

ANICI Damian

From: sch4p4(6) Personal informati@upstream.originenergy.com.au>
Sent: Thursday, 7 May 2020 1:15 PM
To: SELLARS Amelia
Subject: RE: Information request for Denison Mahalo
Attachments: 200408_Mahalo TGDE Assessment.pdf

Follow Up Flag: Follow up
Flag Status: Flagged

Hi Amelia,

See below for the information requested:

The application supporting material describes the ecosystem dependency on groundwater spatially, however does not describe temporal dependency. Confirm whether there are any temporal changes to ecosystem dependency on groundwater

Section 5.3.1.5 GDEs of the Supporting Information Report describes the mapped GDEs within the petroleum leases and potential dependency on groundwater for ecosystem function, however does not describe any potential dependencies on groundwater for GDEs outside of the petroleum leases that may be impacted. Please confirm that there are no potential impacts to mapped GDEs outside of the petroleum lease area that may be impacted by the exercise of groundwater rights

The attached provides additional assessment of RE dependency on groundwater. This extra work confirms that:

- groundwater levels are too deep for REs to be reliant/dependent on this groundwater; or
- riparian vegetation is unlikely to be dependent on groundwater.

In terms of temporal dependency of these REs on groundwater, the work demonstrates limited potential for interaction over time (e.g. seasonal variation in groundwater levels) given:

- the significant depth to groundwater compared to the maximum potential root depth of REs; and
- surface water availability.

The attached includes an assessment of REs both within and outside of the PLs and confirms no potential significant impacts from the exercise of underground water rights.

The application supporting material describes the regional and local groundwater quality, distribution of potential Groundwater Dependent Ecosystems (GDEs), springs within the project site, and potential drawdown to groundwater bores. Please describe ecological impacts (e.g. subsidence, changes to overland flow) to the environmental value of land and its use for irrigation, cropping, and agriculture that may occur due to the decline in water level and/or pressure as a result of the exercise of underground water.

While there is no confirmed subsidence resulting from coal seam gas development in Australia, this Independent Expert Scientific Committee (IESC) document (https://www.environment.gov.au/system/files/resources/e9b69ac4-647c-4bbc-84db-83642227ab0d/files/background-review-subsidence_0.pdf) details how subsidence is least likely where production involves:

- minimal volumes of produced water;
- there is limited connectivity between the coal seams and adjoining formations; or
- the overlying strata are dominated by sandstone and other more competent rocks.

Minimal volumes of produced water

Section 5.3.1.1 of the of the Supporting Information Report for the EA amendment application provides a water production profile over the life of the PLs. This information demonstrates minimal water production of up to 2.2 ML/day compared to other CSG developments with up to 20+ ML/day of water production. This is partly due to the relatively few production wells proposed (up to 95 production wells) compared to larger gas developments (many hundreds of wells), and localised intra-seam faulting providing compartmentalisation acting as barrier to groundwater flow within the Bandanna Formation. The barrier effect is shown in Figure 6 of the Supporting Information Report showing a steep decline in water production from ~ Year 3 when groundwater within individual faulted 'compartments' is extracted with relatively small volumes of water subsequently entering these 'compartments'. Less than 0.2 ML/day of produced water is forecast for the most of the operational life of the PLs.

Limited connectivity between the coal seams and adjoining formations

Figure 5 of the Supporting Information Report provide the regional hydrostratigraphy within the PLs including the regionally present Rewan Group aquitard which limits connectivity between the Bandanna Formation and overlying aquitards. Drawdown results including those presented in the attached shows limited drawdown to overlying strata with a maximum of 1.6m of drawdown to shallow units with a thickness of approximately 30m. Keep in mind that this maximum drawdown prediction is very localised and based on the 95thile uncertainty analysis from the Surat CMA UWIR model – this represents a gross overestimation of drawdown due to the extreme values for hydraulic parameters used in OGIA's uncertainty analysis (e.g. hydraulic conductivity is increased by a factor of 5 over measured conductivity).

The overlying strata are dominated by sandstone and other more competent rocks

The overlying strata are not dominated by Sandstone and other competent rocks, however the limited water production and limited connectivity / drawdown to shallow units pose a limited risk of subsidence in the area. Accordingly, changes to existing overland flow regimes are not expected.

Existing land uses within the area are shown in Table 5.2 of the Water Assessment for the application:

Table 5.2 Summary of the Current Land Use within the Mahalo Development Area

Land Use Category			Area (km ²)	Percentage of Total Area
Primary	Secondary	Tertiary		
Conservation and natural environments	Other minimal use	Other minimal use	0.51	0.11%
		Residual native cover	3.15	0.67%
Production from dryland agriculture and plantations	Cropping	Cropping	31.47	6.71%
Production from relatively natural environments	Grazing native vegetation	Grazing native vegetation	433.70	92.46%
Water	Reservoir / dam	Reservoir / dam	0.23	0.05%
Total			469.05	100%

This table shows that 92% of the land use is grazing with limited cropping. The application demonstrates how produced water would be managed in accordance with existing EA limits (e.g. ANZECC) and/or EoW Code approvals (e.g. ANZECC) to maintain or enhance these existing land uses.

Limited impacts to groundwater bores are predicted due to groundwater drawdown. These bores would be managed in accordance with the *Water Act 2000* framework as described in Section 5.3.2 of the application including baseline assessments, and make good requirements if required.

Approval of the EA application does not change the need to gain new approvals or operate under existing approvals under the broader QLD environment and access framework including multiple approvals under the following:

- *Petroleum Act 1923 / Petroleum and Gas (Production and Safety) Act 2004* (e.g. CCAs)
- *Water Act 2000* (e.g. UWIR, baseline assessments, make good, water licencing)
- *Regional Planning Interests Act 2014* (e.g. RIDA in strategic cropping areas)
- *Waste Reduction and Recycling Act 2011* (e.g. End of Waste approvals for beneficial use of produced water such as dust suppression and irrigation)

The GasFields Commission provides a handy summary of the broader QLD environment and access framework (<https://gasfieldscommissionqld.org.au/gas-industry/regulatory-framework>).

Queensland's land access laws provide a balance between economic development and landholder rights. These laws mean that a resource authority holder, and its staff or agents, cannot generally enter private land to undertake advanced activities unless they have entered into one of the following: a Conduct and Compensation Agreement, a Deferral Agreement, or an Opt-Out Agreement with the affected landholder. Resource companies conducting exploration activities must also comply with the conditions of the Land Access Code 2016, which provides best practice guidelines for communication between resource companies and landholders, and imposes mandatory conditions on resource companies conducting activities on land. These mandatory conditions relate to key concerns landholders have regarding induction into the landholder's specific land access conditions, access points, use of roads and tracks, activities conducted around livestock and property, weeds and declared pests, camps, items brought onto land and gates, grids and fences. For more information about land access, refer to the publication: A guide to land access in Queensland. A Land Access Ombudsman was also established in 2018 as an independent, impartial body to help landholders and resource companies resolve alleged breaches of conduct and compensation agreements and make good agreements. The GasFields Commission Queensland is an independent statutory body that facilitates stakeholder connections as well as engaging with and informing the community about aspects of Queensland's petroleum and gas industry.

The Water Assessment Report prepared by Klohn Crippen Berger in September 2019 assesses the potential water-related impacts of up to 95 gas production wells, however the application is for up to 190 wells. Please provide information on further impacts (including both spatial and temporal) associated with the additional wells not described in the report.

While the Water Assessment Report described 95 production wells, the UWIR model used to simulate groundwater drawdown modelled complete dewatering of the Bandanna Formation coals by assigning fixed-pressure boundary conditions (using the MODFLOW-USG drain package) within the area of the PLs. This is a highly conservative modelling approach of the UWIR which results in an overestimation of water production and associated drawdown predictions. This modelling approach is further described in Section 2.3.3 and 3.3.3 of the Surat CMA UWIR modelling report:

https://www.dnrme.qld.gov.au/_data/assets/pdf_file/0008/1460627/groundwater-modelling-report-surat-cma.pdf

Due to this modelling approach, the findings of the groundwater impact assessment are independent of the number of wells proposed by the amendment application. The number of proposed wellpads for the application is more relevant to surface disturbance and potential ecological impacts.

The Water Assessment Report prepared by Kohn Crippen Berger in September 2019 relies heavily on data from the 2019 Surat Cumulative Management Area Underground Water Impact Report (UWIR), which was not approved until 12 November 2019. Were there any material changes between the use of the draft 2019 UWIR and the final approved UWIR?

The groundwater model for the 2019 UWIR was utilised to simulate water production within the area of the PLs prior to the approval of the UWIR. The OGIA have advised that minimal or no changes were made to the model following simulation of groundwater extraction within the PLs. The consultation report for the UWIR describes changes made during the consultation process limited to text changes to the report only (e.g. no modelling changes required):

https://www.dnrme.qld.gov.au/_data/assets/pdf_file/0006/1461237/uwir-submissions-summary.pdf

I'm happy to provide more info if required.

Cheers,

sch4p4(6) Pers

Strategic Approvals | Exploration & New Ventures

Origin

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I pay my respect to the Traditional Owners whose land we live and work on. I acknowledge their Elders - past, present and emerging.

From: SELLARS Amelia <Amelia.Sellars@des.qld.gov.au>
Sent: Wednesday, 29 April 2020 3:26 PM
To: sch4p4(6) Personal informat@upstream.originenergy.com.au>
Subject: Information request for Denison Mahalo

Hi sch4p

Apologies for not attending this morning's meeting, I was in another meeting with Rachel and Clancy but I am officially back with the team now.

I've attached the information request for Denison Mahalo that Clancy signed off today.

Let me know if you have any questions.

Cheers



Amelia Sellars
Principal Environmental Officer
Energy and Extractive Resources
Environmental Services and Regulation
Department of Environment and Science

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8 April 2020

APLNG Pty Ltd
Email Delivery: [sch4p4(6) Per]@upstream.originenergy.com.au

[sch4p4(6) Perso]

Strategic Approvals – Exploration & New Ventures

Dear [sch4p4(6) Per]

Mahalo Development Area TGDE Drawdown Impact Supplementary Information

1 INTRODUCTION & BACKGROUND

Predicted groundwater level drawdown, as a result of proposed gas development at Australian Pacific LNG Pty Ltd's (APLNG) Mahalo Development Area (the Project), was completed by the Office of Groundwater Impact Assessment (OGIA). Simulation of the Project development was completed using OGIA's Surat Cumulative Management Area (CMA) groundwater model, with results comprising the base case drawdown prediction and uncertainty analysis results. These results were provided in the Mahalo Development Area Water Assessment Report (KCB, 2019), along with the interpretation of potential impacts to terrestrial groundwater dependent ecosystems (TGDE) as a result of the predicted drawdown. The water assessment report was provided to the Department of Agriculture, Water and the Environment (DAWE), formerly the Department of Environment and Energy (DoEE), in September 2019.

Following a review of the water assessment report DAWE requested additional information regarding potential impacts to potential TGDEs as a result of the Project development. This supplementary letter provides additional localised information regarding the predicted groundwater level drawdown within the vicinity of mapped TGDEs.

2 OGIA MODEL RESULTS

The predicted groundwater level drawdown results provided by OGIA for the Project development comprised a "Base Case" groundwater level drawdown, which are predictive results based on the calibrated parameters for the model domain; and, uncertainty analysis groundwater level drawdowns based on a null space Monte Carlo (NSMC) approach for uncertainty analysis. The water assessment report presented potential drawdown impacts based on the "Base Case" groundwater level drawdown, however, the potential drawdown impacts discussed in this document are based on the 95th percentile drawdown results from the uncertainty analysis. It is important to note that the 95th percentile drawdown represents the 95th percentile of a statistical analysis of groundwater levels from 450 realisations of groundwater model parameter variations. Therefore, the drawdown extent presented as the 95th percentile would capture 95% of the drawdown extent from the 450 realisations. The remaining 5% of realisation results, beyond the

95th percentile are considered outliers. Therefore, the 95th percentile drawdown extent presented in the figures of this document represents the statistical upper-bound of predicted drawdown extent for the project development.

The drawdown results across the Project area, based on the 95th percentile uncertainty analysis from the model, is presented in Figure 2-1. The drawdown results indicate that the maximum 95th percentile drawdown within Layer 1 of the model ranges from 0.2 m to 1.6 m; with the 0.2 m drawdown contour extending approximately 10 km to the north of the Project area. In relation to areas of mapped TGDEs, there are two areas where the predicted 95th percentile drawdown coincides with mapped TGDEs, and these are located to the north of the Project area (Northern Drawdown Area) and along Shotover Creek, within the Project area. Further discussions on these mapped TGDEs and the potential impacts on them as a result of the predicted 95th percentile drawdown is provided in the following sections.

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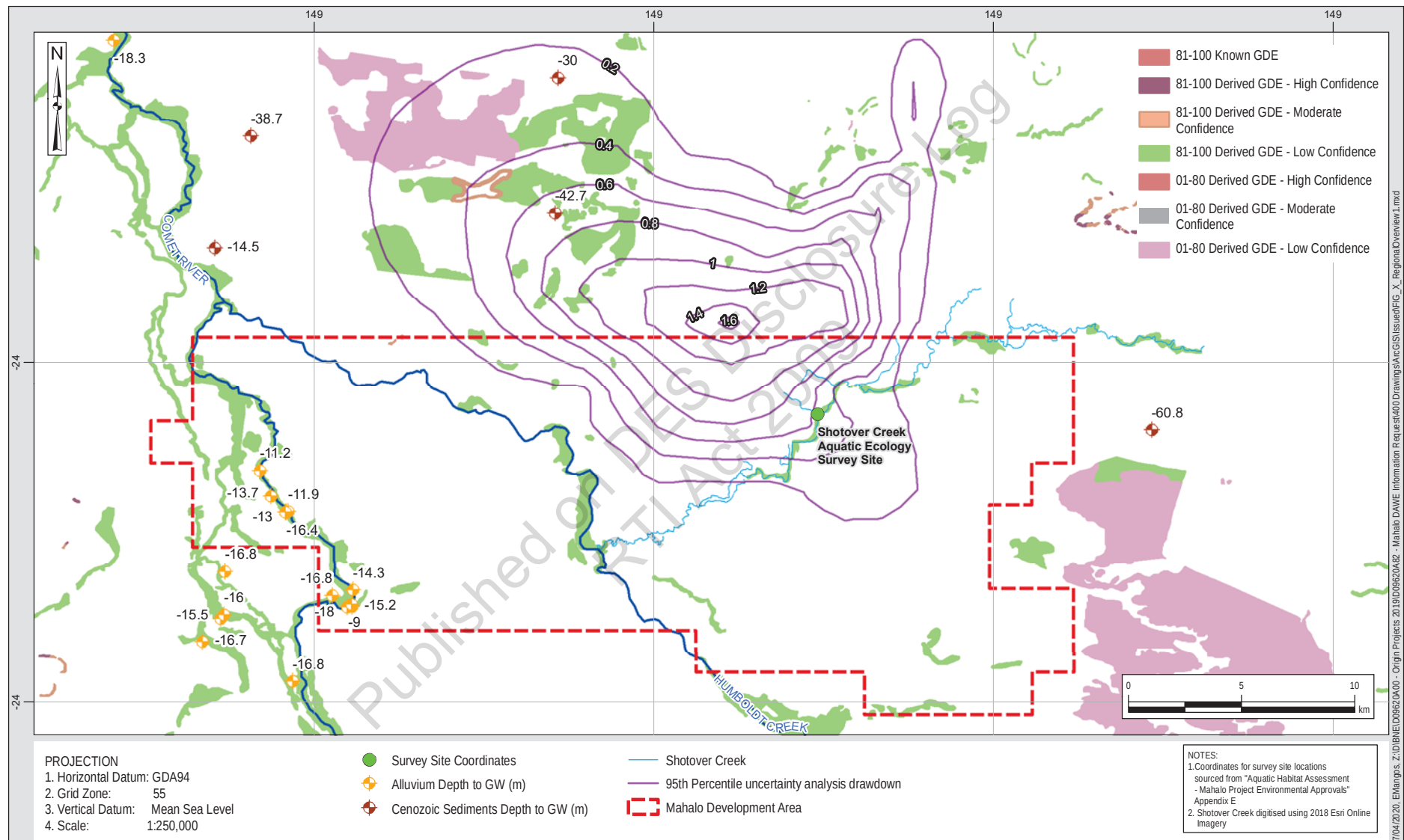


Figure 2-1: Predicted 95th Percentile Uncertainty Analysis Groundwater Level Drawdown (Layer 1) – Mahalo Development Area

3 TGDE IMPACT ASSESSMENT

The discussion surrounding potential impacts to the mapped TGDEs in the Northern Drawdown Area and along Shotover Creek, as a result of the predicted 95th percentile drawdown is provided in the following sections.

3.1 Northern Drawdown Area

Maximum predicted groundwater level drawdown (95th percentile) within the vicinity of the Northern Drawdown Area, and across the mapped TGDE within this area, ranges from approximately 0.2 m to 1 m (Figure 3-1). The Regional Ecosystem (RE), comprising both remnant and non-remnant ecosystems, mapped within the vicinity of the Northern Drawdown area comprise RE 11.4.8 (with dominant tree species *Eucalyptus cambageana*, *Acacia harpophylla*, *Acacia argyrodendron*, *Eremophila mitchellii*) and RE 11.5.3 (with dominant tree species *Eucalyptus populnea*, *Eucalyptus melanophloia*, *Eucalyptus cambageana*, *Eucalyptus brownii*, *Corymbia clarksoniana*, *Corymbia dallachiana*). Based on these dominant tree species within the vicinity of the mapped potential TGDE area, the maximum rooting depth for this potential TGDE is limited to a depth of ~20 m (Eamus et. al. 2006).

The geology within the vicinity of the Northern Drawdown Area comprises Cenozoic Sediments from the surface to ~60 m below ground surface, followed by ~20 m of low permeability Rewan Formation, which is underlain by the Bandanna Formation. Groundwater in the Northern Drawdown Area is observed in the Cenozoic Sediments, with third-party groundwater bores installed and screened within the Cenozoic Sediments (bore locations provided in Figure 3-1). Monitoring of groundwater from these bores indicate that groundwater levels across the Northern Drawdown Area ranges from 30 m to 42.7 m below the ground surface.

The information provided above is summarised in Figure 3-2 as a stratigraphic column, which conceptualises the localised hydrogeological system. This figure highlights the vertical separation / offset between the maximum rooting depth of the identified dominant tree species and the observed groundwater level in the area; with the groundwater level occurring ~22 m below the maximum rooting depth of the identified tree species. As a result, the TGDE identified within the Northern Drawdown Area are not considered to be dependent upon the regional groundwater system, and therefore, are not considered to be impacted by the predicted 95th percentile drawdown resulting from the Project development.

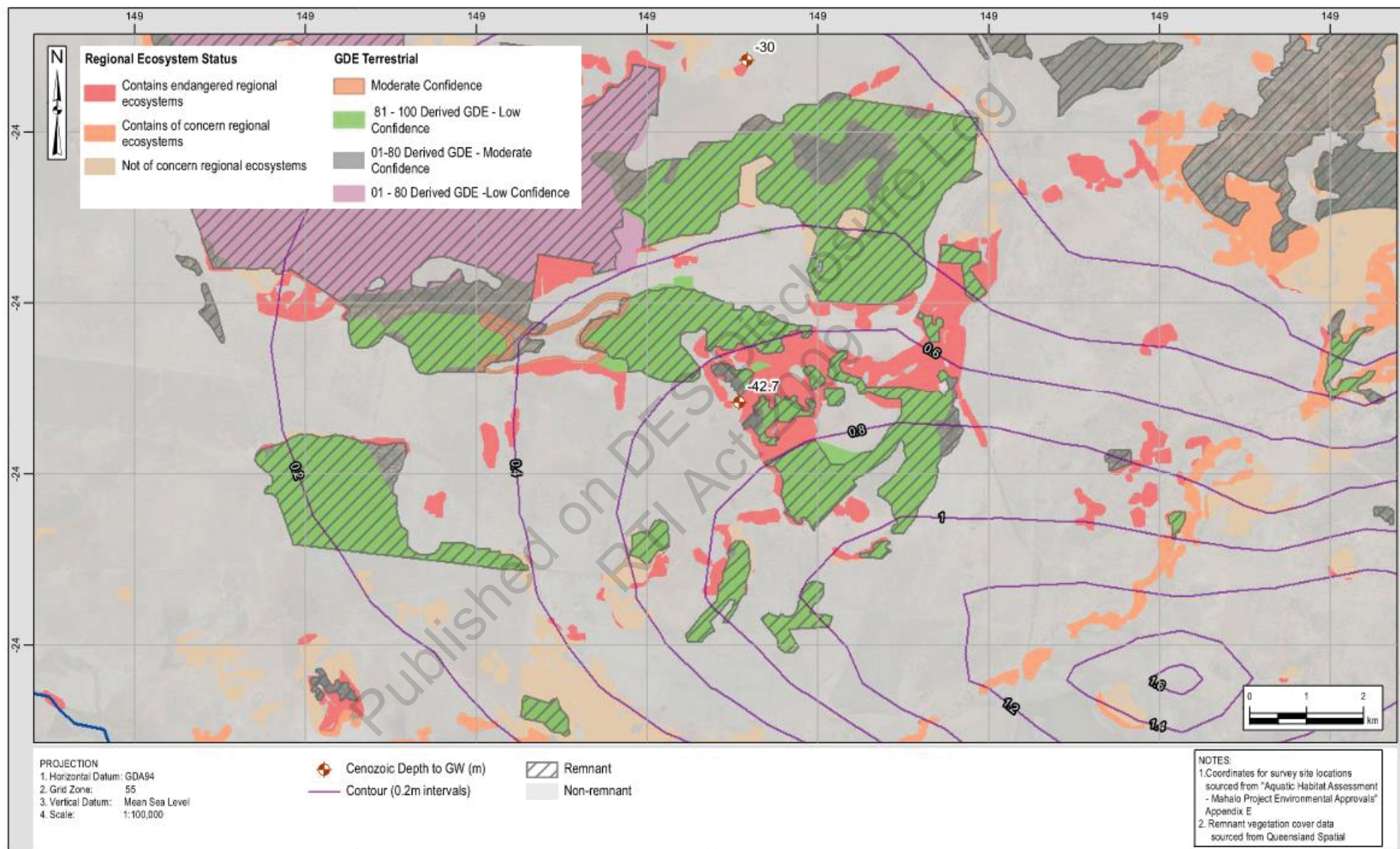
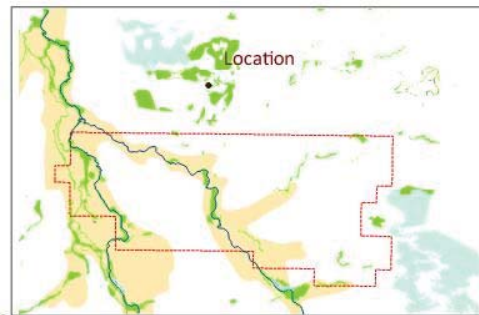
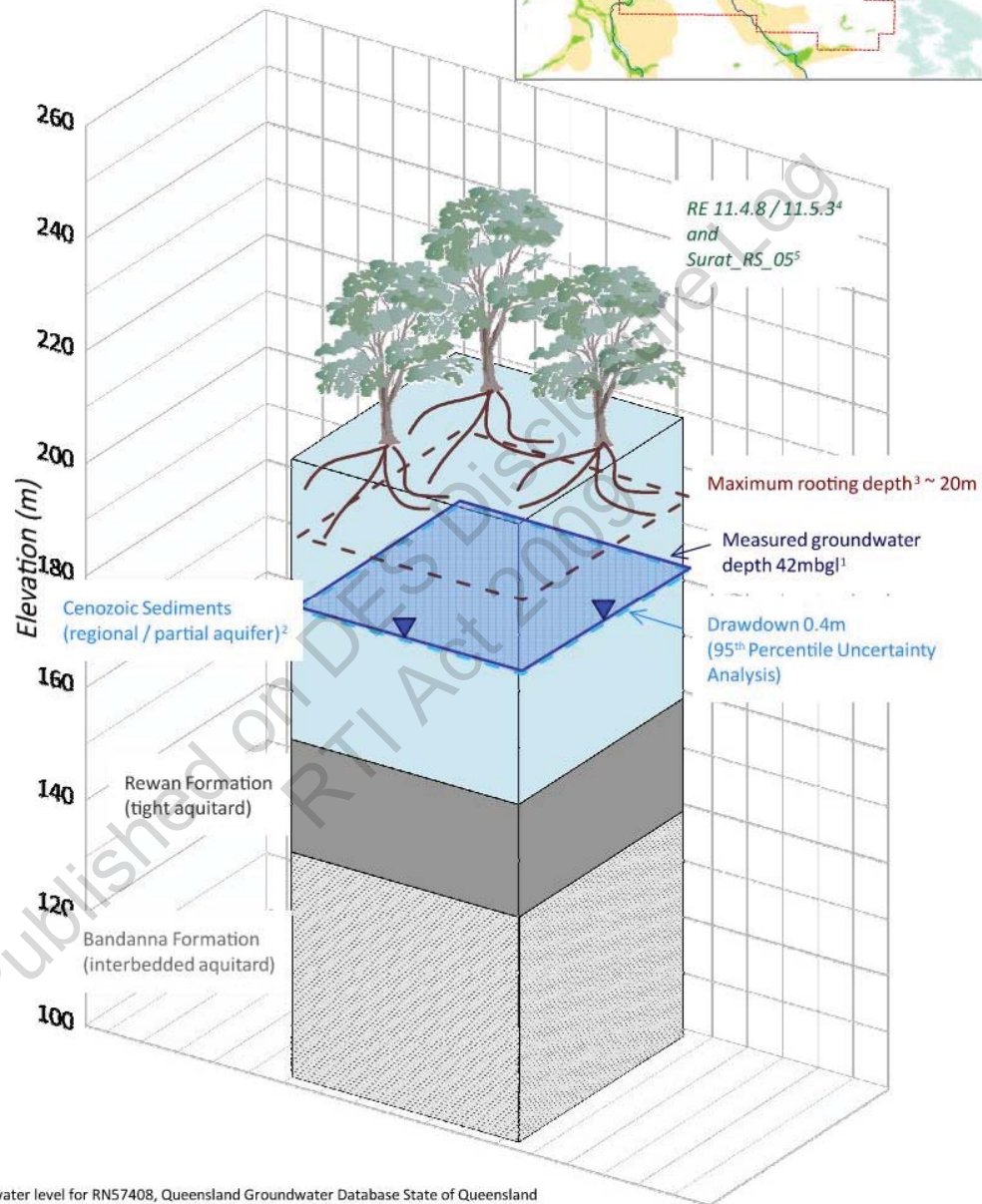


Figure 3-1: Predicted 95th Percentile Uncertainty Analysis Groundwater Level Drawdown (Layer 1) – Northern Drawdown Area

Dominant Tree Species in RE 11.4.8
Eucalyptus cambageana, Acacia harpophylla, Acacia argyrodendron, Eremophila mitchellii

Dominant Tree Species in RE 11.5.3
Eucalyptus populnea, Eucalyptus melanophloia, Eucalyptus cambageana, Eucalyptus brownii
Corymbia clarksoniana, Corymbia dallachiana⁴



1. Measured groundwater level for RN57408, Queensland Groundwater Database State of Queensland (Department of Natural Resources, Mine and Energy) 2020.
2. Aquifer classification from Section 3.3 page, Figure 3-6, UWIR Office of Groundwater Impact Assessment July 2019.
3. Kath, J, K Reardon-Smith, AF Le Brocque, FJ Dyer, E Dafny, L Fritz, and M Batterham. 2014. "Groundwater Decline and Tree Change in Floodplain Landscapes: Identifying Non-Linear Threshold Responses in Canopy Condition." Global Ecology and Conservation 2: 148–60
4. Regional ecosystem descriptions - Remnant regional ecosystems are vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. State of Queensland (Department Environment and Science) 2018.
5. Queensland Government (2017) Groundwater dependent ecosystem mapping rule-sets for the Comet, Dawson and Mackenzie River catchments: version 1.5, Queensland Government, Brisbane.

Figure 3-2: Conceptual Hydrogeological Stratigraphic Column

3.2 Shotover Creek

Maximum groundwater level drawdown (95th percentile) within the vicinity of the Shotover Creek area ranges from 0.4 m to 0.6 m (Figure 3-3). An ecological survey along Shotover Creek, and within the area of the predicted drawdown, has been previously undertaken. The results from this survey are presented in a summary table in Figure 3-3, however, the dominant RE that has been identified in this area is RE 11.3.25, with *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines being verified as the most dominant vegetation type.

The geology within the vicinity of Shotover Creek is similar to what is observed at the Northern Drawdown Area, with a profile comprising Cenozoic Sediment, Rewan Formation and Bandanna Formation, however, the Rewan Formation is thicker in this area (~200 m thick). In addition to these geological units, Quaternary alluvium (Qa) has also been mapped within, and adjacent to, the drainage line of Shotover Creek. The extent of this alluvium is mapped from the confluence of Shotover Creek and Humboldt Creek to ~10 km upstream in Shotover Creek.

The closest groundwater level monitoring points to Shotover Creek is ~10 km to the northwest and ~10 km to the east, with groundwater levels of 42.7 m and 60 m below the ground surface, respectively (Figure 2-1). These observed groundwater levels are well below the maximum rooting depths (~20 m below ground surface) for the identified dominant tree species, *Eucalyptus tereticornis*, within the Shotover Creek area. Furthermore, field verification of the RE along Shotover Creek confirms that the riparian vegetation present along Shotover Creek represents RE 11.3.25 and not RE 11.3.2 as indicated by Government mapping. Attachment A provides confirmation of the RE for riparian vegetation along Shotover Creek contrasting against the mapped RE 11.3.2, as shown in Table 3.1.

Table 3.1: Shotover Creek RE Comparison (Field Verified vs. Mapped)

RE Code	Short Description	Dominant Tree Species	Landform Association	Wetland Association	Relevant Comments	Mapped GDE?
11.3.25 ¹ (field verified)	<i>Eucalyptus tereticornis</i> or <i>E. camaldulensis</i> woodland fringing drainage lines	<i>Eucalyptus tereticornis</i> (observed)	Occurs on fringing levees and banks of major rivers and drainage lines of alluvial plains throughout the region.	Riverine wetland or fringing riverine wetland.	Often associated with RE 11.3.2 which may occur on adjacent alluvial plains. In highly cleared subregions a narrow fringe of riparian vegetation is often the only surviving woody vegetation	No
11.3.2 ² (QLD Govt mapping)	<i>Eucalyptus populnea</i> woodland on alluvial plains	<i>Eucalyptus populnea</i>	Occurs on Cainozoic alluvial plains.	Palustrine wetlands (non-riverine or non-channel systems)	N/A	Yes

As shown in Table 3.1, RE 11.3.25 only occurs along drainage lines which indicates species dependence more on surface water than groundwater. Based on the observed regional groundwater levels, the field verified RE 11.3.25 surface water dependence, and the predicted 95th percentile groundwater level drawdown of less than 0.6m, the Project is not considered likely to impact the riparian vegetation (mapped as a potential TGDE) associated with Shotover Creek.

¹ <https://apps.des.qld.gov.au/regional-ecosystems/details/?re=11.3.25>

² <https://apps.des.qld.gov.au/regional-ecosystems/details/?re=11.3.2>

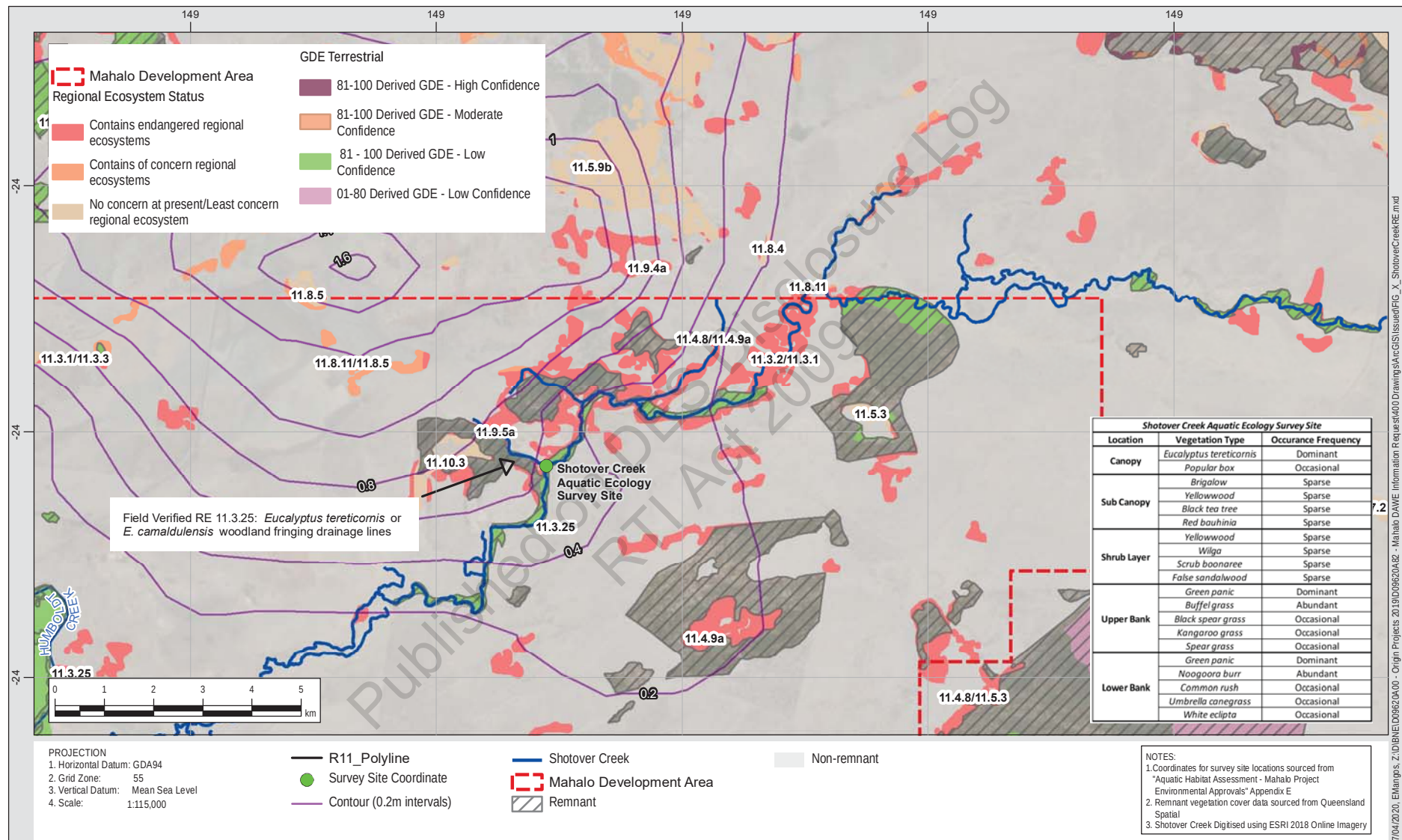


Figure 3-3: Predicted 95th Percentile Uncertainty Analysis Groundwater Level Drawdown (Layer 1) – Shotover Creek

4 DOCUMENT CLOSURE

KCB is pleased to provide this supplementary information regarding the potential drawdown impacts to TGDEs as a result of the Mahalo Development Area. Should you have any queries regarding this document, please do not hesitate to contact the undersigned on [sch4p4(6) Personal info] or [sch4p4(6) Pers]@klohn.com.

Yours truly,

KCB AUSTRALIA PTY LTD.



[sch4p4(6) Personal info]

Principal Hydrogeologist

[sch4p4(

REFERENCES

Eamus D, Froend R, Loomes R, Hose G and Murray B (2006). A functional methodology for determining the groundwater regime needed to maintain the health of groundwater dependent vegetation. Australian Journal of Botany 54: 97-114.

ATTACHMENT A

Shotover Creek Aquatic Habitat Assessment

Site Code: R11 **Location:** Shotover Creek, Humboldt **Stream order:** 4 **Latitude:** -24.1017 **Longitude:** 148.8137 **Date:** 20/02/2018 **Season:** Wet



Upstream



Left Bank



Downstream



Right Bank

General Site Description

Site attributes

Fourth order watercourse; well defined bed and banks; no local catchment erosion detected; bankfull width approximately 15 m and bankfull height approximately 3 m; isolated deep (>0.5 m) pool at the time of assessment; in-stream habitat included shallow pool, deep pool, large woody debris and fringing macrophytes; bed substrates comprised approximately 20% cobble (64-256 mm), 10% pebble (4-64 mm), 5% gravel (2-4 mm), 20% sand (0.05-2 mm) and 45% silt/clay (<0.05 mm); substrates in the edge habitat comprised approximately 20% cobble (64-256 mm), 10% pebble (4-64 mm), 5% gravel (2-4 mm), 15% sand (0.05-2 mm) and 50% silt/clay (<0.05 mm); clay loam banks; upstream and adjacent land use includes moderate cattle grazing on a mix of cleared land and remnant vegetation.

Aquatic and riparian vegetation

Study reach positioned within remnant vegetation state mapped as RE 11.3.2/11.3.1, but reflective of RE 11.3.25 – '*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines'; riparian vegetation included woodland dominated by Queensland blue gum (*Eucalyptus tereticornis*), with occasional poplar box (*E. populnea*); sparse sub-canopy of brigalow (*Acacia harpophylla*), yellowwood (*Terminalia oblongata*), black tea tree (*Melaleuca bracteata*) and red bauhinia (*Lysiphyllum carronii*); sparse shrub layer of yellowwood, wilga (*Geijera parviflora*), scrub boonaree (*Alectryon diversifolius*), false sandalwood (*Eremophila mitchellii*) and *Acacia* spp.; ground layer of the upper bank dominated by green panic (*Megathyrsus maximus*)*, with abundant buffel grass (*Cenchrus ciliaris*)*, occasional black spear grass (*Heteropogon contortus*) and kangaroo grass (*Themeda triandra*); ground layer of the lower bank dominated by green panic*, with abundant forest bluegrass (*Bothriochloa bladhii*) and Noogoora burr (*Xanthium occidentale*)*. Occasional fringing semi-aquatic macrophytes, including common rush (*Juncus usitatus*) (little), umbrella canegrass (*Leptochloa digitata*) (little) and white eclipta (*Eclipta prostrata*) (little).

Erosion risk

Low – banks appeared to be moderately stable, and 50-79% of surfaces covered by vegetation, gravel or larger material.

Aquatic fauna, including breeding habitat

The waterway provides seasonal, opportunistic habitat for waterfowl and wader birds, fish and turtles. Unlikely habitat for platypus.

Endangered, Vulnerable, Near Threatened (EVNT), Special Least Concern (SLC), or Priority flora and fauna

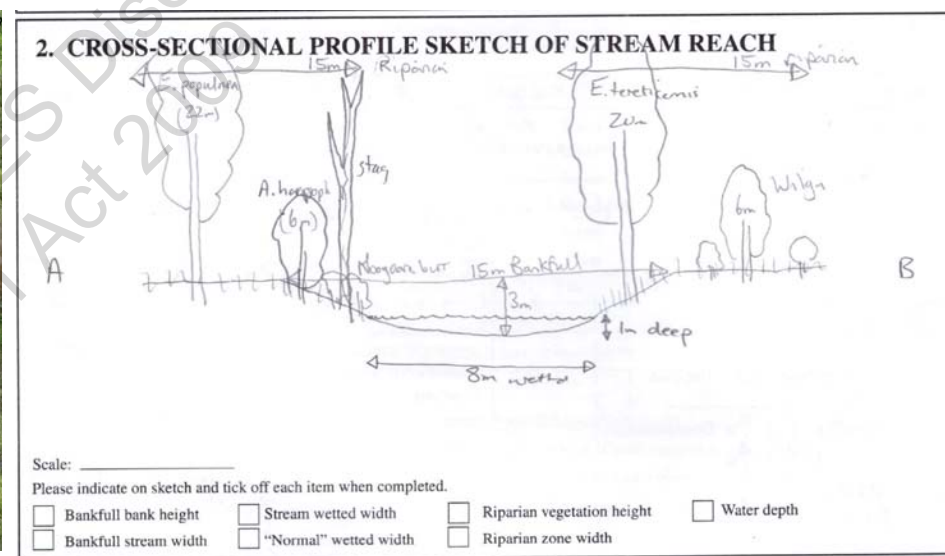
No EVNT, SLC or Priority aquatic flora or fauna species were detected at the time of the site visit (although no fauna survey effort undertaken). The Critically Endangered (EPBC Act) southern snapping turtle (*Elseya albagula*) and Vulnerable Fitzroy River turtle (*Rheodytes leukops*) are recorded from the Comet River drainage sub-basin (DES 2018). The waterway lacks habitat features suitable for these species.

Physico-chemical water quality

Collection time: 11:30 EST; water temp.: 29.4°C; specific conductivity: 130 $\mu\text{S}/\text{cm}$ (fresh); turbidity: 87 NTU (moderate to poor clarity); dissolved oxygen: 62.7%, 4.79 (low); pH 7.01 (neutral). Summary: Normal (low DO likely influenced by a combination of shading, time of day, poor light penetration into turbid water, lack of flow, and oxygen consumption by aerobic bacteria).

Overall aquatic values

Low.



Report

Environmental Authority EPPG00872113 Amendment Application - Supporting Information Report

Australia Pacific LNG Upstream

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1. Introduction

Origin Energy Resources Limited, as the upstream operator of Australia Pacific LNG Pty Ltd (Australia Pacific LNG) and Santos QNT Pty Ltd (Santos), as joint holders and operators of the Denison Trough/Mahalo tenures, are applying to amend Environmental Authority (EA) EPPG00872113. EA EPPG00872113 authorises petroleum activities within Authority to Prospect (ATP) 1191 and Petroleum Leases (PLs) 450, 451, 457 and 1012, situated within the Denison Trough, on the western flank of the Bowen Basin.

The EA amendment application comprises the following documents:

- Completed amendment application form; and
- Supporting Information Report (this document).

1.1. Overview

The proposed amendment seeks to:

- 1) Authorise PL1082 and PL1083 as additional resource tenures for the EA; and
- 2) Amend *Schedule A, Table 1 - Scale and Intensity for the Activities* to authorise 190 additional petroleum wells within PL1082 and PL1083.

In September 2019, Australia Pacific LNG and Santos applied to the Department of Natural Resources, Mines and Energy for the new PLs over the area of ATP1191. Section 121(1)(f) of the *Petroleum and Gas Act 2004* requires a relevant EA to be issued prior to the relevant minister granting the PL tenure.

1.2. Land Details

ATP1191 is located approximately 40 km north-northeast of Rolleston, in the Central Highlands Regional Council as shown on Figure 1.

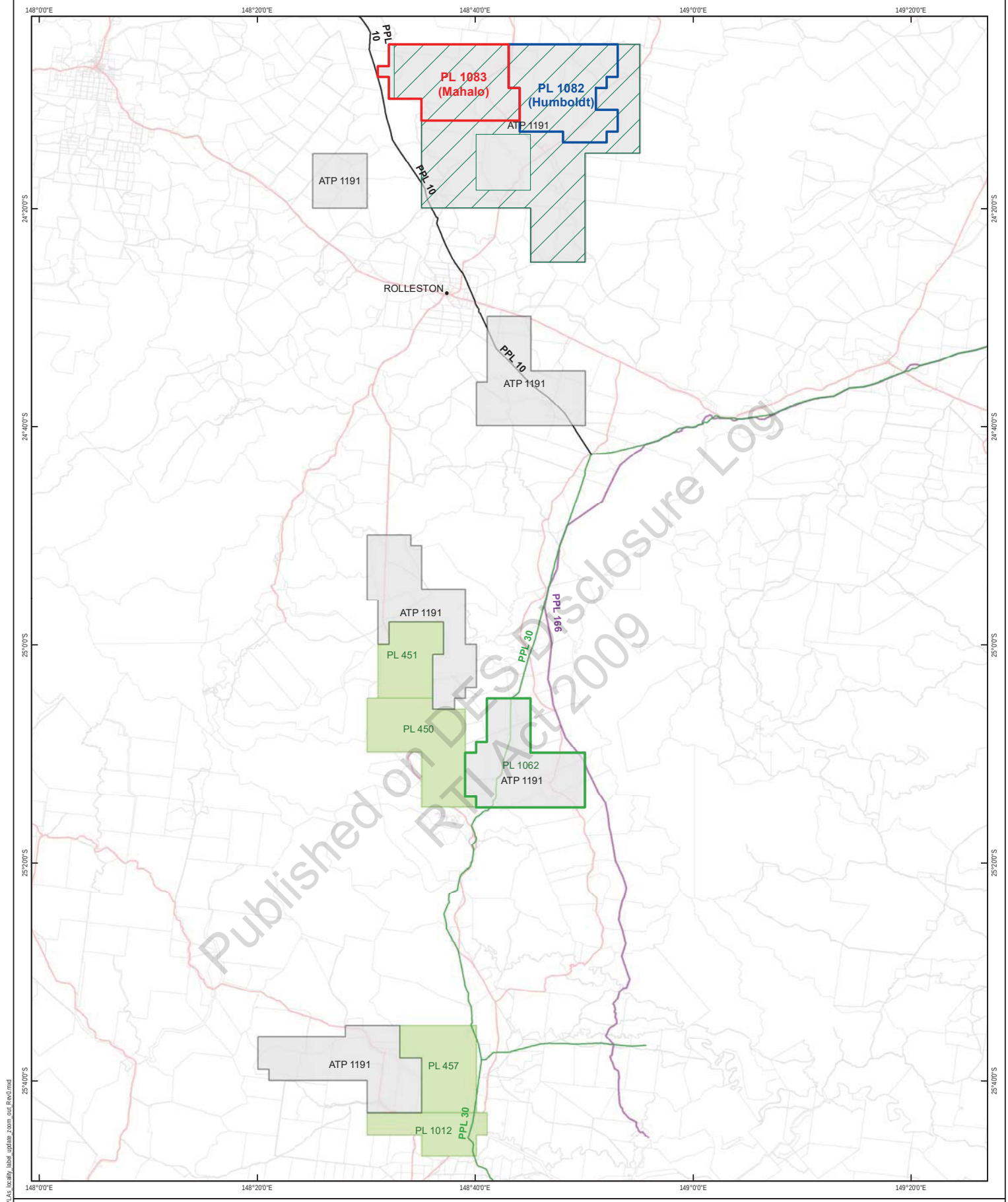
PL1082 and PL1083 are approximately 470 km² in size consisting of the contiguous sub-blocks shown in Table 1.

Table 1: Tenure Details

Tenure Details			
Tenure number	PL1082		
Tenure holders	Australia Pacific LNG Pty Limited Santos QNT Pty Ltd		
Status	Application		
Local Authority	Central Highlands Council, approx. 30km north east of Rolleston		
Sub-blocks	BIM: Charleville	BLOCK: 129	D, E, J, K, O, P, T, U, Z
		BLOCK: 130	A, B, C, D, E, F, G, H, J, K, L, M, N, O, P, Q, R, S, T, U, W, X, Y, Z
		BLOCK: 131	A, B, C, F, G, H, L, M, N, Q, R, V
		BLOCK: 201	E, K, P
		BLOCK: 202	A, B, C, D, E, F, G, H, J, K, L, M, N, O, P, T, U
		BLOCK: 203	A, F, G, H, L, M, N, Q, R
Tenure number	PL1083		
Tenure holders	Australia Pacific LNG Pty Limited Santos QNT Pty Ltd		
Status	Application		
Local Authority	Central Highlands Council, approx. 30km north east of Rolleston		
Sub-blocks	BIM: Charleville	BLOCK: 127	C, D, E, H, J, K, M, N, O, P, S, T, U, X, Y, Z

Tenure Details			
		BLOCK: 128	A, B, C, D, E, F, G, H, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z
		BLOCK: 129	A, B, C, F, G, H, L, M, N, Q, R, S, V, W, X, Y
		BLOCK: 200	A, B, C, D, E, F, G, H, J, K
		BLOCK: 201	A, B, C, D, F, G, H, J

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Legend

- Town
- Main Roads
- PPL 10, DENISON GAS (QUEENSLAND) PTY LTD
- PPL 30, JEMENA QUEENSLAND GAS PIPELINE (1) PTY LTD
- PPL 166, SANTOS GLNG PTY LTD
- PL 1083 (Mahalo) - Application
- PL 1082 (Humboldt) - Application
- PL 1062 (Arcadia West) - Application
- Petroleum Leases Granted out of ATP 1191 / ATP 337 (Santos QNT Pty Ltd)
- Mahalo Farm Out
- Authority to Prospect 1191 (ATP 1191)
- Cadastral Boundaries

Scale: 1:600,000 (at A3)

0 5 10 20 Kilometres

Coordinate System: GCS GDA 1994

Mahalo & Humboldt Petroleum Lease Applications Locality Map

Date: 13 August 2019

Map Number	Doc No	Rev
1 of 1	Map ID GISWR_67368	0

0	Issued For Use	sch4p4(6) Personal info	13/08/2019	20/06/2019		
A	Issued For Review					
Rev	Description	Drawn	Check	QA	Approved	Date

2. Proposed Amendment 1: PL1082 and PL1083

2.1. Scope

The scope of amendment 1 is to authorise petroleum production under PL1082 and PL1083 as additional resource authorities for the EA. The EA currently authorises petroleum exploration activities within ATP1191 and production activities within PLs 450, 451, 457, and 1012.

Authorised and incidental activities for ATPs and PLs are prescribed under Chapter 2, Part 1, Division 1, and Chapter 2, Part 2, Division 2 (respectively) of the *Petroleum and Gas (Production and Safety) Act 2004*. The authorised and incidental activities for ATPs and PLs are substantially the same; the key difference is that petroleum production (e.g. the sale of gas) is only authorised under PLs in accordance with s15(1) and s109(1)(c) of the *Petroleum and Gas (Production and Safety) Act 2004*. Refer to section 2.1.1 below.

2.1.1. Authorised activities under ATPs/PLs

The activities authorised (including incidental activities) under an ATP or a PL are substantially the same if authorised; the key difference being that *petroleum production* is only authorised under a PL (s109(1)(c)). Relevant excerpts of the *Petroleum and Gas (Production and Safety) Act 2004* are compared in **Table 2** below (emphasis added on s109(1)(c)).

Table 2: Authorised and Incidental Activities under ATPs and PLs

Authorised activities - ATP	Authorised activities - PL
Part 1 Authorities to prospect	Part 2 Petroleum leases
Division 1 Key authorised activities	Division 1 Key authorised activities
32 Exploration and testing	109 Exploration, production and storage activities
(1) The authority to prospect holder may carry out any of the following activities in the area of the authority—	(1) The lease holder may carry out the following activities in the area of the lease—
(a) exploring for petroleum;	(a) exploring for petroleum;
(b) testing for petroleum production;	(b) subject to section 152—
	(i) testing for petroleum production; and
(c) evaluating the feasibility of petroleum production;	(ii) evaluating the feasibility of petroleum production; and
	(iii) testing natural underground reservoirs for storage of petroleum or a prescribed storage gas;
N/A	(c) petroleum production;
(d) evaluating or testing natural underground reservoirs for the storage of petroleum or a prescribed storage gas;	(d) evaluating, developing and using natural underground reservoirs for petroleum storage or to store prescribed storage gases, including, for example, to store petroleum or prescribed storage gases for others;
(e) plugging and abandoning, or otherwise remediating, a bore or well the holder reasonably believes is a legacy borehole and rehabilitating the surrounding area in compliance with the requirements prescribed under a regulation.	(e) plugging and abandoning, or otherwise remediating, a bore or well the lease holder reasonably believes is a legacy borehole and rehabilitating the surrounding area in compliance with the requirements prescribed under a regulation.
(2) However, the holder must not carry out any of the following—	2) However, the holder must not carry out any of the following—
(a) extraction or production of a gasification or retorting product from coal or oil shale by a chemical or thermal process;	(a) extraction or production of a gasification or retorting product from coal or oil shale by a chemical or thermal process;
(b) exploration for coal or oil shale to carry out extraction or production mentioned in paragraph (a);	(b) exploration for coal or oil shale to carry out extraction or production mentioned in paragraph (a);
(c) GHG stream storage.	(c) GHG stream storage.
(3) The carrying out of activities mentioned in subsection (1), other than exploring for petroleum, is subject to section 73.	N/A

Authorised activities - ATP	Authorised activities - PL
(4) The rights under subsection (1) may be exercised only by or for the holder.	(3) The rights under subsection (1) may be exercised only by or for the holder. (4) The right to store petroleum or prescribed storage gases for others is subject to part 6.
33 Incidental activities (1) The authority to prospect holder may carry out an activity (an incidental activity) in the area of the authority if carrying out the activity is reasonably necessary for, or incidental to, an authorised activity under section 32(1) for the authority or another authority to prospect.	112 Incidental activities (1) The lease holder may carry out an activity (an incidental activity) in the area of the lease if carrying out the activity is reasonably necessary for, or incidental to— (a) another authorised activity for the lease; or (b) an authorised activity for another petroleum lease or an authority to prospect.
Examples of incidental activities— 1 constructing or operating plant or works, including, for example, communication systems, pipelines associated with petroleum testing, powerlines, roads, separation plants, evaporation or storage ponds, tanks and water pipelines	Examples of incidental activities— 1 constructing or operating plant or works, including, for example, communication systems, compressors, powerlines, pumping stations, reservoirs, roads, evaporation or storage ponds and tanks
2 constructing or using temporary structures or structures of an industrial or technical nature, including, for example, mobile and temporary camps	2 constructing or using temporary structures or structures of an industrial or technical nature, including, for example, mobile and temporary camps
3 removing vegetation for, or for the safety of, exploration or testing under section 32(1) Note— See also part 10, section 239, chapter 5 and section 20.	3 removing vegetation for, or for the safety of, exploration or testing under section 152(1) Note— See also part 10, section 239, chapter 5 and section 20(2).
(2) However, neither of the following activities is an incidental activity— (a) constructing or using a structure, other than a temporary structure, for office or residential accommodation; Note— For development generally, see the Sustainable Planning Act 2009, chapter 6.	(2) However, constructing or using a structure, other than a temporary structure, for office or residential accommodation is not an incidental activity. Note— For development generally, see the Sustainable Planning Act 2009, chapter 6 (Integrated development assessment system (IDAS)).
(b) the processing of gaseous petroleum, other than gaseous petroleum produced as an unavoidable result of ATP production testing. (3) In this section— gaseous petroleum means petroleum in a gaseous state. processing , of gaseous petroleum, means treating the petroleum to be suitable for transport.	N/A

Table 2 demonstrates that additional petroleum activities authorised by the proposed amendment are limited to *petroleum production* being the long-term operation of petroleum wells consistent with the s15(1) of the *Petroleum and Gas (Production and Safety) Act 2004*:

15 When petroleum is produced

(1) Petroleum is produced when it is—

(a) recovered to ground level from a natural underground reservoir in which it has been contained; or

(b) released to ground level from a natural underground reservoir from which it is extracted.

The existing operation of petroleum wells for exploration is authorised consistent with s14 of the *Petroleum and Gas (Production and Safety) Act 2004*.

3. Proposed Amendment 2: Additional petroleum wells

3.1. Scope

The scope of amendment 2 is to authorise 190 additional petroleum wells within PLs 1082 and 1083 in *Schedule A, Table 1* of the EA. The additional wells will be constructed and operated in accordance with the DNRME *Code of Practice the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland*¹. The code outlines mandatory requirements and good practice for drilling and completion of gas wells to ensure long-term well integrity and protection of groundwater resources including the many mandatory and best practice requirements detailed in Section 5.

Ancillary activities will be undertaken for the additional wells, including the following:

- Installation, operation and maintenance of gas and water gathering flowlines.
- Installation, operation and maintenance of associated supporting infrastructure (e.g. access roads, power and communication systems, laydowns, stockpiles and storage areas).
- Management of produced water.
- Decommissioning and rehabilitation of infrastructure and disturbed areas.

All infrastructure is offered to landholders in the first instance to allow them to leverage the infrastructure for their operations. If the infrastructure is no longer required, it will be removed and re-used, recycled, or disposed of. The disturbed area will then be rehabilitated in accordance with the current EA conditions.

3.1.1. Location of additional wells

Consistent with the existing EA conditions, well sites will generally be constructed in an operational area of up to approximately 1.2 ha for the initial construction of the well. Following construction, sites will be partially rehabilitated, leaving an area of up to approximately 0.4 ha allowing for well maintenance if required during operation of the well. Following drilling and completion, a pump will be installed to dewater the coal seam and facilitate gas production.

Well sites would be located in accordance with the existing land disturbance and water management conditions of the EA (e.g. Schedule F, and Schedule G), including avoidance of the following:

- endangered regional ecosystems (REs);
- nature refuges and koala habitat including a 200m buffer / protection zone;
- essential habitat;
- essential regrowth habitat;
- of concern REs;
- wetlands of high ecological significance including a 200m buffer / protection zone;
- wetlands of other environmental value; and
- watercourses.

In accordance with existing Condition F8 of the EA, well sites would also be located and designed with reference to the Queensland Environmental Offsets Policy Significant Residual Impact Guideline² to avoid significant residual impacts to prescribed environmental matters. Additional environmental design requirements are detailed in Section 5.

¹ https://www.dnrme.qld.gov.au/data/assets/pdf_file/0006/1461093/code-of-practice-petroleum-wells-bores.pdf

² https://environment.des.qld.gov.au/data/assets/pdf_file/0017/90404/significant-residual-impact-guide.pdf

An internal disturbance approval process ensures the project execution aligns with conditions of approvals and management commitments, particularly avoidance of key environmental impacts where there are reasonable and practicable design alternatives. The disturbance approval process occurs over a number of stages:

1. **Preliminary concept developed** - Conceptual Layout (well spacing, number, type) is designed based on reservoir modelling
2. **Constraints assessment** - Conceptual layout is updated giving consideration to the constraints including an environmental constraint assessment (ecology assessment/EA conditions), landholder requirements and engineering constraints
3. **Layout finalised** - A final site assessment to assess the proposed infrastructure locations and the layout is finalised
4. **Approvals obtained** - Required approvals are obtained, for example, environmental authority approvals or land access; and
5. **Design completed** - Detailed design is completed and construction commences.

4. Legislative Considerations

4.1. Environmental Protection Act 1994

4.1.1. Application Requirements (s226)

Section 226 of the EP Act sets out the requirements for making an application to amend an EA. Table 3 lists these requirements and where they are addressed in the application material.

Table 3: s226 Application Requirements

Application requirement (s226)(1)	Where addressed in application material
(a) Made to the administering authority;	The application was made to the Department of Environment and Science
(b) Be in the approved form;	The approved form was used.
(c) Be accompanied by the prescribed fee;	The prescribed fee was paid to the Department of Environment and Science.
(d) Describe the proposed amendment;	Refer to section 2 and 0.
(e) Describe the land that will be affected by the proposed amendment; and	Sections 1.2, 3.1.1 and 0 describe the land that will be affected by the proposed amendment.
(f) include any other document relating to the application prescribed by regulation	N/A - No other documents have been prescribed
Application requirement (s226A)(1)	Where addressed in application material
(a) Describe any development permits in effect under the Sustainable Planning Act 2009 for the carrying out of the relevant activity for the authority;	N/A - There are no development permits in effect under SPA relevant to the carrying out of the resource activity.
(b) State whether each relevant activity will, if the amendment is made, comply with any eligibility criteria for the activity;	N/A - there are no eligibility criteria to the activity.
(c) If the application states that each relevant activity will, if the amendment is made, comply	N/A - there are no eligibility criteria to the activity.

with any eligibility criteria for the activity—include a declaration that the statement is correct;	
(d) State whether the application seeks to change a condition identified in the authority as a standard condition;	N/A - the application does not seek to change any conditions identified by the authority as standard conditions
(e) If the application relates to a new relevant resource tenure for the authority that is an exploration permit or GHG permit—state whether the applicant seeks an amended environmental authority that is subject to the standard conditions for the relevant activity or authority, to the extent it relates to the permit;	N/A - The application does not relate to an exploration permit or GHG permit. The application relates to a new petroleum production permit.
(f) Include an assessment of the likely impact of the proposed amendment on the environmental values, including:	Refer to section 5 of this Supporting Information Report.
(i) a description of the environmental values likely to be affected by the proposed amendment;	
(ii) details of any emissions or releases likely to be generated by the proposed amendment;	
(iii) a description of the risk and likely magnitude of impacts on the environmental values;	
(iv) details of the management practices proposed to be implemented to prevent or minimise adverse impacts; and	
(v) if a PRCP schedule does not apply for each relevant activity - details of how the land the subject of the application will be rehabilitated after each relevant activity ends;	Refer to 5.5.2 of this Supporting Information Report.
(g) Include a description of the proposed measures for minimising and managing waste generated by any amendments to the relevant activity;	N/A - Refer to Question 18 of the approved form submitted with this application.
(h) Include details of any site management plan or environmental protection order that relates to the land the subject of the application.	N/A - There are no known site management plans or environmental protection orders relating to the land the subject of the application.

4.1.2. Requirements for site-specific applications (s227)

In accordance with section 227 of the EP Act, an application must state the matters mentioned in section 126(1) and comply with section 126(2), if the application:

- relates to an environmental authority; and
- the proposed amendment would result in changes to the management of produced water; and
- the activity in an ineligible ERA.

Table 4 lists these requirements and where they are addressed in the application material.

Table 4: s126(1)/(2) Application Requirements

Application requirement (s126)(1)	Where addressed in application material
(a) the quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity;	Refer to section 5.3.1.1 Up to approximately 3,400 ML of produced water would be generated from the proposed additional wells at the forecast production rate shown in Figure 6
(b) the flow rate at which the applicant reasonably expects the water will be generated;	Refer to section 5.3.1.1
(c) the quality of the water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out;	Refer to section 5.3.1.2 and Table 10: <i>Regional Groundwater Quality</i>
(d) the proposed management of the water including, for example, the use, treatment, storage or disposal of the water;	Refer to section 5.5.2 Water volumes associated with the Project will be managed via the existing approvals under EA and / or End of Waste Codes under the <i>Waste Reduction and Recycling Act 2011</i> . Water management beneficial uses authorised by these approvals include: <ul style="list-style-type: none"> • dust suppression and construction; • irrigation; • landscaping and revegetation; and • stock watering.
(e) the measurable criteria (the management criteria) against which the applicant will monitor and assess the effectiveness of the management of the water, including, for example, criteria for each of the following— i. the quantity and quality of the water used, treated, stored or disposed of; ii. protection of the environmental values affected by each relevant CSG activity; iii. the disposal of waste, including, for example, salt, generated from the management of the water;	The measurable criteria are listed in section 5.5.2
(f) the action proposed to be taken if any of the management criteria are not complied with, to ensure the criteria will be able to be complied with in the future.	Refer to section 5.5.2. A review and update of the water management scheme for the project will be undertaken throughout a continuous improvement cycle that may be triggered by the failure to meet the management criteria.
Application requirement (s126)(2)	Where addressed in application material
The proposed management of the water can not provide for using a CSG evaporation dam in connection with carrying out a relevant CSG activity unless— (a) the application includes an evaluation of— i. best practice environmental management for managing the CSG water; and	N/A - Evaporation Dams are not authorised on Petroleum Leases.

ii. alternative ways for managing the water; and	
(b) the evaluation shows there is no feasible alternative to a CSG evaporation dam for managing the water.	N/A.

4.1.3. Exercise of underground water rights (s227AA)

In accordance with section 227AA of the EP Act, an application must state the matters mentioned in section 126A(2), if the application:

- Relates to a site-specific EA for a resource project that increases a petroleum lease; and
- The proposed amendment involves changes to the exercise of underground water rights.

Table 5 lists these requirements and where they are addressed in the application material.

Table 5: s126A(2) Application Requirements

Application requirement (s126A(2))	Where addressed in application material
(a) any proposed exercise of underground water rights during the period in which resource activities will be carried out under the relevant tenure;	The proposed amendment would result in the exercise of underground water rights associated with petroleum production.
(b) the areas in which underground water rights are proposed to be exercised;	The underground water rights are proposed to be exercised within PL1082 and PL1083.
(c) for each aquifer affected, or likely to be affected, by the exercise of underground water rights— i. a description of the aquifer; and	Section 0 and Figure 5 of the Supporting Information Report presents the regional hydrostratigraphy.
ii. an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers and surface water; and	Section 0 of the Supporting Information Report describes aquifer interactions.
iii. a description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights; and	Section 5.3 of the Supporting Information Report presents the areas and predicted water level decline.
iv. the predicted quantities of water to be taken or interfered with because of the exercise of underground water rights during the period in which resource activities are carried out;	Refer to Section 5.3.1.1.
(d) the environmental values that will, or may, be affected by the exercise of underground water rights and the nature and extent of the impacts on the environmental values;	Section 5.3 of the Supporting Information Report presents the environmental values for groundwater relevant to the proposed amendment.
(e) any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or	There are no impacts to groundwater quality proposed as part of this application.

after the period in which resource activities are carried out;	Section 5.3 of the Supporting Information Report presents the environmental values for groundwater relevant to the proposed amendment.
(f) strategies for avoiding, mitigating or managing the predicted impacts on the environmental values stated for paragraph (d) or the impacts on the quality of groundwater mentioned in paragraph (e).	Section 5.3 of the Supporting Impact Report describes groundwater management.

4.1.4. The Standard Criteria (EP Act)

The standard criteria (as defined by Schedule 4 of the EP Act) are required to be considered by the administering authority for both a major and minor amendment application. Refer to Table 6 for an assessment of the proposed amendment against the standard criteria.

Table 6: Standard Criteria (s241)

Schedule 4 EP Act	Relevance
<p><i>(a) the following principles of environmental policy as set out in the Intergovernmental Agreement on the Environment -</i></p> <p><i>(i) the precautionary principle;</i></p> <p><i>(ii) intergenerational equity;</i></p> <p><i>(iii) conservation of biological diversity and ecological integrity; and</i></p>	<p>The proposed amendments were contemplated within the context of intergenerational equity and sustainable development. The amendments will not result in significant or permanent impact to the existing environmental values of the PL area.</p> <p>Petroleum activities undertaken within the PLs will be conducted in accordance with the conditions of the EA and the mitigation measures described in Section 5 to conserve biological diversity and ecological integrity.</p> <p>The proposed amendments were contemplated within the context of the precautionary principle. The amendments do not pose a threat of serious or irreversible environmental harm, and scientific uncertainty does not exist as to the level of potential environmental harm as demonstrated in the supporting information provided with this amendment application.</p> <p>Compliance with the existing conditions of the EA and the mitigation measures described in Section 5 will be met during the conduct of authorised activities to achieve best practice environmental management (BPEM).</p>
<p><i>(b) any Commonwealth or State government plans, standards, agreements or requirements about environmental protection or ecologically sustainable development</i></p>	<p>The proposed activities will be undertaken in accordance with the applicable requirements of the following:</p> <ul style="list-style-type: none"> • EP Act • EPBC Act • <i>Petroleum and Gas (Production and Safety) Act (P&G Act)</i> • <i>Nature Conservation Act 1992 (NC Act)</i> • <i>Vegetation Management Act 1999 (VM Act)</i> • <i>Regional Planning Interests Act 2014</i> • <i>Water Act 2000</i> • <i>Environmental Offsets Act 2014</i> <p>The relevance of these Acts to this application is referenced throughout the supporting information.</p>
<p><i>(c) any relevant environmental impact study, assessment or report</i></p>	<p>Relevant assessments and reports are described throughout this supporting information report.</p>

Schedule 4 EP Act	Relevance
<i>(d) the character, resilience and values of the receiving environment</i>	Refer to Section 5.
<i>(e) all submissions made by the application and submitters</i>	N/A
<i>(f) Best Practice Environmental Management (BPEM) for activities under any relevant instrument, or proposed instrument, as follows-</i> <i>(i) an environmental authority;</i> <i>(ii) a transitional environmental program;</i> <i>(iii) an environmental protection order;</i> <i>(iv) a disposal permit;</i> <i>(v) a development approval;</i>	BPEM of the proposed activities will be achieved through compliance with the existing conditions of the EA and implementation of environmental management measures described in this report.
<i>(g) financial implications of the requirements under an instrument, or proposed instrument, mentioned in paragraph (g) as they would relate to the type of activity or industry carried out, or proposed to be carried out under the instrument;</i>	The EA holders will continue to provide adequate funds, equipment and staff time to comply with the existing conditions of the EA.
<i>(h) public Interest</i>	The extraction of oil and gas is in the public interest as it facilitates the production of energy required to meet the needs of customers in Queensland and other Australian States and Territories. Resources produced also generate taxes and royalties to the Queensland Government which provide an ongoing source of revenue to support Government services provided to the general public.
<i>(i) site management plan (SMP)</i>	There are no relevant SMPs applicable to this amendment application.
<i>(j) integrated environmental management system (IEMS) or proposed IEMS</i>	N/A
<i>(k) other matters prescribed under a regulation</i>	Refer to Section 4.2.

4.2. Environmental Protection Regulation 2019

4.2.1. Environmental Objective Assessment

Chapter 4 of the EP Reg describes the matters to be considered by the administering authority in making an environmental management decision. For the purposes of this amendment application, section 35 of the EP Reg requires the administering authority to:

- carry out an environmental objective assessment against the environmental objective and performance outcomes mentioned in Schedule 8, Part 3, divisions 1 and 2; and
- consider the environmental values declared under the EP Reg.

The proposed amendment would protect the environmental values of air, water, wetlands, noise and land as the application does not include the discharge of air, water or noise contaminants/emissions above the existing authorisations of EPPG00872113. In addition, there will be no alteration of the hydrology of wetlands above the existing authorisations of EPPG00872113.

Refer to Table 7 and Table 8 for an assessment of the proposed amendment against the environmental objectives and performance outcomes relating to groundwater and waste.

Table 7: Schedule 8, Part 3, Division 1 - Groundwater

Schedule 8, Part 3, Division 1 EP Reg	Relevance to amendment application
GROUNDWATER	
Environmental Objective	
The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.	Section 5.2 and 5.3 demonstrates the continued protection of environmental values of groundwater and associated surface ecological systems from the proposed amendments.
Performance Outcomes	
1 Both of the following apply— (a) there will be no direct or indirect release of contaminants to groundwater from the operation of the activity;	The proposed amendment does not include the release of contaminants to groundwater. Section 5.3 demonstrates the continued protection of environmental values of groundwater and any associated surface ecological systems from this amendment.
(b) there will be no actual or potential adverse effect on groundwater from the operation of the activity.	
2 The activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.	

Table 8: Schedule 8, Part 3, Division 1 - Waste

Schedule 8, Part 3, Division 1 EP Reg	Relevance to amendment application
WASTE	
Environmental Objective	
<i>Any waste generated, transported or received as part of carrying out the activity is managed in a way that protects all environmental values.</i>	The proposed amendment would result in the generation of produced water
Performance Outcomes	
1 Both of the following apply— (a) <i>waste generated, transported or received is managed in accordance with the waste and resource management hierarchy in the Waste Reduction and Recycling Act 2011;</i>	Refer to Section 6. Section 5 describes produced water management in accordance with the <i>Waste Reduction and Recycling Act 2011</i> .
(b) <i>if waste is disposed of, it is disposed of in a way that prevents or minimises adverse effects on environmental values.</i>	Sections 5 and 6 describe the beneficial use of produced water to prevent or minimises adverse effects on environmental values in accordance with conditions B7-B12 of the EA and/or approvals under the <i>Waste Reduction and Recycling Act 2011</i> .

4.2.2. Waste and Resource Management Hierarchy (Waste Reduction and Recycling Act 2011) (WRR Act)

Section 5 describes produced water management in accordance with the *Waste Reduction and Recycling Act 2011*.

4.2.3. Prescribed matters for particular resource activities (s24AA EP Regulation)

Section 226 of the EP Act specifies the general requirements for an EA amendment application. This includes item (1)(n) which specifies any other documents relating to the application prescribed under a regulation. Section 24AA of the EP Reg describes the prescribed documents for an application for environmental authority for a CSG activity. The proposed amendment includes the management of produced water via beneficial uses (e.g. Priority 1 uses in accordance with the DES CSG Water Management Policy).

4.3. Environmental Protection Policies (EPP)

Section 35 of the *EP Reg* requires consideration of the management hierarchy, the environmental values, the quality objectives and the management intent of all relevant EPPs. It is considered that the proposed activities will not impact on the environmental values and quality objectives of Air, Noise or Water as described in the Environmental Protection Policies.

4.3.1. Additional Regulatory Requirements (EPP)

Chapter 4 of the *EP Reg* includes additional regulatory requirements, which must be considered by the administering authority in making an environmental management decision where the management decision relates to an activity mentioned in either section 58 or 63. However, the amendment application does not relate to an activity mentioned in sections 58 or 63 of the EP Reg as there is no release of water or waste to wetlands for treatment, nor does the activity involve the direct release of waste to groundwater.

4.4. Environmental Offsets Act 2014

In accordance with s207(1)(c) of the EP Act, the administering authority may impose an environmental offset condition on an environmental authority. However, s14(2) of the *Environmental Offsets Act 2014* (EO Act) states that an offset condition may only be imposed on an environmental authority if the proposed activity will, or is likely to have a significant residual impact on the prescribed environmental matter, and all reasonable on-site mitigation measures for the prescribed activity have been, or will be, undertaken. The proposed additional wells will be located to avoid significant residual impacts on prescribed environmental matters as described in Section 2.

Condition F8 of the EA prohibits significant residual impacts to prescribed environmental matters associated with activities subject to this amendment application.

5. Relevant Environmental Values

The following provides a description of environmental values relevant to the amendment, as well as relevant potential impacts to environmental values and the management practices to be implemented. The current Denison/Mahalo EA EA00872113 authorises impacts to environmental values, and the proposed amendment does not substantially change the potential impacts to the environmental values, beyond what is authorised on the EA.

5.1. Air Quality

Environmental Objective (EP Reg): The activity will be operated in a way that protects the environmental values of air.

The proposed activity will be operated in a way that protects the environmental values of air. The proposed amendment does not change the potential impacts to the environmental values for air, beyond what is authorised on the EA. Petroleum activities on the new PL1082 and PL1083 will not cause an environmental nuisance from air emissions at a sensitive place, other than where an alternative arrangement is in place for potential nuisance impacts (condition A11).

5.1.1. Environmental Values

The EP Act provides the framework for the management of the air environment in Queensland. The *Environmental Protection (Air) Policy 2019* (EPP Air) sets the environmental values, as follows:

The environmental values to be enhanced and protected are quality of air environment that is conducive to:

- *Protecting the health and biodiversity of ecosystems;*
- *Human health and wellbeing;*
- *Protecting aesthetics of the environment, including the appearance of buildings, structures and other property; and*
- *Protecting agricultural use of the environment.*

Sensitive Places

There are no towns within the 470 km² area of the PLs and only 11 potential sensitive receptors located within PL1082 and PL1083. These sensitive receptors will be ground-truthed once the location is infrastructure and finalised. The relative scarcity of sensitive receptors within the PLs reflects the agricultural land use of the area.

Climate

The nearest Bureau of Meteorology monitoring station is located at the Rolleston Airport, approximately 20km south of the PLs. The climatic conditions over the area, particularly in relation to the generation of dust and the transport and dispersion of air pollutants, are summarised as follows:

- The prevailing wind direction for autumn, winter and spring is south to south easterly. The prevailing wind directions for summer are north east and southerly.
- The average wind speed is 2.5m/s, considered light on the Beaufort scale.
- Heaviest rainfall occurs between November and March of each year, with the highest average rainfall in December (96mm) and the lowest average rainfall in July (13.4) (data based on a five-year period)
- The warmest average monthly temperatures are from November to February, all above 25°C. The lowest temperatures are from June to August, with an average of 15.5°C.

Ambient Air Quality

The air quality within the development area and adjacent surrounds is considered to be consistent with a rural setting and therefore of high quality. Localised air quality impacts are from dust generated from stock movements, dust of natural origin, bushfires and controlled burns, vehicular movements on unsealed roads, and from other gas/mining operations in the region.

DES monitors ambient air quality in major population centres to assess compliance against the National Environment Protection (Ambient Air Quality) Measure (NEPM) and the EPP Air. The closest DES monitoring stations to the Denison/Mahalo tenures is located in Toowoomba. This monitoring station was operational from July 2003 to December 2010, and recorded ambient concentrations of oxides of nitrogen (NO/NO₂), carbon monoxide (CO), ozone (O₃) and fine particulate matter (PM₁₀ and PM_{2.5}). The Toowoomba monitoring station observations have been used to characterise the existing air quality in the development area for NO₂, CO and O₃. More recently, Origin Energy, as part of the GISERA Surat Basin Air Quality study, funded three air quality monitoring stations at Hopeland, Miles Airport and Condamine.

The highest maximum monthly concentration recorded at the Miles Airport has been adopted to represent background air quality for the PLs. Table 9 shows the background air quality and air quality objectives (based on Schedule 1 of the EPP Air). The background air quality levels show in Table 9 are considered to be a conservative estimate given the remote and rural nature of the area with no significant existing air emission sources apart from agricultural operations and existing petroleum exploration activities.

Table 9: Background air quality

Pollutant	Averaging Period	Concentration ¹ (µg/m ³)	Objective (µg/m ³)
NO ₂	1 hour	47	250
	Annual ²	4.1	62
CO	8 hours	1,500	11,000

Notes:

1 - The 70th percentile has been used to represent background concentrations of NO₂.

2 - The annual average is the highest annual average concentration from the monitoring period.

5.1.2. Environmental values assessment and mitigation measures

The proposed activity will be operated in a way that protects the environmental values of air. The proposed amendment does not change the potential impacts to the environmental values for air, beyond what is authorised on the EA. No new fuel burning or combustion facilities that will trigger ERA levels are proposed in this application.

Emissions to the ambient air environment from petroleum activities carried out on the development area include:

- Exhaust fumes from temporary use of generators, construction machinery and equipment;
- Fugitive emissions from wells and associated infrastructure; and
- Dust generated by construction machinery and equipment use and vehicle movements on site.

Through the implementation of the management practices listed below, the residual risk and magnitude of potential impacts to the air environment is considered low to negligible and limited in extent and duration.

Construction and operational controls

- Operation of the proposed wells and ancillary infrastructure will not require fuel burning equipment; this infrastructure would use electrically driven motors powered from the local electricity transmission network.
- Alternative arrangements will be entered into as required as specified under the EA.
- Sensitive receptors and sensitive environmental areas will be considered during development, through the siting of infrastructure based on environmental constraints, GIS data and landholder information, thereby ensuring infrastructure is preferentially located away from these areas.
- Emissions from vehicles, plant and equipment will be managed through regular maintenance to ensure all machinery is in good working order and does not generate excessive air emissions. Plant and equipment must be operated in their proper and effective condition.
- Fugitive emissions will be mitigated through appropriate well design and construction, undertaken in accordance with the acceptable industry standard, including compliance with the requirements of the DNRME *Code of Practice For the construction and abandonment of petroleum wells and associated bores in Queensland*³ and the *Code of Practice For leak management, detection and reporting for petroleum operating plant*⁴.
- Dust suppression measures will be implemented. Produced water may be used for dust suppression, in accordance with the EA conditions or an approval under the *Waste Reduction and Recycling Act 2011*.
- The disturbance area and duration of disturbance will be minimised through project design and planning, progressive disturbance, and progressive rehabilitation.
- Waste gas will be flared in accordance with Condition D1 of the EA.

Rehabilitation and Maintenance

- Disturbed areas will be rehabilitated as soon as reasonably practicable to minimise areas exposed to wind erosion and dust.
- All vehicles and machinery will be fitted with appropriate emission control equipment and will be maintained.
- Preventative maintenance programs will be implemented to ensure equipment operates efficiently.
- Low emissions technologies will be used, as appropriate.
- In the event of an environmental nuisance complaint, an incident report will be raised and investigated.
- Any complaints relating to air quality including environmental nuisance will be recorded in line with the EA conditions and actioned in a timely manner.

5.2. Water (surface water and wetlands)

Environmental Objective (EP Reg): The activity will be operated in a way that protects the environmental values of waters and wetlands.

The proposed activity will be operated in a way that protects the environmental values of waters and wetlands. The current EA conditions limit activities within wetlands, lakes, springs and watercourses,

³ https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0006/1461093/code-of-practice-petroleum-wells-bores.pdf

⁴ https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0009/1258038/code-of-practice-leak-management.pdf

and the proposed amendment does not change the potential impacts to the environmental values for waters and wetlands, beyond what is currently authorised.

5.2.1. Environmental values

Wetlands

A review of PLs 1082 and 1083 on the DES 'Wetland Info' website was undertaken. The area includes lacustrine and palustrine wetlands shown on Figure 2. Lacustrine wetlands are open water dominated systems (e.g. dams and lakes). In turn, palustrine wetlands lack open or flowing water (e.g. marsh or bogs).

There is one palustrine wetland mapped within the area listed as high ecological significance (HES). This HES wetland is located adjacent to the Comet River flow channel and may be considered as within the floodplain of the channel.

The lacustrine wetlands in most cases would provide water for farming activities including, but not limited to, livestock watering, and irrigation, and as a secondary means as a habitat for aquatic and terrestrial flora and fauna.

Watercourses

PLs 1082 and 1083 are located within the Comet River catchment consisting of a network of watercourses (Figure 2) that are largely ephemeral and typically only flow during and immediately after significant rainfall events. Larger watercourses such as the Comet River, may contain perennial waterholes isolated by dry river channels during the dry season. The Comet River sub-catchment is heavily influenced by anthropogenic pressures. The State of Rivers Survey identified that the catchment was regarded as being in a moderate to poor condition, with prominent bank instability caused by the presence of stock within the riparian zone, runoff, and vegetation clearing.

Flood modelling indicates that for a 1 in 100-year flood event, flooding may occur within the area in proximity to the Comet River and Humboldt Creek. Humboldt Creek is generally located at elevations greater than 300 m AHD and within broad, partially confined sinuous valleys and consisting of a single channel. This channel is predominately stable with sediment accumulation typically found as side or point bars. Located further downstream of this creek, and towards the Comet River, the geomorphology of these creeks becomes a laterally unconfined valley setting with a higher degree of sinuosity.

Surface water flow is monitored at DNRME gauging station 130506A in the Comet River located immediately downstream of the area. Flow data indicates the majority of the flow, up to approximately 160 ML/day, occurs during December to March in response to wet season rainfall events with little or no flow during other periods highlighting the ephemeral nature of the watercourse

Springs

There are no springs located within or nearby PLs 1082 and 1083 as shown on Figure 3. The nearest spring complex, Kullanda, sources water from the Clematis Group and is located approximately 20 km northeast of the PLs.

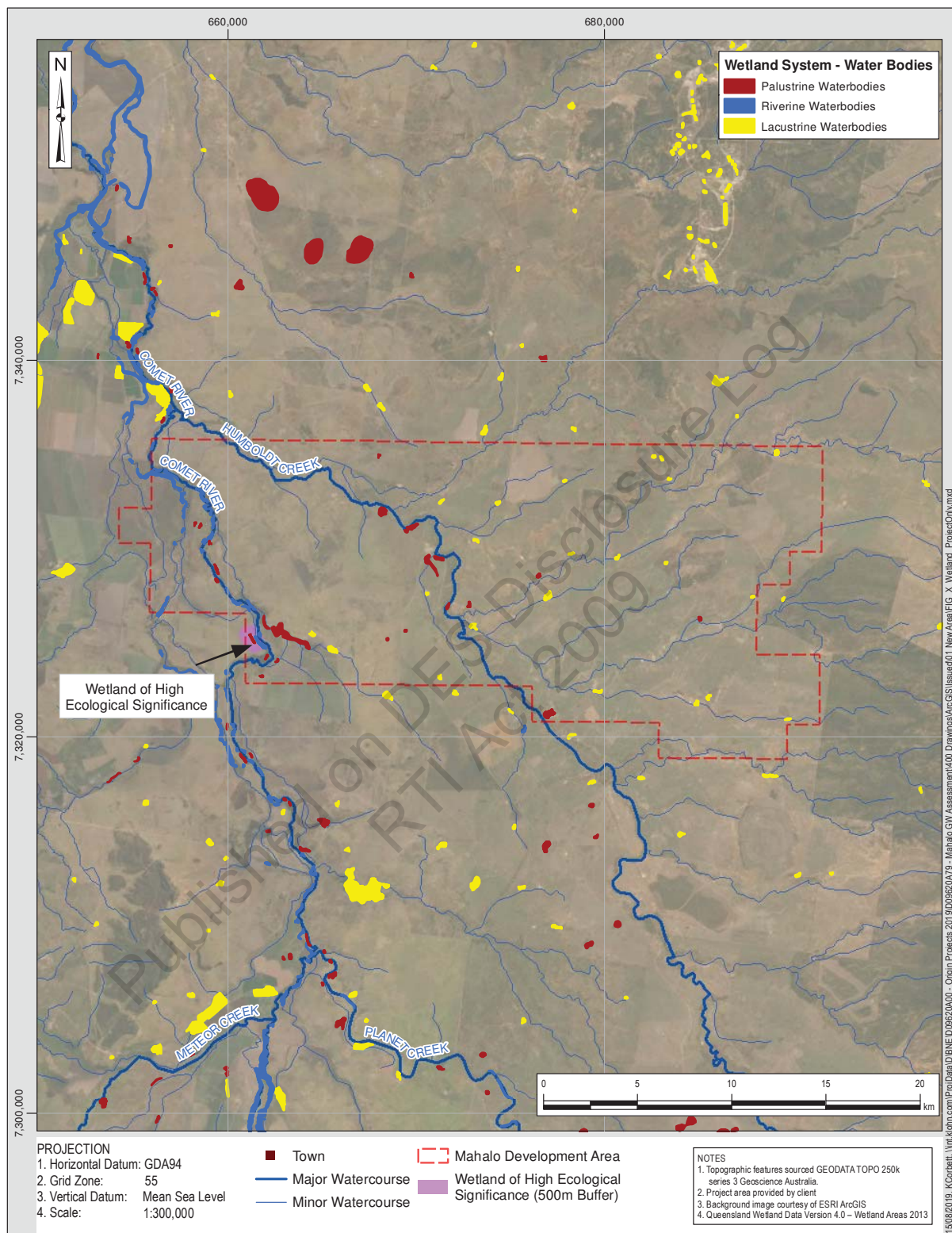


Figure 2 - Watercourses and Wetlands within PLs 1082 and 1083

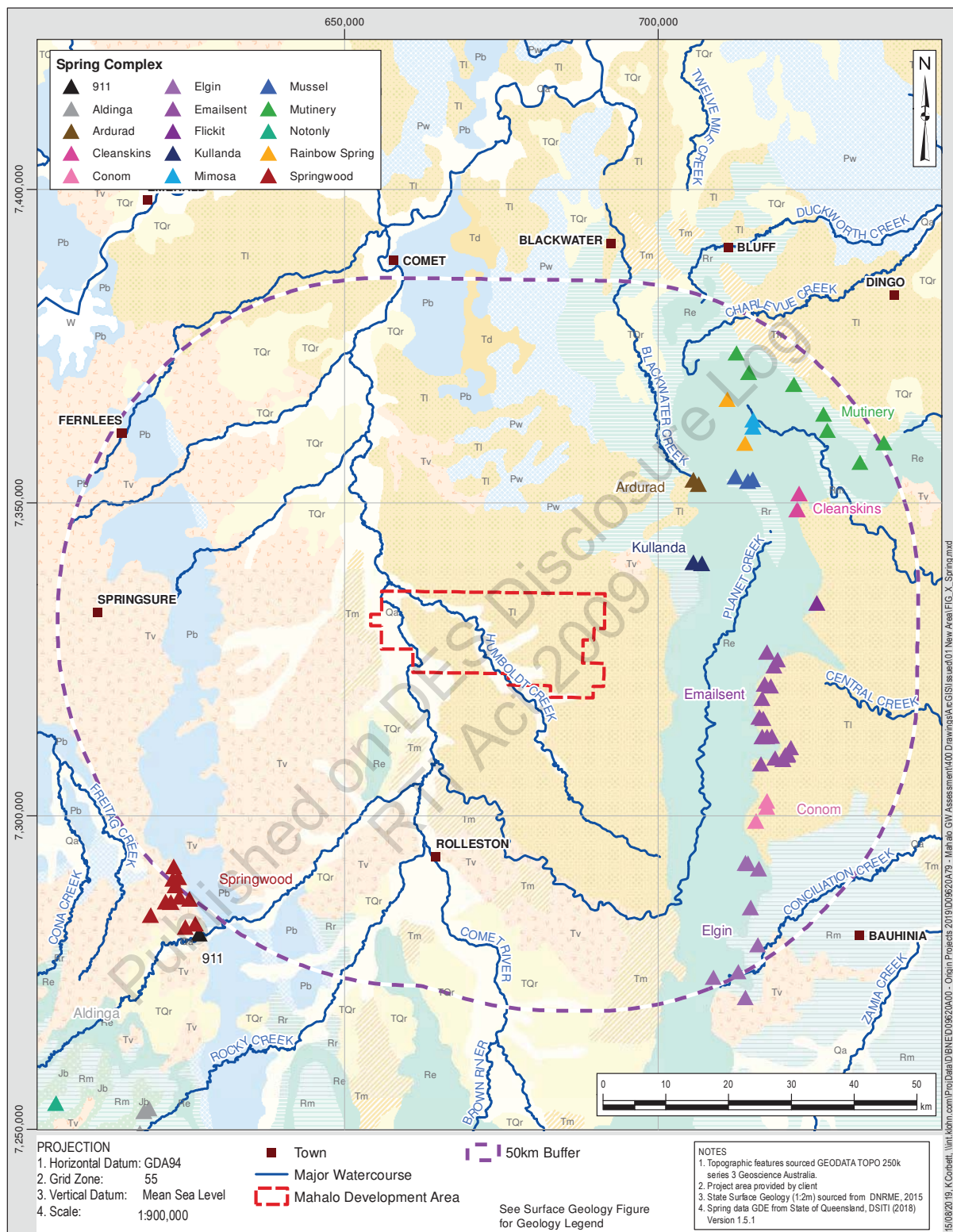


Figure 3 - Springs (not located within or nearby PLs 1082 and 1083)

5.2.2. Environmental values assessment and mitigation measures

Avoidance of Direct Disturbance

As described in Section 3.1.1, the additional proposed wells and associated infrastructure would be located in accordance with the existing water management conditions of the EA, including avoidance of the following:

- wetlands of high ecological significance including a 200m buffer / protection zone;
- wetlands of other environmental value; and
- watercourses.

There are no springs located within PLs 1082 or 1083.

No Surface Water Extraction

The proposed amendment does not include the extraction of surface water.

Produced Water Management

Produced water would be managed as described in Section 5.2, including no discharges to surface water. Irrigation beneficial uses of produced water would be managed to minimise localised runoff to avoid discharge to surface waters.

Floodplains

Well pads for the additional wells will be preferentially located outside of floodplain areas associated with the Comet River and Humboldt Creek. Well pads located within these areas will be designed to:

- minimise concentration of flood flows;
- minimise diversion of flood flows from natural drainage paths / flow distributions;
- not increase the local duration of floods, or the risk of detaining flood flows.

Chemical and Fuel Management

Chemicals and fuel will be stored, transported and handled on-site will be effectively contained and where relevant, meet the relevant Australian Standards (e.g. AS 1940:2017 for the storage and handling of flammable and combustible liquids).

The proposed amendment would not significantly increase the risk and likely magnitude of impacts on the environmental values of surface water of the area given the avoidance of disturbance to surface water, no discharge to or extraction from surface waters, and implementation of the above management measures.

5.3. Groundwater

Environmental Objective (EP Reg): The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.

In Queensland, the *Petroleum and Gas (Production and Safety) Act 2004* authorises petroleum tenure holders to undertake activities related to petroleum exploration and production. Petroleum tenure holders have a statutory right to take or interfere with underground water (or groundwater).

The proposed activity will be operated in a way that protects the environmental values of groundwater. The proposed amendment does not change the potential impacts to the environmental values for groundwater, beyond what is authorised on the EA.

5.3.1. Environmental values

Geological Setting

The regional geology of the area comprises sediments from the Early Permian to Middle Triassic age Bowen Basin. The Bowen Basin is an elongated, north to south trending basin extending over 160,000 km² from central Queensland, south beneath the Surat Basin, and into New South Wales, where it connects with the Gunnedah and Sydney basins (OGIA 2016).

The Bowen Basin contains up to 10 km of terrestrial and shallow-marine sediments (Green 1997; R. Korsch and Totterdell 2009). The southern Queensland and northernmost New South Wales portion of the basin is overlaid by up to 2.5 km of Early Jurassic to Early Cretaceous Surat Basin sedimentary sequences (Fielding et al. 2000; R. Korsch and Totterdell 2009). In the vicinity of the area, sediments from the Surat Basin have been eroded and the Bowen Basin units reside under Cenozoic cover.

The area is located on the mid-western extent of the Bowen Basin, on the southern end of the Comet Ridge crest, and is flanked by the Taroom Trough to the east and the Denison Trough to the west (Green 1997; Fielding et al. 2000; R. Korsch and Totterdell 2009). Having developed inbound of an active convergence margin during the New England Orogeny, the Bowen Basin formed within a backarc tectonic setting (R. Korsch and Totterdell 2009), concurrently with the Gunnedah Basin.

Regionally, Cenozoic sedimentary deposits overlay the Bowen Basin units, formed through subsidence-related faulting and erosion, in conjunction with fluvial sedimentary depositional processes (Larone and Shlomi 2007; Nichols and Fisher 2007; R. J. Korsch et al. 2009). Crustal thinning due to extensional tectonic events resulted in magma upwelling and intermittent volcanism, expressed as basaltic lava flows in the vicinity of the Project as well as interbedded tuff and volcanolithic fragments within the Cenozoic sedimentary sequences (R. Korsch and Totterdell 2009).

Structural Elements

PLs 1082 and 1083 are situated in the eastern extent of the north-northwest to south-southeast trending Denison Trough (Olgers et al. 1963; Totterdell 1990), which is bounded by the Anakie Inlier and the Colinsville, Springsure and Roma shelves in the west, and the Comet Platform to the east (Totterdell 1990).

Early Permian east-west or northeast-southwest extension formed a series of half-grabens across the Denison Trough (McLoughlin 1986). Recent studies have indicated that a complex interplay of volcanism, mechanical extension, thermal cooling, thrust related flexuring of the lithosphere and dynamic platform tilting resulted in block subsidence during the Late Carboniferous to Early Permian, resulting in rapid sedimentary infill forming a thin veneer across the Trough (R. Korsch and Totterdell 2009). Extension was followed by mid-Permian mild compression, then more intense northeast-southwest oriented compression in the Late Triassic (McLoughlin 1986; R. J. Korsch et al. 2009; R. Korsch and Totterdell 2009).

Various northwest to southeast trending extensional bounding-faults of half-grabens, resulting from block subsidence during the Late Carboniferous to Early Permian, occur regionally across the Denison Trough (R. Korsch and Totterdell 2009; R. J. Korsch et al. 2009).

In addition to faulting, a series of regional scale, meridional en échelon synclines and anticlines occur adjacent to the faulting in a north-northwest to south-southeast orientation (McLoughlin 1986). Folds such as the Springsure Anticline, Inglis Serocold Anticline, Rewan Syncline and Consuelo Anticline are located to the southwest of the Project, and the Mimosa Syncline to the southeast (McLoughlin 1986; R. Korsch and Totterdell 2009; R. J. Korsch et al. 2009). Small-scale, discontinuous folds occur sporadically across the area, and are likely parasitic to the larger folds previously mentioned (McLoughlin 1986). The structural history of this area (Denison Trough) indicates that the major folding

event effecting the Permian rocks occurred between the Triassic and Jurassic (Power 1967; McLoughlin 1986).

Regional Hydrostratigraphy

The mapped geology within the vicinity of PLs 1082 and 1083 is presented on Figure 4. Stratigraphic units of relevance include:

- Quaternary alluvial deposits located along the Comet River and major tributaries;
- Surficial Cenozoic deposits;
- Localised basalt;
- Early to Middle Triassic sediments of the Clematis Group;
- Early Triassic sediments of the Rewan Group;
- Late Permian sediments of the Bandanna Formation; and
- Late Permian sediments of the Back Creek Group (including the Black Alley Shale and Aldebaran Sandstone).

Figure 4 shows how the Rewan Group (Rr), a regional aquitard, is present within the entirety of PLs 1082 and 1083.

Figure 5 presents the hydrostratigraphic column for the units occurring in PLs 1082 and 1083. The figure also indicates the hydrogeology condition of each unit as presented by OGIA (OGIA 2019), as well as the relevance to the area.

A summary of each of these units is provided in the following sections (from youngest to oldest):

Alluvium

The Quaternary alluvium comprises an unconsolidated and heterogeneous profile of sediments, deposited during periods of fluvial flooding events as overbank deposits (Laronne and Shlomi 2007; Nichols and Fisher 2007). The alluvium consists of fine to coarse-grained gravels and channel sands interbedded with clays. Published geological mapping indicates the presence of Quaternary alluvium up to 3 km either side of the Comet River and Humboldt Creek within the area. Quaternary alluvial sediments overlie sub-cropping Triassic and Permian bedrock, basalt and Cenozoic-age sediments.

Cenozoic Deposits

Quaternary colluvium is mapped as occurring within the PLs, and consists of clay, silt, sand and gravel.

Cenozoic-age sediments comprise a discontinuity of consolidated and semi-consolidated heterogeneous sediment / weathered residual deposits (referred to as the Emerald Formation) that overlie the northeastern portion of the Comet River catchment, infilling valley floors. These deposits consist of deeply weathered fluvialite and lacustrine claystone and siltstone, quartzose sandstone, pebbly sandstone, and gravel. Cenozoic-sediments are widely distributed over the PLs.

Basalt

Basalt occurs within the PLs, with major flows towards the west and south. The basalt comprises mostly olivine basalt with some areas of nephelinite and basanite (Olgers et al. 1963). The basalt presents as flat lying lava flows, unconformably overlying the sedimentary units. The basalt in the PLs is considered an aquifer.

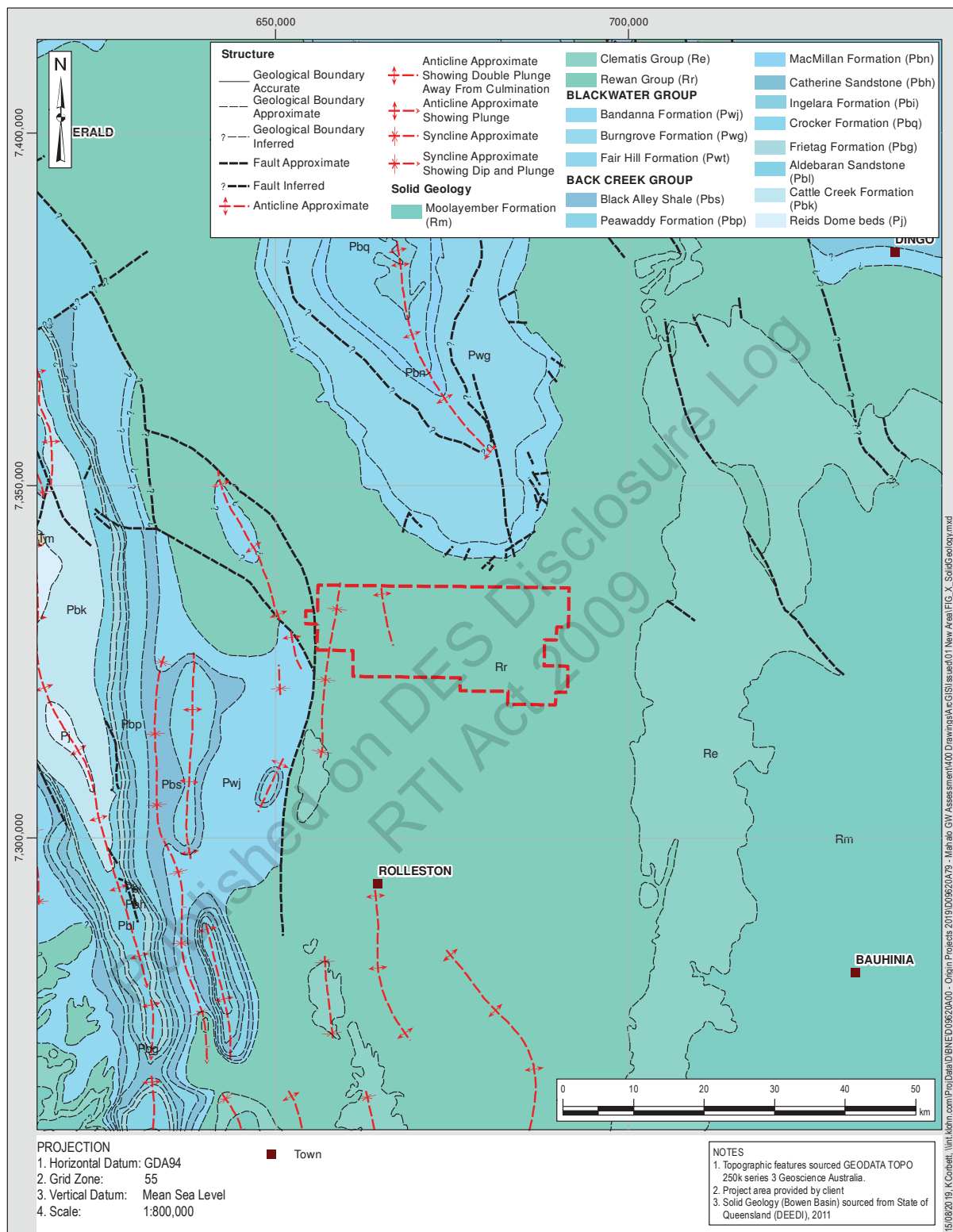


Figure 4 - Solid Geology of PLs 1082 and 1083

Figure 5 - Hydrostratigraphy within PLs 1082 and 1083 (after R. J. Korsch et al. 1997; OGIA 2019)

Age		Formation		Hydrostratigraphic Description	Relevance to PLs 1082 and 1083
Quaternary		Alluvium		Aquifer	Mapped associated with watercourses
Tertiary		Sediments		-	Deposits across the PLs
		Basalt		Aquifer	Located west of the PLs
Triassic	Middle	Moolayember Formation		Tight Aquitard	Located east of the PLs
		Showground Sandstone	Clematis Group	Major Aquifer	Located east of the PLs
	Early				
Permian	Late	Rewan Group		Tight Aquitard	Sub-crops in the PLs
		Bandanna Formation		Interbedded Aquitard	Target CSG formation
	Early	Back Creek Group	Black Alley Shale		Sub-crops west of the PLs
			Peawaddy Formation		
			Catherine Sandstone		
			Ingelara Formation		
			Freitag Formation		
			Upper Aldebaran Sandstone		
			Lower Aldebaran Sandstone		
			Cattle Creek Formation	Productive Coal Seam	
			Reids Dome Beds	-	

Moolayember Formation

The Middle to Upper Triassic Moolayember Formation comprises interbedded mudstones, lithic, medium to coarse-grained sandstone, carbonaceous shales, siltstones, and conglomerates, and is the youngest formation within the Bowen Basin (Green et al. 1997; Green 1997). The lower part of the Moolayember Formation was deposited in a lacustrine depositional environment that grades upwards into an alluvial plain with alluvial fans on the eastern margin (Golin and Smyth 1986). The thickness of this formation varies from 200 m on the Springsure Shelf to nearly 1,500 m in the centre of the Taroom Trough (Radke et al. 2000). The Moolayember Formation is characterised as a tight aquitard (OGIA 2019b). The formation is limited in spatial distribution within the vicinity of the PLs.

Clematis Group

The Lower to Middle Triassic Clematis Group (formally, Clematis Sandstone) consists of: medium to coarse-grained, cross-bedded, quartzose to sub-labile and micaceous sandstone; siltstone, mudstone and granule to pebble conglomerate; some fine conglomerate; and grey and red mudstone, deposited within a fluvial environment. The Clematis Group includes two geological formations within the Denison Trough: The Expedition Sandstone (a quartzose sandstone, conglomerate, siltstone and mudstone package) and The Glenidal Formation (thinly bedded, very fine to medium-grained sandstone with common siltstones and mudstones), which conformably overlies the Early Triassic Rewan Group (Brakel et al. 2009). The Expedition Sandstone is equivalent to the Showgrounds Sandstone in the Taroom Trough (Hoffmann, Green, and Gray 1997).

The Clematis Group is considered to be a major aquifer of the Great Artesian Basin (GAB). The formation is limited in spatial distribution within the vicinity of the Project. Outcrops of the Clematis Group are located east of the PLs within the Expedition Range (Olgers et al. 1963; Brakel et al. 2009). It is not considered a significant aquifer in the local area in terms of third-party groundwater use, however is the source of a number of GAB spring complexes located some distance from the PLs. The Clematis Group is separated from the Bandanna Formation (target for CSG production) by a thick sequence of the Rewan Group aquitard.

Rewan Group

The Early Triassic Rewan Group conformably overlies Permian sediments, and predominantly consists of lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base), deposited in a fluvial-lacustrine environment (Brakel et al. 2009). This sedimentary sequence thickens towards the centre of the Taroom Trough, east of the Project, and outcrops to the northeast. The Rewan Group is considered to be a tight aquitard (OGIA 2019).

Bandanna Formation

The Late Permian Bandanna Formation conformably overlies the Late Permian Back Creek Group (McLoughlin 1986), and consists of calcareous sandstone, calcareous shale, mudstone, permeable coal seams, and concretionary limestone (Huleatt 1991).

The calcareous sediments of the Bandanna Formation are interbedded with regionally discontinuous coal seams, which are the target for gas production for the PLs, as well as much of the coal mining in the Bowen Basin (Huleatt 1991). Individual coal seams can be identified, with the PLs targeting the Castor, Pollux, Aries and Orion seams.

The sedimentary sequences of the Bandanna Formation deepen towards the southeast, and outcrop north of the PL area (Huleatt 1991). The Bandanna Formation is one of the most widespread and youngest coal-bearing Permian sequences in the Bowen Basin, and correlates with the upper sections of the Baralaba Coal Measures in the southeast and the upper part of the Rangal Coal Measures in the southwest of the basin (Huleatt 1991).

The Bandanna Formation is considered as an interbedded aquitard (OGIA 2019).

Back Creek Group

The Late Permian Back Creek Group comprises quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite. The Back Creek Group contains various Permian sedimentary units, most notably the Black Alley Shale, Aldebaran Sandstone, the Cattle Creek Formation, and the Reids Dome Beds (Bowen Basin basement sequence).

Directly underlying the Bandanna Formation (and confining the earlier successions of the Back Creek Group) is the Black Alley Shale, composed of marine mudstone facies, which becomes increasingly sandy northwards of the northern Taroom Trough (Ayaz et al. 2016). The Black Alley Shale varies in thickness between 7 and 200 m in the southern extents of the Bowen Basin, and thickens into the Denison Trough (Ayaz et al. 2016). The Black Alley Shale is most likely the result of deposition from an eastward progradation of deltaic lobes during a minor transgression or restricted marine event in the Bowen Basin.

The Aldebaran Sandstone is a thick sequence of sandstones, conglomerates and minor mudstones and coals which accumulated within, and eventually beyond, the Denison Trough during the early Permian (Olgers et al. 1963). The unit reaches a maximum thickness of over 700 m and is covered by up to 1,400 m of Permo-Triassic strata of the upper Bowen Basin, Jurassic strata of the Surat Basin and Cenozoic basalt and alluvium. In the far south, it directly overlies the Reids Dome Beds (J. C. Baker 1991). The Aldebaran Sandstone represents a deltaic depositional environment that gradually replaced the marine environment of the Cattle Creek Formation (Dickins and Malone 1973).

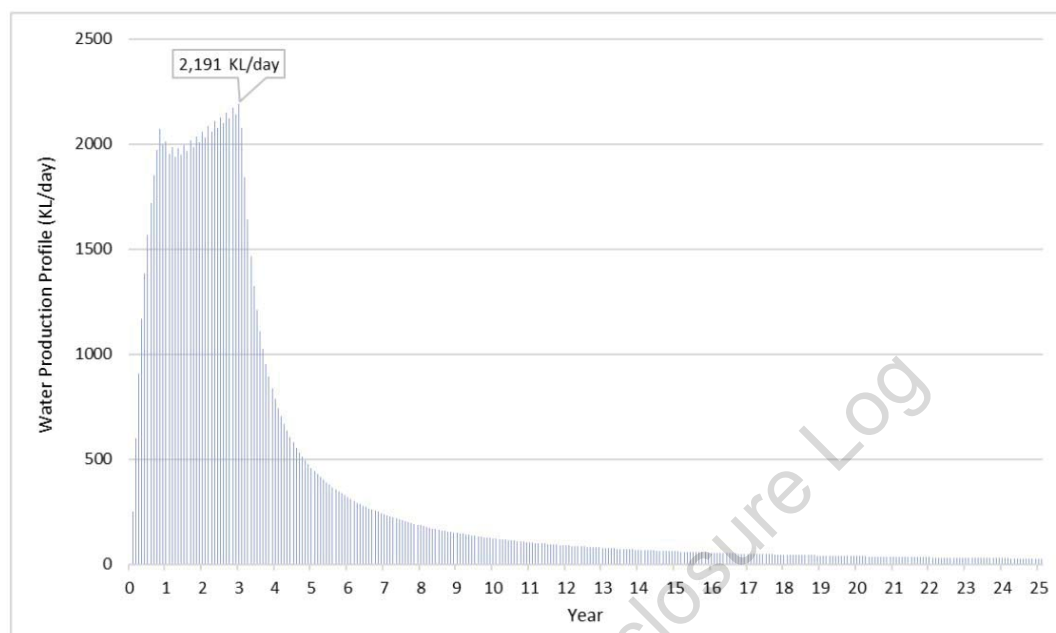
Horizons of the Cattle Creek Formation comprises dark grey, poorly sorted and poorly bedded conglomeratic silty sandstone and mudstone containing scattered large angular boulders, with thin interbeds of limestone and calcareous sandstone (Dickins and Malone 1973). Coal is also present within the Cattle Creek Formation, and has recently been a target for gas exploration (OGIA 2019). The Cattle Creek Formation was deposited within a shallow marine shelf to prodelta depositional environment (Dickins and Malone 1973; Jackson, Hawkins, and Bennett 1980).

The Reids Dome Beds, the lowest unit of the Back Creek Group, outcrop in areas of the Springsure Anticline and as a thin sequence approximately 110 km west of Springsure (Dickins and Malone 1973). These beds have a maximum thickness of approximately 2,760 m, and consist of: a basal unit of black shale and mudstone with coal seams interbedded with hard carbonaceous sandstones and orthoquartzites; a middle unit of black to grey carbonaceous micaceous shale, siltstone and sandstone with minor coal and thin dolomite beds with local thick beds of polymictic conglomerate (particularly in the south); and an upper unit of interbedded fine- to coarse-grained carbonaceous sandstone, dark carbonaceous siltstone, shale and coal (Olgers et al. 1963; Dickins and Malone 1973).

5.3.1.1 Water production

Up to approximately 3,400 ML of produced water would be generated from the proposed additional wells at the forecast production rate shown on Figure 6. The forecast production rate peaks at approximately 2.2 ML/day and rapidly declines to less than 0.2 ML/day for the majority of the operational life of the wells. Produced water will be managed to achieve water quality limits and requirements to support beneficial uses, this may include treatment of the produced water via reverse osmosis. Produced water and water treatment by-products such as brine would be stored in tanks; water treatment by-products would be removed from the PLs and disposed at an off-site facility licenced under the EP Act.

Figure 6 - Water Production Rate



5.3.1.2 Groundwater Quality

Groundwater chemistry within the Bowen Basin has been considered using information reported by OGIA (2019) and data sourced from the groundwater database (GWDB). Table 10 presents a summary of regional groundwater chemistry from OGIA (2019) for formations present within PLs 1082 and 1083.

Table 10: Regional Groundwater Quality

Analyte	Percentile	Alluvium	Basalt	Moolayember Formation	Clematis Group	Rewan Group	Bandanna Formation	Bandanna Formation (coal seams)	Undivided lower Bowen Basin	Undivided Permian Upper
Ca	25 th	30	22	14	9	27	2	7	28	32
	50 th	46	46	27	24	81	6	11	38	62
	75 th	77	80	89	39	281	32	13	58	84
Mg	25 th	22	15	5	5	51	1	5	34	36
	50 th	40	52	22	14	72	1	6	49	52
	75 th	80	98	81	39	201	36	9	76	85
Na	25 th	100	75	119	32	252	272	1,210	80	143
	50 th	205	106	384	76	706	498	1,470	164	372
	75 th	500	155	1,124	120	2,326	935	1,715	1,097	628
K	25 th	0.1	0.1	0.1	8	0.1	0.1	23	1	1
	50 th	1	1	1	12	1	1	39	4	3
	75 th	3	3	6	16	8	2	62	8	6
Alkalinity	25 th	308	244	150	120	143	549	967	317	474
	50 th	403	393	282	323	342	676	1,150	534	722
	75 th	512	537	461	465	382	993	1,520	743	891
Cl	25 th	84	86	99	34	273	51	1,230	58	137
	50 th	250	170	445	50	1,141	177	1,420	164	343
	75 th	780	310	1,655	69	4,215	866	1,975	1,610	595
SO ₄	25 th	5	3	0.1	2	1	1	0.1	14	0.1
	50 th	15	9	5	6	26	1	0.1	25	16
	75 th	70	19	24	17	165	12	4	84	85
F	25 th	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.2	0.2
	50 th	0.2	0.2	0.3	0.2	0.3	1.5	0.4	0.3	0.4
	75 th	0.3	0.3	0.6	0.2	0.5	2.3	0.5	0.5	0.6
TDS	25 th	649	537	538	227	1,139	946	3,539	731	1,244

Analyte	Percentile	Alluvium	Basalt	Moolayember Formation	Clematis Group	Rewan Group	Bandanna Formation	Bandanna Formation (coal seams)	Undivided lower Bowen Basin	Undivided Permian Upper
pH	50 th	1,064	826	1,402	522	2,648	1,577	4,437	992	1,770
	75 th	2,016	1,179	3,657	745	7,009	2,768	5,026	3,762	2,342
	25 th	7.6	7.7	7.5	7.1	7.4	7.8	8	7.9	7.9
	50 th	7.9	7.9	7.9	7.8	7.4	8.1	8.2	8.1	8
SAR	75 th	8.2	8.2	8.2	8	7.6	8.2	8.4	8.3	8.1
	25 th	3	2	5	2	6	15	71	2	3
	50 th	5	3	13	2	17	45	86	8	8
	75 th	12	6	26	4	29	97	102	20	15

A summary of the average water quality of produced water from limited samples taken within PLs 1082 and 1083 is provided below in Table 11.

Table 11: Local Produced Water Quality

Parameter	Unit	Average Value
Total dissolved solids	mg/L	7,417
Electrical conductivity	µS/cm	12,254
Total alkalinity	mg/L	190
Sodium adsorption ratio	-	34
Sodium [†]	mg/L	2 421
Calcium [†]	mg/L	273
Magnesium [†]	mg/L	36
Iron (total)	mg/L	23
Iron (filtered)	mg/L	4
Strontium (total)	mg/L	24
Ammonia as N (total)	mg/L	2.2
Potassium [†]	mg/L	59
Barium [†]	mg/L	10.5
Chloride [†]	mg/L	3 870
Sulphur/Sulphate as SO ₄ [†]	mg/L	14
Bromide (total)	mg/L	15.2
Iodide (total)	mg/L	23.1
Fluoride [†]	mg/L	0.5
Silicon as Si (filtered)	mg/L	6.9
Silicon as SiO ₂ (filtered)	mg/L	14.7

Parameter	Unit	Average Value
Aluminium (total)	mg/L	0.43
Aluminium (filtered)	mg/L	0.03
Antimony (total)	mg/L	0.0008
Antimony (filtered)	mg/L	0.0004
Arsenic (total)	mg/L	0.005
Arsenic (filtered)	mg/L	0.002
Boron [†]	mg/L	0.99
Cadmium [†]	mg/L	0.0036
Chromium (III+VI) [†]	mg/L	0.052
Cobalt [†]	mg/L	0.003
Copper [†]	mg/L	0.021
Lead [†]	mg/L	0.0091
Lithium [†]	mg/L	0.125
Manganese [†]	mg/L	0.29
Mercury [†]	mg/L	0.00086
Molybdenum [†]	mg/L	0.0065
Nickel [†]	mg/L	0.007
Selenium [†]	mg/L	0.010
Tin [†]	mg/L	0.002
Vanadium [†]	mg/L	0.0023
Zinc [†]	mg/L	0.22

[†] Total and filtered results were combined into a single dataset when the numbers were closely aligned, or if for each sample, only one of the total/filtered parameter was analysed for.

The electrical conductivity of the produced water demonstrates the minimal local environmental values of the Bandanna Formation as a groundwater resource. Produced water quality is not expected to significantly change during operation of the additional petroleum wells based on the water quality from existing operating wells and the confined nature of the Bandanna Formation. As illustrated in Section 5.3.1.4, the relative paucity of groundwater bores indicates the general low availability of groundwater and and/or poor groundwater quality within the PLs.

5.3.1.3 Surat Cumulative Management Area (CMA)

PLs 1082 and 1083 are located within the Surat Cumulative Management Area (CMA). Potential impacts associated with petroleum activities within the CMA are assessed and managed by the Queensland Office of Groundwater Impact Assessment (OGIA). The OGIA is required to prepare an Underground Water Impact Report (UWIR) for the CMA. The *Water Act 2000* defines the requirements for a UWIR, which include, but are not limited to:

- The quantity of water historically produced and an estimate of the quantity of water to be produced because of the exercise of underground water rights.
- For each aquifer affected or likely to be affected a description of the aquifer and an analysis of the movement of groundwater between aquifers, including the changes due to the exercising of underground water rights.
- A Water Monitoring Strategy (WMS), including:
 - The rationale for the strategy and locations to be monitored; and
 - The parameters to be measured and their measurement frequency.
- A Spring Impact Management Strategy, including:
 - An assessment of the hydraulic connection between the spring and underlying aquifer(s);
 - The predicted risk to the spring due to declining water levels at its location, and likely impact on ecosystem and ecological values of the spring due to declining water levels; and
 - Options available and a strategy for preventing or mitigating predicted impacts on the spring.

5.3.1.4 Groundwater Bores

There are 30 registered groundwater bores located within PLs 1082 and 1083 as shown on Figure 7, with 15 registered as existing bores and the remainder known to be abandoned or destroyed. Baseline assessments of eight bores in the vicinity of existing appraisal activities have been undertaken. Only two of these bores surveyed during the assessment were correlated to bores registered within the groundwater database. The location of bores for which a baseline assessment has been undertaken are shown on Figure 8. Only two of the bores were installed with a pump and used for water supply purposes, with the remainder abandoned.

As required under the *Water Act 2000* and the Surat CMA UWIR WMS, further baseline assessments will be undertaken prior to production activities. Under the *Water Act 2000*, petroleum tenure holders are required to undertake baseline assessment of water bores prior to commencement of production. Baseline assessments are undertaken in accordance with the 'Baseline Assessment Guideline' (DES 2017), to obtain information such as:

- bore status;
- bore type and purpose;
- information related to the construction of the bore, including
 - depth installed;
 - screen interval and source aquifer;
 - groundwater level and quality and field gas measurement; and
 - bore equipment including pump depth, pumping frequency and flow rate.

5.3.1.5 Groundwater Dependent Ecosystems (GDEs)

The distribution of potential terrestrial GDEs, as mapped by the Queensland Groundwater Dependent Ecosystems and Potential GDE Aquifer Mapping, Version 1.5⁵ within the vicinity of the PLs is shown on Figure 9. The potential GDEs are generally located in the vicinity of the watercourses, such as the Comet River and associated tributaries (Humboldt Creek, Planet Creek, Meteor Creek). The GDE mapping data provides the following categories of "confidence in the groundwater dependence of the ecosystem"⁶:

1. Known GDE.
2. Derived GDE - high confidence.

⁵ <https://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/>

⁶ <https://wetlandinfo.des.qld.gov.au/wetlands/facts-maps/gde-background/gde-faq/field-descriptions.html>

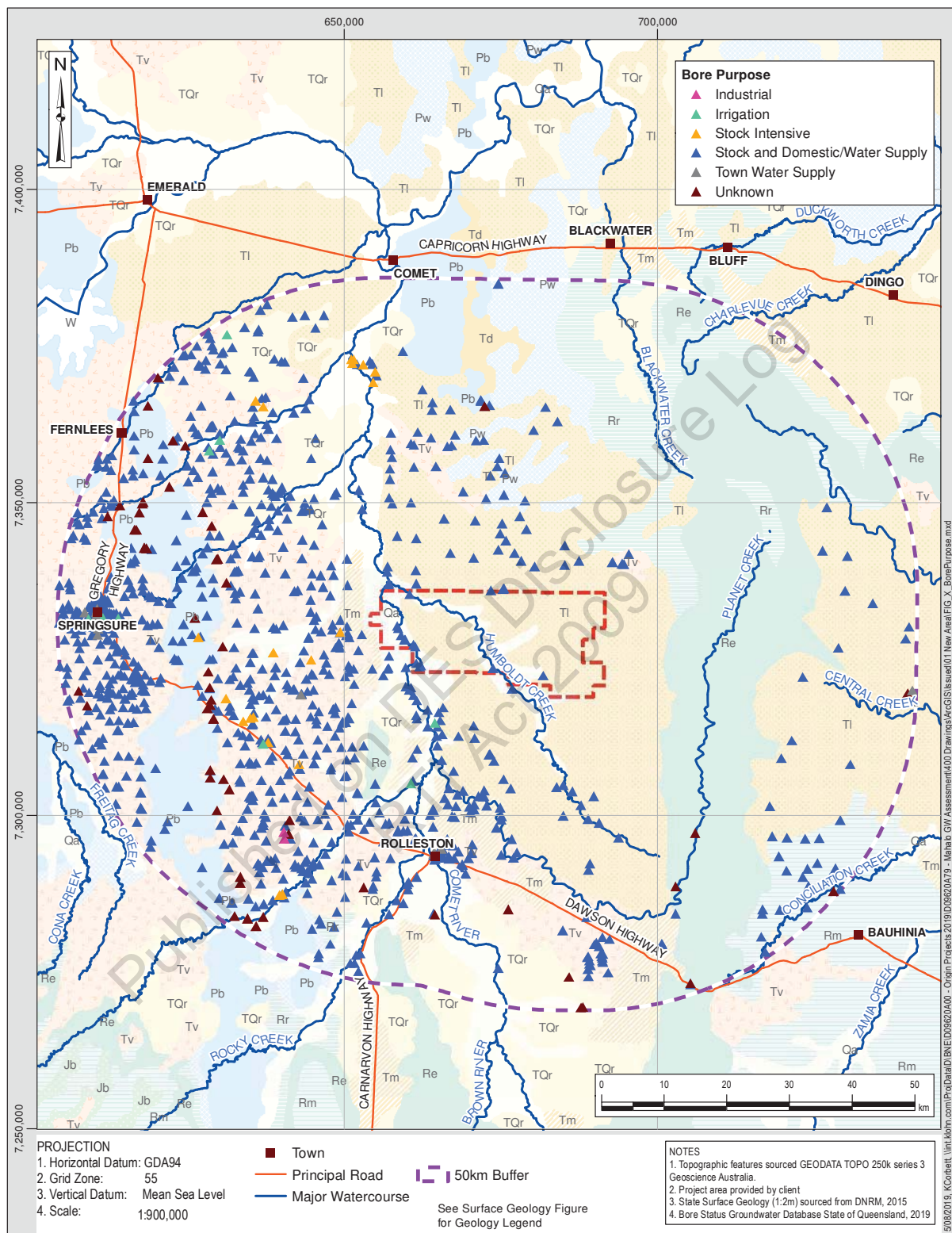


Figure 7 - Registered Groundwater Bores within PLs 1082 and 1083

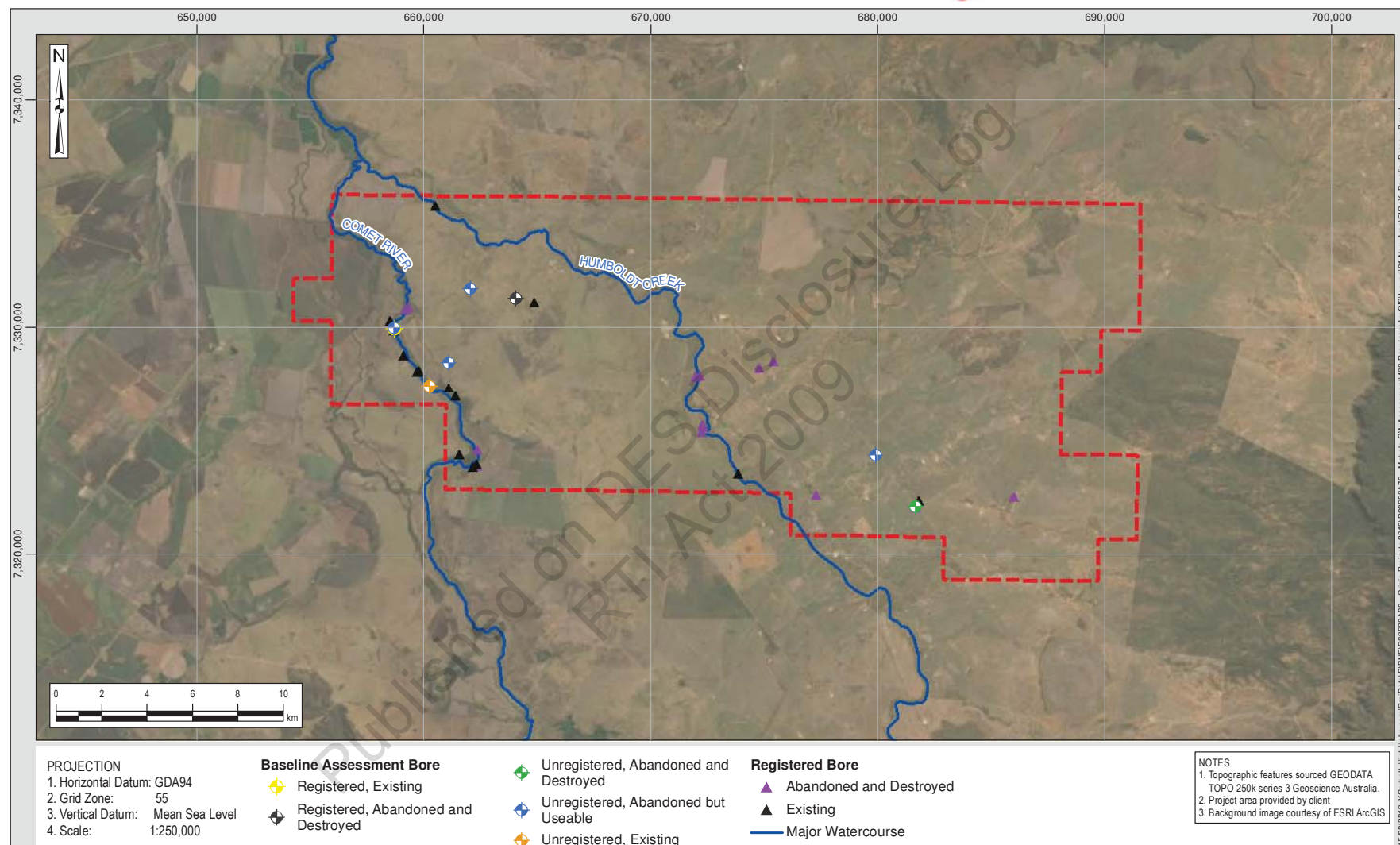


Figure 8 - Completed Baseline Assessments within PLs 1082 and 1083

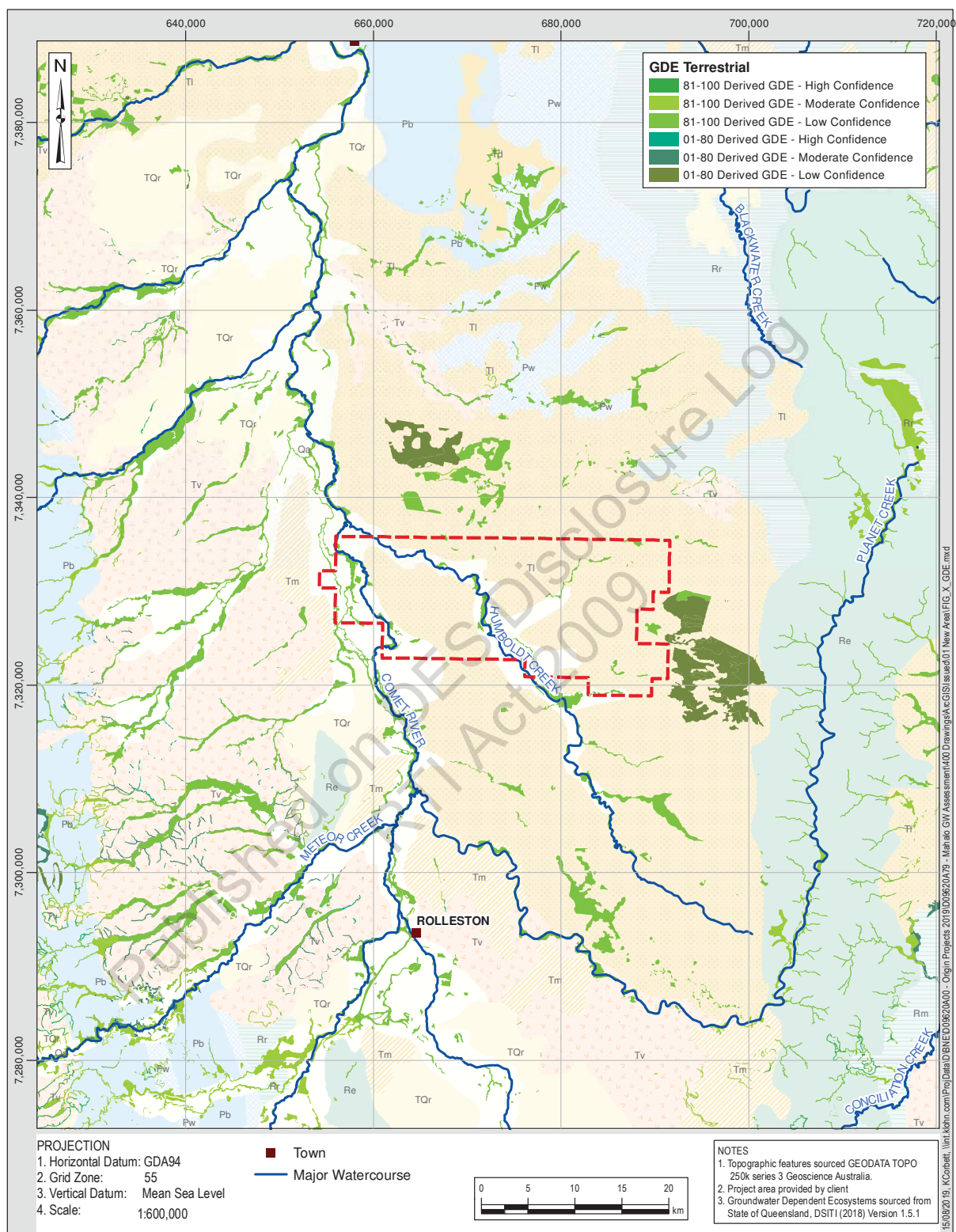


Figure 9 - Potential GDEs within the PLs and Surrounds

3. Derived GDE - moderate confidence.
4. Derived GDE - low confidence.
5. Unknown confidence.

The potential GDEs mapped within the PLs are “Derived GDE - Low confidence”; based on expert opinion, these GDEs are unlikely to be dependent on groundwater for ecosystem function of the RE. The QLD WetlandMaps⁷ mapping provides the potential shallow aquifers (groundwater source for the GDE) for these low confidence GDEs as being from the following mapping rule sets:

- SURAT_RS_01D: Quaternary alluvial aquifers with fluctuating, intermittent groundwater connectivity regime and neutral pH
- SURAT_RS_05: Permeable old loamy or sandy plain aquifers with fresh, intermittent groundwater connectivity regime

The QLD WetlandMaps mapping provides the dominant recharge process for these shallow aquifers as “infiltration (local)” being the localised infiltration of shallow aquifers from rainfall.

For the alluvium aquifer adjacent to the Comet River, the depth to groundwater is recorded as ranging between 9 and 18 mbGL. For the Cenozoic aquifer, the depth to groundwater is recorded as ranging between 30 and 42.7 mbGL. For the potential terrestrial GDEs to be reliant on groundwater from the alluvium and Cenozoic sediments, the vegetation would be required to extend their roots to this depth.

5.3.2. Environmental values assessment and mitigation measures

Well Construction

The additional proposed wells are required to be constructed in accordance with the DNRME *Code of Practice for the Construction and Abandonment of Coal Seam Gas and Petroleum Wells, and Associated Bores in Queensland*⁸ (The Code). Requirements of this code relevant to the proposed amendment are described below.

Well mechanical integrity

A critical component of maintaining a high degree of protection of the various aquifers within the Surat and Bowen Basin sequences is through the robustness and longevity of the well construction itself. The well is required to isolate the production fluids from the aquifer units during its working life and beyond, even after it has been formally abandoned by the mandated well abandonment processes (including pressure cementing). It is this robustness of construction that permits the well to maintain its integrity.

Throughout the entire process, stringent quality control and testing is undertaken to ensure the integrity of the casing and seals. These quality control procedures are implemented through the material selection and sourcing process and installation.

Maintaining a gas production well’s integrity is essential for the two following reasons:

- To isolate the internal conduit of the well, namely the well casing pipe, from the surface and subsurface environment. This is critical in protecting the environment, including the groundwater, and in enabling well drilling and production; and
- To isolate and contain the wells produced fluid (i.e. the gas) to a production well casing pipe within the well.

⁷ <https://wetlandinfo.des.qld.gov.au/wetlandmaps/>

⁸ https://www.dnrme.qld.gov.au/data/assets/pdf_file/0006/1461093/code-of-practice-petroleum-wells-bores.pdf

Groundwater is protected from the contents of the gas well during drilling, and production by a combination of drilling muds used in the process, steel casing and cement sheaths, and other mechanical isolation devices installed as a part of the well construction process. The construction of the well is done to prevent communication (the migration and/or transport of fluids between these subsurface layers).

The primary method used for protecting groundwater during drilling operations consists of drilling the well borehole through the groundwater aquifers (and aquitards) and then cementing this steel pipe into place using specialised cement types prior to advancing into deeper petroleum units. The casing and cement are specifically selected to accommodate a number of factors including formation types, groundwater quality, gas characteristics and operational conditions. The steel casing protects the zones from material inside the wellbore during subsequent drilling operations and, in combination with other steel casing and cement 'sheaths' that are subsequently installed, protects the groundwater with multiple layers of protection for the life of the well.

Petroleum and Gas legislation specifically address groundwater protection, including requirements for the surface casing to be set below the lowest groundwater aquifer. The steel casing protects the zones from material inside the wellbore during subsequent drilling operations and, in combination with other steel casing and cement 'sheaths' that are subsequently installed, protects the groundwater with multiple layers of protection for the life of the well.

The coal seams containing gas produce into the well through a well screen or perforations in the steel pipe and cement sheaths opposite the respective coal seams, with the produced gas being contained within the well pipe and the production all the way to the surface. The concrete annular seal between the casing and the formation. This containment is what is meant by the term 'well integrity'.

Regular monitoring takes place during drilling and production operations to ensure that these operations proceed within established parameters and in accordance with the well design, well plan, and permit requirements. This includes testing of the well integrity during well construction and over the life of the well.

Drilling and Well Completions

Drilling a typical oil or gas well consists of several cycles of drilling, running casing (steel pipe for well construction), and cementing the casing in place to ensure isolation. In each cycle, steel casing is installed in sequentially smaller sizes inside the previous installed casing string. The last cycle of the well construction is well completion including perforating the steel pipe opposite the coal seam.

Casing

To ensure long term casing integrity, detailed specifications have been developed for all well casings and well completion materials. These materials have been specifically designed and selected for the proposed application and lifecycle of the well. All materials are inspected prior to installation to ensure compliance with specifications. A similar process of inspections and testing are utilized throughout the drilling and casing installation program.

Logging the borehole

Borehole and well logging are carried out at gas well sites at various stages of the wells drilling and completion. Upon completion of the drilling of a borehole section, and before casing is installed and cementing operations begin, sensor instruments are run into the open (uncased) drilled borehole on a data cable. The information collected and the process used is typically referred to as 'well logging' or 'geophysical borehole logging'. Typical geophysical logging methods that are run in a well are designed for the specific location, geology, resource and well design.

Logging produces detailed information on all rock formations logged and the groundwater quality they might contain. Logging also determines the actual depth and thickness of the subsurface formations in the drilled hole.

This information is important in design of the production well and allows installation of casing strings in exactly the right place to achieve the well design objectives and to properly achieve the isolation benefits of the casing and cement.

A key result of the cased-hole logging program is to know the exact location of the casing, casing collars and quality of the cement job relative to each other and relative to the subsurface formation locations. This ensures that the well drilling and construction is adequate and achieves the desired design integrity and longevity objectives. It is also used to provide information in subsequent surveys of well integrity and seals over the production life of the gas well.

Well Completion Design

The well design and specifications include wellbore preparation, mud removal, casing pipe running and cement placement to provide barriers that prevent fluid migration and well leakage. The selection of the materials for cementing and casing, and the process of cement placement are important considerations in designing the well such that it ensures optimum performance of the barrier system to protect groundwater and isolate the hydrocarbon bearing zones. The well design process also includes contingency planning to mitigate and eliminate the risk failure due to unforeseen events.

Casing design and completion

The first borehole drilled is for installing the conductor pipe. This is followed by a series of sequentially drilled deeper boreholes designed to install the various sleeved or sheathed casing pipes as follows: surface casing, intermediate casing (if necessary), and the production casing. Casing pressure tests are carried out at each stage to ensure integrity of the casing pipe for further drilling or operational conditions. These tests are conducted at pressures that will determine whether the casing integrity is adequate to meet the well design and construction objectives.

Cementing

Cement types, additives and mixes are engineered products and are selected and designed to address site-specific conditions relevant to a particular well. Cement mixtures and installation techniques are employed to provide a robust seal that isolates the well from the surrounding formations, and protects the well materials from potentially aggressive groundwater or formation conditions. The selected cement types, additives and mixing fluid are specifically designed and laboratory tested in advance to ensure they meet the requirements of the well design and subsurface conditions at the well location.

Placement of the cement is carried out in such a manner (and using appropriate centralising equipment) as to completely surround the casing pipe to achieve successful seal isolation and pipe integrity. That is, effective isolation of the well pipe from the various subsurface formations requires complete and even annular filling and tight cement interfaces with the formation and casing. Complete displacement of drilling fluid by cement (to eliminate 'bubbles' or voids) and good bonding of the cement interfaces between the drilled hole and the casing immediately above the gas-bearing coal are important factors taken into account when designing and completing the well to ensure effective and long-lasting well and seal integrity.

The following well design, materials selection and cement procedures are typically implemented at well completion sites:

- A well design team prepares an appropriate well completion design based on a detailed assessment of borehole core, the regional geological model, reservoir analysis, and the history of nearby wells. Historical problems encountered in the area (lost returns, irregular hole erosion, poor hole cleaning, poor cement displacement, etc.) are considered during the design process;
- Computer simulation and completion planning is carried out to optimise cement placement procedures;
- Drilling contractors are selected based on their reputation, adherence to industry best practice methods and regulatory requirements. Importantly, as it effects cementing, they are required to use established, effective drilling practices to achieve a uniform, stable well

borehole with desired hole geometry. Additionally, they are required to satisfy health-safety-environmental requirements with regard to their personnel and equipment. They are required to ensure that their cementing equipment provides adequate mixing, blending and pumping of the cement in the field;

- Drilling contractors are required to ensure that the drilling fluid selection is appropriate for the designed well and the geologic conditions likely to be encountered, and present a low risk to the environment;
- Site drilling and cementing equipment are selected to adequately achieve the well design that will meet the well design objective and ensure effective isolation;
- Prior to cementing a section of well casing pipe in place, drilling contractors ensure that appropriate well borehole preparation, hole cleaning, and conditioning measures are implemented to ensure the cementing works are effective;
- Drilling contractors are required to employ casing pipe centralisers to help centre the casing pipe within the borehole and provide for good mud removal and cement placement, especially in critical areas, such as coal seam zones, and groundwater aquifers;
- Drilling contractors are required to use appropriate cement testing procedures to ensure cement slurry quality and designs are adequate. These include implementation of appropriate cement slurry quality controls - with testing to measure the following parameters depending on site- specific geological and groundwater quality conditions:
 - Slurry density
 - Thickening time
 - Fluid loss control
 - Free fluid
 - Compressive strength development
 - Fluid compatibility (cement, mix fluid, mud)
 - Sedimentation control
 - Expansion or shrinkage characteristics of the set cement
 - Static gel strength development
 - Mechanical properties (Young's Modulus, Poisson's Ratio, elastic/compressibility characteristics, etc.)
- Cement design may include placement in two stages, using a 'lead' cement of lower density and a 'tail' cement of higher density and compressive strength. Typically, the tail cement is used to isolate critical intervals in the well; and
- Appropriate setting times are adhered to ensure that the cement seals are optimal prior to commencing further drilling, and/or operational testing.

Groundwater Drawdown Modelling

Klohn Crippen Berger Ltd (KCB) has assessed potential groundwater drawdown from long term operation of the proposed additional wells in a Water Assessment Report⁹. OGIA have modelled the groundwater drawdown of produced water extraction from the Bandanna coal formation within PLs 1082 and 1083 using their numerical groundwater model for the 2019 Underground Water Impact Report (UWIR) for the Surat Cumulative Management Area¹⁰ (CMA). The outputs of the model were then provided to KCB to analyse the model outputs and assess the potential impacts of predicted groundwater drawdown.

Groundwater Bores

Potential long-term drawdown impacts to groundwater bores were also modelled and assessed against the *Water Act 2000* bore threshold of 2 m for an unconsolidated aquifer and 5 m for a consolidated aquifer. The UWIR model indicated that 4 groundwater bores will experience drawdown in exceedance

⁹ <http://epbcnotices.environment.gov.au/entity/annotation/cb63101e-e6ea-e911-8923-00505684324c/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1574417176333>;
<http://epbcnotices.environment.gov.au/entity/annotation/feac3129-e6ea-e911-8923-00505684324c/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1574417176333>

¹⁰ https://www.dnrme.qld.gov.au/data/assets/pdf_file/0019/1461241/uwir-full-report.pdf

of these impact thresholds. However, these four bores are recorded as sourcing water from the Bandanna Formation, the target gas formation for the Project. The recorded use for these bores is for stock and domestic purposes. However, as demonstrated by the produced water quality, the relatively high salinity (e.g. electrical conductivity of approximately 12,000 $\mu\text{S}/\text{cm}$) of groundwater in the Bandanna Formation would not allow for untreated stock and domestic use. In addition, the groundwater database and drilling logs suggest alternate, non-coal, water sources for these bores. These bores, if in use, are likely to access groundwater formations shallower than the Bandanna Coal Formation, where the drawdown predicted would be of a smaller magnitude. Baseline bore assessments will be undertaken as required by the *Water Act 2000* to determine the groundwater source for these bores.

If it is confirmed that these bores are sourcing water from the Bandanna Formation, the 'make good' requirements under the *Water Act 2000* as applicable, including one or more of the of the following measures:

- adding a rising main to lower the pump setting in the bore;
- increasing the water column above the pump;
- improving the pressure at the bore head, including new headworks and piping, if the affected supply is artesian;
- changing the pump so that it is better suited to the decreased water level in the bore;
- deepening the bore to allow it to tap a deeper part of the aquifer;
- reconditioning of the water bore to improve its hydraulic efficiency;
- drilling a new bore;
- providing an alternate water supply; or
- providing the water bore owner compensation (monetary or otherwise) to offset reduced water supply from the bore.

Given the existing water quality of the Bandanna Formation, and baseline assessment 'make good' requirements of the *Water Act 2000*, impacts to existing groundwater users are considered unlikely.

Springs

There are no springs within or nearby the PLs; the closest spring is located approximately 30km from the PLs as shown on Figure 3. Potential impacts to far-field spring complexes and watercourse springs were considered with respect to the *Water Act 2000* impact threshold for springs (0.2 m drawdown) using the predicted drawdown to the known groundwater sources for the springs. Exceedance of this spring impact threshold was not predicted.

GDEs

The groundwater model predicts drawdown within the uppermost layer of the model, which simulates the alluvium, basalt and Cenezoic sediments. These shallow aquifers are relevant to the GDE mapping rule sets described in Section 5.3.1. The maximum drawdown predicted at the location of the potential low confidence GDEs is 0.3 m drawdown predicted in the area underlying the potential GDEs. Based on groundwater level records for this area as well as the potential GDEs classified as 'low confidence', the water table is considered too deep (greater than ~30 m) for the vegetation roots to reach and therefore has very limited potential to be impacted.

UWIR

Groundwater production from PLs 1082 and 1083, including the proposed additional wells, will be included in future revisions of the Surat CMA UWIR or a standalone UWIR, providing an additional level of impact assessment under the *Water Act 2000*, duplicating the requirements of the EP Act.

The proposed amendment would not significantly increase the risk and likely magnitude of impacts on the environmental values of groundwater of the area given the results of site-specific groundwater modelling, and implementation of the above mitigation measures.

5.4. Noise

Environmental Objective (EP Reg): The activity will be operated in a way that protects the environmental values of the acoustic environment.

The proposed activity will be operated in accordance with the existing EA conditions and will protect the environmental values of the acoustic environment. Petroleum activities will not cause an environmental nuisance from noise at a sensitive place, other than where an alternative arrangement is in place. The proposed amendment does not change the potential impacts to the environmental values for the acoustic environment, beyond what is authorised on the EA.

5.4.1. Environmental values

The EP Act provides the framework for the management of the acoustic environment in Queensland. The *Environmental Protection (Noise) Policy 2019* (EPP Noise) sets the environmental values and acoustic quality objectives, as follows:

The environmental values are identified as the qualities of the acoustic environment conducive to:

- *Protecting the health and biodiversity of ecosystems;*
- *Ensuring a suitable acoustic environment for individuals to sleep, study or learn, or be involved in recreation including relaxation and conversation; and*
- *Protecting the amenity of the community.*

Sensitive Places

Desktop assessments have identified that there are 11 potential homesteads located within PL1082 and PL1083. Homesteads and other sensitive receptors will be ground-truthed once the location is infrastructure and finalised.

Site Topography

The Project Area is characterised by undulating land with alluvial lowlands and elevated sandstone landforms. The local ground elevation across the project varies from 188m to 290m above Australian Height Datum.

Background Noise Levels

The existing noise environment throughout the area is typical of sparsely populated, rural settings with low ambient noise dominated by natural sources. The environmental value adopted for the development area is a rural acoustic environment conducive to the wellbeing of the community, including its social and economic amenity, and the wellbeing of an individual, including the opportunity to have sleep, relaxation and conservation without unreasonable interference from intrusive noise (above background levels). In accordance with Schedule C of the EA, the deemed background noise levels for the EA are:

- 7:00am-6:00p: 35 dBA.
- 6:00pm-10:00pm: 30 dBA.
- 10:00pm-6:00am: 25 dBA.
- 6:00am-7:00am: 30 dBA.

5.4.2. Environmental values and mitigation measures

The proposed amendment does not change the potential impacts to the environmental values for the acoustic environment, beyond what is authorised on the EA. There are no proposed emissions or releases that would cause an environmental nuisance for noise, at a sensitive place proposed as part of this application.

Through the implementation of the management practices listed below, the residual risk and magnitude of potential impacts to the acoustic environment is considered low to negligible and limited in extent and duration.

Noise modelling would be conducted prior to construction and operational of the additional wells to identify potential noise emissions in exceedance of the acoustic quality objectives listed in Schedule 1 of the EPP Noise. Section 8(2) of the EPP Noise prescribes the management hierarchy for potential exceedances of these acoustic quality objectives as follows:

Table 12: Noise Management Measures (EPP Noise)

Section 8(2) of EPP Noise <i>To the extent it is reasonable to do so, noise must be dealt with in the following order of preference—</i>	Management Measures
<i>firstly—avoid the noise;</i>	The results of noise modelling are used to inform the location of the proposed wells with respect to sensitive receptors.
<i>secondly—minimise the noise, in the following order— firstly—orientate an activity to minimise the noise;</i>	To the extent necessary, the location of noise generating equipment (e.g. pumps) can be orientated on the well pad to minimise the resultant noise level at sensitive receptors.
<i>secondly—use best available technology to minimise the noise;</i>	Noise generating equipment (e.g. pumps) with lesser noise emissions can potentially be substituted.
<i>thirdly—manage the noise.</i>	<ul style="list-style-type: none"> • Undertaking construction during daytime hours only. • Treatment of the noise at the source, including: <ul style="list-style-type: none"> – Noise enclosures or barriers orientated between the noise source and the sensitive receiver. • Where appropriate, and in consultation with owner/occupier, treatment of the noise at the receptor, including: <ul style="list-style-type: none"> – Installation of window glazing. – Installation of insulation. – Installation of air conditioning. • Alternative arrangements with the occupier of the sensitive receptor to offset potential noise impacts and avoid nuisance events.

In accordance with the management hierarchy, one of, or a combination of the management measures listed in Table 12 can be implemented for the proposed wells to avoid / minimise / manage noise.

5.5. Land Resources

Environmental Objective (EP Reg): The activity will be operated in a way that protects the environmental values of land including soils, subsoils, landforms and associated flora and fauna.

The proposed activity will be operated in accordance with existing EA conditions and will protect the environmental values of land. The current EA regulates land impacts for the development, and the proposed amendment does not change the potential impacts to the environmental values for land, beyond what is authorised on the EA.

5.5.1. Environmental values

Land-Use

Figure 10 shows the land uses within PLs 1082 and 1083. The area has been subject to extensive significant previous disturbance as a result of broad scale clearing and ongoing agricultural operations; approximately 93% of the PLs area has been extensively cleared of vegetation with some relatively small areas of remnant vegetation present.

There are four types of primary land use within the PL areas as shown in Table 13. The dominant land use is production from relatively natural environments, specifically grazing from native vegetation. Cropping is also undertaken with negligible artificial water storage activities.

Table 13: Land Uses within PLs 1082 and 1083

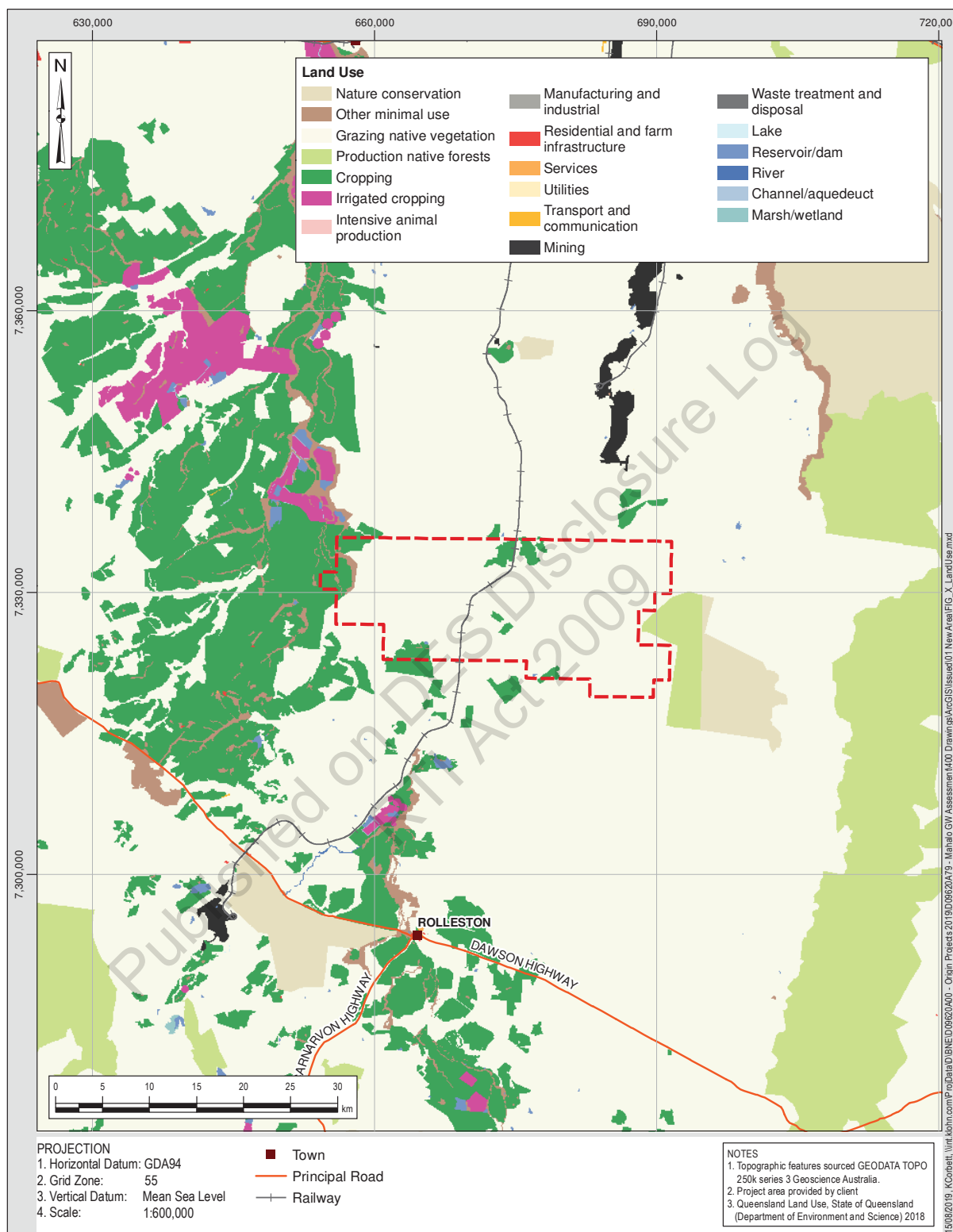
Land Use Category			Area (km ²)	Percentage of Total Area
Primary	Secondary	Tertiary		
Conservation and natural environments	Other minimal use	Other minimal use	0.51	0.11%
		Residual native cover	3.15	0.67%
Production from dryland agriculture and plantations	Cropping	Cropping	31.47	6.71%
Production from relatively natural environments	Grazing native vegetation	Grazing native vegetation	433.70	92.46%
Water	Reservoir / dam	Reservoir / dam	0.23	0.05%

Dominant Ecosystems, Topographic Features and Soils

The PL areas are situated at the intersection of the Shotover, Expedition, and Dawson ranges, and are characterised by undulating land with alluvial lowlands and elevated sandstone landforms. Ground elevation varies from approximately 190m to 290m above Australian Height Datum (AHD). Elevation decreases toward the lower lying alluvial channels of the Comet River and Humboldt Creek which flow generally from the northwest to the south and southeast of the area.

The Atlas of Australian Soils shows the land units and dominant soil types present within PLs 1082 and 1083 including, the following:

- Gently undulating or levels plains (CC21) dominated by Vertosol soils of deep cracking clays with a moderate to strong gilgai microrelief with associated thin surfaced dark loamy duplex soils. Gilgai associated with soils containing shrink-swell properties.
- Level alluvial floodplains associated with major streams (CC23) dominated by Vertosols soils of deep cracking clays.
- Gently or moderately undulating lands (Kd8) dominated by Vertosol soils of mostly deep dark cracking clays with areas of deep red-brown cracking clays.
- Low hilly to hilly terrain no volcanic rocks and appearing as open valleys to mountainous land, gently to moderate side slopes to shallow streams with significant flats (MM7) dominated by Vertosol soils of neutral dark and yellow friable earths with friable brown soils.



- Undulating elevated plains with some steep-scarped dissected margins and occasional low mesa-like residual hills (My21) dominated by Chromosol and Kandosol soils of loamy red massive earths. Kandosols generally have a sandy to loamy-surface soil, grading to porous sandy-clay subsoils.
- Broadly undulating lands (Oc24) dominated by Sodosols of red loamy duplex soils with brown duplex soils. Generally, have impermeable subsoils due to the concentration of sodium.

Regional Interests

The RPI Act restricts the carrying out of resource or regulated activities where the activity is not exempt from the provisions of the RPI Act, or a regional interests development approval (RIDA) has not been granted. A Strategic Cropping Area (SCA) occurs within the area of the PLs as shown on Figure 11.

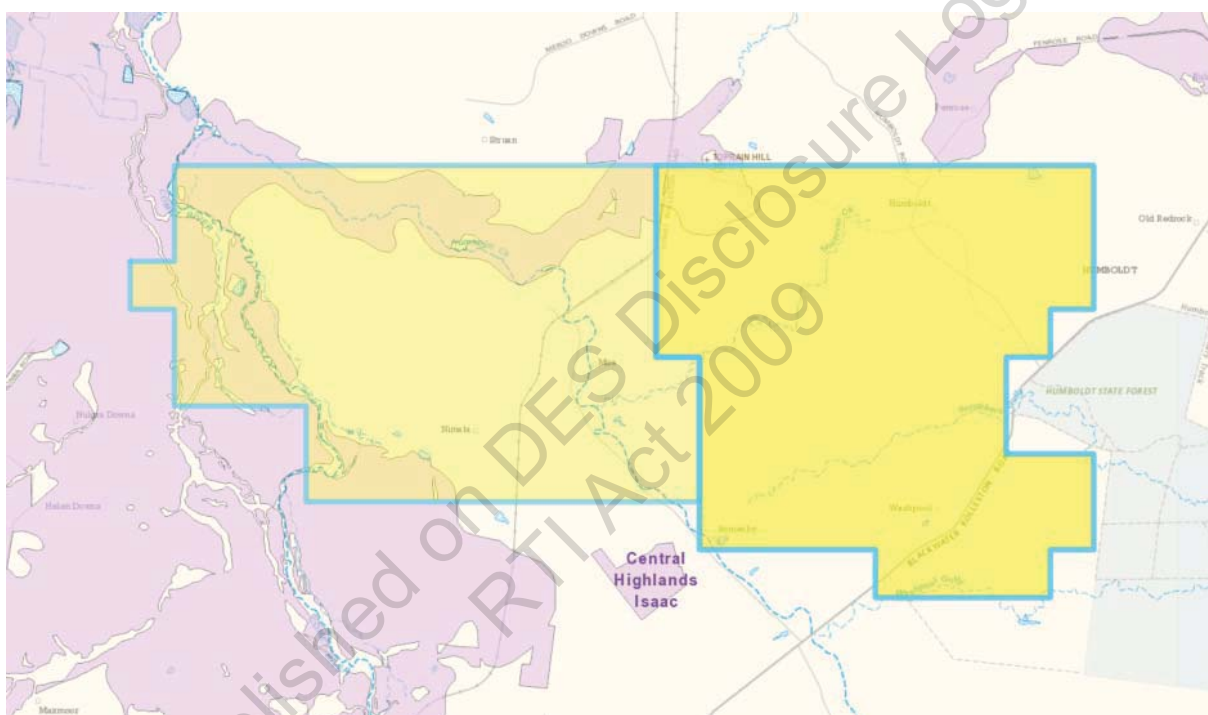


Figure 11 - Strategic Cropping Area within PLs 1082 and 1083

5.5.2. Environmental values assessment and mitigation measures

The following emissions and releases to land may be generated from the proposed activities:

- Residual drilling material; and
- Irrigation from sewage treatment plants associated with temporary drill camps.

All emissions and releases to land will be in accordance with existing EA conditions.

Through the implementation of the management practices outlined below, the residual risk and magnitude of potential impacts to the land environmental values is considered low to negligible and limited in extent and duration.

The proposed amendment would not significantly increase the risk and likely magnitude of impacts on the environmental values of land resources of the area given the extensive previous disturbance as a result of broad scale clearing, and implementation of the above mitigation measures.

Soil Management and Rehabilitation

Soil management would be undertaken during the construction and operation of well pads for the proposed additional wells, including the following:

- Stripping and separate stockpiling of topsoils and subsoils.
- Reinstatement of soils consistent with the surrounding soil horizon.
- Establishing groundcover on long-term soil stockpiles.
- Erosion and sediment controls to minimise the mobilisation / transport of soil resources.

Land disturbance for the proposed additional wells would be rehabilitated in accordance with Condition J2 of the EA to conserve soil resources and re-establish existing contours consistent with surrounding landforms:

Transitional rehabilitation

(J2) *Significantly disturbed areas that are no longer required for the on-going petroleum activities, must be rehabilitated within 12 months (unless an exceptional circumstance in the area to be rehabilitated (e.g. a flood event) prevents this timeframe being met) and be maintained to meet the following acceptance criteria:*

- (a) *contaminated land resulting from petroleum activities is remediated and rehabilitated*
- (b) *the areas are:*
 - i) *non-polluting*
 - ii) *stable landform*
 - iii) *re-profiled to contours consistent with the surrounding landform*
- (c) *surface drainage lines are re-established*
- (d) *topsoil is reinstated; and*
- (e) *either:*
 - i) *groundcover, that is not a declared pest species, is growing; or*
 - ii) *an alternative soil stabilisation methodology that achieves effective stabilisation is implemented and maintained.*

Chemical and Fuel Management

Chemicals and fuel would be stored, transported and handled on-site will be effectively contained and where relevant, meet the relevant Australian Standards (e.g. AS 1940:2017 for the storage and handling of flammable and combustible liquids).

Produced Water Management

Produced water from the proposed additional wells would be stored in tanks and managed in accordance with existing conditions of the EA and / or End of Waste Codes under the *Waste Reduction and Recycling Act 2011*. Water management uses authorised by these approvals include:

- dust suppression and construction;
- irrigation;
- landscaping and revegetation; and
- stock watering.

These existing approvals provide water management standards including the water quality requirements show in Table 14.

Table 14: Water Quality Requirements

Water Quality Parameter	Water Quality Requirements		
	Irrigation	Landscaping and Revegetation	Stock Watering
Total dissolved solids	ANZECC Guidelines Volume 1, Chapter 4, and Volume 3, Chapter 9	< 1,000 mg/L	ANZECC Guidelines Volume 1, Chapter 4.3, Tables 4.3.1, 4.3.2, and 4.3.3
pH		6.0 - 9.5	
Sodium adsorption ratio			
Aluminium	ANZECC Guidelines Volume 1, Chapters 3 & 4, and Volume 3, Chapter 9	Non-toxic to plant growth (e.g. ANZECC Guidelines Volume 3, Section 9.2.1.3)	
Arsenic			
Beryllium			
Boron			
Cadmium			
Chromium			
Cobalt			
Copper			
Fluoride			
Iron			
Lead			
Lithium			
Manganese			
Mercury			
Molybdenum			
Nickel			
Selenium			
Uranium			
Vanadium			
Zinc			

Water management requirements for dust suppression includes the following:

- the amount of water applied for dust suppression does not exceed the amount required to effectively suppress dust;
- dust suppression does not cause on-site ponding or runoff;
- water is applied directly to the area being dust suppressed;
- surrounding vegetation is not harmed; and
- dust suppression does not cause visible salting.

Water management requirements for construction uses includes the following:

- the composition and structure of soils or subsoils is not negatively impacted;
- there is no runoff from the construction site or release to waters; and
- surrounding vegetation is not harmed.

Water quality will be determined through testing prior to dust suppression or construction uses.

Table 15 provides the management criteria to monitor and assess effectiveness of produced water management.

Table 15: Produced Water Management Criteria

Objective	Task	Performance Indicator	Proposed Action for non-compliance
No unauthorised disturbance to land for water management infrastructure	<ul style="list-style-type: none"> Locate non-linear water management infrastructure outside of the following areas: <ul style="list-style-type: none"> endangered regional ecosystems; nature refuges and koala habitat including a 200m buffer / protection zone; essential habitat; essential regrowth habitat; and of concern REs. 	Number of related notifications made under Condition (A9) of the EA	<ul style="list-style-type: none"> Review the design and construction process prescribing the location of non-linear water management infrastructure. Other actions prescribed by DES.
No unauthorised releases from water pipelines	<ul style="list-style-type: none"> Design and construction of pipelines in accordance with the Australasian Pipelines and Gas Association Code of Practice Upstream Polyethylene Gathering Networks - CSG Industry Version 4.0. Implement operation and maintenance plans for pipelines, including isolation vales, and leakage detection. 	Number of related notifications made under Condition (A9) of the EA	<ul style="list-style-type: none"> Review the operation and maintenance plans for pipelines, including isolation vales, and leakage detection. Other actions prescribed by DES.
No unauthorised releases from water storages	<ul style="list-style-type: none"> Implement operation and maintenance plans for water storage structures including leak detection. Seepage monitoring in accordance with Condition G12 of the EA. 	Number of related notifications made under Condition (A9) of the EA	<ul style="list-style-type: none"> Review the operation and maintenance plans for water storage structures including leak detection. Other actions prescribed by DES.
Minimise the generation of water treatment by-products	<ul style="list-style-type: none"> Preferentially manage water using non-treatment methods (e.g. blending). Preferentially use water for construction and dust suppression beneficially uses. 	Volume of produced water treated via reverse osmosis	N/A
Off-site disposal of water treatment by-products	<ul style="list-style-type: none"> Disposal of water treatment by-products at an off-site facility licenced under the EP Act. 	Volume of water treatment by-products disposed off-site	<ul style="list-style-type: none"> Review the storage, handling, and transport of water treatment by-products Other actions prescribed by DES.
Maximise the beneficial use of produced water	<ul style="list-style-type: none"> Maintain a water balance model to optimise the size and capacity of water management infrastructure. Prioritise water management in accordance with the hierarchy defined in the CSG Water Management Policy. Monitor produced water quality changes over time. Record produced water volumes for each beneficial use. 	Volume of produced water beneficially used	N/A

5.6. Terrestrial Ecology

Assessments will be conducted prior to significant disturbance to verify any potential Category A, B or C Environmentally Sensitive Areas, Matters of State Environmental Significance, Queensland Government Regional Ecosystem Mapping and, where required, any potential endangered, vulnerable or near threatened species listed under the *Nature Conservation Act 1992* (NC Act).

5.6.1. Environmental values

Regional Ecosystems

PLs 1082 and 1083 are located within the Brigalow Belt South Bioregion. The Brigalow Belt Bioregion comprises over 269,300 km² in size and is characterised by Brigalow (*Acacia harpophylla*) in a mosaic of open forest and woodland communities on clay soils. Semi-evergreen vine thickets, heath and eucalypt open woodlands are scattered within this region, with small pockets of eucalypt open forests.

As shown in Table 16 and Map 2 within Appendix A, approximately 93% of the area has been cleared and represents non-remnant vegetation. The limited tracts of vegetation are generally located within riparian corridors associated with watercourse areas.

Table 16 provides details of the limited REs within PLs 1082 and 1083.

Table 16: Extent of REs within PLs 1082 and 1083

RE Code	RE Description	Biodiversity status	Area
Non-Remnant	None	None	93.29%
11.10.3	<i>Acacia catenulata</i> and/or <i>A. shirleyi</i> form a distinct but discontinuous low open forest to open forest canopy (8-12, rarely 18m high). Other <i>Acacia</i> spp. such as <i>A. sparsiflora</i> and <i>A. rhodoxylon</i> may form part of the canopy and in places may predominate. Scattered <i>Eucalyptus</i> spp. emergents (up to 25m high) occur, the most frequent being <i>E. decorticans</i> . <i>Eucalyptus exserta</i> is conspicuous in places. Scattered tall shrubs may occur. A low shrubby layer is usually conspicuous. The ground layer is sparse and composed of both grasses and forbs. Occurs on crests and ridge tops formed on consolidated, medium to coarse-grained sediments.	No concern at present	0.11%
11.3.1	Open forest dominated by <i>Acacia harpophylla</i> and/or <i>Casuarina cristata</i> (particularly in southern parts), with or without scattered emergent <i>Eucalyptus</i> spp. such as <i>E. coolabah</i> , <i>E. largiflorens</i> , <i>E. populnea</i> , <i>E. orgadophila</i> , and <i>E. woollsiana</i> . A low tree layer dominated by <i>Geijera parviflora</i> and <i>Eremophila mitchellii</i> is usually present. The vegetation sometimes occurs as low open forest or woodland. Tree height generally about 11-15m and the low tree (to tall shrub) understorey layer is between 2 and 8m high (where present). Ground cover is generally sparse. Associated with Cainozoic alluvial plains which may be occasionally flooded. Landforms range from level to very gently sloping plains, alluvial flats, drainage floors, back-swamps and abandoned channels. Associated soils are predominantly deep to very deep cracking clays, sometimes with gilgai or texture contrast soils with sandy surface (particularly where <i>Eucalyptus populnea</i> is present).	Endangered	0.68%
11.3.11	Semi-evergreen vine thicket or semi-deciduous notophyll rainforest, frequently with emergent <i>Eucalyptus tereticornis</i> or <i>E. raveretiana</i> . Common species include <i>Diospyros humilis</i> , <i>D. geminata</i> , <i>Brachychiton australis</i> , <i>B. rupestris</i> , <i>Geijera salicifolia</i> , <i>Lysiphyllum</i> spp., <i>Mallotus philippensis</i> and <i>Streblus brunonianus</i> . Occasional shrubs such as <i>Carissa ovata</i> may be present. Forbs such as <i>Nyssanthus</i> spp. May also be present. Occurs on Cainozoic alluvial plains.	Endangered	0.07%
11.3.2	<i>Eucalyptus populnea</i> woodland to open woodland. <i>E. melanophloia</i> may be present and locally dominant. There is sometimes a distinct low tree layer dominated by species such as <i>Geijera parviflora</i> , <i>Eremophila mitchellii</i> , <i>Acacia salicina</i> , <i>Acacia pendula</i> , <i>Lysiphyllum</i>	Of concern	0.9%

RE Code	RE Description	Biodiversity status	Area
	<i>spp.</i> , <i>Cassia brewsteri</i> , <i>Callitris glaucophylla</i> and <i>Acacia excelsa</i> . The ground layer is grassy dominated by a range of species depending on soil and management conditions. Species include <i>Bothriochloa decipiens</i> , <i>Enteropogon acicularis</i> , <i>Aristida ramosa</i> and <i>Tripogon loliiformis</i> . Occurs on Cainozoic alluvial plains with variable soil types including texture contrast, deep uniform clays, massive earths and sometimes cracking clays.		
11.3.25	<i>Eucalyptus camaldulensis</i> or <i>E. tereticornis</i> woodland to open forest. Other tree species such as <i>Casuarina cunninghamiana</i> , <i>E. coolabah</i> , <i>Melaleuca bracteata</i> , <i>Melaleuca viminalis</i> , <i>Livistona spp.</i> (in north), <i>Melaleuca spp.</i> and <i>Angophora floribunda</i> are commonly present and may be locally dominant. An open to sparse, tall shrub layer is frequently present dominated by species including <i>Acacia salicina</i> , <i>A. stenophylla</i> or <i>Lysiphyllum carronii</i> . Low shrubs are present, but rarely form a conspicuous layer. The ground layer is open to sparse and dominated by perennial grasses, sedges or forbs such as <i>Imperata cylindrica</i> , <i>Bothriochloa bladhii</i> , <i>B. ewartiana</i> , <i>Chrysopogon fallax</i> , <i>Cyperus dactyloides</i> , <i>C. difformis</i> , <i>C. exaltatus</i> , <i>C. gracilis</i> , <i>C. iria</i> , <i>C. rigidellus</i> , <i>C. victoriensis</i> , <i>Dichanthium sericeum</i> , <i>Leptochloa digitata</i> , <i>Lomandra longifolia</i> or <i>Panicum spp.</i> Occurs on fringing levees and banks of major rivers and drainage lines of alluvial plains throughout the region. Soils are very deep, alluvial, grey and brown cracking clays with or without some texture contrast. These are usually moderately deep to deep, soft or firm, acid, neutral or alkaline brown sands, loams or black cracking or non-cracking clays, and may be sodic at depth	Of concern	0.73%
11.3.3	<i>Eucalyptus coolabah</i> woodland to open woodland with a grassy understorey. A mid layer is often absent but scattered tree or shrub species, such as <i>E. populnea</i> , <i>Melaleuca bracteata</i> , <i>Acacia stenophylla</i> , <i>Alectryon oleifolius</i> , <i>Terminalia oblongata</i> (in the north) and <i>Acacia pendula</i> , <i>A. cambagei</i> , and occasionally <i>Duma florulenta</i> may be present. The ground layer is dominated by a range of grass and forb species depending on season, soil and management conditions. Can include small areas of grassland with scattered trees. Occurs on Cainozoic alluvial plains or levees with clay or sometimes texture contrast soils.	Of concern	0.69%
11.4.8	Woodland to open forest dominated by <i>Eucalyptus cambageana</i> and <i>Acacia harpophylla</i> or, sometimes in the north, <i>A. argyrodendron</i> . <i>E. thozetiana</i> is sometimes present on shallower soils. There is a moderately dense low tree layer (5m high) layer dominated by species such as <i>Eremophila mitchellii</i> and a low shrub layer (2m high) dominated by species such as <i>Carissa ovata</i> and <i>Geijera parviflora</i> . Occurs on level to gently undulating plains formed from Cainozoic deposits. Associated soils are usually deep texture contrast with thin loamy or sandy surface horizons overlying strongly alkaline clay subsoils. Surface or subsurface gravel is common.	Endangered	1.41%
11.4.9a	Open forest, occasionally woodland, dominated by <i>Acacia harpophylla</i> usually with a low tree mid-storey of <i>Terminalia oblongata</i> and <i>Eremophila mitchellii</i> . <i>Casuarina cristata</i> sometimes replaces <i>Acacia harpophylla</i> in the overstorey and <i>Lysiphyllum cunninghamii</i> sometimes co-dominates. Other low tree or shrub species such as <i>Alectryon diversifolius</i> , <i>Carissa ovata</i> , <i>Pittosporum spinescens</i> , <i>Ehretia membranifolia</i> , <i>Geijera parviflora</i> and <i>Flindersia dissosperma</i>	Endangered	1.48%

RE Code	RE Description	Biodiversity status	Area
	may occur in the mid-storey or low shrub layer. <i>Acacia harpophylla</i> trees have been recorded as 11- 17m high, the mid-storey layer 2- 8m high and the low shrub layer 1-2m high. Occurs on level to gently undulating Cainozoic plains, including weathered basalt. Associated soils are predominantly moderately deep to deep cracking clays that may be brown, red-brown or grey-brown, and with much surface gravel in some areas.		
11.5.3	<i>Eucalyptus populnea</i> +/- <i>E. melanophloia</i> +/- <i>Corymbia clarksoniana</i> +/- <i>C. dallachiana</i> and occasionally <i>E. cambageana</i> or <i>E. brownii</i> dominate the tree layer (14m median height and 11-15m range) woodland. Localised areas may be dominated by <i>E. melanophloia</i> , occasionally <i>E. crebra</i> and other canopy species. There is generally a distinctive low tree layer (8, 6-11m high) dominated by species such as <i>Eremophila mitchellii</i> , <i>Geijera parviflora</i> , <i>Archidendropsis basaltica</i> , <i>Erythroxylum australe</i> , <i>Cassia brewsteri</i> , <i>Ventilago viminalis</i> and occasionally <i>Allocasuarina luehmannii</i> or <i>Callitris glaucophylla</i> . A low shrub layer (2-6m high) dominated by species such as <i>Carissa ovata</i> , <i>Erythroxylum australe</i> , <i>Capparis lasiantha</i> is also often present. Occurs on flat to gently undulating plains formed from Cainozoic sediments. Associated soils are generally deep texture contrast with thick sandy surface horizons with some deep red earths.	No concern at present	0.25%
11.5.5c	<i>Eucalyptus melanophloia</i> predominates forming a distinct but discontinuous canopy (12-18m high) often in association with <i>E. populnea</i> which may dominate localised areas. Scattered other <i>Eucalyptus</i> spp. may be present such as <i>E. chloroclada</i> (in south) <i>Corymbia tessellaris</i> (in north) and sometimes <i>E. crebra</i> . <i>Callitris glaucophylla</i> dominates the lower tree layer (9-12m high), with occasional <i>Acacia</i> spp. and <i>Allocasuarina luehmannii</i> trees. The shrub layer is often absent or sparse but may be prominent and dominated by tall shrubs such as <i>Geijera parviflora</i> and <i>Eremophila mitchellii</i> and scattered low shrubs, especially in disturbed areas. The ground layer is sparse to open, and dominated by perennial grasses such as <i>Aristida</i> spp., <i>Bothriochloa decipiens</i> and <i>Eragrostis</i> spp. Occurs on undulating plains and rises formed on Cainozoic deposits. Associated soils are usually deep texture contrast soils, with thick, sandy surface horizons overlying yellow, mottled clay subsoil's	No concern at present	0.14%
11.8.11	Grassland dominated by <i>Dichanthium sericeum</i> , <i>Aristida</i> spp., <i>Astrebla</i> spp. and <i>Panicum decompositum</i> with or without trees such as <i>Eucalyptus orgadophila</i> , <i>E. melanophloia</i> , <i>Corymbia erythrophloia</i> and <i>Acacia salicina</i> , (height 11+/-3 m). However, dominance and cover may vary with seasonal and other environmental conditions. Frequently occurring and sometimes locally dominant, species include the grasses <i>Aristida lazaridis</i> , <i>A. ramosa</i> , <i>Bothriochloa ewartiana</i> , <i>Dichanthium sericeum</i> , <i>Chrysopogon fallax</i> , <i>Heteropogon contortus</i> , <i>Enneapogon gracilis</i> , <i>Themeda triandra</i> and <i>Tragus australianus</i> and the herbs <i>Brunoniella australis</i> , <i>Evolvulus alsinoides</i> , <i>Galactia tenuiflora</i> and <i>Indigofera linnaei</i> . Isolated emergent trees (tree height 12+/-4 m - species including <i>Eucalyptus orgadophila</i> , <i>E. melanophloia</i> and <i>Corymbia erythrophloia</i>) or small areas of open woodland may also be present. Occurs on Cainozoic igneous rocks, particularly fresh basalt, and is generally associated with undulating to gently undulating rises. It usually occurs on the crests and middle and upper slopes (slopes 2-6%), although also present on lower slopes	Of concern	0.01%

RE Code	RE Description	Biodiversity status	Area
	and flat areas (slopes 0-2%). Associated soils are moderately shallow to deep cracking clay soils, dark brown to reddish brown in colour, often self-mulching, and with gravel, stone or linear gilgai sometimes present. Surface stone 10-15 cm diameter is present in the south-western remnants.		
11.8.4	<i>Eucalyptus melanophloia</i> and/or <i>E. crebra</i> +/- <i>E. orgadophila</i> +/- <i>Corymbia erythrophloia</i> grassy open woodland. <i>Macrozamia moorei</i> is a conspicuous element of the mid layer in the Central Highlands. Localised patches of <i>Corymbia citriodora</i> occur on volcanic plugs such as Minerva Hills. Generally occurs on slopes of mountains and hills formed from Cainozoic igneous rocks usually with shallow stony soils and extensive outcropping.	No concern at present	0.02%
11.8.5	<i>Eucalyptus orgadophila</i> grassy open woodland. <i>Eucalyptus orgadophila</i> predominates and forms a distinct but discontinuous canopy sometimes with other sub-dominant species such as <i>Corymbia erythrophloia</i> , <i>E. melanophloia</i> and occasionally <i>E. crebra</i> . Shrubs are usually scarce and scattered although a well-defined shrubby layer does develop in some areas. On the lower slopes at better sites, softwood scrub species may form tall and low shrub layers under the canopy of <i>Eucalyptus orgadophila</i> . The ground layer is moderately dense to dense, and dominated by species that include the grasses <i>Aristida lazardis</i> , <i>A. ramosa</i> , <i>Bothriochloa ewartiana</i> , <i>Dichanthium sericeum</i> , <i>Chrysopogon fallax</i> , <i>Heteropogon contortus</i> , <i>Enneapogon gracilis</i> , <i>Themeda triandra</i> and <i>Tragus australianus</i> and the herbs <i>Brunoniella australis</i> , <i>Evolvulus alsinoides</i> , <i>Galactia tenuiflora</i> and <i>Indigofera linnaei</i> . Occurs on undulating plains, rises, low hills or sometimes flat tablelands on top of mountains, formed from basalt. Generally soils are shallow to moderately shallow, often rocky or stony clays.	No concern at present	0.01%
11.9.4a	Semi-evergreen vine thicket generally dominated by a low tree layer (5-10m high) which is floristically diverse and variable. Common codominant species include <i>Croton insularis</i> , <i>Denhamia oleaster</i> . There is also a tall and low shrub layer (2-6m high) dominated by species such as <i>Ehretia membranifolia</i> , <i>Apophyllum anomalum</i> , <i>Geijera parviflora</i> , <i>Capparis</i> spp., <i>Croton phebaloides</i> , <i>Erythroxylum australe</i> , <i>Alectryon diversifolius</i> and <i>Carissa ovata</i> . Emergents (16-25m high) are usually present including species such as <i>Cadellia pentastylis</i> and <i>Brachychiton</i> spp. usually on better sites, and <i>Eucalyptus orgadophila</i> and <i>Casuarina cristata</i> on drier, poorer sites. Vines are frequent. The ground layer is very sparse, and is most frequently composed of <i>Ancistrachne uncinulata</i> and <i>Eragrostis megalosperma</i> . Occurs on steep upper and middle slopes where heavy clay soils have formed from sediments. It may grade into <i>Acacia harpophylla</i> , softwood spp. (11.9.5a) on the lower slopes. It is prominent on the steep slopes of sandstone ranges, where shale has been exposed, and aspect, rainfall and runoff provide sufficient available water for its development. The soils are generally shallow, brown or grey-brown loams or light clays grading into medium or heavy clays. The soil reaction may become strongly acidic or alkaline at depth, depending on the acidity of parent material. May also occur on deep texture contrast soils, where a thin sandy colluvium overlies the clay subsoil. Loose fragments of sandstone may be present over the soil surface.	Endangered	0.02%

RE Code	RE Description	Biodiversity status	Area
11.9.5a	Open forest dominated by <i>Acacia harpophylla</i> and/or <i>Casuarina cristata</i> (10-20m) or <i>Acacia harpophylla</i> with a semi-evergreen vine thicket understorey. Open forest dominated by <i>C. cristata</i> is more common in southern parts of the bioregion. A prominent low tree or tall shrub layer dominated by species such as <i>Geijera parviflora</i> and <i>Eremophila mitchellii</i> , and often with semi-evergreen vine thicket species is often present. The latter include <i>Flindersia dissosperma</i> , <i>Brachychiton rupestris</i> , <i>Excoecaria dallachyana</i> , <i>Macropteranthes leichhardtii</i> and <i>Acalypha eremorum</i> in eastern areas, and species such as <i>Carissa ovata</i> , <i>Owenia acidula</i> , <i>Croton insularis</i> , <i>Denhamia oleaster</i> and <i>Notelaea microcarpa</i> in south-western areas. <i>Melaleuca bracteata</i> may be present along watercourses. Occurs on fine-grained sediments. The topography includes gently undulating plains, valley floors and undulating footslopes and rarely on low hills. The soils are generally deep texture-contrast and cracking clays. The cracking clays are usually black or grey to brown or reddish-brown in colour, often self-mulching and sometimes with gilgai microrelief in flatter areas. Some texture contrast soils are shallow to only moderately deep.	Endangered	0.19%

As shown in Table 4 and on Map 2 within Appendix A, approximately 93% of the area has been cleared and represents non-remnant vegetation. The limited tracts of vegetation are generally located within riparian corridors associated with watercourses in the area.

Environmentally Sensitive Areas

Appendix B shows the location of the following environmentally sensitive areas (ESAs) within PLs 1082 and 1083:

- Endangered Regional Ecosystems (Category B);
- Of Concern Regional Ecosystems (Category C); and
- Essential Habitat (Category C).

Matters of State Environmental Significance

Appendix C details the matters of state environmental significance (MSES) from DES' environmental reports for PLs 1082 and 1083. Table 17 summarises the MSES detailed in these reports.

Table 17: Extent of MSES within PLs 1082 and 1083

MSES	Total Area PL Area	Extent within PLs Area
1a Protected Areas- estates	0 ha	0%
1b Protected Areas- nature refuges	0 ha	0%
2 State Marine Parks- highly protected zones	0 ha	0%
3 Fish habitat areas (A and B areas)	0 ha	0%
4 Strategic Environmental Areas (SEA)	0 ha	0%
5 High Ecological Significance wetlands on the map of Referable Wetlands	3.75 ha	0.01%
6a High Ecological Value (HEV) wetlands	0 ha	0%
6b High Ecological Value (HEV) waterways	0 ha	0%
7 Threatened species and Iconic species	0 ha	0%

MSES	Total Area PL Area	Extent within PLs Area
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	2602.92 ha	5.55%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	5.27 ha	0.01%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	43.64 ha	0.09%
8d Regulated Vegetation - Essential habitat	1503.4 ha	3.21%
8e Regulated Vegetation - intersecting a watercourse	365.3 km	N/A
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	96.3 ha	0.21%
9a Legally secured offset areas- offset register areas	0 ha	0%
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0 ha	0%

5.6.2. Environmental values assessment and mitigation measures

As described in Section 3.1.1, well sites would be located in accordance with the existing land disturbance and water management conditions of the EA (e.g. Schedule F, and Schedule G), including avoidance of the following:

- endangered regional ecosystems (REs);
- nature refuges and koala habitat including a 200m buffer / protection zone;
- essential habitat;
- essential regrowth habitat;
- of concern REs;
- wetlands of high ecological significance including a 200m buffer / protection zone;
- wetlands of other environmental value; and
- watercourses.

Site-specific ecological assessments would be conducted to confirm the presence / absence of these environmental values and MSES prior to land disturbance. In accordance with existing Condition F8 of the EA, well sites would also be located and designed with reference to the Queensland Environmental Offsets Policy Significant Residual Impact Guideline to avoid significant residual impacts to prescribed environmental matters.

Rehabilitation

Land disturbance for the proposed additional wells would be rehabilitated in accordance with Condition J3 and J4 of the existing EA:

Final rehabilitation acceptance criteria

(J3) *All significantly disturbed areas caused by petroleum activities which are not being or intended to be utilised by the landholder or overlapping tenure holder, must be rehabilitated to meet the following final acceptance criteria measured either against the highest ecological value adjacent land use or the pre-disturbed land use:*

- greater than or equal to 70% of native ground cover species richness*
- greater than or equal to the total per cent of ground cover*

- (c) *less than or equal to the per cent species richness of declared plant pest species; and*
- (d) *where the adjacent land use contains, or the pre-clearing land use contained, one or more regional ecosystem(s), then at least one regional ecosystem(s) from the same broad vegetation group, and with the equivalent biodiversity status or a biodiversity status with a higher conservation value as any of the regional ecosystem(s) in either the adjacent land or pre-disturbed land, must be present.*

Final rehabilitation acceptance criteria in environmentally sensitive areas

- (J4) *Where significant disturbance to land has occurred in an environmentally sensitive area, the following final rehabilitation criteria as measured against the pre-disturbance biodiversity values assessment (required by conditions (F1) and (F2)) must be met:*
- (a) *greater than or equal to 70% of native ground cover species richness*
 - (b) *greater than or equal to the total per cent ground cover*
 - (c) *less than or equal to the per cent species richness of declared plant pest species*
 - (d) *greater than or equal to 50% of organic litter cover*
 - (e) *greater than or equal to 50% of total density of coarse woody material; and*
 - (f) *all predominant species in the ecologically dominant layer, that define the pre-disturbance regional ecosystem(s) are present.*
 - (g) *relinquishment notice being lodged with the administering authority for the Petroleum and Gas (Production and Safety) Act 2004.*

Potential Offsite Impacts

The following management measures would be undertaken for construction of the proposed additional wells to minimise potential offsite impacts to terrestrial ecological values:

- Prohibition of keeping domestic animals (e.g. dogs or cats) within PLs 1082 and 1083 and surrounds by personnel employed for the construction and operation of petroleum activities
- Implementation of a weed, pest and biosecurity management plan including compliance with obligations under the QLD *Biosecurity Act 2014*, including hygiene procedures to manage unintentional introduction and spread of *Phytophthora cinnamomi* and Myrtle Rust
- A speed limit of 60 km/hr will be enforced on non-public roads within PLs 1082 and 1083 to minimise potential collision of vehicles with fauna
- Management of putrescible waste to reduce potential attraction of predatory fauna and pest species
- Disturbed land will be minimised and progressively stabilised following construction
- Dust suppression would be undertaken including the watering of disturbed areas as required
- Activities with the potential to generate increased dust (e.g. soil stripping) will be minimised during windy conditions
- Noise attenuation devices (e.g. mufflers) will be installed and maintained on all significant noise generating equipment operating adjacent to REs
- Site vehicles will be equipped with fire extinguishers
- Flammable material will not be stockpiled or stored near hot work activities (including vegetation stockpiles)
- Smoking areas will be designated with provision for containers for safe disposal of cigarette butts

- Hot works permits will be followed at all times where applicable
- Construction activities will be undertaken in accordance with the Risk Minimisation Requirements of the QLD Department of Agriculture and Fisheries Queensland Biosecurity Manual
- A pre-clearance weed survey will be conducted to identify the presence of declared weeds.
- Reinstated areas will be monitored for the presence of weeds
- All waste will be stored, handled and transported in accordance with the waste and resource management hierarchy, waste and resource management principles prescribed by the *Waste Reduction and Recycling Act 2011*.

The proposed amendment would not significantly increase the risk and likely magnitude of impacts on the environmental values of terrestrial ecology of the area given the extensive previous disturbance as a result of broad scale clearing, ongoing agricultural operations, avoidance of disturbance to terrestrial ecological values, rehabilitation of disturbance, and implementation of the above management measures.

6. Waste Management

Environmental Objective (EP Reg): Any waste generated, transported, or received as part of carrying out the activity is managed in a way that protects all environmental values.

The current EA regulates waste management for the project, and the proposed amendment does not change waste management for the project, beyond what is authorised on the EA.

Waste Management

All waste generated, transported, or received as part of the Denison/Mahalo Project is managed in accordance with the Waste and Resource Management Hierarchy, as specified in the *Waste Reduction and Recycling Act 2011*. The hierarchy lists waste and resource management options that should be considered in the preferred order:

- (a) *AVOID unnecessary resource consumption;*
- (b) *REDUCE waste generation and disposal;*
- (c) *RE-USE waste resources without further manufacturing;*
- (d) *RECYCLE waste resources to make the same or different products;*
- (e) *RECOVER waste resources, including the recovery of energy;*
- (f) *TREAT waste before disposal, including reducing the hazardous nature of waste;*
- (g) *DISPOSE of waste only if there is no viable alternative.*

All waste generated associated with the proposed amendment will be beneficially used or disposed of in a way that prevents and minimises adverse impacts on environmental values. This includes the beneficial use of all produced water through irrigation, dust suppression, construction, and water supply in accordance with Conditions B7-B12 of the EA and/or approvals under the *Waste Reduction and Recycling Act 2011*.

Types of waste

Wastes that will be generated from activities on the Denison/Mahalo Project Area comprise:

- *General waste* - those not defined as regulated waste under legislation. General wastes comprise putrescible wastes (easily decomposed, recyclable by composting) and non-putrescible wastes (not easily decomposed, may be recyclable);
- *Recyclable waste* - this waste type is able to be reconditioned, reprocessed or reused; and
- *Regulated waste* - regulated wastes are those that require specific controls or actions as defined by legislation. Listed, hazardous, regulated, controlled or trackable wastes typically have unique handling and disposal requirements in order to manage specific associated hazards.

The typical wastes expected to be generated as part of the Project are:

Table 18: Typical Waste Streams

Source	Waste	Characteristics / nature
Earthworks/Clearing vegetation	Soils	Inert material - Reused in rehabilitation
	Green waste	Organic material - Reused in rehabilitation
Production Activities	General construction waste (e.g. pipe off-cuts, concrete, rubble, timber, pallets)	General and recyclable waste.
	Produced water	Non-regulated waste. Beneficially re-used where applicable
	Waste oils, grease and fuels, empty fuel containers	Regulated waste

Source	Waste	Characteristics / nature
	Residual drilling materials	Inert material - Reused in drilling process until unsuitable for reuse
	Used chemicals, empty chemical, paint, solvent containers	Regulated waste
General Activities/Temporary Camps	Putrescible and general waste	General waste and recyclable waste
	Paper and cardboard	Recyclable waste
	Batteries	Regulated
	Treated effluent and grey water	Regulated waste - Treated and used for onsite irrigation

7. Estimated Rehabilitation Cost

The EP Act requires estimated rehabilitation cost to be in place prior to significant disturbance to land. The ERC for the Project will be amended as required and prior to any new significant disturbance occurring as a result of this amendment application.



Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
pl: 1082

Published on DES Disclosure Log
RTI Act 2009

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Natural Resources, Mines and Energy website

<https://www.dnrme.qld.gov.au/>

Please direct queries about these reports to: Queensland.Herbarium@dsiti.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: pl: 1082

Size (ha)	23,451.41
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Isaac - Comet Downs
Catchment(s)	Fitzroy

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	1,437.47	6.13
Of concern	272.84	1.16
No concern at present	201.1	0.86
Total remnant vegetation	1,911.42	8.15

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2017) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Natural Resources, Mines and Energy website.

<https://www.dnrme.qld.gov.au/>

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
11.10.3	Acacia catenulata or A. shirleyi open forest on coarse-grained sedimentary rocks. Crests and scarps	No concern at present	49.32	0.21
11.3.1	Acacia harpophylla and/or Casuarina cristata open forest on alluvial plains	Endangered	12.99	0.06
11.3.2	Eucalyptus populnea woodland on alluvial plains	Of concern	272.84	1.16
11.4.8	Eucalyptus cambageana woodland to open forest with Acacia harpophylla or A. argyrodendron on Cainozoic clay plains	Endangered	656.95	2.8
11.4.9a	Acacia harpophylla shrubby woodland with Terminalia oblongata on Cainozoic clay plains	Endangered	674.35	2.88
11.5.3	Eucalyptus populnea +/- E. melanophloia +/- Corymbia clarksoniana woodland on Cainozoic sand plains and/or remnant surfaces	No concern at present	84.6	0.36
11.5.5c	Eucalyptus melanophloia, Callitris glaucophylla woodland on Cainozoic sand plains and/or remnant surfaces. Deep red sands	No concern at present	67.19	0.29
11.9.5a	Acacia harpophylla and/or Casuarina cristata open forest on fine-grained sedimentary rocks	Endangered	93.19	0.4
non-rem	None	None	21,539.99	91.85

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the SOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
11.10.3	Pre-clearing 378000 ha; Remnant 2017 331000 ha	24a	None	Medium

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
11.3.1	Pre-clearing 781000 ha; Remnant 2017 78000 ha	25a	None	Low
11.3.2	Pre-clearing 1926000 ha; Remnant 2017 506000 ha	17a	Contains palustrine wetland (e.g. in swales).	Low
11.4.8	Pre-clearing 724000 ha; Remnant 2017 67000 ha	25a	Contains palustrine wetland (e.g. in swales).	Low
11.4.9a	Pre-clearing 999000 ha; Remnant 2017 90000 ha	25a	None	Low
11.5.3	Pre-clearing 981000 ha; Remnant 2017 372000 ha	17a	None	Low
11.5.5c	Pre-clearing 386000 ha; Remnant 2017 134000 ha	17b	None	Low
11.9.5a	Pre-clearing 2272000 ha; Remnant 2017 163000 ha	25a	None	Low
non-rem	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
11.10.3	Habitat for threatened flora species including <i>Acacia deuteroneura</i> , <i>A. wardellii</i> and <i>Bertya calycina</i> .
11.3.1	Habitat for threatened fauna species including painted honeyeater, <i>Grantiella picta</i> particularly in subregion 35 (Oliver et al. 2003).
11.3.2	Habitat for threatened flora species <i>Homopholis belsonii</i> .
11.4.8	Larger gilgai may provide ephemeral wetland habitat.
11.4.9a	Potential habitat for NCA listed species: <i>Cadellia pentastylis</i> , <i>Solanum adenophorum</i> , <i>Solanum dissectum</i> , <i>Solanum elachophyllum</i> , <i>Solanum johnsonianum</i> , <i>Xerothamnella herbacea</i>
11.5.3	Potential habitat for NCA listed species: <i>Sannantha brachypoda</i>
11.5.5c	Potential habitat for NCA listed species: <i>Tylophora linearis</i>
11.9.5a	Habitat for threatened fauna species including <i>Jalmenus eubulus</i> , pale imperial hairstreak butterfly (Eastwood et al. 2008)
non-rem	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

<https://publications.qld.gov.au/dataset/redd/resource/>

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	21,539.99	91.85
17a	Woodlands dominated by <i>Eucalyptus populnea</i> (poplar box) (or <i>E. brownii</i> (Reid River box)) on alluvium, sand plains and footslopes of hills and ranges. (land zones 3, 5, 10, 9, 4, 11, 12, [8]) (BRB, MUL, DEU, MUL, EIU)	357.44	1.52
17b	Woodlands to open woodlands dominated by <i>Eucalyptus melanophloia</i> (silver-leaved ironbark) (or <i>E. shirleyi</i> (shirley's silver-leaved ironbark)) on sand plains and footslopes of hills and ranges. (land zones 5, 12, 3, 11, 9, 7) (BRB, DEU, EIU, SEQ, NET, GUP, NWH)	67.19	0.29
24a	Low woodlands to tall shrublands dominated by <i>Acacia</i> spp. on residuals. Species include <i>A. shirleyi</i> (lancewood), <i>A. catenulata</i> (bendee), <i>A. microserpa</i> (bowyacka), <i>A. clivicola</i> , <i>A. sibirica</i> , <i>A. rhodoxylon</i> (rosewood) and <i>A. leptostachya</i> (Townsville wattle). (land zones 7, 10, 5, 12, 11, [9, 3]) (MUL, CHC, BRB, GUP, EIU, MGD, DEU, NWH, [CYP])	49.32	0.21
25a	Open forests to woodlands dominated by <i>Acacia harpophylla</i> (brigalow) sometimes with <i>Casuarina cristata</i> (belah) on heavy clay soils. Includes areas co-dominated with <i>A. cambagei</i> (gidgee) and/or emergent eucalypts (land zones 4, 9, 3, 11, 7, 12, [5, 8]) (BRB, MUL, MGD, DEU, [SEQ])	1,437.47	6.13

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/>

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act 1999*. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2012 (PDF)* section 3.3.1 of:

<https://publications.qld.gov.au/dataset/redd/resource/>

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

<http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/>

Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the

geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

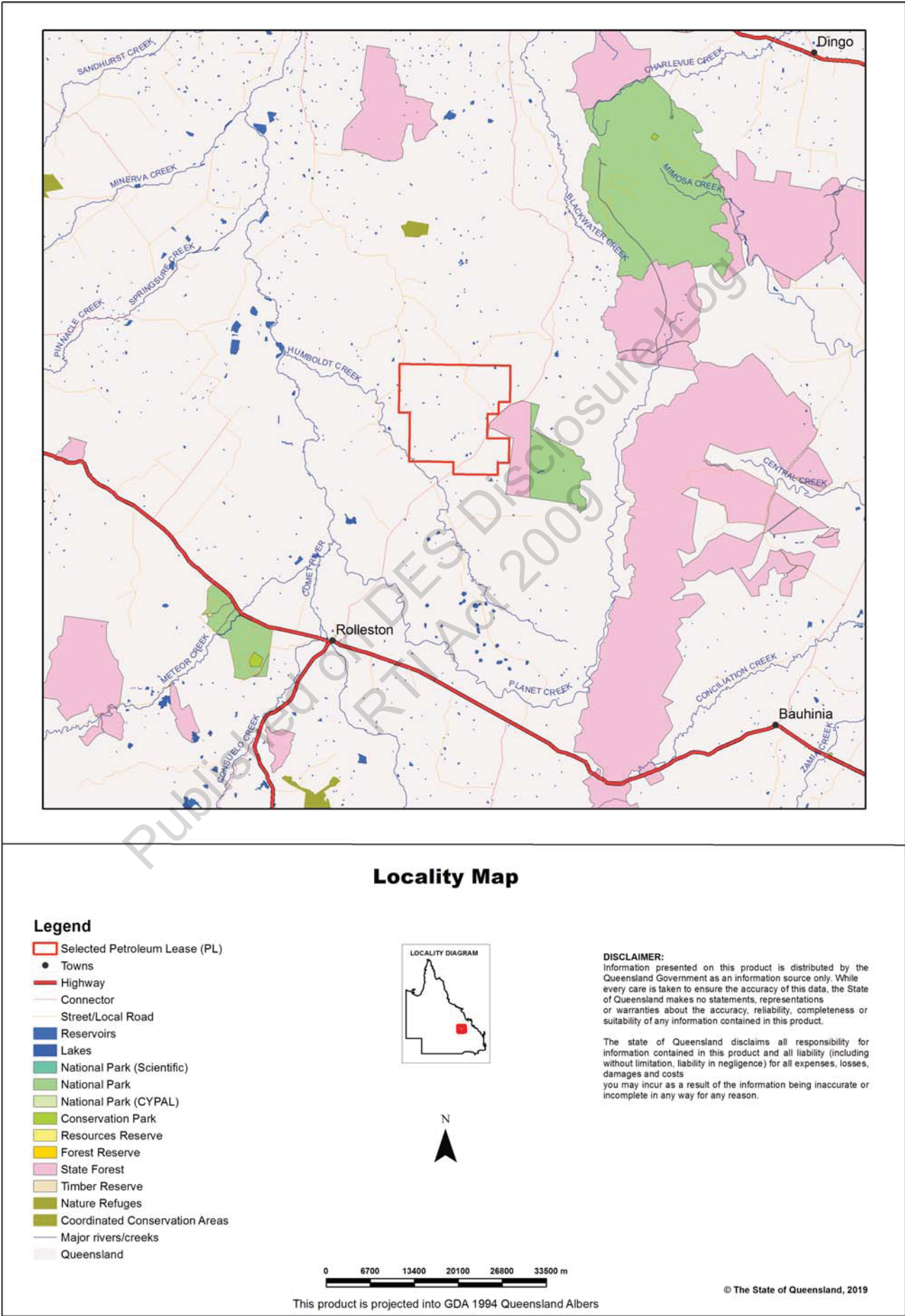
Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
11.10.3	Available	Not currently available
11.3.1	Available	Not currently available
11.3.2	Available	Not currently available
11.4.8	Available	Not currently available
11.4.9a	Available	Not currently available
11.5.3	Available	Not currently available
11.5.5c	Available	Not currently available
11.9.5a	Available	Not currently available
non-rem	Not currently available	Not currently available

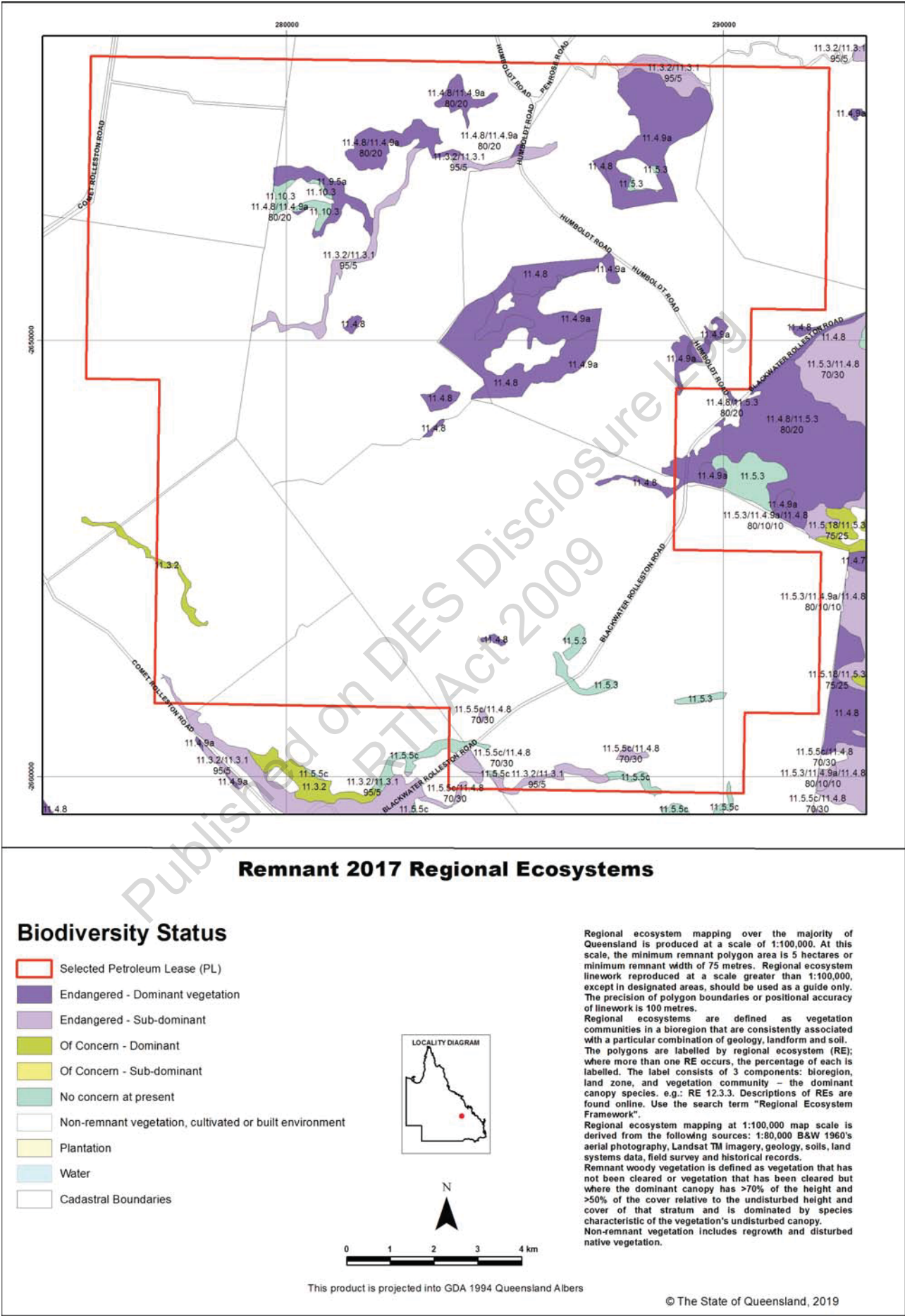
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Maps

Map 1 - Location



Map 2 - Remnant 2017 regional ecosystems



Pre-clearing Regional Ecosystems

Biodiversity Status

- Selected Petroleum Lease (PL)
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Water
- Cadastral Boundaries

LOCALITY DIAGRAM

Scale: 0 1 2 3 4 km

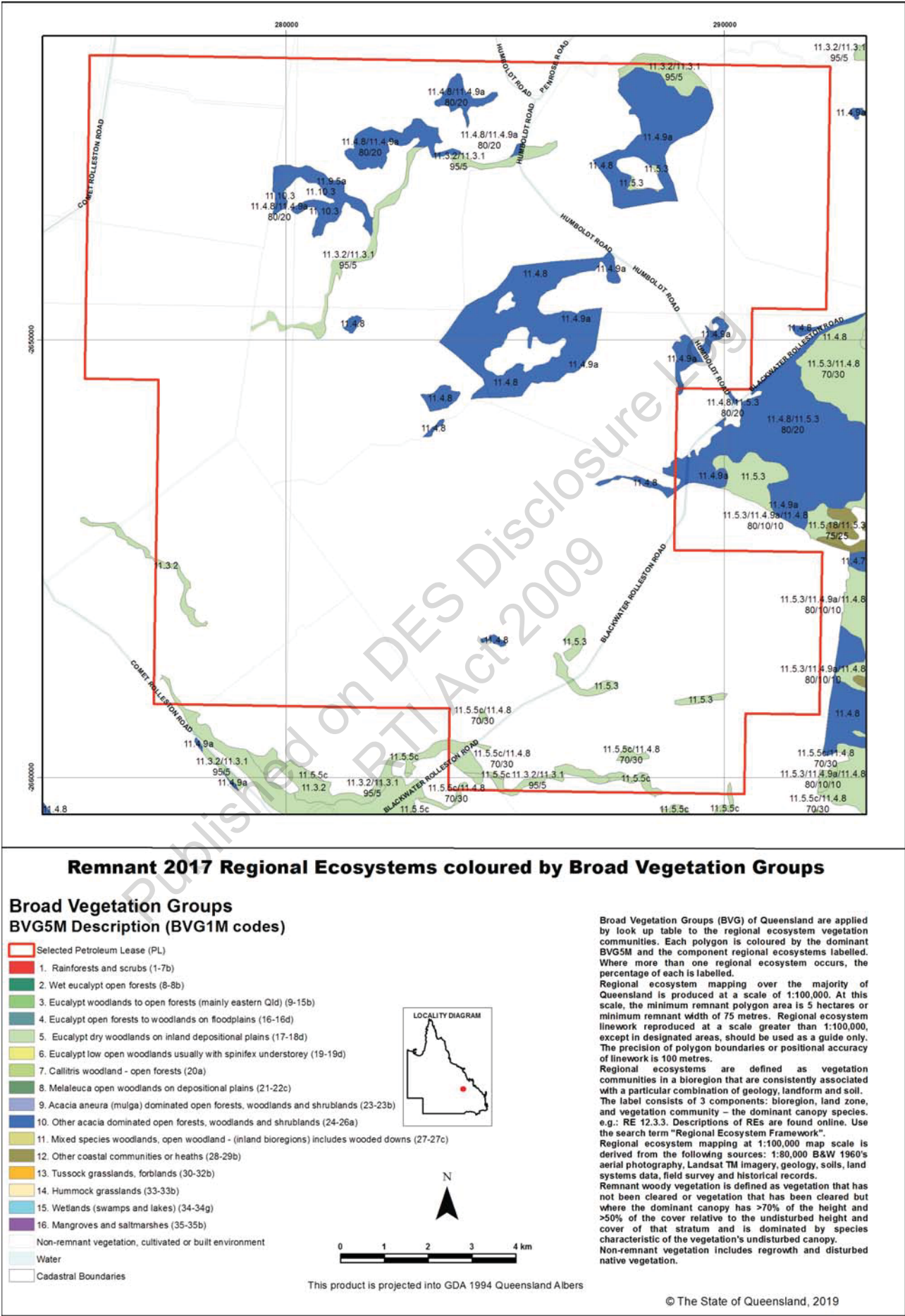
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.

Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".

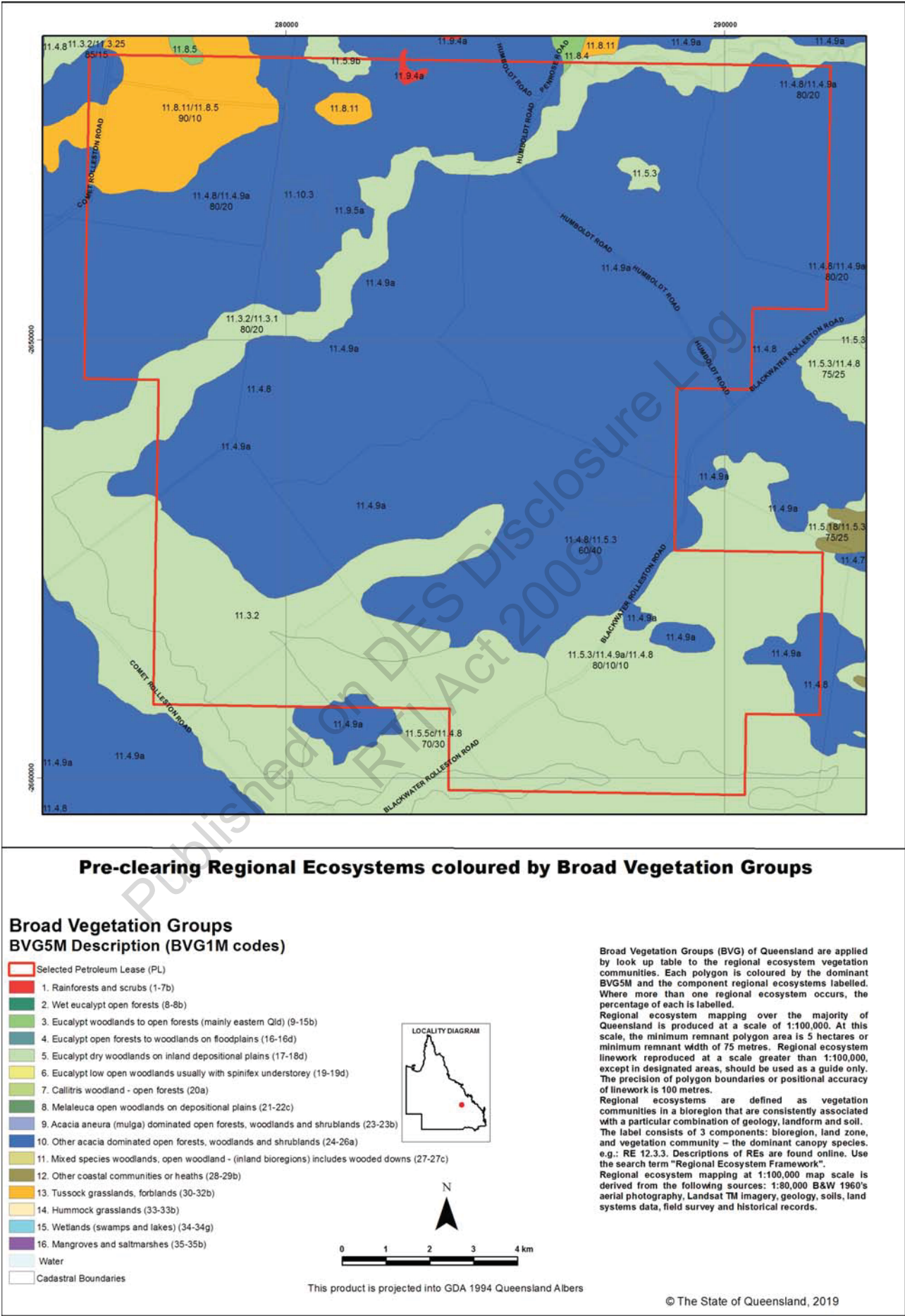
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

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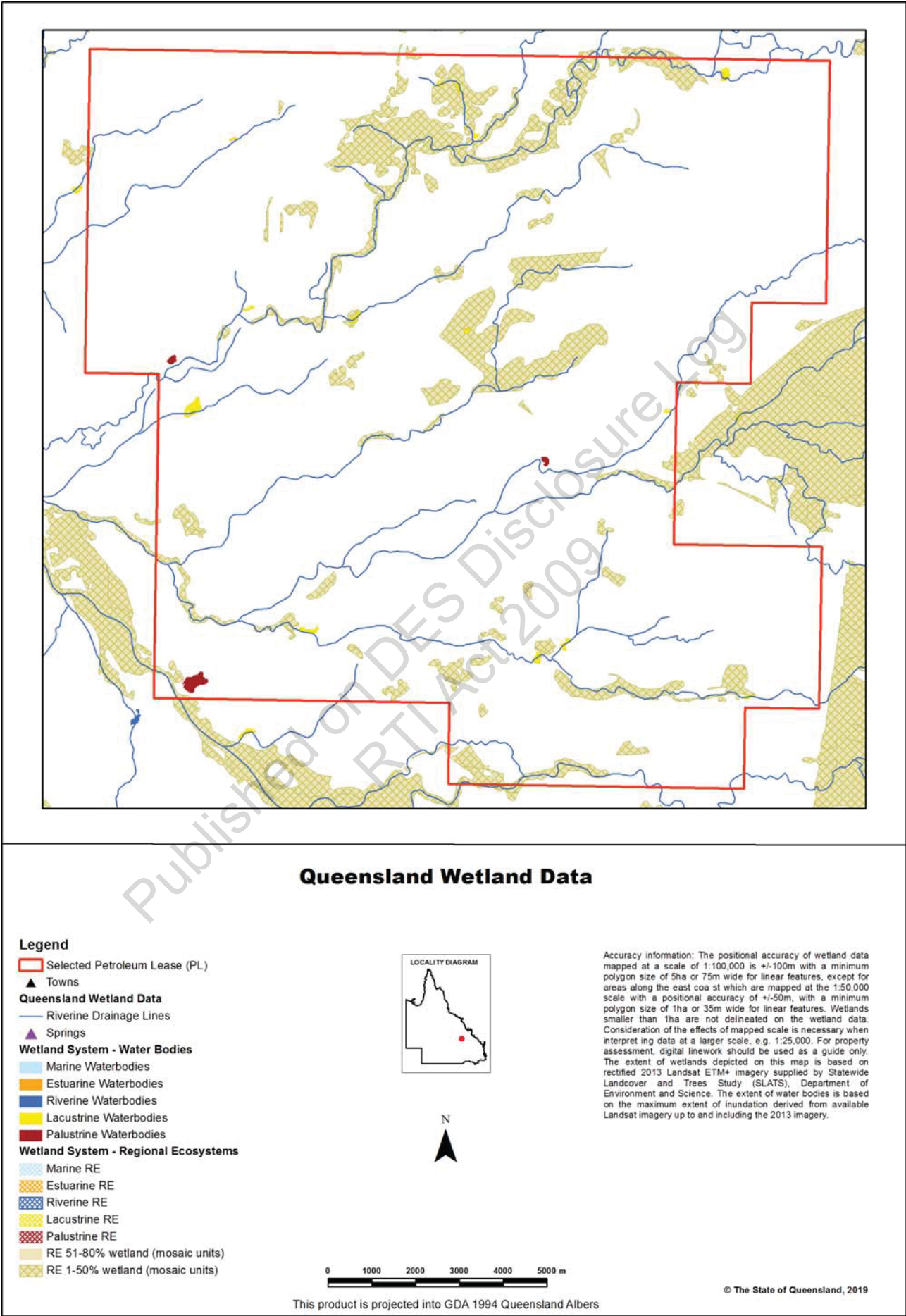
Map 4 - Remnant 2017 regional ecosystems by BVG (5M)



Map 5 - Pre-clearing regional ecosystems by BVG (5M)



Map 6 - Wetlands and waterways



Links and Other Information Sources

The Department of Environment and Science's Website -

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/>

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

<https://publications.qld.gov.au/dataset/redd/resource/>

The methodology for mapping regional ecosystems can be downloaded from:

<https://publications.qld.gov.au/dataset/redd/resource/>

Technical descriptions for regional ecosystems can be obtained from:

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/>

Benchmarks can be obtained from:

<http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/>

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

<http://dds.information.qld.gov.au/dds/>

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

<http://www.dnrm.qld.gov.au/mapping-data/queensland-globe>

References

Neldner, V.J., Niehus R.E., Wilson, B.A. McDonald, W.J.F., Ford, A.J. and Accad, A. (2017) The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 3.0. Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts.

<https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086>

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S. and Butler, D.W. (2017) *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*. Version 4.0. Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts.

<https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4>

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/>

- Regional Ecosystem Description Database

The datasets listed below are available for download from:

<http://dds.information.qld.gov.au/dds/>

- Biodiversity status of pre-clearing and 2017 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

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Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- <i>Vegetation Management Act 1999</i>

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Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
pl: 1083

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Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Natural Resources, Mines and Energy website

<https://www.dnrme.qld.gov.au/>

Please direct queries about these reports to: Queensland.Herbarium@dsiti.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: pl: 1083

Size (ha)	23,453.62
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Isaac - Comet Downs
Catchment(s)	Fitzroy

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	379.29	1.62
Of concern	821.19	3.5
No concern at present	46.03	0.2
Total remnant vegetation	1,246.51	5.31

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2017) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Natural Resources, Mines and Energy website.

<https://www.dnrme.qld.gov.au/>

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
11.3.1	Acacia harpophylla and/or Casuarina cristata open forest on alluvial plains	Endangered	308.03	1.31
11.3.11	Semi-evergreen vine thicket on alluvial plains	Endangered	34.44	0.15
11.3.2	Eucalyptus populnea woodland on alluvial plains	Of concern	149.72	0.64
11.3.25	Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines	Of concern	341.23	1.45
11.3.3	Eucalyptus coolabah woodland on alluvial plains	Of concern	327.06	1.39
11.4.8	Eucalyptus cambageana woodland to open forest with Acacia harpophylla or A. argyrodendron on Cainozoic clay plains	Endangered	4.06	0.02
11.4.9a	Acacia harpophylla shrubby woodland with Terminalia oblongata on Cainozoic clay plains	Endangered	22.16	0.09
11.5.3	Eucalyptus populnea +/- E. melanophloia +/- Corymbia clarksoniana woodland on Cainozoic sand plains and/or remnant surfaces	No concern at present	33.32	0.14
11.8.11	Dichanthium sericeum grassland on Cainozoic igneous rocks	Of concern	3.18	0.01
11.8.4	Eucalyptus melanophloia open woodland on Cainozoic igneous rocks.	No concern at present	9.54	0.04
11.8.5	Eucalyptus orgadophila open woodland on Cainozoic igneous rocks	No concern at present	3.18	0.01
11.9.4a	Semi-evergreen vine thicket or Acacia harpophylla with a semi-evergreen vine thicket understorey on fine-grained sedimentary rocks	Endangered	10.59	0.05
non-rem	None	None	22,207.11	94.69

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the SOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
11.3.1	Pre-clearing 781000 ha; Remnant 2017 78000 ha	25a	None	Low
11.3.11	Pre-clearing 18000 ha; Remnant 2017 2000 ha	7a	None	Low
11.3.2	Pre-clearing 1926000 ha; Remnant 2017 506000 ha	17a	Contains palustrine wetland (e.g. in swales).	Low
11.3.25	Pre-clearing 795000 ha; Remnant 2017 512000 ha	16a	Riverine wetland or fringing riverine wetland.	Low
11.3.3	Pre-clearing 930000 ha; Remnant 2017 272000 ha	16c	Floodplain (other than floodplain wetlands).	Low
11.4.8	Pre-clearing 724000 ha; Remnant 2017 67000 ha	25a	Contains palustrine wetland (e.g. in swales).	Low
11.4.9a	Pre-clearing 999000 ha; Remnant 2017 90000 ha	25a	None	Low
11.5.3	Pre-clearing 981000 ha; Remnant 2017 372000 ha	17a	None	Low
11.8.11	Pre-clearing 606000 ha; Remnant 2017 173000 ha	30b	None	Low
11.8.4	Pre-clearing 217000 ha; Remnant 2017 151000 ha	11a	None	High
11.8.5	Pre-clearing 631000 ha; Remnant 2017 347000 ha	11a	None	Low
11.9.4a	Pre-clearing 189000 ha; Remnant 2017 33000 ha	7a	None	Low
non-rem	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
11.3.1	Habitat for threatened fauna species including painted honeyeater, <i>Grantiella picta</i> particularly in subregion 35 (Oliver et al. 2003).
11.3.11	Potential habitat for NCA listed species: <i>Macropteranthes leiocaulis</i>
11.3.2	Habitat for threatened flora species <i>Homopholis belsonii</i> .
11.3.25	Shown to be associated with a high fauna species richness in the Taroom area (Venz et al. 2002). Within parts of the Fitzroy catchment, this RE is known habitat for the threatened freshwater turtle <i>Rheodytes leukops</i> . Known to be important habitat for other riparian freshwater turtle species.
11.3.3	Mature trees provide hollows for fauna especially nesting birds. Associated with a high number fauna species (Dick 1992, Venz et al. 2002). 11.3.3c: Mature trees provide hollows for fauna especially nesting birds. Associated with a high number fauna species (Dick 1992, Venz et al. 2002).
11.4.8	Larger gilgai may provide ephemeral wetland habitat.

Regional Ecosystem	Special Values
11.4.9a	Potential habitat for NCA listed species: <i>Cadellia pentastylis</i> , <i>Solanum adenophorum</i> , <i>Solanum dissectum</i> , <i>Solanum elachophyllum</i> , <i>Solanum johnsonianum</i> , <i>Xerothamnella herbacea</i>
11.5.3	Potential habitat for NCA listed species: <i>Sannantha brachypoda</i>
11.8.11	Habitat for threatened plant species including <i>Trioncinia retroflexa</i> and <i>Dichanthium queenslandicum</i> . <i>T. retroflexa</i> is currently known from three small populations.
11.8.4	Potential habitat for NCA listed species: <i>Acacia arbiana</i> , <i>Acacia islana</i> , <i>Bertya pedicellata</i> , <i>Grevillea hockingsii</i> , <i>Haloragis exalata</i> subsp. <i>velutina</i> , <i>Marsdenia brevifolia</i> , <i>Sannantha brachypoda</i>
11.8.5	In southern part of bioregion, habitat for a number of threatened plant species including <i>Picris evae</i> and <i>Thesium australe</i> and near threatened species <i>Digitaria porrecta</i> and <i>Discaria pubescens</i> .
11.9.4a	Habitat for threatened plant species including <i>Cadellia pentastylis</i> .
non-rem	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

<https://publications.qld.gov.au/dataset/redd/resource/>

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	22,207.11	94.69
11a	Moist to dry open forests to woodlands dominated by <i>Eucalyptus orgadophila</i> (mountain coolibah). Some areas dominated by <i>E. tereticornis</i> (blue gum), <i>E. melliodora</i> (yellow box), <i>E. albens</i> (white box), <i>E. crebra</i> (narrow-leaved red ironbark) or <i>E. melanophloia</i> (silver-leaved ironbark). (land zones 8, 11, 4, [3]) (BRB, SEQ, EIU)	12.71	0.05
16a	Open forest and woodlands dominated by <i>Eucalyptus camaldulensis</i> (river red gum) (or <i>E. tereticornis</i> (blue gum)) and/or <i>E. coolabah</i> (coolabah) (or <i>E. microtheca</i> (coolabah)) fringing drainage lines. Associated species may include <i>Melaleuca</i> spp., <i>Corymbia tessellaris</i> (carbeen), <i>Angophora</i> spp., <i>Casuarina cunninghamiana</i> (riveroak). Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (MGD, BRB, GUP, CHC, MUL, DEU, EIU, NWH, SEQ, [NET, WET]) (All bioregions except CYP and CQC)	341.23	1.45

BVG (1 Million)	Description	Area (Ha)	% of AOI
16c	Woodlands and open woodlands dominated by <i>Eucalyptus coolabah</i> (coolabah) or <i>E. microtheca</i> (coolabah) or <i>E. largiflorens</i> (black box) or <i>E. tereticornis</i> (blue gum) or <i>E. chlorophylla</i> on floodplains. Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (All bioregions except WET, principally GUP, BRB, MUL).	327.06	1.39
17a	Woodlands dominated by <i>Eucalyptus populnea</i> (poplar box) (or <i>E. brownii</i> (Reid River box)) on alluvium, sand plains and footslopes of hills and ranges. (land zones 3, 5, 10, 9, 4, 11, 12, [8]) (BRB, MUL, DEU, MUL, EIU)	183.04	0.78
25a	Open forests to woodlands dominated by <i>Acacia harpophylla</i> (brigalow) sometimes with <i>Casuarina cristata</i> (belah) on heavy clay soils. Includes areas co-dominated with <i>A. cambagei</i> (gidgee) and/or emergent eucalypts (land zones 4, 9, 3, 11, 7, 12, [5, 8]) (BRB, MUL, MGD, DEU, [SEQ])	334.26	1.43
30b	Tussock grasslands dominated by <i>Astrebla</i> spp. (mitchell grass) or <i>Dichanthium</i> spp. (bluegrass) often with <i>Iseilema</i> spp. on undulating downs or clay plains. (land zones 9, 3, 4, 8, [5]) (MGD, CHC, GUP, BRB, [EIU, DEU, NWH])	3.18	0.01
7a	Semi-evergreen vine thickets on wide range of substrates. (land zones 8, 9, 11, 12, 5, 4, 3, 10, [7]) (BRB, EIU, SEQ, CQC, [WET, GUP]) (Tracey 1982 11)	45.03	0.19

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/>

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act 1999*. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2012 (PDF)* section 3.3.1 of:

<https://publications.qld.gov.au/dataset/redd/resource/>

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

<http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/>

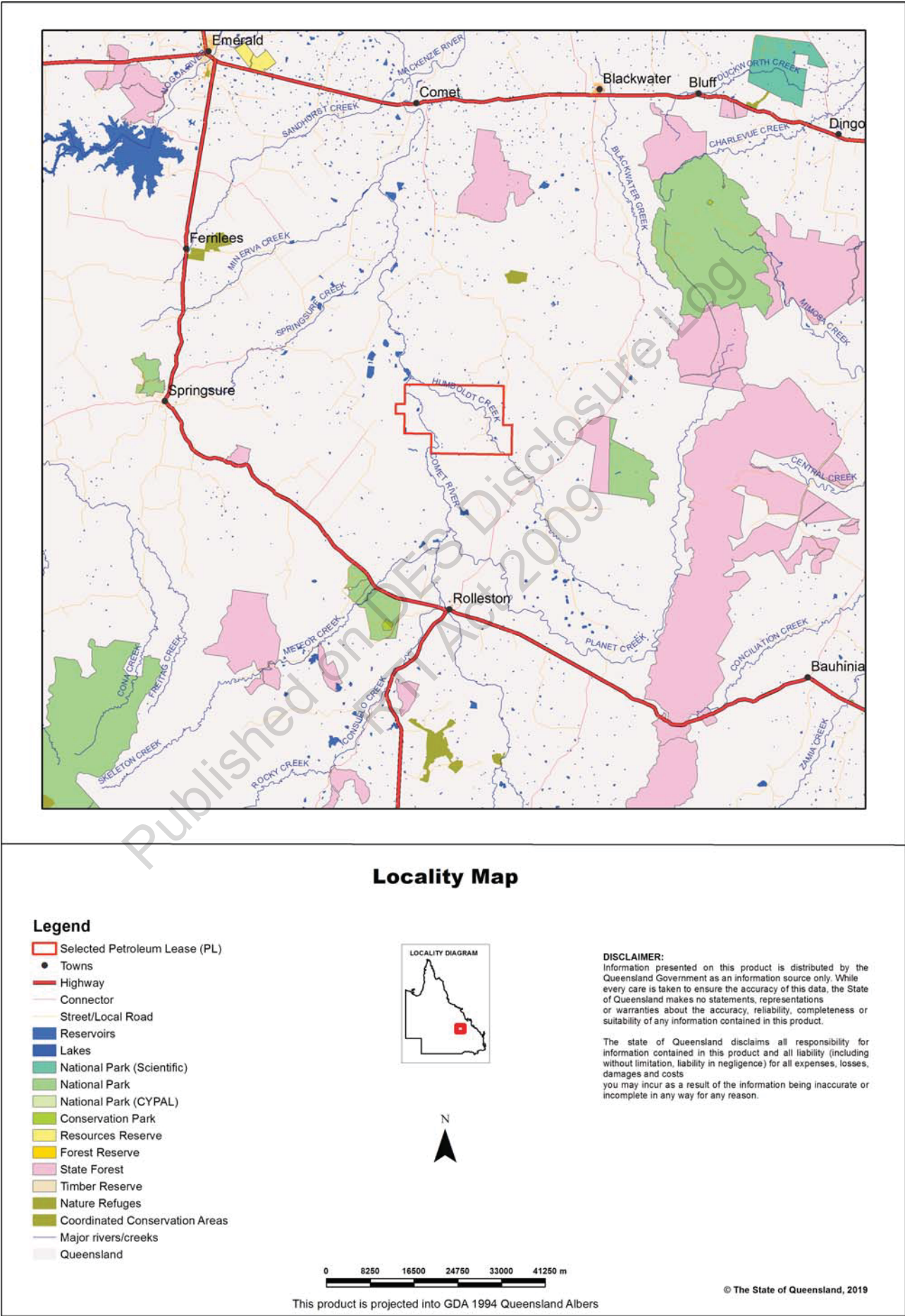
Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

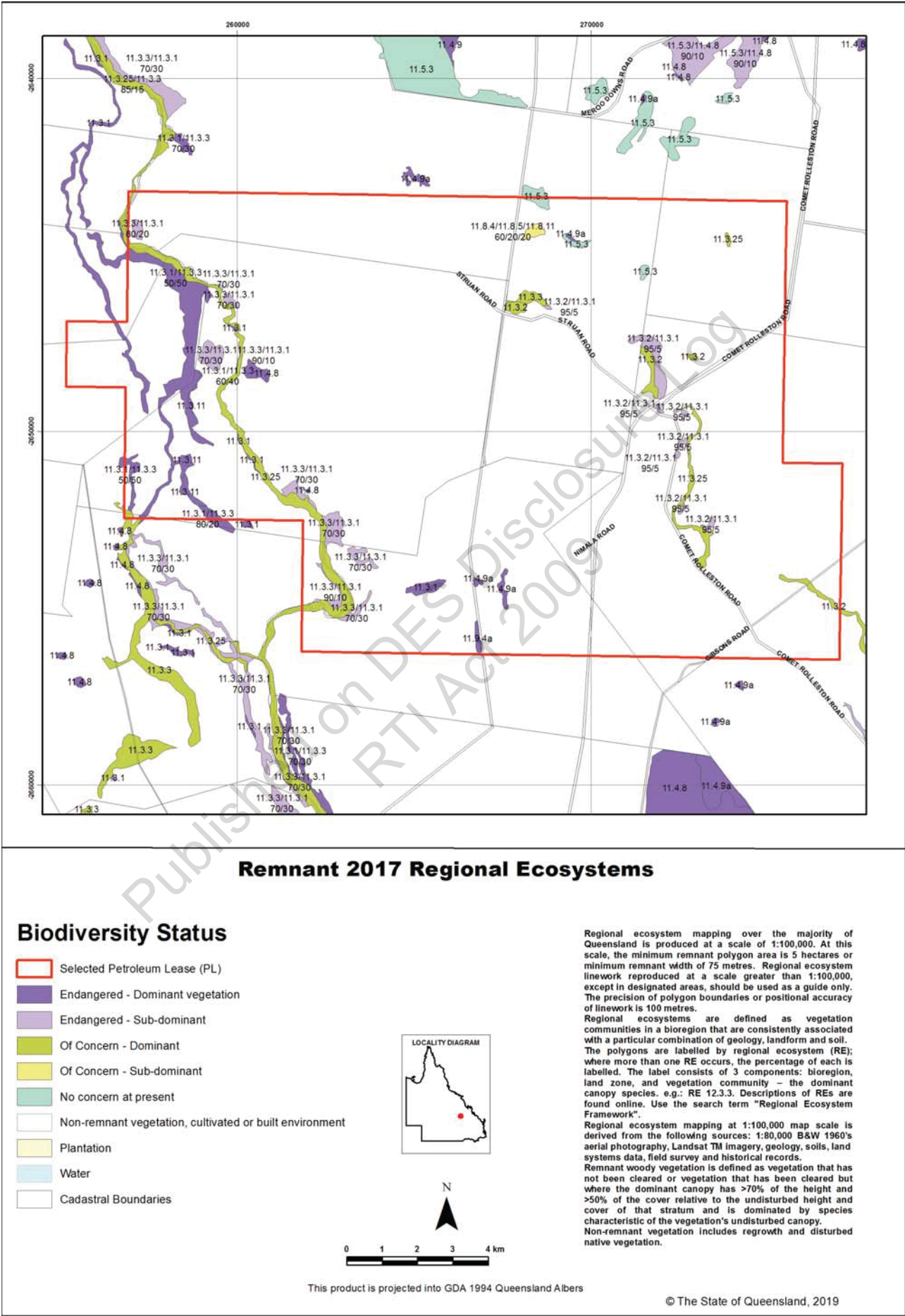
Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
11.3.1	Available	Not currently available
11.3.11	Available	Not currently available
11.3.2	Available	Not currently available
11.3.25	Available	Not currently available
11.3.3	Available	Not currently available
11.4.8	Available	Not currently available
11.4.9a	Available	Not currently available
11.5.3	Available	Not currently available
11.8.11	Available	Not currently available
11.8.4	Available	Not currently available
11.8.5	Available	Not currently available
11.9.4a	Available	Available
non-rem	Not currently available	Not currently available

Maps

Map 1 - Location



Map 2 - Remnant 2017 regional ecosystems



Pre-clearing Regional Ecosystems

Biodiversity Status

- Selected Petroleum Lease (PL)
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Water
- Cadastral Boundaries

LOCALITY DIAGRAM

Legend:

- Selected Petroleum Lease (PL)
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Water
- Cadastral Boundaries

Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.

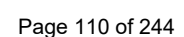
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".

Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

This product is projected into GDA 1994 Queensland Albers

© The State of Queensland, 2019

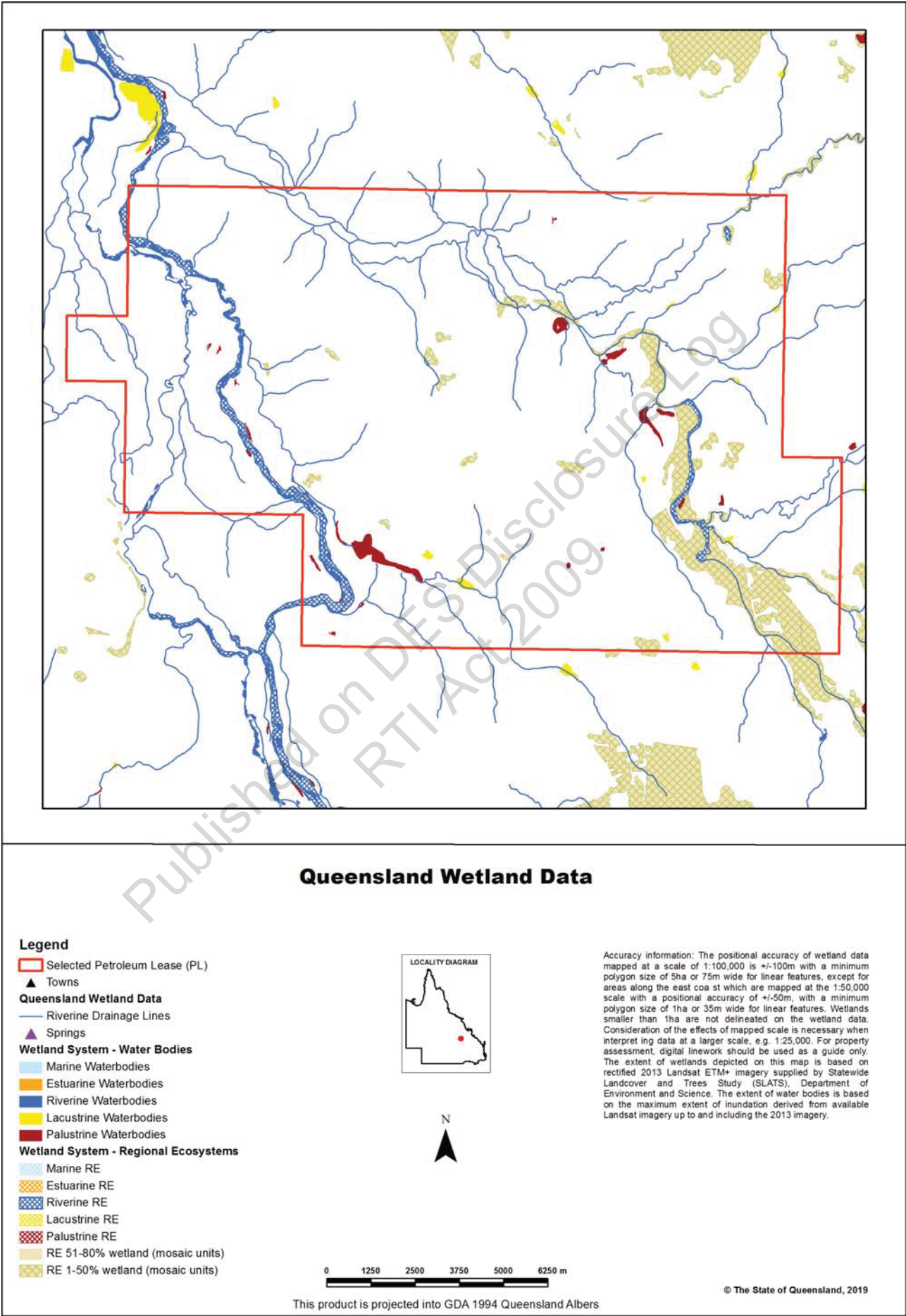
Page 14 20-224



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Map 6 - Wetlands and waterways



Links and Other Information Sources

The Department of Environment and Science's Website -

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/>

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

<https://publications.qld.gov.au/dataset/redd/resource/>

The methodology for mapping regional ecosystems can be downloaded from:

<https://publications.qld.gov.au/dataset/redd/resource/>

Technical descriptions for regional ecosystems can be obtained from:

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/>

Benchmarks can be obtained from:

<http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/>

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

<http://dds.information.qld.gov.au/dds/>

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

<http://www.dnrm.qld.gov.au/mapping-data/queensland-globe>

References

Neldner, V.J., Niehus R.E., Wilson, B.A. McDonald, W.J.F., Ford, A.J. and Accad, A. (2017) The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 3.0. Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts.

<https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086>

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S. and Butler, D.W. (2017) *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*. Version 4.0. Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts.

<https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4>

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

<http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/>

- Regional Ecosystem Description Database

The datasets listed below are available for download from:

<http://dds.information.qld.gov.au/dds/>

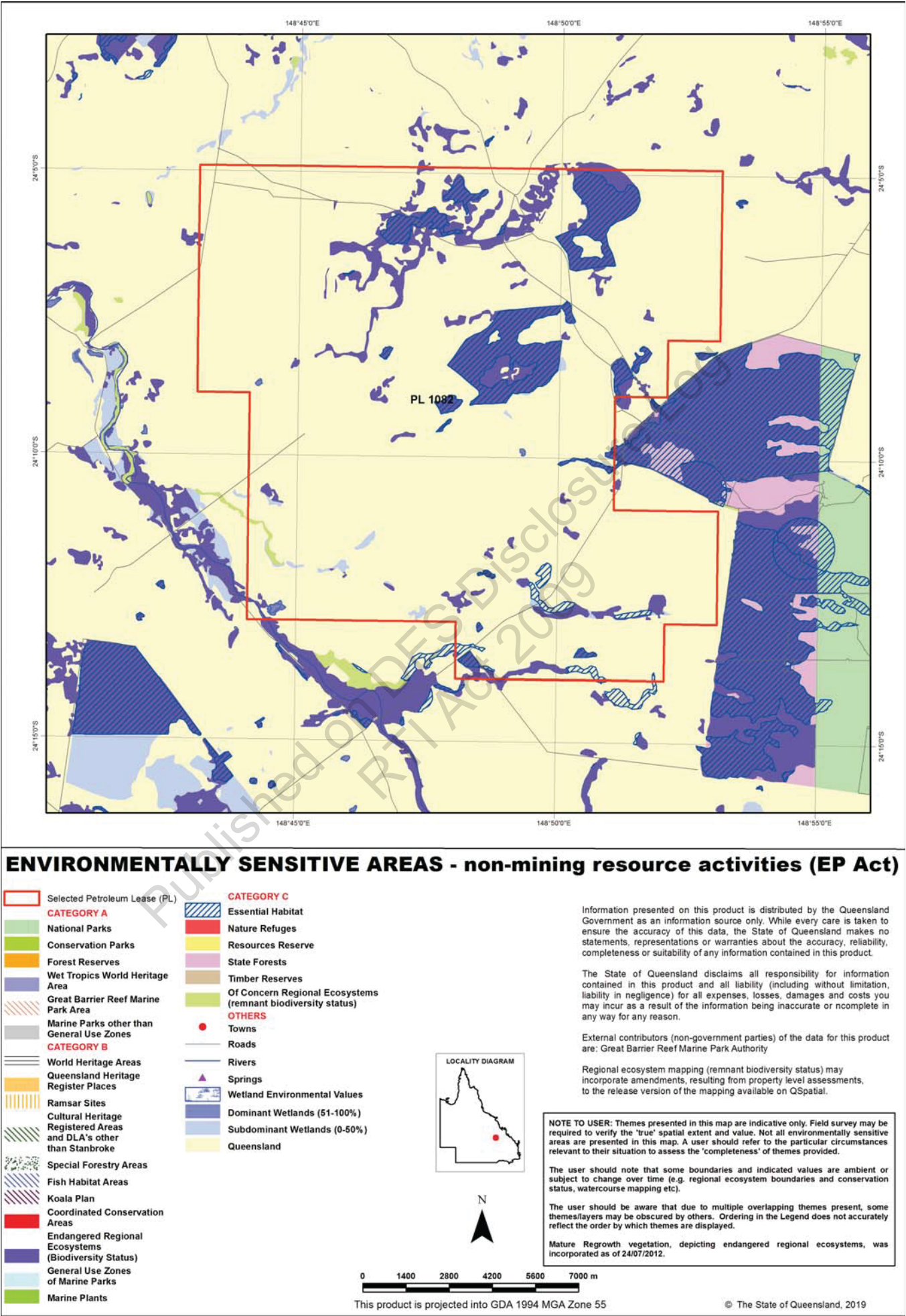
- Biodiversity status of pre-clearing and 2017 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

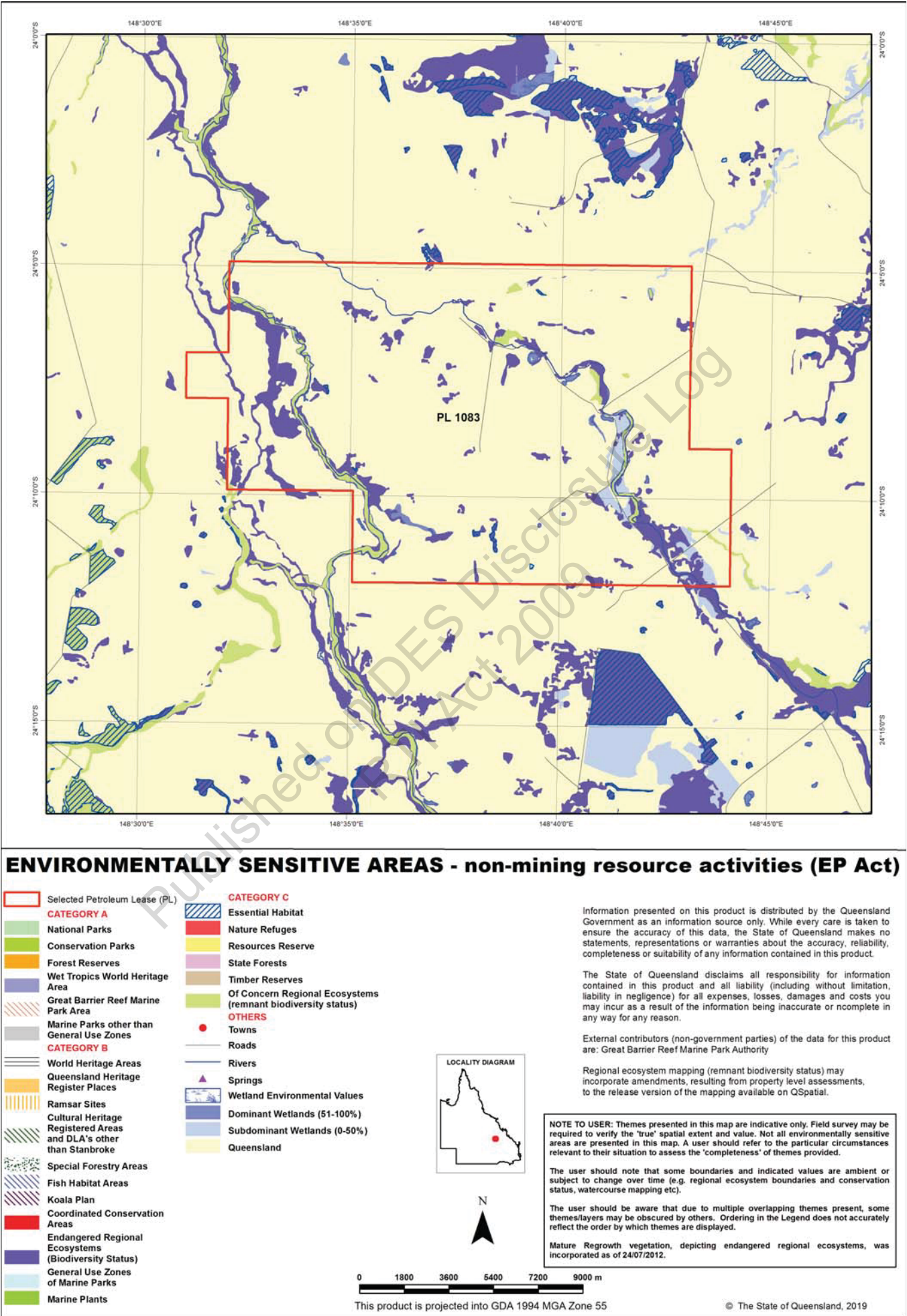
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Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- <i>Vegetation Management Act 1999</i>

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Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
pl: 1082

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Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

Disclaimer

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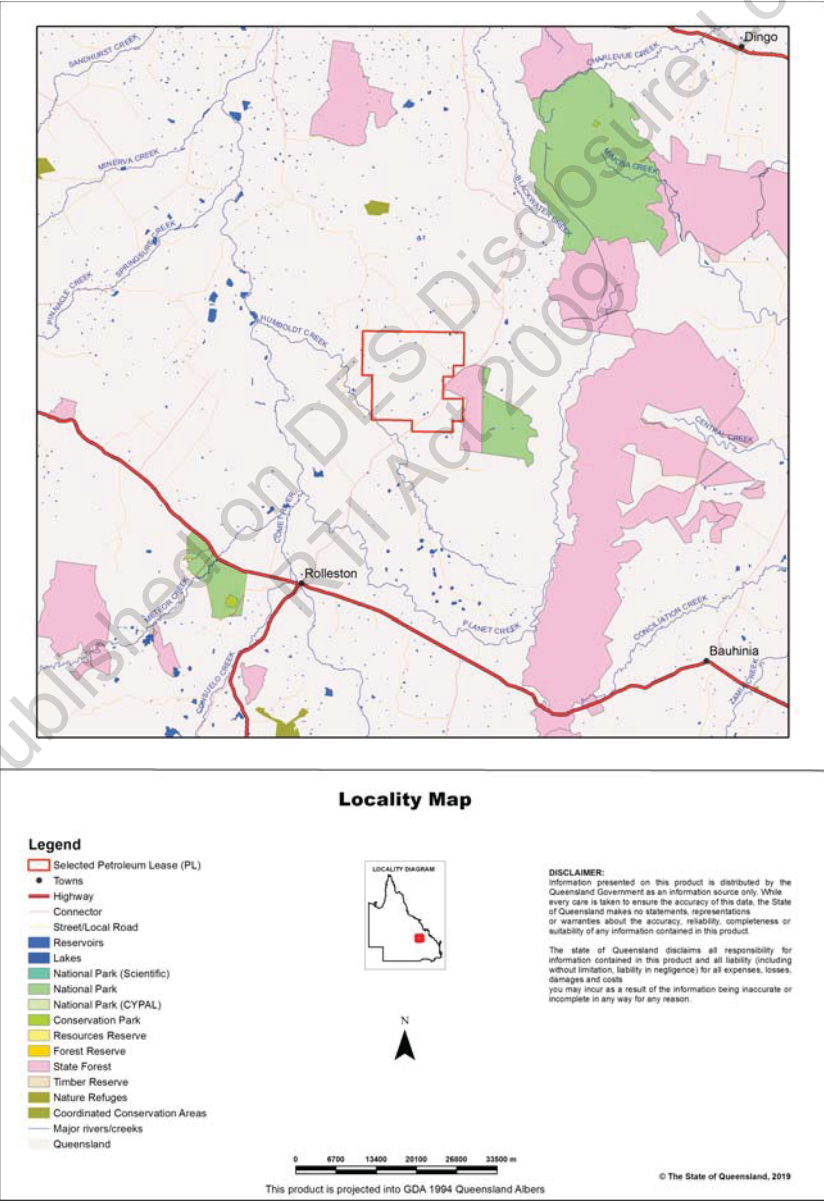
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Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI pl: 1082

Size (ha)	23,451.41
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Isaac - Comet Downs
Catchment(s)	Fitzroy



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;
- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;
- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;
- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;
- Regulated vegetation under the *Vegetation Management Act 1999* that is:
 - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
 - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
 - Category R areas on the regulated vegetation management map;
 - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;
 - Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;
- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;
- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Referable Wetlands under the Environmental Protection Regulation 2008;
- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;
- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	0.0 ha	0.0 %
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways **	0.0 km	Not applicable
7 Threatened species and Iconic species	0.0 ha	0.0 %
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	1737.9 ha	7.4%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	0.0 ha	0.0 %
8c Regulated Vegetation - Category R (GBR riverine regrowth)	15.67 ha	0.1%
8d Regulated Vegetation - Essential habitat	1474.71 ha	6.3%
8e Regulated Vegetation - intersecting a watercourse **	143.8 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0.0 ha	0.0 %
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Referable Wetlands

(no results)

6a. High Ecological Value (HEV) waters - wetlands

(no results)

6b. High Ecological Value (HEV) waters - waterways

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7. Threatened wildlife and special least concern animal

(no results)

Threatened and special least concern species records

(no results)

Note: The Threatened and Special Least Concern Animal (7) layer originates from the previous MSES version (4.1, dated at 2014). The layer does not represent all currently listed species and is subject to review.

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

To request a species list for an area, or search for a species profile, access Wildlife Online at:

<https://www.qld.gov.au/environment/plants-animals/species-list/>

Refer to **Map 3 - MSES - Species** for an overview of the relevant MSES.

MSES - Regulated Vegetation

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.4.9a	E-dom	rem_end
11.3.2/11.3.1	E-subdom	rem_end
11.4.8	E-dom	rem_end
11.9.5a	E-dom	rem_end
11.4.8/11.4.9a	E-dom	rem_end
11.5.5c/11.4.8	E-subdom	rem_end
11.5.3/11.4.9a/11.4.8	E-subdom	rem_end
11.3.2	O-dom	rem_oc
11.4.8/11.5.3	E-dom	rem_end

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Not applicable

For further information relating to regional ecosystems in general, go to:

<https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/>

For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:

<https://environment.ehp.qld.gov.au/regional-ecosystems/>

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Regulated vegetation map category	Map number	RVM rule
R	8649	4

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Not applicable

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

(no results)

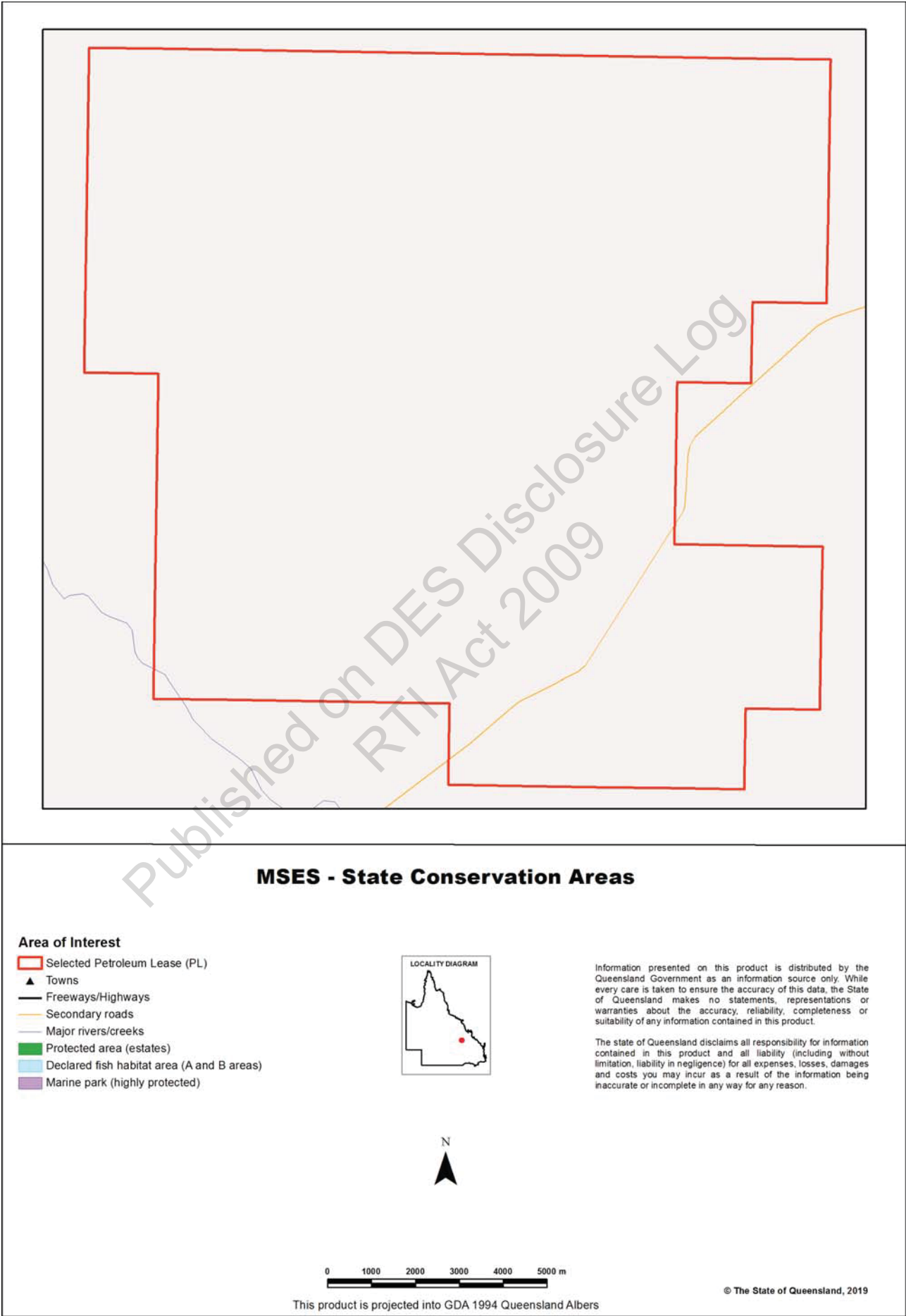
9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(no results)

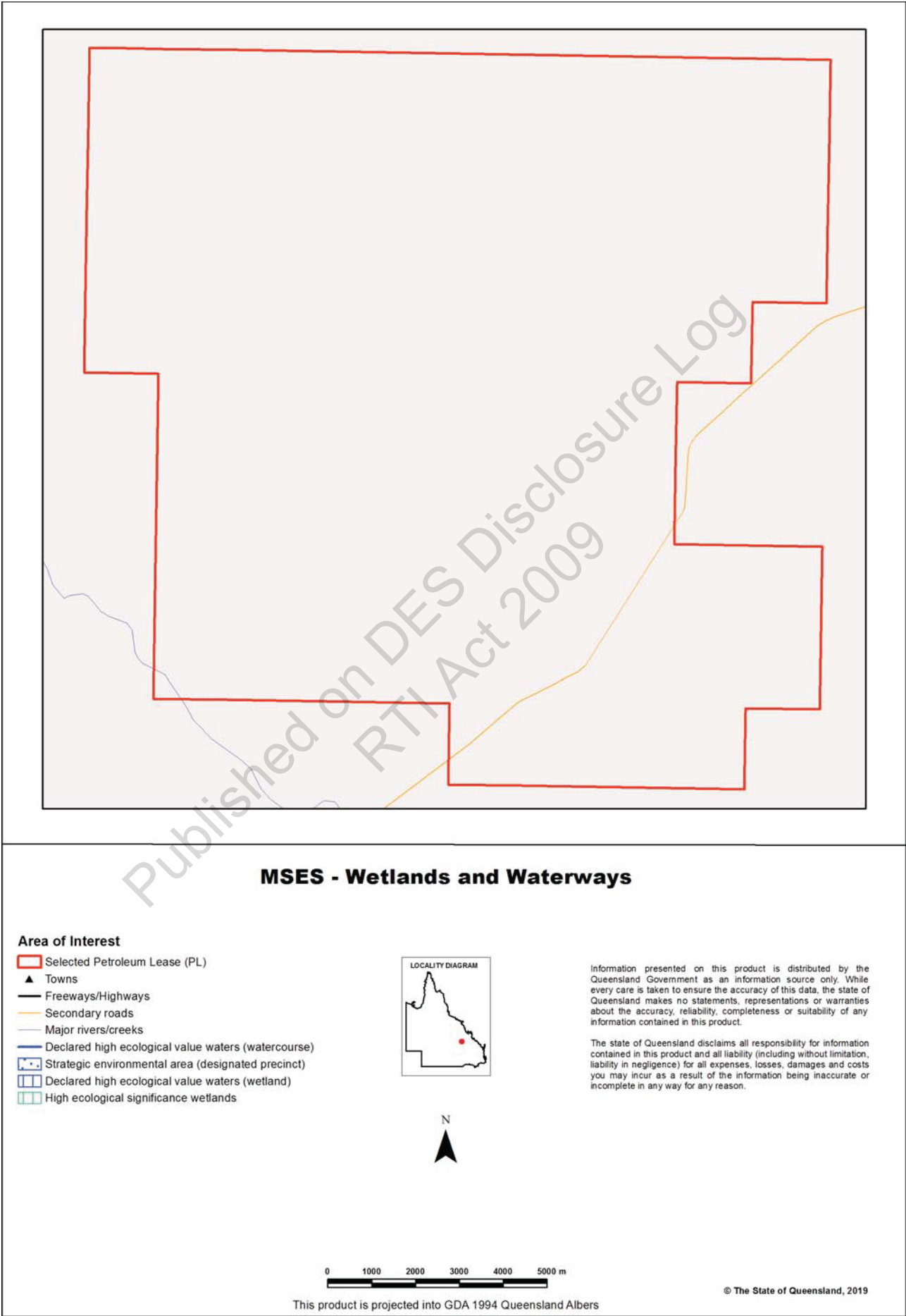
Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

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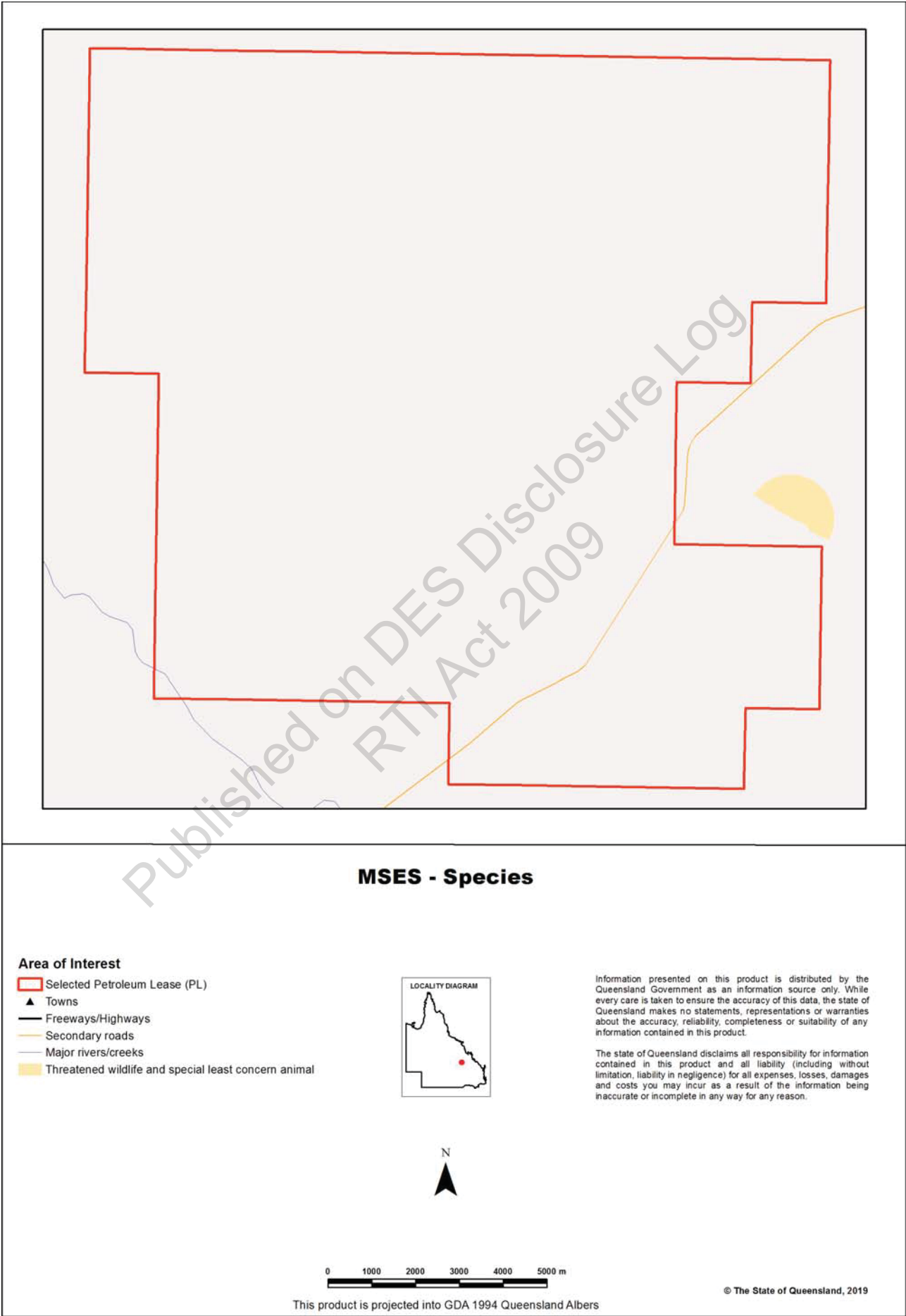
Map 1 - MSES - State Conservation Areas



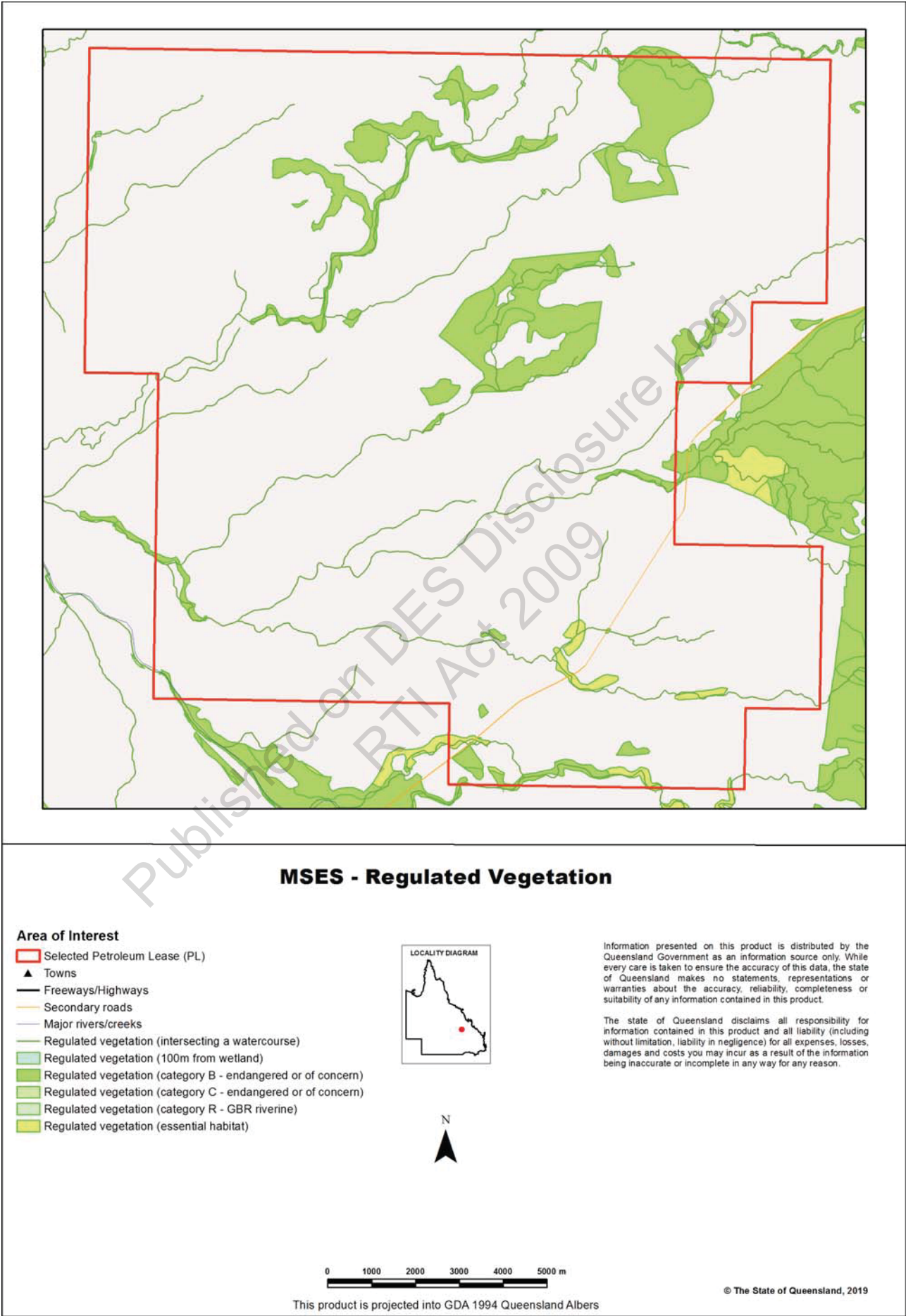
Map 2 - MSES - Wetlands and Waterways



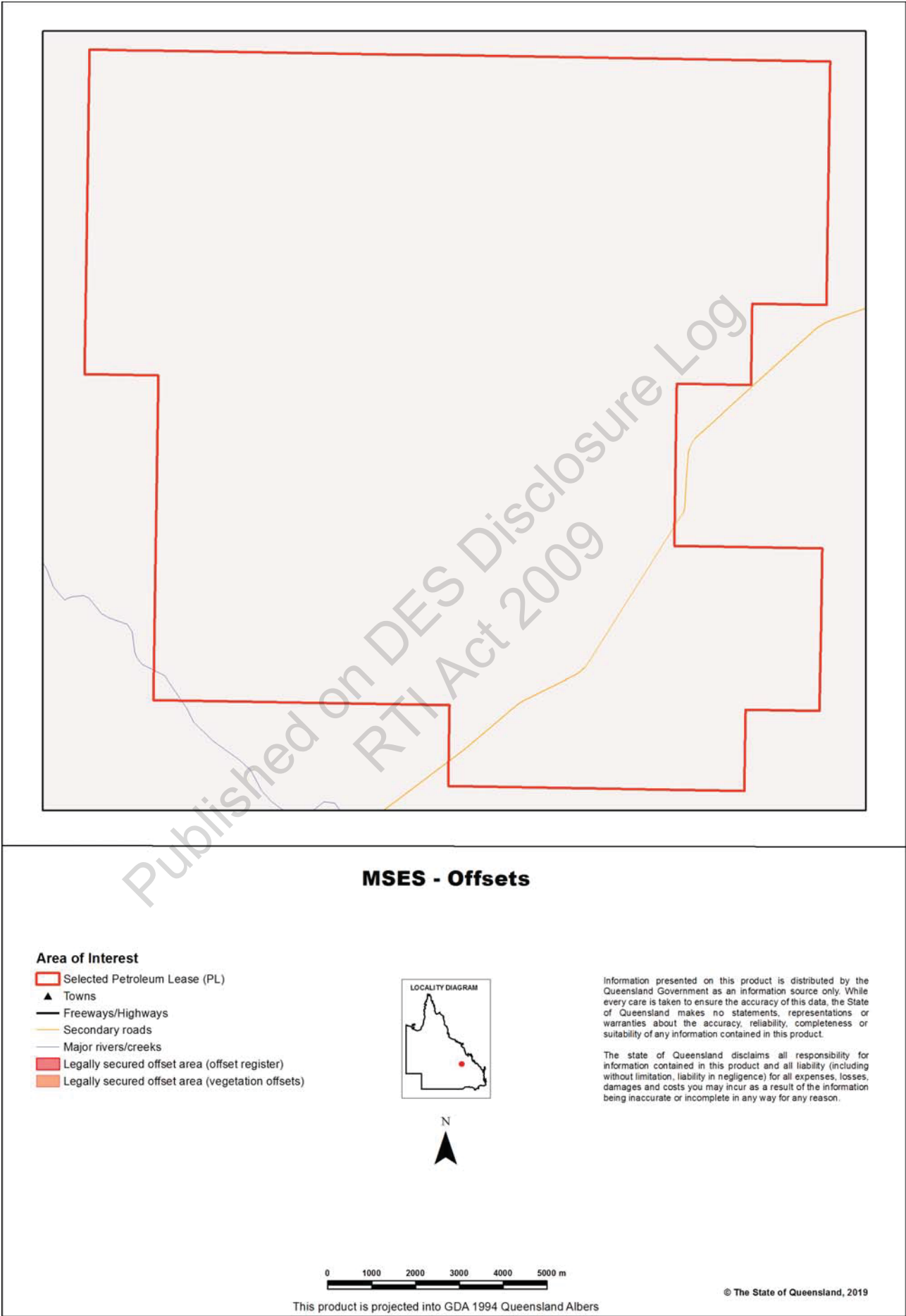
Map 3 - MSES - Species



Map 4 - MSES - Regulated Vegetation



Map 5 - MSES - Offset Areas



Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

<http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html> .

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Appendix 2 - Source Data

The datasets listed below are available on request from:

<http://qldspatial.information.qld.gov.au/catalogue/custom/index.page>

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	current QSpatial data (http://qspatial.information.qld.gov.au)
Protected Areas-Estates and Nature Refuges	- Protected areas of Queensland - Nature Refuges - Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Referable Wetland - wetland layers: - Wetland management area wetlands - Wetland protection area wetlands
wetlands in HEV waters	HEV waters: - EPP Water (multiple locations) intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 4, 2015) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000) - latest version 1.4
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various)
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map - latest version 8.0
VMA Essential Habitat	Vegetation management - essential habitat map - latest version 4.41
VMA Wetlands	Vegetation management wetlands map - latest version 2.41
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map - latest version 1.41

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- <i>Environmental Protection Act 1994</i>
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- <i>Nature Conservation Act 1992</i>
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- <i>Vegetation Management Act 1999</i>

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Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
pl: 1083

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Environmental Reports - General Information

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Figures in tables may be affected by rounding.

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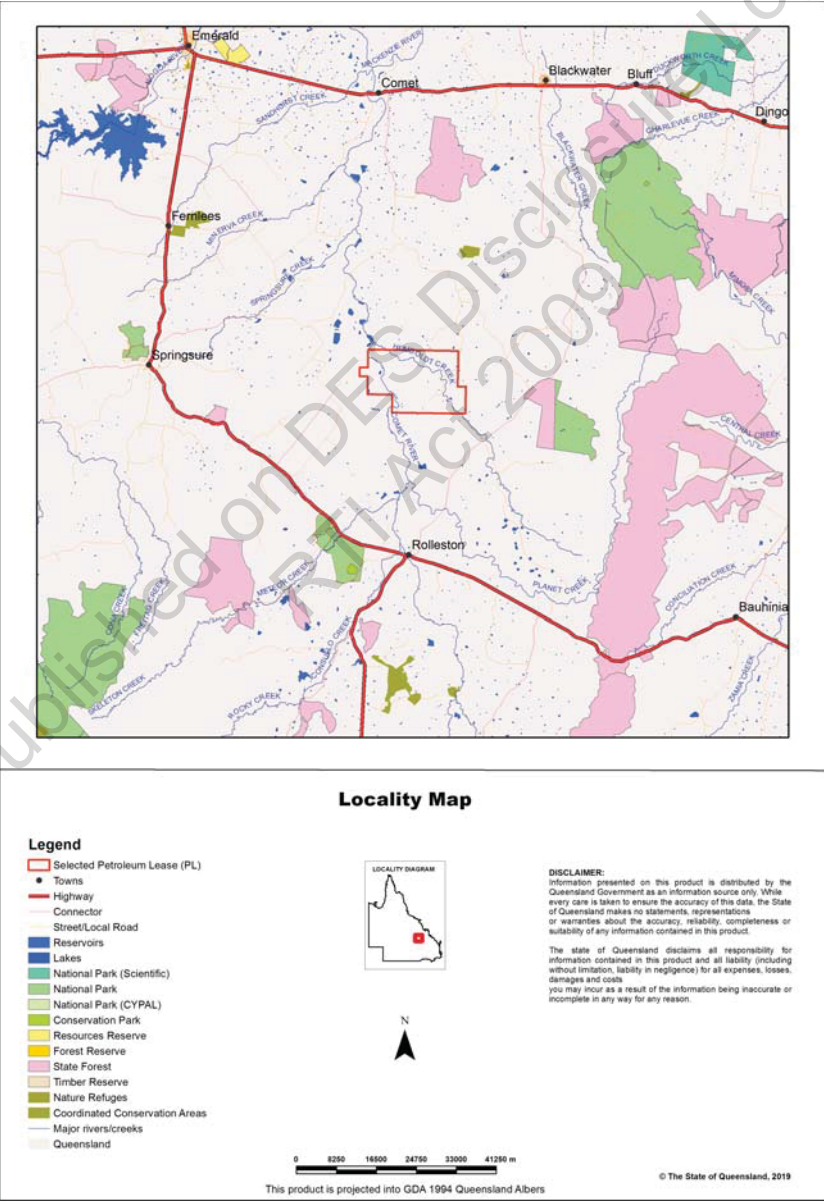
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Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI pl: 1083

Size (ha)	23,453.62
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Isaac - Comet Downs
Catchment(s)	Fitzroy



Matters of State Environmental Significance (MSES)

MSES Categories

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- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;
- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;
- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;
- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;
- Regulated vegetation under the *Vegetation Management Act 1999* that is:
 - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
 - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
 - Category R areas on the regulated vegetation management map;
 - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;
 - Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;
- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;
- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Referable Wetlands under the Environmental Protection Regulation 2008;
- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;
- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	3.75 ha	0.0%
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways **	0.0 km	Not applicable
7 Threatened species and Iconic species	0.0 ha	0.0 %
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	865.02 ha	3.7%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	5.27 ha	0.0%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	27.97 ha	0.1%
8d Regulated Vegetation - Essential habitat	28.69 ha	0.1%
8e Regulated Vegetation - intersecting a watercourse **	221.5 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	96.3 ha	0.4%
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Referable Wetlands

Natural wetlands that are 'High Ecological Significance' (HES) on the Map of Referable Wetlands are present.

6a. High Ecological Value (HEV) waters - wetlands

(no results)

6b. High Ecological Value (HEV) waters - waterways

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7. Threatened wildlife and special least concern animal

(no results)

Threatened and special least concern species records

(no results)

Note: The Threatened and Special Least Concern Animal (7) layer originates from the previous MSES version (4.1, dated at 2014). The layer does not represent all currently listed species and is subject to review.

*Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL).
Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)

To request a species list for an area, or search for a species profile, access Wildlife Online at:

<https://www.qld.gov.au/environment/plants-animals/species-list/>

Refer to **Map 3 - MSES - Species** for an overview of the relevant MSES.

MSES - Regulated Vegetation

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.3.1	E-dom	rem_end
11.3.3/11.3.1	E-subdom	rem_end
11.8.4/11.8.5/11.8.11	O-subdom	rem_oc
11.4.9a	E-dom	rem_end
11.3.2	O-dom	rem_oc
11.3.2/11.3.1	E-subdom	rem_end
11.3.3	O-dom	rem_oc
11.3.1/11.3.3	E-dom	rem_end
11.3.11	E-dom	rem_end
11.4.8	E-dom	rem_end
11.9.4a	O-dom	rem_oc

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.3.1/11.3.3	E-dom	hvr_end
11.3.11	E-dom	hvr_end

For further information relating to regional ecosystems in general, go to:

<https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/>

For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:

<https://environment.ehp.qld.gov.au/regional-ecosystems/>

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Regulated vegetation map category	Map number	RVM rule
R	8649	4

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Regulated vegetation map category	Map number	RVM rule
B	8649	2
R	8649	4
A	0	1
B	0	2

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

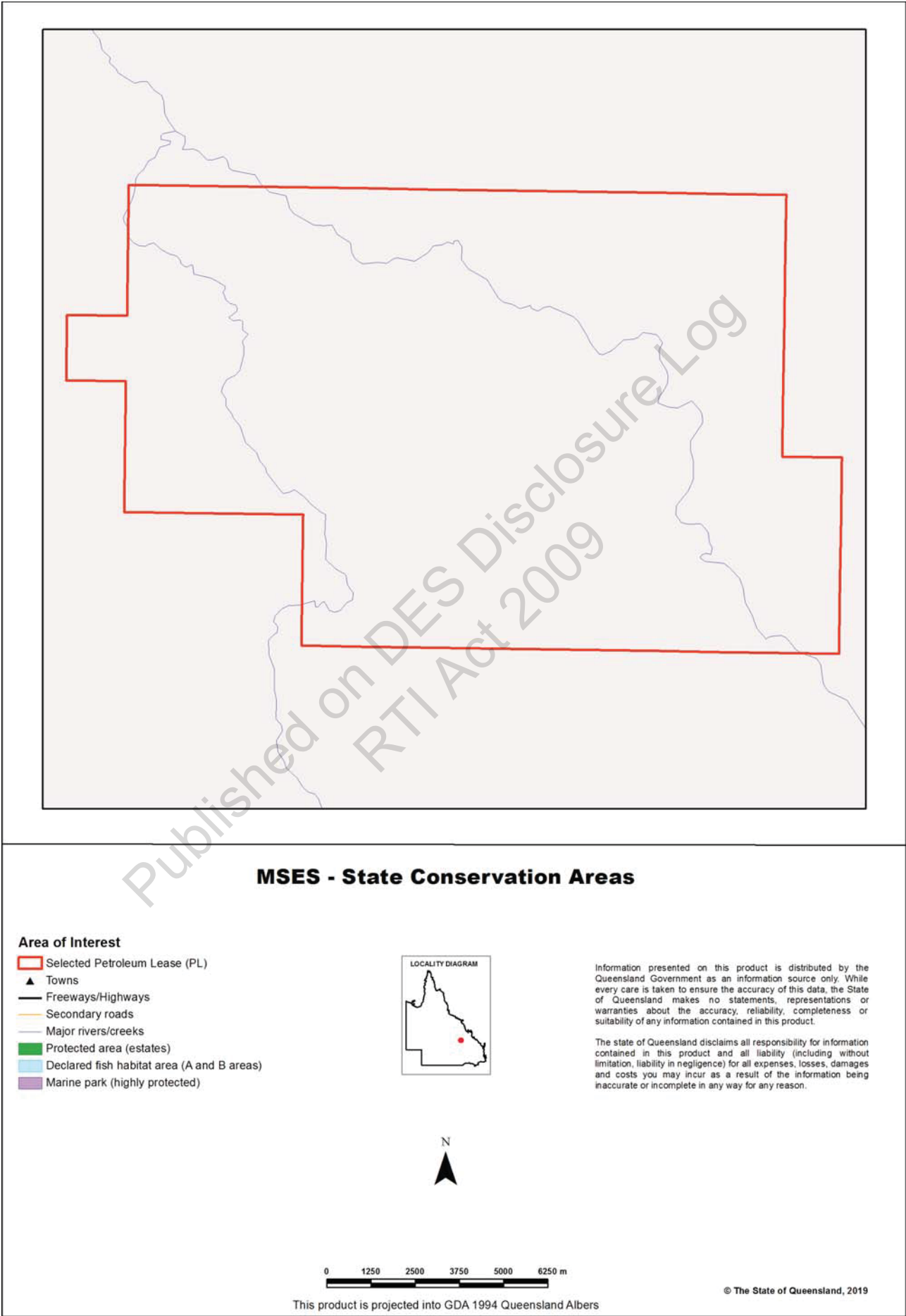
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

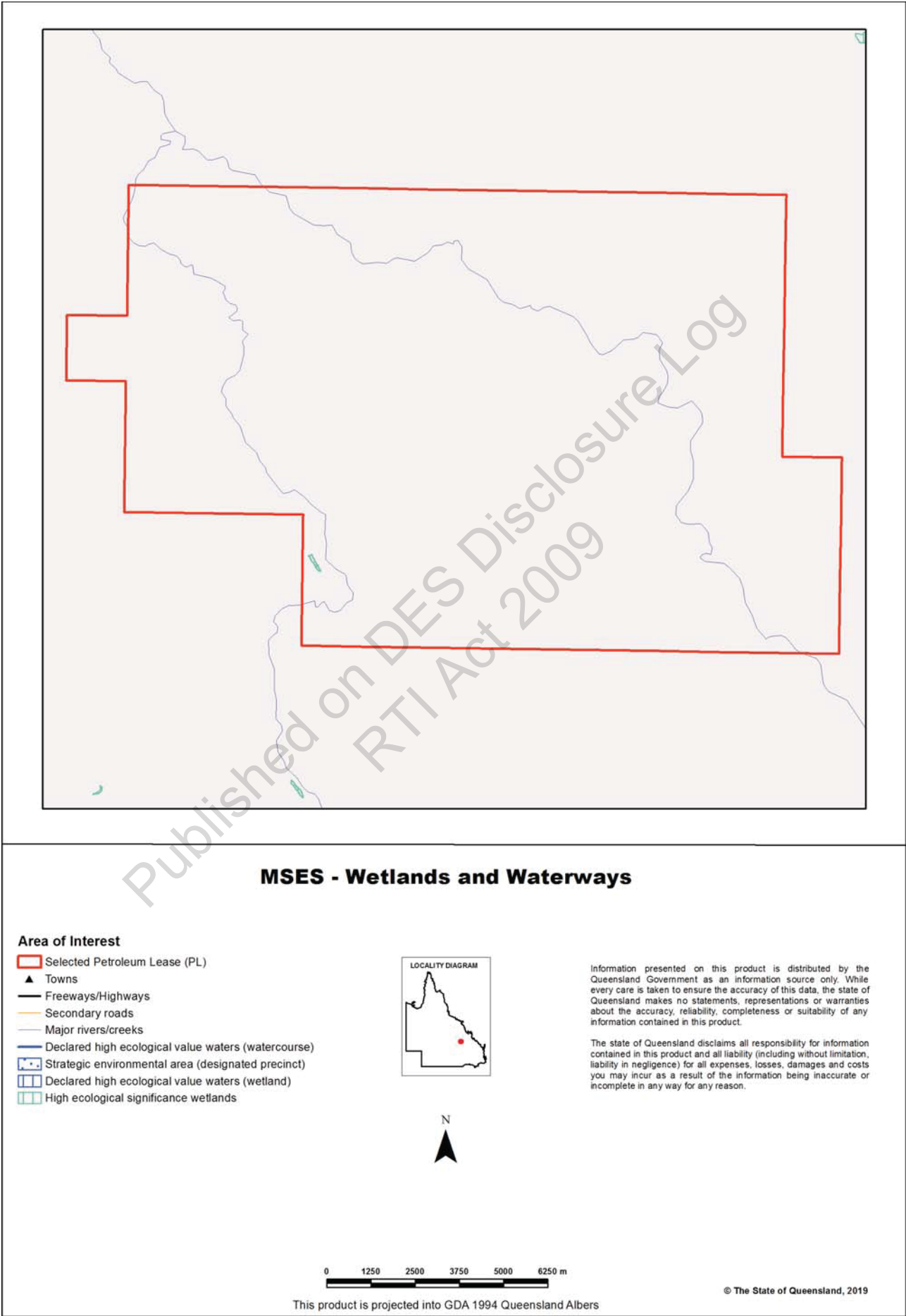
(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

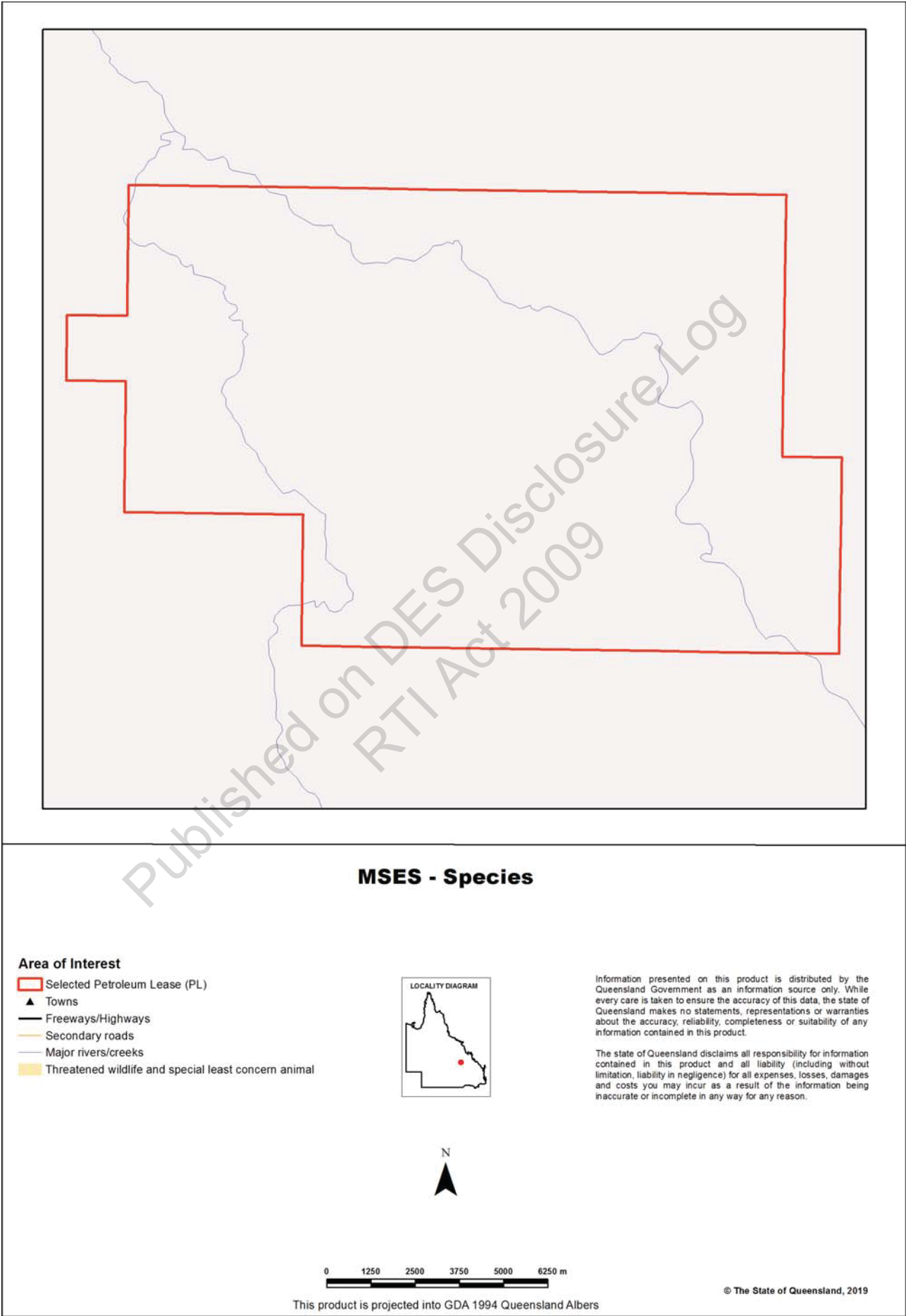
Map 1 - MSES - State Conservation Areas



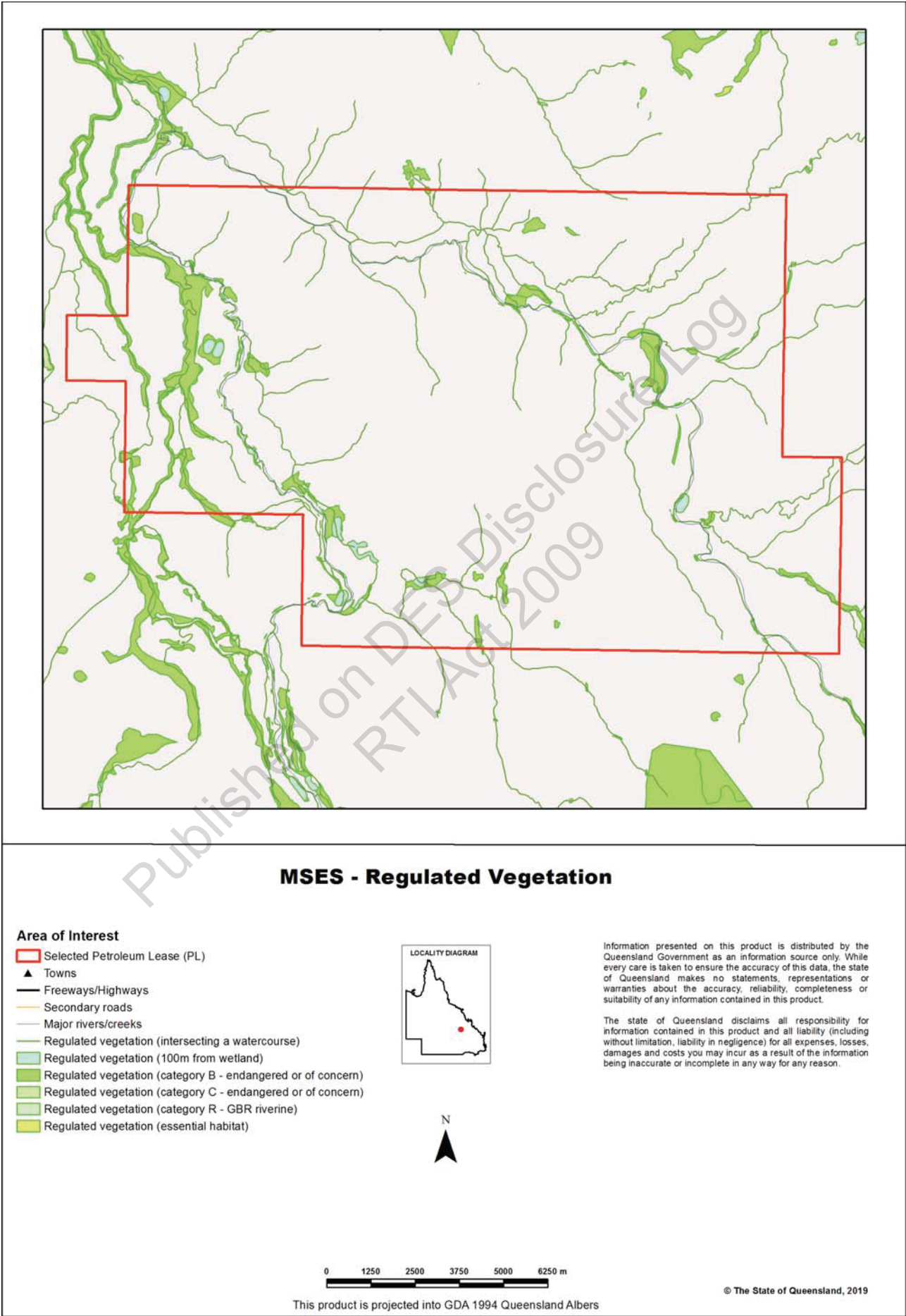
Map 2 - MSES - Wetlands and Waterways



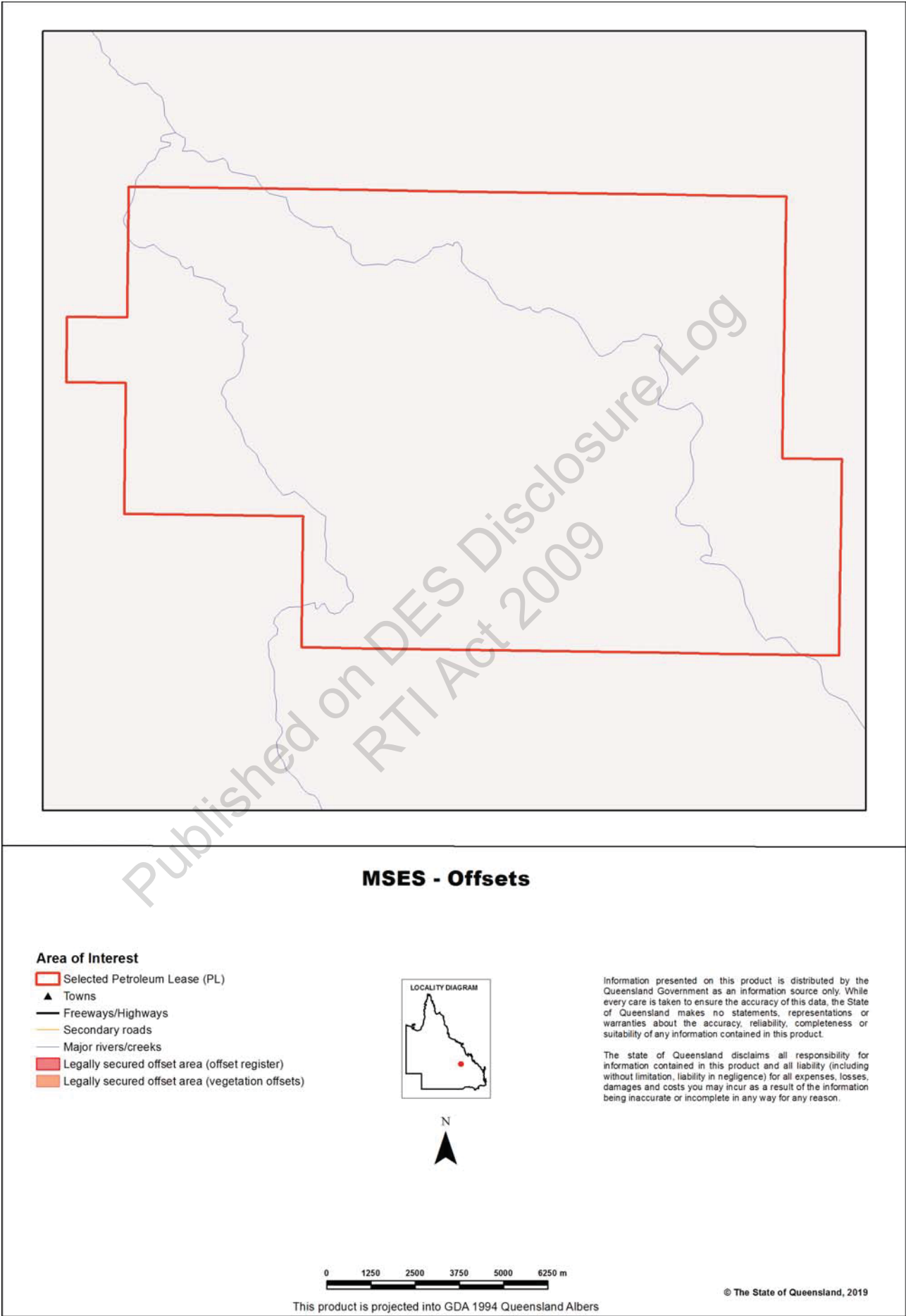
Map 3 - MSES - Species



Map 4 - MSES - Regulated Vegetation



Map 5 - MSES - Offset Areas



Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

<http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html> .

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Appendix 2 - Source Data

The datasets listed below are available on request from:

<http://qldspatial.information.qld.gov.au/catalogue/custom/index.page>

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	current QSpatial data (http://qspatial.information.qld.gov.au)
Protected Areas-Estates and Nature Refuges	- Protected areas of Queensland - Nature Refuges - Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Referable Wetland - wetland layers: - Wetland management area wetlands - Wetland protection area wetlands
wetlands in HEV waters	HEV waters: - EPP Water (multiple locations) intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 4, 2015) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000) - latest version 1.4
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various)
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map - latest version 8.0
VMA Essential Habitat	Vegetation management - essential habitat map - latest version 4.41
VMA Wetlands	Vegetation management wetlands map - latest version 2.41
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map - latest version 1.41

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- <i>Environmental Protection Act 1994</i>
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- <i>Nature Conservation Act 1992</i>
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- <i>Vegetation Management Act 1999</i>

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Klohn Crippen Berger

Australia Pacific LNG

Mahalo Development Area

Water Assessment Report

Volume 1

Main Report



D09620A79

ISO 9001
ISO 14001
OHSAS 18001

September 2019

Australia Pacific LNG

Mahalo Development Area

Water Assessment Report



D09620A79



September 2019

EXECUTIVE SUMMARY

Klohn Crippen Berger Ltd (KCB) has been commissioned by Australia Pacific LNG Pty Ltd (APLNG), to undertake an assessment of potential water-related impacts of proposed gas production within the Mahalo Development Area (the Project), in the Bowen Basin, Queensland.

The assessment has been undertaken to consider the potential impact to water resources and water-dependent assets under the *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)* as a result of the proposed Project activities. The assessment has been conducted with reference to the 'Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources', 'Significant impact guidelines 1.1 – Matters of National Environmental Significance' and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) information guidelines.

The assessment has been prepared for submission to accompany APLNG's *EPBC Act* referral for the Mahalo Development Area to the Commonwealth Department of Environment and Energy (DoEE).

Description of the Proposal

The Mahalo Development Area covers an area of approximately 469 km² and is located ~30 km north of the township of Rolleston, Central Queensland. Proposed production activities include: the installation of up to 95 gas production wells; their connection to gas and water gathering lines; water management facilities; and ancillary infrastructure.

The Mahalo Development Area is located within the Surat Cumulative Management Area (CMA). The Office of Groundwater Impact Assessment (OGIA) was established under the Queensland *Water Act 2000* and is responsible for: predicting impacts on water pressures in aquifers; developing water monitoring and spring management strategies; and assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within the Surat CMA. These predictions, strategies and responsibilities are set out in the Surat CMA Underground Water Impact Report (UWIR), prepared and maintained by OGIA.

Hydrology and Hydrogeology Context

The Mahalo Development Area is located within the Comet River Sub-Basin, a part of the Fitzroy Basin. Key watercourses within the vicinity of the Project include Comet River, Meteor Creek, Planet Creek and Humboldt Creek. Watercourse flows in the Project are characteristically ephemeral.

The target gas producing formation for the Project is the Bandanna Formation, of the Permo-Triassic Bowen Basin. Groundwater systems in the Mahalo Development Area include: Cenozoic-age deposits comprising alluvium associated with the Comet River; basalt and Cenozoic sediments; Triassic Rewan Group; and Permian coal measures.

Groundwater is predominantly used for stock and domestic purposes, with the majority of third-party bores (60% within a 50 km radius) screened within the basalt unit located to the west of the Mahalo Development Area. Only 30 bores are recorded directly within the Mahalo Development Area, indicating the generally poor water quality and availability.

There are minimal potential groundwater dependent ecosystems (GDE) within the vicinity of the Project. Potential terrestrial GDEs (identified from GDE mapping datasets) are located within proximity to the Mahalo Development Area and are listed as low-confidence GDEs. Available groundwater levels indicate the depth to groundwater is greater than 30 metres below ground, supporting the low-confidence GDE category.

Impact Assessment

Outputs from the Surat CMA numerical model, used for the 2019 Surat CMA UWIR, have been used to consider potential drawdown impacts to groundwater.

Potential impacts to water-dependent assets have been considered with respect to the Queensland *Water Act 2000* trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifers; 2 m drawdown in unconsolidated aquifers) using the predicted drawdown outputs from the Surat CMA numerical model. Four bores attributed by OGIA to be screened across the Bandanna Formation (the target gas producing formation) have a predicted drawdown of more than the trigger threshold for a consolidated aquifer (5 m). The *Water Act 2000* requires future baseline assessments to be undertaken to confirm the source aquifer for these bores. Regardless, given the mandatory requirements under the *Water Act 2000* to 'make good' potential drawdown impacts to bores, impacts to existing groundwater users are considered unlikely. Impacts to potential terrestrial GDEs are considered unlikely based on the limited and localised magnitude of drawdown predicted in the hydrostratigraphic units that could provide groundwater to the potential GDEs and the low-confidence status of the GDEs (supported by groundwater level data). Based on the proposed project activities, impacts to surface water are also considered unlikely.

Monitoring, Mitigation and Management

In addition to the mandatory baseline bore assessments and 'make good' requirements of the *Water Act 2000*, Queensland legislation requires implementation of the following measures:

- Production wells will be designed, constructed and decommissioned in accordance with the *"Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 1"*. This code outlines mandatory requirements and good practice including hydraulic isolation of gas producing formations.
- 100% beneficial use and management of produced water in accordance with approvals under the *Waste Reduction and Recycling Act 2011* and/or *Environmental Protection Act 1994* including ANZECC water quality limits for irrigation.
- Storage of produced water and waste in accordance with the guidelines '*Structures which are dams or levees constructed as part of environmentally relevant activities*' (DES 2019) and the '*Manual for Assessing Consequence Categories and Hydraulic Performance of Structures*' (DES 2016a) prescribed under the *Environmental Protection Act 1994*.
- Preparation of a UWIR inclusive of the Mahalo Development Area in accordance with the *Water Act 2000* for approval by the Department of Environment and Science (DES).
- Monitoring of groundwater in accordance with the UWIR approved under the *Water Act 2000*.

- Monitoring and reporting of the volume of produced water in accordance with the *Petroleum and Gas (Production and Safety) Act 2004*.

Conclusion

A water assessment of the Mahalo Development Area has been undertaken to consider the potential impacts with respect to the *EPBC Act*. Water resources and water-dependent assets have been considered in the context of the hydrological and hydrogeological systems, as well as the potential impacts associated with this development.

It is concluded that the proposed development of the Mahalo Development Area will not have a significant impact on water resources.

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1 INTRODUCTION

Klohn Crippen Berger Ltd (KCB) has been commissioned by Australia Pacific LNG Pty Ltd (APLNG), to undertake an assessment of potential water-related impacts of the proposed gas production within the Mahalo Development Area (the Project), in the Bowen Basin, Queensland.

The objective of this report is to assess the potential impact to water resources and water-dependent assets under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth of Australia 2018) as a result of the proposed activities associated with the Project. This assessment is conducted with reference to the following guidelines:

- Department of the Environment and Energy (DoEE) Significant Impact Criteria provided in 'Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources' (DoEE 2013b) (Section 2.1.1);
- DoEE Significant impact guidelines 1.1 – Matters of National Environmental Significance (DoEE 2013a) (Section 2.1.1); and
- The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) information guidelines (IESC 2018) (Section 1.2.1).

This assessment was prepared to accompany APLNG's EPBC Act Referral for the Mahalo Development Area to the DoEE.

1.1 Project Overview

The Project is located approximately 30 km north of the township of Rolleston, as shown in Figure 1.1, and located on Authority to Prospect (ATP) 1191. The gas target for the Project is within the Bandanna Formation, of the Permo-Triassic Bowen Basin.

Gas production activities are planned to commence in 2021. The Project will involve the progressive development of gas infrastructure including the following activities:

- 95 gas production wells;
- Ancillary linear infrastructure including gas and water pipelines, access tracks, power lines, and communication lines;
- Gas compression facilities;
- Water management infrastructure; and
- Other ancillary activities and facilities to support gas field development

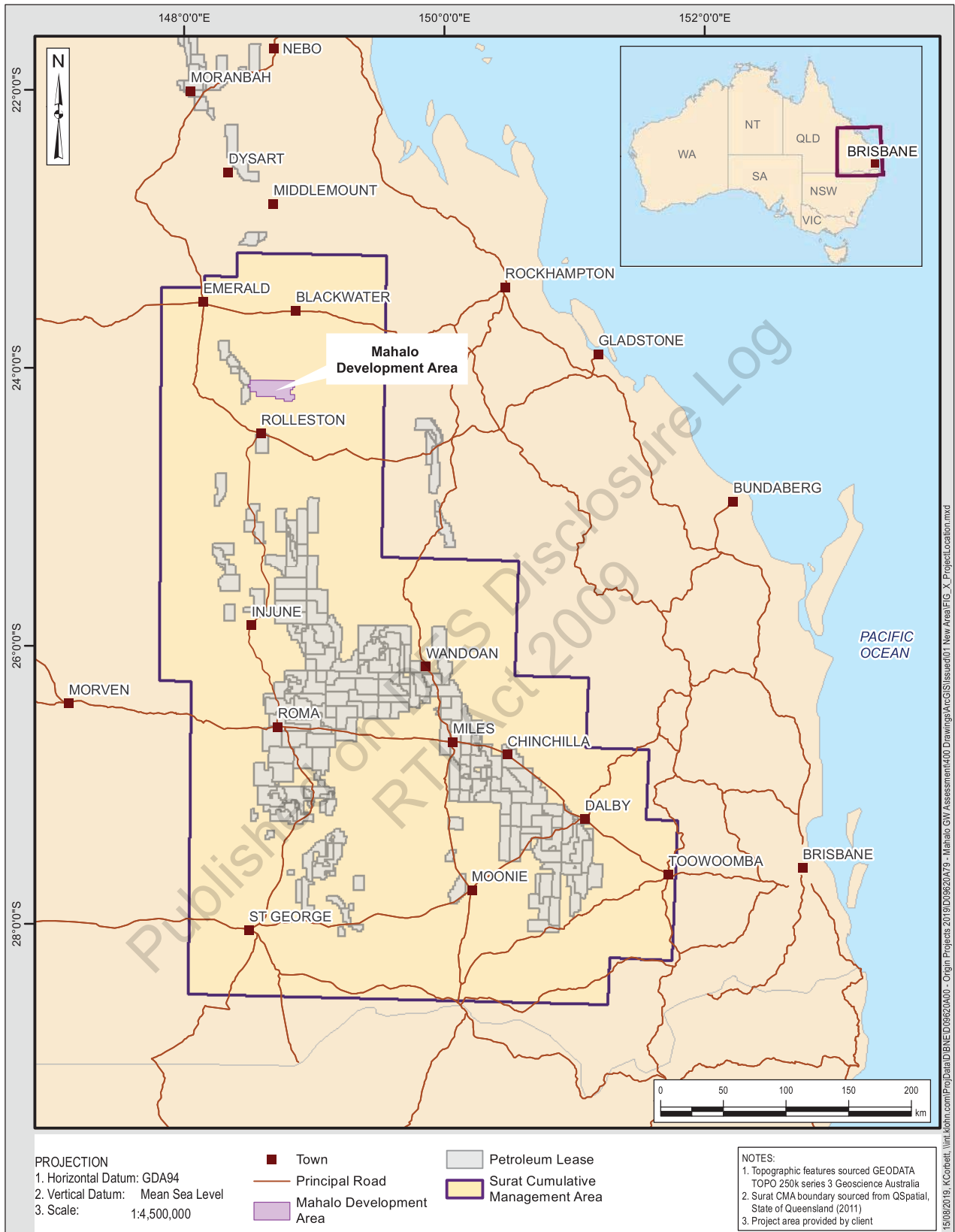


Figure 1.1 Project Location

1.2 Report Structure

This report has been prepared to accompany the Mahalo Development Area *EPBC Act* Referral to be submitted to the DoEE, and the IESC (if deemed required). This report is structured to include the following:

Section 1: Introduction to the Project, report purpose and structure.

Section 2: Statutory Context, including an overview of the relevant Queensland and Commonwealth legislation related to water and gas development / production.

Section 3: Proposal Description.

Section 4: Assessment Methodology, including the existing environment and environmental values, and impact assessment.

Section 5: Existing Environment, including a review of the climate, topography and land use.

Section 6: Hydrological Context and Conceptualisation.

Section 7: Hydrogeological Context and Conceptualisation.

Section 8: Numerical Groundwater Modelling, including predicted extent of drawdown.

Section 9: Impact Assessment.

Section 10: Monitoring, Mitigation and Management.

Section 11: Assessment against the Significant Impact Criteria.

1.2.1 IESC Checklist

The IESC is a statutory body under the *EPBC Act* (Commonwealth of Australia 2018). The IESC's key function is to provide scientific advice to the Commonwealth Environment Minister and relevant state ministers in relation to coal seam gas (CSG) or large coal mining development proposals that are likely to have a significant impact on water resources.

To allow the IESC to provide robust scientific advice to government regulators on water-related impacts of CSG, an information guideline (IESC 2018) has been developed outlining the information considered necessary for the IESC to undertake the relevant assessment. Table 1.1 provides the information checklist and the relevant sections of this report that address each checklist item. It should be noted that some items in the guideline are not required for this Project, which include: Final landform and voids – coal mines and Acid-forming materials and other contaminants of concern. Some checklist items are also addressed in supporting reports as indicated in the table.

This assessment has been undertaken using the Office of Groundwater Impact Assessment's (OGIA) assessment and associated modelling tools to identify project specific risks and impacts and to make reference to cumulative assessment and management in the Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) (further detail is provided in Section 2.2.2).

The IESC published a fact sheet in 2019 (IESC 2019), which outlines considerations related to using OGIA's outputs for environmental assessments. Consideration has been given to the information detailed in the fact sheet during the preparation of this assessment.

A risk assessment of the chemicals proposed to be used in gas extraction activities has been completed separately to this water assessment report by EHS Support (2019). The chemical risk assessment included all proposed chemicals for drilling fluids and treatment of produced water. Potential water-related impacts associated with chemicals used as part of the Project have not been included in this report and are addressed in the chemical risk assessment report.

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Table 1.1 IESC Checklist and Sections Addressed in this Report

Checklist Title	Checklist Item	Section Addressed
Description of the Proposal		
Description of the Proposal	Provide a regional overview of the proposed project area including: a description of the geological basin; coal resource; surface water catchments; groundwater systems; water-dependent assets; and past, present and reasonably foreseeable coal mining and CSG developments.	Section 3.1
	Describe the proposal’s location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Section 3
	Describe the statutory context, including information on the proposal’s status within the regulatory assessment process and any applicable water management policies or regulations.	Sections 2 and 3.2
	Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Risk Assessment		
Risk Assessment	Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk assessment approach consideration should be given to the complexity of the project, and the probability and potential consequences of risks.	Sections 4.3, 9.5 and 11
	Incorporate causal mechanisms and pathways identified in the risk assessment in conceptual and numerical modelling. Use the results of these models to update the risk assessment.	
	Assess risks following the implementation of any proposed mitigation and management options to determine if these will reduce risks to an acceptable level based on the identified environmental objectives.	
	The risk assessment should include an assessment of: - all potential cumulative impacts which could affect water resources and water-related assets; and - mitigation and management options which the proponent could implement to reduce these impacts.	
Groundwater		
Context and Conceptualisation	Describe and map geology at an appropriate level of horizontal and vertical resolution including: - definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data. - geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.	Section 7
	Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	
	Define and describe or characterise significant geological structures (e.g. faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. - Site-specific studies (e.g. geophysical, coring / wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g. damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays). - Discussion on how this fits into the fault’s potential influence on regional-scale groundwater conditions should also be included.	
	Provide hydrochemical (e.g. acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g. stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	

Checklist Title	Checklist Item	Section Addressed
	Provide site-specific values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	
	Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	
	Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	
Analytical and Numerical Modelling	Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Section 8 and Surat CMA UWIR (OGIA 2019b)
	Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	
	Undertake groundwater modelling in accordance with the <i>Australian Groundwater Modelling Guidelines</i> (Barnett et al. 2012), including independent peer review.	
	Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	
	Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	
	Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters 2018).	
	Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	
	Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	
	Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	
	Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters 2018).	
	Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	
	Provide a program for review and update of models as more data and information become available, including reporting requirements.	
	Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	
	Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	
	Undertake model verification with past and/or existing site monitoring data.	
Impacts to Water Resources and Water-Dependent Assets	Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: <ul style="list-style-type: none"> - any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. - the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. 	Sections 8, 8.5 and Surat CMA UWIR (OGIA 2019b)

Checklist Title	Checklist Item	Section Addressed
	<ul style="list-style-type: none"> - the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units. - the possible fracturing of and other damage to confining layers. - For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal. 	
	Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	Sections 6 and 7
	For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Section 8.5
	Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	Section 2
	Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination	Section 9.4
	Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 10
Data and Monitoring	Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Section 7
	Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Section 7
	Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	Section 10
	Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Section 10
	Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	Section 10
Surface Water		
Context and Conceptualisation	<p>Describe the hydrological regime of all watercourses, standing waters and springs across the site including:</p> <ul style="list-style-type: none"> - geomorphology, including drainage patterns, sediment regime and floodplain features; - spatial, temporal and seasonal trends in streamflow and/or standing water levels; - spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides); and - current stressors on watercourses, including impacts from any currently approved projects. 	Section 6
	Describe the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	

Checklist Title	Checklist Item	Section Addressed
	Provide an assessment of the frequency, volume, seasonal variability and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.	
Analytical and Numerical Modelling	Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Section 4.2.2
	Describe and justify model assumptions and limitations and calibrate with appropriate surface water monitoring data.	
	Use methods in accordance with the most recent publication of <i>Australian Rainfall and Runoff</i> (Ball et al. 2016).	
	Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	
	Develop and describe a program for review and update of the models as more data and information becomes available.	
	Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	
Impacts to Water Resources and Water-Dependent Assets	Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider: - impacts on streamflow under the full range of flow conditions. - impacts associated with surface water diversions. - impacts to water quality, including consideration of mixing zones. - the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets. - landscape modifications such as subsidence, voids, post rehabilitation landform collapses, on-site earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Section 9.4
	Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Section 2
	Identify processes to determine surface water quality guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets.	Section 4.2.2
	Propose mitigation actions for each identified significant impact.	
	Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	
	Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and reasonably foreseeable) are considered in combination.	
	Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	
	Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	Section 4.2.2
	Develop and describe a surface water monitoring program that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions and assess the effectiveness of mitigation and management measures. The program will: - include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals); - comparison of physico-chemical data to national/regional guidelines or to site-specific guidelines derived from reference condition monitoring if available; and - identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.	
Data and Monitoring		

Checklist Title	Checklist Item	Section Addressed
	Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	
	Describe the rationale for selected monitoring parameters, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	
	Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and describe data methods, including whether missing data have been patched.	
	Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.	
	Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	
Water-Dependent Assets		
Context and Conceptualisation	Identify water-dependent assets, including: - water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna) (see Doody et al. [in press]). - public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	Sections 6 and 7
	Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody et al. [in press]).	
	Identify the hydrogeological units on which any identified GDEs are dependent (see Doody et al. [in press]).	
	Identify GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox (Richardson et al. 2011) and GDE Atlas (CoA 2017a) may assist in identification of GDEs (see Doody et al.).	
	Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	
	Describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015).	
	Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	
Impacts, Risk Assessment and Management of Risks	Provide an assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs (see Doody et al.).	Section 9.4
	Provide estimates of the volume, beneficial uses and impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.	
	Describe the potential range of drawdown at each affected bore, and clearly articulate of the scale of impacts to other water users.	
	Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	
	Indicate the vulnerability to contamination (e.g. from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	
	Identify the proposed acceptable level of impact for each water-dependent asset based on leading-practice science and site-specific data, and ideally developed in conjunction with stakeholders.	
	Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	
	Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	

Checklist Title	Checklist Item	Section Addressed
Data and Monitoring	Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions and test potential responses to impacts of the proposal (see Doody et al.).	Section 10
	Develop and describe a monitoring program that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change (see Doody et al. [in press]).	
	Consider concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design, see Doody et al. [in press]).	
	Describe the proposed process for regular reporting, review and revisions to the monitoring program.	
	Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna (QLD Government 2015)).	
Water and Salt Balance, and Water Quality		
Water and Salt Balance, and Water Quality	Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Produced Water Management Plan (Golder 2019)
	Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	
	Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	
	Provide salt balance modelling that includes stores and the movement of salt between stores and takes into account seasonal and long-term variation.	
Cumulative Impacts		
Context and Conceptualisation	Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 9.4 and Surat CMA UWIR (OGIA 2019b)
	Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	
Impacts	Provide an assessment of the condition of affected water resources which includes: - identification of all water resources likely to be cumulatively impacted by the proposed development; - a description of the current condition and quality of water resources and information on condition trends; - identification of ecological characteristics, processes, conditions, trends and values of water resources; - adequate water and salt balances; and - identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	
	Assess the cumulative impacts to water resources considering: - the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally; - all stages of the development, including exploration, operations and post closure / decommissioning; - appropriately robust, repeatable and transparent methods;	

Checklist Title	Checklist Item	Section Addressed
	- the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and - opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.	
Mitigation, Monitoring and Management	Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	
	Identify cumulative impact environmental objectives.	
	Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	
	Describe appropriate reporting mechanisms.	
	Propose adaptive management measures and management responses.	
Subsidence – Underground Coal Mines and Coal Seam Gas		
Subsidence – Underground Coal Mines and Coal Seam Gas	Provide predictions of subsidence impact on surface topography, water-dependent assets, groundwater (including enhanced connectivity between aquifers) and the movement of water across the landscape (See CoA 2014b; CoA 2014c). Consider multiple methods of predictions and apply the most appropriate method. Consider the limitations of each method including the adequacy of empirical data and site-specific geological conditions and justify the selected method.	Section 9.3
	Describe subsidence monitoring methods, including the use of remote or on-ground techniques and explain the predicted accuracy of such techniques.	
	Provide an assessment of both conventional and unconventional subsidence. For project expansions, an evaluation of past or current effects of geological structures on subsidence and implications for water resources and water-dependent assets should be provided.	
	Consider geological strata and their properties (strength/hardness/fracture propagation) in the subsidence analysis and/or modelling. Anomalous and near-surface ground movements with implications for water resources and compaction of unconsolidated sediment should also be considered.	
CSG Well Construction and Operation		
CSG Well Construction and Operation	Describe the scale of fracturing (number of wells, number of fracturing events per well), types of wells to be stimulated (vertical versus horizontal), and other forms of well stimulation (cavitation, acid flushing).	Chemical Risk Assessment Report (EHS Support 2019)
	Describe proposed measuring and monitoring of fracture propagation.	
	Identify water source for drilling and hydraulic stimulation and outline the volume of fluid and mass balance (quantities/volumes).	
	Describe the rules (e.g. water sharing plans) covering access to each water source used for drilling and hydraulic stimulation and how the project proposes to comply with them.	Produced Water Management Plan (Golder Associates 2019)
	Quantify and describe the quality and toxicity of flowback and produced water and how it will be treated and managed.	
	Assess the potential for inter-aquifer leakage or contamination.	
	The use of drilling and hydraulic fracturing chemicals should be informed by appropriately tiered deterministic and/or probabilistic hazard and risk assessments, based on ecotoxicological testing consistent with Australian Government testing guidelines (see CoA 2012; MRMMC-EPHC-NHMRC 2009).	No hydraulic fracturing is proposed in the Mahalo Development Area.
	Propose waste management measures (including salt and brines) during both operations and legacy after closure.	
	List the chemicals proposed for use in drilling and hydraulic stimulation including: - names of the companies producing fracturing fluids and associated products; - proprietary names (trade names) of compounds (fracturing fluid additives) being produced; - chemical names of each additive used in each of the fluids;	

Checklist Title	Checklist Item	Section Addressed
	<ul style="list-style-type: none"> - Chemical Abstract Service (CAS) numbers of each of the chemical components used in each of the fluids; - general purpose and function of each of the chemicals used; - mass or volume proposed for use; - maximum concentration (mg / L or g / kg) of the chemicals used; - chemical half-life data, partitioning data, and volatilisation data; - ecotoxicology; and - any material safety data sheets for the chemicals or chemical products used. 	
	Chemicals for use in drilling and hydraulic fracturing must be identified as being approved for import, manufacture or use in Australia (that is, confirmed by NICNAS as being listed in the Australian Inventory of Chemical Substances (see CoA 2017b)).	

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2 STATUTORY CONTEXT

This water assessment report has been prepared with consideration to key policies and legislation from the Commonwealth of Australia and the State of Queensland. This section provides an overview of applicable legislation / policies to this assessment.

2.1 Commonwealth Legislation

2.1.1 Environment Protection and Conservation Act 1999

The *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)* (Commonwealth of Australia 2018) is the central piece of environmental legislation at the Commonwealth level. It provides for the protection of environmental values, including matters of national environmental significance (MNES). Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process under this Act. Water resources in relation to large coal mining and CSG development projects are a MNES. The Project constitutes a CSG development under the EPBC Act, and as such is being referred to the Department of the Environment and Energy (DoEE).

The regulatory guideline relevant to the Project, developed from the amendment to the *EPBC Act* identifying water resources as being a MNES, is the *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DoEE 2013b).

Significant impact guidelines 1.3: Coal seam gas and large coal mining developments

The '*Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources*' (DoEE 2013b) identify a 'significant impact' as '*an impact which is important, notable, or of consequence, having regard to its context or intensity*'.

Section 5.2 and 5.3 of the guidelines, identify that for a water resource a 'significant impact' may occur where, as a result of the action, one of the following changes to the hydrological characteristics of a water resource are of a sufficient scale or intensity to significantly reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes:

- a. changes in the water quantity, including the timing of variations in water quantity;
- b. changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large-scale subsidence); and
- c. changes in the area or extent of a water resource.

DoEE have identified the following aspects that may need to be considered when assessing the above hydrological characteristics:

- flow regimes (volume, timing, duration and frequency of surface water flows);
- recharge rates to groundwater;
- aquifer pressure or pressure relationships between aquifers;
- groundwater table and potentiometric surface levels;
- groundwater-surface water interactions;

- river-floodplain connectivity;
- inter-aquifer connectivity; and
- coastal processes including changes to sediment movement or accretion, water circulation patterns, permanent alterations in tidal patterns, or substantial changes to water flows or water quality in estuaries.

The significant impact guidelines 1.3, section 5.4, provide guidance on changes to water quality which state that a significant impact on a water resource may occur where, as a result of the action:

- there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised, and as a result the action:
 - ◆ creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality;
 - ◆ substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality;
 - ◆ causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment;
 - ◆ seriously affects the habitat or lifecycle of a native species dependent on a water resource;
 - ◆ causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource; or
- there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives); or
- high quality water is released into an ecosystem which is adapted to a lower quality of water.

Both changes to the hydrological characteristics and water quality, as a result of the proposed activities, have been assessed as part of this assessment for the identification of potential impacts. Where required, management and mitigation measures will be implemented to avoid potential impacts. These measures are discussed in Section 10.

Matters of National Significance: Significant Impact Guidelines 1.1

The significant impact guidelines 1.1 (DoEE 2013a) identify a 'significant impact' as an "impact which is important, notable, or of consequence, having regard to its context or intensity". A 'significant impact' on a critically endangered and endangered species, may occur where, as a result of the action, there is a real chance or possibility that it will:

- lead to a long-term decrease in the size of a population;
- reduce the area of occupancy of the species;
- fragment an existing population into two or more populations;
- adversely affect habitat critical to the survival of a species;

- disrupt the breeding cycle of a population;
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat;
- introduce disease that may cause the species to decline; or
- interfere with the recovery of the species.

For ecological communities, a 'significant impact' may occur, where, as a result of the action, there is a real chance or possibility that it will:

- reduce the extent of an ecological community;
- fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines;
- adversely affect habitat critical to the survival of an ecological community;
- modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns;
- cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting;
- cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to:
 - ♦ assisting invasive species, that are harmful to the listed ecological community, to become established; or
 - ♦ causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community; or
- interfere with the recovery of an ecological community.

2.2 State Legislation

2.2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2018b) is an Act relevant to exploring for, recovering and transporting by pipeline, petroleum and fuel gas, and ensuring the safe and efficient undertaking of those activities. The key purpose of this Act is to facilitate and regulate the undertaking of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry.

This Act identifies underground water rights for petroleum tenures, and states that the holder of a petroleum tenure may take or interfere with underground water in the area of the tenure if the

taking or interference happens during the course of, or results from, the carrying out of another authorised activity for the tenure.

The Act prescribes mandatory compliance with the Queensland Department of Natural Resources, Mines, and Energy's (DNRME) '*Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 1*' (DNRME 2018). The purpose of this Code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and gas and the protection of groundwater resources.

2.2.2 Water Act 2000

General Purpose of the Water Act

The *Water Act 2000* (State of Queensland 2019e) is an Act to provide for the sustainable management of water and the management of impacts on underground water, among other purposes. This Act provides a framework for:

- the sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water;
- the sustainable and secure water supply and demand management for designated regions;
- the management of impacts on underground water caused by the exercise of underground water rights by the resource sector; and
- the effective operation of water authorities.

This Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam.

Water Act and Petroleum and Gas Activities

The *Water Act 2000* provides for the identification and management of potential impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which are regulated under the *Petroleum and Gas (Production and Safety) Act 2004*. The Act also outlines the requirements for make good agreements, if required, associated with the impacts to underground water.

Chapter 3 of the *Water Act 2000* has a stated purpose to provide for the management of impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which includes petroleum tenure holders. To achieve the stated purpose, a regulatory framework is provided which requires:

- Resource tenure holders to monitor and assess the impacts of the exercise of underground water rights on water bores and to enter into make good agreements with the owners of the groundwater bores as necessary;
- The preparation of underground water impact reports (UWIR) that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs; and

- Managing the cumulative impacts of the activities of two or more resource tenure holders' underground water rights on underground water.

Under this regulatory framework, where there is an area of concentrated development, a cumulative management area (CMA) can be declared. The Project is located within the Surat CMA, which was declared by the Queensland Government in 2011. The Office of Groundwater Impact Assessment (OGIA) was established under the *Water Act 2000* and is responsible for: predicting regional impacts on water pressures in aquifers; developing water monitoring and spring management strategies; and assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within CMAs. These predictions, strategies and responsibilities are set out in the Surat CMA UWIR, prepared and maintained by OGIA.

The Surat CMA UWIR was first published by Queensland Water Commission (QWC) in 2012 (QWC 2012) to assess the cumulative impacts to the Surat Basin and southern Bowen Basin, as a result of the expansion of CSG production by multiple, adjacent developers. A second UWIR was published by OGIA in September 2016 (OGIA 2016b), with the most recent update (consultation draft) published in 2019 (OGIA 2019b).

OGIA also provide tenure holders with their obligations to comply with the Surat CMA UWIR Water Monitoring Strategy (WMS). The WMS includes:

- installation, maintenance and collection of data from the groundwater monitoring network including water pressure and water chemistry;
- monitoring of associated water volumes;
- a program for baseline assessment; and
- tenure holder reporting of the data and activities relating to the above components.

OGIA has also provided APLNG with groundwater modelling outputs from the 2019 UWIR numerical model to inform this assessment, which is detailed further in Sections 4.2 and 8.

Trigger Thresholds

Under Section 362 of the *Water Act 2000*, a bore trigger threshold, for a consolidated aquifer, of 5 m applies (2 m for an unconsolidated aquifer). The 5 m threshold represents the maximum allowable groundwater level decline in a groundwater bore, due to a petroleum tenure holder's activities, prior to triggering an investigation into the water level decline.

Under Section 379 of the *Water Act 2000* a spring trigger threshold for an aquifer applies. This includes vent springs / complexes and watercourse springs (i.e. gaining streams). This threshold value (0.2 m) represents the maximum allowable decline in the water level of an aquifer in connection with a spring, at the spring location, prior to triggering an investigation into the water level decline.

2.2.3 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (State of Queensland 2018a) is an Act with the objective to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

This Act states that ‘to carry out an environmentally relevant activity (ERA) an environmental authority (EA) is required’. A resource activity, specifically a petroleum and/or gas activity, is defined as an ERA.

Environmental Authority – EPPG00872113

APLNG currently holds an EA (EPPG00872113) authorising petroleum activities within the Mahalo Development Area¹. EA EPPG00872113 will be amended under the *Environmental Protection Act 1994* (State of Queensland 2018a) to seek authorisation for the full scope of the Project described in Section 1.1. It is noted that the EA currently authorises the construction and operation of up to 131 production wells, ancillary linear infrastructure, gas compression facilities, water management infrastructure, and other ancillary activities to support gas field development across several tenures. Notwithstanding, EA EPPG00872113 will be amended for the Project and to facilitate approval of the Petroleum Leases (PLs) under the *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2018b). Section 227AA of the *Environmental Protection Act 1994* requires a comprehensive assessment of potential groundwater impacts from petroleum and gas production under PLs, including the following:

(c) for each aquifer affected, or likely to be affected, by the exercise of underground water rights—

(i) a description of the aquifer; and

(ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers and surface water; and

(iii) a description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights; and

(iv) the predicted quantities of water to be taken or interfered with because of the exercise of underground water rights during the period in which resource activities are carried out;

(d) the environmental values that will, or may, be affected by the exercise of underground water rights and the nature and extent of the impacts on the environmental values;

(e) any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or after the period in which resource activities are carried out;

(f) strategies for avoiding, mitigating or managing the predicted impacts on the environmental values stated for paragraph (d) or the impacts on the quality of groundwater mentioned in paragraph (e).

The Queensland Department of Environment and Science (DES) guideline *Application requirements for activities with impacts to water* (DES 2017b) provides a summary of the

¹ EPPG0072113 authorises activities within ATP1191, ATP337, PL450, PL451, PL457, PL1012. Mahalo Development Area is located on a portion of ATP1191

environmental impact assessment framework for projects with potential impacts to groundwater resources and information requirements including:

- *A groundwater impact assessment must include:*
 - ◆ *Detailed assessment of current groundwater resources including geological and geochemical characteristics.*
 - ◆ *Hydrogeological assessment of groundwater resources including groundwater flow characteristics, storativity, hydraulic conductivity and permeability in zones to be impacted by the proposed activities.*
 - ◆ *Details on how seepage detection between deep and shallow groundwater will be considered and managed.*
 - ◆ *Connectivity with surface water resources.*
 - ◆ *Impact on groundwater quality as a result of the proposed ERA.*
 - ◆ *Impact on groundwater flow regimes and drawdown.*
 - ◆ *Impact on existing users.*
 - ◆ *Numeric groundwater modelling of groundwater resources and expected impacts of the proposed ERA.*

Section 227 of the *Environmental Protection Act 1994* requires an assessment of potential surface water impacts from the management of coal seam water produced by the Project, including the following:

- (a) the quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity;*
- (b) the flow rate at which the applicant reasonably expects the water will be generated;*
- (c) the quality of the water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out;*
- (d) the proposed management of the water including, for example, the use, treatment, storage or disposal of the water;*
- (e) the measurable criteria (the management criteria) against which the applicant will monitor and assess the effectiveness of the management of the water, including, for example, criteria for each of the following—*
 - (i) the quantity and quality of the water used, treated, stored or disposed of;*
 - (ii) protection of the environmental values affected by each relevant CSG activity;*
 - (iii) the disposal of waste, including, for example, salt, generated from the management of the water;*
- (f) the action proposed to be taken if any of the management criteria are not complied with, to ensure the criteria will be able to be complied with in the future.*

Under the *Environmental Protection Act 1994*, streamlined model conditions for petroleum activities have been developed for incorporation into EA's. These are provided in a guideline published by DES (2016b). The streamlined conditions are based on acceptable management approaches and constraints to protect environmental values.

2.2.3.1 Environmental Protection Regulation 2008

The *Environmental Protection Regulation 2008* (State of Queensland 2019b) is a subordinate legislation which supports the operation of the *Environmental Protection Act 1994* and prescribes the detail for the processes contained in the Act.

Section 24AA of the *Environmental Protection Regulation 2008* is relevant to this application and includes the documents prescribed for an application for an environmental authority for a CSG activity.

2.2.3.2 CSG Water Management Policy 2012

The primary objective of the Coal Seam Gas Water Management Policy 2012 (DEHP 2012) relates to the management and use of CSG water under the *Environmental Protection Act 1994*. The role of the policy is to:

- clearly state the government's position on the management and use of CSG water;
- guide CSG operators in managing CSG water under their environmental authority; and
- ensure community understanding about the government's preferred approach to managing CSG water.

The *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019c) and *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019b) support the objective of the CSG Water Management Policy 2012, by specifying the standards required to be met where associated water is to be used for beneficial purposes.

2.2.4 Water Supply (Safety and Reliability) Act 2008

The *Water Supply (Safety and Reliability) Act 2008* (State of Queensland 2017a) is an Act that provides for the safety and reliability of water supply. The purpose of this Act is achieved primarily by providing:

- a regulatory framework for providing water and sewerage services in the State, including functions and powers of service providers;
- a regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health;
- the regulation of referable dams;
- flood mitigation responsibilities; and
- the protection of the interests of customers of service providers.

The key component of the Act relevant to the Project relates to the regulation of referable dams.

2.3 Environmental Values and Water Resource Management

2.3.1 Environmental Values

The *Environmental Protection Act 1994* (State of Queensland 2018a) defines an Environmental Value (EV) as:

- a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or
- another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

Under the *Environmental Protection Act 1994*, the *Environmental Protection (Water) Policy 2009* (State of Queensland 2016) is established as subordinate legislation to achieve the object of the Act in relation to Queensland waters. The purpose of the *Environmental Protection (Water) Policy 2009* is achieved by:

- identifying environmental values and management goals for Queensland waters;
- stating water quality guidelines and water quality objectives to enhance or protect the environmental values;
- providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- monitoring and reporting on the condition of Queensland waters.

The Mahalo Development Area is located within the eastern tributaries of the Comet River Sub-Basin. The *Environmental Protection (Water) Policy 2009* provides defined EVs and water quality objectives (WQOs) for the Comet River Sub-Basin under Schedule 1 of the policy and are detailed in DEHP² (2011). EVs for the Comet River Sub-Basin are presented in Table 2.1 and include both the values for surface water and groundwater.

Table 2.1 Environmental Values for the Comet River Sub-Basin waters within the vicinity of the Mahalo Development Area (State of Queensland 2013)

Water	Environmental Values											
	Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual
Comet River Sub-Basin (WQ1307)												
Comet western tributaries – developed areas	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Comet eastern tributaries – developed areas	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Comet main channel – developed areas (including Comet weir waters)	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Fresh waters in undeveloped areas	✓		✓	✓		✓	✓	✓	✓	✓		✓
Groundwater	✓	✓	✓	✓			✓			✓	✓	✓

✓ denotes the EV is selected for protection. Blank indicates that the EV is not chosen for protection.

² Note that the Queensland Department of Environment and Heritage Protection (DEHP) is now the Department of Environment and Science (DES)

Draft EVs have also been recently prepared for the Fitzroy Basin groundwater systems (State of Queensland 2018g). The draft EVs have been developed for alluvial and fractured rock systems, and the deposits overlying the Great Artesian Basin (GAB). Units underlying the GAB are also considered. Table 2.2 presents the draft groundwater EVs for each of the categories outlined in the plan (State of Queensland 2018c; 2018d; 2018e; 2018f).

Table 2.2 Draft Environmental Values for the Fitzroy Basin Groundwater within the vicinity of the Mahalo Development Area (State of Queensland 2018c; 2018d; 2018e; 2018f)

Water	Environmental Values											
	Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual
Comet (Fitzroy Alluvium) – GWQ1301	✓	✓	✓	✓								✓
Eastern Basement with Basalt Remnants (Fitzroy Fractured Rock) – GWQ1302	✓	✓	✓	✓	✓					✓	✓	✓
Saline Tertiary Sediments & Central Moderately Saline Weathered Remnants (Fitzroy Cainozoic deposits) – GWQ1303	✓	✓		✓						✓	✓	✓
Central Bowen Saline Zone (Fitzroy earlier basins) – GWQ1309	✓	✓	✓	✓	✓						✓	✓
Bowen Non-Coal Bearing (Fitzroy earlier basins) – GWQ1309	✓			✓						✓		✓
Bowen Clematis Outcrop – GWQ1309	✓			✓						✓		✓

✓ denotes the EV is selected for protection. Blank indicates that the EV is not chosen for protection.

WQOs to protect the EVs are defined in DEHP (2011) and include separate WQOs to protect the aquatic ecosystem EV and other EVs (e.g. human use EVs). As the plan is still in draft, no WQOs are currently available for the Fitzroy Basin groundwater.

2.3.2 Water Resource and Resource Operations Plans

Water Plan (Fitzroy Basin) 2011

The surface water resource of the Comet River Sub-Basin is managed under the Queensland Water Resource Plan framework as part of the *Water Plan (Fitzroy Basin) 2011* (State of Queensland 2017b). The purpose of the plan is to:

- define the availability of water in the plan area;
- provide a framework for sustainably managing water and the taking of water;
- identify priorities and mechanisms for dealing with future water requirements;
- provide a framework for establishing water allocations;
- provide a framework for reversing, where practicable, degradation in natural ecosystems;
- regulate the taking of overland flow water; and

- regulate the taking of groundwater.

Fitzroy Basin Resource Operations Plan

The Fitzroy Basin Resource Operations Plan (ROP) (DNRM 2015) provides the process to implement the *Water Plan (Fitzroy Basin) 2011*. The key function of the ROP is to provide the operating and environmental management rules and monitoring requirements to resource operations licence holders.

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3 PROPOSAL DESCRIPTION

3.1 Project Overview

3.1.1 Project Location and Regional Overview

The Mahalo Development Area covers an area of approximately 469 km² and is located ~30 km north of the township of Rolleston, Central Queensland. The Project is located on the northern most area of ATP1191, as shown in Figure 1.1.

A summary of the regional Project setting is provided below, with further detail (as indicated below) included in the remainder of the report:

- The gas producing targets for the Project are within the Bandanna Formation, of the Permo-Triassic Bowen Basin (Section 7.1).
- The Project is located in the Comet River Sub-Basin, which forms part of the larger Fitzroy Basin (Section 6).
- Groundwater systems in the Mahalo Development Area include Cenozoic-age deposits comprising alluvium associated with the Comet River, basalt and Cenozoic sediments, as well as the Bowen Basin units (Section 7).
- Water-dependent assets identified in the Mahalo Development Area include third-party groundwater bores, third-party surface water users and potential terrestrial groundwater dependent ecosystems (GDEs) (Section 7.9 and 7.10).

Other Developments

The Project is located in the vicinity of other resource tenures, including:

- Conventional gas fields are located adjacent to the Project on PL41, PL54, PL67, and PL173, immediately to the west of the Project, targeting formations below the Bandanna Formation.
- The Rolleston Open Cut coal mine is located ~28 km southwest of the Project. The mine, which has been in operation since 2005, operates on Mining Lease (ML) 70415, ML70458, ML70307 and ML70416.
- The Blackwater mine is located ~8 km north of the Mahalo Development Area. The mine is located on several mining leases including ML70139, ML1907, ML1767, ML1773, ML1792 and ML1771.

3.2 Project Approval Status

The *Petroleum and Gas (Production and Safety) Act 2004* identifies underground water rights for petroleum tenures, and in summary, states that the holder of a petroleum tenure may take or interfere with underground water. APLNG intend to exercise their underground water rights for the Mahalo Development Area.

A summary of the Project's approval status within the legislative / regulatory framework is provided in the following:

- APLNG have been authorised to conduct petroleum activities in the Mahalo Development Area in accordance with its EA (EPPG00872113), under the *Environmental Protection Act 1994* (State of Queensland 2018a). The EA came into effect on June 23, 2016.
- APLNG are currently preparing to apply for an amendment of the Project EA (EPPG00872113) under the *Environmental Protection Act 1994* to authorise production activities.
- The Project is now being referred to the DoEE for consideration under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* (Commonwealth of Australia 2018). This assessment report has been prepared to support APLNG's referral under the *EPBC Act*.

As previously discussed, the Project is located within the Surat CMA, which was declared in 2011 by the Queensland Government. OGIA is responsible for: predicting regional impacts on water pressures in aquifers; developing water monitoring and spring management strategies; and assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within CMAs. These predictions, strategies and responsibilities are set out in the Surat CMA UWIR, prepared and maintained by OGIA.

Production within the Mahalo Development Area was recently planned, and therefore production from the Project was not included in the 2019 UWIR (OGIA 2019b). OGIA will assess the adequacy of the UWIR during the annual evaluation / review process. At this time, OGIA will then assess and decide whether a new UWIR is required. Regardless, a new UWIR is required no later than 2022, which will include the proposed production within the Mahalo Development Area.

3.3 Project Components

The Project will involve the progressive development of gas infrastructure, planned to commence in 2021, including the following activities:

- 95 gas production wells;
- Ancillary linear infrastructure including gas and water pipelines, access tracks, power lines, and communication lines;
- Gas compression facilities;
- Water management infrastructure; and
- Other ancillary activities and facilities to support gas field development

Infrastructure will be located in accordance with APLNG's '*Environmental Constraints Planning and Field Development Protocol*' (APLNG 2019a).

The existing EA (EPPG00872113) authorises the construction and operation of up to 131 wells (over several tenures including the Mahalo Development Area), ancillary linear infrastructure, gas compression facilities, water management infrastructure, and other ancillary activities to support gas field development.

3.3.1 Project Activities and Infrastructure

3.3.1.1 Gas Production Wells and Water Production

Groundwater abstraction is required as part of the gas production process. Groundwater is abstracted (pumped) from production wells to depressurise the target production coal seams. Depressurisation generates gas flow and sustains groundwater flow from the well to maintain the target producing operational pressure for each production well. A summary of the proposed production wells is provided in the following:

- CSG production wells will be drilled and constructed in accordance with the '*Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 1*' (DNRME 2018). The purpose of this Code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and the protection of groundwater resources.
- Subject to relevant approvals, gas production and its associated water extraction will commence in 2021.
- The operating life of individual CSG production wells is anticipated to be between 20 and 30 years. Gas production is planned to cease by approximately 2050.

Produced water volumes and rates are predicted using a stochastic reservoir modelling tool which produces probabilistic distributions applied to several key reservoir parameters (i.e. permeability, porosity and net coal). The model predictions generate production profiles (type curves). These production profiles are used in field development planning to provide a water forecast. Type curves are updated during the life of the project as more information (e.g. further and refined key reservoir parameters) becomes available.

Figure 3.1 presents the predicted water extraction rate for the Project. Peak water production is predicted to occur at the end of the third year, with a peak rate of ~2 ML/day. The estimated annual total for the life of the Project, as well as the cumulative water production volume, is presented in Figure 3.2. The total groundwater that will be abstracted for the duration of the Project is estimated at ~3.4 GL.

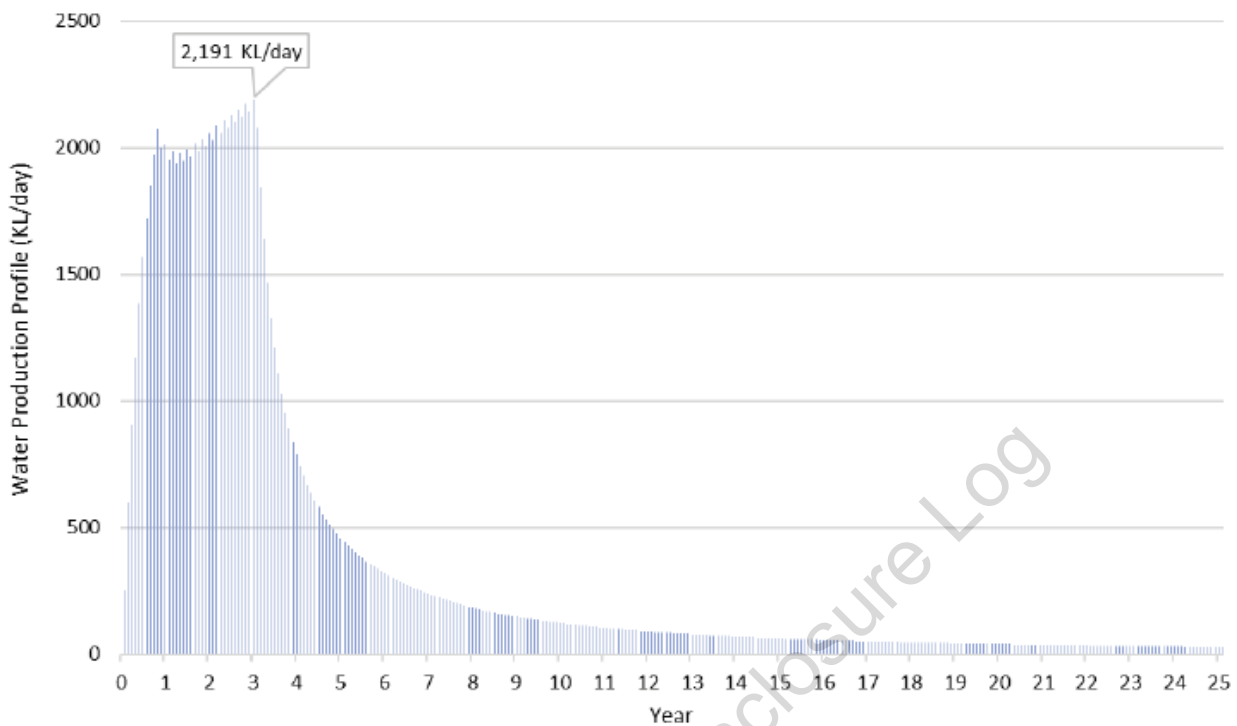


Figure 3.1 Predicted Water Production Rate (Golder 2019)



Figure 3.2 Predicted Annual Water Production and Cumulative Volume (Golder 2019)

Table 3.1 presents a summary of the produced water quality from existing gas wells within the Mahalo Development Area, with samples collected between 2013 and 2018. The electrical conductivity (EC) from all of the samples ranges between 12,000 to 14,000 $\mu\text{S}/\text{cm}$.

Table 3.1 Produced Water Quality

Sample Location	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	CO ₃ (mg/L)	HCO ₃ (mg/L)	Cl (mg/L)	SO ₄ (mg/L)	TDS (mg/L)	EC (µS/cm)
Mira 2	2,300	290	40	12	<1	640	3,800	15	8,640	12,000
Mira 4	2,800	370	42	14	<1	180	4,700	<0.1	10,080	14,000
Mira 6	2,700	330	40	14	<1	110	4,500	<0.1	9,360	13,000
MIR-PW002	2,400	350	35	310	<5	210	4,100	1.3	8,200	13,700
MIR-PW003	2,500	350	34	55	<5	86	3,900	<0.5	7,900	13,200
MIR-PW004	2,600	360	36	37	<5	94	3,900	<0.5	8,200	13,600
MIR-PW005	2,500	330	34	71	<5	77	3,900	<0.5	7,900	13,100

NOTES: 1 – Total Dissolved Solids; 2 – Mira Water samples are reproduced from Petroleum Services, 2018; 3 – MIR-PW Water samples are reproduced from SGS, 2013; mg/L – milligrams per Litre, µS/cm – micro-Siemens per centimetre

3.3.1.2 Produced Water Management

Water management will be undertaken in accordance with the Mahalo Development Area Produced Water Management Plan (Golder 2019), which has been developed to meet the requirements of the CSG Water Management Policy (DEHP 2012) and to maximise the beneficial use of produced water (i.e. full beneficial reuse of all water produced from the Project).

APLNG's strategy for produced water management is based on the CSG Water Management Policy prioritisation hierarchy (DEHP 2012). The prioritisation hierarchy for managing and using CSG water is:

- Priority 1 – CSG water is used for a purpose that is beneficial to one or more of the following:
 - ◆ the environment;
 - ◆ existing or new water users; and/or
 - ◆ existing or new water-dependent industries.
- Priority 2 – After feasible beneficial use options have been considered, treating and disposing CSG water in a way that firstly avoids, and then minimises and mitigates, impacts on environmental values.

Figure 3.3 presents the indicative water management process for the Project. Further details on the management of the produced water is provided in the Produced Water Management Plan (Golder 2019). A summary of key aspects relevant to this report is provided in the following sections.

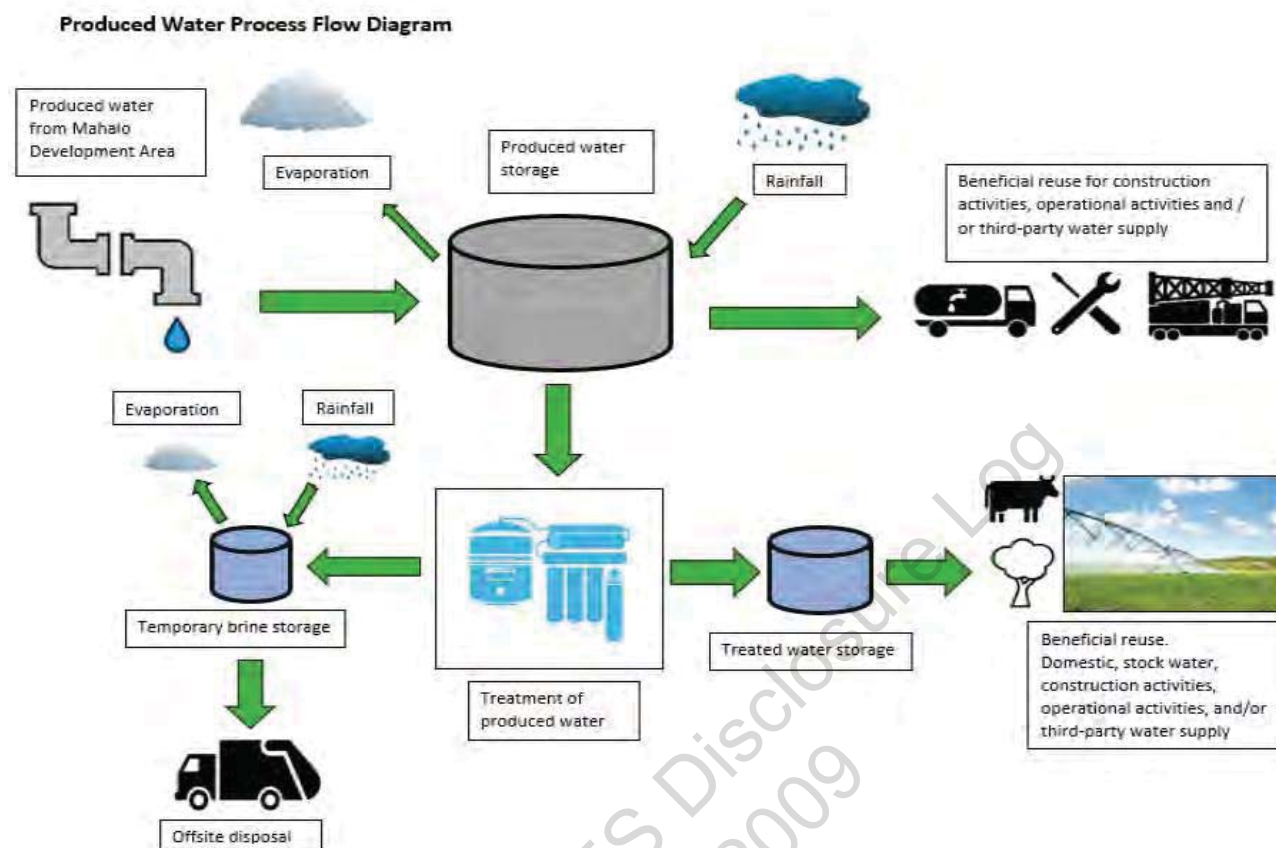


Figure 3.3 Produced Water Process Flow Diagram (Golder 2019)

Produced Water Management Infrastructure

Produced water for the Project will be transferred to water management infrastructure including above-ground dams and/or tanks constructed and operated in accordance with the relevant guidelines such as the *'Manual for assessing consequence categories and hydraulic performance of structures'* (DES 2016a), and *'Structures which are dams or levees constructed as part of environmentally relevant activities'* (DES 2019d).

Water will be transferred at low pressure through underground HDPE pipelines designed and installed in accordance with Australian Pipelines and Gas Association (APGA) Code of Practice Upstream Polyethylene Gathering Networks-CSG Industry Version 4.0 (APGA 2017).

Water management infrastructure will be located in accordance with APLNG's *'Environmental Constraints Planning and Field Development Protocol'* (APLNG 2019a).

Beneficial Uses

Produced water used in any beneficial use will be fit for purpose and in compliance with existing Queensland regulatory requirements, including the conditions of the Mahalo EA or end of waste codes under the *'Waste Reduction and Recycling Act 2011'* (State of Queensland 2019h), including compliance with ANZECC water quality limits for irrigation beneficial uses.

Brine and Salt Management

Saline waste (i.e. brine and salt) will be managed in accordance with the Mahalo Development Area Produced Water Management Plan (Golder 2019).

Water treatment by-products, including brine, will be stored on site prior to disposal off-site at a regulated waste facility authorised under the *Environmental Protection Act 1994* (State of Queensland 2018a).

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4 ASSESSMENT METHODOLOGY

4.1 Methodology and Data Sources

4.1.1 Assessment Area

The existing environment within the vicinity of the Mahalo Development Area, for this Water Assessment Report, was considered through a desktop assessment to establish the baseline groundwater conditions, EVs and potential receptors.

The assessment area, for the purposes of this report, includes surface water features, hydrogeological units underlying the Project within the Bowen Basin and overlying Cenozoic and Quaternary units / deposits. For the identification of groundwater receptors relevant to this Project, a 50 km buffer around the Mahalo Development Area was established to capture potential adjacent groundwater receptors that may be impacted by the proposed development.

4.1.2 Information and Data Sources

A preliminary desktop assessment utilised data and information provided by APLNG, OGIA and publicly available reports and data. Primary data and information utilised in this assessment includes:

Datasets:

- Registered bore data from the Queensland Department of Natural Resources, Mines and Energy (DNRME) Groundwater Database (GWDB) (DNRME 2019)
- Queensland Spring Register, published by the Queensland Herbarium (Queensland Herbarium 2018)
- Potential Groundwater Dependent Ecosystem (GDE) mapping published by the Department of Science and Environment (DES 2018b)
- Surface water flow and quality data sourced from the Queensland Government Water Monitoring Information Portal (State of Queensland 2019c)
- Surat CMA aquifer attribution dataset, provided by OGIA (OGIA 2019c)
- Petroleum well completion reports, sourced from Queensland QDEX database (State of Queensland 2019a)
- Baseline bore assessment details, provided by APLNG

Reports:

- Underground Water Impact Report for the Surat CMA (OGIA 2019b)
- Hydrogeological Conceptualisation Report for the Surat CMA (OGIA 2016a)
- Environmental Protection Policy (Water) 2009 – Comet River Sub-Basin Environmental Values and Water Quality Objectives (DEHP 2011)

4.2 Impact Assessment

4.2.1 Groundwater

OGIA simulated the predictive model scenario for APLNG using the regional groundwater flow model that underpins the Surat CMA UWIR (OGIA 2019b), and based on the proposed development information provided by APLNG (e.g. number and location of wells, production scheduling and durations). Modelling included simulations to provide impact predictions from the Project³, including results of the predictive uncertainty analysis completed by OGIA for the 2019 UWIR.

Outputs from the modelling have been processed by KCB for this assessment. The results of the modelling have been processed and considered as part of this assessment (Sections 8 and 9.4).

The assessment criteria used to consider the groundwater drawdown impacts associated with the Project refers to the *Water Act 2000*, trigger thresholds, as outlined in Section 2.2.2:

- Bore trigger threshold, represents the maximum allowable groundwater level decline in a groundwater bore, due to petroleum tenure holders' activities, prior to triggering an investigation into the water level decline.
 - ♦ For a consolidated aquifer – 5 m
 - ♦ For an unconsolidated aquifer – 2 m
- Spring trigger threshold, represents the maximum allowable decline in the water level of an aquifer in connection with a spring, at the spring location, prior to triggering an investigation into the water level decline.
 - ♦ Spring – 0.2 m

Potential impacts to the source aquifers for GDEs and spring complexes have been assessed using the predicted drawdown from the UWIR numerical model with consideration to hydrogeological conceptual understanding of the system. Groundwater and surface water interactions have also been considered through the conceptual understanding of the system.

Other potential impacts associated with the Project in relation to groundwater are presented in Section 9.1.1, with the relevant mitigation, management and monitoring measures to address these potential impacts provided in Section 10.

4.2.2 Surface Water

The IESC checklist identifies that analytical and/or numerical modelling is to be undertaken for the assessment of impacts to surface water. The proposed Project does not include any extraction from, or discharges to surface water or significant interaction with surface waterbodies and therefore direct impacts to surface water are not anticipated. Therefore, as a result, modelling was not deemed necessary as part of this assessment.

³ Note that coal mines in the vicinity of the Project are not included in the UWIR model.

A review of other potential indirect impacts to surface water as a result of the Project are discussed in Section 8.5. Relevant mitigation, management and monitoring measures to address these potential impacts are provided in Section 10.

4.3 Risk Assessment

The IESC checklist identifies that a risk assessment should be conducted from an early stage of the Project. Throughout the assessment, risks and uncertainties associated with the Project have been considered and appropriate mitigation and management strategies developed. Section 9.5 presents the risk assessment results with both pre- and post-mitigation risks assessed.

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5 EXISTING ENVIRONMENT

5.1 Topography

The topography of the Mahalo Development Area ranges in elevation between ~185 mAHD⁴ towards the west and 290 mAHD in the east, as shown in Figure 5.1. The elevation of the wider study area increases to ~1,000 mAHD in the northeast, associated with the Expedition Range. Lower lying areas across the wider Project area are associated with drainage features, which are discussed further in Section 6.

5.2 Climate

The climate of the Mahalo Development Area is classified as subtropical with a moderately dry winter, based on the modified Köppen classification system (BOM 2005).

Climate statistics sourced from the Bureau of Meteorology (BOM) are presented in Table 5.1 for the climate station Springsure Comet Street⁵ (35065), located 40 km west of the Mahalo Development Area, with rainfall statistics for the Somerby climate station (35063) also presented. The location of the climate stations are shown on Figure 5.1.

Table 5.1 Climate Statistics for Springsure Comet Street and Somerby, Site Numbers 35065 and 35063 (BOM 2019a; 2019b)

Statistic Element	Springsure Comet Street (35065)			Somerby (35063)
	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean rainfall (mm)	Mean rainfall (mm)
Period of Record	1938 to 2018	1938 to 2018	1938 to 2018	1924 to 2018
January	34.0	20.9	110.6	88.3
February	32.5	20.5	109.4	89.9
March	31.6	18.9	70.6	58.4
April	29.0	14.9	39.0	35.8
May	25.3	10.9	34.7	32.3
June	22.3	7.3	38.0	28.9
July	22.2	6.4	28.3	24.2
August	24.1	7.6	23.9	20.3
September	27.6	11.3	30.2	24.6
October	30.6	15.2	48.3	46.3
November	32.8	17.9	64.1	65.8
December	34.0	19.8	92.2	98.1
Annual	28.8	14.3	688.2	606.9

⁴ mAHD – metres above Australian Height Datum

⁵ Temperature data not available for Somerby climate station

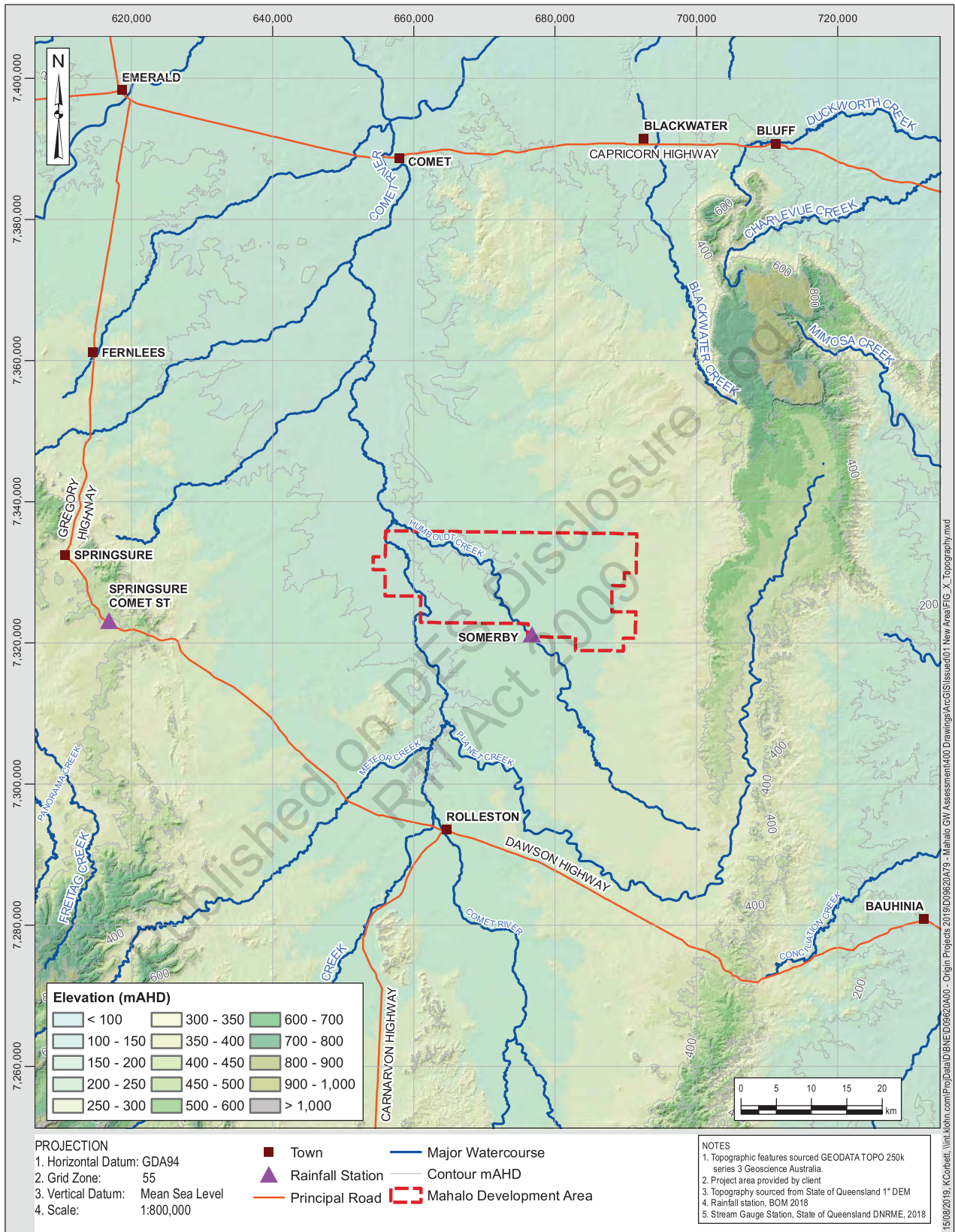


Figure 5.1 Topography within the Vicinity of the Mahalo Development Area

Mean maximum temperatures range between $\sim 34^{\circ}\text{C}$ in the summer months and $\sim 22^{\circ}\text{C}$ in the winter months. Mean minimum temperatures range between $\sim 21^{\circ}\text{C}$ in the summer months and $\sim 6^{\circ}\text{C}$ in the winter months. The highest rainfall occurs during December to February, with the lowest rainfall occurring during April to September.

Evaporation data is not available for any nearby climate stations. Based on a review of the BOM evaporation spatial data for Australia (BOM 2006), the average annual evaporation in the vicinity of the Project is between 2,000 and 2,400 mm. The highest evaporation occurs during the summer months (December to February; 700 to 800 mm), while the lowest evaporation occurs during the winter months (June to August; 300 to 400 mm).

Figure 5.2 presents daily rainfall between 1960 and 2018 for the Somerby climate station, and a rainfall excess / deficit trend for the same period. Rainfall excess / deficit trends present a running deviation of long-term actual rainfall against the average. This provides seasonal-scale identification of trends (wet / dry) and longer term (e.g. decadal) deviation from average conditions. These trends result in a natural tempering of peaks for rainfall events, and therefore support the correlation of rainfall events to aquifer responses.

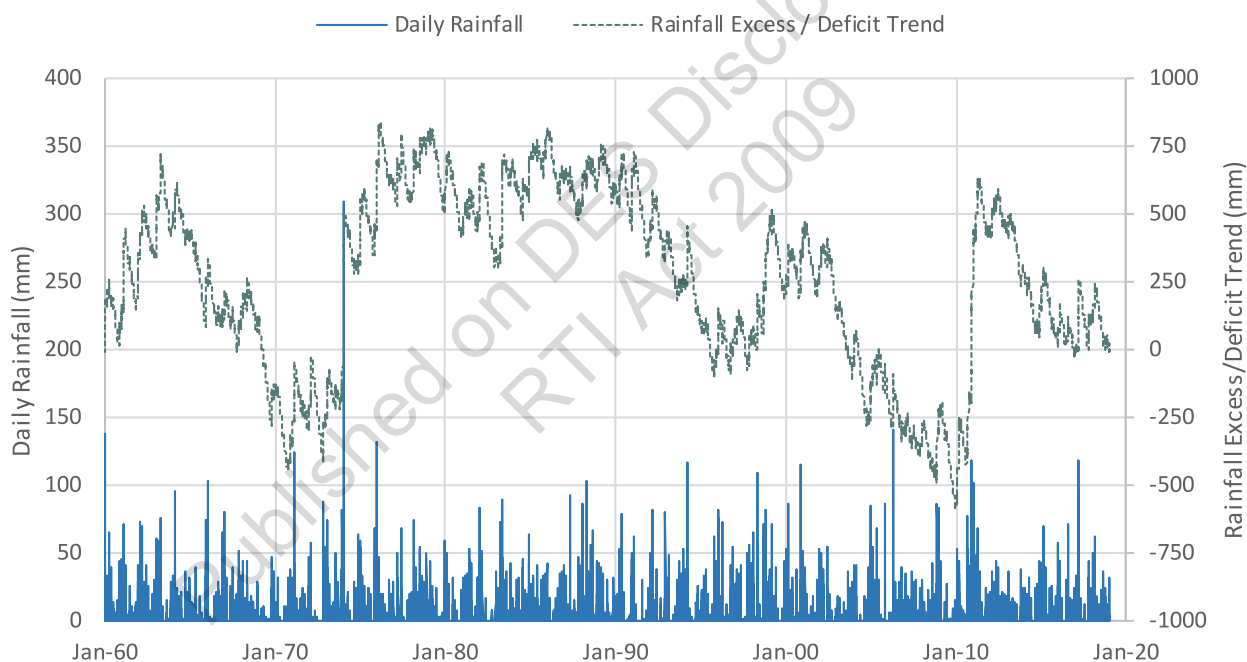


Figure 5.2 Daily Rainfall and Rainfall Excess / Deficit Trend (Somerby #35063)

Observations from the rainfall / excess deficit trend include:

- The overall rainfall trend is characterised by the cyclic nature of the wet and dry seasons, with annual fluctuations of ~ 250 mm evident across the record.
- Large rainfall events occurred in 1974 and 2010, resulting in the increase in the trend in 1974 due to a rainfall event of ~ 300 mm, whereas the 2010/11 event occurred as a result of several months of above average rainfall (e.g. 752 mm over 70 days).
- The general trend shows an overall decline between 1985 to 1998, which is followed by an increase to 2000.

- From 2000, there is a general decline to 2010, where an increase is observed in response to the large rainfall event in 2010. This is then followed by another period of decline to present.

5.3 Land Use

Land use information specific to the Mahalo Development Area has been sourced from the Queensland Government datasets (DES 2018a). The land use dataset classifies land use type using the Australian Land Use and Management (ALUM) Classification system which provides a nationally consistent method to collect and present land use information in Australia. This classification system categorises 32 land use classes and subclasses. There are six primary classes used in the ALUM classification system and these are further divided into secondary and tertiary classes. A description of the primary classes (ABARES 2010) is detailed below:

- Conservation and natural environments – Land is used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems already present.
- Intensive uses – Land is subject to substantial modification, generally in association with closer residential settlement, commercial or industrial uses.
- Production from dryland agriculture and plantations – Land is used mainly for primary production, based on dryland farming systems.
- Production from irrigated agriculture and plantations – Land is used mainly for primary production, based on irrigated farming.
- Production from relatively natural environments – Land is used mainly for primary production based on limited change to the native vegetation.
- Water – Although primarily land cover types, water features are regarded as essential to the classification.

Figure 5.3 presents the land use across the wider Project area, with a summary of the land use distribution (area and percentage) directly within the Mahalo Development Area provided in Table 5.2. There are four types of primary land use within the Mahalo Development Area. The dominant land use is production from relatively natural environments, specifically grazing from native vegetation. Cropping is also undertaken in the Mahalo Development Area.

Table 5.2 Summary of the Current Land Use within the Mahalo Development Area

Land Use Category			Area (km ²)	Percentage of Total Area
Primary	Secondary	Tertiary		
Conservation and natural environments	Other minimal use	Other minimal use	0.51	0.11%
		Residual native cover	3.15	0.67%
Production from dryland agriculture and plantations	Cropping	Cropping	31.47	6.71%
Production from relatively natural environments	Grazing native vegetation	Grazing native vegetation	433.70	92.46%
Water	Reservoir / dam	Reservoir / dam	0.23	0.05%
Total			469.05	100%

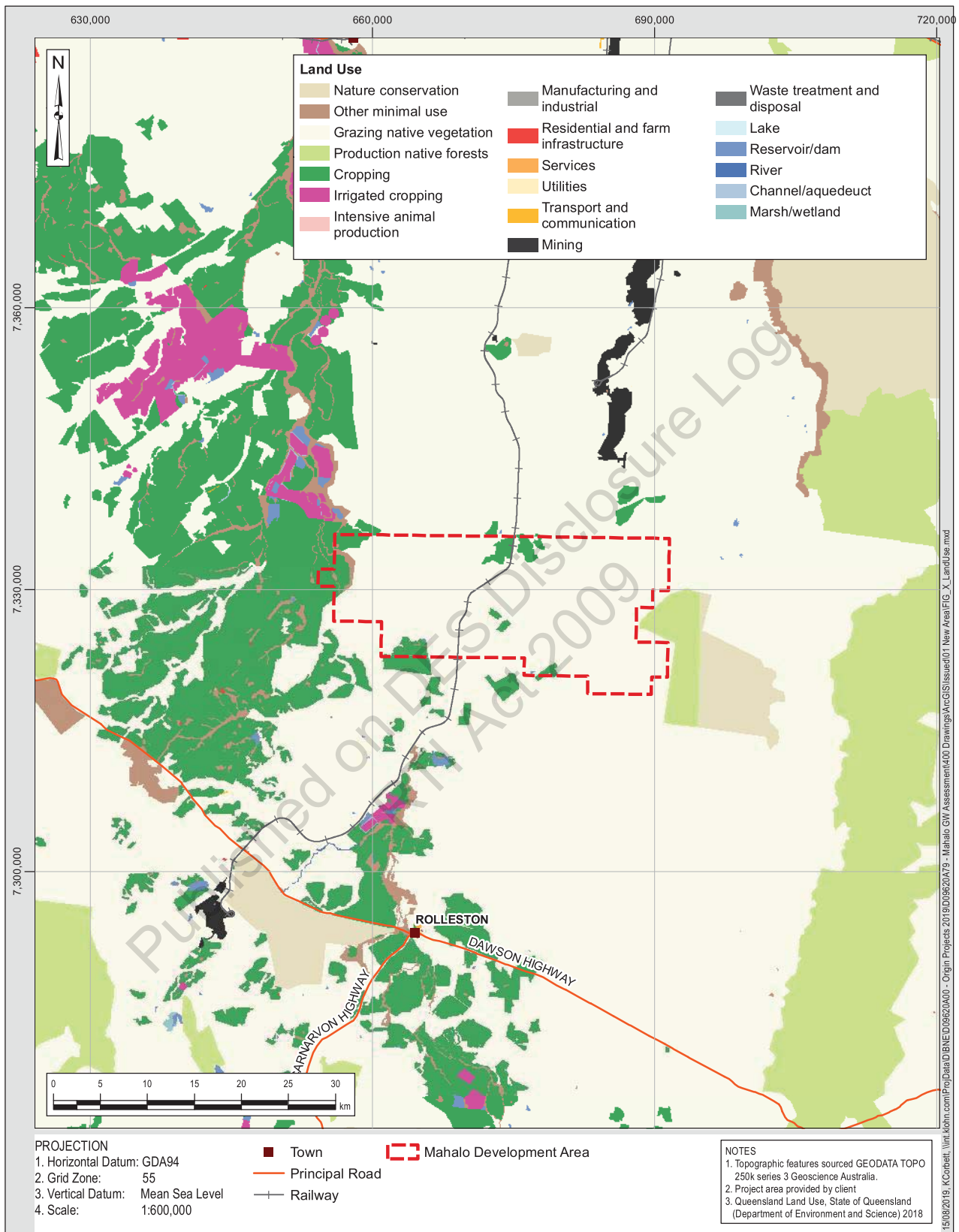


Figure 5.3 Mahalo Development Area Current Land Use

6 HYDROLOGICAL CONTEXT AND CONCEPTUALISATION

6.1 Location and Catchment Context

The Mahalo Development Area is located in the Comet River Sub-Basin, part of the Fitzroy Basin (State of Queensland 2017b). The Fitzroy River Basin is the second largest externally drained basin in Australia and the largest on the eastern coast of the continent. Covering an area of 150,000 km², the basin contains several significant tributaries, including the Nogoa, Comet, Mackenzie and Dawson Rivers. The basin discharges into the Coral Sea east of Rockhampton.

The Comet River catchment is bounded by the Expedition and Shotover Ranges in the east, the Carnarvon Range in the south and the Buckland Tableland in the west (URS 2014b). The catchment consists of an extensive network of watercourses that are largely ephemeral and typically only flow during and immediately after significant rainfall events (URS 2014b). Larger watercourses such as the Comet River, may contain perennial waterholes isolated by dry river channels during the dry season (URS 2014a).

6.2 Watercourses

Key watercourses associated with the Mahalo Development Area are shown in Figure 6.1 and include:

- Comet River: commences in the Carnarvon Range located south of Rolleston and joins the Nogoa River north of the Comet township, forming the Mackenzie River; draining to the Fitzroy River. The Comet River traverses relatively flat topography resulting in a meandering flow path.
- Meteor Creek: starts in the Carnarvon Range and merges with the Comet River 18 km upstream of the Mahalo Development Area.
- Planet Creek: commences in the Expedition Range, east of the Mahalo Development Area. Planet Creek merges with the Comet River 14 km upstream of the Mahalo Development Area.
- Humboldt Creek: starts 35 km to the southeast of the Mahalo Development Area and on a northwesterly path, traverses the Mahalo Development Area before joining with the Comet River north of the Mahalo Development Area.

The watercourses within the Mahalo Development Area are classified as Stream Order 1 to Stream Order 7 based on the Strahler method, with the majority comprising Stream Order 5 (DNRM 2010). A list of watercourses and associated stream orders within the Mahalo Development Area are presented in Table 6.1.

Table 6.1 Stream Order Classification

Sub-Catchment	Stream	Stream Order(s)
Comet River (Fitzroy Basin)	Humboldt Creek	4, 5, 6
	Planet Creek	1, 2, 3, 4, 5
	Meteor Creek	3, 4, 5, 6
	Comet River	7

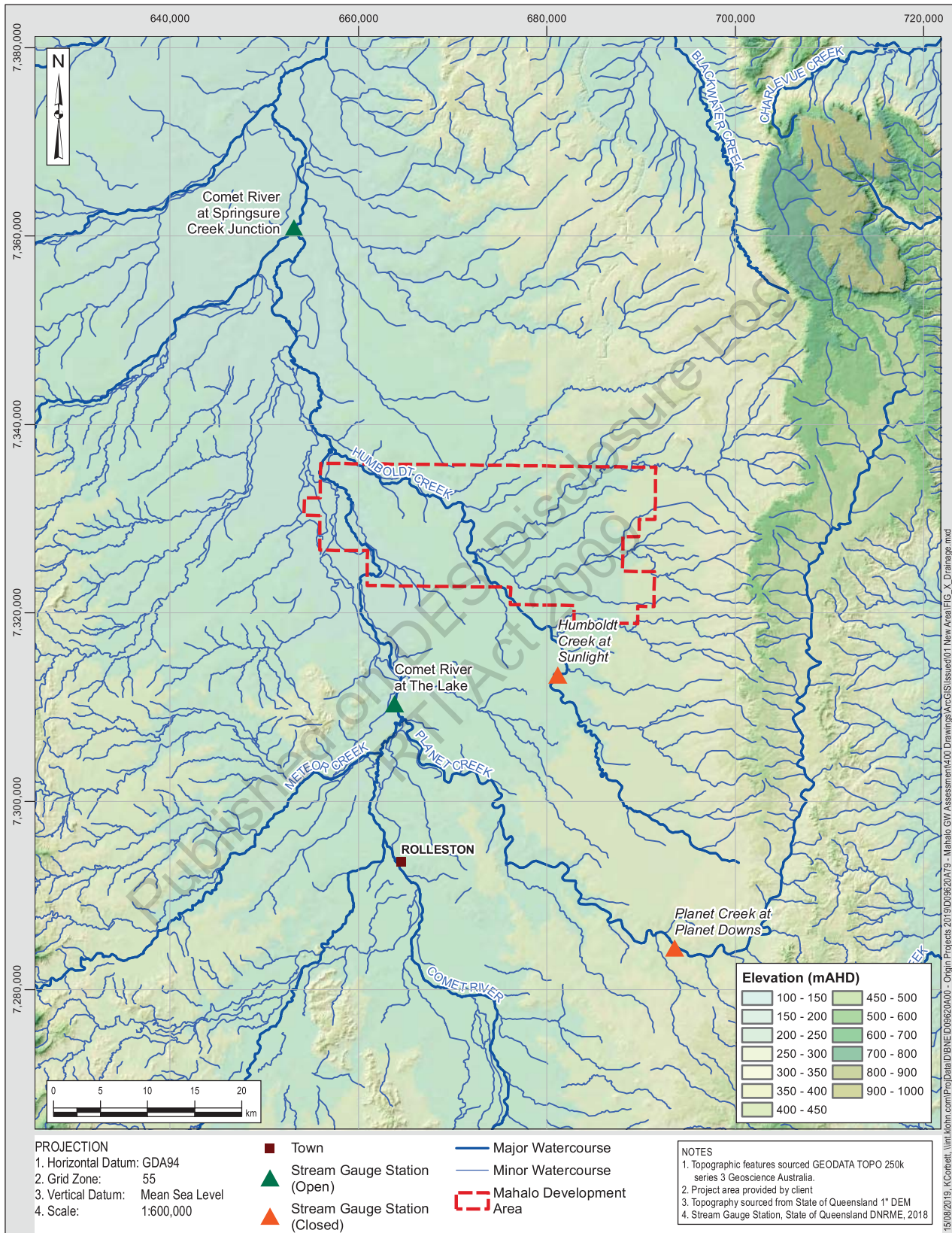


Figure 6.1 Watercourses in the Vicinity of the Mahalo Development Area

The Comet River sub-catchment is heavily influenced by anthropogenic pressures. The State of Rivers Survey (DNRM 2000) identified that the catchment was regarded as being in a moderate to poor condition, with prominent bank instability caused by the presence of stock within the riparian zone, runoff, and vegetation clearing.

Humboldt and Planet Creeks are generally located at elevations greater than 300 mAHD. These watercourses are described by URS (2014b) as located within broad, partially confined sinuous valleys and consisting of a single channel. The channels are predominately stable with sediment accumulation typically found as side or point bars. Located further downstream within these creeks, and towards the Comet River, the geomorphology of these creeks becomes a laterally unconfined valley setting with a higher degree of sinuosity.

Photographs of the Comet River sourced from the Queensland Government Water Monitoring Portal (State of Queensland 2019c) are shown in Figure 6.2. The photographs are taken at the 'Comet River at the Lake' gauging station between 2008 and 2011. The January 2011 photographs show the river following one of the highest recorded rainfall events, while the March 2008 photographs show the river during a lower flow event. High rainfall or flood events have the potential to cause rapid changes in the channel morphology, including sediment and debris build up within the river, as shown in the photograph from October 2010. Further discussion on flow is included in Section 6.5.



Figure 6.2 Photographs of Comet River (130506A Comet River at the Lake) (Sourced from State of Queensland 2019c)

6.3 Wetlands

The Mahalo Development Area does not contain any wetlands listed in the *'Directory of Important Wetlands in Australia'* (Environment Australia 2001). However, there are two wetlands listed in proximity to the Project, as shown on Figure 6.3. These include:

- Fairbairn Dam, located 62 km northwest of the Mahalo Development Area. This wetland has resulted from the damming of a valley of the Nogoa River. Fairbairn Dam is an important dry season refuge for water birds and is a significant, large, permanent water body in central Queensland. Although artificial, it provides the equivalent of a natural lake and swamp habitat (DoEE 2019).
- Lake Nuga Nuga, located 90 km south of the Mahalo Development Area. The wetland lies in the broad valley between the Expedition and Carnarvon ranges with Mount Warrinilla at its northern extent. The significance of the wetland is listed as a large water body in an otherwise semi-arid area (DoEE 2019).

Lake Nuga Nuga is located upstream of the Mahalo Development Area and is therefore not considered to be of concern to the Project. Fairbairn Dam is located in the catchment of the Nogoa River, which merges with the Comet River downstream of the Mahalo Development Area, and therefore also not of concern to the Project.

A review of the Mahalo Development Area on the DES 'Wetland Info' website (DES 2019a) was undertaken. The Mahalo Development Area includes lacustrine and palustrine wetlands. Lacustrine wetlands are open water dominated systems (e.g. dams and lakes). In turn, palustrine wetlands lack open or flowing water (e.g. marsh or bogs).

There is one palustrine wetland mapped within the Mahalo Development Area listed as high ecological significance (HES). This HES wetland is located adjacent to the Comet River flow channel and may be considered as within the floodplain of the channel (Figure 6.4).

The lacustrine wetlands in most cases would provide water for farming activities including, but not limited to, livestock watering and irrigation, and also are a secondary means as a habitat for aquatic and terrestrial fauna and flora.

6.4 Flood Regime

Floodplain mapping sourced from the Queensland Government (DNRM 2013) is presented in Figure 6.5. The mapping indicates that Planet Creek, Meteor Creek and Humboldt Creek are located in flood areas.

Flood modelling maps are available through Queensland Globe (DNRM 2017). Flood modelling mapping for a 1% annual exceedance probability (AEP), or 1 in 100-year flood, are available. The mapping indicates that for a 1 in 100-year flood event, flooding may occur in the Comet River as well as all three of the main tributaries: Meteor Creek, Planet Creek and Humboldt Creek.

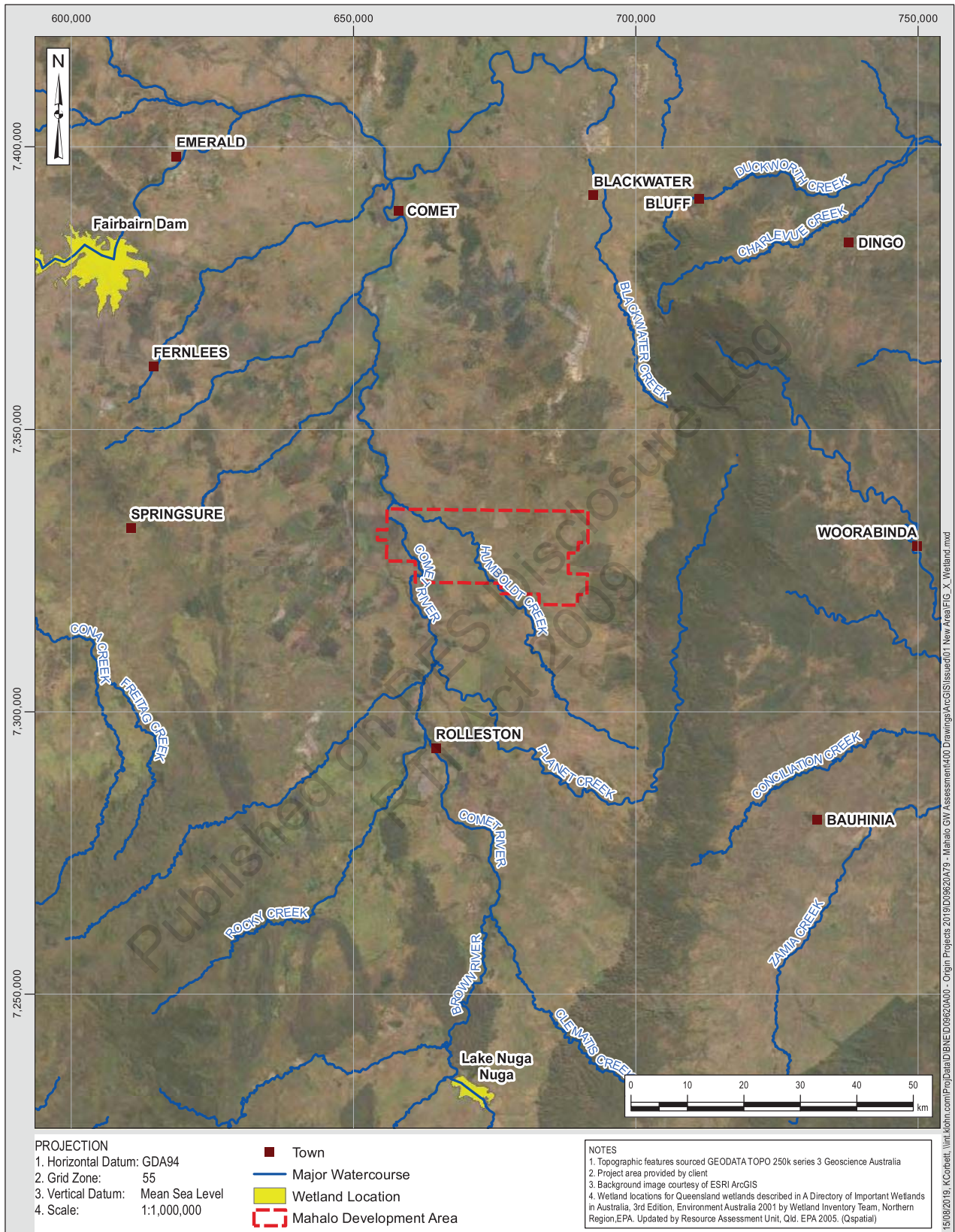


Figure 6.3 Location of Important Wetlands within Proximity to the Mahalo Development Area

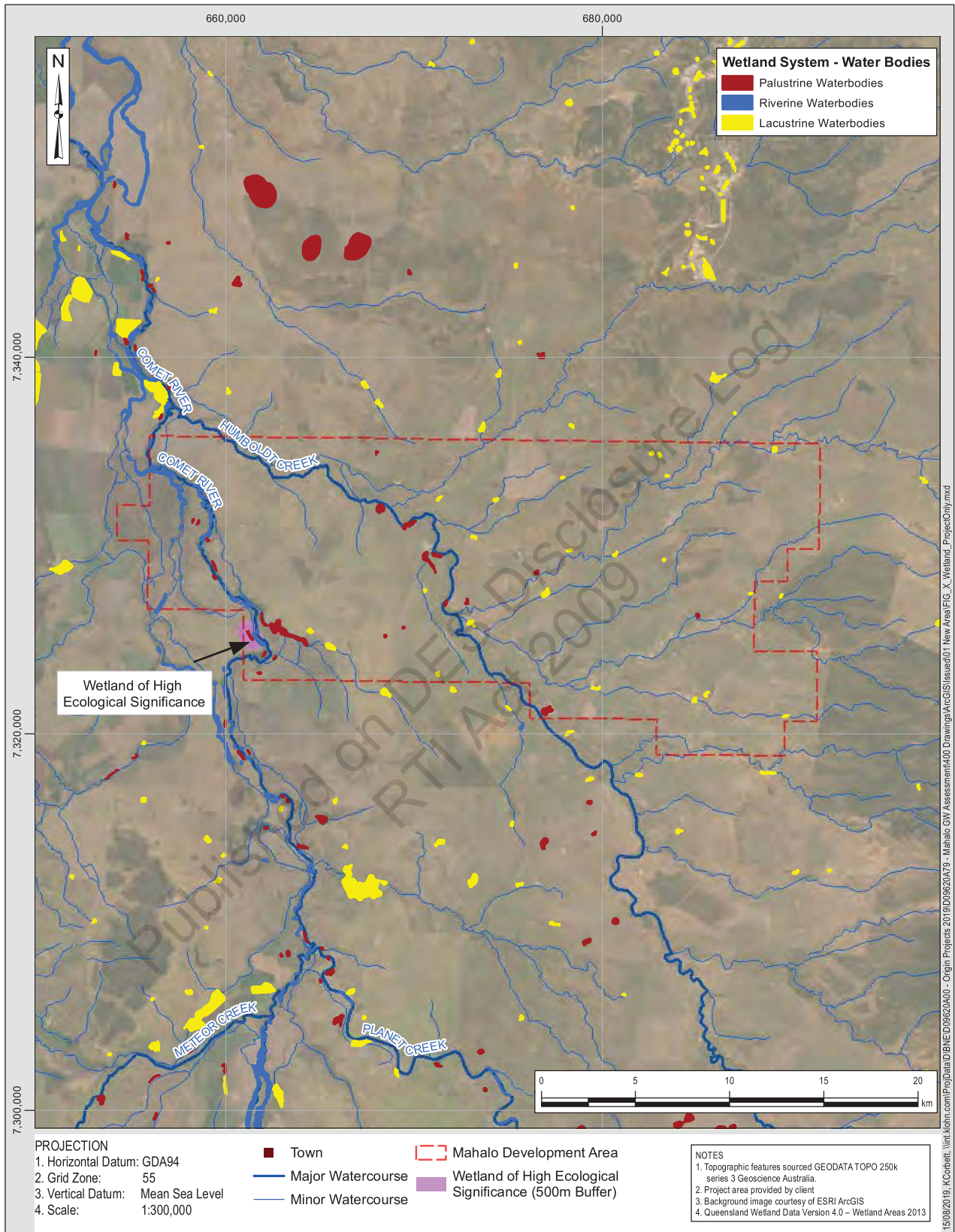


Figure 6.4 Location of Lacustrine and Palustrine Wetlands

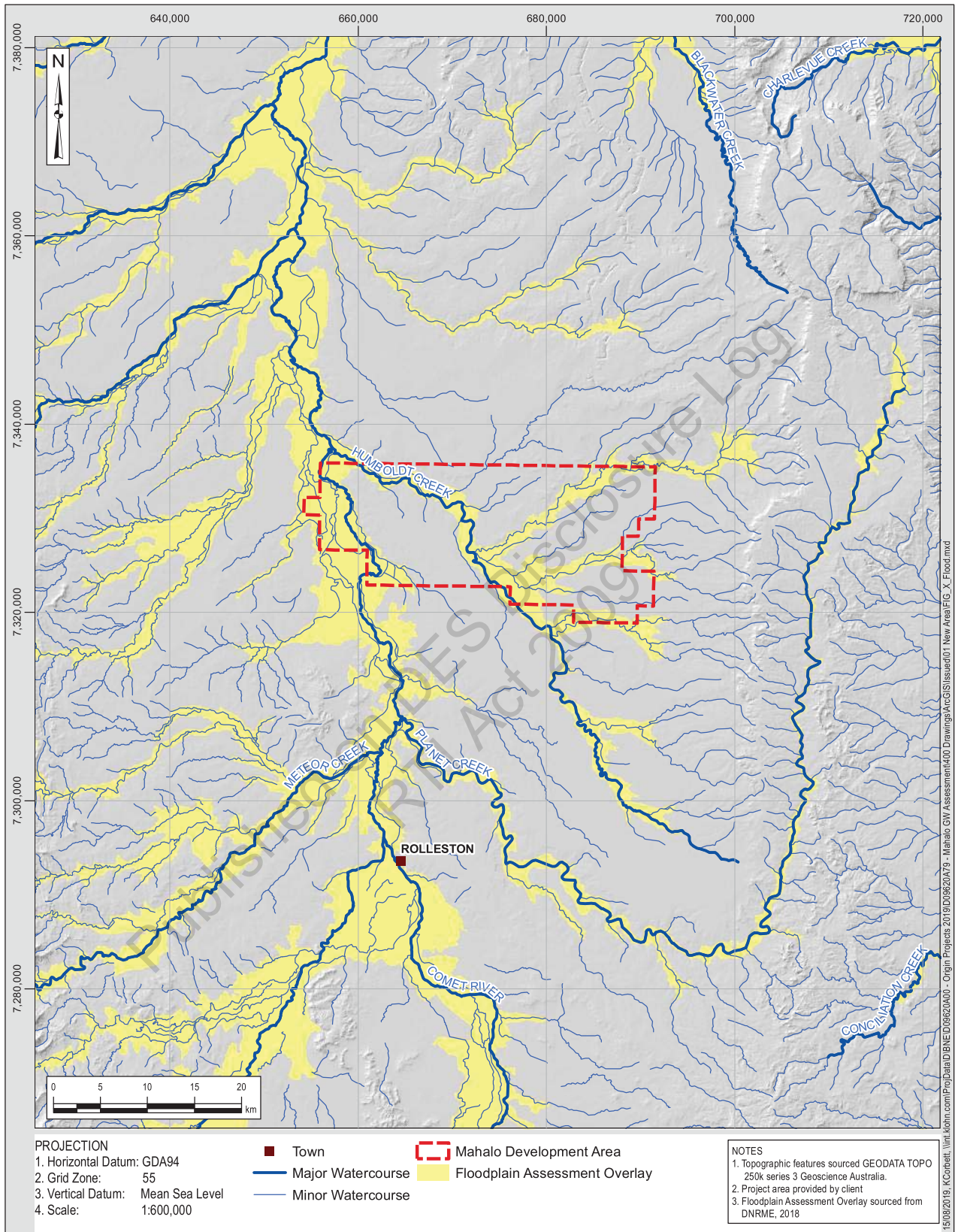


Figure 6.5 Floodplain Assessment Overlay – Flood Extent for 1% AEP

6.5 Surface Water Flow

6.5.1 Watercourse Classification

Hydrologic flow can be classified into three regimes, permanent, semi-permanent and ephemeral based on Kennard et al. (2010):

- **Permanent:** Stream discharge persists during both high rainfall (typically summer wet season) and low rainfall (typically winter dry season) periods. During drought years, some cease to flow periods may occur, however non-flowing, connected pools will persist throughout the waterway channel.
- **Semi-Permanent:** A watercourse that contains water for more than 70% of the time on average. These watercourses experience high discharges during heavy rainfall periods (i.e. summer wet season), however are typically reduced to a series of disconnected, non-flowing series of pools during the dry season.
- **Ephemeral:** These watercourses will typically only experience surface water flow during or immediately after heavy or sustained rainfall events (i.e. summer wet season). Following periods of flow surface water will persist in the form of non-flowing, disconnected pools separated by dry / exposed stream beds. Surface water (flowing or non-flowing) is only present for a small part of the hydrological cycle.

The watercourses across the Mahalo Development Area are characteristically ephemeral and typically flow only during significant runoff events.

6.5.2 Levels and Flow

Surface water flow in the vicinity of the Mahalo Development Area is currently monitored at two DNRME gauging stations:

- Comet River at the Lake (130506A), located within the Project boundary.
- Comet River at Springsure Creek Junction (130510A), located downstream of the Project.

There are several closed stations, which are no longer monitored. Table 6.2 provides details of both the open and closed stations, with the location of the stations shown on Figure 6.1 and a discussion of the data provided below.

Table 6.2 Summary of Surface Water Gauges (Open and Closed)

Number	Station	Easting (Z55) (m)	Northing (Z55) (m)	Status	Period of Operation	Location in Relation to Project
130506A	Comet River at The Lake	663829	7310321	Open	Feb 1972 to present	Upstream
130510A	Comet River at Springsure Creek Junction	653128	7360864	Open	Jun 2007 to present	Downstream
130507A	Planet Creek at Planet Downs	693554	7284390	Closed	Dec 1972 to Mar 1993	Upstream
130505A	Humboldt Creek at Sunlight	681176	7313357	Closed	Aug 1971 to Oct 1988	Upstream
130508A	Meteor Creek at Springwood	629813	7281897	Closed	Dec 1972 to Nov 1988	Upstream

Comet River at the Lake (130506A)

Surface water flow and stage height data is available for the Comet River (130506A – Comet River at The Lake) between February 1972 and February 2019. The flow gauge is located downstream of the confluence of Meteor Creek and Planet Creek with the Comet River.

The monthly median daily discharge is shown in Figure 6.6 and indicates the majority of the flow occurs during December to March in response to wet season rainfall events, highlighting the ephemeral nature of the watercourse. The stage height is presented in Figure 6.7 and highlights the seasonality in the response.

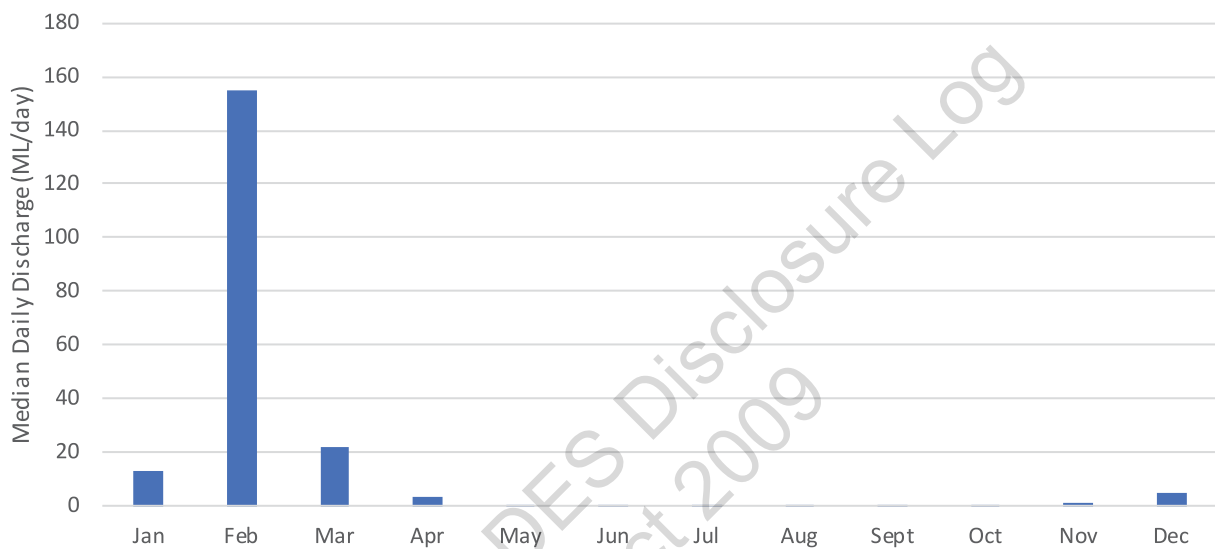


Figure 6.6 Monthly Median Daily Discharge at Comet River at The Lake (130506A), 1972 to 2019

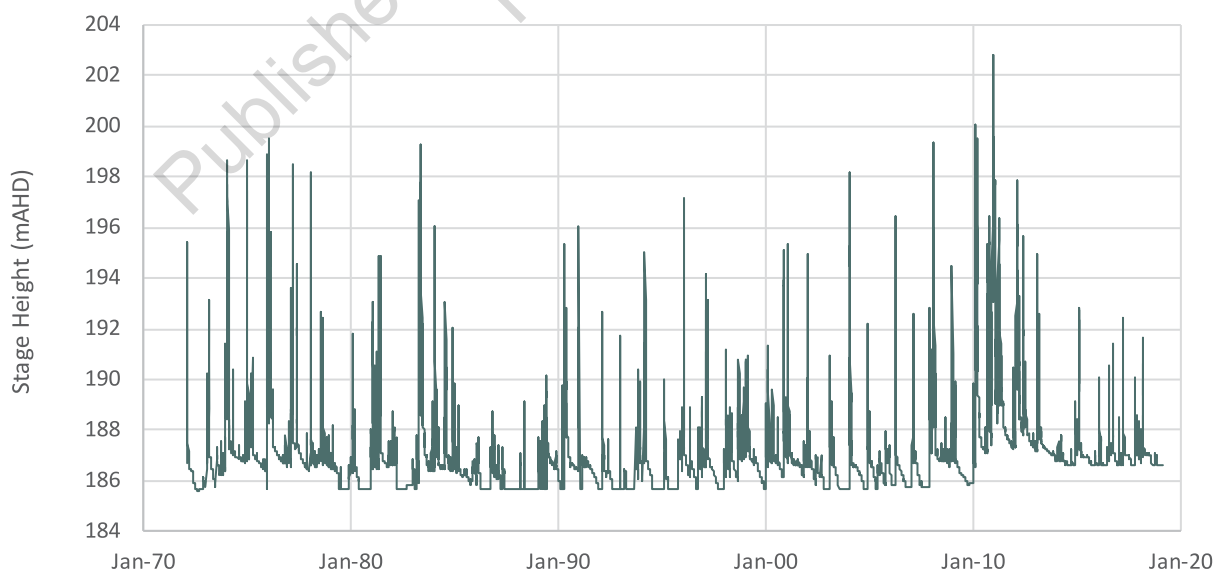


Figure 6.7 Stage Height at Comet River at The Lake (130506A), Upstream of Mahalo Development Area

The cumulative exceedance probability for the average daily recorded flow is shown in Figure 6.8 and indicates that flows are present in the Comet River, upstream of the Mahalo Development Area, for 51% of the gauged period. The flow, which is exceeded 5% of the time, is approximately 2,100 ML/day which is also identified as a flow which is equaled or not exceeded 95% of the time based on the available record. This highlights the ephemeral nature of the watercourse.

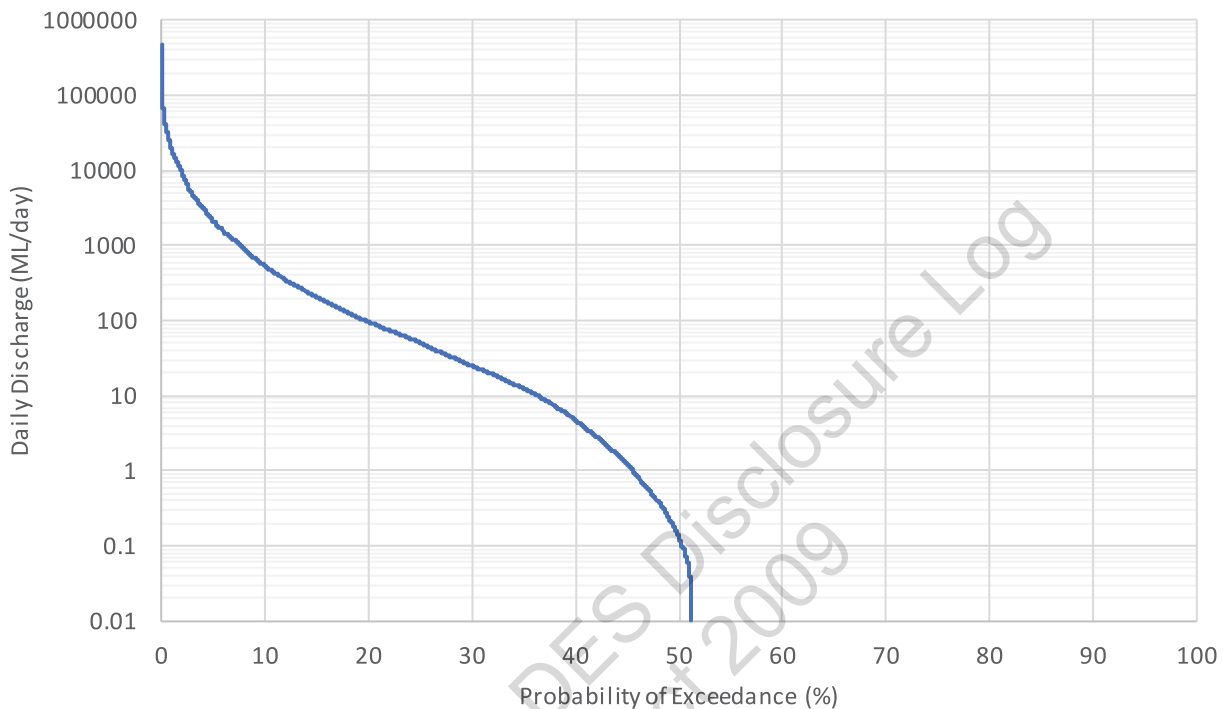


Figure 6.8 Cumulative Exceedance Probability for Recorded Daily Discharge at Comet River (130506A – Comet River at The Lake)

Comet River at Springsure Creek Junction (130510A)

Monitoring downstream of the Mahalo Development Area is available from a gauging station at the Comet River at Springsure Creek Junction (130510A) between June 2007 and February 2019. The gauge is located downstream of the confluence with Humboldt Creek.

The monthly median daily discharge is presented in Figure 6.9, and indicates the majority of flow occurs between December to March. The stage height graph, presented in Figure 6.10, shows extended periods where no flow is registered. These periods generally correspond with the dry season / winter months when lower rainfall is experienced.

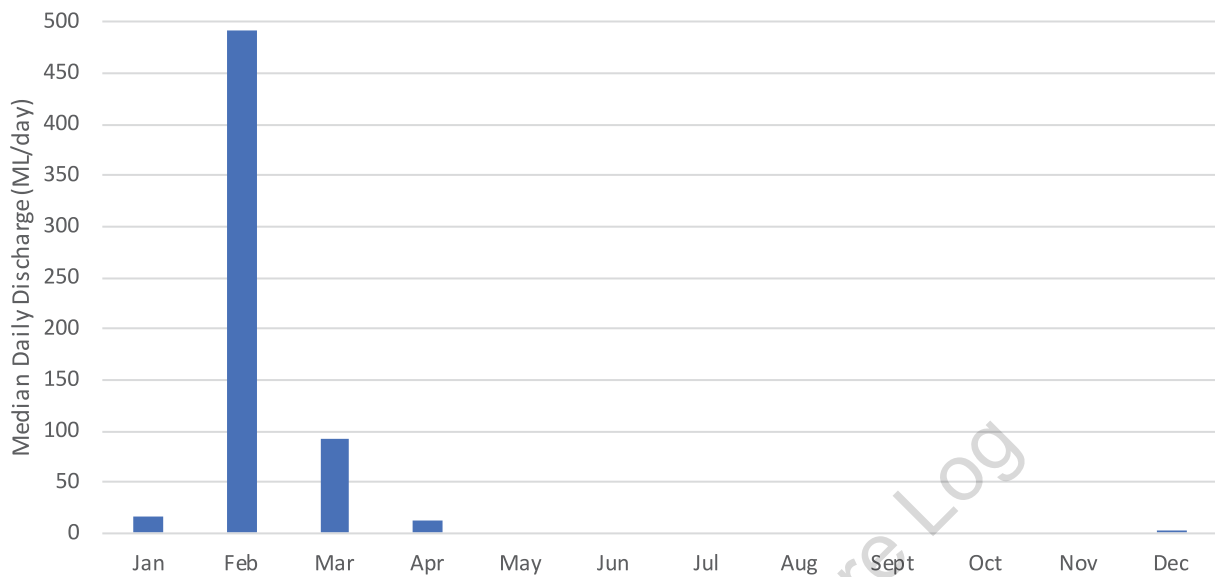


Figure 6.9 Monthly Median Daily Discharge Comet River at Springsure Creek Junction (130510A), 2007 to 2019

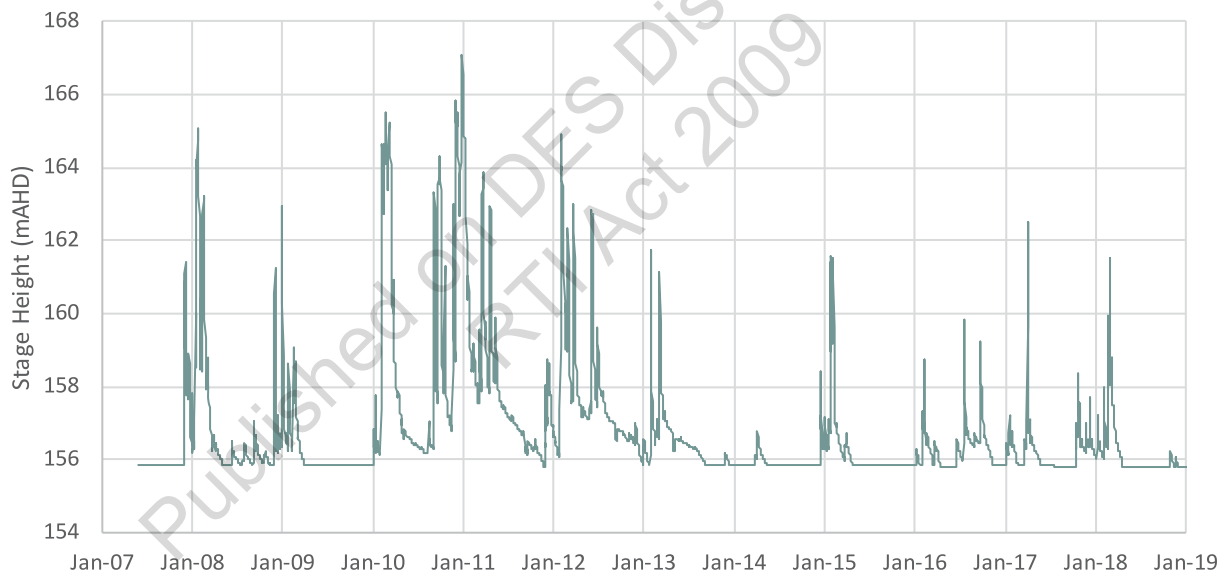


Figure 6.10 Stage Height at Comet River at Springsure Creek Junction (130510A), Downstream of Mahalo Development Area

The cumulative exceedance probability for the average daily recorded flow is shown in Figure 6.11. The graph indicates that flows greater than 0.01 ML/day are present 52.4% of the gauge period. The flow which is exceeded 5% of the time is approximately 5,950 ML/day, which is also identified as a flow that is equaled or not exceeded 95% of the time based on the available record.

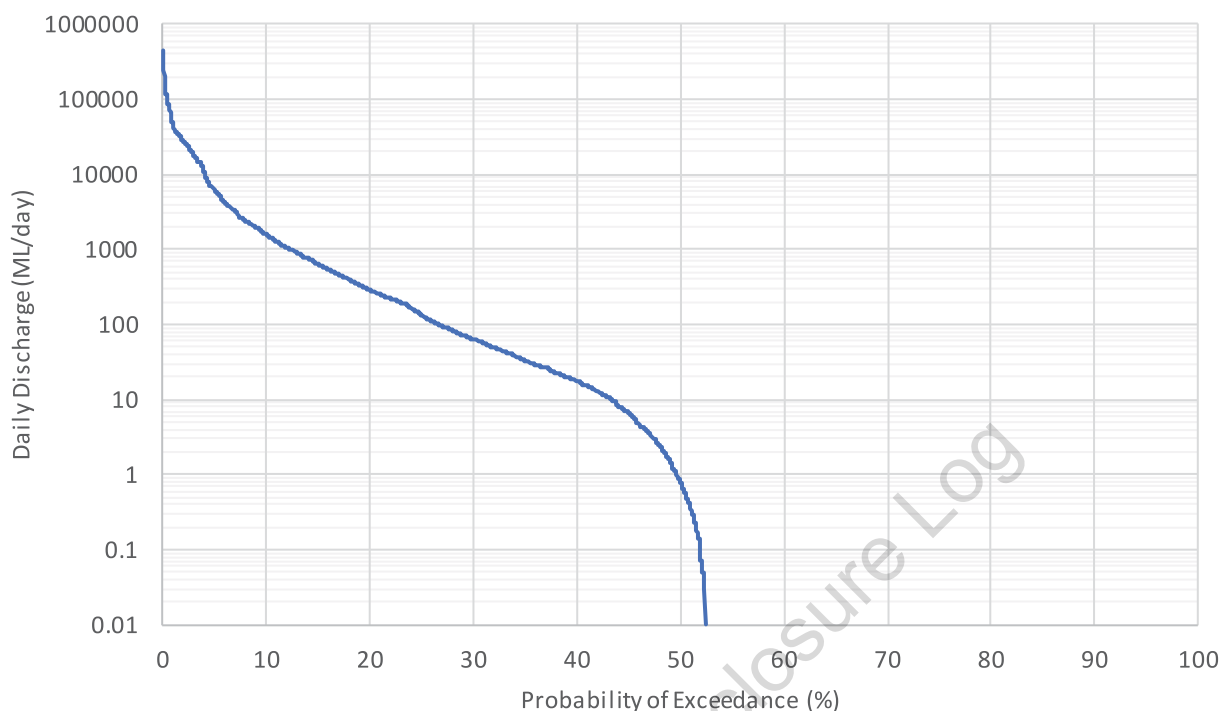


Figure 6.11 Cumulative Exceedance Probability for Recorded Daily Discharge for the Comet River at Springsure Creek Junction (130510A)

6.6 Surface Water Quality

Available surface water quality data was sourced from DNRME for the flow gauge at Comet River at The Lake (130506A). Data is available between 1972 and 2019 and summarised in Table 6.3.

Table 6.3 Summary of Surface Water Quality for Comet River (Comet River at The Lake – 130506A)

Parameter	Count	5 th Percentile	95 th Percentile	Mean	Standard Deviation
Field EC @ 25°C	83	109	591	273	174.3
Turbidity (NTU)	64	2.3	2,493	781	891.3
Colour True (Hazen units)	34	5	57	23	17.3
Water Temperature (°C)	62	13	32	23	5.7
Field pH (pH units)	59	7.2	8.5	7.9	0.4
Total Alkalinity as CaCO ₃ (mg/L)	59	52.8	273.4	152.4	70.9
TDS (mg/L)	59	80.3	358.6	197.3	93.9
Calcium as Ca soluble (mg/L)	83	9.5	44.0	21.9	10.8
Chloride as Cl (mg/L)	56	4.5	37.0	16.8	19.4
Magnesium as Mg soluble (mg/L)	83	4.2	35.3	14.2	9.4
Potassium as K (mg/L)	57	2.4	7.0	4.3	1.5
Sodium as Na (mg/L)	59	6.6	36.2	19	15.4
Sulphate as SO ₄ (mg/L)	44	1.0	13.6	5.9	5.2
Fluoride as F (mg/L)	57	0.1	0.26	0.15	0.06
Iron as Fe soluble (mg/L)	39	0	1.6	0.13	0.3

Timeseries data for EC for the Comet River (130506A) has been available since 2010 and is presented in Figure 6.12. The data shows the EC ranges between ~ 100 and ~ 900 $\mu\text{S}/\text{cm}$. The mean daily discharge is also included in Figure 6.12 and highlights the relationship between the EC and surface water flow. Periods in the record, such as January 2012 to January 2014, show EC at its lowest during high flow events, and increasing as flow recedes / ceases.

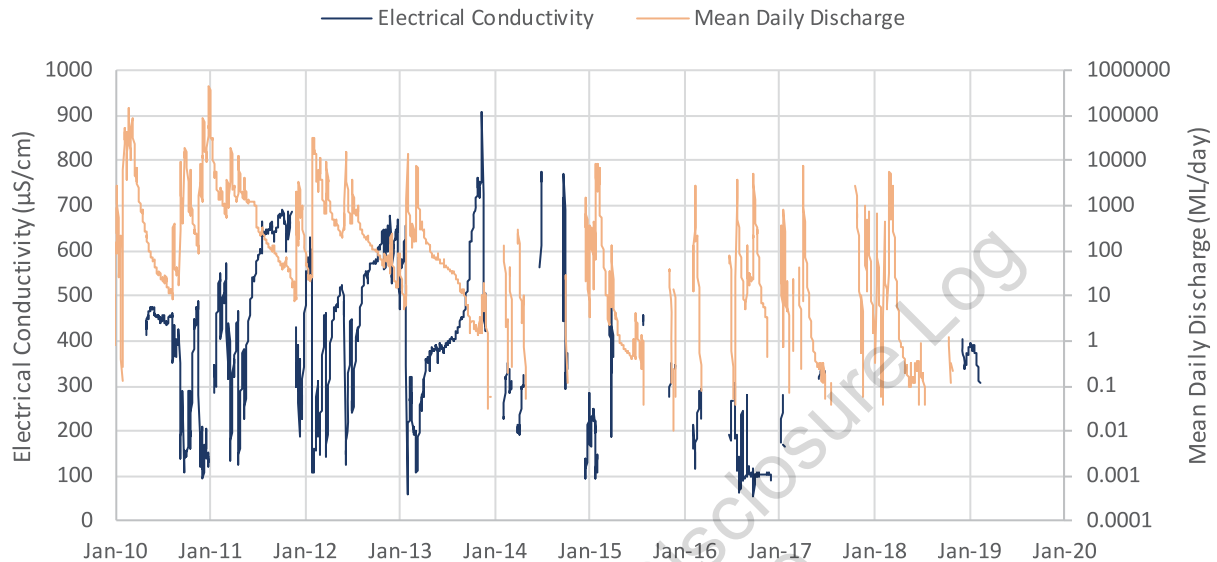


Figure 6.12 Electrical Conductivity at Comet River at the Lake (130506A)

Piper and Durov diagrams have also been prepared for surface water quality monitored at the Comet River (130506A) flow gauge. These are presented in Figure 6.13. The surface water is characterised as a calcium-magnesium-bicarbonate water type.

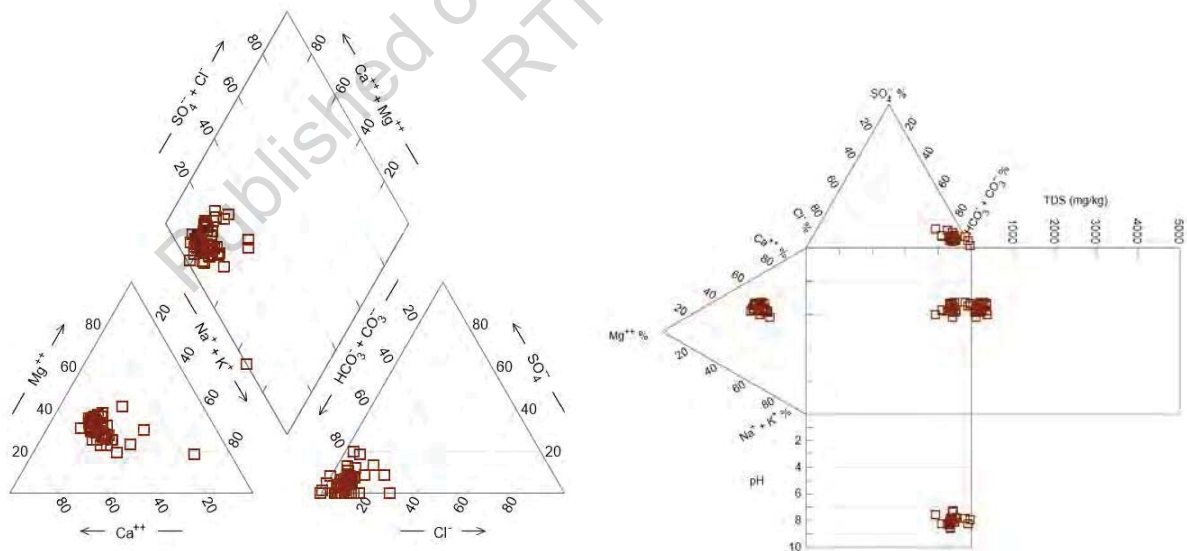


Figure 6.13 Piper and Durov Diagram for Surface Water Samples from Comet River at the Lake (130506A)

6.7 Aquatic Ecology

The aquatic habitat of watercourses in the Comet River catchment comprises watercourse channels during flowing conditions, as well as isolated perennial waterholes present during the dry season. The lacustrine and palustrine wetlands also provide a habitat for aquatic fauna and flora. The State of the Rivers assessment, identified the aquatic habitat of the Comet River catchment as being poor to very poor, although the larger watercourses, such as the Comet River, supported a moderate amount of aquatic habitat (DNRM 2000; URS 2014a).

6.8 Existing Surface Water Users

The Comet River forms part of the Comet Water Management Area (CWMA), as defined under the Fitzroy Basin ROP (DNRM 2015). Flow management locations for water allocations for the CWMA in the vicinity of the Project are listed in Table 6.4.

Table 6.4 Flow Management Locations for Water Allocation (DNRM 2015)

Location	AMTD (km)	Flow Management Location
Comet A	0.0 – 52.6	GS 130504B – Comet River at Comet Weir
Comet B	52.6 – 124.2	GS 130510A – Comet River at Springsure Creek junction
Comet C	124.2 – 199.2	GS 130506A – Comet River at The Lake

The Fitzroy Basin ROP identifies 10 surface water allocations between the Comet C (upstream of Project) and Comet B (downstream of Project) management locations (Figure 6.1). A summary of the surface water allocations and associated annual and daily limits are shown in Table 6.5.

Table 6.5 Summary of Surface Water Users in the Vicinity of the Project

Water Allocation Number	Location	Nominal Volume (ML/water year)	Daily Volumetric Limit (ML/day)
1141	Comet B	1,596	95
1142	Comet B	1,596	95
1143	Comet B	1,121	95
1144	Comet B	1,121	95
1145	Comet B	1,121	95
1146	Comet B	2,184	130
1147	Comet B	2,184	130
1148	Comet B	1,735	147
1149	Comet B	1,735	147
1150	Comet B	1,735	147

7 HYDROGEOLOGICAL CONTEXT AND CONCEPTUALISATION

7.1 Geological Setting

The regional geology of the Mahalo Development Area comprises sediments from the Early Permian to Middle Triassic age Bowen Basin. The Bowen Basin is an elongated, north to south trending basin extending over 160,000 km² from central Queensland, south beneath the Surat Basin, and into New South Wales, where it connects with the Gunnedah and Sydney basins (OGIA 2016a).

The Bowen Basin contains up to 10 km of terrestrial and shallow-marine sediments (Green 1997; R. Korsch and Totterdell 2009). The southern Queensland and northernmost New South Wales portion of the basin is overlaid by up to 2.5 km of Early Jurassic to Early Cretaceous Surat Basin sedimentary sequences (Fielding et al. 2000; R. Korsch and Totterdell 2009). In the vicinity of the Mahalo Development Area, sediments from the Surat Basin have been eroded and the Bowen Basin units reside under Cenozoic cover.

The Project is located on the mid-western extent of the Bowen Basin, on the southern end of the Comet Ridge crest, and is flanked by the Taroom Trough to the east and the Denison Trough to the west (Green 1997; Fielding et al. 2000; R. Korsch and Totterdell 2009). Having developed inbound of an active convergence margin during the New England Orogeny, the Bowen Basin formed within a backarc tectonic setting (R. Korsch and Totterdell 2009), concurrently with the Gunnedah Basin.

Regionally, Cenozoic sedimentary deposits overlay the Bowen Basin units, formed through subsidence-related faulting and erosion, in conjunction with fluvial sedimentary depositional processes (Laronne and Shlomi 2007; Nichols and Fisher 2007; R. J. Korsch et al. 2009). Crustal thinning due to extensional tectonic events resulted in magma upwelling and intermittent volcanism, expressed as basaltic lava flows in the vicinity of the Project as well as interbedded tuff and volcanolithic fragments within the Cenozoic sedimentary sequences (R. Korsch and Totterdell 2009).

7.1.1 Structural Elements

The Project is situated in the eastern extent of the north-northwest to south-southeast trending Denison Trough (Olgers et al. 1963; Totterdell 1990), which is bounded by the Anakie Inlier and the Collinsville, Springsure and Roma shelves in the west, and the Comet Platform to the east (Totterdell 1990).

Early Permian east-west or northeast-southwest extension formed a series of half-grabens across the Denison Trough (McLoughlin 1986). Recent studies have indicated that a complex interplay of volcanism, mechanical extension, thermal cooling, thrust related flexuring of the lithosphere and dynamic platform tilting resulted in block subsidence during the Late Carboniferous to Early Permian, resulting in rapid sedimentary infill forming a thin veneer across the trough (R. Korsch and Totterdell 2009). Extension was followed by mid-Permian mild compression, then more intense northeast-southwest oriented compression in the Late Triassic (McLoughlin 1986; R. J. Korsch et al. 2009; R. Korsch and Totterdell 2009).

Various northwest to southeast trending extensional bounding-faults of half-grabens, resulting from block subsidence during the Late Carboniferous to Early Permian, occur regionally across the Denison Trough (R. Korsch and Totterdell 2009; R. J. Korsch et al. 2009).

In addition to faulting, a series of regional scale, meridional en échelon synclines and anticlines occur adjacent to the faulting in a north-northwest to south-southeast orientation (McLoughlin 1986). Folds such as the Springsure Anticline, Inglis Serocold Anticline, Rewan Syncline and Consuelo Anticline are located to the southwest of the Project, and the Mimosa Syncline to the southeast (McLoughlin 1986; R. Korsch and Totterdell 2009; R. J. Korsch et al. 2009). Small-scale, discontinuous folds occur sporadically across the Mahalo Development Area, and are likely parasitic to the larger folds previously mentioned (McLoughlin 1986). The structural history of this area (Denison Trough) indicates that the major folding event effecting the Permian rocks occurred between the Triassic and Jurassic (Power 1967; McLoughlin 1986).

Further discussion related to the structural elements directly within the Mahalo Development Area is included in Section 7.3.

7.2 Regional Hydrostratigraphy

The mapped geology within the vicinity of the Project is presented in Figure 7.1 and Figure 7.2.

Stratigraphic units of relevance to the Project include:

- Quaternary alluvial deposits located along the Comet River and major tributaries;
- Surficial Cenozoic deposits;
- Localised basalt;
- Early to Middle Triassic sediments of the Clematis Group;
- Early Triassic sediments of the Rewan Group;
- Late Permian sediments of the Bandanna Formation; and
- Late Permian sediments of the Back Creek Group (including the Black Alley Shale and Aldebaran Sandstone).

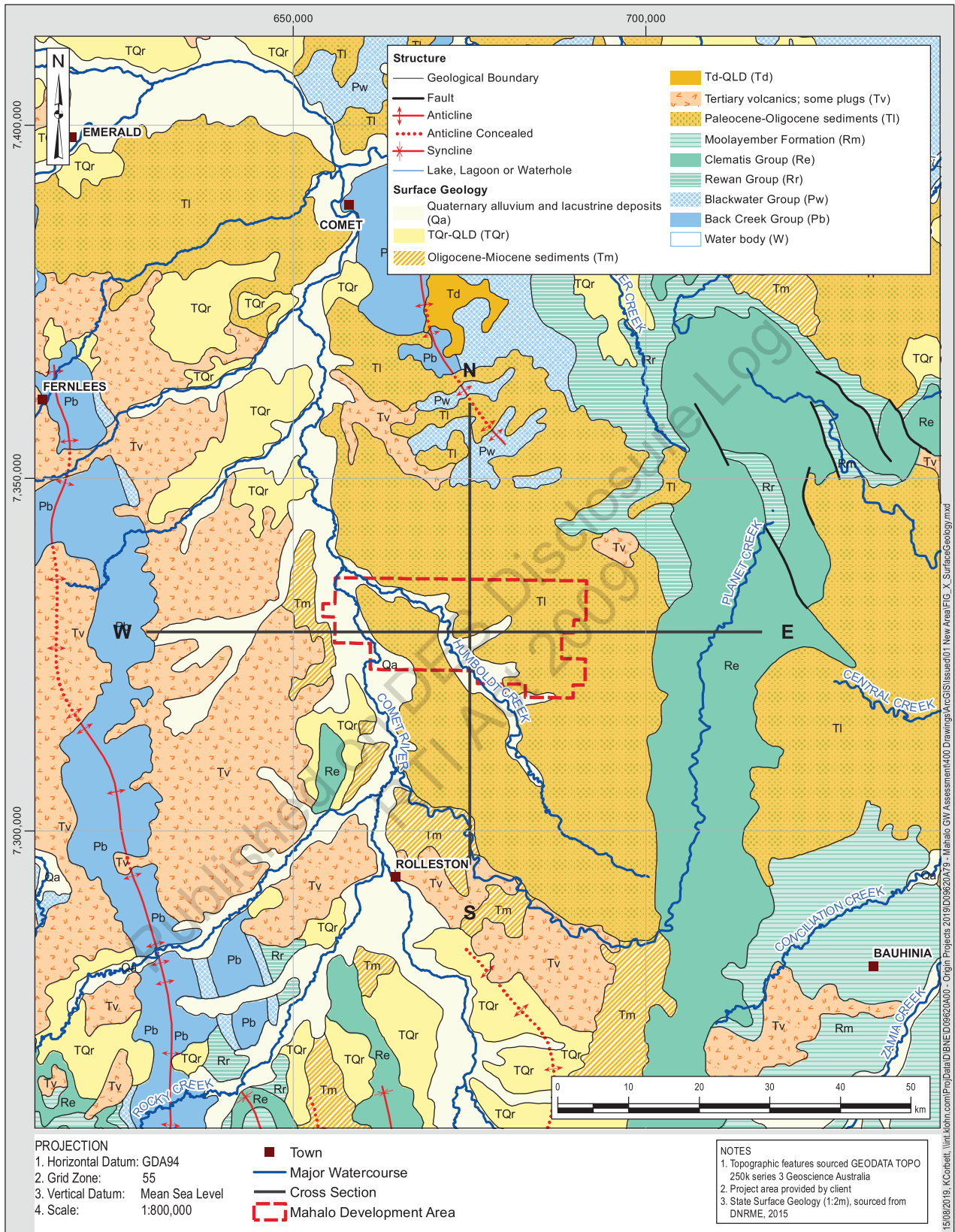


Figure 7.1 Surface Geology within the Vicinity of the Mahalo Development Area

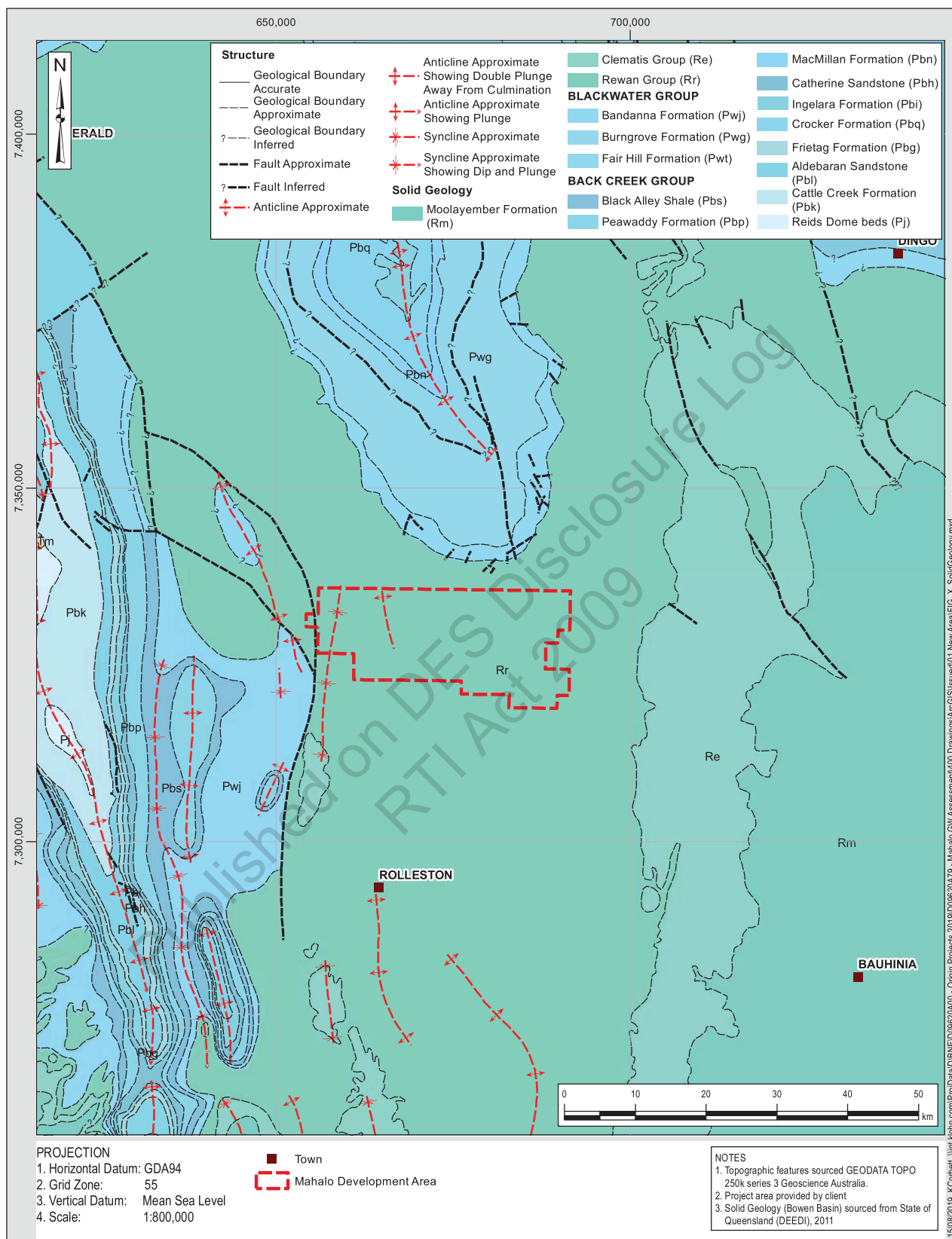


Figure 7.2 Solid Geology within the Vicinity of the Mahalo Development Area

Table 7.1 presents the hydrostratigraphic column for the units occurring in the vicinity of the Project. The table also indicates the hydrogeology condition of each unit as presented by OGIA (OGIA 2019b), as well as the relevance to the Mahalo Development Area.

Table 7.1 Hydrostratigraphy within the Mahalo Development Area (after R. J. Korsch et al. 1997; OGIA 2019b)

Age		Formation		Hydrostratigraphic Description (OGIA 2019b)	Relevance to Mahalo Development Area
Quaternary		Alluvium		Aquifer	Mapped associated with watercourses
Tertiary		Sediments		-	Deposits across the Mahalo Development Area
		Basalt		Aquifer	Located west of Mahalo Development Area
Triassic	Middle	Moolayember Formation		Tight Aquitard	Located east of Mahalo Development Area
		Showground Sandstone	Clematis Group	Major Aquifer	Located east of Mahalo Development Area
	Early				
Permian	Late	Rewan Group		Tight Aquitard	Sub-crops in Mahalo Development Area
		Bandanna Formation		Interbedded Aquitard	Target CSG formation
		Back Creek Group	Black Alley Shale	-	Sub-crops west of Mahalo Development Area
	Peawaddy Formation				
	Catherine Sandstone				
	Ingelara Formation				
	Freitag Formation				
	Upper Aldebaran Sandstone				
	Lower Aldebaran Sandstone				
	Early	Cattle Creek Formation	Productive Coal Seam		
Reids Dome Beds		-			

A summary of each of these units is provided in the following sections (from youngest to oldest).

Alluvium

The Quaternary alluvium comprises an unconsolidated and heterogeneous profile of sediments, deposited during periods of fluvial flooding events as overbank deposits (Laronne and Shlomi 2007; Nichols and Fisher 2007). The alluvium consists of fine- to coarse-grained gravels and channel sands interbedded with clays. Published geological mapping (Figure 7.1) indicates the presence of Quaternary alluvium up to 3 km (wide) on either side of the Comet River and Humboldt Creek within the Mahalo Development Area. Quaternary alluvial sediments overlie sub-cropping Triassic and Permian bedrock, basalt and Cenozoic-age sediments. Further discussion of this unit, local to the Mahalo Development Area is provided in Section 7.3.

Cenozoic Deposits

Quaternary colluvium is mapped as occurring within the Mahalo Development Area, and consists of clay, silt, sand and gravel.

Cenozoic-age sediments comprise a discontinuity of consolidated and semi-consolidated heterogeneous sediment / weathered residual deposits (referred to as the Emerald Formation) that overlie the northeastern portion of the Comet River catchment, infilling valley floors. These deposits consist of deeply weathered fluvial and lacustrine claystone and siltstone, quartzose sandstone, pebbly sandstone, and gravel. Cenozoic-sediments are widely distributed over the Mahalo Development Area. Further discussion of this unit, local to the Mahalo Development Area is provided in Section 7.3.

Basalt

Basalt occurs within the Mahalo Development Area, with major flows towards the west and south. The basalt comprises mostly olivine basalt with some areas of nephelinite and basanite (Olgers et al. 1963). The basalt presents as flat lying lava flows, unconformably overlying the sedimentary units. The basalt in the Mahalo Development Area is considered an aquifer. Further discussion of this unit, local to the Mahalo Development Area is provided in Section 7.3.

Moolayember Formation

The Middle to Upper Triassic Moolayember Formation comprises interbedded mudstones, lithic, medium to coarse-grained sandstone, carbonaceous shales, siltstones, and conglomerates, and is the youngest formation within the Bowen Basin (Green et al. 1997; Green 1997). The lower part of the Moolayember Formation was deposited in a lacustrine depositional environment that grades upwards into an alluvial plain with alluvial fans on the eastern margin (Golin and Smyth 1986). The thickness of this formation varies from 200 m on the Springsure Shelf to nearly 1,500 m in the centre of the Taroom Trough (Radke et al. 2000). The Moolayember Formation is characterised as a tight aquitard (OGIA 2019b). The formation is limited in spatial distribution within the vicinity of the Project.

Clematis Group

The Lower to Middle Triassic Clematis Group (formally, Clematis Sandstone) consists of: medium to coarse-grained, cross-bedded, quartzose to sub-labile and micaceous sandstone; siltstone, mudstone and granule to pebble conglomerate; some fine conglomerate; and grey and red mudstone, deposited within a fluvial environment. The Clematis Group includes two geological formations within the Denison Trough: the Expedition Sandstone (a quartzose sandstone, conglomerate, siltstone and mudstone package) and the Glenidal Formation (thinly bedded, very fine to medium-grained sandstone with common siltstones and mudstones), which conformably overlies the Early Triassic Rewan Group (Brakel et al. 2009). The Expedition Sandstone is equivalent to the Showgrounds Sandstone in the Taroom Trough (Hoffmann, Green, and Gray 1997).

The Clematis Group is considered to be a major aquifer of the Great Artesian Basin (GAB). The formation is limited in spatial distribution within the vicinity of the Project. Outcrops of the Clematis Group are located east of the Project within the Expedition Range (Olgers et al. 1963; Brakel et al. 2009). It is not considered a significant aquifer in this study in terms of third-party

groundwater use, however is the source of a number of GAB spring complexes (Section 7.9.1). The Clematis Group is separated from the Bandanna Formation (target for CSG production) by a thick sequence of the Rewan Group aquitard.

Rewan Group

The Early Triassic Rewan Group conformably overlies Permian sediments, and predominantly consists of lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base), deposited in a fluvial-lacustrine environment (Brakel et al. 2009). This sedimentary sequence thickens towards the centre of the Taroom Trough, east of the Project, and outcrops to the northeast.

The Rewan Group is considered to be a tight aquitard (OGIA 2019b).

Bandanna Formation

The Late Permian Bandanna Formation conformably overlies the Late Permian Back Creek Group (McLoughlin 1986), and consists of calcareous sandstone, calcareous shale, mudstone, permeable coal seams, and concretionary limestone (Huleatt 1991).

The calcareous sediments of the Bandanna Formation are interbedded with regionally discontinuous coal seams, which are the target for the Project CSG production, as well as much of the coal mining in the Bowen Basin (Huleatt 1991). Individual coal seams can be identified, with the Project targeting the Castor, Pollux, Aries and Orion seams.

The sedimentary sequences of the Bandanna Formation deepen towards the southeast, and outcrop north of the Mahalo Development Area (Huleatt 1991). The Bandanna Formation is one of the most widespread and youngest coal-bearing Permian sequences in the Bowen Basin, and correlates with the upper sections of the Baralaba Coal Measures in the southeast and the upper part of the Rangal Coal Measures in the southwest of the basin (Huleatt 1991).

The Bandanna Formation is considered as an interbedded aquitard (OGIA 2019b).

Back Creek Group

The Late Permian Back Creek Group comprises quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite. The Back Creek Group contains various Permian sedimentary units, most notably the Black Alley Shale, Aldebaran Sandstone, the Cattle Creek Formation, and the Reids Dome Beds (Bowen Basin basement sequence).

Directly underlying the Bandanna Formation (and confining the earlier successions of the Back Creek Group) is the Black Alley Shale, composed of marine mudstone facies, which becomes increasingly sandy northwards of the northern Taroom Trough (Ayaz et al. 2016). The Black Alley Shale varies in thickness between 7 and 200 m in the southern extents of the Bowen Basin, and thickens into the Denison Trough (Ayaz et al. 2016). The Black Alley Shale is most likely the result of deposition from an eastward progradation of deltaic lobes during a minor transgression or restricted marine event in the Bowen Basin.

The Aldebaran Sandstone is a thick sequence of sandstones, conglomerates and minor mudstones and coals which accumulated within, and eventually beyond, the Denison Trough during the early

Permian (Olgers et al. 1963). The unit reaches a maximum thickness of over 700 m and is covered by up to 1,400 m of Permo-Triassic strata of the upper Bowen Basin, Jurassic strata of the Surat Basin and Cenozoic basalt and alluvium. In the far south, it directly overlies the Reids Dome Beds (J. C. Baker 1991). The Aldebaran Sandstone represents a deltaic depositional environment that gradually replaced the marine environment of the Cattle Creek Formation (Dickins and Malone 1973).

Horizons of the Cattle Creek Formation comprises dark grey, poorly sorted and poorly bedded conglomeratic silty sandstone and mudstone containing scattered large angular boulders, with thin interbeds of limestone and calcareous sandstone (Dickins and Malone 1973). Coal is also present within the Cattle Creek Formation, and has recently been a target for CSG exploration (OGIA 2019b). The Cattle Creek Formation was deposited within a shallow marine shelf to prodelta depositional environment (Dickins and Malone 1973; Jackson, Hawkins, and Bennett 1980).

The Reids Dome Beds, the lowest unit of the Back Creek Group, outcrop in areas of the Springsure Anticline and as a thin sequence approximately 110 km west of Springsure (Dickins and Malone 1973). These beds have a maximum thickness of approximately 2,760 m, and consist of: a basal unit of black shale and mudstone with coal seams interbedded with hard carbonaceous sandstones and orthoquartzites; a middle unit of black to grey carbonaceous micaceous shale, siltstone and sandstone with minor coal and thin dolomite beds with local thick beds of polymictic conglomerate (particularly in the south); and an upper unit of interbedded fine- to coarse-grained carbonaceous sandstone, dark carbonaceous siltstone, shale and coal (Olgers et al. 1963; Dickins and Malone 1973).

7.3 Local Hydrogeology

The Mahalo Development Area is directly underlain by alluvium associated with the Comet River and Humboldt Creek, Cenozoic deposits and basalt. The Rewan Group subcrops beneath the surficial deposits.

Two cross sections, oriented north-south and west-east through the Mahalo Development Area are presented in Figure 7.3 and Figure 7.4. The location of the cross sections is shown on Figure 7.1. The sections have been prepared using the OGIA groundwater model geometry (OGIA 2019d). The north-south section shows the Bandanna Formation dipping to the south, with Cenozoic cover present across the majority of the surface. The east-west section highlights the presence of the basalt towards the west, and the Rewan Group thickness, which increases towards the east, where the Clematis Group is present.

Discussion related to the local hydrogeology and conceptual understanding is provided in the following sections.

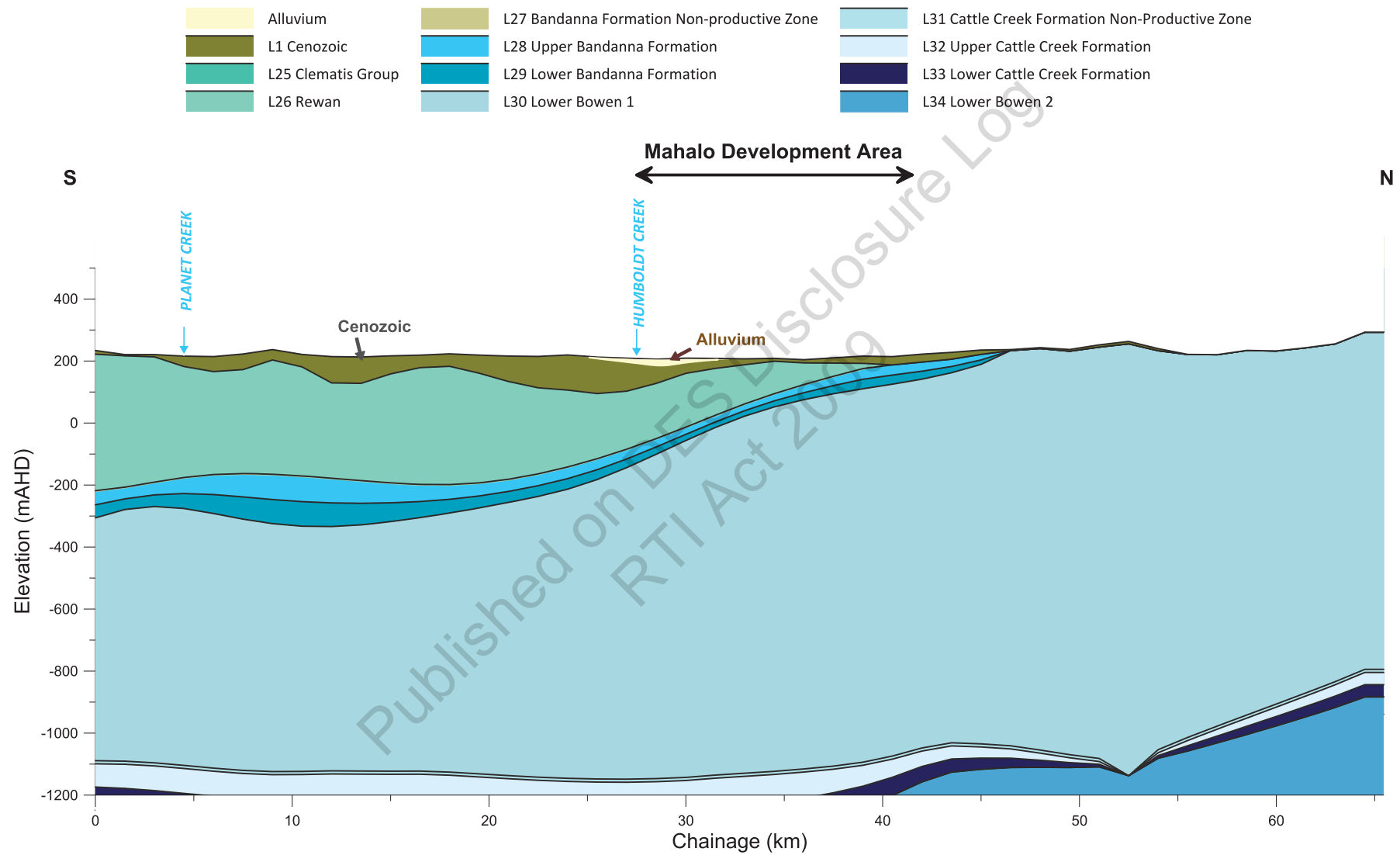


Figure 7.3 North-South Oriented Cross Section

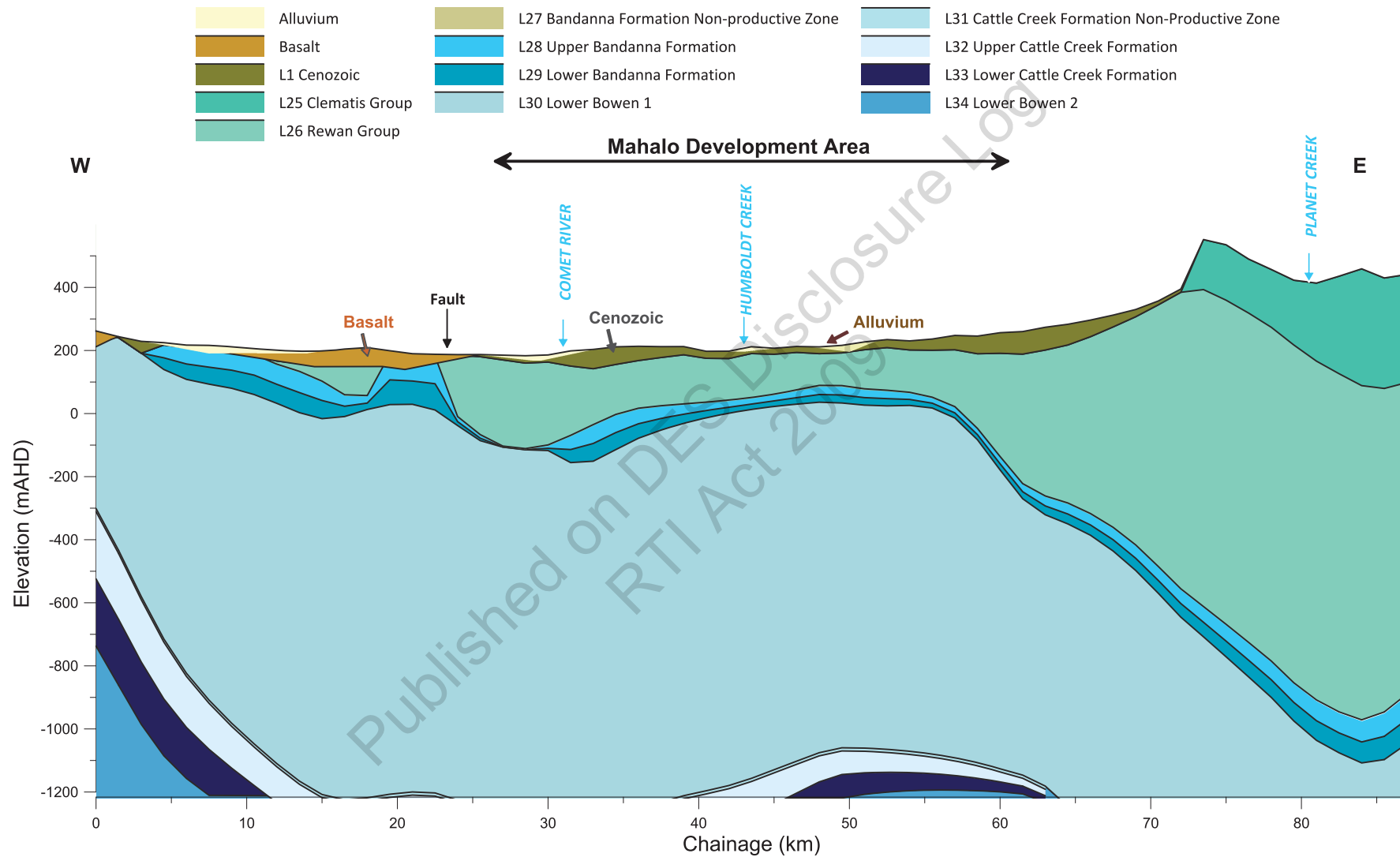


Figure 7.4 West-East Oriented Cross Section

As discussed previously, the mapped alluvium in the Mahalo Development Area is associated with the Comet River and Humboldt Creek. A review of available data from the GWDB 'stratigraphy table' (DNRME 2019) indicates the alluvium associated with these systems is up to 24 m thick. Figure 7.5 presents the available thickness data from the GWDB for the alluvium and also includes the location of bores inferred to have intersected alluvium (where thickness information is not available) (see Section 7.10).

Figure 7.5 also presents the distribution and thickness of the basalt, sourced from GWDB records. The records indicate the basalt is up to 90 m thick, with a mean thickness of ~40 m. The locations of bores inferred to have intersected the basalt are also shown and are generally located to the west of the Mahalo Development Area.

There are also intercalations through the Cenozoic sediments. This is evident in the borehole log for Loweby-1 borehole log (a gas well drilled in 1992), which is logged from 100 m onwards (base of the Cenozoic to 120 m), and a fluvial sequence, largely comprising interbedded sandstone, siltstone and claystone beds with minor intervals of basaltic lava flows. The upper claystone units are described as brown-yellow-grey in colour, expansive, blocky and soft and are considered to be genetically related to the basalt flows and represent heavily weathered / altered olivine-bearing basalt. The brown / yellow colour is due to the alteration of olivine to montmorillonite, a member of the smectite group of clays (Baker and Haggerty 1967).

The basalt is also mostly separated from the Bandanna Formation by the Rewan Group aquitard; however, it is likely in the far southwest the basalt lies directly above the Bandanna Formation. A review of lithology records from the GWDB indicates that there is a highly weathered section (~22 m thickness at RN158563), with high clay content in this transition zone between the basalt and non-weathered rock of the Bandanna Formation. This likely represents the pre-basalt weathered surface, which has been altered by the lava flow. This portion of the strata will limit the direct connectivity between the Bandanna Formation and basalt. Further discussion of the Bandanna Formation and basalt is provided in the discussion of groundwater elevations in Section 7.6.

Isopachs for the Rewan Group and Bandanna Formation are presented in Figure 7.6. The Rewan Group aquitard is present across most of the Mahalo Development Area, with a thickness of up to 400 m directly underlying the tenure. The thickness increases up to ~1,500 m to the east and south. The Bandanna Formation is up to ~200 m thick within the tenure area. The target coal seams (Castor, Pollux, Aries and Orion seams) have been intersected during exploration activities and range in thickness from 0.2 m to 7.3 m (where encountered).

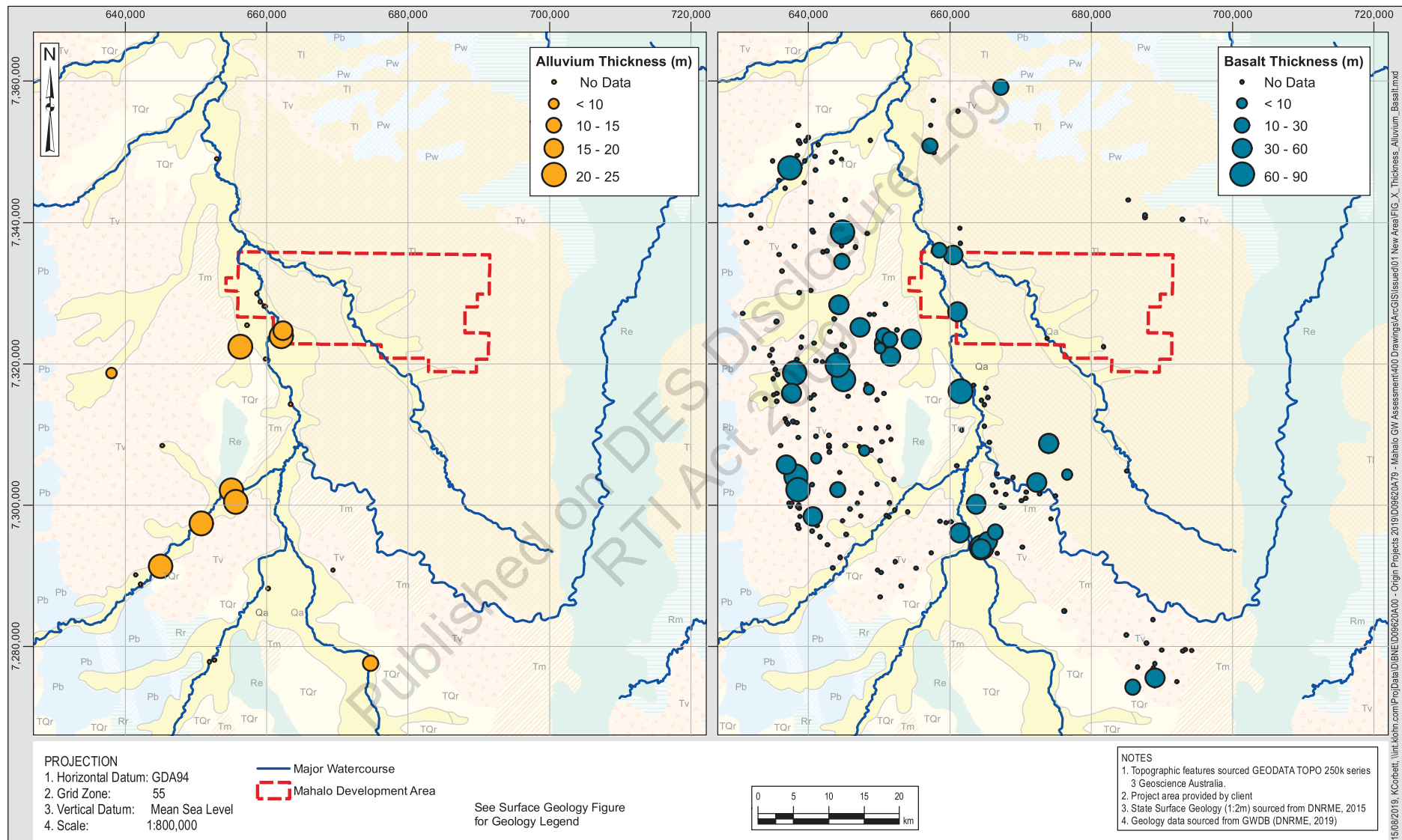


Figure 7.5 Location of Mapped Alluvium and Basalt within the Vicinity of the Mahalo Development Area

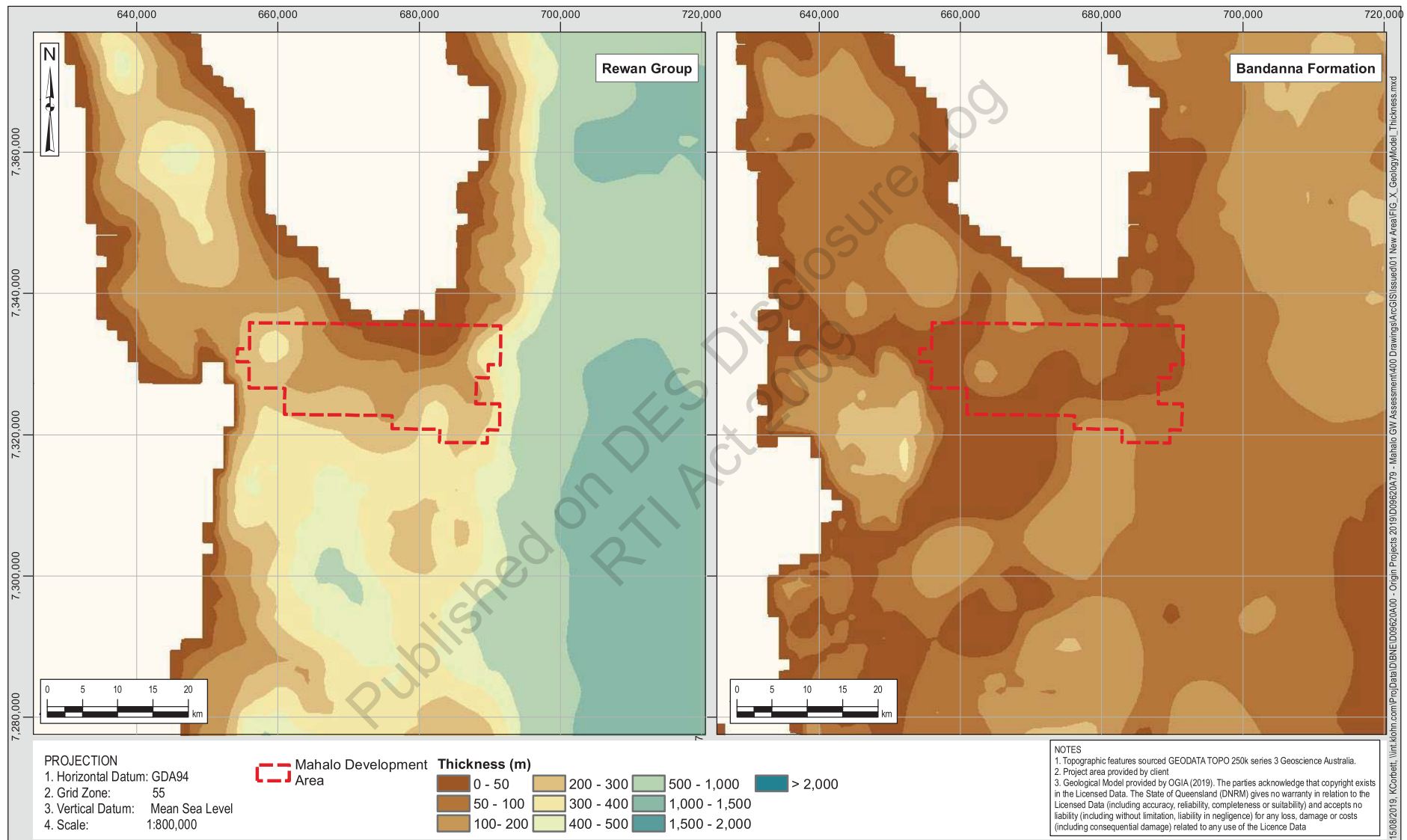


Figure 7.6 Formation Isopachs for Rewan Group and Bandanna Formation (sourced from OGIA 2019d)

7.3.1 Local Structure

The structural geological mapping of the local area identified a fault structure to the west of the Mahalo Development Area and several small-scale, discontinuous anticlines and synclines. Figure 7.7 presents the results of a seismic survey completed across the western tenure boundary. Interpretation of the seismic survey, included in the figure, identifies the top of the coal seam (upper blue line), and an inferred fault displaying a throw of ~ 500 m, which is interpreted to increase across the fault towards the south. The seismic data indicates that there is a ~ 1 km zone of fault rubble, resulting in limited connectivity between the coal seams on the east and west of the fault. The top of the coal is also eroded on the western side of the fault. This fault structure is represented in the UWIR numerical model (Section 8) as part of the model domain geometry.

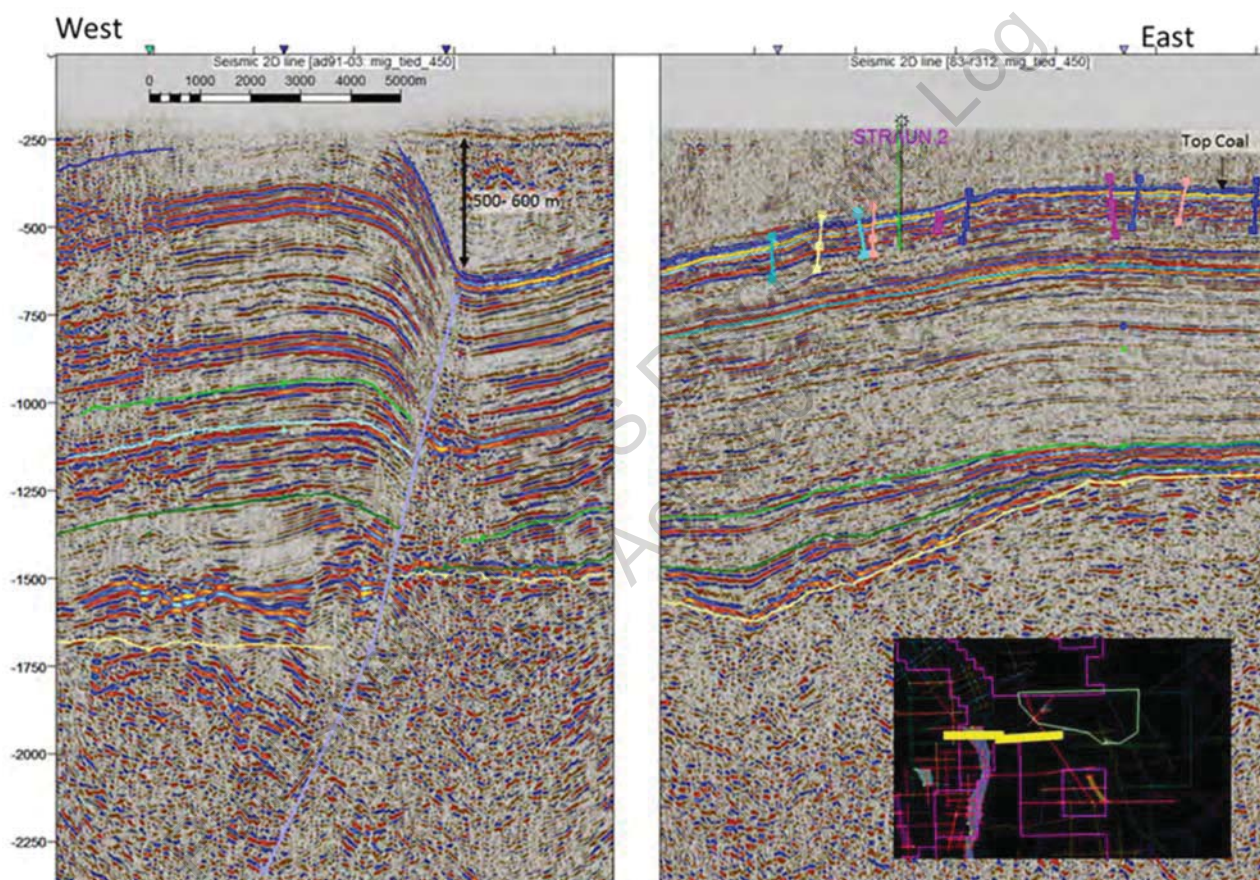


Figure 7.7 Seismic Survey – Western Project Boundary

7.4 Aquifer / Aquitard Hydraulic Properties

OGIA (2019b) present a range of hydraulic conductivity values, which have been estimated from core, drill stem tests (DSTs) and pumping tests within the Surat CMA. The data, which was compiled as part of the 2016 UWIR (OGIA 2016a) from a range of sources including the GWDB, Queensland Petroleum Exploration Database (QPED), GAB Water Resource Assessment (Smerdon et al. 2012) and public domain sourced investigations undertaken by other CSG proponents. As new data has become available since 2016, the compilation of hydraulic properties within the 2019 UWIR (2019b) includes results for some 8,100 core tests, 7,700 drill stem tests and more than 100 aquifer pumping tests across the Surat CMA.

Figure 7.8 presents the measured hydraulic conductivity values presented in the 2019 UWIR. The figure also presents the pre- and post-calibrated groundwater model ranges for each formation.

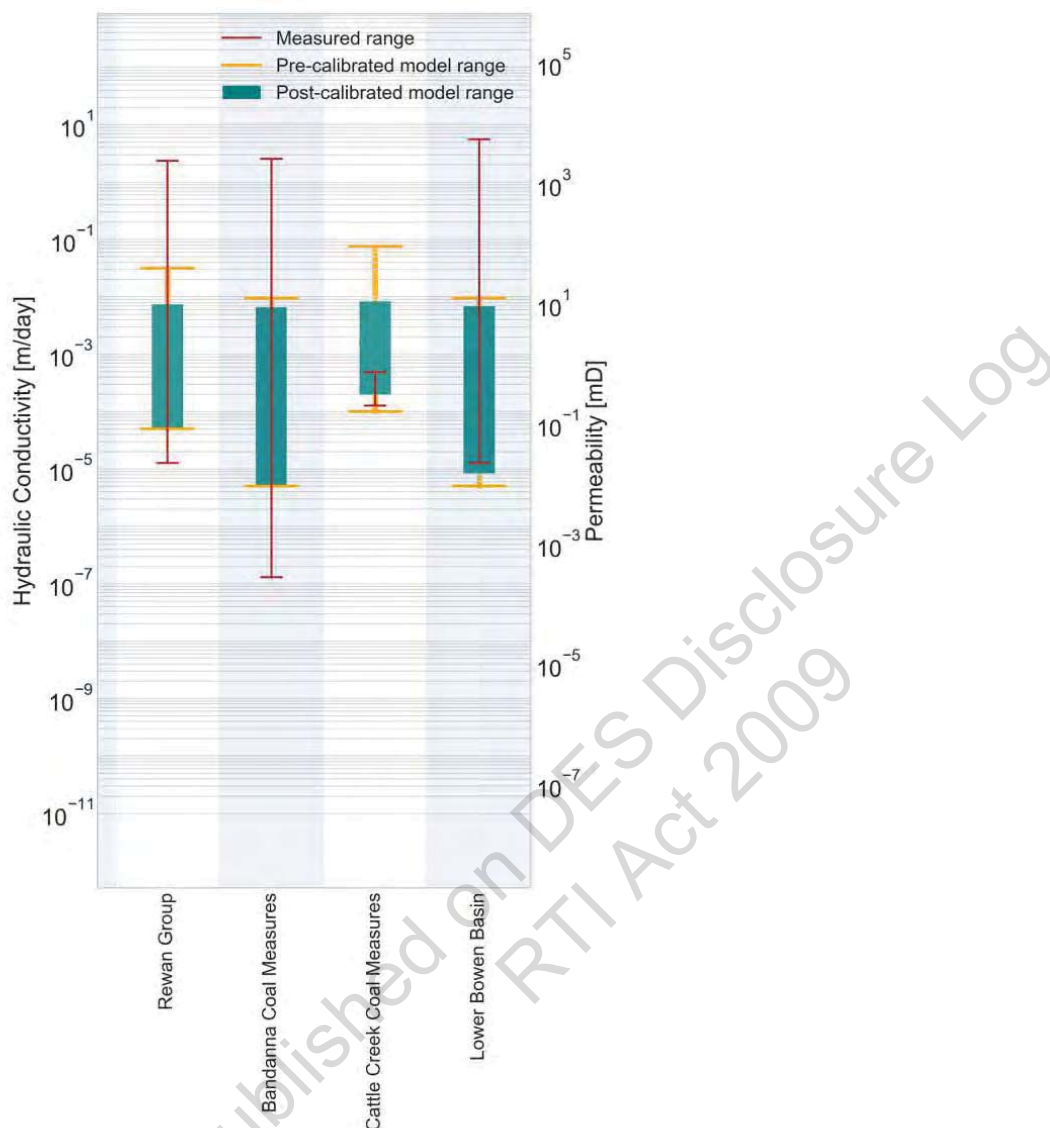


Figure 7.8 Horizontal Permeability Ranges for the Surat CMA (adapted from OGIA 2019b)

Site-specific data is also available for the Bandanna Formation, from 26 DSTs undertaken at appraisal wells within the Mahalo Development Area. The data is presented in Table 7.2, with individual test data provided in Appendix I. Additional testing of the Bandanna Formation permeability will be undertaken routinely as appraisal activities continue, and CSG production wells are drilled.

Further discussion related to the hydraulic conductivity in the Mahalo Development Area, with regards to those adopted in the UWIR model (within the Mahalo Development Area), is provided in Section 8.2.1.

Table 7.2 Site-Specific Bandanna Horizontal Hydraulic Conductivity Statistics

Statistic	Hydraulic Conductivity - Site-Specific DST/MST (m/day)
10 th Percentile	2.92×10^{-4}
90 th Percentile	2.68×10^{-1}
Median	6.77×10^{-3}
Geomean	9.74×10^{-3}

OGIA (2016a) includes further discussion on the hydraulic properties in the various hydrostratigraphic units (excluding the Bandanna Formation). A summary of the information collated and presented in OGIA (2016b) is provided in Table 7.3.

Table 7.3 Summary of Hydraulic Properties for Hydrostratigraphic Units in the Mahalo Development Area

Unit	Summary
Alluvium	Hydraulic conductivity of alluvial aquifers ranges between 2 and 116 m/day (10 th and 90 th percentiles), with a median value of 16 m/day.
Basalt	Hydraulic conductivity of the basalt is reported to range between 0.1 and 8 m/day (10 th and 90 th percentiles), with a median value of 1 m/day.
Moolayember Formation	Horizontal hydraulic conductivity is reported between 1.4×10^{-4} and 4.3×10^{-1} m/day (median of core, DST and pumping tests). Wide ranging hydraulic conductivity values are associated with a permeability-depth relationship, with lower values reported for the formation occurring in deeper parts of the basin.
Clematis Group	Horizontal hydraulic conductivity values are reported between 2×10^{-6} and 15 m/day, with median values estimated between 1.6×10^{-4} and 4.2×10^{-1} m/day (from the different testing methods). A permeability-depth relationship also exists within the Clematis Group, with lower permeability associated with greater depth. Significant amount of testing has been undertaken on the eastern extent of the Expedition Range, east of the Mahalo Development Area (Figure B-17, OGIA 2016a).
Rewan Group	Median horizontal hydraulic conductivity is reported between 4.0×10^{-5} and 4.2×10^{-4} m/day. Low values are consistent with the interpretation of the Rewan Group as a primary aquitard overlying the Bandanna Formation.
Units underlying the Bandanna Formation	Horizontal hydraulic conductivity for the older Permian units are reported between 1.4×10^{-5} and 1.2×10^{-4} m/day.

No specific testing has been undertaken on the hydraulic properties associated with the western fault structure, however based on the understanding discussed in Section 7.3.1, it is inferred that there will be limited connectivity between the units on the eastern and western sides of the fault.

7.5 Groundwater Recharge

Recharge processes within the Surat CMA are summarised in the 2019 UWIR (OGIA 2019b). Key processes of recharge include localised recharge, preferential pathway flow and diffuse recharge:

- Localised recharge occurs beneath drainage features including rivers, and free-draining unconsolidated sedimentary cover, such as alluvium.
- Preferential pathway flow arises from changes in permeability within aquifers and in overlying regolith, providing conduits for water to infiltrate. Zones of higher permeability may include fissures, faults, joints, tree roots and high-permeability beds within individual formations and along bedding planes (Kellett et al. 2003; Sucklow et al. 2016). This mechanism is considered the dominant recharge process in the GAB (Kellett et al. 2003).

- Diffuse recharge is the process by which rainfall infiltrates directly into outcropping hydrostratigraphic units. This is expected to occur within all outcrop areas and therefore this process applies to the largest spatial extent across the Surat CMA (Kellett et al. 2003).

Recharge in the Mahalo Development Area will occur as diffuse recharge with rainfall infiltration occurring at outcropping aquifers. Estimates of long-term average recharge rates have been made by OGIA as part of the 2016 UWIR (OGIA 2016a) using the chloride mass balance recharge estimation method. For the units outcropping within the vicinity of the Project, the following recharge rates were estimated by OGIA⁶:

- Basalt – 9.9 mm/year
- Moolayember Formation (outcrops to southeast) – 2.5 mm/year
- Clematis Group (outcrops to east) – 26.9 mm/year
- Rewan Group (outcrops to east) – 1.2 mm/year
- Bandanna Formation (outcrops to north and west) – 5.0 mm/year
- Older Permian Units (outcrops to north and west) – 6.8 mm/year

Recharge into the alluvium associated with the Comet River, Humboldt Creek and other tributaries of Comet River is estimated as 6.8 mm/year (mean value) (OGIA 2016a), and will primarily occur from streamflow infiltration, direct infiltration of rainfall and drainage from adjacent rock units (where suitable hydraulic conditions exist). Recharge from the alluvium into the units underlying may also occur. Further discussion on this mechanism in the Mahalo Development Area is provided in Section 7.8.

7.6 Groundwater Levels and Flow

Several monitoring bores have been installed in the vicinity of the Project (Figure 7.9). The majority of these monitoring bores are installed to monitor groundwater in the vicinity of the Rolleston Open Cut coal mine, located to the southwest of the Mahalo Development Area. There are also several monitoring bores installed and monitored by the DNRME. The following section provides a summary of the available groundwater monitoring data.

⁶ Note that revised estimates of recharge have been made as part of the 2019 UWIR, however the supporting reports which provide the estimates on a formation scale had not been published at the time of preparation.

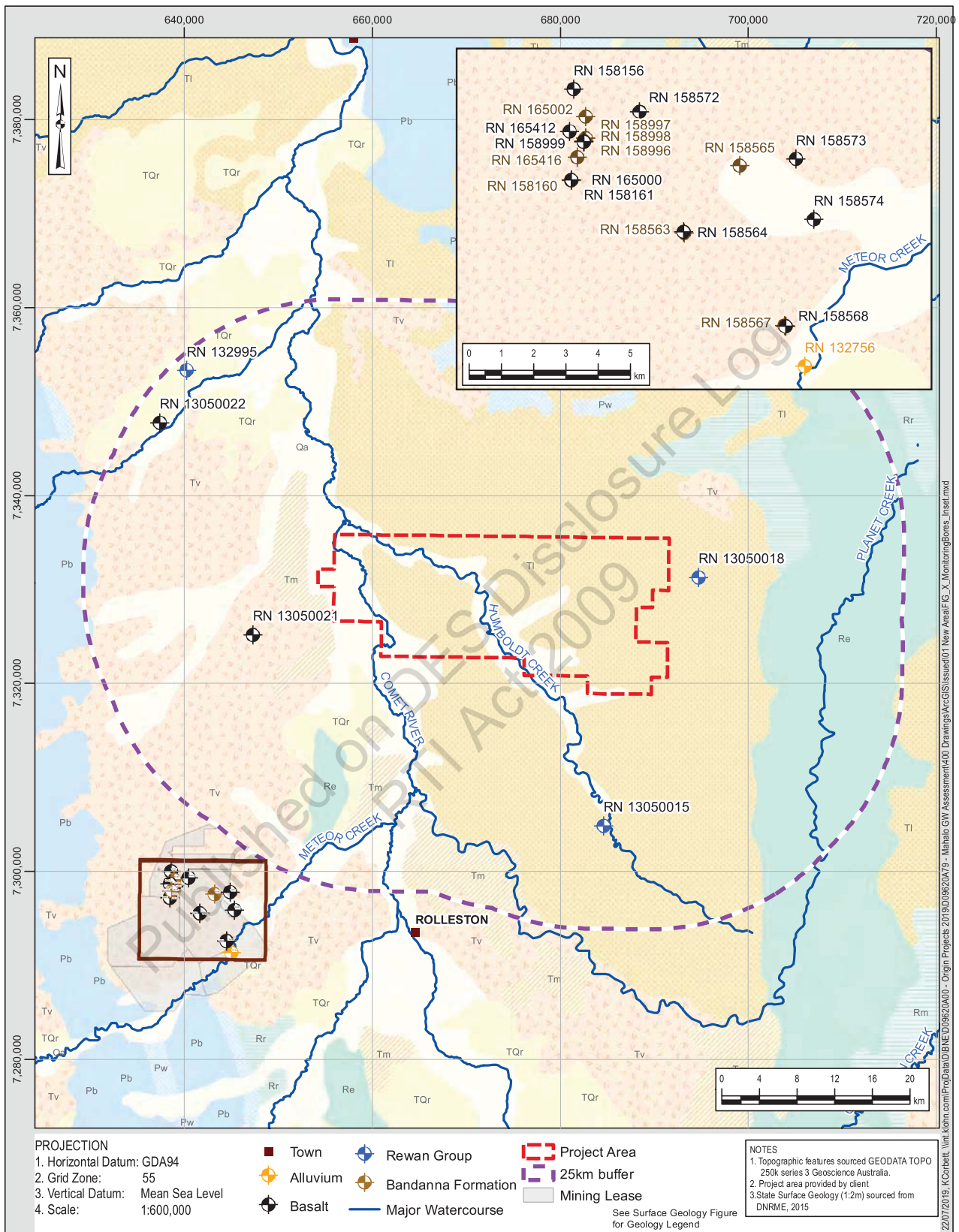


Figure 7.9 Location of Monitoring Bores in the Vicinity of the Project

Alluvium

One monitoring bore (RN132756), with transient groundwater elevations, screened within alluvium (Meteor Creek), is located to the southwest of the Project near the Rolleston Coal Mine. Based on the available information from the GWDB, 22 m of alluvium was encountered at this location, and generally comprised clay / silt to a depth of 15 m, after which a coarser horizon was encountered.

Figure 7.10 shows the groundwater elevation hydrograph for this bore based on available data (October 2011 and December 2012). The groundwater elevation is between 224.2 and 225.4 mAHD, and the depth to water is between ~10 and 11 mbGL⁷, indicating a saturated thickness of ~11 to 12 m within the alluvium at this location. The period of record is short; however, the hydrograph shows that fluctuations in groundwater levels are influenced by rainfall events which is indicated by the strong correlation with the rainfall excess / deficit trend.

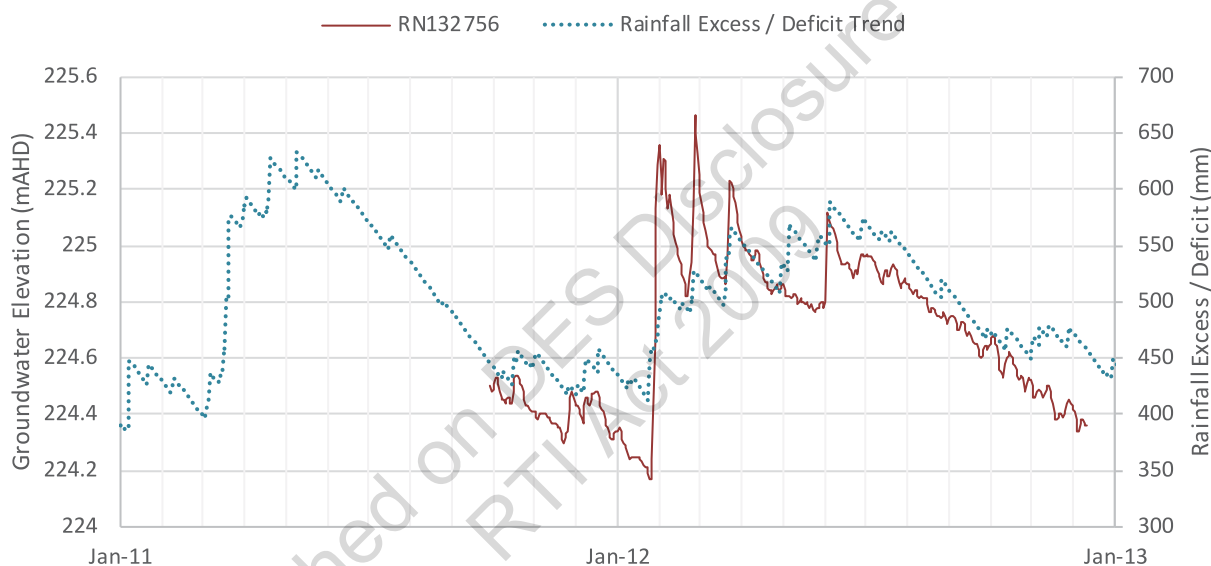


Figure 7.10 Alluvium Groundwater Elevation Hydrograph (RN132756)

A review of the GWDB for additional groundwater levels for the alluvium was undertaken. Several records were available for the alluvium associated with Comet River, directly within the Mahalo Development Area, as shown in Figure 7.11. The figure shows all available records (regardless of time) and indicates a groundwater gradient with the direction of surface water flow. Groundwater levels range between 144 and 184 mAHD (Comet River alluvium), with the depth to groundwater between 11.2 and 18.3 mbGL.

One bore (RN165700), located within the Mahalo Development Area, was drilled in 2019 and has a groundwater elevation of 173 mAHD. The bore is reported to have intersected 24 m of alluvium and generally comprised clay, sand and gravel. The depth to groundwater was 13 mbGL, with a saturated thickness of ~11 m within the alluvium.

⁷ mbGL – metres below ground level

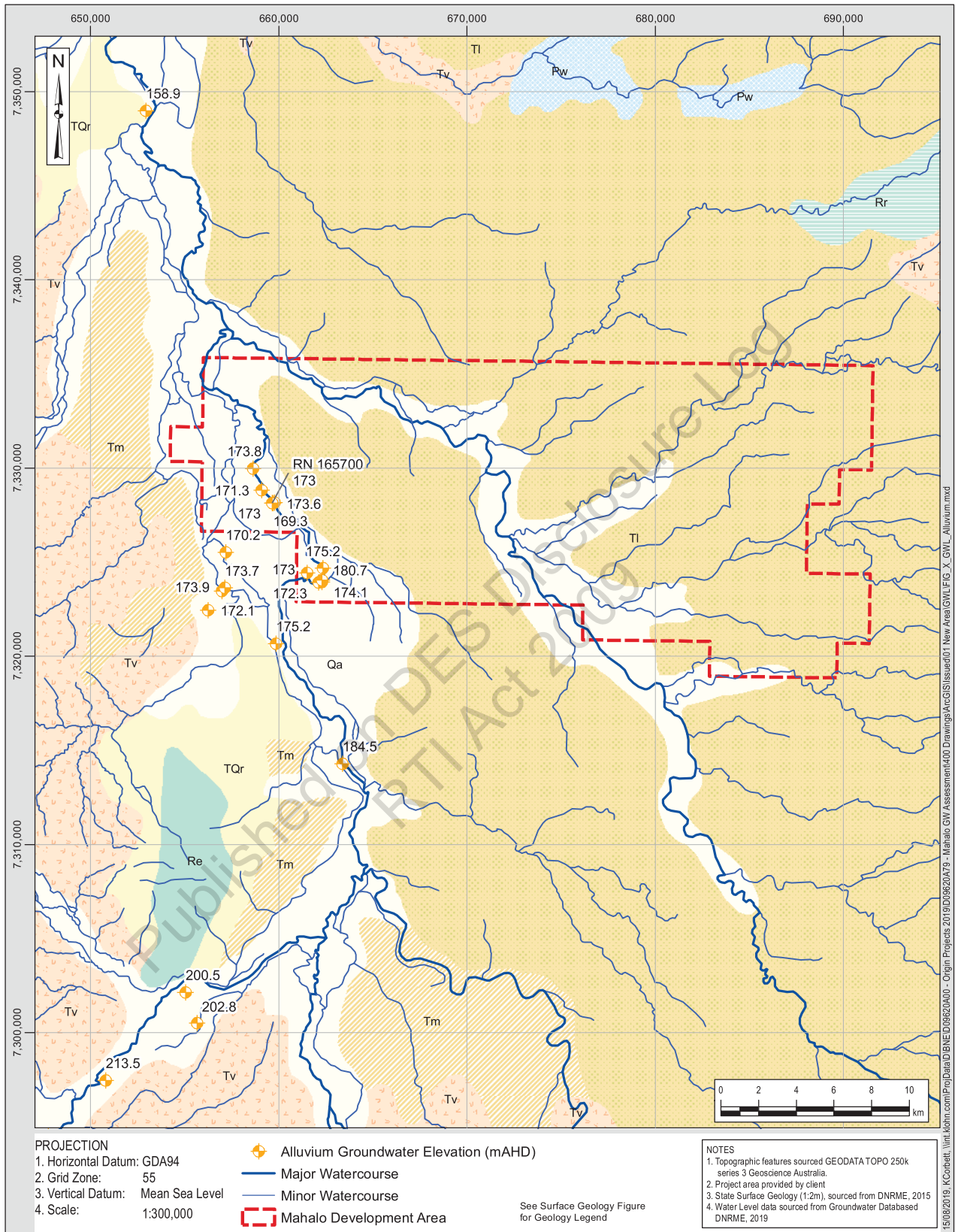


Figure 7.11 Alluvium Groundwater Elevation (GWDB Data)

Cenozoic Sediments

There are no dedicated monitoring bores screened within the Cenozoic sediments within the vicinity of the Project. A review of the GWDB for groundwater levels for the Cenozoic sediments was undertaken. From the available data (regardless of time), groundwater elevations have ranged between 167 and 247 mAHD, with the depth to groundwater between 10 and 60 mbGL.

Figure 7.12 presents the groundwater elevations within the vicinity of the Mahalo Development Area. From the limited data, it is inferred that groundwater flows towards the west / northwest.

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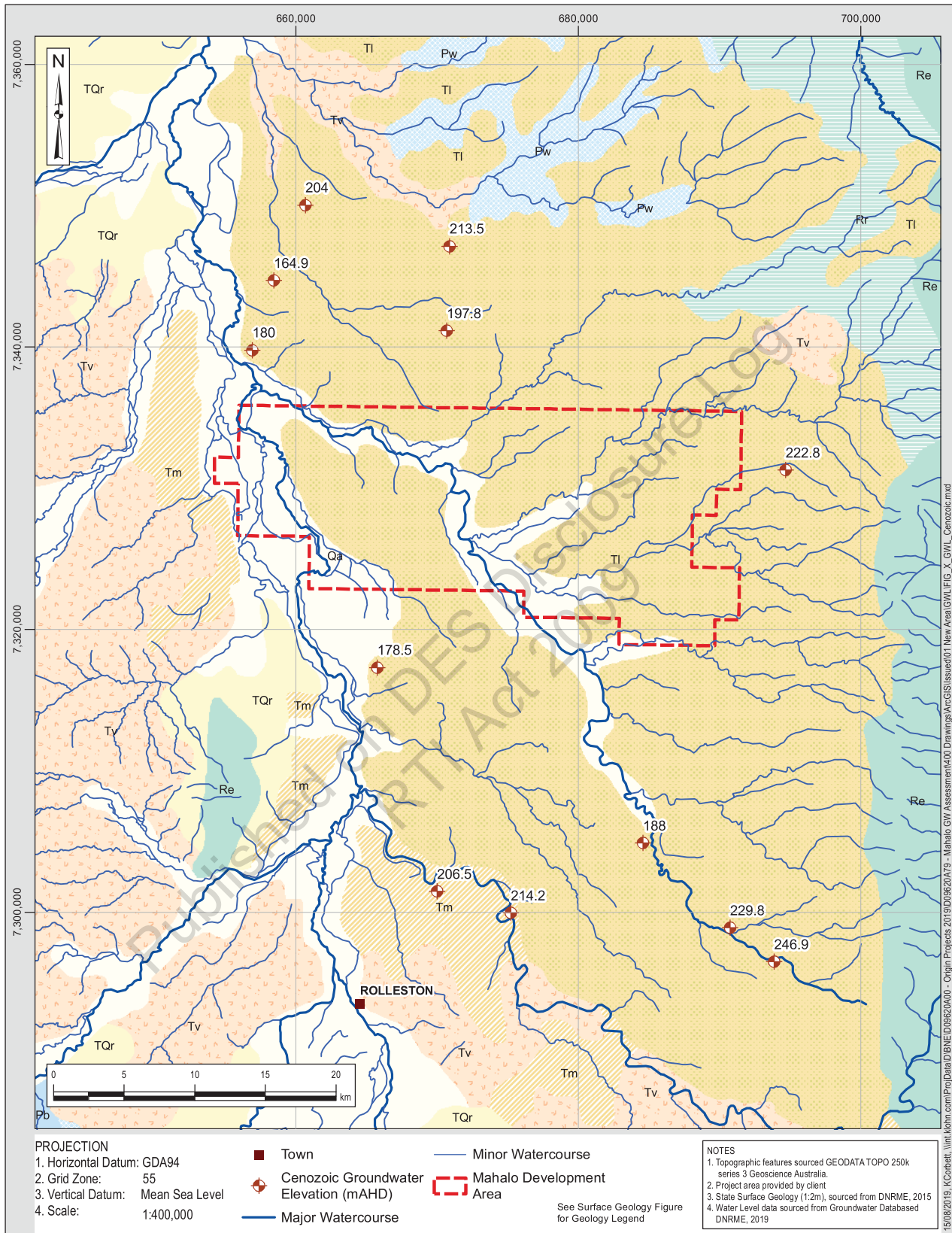


Figure 7.12 Cenozoic Sediments Groundwater Elevation (GWDB Data)

Basalt

Transient groundwater elevations for ten monitoring bores screened within the basalt are available from the GWDB. These monitoring bores are located to the southwest and northwest of the Project. Monitoring bores in the southwest are classified in the GWDB as mine monitoring bores.

Figure 7.13 presents the available data for monitoring bores recording groundwater elevations between 260 and 210 mAHD, with groundwater elevations between 200 and 170 mAHD presented in Figure 7.14. Observations from the hydrographs include:

- Groundwater elevations in the basalt to the southwest range between ~215 and ~258 mAHD, with the highest elevation recorded at monitoring bore RN158156. Groundwater elevations in the basalt to the northwest range between ~179 and 190 mAHD, with the lowest groundwater elevation observed in monitoring bore RN13050022.
- Generally, the groundwater elevations follow the rainfall / deficit trend, with an increase in groundwater elevations after the 2010/11 wet season event, which was followed by a steady decline.
- In contrast to the alluvium hydrograph (Figure 7.10), where an almost instantaneous response to the rainfall event is observed, the basalt in the northwest displays a slower response to the rainfall event in some locations (e.g. RN13050021), with peak groundwater levels occurring approximately one year after the wet season rainfall. The response in the basalt to the southwest appears less delayed than in the northwest, with an up to 15 m increase in elevation observed in response to the wet season event (e.g. RN158574).

A review of the GWDB for additional groundwater levels for the basalt was undertaken. Available records, which have been reported since 2000 are presented on Figure 7.15. Groundwater elevations range between 140 and 200 mAHD.

Based on the available data, the groundwater flow direction within the basalt is inferred to be in a northerly direction.

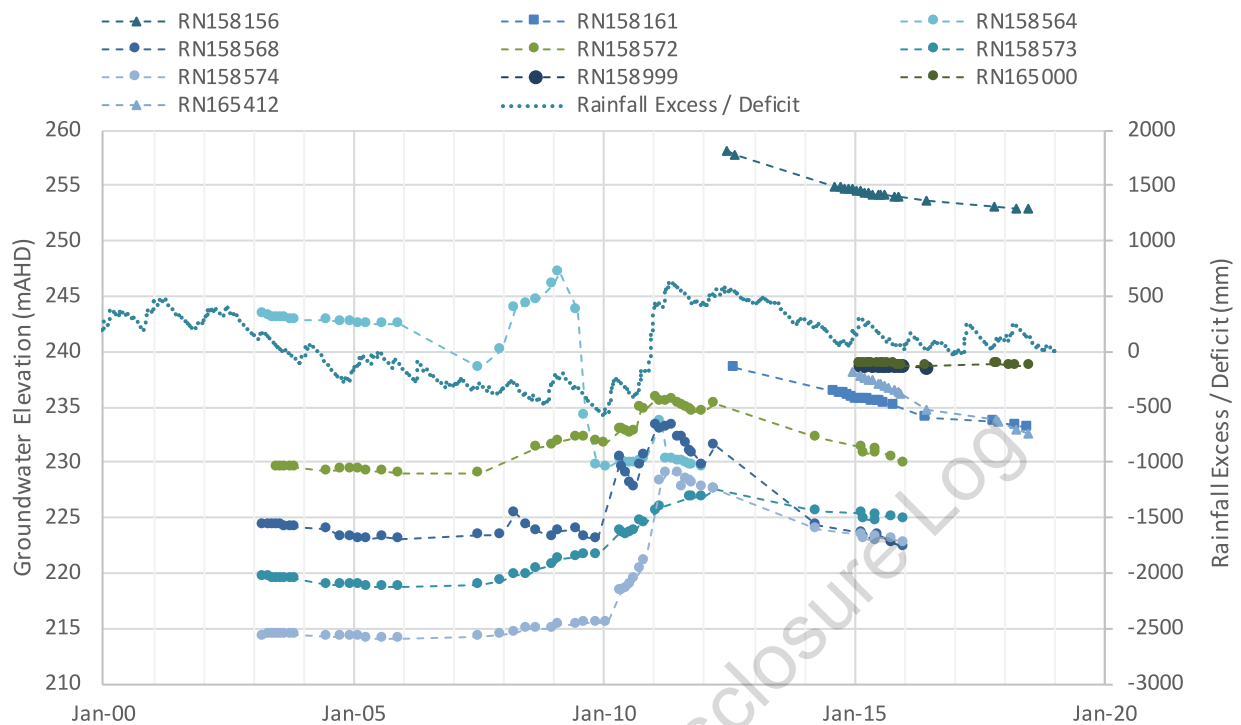


Figure 7.13 Basalt Groundwater Elevation Hydrograph (Elevation 210 to 260 mAHD)

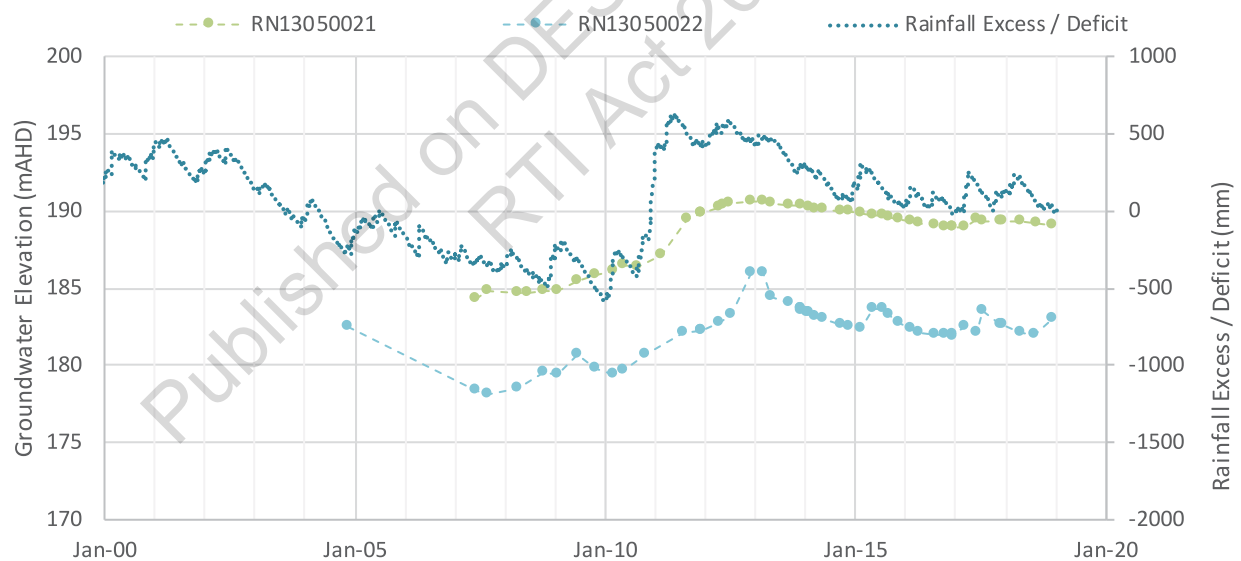


Figure 7.14 Basalt Groundwater Elevation Hydrograph (Elevation 170 to 200 mAHD)

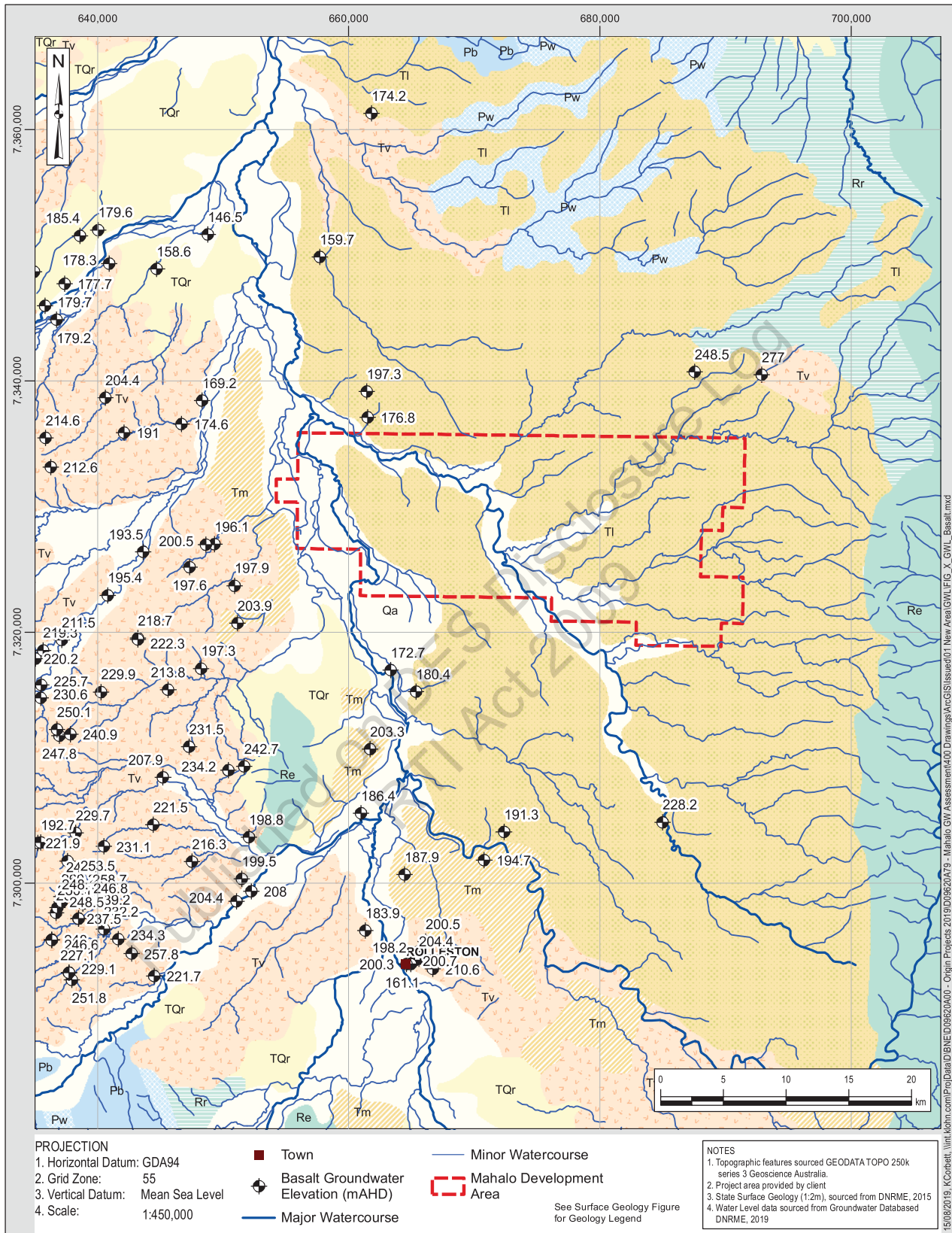


Figure 7.15 Basalt Groundwater Elevations (GWDB Data)

Rewan Group

Groundwater elevations recorded at three monitoring bores screened within the Rewan Group are presented in Figure 7.16. The groundwater elevations range between ~177 and ~223 mAHD.

The hydrograph for RN13050015 indicates some influence from the rainfall events, however the correlation with the overall trend is weak. Groundwater elevations monitored at RN13050018 remained static over the monitoring period, and it is not known whether this is the true groundwater elevation or if there is an issue with this monitoring bore that is compromising the groundwater levels observed in it. Based on the bore construction information, the recorded groundwater elevation indicates a water column height of ~0.7 m within the bore.

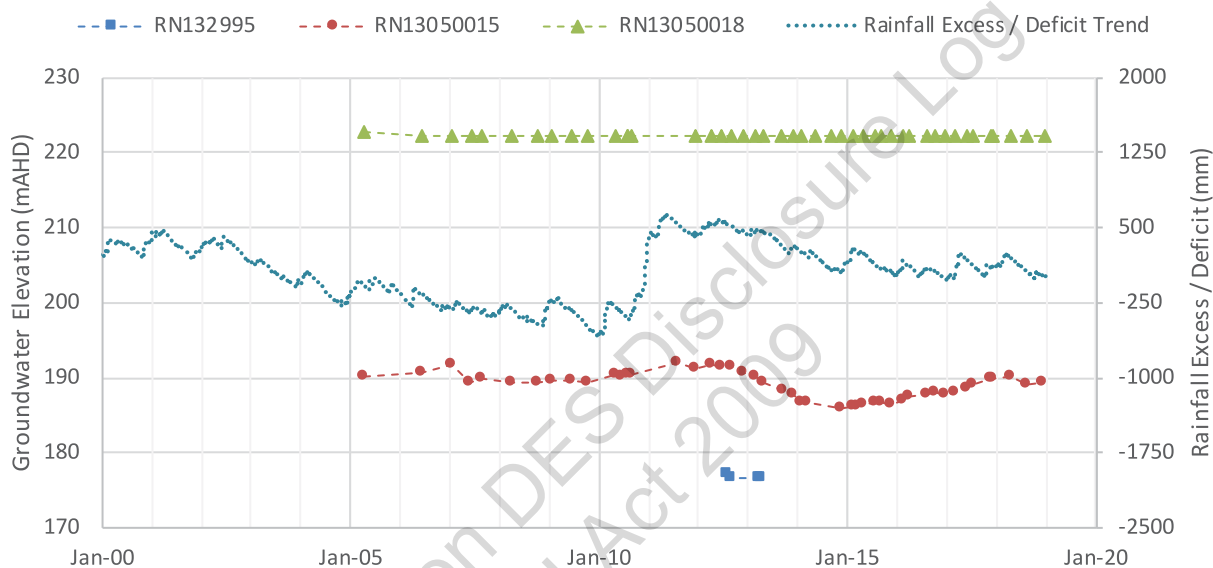


Figure 7.16 Rewan Group Groundwater Elevation Hydrograph

Bandanna Formation

There are nine monitoring bores with groundwater elevation data available for the Bandanna Formation (Figure 7.17) in the GWDB (recorded between 2005 and 2018). The majority of these bores were installed to monitor groundwater elevations at the Rolleston Open Cut coal mine, located 21 km southwest of the Mahalo Development Area.

Based on the available data, groundwater elevations range between ~195 and 238 mAHD. There is also some correlation between groundwater levels and the rainfall trend (for RN158567) over the available monitoring period.

The hydrograph for RN158563 shows a decline in groundwater level between 2006 and 2012. This monitoring bore is located adjacent to the open cut operations at the Rolleston mine and shows a response to dewatering associated with the mining activities. The response of groundwater levels to dewatering activities occurs adjacent to the open cut pit (RN158563). Groundwater level drawdown, as a result of mining activities, was not observed at RN158567. This bore is located ~4 km southeast of RN158563 and shows an increasing trend in groundwater elevation during the same period (2008 to 2011).

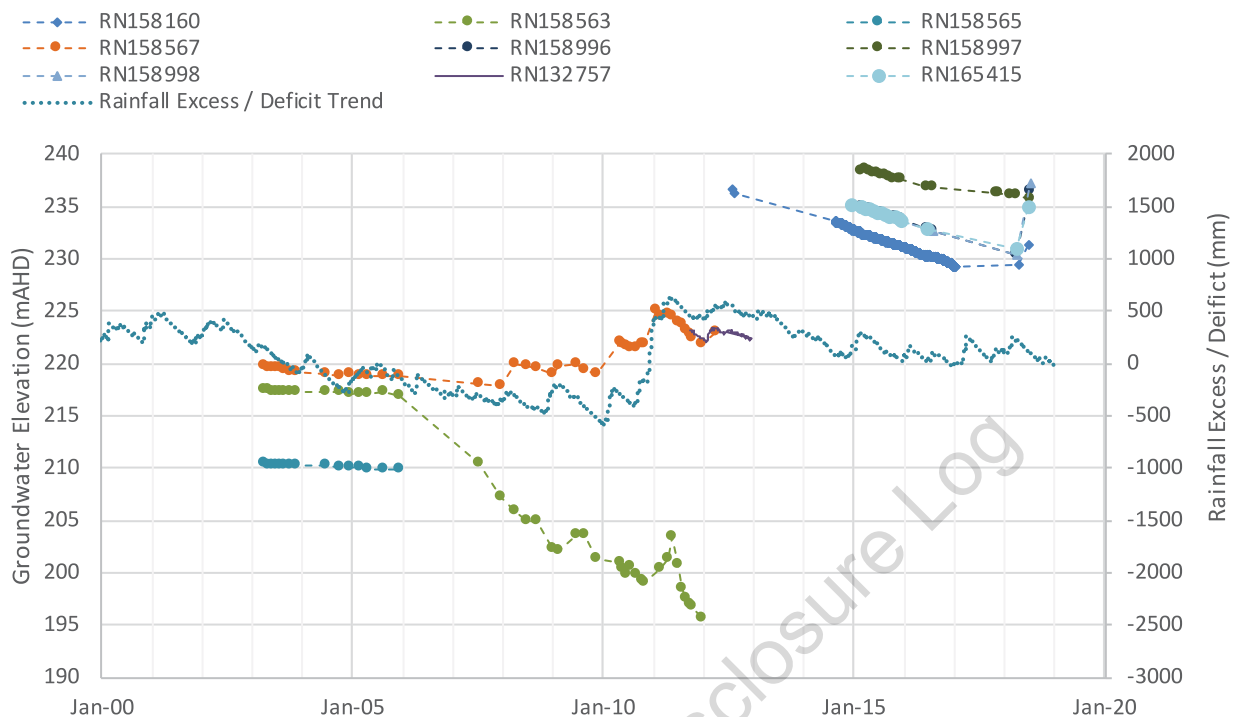


Figure 7.17 Bandanna Formation Groundwater Elevation Hydrograph

Paired Monitoring Sites

There are two monitoring locations to the southwest of the Mahalo Development Area where paired monitoring bores are installed.

RN158563, screened within the Bandanna Formation, is located in close proximity to RN158564, screened within the basalt. The groundwater elevation hydrographs for these two sites are shown in Figure 7.18. The Bandanna Formation groundwater elevation was discussed in the previous section and shows a response to mining activity. The basalt groundwater elevation is ~25 m higher than the Bandanna Formation. The hydrograph shows that there is potentially an initial response within the basalt to drawdown in the Bandanna Formation at this location, with a 4 m water level drawdown in the basalt, compared to 8 m of drawdown in the Bandanna Formation (December 2005 to July 2007). The decline in the basalt is not sustained for the full period presented in the Bandanna Formation response. The climate also exhibited a declining trend during the same period.

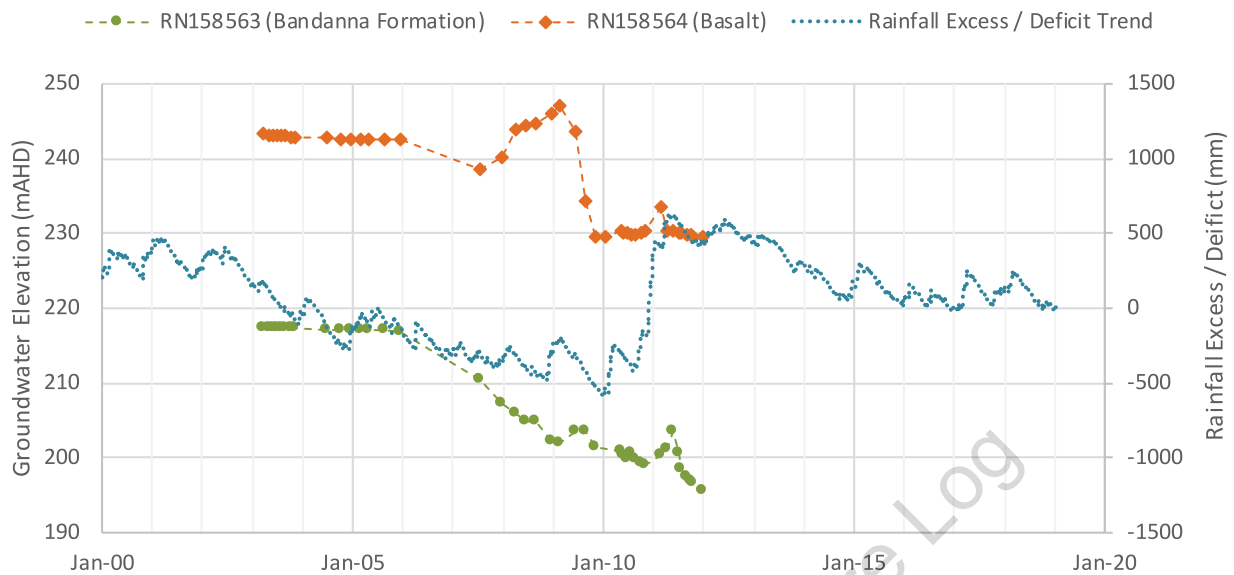


Figure 7.18 Bandanna Formation (RN158563) and Basalt (RN158564) Groundwater Elevation Hydrograph

Figure 7.19 presents hydrographs for a paired site with one bore screened within the alluvium and one within the Bandanna Formation. The groundwater elevation within the alluvium is ~2 m higher than the Bandanna Formation, suggesting a downwards gradient from the alluvium. As discussed earlier, the groundwater response to rainfall infiltration within the alluvium is almost instantaneous. When comparing with the Bandanna Formation response for the same period, the groundwater elevation within the Bandanna Formation also responds to the event, however does not decline in the month after (as shown in the alluvium) and continues to reach a peak elevation ~two months after the rainfall event. The hydrographs also highlight the confined nature of the Bandanna Formation, with the groundwater elevation located above the top of the unit (noting that the screened interval is between 74 and 80 mbGL).

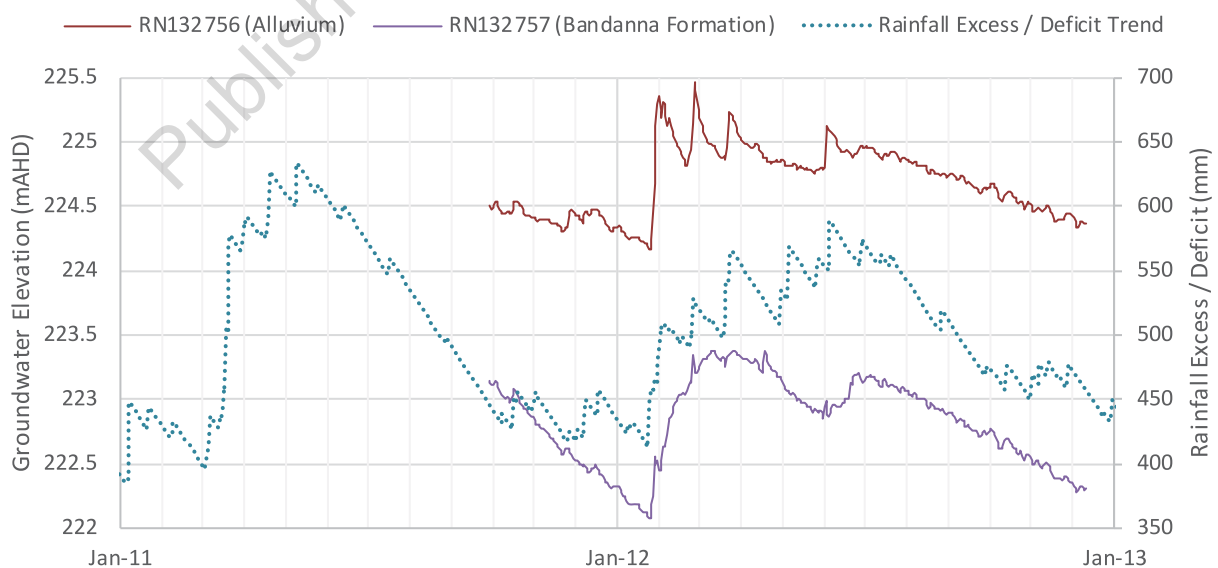


Figure 7.19 Alluvium (RN132756) and Bandanna Formation (RN132757) Groundwater Elevation Hydrograph