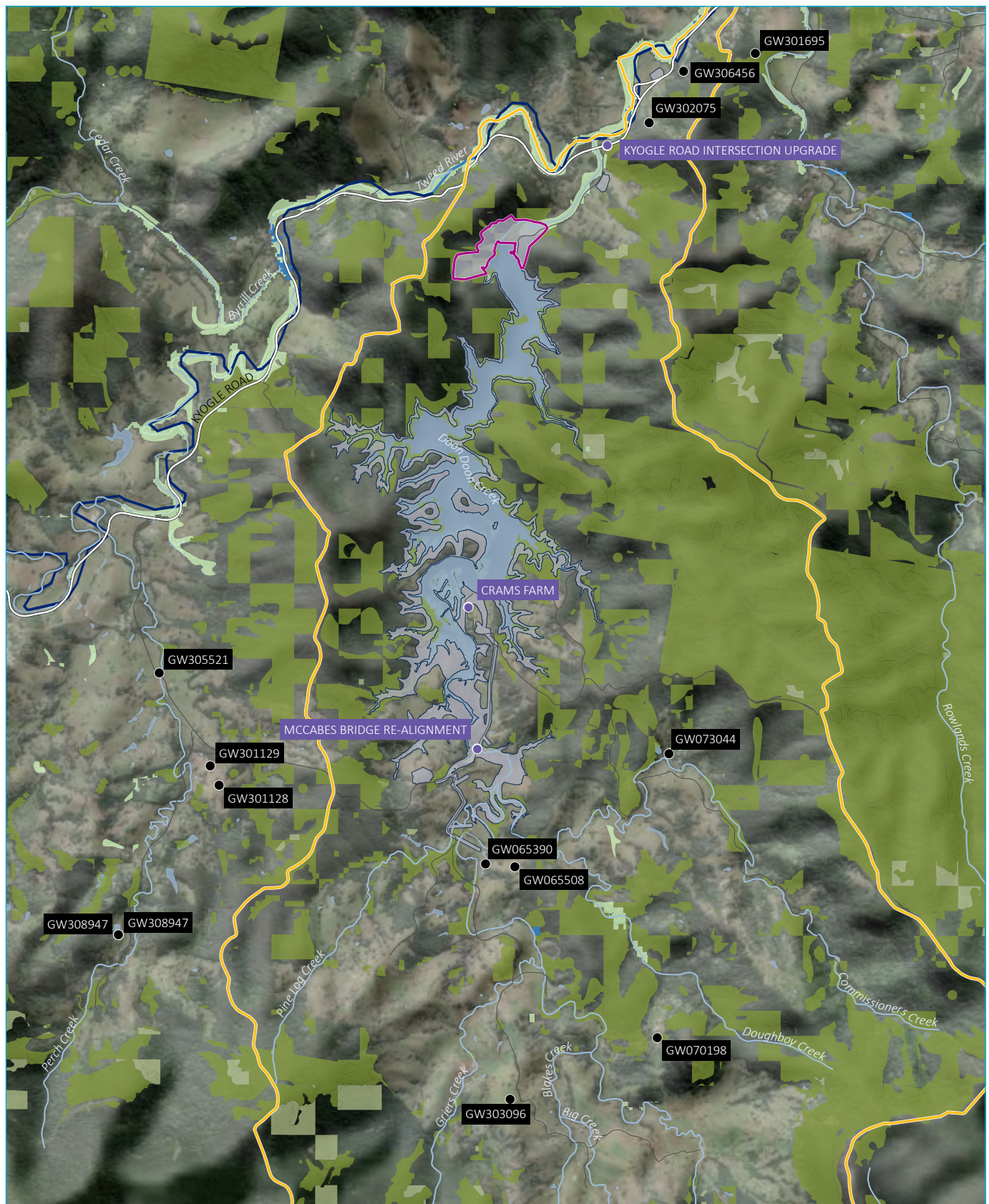
There are no third party landholder bores within the new FSL inundation area and construction areas. The two closest bores to the new FSL inundation area (GW065390 and GW065508) are both deemed to be abandoned. Potential rises in groundwater levels are not expected to migrate beyond the FSL inundation area. Therefore there are no expected groundwater impacts to third party landholder bores.

7.2.2 Potential groundwater dependent ecosystems

There are no high priority WSP listed GDEs in the study area, although there are some mapped areas of BoM high potential terrestrial GDEs. Field verification (EMM 2024b) of potential GDEs found that these vegetation types are not unique in the context of the development site, with no indication of groundwater utilisation in these areas. Impacts to potential GDEs resulting from changes to groundwater levels and/or groundwater quality are not anticipated due to the Proposal. This is due to an absence of potential GDEs (both terrestrial and aquatic), presumably owing to the regional high rainfall volumes, the typical depths to groundwater, and the predominance of groundwater occurrence in fracture networks. There may be some opportunistic use of groundwater from the shallow alluvium by riparian vegetation upstream of the existing dam groundwater, however these area are recharged by river flow and rainfall, and thus not solely groundwater dependent (EMM 2024b). These areas are also predominantly cleared, and any vegetaion here could presumably experience greater access to groundwater from the Proposal owing to the increased inundation FSL.

A small stand of sub-tropical rainforest in the study areas east and some River Oak trees in the Proposal construction area (in the north), were confirmed in the field (refer to the *Biodiversity Development Assessment Report* (BDAR)). The River Oak will be directly impacted by the Proposal, with further details included in the *Biodiversity Development Assessment Report* (EMM 2024). The sub-tropical rainforest is expected to receive more water, as it's on the edge of the FSL inundation area.

Furthermore, all direct and indirect impacts to biodiversity including native vegetation, threatened ecological communities, threatened flora and threatened flora have been assessed and offset where required by way of an offset credit liability under the biodiversity offset scheme. Therefore any potential impacts to potential GDEs within the proposed development area, resulting from the Proposal, have therefore been adequately assessed and require no additional consideration.



Source: EMM (2024); ESRI (2024); BoM (2023); DCSSS (2023); DPIE (2021)



KEY

- ▬ Construction disturbance footprint
- ▬ Development site
- ▬ Study area
- Infrastructure upgrade location
- NGIS bore

- Groundwater dependent ecosystem (GDE)
- Aquatic
- ▬ High potential GDE
 - ▬ Moderate potential GDE
 - ▬ Low potential GDE
- Terrestrial
- ▬ High potential GDE
 - ▬ Moderate potential GDE
 - ▬ Low potential GDE

- Existing environment
- ▬ Major road
 - ▬ Minor road
 - ▬ Named watercourse

Proposed footprint and groundwater users

Clarrie Hall Dam EIS
Groundwater Impact Assessment
Figure 7.1



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7.3 Risk assessment and management framework

An evaluation of the Proposal activities, and the potential impacts to water and water receptors has been completed. The Proposal activities are outlined in Chapter 2, and the impact assessment is outlined above.

A risk assessment matrix has been used to quantify the potential risks of the Proposal on water receptors and is outlined in Table 7.2.

Table 7.2 Risk matrix

		Likelihood				
		1. Rare	2. Unlikely	3. Possible	4. Likely	5. Almost certain
Consequence	5. Severe	Medium (5)	High (10)	High (15)	Extreme (20)	Extreme (25)
	4. High	Medium (4)	Medium (8)	High (12)	Extreme (16)	Extreme (20)
	3. Moderate	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	2. Minor	Low (2)	Medium (4)	Medium (6)	Medium (8)	High (10)
	1. Negligible	Low (1)	Low (2)	Low (3)	Medium (4)	Medium (5)

The classification of likelihood for activities is as follows:

1. Rare: an event that with low probability to occur during the lifetime of an operation or project. Less than 1% annual probability of occurrence.
2. Unlikely: an event that is unlikely to occur during the lifetime of an operation or project. More than 1% annual probability of occurrence.
3. Possible: an event that may occur during the lifetime of an operation or project. More than 10% annual probability of occurrence.
4. Likely: an event which will probably occur during the lifetime of an operation or project. Around one occurrence per year.
5. Almost certain: a recurring event during the lifetime of an operation or project. More than two occurrences per year.

The classification of environmental consequence is as follows:

1. Negligible: minimal change to the existing situation. This could include for example impacts which are beneath the levels of detection, impacts that are within the normal bounds of variation or impacts that are within the margin of forecasting error.
2. Minor: impacts are recognisable/detectable but acceptable and may be contained on-site. These impacts are unlikely to be of importance in the decision making process but are relevant in the consideration of standard mitigation measures. Impacts tend to be short-term (<12 month recovery period) or temporary and/or occur at a local scale.

3. Moderate: the effects of the impact are relevant to decision-making including the development of environmental mitigation measures. Impacts can range from long-term to short-term in duration (1 to 4 year recovery period). Impacts occur mostly near the source, which is apparent and requires mitigation to be within limits of acceptability. Moderate sensitivity of environmental receptors to impact.
4. High: the impact is considered likely to be important to decision-making. Impacts tend to be permanent or irreversible or otherwise long-term (>5 year recovery period). Impacts can occur over large or medium size areas. High to moderate sensitivity of environmental receptors to impact.
5. Severe: the impact is considered critical to the decision-making process. Impacts tend to be permanent or irreversible or otherwise long-term and can occur over large areas. Very high sensitivity of environmental receptors to impact.

7.4 Residual risk summary

The following summary table (Table 7.3) considers management and mitigation measures for each water affecting activities characterised in Table 7.1. A qualitative residual risk to groundwater following the implementation of relevant management and mitigation measures is discussed in both tables with consideration of AIP criteria. Overall potential groundwater impacts are low and will not exceed the AIP Criteria Level 1 impact considerations for both the fractured and porous rock groundwater systems, and the alluvial groundwater systems.

Table 7.3 Potential impacts from groundwater affecting activities

Water affecting activity and potential impact	Project phase	Receptors potentially impacted	Risk ranking	Comment
Groundwater quantity				
Project construction, excavation and blasting, with possible, minor interception of groundwater causing potential localised drainage of groundwater from the New England Fold Belt.	Construction	Terrestrial and aquatic GDEs	Low	Unlikely to occur and with negligible significance given plants reliance on other water sources and absence of landholder bores.
Groundwater pressure/level increase in the Clarence Moreton Basin groundwater system up hydraulic gradient of the Proposal.	Operation	Terrestrial and aquatic GDEs	Low	Unlikely to occur and with negligible significance given plants reliance on other water sources and absence of landholder bores.
Groundwater quality				
Chemical and fuel spills at land based construction, road and laydown areas.	Construction	Terrestrial and aquatic GDEs	Low	Unlikely to happen and with minor, very localised significance.
Blasting causing potential groundwater contamination.	Construction	Terrestrial and aquatic GDEs	Low	Unlikely to happen and with minor, very localised significance.
Surface water-groundwater interaction				
Potential changes to surface water and groundwater interaction both upgradient and down gradient of the dam wall.	Operation	None	Low	No groundwater receptors.

8 Monitoring and management

The following monitoring and management measures are proposed:

- Handling and storage of fuel and oil within the site will be in accordance with *Australian Standards, AS 1940-2004 (Storage and Handling of Flammable and Combustible Liquids)* and *NSW Work Cover 2005 Code of Practice for Storage and Handling of Dangerous Goods* to reduce the risk of any spills or environmental release. Above ground fuel storage in a bunded facility will be implemented as required and refuelling will occur over a hard stand area.
- Safety Data Sheets (SDS) will be kept in the site safety system for all chemicals used on site. The SDSs will contain information on the environmental impacts of the use of certain chemicals and include detail on emergency response, clean up and disposal. Handling and storage of all chemicals within the Proposal site will be in accordance with *Dangerous Goods Act 1975 (NSW)*, and Australian standards, including *AS 1940-2004 (Storage and Handling of Flammable and Combustible Liquids)*.
- The detailed design phase of works will ascertain the depth to the watertable in areas proposed to be quarried, or will commit to lateral expansion and the maintenance of the new quarry base at or above the current quarry base, to prevent intersection of the watertable.
- Quarry rehabilitation will occur consistent with the *Rehabilitation and Closure Strategy* (IEMA 2023) prepared for the Proposal.
- A Water Management Plan will be developed for the Proposal, outlining site specific surface water and groundwater measures implemented to prevent potential negative impacts to water resources during the construction and operational Proposal phases.

9 Conclusions

This GIA has been prepared for the proposed Clarrie Hall Dam raising project in far north coast region of NSW. Council proposes to raise the existing Clarrie Hall Dam by 8.5 m to a height of 70 mAHD, and construct a new enlarged concrete spillway higher on the west abutment. The new FSL inundation area and operational footprint is 209 ha, or approximately 248 ha for the area between the proposed FSL and the PMF.

Potential groundwater impacts relate to:

- Groundwater quality impacts from quarrying and Proposal construction. Spills of hazardous materials/chemicals and/or the generation of liquid waste can potentially contaminate groundwater. Similarly, the use of blasting substances may result in residual substances occurring at the face of blasted material, blasting substances leaching from stockpiled material during rain events and/or the introduction of blast material into the groundwater system where blasting occurs. Potential groundwater contamination incidences, if they even occur, are expected to be minor and localised to within the construction area.
- Groundwater pressure/level increases in the Clarence Moreton Basin groundwater system up hydraulic gradient of the Dam, owing to increased recharge from higher FSL. This could occur underlying the FSL inundation area and where there are fractures and rock openings that permitted groundwater entry. Potential rises in groundwater levels are not expected to migrate beyond the FSL inundation area as the potentially highly transmissive alluvium is very localised and minor in extent, and the fractured and porous rock units have low transmissivity based on inferred airlift yields.

There are no third party landholder bores in the immediate vicinity of the Proposal, including the operational and construction areas. The two closest bores to the FSL inundation area (GW065390 and GW065508) are both deemed to be abandoned. There are no high priority WSP listed GDEs in the study area. With the exception of the River Oak, impacts to potential GDEs are not anticipated due to the Proposal. This is due to an absence of potential GDEs (both terrestrial and aquatic), presumably owing to the regional high rainfall volumes, the typical depths to groundwater, and the predominance of groundwater occurrence in fracture networks.

The risk ranking for all potential groundwater impacts is low. A Water Management Plan will be developed for the Proposal.

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Appendix A

Bore logs

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 15 March 2023

ID: HA_A1

Easting: 529,294 mE
Northing: 6,849,887.65 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 1.3 mbgl

Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA	Alluvium		SILT: loose, light brown, no plasticity		Dry		0
				Silty SAND: loose, light to dark brown, very fine to medium grained, well graded		Dry		
				Silty CLAY: firm to stiff, orange-brown mottled		Moist		
			end of hole in stiff CLAY @1.3 mbgl					

Company:

Termination details: Borehole terminated at depth of 1.3 mbgl

Driller: Josh Radford

☒ Water strike/s intercepted during drilling

☒ Standing water level after drilling

☒ Field flow and water quality measurements

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 15 March 2023

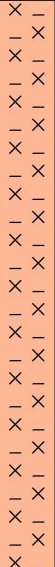
ID: HA_A2

Easting: 529,327.07 mE
Northing: 6,849,881.22 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A
Screen interval: N/A

Drilling method: Hand auger
Total depth: 2 mbgl

Standing water level: N/A
Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0				TOPSOIL/SILT: loose, grey to brown		Dry		0
				Silty CLAY: soft to firm, dark to light brown, low plasticity		Dry		
		Alluvium		CLAY: firm to stiff, orange-grey mottled, medium plasticity, massive		Moist		
2	62 mm HA			end of hole in stiff CLAY @2 mbgl				

Company:

Driller: Josh Radford

Termination details: Borehole terminated at depth of 2.0 mbgl

☒ Water strike/s intercepted during drilling

☐ Field flow and water quality measurements

✖ Standing water level after drilling

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 15 March 2023

ID: HA_B1

Easting: 529,477.76 mE
Northing: 6,849,375.73 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

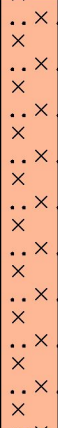
Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 1.3 mbgl

Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0				TOPSOIL: dark brown, loose				0
				Sandy SILT: loose, brown; sand is very fine to fine grained		Dry		
				SAND: very loose, brown-orange mottled, very fine to medium grained, well graded		Moist		
1						Saturated		
						Poor recovery below water table		
				SAND: end of hole in saturated sand @1.3 mbgl				

Company:

Termination details: Borehole terminated at depth of 1.3 mbgl

Driller: Josh Radford

 Water strike/s intercepted during drilling

 Standing water level after drilling

 Field flow and water quality measurements

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford

Date completed: 15 March 2023

ID: HA_B2

Easting: 529,453.59 mE
Northing: 6,849,404.96 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 1.4 mbgl

Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA			Silty CLAY: Soft, dark brown to grey, low plasticity; trace sand, fine		Moist		0
				Sandy CLAY: soft, dark brown, low plasticity, with tree roots		Dry		
				Sandy CLAY: firm, orange to brown, low plasticity; sand is very fine to fine grained		Dry to Moist		
1	end of hole in firm CLAY @1.4 mbal							

Company:

Termination details: Borehole terminated at depth of 1.4 mbgl

Driller: Josh Radford

☒ Water strike/s intercepted during drilling

☒ Standing water level after drilling

☒ Field flow and water quality measurements

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 14 March 2023

ID: HA_C1

Easting: 529,718.16 mE
Northing: 6,848,987.93 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 1.9 mbgl

Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)	
			Graphic	Description (See AS1726-2017)					
0	62 mm HA	Alluvium		TOPSOIL/Silty CLAY	Dry			0	
				Silty CLAY: soft, brown, low plasticity, massive					
1				Clayey SILT: Medium dense, light brown to orange, low plasticity	Dry				
				CLAY: stiff, dark brown, medium to high plasticity	Dry				
			end of hole in firm CLAY @1.9 mbgl						

Company:

Termination details: Borehole terminated at depth of 1.9 mbgl

Driller: Josh Radford

☒ Water strike/s intercepted during drilling

☒ Standing water level after drilling

☒ Field flow and water quality measurements

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 14 March 2023

ID: HA_C2

Easting: 529,722.57 mE
Northing: 6,849,012.12 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 2.1 mbgl

Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA	Alluvium		TOPSOIL: dark brown, loose	Dry	Increasing CLAY below 1 mbgl		0
				Silty CLAY: soft, light brown, low plasticity, crumbly texture, massive; trace fine grained sand				
				Clayey SAND: medium dense, light brown to orange, low plasticity; sand is very fine to fine grained				
-2			end of hole in clayey SAND @2.1 mbgl					

Company:

Termination details: Borehole terminated at depth of 2.1 mbgl

Driller: Josh Radford

☒ Water strike/s intercepted during drilling

☒ Standing water level after drilling

☒ Field flow and water quality measurements

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 15 March 2023

ID: HA_C3

Easting: 529,730.06 mE
Northing: 6,849,037.52 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 2.2 mbgl

Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA	Alluvium		TOPSOIL/Clayey SILT: brown	Dry	Dry		0
				Sandy SILT: loose, brown, no plasticity; with sand, very fine to fine grained				
				Silty SAND: very loose, light brown, very fine to medium grained, well graded				
				Clayey SAND: medium dense, dark brown, fine to medium grained, well graded; with silt				
1				trace charcoal @1.4-1.5 mbgl	Dry			
2				end of hole in Clayey SAND @2.2 mbgl	Slightly moist			

Company:

Driller: Josh Radford

Termination details: Borehole terminated at depth of 2.2 mbgl

☒ Water strike/s intercepted during drilling

☐ Field flow and water quality measurements

✖ Standing water level after drilling

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford

Date completed: 14 March 2023

ID: HA_C4

Easting: 529,736.54 mE
Northing: 6,849,052.96 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level: N/A

Screen interval: N/A

Total depth: 1.4 mbgl

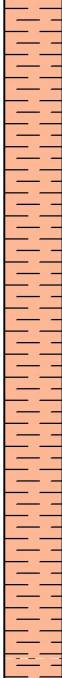
Date of water level: N/A

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA			TOPSOIL/Sandy CLAY: brown		Dry		0
				Sandy SILT: very loose, brown; sand is very fine to fine grained		Dry		
				SAND: loose, brown, very fine to fine grained, well graded, trace silt and clay	Dry			
							</	

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore		ID: HA_D1	
Project:	Clarrie Hall Dam EIS	Easting:	529,485.74 mE
Project number:	E230039	Northing:	6,848,130.21 mS
Client:	KBR Australia	Spatial reference:	MGA Zone 56
Site:	Doon Doon Creek	Elevation (collar):	N/A
Logged by:	Josh Radford	Elevation (ground):	
Date completed:	14 March 2023	Nominal diameter:	62 mm

Screened lithology:	N/A	Drilling method:	Hand auger	Standing water level:	
Screen interval:	N/A	Total depth:	1.35 mbgl	Date of water level:	

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA			TOPSOIL/Sandy CLAY: loose, brown, with grass roots		Dry		0
				Sandy CLAY: soft to firm, brown to light brown, low plasticity		Dry		
				CLAY: firm, dark brown, medium to high plasticity; trace very fine sand		Dry Slow penetration below 0.7 mbgl		
1				end of hole in firm CLAY @1.35 mbgl				

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Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 14 March 2023

ID: HA_D2

Easting: 529,436.69 mE
Northing: 6,848,134.54 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level:

Screen interval: N/A

Total depth: 2.1 mbgl

Date of water level:

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA	Alluvium		TOPSOIL: dark brown		Dry		0
				Sandy SILT: very loose, light brown; sand is very fine to fine grained				
								
								
								
								
								
								
								
								
								
								
								
								
								
1								
								
								
								
								
								
								
								
								
								
								
								
								
								
								
								
								

EMM Sydney Office
Level G, 20 Chandos Street
St Leonards NSW 2065
(02) 9493 9589

Soil bore

Project: Clarrie Hall Dam EIS
Project number: E230039
Client: KBR Australia
Site: Doon Doon Creek
Logged by: Josh Radford
Date completed: 14 March 2023

ID: HA_D3

Easting: 529,407.95 mE
Northing: 6,848,124.4 mS
Spatial reference: MGA Zone 56
Elevation (collar): N/A
Elevation (ground):
Nominal diameter: 62 mm

Screened lithology: N/A

Drilling method: Hand auger

Standing water level:

Screen interval: N/A

Total depth: 2.2 mbgl

Date of water level:

Depth (m)	Method	Formation	Lithology		Water obs.	Additional notes	Well completion	RL (mAHD)
			Graphic	Description (See AS1726-2017)				
0	62 mm HA			TOPSOIL	Dry			0
				Sandy SILT: loose, light brown; sand is very fine to fine grained				
				Silty SAND: loose, light brown to orange, no plasticity; sand is very fine to fine grained	Dry			
1				SAND: very loose, brown to orange, fine to medium grained; trace pebbles, fine	Dry			
				Gravelly SAND: loose, dark brown to brown, low plasticity, well graded; with fine to coarse volcanic gravel	Moist			
end of hole with refusal in GRAVEL @2.2 mbal								

Company:

Termination details: Borehole terminated at depth of 2.2 mbgl

Driller: Josh Radford

 Water strike/s intercepted during drilling

 Standing water level after drilling

 Field flow and water quality measurements

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