Central Queensland Coal Project

Chapter 16 – MNES

Supplementary Environmental Impact Statement

CDM Smith

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Central Queensland Coal Project

Chapter 16 – Matters of National Environmental Significance

20 December 2018

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16 Matters of National Environmental Significance

Central Queensland Coal Pty Ltd (Central Queensland Coal) and Fairway Coal Proprietary Limited (Fairway Coal) (the joint Proponents), propose to develop the Central Queensland Coal Project (the Project). As Central Queensland Coal is the senior proponent, Central Queensland Coal is referred to throughout this Environmental Impact Statement (EIS). The Project comprises the Central Queensland Mine where coal mining and processing activities will occur along with a train loadout facility (TLF). It is intended that all aspects of the Project will occur as a single resource activity, authorised by mining leases and a site-specific Environmental Authority (EA).

The Project is located near the Central Queensland Coast approximately 130 kilometres (km) northwest of Rockhampton. The Project will be located within Mining Lease (ML) 80187 and ML 700022, which are adjacent to Mineral Development Licence (MDL) 468 and Exploration Permit for Coal (EPC) 1029, both of which are held by the Proponent.

The Project will involve mining a maximum combined tonnage of up to 10 million tonnes per annum (Mtpa) of semi-soft coking coal (SSCC) and high grade thermal coal (HGTC). Development of the Project is expected to commence in 2019 and extend for approximately 19 years until the current reserve is depleted.

Access to the Project will be via the Bruce Highway. The Project will require the hiring of approximately 275 employees during construction and between 100 (2019) to 500 (2030) employees during operation, with the workforce reducing to approximately 20 people during decommissioning. The Project labour resources will be sourced from within the general local area (Marlborough, Ogmore, St Lawrence, Clairview, Yaamba and The Caves) as a daily commute workforce. Where there are shortages in the number of the operational workforce being drawn from the local area, workers will be sourced from the local region including from Yeppoon, Rockhampton and Emu Park. Central Queensland Coal and Fairway Coal will manage the Project construction and operations with the assistance of contractors.

This chapter of the EIS describes the potential impacts associated with the Project on Matters of National Environmental Significance (MNES) as set out under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). The referral for this Project was submitted to the Department of Environment and Energy (DotEE) on 22 December 2016 (EPBC 2016/7851). This chapter of the EIS has been prepared in response to a decision made under section 75 of the EPBC Act by DotEE on 3 February 2017 to declare the Project a controlled action. Controlling provisions include:

- World Heritage properties (sections 12 and 15A);
- National Heritage places (sections 15B and 15C);
- Listed threatened species and communities (sections 18 and 18A);
- Listed migratory species (sections 20 and 20A);
- Great Barrier Reef Marine Park (sections 24B and 24C); and
- Water resources in relation to large coal mining development (sections 24D and 24E).

The EPBC Act provides for the protection of the environment, in particular MNES. Under the EPBC Act, a person must not take an action that has, will have, or is likely to have a significant impact on any MNES without approval from the Australian Government Environment Minister or the Minister's delegate. A proposed action likely to significantly impact MNES should be referred, to obtain a decision on whether a proposed action will need formal assessment and approval under the EPBC Act.

For this Project, the EIS process is accredited under the bilateral assessment between the Commonwealth and Queensland Governments. As such, the EIS process under the EPBC Act will run concurrently with the Queensland EIS process.

The following information in this chapter addresses the requirement for a stand-alone MNES assessment as detailed in the Project's Terms of Reference (ToR) published by the Queensland Department of Environment and Science (DES) [formerly known as the Department of Environment and Heritage Protection (EHP)] in April 2017. The chapter summarises the results of desktop and field-based assessments of the Project area as part of terrestrial and aquatic ecology, and surface and groundwater assessments using the results to define the potential impacts to the MNES of concern.

This chapter has been updated since the EIS taking into account comments received during the submission period. Comments received during the submission period included:

- Consideration of export volumes at Dalrymple Bay Coal Terminal;
- Further description of the Outstanding Universal Values of the GBRWHA as they relate to Broad Sound;
- Further information required on the potential occurrence in the Project area or surrounds (including Broad Sound) of EPBC Act-listed species (threatened and migratory) including Red Goshawk, large marine fauna and migratory shorebirds;
- Further information on the potential impacts of groundwater drawdown to MNES values associated with the Project area and proposed mitigation measures;
- Clarification of potential impacts on MNES fauna species due to vegetation clearing; and
- Clarification on the potential use of the Mamelon property as an environmental offset site for impacts associated with the Project.

The following provides updated information to that provided in the EIS, in response to the submissions relating to EIS Chapter 16 – MNES. Appendix A13 includes the full details of all submissions received for the Project.

16.1 Title of the Action

The title of the action is the Styx Coal Mine Project (EPBC ref 2016/7851).

16.2 Proponent

The Project will be developed and operated by Central Queensland Coal and Fairway Coal. Both companies are associates of Waratah Coal Pty Ltd (Waratah Coal), which has over 25 years' experience developing, funding and managing a range of major resource projects. Waratah Coal is an Australian coal exploration and coal development company. Waratah Coal holds extensive mining concessions within the rich mineral basins of Laura, Bowen, Galilee, Surat, Moreton, Maryborough, Nymboida and the Northern Territory, in addition to the Styx Basin.

Waratah Coal has been operating for over 10 years and has formed major international alliances in China and domestically during this time. From 2005 to 2009, Waratah Coal was dual-listed on the Toronto Stock Exchange and Australian Stock Exchange. In 2009, Waratah Coal was privatised and incorporated into Mineralogy Pty Ltd. Waratah Coal is committed to the economic development of regional growth in Queensland through the growth of mineral wealth while operating with an excellent record in the area. Waratah Coal aims to be a valued member of the local community and to openly engage and build trust and respect in Queensland over time.

Fairway Coal owns MDL 468 which will form the Project. Both Fairway Coal and Central Queensland Coal are registered as suitable operators with DES (#701901 and #686364, respectively), meaning the company is registered as being suitable to carry out industrial activities requiring an EA.

The contact details for Central Queensland Coal are:

Address:	Level 17, 240 Queen Street Brisbane Qld 4001
Postal Address:	GPO Box 1538 Brisbane Qld 4001
Telephone:	0418872181
Email:	nharris@cqcoal.com

Further information regarding the overarching company, Waratah Coal, can be obtained from the following website: http://waratahcoal.com/

16.3 Environmental Health and Safety Policy

Central Queensland Coal recognises its responsibility for implementing sound environmental stewardship of the environment in which it works. We will care for and manage the environment to deliver better environmental practice outcomes. Our commitment extends to all of those who work with and for Central Queensland Coal.

Central Queensland Coal recognise that operational success depends heavily on a shared commitment to setting and maintaining a high standard of cultural heritage, community, environment and safety performance. Central Queensland Coal is committed to supporting and strengthening local community relations with landowners and interested parties who have interests within or surrounding the Project. This will be achieved by managing the correct balance between pursuing the company's mining interests and preserving the interests of existing landholders as outlined in their Environmental Management System (EMS) which is being developed and is consistent with ISO14001 principles.

In executing our environmental policy, we will:

- Comply with all legislation and regulations;
- Incorporate environmental better practice into our core business plans and management processes;
- Provide adequate resources to meet our commitments;

- Train our workforce and contractors to meet our standards;
- Communicate our planned actions, targets and results to all stakeholders;
- Identify, minimize and mitigate environmental disturbance throughout our business;
- Measure our performance;
- Enforce our standards with partners and contractors; and
- Improve our performance through continuous planning.

This environmental policy confirms the company's intent towards creating and implementing sound environmental management practices. All management, employees and contractors of Fairway Coal will uphold and implement this policy.

The EMS will include specific operating procedures that incorporate organisational structures, planning activities, responsibilities, site practices, procedures, processes, and identify resources required for the development, implementation, review and maintenance of the safety and health policy.

As part of this process Central Queensland Coal is nominated as responsible for endorsing and approving all mitigation measures and environmental monitoring programs outlined in this document.

Neither Fairway Coal or Central Queensland Coal have proceedings against them under any law of the Commonwealth or State relating to the protection of the environment or the conservation and sustainable use of natural resources.

16.4 The Central Queensland Coal Project

16.4.1 Project Justification

The Project will produce both coking (SSCC) and thermal (HGTC) coal for export. Thermal and coking coals are in demand globally to generate electricity and steel, respectively. The following sections consider coal pricing forecasts and future demand for SSCC and HGTC.

16.4.2 Value of Coal Exported

The Project is anticipated to produce an estimated 49.3 million tonnes of semi-soft coking and high-grade thermal coal over the life of the Project. The majority of coal produced is anticipated to be semi-soft coking coal, with high grade thermal coal to be produced only during 2029 and 2030 of the Project.

The exchange rate outlook for Australia is anticipated to remain, at least in the medium term, at approximately ~US$0.76. The price of semi-soft coking coal is anticipated to decrease marginally from US$130 per tonne to approximately US$125 per tonne (or AU$171 per tonne to approximately AU$164 per tonne) in the short to medium term. The price of high grade thermal coal is anticipated to remain at approximately US$95 per tonne (or AU$125 per tonne) in the medium term.

Based on the assumed coal prices and exchange rate, the total export value of the coal produced is estimated to be AUD$7.9 billion over the life of the project. Assuming Queensland coal mining royalty rates remain unchanged throughout the life of the Project, this will yield royalties of approximately $738.8 million over the life of the Project.

It is pertinent to note that both coal prices and exchange rates are subject to fluctuations and shocks, so these estimates are intended to be indicative only, based on the current trade environment.

The anticipated production, export value and royalties generated over the life of the Project, based on export price forecast data is presented in Table 16-1.

Table 16-1 Anticipated production, export value and Queensland government coal mining royalties

Year	Production of Saleable Coal (Tonnes)		Export Price (AUD/t)		Export Value ($m AUD)			Royalties ($m)
	HGTC	SSCC	HGTC	SSCC	HGTC	SSCC	Total	Total
2019	-	776,547	$125	$171	-	$132.8	$132.8	$12.7
2020	-	1,557,629	$125	$171	-	$266.4	$266.4	$25.6
2021	-	1,585,876	$125	$171	-	$271.3	$271.3	$26.0
2022	-	1,550,328	$125	$171	-	$265.2	$265.2	$25.4
2023	-	3,103,832	$125	$164	-	$510.5	$510.5	$47.9
2024	-	3,088,214	$125	$164	-	$507.9	$507.9	$47.6
2025	-	3,101,055	$125	$164	-	$510.0	$510.0	$47.8
2026	-	3,064,975	$125	$164	-	$504.1	$504.1	$47.3
2027	-	3,124,445	$125	$164	-	$513.9	$513.9	$48.2
2028	-	3,180,912	$125	$164	-	$523.2	$523.2	$49.1
2029	950,000	4,715,467	$125	$164	$118.8	$775.6	$894.3	$82.3
2030	3,800,000	4,582,679	$125	$164	$475.0	$753.7	$1,228.7	$109.1
2031	-	3,177,845	$125	$164	-	$522.7	$522.7	$49.0
2032	-	3,144,760	$125	$164	-	$517.2	$517.2	$48.5
2033	-	1,538,000	$125	$164	-	$253.0	$253.0	$23.7
2034	-	1,542,739	$125	$164	-	$253.7	$253.7	$23.8
2035	-	1,553,762	$125	$164	-	$255.6	$255.6	$24.0
2036	-	1,573,366	$125	$164	-	$258.8	$258.8	$24.3
2037	-	241,226	$125	$164	-	$39.7	$39.7	$3.7
2038	-	-			-	-	-	-
Total	**4,750,000**	**46,203,657**	**-**	**-**	**$593.8**	**$7,635.3**	**$8,229.0**	**$766.0**

Note: HGTC – High Grade Thermal Coal, SSCC – Semi Soft Coking Coal

16.4.2.1 Alternative Scenario

An additional independent forecast of coal export prices has been provided to inform an alternative scenario, and thus a likely range of values, for the Central Queensland Coal Project export valuation and subsequent Queensland Government royalties estimate.

The alternative SSCC export price scenario, is based on a historic average ratio to hard coking coal prices. Since the introduction of quarterly price contracts in April 2010, the price of SSCC has maintained an average of 72.8% of the price of hard coking coal and this relationship is expected to hold in the future. The thermal coal price forecast is based on understanding of market supply and demand fundamentals up to 2022, after which point it has been indexed with inflation.

Coal Price Forecast – Semi-soft Coking Coal and High Quality Thermal Coal

Semi-soft coking coal (SSCC) is used with hard coking coal to make coke, which in turn is used to produce steel. While hard coking coal is a necessary input into the production of coke due to its coking properties, semi-soft coal is not necessary for technical reasons, but provides a more economic blend of coke, and therefore is widely used across the coke and steel sectors.

As a result, the prices of hard coking coal and SSCC are closely linked, generally moving in similar directions, with semi-soft coal priced at a discount to hard coking coal. While in the short term this discount fluctuates, over a longer period it has consistently averaged 72.8%.

To forecast prices for SSCC, hard coking coal prices have been forecast, and then applied the historical ratio of SSCC prices to hard coking coal prices to forecast the SSCC price across the period 2018-43. The results are discussed below. A summary of the SSCC price forecast is presented at Table 16-2.

Table 16-2 Semi-soft coking coal price forecast

US$/t	2018	2023	2028	2033	2038	2043
Semi-soft Coking Coal	146	104	118	132	149	168

Thermal coal is used to produce electricity. It is priced independently of coking coal. Since 2009, the average monthly prices of Newcastle benchmark thermal coal (6,000 kcal/kg NAR basis) has been $US83.49. The average price in 2017 was US$88.20 and in January 2018, prices were consistently above $US100/t.

The forecast prices for high quality thermal coal across the period 2018-43, are discussed below. A summary of the high quality thermal coal price forecast is presented at Table 16-3.

Table 16-3 High quality thermal coal price forecast

US$/t	2018	2023	2028	2033	2038	2043
High Quality Thermal Coal	146	104	118	132	149	168

Coking Coal - Historic Pricing Dynamics

In April 2010 (the start of the Japanese Financial Year), coking coal price contracts moved from an annual basis to a quarterly basis across the industry. Since then, most metallurgical coal – including hard coking coal, semi-soft coal and pulverised coal injection (PCI) coal - has been sold on a quarterly price basis. This has predominantly been driven by the rise of China and India as the largest markets for coking coal imports over the last decade, which has had broader implications than simply changing trade flows and patterns.

China and India both have domestic metallurgical coal production (in China's case a significant volume) which competes against imports. Therefore, some Chinese consumers only buy imported coal when it is opportune to do so, generally through spot contracts. As a result, there is much more spot buying of coking coal compared to a decade ago. This has been facilitated or encouraged by the move to spot price mechanisms from suppliers, led by BHP Billiton, the largest exporter of coking coal. This resulted in the development of a spot price index in early 2011.

For the purposes of this forecast, historical quarterly prices have been considered for analysis, as they are the most transparent and are still widely applied. Over nearly eight years of quarterly contract pricing, contract prices for hard coking coal have averaged US$177/t, with a minimum of US$81/t and a maximum of US$330/t, as shown at Figure 16-1.

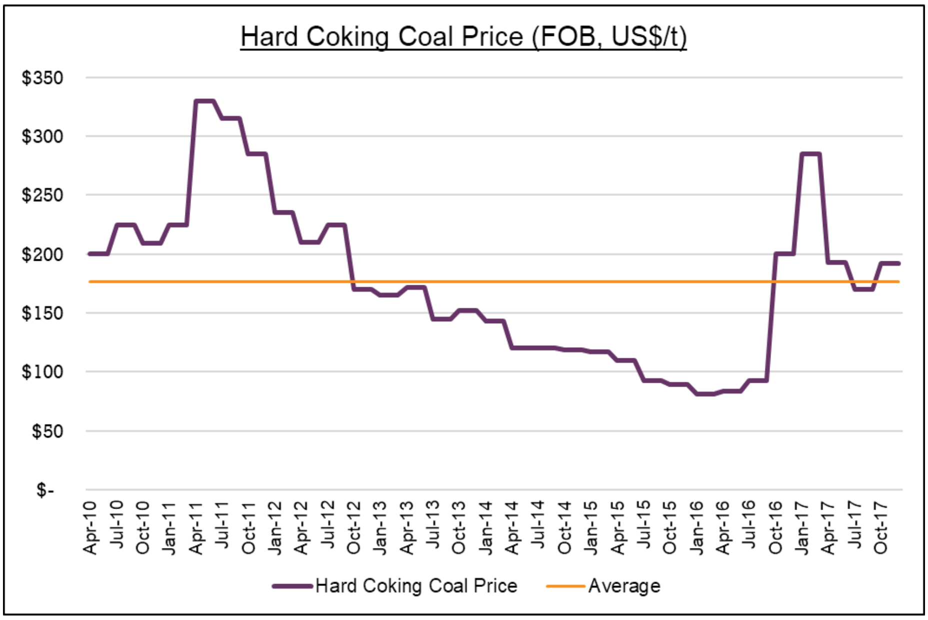

Figure 16-1 Hard coking coal prices (Free on Board (FOB), US$/t

It should be noted that even if annual pricing structures are included, and a 10-year sample is taken from 2008-17, the average hard coking coal price remains high at US$182/t. These high average prices over a sustained period illustrate the relative scarcity of hard coking coal.

In terms of historical semi-soft coal pricing, over the same period (starting in April 2010 when quarterly price contracts commenced), prices have averaged US$127/t, with a minimum of US$66/t and a maximum of US$264/t, as shown at Figure 16-2.

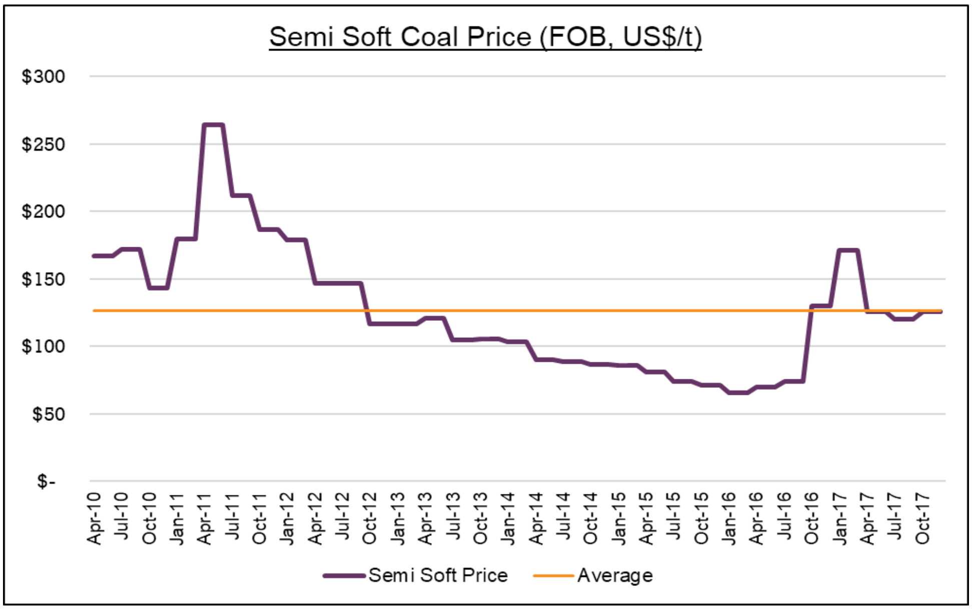

Figure 16-2 Semi soft coking coal prices FOB, US$/t

As with hard coking coal, the average price over a 10-year period from January 2008 to December 2017 (including some annual contract periods) is slightly higher than the average since April 2010, at US$131.80/t.

As both hard coking coal and semi-soft coal are used in the coke making process and are to a point substitutes for each other, movements in their prices tend to mirror each other (see Figure 16-3).

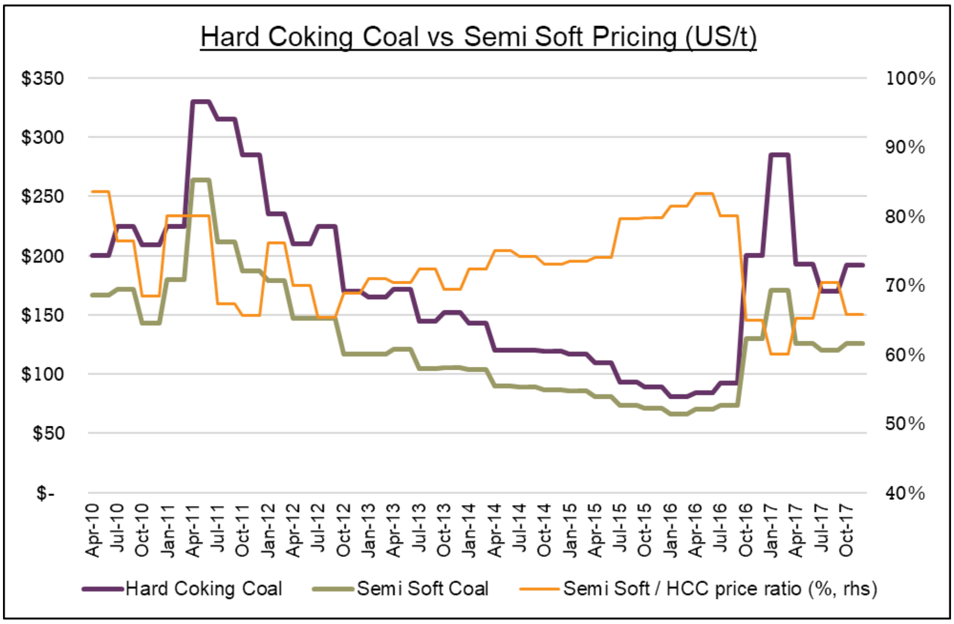

Figure 16-3 Hard coking coal versus semi-soft coking coal prices US$/t

The ratio of semi-soft to hard coking coal prices has averaged 72.8% since the introduction of quarterly price contracts in April 2010. This ratio has ranged from 60% to 84% across the period and is generally lower in periods of very high hard coking coal pricing such as October 2016 to March 2017. As hard coking coal prices weaken, the ratio of semi-soft prices to hard coking coal prices increases – this is clearly illustrated in the period from 2013-2016. This acts as a self-regulating floor for both supply and prices of semi-soft coal.

Semi-Soft Coal Price Forecast

The price forecast for semi-soft (and hard coking coal) for 2018-43 is presented at Table 16-4. To forecast semi-soft prices, the historic average ratio of semi-soft to hard coking coal prices (72.8%) has been applied to the hard coking coal price forecast. It is quite possible that SSCC prices will range around this average ratio (72.8%) over the 25-year forecast period, possibly as widely as the range identified between 2010 and 2017 above (60.0% to 83.5%), based on the prevailing market conditions at the time.

The annual price forecast for semi-soft coal for 2018-43 is shown at Table 16-4 (and hard coking coal as a reference point). All prices are in nominal dollars and are rounded to the nearest dollar.

Table 16-4 Semi-soft coking coal price forecast, 2018-43

Year	HCC Price Forecast (US$/t)	Semi-soft Price Forecast (US$/t)
2018	200	146
2019	175	127
2020	150	109
2021	140	102
2022	140	102
2023	143	104
2024	147	107
2025	150	109
2026	154	112
2027	158	115
2028	161	118
2029	165	120

Year	HCC Price Forecast (US$/t)	Semi-soft Price Forecast (US$/t)
2030	169	123
2031	173	126
2032	177	129
2033	182	132
2034	186	135
2035	191	139
2036	195	142
2037	200	145
2038	205	149
2039	210	153
2040	215	156
2041	220	160
2042	225	164
2043	230	168

The forecast is based on the collation of broker and bank forecasts of hard coking coal prices. The range of these price forecasts (as at January 2018) is presented at Figure 16-4.

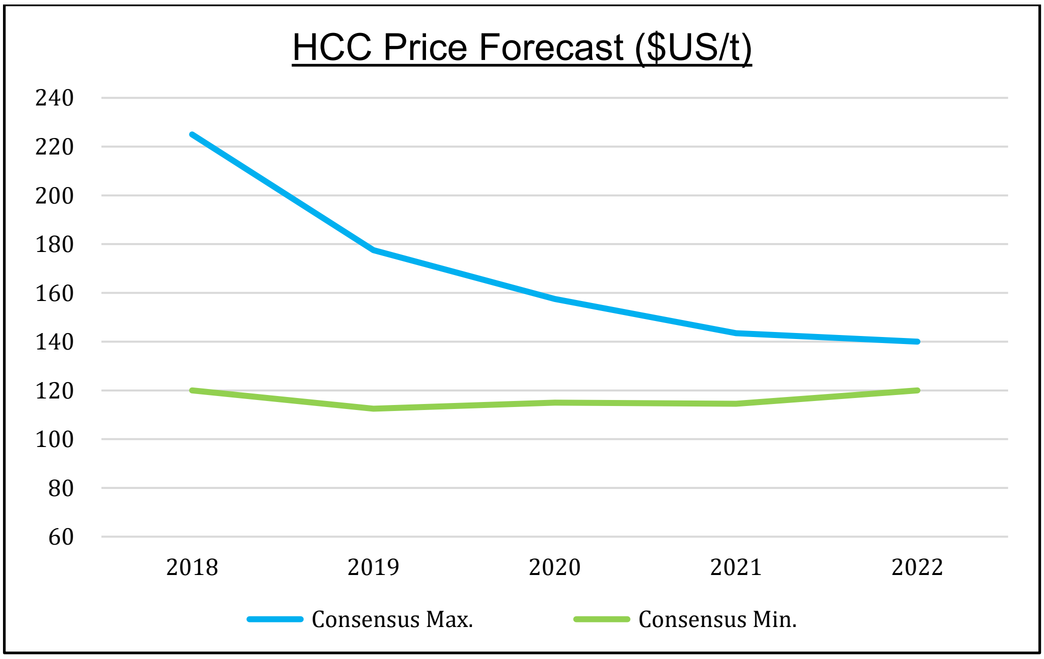

Figure 16-4 Hard coking coal price forecast US$/t

A consensus view of SSCC forecasts is not available. It should also be noted that the consensus view changes regularly as banks and brokers update their forecasts. Often, the forecasts follow market movements and therefore there is a lag effect.

A chart of the range of consensus views along with the SEIS hard coking price forecast is presented at Figure 16-5. Note that beyond 2022, the SEIS forecast is increased by inflation each year (assumed to be 2.4%).

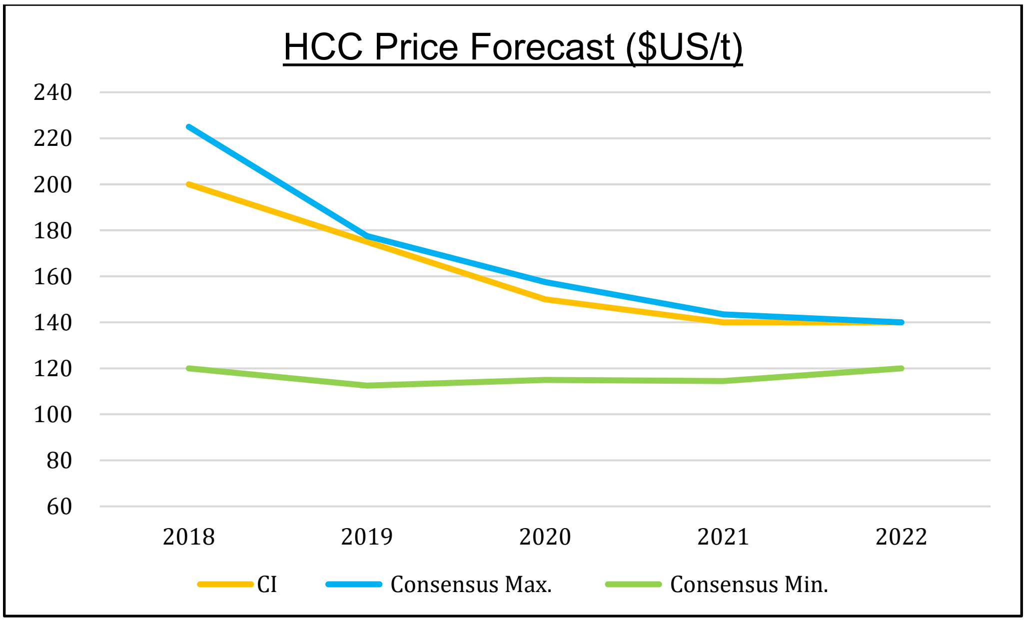

Figure 16-5 Hard coking coal price forecast US$/t (including SEIS forecast)

Central Queensland Coal Semi-Soft Coal

To accurately assess the potential price for the Project's semi-soft coal, it is necessary to understand the relative coal quality of the Project's coal compared to established benchmarks. Based on a range of coal quality parameters shown at Table 16-5 (provided by Waratah Coal in June 2017), it was assessed that The Project's SSCC could be classified as a Newcastle-type SSCC and therefore be priced as a Newcastle SSCC. As can be seen from Table 16-5, the Project's coal quality is consistently within the range of traded Newcastle SSCC.

Table 16-5 Relative coal quality semi soft coking coal

Coal	Total Moisture %	Ash (%)	Volatile Matter (%)	Phosphorus (%)	Sulphur (%)
NSW SS: min.	9.0	5.0	33.5	0.00	0.45
NSW SS: max.	12.0	10.5	39.0	0.07	1.10
Central QLD SS	10.0	6.5	32.0	0.01	0.55

While there is no benchmark specification for SSCC, the Project's coal properties generally fall within the range of traded SSCC through Newcastle. The Project has; however, a lower than average volatile matter % and a lower ash content, both of which will be viewed favourably by customers. Overall, Central Queensland Coal is of the view that the Project's SSCC will be priced in line with other Newcastle SSCC.

Thermal Coal – Historic Pricing Dynamics

Like hard coking coal, seaborne thermal coal was historically priced on an annual contract basis, agreed to between Japanese power utilities and Australian coal producers for each Japanese financial year (April – March). However, the larger size of the seaborne thermal coal market (approximately three times the hard coking coal seaborne market) and the rapid rise of China and India as major importers has resulted in a significant volume of thermal coal being traded on a spot or index basis.

In 2009, the combined market share of China and India jumped sharply to around 20%, up from 10% in 2008, and it has stayed well above 20% ever since. As well as the volume impact, this had a significant impact on how thermal coal was traded, with the traditional Japanese annual contract structure becoming less important, while India and China purchased large volumes of imports that were priced on an index or spot basis.

Average monthly prices of Newcastle benchmark thermal coal (6,000 kcal/kg NAR basis) since 2009 are presented at Figure 16-6.

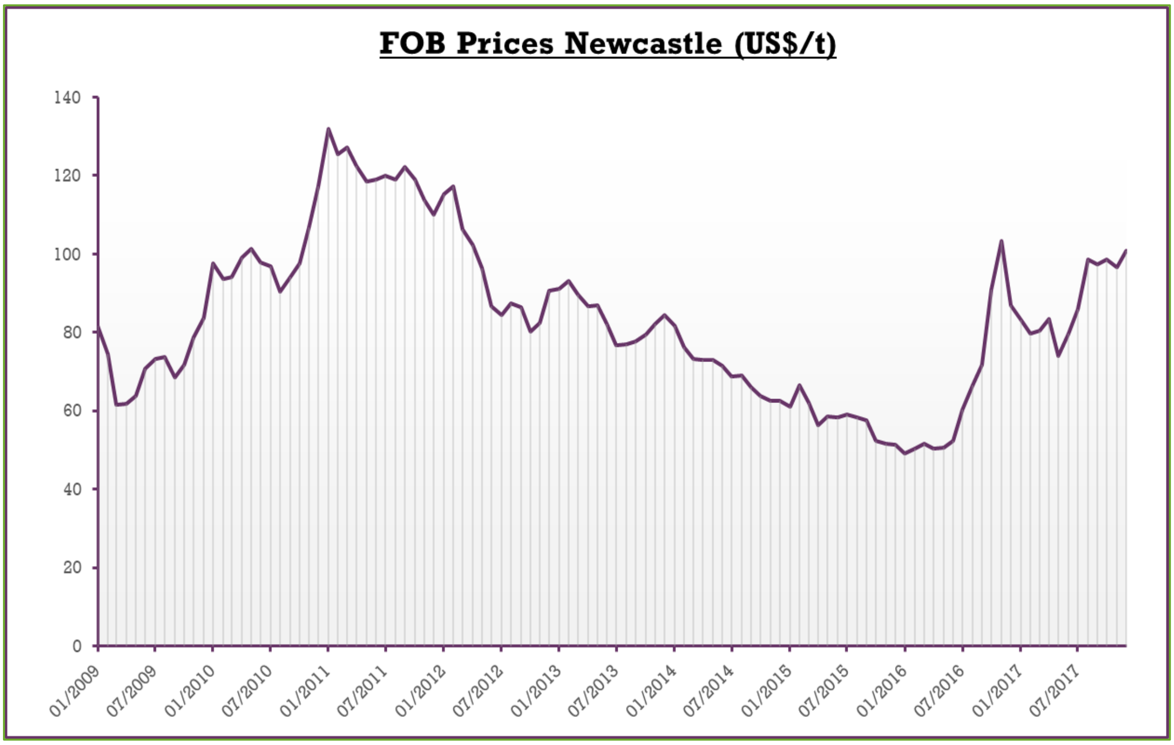

Figure 16-6 Average monthly prices of Newcastle benchmark thermal coal US$/t

For the purposes of the SEIS forecast, historical monthly average prices have been used for analysis, as they are highly transparent and cover the analysis period. The average price over this nine year period was US$83.49/t. For reference, the average price over an eight year period to December 2017 was $US84.80, and the average price over a 10-year period to December 2017 was US$87.98.

Thermal Coal Price Forecast

The price forecast for Newcastle benchmark thermal coal (6,000 kcal/kg NAR basis) for 2018-43 is shown at Table 16-6. The forecast is based on our understanding of market supply and demand fundamentals out to 2022, after which the price is indexed for inflation.

The actual average Newcastle benchmark thermal coal price for 2017 was US$88.20/t. Reported prices in January 2018 were all above US$100/t although the monthly average was not available at time of this report.

Table 16-6 Price forecast for Newcastle benchmark thermal coal (US$/t)

Year	Thermal Coal Price Forecast (US$/t)
2018	87
2019	87
2020	84
2021	80
2022	76
2023	78
2024	80
2025	82
2026	84
2027	86
2028	88
2029	90
2030	92
2031	94
2032	96
2033	99
2034	101
2035	103
2036	106
2037	108
2038	111
2039	114
2040	116
2041	119
2042	122
2043	125

The forecast is based on the collation of broker and bank forecasts of thermal coal prices. The range of these price forecasts (as at January 2018) is presented at Figure 16-7.

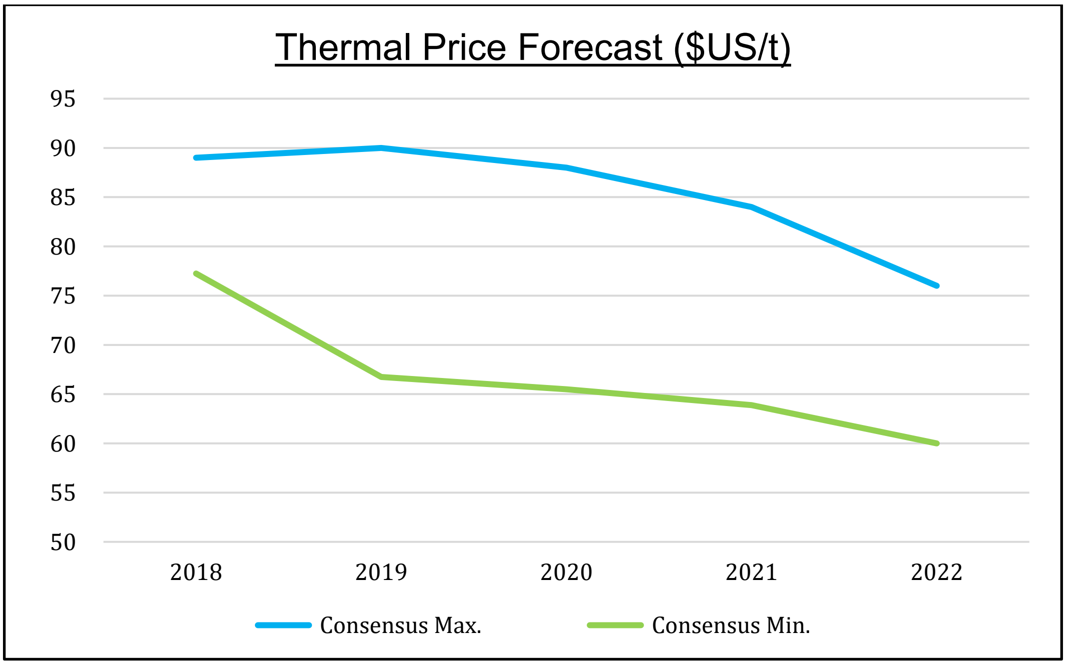

Figure 16-7 Average monthly prices of Newcastle benchmark thermal coal US$/t

The consensus view changes regularly as banks and brokers update their forecasts. Often, the forecasts follow market movements and therefore there is a lag effect. For example, thermal coal prices rose strongly in the back half of 2016 and have stayed elevated since and the consensus average price for 2019 has risen US$13/t from January 2017 to January 2018 (US$65/t to US$78/t), and the consensus average price for 2020 has risen US$8/t over the same period (US$66/t to US$74/t).

A chart of the range of consensus views along with the SEIS thermal coal price forecast is presented at Figure 16-8. Note that beyond 2022, the forecast is increased by inflation each year (assumed to be 2.4%).

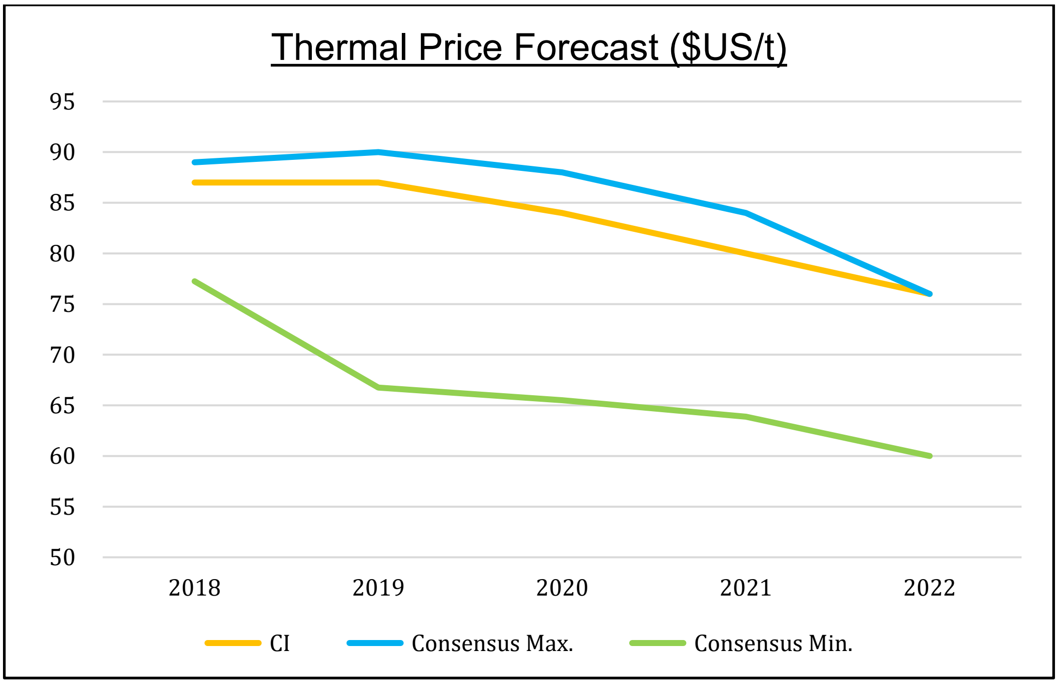

Figure 16-8 Thermal coal price forecast US$/t (including SEIS forecast)

Central Queensland Thermal Coal

To accurately assess the potential price for the Project's thermal coal, it is necessary to understand the relative coal quality of the Project compared to established benchmarks. Based on a range of coal quality parameters shown at Table 16-7 (based on a December 2011 coal quality report by Salva Resources), it is considered that the Project's thermal coal could be classified as a Newcastle-type thermal coal and therefore its pricing could be linked to Newcastle thermal coal. As can be seen from the coal quality data shown at Table 16-7, the Project's thermal coal quality is consistently within the range of traded Newcastle thermal coals.

Table 16-7 Relative coal quality thermal coal

Coal	Calorific Value (Net as Received)	Ash (%)	Volatile Matter (%)	Total Moisture (%)	Sulphur (%)
Newcastle thermal: min.	5,850	n/a	27.0	n/a	n/a
Newcastle thermal: max.	n/a	14.0	35.0	15.0	0.75%
Central Queensland Thermal	6,473 (Gross as Received)	9.3	28.6	10.0	0.51%

The Project's thermal coal has low ash levels and high energy content, the latter around 5% above the standard Newcastle specification. Both characteristics will be viewed favourably by customers.

The Project's thermal coal also has a moderate sulphur content, while its moisture content and volatile matter are well within acceptable ranges for Newcastle-specification thermal coal.

Based on the coal quality data, it is expected that the Project's thermal coal would be priced in line with Newcastle thermal coal. It is possible; however, that the Project's thermal coal may receive a small premium to Newcastle benchmark pricing due to its favourable ash and energy levels. The Commodity Insights price forecast for thermal coal and SSCC which has been used to inform the alternative export value and Queensland Government royalties scenario are presented in Table 16-8.

Table 16-8 Thermal coal and semi-soft coking coal price forecast, 2018-2037

Year	USD/t		AUD/t	
	TC	SSCC	TC	SSCC
2018	$87	$146	$114	$192
2019	$87	$127	$114	$167
2020	$84	$109	$111	$143
2021	$80	$102	$105	$134
2022	$76	$102	$100	$134
2023	$78	$104	$103	$137
2024	$80	$107	$105	$141
2025	$82	$109	$108	$143
2026	$84	$112	$111	$147
2027	$86	$115	$113	$151
2028	$88	$118	$116	$155
2029	$90	$120	$118	$158
2030	$92	$123	$121	$162
2031	$94	$126	$124	$166
2032	$96	$129	$126	$170
2033	$99	$132	$130	$174
2034	$101	$135	$133	$178
2035	$103	$139	$136	$183
2036	$106	$142	$139	$187
2037	$108	$145	$142	$191

Source: Central Queensland Coal

Note: TC - Thermal Coal, SSCC - Semi-soft coking coal

The annual coal price forecast for thermal coal and SSCC was used to inform calculations of the export value of the Project's operations and the subsequent Queensland Government royalties expected to be generated. The results of analysis are reported in Table 16-9. Using the coal price forecasts discussed above it can be seen that the anticipated export prices are significantly lower between 2018 and 2030, though become marginally higher between 2031 and 2033, relative to the Waratah Coal forecasts.

This necessarily results in a total export value over the life of the Project that is approximately $494.6 million (AUD) lower than under the original assumptions. Similarly, the expected Queensland Government royalties that will be generated under the Commodity Insights coal price forecast are significantly lower than in the original case, amounting to approximately $62.7 million (AUD).

The alternative coal forecast can be used to provide a range of estimates of the total export value of the Central Queensland Coal Project production and the expected Queensland Government royalties to be generated from these exports.

The two price outlook scenarios suggest that the total value of Central Queensland Coal Project exports will be in the order of $7,781.4 million (AUD) to $8,229.0 million (AUD) and the resulting

Queensland Government royalties generated will be between $703.3 million (AUD) and $766.0 million (AUD) over the life of the Project.

Table 16-9 Production, export value and Queensland government coal mining royalties, commodity insights coal price forecast

Year	Production of Saleable Coal (Tonnes)		Export Price (AUD/t)		Export Value ($m AUD)			Royalties ($m)
	HGTC	SSCC	HGTC	SSCC	HGTC	SSCC	Total	Total
2019	-	776,547	$114	$167	-	$129.8	$129.8	$12.3
2020	-	1,557,629	$111	$143	-	$223.4	$223.4	$19.4
2021	-	1,585,876	$105	$134	-	$212.8	$212.8	$17.9
2022	-	1,550,328	$100	$134	-	$208.1	$208.1	$17.5
2023	-	3,103,832	$103	$137	-	$424.7	$424.7	$36.0
2024	-	3,088,214	$105	$141	-	$434.8	$434.8	$37.4
2025	-	3,101,055	$108	$143	-	$444.8	$444.8	$38.5
2026	-	3,064,975	$111	$147	-	$451.7	$451.7	$39.6
2027	-	3,124,445	$113	$151	-	$472.8	$472.8	$42.0
2028	-	3,180,912	$116	$155	-	$493.9	$493.9	$44.7
2029	950,000	4,715,467	$118	$158	$112.5-	$744.5	$857.0	$76.9
2030	3,800,000	4,582,679	$121	$162	$460.0	$741.7	$1,201.7	$105.5
2031	-	3,177,845	$124	$166		$526.9	$526.9	$49.6
2032	-	3,144,760	$126	$170	-	$533.8	$533.8	$51.0
2033	-	1,538,000	$130	$174	-	$267.1	$267.1	$25.8
2034	-	1,542,739	$133	$178	-	$274.0	$274.0	$26.8
2035	-	1,553,762	$136	$183	-	$284.2	$284.2	$28.3
2036	-	1,573,366	$139	$187	-	$294.0	$294.0	$29.5
2037	-	241,226	$142	$191	-	$46.0	$46.0	$4.7
2038	-	-	-		-	-	-	-
Total	**4,750,000**	**46,203,657**			**$572.5**		**$7,781.4**	**$703.3**

Source: Derived from Commodity Insights 2018

16.4.3 Project Benefits

The Project is predicted to provide a significant contribution to these economic benefits, including employment and a boost to the townships of Ogmore, St Lawrence and Marlborough, as described in detail within Chapter 19A –Economics.

The Project is anticipated to result in a range of beneficial impacts including:

- Economic stimulus to the regional, state and national economies during the construction and operational phases of the project;
- Export revenues from coal produced across the life of the mine is estimated to be in the order of $7.78 billion to $8.23 billion, which assuming royalty rates remain unchanged would yield royalties of approximately $703.3 million to $766.0 million over the life of the mine;
- Increased employment opportunities within Central Queensland which would help to reverse the trend of increasing unemployment within the region; and
- Opportunities for suppliers in the Central Queensland region to support the construction and operation of the Project.

The Project will provide key social and economic benefits to the locality, region and state including flow on business, employment skills and training programs, and royalties and taxes.

16.4.3.1 Flow on Business

A significant proportion of this investment will flow directly into the regional economy from the goods and services required during the construction and operation phases. During the construction stage the predominant economic advantage comes from capital expenditure (CAPEX) on goods and services. This will continue during operations but at a reduced demand. Goods and services expected to be sourced locally and from the region include:

- Consumables (food, beverages etc.) for the workforce;
- Fuel supply and transport;
- Housing;
- Light engineering and engineering support services;
- Professional and technical services;
- Road transport services for consumables, equipment and supplies;
- Tools, plant and equipment;
- Training and personnel management services; and
- Vehicle hire or purchasing.

Ongoing supply lines during the operational phase of the Project are likely to be from regional centres such as Rockhampton and Mackay. As such the flow on effects are expected to benefit these centres through the provision of goods and services. Indirect businesses and infrastructure development are also expected to benefit from the additional personnel in the region. Beyond local and regional suppliers, the Project will also require support from the broader Queensland supply and services base for technical and specialist skills or equipment to deliver and sustain operations.

16.4.3.2 Employment, Skills and Training

Throughout the three phases of the Project (construction, operation and decommission) the Project will provide potential employment opportunities in Ogmore, St Lawrence and Marlborough, in addition to the broader regional area.

During the construction phase employment demand for the project is expected to peak in 2020, resulting in the following employment impacts:

- Central Queensland: Total employment contribution of 117 FTEs, comprising 46 direct FTEs and 71 indirect FTEs;
- Rest of Queensland: Total employment contribution of 52 FTEs, comprising 18 direct FTEs and 34 indirect FTEs; and
- National: Total employment contribution of 53 direct FTEs, comprising 18 direct FTEs and 35 direct FTEs.

Operational employment effects of the project are anticipated to peak in 2030, resulting in the following employment impacts:

- Central Queensland: Total employment impacts of 2,858 FTEs, comprising 1,681 direct FTEs and 1,177 indirect FTEs;

- Rest of Queensland: Total employment impacts of 724 FTEs, comprising 420 direct FTEs and 304 indirect FTEs; and
- National: Total employment impacts of 782 FTEs, comprising 420 direct FTEs and 362 indirect FTEs.

Operational employment impacts will vary throughout the operational life of the mine in response to changes in production. The Project will ensure employees are appropriately trained in their relevant industry skills and provide training programs to further develop industry skills.

As outlined above, a significant proportion of total employment effects will be in flow on or indirect employment, which will ease some pressure in the local community resulting from recent down-sizing of workforces and add to the over 44,000 directly employed throughout the Australian coal industry as of February 2017 (ABS 2017).

16.4.3.3 Royalties and Taxes

Economic modelling for the Project (see Chapter 19A - Economics) indicates that the Project will contribute approximately $7.78 billion to $8.23 billion of coal exports over the life of the mine. Two alternative pricing scenarios were presented in estimating the total export value of the coal produced over the life of the Project, one based on coal price data provided by Central Queensland Coal and the other based on a range of data sources regarding likely price movements for semi-soft coking coal and high grade thermal coal over the life of the Project. Both scenarios assumed the exchange rate outlook for Australia is anticipated to remain, at least in the medium term, at approximately ~US$0.76.

The assumptions made for each scenario are summarised below.

Based on pricing data provided by Central Queensland Coal:

- The price of semi-soft coking coal is anticipated to decrease from US$130 per tonne to approximately US$125 per tonne in the short to medium term; and
- The price of high grade thermal coal is anticipated to remain at approximately US$95 per tonne for the medium term.

Alternative Scenario:

- The price of semi-soft coking coal is anticipated to range between US$102 per tonne and US$146 per tonne; and
- The price of high grade thermal coal is anticipated to range between US$76 per tonne and US$108 per tonne.

Thus, based on these anticipated prices and exchange rate, the total export value of the coal produced is estimated to be in the order of AUD$7.78 billion to $8.23 billion of the life of the mine. Assuming Queensland coal mining royalty rates remain unchanged, this will yield royalties of approximately $703.3 million to $766.0 million over the life of the mine.

It is pertinent to note that both coal prices and exchange rates are subject to fluctuations and shocks, so these estimates are intended to be indicative only, based on the current trade environment.

16.4.4 Project Description

Central Queensland Coal Proprietary Limited (Central Queensland Coal) and Fairway Coal Proprietary Limited (Fairway Coal) (the joint Proponents), propose to develop the Central Queensland Coal Mine Project (the Project). As Central Queensland Coal is the senior proponent, Central Queensland Coal is referred to throughout this Supplementary Environmental Impact Statement (SEIS). The Project comprises the Central Queensland Coal Mine where coal mining and processing activities will occur along with a TLF.

The Project is located 130 km northwest of Rockhampton in the Styx Coal Basin in Central Queensland (see Figure 16-9). The Project is located within the Livingstone Shire Council (LSC) Local Government Area (LGA). The Project is generally located on the “Mamelon” property, described as real property Lot 11 on MC23, Lot 10 on MC493 and Lot 9 on MC496. The TLF is located on the “Strathmuir” property, described as real property Lot 9 on MC230. A small section of the haul road to the TLF is located on the “Brussels” property described as real property Lot 85 on SP164785.

The Project will involve mining a maximum combined tonnage of up to 10 Mtpa of SSCC and HGTC. The Project will be located within ML 80187 and ML 700022, which are adjacent to MDL 468 and EPC 1029, both of which are held by the Proponent. It is intended that all aspects of the Project will be authorised by a site specific EA.

Development of the Project is expected to commence in 2019 with initial early construction works and extend operationally for approximately 19 years until the depletion of the current reserve, and rehabilitation and mine closure activities are successfully completed.

The Project consists of two open cut operations that will be mined using a truck and shovel methodology (Figure 16-10). The run-of-mine (ROM) coal will ramp up to approximately 2 Mtpa during Stage 1 (2019 - 2022), where coal will be crushed, screened and washed to SSCC grade with an estimate 80% yield. Stage 2 of the Project (2023 - 2038) will include further processing of up to an additional 4 Mtpa ROM coal within another coal handling and preparation plant (CHPP) to SSCC and up to 4 Mtpa of HGTC with an estimated 95% yield. At full production two CHPPs, one servicing Open Cut 1 and the other servicing Open Cut 2, will be in operation. Rehabilitation works will occur progressively through mine operation, with final rehabilitation and mine closure activities occurring between 2036 to 2038.

A TLF will be developed to connect into the existing Queensland Rail North Coast Rail Line. This connection will allow the product coal to be transported to the established coal loading infrastructure at the Dalrymple Bay Coal Terminal (DBCT).

Access to the Project will be via the Bruce Highway. The Project will employ a peak workforce of approximately 275 people during construction and between 100 (2019) to 500 (2030) during operation, with the workforce reducing to approximately 20 during decommissioning. Central Queensland Coal will manage the Project construction and ongoing operations with the assistance of contractors.

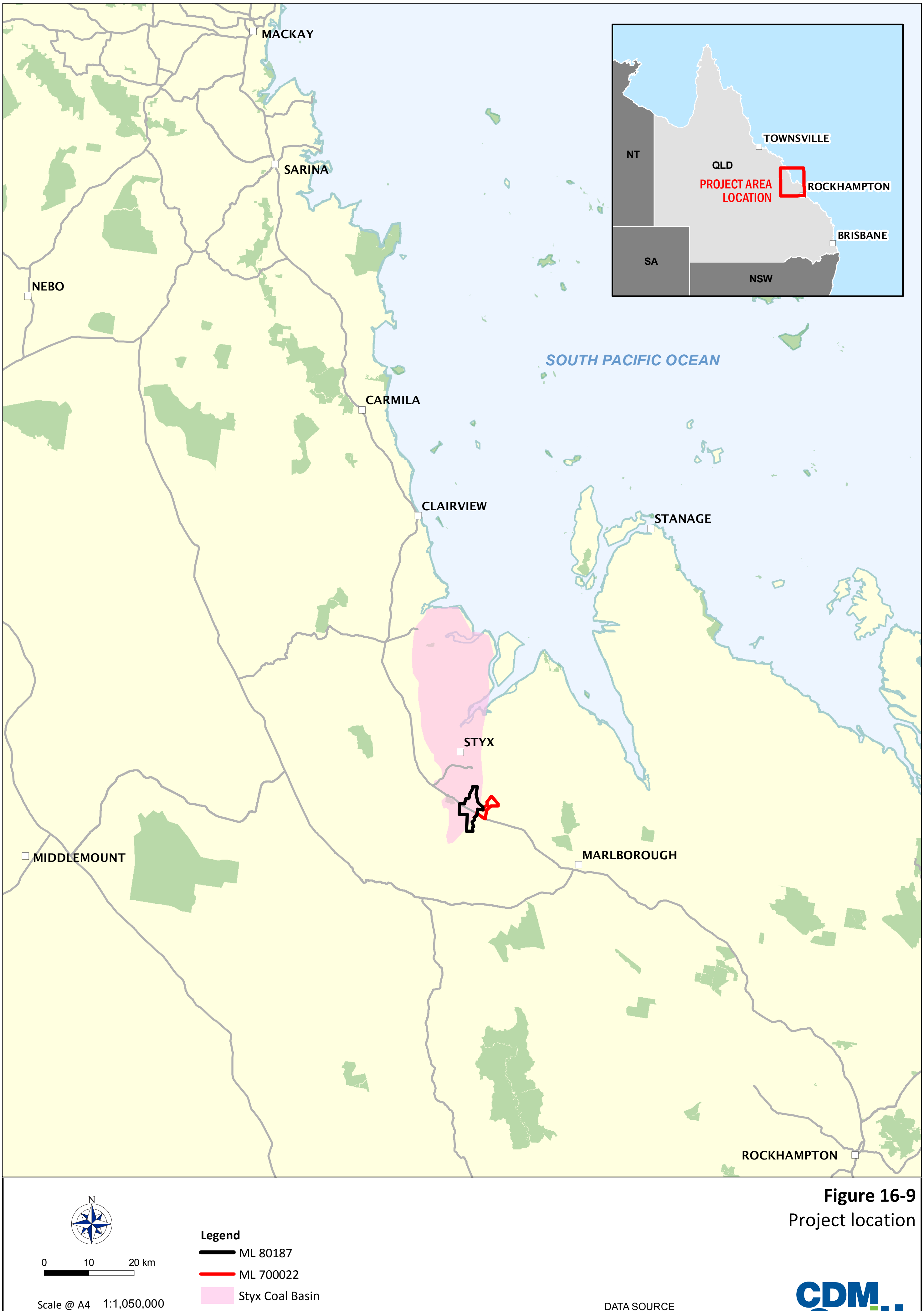

Figure 16-9
Project location

Scale @ A4 1:1,050,000
Date: 22/11/18
Drawn: Gayle B.

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 3_Supp_Report_Project Description\1000111 project location__3-1.mxd 11/22/2018

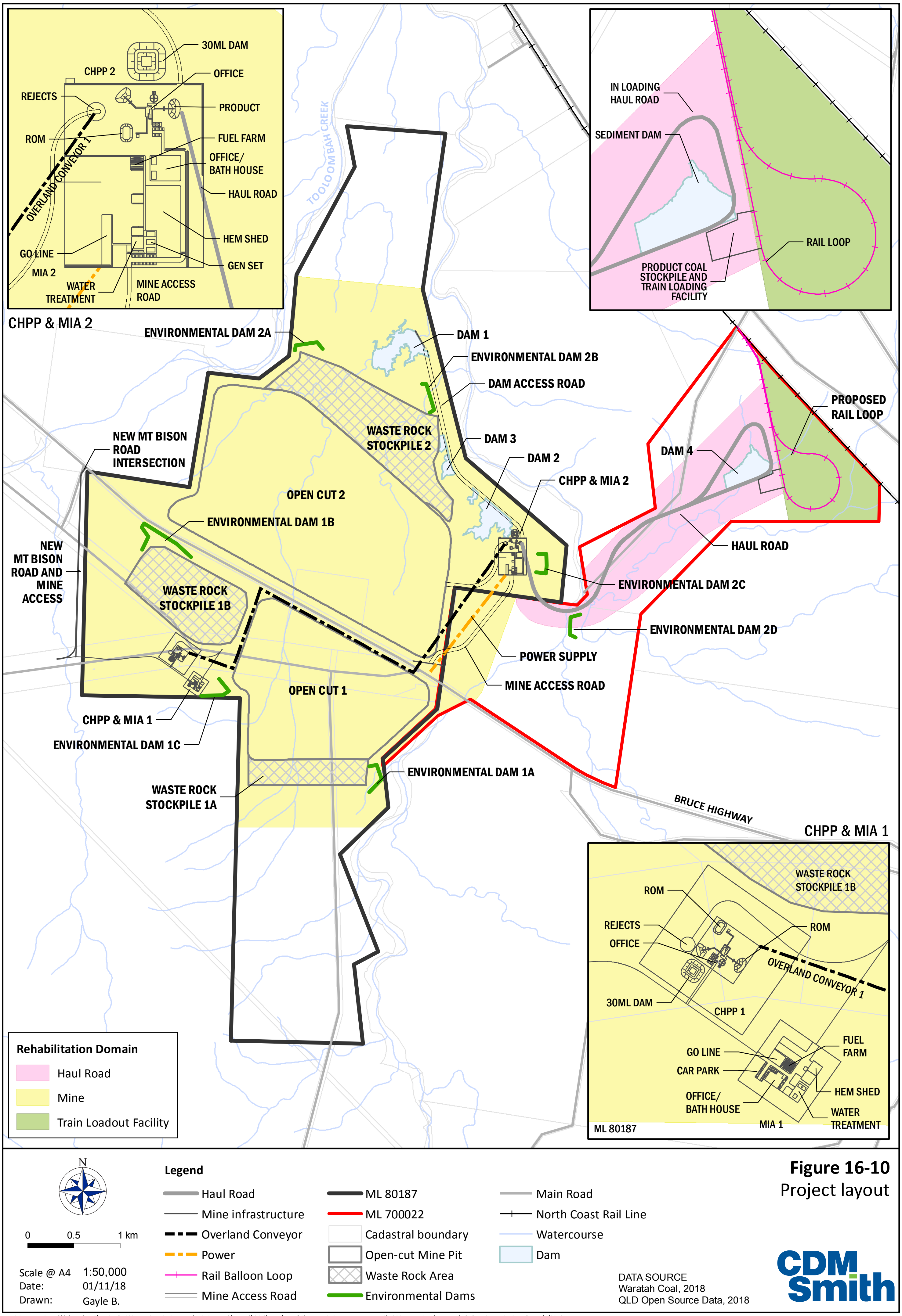

Figure 16-10
Project layout

16.4.5 Project Layout – Amendments

Project optimisation studies finalised since the release of the EIS have resulted in several material changes to the description of the Project. Similarly, comments provided to the EIS and original SEIS have resulted in additional changes. This has led to a number of changes which reduce the potential impacts to some MNES values associated with the Project area and surrounds. These changes are outlined in Table 16-10 and described in the following sections. The updated general arrangement for the Project is shown at Figure 16-10.

Table 16-10 Material changes to the Project description since the EIS release

Aspect	EIS Project Description	SEIS Project Description
Mine Pits and Waste Stockpile		
Mine Pit Layout – Pit 2 and Pit 4	The EIS proposed two pits (Open Cut 2 and Open Cut 4) on the eastern side of the Bruce Highway.	The SEIS proposes one pit on the eastern side of the Bruce Highway. The single pit is a result of combining Open Cut 2 and Open Cut 4. This pit is now referred to as Open Cut 2.
Mine Pit Layout – Pit 1	The EIS proposed a single mine pit (Open Cut 1) on the western side of the Bruce Highway.	The SEIS still proposes a single mine on the western side of the Bruce Highway; however, the pit is now significantly smaller than proposed in EIS.
Mining Sequence	The EIS proposed a south to north mining direction in Open Cut 1 and Open Cut 2.	The SEIS proposes a north to south mining direction in Open Cut 2 and a west to east mining direction in Open Cut 1.
Open Cut 1 void	The EIS was based on a void being retained in Open Cut 1.	Open Cut 1 will now be back-filled and no void will be retained.
Open Cut 4 void	The EIS was based on a void being retained in Open Cut 4.	Open Cut 4 now forms part of Open Cut 2. No void will be retained in Open Cut 2.
Waste Rock Stockpile 1	The EIS proposed a single waste dump on the western side of the Bruce Highway.	The SEIS proposes two waste dumps on the western side of the Bruce Highway. Waste Rock Stockpile 1b will be removed during rehabilitation.
Waste rock stockpile areas	The EIS proposed a disturbance area of 133 ha for waste dump area 1 and 164 ha for waste dump 2.	The SEIS proposes a combined disturbance area of 161 ha for Waste Rock Stockpile 1a (72.7 ha) and 1b (88.5 ha) and 245 ha for Waste Rock Stockpile 2.
		The updated SEIS proposes a combined disturbance area of 118.8 ha for Waste Rock Stockpile 2. This amounts to a significantly reduced total disturbance area of 243.5 ha for the three waste rock stockpiles compared to a total 406 ha for the three waste rock stockpiles as proposed in the original SEIS.
Redesign of Open Cut 4 (now incorporated in Open Cut 2) to avoid Semi-Evergreen Vine Thicket (SEVT)	The Open Cut 4 area was predicted to clear the edge (0.4 ha) of a SEVT Threatened Ecological Community (TEC) adjacent to Tooloombah Creek.	Open Cut 2 has been redesigned to avoid impacts to SEVT and includes a 100 m buffer between Open Cut 2 and the TEC.
Blasting activities requiring the closure of the Bruce Highway	The EIS identified the requirement to close the Bruce Highway during blasting activities within a 500 m distance.	Following discussions with the Department of Transport and Main Roads (DTMR), it has been determined by Central Queensland Coal that no

Aspect	EIS Project Description	SEIS Project Description
		closure of the Bruce Highway will occur due to blasting.
Conveyor Arrangement		
Location of the conveyor	The EIS proposed the conveyor between coal handling and preparation plant (CHPP) 1 and CHPP 2 would be located beneath the Deep Creek road bridge.	The SEIS proposes the conveyor will now be located outside of the Deep Creek channel and constructed in a new culvert arrangement passing beneath the Bruce Highway.
Site Access and Internal Roads		
Entry point to the eastern infrastructure area and Open Cut 2 and Open Cut 4	The EIS proposed the entry point to the eastern infrastructure approximately 3.3 km from Deep Creek, travelling to the north along the Bruce Highway.	The new access road to the eastern infrastructure will be located approximately 600 m from Deep Creek, travelling to the north along the Bruce Highway.
Internal access and overburden haul between eastern entry point and the CHPP and mine infrastructure area (MIA) 2	The EIS proposed a small internal access and overburden haul road between the eastern entry point and CHPP and MIA 2.	The Project will now utilise a smaller internal access road (1.5 km in length) from the new eastern entry point to the CHPP and MIA 2.
Relocation of MIA 2 access road to avoid Brigalow	The proposed access road to MIA 2 impacts 0.2 ha of a small patch of Brigalow TEC.	The new access road to MIA avoids the Brigalow TEC altogether.
Light Vehicle access road to Dam 1	The EIS did not include a light vehicle assess road between CHPP and MIA 2 and Dam 1.	A light vehicle access road has been included to provide access from the CHPP and MIA 2 to Water Dam 1.
Bruce Highway Closure	The EIS proposed periodic closures to the Bruce Highway may be required during blasting activities.	The Project commits to ensuring all Project related activities are conducted in a manner that avoids the need for any closure of the Bruce Highway. No closures of the Bruce Highway are proposed.
Train Loadout Facility		
Train loading method	The EIS proposed coal would be loaded into wagons by front end loaders, with a separate veneering station.	The train loadout facility design now includes an overhead bin, flood loading the rail wagons. A veneering station will be attached to the overhead loader.
Water Supply and Dams		
Construction and operation water supply from Tooloombah Creek	The EIS indicated water permits will be sought to provide a construction and operation water supply.	No water permits to harvest water from Tooloombah Creek are anticipated.
Additional Water Supply Dams		Two additional water supply dams have been located on the eastern side of the Bruce Highway and included in the mine water balance
Dam 5	A pit dewater dam (Dam 5) located on the western side of the Bruce Highway and nearby two listed wetlands was proposed in the EIS and original SEIS.	To address the concern around perceived impacts to the Wetland 2, Dam 5 will no longer form part of the Project.
Power Supply		
Power connection to the Project	The EIS indicated an option to connect to existing the 11 kV transmission line.	The connection has now been confirmed with Ergon Energy. The existing line is 22 kV not 11 kV as originally reported.

16.4.5.1 Mine Pits and Overburden Stockpiles

Mine Layout

Open Cut 2

Changes to the mine layout have resulted in Open Cut 2 and Open Cut 4 being amalgamated. The amalgamation of the two pits facilitates a mining sequence that enables earlier backfilling of Open Cut 2, and consequently, earlier commencement of the progressive rehabilitation program. The new disturbance area for Open Cut 2 is 500 ha compared to a combined disturbance area of 400 ha for Open Cut 2 and Open Cut 4. This represent an increase in the mining area of 100 ha.

Open Cut 1

The EIS layout for Open Cut 1 covered a disturbance area of 311 ha. Following the mine design and mine sequencing optimisation studies, the area of Open Cut 1 has been significantly reduced. The new disturbance area for Open Cut 1 is 247.7 ha representing a reduction in the mining area of 64 ha.

Open Cut 4

Open Cut 4 has been amalgamated into Open Cut 2 and is no longer considered a standalone pit.

Waste Rock Stockpiles

Waste Rock Stockpiles 1a and 1b

The EIS originally proposed a single waste dump on the western side of the Bruce Highway and to the south of Open Cut Pit 1. A retained void in Open Cut 1 was also proposed in the EIS. Since the release of the EIS, further planning and design has been carried around in respect of Waste Rock Stockpile 1. There will now be two waste rock stockpiles associated with Open Cut 1, these being Waste Rock Stockpile 1a and Waste Rock Stockpile 1b.

The original Waste Rock Stockpile 1 design progressed into an area of juvenile Brigalow regrowth and also into an area of preferred Koala (*Phascolarctos cinereus*) habitat. The reduction in the pit area for Open Cut 1 (as discussed previously) has provided an opportunity to reduce potential impacts to the Brigalow regrowth and preferred Koala habitat by enabling a second overburden waste dump to be located in a section of the area of the original Open Cut 1 pit.

The newly proposed Waste Rock Stockpile 1b has been located in an area of previously cleared non-remnant vegetation and outside of the Wetland Protection Area buffer zone. As a consequence of including the second waste rock stockpile, the disturbance footprint for Waste Stockpile 1a has been reduced such that it reduces disturbance to areas of preferred Koala habitat that would have previously been disturbed and it further avoids a large area of the juvenile Brigalow regrowth. This is discussed further in SEIS Chapter 14 – Terrestrial Ecology.

The overburden material from both waste rock stockpiles but commencing with material from Waste Rock Stockpile 1b, will be pushed back into Open Cut 1 as mine development permits as part of the progressive rehabilitation program. During mine closure activities, the remaining overburden material in Waste Rock Stockpile 1b will be used to infill Open Cut 1. Overburden waste material from Waste Rock Stockpile 1a will be used for the final infill of Open Cut 1. Once landforming of the final surface for Open Cut 1 is complete, remaining mineral waste material in Waste Rock Stockpile 1a will be reshaped and rehabilitated. Rehabilitation of Waste Rock Stockpile 1a is discussed further in Chapter 11 – Rehabilitation and Decommissioning.

Waste Rock Stockpile 2

The disturbance area for Waste Rock Stockpile 2 was 164 ha as proposed in the EIS. The revised disturbance area for Waste Rock Stockpile 2 following the change in mining operations is now was 124.5 ha. This amounts to a decrease in the Waste Dump 2 disturbance area of 39.5 ha to that reported in the EIS.

Retained Voids

No void will be retained in Open Cut 1. The original mine plan had a void retained in Open Cut 1. Through optimisation of the mine plan to minimise the volume of overburden waste retained in out of pit overburden stockpile areas, no void will be retained in Open Cut 1. The removal of these voids will have positive benefits in terms of rehabilitation, minimising potential for negative impacts to water quality and reducing potential long-term depressurisation and drawdown impacts to groundwater. These benefits are discussed in detail in Chapter 10 – Groundwater of the SEIS and summarised in Section 16.9.3 of this chapter.

The original mine plan also had a void retained in Open Cut 4. Open Cut 4 has now been incorporated into Open Cut 2. The mine plan originally had no void retained in Open Cut 2 and this is still the case notwithstanding the incorporation of Open Cut 4 into the pit design.

Avoidance of Semi-Evergreen Vine Thicket TEC

As part of the optimisation of the mine design and mine schedule, Central Queensland Coal has redesigned the north edge of Open Cut 2 to avoid clearing 0.4ha of semi-evergreen vine thicket (SEVT) threatened ecological community (TEC). In addition, a buffer of 100 m has been applied between the SEVT TEC community and the edge of Open Cut 2.

16.4.5.2 Coal Conveyor Arrangement

The conveyor arrangement proposed in the EIS has been redesigned and repositioned and will no longer be located under the existing Deep Creek road bridge. The conveyor will now pass beneath the Bruce Highway at a location that will be determined in conjunction with DTMR. As the conveyor will not be required until 2029, the design of the culvert and conveyor arrangement has not been finalised; however, an indicative design is shown in Section 16.7.1.3.

The final design and construction of the culvert arrangement that will accommodate the conveyor beneath the Bruce Highway will be undertaken to be consistent with the DTMR design guidelines and standards in place at the time of construction. It is; however, anticipated that a small section of the Bruce Highway will require minor diversions to enable the construction of the culvert.

16.4.5.3 Site Access and Internal Roads

The original entry point to the Project infrastructure on the eastern side of the Bruce Highway was located approximately 3.3 km from Deep Creek and approximately 28.3 km north of Marlborough when travelling north along the Bruce Highway. After optimisation of the mine design, the entry point will now be located approximately 600 m north of Deep Creek and approximately 25 km north of Marlborough. The location of the new entry point provides a shorter and more direct access road to the CHPP / MIA 2 reducing disturbance to Koala habitat (by approximately 0.8 ha) and avoiding 0.2 ha of Brigalow vegetation (listed as a TEC) that would have occurred with the construction of the original access point.

The western access from the Central Queensland Coal mine site to the Bruce Highway has not changed from that described in the EIS. The entry point is indicatively located approximately 29 km north of Marlborough.

A light vehicle road connecting CHPP and MIA 2 to Water Dam 1 has been added to the Project's infrastructure requirement.

The location of the entry points / access roads are shown at Figure 16-10.

16.4.5.4 Train Load Out Facility

The original TLF design reported in the EIS incorporated loading of the wagons by front end loader directly from product coal stockpiles into awaiting wagons. Since the release of the EIS further design of the TLF has been completed. The TLF will now include overhead loading of the wagons which includes the veneering station.

Product coal will now be reclaimed from the TLF product coal stockpile via bulldozer and coal valve operation discharging coal onto a single reclaim tunnel conveyor. Reclaimed coal will be conveyed to the train load-out bin for loading into the wagons.

The TLF will include equipment for spraying of a chemical veneer on coal after loading to minimise dust generation during transportation.

16.4.5.5 Water Supply and Dams

The EIS reported water permits will be sought to take water from Tooloombah Creek during construction. Since the EIS, further water demand assessment has been undertaken. This assessment has confirmed that there will be adequate water availability through using existing farm dam water supplies until the Raw Water Dam becomes operational. Should make-up water be required during construction, this will be trucked to site.

The operational water requirement will be supplied from harvesting on-lease stormwater runoff, mine affected water from pit dewatering activities and water reuse within the CHPP. Consequently, Central Queensland Coal does not anticipate a requirement to obtain water permits to harvest water from Tooloombah Creek.

Dam 5 was originally proposed to be located on the western side of the Bruce Highway, capturing overland flows to support mining operations associated with Open Cut 1, CHPP 1 and MIA 1. This dam has been removed to avoid potential for negative impacts to the mapped wetland (as described under the Queensland *Vegetation Management Act 1999*) located on the western boundary of the ML. Water will now be pumped from Dam 1 to the dam located at MIA 1, via the conveyor culvert when operational.

Overland flows will continue to be diverted away from the operational mining area on the western side of the Bruce Highway. Flows will continue to report to the existing wetland and to Tooloombah Creek as currently occurs.

16.4.5.6 Power Supply

The EIS reported consideration of an option to connect into the existing 11 kilovolt (kV) transmission line maintained by Ergon Energy which provides power to the nearby township of Ogmore. It was originally considered there was limited capacity within this transmission line to support the Project. After discussions with Ergon it was identified that the existing transmission line was 22kV, rather than 11 kV, and that there was capacity to support the Project. Consequently, Ergon has agreed to terms to provide the Project access to the transmission line. The available capacity is limited and as such, will be used as a power supply to office and administration areas. Generators will still be required for the operations of the two MIAs and CHPPs. The location of the access and termination points are shown at Figure 16-10.

16.4.5.7 Accommodation Camp

The EIS referred to the proposed establishment of an overflow accommodation camp to be located on the Mamelon property, on the western side of the Bruce Highway (outside of the ML). The establishment of the camp also included the realignment of the Mount Bison Road to provide access to the camp, and to also allow access to the mine infrastructure on the western side of the Bruce Highway. Since the release of the EIS Central Queensland Coal has been in discussions with the owners of the Marlborough Caravan Park in regard to upgrading the facilities there to provide additional accommodation for construction and operational workforce.

The Caravan Park owners are currently working with the Livingston Shire Council (LSC) to explore this option. Any approvals required for the expansion of the Marlborough Caravan Park will be sought by the owners. The expansion of the Marlborough Caravan Park is expected to provide increased local employment and services opportunities in the Marlborough area. As the operation of the workers camp would have been under contract from an external service provider, the expansion of the Marlborough Caravan Park and the opportunity for local employment is a better outcome for the Marlborough area.

Based on the changes to the accommodation camp, the requirement to realign the entry to Mount Bison road has been pushed out to at least 2027, to be ready for the commencement of construction activities on the western side of the Bruce Highway.

16.4.6 Relationships to Other Projects

The Project is interrelated with other external infrastructure projects which are not encompassed in this EIS assessment or approval process. The potentially interrelated projects below may be undertaken as part of supporting and servicing the Project following further design and consultation with stakeholders. Should these projects be required they will be subject to separate assessment and approvals undertaken by the respective service providers. They are provided here for the sake of completeness and are:

- Accommodation camp at the Marlborough Caravan Park; and
- Realignment of the existing Mount Bison Road entrance.

Any related developments will be constructed and owned by third party service providers who will obtain any necessary approvals (local, state or federal government approvals) to construct or maintain the infrastructure.

16.4.7 Project Context and Areas

16.4.7.1 Regional Context

The Project is located within the LSC LGA which spans an area of approximately 11,770 km^2. It is located in the Capricornia region of central Queensland encompassing lands to the north and east of Rockhampton and is located 8 km south of the Great Barrier Reef World Heritage Area (GBRWHA). The LSC area encompasses a variety of land uses and industries dominated by cattle grazing and tourism with an extensive urban conurbation in the Yeppoon area. Although relatively small the region has several national parks, state forests and important wetlands with significant EV.

16.4.7.2 Landscape Context

The Project is largely located within the Marlborough Plains subregion, one of the 13 subregions of the Brigalow Belt North bioregion. The southern portion of the Mine Lease (ML) occurs in the adjacent Nebo-Connors Ranges subregion. The Project area is located close to the boundary of the Brigalow Belt South bioregion located to the south. Vegetation within the Marlborough Plains subregion is dominated by alluvial plains and colluvial slopes, usually supporting woodlands characterised by Poplar Gum (*Eucalyptus platyphylla*), Ghost Gum (*Corymbia dallachiana*), Forest Red Gum (*E. tereticornis*) and paperbarks (*Melaleuca* spp.) with low rises supporting Narrow-Leaved Ironbark (*E. crebra*).

Large sections of the Brigalow Belt North bioregion have been cleared of remnant native vegetation for grazing, agriculture and mining. Remaining vegetation is generally confined to rockier hilly areas, linear strips of roadside vegetation, riparian vegetation and relatively small isolated remnants. Thus, clearing over the past 150 years has resulted in a highly fragmented landscape with remnant vegetation patches separated by large expanses of cleared land.

Areas to the north and east of the Project area have been substantially impacted by vegetation clearing associated with cattle grazing activity. Connectivity between remaining tracts of vegetation is tenuously maintained by thin strips of riparian vegetation along creek lines such as Tooloombah Creek and Deep Creek which border the Project. Nevertheless, woodland and open forest habitat remaining in the south and west of the site remains contiguous with an extensive tract of remnant vegetation, which includes Tooloombah Creek Conservation Park. To the west of the Project remains extensive tracts of remnant forest associated with the nearby Broadsound Range.

The Project is located within the Styx River catchment whose main tributaries include Deep, Granite, Montrose, Stoodleigh, Tooloombah, Waverly and Wellington Creeks. The catchment is bordered by the Connors Ranges in the Northwest and the Broadsound Ranges to the Southwest and empties into the Coral Sea near Rosewood Island. The lower Styx River is part of Broad Sound, a large wetland listed in the Directory of Important Wetlands of Australia (DIWA).

Vegetation within the Project area and immediate surrounds comprises:

- Heavily disturbed habitats that have previously undergone significant clearing for cattle production;
- Substantial areas of less disturbed eucalypt woodland; and
- Linear remnants of open forest vegetation largely associated with the creek systems adjacent to the Project boundary.

16.4.7.3 Local Context

Elevations across the Styx catchment range from 0 to 540 m above sea level. The mine area and TLF area predominantly comprises flat or undulating lands, with sharper topographical relief restricted to the southern portion of ML 80187. The land within the Project disturbance area can be described as gently undulating.

The Project area drains via several smaller creeks and tributaries to the Styx River and estuary, and into the Coral Sea. ML 80187 is bordered by Deep Creek on the eastern boundary and Tooloombah Creek on the northeast boundary. The both creeks meet approximately 2 km north of the ML boundary, thereupon merging to become the Styx River. The haul route crosses Deep Creek to the immediate east. The TLF is located approximately 2 km to the northeast in cleared grazing lands.

16.4.7.4 Land Tenure

The land tenure associated with the Project layout is summarised in Table 16-11. The mine area is located entirely within part of the Mamelon cattle property, situated on Lot 3 on HLN29 and Lot 4 on HLN225, both of which are freehold tenures. An east-west oriented, un-named road reserve also traverses the mine area, although no formed road exists there. the Project is located on the Mamelon property, described as real property Lot 11 on MC23, Lot 10 on MC493 and Lot 9 on MC496. The TLF is located on Strathmuir property, described as real property Lot 9 on MC230. All infrastructure associated with the Project will be located within the LSC LGA.

Table 16-11 Land tenure

Property description	Property name	Tenure	Current use	Proposed use	Owner and occupier
Central Queensland Coal mine area					
Lot 9 MC496	Mamelon Station	Freehold	Grazing	Mining	QNI Metals Pty Ltd
Lot 10 MC493					
Lot 11 MC23					
Lot 1 on RL3001					
AAP16117	Mt Bison Road	Road Reserve	Grazing	Mining	Livingstone Shire Council
Haul road and TLF					
Lot 9 on MC230	Strathmuir	Freehold	Grazing	Transport Corridor	Russell Charles Smith, Elizabeth Joan Smith and Edward George Smith
Lot 85 on SP164785	Brussels	Freehold	Grazing	Transport Corridor	Scott Robert McCartney
Lot 9 on MC230	Strathmuir	Freehold	Grazing	TLF	Russell Charles Smith, Elizabeth Joan Smith and Edward George Smith

16.4.7.5 The Project Area

The overall Project area comprises the following:

- A mine area on the current ML 80187 (herein referred to as the Central Queensland Coal mine area) comprising 2,276 ha, of which 1,090.8 ha associated with the mining and associated infrastructure areas will be disturbed;
- A haul road approximately 5.4 km long and 25 m wide extends northeast from the Central Queensland Coal mine area to the TLF. Altogether, including an associated environmental dam on ML 700022, the approximate disturbance area will be 26 ha; and
- A TLF on ML 700022 covering a proposed disturbance area of approximately 8 ha.

The total disturbance area for the Project is approximately 1,124.8 ha.

16.4.8 Project Consultation

The ToR was publicly advertised for comment by DES from 10 April 2017 to close of business 8 June 2017. The extension of the public comment period was proposed by the proponent as the Project area was under the damaging influences of Cyclone Debbie during the public review period. A total of 23 submissions were received by DES for consideration in finalising the ToR, most of which came from government agencies.

The most common issues raised in these submissions included:

- Downstream greenhouse gas (GHG) emissions;
- Impacts to the Great Barrier Reef Marine Park;
- Offset package to compensate for significant residual impacts;
- Ongoing communications and liaison with stakeholders and the community;
- Aboriginal and Torres Strait Islander specific plans and strategies;
- Surface water and groundwater impacts;
- Groundwater dependent ecosystems (GDEs) and stygofauna impacts;
- Transport impacts;
- Local industry participation;
- Emergency and health services capacity;
- Impacts to arable land;
- Fish passage and connectivity for aquatic fauna;
- Impacts to the aquatic environment; and
- Potential for flooding.

The final ToR was issued on 4 August 2017 and encompassed the relevant and applicable issues raised during the consultation.

Consultation was undertaken in 2015 with representatives from government agencies, service providers and businesses from the local community to inform the scope and assessment of the Project during the preparation of the EIS. Consultation and discussions with landowners near the Project area commenced in 2012. Meetings and discussions have been held with landholders regarding exploration activities. However, consultation regarding the impacts of the Project's development will begin formally with the publication of the EIS.

Discussions with the Traditional Owners commenced in 2017 and separate Cultural Heritage Management Plans (CHMP) are under development with the Darumbal People, the Barada Kabalbara Yetimarala People #1 and Barada Kabalbara Yetimarala People #2. The CHMPs will address the management of cultural heritage on land within the two MLs. Further detail regarding the Project consultation process and relevant stakeholders is discussed in Chapter 1 – Introduction.

16.4.8.1 Ongoing Consultation during EIS development

Targeted consultation was undertaken with meetings and discussions held with representatives from the following agencies and organisations:

- Councils (LSC and RRC);
- Department of Environment and Science;
- Department of Natural Resources, Mines and Energy;
- Department of State Development;
- Department of Infrastructure, Local Government and Planning;
- Department of Transport and Main Roads;
- Department of National Parks, Recreations, Sport and Racing;
- Department of Agriculture and Fisheries;
- Department of Energy and Water Supply;
- Department of the Environment and Energy (Commonwealth);
- Federal Member for Capricornia;
- State Member for Mirani;
- Aurizon;
- Queensland Rail;
- Pacific National;
- Ergon Energy;
- Powerlink;
- Telstra;
- Darumbal People;
- Barada Kabalbara Yetimarala People;
- Scorpion Energy Pty Ltd – EPC 2128;
- Waratah Coal Pty Ltd – EPC 2268; and
- Arrow Energy Pty Ltd – Authority to Prospect (ATP) 700.

The purpose of the meetings was to update and brief agencies and stakeholders on the status of the Project, along with identifying and discussing potential impacts and management options.

A second community consultation meeting was held on 19 July 2018 at the Marlborough Community Hall. The purpose of this forum was for the project management team to provide updates about the Project's development and how comments to the EIS have been addressed, and provide the community with further opportunity to provide input and feedback. Flyers advertising the meeting were placed at various businesses at Clairview, St Lawrence, Marlborough, Yaamba and The Caves. Residents of Marlborough and Ogmore were advised of the meeting via the local mail delivery system. Approximately 40 people attended the meeting.

In addition to the community meeting, interviews were held with property owners that immediately adjoin the Project site. Various businesses at The Caves, Yaamba, Rockhampton and St Lawrence were also consulted. Both LSC and RRC were briefed on the Project as part of this engagement process. The Capricorn Conservation Council were also briefed in person on the updated Project design and progress of the EIS.

16.4.8.2 Consultation Beyond EIS Stage

Following the Project's EIS approval, engagement with Project stakeholders and the community will continue for the life of the Project and be delivered through a Stakeholder and Community Engagement Plan. The Plan will be designed to maximise community and stakeholder input into the Project's development and delivery (including mine decommissioning) through capacity building and two-way communication mechanisms which will be in place for the life of the Project.

16.4.8.3 Affected and Interested Persons

In addition to the individuals, groups and businesses mentioned above, there are a wider range of interested and affected persons that may be impacted by, or have interest in, the Project. The identified stakeholders are represented in Figure 16-11 and directly affected landowners and tenement holders are outlined in Chapter 3 – Description of the Project.

Where practicable, communication and engagement activities will be prioritised in the following order:

- Key stakeholders and directly affected landholders;
- Local communities, neighbouring landholders, and other stakeholders; and
- General public and wider regional community.

Figure 16-11 Project stakeholders

Key coninuing Project consultation activities include:

- Meetings with directly affected and neighbouring land owners to discuss the Project and the management of its impacts;
- Meetings with recognised Indigenous parties;
- Discussions with resource companies owning tenements that overlap the Project's ML application areas;
- Ongoing group meetings with representatives of the local community throughout 2017;
- Development of Project fact sheets for upload to the Project website as needs are identified;
- Consultation with the LSC and DTMR regarding affected roads and road reserves;
- Meetings to progress social impact management action plans including Department of State Development, LSC, Queensland Ambulance Service (QAS), Queensland Fire and Emergency Service (QFES) and Skills Queensland;
- Maintaining the Project website;
- Development of a Local Content Strategy and engagement with local businesses at one or more events to determine whether their capabilities can be drawn upon; and

- Planning for the implementation of a community advisory group or similar where interested members of the local community can meet and discuss the Project regularly.

For further information, please refer to Appendix A14 – Stakeholder Engagement Plan and Appendix A17 – Social Impact Assessment.

16.5 Alternatives to the Project

During the early Project design process, a number of alternative scenarios were considered to evaluate the relative social, economic and environmental advantages and disadvantages of different Project alternatives. These have been further developed as discussed in Section 16.4.5. The following discusses the results from the original analysis which were used to select the original Project scope. Section 16.4.5 outline the material changes to the Project described in the EIS and Section 16.7 describes the Project in the SEIS. A more detailed description of the Project is at Chapter 3 – Description of the Project.

Alternative scenarios considered were those that are practicable, feasible and available to Central Queensland Coal. These included locality, technological and conceptual alternatives. The particular scenarios assessed as part of the EIS included the following alternative actions:

- No development scenario;
- Locality alternatives;
  - MIA
  - Transport corridor
  - TLF
  - Mine access road for the workforce
- Technological alternatives;
  - Mining methods
  - Rejects and tailings management
- Conceptual alternatives;
  - Open cut pit configurations
  - Water supply
  - Energy supply
  - Alternative accommodation during the construction and operational phases.

The following subsections discuss each of the alternative scenarios. A more detailed discussion including analysis against the principles of Ecologically Sustainable Development is provided in Chapter 2 – Project Need and Alternatives.

16.5.1 No Development Scenario

The no development scenario predicts the future scenario which would exist in the absence of any Project. The no development scenario would avoid the potential impacts of the Project on the existing environment including MNES and cattle grazing would likely continue to be the primary land use.

This scenario would also have a significant impact socially and economically in terms of employment and supply chain opportunities not realised. The region will not benefit from employee opportunities, financial donations to community groups, training programs or receive local business support. With the significant reduction in the resource industry workforce within central Queensland the broader region will continue to experience social and economic stress.

In economic terms, the no development scenario would result in a loss to the Queensland Government of between $669.3 million (AUD) and $738.8 million (AUD) over the life of the Project.

16.5.2 Locality Alternatives

16.5.2.1 Mine Location

The mine location is determined by the targeted coal deposit and ML 80187, held by Central Queensland Coal and Fairway Coal. The proposed ML boundaries are defined by existing geological conditions which are suitable to mining based on the results of exploration studies undertaken within the MLs. As such alternative mine locations are not available to Central Queensland Coal. The existing location is suitable for development of a mine as the proposed location:

- Is in the Styx Coal Basin which has previously supported coal mining;
- Is not within any Environmentally Sensitive Areas (although a small section of the Project does lie within an area shown as Strategic Cropping Land (SCL) on the SCL trigger map (see Chapter 5 – Land for more information);
- Is within close proximity to the existing North Coast Rail Line which connects to the existing Goonyella rail and port infrastructure system;
- Has direct access to the area off the Bruce Highway; and
- The rail distance between the Project and Port of Hay Point and the DBCT is 190 km.

16.5.2.2 Mine Infrastructure Area

Two options were considered for the operation of the Mine Infrastructure Area (MIA) and CHPP. The original concept was for a single MIA and CHPP servicing all three open cut pits. This concept was optimised to allow for the future extraction of SSCC. Further assessment of the mine operability resulted in decision to move towards two smaller MIA and CHPPs. One MIA and CHPP will be located on the western side of the Bruce Highway and will service Open Cut 1. The second MIA and CHPP will be located on the eastern side of the Bruce Highway servicing Open Cut 2. The use and development of two MIAs and CHPPs concept was adopted, as a balance between the long term haulage of ROM coal, reject material and product coal while allowing for the economic extremities of the mine area. A further key reason was to significantly reduce the volume of trucks crossing the Bruce Highway moving to and from the single MIA / CHPP as originally proposed.

16.5.2.3 Transport Corridor Locations

A preliminary study of five options was undertaken by Central Queensland Coal to identify potential haul road and TLF locations. Two options were ruled out as a feasible alternative because of the relatively longer haulage distances required (approximately 20 km and 42 km) and the need to use public roads (i.e. Ogmore and Kooltandra roads and the Bruce Highway) to haul coal to the respective TLFs.

Three options were selected for detailed consideration. This assessment considered a number of economic, environmental and social criteria including: earthwork volumes, capital expenditure (CAPEX) and operating expenses (OPEX), impacted areas of mapped EVs (including Threatened Ecological Communities, habitat for threatened MNES fauna, SCL and watercourses), and impacted landholdings and roads. The three options evaluated were:

- Option 1 – the haul road is approximately 3 km in length, heading north from the MIA and adjacent to Deep Creek for approximately 2.5 km before crossing Deep Creek and running approximately 0.5 km to the northeast to connect to the TLF. The rail connection is approximately 1.5 km in length in a northeast direction to the North Coast Rail Line;
- Option 2 – the haul road is approximately 2.5 km in length, heading north from the MIA and adjacent to Deep Creek for approximately 2 km before crossing Deep Creek and running approximately 0.5 km to the northeast to connect to the TLF. The rail connection is approximately 1.5 km in length in a northeast direction to the North Coast Rail Line; and
- Option 3 - the haul road is approximately 4.5 km in length, initially heading southeast from the MIA for approximately 2 km before crossing Deep Creek and running approximately 0.1 km to the east and then heading approximately 2.4 km to the east to connect to the TLF. The rail connection is approximately 3.5 km in length in a northeast direction to the North Coast Rail Line.

The assessment identified all three options as being suitable for the Project. The amount of disturbance to REs were similar between the three options assuming the design of the haul road and TLF for Option 1 avoids Endangered TEC. Options 1 and 2 both affect areas of mapped SCL noting; however, that no cropping has occurred in the area. All three routes affect two landholders, with one being a related party to the Project and consents to the land being used for the haul road. All three options were located on land held under freehold title although Options 1 and 2 both had uncertainty associated with a potential boundary waterway crossing whereas Option 3 has a road easement through Deep Creek which will be utilised as the haul road crossing and thereby avoids impacts to Native Title. Following this assessment, a ground-truthing exercise was carried out to confirm the vegetation types within the disturbance footprints of the three options.

The area of the crossing of Deep Creek proposed for Option 3 has not been excluded from the original underlying EPC, whereas the crossing locations for Options 1 and 2 have. To avoid the need to obtain a further underlying EPC to cover the area excluded from the original EPC, Central Queensland Coal has adopted Option 3 in this regard.

Following this, Option 3 was considered the best option notwithstanding it required the longest haul road and civil works associated with the creek crossing. No SCL areas were mapped along this haul road corridor, the TLF or rail connection. Similar to Options 1 and 2, Option 3 impacts two landholders, with one of the two land holders already consenting to the haul road development. One MDL is affected by the haul road and TLF; however, this MDL is held by Central Queensland Coal. Option 3 does not traverse land with Native Title, whereas Options 1 and 2 cross a potential boundary waterway crossing and for Option 2 the TLF and haul road to the east of Deep Creek are on land held under Pastoral Lease within the Darumbal Native Title Claim area.

16.5.2.4 Mine Access Road

The Mine will be accessed from the Bruce Highway via two new turn out lanes. Various options were assessed regarding the location of the entry turnout locations; however, at this point in time the current locations accessing the east and west pit areas were considered the most appropriate given the locations of Open Cut 1 and Open Cut 2 (see Chapter 6 – Traffic and Transport).

16.5.3 Technological Alternatives

The technology used in processes can greatly influence the level of environmental impact of an activity. Advancements in technology allow us to conduct operations far more efficiently than historically. This efficiency can translate to a smaller footprint (the amount of surface area disturbed), less waste generated, cleaner and safer operations, and greater compatibility with the environment. Various technologies were considered for transferring coal from Open Cut 1 to the MIA and reject and tailings management during concept development of the mine. These considerations are discussed in the following sections.

16.5.3.1 Assessment of Alternative Mining Methodologies

A conceptual study to determine the most appropriate mining methodologies was carried out by Central Queensland Coal. The study examined key mine design parameters to the application of various mining technologies. Those considered included:

- Open cut pit mining; and
- Underground longwall mining.

The key mine design parameters included: percentage recovery, annual production volumes, value per tonne of ROM and the mining design limitations of each mining method. These were compared using a margin ranking process to identify the most suitable method for the site.

The Project mining operation will target up to 10 seams of coal in a relatively shallow environment, necessitating the use of an open cut mining method to an economical cut-off depth. The open cuts will utilise a truck and shovel operation to extract both overburden and coal in a strip / terrace mine configuration. Small voids were to be retained under the original plan; however, after discussions with DES, no voids will be retained.

Underground mining was not considered to be an economical option due to the thin coal seams being extracted and the requirement to simultaneously target multiple seams for extraction to maintain product coal quality.

16.5.3.2 Assessment of Alternative Rejects and Tailings Management Technologies

Rejects consist of both coarse and fine waste rock particles produced after the coal has been processed in the CHPP. The coarse rejects will be deposited by truck, initially in the voids within the waste rock stockpiles. The waste rock stockpile peaks will then be dozed to cover the coarse rejects, and subsequently overlain by topsoil as part of rehabilitation.

Two main options were assessed for the management of the reject fines from the CHPP. The use of tailings (fines suspended in waste water) storage dams and the avoidance of tailings storages through the implementation of paste thickeners and filter pressing technology. Plate press technology, another common technique used in developing countries, was also initially considered but discounted due the high labour costs involved if implemented within Australia.

Tailings dams are used to manage the waste water containing suspended fine particles from the CHPP. This process decants the water for reuse into the CHPP and allows the fine sediments to settle at the bottom of the dam. The fines can periodically be removed. This option of tailings management requires a large area for the storage pond, greater evaporative losses of water from the mine site, ongoing monitoring of water levels to reduce the risk of uncontrolled discharges, and presents some risk of dam wall failures as well as more costly rehabilitation.

Thickeners and filter press technology allows process water to be directly recycled back to the mineral processing plant (approximately 60%), reducing water losses, process chemical losses, seepage and reducing processing plant water demand. The solid fines rejects are then discarded in pit with the coarse rejects.

The preferred method is to truck all coarse reject and dewatered fine reject material to in-pit and out of pit waste rock stockpiles. Filter pressing of fine rejects is an accepted process in coal preparation plants throughout Australia. The process is most in line with ESD principles identified in cleaner production, including water reclamation, maximising density of tailings, avoiding storages and reusing for mine backfill thereby eliminating the risks of failures (Edraki et al. 2014).

16.5.3.3 Open Cut Pit Configuration and Optimisation

The mining method considered was based on the occurrence of multiple gently dipping thin coal seams and some surface constraints. As a result, a strip / terrace mining method was selected.

The nature of the thin coal seams lends itself to a coal seam aggregation process which was conducted to develop proper coal working sections. The coal working sections were used in the determination of the economic pit limits through a margin ranking process. Alpha Mine Planning 4U conducted a margin ranking exercise and typical industry costs were used (all-inclusive cost – from pit to port).

Various washability data sets were available for the ranking exercise but to deliver the anticipated product coal qualities, a sink float setting of 1.5 was used. The net outcome of the margin rank resulted in various cut-off margins for the associated basal coal seam. These were used to ultimately determine the final pit limits and preferred basal coal seam.

This exercise further identifies the sequence and mining direction of the various pits, which resulted in a generalised direction from south to north. This has since changed to a north south direction in Open Cut 2 and west to east direction in Open Cut 1 and is discussed in detail in section 16.7.

The use of this optimisation process incorporated both the economic and environmental Ecologically Sustainable Development (ESD) concepts into the decision making criteria to find the optimal pit layout which minimises over burden and waste rock removal.

16.5.3.4 Water Supply

The overall maximum water demand is 2.2 ML (including fire water) per day for the 10 mtpa ROM coal scenario. The water balance for the Project does not forecast a water deficit for any year during the operations phase of the Project. This is discussed in more detail in Section 16.10.

A reliable source of water is required for the construction and operation of the Project. The total water requirement from offsite supplies will vary in relation to water use and the availability of onsite supplies.

Water supply options investigated for supplying raw water to the mine have included:

- Onsite capture (mine dewatering and rainfall harvesting);
- External supply; and
- Onsite reuse.

Following ESD analysis no one option is considered solely suitable for the Project. Water will be sourced using all available options, onsite and offsite water supplies and onsite reuse of water to have the most sustainable outcome available.

During construction and the establishment of the external water supply, water will be required to be trucked in and stored onsite.

16.5.3.5 Alternative Energy Sources

The average expected energy demand for the Project during operations will be in the order of 3 to 5 megawatt (MW) with an estimated annual usage of 35 Gigawatt hour (GWh) based on 365 days, 24 hours per day operation. An assessment was undertaken during the feasibility studies to determine the most cost-effective method for power supply.

Powerlink and Ergon Energy were consulted regarding connections into their existing networks. There is also a regional 275 kilovolt (kV) line which crosses the southwest ML boundary. From discussions with Powerlink it is not feasible to connect to this power supply. Currently there is no transformer in the area to step down the high voltage for mine supply. Consequently, this option is no longer under consideration.

The EIS reported an option to connect into the existing 11 kilovolt (kV) transmission line maintained by Ergon Energy which provides power to the nearby township of Ogmore was under consideration. It was originally considered that there was limited capacity within this transmission line to support the Project. After discussions with Ergon it was identified that the existing transmission line was 22kV, rather than 11 kV, and that there was some capacity to support the Project. Consequently, Ergon has agreed to terms to provide the Project access to the transmission line. The available capacity is limited and as such, will be used as a power supply to office and administration areas. Generators will still be required for the operations of the two MIAs and CHPPs.

Given the limited capacity, 415 volt (V), three-phase dual fuel generators will also be used to provide power onsite. Conceptually the generator configuration will be two 300 kilovolt amperes (kVA) (or potentially two 350 kVa) 415 V dual fuel generator sets mounted in a fully bunded area adjacent to the MIA/CHPP 415 V Switchroom. The CHPP substation will have three 8000 kVA 415 V dual fuel generator sets mounted in a fully bunded area adjacent to the CHPP 415 V Switchroom.

16.5.3.6 Alternative Accommodation

Accommodation options for workers both during the construction and operation phase have been assessed. As the Project will be commute from local towns, Central Queensland Coal considered offsite accommodation at regional towns (i.e. Ogmore, Marlborough, St Lawrence, Yaamba, The Caves and Rockhampton) as well as assisting the local Marlborough Caravan Park to re-develop a previously existing accommodation village on the outskirts of Marlborough.

Central Queensland Coal intends to staff the Project predominately as a daily commute operation using a local work force to the extent possible and encouraging personnel to live in the local area. There may be a need for some drive-in drive-out from further afield and the close proximity to regional towns supports this approach. Consequently, the use of existing accommodation at nearby townships is the preferred option. The Project will investigate establishing a bus service to transport staff to and from local townships when the annual production exceeds 5 Mtpa.

The focus on using a local workforce to the extent possible enables the workforce to stay connected with family and the community when compared to utilising an accommodation camp. This is seen as being in-line with extant best practice in the resource sector. However, where these local and regional towns are not able to service the personnel, an accommodation camp will be developed outside the ML. The potential accommodation camp is outside the scope of this EIS.

16.6 Assessment of Project Against ESD Principles

Ecologically Sustainable Development as defined in the National Strategy for Ecologically Sustainable Development (NSESD) is development which aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations. The NSESD was adopted by all levels of Australian Government in 1992 and provides broad strategic directions and framework for governments to direct policy and decision-making. The key objectives of the NSESD are:

- To enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- To provide for equity within and between generations; and
- To protect biological diversity and maintain essential ecological processes and life-support systems.

While planning and designing the Project, Central Queensland Coal has considered the guiding principles of ESD as outlined in the NSESD. The guiding principles of ESD and how they are addressed in the EIS are outlined in Table 16-12.

Table 16-12 Guiding principles of ESD addressed in the EIS

Guiding principle of ESD	EIS section
Enhance individual and community well-being and welfare	The Project is anticipated to provide significant benefits to the wider community in terms of employment opportunities and increased government revenues as outlined in Chapter 19A - Economic. The Project has been designed such that the mining operations proposed can coexist with existing agricultural land uses and environmental values within the region. These elements ensure that the Project will result in an enhancement of individual and community well-being in the region.
Intergenerational equity	Prepare and implement management plans for waste rock, general waste, soils, land, water and rehabilitation to minimise the legacy risks of the Project. Removal of all originally proposed voids
Protect biological diversity and maintain essential ecological processes	The Project has been designed to minimise impacts to ecological and environmental values throughout the Project area. This is demonstrated by the Projects water management strategy, coal handling strategy and the size and placement of the MIA which means there will be limited direct impacts on remnant vegetation. The haul road and TLF options underwent assessment which considered RE’s and TEC’s as key criteria in the decision. Mitigation measures to protect biological diversity during the construction and operation phase are outlined in Chapter 9 – Surface Water and Chapter 14 – Terrestrial Ecology. Water and fire management plans will be prepared to protect ecological processes. Offsets and methods for developing offsets are discussed in Chapter 14 – Terrestrial Ecology.

Guiding principle of ESD	EIS section
Decision making based on long and short term considerations	Chapter 5 – Land, Chapter 9 – Surface Water, Chapter 10 – Groundwater, Chapter 14 – Terrestrial Ecology, Chapter 19A – Economics and Chaper 19B – Social Impacts, present the long-term and short-term economic, environmental, social and equity impacts of the Project to enable informed decision making. The EIS demonstrates that the Project has been designed, sited and will be constructed and operated considering the short and long-term potential impacts. This ensures potential impacts are identified and managed adequately and sustainably.
The precautionary principle	An assessment of the level of risk of environmental harm from the Project, consistent with the precautionary principle has been undertaken by Central Queensland Coal. Findings are detailed throughout the EIS. Mitigation measures proposed have also been developed based on the precautionary principle ensuring that Project's environmental management criteria and objectives are best practice, notwithstanding any uncertainty of impacts occurring. This includes, for example, the requirement of the Project to pay financial assurance ahead of construction and offsetting potential ecological impacts.
Global environmental impact	Greenhouse gas emissions, mitigation, and reduction options from Project construction and operation are discussed in Chapter 12 – Air Quality (although individually the Project will have a negligible impact on the global environment). The Project has been designed and will be constructed and operated such that greenhouse gas emissions are minimised and mitigated where practicable. The Project will be a very small contributor to Australia's national greenhouse gas inventory. The Project will have no impact on any internationally protected species or sites.
Development of a strong, growing and diversified economy which can enhance the capacity for environmental protection	Economic impacts of the Project and mitigation measures for potential adverse impacts are considered in Chapter 19A –Economics. The Project will contribute significantly to local, State and National economies through a combination of direct and indirect employment impacts.
Enhancing international competitiveness in an environmentally sound manner	With the adoption of the latest mining methods and good practice environmental management, environmental impacts will be minimised and the Project will enhance international competitiveness in the coal mining industry. Mining methods are detailed in Chapter 3 – Description of the Project. As outlined above the design of the Project is such that minimal direct environmental impacts are anticipated and mitigation measures to manage impacts have been proposed which will ensure the Project is undertaken in an environmentally sound manner.
Cost effective and flexible policy instruments	The design of the Project has considered current Queensland and Commonwealth Government policy.
Community involvement in decisions and actions	The EIS process includes a number of opportunities for public comment, during the development of the ToR, public exhibition of the EIS and targeted consultation of the draft EA and ML. Chapter 1 – Introduction describes the stakeholder consultation program that was undertaken for the Project. Chapter 19B – Social Impacts outlines Central Queensland Coal's ongoing commitments to the local community.

16.7 Project Construction and Operation

This section provides an overview of the various activities and their expected timing for the construction and operation phases of the Project. For a more detailed description refer to Chapter 3 – Description of the Project.

16.7.1 Construction

The construction of the Open Cut 2, the initial CHPP, the haul road and TLF and associated mine infrastructure located on the east of the Bruce Highway is planned to commence simultaneously in

2019. Open Cut 1 will commence development at approximately 2027 coinciding with the construction of the second CHPP and MIA.

The commencement date for construction is dependent upon the timing of the Project approvals process. An indicative timeframe was prepared for the EIS, with Year one set as 2019. This schedule remains in place as there is potential for early works to commence in 2019 following receipt of the ML and EA for the Project.

The timing for the Project development schedule has changed slightly from the EIS due to amendments to the Project layout as discussed in the following section. The updated schedule is shown at Figure 16-12.

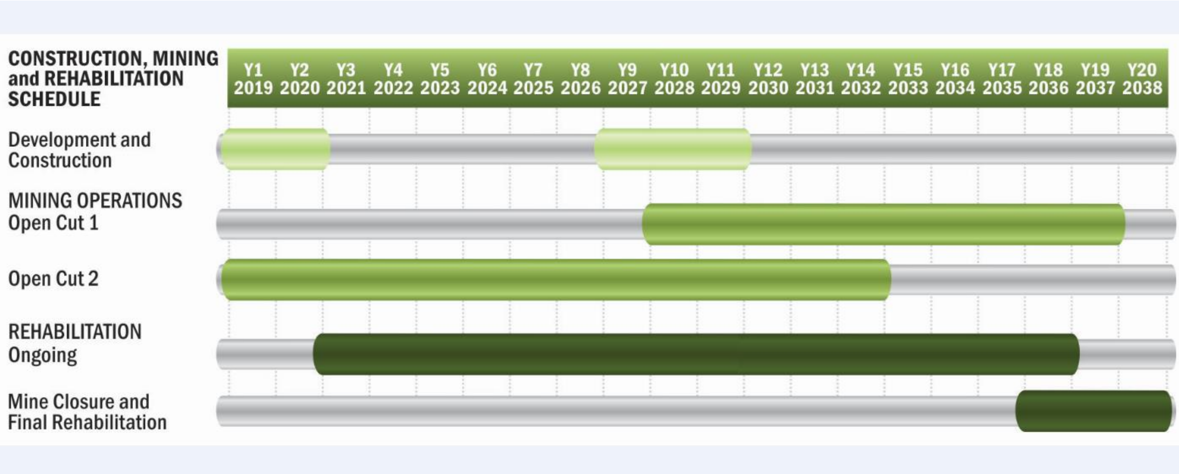

Figure 16-12 Indicative Project development schedule

The construction of the Open Cut 2, the initial CHPP, the haul road and TLF and associated mine infrastructure located on the east of the Bruce Highway is planned to commence simultaneously in 2019.

Key infrastructure to be constructed for the Project includes:

- Two open cut pits (Open Cut 1 and Open Cut 2);
- Three overburden waste stockpiles (1a, 1b and 2);
- Two CHPPs (CHPP 1 and CHPP 2) and product coal stockpiles;
- Two ROM coal stockpile areas and ROM dump stations (comprising dump hopper, product conveyor, crushers and surge bin);
- ROM coal haul roads and waste rock haul roads;
- Product stockpile and conveyor from Open Cut 1 to the product coal stockpile East;
- Waste management facilities;
- Water supply pipeline and management facilities, including raw water supply, storage and a WTP to treat water to potable quality;
- Mine affected water dams, sediment affected water dams and clean water dams;
- Light and heavy vehicle internal roads;

- Main gate and security building;
- Power distribution lines and substation; and
- Product coal haul road from the CHPP 2 to the TLF, TLF product coal stockpile area, rail loop and rail spur.

16.7.1.1 Site Preparation

The initial site clearance works will be focused on the site access road, internal access roads, dams and laydown areas for construction, MIA 2, CHPP2 and TLF. These are all located in the eastern side of the Bruce Highway. Site preparation for the infrastructure associated with Open Cut 1, on the western side of the Bruce Highway will not commence until 2027.

Site clearance will include clearance of vegetation, soil removal and storage, bulk earthworks and temporary drainage works. These works will be conducted in accordance with the Project's vegetation and soil management measures.

Site clearance activities will be staged during the construction phase on an as needed basis to coincide with construction requirements and to minimise the extent and duration of cleared areas at any one time. Suitable soil resources for use in rehabilitation will be stripped from areas where construction and mining operations will occur. Topsoils and subsoils will be stripped, handled and stored in a manner in line with industry best practice to prevent the deterioration of soil quality (refer to Chapter 11 – Rehabilitation and Decommissioning).

Site preparation activities will include the following:

- Construction of the mine access points on the Bruce Highway;
- Site security;
- Site clearance;
- Civil works;
- Environmental protection measures;
- Washdown facilities;
- Erosion and sediment controls;
- Concrete batch plant (concrete will be batched onsite, with suitable batching materials delivered to site by contracted supplier);
- Mobilisation to site;
- Utilisation of existing accommodation at Ogmore, Marlborough and St Lawrence, where possible;
- Crib hut;
- Fencing;
- Amenities;
- Access road / haul road establishment;
- Establishment of yards;

- Installation of temporary water supply with potable water trucked to the site until a water treatment plant (WTP) is installed;
- Sewerage management infrastructure with effluent trucked from site by a licensed contractor to a licensed waste disposal facility;
- Demountable offices;
- Car park; and
- Establishment of laydown and storage areas.

16.7.1.2 Civil Works

Civil works including construction of structure foundations, permanent laydown areas and hardstands will commence following grant of the Mining Lease and EA. It is expected that civil works required during the construction phase will be completed within 2019; however, there may be requirements for further civil works during the operations and decommissioning phases. Civil works for the infrastructure on the western side of the Bruce Highway will not commence until 2027. Typical civil works that will be undertaken as part of the Project include, but are not limited to:

- Civil earthworks, including foundation construction;
- Installation of permanent and temporary drainage;
- Trenching and laying of reticulated services and any other underground pipelines and services;
- Installation of powerlines and substations;
- Road formation construction, surfacing and finishing required for unsealed roads;
- Conveyor footings;
- Earthworks for the establishment of drainage diversions;
- Dams, including raw water dams, sediment affected water dams, mine affected water dams and clean water; and
- TLF, rail loop and rail spur formation construction, track laying and finishing for TLF.

Installation of permanent drainage will be undertaken to accommodate drainage requirements for both the construction and operational phases. This could include such things as culverts, longitudinal catch drains, sediment basins and detention basins.

16.7.1.3 Coal Conveyor Arrangement

A conveyor is proposed to transport product coal from Open Cut 1, under the Bruce Highway via a new culvert arrangement, to the product coal stockpiles located on the eastern side of the Bruce Highway. The conveyor was originally proposed to be located under the existing Deep Creek road bridge; however, because of concerns regarding potential impacts to water quality during periods of flood, the conveyor has been repositioned away from Deep Creek.

The conveyor culvert general arrangement is shown in Figure 16-13. The final location of the culvert will be determined in consultation with the DTMR. Following confirmation of the final location all approvals and permits to construct the conveyor will be sought from DTMR.

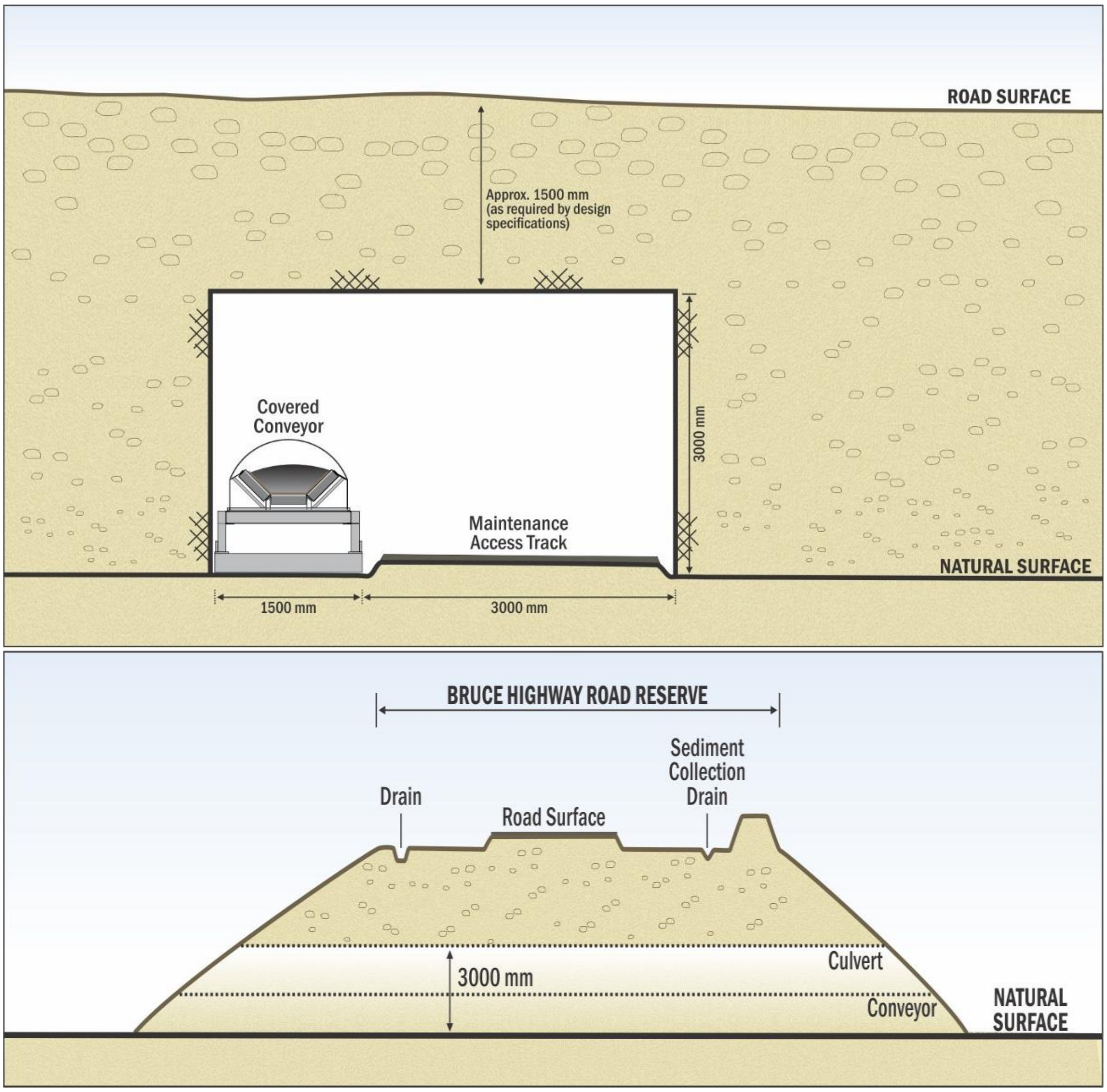

Figure 16-13 New conveyor arrangement under the Bruce Highway (from 2028 onwards)

16.7.1.4 Building and Structures

Construction of buildings and structures will occur after the civil works. Installation of plant and related building components will follow superstructure erection, including the installation of pipe works, cables and instrumentation. Where possible, main plant components will be pre-fabricated and delivered complete to site to minimise the requirement for on-site assembly work.

The construction management office area will be located near the MIA supporting Open Cut 2. The facilities will be of a temporary nature and will be replaced by the permanent administration facilities towards the end of construction. The temporary facilities will include:

- Demountable buildings including offices, workshops, meeting rooms, crib rooms / kitchen, toilets, first aid, communications and storage;
- Car park;
- A light vehicle washdown slab;
- Power supply from diesel generators;

- Temporary construction water storage;
- A temporary potable water storage, until permanent facilities are installed; and
- Temporary wastewater storage, until permanent facilities are installed.

16.7.1.5 Coal Handling and Preparation Plant

Construction of the two CHPPs, ROM coal and product conveyors and stockpiles is anticipated to last approximately 12 months. Given the height and size of the CHPP modules, product stockpiles, surge bin and crushing facilities, the use of cranes, lifts and multistorey scaffolding is anticipated. All work will be in accordance with recognised building standards and regulations.

16.7.1.6 Construction Water Requirements

Both potable and construction water will be required for the construction phase of the Project. For construction water, existing farm dams and a newly constructed Dam 1will be used to supply water. Potable water will either be transported to site by water tankers during construction or involve treatment of groundwater bore or raw water supplies to drinking water standard via a batch water treatment plant (WTP). All potable water will be procured, transported, treated, monitored and stored in compliance with the Australian Drinking Water Guideline 2011 (NHMRC and NRMMC 2011).

16.7.2 Construction Materials, Plant and Equipment

Quarry materials for the construction of the access road and haul road base material will be sourced from existing quarries or from competent materials located within the MLs. Once access to site is established, materials will be sourced from a combination of on-lease deposits where possible and licensed offsite quarries. It is not anticipated that forestry materials will be required by the Project.

The exact location and quality / suitability of the competent material deposits existing within the MLs are yet to be determined, although it is expected that appropriate materials for foundations can be sourced on-lease. This will also include the overburden extracted as part of the mining operations.

Hazardous materials will be used and stored onsite during the construction of the mine. Hazardous materials that will be used during construction include diesel fuels, lubrication oils, paints and thinners, and protective coatings. Further details regarding the usage and storage are discussed in Chapter 21 – Hazard and Risk.

All materials, plant and equipment will be delivered to the Project via road. Large and oversize loads are anticipated, particularly during the CHPP, dump station, stacker / reclaimer and heavy mining equipment construction and installation phase. Loads will mostly be hauled from either the Port of Brisbane, Port of Mackay or the Port of Gladstone.

Construction traffic will involve rigid and articulated vehicles, and light goods vehicles. Traffic flows and vehicles types are expected to vary over the construction period, reflecting the types of materials and equipment required at a specific time. The Project will use standard construction equipment, general trade equipment and specialised equipment as required (refer Table 3-9, Chapter 3 – Description of the Project for an indicative list of required construction equipment).

16.7.3 Operations

16.7.3.1 Mine Pits – Amendments

Open Cut 2

Changes to the mine layout since the submission of the original EIS have resulted in Open Cut 2 and Open Cut 4 being amalgamated. Further exploration information has been added to the geological model, creating a more accurate economic model for the Project. A lower strip ratio, combined with the availability of better quality raw coal, highlights the economic benefits available in the northern end of Open Cut 2, rather than the southern end, adding to the commercial security of the project.

The amalgamation of the two pits facilitates a mining sequence that enables earlier backfilling of Open Cut 2, and consequently, earlier commencement of the progressive rehabilitation program. This has increased the overall area of impact by 100 ha, including an additional 1.8 ha of remnant vegetation, but has avoided a patch of SEVT which is an EPBC Act-listed Threatened Ecological Community (TEC) as identified in Section 16.10.

Commencing operations in the northern end of Open Cut 2 reduces the amount of material required to be placed in Overburden Stockpile 2, particularly in the early years. The change in the Open Cut 2 mining schedule allows the mine to reach a steady state mining sequence moving from north to south, where the overburden waste material is placed directly back into the excavated pit area, much earlier than commencing mining operations in the south.

Open Cut 1

The EIS layout for Open Cut 1 covered a disturbance area of 310 ha. Following the mine design and mine sequencing optimisation studies, the area of Open Cut 1 has been significantly reduced. The new disturbance area for Open Cut 1 is 247 ha representing a reduction in mining area of 63 ha. No remnant vegetation or identified MNES will be impacted.

The Open Cut 1 geological model was updated with the most recent exploration information which then created a more accurate economic model for the Open Cut 1 mining area. Subsequently the mining sequence was changed in line with the new economic model. Aside from the economic benefits that will result from the updated mine schedule for Open Cut 1, the updated schedule will result in a reduction in the amount of overburden waste material that is required to report to Overburden Stockpile 1a and 1b.

16.7.3.2 Mine Sequencing

The mining schedule is based on the development of two open cut operations producing a total of up to 10 Mtpa of ROM. Open Cut 2 will be developed initially in 2019 and is anticipated to operate until 2032. Open Cut 1 is anticipated to commence development in 2027, operations in 2028 and continue operations until 2037. The proposed open cut mine layouts and sequencing of each open cut are shown in Figure 16-14. Mining operations will be up to seven days a week and 24 hours per day.

Mining of Open Cut 1 will commence at the western edge of the pit with mining operations then progressing towards the east. Mining of Open Cut 2 will commence in the northern end and progressing generally in a southern direction.

Being terrace mines both open cut operations will advance across strike. The mining schedule for both pits was established to commence operations in areas where the Margin Ranking for that pit was acceptable, focused on all seams suitable for mining and minimising interaction with the Bruce

Highway. It is anticipated that operations in the open cuts will continue for approximately 20 years which comprises 18 years of mining (2019 - 2037) and three years (2036 - 2038) to finalise the rehabilitation program. The rehabilitation program will be ongoing through the life of the mine, commencing in 2020.

Whilst the initial mining approach is based around truck and shovel operations, Central Queensland Coal will continue to review alternative mining methods to optimise product coal outputs. Other mining methods to improve resource recovery may be considered as the Project progresses. Refer to Table 3-9 of Chapter 3 – Description of the Project for an indicative list and schedule of required mining equipment.

Subject to statutory approvals, initial soil removal from Open Cut 2 is scheduled to commence in 2019. First shipment of product coal is scheduled in Q1 2020. Construction of mine facilities will commence immediately after grant of the MLs. Mining is to commence on the MLs simultaneously with the construction of the mine facilities. The years of mining for each of the open cut operations are shown at Table 16-13.

Table 16-13 Mining schedule

Mine operation	Years of operation
Open Cut 2 (east)	2019 –2032
Open Cut 1 (west)	2028 –2037
Mine Closure)	2036 –2038

16.7.3.3 Mining Method

Open cut mining methods will target the multiple seams during mining of the two pits. Mine development will commence with the removal of vegetation and topsoil by scrapers in accordance with relevant management plans to avoid and minimise impacts. Cleared material will be placed on dedicated topsoil stockpiles or placed directly onto reshaped final landforms if available. The initial box cut will be developed utilising a ramp formed in the low wall of each of the two pits. It is proposed that most of the waste rock will be dumped to the ex-pit waste rock stockpiles for the initial strips and then in-pit for the remaining strips.

The upper portion of weathered overburden, where possible, will be free dug and removed. Where the overburden materials become competent and the free digging operations cease, a drill and blast operation will be utilised to fracture strata. Some of the weathered sandstones and fresh sandstones will be used for concurrent civil works and construction of haul roads.

Coal mining will be undertaken using a fleet consisting of excavators, front end loaders and trucks to mine the coal seams, with the coal hauled to the CHPP for benefaction. Inter-burden waste between the main coal seams is then blasted and this waste is mined by the excavators and hauled by trucks to waste rock stockpiles in the previous strips. The next coal seam is mined in the block, with the coal mining and parting operation planned to be performed in a series of sections along the pit.

Initial out-of-pit dumping to mineral waste dumps is required as the box cuts are developed. The ex-pit dumping for Open Cut 1 occurs in 2027 and lasts until 2029 and will be to an indicative maximum height of 40 m (Reduced Level (RL) 80 m). The ex-pit dumping for Open Cut 2 will commence in 2019 and continue until 2024 and will be to an indicative maximum height of 45 m (RL 75 m). Rehabilitation of the out-of-pit dumps will continue through the life of the mine (refer to Chapter 11 – Rehabilitation and Decommissioning).

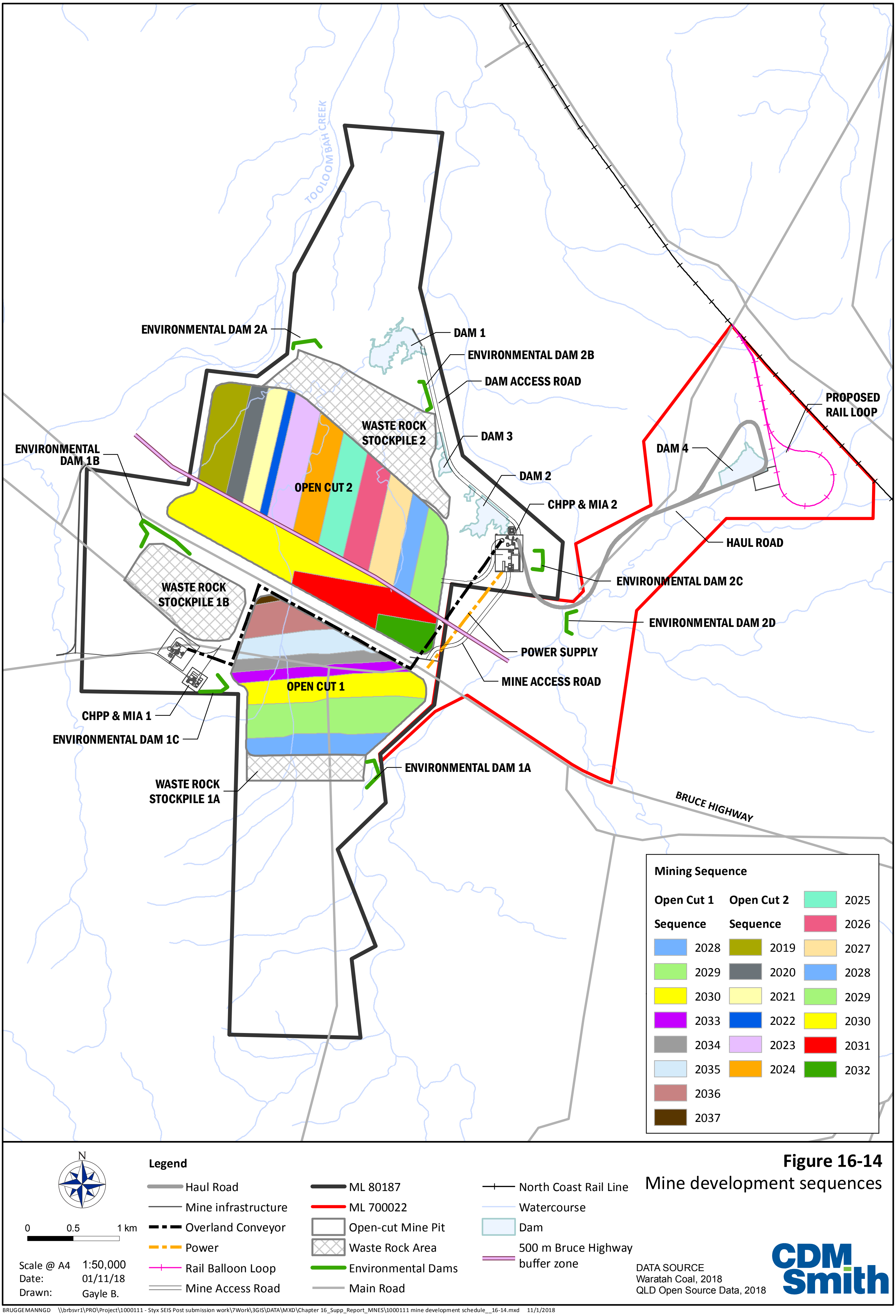

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Figure 16-14
Mine development sequences

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 16_Supp_Report_MNES\1000111 mine development schedule__16-14.mxd 11/1/2018

16.7.3.4 Blasting

Blasting will be required to break and fragment the overburden and interburden horizons in each of the two open cut pits. This allows the fragmented rocks to be excavated and transported to the waste rock stockpiles and for the coal seam to be mined productively. Blasting may not be required to break the coal seam as generally the coal seams are less than 3 m thick.

Blasting will be carried out in accordance to blasting management standard operating procedures. Blasting will generally occur on Monday to Sunday between 6 am and 6 pm. Blasting outside these hours will be covered by a specific Blast Management Plan developed for each individual occurrence and will incorporate a notification procedure informing all related and impacted parties. Blasting activities will be carried out in accordance with the Project's EA so that ground vibration and airblast overpressure (the wave explosive energy released into the atmosphere) are within approved blasting limits (see Chapter 23 – Draft EA Conditions). Blasting activities will account for the direction the wind is blowing to reduce the risk of potential airblast overpressure impacts at noise sensitive receptors.

It is envisaged that an explosives contractor will provide the explosives for the site. The preferred option for storage and supply of bulk explosives is for the blasting contractor to store the chemicals in a remote location offsite, and then transport the explosives to site in specially designed trucks for loading into the blast holes. The blasting contractor, through a specifically designed initiation system, connects each primed blast hole together with detonating cord. The speed at which each blast progresses is determined by the site Blast Engineer to minimise noise and vibration.

Over the life of the mine, the volume of bulk explosives used per annum will average approximately 18,400 tonnes per year.

Following discussions with DTMR since the release of the EIS and original SEIS, Central Queensland Coal has agreed to avoid undertaking blasting activities that will require any closure of the Bruce Highway. For clarity, Central Queensland Coal is not proposing any Project related activity that will require the closure of the Bruce Highway.

16.7.3.5 Coal Handling System

The coal handling system consists of a ROM coal system, a product coal system and a rejects waste system. This incorporates simultaneous coal feed from the two open cut mines supplying the CHPPs. Materials handling capacity has been set at a maximum of 2.5 Mtpa of ROM coal for each CHPP. A schematic showing the coal handling system is shown in Figure 16-15.

Raw Coal Layout

Raw coal from the open cut operations will be transferred by truck to one of two 100,000 t capacity ROM pads. There will be one ROM pad, ROM bin and primary crusher arrangement servicing each of the open cut operations. Secondary and tertiary crushing stations will be located immediately after the primary crushing station. This stockpile will be no more than 30 m high.

Coal will be dumped directly into a ROM bin when the CHPPs are running at capacity or deposited into the ROM stockpiles to allow surge capacity. Reclaim feed to the ROM bin from the stockpile will be by front end loader. An elevated ROM pad will be constructed using a reinforced concrete design around the crusher pocket.

Primary crushing takes place immediately under the ROM feed bin. The primary sizer is a low speed sizer, a combination of high torque and low roll speeds with a unique tooth profile.

Raw Coal Conveyor

ROM coal conveyors sized at 300 t/hour will deliver sized ROM coal to the overland conveyor streams. A single ROM coal conveyor will service each CHPP. Overland conveyors will then transfer the ROM coal from the crushers to the plant feed bin which will then feed into the CHPP.

Coal Handling Preparation Plant

Two CHPPs will be required to process ROM coal delivered from each of the pits and increase the recovery of the coal resource. Each CHPP will remove (wash) the unwanted sediment and rock from the coal to improve the quality of coal exported to market. The first CHPP will be established to support operations at Open Cut 2. The second CHPP will be established to support operations at Open Cut 1.

A single conveyor sized at 300 t/hour will feed each of the CHPPs from the ROM stockpiles. At this point the feed will become a slurry through addition of water to transport and optimise feed conditions to de-sliming screens. The de-sliming screen will remove sub-sized particles from, and dewater, the dense medium cyclone feed. Screening is achieved by presenting particles to the screen deck surface and moving particles smaller than the aperture through the sieve surface. Vibration of the screen assists this process by stratifying the bed, giving particles more opportunity to present to the screen surface.

Both CHPPs will be based on conventional wet beneficiation processes using proven technology that is used extensively throughout the Australian coal industry, for example Daunia, Caval Ridge, Maules Creek and Bengalla. The coarse coal rejects fraction (>1 mm to 50 mm) will be beneficiated in dense medium cyclones. In this process, the coarse material from the de-sliming screens is mixed with a magnetite / water medium and pumped to a single large diameter dense medium cyclone. Dense medium cyclones separate based on density with the high-density non-coal material reporting to coarse rejects stockpile and the lower density coal reporting to the product coal stockpile after dewatering in coarse coal centrifuges.

The fine ROM coal slurry from the de-sliming screens is pumped to a classifying cyclone module to remove the fine material and the bulk of the water from this stream. The fine coal fraction (<1 mm) will be beneficiated using spirals in a water-based separation. This produces dewatered fine coal that report to the product stockpile. Spirals reject is dewatered on high frequency screens with the coarse spirals reject particles reporting with the dense medium cyclone reject on the plant reject conveyor and the fine spiral reject particles reporting to the tailings thickener.

The proposed tailings system will be a simple filter press system. The filter press system requires the fine particles to be conditioned with flocculants, a process carried out within thickening tanks. The thickening process forms an aqueous tailings slurry allowing tailings to be transported via a pipe network to the filter press system. The filter press method utilizes filter presses to dewater tailings forming a dry paste. The water is recycled to each of the CHPPs while the tailings paste is conveyed to the rejects surge bin for disposal amongst the significantly more prolific overburden waste material. Excess water from the rejects containment structures is also recycled.

Coarse rejects will report from the CHPP to awaiting empty haul trucks via the coarse rejects conveyor which is sized at 100 t/hour. Loaded haul trucks will empty the coarse rejects to the coarse rejects emplacement area.

The reagents required to operate the flotation cell (diesel and Methyl Isobutyl Carbinol) will be provided and stored in a purpose-built storage. The storage will consist of one storage tank for each of the reagents located in a fully bunded area. The diesel tank will also be used for light vehicle and product stockpile dozer refuelling. Pumps and piping will transport the reagents from the storage tanks to the flotation circuit.

Product Coal Handling

Both CHPPs will have a single product coal conveyor sized at 250 t/hour discharging washed coal to a product coal stockpile sized at 15,000 t capacity. Product coal stacking will be via a conventional elevated gantry conveyor.

The product coal stockpile at the TLF will have an operational capacity of 100,000 t. Product coal will be reclaimed from the TLF product coal stockpile via bulldozer and coal valve operation discharging coal onto a single reclaim tunnel conveyor. Reclaimed coal will be conveyed to the train load-out bin for loading into the wagons.

There will be approximately 1,110 train movements per year on average, subject to train and shipping schedules. A rail haulage provider will contract the rolling stock to transport coal. Product coal stockpiles will be less than 20 m high.

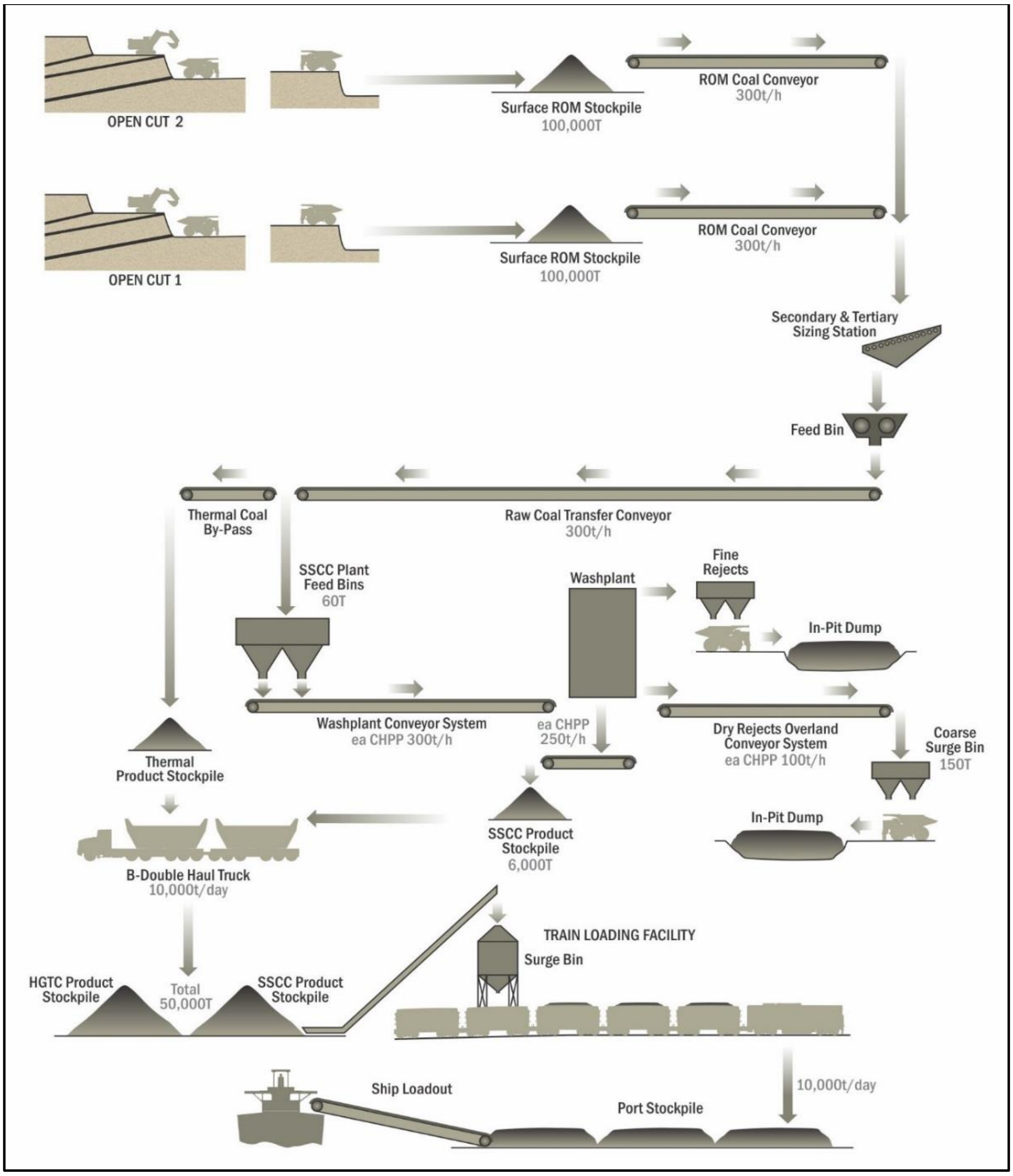

Figure 16-15 Coal handling system

16.7.3.6 Rejects and Tailings Disposal

Rejects and tailings disposal will be conducted in accordance with the Project's Mineral Waste Management Plan. Over the life of the mine, the total volume of excavated waste rock from open cut activities (i.e. overburden, interburden and fines from the CHPPs) is expected to be approximately 745 million bank cubic metres (Mbcm). This equates to approximately 893 million loose cubic metres (Mlcm) due to an average swell factor of 20%. The estimation of tonnage and volumes of waste rock and subsoils to be excavated during each year both annually and cumulatively is presented in Chapter 3 – Project Description Table 3-10.

The preferred method to dispose of mine waste is to truck rejects initially to ex-pit mineral waste dump areas and as the open cuts develop, coarse rejects and filter press tailings will be blended with overburden and disposed of within the overburden waste. These materials will be hauled as back loads to disposal areas using coal haulage trucks after they deliver ROM coal to the ROM stockpile. An estimation of the dump schedule presented in Chapter 3 – Project Description Table 3-11 and is shown at Figure 3-26 to Figure 3-28. Because of the optimised mine plan, there will be no retained voids at the completion of mine closure.

An assessment of overburden and coal (as possible reject material) was undertaken by RGS Environmental Pty Ltd in 2012 to determine the potential environmental issues that may arise from the handling and treatment of these materials as part of the Project. The assessment primarily focused on potential acid-forming (PAF) materials and the potential for AMD to occur. The geochemical testing program used samples collected from coal resource assessment boreholes located in the proposed mine area and considered to be representative of geological conditions across the site. The assessment is discussed in detail inChapter 8 – Waste Rock and summarised below.

The rejects are expected to have a low capacity to be potentially acid forming. No visible pyrite (FeS_2) was reported in the 2012 data set, although possible pyrite was reported in the described lithology. Total sulphur content in potential coal reject samples in 2012 ranged from 0.005% to 0.69% and averaging 0.10%, indicating low sulfur content for rejects. The proportion of sulfur of the total sulfur content, determined by the chromium reducible method (CRS, to distinguish between biogenic and pyritic sulfur for potential oxidation) in the coal reject samples ranged from 19.3% (coal) to 100% (carbonaceous mudstone, roof).

Predicted salinity of the rejects produced during operation is considered to be moderate (average electrical conductivity of ~0.54 dS/cm of potential reject sample analysed) and is consistent with the EC measurements of other overburden and interburden samples (RGS Environmental, 2012). Reject materials (coarse) will report to the out-of-pit waste rock storage facility during the early stages of mining, with rejects from latter stages to report to the in-pit facility, co-disposed with tailings from the two CHPPs.

The sample analysis data shows the sulfur concentration of the majority (98%) of waste rock samples was low (<0.2%), with these materials classified as Non-Acid Forming (NAF), or NAF (Barren) where the ANC/MPA ratio is >10. The acid neutralising capacity (ANC) values were variable, ranging from 7 to 390 kg H_2SO_4/t. Of the 163 samples analysed, two were classified as "Uncertain" with ANC/MPA ratios <2. One sample (Sandstone and Carbonaceous Mudstone) was classified as Potentially Acid Forming (PAF) due to a high sulfur concentration result (8.18%). The pH (1:5 extract) results of all samples ranged from 8.8 to 10.2 (except the single PAF sample, with a pH of 6.8), indicating the waste is alkaline. There is a moderate potential for saline leachate generated from the waste materials, with an average EC of 0.61 dS/cm in the samples.

Predicted salinity of the rejects produced during operation is considered to be moderate (average electrical conductivity ~0.6 dS/cm of potential reject sample analysed) compared to the surface water electrical conductivity range (0.259 to 1.554 dS/cm) recorded in creeks and ponded surface water onsite. The volume of rejects shall be reduced through screening the rejects material and the rejects shall be capped within benign soil to minimise further oxidation and dissolution of metals.

The analytical results of the sulfur concentration of the majority (98%) of waste rock samples was low (<0.2%), with sulfur concentrations being more wide ranging in the unweathered samples analysed from close to the coal seams. The acid neutralising capacity (ANC) values ranged from low to very high (5.3 to 390 kg H_2SO_4/t). Samples classified as NAF (Barren) generally had higher ANC values compared to samples classified as NAF. Of the 147 waste rock samples, 144 samples had calculated negative net acid producing potential (NAPP) values (-1.0 to -390 kg H_2SO_4/t), indicating a significant overall proportion of acid consuming capacity (AC). The three samples with positive NAPP values were described as pyritic sandstone / mudstone. Waste rock samples were alkaline (> pH 7) with 98% samples having high pH (9.0 to 10.0 pH). The minimum pH recorded was 4.8 (the aforementioned pyritic sandstone sample). Electrical conductivity (EC) of samples ranged from low to very high (0.11 to 2.78 dS/cm) with a median EC of 0.61 dS/cm.

Further discussion on the geochemical characteristics of the waste rock material is at Chapter 8 – Waste Rock and Rejects.

16.7.3.7 Water Management System

The following provides a summary of the Project's Water Management System. A detailed assessment is provided in Section 16.10.4.

The maximum total annual demand excluding water re-use is calculated at 804 Megalitres (ML) at 2030 and mining 10 Mtpa ROM. Dust suppression and coal washing form the major water demands. This water requirement will be supplied from harvesting on-lease stormwater runoff, mine affected water from pit dewatering activities and water reuse within the CHPP. These combined sources provide a 99% reliable supply. In times of extreme drought, dust suppression, product moisture correction and coal washing water use will be decreased, and / or alternative water supply options explored to sustain operations. A schematic of the proposed water management network for the Project is shown in Figure 16-16.

Project Water Demand

Project water usage including potable water, emergency use water (fire), raw water and mine water is outlined in Table 16-14. The water demand for the final rehabilitation and mine closure activities in 2036 to 2038 will likely be significantly lower than the demands during the operation of the mine. Water requirements during rehabilitation stages is assumed to be 20ML sourced from environmental dams and pit dewatering and will be finalised during detailed design.

Table 16-14 Mine water demands

Year	ROM (Mt)	Potable Demand (ML)	CHPP Demand (ML)	Dust Suppression Demand (ML)	Washdown Demand (ML)	Sewer (ML)	Total Water Demand (ML)
2019	1	6.3	60	150	36	5.6	255
2020	2	6.3	121	150	36	5.6	320
2021	2	6.3	121	150	36	5.6	320
2022	2	6.3	121	150	36	5.6	320
2023	4	6.3	242	150	36	5.6	440
2024	4	6.3	242	150	36	5.6	440
2025	4	6.3	242	150	36	5.6	440
2026	4	6.3	242	150	36	5.6	440
2027	4	6.3	242	150	36	5.6	440
2028	4	6.3	242	150	36	5.6	440
2029	7	6.3	424	150	36	5.6	630
2030	10	6.3	606	150	36	5.6	804
2031	4	6.3	242	150	36	5.6	440
2032	4	6.3	242	150	36	5.6	440
2033	2	6.3	121	150	36	5.6	320
2034	2	6.3	121	150	36	5.6	320
2035	2	6.3	121	150	36	5.6	320
2036	0.3	6.3	18	150	36	5.6	215

The water within the mine site can be divided into four main classes as follows:

- Raw water – clean water runoff from catchments that are undisturbed or relatively undisturbed by mining activities;
- Sediment laden water – surface water runoff from disturbed catchments such as the active MIA and overburden stockpiles, all of which could contain elevated levels of sediment;
- Mine affected water – water collected in open mine pits from groundwater ingress or surface water runoff, likely to contain elevated levels of salts and metals; and
- Contaminated water - surface water runoff and process water which could potentially contain hydrocarbons, salts or other chemical contaminants, possibly because of unintended spills.

The primary objective of site water management is to separate clean water and dirty water runoff for appropriate management, to maximise water harvesting for supply operations, to contain contaminated water for reuse and to prevent uncontrolled discharges. The proposed water management system for the Project principally comprises the following components:

- The collection of mine affected water in water storages for reuse;
- The collection of sediment laden runoff from the MIAs, TLF and waste rock stockpiles, for treatment and reuse and / or discharge;
- The transfer of water from the raw water dams, pit dewatering and environment dams to the process water dam at each MIA / CHPP where it is used for coal washing;
- The decant of effluent from coal washing activities and reuse of decant water within the CHPPs;
- The use of water by the workforce, industrial processes, dust suppression and for firefighting (if required); and
- The managed release of mine affected water to receiving waters, governed by flow conditions, and water quality objectives.

Potable Water

A potable water demand of approximately 6.3 ML/annum is estimated for the MIA and CHPP operations at full capacity. All potable water will be procured, transported, treated monitored and stored in compliance with the Australian Drinking Water Guideline 2011 (NHMRC and NRMMC 2011). Potable water will be transported to site by water tankers initially during construction. A batch water treatment plant (WTP) will be commissioned and will involve treatment of groundwater bore or raw water supplies to drinking water standards. The capacity of the WTP will be 18 kilolitres per day (kl/d). The WTP would be modular in design and can be readily procured, installed and operated to comply with the Australian Drinking Water Guideline 2011 (NHMRC and NRMMC 2011). Additional unit/s can be added if required to meet any increases in demand. Sludge from the water treatment effluent stream will be disposed of in-pit or transported offsite to an authorised waste facility.

Clean Water Runoff Management

Clean water is defined as runoff from catchments undisturbed by mining and non-mining activities. The mine has been designed to avoid any diversions of defined watercourses of high environmental value, namely Deep Creek and Tooloombah Creek. However, low order tributary gullies that discharge into Deep Creek and Tooloombah Creek and that transect the ML are diverted around mine affected areas. These clean water diversions are aimed at maintaining the health of defined watercourses of higher environmental value and to reduce contamination of otherwise clean water runoff.

Contaminated Water management

Several types of dams will be required to hold mine affected runoff, including:

- Environmental dams that capture rainfall runoff from the two CHPP / MIA areas, TLF and waste rock stockpile areas. The primary function of the environment dams is to capture sediment laden runoff for sediment removal. A perforated riser pipe outlet is proposed to allow gravity draining of the sediment dam within 48 hours of filling. A gated outlet is proposed for potentially storing water for use (overburden and CHPP environment dams) or for stockpile spray and supplementary fire supply (TLF environment dam – Dam 4). Oil / water separators are proposed for vehicle wash and workshop areas to treat hydrocarbon contaminated runoff prior to release or containment in environment dams;
- A PWD located at each MIA that supplies water to the CHPP. The PWD holds a 14-day CHPP demand volume to buffer against water supply maintenance and breakdown. The PWD is kept full from transfers from the pit dewatering (priority 1) and the raw water dam (Dam 1) (priority 2). The PWD does not discharge to the environment and has a design storage allowance to ensure overtopping does not occur;
- CHPP dewatering ponds that accept high moisture coal fines from coal washing and facilitate decant return to the PWD for reuse within the CHPP. The dewatered fines are then stored in exhausted mine pits; and
- Open cut pits that contain a sump (nominally 5 ML) from which groundwater inflow and rainfall runoff is stored. Water is transferred from the pit sump to an ex-pit dam at an indicative rate of 100 L/s.

A water balance simulation model of the water management network depicted in Figure 16-16 was used to determine the net annual balance of water to be held in storages, reliability of supply, the water reuse potential and raw water requirements. The mine water balance is discussed in detail

Section 9.7 of Chapter 9 – Surface Water. The water deficit over the 19 years of mining operations is predicted to be minimal, with any deficit most likely to occur during peak production years.

The following conclusions can be made from the results:

- For MIA 1 and MIA2 Process Dams, the inflows and water transfers were able to meet the CHPP demand; and
- For Dam 1, the maximum storage capacities reached 700 ML, and was able to supply the mine demand for the majority of historical climate simulations.

The water deficit over the 19 years of mining operations is predicted to be minimal, with any deficit most likely to occur during peak production years. The demand over the 18-year mining simulation showed no possible water supply deficits with a predicted reliability of supply greater than 99%. Dam 1 does not dry out and is able to provide a reliability of 99% water supply for the Project needs.

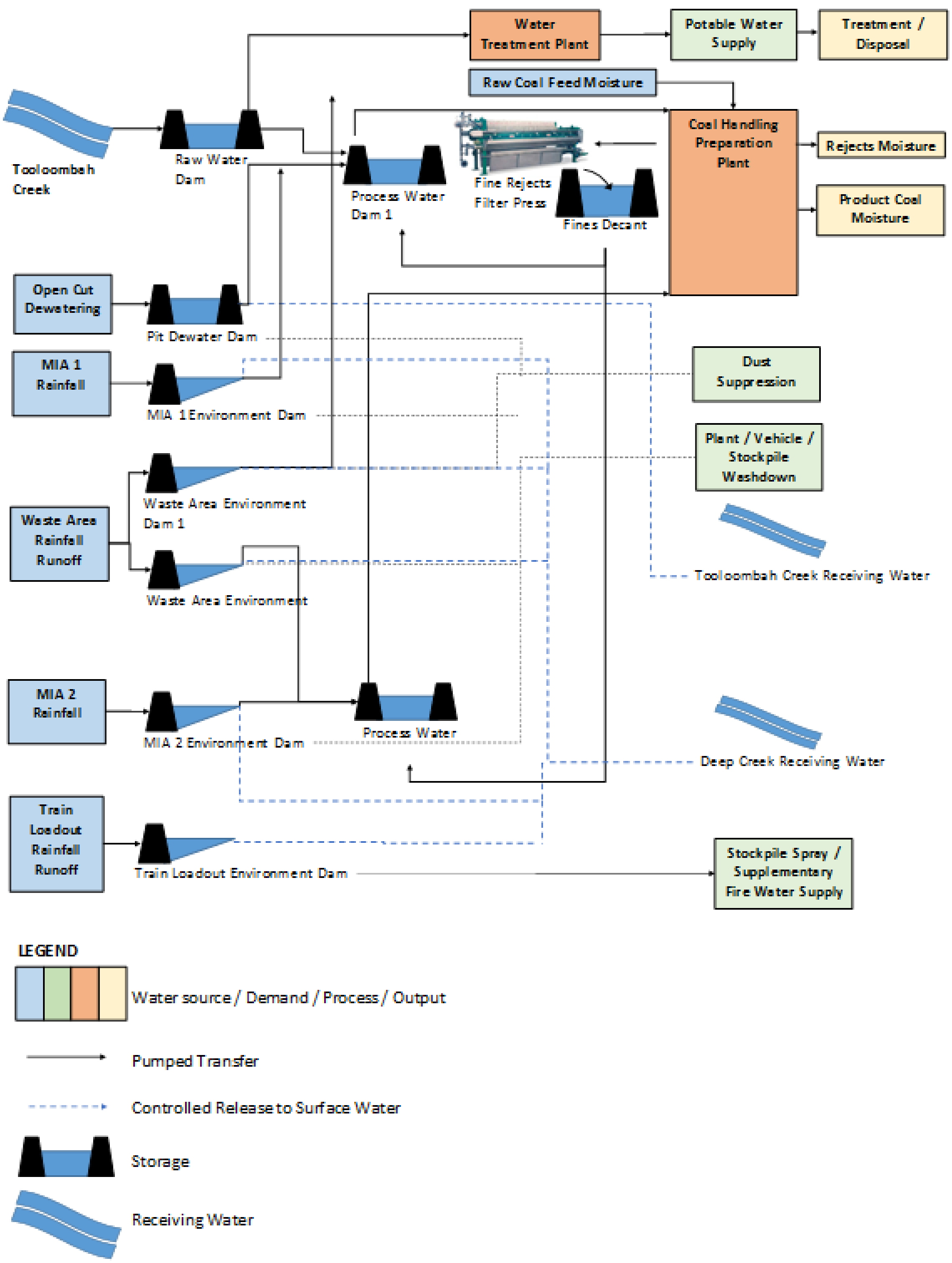

Figure 16-16 Water management network schematic

All proposed storages and levees have undergone preliminarily assessment under the DES Manual for Assessing Consequence Categories and Hydraulic Performance of Structures to determine the minimum hydraulic performance requirements. A summary of the consequence assessment is shown in Table 16-15.

Table 16-15 Consequence assessment summary

Storage	Scenario	Consequence Category	Overall Consequence Category	Comments
Dam 1	Failure to Contain	Low	Significant	Clean water (treated by prior environmental and holding dams) with negligible environmental harm expected from overtopping discharge when conducted in a controlled manner consistent with approval conditions.
	Dam Break	Significant		The 700 ML storage capacity is not considered a likely risk to populations and infrastructure downstream; however it is a final receiving location and may be subject to cascading failure. This risk will be incorporated into the dam and spillway design.
Dam 2 – 600 ML	Failure to Contain	Significant	Significant	Possible harm to the receiving environment of moderate or significant values; however the harm is unlikely to meet the thresholds for the "High" consequence category.
	Dam Break	Low		Possible harm to the receiving environment of moderate or significant values due to contaminant release. Volume reports via transfer channel to Dam 3.
Dam 3 – 150 ML	Failure to Contain	Significant	Significant	Possible harm to the receiving environment of moderate or significant values; however the harm is unlikely to meet the thresholds for the "High" consequence category.
	Dam Break	Low		Possible harm to the receiving environment of moderate or significant values due to contaminant release. Volume is too small to be considered a risk to populations and infrastructure downstream. The MIA 1 dam has a small containment volume of ~30 ML and is unlikely to result in a downstream population at risk.
Dam 4 – 200 ML (Train Loadout)	Failure to Contain	Significant	Significant	Possible harm to the receiving environment of moderate or significant values, however the harm is unlikely to meet the thresholds for the "High" consequence category.
	Dam Break	Significant		Possible harm to the receiving environment of moderate or significant values due to sediment entrainment on release. Volume is too small to be considered a risk to populations and infrastructure downstream. The Dam 4 has a small containment volume of ~200 ML and is unlikely to result in a downstream population at risk.
MIA 1 Dam (process water)	Failure to contain	Significant	Significant	Possible harm to the receiving environment of moderate or significant values; however, the harm is unlikely to meet the thresholds for the "High" consequence category.
	Dam break	Significant		Possible harm to the receiving environment of moderate or significant values due to contaminant release. Volume is too small to be considered a risk to populations and infrastructure downstream. The MIA 1 dam has a small containment volume of ~30 ML and is unlikely to result in a downstream population at risk.

Storage	Scenario	Consequence Category	Overall Consequence Category	Comments
MIA 2 Dam (process water)	Failure to Contain	Significant	Significant	Possible harm to the receiving environment of moderate or significant values; however, the harm is unlikely to meet the thresholds for the "High" consequence category.
	Dam Break	Significant		Possible harm to the receiving environment of moderate or significant values due to contaminant release. Volume is too small to be considered a risk to populations and infrastructure downstream. The MIA 2 dam has a small containment volume of ~30 ML and is unlikely to result in a downstream population at risk.
Environment Dams	Failure to Contain	Low	Low	Sediment laden, but otherwise clean water with negligible environmental harm expected from overtopping discharge coinciding with extreme rainfall events and consistent with approval conditions.
	Dam Break	Low		Volume is too small to be considered a risk to populations and infrastructure downstream.
Levee	Dam Break	Regulated Structure	Regulated Structure	Levees are designed to prevent ingress of clean flood water into an operational area or containment system.

Water Storage Assessment

Based on the consequence assessment summarised in Table 16-16, the following Design Storage Allowance, Extreme Storm Storage and spillway capacities have been selected in accordance with the DES consequence manual:

- Spillway capacity of 1% Annual Exceedance Probability (AEP) (flood event) with freeboard allowance for wave run-up from a 9.5% AEP wind;
- Design Storage Allowance for a 4.9% AEP wet season;
- Water balance modelling informed the 4.9% AEP wet season storage through Monte Carlo simulation of 127 years of historic climate data and by adding a 50% contingency to the increase in storage volume from 1 November; and
- Extreme Storm Storage for a 9.5% AEP, 72 hr duration rainfall event. The corresponding 9.5% AEP, 72 hr design rainfall depth is 300 mm, per the BoM's Intensity Frequency Duration curves for the Project location.[1]

The MIA1 and MIA 2 dams (PWDs) are designed as turkey's nest storages with no external contributing catchment. Contributing catchments to environment dams are restricted to the area of disturbance generating dirty water runoff i.e. clean water runoff is kept separate and diverted around areas of disturbance. The required storage size for the dams was informed by simulating the mine water balance as discussed in Section 16.9.2 and / or by applying the following performance criteria:

- Dam 1, Dam 2 and Dam 3 combined – Provide 99% reliable water supply for the life of the Project;

[1] IFD curves sourced from: http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtm for coordinates 21.69 m S and 149.66 m E

- Environment Dams – Sized to capture the 4.9% AEP year 24 hr duration storm event in accordance with The DES *Stormwater Guideline* (EHP 2014b);
- Pit dewatering to Dam 2 – Sized to have no non-compliant discharges for the maximum rainfall and assuming licenced discharges, dust suppression and washdown demands, and transfer to the MIA for use within the CHPP; and
- MIA 1 and MIA 2 Dams – Sized to have no non-compliant discharges for the maximum rainfall and assuming return of decant.

A summary of the storage sizing assessment is provided in Table 16-16.

Table 16-16 Storage sizing assessment summary

ID	Storage	Design Capacity (ML)	Regulated Structure (Y/N)	Indicative Footprint (ha)	Design Storage Allowance	Indicative Footprint with DSA (ha)	Extreme Storm Storage (ESS)	Spillway Capacity
1	Dam 1	700	N	22.5	150 ML based on 4.9% AEP wet season volume increase plus 50%	14.6	41 ML based on a storage surface area of 22.5 ha and 300 mm rainfall depth	0.2% AEP rainfall or pump supply rate, whichever is greater.
2	Dam 2	600	N	11.2	130 ML based on 4.9% AEP wet season volume increase plus 50%	14.2	40 ML based on a storage surface area of 11.2 ha and 300 mm rainfall depth	0.2% AEP rainfall or pump supply rate, whichever is greater.
3	Dam 3	150	N	3.6	28 ML based on 4.9% AEP wet season volume increase plus 50%	4.1	9.5 ML based on a storage surface area of 1.6 ha and 300 mm rainfall depth	0.2% AEP rainfall or pump supply rate, whichever is greater.
4	MIA 1 Process Water Dam	30	Y	1.6	17 ML based on 4.9% AEP wet season volume increase plus 50%	2	6 ML based on a storage surface area of 1.6 ha and 300 mm rainfall depth	0.2% AEP rainfall or pump supply rate, whichever is greater.
5	MIA 2 Process Water Dam	30	Y	1.6	17 ML based on 4.9% AEP wet season volume increase plus 50%	2	6 ML based on a storage surface area of 1.6 ha and 300 mm rainfall depth	0.2% AEP rainfall or pump supply rate, whichever is greater.
6	MIA 1 Environment Dam	30	N	1.7*	N/A	N/A	N/A	1% AEP rainfall#
7	MIA 2 Environment Dam	30	N	1.7*	N/A	N/A	N/A	1% AEP rainfall#

ID	Storage	Design Capacity (ML)	Regulated Structure (Y/N)	Indicative Footprint (ha)	Design Storage Allowance	Indicative Footprint with DSA (ha)	Extreme Storm Storage (ESS)	Spillway Capacity
8	Dam 4 TLF Environment Dam	200	N	10.6*	70 ML based on 4.9% AEP wet season volume increase plus 50%	11.7	32 ML based on a storage surface area of 10.6 ha and 300 mm rainfall depth	0.2% AEP rainfall or pump supply rate, whichever is greater.

#1% AEP spillway capacity proposed for environment dams that are not regulated structures
*Dam areas calculated on an assumed average depth of 3m

16.7.4 Mine Infrastructure

16.7.4.1 Mine Industrial Area

MIAs will be located adjacent to each of the CHPPs. The likely MIA arrangement for both CHPPs is shown in Figure 16-10. The key components of the MIA are:

- Administration offices and staff parking;
- Diesel, oil and lubricant storage and handling facilities;
- Vehicle and equipment wash down facilities;
- Vehicle fuelling facilities;
- Workshops and stores facilities;
- Laydown and hardstand areas;
- Electrical power substations and associated facilities;
- Raw water supply for potable water production, firefighting, coal dust suppression and coal washing; and
- Internal road network including light-vehicle access roads, heavy-vehicle haul roads and a site access road.

Diversion structures will be formed at each of the MIAs to direct clean water around the area and direct potentially contaminated water to an environmental control pond. Areas storing fuels or oils and washdown areas will be appropriately designed and bunded with runoff from these areas directed to a sump to separate oils and water prior to releasing water to the environment control pond.

16.7.4.2 Fuel Facility

During peak production, it is estimated that approximately 163.58 ML of diesel fuel will be consumed. This consumption rate will decrease to approximately 0.73 ML as the open cut operations cease.

The fuel storage facility will be located at the MIA and will comprise several interconnected self-bunded bulk diesel storage tanks. It is anticipated that approximately 770,000 L of diesel will be stored onsite at the two fuel storage areas. Diesel will be reticulated to heavy vehicle service bays, and heavy and light vehicle bowsers. Access to the fuel facility will be via the internal MIA access roads. The fuel facility will be designed and located at a safe operating distance from other MIA and surrounding facilities in accordance with Australian Standard AS1940 - The Storage and Handling of Flammable and Combustible Liquids.

There will be no in-field fuel storage. Fuel trucks will transfer fuel from the fuel storage tanks to mine vehicles.

16.7.4.3 Diesel Oil Lubricant Storage and Handling Facilities

The petroleum, oil and lubricant will be located at the MIA. The diesel, oil and lubricant facility is anticipated to store various quantities of transmission oil, hydraulic oil, diesel engine oil, final drive oil and waste oil. In addition, the facility will have a storage capacity for lubricants and coolants. The diesel, oil and lubricant facility will also comprise:

- Self-bunded lube and oil storage tanks for several different types of oil and lubricants;
- Hardened on ground oil and lube tanker unloading area, allowing for oil transfer from the delivery vehicle to the storage tanks; and
- Some reticulation of oils and lubricants depending on the final configuration of the MIA facilities.

16.7.4.4 Washdown Facilities

Heavy vehicle and light vehicle washdown facilities will be located at the MIA. The washdown facilities will comprise:

- Prewash bays to remove excessive amounts of large material;
- Washpad for washing with handheld high pressure water cannons;
- Grit traps and oil / water separators; and
- Reticulation of washdown water to an environmental water storage pond.

16.7.4.5 Power Supply

Power to the site will be supplied via a combination of a new 22 kV power line supplying 63 kVa and multiple 415 V, three-phase diesel generators. Ergon will provide a connection to the existing 22 kV transmission line which provides power to the nearby township of Ogmore. The connection will terminate at the ML boundary, where Central Queensland Coal will develop new transmission lines to the MIA on the eastern side of the Bruce Highway. The power supply will be used to supply power to the offices and administration areas. Ergon will be responsible for obtaining all approvals for the new connection.

The additional 415 V, three-phase diesel generators will be installed initially at the MIA and the CHPP on the eastern side of the Bruce Highway to service those operations. The MIA will incorporate two 300kVA (or potentially two 350 kVa) 415 V diesel generator sets mounted in a fully bunded area adjacent to the MIA 415 V Switchrooms. The normal mode of operation for the generators is synchronised and connected to the load through a bus tie. The generators will be sized to provide redundancy with each generator capable of carrying the total load.

The generators will include their own diesel day tanks capable of holding sufficient diesel for a minimum of seven days' operation on full load. The generators will be hired to minimise initial capital costs and the hire company will be responsible for all repairs and maintenance.

Each CHPP area will be serviced by a substation located at the CHPP. Conceptually the CHPP substation will have three 800 kVA 415 V diesel generator sets mounted in a fully bunded area adjacent to the CHPP 415 V Switchroom. The normal mode of operation for the four generators is synchronised and connected to the load through bus ties with an interconnecting cable installed between the two substations. The generators will be sized to provide redundancy with three generators capable of carrying the total load. Like the generators used at the MIA, each have their own diesel tanks capable of holding sufficient diesel for a minimum of seven days' operation on full load.

The switchrooms house the motor control centres (MCC), programmable logic controls (PLC) and instrumentation equipment, as well as the 415 V Distribution Board which supply light and power. The area lighting consists of hinged lighting towers fitted with 1,000 W floodlights.

In parallel to the development of the new 22 kV / 63 kVa connection, Central Queensland Coal are currently in discussion with Ergon in regard to options to relocate a small section of the existing 22kV transmission line to support ongoing mining operations on the eastern side of the Bruce Highway. A key requirement of any relocation of the transmission line infrastructure will be no reduction to the current level of supply to the township of Ogmore.

There is also a regional 275 kV line which crosses the southwest EPC boundary. From discussions with Powerlink (275 kV), it is not feasible to connect to this power supply. Currently there is no transformer in the area to step down the high voltage for mine supply. Consequently, this option is not under consideration.

Central Queensland Coal notes Powerlink and Ergon have standard requirements for working around its infrastructure. This includes the requirement to ensure access is retained to the existing Ergon and Powerlink transmission line easements. Should the existing access arrangements need to be changed because of mining activities, Central Queensland Coal will work with Powerlink and Ergon to find alternative routes to the easements. Central Queensland Coal will also ensure all Blast Management Plans take into consideration the Powerlink and Ergon Transmission Lines. Should there be potential for impact to either transmission line infrastructure, Central Queensland Coal will work with Powerlink and Ergon to address any potential risks.

16.7.4.6 Onsite Road Infrastructure

Access to the Operational Area of the Project will be via the Bruce Highway which will have new turn out lanes constructed connecting to the entry points to the north-eastern and south-western operational areas. The turnout lanes will be designed to DTMR standards (see Chapter 6 – Traffic and Transport for further details).

Current designs indicate a requirement of approximately 15 km of roads for access around the MIA and CHPP. Roads will rely on existing farm access tracks wherever possible and, during their construction, clearance of any sensitive environmental features such as remnant vegetation will be avoided to the extent practicable.

16.7.4.7 Sewerage

At the commencement of construction temporary shower and toilet facilities will be used at the mine site. Shower and toilet facilities at each MIA will be pumped out at an appropriate schedule and taken by licenced contractors to a licenced facility for treatment.

16.7.4.8 Lighting

Artificial lighting will be designed, installed, operated and maintained in accordance with AS 4282:1997 Control of the Obtrusive Effects of Outdoor Lighting, to minimise the amount of light spill. Controls stipulated in this standard include consideration of the location and orientation of lighting as well as the selection and maintenance of luminaries. Any further mitigation (for example shielding, further restricting the use of lighting) will be implemented on an as needed basis.

16.7.5 Considerations of Export Volumes at Dalrymple Bay Coal Terminal

The product coal will be transported to DBCT for export. No approvals, in addition to those already in place, will be necessary to support the Project.

The Project will generate increased rail traffic volume and take advantage of the available capacity of the North Coast Rail Line within existing approvals already in place for the infrastructure, thereby increasing operational efficiency, in line with other coal supply chain infrastructure expansions at the DBCT. The DBCT is one of two terminals at the Port of Hay Point (the Port). The Port is vital infrastructure for coal mines in central Queensland and is one of the largest coal export ports in the world. The DBCT component of the Port currently has an approved export capacity of 85 Mtpa with plans to increase this capacity in the future. DBCT's throughput has been historically under the approved terminal capacity of 85 Mtpa (refer to Figure 16-17) and thus DBCT is able to take advantage of demand increases.

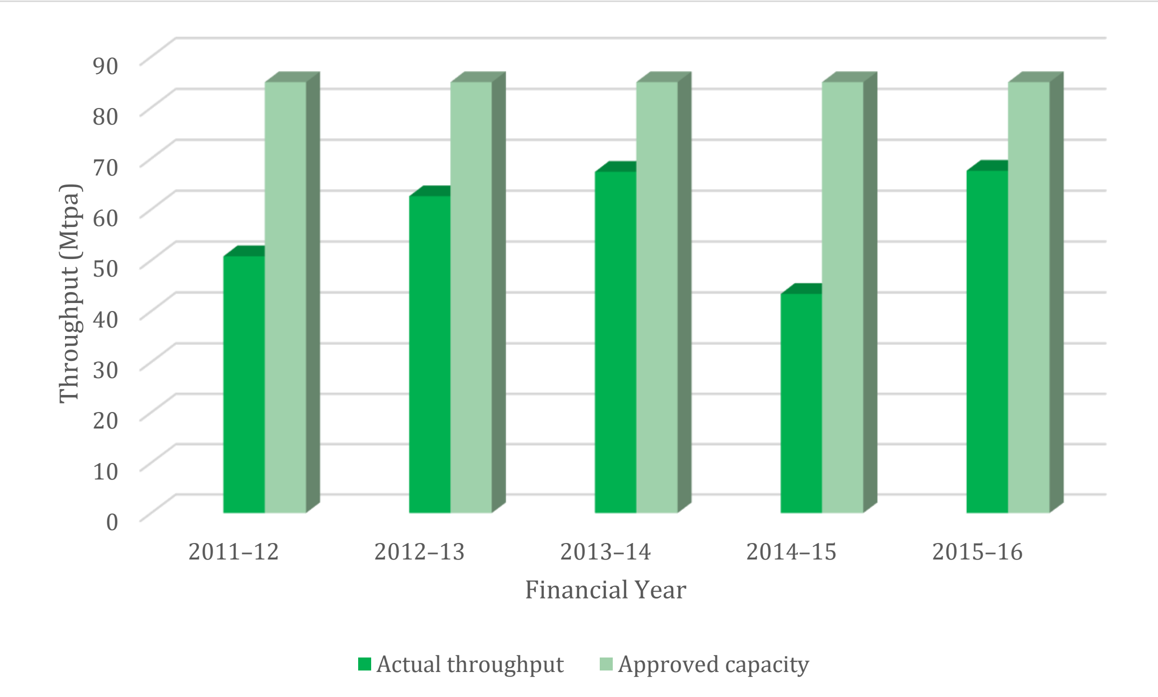

Figure 16-17 DBCT's actual throughput and approved capacity from 2011 to 2016

DBCT anticipates supporting expanding miners initially with the unutilised terminal capacity and any new demands will be satisfied by incremental expansions outlined in the *DBCT Management – Master Plan 2016* (the Plan). The Plan outlines an incremental expansion pathway for DBCT to ensure the terminal has the capacity to support the increases in coal demand (DBCTM 2016). The expansion pathway includes three stages that will see the terminal throughput increase from 85 Mtpa up to 136 Mtpa should the demand for coal continue to rise. The Port also has approval for capital/maintenance dredging to ensure ships are not departing the Port short-loaded due to draught depth restrictions and the Port exports coal efficiently. Despite the proposed increases in throughput, increased dredging has not been identified as a requirement to support these increases.

The expansion pathway as outlined in the Plan and the capital/maintenance dredging program have been developed to meet legislative requirements and environmental management guidelines/plans. This has been at the forefront of Port operations and development given the proximity of the Port to the Great Barrier Reef. These requirements and guidelines/plans include:

- The *Sustainable Ports Development Act 2015* - developed in response to UNESCO's position on the protection of the Great Barrier Reef. Focuses on future development of existing export coal facilities;
- The *North Queensland Bulk Ports Sustainability Plan 2015+* - sets a benchmark for whole-of-business sustainability planning in the Australia Port industry*;*
- The *Reef 2050 Long-term Sustainability Plan* – provides an overarching strategy for managing the Great Barrier Reef. North Queensland Bulk Ports was proactively involved in the development of this plan; and
- The *Port of Hay Point Environmental Management Plan* – outlines the environmental management practices and controls required by NQBP for current and potential users of the Port of Hay Point.

Given the above, it is confirmed that DBCT can support the Project through the unutilised port capacity, future capacity would also be available if needed through the expansion pathway as outlined in the Plan. The current maintenance dredging program will also be sufficient to support the Project's shipping requirements.

16.7.6 Mine Decommissioning and Rehabilitation

The Project is not expected to be decommissioned for approximately 20 years or following depletion of the target coal resource. Progressive rehabilitation is proposed to be carried out as operations progress (opposed to a large operation once mining is complete). Thus, staged treatments will be applied as soon as areas become available for such. Rehabilitation of the MIAs; however, will take place once mining is completed and plant and structures decommissioned.

The review and audit of rehabilitation work undertaken during operations will be required as part of the Project's EA. More specifically, the Plan of Operations will set out the proposed program of actions to comply with the EA conditions including a program to rehabilitate any disturbed land. This Plan will also provide for compliance measures obliged by applicable legislation. The rehabilitation and decommissioning approaches, including figures showing the modelled final landforms, are described in detail in Chapter 11 – Rehabilitation and Decommissioning.

The Plan of Operations will be submitted to DES prior to any disturbance occurring onsite and will be reviewed by an independent suitably qualified auditor. Approval by DES to renew the Plan of Operation will take place on a five-year basis at most but more likely annually. DES may suspend or cancel the EA in the event of inadequacy or non-compliance of operations in meeting the Plan of Operations. In addition to this, the EA will require Central Queensland Coal to provide financial assurance to DES prior to any activities taking place onsite to cover any costs or expenses incurred in the highly unlikely event that the conditions of the EA are not met. This includes, for example, conditions relating to rehabilitation.

This section specifically identifies the following key aspects relating to the rehabilitation of the Project:

- The control and management of mine waste;
- Proposed rehabilitation methods;
- The management of topsoil resources for use in rehabilitation of the site;
- Description of the planned progressive rehabilitation and revegetation of areas across the mine site;
- The integration with on-going and future rehabilitation activities across the wider mining area; and
- Rehabilitation monitoring and maintenance requirements which may apply.

Decommissioning and rehabilitation are discussed in detail in Chapter 11 - Rehabilitation and Decommissioning and summarised in the following sections. The level of detail provided is commensurate to the level of risk associated with each key closure issue and the time to closure. It sets out acceptable and realistic criteria for rehabilitation and closure that would allow the Project to meet the principles of Ecologically Sustainable Development without any unacceptable liability to the State.

16.7.6.1 Progressive Rehabilitation Program

Progressive rehabilitation will apply to the open cuts and waste rock stockpiles. The main features of the progressive rehabilitation process are:

- Constructing a stable land form for all disturbed areas;
- Topsoil spreading across available reshaped areas;
- Contour ripping immediately after topsoil placement to control erosion;
- Revegetation with an appropriate seed mix prior to the wet season; and
- Management of rainfall and runoff from the rehabilitated landform in sediment dams.

The proposed mine life is 20 years including the final four-year rehabilitation period. The indicative program for progressive rehabilitation is described below. Progressive rehabilitation will occur in accordance with the Plan of Operations. The Plan of Operations will identify areas to be rehabilitated and refer to the Rehabilitation Plan for specific rehabilitation details for each domain. The proposed rehabilitation program is summarised below.

16.7.6.2 Construction

Infrastructure construction to commence six months before the commencement of mining. All works areas to be cleared and grubbed with disposal of vegetation. Topsoil and subsoil to be stripped and separately stockpiled for future use. Primary sediment controls such as dams to be constructed in this phase.

Operational Years 2019 to 2037

Waste rock stockpiles will be utilised for coal rejects (filter press tailings – refer Chapter 8 – Waste Rock and Rejects for further disposal details). During the operational life of the mine (including during decommissioning) EPDs will be stabilised and contoured to minimise potential erosion. As part of the progressive rehabilitation activities, EPDs will be reshaped, stabilised, topsoiled and seeded.

Post-mining Completion Works Years 2036 to 2038

All waste rock stockpiles will be rehabilitated. Mine infrastructure will be decommissioned and dismantled for removal from site with the individual locations rehabilitated accordingly. Dams and access roads will remain for future beneficial use or decommissioned. Rehabilitated areas will be monitored and if necessary reworked to achieve the required completion criteria.

The aim of progressive rehabilitation is to minimise the amount of land disturbed at any one time. The final landform sections are shown in Figure 11-16 and 11-17 of Chapter 11 - Rehabilitation and Decommissioning. The indicative program for progressive rehabilitation is shown in Figure 11-18 to Figure 11-22 of Chapter 11 – Rehabilitation and Decommissioning. These show rehabilitation at various stages, including ex-pit waste rock stockpiles and in-pit dumping where rehabilitation has been completed in the years 2021, 2024, 2030, 2036 and the final landform (2038). The final landform of the rehabilitated pits and waste rock stockpiles lie outside the post mining 0.1% AEP flooding (Figure 11-23 of Chapter 11 - Rehabilitation and Decommissioning). Progressive rehabilitation will also include the rehabilitation of any areas disturbed during construction that are not required for ongoing operations.

16.7.6.3 Landforming

The cumulative volume of excavated waste from open cut activities is expected to include approximately 745 Mbcm consisting of waste rock, subsoils and fines from the CHPPs. As operations commence, waste rock from the open cuts will initially be stored in the ex-pit waste rock stockpiles. As mining in the open cuts progress, the stored waste rock will be backfilled in-pit as part of the progressive rehabilitation. As such it is not anticipated that extensive rehabilitation will be required of the waste rock stockpile areas over and above re-seeding. This will; however, be assessed as mining progresses. All dry filter press tailings have final disposal within the pit.

Expired pit areas will have the reject waste and overburden returned and will be profiled to the final desired landform specifications. Subsoil and topsoil will be replaced on the profiled landform in the reverse order to which it was stripped from the open cut domains; that is the subsoil is placed on top of the overburden and the topsoil on top of the subsoil at an appropriate thickness.

Before the topsoil is spread, the profiled landform will be scarified parallel to the contour to a nominal depth of 50 to 100 millimetres (mm) to break up any hard setting surfaces and prevent lamination of the topsoil and profiled landform. Dependant of the quantities originally recovered, topsoil will be spread to a nominal depth of between 100 to 150 mm where possible.

Where required, contour banks will be progressively installed to minimise rill erosion and direct water off the profiled landform to either a stabile surface or dedicated stabilised drainage paths or flumes constructed on the final landform. The heights and depths of these contour banks will be determined through ongoing landform design. At the finalisation of this process a pre-vegetation landform will have been constructed. Finalised landforms will initially be sown with either a cover crop or perennial native vegetation. Areas intended for ongoing nature conservation will be over sown with non-invasive perennial grasses as an interim measure until the area becomes available for inclusion in the ongoing revegetation program.

16.7.6.4 Revegetation

Revegetation activities will typically commence at the completion of land forming, such as, reshaping, re-topsoiling and drainage works. The timing of these works will ideally be scheduled to enable a preferred seasonal sowing of pasture or tree seed. Where surfaces have been prepared, the nominated revegetation specification for tree, shrub and pasture species, will be sown using seed stock or planted depending on the species, slope gradients and final land use. Rehabilitation will utilise locally relevant tree and shrub species at a density and richness consistent with the desired post-mine landform. Plant selection for areas to be returned to a bushland landform will be based on the following criteria:

- The species will successfully establish on the available growth medium;
- The species will bind the soil; and
- The species diversity will result in a variety of structure and food and habitat resources.

Native flora used for rehabilitation will be endemic to the area, in keeping with the existing vegetation communities present prior to clearing and ensuring habitat for extant fauna on the site is reinstated. Vegetation will be established through a combination of direct seeding or planting of tube stock from local propagules. Seed will be collected from site where possible and treated if necessary to ensure it is adapted to environmental conditions in the area. Tree and shrub establishment onsite will be dominated by the direct seeding method, currently being used at most coal mines in the Bowen Basin. An initial tree and shrub mix that could be used for rehabilitation is provided in Chapter 11 - Rehabilitation and Decommissioning and is based on the current suite of flora species found in the Project area. The final species mix will depend on the final agreed Rehabilitation Plan and will be reviewed periodically depending on changes in best practice, technology and rehabilitation monitoring results.

16.8 Legislative Background

Under the EPBC Act, the following MNES are protected:

- World Heritage Properties;
- National Heritage Places;
- Ramsar wetlands of international importance;
- The Great Barrier Reef Marine Park (GBRMP);
- Listed threatened species and communities;
- Migratory species protected under international agreements;
- The Commonwealth marine environment;
- Nuclear actions (that may have significant impacts on the environment); and
- Water resources as related to coal seam gas and large coal mining developments.

Under Part 3 of the EPBC Act, the three relevant controlling provisions for this Project are:

- World Heritage properties (sections 12 and 15A);
- National Heritage places (sections 15B and 15C);
- Listed threatened species and communities (sections 18 and 18A);

- Listed migratory species (sections 20 and 20A);
- Great Barrier Reef Marine Park (sections 24B and 24C); and
- Water resources in relation to large coal mining development (sections 24D and 24E).

Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process. The EPBC Act Policy Statement 1.1: Significant Impact Guidelines (DotE 2013) define the criteria used in this EIS against which an action (that is the proposed works) may be judged as having (or not having) a significant impact.

The EPBC Act also sets out the principles of ecologically sustainable development in Section 3A. The proponent has ensured the MNES assessment for the Project has complied with these principles wherever considered appropriate.

16.8.1 Other Approvals and Conditions

A detailed description of the legislation, policy, and planning framework pertaining to the Project is provided in Chapter 1 – Introduction of this EIS.

A list of those related to biodiversity and water management are below:

- EPBC Approval for a Controlled action under the EPBC Act;
- *National Greenhouse and Energy Reporting Act 2007* (NGER Act);
- EA under the *Environmental Protection Act 1994* (EP Act);
- Notification of Land – for Notifiable Activities under the EP Act; and
- Permit to Take Protected Plant or Interfere with a Breeding Place under the *Nature Conservation Act 1992*.

16.9 Environmental Context - Land

Many of the potential impacts on the relevant MNES are indirect impacts that arise due to direct impacts on intermediary receptors of the environment. To assess the potential impacts on MNES it is therefore necessary to assess the impacts on these intermediaries first. This section provides an overview of key aspects of the environmental context associated with land (soils and geology) that will be relevant to the Project.

The following provides a summary of the findings related to the assessment of local geology and soil types in the Project area and surrounds as detailed in Chapter 5 – Land.

To adequately assess the potential impacts the Project may have on soils and the current land use within the Project area, the following detailed assessments have been undertaken:

- Desktop assessment, including review of publicly available literature, databases, maps and resources relevant to the geology, soils and landforms in the Project area; and
- Field surveys and laboratory analyses undertaken focusing on characterisation of soils for land use suitability, agricultural value and potential rehabilitation (as required) as part of the EIS process to improve understanding of soils within the Project area. A detailed field soil survey of the Central Queensland Coal mine area was conducted over a four-day period in April 2017.

16.9.1 Existing Environment

16.9.1.1 Topography

Elevations across the Styx catchment range from 0 to 540 m above sea level. The area predominantly comprises flat or undulating lands, draining via several smaller creeks and tributaries to the Styx River and estuary, and into the Coral Sea (see Figure 16-18). The land within the Project area can be described as gently undulating.

A LiDAR survey was conducted of the EPC 1029 area. Based on this data, elevations within the EPC area vary between 4.5 and 155 m Australian Height Datum (AHD), with the Project area located between 11.4 and 43.8 m AHD.

Based on the Capricornia Coastal Lands program (DPI, 1995), the ML area contains the following geomorphological land units:

- Broad, level to gently undulating alluvial plains and fans on alluvium, including some areas of gilgai microrelief (melonhole);
- Level to gently undulating plains and rises on sedimentary rocks and unconsolidated sediments, including some minor to severe melonhole;
- Undulating rises and low hills on deeply weathered sedimentary and metamorphic rocks;
- Dissected low plateaus on gently dipping sedimentary rocks; and
- Rolling low hills and rises on hard sedimentary rocks.

16.9.1.2 Geology

The economic Cretaceous coal measures targeted for mining are the Styx Coal Measures, contained within the Styx Basin, a small, Early Cretaceous, intracratonic sag basin that covers an area of approximately 300 km^2 onshore and 500 km^2 offshore in the Broad Sound area. The known coal bearing strata of the basin are referred to as the Styx Coal Measures and consist of quartzose, calcareous, lithic and pebbly sandstones, pebbly conglomerate, siltstone, carbonaceous shale and coal.

The Styx Basin is relatively undeveloped, except for two small scale, government owned mines that were in operation from 1919 to 1963. The Ogmore and Bowman collieries, located close to the north and northeast of ML80187 respectively, produced small qualities of low quality coal, for use in steam trains and other boiler requirements.

The majority of the Styx Coal Measures are concealed beneath Tertiary sediment. Queensland Geological Survey mapping shows the eastern margin of the Styx Basin extends to the eastern edge of the terrestrial Cainozoic sediments that conceal it. The Styx Coal Measures outcrop in the western margin of the Styx Basin as low forested hills. These outcrops form a series of detached hills, orientated north-south, that continue for about 60 km northward to the coastline near the Port of St Lawrence. The outcrops generally form small hills and hillocks, but at their greatest height, are 100 metres above the low-lying sediment flats to the east. The hills are probably the coal-barren basal section of the Styx Coal Measures sequence, which consists of thick beds of quartz-dominant sandstones.

The coal seams that comprise the Styx Coal Measures are generally thin, commonly less than two metres in thickness. Seam splitting is common and seam thicknesses vary considerably. All seams are potentially economically exploitable, despite their relatively small thicknesses. Coal quality throughout the deposit is generally consistent and all seams demonstrate coking properties. The coal seams are relatively shallow, and the average cumulative thickness of the full sequence of coal is approximately 6 m, contained within a sequence of approximately 120 m of coal bearing strata. The coal seams dip generally to the east in the area west of the Bruce Highway, with the lowest coal seam in the sequence sub-cropping in the western part of ML 80187.

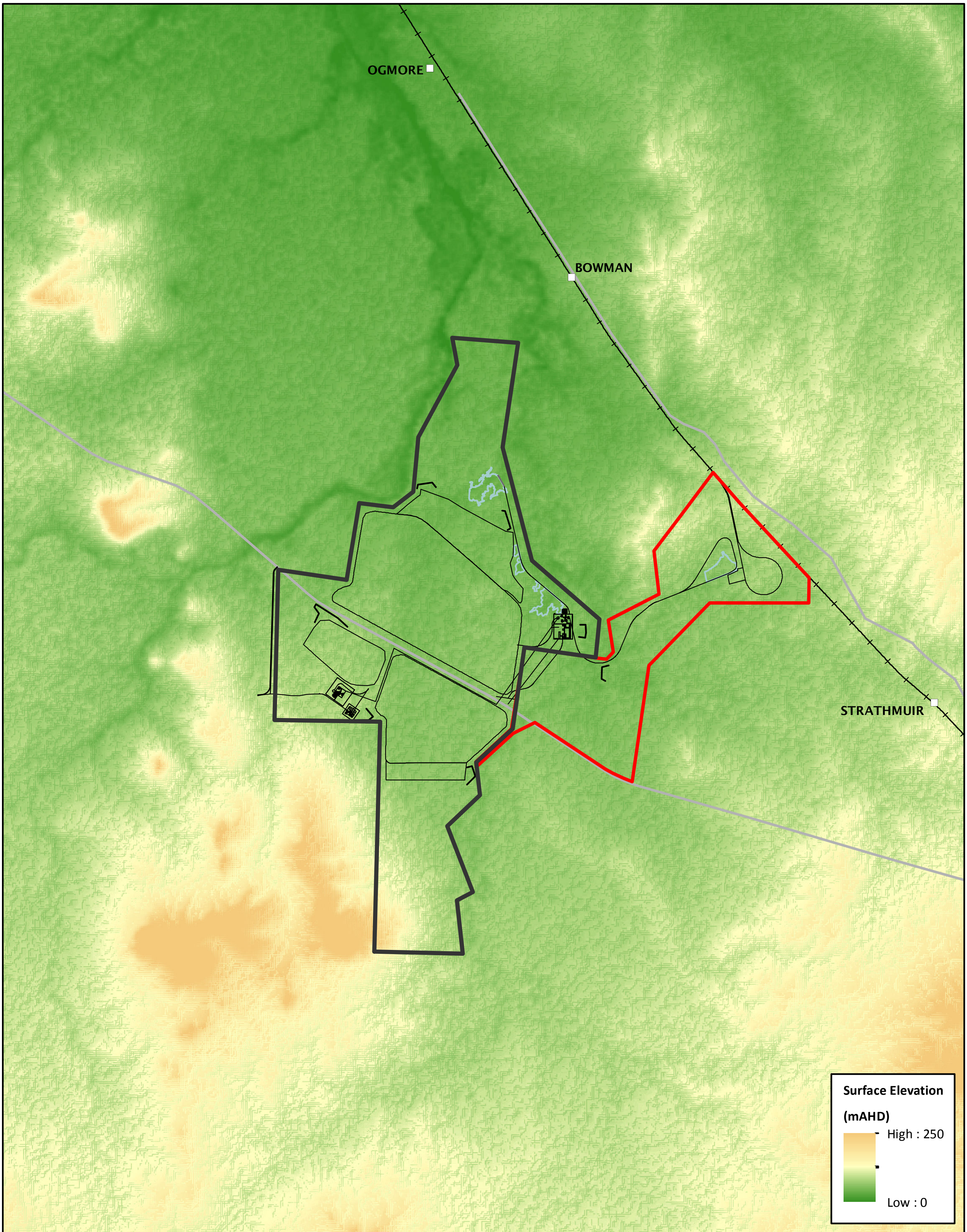

Figure 16-18
Site topography

N

0 1 2 km

Scale @ A4 1:80,000
Date: 19/10/18
Drawn: Gayle B.

Legend

- ML 80187
- ML 700022
- Mine infrastructure
- Main Road
- North Coast Rail Line
- Dam

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
1 Second SRTM v1.0 DEM
Geoscience Australia, 2011

CDM Smith

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16.9.1.3 Soils

During the soil sampling field assessment in February 2017, 11 full soil samples were collected, and 16 soil observations undertaken. There was reasonable alignment between the soil orders mapped by desktop analyses and the soil classifications made by field investigations.

Soil profile description and classification identified the following five soil orders within the Project area:

- Dermosols: non-cracking clays with structured subsoil and lacking strong texture contrast between the topsoil and subsoil;
- Sodosols: soils which have a clear and strong texture contrast from the A horizon and a slightly acidic and sodic B horizon;
- Rudosols: soils with minimal A horizon development, little or no texture or colour change with depth change (apart from the darkening of an A1 horizon) unless stratified or buried soils are present;
- Kandosols: soils which lack strong texture contrast, have massive or only weakly structured B horizons and are not calcareous throughout; and
- Vertosols: clayey soils (having a field texture of 35% clay or greater throughout the profile) with vertic (shrink-swell) properties.

Soil Fertility

pH

Soil pH has a strong influence on the solubility and form of chemical compounds, the availability of ions in the soil solution as well as microbial activity. Surface soil pH measured from samples collected across the mine ML varied from strongly acid (pH of 5.3) to mildly alkaline (that is pH exceeding 7.5 pH). Several soil core samples displayed increasing alkalinity with depth changing by as much as 6.3 pH (at the surface) to 9.1 pH (at 1.2 m below the surface) in one case. The results suggest a correlation between soil pH and soil salinity, with the more alkaline conditions corresponding to more saline (and sodic) conditions. Soil pH results are summarised by soil type and horizon in Figure 16-19.

Cation Exchange Capacity

Cation Exchange Capacity (CEC) is a useful indicator of soil fertility as it indicates the soils ability to supply the important plant nutrients Ca, Mg, K, and Na. A low CEC indicates a low potential for a soil to store and release nutrients. Most soil samples across the Project area contain CEC levels that are considered to be very low (<6) to low (<12).

Exchangeable Calcium and Exchangeable Potassium results were generally very low to low. Exchangeable Magnesium results were generally rated moderate to high. Exchangeable Sodium results were generally rated as very low.

Total Organic Carbon

Organic carbon is a vital component of soils, as it not only represents the carbon content of soils, but can indicate the nutrient holding capacity and fertility of a soil. Samples generally recorded low to medium levels of total organic carbon.

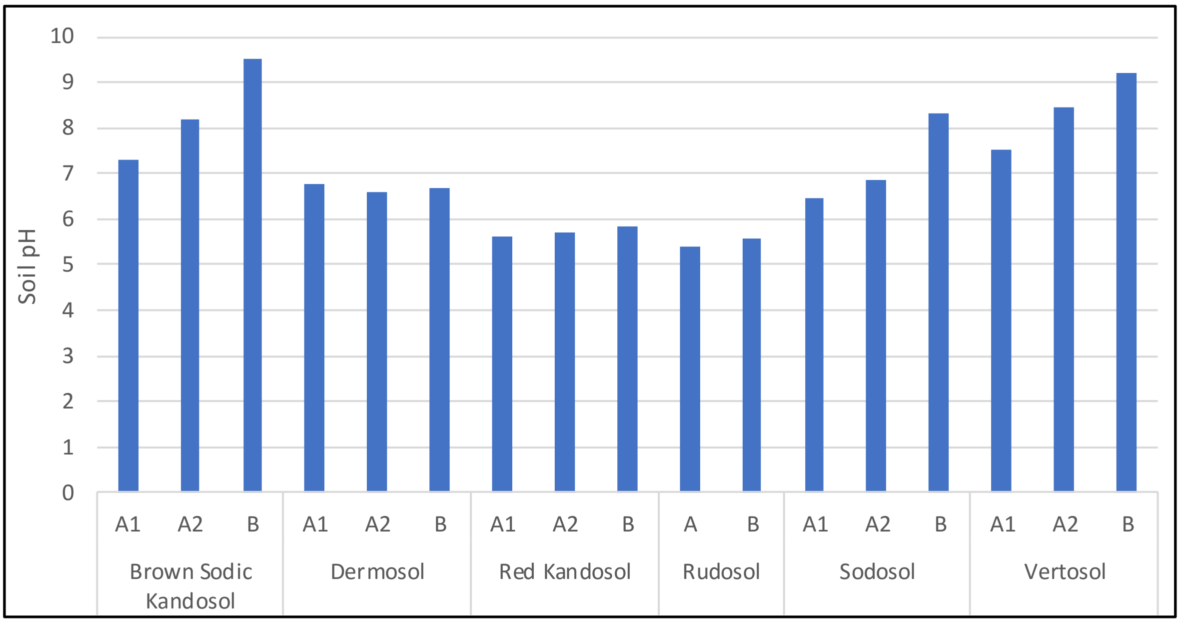


Figure 16-19 Soil pH_{H2O} averaged by soil type and horizon

Emerson Aggregate Test

The Emerson Aggregate Test measures the soil dispersion potential of soils. All but one of the soil samples were rated as between Class 1 and Class 4 based on the Emerson aggregate test undertaken at the laboratory. A single result was rated as Class 8 (SS01 at 0.5 – 0.6 tested depth) and is considered an anomaly as the laboratory advised that this sample was pure sand, with no reaction, no dispersion and no ribboning.

Of the samples analysed 14 were rated as Class 1 or Class 2. These sample locations indicate soils that have greater dispersive potential and, when disturbed, are prone to erosion and soil structural decline. Of the remaining 13 samples, ten were rated as Class 3 and three were rated as Class 4. These samples are considered to only have moderate dispersive tendencies, can be remoulded and will not readily disperse in water.

Sodicity

Exchangeable Sodium Percentage (ESP) measures the sodicity of a soil which, along with the Emerson aggregate test, is directly related to a soils structural stability and erosion potential. A combination of non-sodic, sodic and strongly sodic soils was identified from the soil samples. These results indicate that there are some areas of increased erosion potential associated with sodic soils in the area.

Electrical Conductivity

Electrical conductivity (EC) relates to the degree of salinity in the soil. The higher the EC value, the more soluble salt is in the soil. High soil salinity can be a limitation for vegetation growth, particularly for salt-sensitive species. Samples were generally rated Very Low to Medium across the Project area, indicating soil salinity is generally not a limitation for vegetation growth. The exceptions were samples taken from four sites at depths below 0.5 metres below ground level (mbgl), which rated between high to very high soil salinity, indicating a build-up of salts in some subsoils.

Acid Sulphate Soils

Acid sulphate soils (ASS) are generally associated with low energy coastal environments. Acid sulfate soils can; however, form inland when there are sources of sulfide and soils are saturated for long periods of time in favourable conditions. ASS can be classified as:

- Actual Acid Sulphate Soils (AASS) which are soils that have already reacted with oxygen to produce acid; or
- PASS which is soil that contains iron sulphide but has not been exposed to oxygen (e.g. soil below the water table) and therefore has not produced sulphuric acid (although it has the potential to do so).

The CSIRO National ASS mapping illustrates the entirety of EPC 1029 is described as having a low to extremely low probability of containing ASS. The National ASS mapping (Fitzpatrick et al. 2011) in relation to the proposed mine, and the location of the 10 m AHD contour is shown at Figure 16-20. The Project area straddles the low to extremely low ASS categories and is located beyond the 20 m contour.

Geochemical characterisation was undertaken by RGS (2012) for a total of 195 samples (including overburden, potential rejects, and fine coal reject samples) from 15 bore holes covering a range of depths from 11.6 meters below ground level (mbgl) to 147 mbgl in various lithologies. The majority of samples were classifiable as non-acid forming (NAF). A total of four samples had positive Net Acid Production Potential (NAPP), two of which were classifiable as potentially acid forming (PAF; with ANC / MPA ratio <2 and NAPP >10 kg H_2SO_4/t), two as low capacity PAF (with Sulphide-sulphur (SCR) >0.2 % and NAPP between 0 and 10 kg H_2SO_4/t) and one sample was classified as uncertain (UC; with ANC / MPA ratio <2 and NAPP <0 kg H_2SO_4/t).

There was no discernible trend for which type of materials (waste rock or potential coal reject) would be more likely to be PAF. As such fine coal rejects (21 samples) were also analysed to provide an indication of the acid potential and composition of the coal processing waste stream. Similar to the potential rejects and waste rock results the fine jects were largely classifiable as NAF with ANC / MPA ratios indicative of negligible risk. The acid potential for the fine rejects (tested to date) were summarised as follows:

- One sample was potentially acid forming (PAF-low capacity) (with NAPP 4.2 kg H_2SO_4/t) – this sample was located outside of the mining lease and nearby to Ogmore;
- All other samples were non-acid forming (NAF) (most with relatively high buffering capacity); and
- Seven samples were acid consuming with acid neutralization capacity greater than 100 kg H_2SO_4/t.

Based on the assessments undertaken to date, the project disturbance area has a low to extremely low probability of containing ASS. Potential disturbance of ASS from off-site groundwater drawdown is discussed in Section 16.11.3. Analysis indicates the potential for ASS exposure in response to mine dewatering is low. The areas most at risk of exposure of ASS occurs within the ML where drawdowns of more than 10 m are predicted, and any development of acid drainage in this area will drain toward the mine pits during mining and post-mining recovery. Back filling of mine pits with materials have neutralising capacity will provide adequate management of this risk.

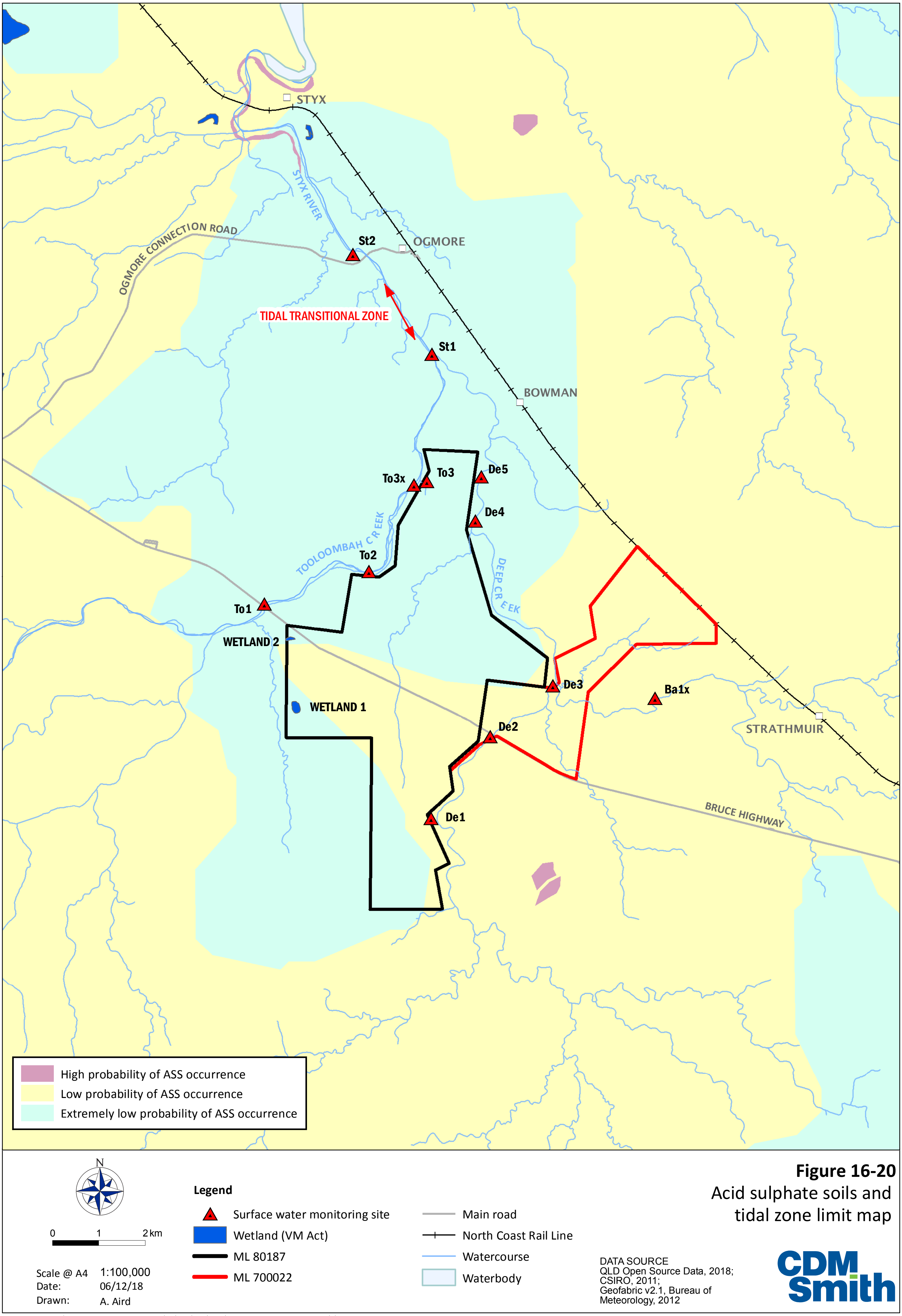


Figure 16-20
Acid sulphate soils and tidal zone limit map

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 acid sulphate soils.mxd 12/6/2018

16.9.2 Great Barrier Reef – Land Use and Water Quality Targets

A number of documents have been recently developed to improve management of the Great Barrier Reef World Heritage Area. As part of a range of approaches this includes improving land use in the catchment thereby improving water quality of rainfall run off entering the GBR lagoon. The following sections summarises those documents considered pertinent to activities associated with the Project.

16.9.2.1 The Reef 2050 Plan

The Reef 2050 Plan is the overarching framework for protecting and managing the GBR from 2015 to 2050 (DotEE 2015). The plan is a key component of the Australian Government's response to the recommendations of the United Nations Educational, Scientific and Cultural Organisation World Heritage Committee (DotEE 2015). It includes a description of existing management arrangements, future steps for the protection and adaptive management of the reef, an implementation plan and an outline of the integrated monitoring and reporting program.

Seven overarching themes with associated actions, targets, objectives and outcomes are embedded into the plan. The seven themes are ecosystem health, biodiversity, heritage, water quality, community benefits, economic benefits and governance. Each theme and their associated actions have been reviewed for relevance to the Project. By meeting the Reef 2050 Water Quality Targets (WQT), the Project would contribute to improving ecosystem health and water quality.

16.9.2.2 Reef 2050 Water Quality Improvement Plan 2017 – 2022

The new five-year Reef 2050 Water Quality Improvement Plan 2017 – 2022 now aligns with the Australian and Queensland Governments' Great Barrier Reef 2050 Long-Term Sustainability Plan (DotEE 2015), agreed in 2015. The Reef 2050 Water Quality Improvement Plan is a joint commitment of the Australian and Queensland governments and is a collaborative program of coordinated projects and partnerships designed to improve the quality of water flowing to the GBR.

The Reef 2050 Water Quality Improvement Plan seeks to improve the water quality flowing from the catchments adjacent to the Reef. The Reef 2050 Water Quality Improvement Plan builds on previous water quality plans developed in 2003, 2009 and 2013 by:

- Including all sources of land-based water pollution: agriculture, industry, urban and public lands, while recognising that the majority of water pollution still arises from agricultural activities;
- Incorporating the human dimensions of change: our social, cultural and economic values and how they drive our adoption of actions to improve water quality setting individual targets for reducing water pollution from the catchments; and
- Enabling better prioritisation where the most management action is needed.

The outcome of the Reef 2050 Water Quality Improvement Plan is 'Reef water quality supports the outstanding universal value of the GBR, builds resilience, improves ecosystem health, and benefits communities.' The new targets define the reductions needed for each of the catchments by 2025. This is a new level of specificity from the Reef 2050 Long-Term Sustainability Plan targets that commit to achieving reductions of up to 80% in dissolved inorganic nitrogen and 50% in sediments.

Under the Reef 2050 Water Quality Improvement Plan, pollutant loads are assessed through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program, using a combination of monitoring and modelling data. The Paddock to Reef Program includes catchment scale water quality monitoring of pollutant loads entering the GBR lagoon that is implemented through the Great Barrier Reef Catchment Loads Monitoring Program.

16.9.2.3 2017 Scientific Consensus Statement - Land Use Impacts on Great Barrier Reef Water Quality and Ecosystem Condition

The 2017 Scientific Consensus Statement provides the scientific understanding underpinning the design and implementation of the Reef 2050 Water Quality Improvement Plan. The 2017 Scientific Consensus Statement covers all land-based pollutant sources including urban diffuse, point source and industrial discharge. Notwithstanding all land based pollutant sources have been considered as part of the Consensus Statement, the emphasis is on the agricultural diffuse sources of pollutants as the dominant contributor of land-based pollutant loads at a regional and GBR-wide scale.

The overarching consensus is:

- Key GBR ecosystems continue to be in poor condition. This is largely due to the collective impact of land runoff associated with past and ongoing catchment development, coastal development activities, extreme weather events and climate change impacts such as the 2016 and 2017 coral bleaching events; and
- Current initiatives will not meet the water quality targets. To accelerate the change in on-ground management, improvements to governance, program design, delivery and evaluation systems are urgently needed. This will require greater incorporation of social and economic factors, better targeting and prioritisation, exploration of alternative management options and increased support and resources (Waterhouse et. al, 2017).

Of relevance to this discussion, the consensus specifically concluded:

- The decline of marine water quality associated with landbased run-off from the adjacent catchments is a major cause of the current poor state of many of the coastal and marine ecosystems of the GBR. Water quality improvement has an important role in ecosystem resilience; and
- The main source of the primary pollutants (nutrients, fine sediments and pesticides) from GBR catchments is diffuse source pollution from agriculture. These pollutants pose a risk to GBR coastal and marine ecosystems.

The consensus reported the greatest water quality risks to the GBR and coastal ecosystems are from discharges of:

- Nutrients, which are an additional stress factor for many coral species, promote crown-of-thorns starfish population outbreaks with destructive effects on mid-shelf and offshore coral reefs, and promote macroalgal growth;
- Fine sediments, which reduce the light available to seagrass ecosystems and inshore coral reefs; and
- Pesticides, which pose a toxicity risk to freshwater ecosystems and some inshore and coastal habitats.

The main source of excess nutrients, fine sediments and pesticides from GBR catchments is diffuse source pollution from agriculture, with other land uses, contributing relatively small but concentrated pollutant loads. At the regional scale, Fitzroy, the Wet Tropics and Burdekin are the major contributors of these river pollutant loads. Grazing contributes the largest proportion of sediment and particulate nutrients to the GBR primarily through sub-surface (gully, streambank and rill) erosion.

The Fitzroy catchment is one of several catchments which contribute to the highest exposure of coastal or marine ecosystems to pollutants. As such, it is considered a high priority area for reducing fine sediment and particulate nutrients.

16.9.2.4 Existing Great Barrier Reef Catchment Load Monitoring

The Great Barrier Reef Catchment Loads Monitoring Program provides measures of annual loads (mass) of total suspended solids (TSS) and nutrients (nitrogen and phosphorus) from 14 priority basins, in six natural resource management (NRM) regions, that discharge to the GBR. For 12 of these priority basins annual pesticide loads and summed annual toxic loads of pesticides are also described.

The NRM regions and priority catchments are:

- Cape York region – Normanby catchment;
- Wet Tropics region – Barron, Mulgrave-Russell, Johnstone, Tully and Herbert catchments;
- Burdekin region – Burdekin and Haughton catchments;
- Mackay Whitsunday region – O'Connell, Pioneer and Plane catchments;
- Fitzroy region – Fitzroy catchment; and
- Burnett Mary region – Burnett and Mary catchments.

This monitoring program is part of the Reef Water Quality Protection Plan (Reef Plan), and the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef Program). It also provides load data to validate and calibrate catchment models, which assist in evaluating progress towards the water quality targets of Reef Plan.

Catchment loads have been monitored annually since 2009 and are variable between catchments and years depending on the variability in discharge together with land use and vegetation cover. Loads are calculated for the monitored area of each catchment and as such do not represent the total load discharged to the GBR lagoon.

The total annual monitored loads for all NRM regions and catchments are presented in Table 5-39 of Chapter 5. The relatively small load reported for the 2013-2014 period is attributed to very low end-of-system discharges (the lowest recorded between the 2006–2016 monitoring years) (see Garzon-Garcia et al 2015).

The Fitzroy NRM region is approximately 37 per cent of the total GBR catchment area (~423,122 km^2). The region is comprised of six drainage basins: Styx, Shoalwater, Water Park Creek, Fitzroy, Calliope and Boyne as shown on Figure 5-20 of Chapter 5. The annual monitored loads for the Fitzroy NRM area (Fitzroy catchment) which covers an area of approximately152,000 km^2 (with a monitored surface area of approximately 139,159 km^2) are presented in Table 5-40 of Chapter 5. No outputs specific to the Styx Drainage Basin are reported as part of the ongoing Great Barrier Reef Catchment Loads Monitoring Program.

16.9.3 Soil Loss Estimation – Grazing of Native Pasture

Surface water runoff is an important factor affecting off-site sediment transportation in grazed environments. Degradation of pastureland from cattle grazing and in particular overstocking of cattle and the clearing of woody vegetation can contribute to heightened rates of surface runoff and erosion. Shellberg and Brooks (2013) report cattle grazing as a primary agent for accelerating gully erosion on highly-erodible sodic soils. Increased runoff resulting in erosional processes can lead to on-site effects such as reductions to pasture productivity and off-site effects including the sedimentation of receiving waters and offsite habitats. Cattle grazing intensity and impacts are often concentrated along river frontage terraces and elevated floodplains often resulting in alluvial gullies eroding into terraces and elevated floodplains (Shellberg and Brooks 2013).

In this section an assessment of the potential mobilised sediment volumes that could be generated as a result of the erosional processes because of the existing cattle grazing on the Mamelon property are discussed. The results are particularly relevant given it is Central Queensland Coal's intention to remove grazing activities from the Mamelon property and to allow the natural regeneration of the vegetation outside of the mine disturbance area to replenish. This assessment is provided in detail in Chapter 5 – Land.

Soil Loss Estimation

The mobilisation of sediments from grazed environments occurs through different mechanisms and at differing scales. Within the Project area the typical mechanisms that exist within the more frequently grazed areas are sheet erosion, gully erosion and stream bank erosion. Hillslope erosion is also a contributing mechanism within the Project area although these areas are not grazed to the same extent as the more productive undulating to gently undulating country.

In the absence of specific data for the Styx catchment, erosion estimations for land under grazing were undertaken using the HowLeaky? model developed for the Eden Bann Weir EIS. These estimations have been considered as a surrogate to estimate potential sediment loads leaving the Mamelon property due to grazing activities. The HowLeaky? model was set up using *inter alia* best available soil, vegetation and soil nutrient information for two representative soil types at Yaamba and Rockwood in Central Queensland. Land use and management comprised of three grazing regimes to represent potential current land use practice.

The results from the Yaamba analysis were considered appropriate for the assessment given the proximity to the Mamelon property and similarities in climate trends, land use and soil types. The grazing system parameters used for the assessment of sediment generation from grazing on Mamelon are described in Table 16-17. These grazing systems are considered appropriate as to what may occur at the Mamelon Property. Discussion regarding irrigation has been excluded from the assessment as irrigation is not a current land use undertaken at Mamelon.

Table 16-17 Grazing system parameters

Grazing System	Description
A - Stocking rates well within land systems production capability, resultant resilient grazing land use, infrastructure used to exclude stock from vulnerable areas. Very conservative stocking – typical cover in 60% October cover.	Grazing management recognises production capability and resilience of different land types and grazing adjusted accordingly. Landscape features all managed where appropriate (conservative grazing pressure, use of fire, summer spelling, riparian fencing, exclusion from gullies areas). Simulation conditions: I High green and litter cover all year with seasonal variation. Soil cover at 50-75% with peak in summer growing season. Summer spelling applied when pasture condition deteriorates Probably not realistic to maintain across all seasons. II Uses time series of soil cover derived from CGI (Satellite imagery).

Grazing System	Description
B - Highly responsive stocking rates based on land condition and seasonal forecasts Low stocking – typical cover in 44% October cover, (B).	Grazing management recognises production capability of different land types and stocking adjusted accordingly (use of fire, summer spelling) Simulation conditions: Low stocking rate with 44% cover in October. This description mimics the low stocking rate from the Wambiana grazing study (O'Reagain et al, 2008).
C - Fixed stocking rates best suited to average conditions that result in over grazing in drier seasons High stocking - typical cover in 34% October cover.	Grazing management assumes uniform land resources, fixed stocking rates. Simulation conditions: High stocking rate with 33% cover in October. This description attempts to mimic the high stocking rate from the Wambiana grazing study (O'Reagain et al, 2008).
D - Stocking rates well above the land systems capacity to support grazing, even in average conditions. Degraded pasture composition Extreme stocking - typical cover in 20% October cover Poor soil.	Grazing management assumes uniform land resources, fixed stocking rates based on average to good seasonal conditions (results in over grazing and stock loose condition when rainfall deficits occur. Simulation conditions: Very high stocking rate such that total soil cover never exceeds 35% and gets as low as 15% at the end of the dry season. A poor soil type is used to describe hydrologic response resulting from scalds and degraded surface structure.

Annual sediment loads (reported as TSS) and event mean concentrations (EMC) for Yaamba were generated using the model and are presented in Table 5-42 of Chapter 5. Annual water balance summaries used for the modelling are provided in Table 5-43 of Chapter 5.

To assess the potential sediment generation that may result from grazing activities within the Project area, the slope within ML 80187 and ML 700022 was analysed. Slope was divided into four categories and the corresponding area in ha is presented in Table 5-44 of Chapter 5. Slope categories 1% and 3% equate respectively to the "Upland Slopes" and "Floodplains" categories used in the HowLeaky? Model developed for the Eden Bann Weir EIS. An analysis of the slope and topography is shown at Figure 5-21 in Chapter 5.

Soil types used for the HowLeaky? Model developed for the Eden Bann Weir EIS and specifically for Yaamba were considered appropriate for this assessment. The majority of the "Floodplain" category is a mix of vertosol / sodosols and the "Hillslope" category is mostly sodosols which equate to the criteria used for Yaamba in the Eden Bann EIS model.

By using the same criteria used for the Eden Bann Weir EIS against the representative areas within ML 80187 and ML 700022 the estimated annual off-site sediment loads (t/ha) against three differing stocking regimes were derived. The results for ML 80187 and ML 700022 are presented at Table 16-18 and Table 16-19 respectively. The results should be considered as indicative rather than as absolute. To be consistent with the approach used in the Eden Bann Weir EIS areas of hill slope >1 but <3% and ≥3% were not assessed. This amounts to total areas of 1,869 ha and 587 ha used in the assessment on ML 80187 and ML 700022 respectively. A total area of 565 ha was not used in the assessment that would also likely contribute to the annual generation of sediment whilst under grazing.

Table 16-18 Estimated annual pollutant load for ML 80187

Landscape, land use and management	Runoff (mm/yr)	Hill slope erosion (t/ha)	Annual off-site pollutant loads – Sediment (t/ha)	Area (ha)	Estimated annual sediment generation (t/ha)
Floodplains: mix of vertosol/sodosols; based on sodosol (loamy surface; moderate deep A, deep B; slowly permeable (group 210)); 1% slope, 100 m slope length					
Low stocking pasture 44% October (B)	108	1.7	0.34	1,748	595
Moderate stocking pasture 34% October (C)	121	3.6	0.72		1,259
Excess stocking pasture 20% October (D)	139	7.9	1.60		2,797
Upland slopes: slopes with sodosols (shallow sandy surface; deep A, shallow B; slowly permeable (group 270)); 3% slope, 100 m slope length					
Moderate stocking pasture 34% October (C)	123	9.3	1.90	121	230

Table 16-19 Estimated annual pollutant load for ML 700022

Landscape, land use and management	Runoff (mm/yr)	Hill slope erosion (t/ha)	Annual off-site pollutant loads – Sediment (t/ha)	Area (ha)	Estimate annual sediment generation (t/ha)
Floodplains: mix of vertosol/sodosols; based on sodosol (loamy surface; moderate deep A, deep B; slowly permeable (group 210)); 1% slope, 100 m slope length					
Low stocking pasture 44% October (B)	108	1.7	0.34	535	182
Moderate stocking pasture 34% October (C)	121	3.6	0.72		385
Excess stocking pasture 20% October (D)	139	7.9	1.60		856
Upland slopes: slopes with sodosols (shallow sandy surface; deep A, shallow B; slowly permeable (group 270)); 3% slope, 100 m slope length					
Moderate stocking pasture 34% October (C)	123	9.3	1.90	52	99

The results of the assessment show that for areas of 1% slope under grazing regimes B, C and D as described at Table 16-17, the estimated annual sediment generation potential ranges between 595 to 2,797 t/ha and 182 to 856 t/ha for ML 80187 and ML 700022 respectively. For areas of 3% slope under grazing regime C, the estimated annual sediment generation is 230 t/ha and 99 t/ha for ML 80187 and ML 700022 respectively.

It is important to note that the model outputs are generated on the assumption that the grazing regime and vegetative cover apply across the entire areas of 1% and 3% slope and that the run-off and hill-slope erosion coefficients are uniformly applied within the areas of 1% and 3% slope. In reality, these circumstances would not exist and as such, these outputs are considered to be indicative of the potential sediment loads that could be generated under each of the nominated grazing regimes.

Central Queensland Coal has committed to the destocking the majority of the Mamelon property to allow for the natural regeneration of vegetation across the property. The small portion of the property that is not proposed to be destocked is on land of >3% slope and was not considered in the assessment at Table 16-18. The destocking of Mamelon will allow for the natural regeneration of land undisturbed by the mine and allow for the continued progressive rehabilitation of land disturbed by the mine. Noting the Project will be implementing a wide range of specifically engineered and designed sediment control measures to prevent sediment from leaving the site, there is expected to be a significant reduction in mobilised sediments compared to that of the current grazing regime.

The RUSLE soil loss estimate calculations undertaken for the site (see Section 16.9.4.3) indicates potential soil loss rates ranging from 67 to 1,392 tonnes per hectare per year and erosion hazard categories ranging from very low to very high depending on soil characteristics and slope. Estimated soil loss rates assume no erosion and sediment controls are implemented. With the installation, operation and maintenance of drainage, erosion and sediment controls, at least 95% of sediments up to 0.045 mm diameter (i.e. ~64 to ~1,322 tonnes per hectare) would be captured and retained within the site under typical flow conditions through rapid settlement of coarse-grained particles during all storm events and settlement of fine grained particles under controlled conditions. The resultant amount of sediment that would potentially not be contained vial engineered erosion and sediment controls would be between 3 to 70 tonnes per hectare. As outlined above, this represents a significant reduction in downstream sedimentation compared with the current grazing regimes implemented at the Mamelon property.

It is expected that the reduction of mobilised sediments will continue post mining as the intention is to set aside the property for nature conservation purposes. A key aspect of the destocking approach is to allow the vegetation communities within the riparian corridors to regenerate without being subjected to ongoing grazing pressures. As vegetation coverage continues to increase within the riparian corridors and across the property more generally with the absence of grazing, the potential for sediments to mobilise reduces and will continue to do so.

16.9.4 Potential Impacts to Land and Management Approach

16.9.4.1 Potential Impacts

This section describes the key components of the Project which could affect EVs associated with land. Management measures have been determined in response to these potential impacts and best reflect the requirements for land management throughout the construction, operation and rehabilitation phases of the Project.

Land Disturbance

The Project will disturb 1,124 ha of land. The clearing of vegetation and other earthmoving activities associated with construction of the mine and mine facilities can initiate soil erosion if not done in a controlled manner, releasing sediments into nearby water systems and decreasing the overall value of the land. Minimising disturbance will be vital in minimising associated impacts to land and soils. The impacts resulting from each of individual disturbance activities will vary, however they are not anticipated irreversible.

As the proposed mine will be an open cut mine, a change to existing and potential land use within the Project and adjacent areas will be moderate, with most land disturbance limited to areas associated with the MIA, open cut pit mines and waste rock areas. Within the CHPP / MIA areas, land degradation may occur as the result of compaction and / or topsoil removal, resulting in a reduction in land suitability, post mining. However, such areas would be relatively small and measures would be employed to recover most, if not all, of such affected areas, for example by ripping and deep ploughing of compacted surfaces post-mining.

The key potential soil impacts that will affect the Project site are physical soil disturbance, contamination of soils and degradation of soils. The physical degradation of soil may occur because of the use of heavy machinery, leading to severely limited revegetation potential, decreased water infiltration and, in some instances, increased erosion. Soil quality can also be affected by poor topsoil stripping and handling.

The clearing of vegetation and other earthmoving activities associated with construction of the Central Queensland Coal mine and mine facilities can initiate soil erosion if not done in a controlled manner, releasing sediments into nearby water systems and decreasing the overall value of the land.

Soil and Land Contamination

Contamination can affect future soil use and land suitability. If not managed correctly, contamination of soils may occur because of Project activities related infrastructure components such as the CHPP, ROM dump station and mine affected water dams. Storage of hazardous and other chemicals also presents a risk to soils as spills can result in significant contamination.

ASS or PASS are not anticipated to occur within the Project area. As such there is very little, if any, risk of ASS-related contamination.

Erosion and Stability

Mining activities have the potential to increase the risk of erosion, particularly when soils are subject to flooding, wind, sodic in nature, or are on steep slopes. Within the Project area erosion is most likely to occur in areas because of excavation activities, including:

- Cut and cover;
- Topsoil stripping and stockpiling of materials; and
- Construction of infrastructure areas including roads, machinery pads and dams.

Across the Project site there are some areas with subsoils (B horizons) displaying strongly sodic or dispersive properties. These soil properties will further increase the likelihood of erosion occurring if not properly managed. Sodosols within the central section of the transport corridor have physical and chemical properties that make them relatively more susceptible to erosion (highly sodic). The risk of erosion on land within the transport corridor is most likely to occur following site clearance and prior to construction of the road.

16.9.4.2 Destocking and Revegetation of Mamelon Property

Central Queensland Coal has committed to the destocking the majority of the Mamelon property. The property is substantially larger than the proposed Project footprint (6,478 ha and 1,124 ha respectively). The destocking of Mamelon will allow for the natural regeneration of land undisturbed by the mine and allow for the continued progressive rehabilitation of land disturbed by the mine. As detailed in the following sections the Project will be implementing a wide range of specifically engineered and designed sediment control measures to prevent sediment from leaving the site. As such, there is expected to be a significant reduction in mobilised sediments compared to that of the current grazing regime.

Soil loss estimate calculations have been undertaken for the site (summarised in Section 16.9.4.3, also refer Section 5-6 of Chapter 5 – Land for detailed calculations) indicating a maximum soil loss of 67 to 1,392 tonnes per hectare per year, assuming no erosion and sediment controls are implemented as part of Project activities. With the installation, operation and maintenance of sediment basins, at least 95% of sediments (up to 0.045mm diameter) would be captured and retained. As outlined in Section 16.9.3, this represents a significant reduction in downstream sedimentation compared with the current grazing regime.

It is expected that the reduction of mobilised sediments will continue post mining as the intention is to set aside the property for nature conservation purposes. A key aspect of the destocking approach will be to allow the vegetation communities within the riparian corridors to regenerate without being subjected to ongoing grazing pressures. As vegetation coverage continues to increase within the riparian corridors and across the property more generally combined with the absence of grazing, the potential for sediments to mobilise reduces and will continue to do so.

16.9.4.3 Erosion and Sediment Control Management

This Erosion and Sediment Control (ESC) management framework section has been developed to outline the key principles for managing erosion and sediment control issues during construction of the Project.

Erosion and sediment control management is based on principles designed to minimise the overall environmental impact of the proposed mine development. The objective is to minimise the pollution of surface waters resulting from construction and operation activities and includes the incorporation of specific measures and structures to minimise erosion and sedimentation associated with the Project, to be implemented in conjunction with a range of management techniques. Principles include minimising the extent of ground disturbance, controlling clean water movement through the site, implementing erosion control strategies to prevent on site impacts and sediment control strategies to prevent off site impacts, progressive stabilisation of the site and monitoring of controls throughout construction and operation.

An Erosion and Sediment Control Plan (ESCP) will be developed and implemented prior to the commencement of construction. The ESCP will be developed in accordance with *Best Practice Erosion and Sediment Control* (IECA 2008) and the EHP Stormwater Guideline: Environmentally Relevant Activities (EHP 2014b) and will contain standard erosion control measures as well as specific measures applicable to particular areas. Details will be provided on the construction methods, material specifications, dimensions, expected performance outcomes and the proposed staging for installation of controls. The ESCP will also detail the monitoring, maintenance and reporting program for erosion and sediment control structures and practices:

- Installation of sediment control devices downslope of any disturbed areas;
- Diversion of clean water around disturbed areas;
- Policies to avoid and minimise earthmoving activities during intense rainfall events;
- Installation of drainage and erosion control devices; and
- A construction and operations plan that minimises the extent and duration of soil disturbance.

The ESCP will be focussed on construction activities in the initial development area to the east of the Bruce Highway in accordance with the mine schedule. A follow-up ESCP will be developed prior to the commencement of construction activities to the west of the Bruce Highway currently scheduled for 2027. The ESCP will consider and address the variables in a seasonal context to measure [using the Revised Universal Soil Loss Equation (RUSLE)] and manage the risk of soil erosion from all activities associated with the mine, haul road and TLF. Soil conservation and site rehabilitation will also be integrated into the detailed ESCP.

During mine construction and operation, sediment can be mobilised and transported by surface water during rainfall events, ultimately discharging into Tooloombah and / or Deep Creek drainage lines and potentially impacting water quality and aquatic habitats. Erosion and sedimentation during the operation phases is most likely to occur from stormwater runoff from the coal stockpile, MIA and from ongoing earthworks associated with the maintenance of roads and dams. Stormwater runoff will be captured in appropriately designed structures and contained for treatment to avoid off site sedimentation and associated adverse impacts to the receiving environment.

Erosion Hazard and Risk

The site erosion hazard and erosion risk are important in determining the appropriate erosion and sediment controls to be implemented as part of the Project's construction and operation phases. Soil erosion hazard can be described as the susceptibility of a parcel of land to the prevailing agents of erosion and soil erosion risk is the likelihood of environmental harm occurring due to disturbance activities of the Project.

An assessment of soil erosion susceptibility is provided in Table 16-20 which lists influencing factors for each soil type.

Table 16-20 Soil erosion susceptibility

Soil Order	Sodicity	Emerson Class	Texture	Landform	Vegetation cover	Erosion susceptibility
Dermosol	Non-sodic	Class 3	Loam	Undulating plain	Cleared with mixed eucalypt open forest	Low susceptibility due to low relief and non-dispersive soils
Sodosol	Sodic	Class 3 – Class 1	Clay loam – sandy clay	Gently undulating plains	Cleared	Highly susceptible when disturbed
Kandosol	Non-sodic	Class 4	Clay loam	Undulating rises	Variable but mostly cleared	Moderate-High on slopes in high intensity rainfall areas.
Rudosol	Non-sodic	Class 3	Loamy sand	Gently undulating plain	Grazed but not cleared	Low susceptibility due to sandy texture and flat terrain
Vertosol	Sodic	Class 1 and Class 4	Sandy clay	Level to gently undulating plain	Cleared	High for disturbed soil and stockpiles, but erosion hazard limited by flat terrain

As the mine is in a sub-tropical climate, soil erosion management shall be undertaken in a two-season approach - wet season (December to March) and dry season (April to November). The erosion risk based on average monthly rainfall depth (recorded for nearby Marlborough) and monthly rainfall erosivity (recorded for Rockhampton) referenced from the International Erosion Control Association (IECA) – *Best Practice Erosion and Sediment Control Guidelines* (2008) are shown in Table 16-21. Generally, the erosion risk is highest from December to March and is lowest from July to September.

Table 16-21 Erosion risk based on average monthly rainfall depth (Marlborough)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall erosivity	1202	1259	776	224	259	144	104	109	92	265	431	886
Erosion risk	High			Moderate		Low			Very low	Moderate		High

Source: IECA 2008 Table 4.4.5

Best practice erosion control requires appropriate measures to be employed as soon as reasonable and practicable to limit soil erosion and to protect exposed areas of soil from raindrop impact erosion. Best practice land clearing, erosion control and site rehabilitation depends on the likelihood and intensity of expected wind or rainfall. If construction occurs during the dry season when rainfall is unlikely, then the required erosion protection can be significantly less than if construction occurs during the wet season. Therefore, it is proposed to develop and implement dry season and wet season management strategies to account for the seasonal change in erosion risk.

The region's seasonality also makes it prone to wind erosion, particularly during the dry season. Wind erosion is a key contributor to dust generation which has the potential to impact residents surrounding the site, vegetation communities and the operation of the mine itself if located downwind. The site will employ various erosion control techniques which, if designed, installed and maintained correctly, will reduce the wind erosion hazard to very low in both the dry and wet seasons. Dust suppression measures including watering of roads and stockpiles, will be implemented where required to avoid wind dispersion of sediments into surface water bodies.

The following sections provide an indicative summary of the proposed works and the erosion hazard assessment for these works. The soil loss estimation calculations are used to determine the sediment control standards and techniques for the site.

Soil Loss Estimation

Soil loss for the site is estimated using the RUSLE as an indicator used in the determination of sediment control standards for the Project. The RUSLE is often used to estimate the average long term annual soil loss resulting from sheet and rill erosion under a series of specified conditions. Soil losses calculated by RUSLE are considered best estimates based on long term average rainfall records and represent the amount of soil that would likely be lost without any erosion and sediment controls in place. With appropriate erosion and sediment controls installed and maintained on site in accordance with the ESCP, soil loss will be greatly reduced.

RUSLE Calculation

RUSLE is taken from IECA 2008, Appendix E, page E.3 and was used to estimate soil loss rates. The formula is as follows:

A = K x R x LS x P x C

Where:

A: is the predicted soil loss in tonnes/hectare/year

K: is the soil erodibility factor

R: is the rainfall erosivity factor

LS: is the slope length/gradient factor

P: is the erosion control practice factor

C: is the ground cover and management factor

Each of the Project's construction areas has been divided into sub-catchments based on nominated surface water flow directions and topography. Digital elevation models showing the current site topography were used to calculate soil loss.

Each of the Project construction areas has been divided into sub-catchments based on nominated surface water flow directions and topography. For each of the sub-catchments, soil loss calculations have been completed using the slope gradients and lengths. The calculations have used conservative slopes i.e. steepest disturbed, allowing the nominated ESCs to be sufficient for the worst-case scenario. These will be recalculated based on final design and incorporated into the Primary ESCP.

Soil Erodibility (K factor)

The texture of the soil varied across the site, with soils being classified as loams through to sandy clays. Based on Table E4 in the Guidelines, a K-factor of 0.04 has been adopted across the site for soil loss calculations. This is a conservative number as it reflects the worst-case scenario from laboratory testing of site soils (Dermosol loam, 0.04) and allows for a 20% increase to the K-factors to account for dispersive soils.

Rainfall Erosivity (R factor)

Rainfall erosivity (R factor) is a measurement of the energy associated with rainfall events. The two-year ARI six-hour rainfall event (14.4 mm) was determined using the Bureau of Meteorology Intensity Frequency Duration design rainfalls tool using Project location coordinates and this has been used to calculate the R-factor for the Project using the following formula:

$R = 164.74\ (1.1177)^{S}\ S\ 0.6444$ (Appendix E, page E3.2, IECA 2008)

Where:

S: is the two year ARI, six-hour rainfall event (mm)

The annual R factor is 5,750 based on the 2 year, 6 hour storm event. The monthly percentage erosivity values for Rockhampton have been derived from Table E2 in the Guidelines (IECA 2008) and are presented in Table 16-22.

Table 16-22 Monthly percentage and annual rainfall erosivity (R-factor) values

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Project	20.9	21.9	13.5	3.9	4.5	2.5	1.8	1.9	1.6	4.6	7.5	15.5	**100**

Source: IECA 2008 Guidelines, E3.*2*

Monthly R factor values for the Project have been calculated based on the monthly percentage erosivity values in Table 16-22and these are presented in Table 16-23.

Table 16-23 Monthly and annual rainfall erosivity (R-factor) values

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Project	1,202	1,259	776	224	259	144	104	109	92	265	431	886	**5,750**

Source: IECA 2008 Guidelines, E3.2

Using the monthly R factor values from Table 16-23, the wet season (December to March) R value is 4,123 and the dry season (April to November) R value is 1,627. The indicative construction schedule for the higher erosion risk construction activities is from April to December, however the annual R-factor has been used to allow for any changes to the construction schedule. The typical dry season (April to November) R-Factor is 1,627 which accounts for 28.3% of the annual rainfall erosivity for the Project area. Where practical, high risk disturbance activities such as vegetation clearing will be undertaken during the dry season.

Slope Length / Gradient (LS factor)

The LS factor is a numerical representation of the length-slope combination. The Project area is characterised by slopes from 0.6 – 6%. This represents the topography at the commencement of project construction, with ongoing earthworks during construction and operation to significantly affect both slope gradient and slope length. For processing areas, haul roads, ROM and associated ancillary areas, slopes will reduce, or remain similar to the natural landform (i.e. < 4 %), whereas side slopes of the waste rock stockpiles will be >10 %.

Erosion Control Practice (P factor)

The P-factor measures the combined effect of all support practices and management Variables, as well as structural methods for controlling erosion (IECA 2008). A P-factor of 1.3 has been applied to each of the sub-catchments, which represents a compacted and smooth surface and is the default construction phase condition.

Ground Cover and Management (C factor)

The ground cover and management factor measures the level of soil surface protection provided by various groundcovers, including vegetation, rock, hardstand, paving, soil binders, matting and associated non-erodible material. The C-factor measures the combined effect of all the cover and management variables and non-structural methods for controlling erosion. A C-factor of 1.0 has been adopted which represents no appreciable cover and is the worst-case scenario.

Soil Loss

Site parameters used in soil loss estimation calculations are summarised in Table 16-24.

Table 16-24 Site parameters

Site parameters	
IECA Design rainfall event	5 days (85th percentile)
Annual rainfall	890mm
5-day, 85th %ile rainfall event	41.4mm (Rockhampton)
EHP Design event: 10 yr 24hr storm	10.6mm/hr (254.4mm)
Soil type	Type D (dispersible) (worst case)
Rainfall erosivity (R-factor)	5,750 (Annual)
Soil erodibility (K-factor)	0.05
Erosion control practice (P-factor)	1.3 (compacted and smooth)
Cover factor (c-factor)	1 (0% cover)

Potential soil loss calculations and the associated erosion hazard for defined project areas are provided in Table 16-25.

The proposed site layout is reflected in the key project components as described in Section 16.4.4. Following development, the mine pits will contain all runoff and sediment internally. Mine water storage dams and environmental dams are not included in soil loss calculations as any sediment will be contained within these structures and no additional sediment control devices are required.

16.9.4.4 Erosion and Sediment Control Requirements

The recommended erosion and sediment control measures are based on the erosion hazard and erosion risk. Climate data for the Project area indicates a distinct wet season from December to March, with a drier period from June to September with the erosion risk lower during these months.

Erosion and sediment control measures must be fully implemented prior to or immediately following ground disturbing activities. Table 16-26 summarises the erosion and sediment control requirements for all stages of project construction and operation across the calendar year. Typical measures to be implemented during the Project are discussed below, with specific design, timing and location to be provided within the Progressive ESCPs. At all times, reasonable and practical measures shall be taken to apply best practice erosion control to completed earthworks or to otherwise stabilise such works, prior to anticipated rainfall-including existing unstable, undisturbed, soil surfaces under the management or control of the building or construction works

Table 16-25 Potential soil loss and erosion hazard

Parameter	Mine Pits	Waste Rock Stockpiles	CHPP areas	Dam and mine access roads	Power supply	Conveyor	Haul road to TLF and Dam 4	Rail loop and spur line
Characteristics	Drains internally	Waste rock stockpiles	Compacted gravel surface	Compacted gravel surface	Easement	Easement	Compacted gravel surface	Compacted gravel surface
Catchment area (ha)	747.7	243.3	27.8	12.4	1.4	5.8	26	8
Undisturbed area (ha)	0	0	0	0	0	0	0	0
Rainfall erosivity (R)	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750
Soil erodibility (K)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Slope length (L)	200	200	80	10	40	40	20	40
Slope gradient (S)	4	8	2	2	2	2	4	2
Length gradient (LS)	1.48	3.72	0.41	0.18	0.31	0.31	0.44	0.31
Erosion control (P)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Ground cover (C)	1	1	1	1	1	1	1	1
Standard treatment	Contained runoff	High % rock	Compacted Hardstand	Soil stabilised	Soil stabilised / Vegetated	Soil stabilised / Vegetated	Soil stabilised	Soil stabilised
Potential soil loss (t/ha/yr)	555	1,392	152	67	116	116	163	116
Potential soil loss (m^3/ha/yr)	427	1,070	117	52	89	89	126	89
Soil loss class	5	6	2	1	1	1	2	1
Erosion hazard	High	Very high	Low	Very low	Very low	Very low	Low	Very low

Table 16-26 Erosion and sediment control requirements during construction

Erosion Risk	Rainfall erosivity	Months	ESC Requirements
Very Low	0-60	Sep	▪ Land clearing limited to eight weeks of work if rainfall is reasonably possible. ▪ Disturbed soil surfaces stabilised with minimum 60% cover within 30 days of completion of works if rainfall is reasonably possible. ▪ Unfinished earthworks are suitably stabilised if rainfall is reasonably possible, and disturbance is expected to be suspended for a period exceeding 30 days. ▪ Sediment controls installed and maintained.
Low	60+ to 100	Jun, Jul, Aug	▪ Land clearing limited to maximum eight weeks of work. ▪ Disturbed soil surfaces stabilised with minimum 70% cover within 30 days of completion of works within any area of a worksite. ▪ Unfinished earthworks are suitably stabilised if rainfall is reasonably possible, and disturbance is expected to be suspended for a period exceeding 30 days. ▪ Sediment controls installed and maintained.
Moderate	100+ to 285	Apr, May, Oct, Nov	▪ Land clearing limited to maximum six weeks of work. ▪ Disturbed soil surfaces stabilised with minimum 70% cover within 20 days of completion of works within any area of a work site. ▪ Staged construction and stabilisation of earth batters (steeper than 6H:1V) in maximum 3m vertical increments wherever reasonable and practicable. ▪ Unfinished earthworks are suitably stabilised if rainfall is reasonably possible, and disturbance is expected to be suspended for a period exceeding 20 days. ▪ Sediment controls installed and maintained.
High	285+ to 1500	Dec, Jan, Feb, Mar	▪ Land clearing limited to maximum four weeks of work. ▪ Disturbed soil surfaces stabilised with minimum 75% cover within 10 days of completion of works within any area of a work site. ▪ Staged construction and stabilisation of earth batters (steeper than 6H:1V) in maximum 3m vertical increments wherever reasonable and practicable. ▪ Soil stockpiles and unfinished earthworks are suitably stabilised if disturbance is expected to be suspended for a period exceeding 10 days. ▪ Sediment controls installed and maintained.

An effective ESC strategy considers the interrelated processes of drainage control (minimising water flows through erosion prone areas), erosion control (minimising the detachment of sediment), and sediment control (capturing sediment displaced by up-slope erosion processes). Therefore, the key strategies adopted in the ESCP will involve diversion of water flowing into disturbance areas, minimising erosion within the disturbance areas, and trapping the majority of sediment that is generated before it is mobilised off site.

The following steps will be taken to minimise sedimentation during the active phase of the site:

- The Project has been designed to ensure surface water flows into creeks are maintained as close as possible to natural conditions;
- Diversion drains and banks will be used to redirect any “clean” surface water flows around the main site areas. This minimises the potential for erosion by limiting the amount of water flowing through the disturbance areas and protects infrastructure from flooding during extreme events. Design and sizing of diversion drains, banks and culverts is discussed further in Section 16.10.3.3;

- Exposed soil surfaces will be engineered to minimise erosion potential. This will be achieved through careful material selection, slope grading, and other surface treatments; and
- Any sediment-laden water within the disturbance areas will be captured and treated in a manner which minimises amount of sediment released into the surrounding environment.

Stormwater runoff environmental dams function to capture dirty water runoff generated from disturbed areas such as stockpiles and the MIA and CHPP areas. Environmental dams will have a low flow perforated riser-pipe outlet to discharge treated water to the receiving environment. Environmental dams are located at both MIAs, waste rock stockpiles and the TLF. MIA drainage sumps and proprietary oil removal devices are proposed to capture runoff from truck wash and workshop areas for treatment and reuse or disposal.

Runoff intercepted by or generated from haul roads will be captured in table drains and conveyed longitudinally towards culvert structures. In areas of steeper grade, sediment transport can be effectively managed using check-dam structures within the drain. Where haul roads cross drainage gullies or the Deep Creek watercourse, an appropriately sized culvert will be provided, allowing for fish passage where relevant.

Clean water runoff from local catchments will be diverted around open pit mining areas for events up to and including the 0.1% AEP (1:1,000-year ARI) design flood. The volume of stormwater entering open mine pits and becoming mine affected water is therefore effectively limited to that rain which falls directly on the open pit area. Precipitation received in the open pits will be dewatered to an ex-pit storage for reuse or discharged to receiving waters as controlled discharges under conditions licensed by the Environmental Authority.

The key ESC infrastructure proposed for this site includes:

- Clean water diversions - Diversion drains and bunds are proposed to divert clean water runoff around the mine affected areas, including the open pits and waste areas;
- Dirty water diversions - Dirty water drains collect runoff from waste rock stockpiles and processing facilities within the vicinity of the CHPP, ROM and MIA, and discharge to the CHPP Environmental dams and waste area environmental dams. These dirty water drains will be sized to capture runoff generated from a 1:10-year (24 hour) ARI event;
- Environmental dams - Environmental dams (sediment basins) around the project collect catchment runoff and transfer water to the MIA Dams. Each of the CHPP and MIA's, waste areas and TLF have an environmental dam. Environmental dams are sized to capture the 1:10-year ARI 24 hr duration storm event in accordance with The DES Stormwater Guideline (EHP 2014b); and
- Culvert crossings - The proposed haul road connecting the MIA and CHPP 2 with the TLF crosses several drainage gullies, therefore requiring cross-drainage culvert infrastructure. The crossings are conceptualised as box culvert crossings with capacity to pass a minimum 1:10-year ARI design discharge. Discharges above the design event will pass over the box culvert as a floodway-type arrangement.

The following factors were taken into consideration when determining the level of ESC protection required:

- The properties of the surface materials;
- Local rainfall patterns (depths, intensities, recurrence intervals);

- The nature of the landforms being protected;
- The sensitivity of the receiving environment;
- The risk rating guidelines described in IECA (2008);
- The *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EHP 2016);
- The *Stormwater Guideline for Environmentally Relevant Activities* (EHP 2014b); and
- Stakeholder requirements.

Temporary ESC diversion drains will be designed with capacity to convey a 1:100-year peak flow event. This level of protection is above and beyond the 1:10-year design standard recommended in the IECA guidelines (2008) and has been adopted to ensure that more than adequate protection is provided throughout the life of mine. Temporary structures include all diversion drains and sediment traps that will be removed at mine closure, such as those installed around the plant area.

All permanent ESC structures (i.e. the main site diversion banks around open cut mine areas) will be designed to withstand a 1:1,000-year peak flow event in keeping with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EHP 2016). All environmental dams will be designed as Type 1 sediment basins. These are flow-through type basins, designed to remove 90% of material > 0.045 mm in diameter (silts), and with a sediment storage zone that is 50% of the volume of the water settling zone.

The installation of all ESC measures has been scheduled to maximise protection throughout all phases of site development. Control measures will be put in place prior to soil disturbance wherever practical and will remain in place for the duration of the expected disturbance. Land clearing will be scheduled for the dry season to minimise exposure to rainfall, where practical.

The main site diversion banks in particular will be designed to be installed in stages. The main diversion banks will be installed progressively as the pits are developed. These features will remain in place after site closure. The smaller diversion drains associated with each of the infrastructure areas will be installed shortly after the areas are cleared and reshaped for construction. These features will be removed after the infrastructure areas are decommissioned and the areas are ready for rehabilitation.

Flow diversion banks and drains will be constructed to divert all clean water surface flows around the main work areas to minimise the potential volume water that will need to be managed within the site. The following diversions will be designed:

- Diversion banks will be constructed along the upslope edge of the pits to divert the majority of "clean" surface water around the site. These will be constructed in stages, as the pits are developed;
- Smaller diversion drains are planned for the management of surface water flowing into the MIA and CHPP areas. Alternatively, these smaller areas may be constructed on raised pads to place all sensitive infrastructure above the expected 1:100-year flood level, thus avoiding any need for diversion drains; and
- No diversion drain is required for the ROM pad, as it will be sufficiently built-up such that no surface water will be able to flow into the area.

The critical design factor for surface water diversions is the expected peak flow rate. Peak flow rates typically occur during short, intense storms (e.g. a 1:100-year, 10 min event at 246 mm/hr) rather than during longer storm events (e.g. 1:100-year, 72 hr event averaging 7.16 mm/hr). The main site diversion banks will be designed to convey a 1:1,000-year peak flow event, and all temporary drains will be designed for a 1:100-year peak flow event (critical rainfall durations ranged from approximately 5 to 70 minutes). All diversion banks and drains will be constructed from compacted soil materials.

All diversion banks will be designed assuming a 10:1 gradient (0.10 m/m slope) on the upslope side, and a 3:1 gradient (0.33 m/m slope) for the constructed bank. All diversion drains will be designed assuming an 8:1 gradient (0.13 mm/m slope) on both sides of the drain. Gentler construction angles will increase the design capacity of these features so long as the design flow depth is maintained. Discharge from each diversion structure will be via a level spreader or rock chute, to ensure that the concentrated surface flow is transitioned back to sheet flow in a way that minimises erosion downslope of the outlet.

Minimising Erosion on Disturbed Surfaces

Constructed Landforms

The constructed landforms (i.e. the waste rock stockpiles) represent the largest erosion risk areas and will be constructed with slope angles that are steeper than the surrounding natural land surfaces and are therefore considered the largest potential sources of eroded sediment. The primary strategy for minimising erosion on these landforms is to construct them with low batter slope angles and using erosion-resistant materials, where practical.

All constructed landforms will be designed by a suitably qualified person. As a guiding principal, the outer slopes will consist of several ≤ 10-metre-high lifts. Each lift will be shaped to an approximate 15° slope angle. The upper surface will be designed to be inward sloping to keep any rainfall on the upper surface from running down the slopes. Some progressive rehabilitation may occur (e.g. placement of topsoils, revegetation, etc.) during the active mine phase.

Operational Works Areas

The main operational work areas, such as the plant and stockpile areas, will be gently sloping to flat (<1% slope gradient). Generally, the control of raindrop impact erosion is more important than the control of surface water velocity on flat land (IECA 2008), and thus these areas will be constructed by compacting the competent local soil profile, which is expected to provide some natural armouring capacity, given the high gravel content in these soils. Sediment traps will be installed to collect and remove any sediment that is generated from these areas.

Stockpiles

Topsoil stockpiles will be constructed no higher than 2 m and subsoil stockpiles no higher than 10 m with a slope of ≤ 15° This will help to minimise erosion from the stockpiles by limiting the length and steepness of the outer stockpile slopes. Stockpiles to be retained for a period of greater than three months, and which have not naturally established a groundcover, will be bunded around the perimeter to minimise sediment mobilisation.

Roads

Haul roads will be built up in most areas, so that they are above the natural land surface. They will be designed to be water shedding to avoid flow accumulation which can lead to scouring, and erosion of the road surface and embankments. Haul roads will be constructed using compacted competent local soil materials, which are generally high in gravel content and are therefore considered to be relatively erosion resistant. Sandstone or waste rock material will be additionally utilised where the upper soil profile is found to be unsuitable for road construction.

The haul roads are expected to be sprayed with saline water to minimise dust generation, and this saline water will improve the structural integrity of the roads, such that negligible sediment will be available for erosion and runoff. Any access or haul roads crossing the surface water diversion structures (e.g. haul roads between the northern pit and Waste Rock Stockpile 1a) will be constructed in such a way that they do not interfere with the functioning of the diversions (e.g. use of whoa-boys, bridges, or culverts). Compacted low pass floodways will be installed along the main access road in the lowest-lying areas to maintain the integrity of the road surface.

Dust control

Wind erosion will be controlled through a combination of rock cover and water spraying. Rock cover on waste rock stockpile surfaces will be achieved through the placement of waste rock material. Most of the other disturbance areas are to be constructed using compacted competent local soils, which consist of a significant fraction of gravels to help armour the surfaces. Surfaces that require additional dust control measures, particularly areas that receive a significant volume of vehicle traffic, will also be periodically sprayed with water, as required.

Only non-saline or brackish water will be used wherever practicable, particularly in the vicinity of topsoil stockpiles; however, saline water is expected to be used along the main haul roads due to the sheer volume of water and frequency to which dust suppression will likely occur. Any additional cleared areas that are not required during the operation of the mine will be progressively rehabilitated according to the site rehabilitation strategy. This will restore a native plant cover to the land surface, thus reducing the risk of dust generation from exposed bare soil surfaces.

Sediment and Drainage Controls

Site specific controls and locations will be nominated within the ESCP. There will be a variety of permanent and temporary drainage structures in place that will control and manage the flow of water across the site and prevent the discharge of uncontrolled water from the site. The controls are nominated below. If the design life of ESCs nominated is expected to be exceeded, a review of the controls will be required to determine whether they are still adequate or to revise controls as necessary.

Erosion control measures shall be installed prior to clearing and grubbing operations, wherever possible. Where access to an area is required prior to installation, erosion control measures shall be installed concurrently with clearing operations. Control measures shall be installed within 48 hours of clearing operations.

Once clearing and grubbing, and sediment control devices are installed (i.e. silt fences, inlet/outlet protectors), ditches and channels with accompanying environmental dams shall be constructed, followed by appropriate slope stabilisation controls, placement of rock rip-rap in selected areas, and seeding of slopes and stockpiles, where required.

Environmental Dams

Environmental dams will capture rainfall runoff from the two MIA, TLF and overburden dump areas. The primary function of the environmental dams is to capture sediment laden runoff for sediment removal. A perforated riser pipe outlet is proposed to allow gravity draining of the environmental dam within 48 hours of filling.

Environmental dams are operational during construction and operation of the mine. The environmental dams allow for the capture, treatment and discharge of stormwater generated from the site during a rainfall event which does not exceed the design criteria. Water from the environmental dams will be preferentially used in the mine operation activities, including dust suppression and top up of the MIA process water ponds. Where rainfall exceeds that design criteria, excess water may be transferred to the larger on-site water dams, or safely pass via an emergency spillway to allow discharge to avoid flooding. Even when the environmental dams are full of water, sediment laden stormwater runoff continues to be conveyed through the dams for continued settlement of coarse-grained particles contained in the flow. The environmental dams will be emptied of sediment prior to the commencement of the wet season to maximise the available storage capacity.

Environmental dam design and management are in accordance with the following principals:

- The site has been divided into 18 storm water management sub-catchments;
- Site drainage ditches are designed for a 1 in 10-year Annual Recurrence Interval (ARI), 24-hour storm event;
- Runoff from undisturbed areas will be diverted to naturally vegetated areas via clean water diversions; and
- Stormwater drainage from within the disturbed area that may contain sediments will be conveyed to the environmental dams via drainage channels designed for a 1 in 10-year Annual Recurrence Interval (ARI), 24-hour storm event.

Sediment control structures (i.e. "sediment basins") will be installed in each of the main infrastructure areas to collect and remove sediment from runoff water. Each of the sediment basin will be located at an elevation below the associated disturbance area, and each disturbance area (where required) will be reshaped and bunded so that all drainage is directed into the sediment basin.

All sediment basins will be designed as Type 1 sediment basins, according to the ESCP Guidelines (IECA, 2008). As discussed in the ESCP Guidelines, these types of sediment control measures should be designed to maximise the filtration of sediment-laden water during periods of light rainfall, and the settlement of sediment-laden water during periods of moderate to heavy rainfall. In general, the lighter the rainfall, the higher the expected quality of discharge water.

All sediment traps have therefore been designed to remove ≥ 90% of particles ≥ 0.045 mm in diameter (fine sands) during the design rainfall event. This is above and beyond the design level outlined in the ESCP Guidelines (IECA, 2008), which recommend the sediment traps be designed for "average" site conditions (i.e. sized for half of the 1:1-yr peak flow event). As ≥ 70 % of the soil volume is made up of sand-sized particles, the sediment traps will be able to remove the majority of sediment generated during larger storm events. This design further allows for the removal of particles as small as 0.02 mm diameter (silts) under average flow conditions (i.e. the 1:1-yr peak flow event).

The sediment traps are designed as flow-through cells and are sized such that the retention time of water in the basin is matched to the settling velocity of the critical particle size. Sediment traps will have a minimum length to width ratio of 3:1, a settling zone depth of 0.6 m, a sediment storage zone depth of 0.6 m, and a freeboard requirement of 0.3 m. Discharge from the sediment traps will be via a rock-armoured spillway, sized for the 1:100-yr peak flow rate. Sediment basin standard drawings and construction details are included in Appendix A15 – ESCP Typical Drawings.

Clean Water Diversions

All clean water running through the site (i.e. creeks and drainage lines) will be diverted around or through the site without contamination. This will be achieved through a number of measures including temporary drains, lined channels and permanent and temporary culverts. Clean water diversions bunds are to be re-established and / or constructed upstream of any location that is to be disturbed by construction activities. This is to convey clean water around disturbed areas and to prevent clean water from entering active areas. Clean water runoff will be diverted into either Deep or Tooloombah Creeks. Temporary clean water diversion bund locations and indicative environmental dams are shown on Figure 16-21. Criteria to be implemented on site are shown at Appendix A15 - ESCP Typical Drawings.

Flow Diversion Banks

Flow diversion banks are earth structures which assist in reducing site erosion by reducing the length of slope (and the potential soil loss), increasing the time of concentration of overland flow, directing overland flow to a stable outlet point and directing run-on water around the construction site. These structures are very effective at protecting the site from erosion damage and form a critical part of the ESCP. They are relatively simple to construct and are to be implemented during all stages of the construction program where appropriate. Flow diversion banks are particularly important during vegetation clearing.

The size of the construction catchments has been broken up using flow diversion banks placed at regular intervals down the slope with the intent of slowing the flow of water and diverting surface runoff through sediment controls and into the receiving environment. Recommended maximum spacing of drainage systems down long exposed, non-vegetated or recently seeded slopes are provided at Table 16-27. Flow diversion banks are only required in those areas where clearing takes place. If no clearing is done outside of nominated areas, surface water can continue to flow through existing vegetation to the receiving environment as it naturally does pre-clearing. A typical profile of a flow diversion bank is shown at Appendix A15 – ESCP Typical Drawings.

Table 16-27 Maximum flow diversion bank spacing (IECA 2008, Table 4.3.2)

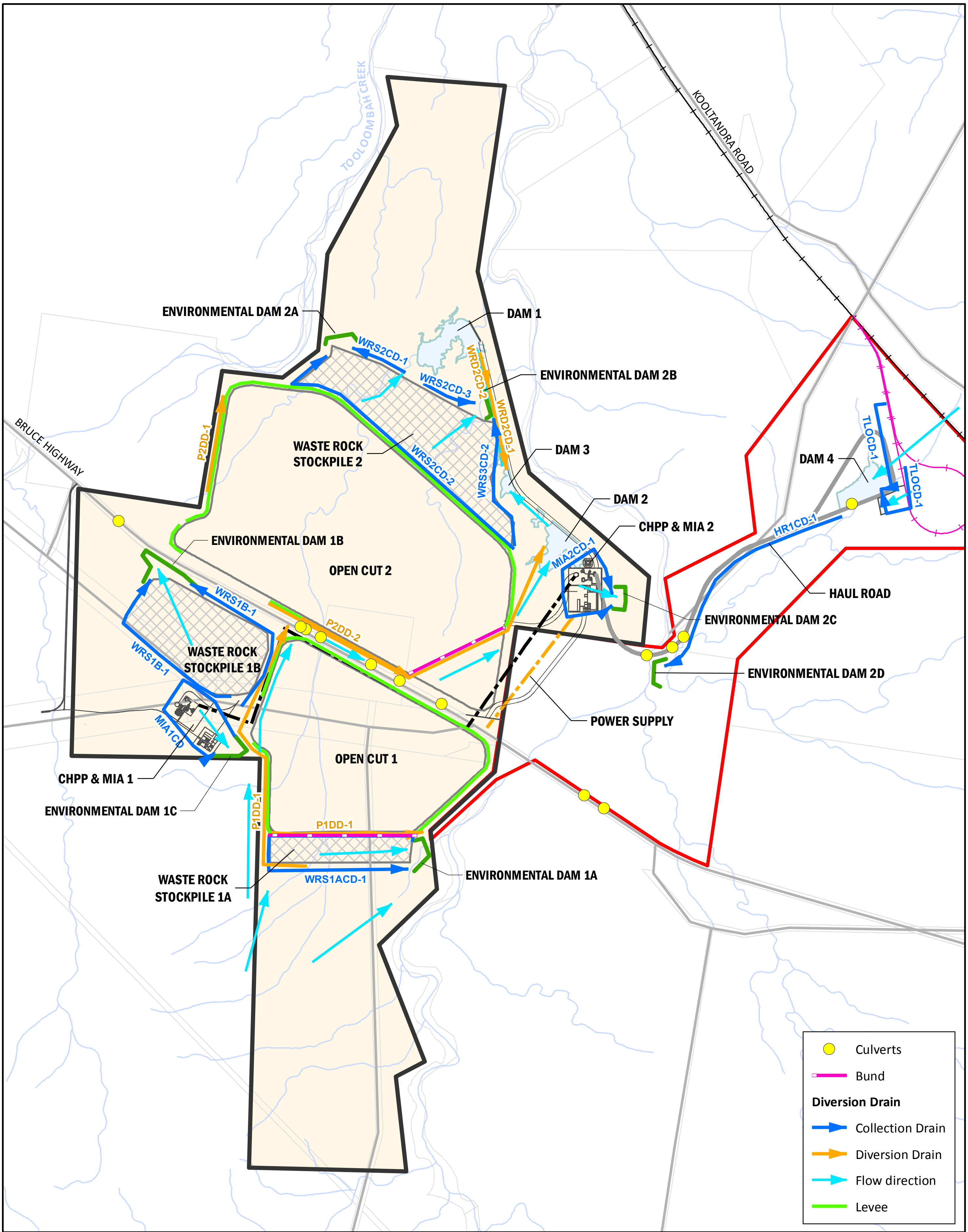
Batter slope (percentage)	Horizontal spacing (m)	Vertical spacing (m)
1%	80	0.8
2%	60	1.2
4%	40	1.6

Reconstruction of Slopes

Steep slopes and batters will require stabilisation during construction, particularly slopes for the environmental dams, soil disposal areas, new roadside ditches or channels and areas with potentially wet soils. Terracing, geotextile, or geo-matting shall be used where required, in combination with riprap at drainage points and with seeding and mulching, where possible.

Surface roughening techniques, such as walking a hillside with tracked equipment, may also be employed to minimise erosion potential for slope faces. Although a reduced batter grade is more desirable from a potential erosion perspective, this also increases the footprint of the alignment which has other environmental implications associated with additional clearing.

Prior to revegetation, any steep batters have the potential to suffer from extensive erosion resulting in downslope sedimentation. Accordingly, construction of batters requires careful consideration of erosion and sediment control issues.



N

0 0.5 1 km

Scale @ A4 1:45,000
Date: 15/11/18
Drawn: Gayle B.

Legend

Haul Road
Mine infrastructure
Overland Conveyor
Power
Road
ML 80187
ML 700022
Open-cut Mine Pit
Waste Rock Area
Environmental Dams
Cadastral boundary
Main road
North Coast Rail Line
Watercourse
Dam

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

Figure 16-21
Mine site drainage

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Mine Site Drainage__9-85.mxd 11/15/2018

Vegetation Buffers

Buffer strips of vegetation will be left intact, wherever possible, between construction works and wetland and / or stream boundaries to help protect water quality. Where possible a 15 m wide vegetated buffer will be left in place during clearing to allow a natural filter between exposed soils and wetland areas. Buffers will also be established where possible in known sensitive areas.

Central Queensland Coal will destock most of the Mamelon property, limiting grazing to already cleared areas in the south-west and south of the property. This area encompasses approximately 1,000 ha. The remaining area, including the creek lines which lie adjacent to the mine area, will be managed and allowed to regenerate. In the longer term, destocking will contribute to localised water quality improvements through long-term restoration of this habitat and will allow vegetation to regrow along the riparian zones of Deep Creek and Tooloombah Creek which are presently mostly cleared. Re-established riparian vegetation will capture sediment run-off from the property and prevent it from entering the watercourses. The restoration of cleared areas will reduce soil erosion on cleared areas of the property, thereby reducing the entrainment of sediments entering creek lines during bouts of heavy rainfall. The removal of cattle from much of the property will also remove a source of long-term sediment and nutrient input into creeks and Broad Sound after rain events.

Sediment Traps

Where runoff from the construction area is unable to be diverted to sediment basins, sediment traps will be used to filter and intercept runoff leaving the site. These sediment traps include a variety of measures including rock socks, mulch, rock checks, sand bags and sediment fences. Sediment traps shall be installed where needed between construction areas and existing water bodies to provide protection against sediment lose where required.

Sediment traps shall be installed as per design details to intercept and detain flow of sediment-laden runoff. The condition and functionality of these sediment fences shall be monitored as part of the regular and storm follow-up inspections. Maintenance shall include repairing/replacing damaged sediment fencing and removal of sediment if necessary.

Road Drainage and Inlet / Outlet Filters

Drainage ditches shall be constructed where required to allow the efficient drainage of adjacent construction areas. Inlet and outlet filters shall be installed to protect storm drains from clogging and/or obstructions, and to maintain runoff water quality consistent with existing conditions. Outfall locations shall be protected to prevent scouring.

Dewatering

Stabilisation measures such as scour protection will be implemented so that dewatering of construction excavations and pits does not result in erosion and sedimentation. Examples of scour protection measures include rock mulching, gravelling and use of erosion control blankets or geofabric. Dewatering of construction excavations will be undertaken with controls in place to avoid accidental pumping of sediment from the base of the excavation.

Stabilised Site Exit Points

During clearing and construction, all site exits points will be stabilised with rock pads or have vibration grids installed to collect sediment from vehicles exiting the site and avoid tracking of sediment onto public roads. The stabilised site exits will be maintained and cleaned or repaired as necessary to ensure they are working efficiently.

Construction Management

The management measures provided below are recommended to be implemented by Central Queensland Coal to minimise the potential erosion risk of the Project. The measures are focussed on the construction activities during the first 10 years of the Project and are relevant to the initial mine development and all associated infrastructure located on the eastern side of the Bruce highway. Work on Open Cut 1 and associated infrastructure located to west of the Bruce Highway is not anticipated to commence until 2027. Prior to the commencement of these construction activities, an updated ESCP will be prepared and certified.

Pre-Construction Management Measures

General mitigation measures to limit the impacts of land disturbance include the following:

- As an overriding principal, minimising all land disturbance, including vegetation clearance, to only that immediately required to achieve development requirements;
- Where possible, vehicle movements will be restricted to existing roads to minimise ground and vegetation disturbance;
- 'No Go Zones' will be shown on the ESC Design Drawing and marked on site prior to any clearing;
- An ESC briefing will be provided as part of site inductions. All relevant personnel will be trained in the requirements of the most current ESCP;
- Installation of perimeter ESCs will be completed prior to any construction;
- Works will be scheduled to minimise the area of active disturbance at any one time; and
- Nominated ESCs will be installed in predetermined locations and downslope of any disturbed lands.

Vegetation Clearing

All clearing works will be conducted in accordance with the following vegetation and soil management requirements:

- Land clearing limited to an area of land suitable to complete eight weeks' worth of construction work if rainfall is predicted (as per Table 4.4.7 in IECA 2008);
- Maximum of 30 days after commencement of site stabilization, for identified areas, before specified minimum ground cover (e.g. organic or rock mulch, synthetic blankets, vegetation or combination thereof) is achieved in all areas except for active areas including haul roads;
- Root stock will be retained in the ground after clearing to reduce erosion and to facilitate rapid rehabilitation, where possible. This is excluding areas of permanent infrastructure, access routes, where operational activities may be impacted, and mining pits where root stock would cause an issue for coal quality;
- Vegetation will be progressively cleared where practical to minimise the area of soil exposed;
- Identify, isolate and protect mature native vegetation where appropriate. Protected vegetation areas are to be identified and clearly marked out on site before commencing clearing works; and
- Vegetation that is cleared is to be preferentially mulched and used to stabilise exposed soils on site or strategically placed to provide habitat for fauna where possible.

Earthworks

It is anticipated that civil works required during the construction phase for Open Cut 2, MIA2, CHPP2 and the TLF, and associated infrastructure on the eastern side of the Bruce Highway, will be completed in approximately ten months from commencement; however, there may be requirements for further civil works during the operations and decommissioning phases. Typical civil works that will be undertaken as part of the development include, civil earthworks, installation of permanent and temporary drainage, and trenching and laying of reticulated services and any other underground pipelines and services. All earthworks and ground disturbance are to conform to the following minimum standards:

- Use of any existing clearings through riparian vegetation, if any, will be maximised while new clearing is minimised;
- Construction activities in watercourses will cease if a risk assessment indicates that any forecast rainfall event could cause unacceptable environmental harm or impact on safety. Construction activities may not recommence until a site inspection has determined that the watercourse has returned to stable flow (or no flow) conditions; and
- Diverting uncontaminated storm water run-off around areas disturbed by construction activities and / or other potentially contaminating activities.

Access Tracks

- Existing tracks or final access road alignments are to be used whenever possible. The duplication of parallel / multiple tracks or turnouts are to be avoided;
- Access track drains are to discharge runoff water in a manner which does not lead to erosion or movement of sediment to surface waters;
- Vehicle movement over both retained vegetation and newly cleared areas where the topsoil is yet to be stripped is to be minimised;
- Suitable sheeting material is to be placed on all internal haul roads to provide additional cover and minimise sediment runoff, as well as providing suitable all-weather access;
- Maximum permitted vehicle speeds identified in the site Safety and Health Management System is to be adhered to;
- All construction vehicles, plant and equipment are only permitted within designated construction areas, and are not allowed within any “No-Go” or environmentally sensitive exclusion zones; and
- Vehicle movement within the site will remain on designated site access routes wherever possible.

Construction of new access tracks may be required during construction. Where possible, access tracks will be constructed to:

- Maintain a vegetation buffer between any access track and nearby watercourses;
- Be positioned along contour lines limiting grade changes;
- Minimise the disturbance of existing ground; and
- Limit construction taking place across existing drainage lines, where construction across drainage lines is unavoidable, provide a means for the transport of water preventing concentrated runoff.

Construction Phase Management Measures

Site clearance activities will be staged during the construction phase on an as needed basis to coincide with construction requirements and to minimise the extent and duration of cleared areas at any one time. Suitable soil resources for use in rehabilitation will be stripped from areas where construction and mining operations will occur. Topsoils and subsoils will be stripped, handled and stored in a manner in line with industry best practice to prevent the deterioration of soil quality. Where practical, Central Queensland Coal will undertake construction activities with a high potential to create erosion risk during the drier months, generally between April and December.

The ESCs nominated in the SEIS, and subsequently in the Project ESCP, are to be in place before any clearing and construction works take place and will remain in place until final rehabilitation has been completed and site stabilisation is achieved. The following mitigation measures are to be implemented during construction:

- Surface water run-on is to be diverted around the perimeter of work areas to the greatest extent possible;
- ESC awareness briefings will occur as part of site inductions. All relevant personnel will be trained in the requirements of the most current ESCP;
- All reasonable and practicable measures will be implemented to control flow velocities in such a manner that prevents soil erosion along drainage paths and at the entrance and exit of all drains and drainage pipes during all storms up to the relevant design storm discharge; and
- Dust suppression measures (use of water trucks and spraying stockpiles with suitable soil binders) are to be implemented.

Topsoil Stockpile Management

Appropriate management of topsoil stockpiles is required to minimise the potential for sediments to mobilise to Deep Creek and Tooloombah Creeks during storm events. The following mitigation measures are to be implemented to avoid losing materials from stockpiles during periods of rain:

- Stockpiles are to be located at least 100 m away from drainage lines / waterways;
- Stockpiles which are exposed for prolonged periods or have been identified as problem soils are to be stabilised where required using soil stabilisers or by other acceptable methods e.g. vegetation;
- Excavated soil is to be stockpiled separately from other materials (e.g. vegetation), where it can be readily recovered for reuse; and
- Stockpiles are not to impede natural or constructed surface drainage channels or access tracks.

Soil Treatment

Maintaining the integrity of the topsoils stripped prior to construction is integral for final rehabilitation, as these soils are necessary for future regeneration of vegetation. Compaction, from stockpiling soils for extended periods of time or handling wet soils, may greatly reduce soil quality.

The following mitigation measures are to be implemented to avoid impacting topsoils:

- In areas where there is little topsoil or there is evidence of existing salinity, topsoil may be ameliorated with mulch, or another approved ameliorant (i.e. gypsum) to facilitate revegetation;
- No topsoil stripping works will occur during significant rainfall events or when significant rainfall events are expected;
- Topsoil stripping will be timed in accordance with site conditions, once topsoil moisture following the wetter months has decreased enough to minimise compaction issues;
- Where practicable, soils will be replaced in the order of excavation;
- The height of topsoil stockpiles is to be no more than 2 m in height with suitable batters (generally 1:3);
- Topsoil stockpiles are to be located on the high side of slopes and are be located away from subsoils; and
- Topsoil is not to be used as backfill material.

Surface Water Management

The following measures are to be implemented to manage impacts to local waterways:

- Maintain average slope gradients as close as possible to pre-existing slope gradients, whilst allowing for natural drainage;
- The erosion potential of longer slopes is to be minimised using contour diversion berms;
- Minimise slope gradients adjacent to waterways;
- Where it is not possible to maintain riparian vegetation, any vegetation that has been cleared near waterways is to be removed from the area and stockpiled away from the watercourse with appropriate erosion controls;
- All water that is actively discharged to a waterway will meet water quality criteria, as listed in the Project's EA;
- Any earthworks that are being carried out near drainage lines will be revegetated and stabilised immediately on completion of the work wherever possible and will minimise slope gradients while maintaining appropriate drainage requirements in areas adjacent to drainage lines; and
- Install temporary earth banks (or other appropriate controls) along cleared slopes, diverting dirty water away from Deep Creek and Tooloombah Creek and into vegetated area.

Land Degradation and Contamination

Contamination impacts shall be remediated with current common contaminated land practices. These impacts are of a low risk following the adoption of mitigation measures listed below. The following mitigation measures are proposed:

- Ensure all refuelling facilities and the storage and handling of oil and chemicals comply with relevant Australian Standards;
- Contaminated material will be removed and placed in an appropriate area for remediation;
- Provision of appropriate spill control materials including booms and absorbent materials at refuelling facilities to contain spills;
- In the event of a large spill, sites will be investigated, managed and remediated in accordance with the requirements of the contaminated land provisions of the EP Act and the DES Draft Guidelines;

- Onsite records will be maintained regarding any activities or incidents that have the potential to result in land contamination;
- Appropriate waste rock and rejects management and disposal; and
- As much as possible, avoiding impact to any areas of soil with sodic properties.

Dust Control

Dust will be maintained using water trucks on haul roads and sprays will be used if required to control dust at topsoil and product stockpiles.

Inspection and Maintenance

The following inspection and maintenance items will be addressed during construction.

Inspection and Reporting Requirements

Site inspections will be undertaken in accordance with the frequencies shown in Table 16-28 when active construction activities are taking place. Normally routine inspections of the construction area will be performed weekly when active construction activities are taking place. Active construction areas will be inspected at least once per week. An example weekly ESC Inspection Checklist is provided in Table 16-29.

Table 16-28 Summary of monitoring measures, trigger values and corrective actions

Monitoring Measure	Frequency	Trigger value	Corrective Action
Inspection of sediment fences, ESC devices, disturbed areas, topsoil stockpiles	Weekly	Structural integrity is retained. 70% capacity of sediment fences remains and 50% capacity for drop inlet structures remains	▪ Maintenance to restore capacity of ESC device and then address source instability. ▪ Other corrective actions as appropriate determined on a case-by-case basis.
Inspection of the integrity of diversion bunds, sediment fences and stormwater drainage channels to verify their condition and effectiveness.	Weekly in response to rainfall events (>25mm in 24 hours (maximum once a day))	Structural integrity is retained. 70% capacity of sediment fences remains and 50% capacity for drop inlet structures remains	▪ Maintenance to restore capacity of ESC device and then address source instability.
Inspection of stormwater discharge outlets from site.	Weekly	No offsite build up of sediment on land. No offsite scouring to the bed or banks of any watercourse or land.	▪ Inspect ESC measures in the catchment draining to the stormwater discharge to ensure they are functional and that the capacity is retained. ▪ Undertake maintenance or repairs as necessary. ▪ Review the adequacy of the installed ESC measures in the catchment draining to the stormwater discharge and assess whether additional measures could be practicably implemented.
Inspection of the integrity and capacity of environmental dams.	Weekly	Accumulation of gross pollutants (litter and waste). Sediment accumulation such that 70% of capacity of environmental dam.	▪ Remove accumulated gross pollutants and sediment to restore capacity of environmental dam.

Table 16-29 Example weekly ESC Inspection Checklist

Weekly ESC Inspection Checklist			
Type of Inspection			
Routine			
Rainfall Event (Before)			
Rainfall Event (After) (cm of rain/duration)			
Intermittent Dewatering			
Area Inspected:			
Inspected BY:		Date	
Item No.	Inspection Items	Compliant (Yes / No)	Comment
1	Have the management practices identified in the ESCP been installed according to specification and in the identified locations		
2	Is there any evidence that sediment is leaving the construction site? If yes, specify		
3	Is there any evidence of erosion on fill slopes, temporary stockpiles? If yes, specify		
4	Do any sediment trapping / filtering devices (i.e. sediment fence) require repair or clean-out to maintain proper function? If yes, specify		
5	Do any velocity reduction devices (i.e. rip-rap aprons) require repair or clean-out to maintain proper function? If yes, specify		
6	Do any runoff diversion features (i.e. lined swales, storm drain inlet protection) require repair or clean-out to maintain proper function? If yes, specify		
7	Do any area in which temporary or permanent vegetative stabilisation measures are being taken show signs of bare spots, insufficient growth or germination? If yes identify locations and specify remedial action (e.g. irrigation, fertilisation, seeding, mulching, maintenance)		
8	Are on-site traffic, parking, equipment laydown, supply and waste storage restricted to those areas specifically designated for those purposes?		
9	Is there any evidence of sediment, debris or mud tracked out of the construction areas?		
Note: Attach additional sheets if needed to identify plans for corrective actions, expected date of implantation, who is to perform the work and any other relevant specifics			

An example pre-wet season checklist to be completed prior to the commencement of the wet season is at Table 16-30. Water quality monitoring will be undertaken in accordance with the Project's EA conditions.

Table 16-30 Example pre-wet season checklist

Pre Wet Season Inspection Checklist			
Type of Inspection: weekly, pre-wet season, weekly during wet season			
Rainfall Event (Before)			
Rainfall Event (After) (cm of rain/duration)			
Area Inspected:			
Inspected BY:		Date	
Item No.	Item	Compliant (Yes / No)	Comment
1	Are site conditions nominated in the Environmental Authority consistent with those assumed within the approved ESCP?		
2	Was the full perimeter of the work site inspected?		
3	Site inspections and monitoring are being carried out at appropriate times and intervals.		
4	Site access is controlled, and the number of access points minimised.		
5	Adequate drainage and sediment controls exist at site entry/exit points.		
6	Adequate drainage, erosion and sediment controls have been placed around the site compound.		
7	Appropriate drainage and sediment controls are installed prior to new areas being cleared or disturbed.		
8	Site personnel have ready access to the ESCP.		
9	ESC measures are being installed in accordance with the approved ESCP.		
10	Adequate supplies of ESC materials stored on-site: such as wire, stakes, sediment fence fabric, filter cloth, clean aggregate		
11	Temporary access roads are stabilised where appropriate.		
12	Sediment deposition is not observed external to the Project area.		
13	Chemicals and diesel products appropriately stored on site.		
14	Emergency spill response plan has been prepared for the site.		
15	Oil / diesel spill containment / response kits available on-site where appropriate.		
16	Waste receptors have been emptied and located in approved locations.		
17	Any contaminated site water, liquid waste and wash-off water has appropriately disposed of to ensure it will not enter any waterways and stormwater systems.		
18	Waste water from construction activities such as wash water, de-watering operations, and dust control has been appropriately captured, treated and disposed of.		
19	Stripped topsoil has been stockpiled and is appropriately controlled to minimise the risk of sediment / turbid water discharge.		
20	Stockpiles located at least 5 m away from top of watercourse banks.		
21	Long-term soil stockpiles adequately protected against wind and rain.		
22	Stockpile sediment control (*Filter Fence* or *Sediment Fence*) is appropriate for the soil type and site conditions.		
23	Drainage Control measures are consistent with the ESCP.		
24	Drainage Control measures are being adequately maintained in proper working order at all times.		

25	Up-slope “clean” water is being appropriately diverted around / through the site in a non-erosive manner.		
26	Stormwater runoff diverted away from unstable slopes.		
27	Flow diversion channels/banks stabilised against erosion.		
28	Flow not unlawfully discharged onto an adjacent property.		
29	Earth batters are free of erosion.		
30	Catch Drains: (a) Adequate depth / width; (b) Adequate flow capacity is being maintained; (c) Stabilised against soil scour; (d) Clear of sediment deposition; (e) Appropriate grass length is being maintained; and (f) Water discharges via a stable outlet.		
31	Channel Linings (mats): (a) Lining is well anchored; (b) Mats overlap in direction of flow; (c) Lining is appropriate for flow conditions; and (d) No damage to the mat by lateral inflows.		
32	Check Dams: (a) Flow is passing over the dams and not around them; (b) Check Dams are not causing excessive channel restriction; (c) Rock Check Dams are not used in shallow drains; and (d) Check Dams are appropriately spaced down the drain.		
33	Temporary Watercourse Crossings: (a) Sediment runoff from the approach roads is controlled; and (b) Likely damage to the crossing and the stream caused by possible overtopping flows is considered acceptable.		
34	Erosion Control measures are consistent with the approved ESCP.		
35	Erosion Control measures are being adequately maintained in proper working order at all times.		
36	Erosion Control Blankets: (a) Blankets are well anchored; (b) Blankets overlap in direction of stormwater flow; (c) Blanket strength is appropriate for site conditions; (d) Synthetic blanket reinforcing will not endanger wildlife; (e) Blankets not damaged by lateral inflows; and (f) Blankets protected against movement by winds.		
37	Mulching (light): (a) Minimum 70% coverage of soil surface; (b) Suitable tackifier used on steep slopes; and (c) Drainage controls preventing mulch displacement.		
38	Mulch (heavy): (a) Minimum 100% coverage of soil; (b) Minimum depth adequate to control weeds; and (c) Drainage controls preventing mulch displacement.		
39	Soil Binders: (a) No adverse environmental impacts observed.		
40	Sediment Control measures are being adequately maintained in proper working order at all times.		

41	Sediment control *Buffer Zones* are protected from traffic and are free of excessive sediment deposits.		
42	Neighbouring properties are being adequately protected from sedimentation.		
43	Entry/Exit Points: (a) Control measures are constructed to appropriate standards; (b) Excessive sediment removed from sediment traps; (c) Excessive sedimentation is not evident on roadway; and (d) Stormwater drainage is controlled such that sediment is not being washed onto the adjacent roadway.		
44	Sediment Fences: (a) Bottom of fabric is securely buried; (b) Fabric is appropriately overlapped at joints; (c) Fabric is appropriately attached to posts; (d) Support posts are at correct spacing (2 m or 3 m with backing); (e) Sediment Fence does not cause flow diversion / bypass; (f) Sediment Fence has regular returns; (g) Lower end(s) of fence is/are returned up the slope; (h) Sediment Fences are free of damage; (i) All fences are free of excessive sediment deposition; and (j) Fences are adequately spaced from toe of fill banks.		
45	Rock Filter Dams (Sediment Traps): (a) Excessive sediment removed from up-slope of all traps; (b) The filtration system is free from sediment blockage; and (c) Rock Filter Dam and spillway are free of damage.		
46	*Temporary Watercourse Crossings* (e.g. construction access) have been reduced to the minimum practical number.		
47	Instream structures are not located on, or adjacent to, unstable or highly mobile channel bends.		
48	Construction works are not unnecessarily disturbing instream or riparian vegetation.		
49	Erosion is not occurring because of stormwater passing down channel banks.		
50	Appropriate temporary erosion control measures are being applied to disturbed areas.		
51	Synthetic reinforced erosion control blankets/mats are not being used where there is a potential threat to wildlife.		
52	*Sediment Fences* have not been placed in areas of actual or potential concentrated flow.		
53	Appropriate material (spoil) de-watering procedures have been adopted.		
54	Site stabilisation/revegetation is occurring in accordance with approved Plans and/or programming.		
55	Exposed areas are adequately stabilised given the site conditions, environmental risk, and construction schedule		
56	Newly seeded areas are developing an appropriate grass cover (not just strike rate), density and grass type.		
57	No newly seeded areas require reseeding.		
58	Soil erosion within revegetated areas is being adequately controlled (i.e. mulching) during the plant establishment phase.		

59	Revegetation is controlling soil erosion as required.		
60	Newly seeded areas have been lightly mulched as specified.		
Note: Attach additional sheets if needed to identify plans for corrective actions, expected date of implantation, who is to perform the work and any other relevant specifics			

Observations made during inspections, along with data captured during environmental monitoring events (i.e. water quality monitoring), will be used to identify required preventative and / or corrective actions. The information will be used:

- To document compliance with the ESCP and the Project's EA conditions; and
- The rationale for modifying the ESCP so that the necessary changes to control measures and / or procedures can be developed and implemented to avoid findings of future potential non-compliance.

Once a preventative or corrective action is identified the closeout of the action is to be tracked to ensure actions are addressed in a timely manner to minimise the likelihood of recurrence.

16.9.5 Potential Impacts from PASS or AASS

Oxidation of PASS material can result in generation of AASS. The generation of AASS can result in the release of sulphuric acid and iron into the soil and groundwater. This in turn can release aluminium, nutrients and heavy metals (particularly aluminium, iron and arsenic) stored within the soil matrix. Once mobilised in this way, the acid, metals and nutrients can seep into waterways, killing fish, other aquatic organisms and vegetation and can degrade concrete, steel pipes and structures to the point of failure. Additionally, low levels of impact include reduced hatching, decline in growth rates, skin and health impacts for aquatic life.

PASS oxidation can result in medium to long-term changes in soil chemistry. Changes in soil chemistry may affect the water quality of tidally influenced areas located at the mine, resulting in reduced biodiversity and potentially death of flora and vegetation. In addition to environmental impacts there is a risk of land sterilisation and deterioration of existing infrastructure should the soil become acidic.

Any activities that have potential to lower the water table may enhance the oxidation of sediments. Where the excavation is below the water table and into potential PASS material, drawdown of the water table may expose PASS material. This can result in the oxidation of PASS and acid generation. The potential impact on groundwater due to dewatering activities include change in pH of soil and water, changes to water quality and changes to the hydraulic regime. This is discussed further in Section 16.11.3.

The risk of disturbing PASS is assessed as low, given the low to extremely low probability of the site containing ASS. Notwithstanding, where there is a potential to disturb PASS, works will require the implementation of management controls. These controls are summarised here and detailed in Chapter 5 – Land.

16.9.5.1 Management Action Planning

Notwithstanding the geochemical analysis suggests the project disturbance area has a low to extremely low probability of containing ASS, the following outlines the indicative management approach that will be adopted by the Project should PASS or AASS be disturbed. It is anticipated that the Project's EA may require an Acid Sulphate Soil Management Plan (ASSMP) be prepared. The following information will form the basis of the ASSMP.

Should an ASSMP be required, the Plan will be reviewed by the mine environmental manager and revised every year, or, because of:

- Any changes to regulatory or statutory requirements;
- Any significant change to the proposed construction locations;
- Development of open cut mining areas; and
- Any incident that requires reporting.

ASS Action Criteria

Action criteria will be set in accordance with Queensland guidelines defining when ASS disturbed during the construction phase of the Project will need to be managed. Soils with existing plus potential acidity below the action criteria may still be ASS but may not require management. The highest laboratory result will be used to assess if the relevant action criterion level has been met or exceeded. Soils that meet or exceed the criteria will require treatment and management.

Noting no PASS is anticipated to be encountered during land based activities the texture range will need to be assessed on a case by case basis. The following target performance criteria will be met for ASS that have been treated using neutralisation:

- The acid neutralizing capacity (ANC) of the treated soil will exceed the existing plus potential acidity of the soil by at least a safety factor of 1.5. Chromium Suite analysis will provide the appropriate rate of liming required to achieve the target performance criteria, inclusive of the 1.5 safety factor;
- The soil pH (pHKCl) will be derived from the Chromium Suite testing and results will be greater than 6.5 after neutralization to achieve the target performance criteria; and
- Excess neutralising agent will stay within the treated soil until all acid generation reactions are complete and the soil has no further capacity to generate acidity. The Chromium Suite analysis will confirm that sufficient buffering capacity exists to prevent further acidification in the treated soil.

Management of ASS Material During Construction

The likelihood of disturbing PASS is assessed as low to extremely low probability. Notwithstanding, the strategy to manage ASS disturbances during construction is avoidance. Where disturbance of ASS occurs, the adopted strategies will be:

- Minimisation of disturbance; and
- Neutralisation.

If PASS is disturbed during construction, excavated material will be segregated and tested (see following section) at the rate of one sample per 500 m^3. Excavated soils determined to contain ASS will be immediately neutralized with lime at the excavation site and managed at the excavation or segregated and isolated from uncontaminated soil and treated at a purposely designed and constructed ASS treatment area. Areas where fill may be placed on PASS will be monitored for any surface disruption outside of the immediate work area.

If ASS is present it will be treated during construction or transported to the ASS treatment area and treated with lime. Where neutralisation is required, the laboratory analysis will provide the appropriate liming rates required to increase the pH to meet the action criteria. Once neutralization is completed the mine environmental manager would determine the replacement of the material at the area of excavation or use of the material onsite at another location. Following treatment, the soil will be reused on site.

The following sections provide an overview of the actions to be taken should ASS be disturbed during construction. A contingency plan listing potential events that may arise during construction activities and activities that will be undertaken if unexpected conditions occur is included at Table 16-31.

Table 16-31 ASS contingency plan

Unexpected Conditions	Action
Possible ASS identified in unexpected locations.	1. Stop excavations in that area; 2. Assess the material for the presence of ASS including field testing and laboratory analysis; and 3. Follow treatment management procedures if confirmed as being ASS using field screen testing.
Validation testing results show neutralisation of the ASS was not effective.	1. Re-assess liming rates, and add additional lime to material; and 2. Re-test to check effectiveness.
Field screening results and laboratory testing do not appear to correlate.	1. Re-test by undertaking additional field screening tests and laboratory testing to calibrate the field screening tests; and 2. Check samples for the presence of shells that can on occasion lead to false negatives. Remove shells and re-test as the presence of shells does not necessarily mean that the soil will have sufficient natural buffering.
The validation testing results indicate too much lime has been added, and the soils are alkaline.	1. Remediate soils before re-use; 2. Remediation would compromise mixing additional ASS with the material (i.e. use the excess lime to neutralise more ASS; and 3. Re-test using field testing and validation testing in accordance with QASSIT Guidelines.
The bund for the ASS treatment area is damaged	1. Repair the bund as soon as possible; 2. Clean-up any ASS that has migrated from the treatment area and return to the treatment area; and 3. Check the surrounding area for impact from the ASS and / or leachate and undertake remedial action as necessary.
Unexpected storms and early onset of the wet season.	1. Other unexpected events which may affect the outcome of the ASS treatment would likely also affect other aspects of the work such as unexpected storms and the early onset of the wet season. Where considerable delays are experienced (i.e. several months) all excavated ASS will be limed using an increased rate based on laboratory data.

ASS treatment during excavation

If only small amounts of ASS are encountered during excavations, this material will be managed by treating with neutralizing lime immediately as it is excavated. The treatment will include:

- Applying lime over the edges of the excavation at a rate of 5 kg lime/m^2 and depending upon the intent of construction place clean fill or other cover on the area;
- Applying lime on the excavated ASS that is to be returned to the excavation at a rate of 5 kg lime/m^2, mixing the lime and controlling leachate;

- Return treated ASS to the excavation; and
- Repeat the procedure as needed throughout the excavation activities.

ASS treatment at the designated treatment area

If large quantities of ASS are encountered during excavations a designated ASS treatment area will be established to accommodate the temporary storage and treatment of this material. The size of the treatment area will depend on the amount of ASS encountered. The ASS treatment area will be developed and located at the mine and will be based on availability of sufficient and suitable area.

The treatment area will be protected from stormwater runoff, be constructed with a compacted or other liner to prevent leaching into the soil and have a 400 mm bund to prevent stormwater runoff except to lime-lined drains and a leachate pond. The Queensland standards will be followed for stockpile areas including:

- Any stockpile will be located at least 30 m from the nearest surface water;
- Stockpiles will be designed to ensure hydraulic isolation with an approved impermeable barrier or compaction;
- 5 kg/m^2 of lime will be worked into the surface soils of the containment area to safeguard against acid leakage into the subsurface;
- The treatment area will be compacted to minimize the potential for water infiltration;
- ASS will be spread in the treatment area in approximately 300 mm thick layers. Lime will be incorporated into the ASS at a rate sufficient to neutralise the acid (starting rate will be 100 kg lime/m^3 ASS and increased/decreased as necessary);
- A leachate / runoff collection system will be incorporated into the treatment area design;
- All leachate / runoff collected in leachate ponds will be monitored and treated appropriately prior to release to keep pH in the range of 5 – 8.5;
- Stockpiles and bunds will be inspected at least daily to ensure they are functioning, and materials or leachate are not causing contamination outside the treatment area;
- Sufficient amounts of lime and other materials will be procured for neutralization and emergency situations (i.e. 16 tonnes as an initial volume which is equivalent to a single truck and dog capacity);
- Stockpiles and treated material will be kept moist or otherwise stabilized to prevent blowing and to minimize the potential for oxidization; and
- Validation testing of the treated material will be carried out by obtaining representative composite samples, at a rate of one sample per 500 m^3, for laboratory testing.

Because acid can be transported by stormwater, excavation works in confirmed areas of ASS would be conducted during dry periods when practical to minimize the risk of overflow with sudden or heavy rain.

Transport vehicles used to haul ASS will be designated for this use only, to prevent cross contamination with clean material. The beds of these vehicles will, where practicable, be lined with a layer of lime which will be inspected by the contractor and replenished on a regular basis. Vehicles will be covered, where practicable, to prevent loss or leakage. Prior to leaving the mine, wheels and external surfaces will be inspected and cleaned where required, to remove residual ASS materials.

Excavations where ASS is found will be protected to prevent stormwater intrusion. This can be accomplished in many ways with the most effective means being employed considering topography, slope and the surrounding conditions. The mine development will already incorporate appropriate drainage design prior to the commencement of excavation activities to minimize the stormwater erosion potential.

The treatment of ASS would be undertaken progressively in a designated treatment area. The treatment area will be bunded with a compacted material to minimize erosion and direct impact by ASS. Once ASS material has been placed in the treatment area it would be allowed to drain (with leachate directed into the leachate management system) and then dosed with a neutralizing agent (lime). The lime will be thoroughly mixed with the soil. Additional quantities of lime above the calculated dosing rate may be required from time to time to allow for difficulties in mixing and to act as a back-up buffer under such situations. The effectiveness of the adopted dosing rate would be confirmed by the regular sample screening of treated material using pH and peroxide pH field tests, with additional lime added as needed.

Placing fill on PASS

The placement of inert fill on top of areas potentially containing ASS may occur. Fill placement will utilize best management practices, such as placement in lifts and mechanical compaction, to create a permanent working surface. If evidence of ASS intruding on the surface is observed a remediation plan will be prepared.

Managing ASS leachate

Water exposed to ASS and found to have a pH of <5.0, including water generated from ASS treatment, will require collection and management. Any leachate generated during the treatment operations will be directed to either collection tanks or ponds and treated in the following manner:

- Leachate and runoff from excavation areas containing ASS, ASS stockpiles and ASS treatment areas will be captured and contained or directed to leachate treatment tanks or ponds prior to discharge. Valves or gates will be installed at the discharge location/s for all tanks / ponds and operated manually by a suitably trained person;
- Treatment and neutralization will be accomplished with dissolved lime slurry, hydrated lime, quicklime or other suitable reagents, with the liming rate determined following assessment of actual pH levels. Discharge of leachate / runoff may occur when the pH of the leachate / runoff has been steady for 24 hours at a pH of 5.0 to 8.5;
- If hydrated lime or quicklime is utilized for neutralization, controls will be implemented, such as regular pH testing, to ensure that overdosing does not occur so pH of the leachate does not rise above pH 8.5;
- Personnel conducting ASS and leachate treatment will be trained in handling chemicals and test equipment;
- pH of leachate / runoff treated in-situ in excavations will be measured daily or whenever the flow rate changes. pH results will determine the application rate for neutralisation lime and the amount of treatment in the tank or pond system prior to discharge; and
- Treated leachate will be discharged at approved discharge locations within the pH range 5.0 – 8.5.

An incident reporting procedure will be implemented to record, investigate and report any spills or unscheduled discharges and releases. When an incident occurs, or is discovered, it will be immediately reported to the mine environmental manager, who will coordinate efforts with the construction manager/s to correct the condition. Contingency measures will be developed (e.g. the erection of bunds around excavation areas, linings for drainage systems), based on an assessment of the mine environmental manager, to eliminate future occurrences.

A vehicle wash down area comprising a hardstand with drainage will be constructed for trucks / equipment handling ASS adjacent to a temporary leachate tank / pond so that truck wash down water can be collected for treatment. Water would be appropriately treated, including for low pH or other contaminants, prior to disposal and be consistent with the quality characteristics outlined in the Project's approvals.

Monitoring

Regular visual monitoring of work areas would be undertaken to identity signs of ASS oxidation. This monitoring would include looking for signs of:

- Unexplained scalding, degradation or death of vegetation;
- Unexplained death or disease of aquatic organisms;
- Areas of green-blue water or extremely clear water indicating high concentrations of aluminium;
- Formation of the mineral jarosite and other acidic salts in exposed or excavated soils;
- Rust coloured deposits on plants and on the banks of drains, water bodies and watercourses indicating iron precipitates;
- Excessive corrosion of concrete and / or steel structures in contact with soil or water;
- Black to very coloured waters indicating de-oxygenation; and
- Any sulphurous smells, e.g., hydrogen sulphide or rotten egg gas.

16.10 Environmental Context - Surface Water

Many of the potential impacts on the relevant MNES are indirect impacts that arise due to direct impacts on intermediary receptors of the environment. To assess the potential impacts on MNES it is therefore necessary to assess the impacts on these intermediaries first. This section provides an overview of key aspects of the environmental context associated with surface waters that are relevant to the Project. The following provides a detailed summary of the findings related to the assessment of surface waters associated with the Project area and surrounds as detailed in Chapter 9 – Surface Water.

To adequately assess the potential impacts the Project may have on local surface water within the Project area, the following assessments have been undertaken:

- Desktop assessment, including review of publicly available literature, databases, maps and resources relevant to surface waters and groundwater in the Project area (refer Table 9-1 in Chapter 9); and
- Project specific surface water sampling assessments were conducted in 2011 and 2012. During this time, eight sampling events were undertaken. Water quality sampling specific to the current Project was carried out in February 2017 with ongoing monthly water quality sampling carried out from May 2017 and throughout 2018. A total of 12 sites were surveyed over the assessments although not all sites were sampled on each occasion (Figure 16-22). A single site

on Granite Creek was assessed in 2011; however, this site has not been returned to in the recent assessments as it is not relevant to the current Project. Site characteristics such as flow conditions, bank stability, and estimated water depth were recorded at each site. Survey site selection was based on Project proximity and the presence of water. Site selection was also guided by the DES Water Monitoring and Sampling Manual (EHP 2010) and *Environmental Protection (Water) Policy 2009.*

16.10.1 Existing Environment

The following sections summarise the existing environmental values as appropriate to groundwater values. Description of local topography is located in Section 16.9.1.1.

16.10.1.1 Climate

A detailed description of the climatic setting of the Project is presented at Chapter 4 – Climate. The following presents brief details to provide context for hydrogeology.

Average climatic conditions (temperature, rainfall and evaporation) of the study area for each month are presented in Figure 16-23. The longest and most continuous rainfall record closest to the Project has been obtained from Bureau of Meteorology (BoM) Station 033189 located at Strathmuir, approximately 7 km east of the Project, with records from 1941 to present. Mean temperature data have been obtained from BoM Station 039083, located at Rockhampton Aero, approximately 112 km from the Project, with records dating back to 1939 (no temperature data are available for the Strathmuir weather station).

The Project region experiences a sub-tropical climate, with cool winters and hot summers. Mean winter (July) temperatures range between approximately 8°C and 25°C, whilst mean summer (December-January) temperatures range between 23°C and 33°C.

The study area experiences a distinct wet season, with more rainfall occurring during the summer months (December to March), and drier periods predominating in the winter and early spring months (June to September). The wet season experiences an increased number of storm events leading to relatively short-lived but intense rainfall events and cyclonic rain depressions can develop over the area. The average annual rainfall at Strathmuir is 759 mm, with the highest average rainfall month (143 mm) being February and the lowest average rainfall month (16 mm) being September (Figure 16-23).

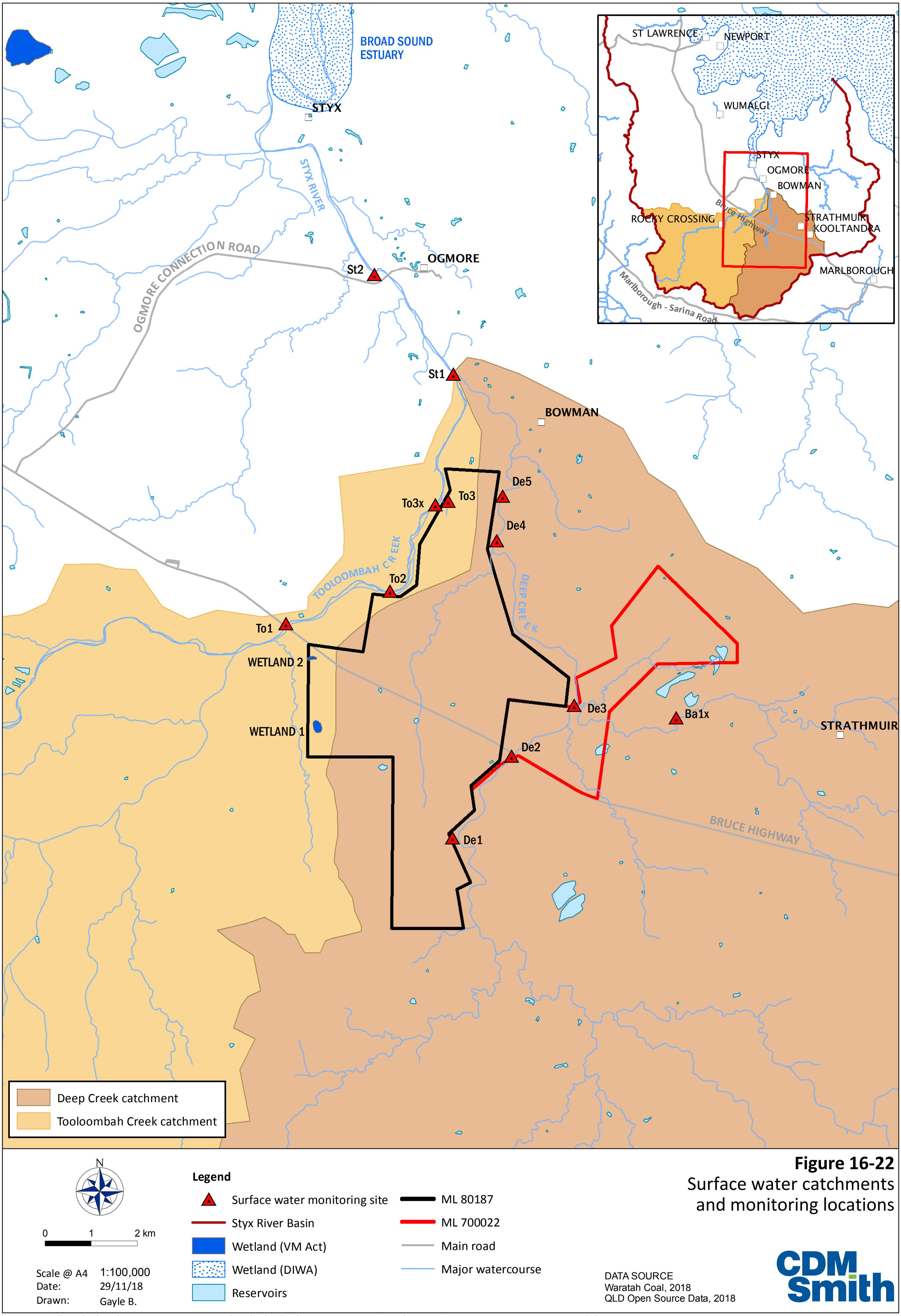


Figure 16-22
Surface water catchments and monitoring locations

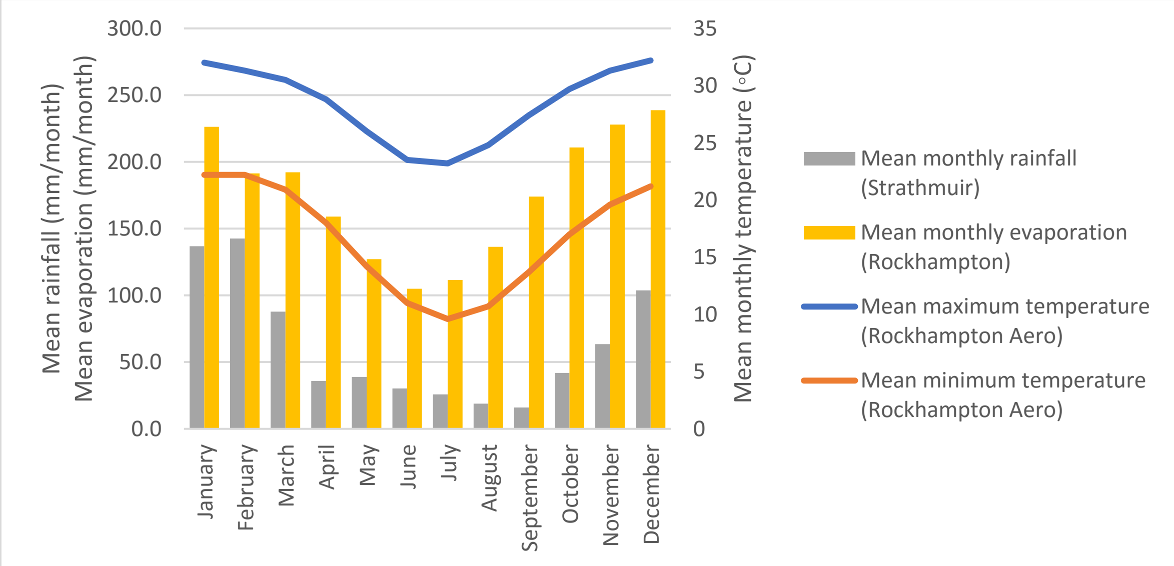


Figure 16-23 Mean climatic conditions

Recharge and stream runoff potential is highest during the summer months, when most rainfall occurs, although long lasting rainfall events at other times of the year could also give rise to sustained rates of recharge.

Cumulative deviation from mean rainfall is the accumulated difference between actual rainfall (e.g. in a month or a year) and the long-term mean, providing an indication of the general climatic trend over time as well as general water availability (soil water, surface water and groundwater). A cumulative deviation from mean (CDFM) plot of monthly rainfall at Strathmuir (BoM Station 033189) and Rockhampton Aero (BoM Station 039083) from January 1941 to February 2018 is presented in Figure 16-24. The plot indicates that climate (rainfall) variability is typical of the Project area, with periods of:

- Above average rainfall occurring from 1950 to 1955 and from 1973 to around 1980 (intra-decadal trends);
- Below average rainfall occurring from approximately 1957 to 1971 and from 1992 to 2009 (intra- to inter-decadal trends); and
- Around average rainfall occurring from 1940 to 1950, from 1978 to 1991 and from 2012 to present (intra- to inter-decadal trends).

The mean monthly evaporation (calculated from the long-term average daily evaporation at Rockhampton Aero (BoM Station 039083)) ranges from a maximum of around 240 mm per month in the summer months to a minimum of around 105 mm per month in the winter months. Total average annual evaporation (around 2,100 mm) is considerably higher than average annual rainfall, and on average evaporation rates exceed rainfall rates in every month of the year (Figure 16-23).

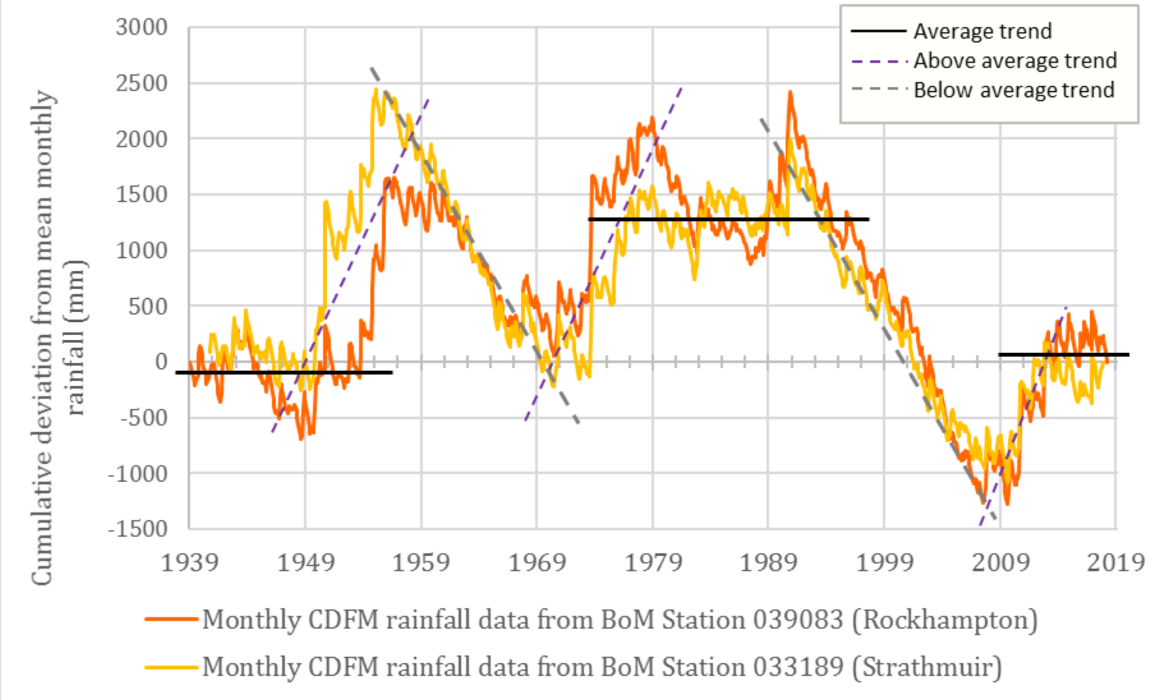


Figure 16-24 Cumulative deviation from mean monthly rainfall from BoM Station 033189 (Strathmuir) and 039083 (Rockhampton Aero)

SILO Data

Long-term rainfall and evaporation data were collected from the Scientific Information for Land Owners (SILO) Climate Data website (Department of Science, Information Technology, Innovation and the Arts (DSITIA 2017)) at the following coordinate location representing the approximate location of the Project:

- Latitude: 22.70 degrees south; and
- Longitude: 149.65 degrees east.

SILO represents a gridded dataset based on records provided by the Bureau of Meteorology (BoM). The data is then processed to fill gaps in data and produce a spatially complete dataset. Figure 16-25 summarises monthly averages of the SILO long-term data.

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

- A distinct wet season during the months of December, January and February, with monthly rainfall averages greater than 100 mm;
- A distinct dry season between the months April through October with less than 50 mm mean monthly rainfall between these months; and
- Evaporation rates that are highest during the summer months, and lowest mid-year. In any given month, the average evaporation is greater than the average rainfall.

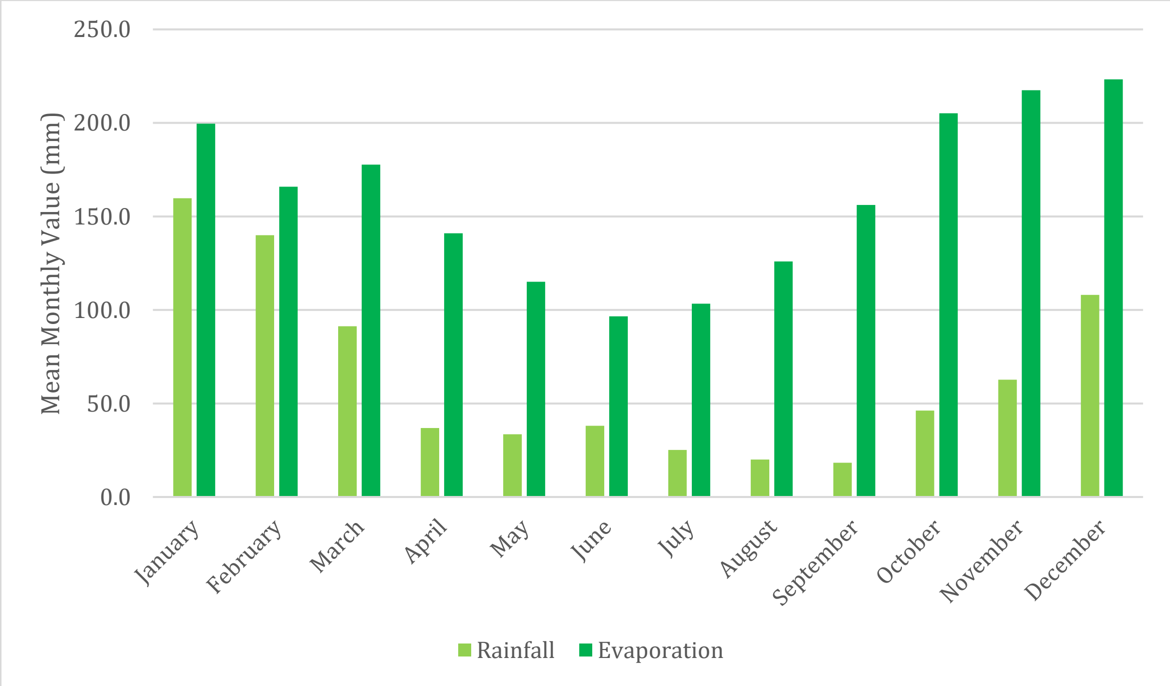


Figure 16-25 Graph of average monthly rainfall and evaporation from SILO

Comparison between data sources

Due to the gridded and somewhat synthetic nature of the long-term SILO data, a comparison with rainfall station data gathered from the nearby Strathmuir rainfall gauge was prepared to assess the validity of long-term SILO climatic data. The Strathmuir rain gauge (33189) was selected due to its 76-year data record and proximity (within 8 km) to the Project site. A comparison of mean monthly rainfall values between the Strathmuir rain gauge and SILO data is presented in Figure 16-26. The graph indicates good agreement between gauge records and data acquired through SILO.

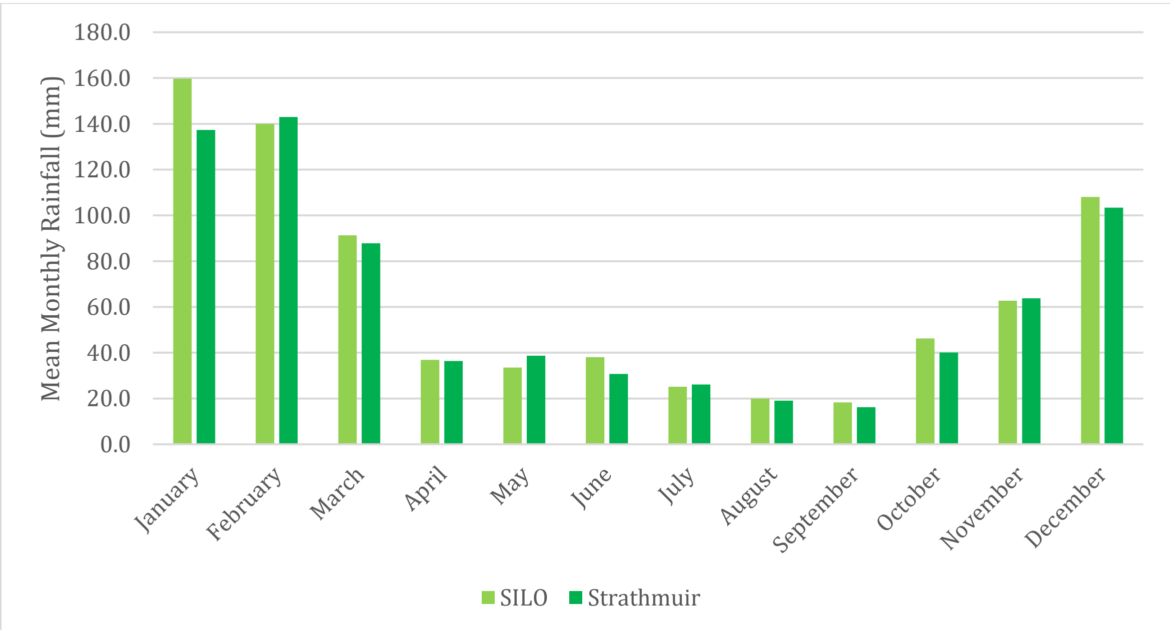


Figure 16-26 Comparison of SILO data to gauge data

16.10.1.2 Hydrology

The Styx River Basin comprises a number of distinct surface water catchments (refer Figure 16-22), including:

- The Middle-Clairview Creeks catchment;
- The Saint Lawrence catchment;
- The Waverley-Amity Creeks catchment;
- The Wellington Creek catchment; and
- The Styx River catchment.

Styx River Catchment

The Project is wholly contained within the Styx River catchment and is bounded by the Styx River's major tributaries, Tooloombah Creek and Deep Creek. Tooloombah and Deep Creeks join around 2 km downstream of the Project area to form the Styx River, and below this confluence other tributaries join Styx River, e.g. Granite Creek. There are no gauged surface water drainages within the Styx River catchment.

The Styx River is tidally influenced downstream of the confluence of Deep and Tooloombah Creeks and discharges to the Broad Sound estuary, which extends from approximately 8 km downstream (north) of the Project, to the coast, approximately 32 km further downstream.

The upper steeper parts of the Tooloombah and Deep Creek sub-catchments are largely uncleared, and water is transported in well defined, often deeply incised, channels. The middle portion of the sub-catchments have largely been cleared for dryland agriculture (grazing and very limited cropping) where topography flattens out. During extreme rainfall events, tributaries and the main channel overflow onto the floodplain. The middle portion of the catchment is prone to surface erosion, with several deeply incised erosional channels present, caused by surface flows during storm events.

The lower part of the Styx River catchment is characterised by coastal and estuarine conditions, where surface water features become tidally influenced. As there is no local gauging of tide heights from which to interpret how far tidal limits extend up into the Styx River catchment the following indicators are used:

- Areas mapped as having high probability of occurrence of ASS (Fitzpatrick et al. 2011):
  - Figure 16-20 shows there is a high probability of ASS extending up along Styx River to within around 7 km of the Project, which probably represents the normal low tide limit (i.e. permanently inundated soils)
- Observations of occurrence of Marine Couch (*Sporobolus virginicus*) along the banks of watercourses:
  - Marine Couch is a widespread ecologically important costal species of the tropics and subtropics that commonly occurs along beaches, estuaries, and in mangrove communities and salt marshes where there is interaction with highly brackish to saline water
  - The extent to which a major assemblage of Marine Couch occurs along Styx River is approximately 4 km downstream of the Project, which probably represents the normal high tide limit (Figure 16-20)

- Some sparse occurrences of Marine Couch are observed further upstream, near the Deep and Tooloombah Creeks confluence (approximately 2.5 km downstream of the Project) at a streambed elevation of approximately 6.5 mAHD, which probably represents the peak tide limit associated with king tides and storm surges (Figure 16-20).

The Styx River discharges to the Great Barrier Reef Marine Park (see Figure 16-27), which is approximately 40 km downstream of the ML area. The Great Barrier Reef Marine Park is listed as a World Heritage Area. The Fitzroy Basin Association Natural Resource Management (NRM) body reports the most significant risk to the entire Great Barrier Reef Marine Park is sediment. It is estimated that approximately 1.95 million tonnes of sediment is deposited each year into the reef from the catchments within the NRM body (Waterhouse et al. 2015). This amounts to 23% of the total sediment load that reaches the Great Barrie Reef (Waterhouse, et al. 2015). This estimation is based on the six Australian Water Resources Council basins within the Fitzroy Region which discharge into the Great Barrier Reef Marine Park: Fitzroy, Styx, Shoalwater, Water Park Creek, Calliope and Boyne (Waterhouse, et al. 2015). The leading land use source of sediment is grazing land which accounts for 85% of the extra sediment entering the Great Barrier Reef Marine Park. It is estimated that the Styx Basin contributes approximately 68.100 t per year of sediment into the reef; however, this load contribution is based on limited monitoring results (Waterhouse et al. 2015).

The Fitzroy Basin Association NRM body manages waters within the Styx Basin. The NRM area covers approximately 156,000 km^2 and is approximately 37% of the total GBR catchment area (423,122 km^2) (Dougall, et al. 2014). The region has been split into 192 Neighbourhood Catchments. The Project is located within the F5 Neighbourhood Catchment which is described as having a high sediment delivery ratio to the Great Barrier Reef, and a low number of landholders within the basin (Waterhouse, et al. 2015).

Cattle grazing is the dominant land use of the area (80%) with most of the catchment undeveloped. Wetlands consist of 14% of the total basin area. There are approximately 187 lacustrine/palustrine wetlands in the Styx drainage basin with the main wetland systems comprised of estuarine (265.8 km^2), palustrine (89.7 km^2) and riverine (52.4 km^2) (EHP 2017a). These wetland areas provide a diverse range of habitats for different wildlife and have been decreasing in size since 2001.

Both Deep Creek and Tooloombah Creek are located outside the ML, but the Project area occurs within their catchments. Several small tributary drainages to Deep Creek and Tooloombah Creek traverse the Project area but these are minor in nature, ranked as either first or second order drainage features and are classified as non-perennial.

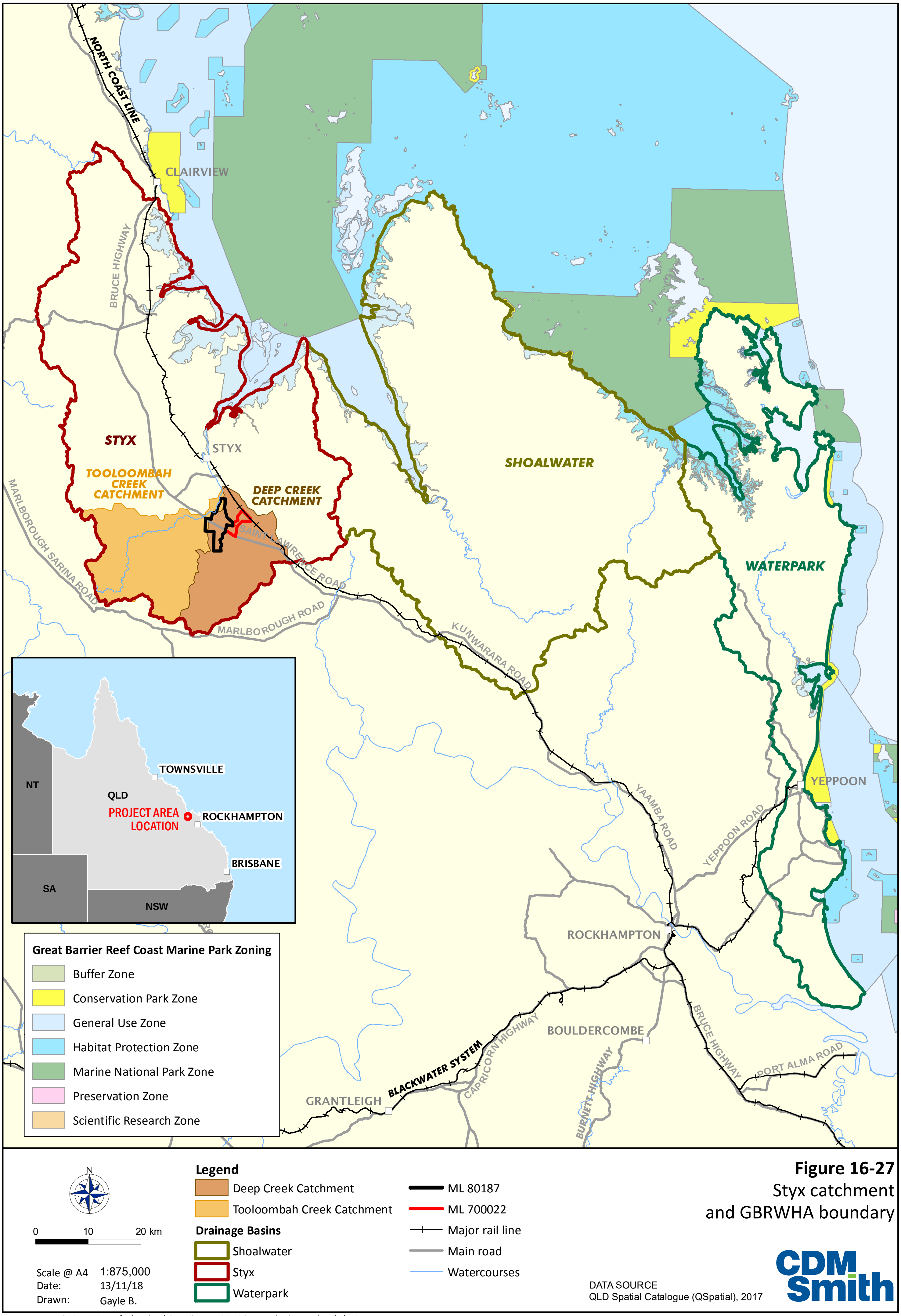


Figure 16-27
Styx catchment and GBRWHA boundary

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\Chapter 9\BES150160.03 R2 drainage and catchment.mxd 11/13/2018

Deep Creek

The tributary headwaters of Deep Creek occur to the south of the Project, at elevations around 90 to 180 mAHD, and the creek runs in a northerly direction along the boundary between ML 80187 and ML 700022 before joining Tooloombah Creek 2 km downstream of the Project. The total catchment area of Deep Creek is 298 km^2. There are no streamflow monitoring data available for Deep Creek; however, the creek is classified as a minor, non-perennial creek (BOM 2011).

The Deep Creek channel is deeply incised (up to around 10 m deep). The channel width is variable, ranging from around 2 m to 3 m wide upstream and 5m to 10 m downstream of the Project. The creek bed is comprised of silts, sands and clays, having a generally smooth channel with little vegetation that would provide resistance to flow.

Pooled surface water in Deep Creek observed during field sampling events in 2011, 2017 and 2018 reported relatively high turbidity, which is possibly the result of the finer streambed substrate being mobilised by turbulent streamflow, as well as possible erosion and stock access. Surface water erosion (sheet and rill) is evident within the southern section of the Project area where the local landowner has improved the land for cattle grazing by installing contour bunds to slow the flow of runoff and increase infiltration across the landscape.

Deep Creek is highly responsive to rainfall, with sharp rises in stream height and turbidity during rainfall events. Anecdotal evidence suggests large seasonal flow events are around 4 m deep and persist for several days only. During high streamflow events, Deep Creek is likely to be a local source of recharge to the near-stream shallow alluvial aquifer, most of which will take the form of bank storage that will drain back to the creek as flow declines (bank storage return). This process, supported by creek gouge to the water table, is expected to sustain isolated pools along the creek bed between flow events. The interaction between surface water and groundwater is discussed further below in this Section and in detail in Section 16.11.

Surface water samples have been periodically collected from monitoring locations along Deep Creek adjacent the eastern boundary of the Project, in 2011, 2012, 2017 and 2018 (refer Figure 16-22). Water salinity data (as electrical conductivity, EC) are presented at Figure 16-28 for 2017 and 2018 sampling events (there is insufficient data to present 2011 and 2012 data), and shows water is generally fresh, ranging from 35.9 to 805 µS/cm EC. A seasonal influence is evident, with a general salinity increase during periods of dry / no flow and following the first flush of salts and nutrients experienced at the beginning of the wet season.

The results of laboratory analysis of water quality for Deep Creek surface water samples are presented, along with seawater and rainfall chemistry from Rockhampton, on a Piper (trilinear) plot on Figure 9-11 of Chapter 9. The major ion composition of water samples collected from surface water monitoring locations in November 2017 and March 2018 are also presented as Stiff patterns in Chapter 9. As expected, the Piper plot and Stiff patterns show Deep Creek water chemistry is more similar to Rockhampton rainfall than it is to seawater. The Stiff patterns also show Deep Creek water quality composition varies between wet and the dry seasons, and is similar to Rockhampton rainfall at the end of the wet season.

Shallow isolated pools have been observed along Deep Creek in localised depressions during most sampling events in 2011, 2012, 2017 and 2018. The presence of these pools is discussed further in this Section and in Section 16.11.1.2.

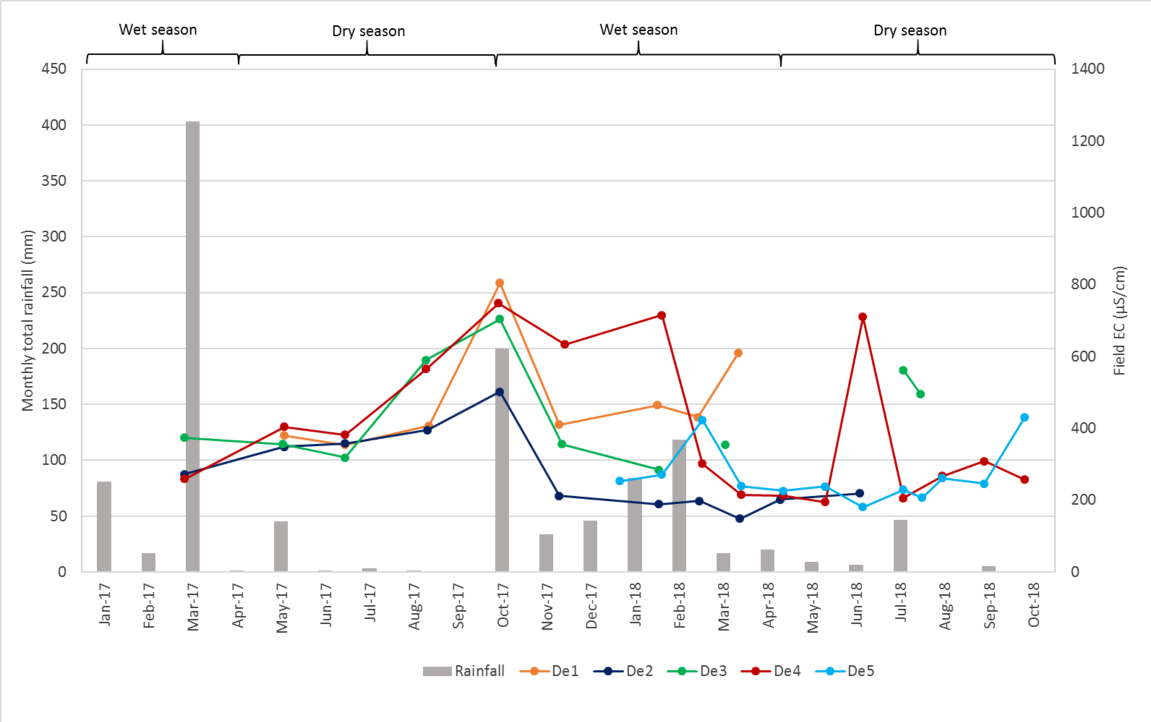


Figure 16-28 Deep Creek field EC - 2017 and 2018

Tooloombah Creek

The tributary headwaters of Tooloombah Creek rise to the southwest of the Project area, where elevations of around 360 m AHD occur. The creek runs in a general north-east direction adjacent to the western Project boundary before joining Deep Creek around 2 km downstream of the Project. The total catchment area of Tooloombah Creek is 369.7 km^2. There are no streamflow data available for Tooloombah Creek; however, like Deep Creek it is classified as a major, non-perennial creek (BoM 2011).

The main channel is significantly deeper than Deep Creek, with steep sided slopes that are fully vegetated and with minimal erosion evident. Upstream of the Project the channel is relatively narrow (4 to 5 m wide) but becomes wider downstream (10 to 15 m wide), with defined gentle meanders down toward the Deep Creek confluence. The Tooloombah Creek streambed is rocky, comprising gravels and boulders, and outcropping sandstone is present within the creek channel near the Bruce Highway bridge (at surface water sample point To1; refer Figure 16-22).

Anecdotally, Tooloombah Creek may have around three flow events in an ‘average year’, with an average water stage height of around 4 m. Flow within the creek has been observed to last for only a day or so, due to the relatively constrained catchment. During extreme rainfall events, such as Cyclone Debbie (late-March 2017), Tooloombah Creek flood heights are observed to rise to around 1 m below the Bruce Highway bridge and, in low lying areas water overflows the banks to cause local flooding. Tooloombah Creek reportedly has a less ‘flashy response’ to rainfall events than Deep Creek.

Water salinity (as EC) data derived from 2017 to 2018 sampling events (refer Figure 16-22) shows salinity is generally higher than Deep Creek, ranging from around 170 to 3,200 µS/cm EC (Figure 16-29). A seasonal influence is evident, with salinity generally increasing during periods of no flow and following the first flush of salts and nutrients experienced at the beginning of the wet season. The higher salinity concentrations of Tooloombah Creek water compared to Deep Creek is possibly due to a greater degree of groundwater – surface water interaction along Tooloombah

Creek than is evident along Deep Creek, or the Tooloombah Creek catchment is generally more saline in nature.

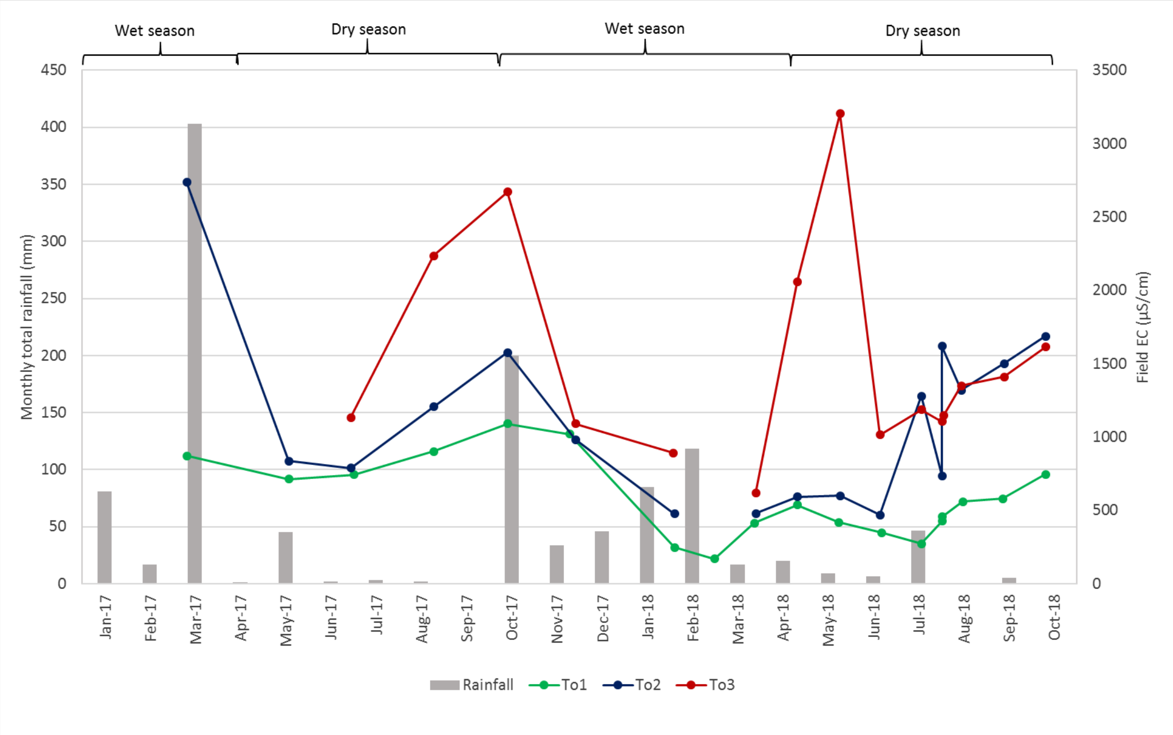


Figure 16-29 Tooloombah Creek field EC – 2017 and 2018

The results of laboratory analysis of water quality for Tooloombah Creek surface water samples are presented, along with seawater and rainfall chemistry from Rockhampton, on a Piper (trilinear) plot on Figure 9-15 in Chapter 9. The major ion composition of surface water samples collected in November 2017 and March 2018 are also presented as Stiff patterns on Figure 9-12 and Figure 9-13 in Chapter 9. The Piper plot and Stiff patterns show that Tooloombah Creek water chemistry is less like Rockhampton rainfall than Deep Creek, with higher concentrations of calcium and chloride. The Piper plot also shows that chloride concentrations increase with distance down the creek (To1 chloride concentrations are generally less than To2 and To3) possibly in response to groundwater discharge and evaporation (refer Section 16.11.1.2 for further discussion). The Stiff patterns also show surface water composition varies between the dry season and the end of wet season likely due to dilution by surface water runoff.

Large pools of water have been observed within the creek during all sampling events in 2011, 2012, 2017 and 2018 when flow events were not occurring. Water held in these pools appears less turbid than Deep Creek pools, due to a combination of catchment hydrology (less erosion and slower flows), possible reduced stock access and increased residence time of pool water enabling sediments to settle. The presence of these pools is discussed further in this Section and in Section 16.11.1.2.

There are two mapped wetlands located in the Project area within the Tooloombah Creek catchment that are specified under the Vegetation Management Act 1999 (Figure 16-22). The more southern ('Wetland 1'), has been mapped as a Wetland Protection Area whilst the more northern of the two wetlands ('Wetland 2'), has been mapped under DNRME vegetation mapping. A detailed description of the wetlands is provided in Section 16.10.1.4.

Deep Creek appears to have a possibly flashier response to rainfall runoff than does Tooloombah Creek. Water quality data also suggests Deep Creek possibly interacts less with groundwater than

Tooloombah Creek, which shows a divergence away from a rainfall signature at the end of the dry season toward perhaps a groundwater signature.

Tidally Influenced Portion of the Styx River Catchment

The tidally influenced sub-catchments of the Styx River catchment, i.e. below the confluence of Tooloombah and Deep Creeks, are dynamic hydrological environments where terrestrial waters mix with estuarine waters providing brackish to saline conditions that are markedly different from the higher sub-catchments. At the confluence of Deep and Tooloombah Creeks the Styx River channel is approximately 10 m to 12 m wide and downstream, near Ogmore Bridge, the channel narrows to approximately 6 m to 7 m before broadening as it opens into the Broad Sound estuary more than 4 km further downstream.

Water samples have been collected periodically from two monitoring locations along Styx River in 2011, 2012, 2017 and 2018 (refer locations on Figure 16-22). As Styx River is tidally influenced, river water salinity varies from fresh (125 µS/cm) to saline (more than 35,000 µS/cm) depending on timing and location of the sampling. Water quality results are presented on a Piper plot (Figure 9-16 in Chapter 9), which shows Styx River water chemistry ranges from predominantly having some similarity with Rockhampton rainfall chemistry to having some similarity to seawater chemistry. This variation in chemical signature is likely due to tidal and seasonal (upper tributary runoff) influences.

Water quality results for St1 and St2 in July 2018 (representative of dry season) presented with Rockhampton rainfall and seawater chemistry (refer Stiff pattern in Figure 9-17 in Chapter 9). The Stiff pattern shows, at the time of sampling, that St2 reported a seawater signature, although less saline than seawater. In comparison, the water quality signature for St1 waters were more similar to Rockhampton rainfall chemistry than seawater.

Groundwater – Surface Water Interactions

Analysis of available hydraulic head, topographical and hydrochemical data shows the main sources of water present in Styx River are derived from tidal (estuarine) waters or surface water runoff. Groundwater baseflow to Styx River, whilst likely occurring, is not significant compared to these other sources. Groundwater interaction with Tooloombah creek is likely more sustained over the dry season than is the case along Deep Creek. Ecological reliance on groundwater (either as baseflow or as a shallow water table) is likely at the northern extent of Tooloombah Creek subject to Project studies (i.e. south of the Bruce Highway crossing) and possible toward the northern extent of the Deep Creek catchment subject to Project studies.

A conceptual understanding of surface water – groundwater interactions in the Styx River catchment has been developed and is presented in detail in Section 16.11.1.2.

16.10.1.3 Existing Waterways and Local Catchments

The Styx River Catchment covers approximately 302,000 ha, and the main tributaries include: Deep, Granite, Montrose, Stoodleigh, Tooloombah, Waverly and Wellington Creeks. The mine area and TLF is situated within the lower catchments of Tooloombah Creek and Deep Creek. Both creeks feed directly into the Styx River (2 km north of the Project area) which discharges into the Broad Sound area approximately 33 km northeast of the Project. The haul road to the TLF crosses Deep Creek and Barrack Creek (Figure 16-30).

Both Tooloombah Creek and Deep Creek are located outside the mine area boundary; however, several associated tributary or drainage features reside within the Project area. These drainage features are minor in nature, are ranked as either first or second order drainage features and are classified as non-perennial.

Surface water features within the Project area include (refer to Figure 16-30):

- Minor un-named drainage lines feeding into Tooloombah Creek:
  - Two 1st order drainage lines
  - One 2nd order drainage line
- Minor un-named drainage lines feeding into Deep Creek:
  - Nine 1st order drainage lines
  - One 2nd order drainage line.

The haul road associated with the TLF crosses:

- Deep Creek as a 4th order drainage line in this area;
- Barrack Creek as a 4th order drainage line; and
- Two un-named tributaries of Barrack Creek as a 3rd order drainage line and a single 1st order drainage line.

The TLF and associated infrastructure intersect two further 1st order drainage line and a single 2nd order drainage line.

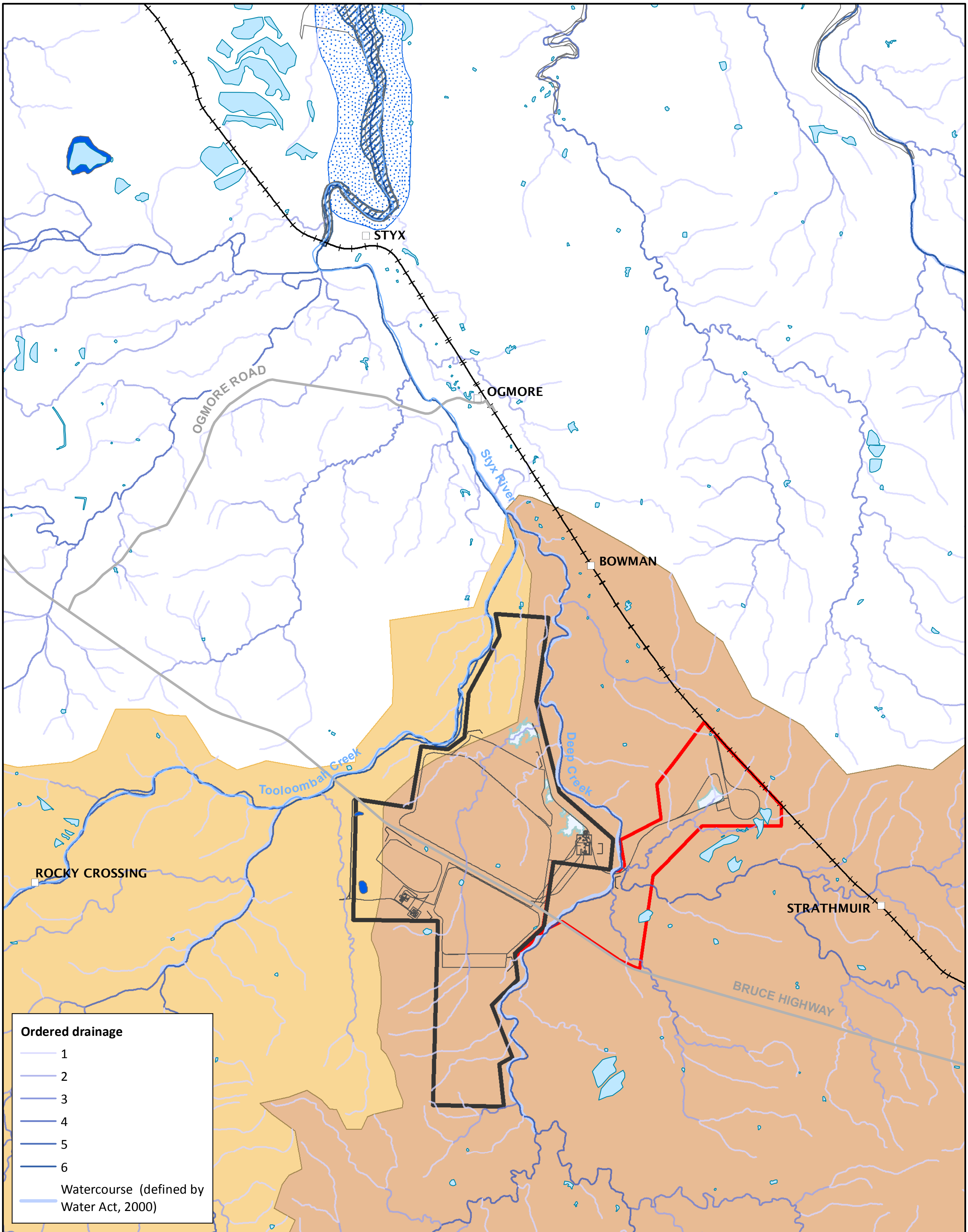
Section 9.4.5 characterises the waterways within the catchment and present observations from site assessments undertaken during the February 2017 wet season. Section 9.5.2 provides further description of their chemical characteristics utilising historical data collected in 2011-2012 and more recently baseline data collected between 2017-2018.

Deep Creek – February 2017 Assessment

Deep Creek borders the Project area to the east, outside of the ML, and will be traversed by the proposed haul road that connects the MIA2 with the TLF. The creek runs in a northerly direction, meeting Tooloombah Creek 2 km downstream of the Project area and forming the Styx River thereafter. Deep Creek was observed in February 2017 with shallow pools less than 1 m in depth along the southern boundary of the Project area (see Plate 16-1).

Most locations inspected during February 2017 were dry with some pools identified at localised depressions. The channel was identified as having some grass growing along the channel floor in places, and with trees and short grasses established along the banks (see Plate 16-2).

The channel bed comprised of silty sand / gravelly substrate, with the channel generally described as smooth with little vegetation which would provide resistance to flow. Several trees were observed to have fallen across the channel, creating an obstruction to flow and causing visible erosion on the banks. The water was highly turbid, indicative of the presence of fines (clays and silts) that are not readily settled by gravity.



Legend

- ML 80187
- ML 700022
- Mine infrastructure
- North Coast Rail Line
- Main Road
- Reservoir
- Directory of important wetland
- Great Barrier Reef Coast Marine Park Zoning
- Wetland (VM Act)

Drainage Catchment

- Deep Creek
- Toolmoobah Creek

N

0 1 2 km

Scale @ A4 1:100,000
Date: 14/11/18
Drawn: Gayle B.

Figure 16-30
Local watercourses, drainage features, wetlands, dams and catchments

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 16_Supp_Report_MNES\1000111 Local watercourses_drainage features_wetlands_dams_catchments__16-19.mxd 11/14/2018

Plate 16-1: Deep Creek Deep beneath Bruce Highway (downstream towards Site De2) showing turbid pooled water (Feb 2017)

Plate 16-2: Deep Creek beneath Bruce Highway (upstream from Site De2) showing a dry, silty sand substrate (Feb 2017)

Tooloombah Creek – February 2017 Assessment

Tooloombah Creek borders the Project area to the west, outside of the ML. Tooloombah Creek was observed in February 2017 with depths of water accumulated within the creek banks greater than 0.5 m. The creek at the highway crossing was identified as having boulders, protruding rock bars and a rocky substrate that was clearly visible under the water. Significant and dense vegetation had established on the banks (see Plate 16-3 and Plate 16-4), creating a stable bank that appeared resistant to scour. Downstream sites featured a more gravelly / cobbled substrate. The rocky substrate produces less silt and therefore lower turbidity than observed in Deep Creek (see Section 16.10.2 for details).

Plate 16-3: Tooloombah Creek upstream of Bruce Highway bridge (Site To1) western boundary (Feb 2017)

Plate 16-4: Tooloombah Creek downstream of Bruce Highway bridge (Site To1) western boundary (May 2017)

Styx River – February 2017 Assessment

Styx River, downstream of the confluence of Deep Creek and Tooloombah Creek, was observed during February 2017 with significant depth of water accumulated within the river banks. The river is tidally influenced, with the water surface level rising significantly on two occasions over the day at Site St2 (refer Figure 16-22). The tidal influence extends upstream towards the confluence of Deep and Tooloombah Creeks with irregular tidal inundation recorded at Site St2. The Styx River at this point supports well established vegetation on the river banks, making the banks stable and resistant to scour (Plate 16-5). The water is visibly saline as evidenced by the clearer green tint colour when compared to the turbid brown colour of waters observed in Deep Creek. This is further supported by electrical conductivity values of 13,103 µs/cm observed in the Styx River (see Section 16.10.2 for details).

Plate 16-5: Styx River, downstream confluence between Deep Creek and Tooloombah Creek (Site St1) (Feb 2017)

Minor Drainage Features

Three un-named surface water features drain the Project area into Deep Creek, along the eastern boundary of the MLA. The most distinct drainage feature is the 2nd order stream that runs through Open Cut 1 in a northeast direction passing under the Bruce Highway and finally discharging to Deep Creek to the northwest of MIA 2. This drainage feature is impounded by two existing farm dams, one of which is located within the proposed Open Cut 1 pit shell. The upper catchment of this 2nd order stream will be diverted towards Deep Creek as a clean water diversion around the proposed mine pits. The middle portions the drainage feature will be mined out as the pits progress.

There are three unnamed surface water features that drain the western section of the Project area into Tooloombah Creek. These features are not clearly defined and are classified as 1st order drainage features.

16.10.1.4 Wetlands and Farm Dams

Wetlands may be defined as: 'Areas of permanent or periodic / intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m' (DERM 2011; DES 2015). In accordance with this definition, three types of wetland systems occur within the Project area and surrounding catchments:

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

There are two wetlands recorded as having high ecological significance, one of which (Ref 688644) (Wetland 2) is located on the western boundary of the ML. The other wetland (Ref 688938) (Wetland 1) is located to the south west of Open Pit 1 (refer Figure 16-30). Detailed descriptions of these wetlands are provided below. Several lakes and rural water storage dams on either side of the Bruce Highway alignment are mapped as artificial wetlands by DES. Wetlands and dams within and surrounding the Project area are listed in Table 16-32.

Table 16-32 Wetlands and dams within and surrounding the Project area

Wetland type	Ref. number	Lot / plan	Description	Area (ha)
Palustrine	696686	10/MC493	Within Project area (Open Cut 1) - Rural Water Storage	0.41
Palustrine	-	10/MC493	Within Project area (Open Cut 1) - Rural Water Storage	0.78
Palustrine	-	9/MC496	Within Project area (Open Cut 2) - Rural Water Storage	0.40
Palustrine	696684	9/MC496	Within Project area – Lake	0.34
Palustrine	-	11/MC23	Within Project area – Rural Water Supply	1.53
Perennial	-	10/MC493	Within Project area – Lake	0.42
Palustrine	688938	10/MC493	Within Project area – Wetland (high ecological significance)	2.98
Palustrine	688644	10/MC493	Within Project area – Wetland (high ecological significance)	0.98
Palustrine	696683	11/MC23	Contour bunds to the south of the Project area	4.95
Palustrine	693160	11/MC23	Contour bunds to the south of the Project area	7.69

Wetland 1

The wetland is roughly circular, encompasses approximately 4 ha and is mapped as a wetland protection area (WPA), as shown on the Queensland map of referrable wetlands of the GBR catchment. The wetland is largely surrounded by eucalypt woodland on sandy soils with a small area of woodland on clay spoils adjacent on the eastern edge. The wetland is characterised by a central stand (covering approximately 2 ha) of Broad-leaved Paperbark (with occasional Forest Red Gum also present) surrounded by a vegetated open area with ground cover only. The wetland was inspected during the February 2017 survey and was completely dry at the time. Following heavy rains in May 2017 the wetland had filled up with limited open water around the edge (Plate 16-6). Cattle were present using the wetland area on all occasions the wetland was inspected. Feral Pigs were also observed using the area.

This wetland is mapped as a GDE in the Bureau of Meteorology's GDE Atlas (BoM 2017) and is classified as a Coastal/ Sub-Coastal non-floodplain tree swamp (Melaleuca and eucalypt) with high potential for reliance on surface expression of groundwater. Targeted GDE sampling works (refer Section 16.12.6.1 for methods) indicate a complicated localised groundwater system. The water table near this location has been measured to be 10.2 mbgl (August 2018) with another zone of moisture at approximately 8 mbgl which appears separated from the water table by calcrete bands and layers of sandstone and clay. The trees and in the centre of the wetland are for the most part accessing the upper zone of moisture which is likely fed seasonally when the wetland is recharged by rains. However, isotopic signatures of deeper soil cores suggest there may also be some influence of groundwater. There is some potential the trees may access deeper soil water that is maintained by groundwater to support transpiration requirements during sustained dry periods when the upper soil water reservoir is otherwise depleted (refer Section 16.11.2.1 for detailed discussion).

A wetland vegetation assessment was carried out in relatively dry conditions in January 2018. The wetland soil was generally damp with some areas of shallow water (10 cm depth) in the centre and north of the wetland. No open water was present (Plate 16-7). The edge of the wetland was dominated by a continuous cover dominated by *Eleocharis pallens*. The centre of the wetland was wetter and dominated to a lesser extent by *Eleocharis sphacelata* with a variety of other species occurring throughout including Swamp Rice Grass (*Leersia hexandra*), Bunchy Sedge (*Cyperus polystachos*), Olive Hymenachne (*Hymenachne amplexicaulis*) and Mexican Primrose-willow (*Ludwigia octovalvis*). Other species present as scattered occurrences include a variety of sedges (*Cyperus cyperoides*, *C. haspan* and *Fimbristylis sieberiana*), Floating Primrose-willow (*Ludwigia peploides*), Common Nardoo (*Marsilea drummondii*) and Budda Pea (*Aeschynomene indica*). Canopy cover in the centre of the wetland was patchy, with a relatively sparse distribution of Broad-leaved Paperbark (generally less than 30% canopy cover where it occurs).

This area is described under the wetland mapping as Regional Ecosystem (RE) 11.5.17 (*Eucalyptus tereticornis* woodland in depressions). There is a single Forest Red Gum present in the wetland but none in the surrounds. It is unlikely soils associated with this community occur. The wetland is located in a natural depression, on a gentle slope and does not occur within a flood / drainage line. Given the surrounding vegetation, landscape position and soil type the wetland has been described as RE 11.3.12, although this remains open to question.

Plate 16-6: WPA in wet conditions (May 2017)

Plate 16-7: WPA during vegetation assessment (January 2018)

Wetland 2

The second mapped wetland (Plate 16-8) encompasses approximately 0.6 ha being 180 m in length and 40 m wide at its widest point. The wetland is surrounded by intact woodland and is likely to be used by cattle. The wetland has been inspected on several occasions with water levels appearing to be relatively constant, thereby indicating the wetland may be permanent.

This wetland is mapped as a GDE in the Bureau of Meteorology's GDE Atlas (BoM, 2017) and is classified as a Coastal/ Sub-coastal floodplain grass, sedge and herb swamp with high potential for reliance on surface expression of groundwater. The water table near this location has been measured to be around 20 mbgl. Targeted GDE sampling (in August 2018) did not find groundwater down to 15 mbgl and indicated surrounding trees were water-stressed. The wetland is considered a surficial feature with no hydraulic link to either shallow perched or regional groundwater aquifers (refer Section 16.11.2.1 for detailed discussion).

Water depth in the centre of the wetland could not be measured but is likely to be in excess of 1 m based on the water depth encountered around the vegetated edges during the vegetation assessment. The wetland is characterised by a dense fringing area of erect aquatic plant species. The centre of the wetland is for the most part covered by floating vegetation (Plate 16-9).

In-situ water quality analyses recorded low turbidity (6.4 ntu) and electrical conductivity (56 µs/cm), with a neutral pH (7.03) present. Laboratory analyses recorded the following:

- Low suspended solids (56 mg/L);
- Similar to surface water samples taken in Deep Creek and Tooloombah Creek total nitrogen (0.9 mg/L) and total phosphorus (0.08 mg/L) were both above the water quality objectives for lowland fresh waters in the Styx River Basin (refer SoQ 2014); and
- Similarly, low levels of metals also recorded elsewhere from surface water sites in the catchment (manganese, barium, aluminium and zinc) excepting iron which was recorded in comparatively high concentrations (0.76 mg/L).

The edges of the wetland feature a dense cover with several species dominating including Giant Sedge (*Cyperus exaltatus*), *Eleocharis sphacelata*, *Digitaria divaricatissima*, and Olive Hymenachne. Open water comprises the remainder of the wetland with floating aquatic vegetation present dominated by a relatively constant cover of Blue Lotus (*Nymphaea caerulea*), with Swamp Lily, and Water Snowflake also present to a lesser extent. Other plant species recorded included Floating Primrose-willow, Common Nardoo, Swamp Rice Grass and Red Water Fern (*Azolla pinnata*).

This area is described under the wetland mapping as RE 11.3.27b (lacustrine wetland). The wetland is fringed by sparse Forest Red Gum and is located on a floodplain and appears connected to an indistinct floodplain drainage line feeding into Tooloombah Creek. The wetland mapping is considered to be correct.

Plate 16-8: View across wetland 2 (January 2018)

Plate 16-9: Floating vegetation in centre of wetland

There are four existing farm dams of varying size within the Project area (see Figure 16-30), all dams are located adjacent to the Bruce Highway. These dams are predominantly used for stock water. There is also catchment contouring within the Mamelon property to the south of the Bruce Highway for capturing and storing overland runoff and preventing erosion. Existing contour bunds will be upgraded to environmental dams that capture runoff from overburden stockpiles and remove sediment prior to discharge to Deep Creek.

16.10.1.5 Existing Water Users

The Ogmore Water Supply System provides non-potable water to the Ogmore township, sourced from Montrose Creek and located northwest of the Project. Water is stored in four reservoirs with a total capacity of 88,000 litres. The creek water is typical of an unprotected surface water catchment and is not suitable for potable uses unless treated.

Surrounding properties source water from Tooloombah and Deep Creek through licenced extractions, as well as from bores and farm dams that capture and store surface runoff.

The Project is predominately situated within the Mamelon cattle grazing property, which runs cattle and produces dryland crops. The Mamelon property is owned by the Proponent and is currently being leased for these uses. Supporting this land use is a series of farm dams and surface contour bunds that capture, and store runoff generated by the local contributing catchments. Groundwater bores also lift water to dams and / or storage tanks in the surrounding region for domestic and stock water use (see Section 16.11.1.2 for a reference to registered and unregistered bores).

There are several surface water entitlements in Tooloombah and Deep Creek for irrigation, stock and domestic supply. The entitlements that may be impacted by the Project by being located adjacent to or downstream of operations include the following:

- 119/CP900367 - Irrigation entitlement (extraction from Deep Creek – 20 ha) located on parcel of land adjacent to the northeast boundary of Mamelon property, separated by Deep Creek, and approximately 1 km downstream of the mine water dam release point located offstream of (but draining into) Deep Creek;
- 1/RP616700 - Domestic / stock supply entitlement (extraction from Tooloombah Creek – 18 ML) located on a parcel of land adjacent to the western boundary of Mamelon property, and straddling the Bruce Highway and Tooloombah Creek. The extraction point appears to supply a small off-stream storage on the western overbank of Tooloombah Creek, on the Bar-H property; and

- 45/MPH26062 - Irrigation entitlement (extraction from Tooloombah Creek – 8 ha) on parcel of land directly bordering the Project to the north and extracting from Tooloombah Creek approximately 3 km downstream of an environmental dam release point.

Although the EIS previously reported water permits will be sought to take water from Tooloombah Creek during construction, this will not be necessary. Since the release of the EIS, further water demand assessment has been undertaken. This assessment has confirmed that there will be adequate water availability through existing farm dam water supplies until the Raw Water Dam becomes operational. Should make-up water be required during construction, this will be trucked to site.

The operational water requirement will be supplied from catchment of on-lease stormwater runoff, mine affected water from pit dewatering activities and water reuse within the CHPP. Consequently, Central Queensland Coal does not anticipate a requirement to obtain water permits to harvest water from Tooloombah Creek.

To retain surface water flows in both Tooloombah and Deep Creeks, diversion banks have been proposed on the western side of the Bruce Highway. The purpose of the diversions is to prevent overland flows from entering the operational mine area by redirecting overland flows that currently report to culverts underneath the Bruce Highway into both creeks. Furthermore, Dam 5 is no longer proposed, and this too will allow overland flows to report to Tooloombah Creek rather than being contained onsite and used for mining purposes. The flooding and stormwater drainage assessment is discussed in detail in Section 16.10.3 and Chapter 9 – Surface Water. Given the above, it is not anticipated that the Project will result in a negative impact to existing water permit holders. Notwithstanding, the Project has made clear public commitments to landholders at two community information sessions that any reduction in water resource availability or quality because of the Project will be addressed by means of make good agreements that will be established with affected landholders.

16.10.2 Surface Water Quality Assessment

16.10.2.1 Environmental Values and Water Quality Objectives

Water Quality Objectives (WQOs) are long-term goals for water quality management. They are numerical concentration levels or narrative statements of indicators established for receiving waters to support and protect the designated Environmental Values (EVs) for those waters. They are generally based on scientific criteria or water quality guidelines but may be modified by other inputs (e.g. social, cultural or, economic inputs).

EVs for water are the qualities of water that support a level of aquatic ecosystem function and / or human water uses. These EVs can be impacted by the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use.

To protect the waterways and associated EVs, WQOs are established for different indicators such as pH, nutrients and toxicants. The EPP (Water) provides provisions to protect and enhance the suitability of Queensland’s waters for various beneficial uses and has established EVs and WQOs for a number of Basins including the Styx Basin. The EVs considered applicable to the Project are outlined in Table 16-33. Water quality objectives associated with the Project for the protection of aquatic ecosystem EVs are summarised in Table 9-7 and Table 9-8 in Chapter 9.

Water quality objectives associated with the ANZECC / ARMCANZ 2000 Guidelines are currently in the process of review. These include the following toxicants in freshwaters; ammonia, boron, chromium III, copper, nitrate and zinc[2]. All revised values where relevant to the Project will be incorporated into Project specific water quality objectives following official release and publication of the accepted revised values.

Table 16-33 Environmental Values for Styx River Basin and adjacent coastal waters

Water	Aquatic ecosystems	Irrigation	Farm supply/use	Stock water	Aquaculture	Human Consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values
Surface Fresh Waters												
Southern Styx fresh waters (including Granite, Tooloombah and Wellington creeks)	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	X	✓

16.10.2.2 Field Assessment – Historical

Water quality sampling was undertaken for the Project in 2011 and 2012. During this time, eight sampling events were undertaken. The sampling locations within the current and historical sampling scopes are presented in Figure 16-22. The relevant scope of each of the sampling locations is shown in Table 16-34. Description of the water quality sampling methods is provided in Section 9.5.2 of Chapter 9. The results from these sampling events are presented in Appendix A5b and Table 9-15 to Table 9-23 in Chapter 9 and are discussed in the following sections.

Table 16-34 Current and historical sampling sites

Site ID	Current Sampling Scope	Historical Sampling Scope
To1	✓	✓
To2	✓	✓
To3	✓	✗
St1	✓	✓
St2	✗	✓
Ba1	✗	✓
Ba1x	✓	✗
De1	✓	✓
De2	✓	✓
De3	✓	✓
De4	✓	✗
De5	✓	✗

[2] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/draft-dgvs#proposed-default-guidelines-values

Monitoring Results

Stream Conditions

The stream/waterway conditions during each sampling event is presented in Table 16-35. Based on the timing of rainfall prior to sampling, and observations during sampling, the sample events represent a range of events from no-flow or baseflow periods to storm flow events. The February and March events present flows likely to largely represent storm flows more than baseflow events. However, it is considered unlikely that any of the sampling rounds coincided with the peak storm discharge.

Table 16-35 Waterway conditions and sites sampled per round

Sample Round	Dates	Rainfall in previous		Deep Creek	Tooloombah Creek	Styx River[1]
		week	month			
1	1-5/6/11	0	18	Baseflow	Baseflow	45 mins after high
2	27-29/9/11	0	7.4	No flow	Baseflow	30 mins after low, outgoing
3	25-26/10/11	0	43	No flow	Baseflow	1 hr before low, outgoing
4	21-22/11/11	0	0.2	No flow	Baseflow	Low, nil
5	13-14/12/11	46	79	No flow	Baseflow	2 hr after high, nil
6	31/1/12	55	137	Storm/base flow	Storm/base flow	1 hr before high, outgoing
7	21-22/2/12	78	211	Storm flow	Storm flow	Mid tide, coming in, outgoing
8	20/3/12	139	298	Storm flow	Storm flow	1.5 hr after low, outgoing

1. Tides taken from Hay Point tidal predictions, using McEwan Inlet, 24 mins after Hay Point (approximately 25 km north of Styx bridge). Flow (outgoing, incoming, nil) based on observations at the St1 site at the time of sampling.

Tooloombah Creek

The two Tooloombah Creek sites were quite similar, more so than was found between the Deep Creek sites. The lack of similarity in water quality characteristics at the Deep Creek sites is likely due to the no flow periods and isolated pools that formed whereas the Tooloombah Creek was flowing for the entire period, albeit slowly during low flow periods. The Tooloombah Creek sites did; however, report differences in dissolved oxygen, with a large increase at the To2 site during the lower flow October round which was not matched at To1. Broadly, the pattern of flow responses to rainfall and prolonged lack of rainfall were similar between the creeks, though Tooloombah Creek displayed a less 'flashy' response than the smaller Deep Creek sites.

Tooloombah Creek recorded the highest salinity (a measure of conductivity and total dissolved solids) of the three freshwater lowland streams prior to December (excluding the peak in TDS seen in Deep Creek in December 2011), which decreased to a lower salinity from January to March 2012. Tooloombah Creek represents the largest of the three freshwater catchments included in the monitoring program, with cleared and eroded lands comparable to the Deep Creek catchment. The elevated salinity is associated with the drier periods and is likely due to the increased proportional influence of groundwater on creek surface flows during baseflow periods. High salinity is found in groundwater in the region. During rain events and due to the larger catchment size, salinity levels were reduced in Tooloombah Creek compared to Deep Creek due likely to greater levels of runoff.

Generally, Tooloombah Creek displayed the following characteristics:

- Dissolved oxygen showed two patterns for the two sites, with a peak at To2 in the October – November low flow period (not seen at To1), and a peak at To1 in January (site To2 was inaccessible and may have been similar). Otherwise dissolved oxygen remained generally within the 70 – 100% saturation range;
- Conductivity, pH and chloride rose gradually to December 2011, followed by a large fall in January, continuing to gradually decrease until March. pH varied from a high of 8.4 to a low of 5.9, conductivity 1,407 to 193.7 µS/cm, and chloride from 366 to 21 mg/L;
- Total dissolved solids, alkalinity, magnesium, sodium, anions and cations showed a gradual decrease to December 2011, and afterwards a similar pattern as seen for conductivity, pH and chloride because of the rains. Potassium did not show any pattern, varying only over a relatively narrow range (2 – 4 mg/L); and
- Nutrients were relatively low or falling prior to the December rainfall event, with rises noted in Ammonia, TKN, TP, and FRP, and Nitrite at To2, during the December to January wet period.

Again, the disturbed areas and grazing activities are reflected in the elevated nutrient levels found in this creek.

Styx River

The two Styx River monitoring sites (St1 and St2) were divided by water quality into the Ogmore Bridge site (St2) and the St1 site located at the confluence of Tooloombah and Deep Creeks. The St1 site was more heavily influenced by runoff from the two creeks, whereas the St2 site showed a larger influence from saline waters (i.e. the estuarine influence).

Water quality at the St1 site showed the interplay between the freshwater runoff from Deep and Tooloombah Creeks, and the influence from the Styx Estuary (i.e. St2). Conductivity was generally seen to increase over the dry period, to a much greater extent than was seen in either Deep or Tooloombah Creeks, while for the other parameters the results were generally a mix of the three sources (i.e. Deep, Tooloombah and Styx Estuary).

When examining the key physical-chemical parameters for the Deep and Tooloombah Creeks with St1 (pH, conductivity, anions and cations), the St1 site was found to be more like Tooloombah Creek than to Deep Creek generally (visually from the data), and more similar to the freshwater creeks overall, which is consistent with the relative sizes of the two catchments (and therefore flows). A multivariate similarity assessment showed similarity of about 71%, compared to the St2 site (with a similarity to all other sites of only 44%).

Generally, the St1 site displayed similar levels and overall patterns to the upstream creeks, with some slight delays in temporal trends evident and reduced flood peak concentrations (from examination of the Fitzroy Basin Association storm flow monitoring). This may be due in part to mixing and influence with the salt wedge from the estuary, evident in the higher salinity levels at this site (especially at depth during low flow periods). A high peak in bioavailable phosphorous (FRP) was seen in December, though this was not observed in the Deep or Tooloombah Creek sites (located further upstream).

For phys-chem properties:

- Dissolved oxygen varied from around 70 to 95% prior to October, rising to very high levels during October to December, dropping again during the post December rain period;
- Conductivity, TDS and alkalinity reflected the overall influence of the estuary during the low-flow period, with a gradual rise (especially at depth for conductivity) to December, followed by a rapid fall with levels matching the upstream creeks during the January to March 2012 period;
- pH remained relatively stable, possibly indicative of the stronger buffering capacity of the more saline waters; and
- Turbidity and suspended solids show the flashy behaviour of the river at this point, strongly influenced by rainfall runoff from the Deep and Tooloombah Creeks.

The St2 site was very similar to the St1 site, except that the saline influence was much more pronounced during the low flow period. In flood / stormflow periods, water quality was very similar between the two sites.

Observations were made of flow direction and tide levels during the monitoring period. On all occasions other than one (September 2011), flow direction was seawards (i.e. outgoing), and the tidal bore was not observed, even though the site was visited on several occasions when the regional tide was predicted to be incoming. Based on the flow observed from the Deep and Tooloombah Creeks on many of the occasions during the low flow period, it is quite possible that outgoing flows prior to December 2011 were the result of tide return, and that in fact incoming tides were missed by the sampling team.

Comparison of Results with Guidelines

Compliance with the guideline levels are summarised in Table 9-11 to Table 9-14 in Chapter 9.

Protection of aquatic ecosystems

Other than conductivity, which exceeded the guideline values in all freshwater streams, median statistics for phys-chem parameters largely met the QWQGs. The exceptions were dissolved oxygen in Deep Creek and suspended solids in Deep and Tooloombah Creeks, and the Styx River.

All waterways showed exceedances for ammonia at virtually all times (dry or flood), with organic nitrogen and total nitrogen almost always above the guidelines at Deep and Tooloombah Creeks, total phosphorous at Deep Creek and the St2 Styx River site, and oxidized nitrogen at the St2 Styx River site.

During rainfall periods, exceedances were also encountered for organic nitrogen, total nitrogen, total phosphorous and bioavailable phosphorous (FRP) at all sites. The St2 Styx River site also recorded exceedances for NOx during rainfall.

The toxicants data show many exceedances across the sites, with the most common being for iron (though based on a low reliability trigger value), aluminium, copper, selenium (except at St1) and zinc (except at Tooloombah). Antimony and vanadium exceeded the guideline value at Deep and Tooloombah Creeks.

Other exceedances were recorded for lead (Deep), chromium (Deep, Tooloombah, Styx at St1), silver (Deep, Tooloombah) tin (Tooloombah) and uranium (Tooloombah – one occurrence only).

The water quality confirms the disturbed nature of the catchment due to catchment disturbance and nutrient inputs, which are consistent with impacts from land clearing, erosion and cattle grazing and the nature of the soils.

Livestock and irrigation

Comparison with the ANZECC water quality guidelines for irrigation indicate that all freshwaters (i.e. all sites other than St2) were suitable for livestock and irrigation with the following exceptions:

- Chloride levels – water in Tooloombah Creek recorded chloride levels unsuitable for sensitive crops, and the Styx River St1 site was unsuitable for sensitive or moderately sensitive crops, all generally at times other than the recorded flood periods. This also means that there may be a risk of cadmium toxicity from using this irrigation water (particularly at St1);
- Sodium levels –the Styx River sites recorded sodium at levels unsuitable for sensitive or moderately sensitive crops with the St2 site suitable at best for tolerant crops;
- Aluminum and iron recorded levels above the recommended Long Term Value (LTV) in irrigation water (from Table 4.2.10 of the ANZECC Guidelines) during wet periods;
- Manganese was variously above the LTV; and
- Phosphorous was above the LTV, though this was noted as intended to minimise bioclogging of irrigation equipment only.

The ANZECC Guidelines for livestock watering indicated TDS levels encountered in the streams were generally in the range regarded as having 'no adverse effects on animals expected'. Of the toxicants aluminum was above the recommended low risk range during wet periods.

Drinking water

When compared to Table 7.3.1 - *Guidelines for drinking water supply in the vicinity of storage off-takes or in groundwater supplies*, before treatment in the QWQG, the recommended water quality objectives were exceeded for manganese and iron, and during rainfall events turbidity and, to a lesser degree, suspended solids. Dissolved oxygen was below the target in Deep Creek but generally above in the other creeks (including the Styx River St1 site).

Based on the Australian Drinking Water Guidelines 2011 (NHMRC and NRMMC, 2011), salinity (as total dissolved solids) can be regarded as of good quality in Deep Creek (except during December flows), fair quality in Tooloombah Creek, and poor to unacceptable at the St1 site (and unacceptable at the St2 site).

Several of the toxic metals did breach the ADWG's and would require removal prior to use in potable water supplies. The key elements included iron and manganese (as mentioned above) and aluminum for aesthetic reasons; and antimony and / or arsenic at the other Creek sites, plus lead at Deep Creek. Exceedances were found during the December to March (wet) period only, except for antimony at Tooloombah Creek in November 2011 (10 µg/L).

16.10.2.3 Field Assessment – February 2017 to October 2018

Surface water assessments were conducted at 11 sites between February 2017 and October 2018 (refer Table 16-34). Site characteristics such as flow conditions, bank stability and water depth were recorded at each site. Survey site selection was based on proximity to the Project and the presence of water. Site selection was also guided by the *Monitoring and Sampling Manual 2009 Environmental Protection (Water) Policy 2009* (EHP 2009a).

Sampling Weather Conditions

The nearest operating rainfall gauge is at Strathmuir (BoM station 033189). The mean rainfall for the months of January and February are 137.3 mm and 143.3 mm, respectively. This station recorded a dry February 2018 except for 3 mm that was recorded on the 13th of that month. January 2018 recorded a total of 62 mm. Two sampling locations were dry at the time of the February 2018 sampling, which is similar to the dry conditions observed during February 2017.

A total of 510 mm of rainfall was recorded at the Strathmuir station in March 2017 and in March 2018 a total of 41.6 mm was recorded. On 30 March 2017, a total of 245 mm was recorded on a single day. This rainfall event was associated with Cyclone Debbie, which formed as a low pressure system over the Coral Sea on 22 March 2017. Rainfall from this cyclone and from March 2017 generally, is associated with the sampling locations having standing water at the time of the May 2017 sampling event. The quarter 1 2018 rainfall and mean temperatures is generally consistent with the historical data with the exception of the increased rainfall recorded in March 2017 as a result of Cyclone Debbie.

The weather conditions from April through to October in 2017 and 2018 are generally representative of historical data where lower amounts of rainfall are recorded during this time. During these months, monthly rainfall recorded was below the monthly mean for all months with the exception of May 2017, October 2017 and October 2018. A total of 76 mm was recorded in October 2018 at the St Lawrence station, which is lower than the 173 mm recorded in October 2017 at the Strathmuir station (171.6 mm recorded at the St Lawrence station in October 2017). A number of sampling locations were often dry during these months, including De1, De2 and De3. In October 2018, 32.6 mm was recorded on the 6 October 2018 and 24.8 mm was recorded on 14 October 2018. Despite these rainfall events, sampling locations De1, De2, De3 and De4 were dry during the October sampling event which ran from 22nd October to 25th October 2018.

Summary descriptions of sample sites are provided in Table 9-24 of Chapter 9 (see also Table 16-101) and water quality sampling method is described in Section 9.5.3.2 of Chapter 9.

Water Quality Assessment Results

Baseline water quality values for samples captured during the seventeen sampling events in 2017-2018 are presented in Appendix A5a and Table 9-25 to Table 9-41 of Chapter 9. The historical results for 2011-2012 and recent data for 2017 – 2018 were collated and the mean, median, 20th and 80th percentiles presented in Table 16-36. The samples are compared against the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values, Water Quality Objectives (EHP 2014a), and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Some of the physical and chemical water quality values at the sampled sites exceeded the WQO for those EVs. The following section provides a discussion of the results for the key parameters.

Turbidity and Suspended Solids

Turbidity shows a seasonal response to rainfall, increasing in the wet season and during residual flows. Water quality within Deep Creek was often elevated above the trigger value of 50 NTU and on occasion in Tooloombah Creek during the 2017 / 2018 wet season (Figure 16-31). Suspended solids exceeded 40 mg/L for twenty-one of the seventy-five water samples. Although turbidity and suspended solids show a seasonal influence it is also likely that natural creek structure and landuse influence levels observed. Exceedances observed in Deep Creek in 2011, 2017 and 2018 are possibly the result of the finer streambed substrate being mobilised by turbulent streamflows and possibly erosion as well as stock having access to the pools.

Turbidity levels in Tooloombah Creek were less turbid than Deep Creek pools, likely due to a combination of catchment hydrology (less erosion and slower flows), reduced stock access and increased residence time of pool water enabling sediments to settle.

Table 16-36 Stream water quality including mean, median, 20th, 80th and 95th percentiles (June 2011 – October 2018)

Parameter	WQOs	Sample number	% Detected	Combined water quality Results				
				Mean	Median	20th%	80th%	95th%
In-situ results								
Water Temperature (°C)	**16 – 34[5]**	186	100%	23.96	24.3	20	28.4	31.35
Dissolved Oxygen (mg/L)	**6.77 – 8.76[3]**	132	100%	15.10	5.59	3.972	8.664	78.1
pH	**6.5 – 8.0[3]**	203	100%	7.74	7.8	7.368	8.112	8.489
Conductivity (µS/cm)	-	269	100%	3,165.16	683	270.96	1968.6	18,169
Turbidity (NTU)	**50[3]**	176	100%	115.27	13.45	5.41	125	732
Laboratory results								
Total Dissolved Solids (mg/L)	**600[4]**	178	100%	2074.92	665.5	309.8	1570	10840
Suspended Solids (mg/L)	**40[3]**	178	84.80%	62.29	13	6	61.6	249.8
Total Alkalinity as $CaCO_3$ (mg/L)	**≥20[1]**	135	100%	126.85	114	72	169	264.6
Sulphate (mg/L)	**250[4]**	178	97.80%	104.78	12.5	5	41.6	643.15
Chloride (mg/L)	-	178	99.40%	868.17	137	39.4	453	6,014.5
Ammonia N (mg/L)	**0.02**	178	84.80%	0.055	0.03	0.02	0.08	0.143
Nitrite N (mg/L)	-	178	1.10%	0.010	0.01	0.01	0.01	0.01
Nitrate N (mg/L)[8]	**0.158[1]**	178	36%	0.018	0.01	0.01	0.02	0.05
Total Nitrogen (mg/L)	**0.5[3]**	178	98.30%	0.939	0.5	0.3	1.26	3.115
Total Phosphorus as P (mg/L)	**0.05[3]**	178	89.90%	0.177	0.05	0.02	0.244	0.758
Reactive Phosphorus (mg/L)	**0.02[3]**	174	16.70%	0.015	0.01	0.01	0.01	0.0435
Fluoride (mg/L)	**2.4[2]**	171	87.10%	0.198	0.2	0.1	0.2	0.5
Aluminium (mg/L)	**0.055[1]**	176	42.60%	0.479	0.02	0.01	0.1	3.23
Arsenic (mg/L)	**0.024[1]**	176	61.90%	0.013	0.002	0.001	0.01	0.1
Barium (mg/L)	**1.0[1]**	174	82.20%	0.098	0.087	0.031	0.112	0.2545
Cadmium (mg/L)	**0.0002[1]**	134	0.70%	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium (mg/L)	**0.001[1]**	176	7.40%	0.001	0.001	0.001	0.001	0.002
Cobalt (mg/L)	**0.0014[2]**	134	4.50%	0.001	0.001	0.001	0.001	0.002
Copper (mg/L)	**0.0014[1]**	176	50%	0.031	0.001	0.001	0.002	0.05
Lead (mg/L)	**0.0034[1]**	176	10.80%	0.015	0.001	0.001	0.01	0.065
Manganese (mg/L)	**1.9[1]**	174	90.80%	0.143	0.0375	0.01	0.146	0.5
Molybdenum (mg/L)	**0.034[1]**	134	12.70%	0.001	0.001	0.001	0.001	0.00235
Nickel (mg/L)	**0.011[1]**	134	48.50%	0.001	0.001	0.001	0.002	0.00335
Selenium (mg/L)	**0.005[1]**	172	7.60%	0.065	0.01	0.01	0.01	0.1
Silver (mg/L)	**0.00005[1]**	134	0%	0.001	0.001	0.001	0.001	0.001
Uranium (mg/L)	**0.01[6]**	134	6%	0.001	0.001	0.001	0.001	0.002
Vanadium (mg/L)	**0.006[2]**	176	3.40%	0.011	0.01	0.01	0.01	0.0125
Zinc (mg/L)	**0.008[1]**	176	17%	0.006	0.005	0.005	0.005	0.025
Iron (mg/L)	**0.35[2]**	176	31.20%	0.281	0.05	0.05	0.08	1.625
Mercury (mg/L)	**0.0006[1]**	134	0%	0.0001	0.0001	0.0001	0.0001	0.0001

Source: 1 – ANZECC 2000 High-reliability TV; 2 - ANZECC 2000 Low-reliability TV; 3 – EPP (Water) 'Aquatic Ecosystem'; 4 – EPP (Water) 'Human Consumer'; 5 – EPP (Water) 'Primary Recreation'; 6 – EPP (Water) 'Irrigation'. 7 – the WQO for dissolved oxygen is based on a conversion from the % saturation to mg/L assuming temperature at 25°C and altitude of 300 mAHD. The dissolved oxygen WQO was a percentage of saturation is 85% to 110%.8 - the ANZECC high reliability TV for Nitrate (as NO_3) of 0.7 mg/L is represented as Nitrate N (0.158 mg/L).

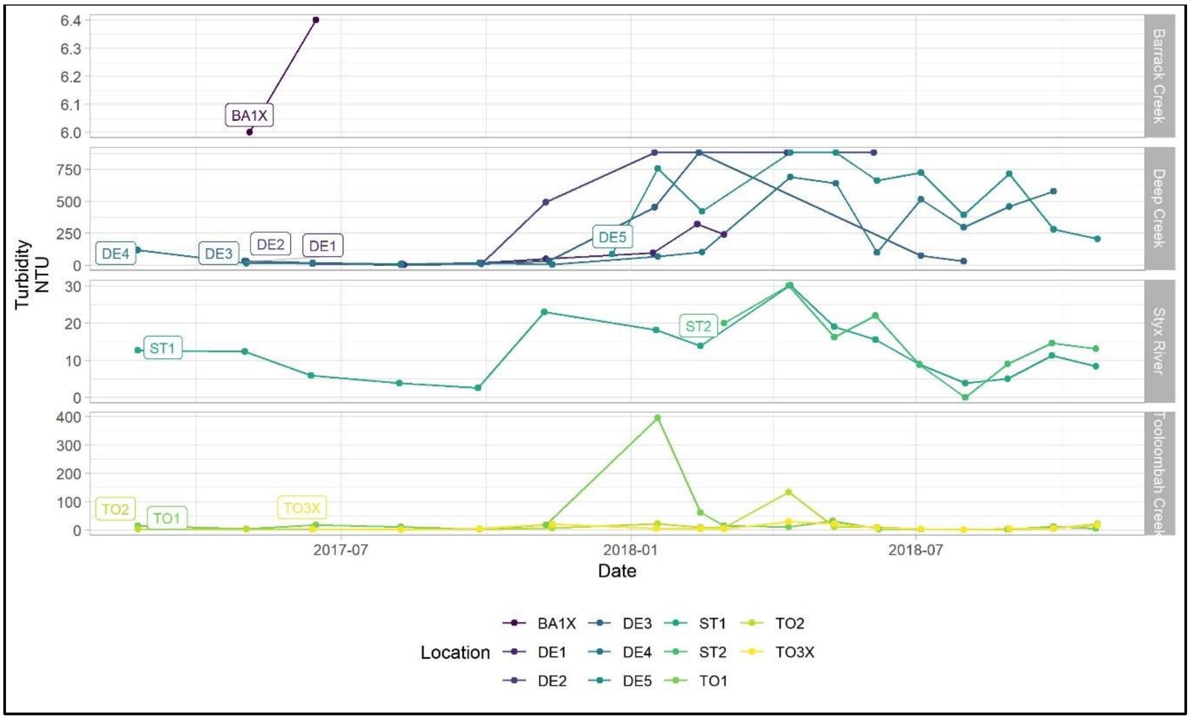


Figure 16-31 2017-2018 turbidity surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

Electrical conductivity

Testing showed that all surface water samples exceeded the ANZECC guideline value for conductivity. High conductivity values can result from excess sodium, magnesium, calcium, chloride, sulphate and bicarbonate in streams. These salts may originate from irrigation water, soils or fertilisers. High salinity values in streams may also result from rising water tables.

The tidally influenced sub-catchments of the Styx River catchment, i.e. below the confluence of Tooloombah and Deep Creeks, are dynamic hydrological environments where terrestrial waters mix with marine waters providing brackish to saline conditions that are markedly different from the higher sub-catchments. Water samples at St1 and St2 in the Styx River show the Styx River is tidally influenced, with electrical conductivity ranging from fresh (125 µS/cm) to brackish (more than 5,000 µS/cm), generally increasing during periods of dry / no flow, and following the first flush of salts experienced at the beginning of the wet season. The higher values at the Styx River site in relation to the other creeks within the catchment is evident in Figure 16-32. The elevated levels are likely the result of estuarine influence in this section of the river, particularly at site St2, with dilution occurring following periods of high rainfall and / or streamflow (refer Figure 16-33).

Deep Creek water chemistry is more similar to rainfall than it is to seawater and varies between wet and the dry seasons. Surface water samples along Tooloombah Creek shows that the salinity is generally higher than Deep Creek regardless of flow conditions, ranging from around 170 to 2,700 µS/cm EC. Tooloombah Creek is a rocky creek and markedly different in form from Deep Creek. The conductivity results likely indicate a differing geological background or parent source between the two creeks.

The major ion composition of surface water samples collected show that Tooloombah Creek water chemistry is less like rainfall than Deep Creek, with higher concentrations of calcium and chloride. Chloride concentrations increase with distance down the creek (To1 chloride concentrations are generally less than To2 and To3) possibly in response to groundwater discharge and evaporation (refer Chapter 10 – Groundwater Section 10.5.6.7 for further discussion).

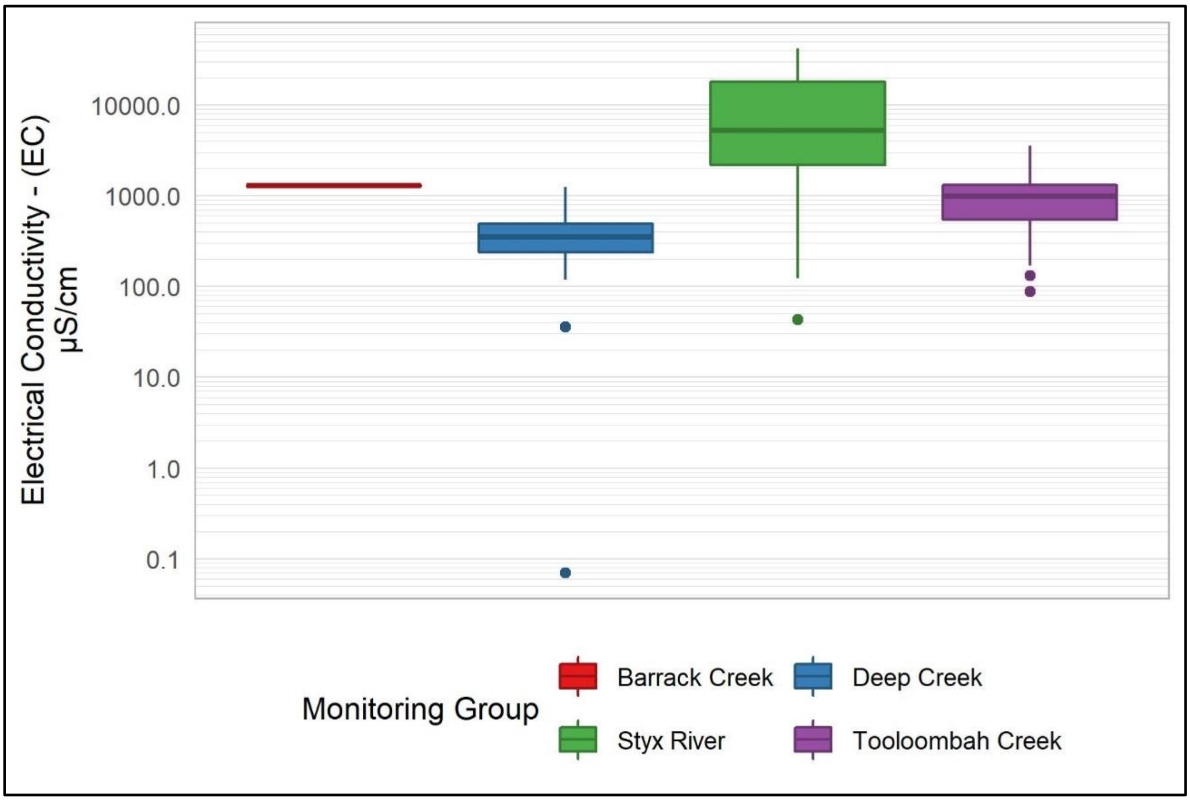


Figure 16-32 2011-2018 electrical conductivity surface water quality box-plot data (log scale) for Barrack, Deep, Tooloombah Creeks and Styx River

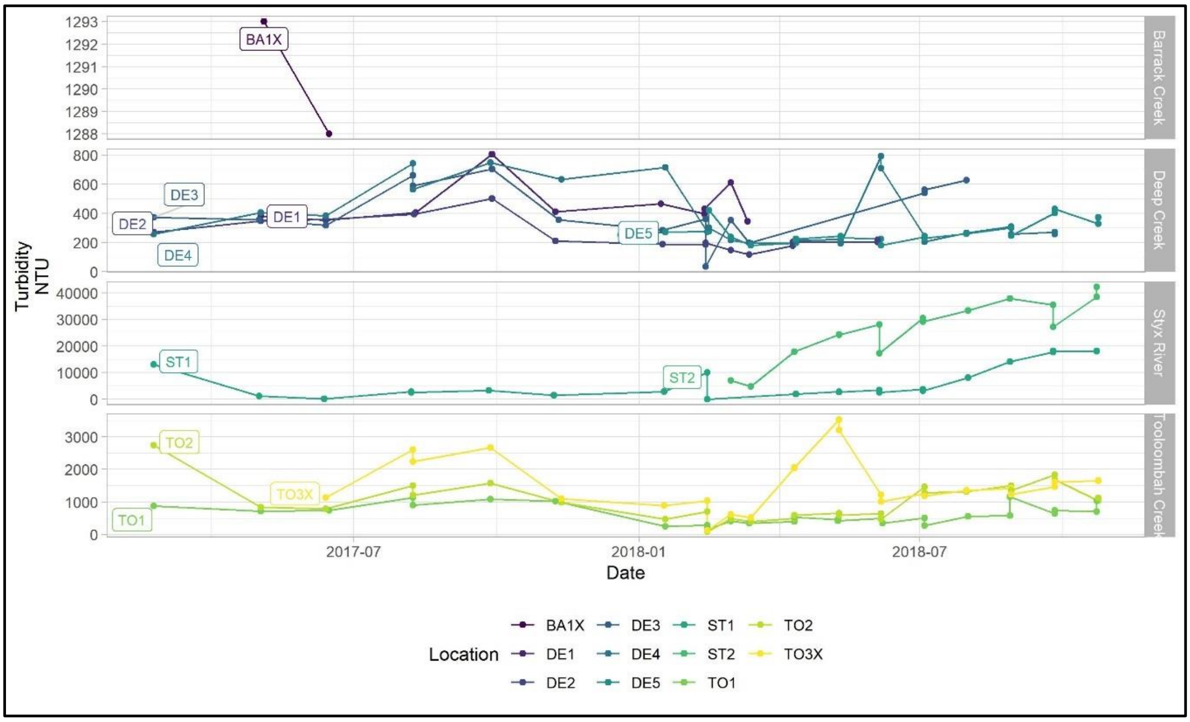


Figure 16-33 2017-2018 electrical conductivity surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

pH

Styx River, Deep Creek and Tooloombah Creek show a broad range of pH over time as illustrated in Figure 16-34. The pH typically sits between 7-8 with Tooloombah Creek reporting more alkaline conditions than the other creeks. Figure 16-35 illustrates the seasonal and highly aligned response in pH over time between the creeks and river. Elevated pH levels typically occurred during low flow conditions and likely represent the influence of local geology and groundwater inflows, with water quality in the Styx River also influenced by tidal conditions.

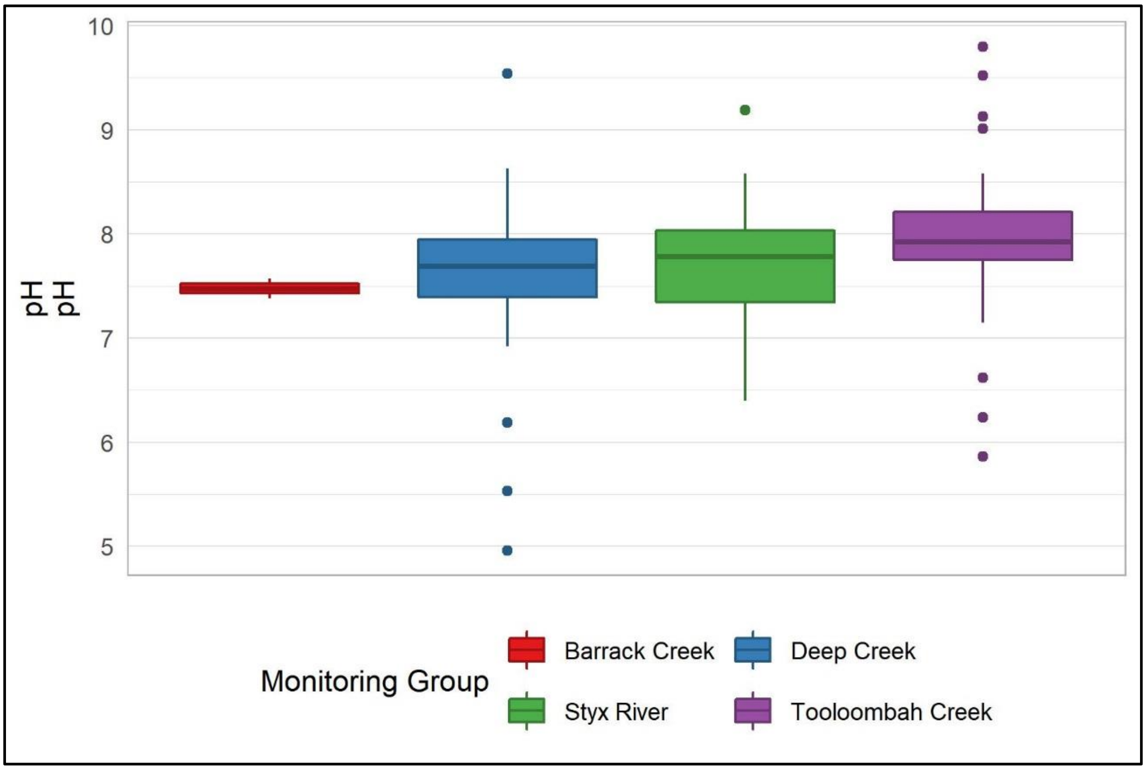


Figure 16-34 2011-2018 pH surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

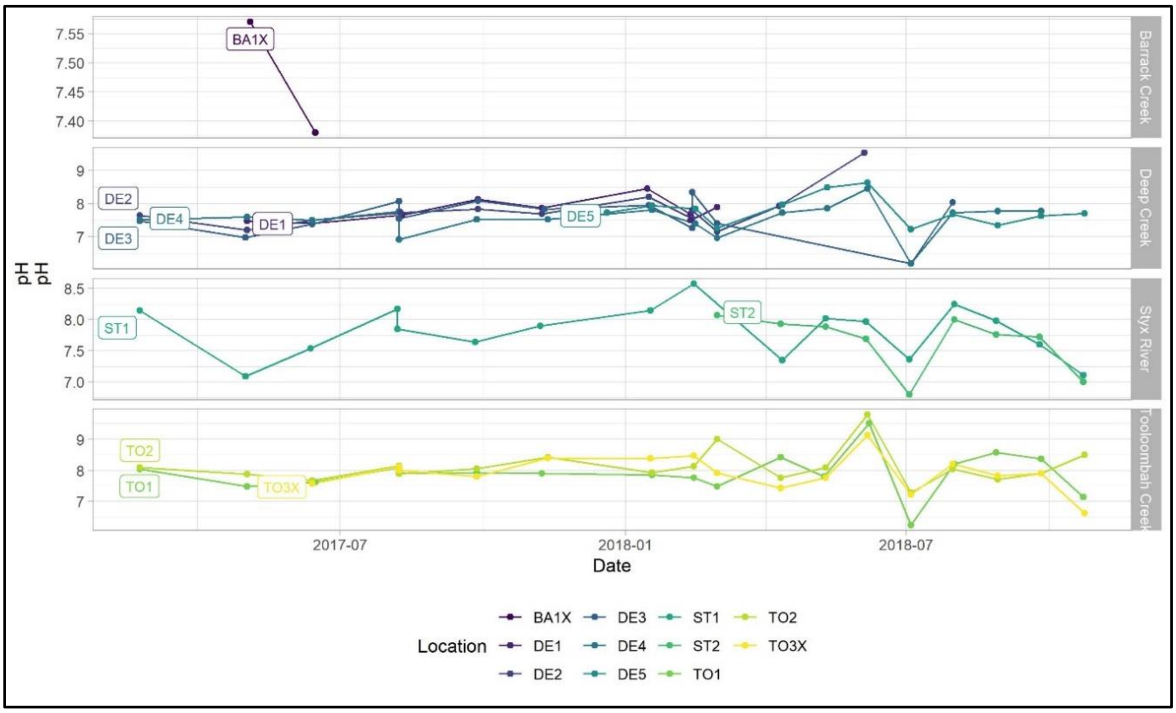


Figure 16-35 2017-2018 pH surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

Nutrients and productivity

Total nitrogen exceeded the guideline value of 0.5 mg/L at Deep and Tooloombah Creeks and Styx River, with Deep Creek reporting consistently higher levels with an average concentration of ~1.0 mg/L (Figure 16-36). Elevated levels occur during both 2017 and 2018 wet season flows as illustrated in Figure 16-37 although exceedances occur within the dry season potentially associated with stock access (particularly to Deep Creek). The greater responsiveness within Deep Creek to wet season total nitrogen concentrations may also be reflective of the relationship between the size of the sub-catchment inputs and its dominant influence on creek flows and quality.

Between 2017-2018 total phosphorous is reported predominantly within the water quality objective of 0.5 mg/L. Exceedances occur as outliers predominantly in Deep Creek but also in Styx River as shown in Figure 16-38. The time series data plots (Figure 16-39) show that exceedances occur within Deep Creek in February 2017 (De2 and De3), between February and June 2018 (De1-De5) and once in September 2018 (De5). These patterns reinforce the positive relationship with wet season flows with exceedances occurring during the low or no-flow periods likely a response to locally introduced organic matter.

Nitrogen and phosphorus in surface water come from a number of sources. Naturally, organic plant matter and silt containing macronutrients can enter waterways from surrounding environments and riparian vegetation. Elevated nutrient levels can often be the result of anthropogenic sources and given the downstream catchment location of the Project, grazing (through direct defecation and pasture runoff) and the erosion of nutrient laden sediments are likely key sources in and upstream of the Project area.

Ammonia-N was typically elevated above the water quality objective of 0.02 mg/L at all locations with the highest concentrations occurring in Styx River and Deep Creek (Figure 16-40). Concentrations are observed to increase during the wet season with sustained flows in 2018 resulting in sustained elevation of ammonia-N concentrations into the months of July and August (see Figure 16-41).

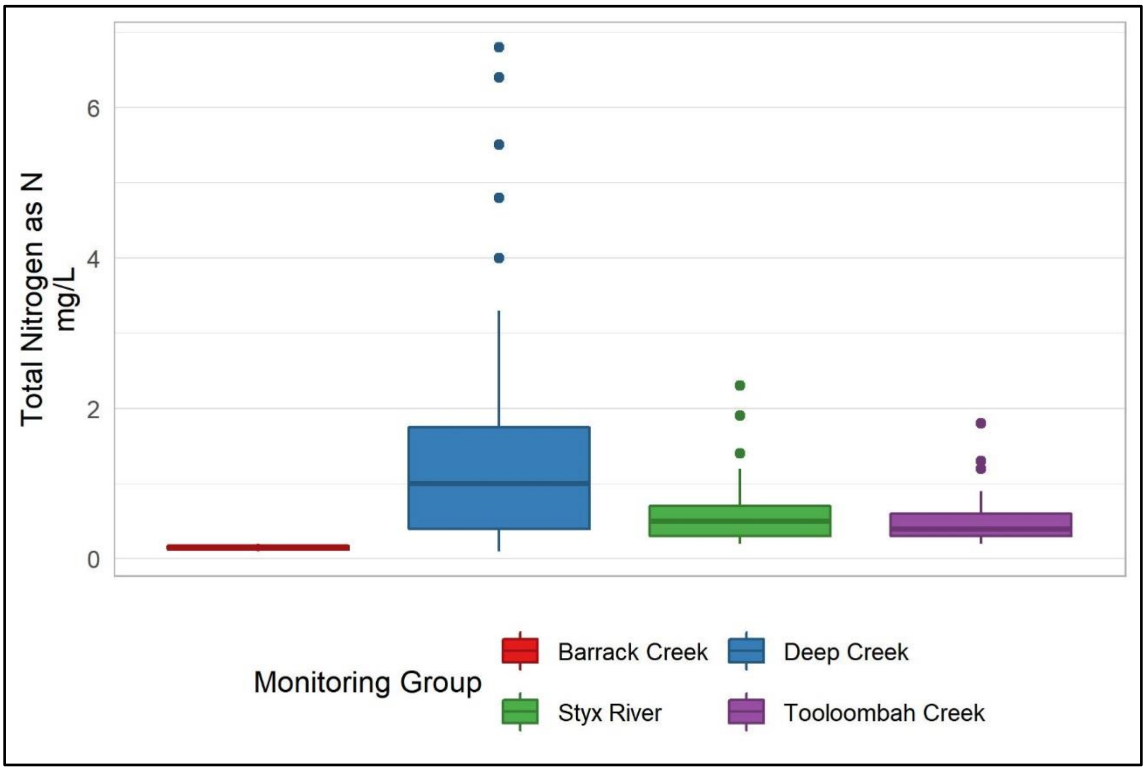


Figure 16-36 2011-2018 total nitrogen surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

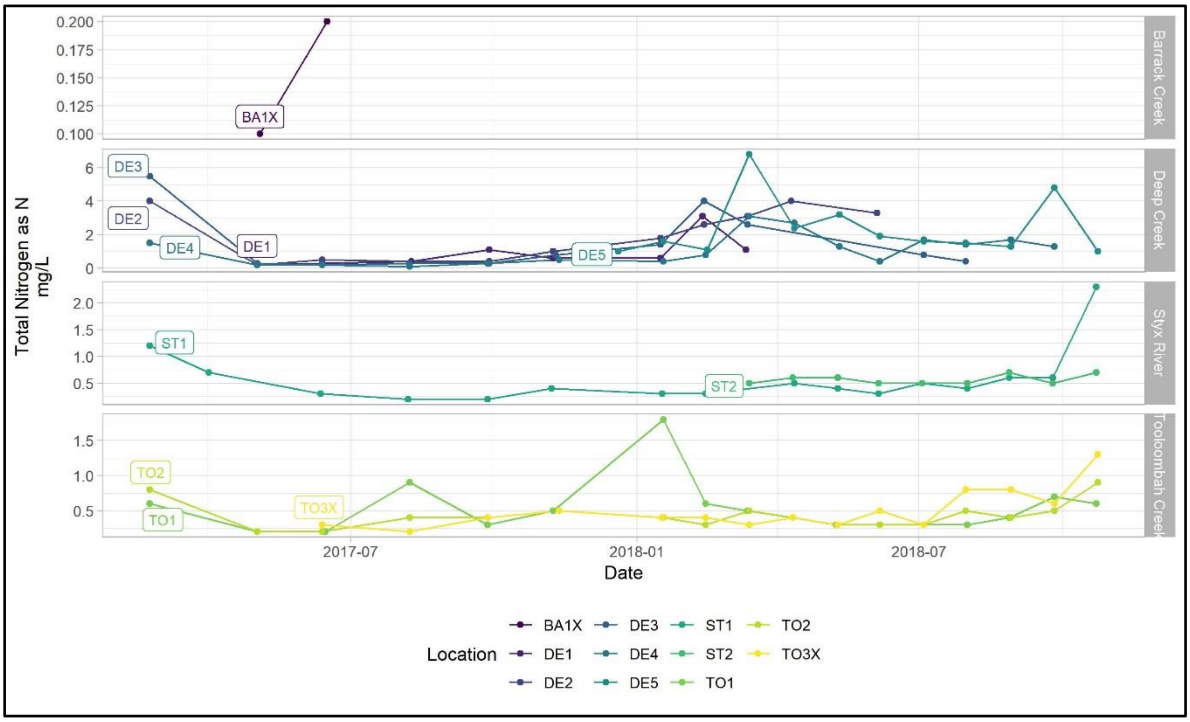


Figure 16-37 2017-2018 total nitrogen surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

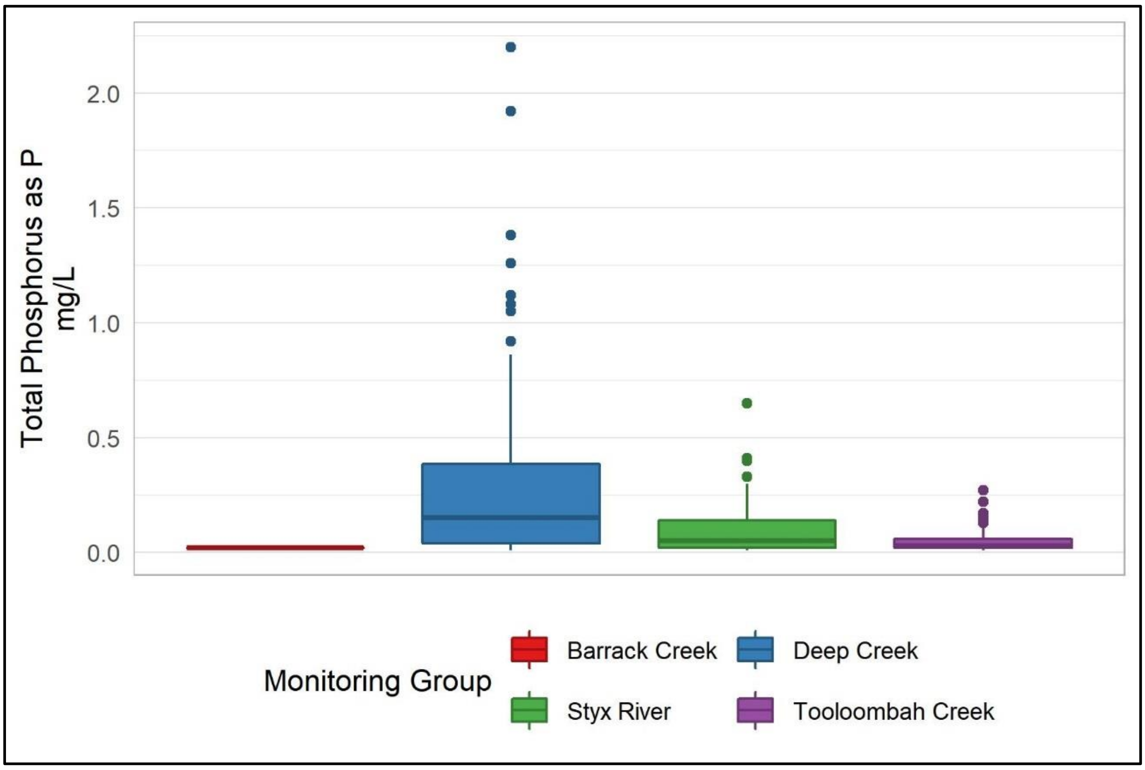


Figure 16-38 2011-2018 total phosphorus surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

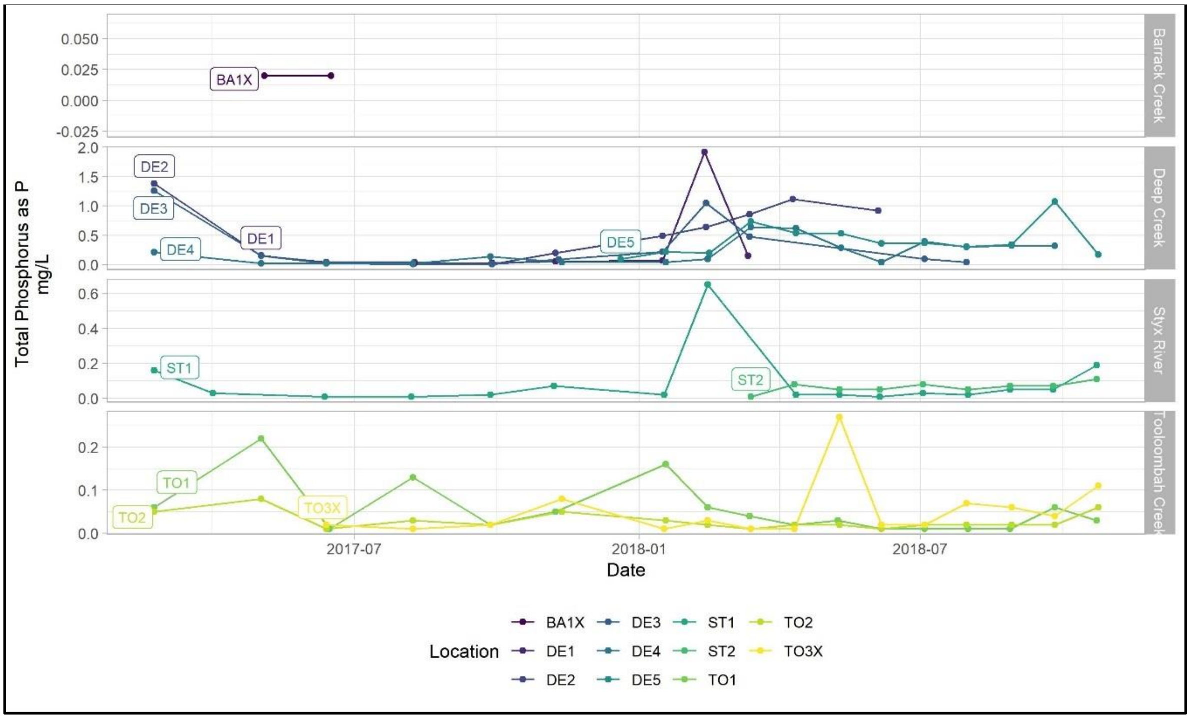


Figure 16-39 2017-2018 total phosphorus surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

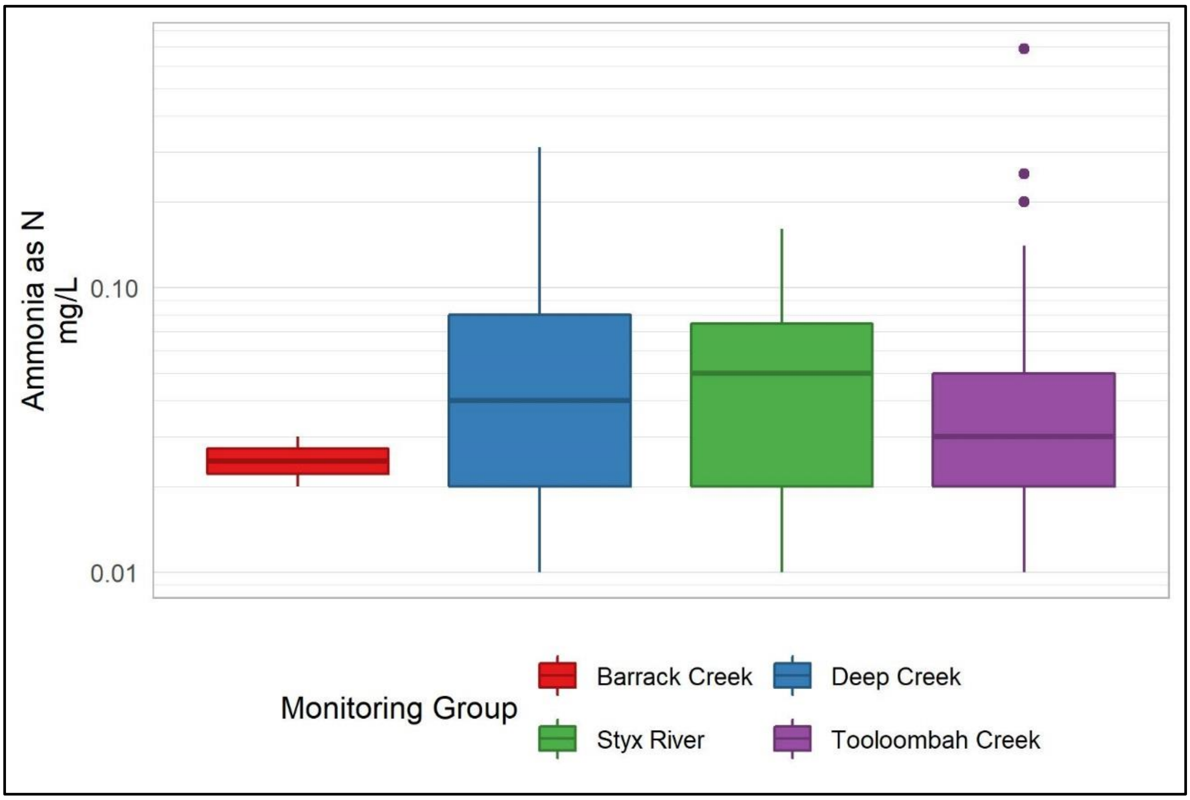


Figure 16-40 2011-2018 ammonia-N surface water quality box-plot data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

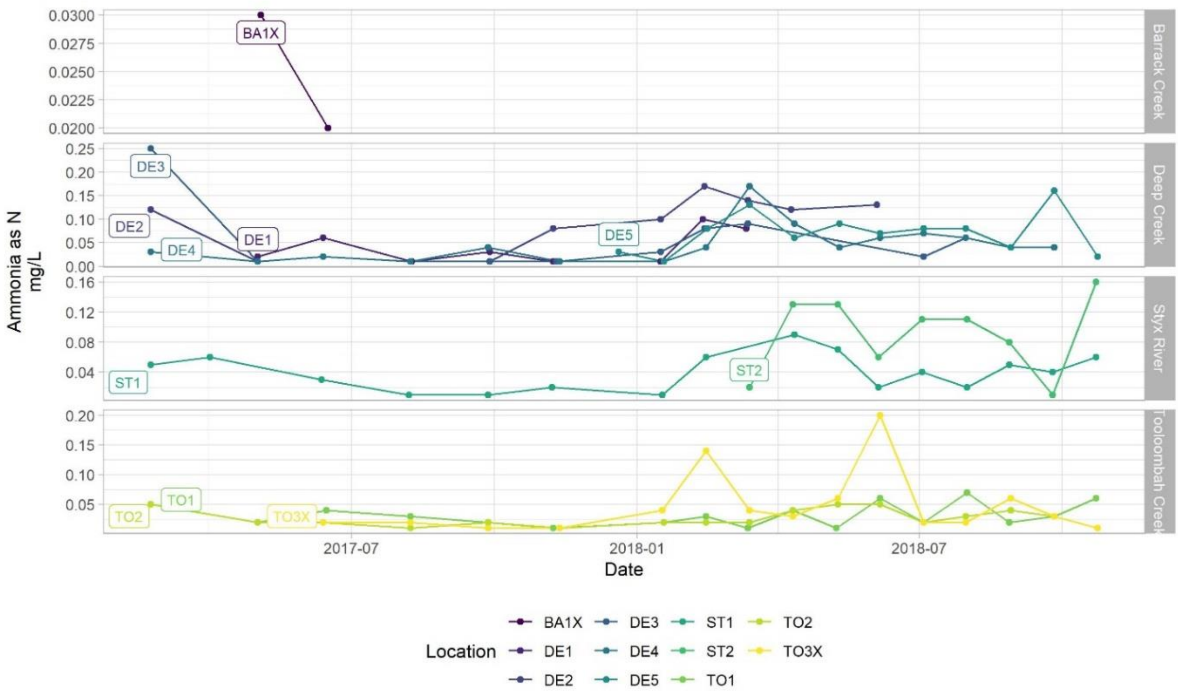


Figure 16-41 2017-2018 ammonia-N surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

Dissolved heavy metals

Surface water systems can often exhibit naturally high heavy metal concentrations due to local geology and soil composition; however, concentration levels can often be increased through environmental disturbance (for example soil erosion) and other anthropogenic activities (for example mining and agriculture). Heavy metals present in a system due to soil erosion are typically associated with sediment particulates and although they will be measures under total metals, they are typically not bioavailable. As such, dissolved metals provide a more accurate concentration of bioavailable metals that can accumulate in the food chain through direct ingestion or passive diffusion (for example direct contact) with organisms (ANZECC guidelines).

Dissolved aluminium concentrations within Deep and Tooloombah creeks occur predominantly above the water quality guideline value of 0.05 mg/L, with concentrations in Styx River greater than this level occurring only occasionally as illustrated by the log-scale box plots in Figure 16-42. The time series plot (Figure 16-43) that spikes occur at all Deep and Tooloombah creek sites in March 2018 which is likely reflective of groundwater inputs following the large rain event in February.

The majority of results for the creeks and river show dissolved copper concentrations generally exceed the water quality guideline value 0.0014 mg/L (Figure 16-44), with Tooloombah Creek reporting the highest spikes in concentrations. Dissolved copper shows a similar seasonal behaviour to aluminium with some spikes following rainfall events in 2017 and 2018 (log-scale time series Figure 16-45). Deep Creek is an exception which reports a higher average dissolved copper concentration throughout the dry season.

Dissolved zinc was consistently higher in Styx River compared with the creek sites, however similar peaks in concentration are observed in both Deep and Tooloombah creeks (Figure 16-46). The water quality guideline of 0.008 mg/L is exceeded at all three waterways with peaks in dissolved zinc concentration occurring within a month following rain events and may indicate groundwater influence (Figure 16-47).

Levels of dissolved lead above the water quality objective of 0.0034 mg/L were reported for Styx River, Deep Creek and Tooloombah Creek with the greatest levels occurring within Styx River (Figure 16-48). Higher levels of reporting in 2011-2012 of 0.01 mg/L (subsequently increased to 0.001 mg/L in 2017-18) contribute to an overall low percentage of detection however the data suggests that elevated levels are observed during first rains and residual flows. This is not well represented in the 2017-2018 time series chart (Figure 16-49) with spikes in dissolved lead only occurring in Styx River in August and October 2018 and in Deep Creek in October 2018. Lead, as with a number of other heavy metals typically becomes more mobile under low pH conditions. This is not reflected in the pH data for the sample events where neutral to alkaline conditions predominated. The form of lead differs between fresh and saltwaters due to chloride interactions and this may account for the higher levels reported within the Styx River in relation the other waterways.

No other dissolved heavy metal exceedances were recorded noting that the interim low reliability triggers applied to vanadium is below the limits of detection used in the analyses.

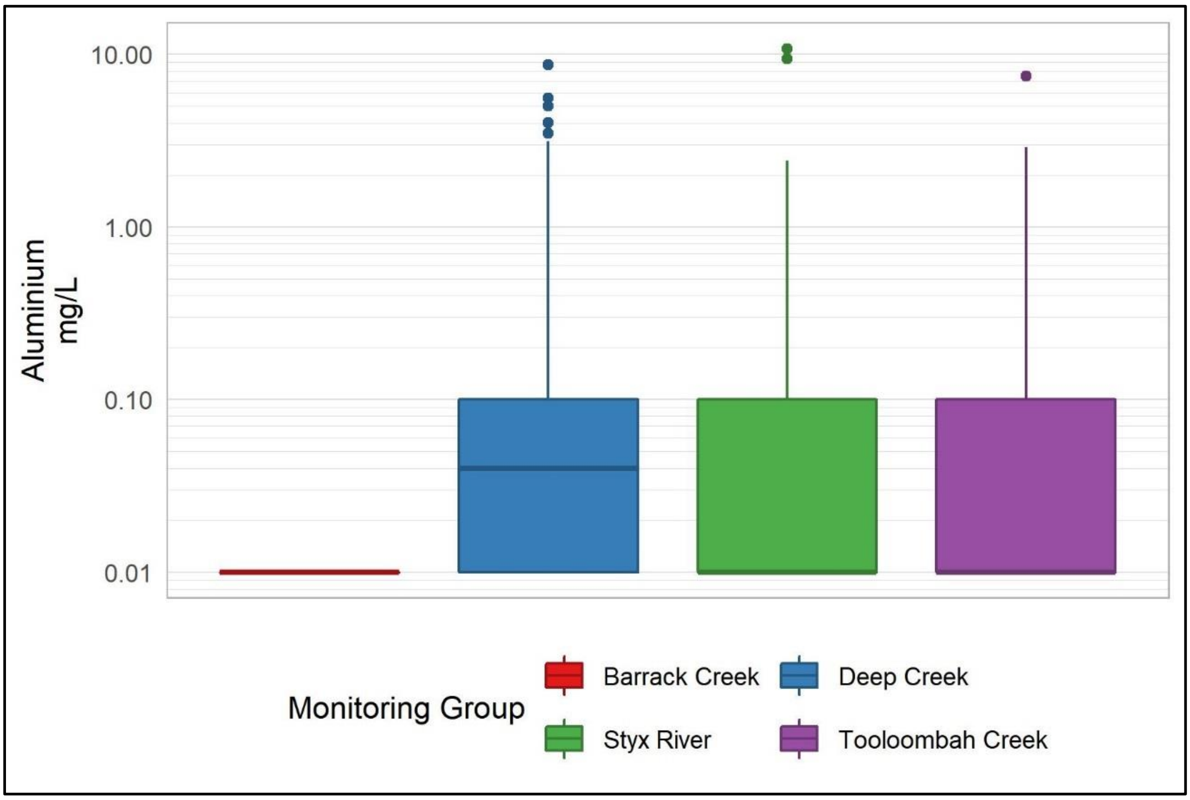


Figure 16-42 2011-2018 dissolved aluminium surface water quality box-plot data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

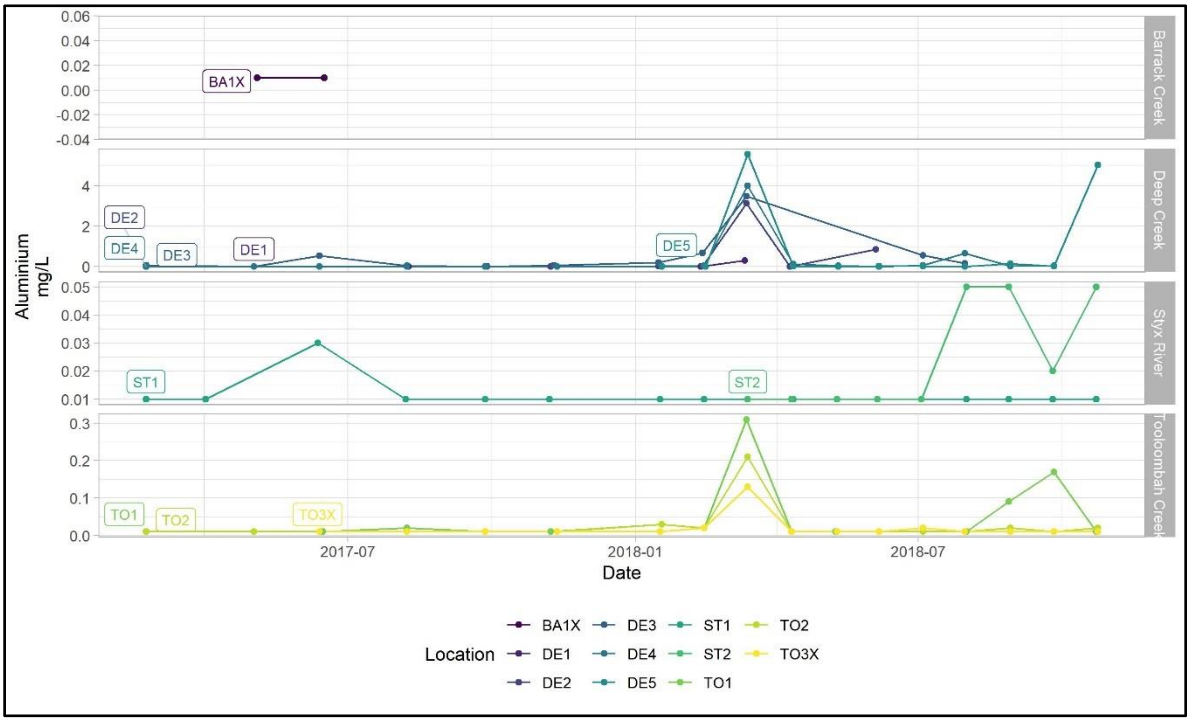


Figure 16-43 2017-2018 dissolved aluminium surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

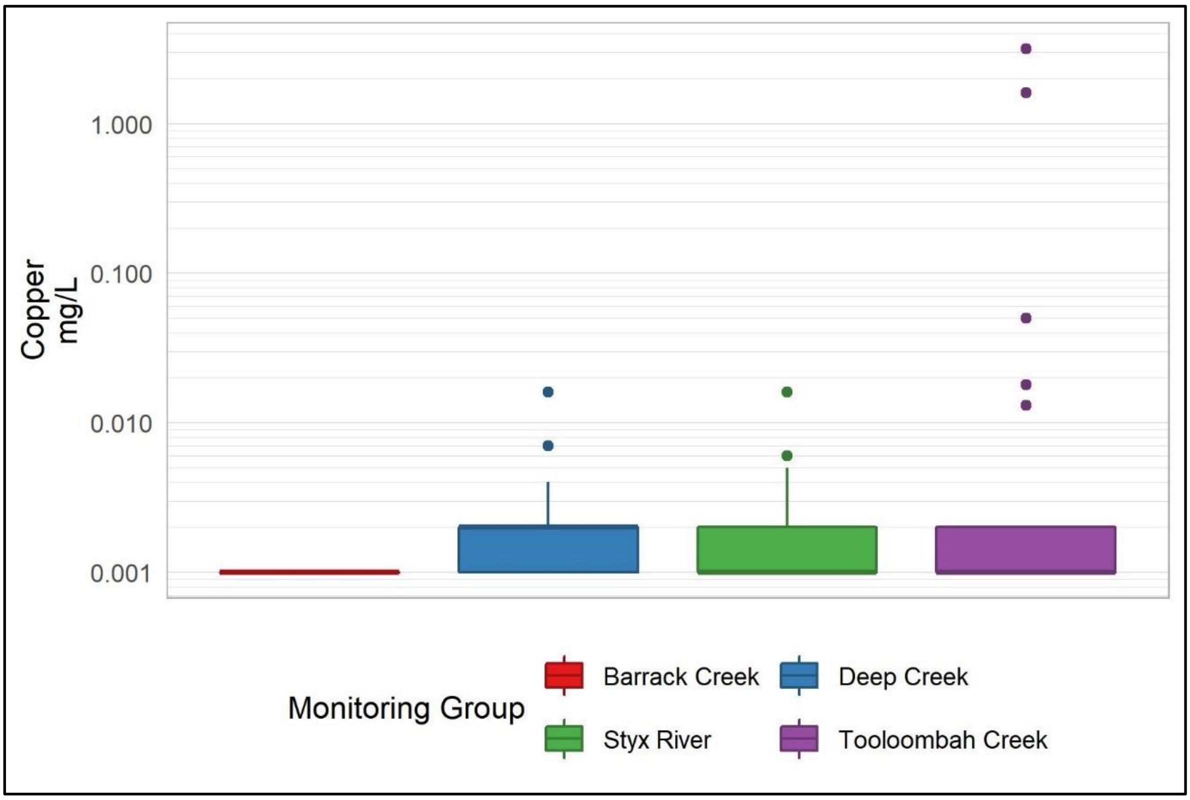


Figure 16-44 2011-2018 dissolved copper surface water quality box-plot data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

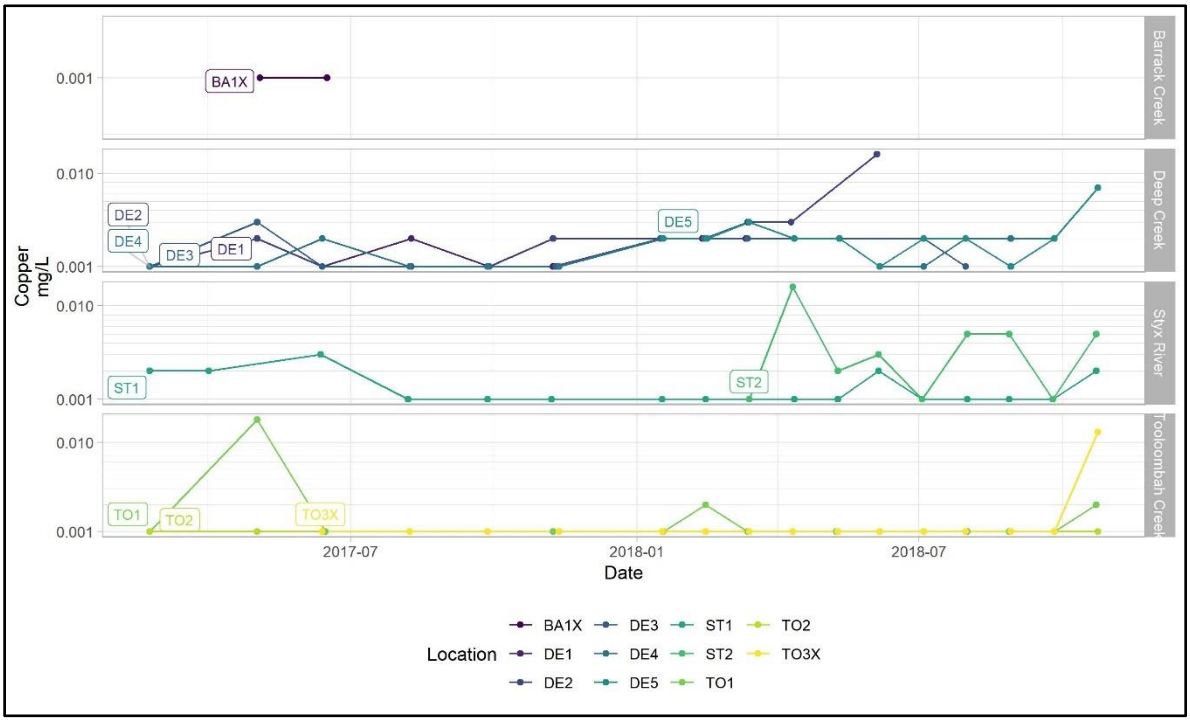


Figure 16-45 2017-2018 dissolved copper surface water quality time-series data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

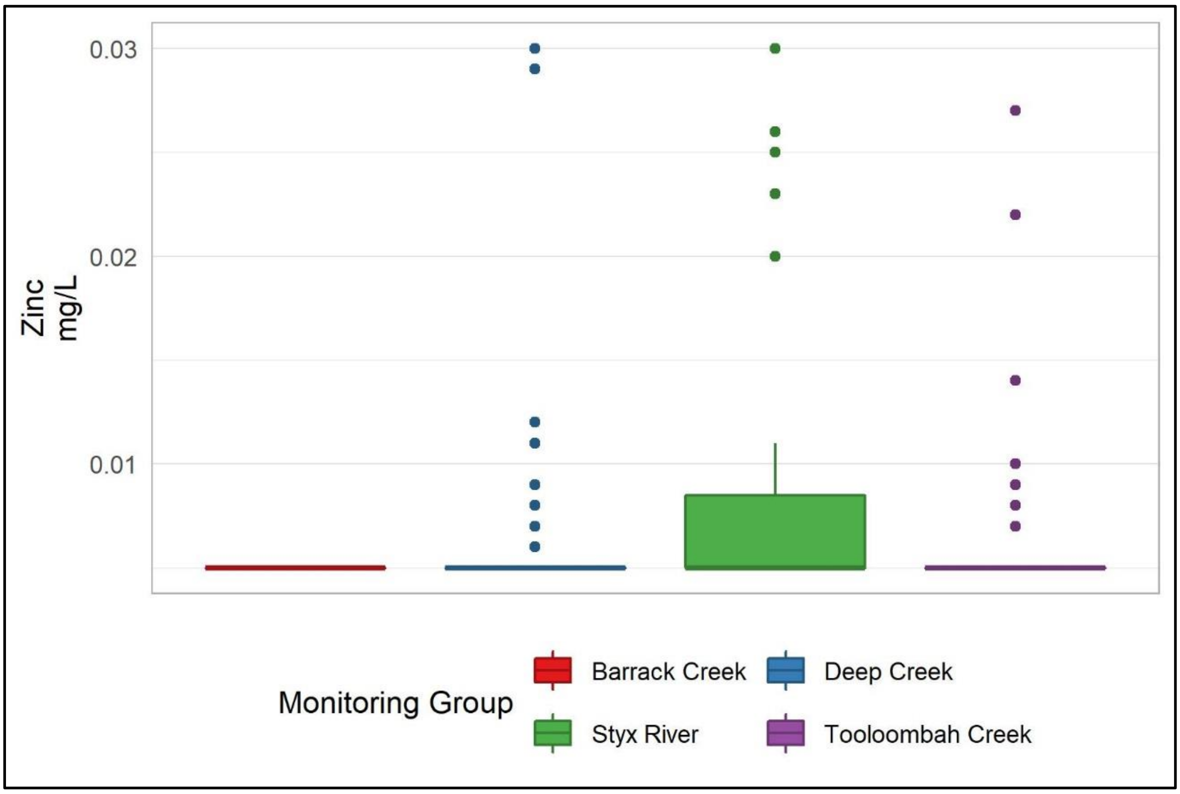


Figure 16-46 2011-2018 dissolved zinc surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

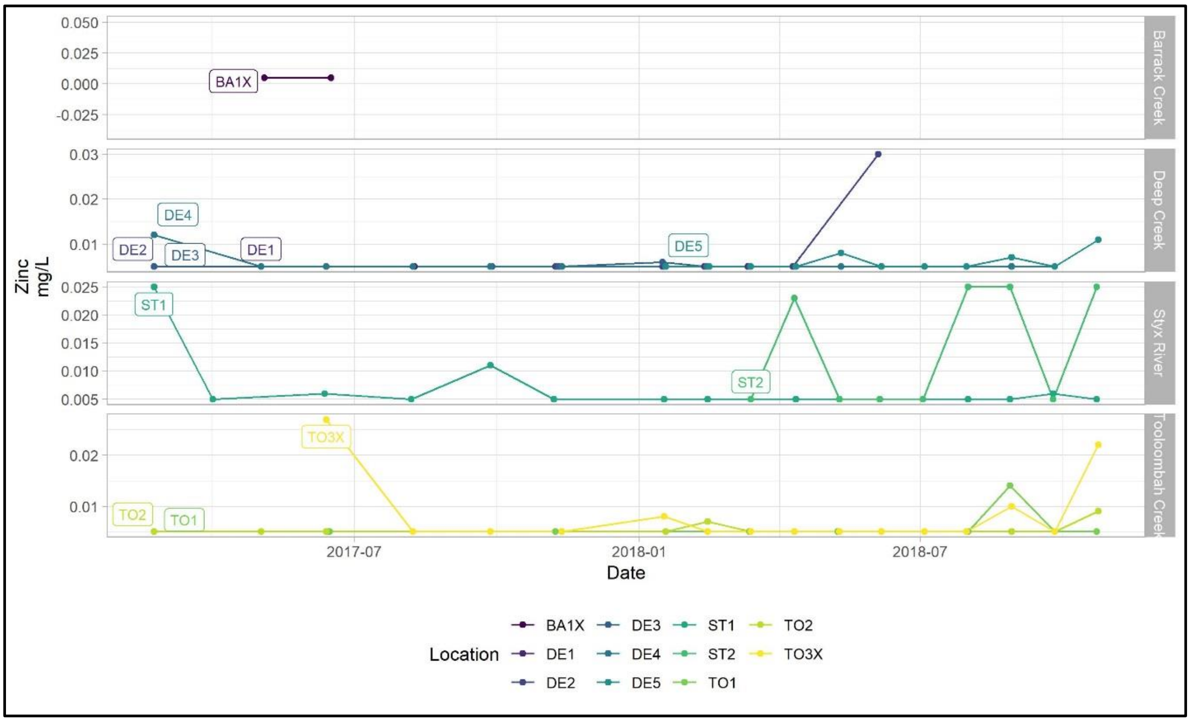


Figure 16-47 2017-2018 dissolved zinc surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

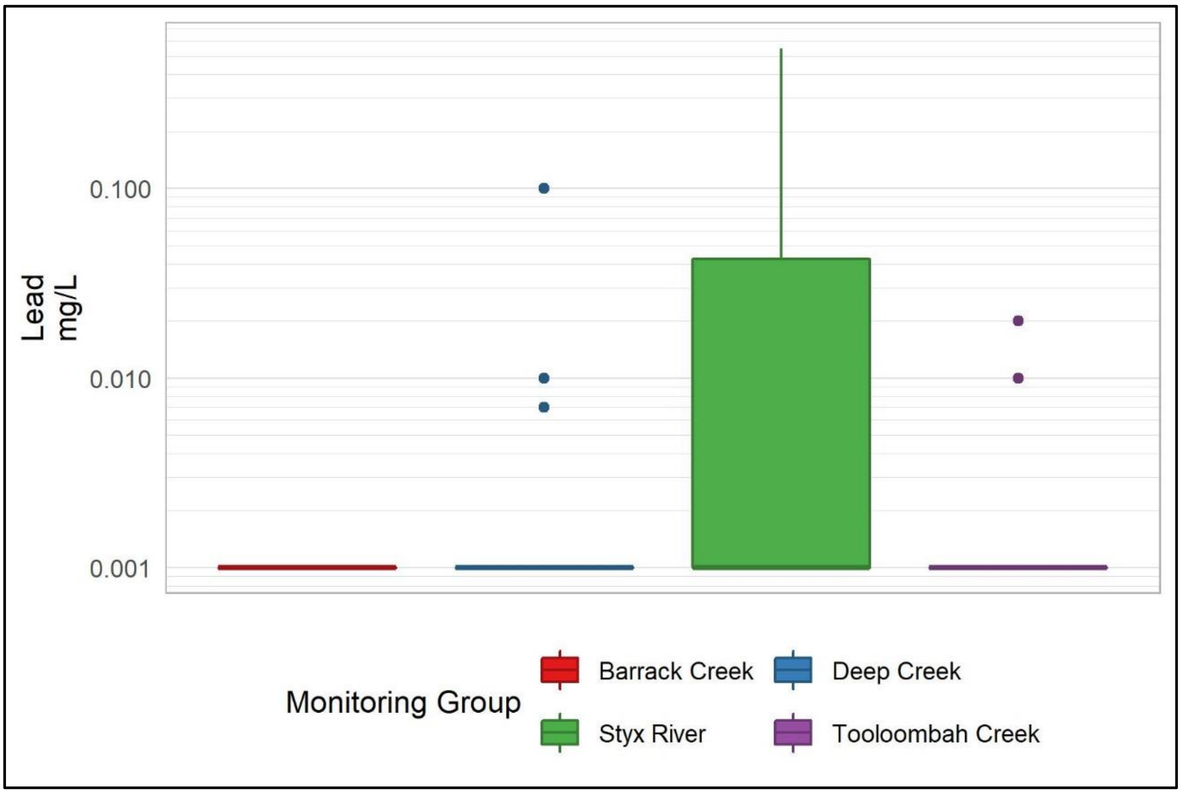


Figure 16-48 2011-2018 dissolved lead surface water quality box-plot data (log scale) for Barrack, Deep, Tooloombah Creeks and Styx River

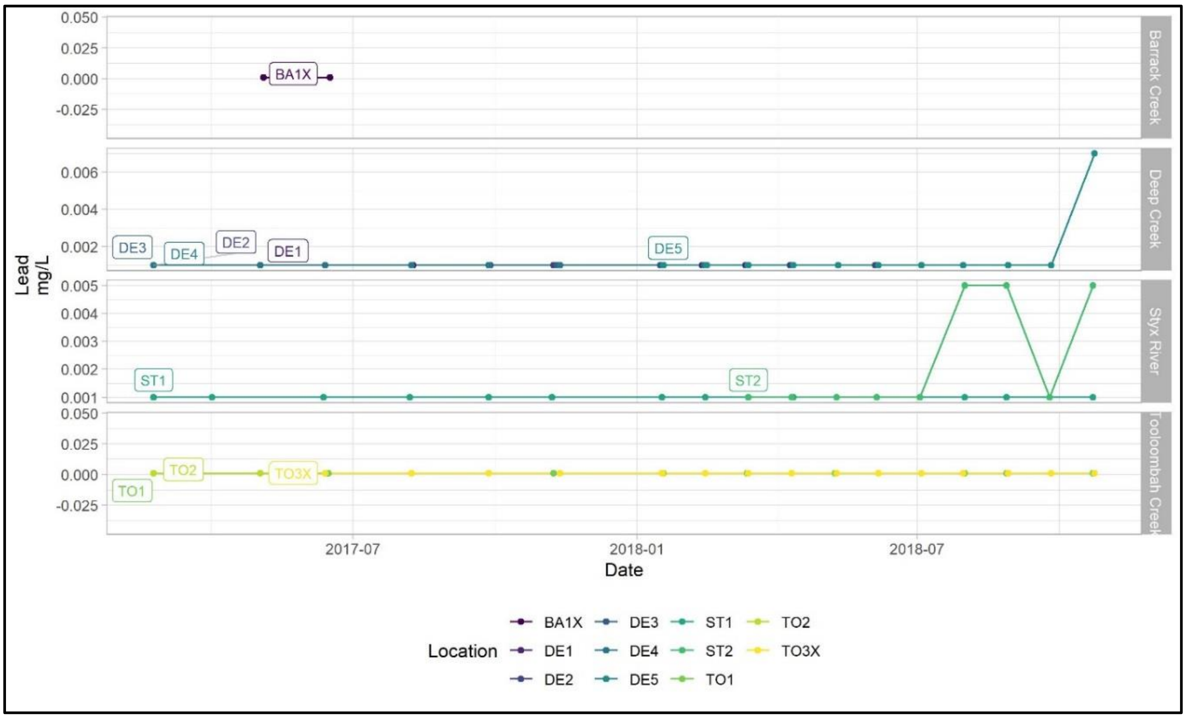


Figure 16-49 2017-2018 dissolved lead surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

16.10.2.4 Proposed Contaminant Trigger Levels and Release Criteria

To protect from environmental harm, release contaminant triggers and investigation levels have been established based on a range of default or model criteria including:

- Model water conditions for coal mines in the Fitzroy basin (version 3) (EHP 2013); and
- Environmental Protection (Water) Policy 2009 - Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014a).

The potential contaminants and release trigger investigation levels are presented in Table 16-37. These trigger values may be revised in the future based on further assessment of site specific data, with the quality characteristic either disregarded if below trigger levels or included as priority contaminants if above trigger levels. For metals and metalloids, trigger levels apply if dissolved results exceed trigger levels. However, total (unfiltered) results for metals and metalloids can be used to disregard a parameter.

Table 16-37 Release contaminant trigger investigation levels, potential contaminants

Quality Characteristic[3]	Trigger level (µg/L)	Basis	Comment on trigger level
Aluminium	55	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Arsenic	13	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Cadmium	0.2	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Chromium	1	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Copper	2	Model Conditions[1]	For aquatic ecosystem protection, based on LOR[5] for ICPMS
Iron	300	Model Conditions[1]	For aquatic ecosystem protection, based on low reliability guideline
Lead	4	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Mercury	0.2	Model Conditions[1]	For aquatic ecosystem protection, based on LOR[5] for CV FIMS
Nickel	11	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Zinc	8	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Boron	370	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Cobalt	90	Model Conditions[1]	For aquatic ecosystem protection, based on low reliability guideline
Manganese	1,900	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Molybdenum	34	Model Conditions[1]	For aquatic ecosystem protection, based on low reliability guideline
Selenium	10	Model Conditions[1]	For aquatic ecosystem protection, based on LOR[5] for ICPMS
Silver	1	Model Conditions[1]	For aquatic ecosystem protection, based on LOR[5] for ICPMS
Uranium	1	Model Conditions[1]	For aquatic ecosystem protection, based on LOR[5] for ICPMS
Vanadium	10	Model Conditions[1]	For aquatic ecosystem protection, based on LOR[5] for ICPMS
Ammonia-N	900	Model Conditions[1]	For aquatic ecosystem protection, based on SMD[4] guideline
Nitrate-N	1,100	Model Conditions[1]	For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (EHP 2013) for TN
Petroleum hydrocarbons (C6-C9)	20	Model Conditions[1]	-
Petroleum hydrocarbons (C10-C36)	100	Model Conditions[1]	-
Fluoride (total)	2,000	Model Conditions[1]	Protection of livestock and short-term irrigation guideline
Sodium (mg/L)	180	EPP Water[2]	Fitzroy Basin Association, drinking water guideline adopted

1 - Model water conditions for coal mines in the Fitzroy basin (version 3) (EHP 2013).
2 - Environmental Protection (Water) Policy 2009 - Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (2014a).
3 - The quality characteristics required to be monitored as per Table 9-12 - Release contaminant trigger investigation levels, potential contaminants will be reviewed once the results of two years monitoring data is available, or if sufficient data is available to adequately demonstrate negligible environmental risk. It may be determined that a reduced monitoring frequency is appropriate or that certain quality characteristics can be removed from the monitoring program.
4 - SMD is slightly moderately disturbed level of protection, guideline refers ANZECC and ARMCANZ (2000).
5. - LOR is typical reporting for method stated. ICPMS/CV FIMS – analytical method required to achieve LOR.

Mine affected water release points represent a potential source of water contaminated by mining activity. This does not include release points for runoff contaminated only by sediment where they are associated with erosion and sediment control structures installed in accordance with the standards and requirements of an ESCP. The proposed release limits for pH and Turbidity are presented at Table 16-38. The end of pipe discharges and target in-stream dilution values for EC are presented at Table 16-39 and Table 16-40 for Tooloombah Creek and Deep Creek respectively.

Table 16-38 Proposed mine affected water release limits – pH, Suspended Solids and Sulphate

Quality characteristic	Release limits	Monitoring frequency
pH (pH Unit)	6.5 (minimum) 9.0 (maximum)	Daily during release* (first sample within two hours of commencement of release)
Suspended Solids (mg/L)	61.6[1]	
Sulphate (SO_4^{2}) (mg/L)	250	

1 Based on the 80th percentile of combined surface water quality database (Styx River, Deep Creek, Tooloombah Creek, Barrack Creek) consisting of 178 datapoints between 2011 and 2018.

Table 16-39 Mine affected water release during flow events for EC- Tooloombah Creek

Receiving waters / stream	Release point (RP)	Gauging station	Gauging station latitude (decimal degree, GDA94)	Gauging station longitude (decimal degree, GDA94)	Receiving water flow recording frequency	Receiving water flow criteria for discharge (m^3/s)	Maximum release rate (for all combined RP flows)	Electrical conductivity release limits (µS/cm)
Tooloombah Creek	RP 5	Gauging Station 1	-22.689224°	149.629838°	Continuous (minimum daily)	Low Flow <0.17m^3/s for a period of 28 days after natural flow events that exceed 0.17 m^3/s	0.17 m^3/s	1,320
						Medium Flow >0.17 m^3/s	<0.113 m^3/s	1,500
							<0.049m^3/s	3,500
						High Flow >0.3 m^3/s	<0.086m^3/s	3,500
							<0.067m^3/s	4,500
						Very High Flow >0.86 m^3/s	<0.191m^3/s	4,500
							<0.156m^3/s	5,500
						Flood >2.04 m^3/s	<0.371m^3/s	5,500
							<0.314m^3/s	6,500

Table 16-40 Mine affected water release during flow events for EC – Deep Creek

Receiving waters / stream	Release point (RP)	Gauging station	Gauging station latitude (decimal degree, GDA94)	Gauging station longitude (decimal degree, GDA94)	Receiving water flow recording frequency	Receiving water flow criteria for discharge (m^3/s)	Maximum release rate (for all combined RP flows)	Electrical conductivity release limits (µS/cm)
Deep Creek	RP 1 RP 2 RP 3 RP 4	Gauging Station 2	-22.730782°	149.663025°	Continuous (minimum daily)	Low Flow <0.16m^3/s for a period of 28 days after natural flow events that exceed 0.16 m^3/s	0.16 m^3/s	495.5
						Medium Flow >0.16 m^3/s	<0.107 m^3/s	1,500
							<0.046m^3/s	3,500
						High Flow >0.38 m^3/s	<0.109m^3/s	3,500
							<0.084m^3/s	4,500
						Very High Flow >1.26 m^3/s	<0.280m^3/s	4,500
							<0.229m^3/s	5,500
						Flood >3.56 m^3/s	<0.647m^3/s	5,500
							<0.548m^3/s	6,500

16.10.3 Flooding and Stormwater Drainage Assessment

This section details the flood assessment conducted for Tooloombah Creek, Deep Creek and the Styx River with the aim of:

- Demonstrating the flood immunity of critical mine infrastructure and haul roads; and
- Assessing impacts on flood behaviour due to mine construction.

Also documented in this section is the conceptualisation and hydraulic performance of the stormwater management system, including diversion drains, culverts, floodways and sediment basins. Further detail is provided in Section 9.6 in Chapter 9 – Surface Water.

The hydrologic and hydraulic modelling has been conducted in terms of Annual Exceedance Probability (AEP) as is recommended by industry with the recent implementation of Australia Runoff and Rainfall 2016 (Ball et al. 2016). The change in terminology comes from a common misinterpretation of Average Recurrence Interval (ARI) terminology, in which it is erroneously assumed that a 1 in 10 year ARI, for example, will only occur exactly once in every ten years.

The AEP better handles this by describing the probability of a magnitude flood event being exceeded in any given year as a percentage probability. However, there are some guidelines and analyses that have not adopted the AEP definition, which ultimately means that the design standard for environmental dams, diversion drains and culverts are still established in terms of Annual Recurrence Interval (ARI). The relationship between AEP and ARI is as follows: 9.5% AEP (10 year

ARI), 4.9% AEP (20 year ARI), 2% AEP (50 year ARI), 1% AEP (100 year ARI) and 0.1% AEP (1,000 year ARI).

16.10.3.1 Hydrologic Assessment

The aim of the hydrologic assessment detailed herein is to produce flood hydrographs for input to hydraulic model simulations that predict flood characteristics such as inundation depth, flood extent, and flow velocities.

Baseline Model Build

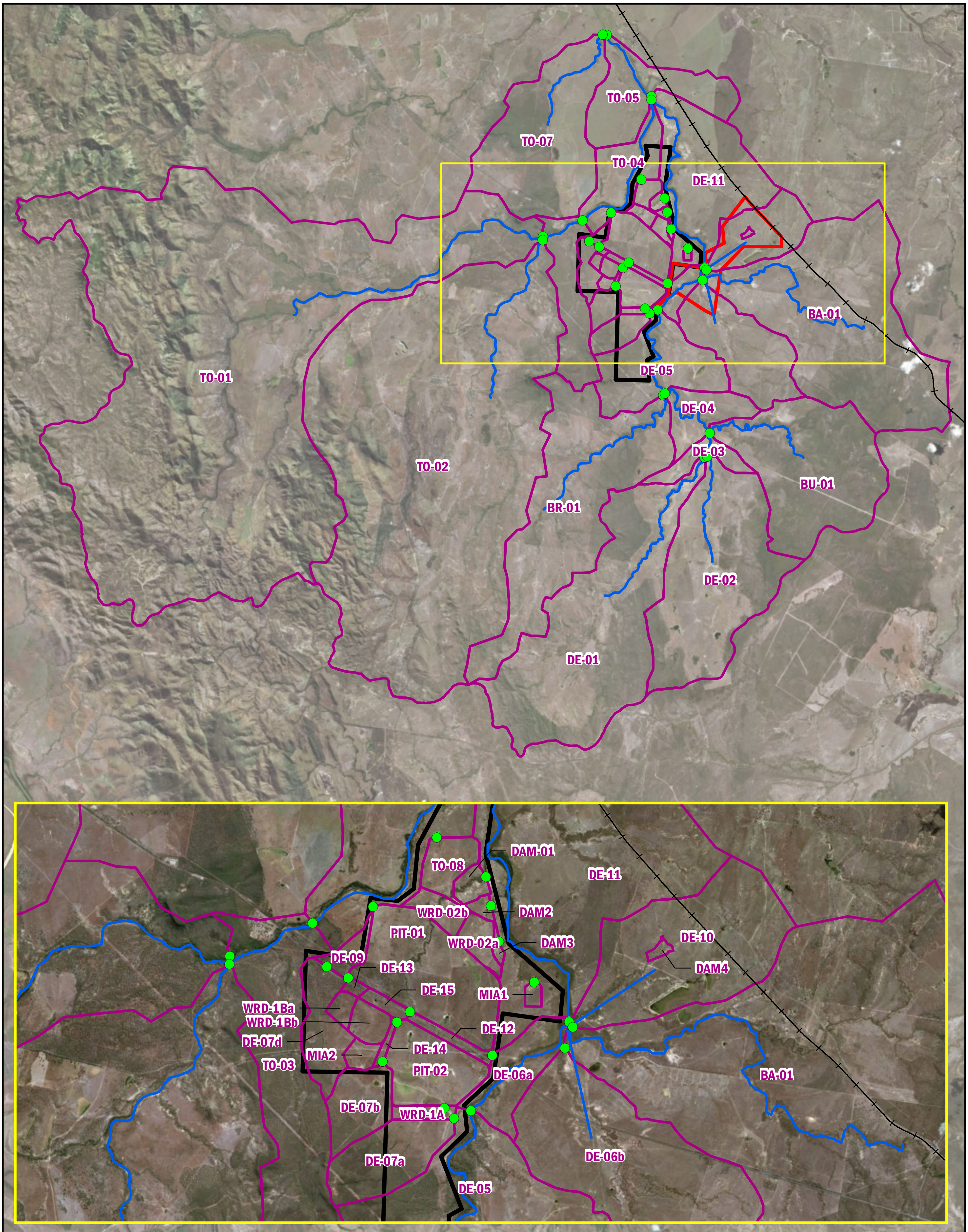
A rainfall-runoff model was constructed using XP-RAFTS, which is a general non-linear rainfall / runoff and streamflow routing program, used to estimate peak flows, flood hydrographs and other channel inputs using actual storm events or design rainfall data. The program calculates flood discharges over time (hydrographs) by simulating rainfall over a catchment also with time, removing losses to calculate the rainfall excess runoff, and routing this runoff through the catchment model.

The sub-catchment delineation and river reach network is shown in Figure 9-48. The temporal distribution of rainfall was defined using the North Coast East zone, Australian Rainfall and Runoff (AR&R16) areal patterns for durations above 12 hours, while point temporal patterns were applied for durations below 12 hours.

To simulate the variability of storm events, ten temporal patterns, referred to as “an ensemble” were tested for each storm duration, following the AR&R16 methodology. Point temporal patterns were based on the frequency of the AEP event, whilst areal patterns were based on catchment area. Design rainfall intensities were determined from the BoM website using the 2016 Intensity-Frequency-Duration (IFD) chart. Point rainfall intensities at the site, for selected storm durations are shown in Table 16-41.

Table 16-41 Design point rainfall intensities (mm/hr)

Event Duration (hr)	9.5% AEP (10 Yr ARI)	4.9% AEP (20 Yr ARI)	2% AEP (50 Yr ARI)	1% AEP (100 Yr ARI)	0.1% AEP (1,000 Yr ARI)
9	15.81	18.37	22.26	25.40	-
12	13.34	15.62	19.13	22.00	-
18	10.24	12.12	15.07	17.53	-
24	8.69	10.37	13.04	15.29	24.08
36	6.64	8.02	10.21	12.07	20.19



N

0 2.5 5 km

Scale @ A4 1:210,000
Date: 14/11/18
Drawn: Gayle B.

Legend

- Nodes – Developed
- Reaches – Developed
- XP-RAFT Catchments
- ML 80187
- ML 700022
- North Coast Rail Line

Figure 16-50
XP-RAFTS catchment delineation - developed case

CDM Smith

Initial simulations were run for standard AEP events (9.5%, 4.9%, 2%, 1% and 0.1%) and durations (9 hours to 36 hour). For each of these cases, the ensemble of ten temporal pattern was interrogated, with the median case peak flow value, as calculated at the MLA boundary (see Figure 16-50) presented in Table 16-42. The interrogation of the ten temporal patterns provided an assessment of the temporal rainfall loading distribution and confirmed the selection of the median peak flow as appropriate for use.

Table 16-42 Peak flow (median temporal pattern) at MLA boundary (J6) (m^3/s)

Event Duration (hr)	9.5% AEP (10 Yr ARI)	4.9% AEP (20 Yr ARI)	2% AEP (50 Yr ARI)	1% AEP (100 Yr ARI)	0.1% AEP (1,000 Yr ARI)
9	1,177	1,470	1,944	2,369	-
12	1,316	1,680	2,272	2,790	-
18	1,421	1,847	2,558	3,144	-
24	1,493	1,827	2,440	2,958	5,528
36	1,400	1,790	2,449	2,990	5,456

Model Verification

In the absence of historical gauged data against which to calibrate, a series of methods were used to provide confidence in the hydrological data and modelling used in this surface water assessment. In summary, these methods included:

- Rainfall temporal pattern variability of storm events using “an ensemble” were tested for each storm duration, following the AR&R16 methodology;
- Hydrographs produced by the XP-RAFTS model, with sensitivity analysis of input parameters;
- Regional flood frequency assessment against 14 local gauged catchments, using AR&R16 tools; and
- Direct comparisons of GoldSim modelled Deep Creek rainfall flow events with nearby gauged Water Park Creek, with similar catchment size and coastal position, although different land use and aspect.

The rainfall assessment is presented above, and the remaining methods are described in the following section.

A comparison between peak flows generated from the hydrological model XP-RAFTS and the Regional Flood Frequency Estimation (RFFE) method for peak flows was carried out to test whether the two methods produced results that were reasonably consistent with each other. The RFFE method is provided as part of AR&R16 as a means of determining parameters of the peak flow distribution from catchment characteristics and flood data from nearby gauges. In this case, 14 local gauged catchments were utilised to obtain the mean and confidence limits for the comparison. This comparison is presented in Figure 16-51.

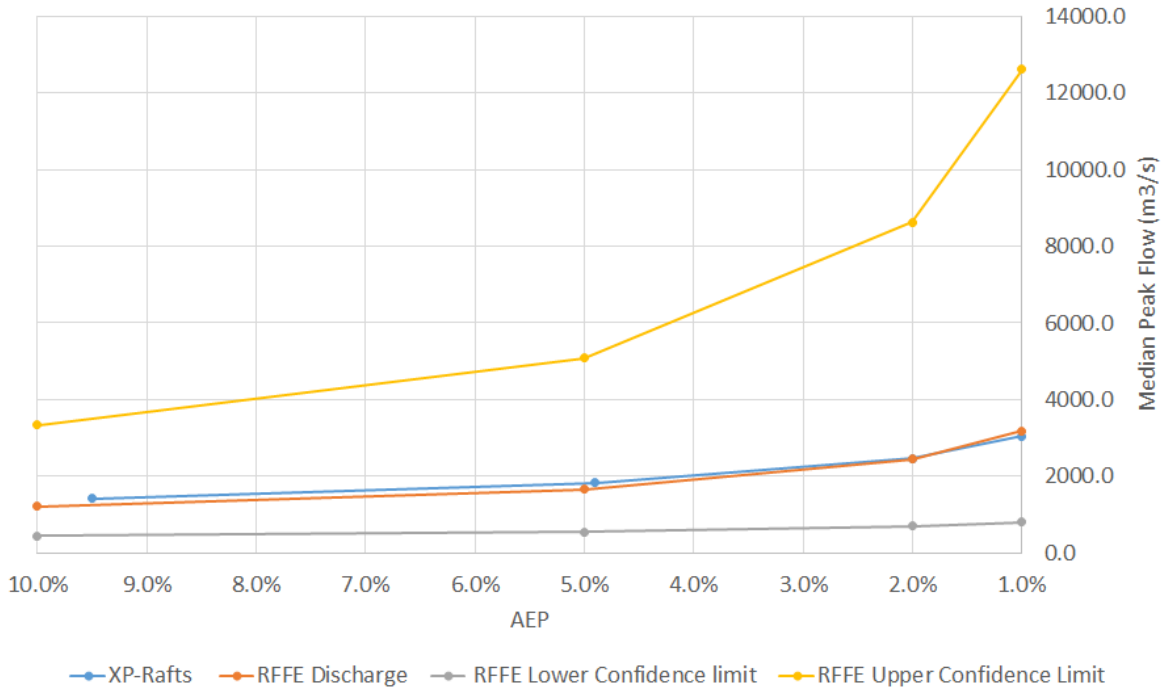


Figure 16-51 Comparison of peak flows of XP-RAFTS and RFFE

It can be seen from Figure 16-51 that results from the two methods are closely correlated, particularly for the smaller AEP events. This correlation provides some confidence that the XP-RAFTS modelling is generally representative of the expected hydrological processes occurring in the catchment.

A comparison of the rainfall and flow rate values for Deep Creek and the adjacent gauged river basin of Water Park Creek was undertaken to confirm the applicability of the regional hydrological parameters used in the hydrological modelling simulations. The details of the two catchments used in the comparison are described in Table 16-43.

Table 16-43 Regional hydrology parameter comparison catchment

Catchment	Area (km^2)	Location (Lat,Long)	Stream Flow Source	Rainfall Data Source
Deep Creek	298	-22.7S, 149.65E	GoldSim realization #101	SILO @ Deep Creek Lat/Long
Water Park Creek	212	-22.85S, 150.65E	Water Park Creek at Byfield, Station 129001A	BoM Daily rainfall data site for station 33008

The rainfall and stream flow data for Deep Creek and Water Park Creek were combined into rainfall event totals. A rainfall event was defined as a sequence of days, one or more, with non-zero daily rainfall totals and non-zero daily stream flow totals, and with one or more subsequent days of zero rainfall. Rainfall event rainfall totals of 10mm or less were excluded as they result in stream flows that are overly sensitive to the existing catchment soil moisture conditions and to pre-storm bursts.

Both sets of flow rate data were divided by the size of each catchment to give a relative result. More than 70 rainfall events where identified using the Deep Creek GoldSim results for realization #101, this realization used daily rainfall data from 1989 to 2006 which roughly corresponds to the Water Park Creek analysed years. The Water Park Creek rainfall and Gauge data was examined for the years; 1980, 1981, 1982, 1989,1990, 1998, 1999 and more than 80 rainfall events were identified.

These years were selected as they represent a reasonable range of high, low and medium rainfall years.

The resulting comparison rainfall event sets are plotted in Figure 16-52 and show that the calculated Deep Creek flow rates give results that correlate with the regional surface water gauging data from Water Park Creek.

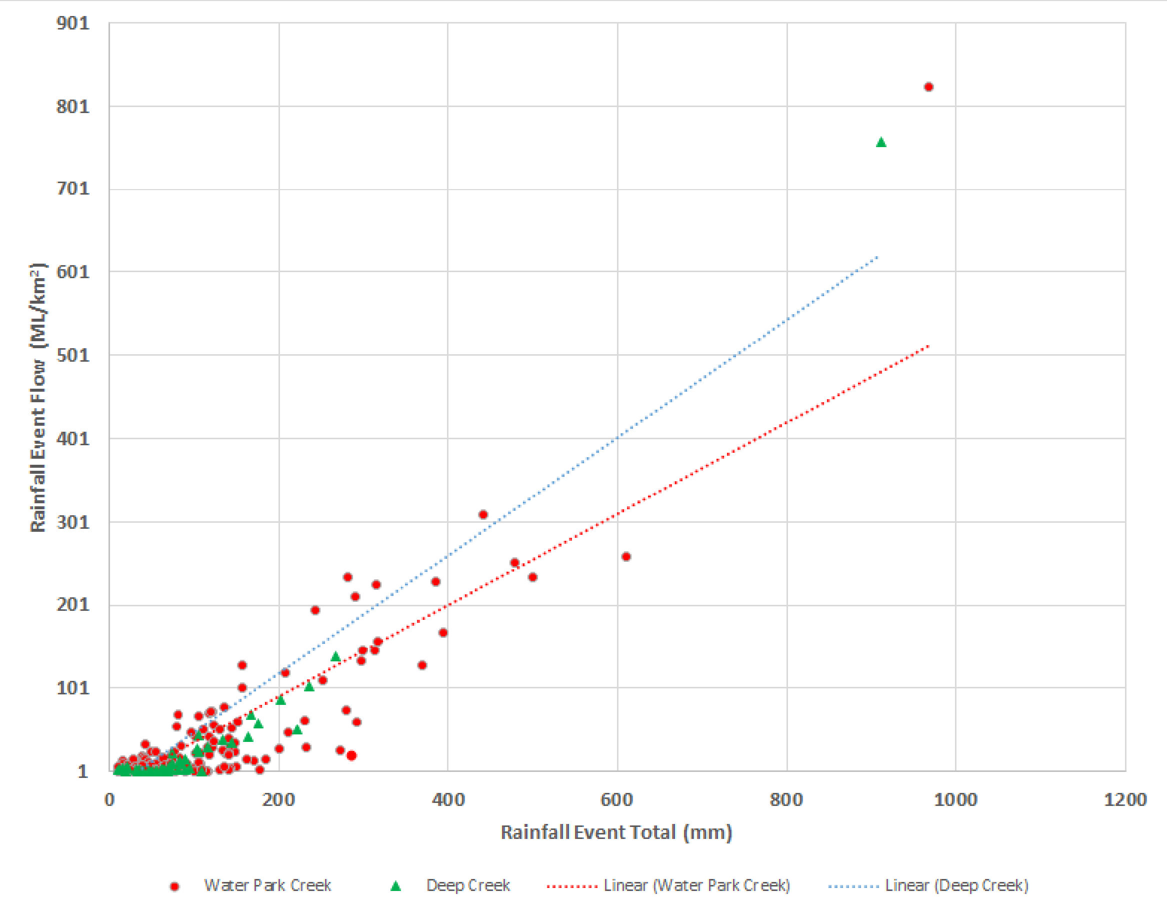


Figure 16-52 Regional rainfall – flow comparison for Water Park Creek and Deep Creek

A sensitivity analysis of the XP-RAFTS hydrological model was carried out to examine the possible outcomes to the flood modelling results if the uncalibrated model calibration parameters are varied. The 24hr critical duration XP-RAFT 100% AEP hydrological model was selected for this analysis. The model has two calibration parameters that are used to adjust the peak flow rate and the overall shape of the resulting hydrographs. The manning's n value for each sub-catchment (selected value: 0.045) and the Storage Coefficient Multiplication Factor Bx value (selected value: 1.0).

The manning's n value describes the relative roughness of the surface of the catchment. For the sensitivity analysis the Manning's n value was varied from 0.025 (short grass) to 0.1 (Dense brush) including the selected value of 0.045 (minor stream flow, high grass, mature field crops). The results are shown in Figure 16-53 and show that the used value of 0.045 is a conservative and reasonable value for Manning's n.

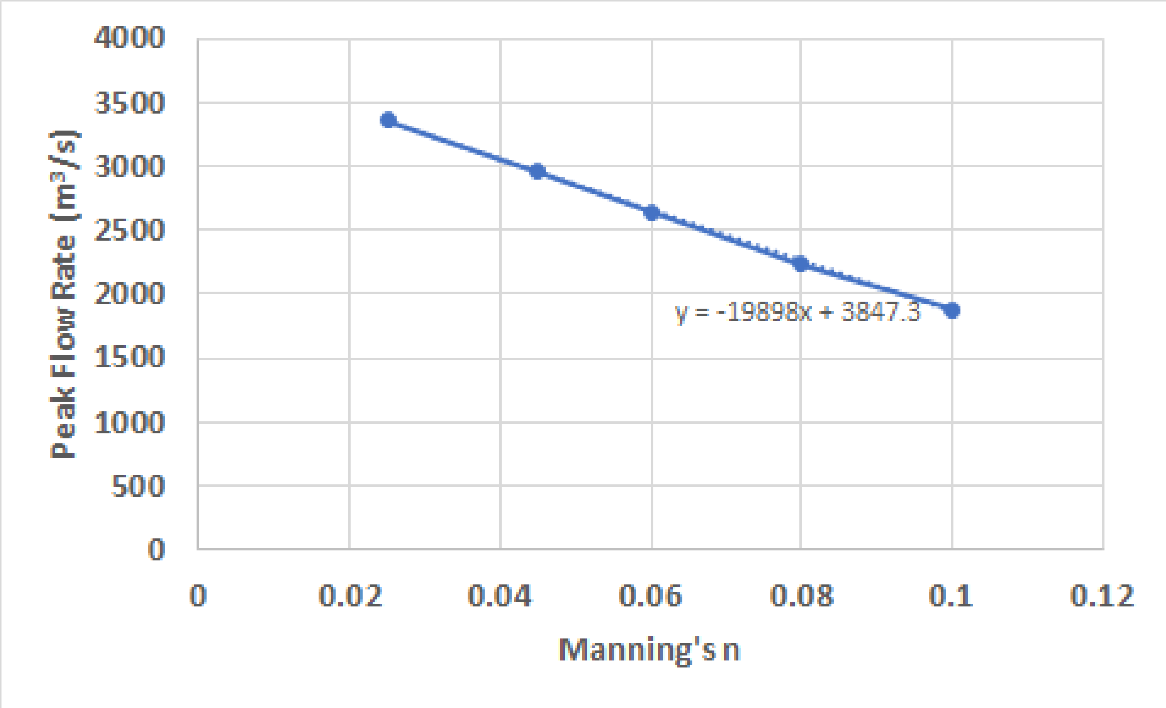


Figure 16-53 XP-RAFTS peak flow sensitivity to Manning's n

During calibration of a gauged catchment the Storage Coefficient Multiplication Factor (BX) may be used to modify the calculated storage time delay coefficient (Bx). The Storage Coefficient Multiplication Factor uniformly modifies all sub-catchment Storage Time Delay Coefficient values previously computed or determined from the default equation. For the sensitivity analysis the Bx value was varied from 0.5 to 2.0. Including the selected value of 1.0. The results are shown in Figure 16-54 and show that the selected value of 1 is a conservative and reasonable value for Bx.

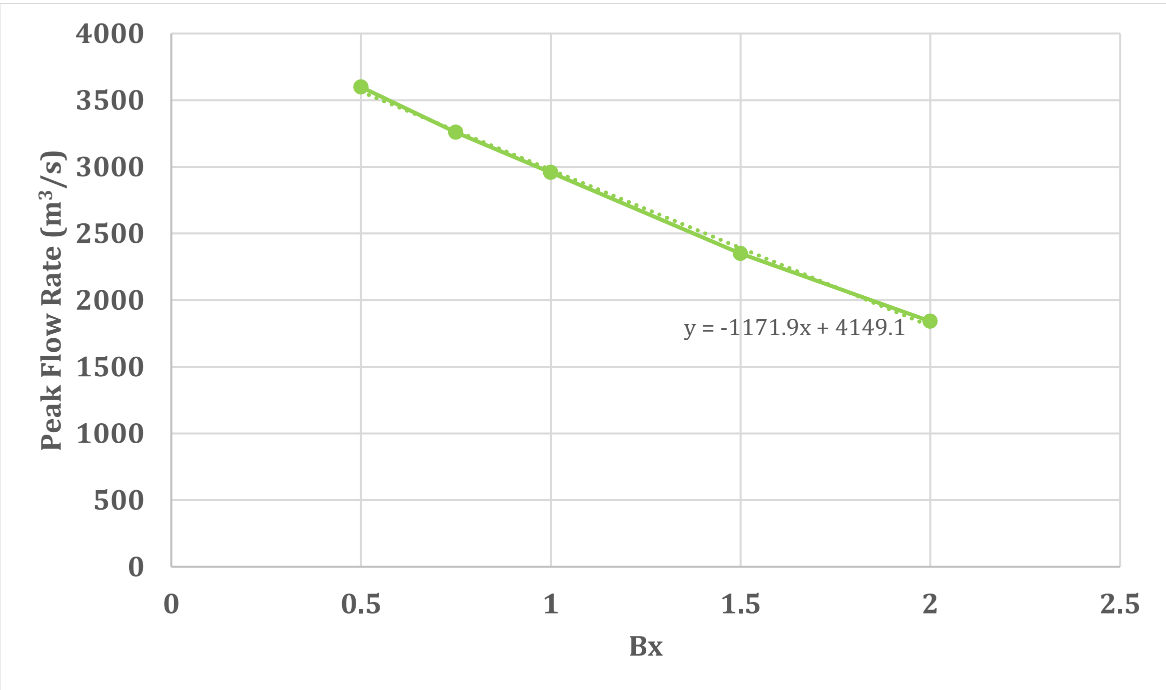


Figure 16-54 XP-RAFTS peak flow sensitivity to the Bx factor

Given that at this stage that the Styx catchment tributaries are ungauged it would be reasonable to use the selected parameters of Manning's n of 0.045 and Bx of 1.0 for the calculation of the XP-RAFTS hydrographs. The selected parameters yield conservative hydrograph peak flows in the upper end of the potential range. These calibration parameters should be re-assessed as the additional gauging data becomes available.

Developed Case Model Build

The developed case model build involved applying the same temporal patterns and design rainfall intensities as the existing case model. Key changes in the developed case model compared to the existing case model include:

- Removing the open pit mine areas from the contributing catchments;
- Applying a higher impervious value to the MIA to simulate the likely increases in the catchment response time caused by topographic changes;
- Diverting the two catchments upstream of Open Cut 1 around the pit;
- Diverting the catchment upstream of Waste Rock Stockpile 1a around and into an environmental dam adjacent to Deep Creek; and
- Applying a lower impervious value to the waste area to simulate the likely decrease in the catchment response time caused by topographic changes.

The updated sub-catchment delineation is shown in Figure 9-54 in Chapter 9. The subcatchments were largely unchanged from the base case.

Baseline Case Results

The base case critical duration storm event peak flows, produced at the confluence of Tooloombah Creek and Deep Creek, and for the 9.5%, 4.9%, 2%, 1% and 0.1% AEP events, are presented in Table 16-44. The corresponding runoff hydrographs are shown in Figure 16-55. The temporal rainfall pattern that generated the median peak flow for the 9.5%, 4.9%, 2%, 1% and 0.1% AEP events has a symmetrical rainfall pattern as evident by the curve shape. Time to peak was in the order of 25 hours.

Table 16-44 Peak flows at the Project area boundary – existing case

Item	9.5% AEP (10 Yr ARI)	4.9% AEP (20 Yr ARI)	2% AEP (50 Yr ARI)	1% AEP (100 Yr ARI)	0.1% AEP (1,000 Yr ARI)
Median Peak Flows (m^3/s) – Existing Case	1,493	1,827	2,440	2,958	5,528
Duration (hr)	24	24	24	24	24

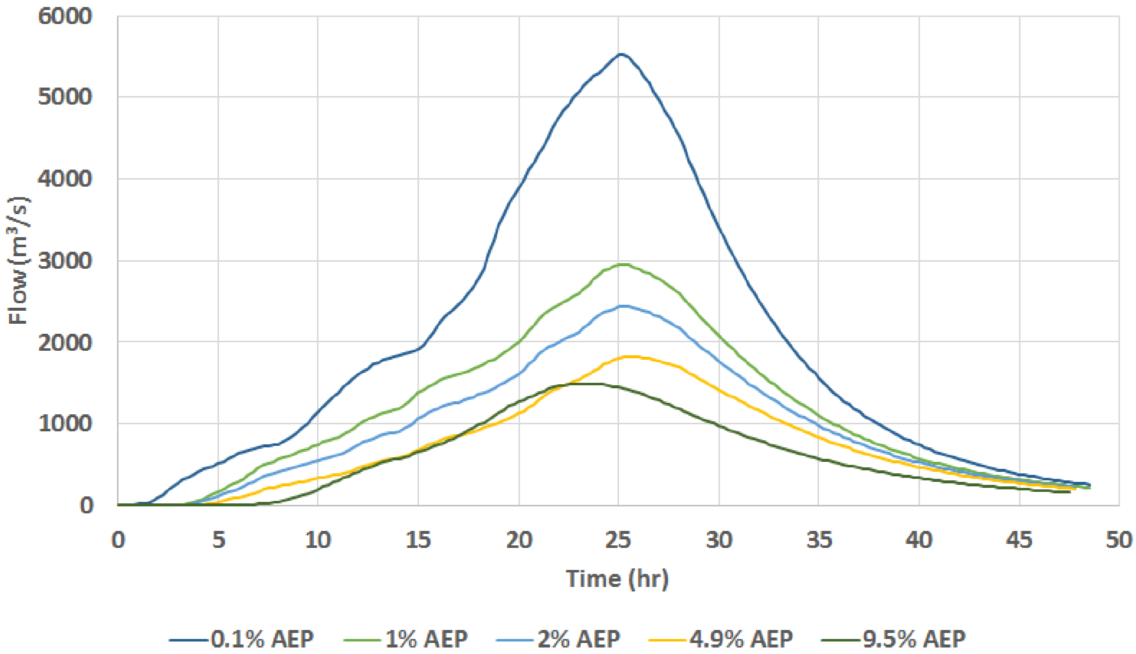


Figure 16-55 Critical storm duration hydrographs – existing case

Developed Case Results

The developed case hydrologic model assumes that the mine is operating at its ultimate configuration; that is, intermediate development cases, or staging, were not considered in this analysis. Thus, the developed case assumed that both the north and south pits were fully mined and no longer contributing catchments within the hydrologic model.

Critical duration peak flows from this model, produced at the confluence of Tooloombah Creek and Deep Creek, are presented in Table 16-45. Both the existing case and the developed case have the same critical storm duration of 24 hrs. The developed case peak flows are lower than existing case peak flows by approximately 1-4% due to the reduction in contributing catchment caused by creating open pit voids – a negligible reduction in the context of the broader catchment.

Table 16-45 Peak flows at the Project area boundary – developed case

Item	9.5% AEP (10 Yr ARI)	4.9% AEP (20 Yr ARI)	2% AEP (50 Yr ARI)	1% AEP (100 Yr ARI)	0.1% AEP (1,000 Yr ARI)
Median Peak Flows (m^3/s) – Existing Case	1,469	1,802	2,407	2,918	5,448
Duration (hr)	24	24	24	24	24

Developed case runoff hydrographs are presented in Figure 16-56. In general, the time to peak runoff was observed to quicken slightly with respect to the existing model. The developed peak median hydrographs demonstrate a small two peak graph, with a faster initial response before a second main peak.

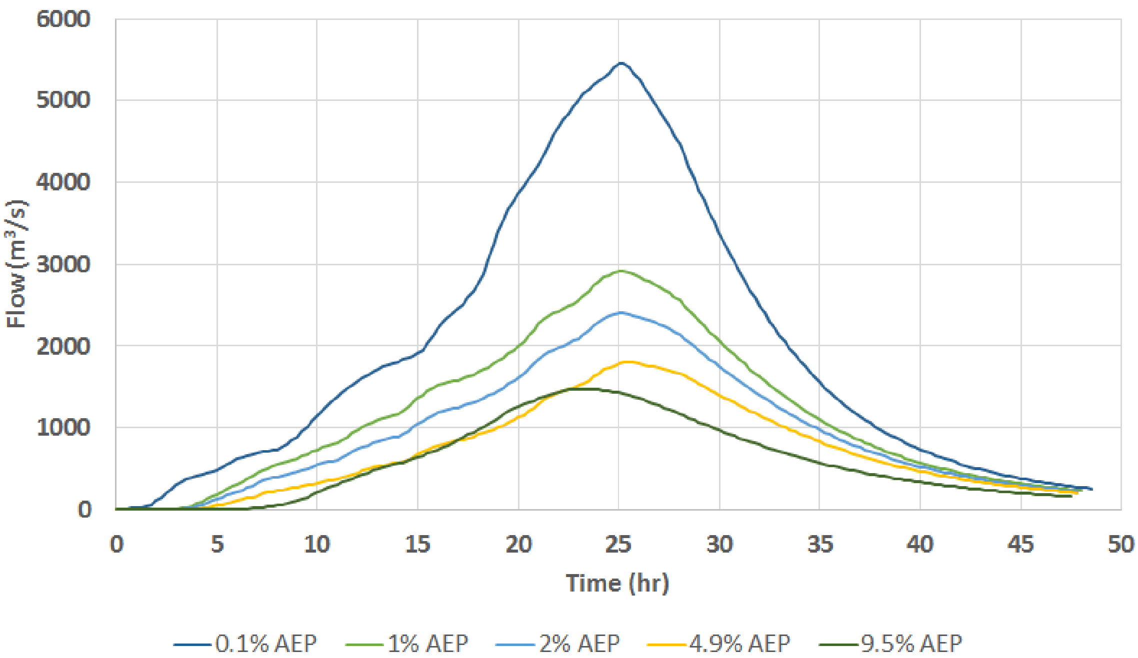


Figure 16-56 Critical storm duration – developed case

It needs to be noted that as the peak flows from hydrologic model are the median of an ensemble of 10 temporal rainfall patterns, the storm hydrograph that corresponds to the existing peak case median flow may not be the same storm pattern that corresponds to the peak developed case median flow.

The biggest impact with regards to flowrate magnitude is at the Deep Creek Bridge location where several catchments are diverted into Deep Creek compared to the existing case. These diversions are unlikely to impact the hydraulic performance of the bridge structure as the peak of the diverted flow is calculated to arrive prior to the main flood peak. This occurs due to the small size of the diverted catchments in comparison to the relatively large catchment upstream of the bridge.

16.10.3.2 Hydraulic Assessment

The aim of the hydraulic assessment is to characterise the Project's impact on localised flood characteristics such as flood depth, extent and velocity, as well as to quantify the immunity of critical infrastructure and the mine pits. Hydrodynamic modelling was used to create thematic maps showing flood extents, water depths and velocities, through input of the flood hydrographs developed by the hydrologic assessment.

Baseline Case Model Build

Hydraulic modelling was conducted using the MIKE21 software package. The program models free surface flows based on two-dimensional implementation of the St. Venant equations for both sub-critical and super-critical flows.

Hydrographs produced by the XP-RAFTS model were adopted as inputs to hydraulic model simulations. Light Detection and Ranging (LiDAR) survey data captured by Vekta on behalf of Yeats Consulting Engineers (date flown 17/06/2011) formed the topographic basis for the flood model.

The 1m-resolution LiDAR dataset was down-sampled to a 10m grid. This grid size ensured numerical stability, provided appropriate definition of the major topographic features (e.g. river channel definition, and resulted in manageable simulation times. Both Tooloombah Creek and Deep Creek were modelled in a single 2D grid. Model dimensions are listed in Table 16-46.

Table 16-46 MIKE21 model dimensions

Item	Description
Grid Cell Size	10 m
Grid Orientation/Rotation	North up (i.e. zero degrees rotation)
Model extent (width x height)	1100 cells x 1520 cells
Model extent (km x km)	11 km x 15.2 km
Model Origin (Lower Left Corner)	769005 m East; 7481505 m North
Map Projection	MGA, Zone 55

The downstream model boundary sits inside the tidally-influenced reach of the Styx River; however, the available tidal plane data were limited, and unable to be reduced to the Australian Height Datum. For this reason, a normal-depth rating curve was developed from the LiDAR and applied at the downstream boundary.

The rating curve sensitivity to changes in parameter values was assessed to determine the accuracy of the rating curve. The LiDAR derived channel section and slope were derived from LiDAR with average data accuracies of ±0.08 m. The cross-section and slope were therefore not included in the sensitivity analysis. The Manning's n value required judgement of the channel conditions and interpretation of literature and were therefore included in the sensitivity analysis. The Manning's 'n' value was altered by ±0.005 to represent the range of values that could reasonably be applied for the channel conditions encountered. The channel roughness sensitivity analysis results for Boundary 1 shows small impact on the results with a maximum water depth difference of approximately 0.25 m relative to the adopted curve for in-channel flows. For Boundary 2 in-channel flows, the water depth difference is within 0.1 m of the adopted curve.

The existing Bruce Highway culverts and bridge infrastructure were modelled in the baseline MIKE21 model (see Figure 16-57 to Figure 16-60). Limited information is available regarding culvert and bridge geometry; as such, Google Earth, Google Streetview and LiDAR elevation values were used to approximate the size of infrastructure. The Deep Creek Bridge was modelled using a pier resistance routine, which allows for the turbulent losses induced by the bridge piers to be modelled at a sub grid scale level. The culvert was represented in the 2D model by lowering the topography to allow water to pass through the embankment. Head losses through the structure were simulated by implementing a locally higher zone of Manning's roughness.

A spatially-distributed roughness map was developed to reflect the variance in resistance to surface flow based on topographic features and vegetation. Land use areas were identified from the high-resolution aerial imagery and ground-truthed during field investigations. The Manning's n values chosen for the model are consistent with literature by Chow 1959 and are summarised in Table 16-47.

Table 16-47 Adopted existing Manning's n roughness values

Land Use	Value
Pasture	0.035
Channel	0.03
Light Brush	0.06
Heavy Brush	0.1

Baseline Case Results

The MIKE21 models were observed to be stable at a 1.0 second time step. Each model was run for a 32 hours of simulation time, which captured the bulk of the flood wave and peak water levels and velocities throughout the model domain. Results were processed to create maps showing depth and velocity maxima. Maps showing the scenarios for the 9.5% AEP and 1% AEP events are shown in Figure 16-57 to Figure 16-60. Maps produced for all modelled scenarios are shown in Figure 9-57 to Figure 9-68 in Chapter 9.

Tooloombah Creek is incised and was not predicted to break out of its banks under any of the modelled scenarios. Deep Creek is less incised. When the bank-full capacity is reached, flow breaks out into defined anabranches before spreading into the broader floodplain. The modelling predicted that the bank-full capacity was in the order of the 2% AEP event. For floods of larger magnitude, water breaks out over the floodplain at low depths and velocities. Breakout flow depths were predicted to be of the order of approximately 0.25 m for the 1% AEP event and approximately 0.75 m in the 0.1% AEP event.

The catchments upstream of proposed Open Cut 1 contribute to widespread flooding at low flow depths due to the site being generally flat and due to the existence of contour bunds which capture and store runoff under current conditions. Flooding across the Open Cut 1 area has depths below 0.25 m and velocities below 0.25 m/s for all the events below the 1% AEP. Both types of flooding behaviour are commonly observed in small coastal creeks in Queensland.

Flood depth and velocity maps show that the proposed pit locations are at risk of flooding under base case conditions due to Open Cut 1 and Open Cut 2 both being located on existing natural drainage features. The presence of several culverts beneath the Bruce Highway between the boundary of Open Cut 1 and Open Cut 2, demonstrates the existence of a minor flow path through the Project site. These culverts were overtopped during events larger than the 9.5% AEP. Deep Creek bridge was overtopped during the 0.1% AEP event, causing widespread breakout flow to pass through the eastern portion of the Project area.

Flood depth and velocities in Deep Creek and Tooloombah Creek for the 9.5% AEP to 1% AEP can generally be summarised as:

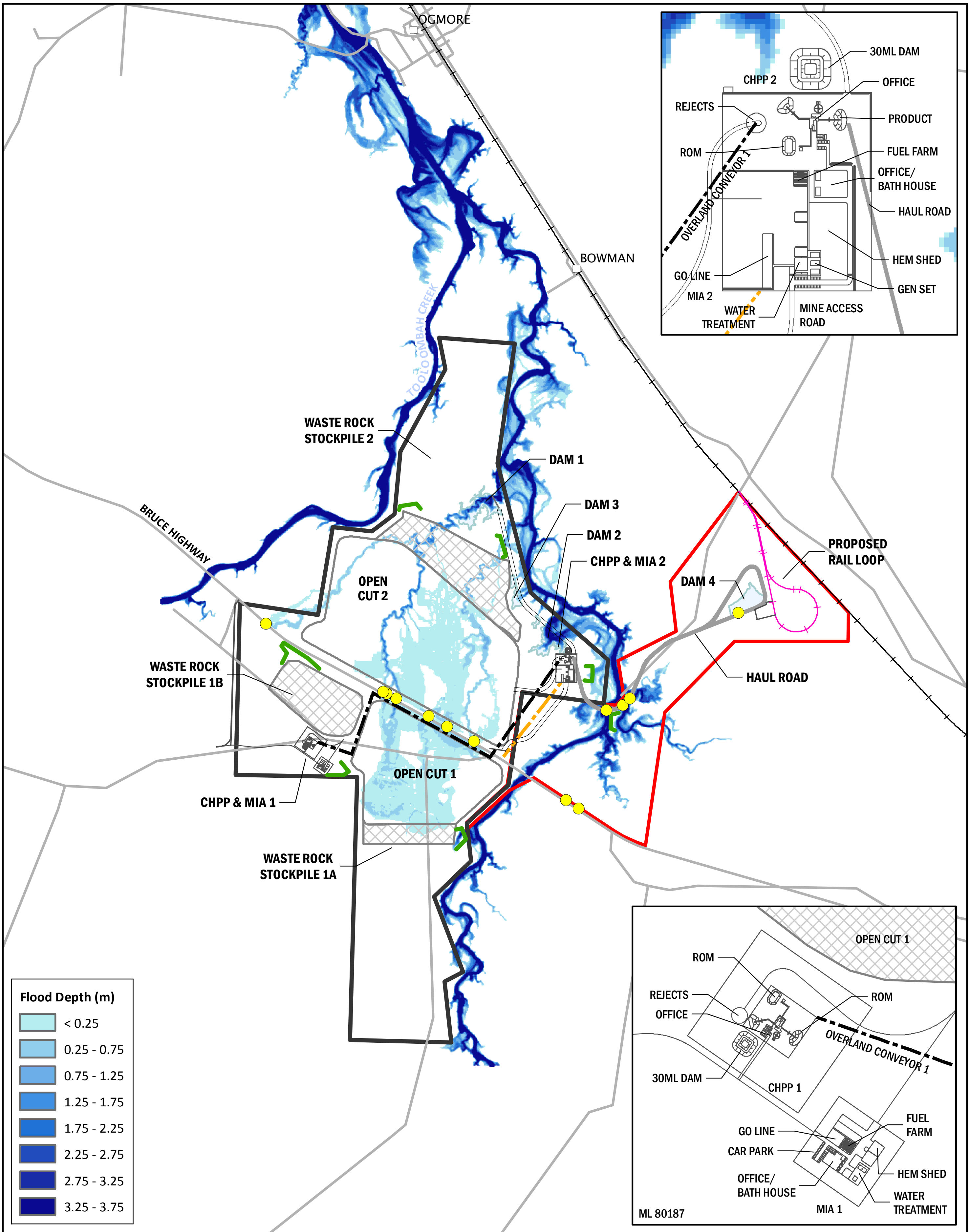
- Deep Creek:
  - In-channel flood depths between 6.5 m and 8.5 m;
  - In-channel flood velocities between 1.5 m/s and 2.0m/s.
- Tooloombah Creek:
  - In-channel flood depths between 6.6 m and 11.7 m;
  - In-channel flood velocities between 1.5 m/s and 2.6 m/s.

Flood depths and velocities in the minor tributary drainage features that traverse the site for the 9.5% -1% AEP events can generally be summarised as:

- 1st order minor tributary:
  - Flood depths between 0.15 m and 0.30 m
  - Flood velocities between 0.3 m/s and 0.5 m/s
- 2nd order minor tributary (main drainage feature in Project area):
  - Flood depths between 1.5 m and 2.4 m
  - Flood velocities between 0.2 m/s and 0.6 m/s.

Flood depths and velocities in Deep Creek, Tooloombah Creek and the minor tributary drainage features that traverse the site for the 0.1% - Probable Maximum Flood (PMF) AEP events can generally be summarised as:

- Deep Creek:
  - In-channel flood depths between 9.0 m and 12.5 m
  - In-channel flood velocities between 2.5 m/s and 3.5 m/s
- Tooloombah Creek:
  - In-channel flood depths between 12 m and 14 m
  - In-channel flood velocities between 3.0 m/s and 4.5m/s
- 1st order minor tributary:
  - Flood depths between 0.35 m and 1.2 m
  - Flood velocities between 0.5 m/s and 1.0 m/s
- 2nd order minor tributary (main drainage feature in Project area):
  - Flood depths between 2.6 m and 3.0 m
  - Flood velocities between 0.8 m/s and1.3 m/s.



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 14/11/18
Drawn: Gayle B.

Legend

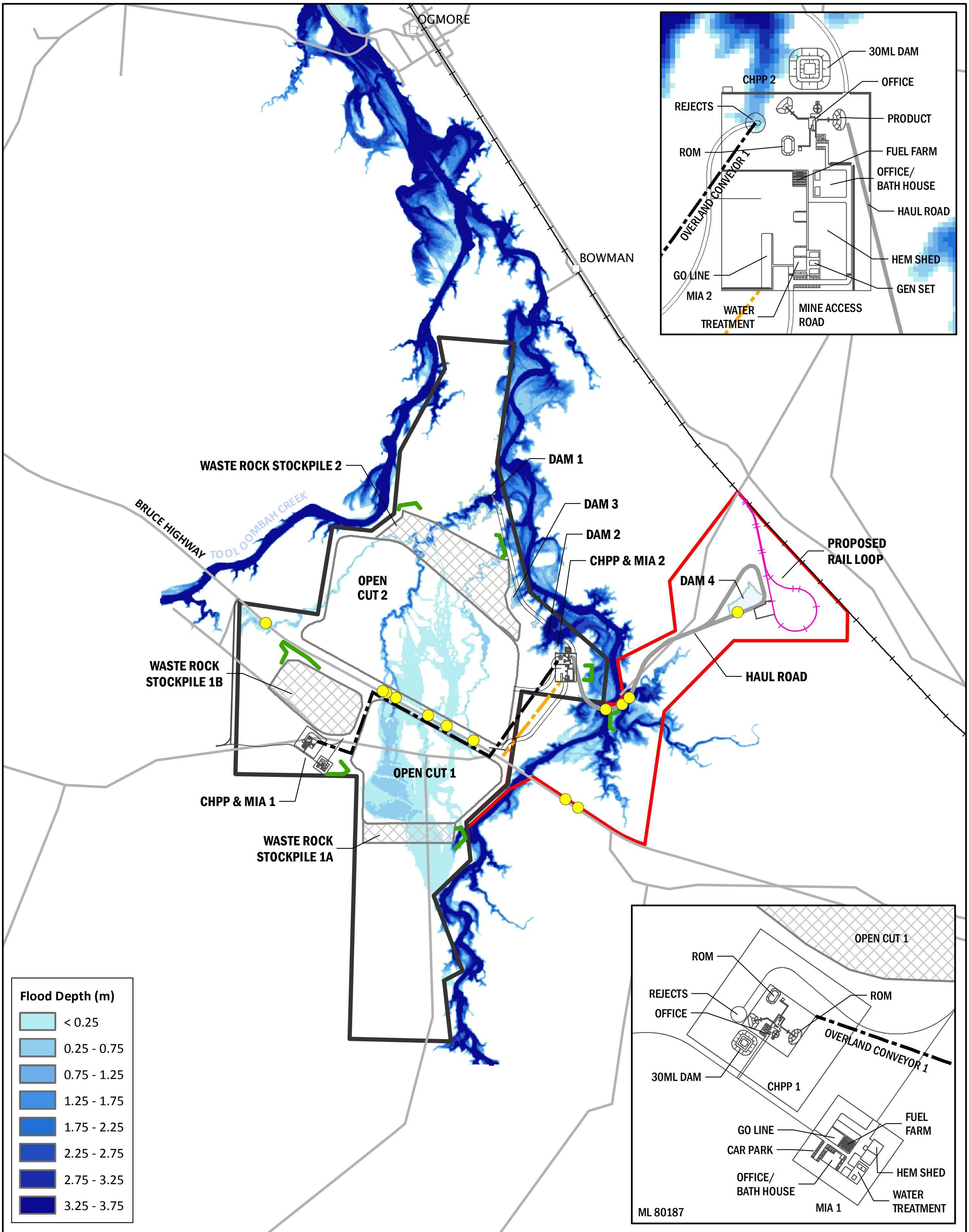
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 16-57
9.5% AEP peak flood depth - existing scenario

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Ex 9p5AEP Depth__9-53 .mxd 11/14/2018



Legend

- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

0 0.5 1 km

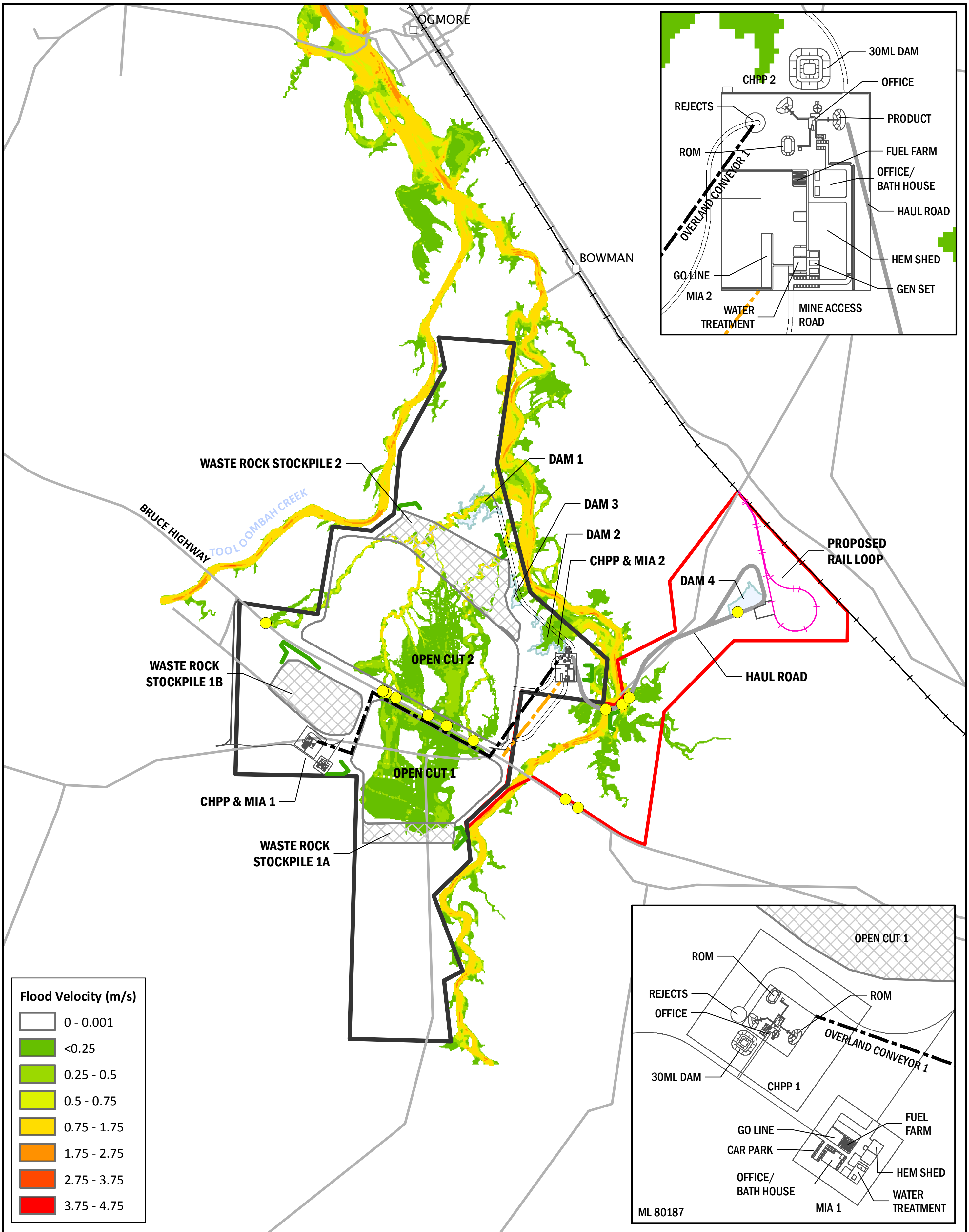
Scale @ A4 1:70,000
Date: 14/11/18
Drawn: Gayle B.

Figure 16-58
1% AEP peak flood depth - existing scenario

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Ex 1AEP Depth__9-56.mxd 11/14/201



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 16-59
9.5% AEP peak flood velocity - existing scenario

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Ex 9p5AEP Vel__9-59.mxd 11/15/2018

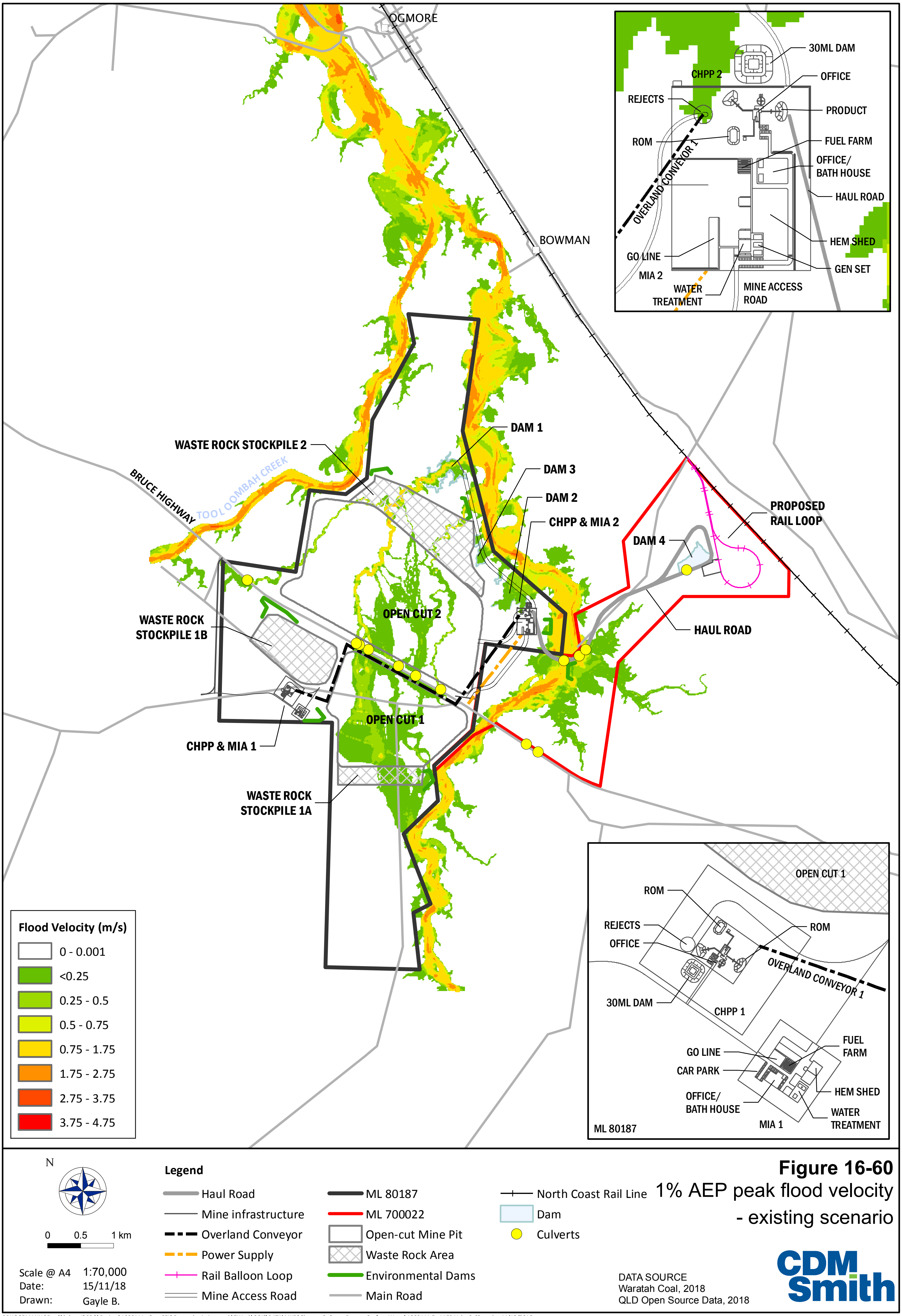


Figure 16-60
1% AEP peak flood velocity - existing scenario

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Developed Case

The developed case model was built by applying the hydrographs (see 'Developed Case Model Build' in Section 16.10.3.2) from the developed case hydrologic model and by making changes to the topographic grid to reflect the 2028 planned expected land form. Key changes (see flooding figures in Chapter 9 – Surface Water, Figure 9-69 to Figure 9-80) in the developed case model topography, compared to the existing case included:

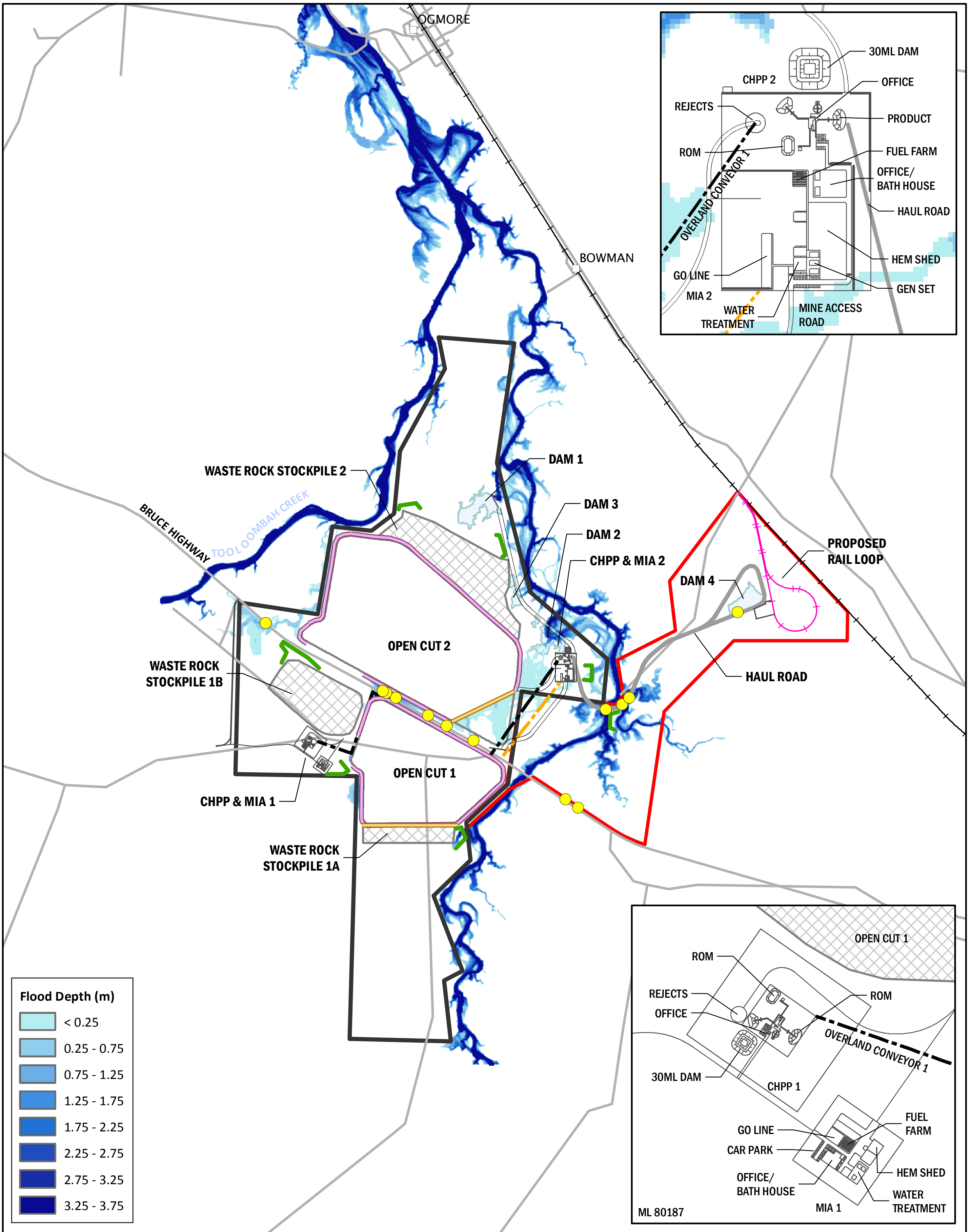
- The addition of a levee along the Open Cut 1 boundary, along the east, west and top of the north boundary of Open Cut 2 to stop breakout flow from passing into the open pit areas;
- The addition of a diversion drain to Open Cut 1 / Waste Rock Stockpile 1a boundary to divert water way from the levee and into Deep Creek;
- The addition of a diversion drain around the west of the Waste Rock Stockpile 1b to direct the water within the upstream catchment into the diversion near the levee;
- The addition of a bund passing across Open Cut 2 at the commencement of mining to the indicative mining extent at 2028;
- The addition of the waste area and MIA environmental dams; and
- The addition of a low-level, three cellbox culvert crossing of Deep Creek and its two tributaries to allow for access to the TLF.

A key assumption in the developed case model for the bund is that Open Cut 2 has advanced to the 2028 mining sequence. This bund will be relocated into the worked area of Open Cut 2 to facilitate the mining sequence from 2028 onwards. The TLF culvert crossing was constructed as a 1D Mike model which was coupled to the MIKE21 model using MIKEFLOOD. This allowed a better representation of the culverts as the large size of this structure precluded its implementation in the 2D domain.

Developed Case Results

Results were processed to create maps showing depth and velocity maxima. Maps showing the scenarios for the 9.5% AEP and 1% AEP events are shown in Figure 16-61 to Figure 16-64. Maps produced for all modelled scenarios are shown in Figure 9-69 to Figure 9-79 in Chapter 9.

Afflux is defined as the change in water levels caused by a change (usually as a result of filling, excavation, or construction of a structure within the floodplain). It can be either positive (higher levels as a result of a change) or negative (lower levels as a results of a change). Afflux maps illustrating the expected changes to peak water levels as a result of the Project for the 9.5% AEP and 1% AEP events are shown in Figure 16-65 and Figure 16-66. Maps for all six flood scenarios are shown in Figure 9-81 to Figure 9-86 in Chapter 9.



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

Haul Road
Mine infrastructure
Overland Conveyor
Power Supply
Rail Balloon Loop
Mine Access Road
Bund
Levee
ML 80187
ML 700022
Open-cut Mine Pit
Waste Rock Area
Environmental Dams
Main Road
North Coast Rail Line
Dam
Culverts

Figure 16-61
9.5% AEP peak flood depth - developed scenario

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Dev 9p5AEP Depth__9-65.mxd 11/15/2018

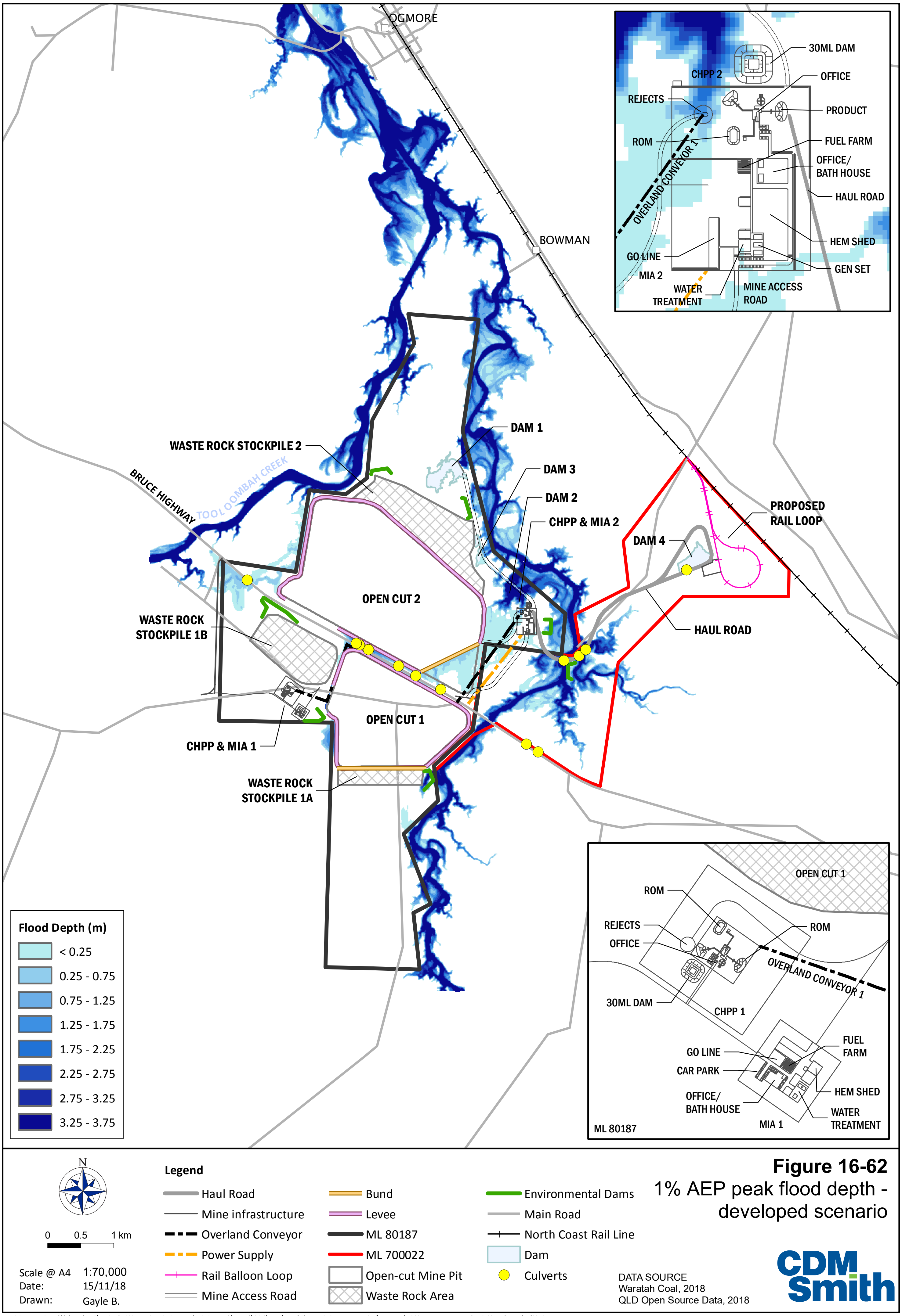
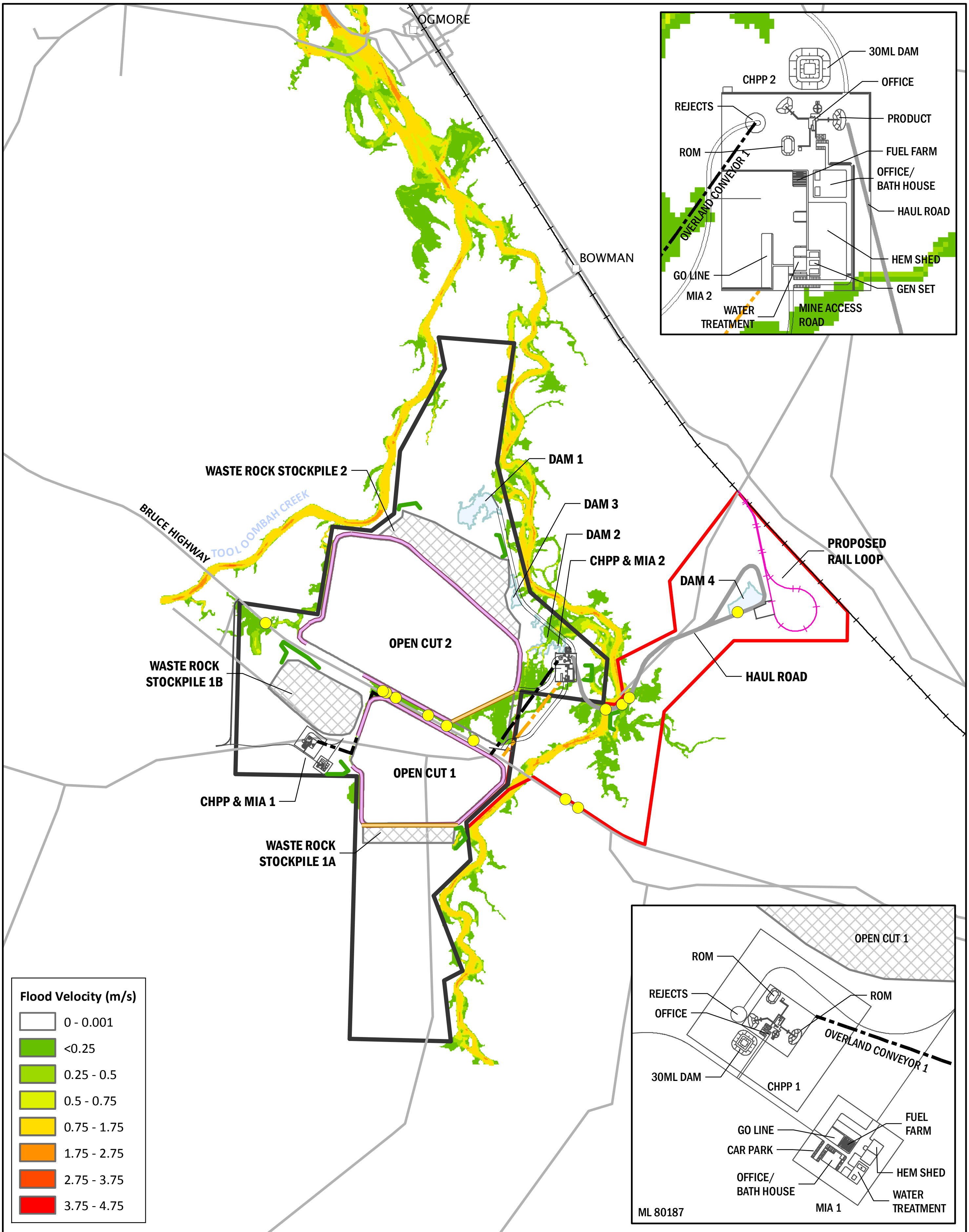


Figure 16-62
1% AEP peak flood depth - developed scenario

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Dev 1AEP Depth__9-68.mxd 11/15/2018



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- Bund
- Levee
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 16-63
9.5% AEP peak flood velocity - developed scenario

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Dev 9p5AEP Vel__9-71.mxd 11/15/2018

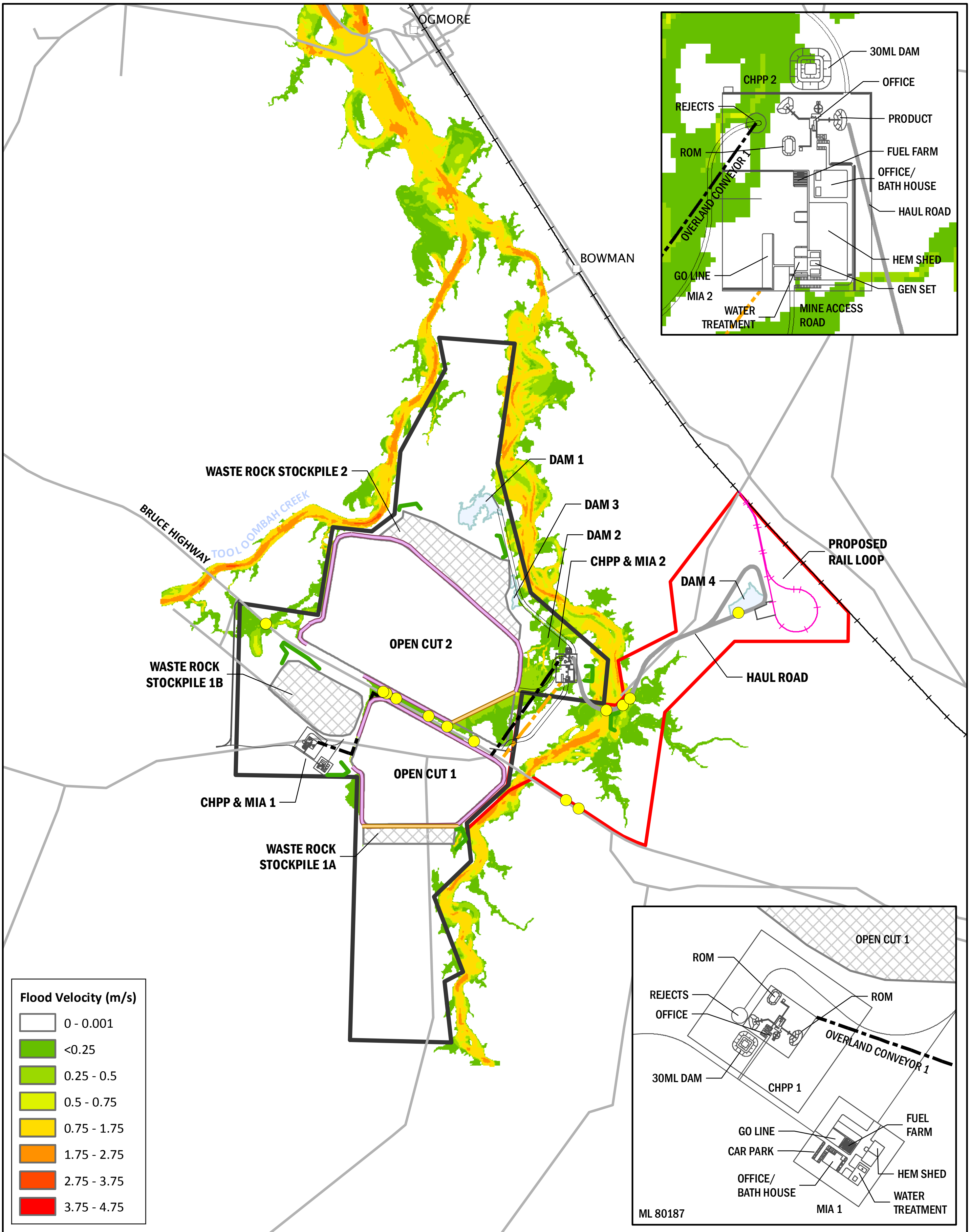


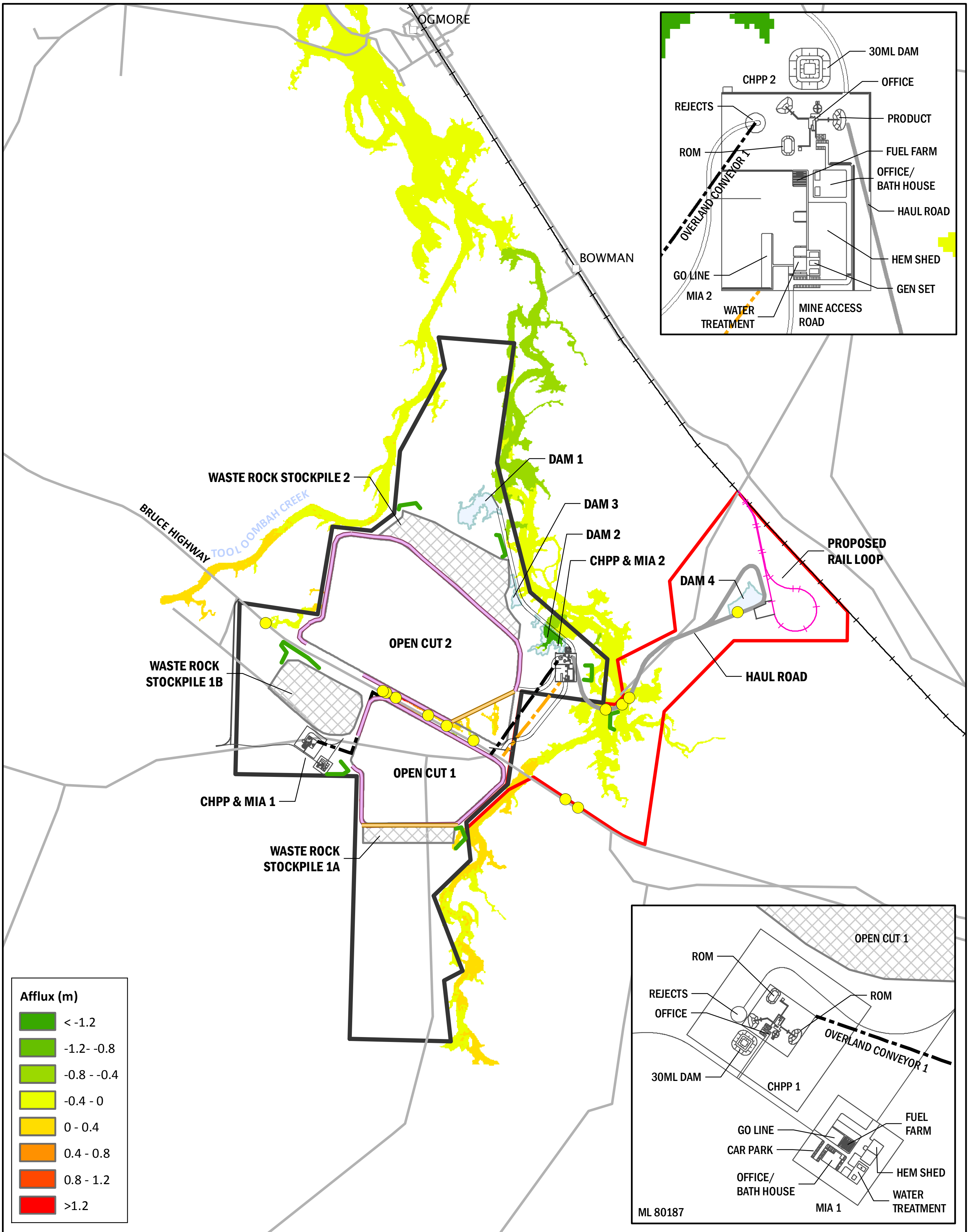
Figure 16-64
1% AEP peak flood velocity - developed scenario

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Dev 1AEP Vel__9-74.mxd 11/15/2018



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

Haul Road	Bund	Environmental Dams
Mine infrastructure	Levee	Main Road
Overland Conveyor	ML 80187	North Coast Rail Line
Power Supply	ML 700022	Dam
Rail Balloon Loop	Open-cut Mine Pit	Culverts
Mine Access Road	Waste Rock Area	

Figure 16-65
9.5% AEP afflux

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 9p5 Afflux__9-77.mxd 11/15/2018

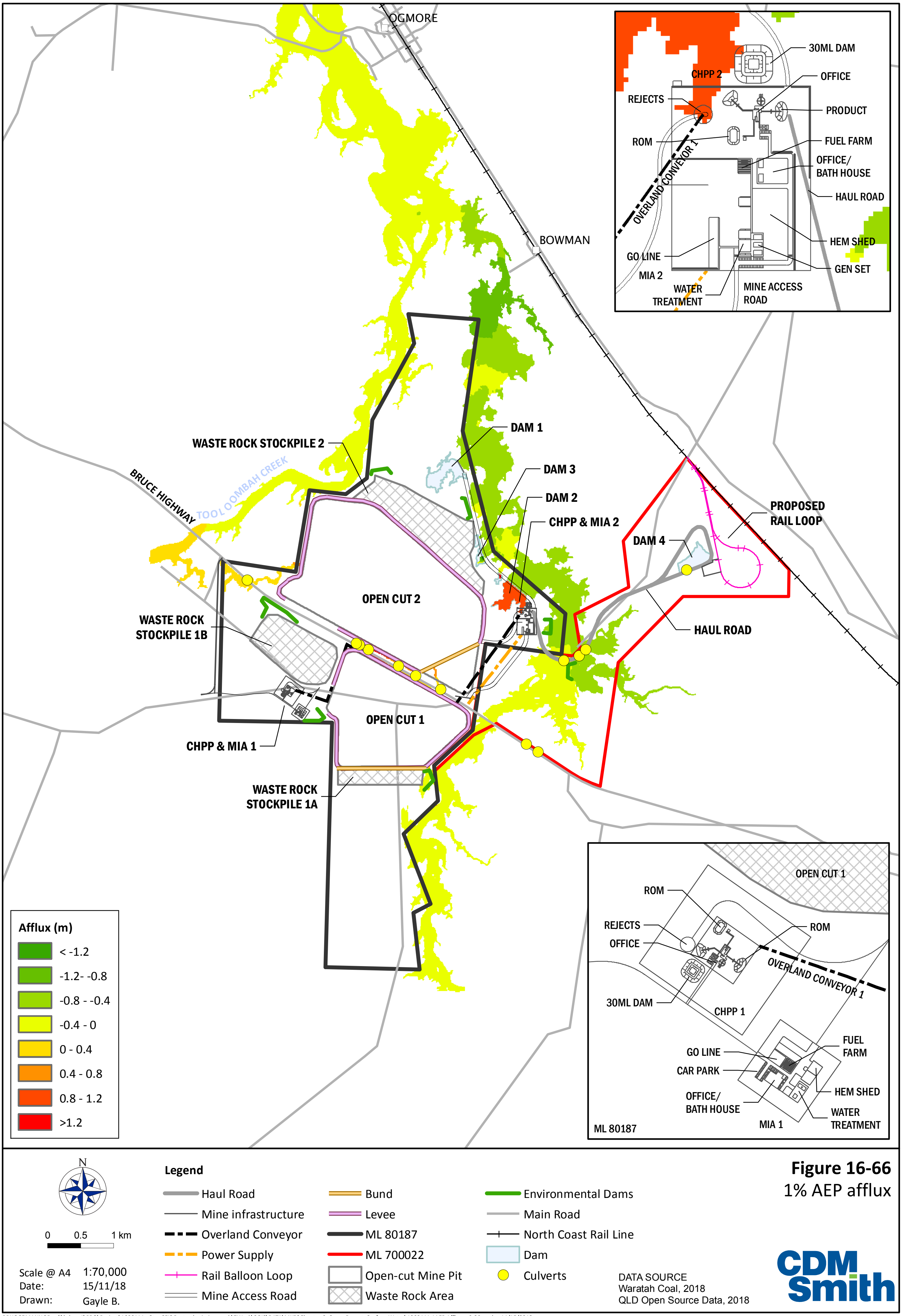


Figure 16-66
1% AEP afflux

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 1AEP Afflux__9-80.mxd 11/15/2018

Discussion of Results

Comparison of Flood Impacts

The existing case and developed case peak water depths, peak water levels and velocities were extracted from the model results at 12 key locations for comparison. The selected key locations are shown in Table 16-48 and depicted in Figure 16-67. The results are shown in Table 16-49. Afflux maps for the 9.5% AEP and 1% AEP events are shown in Figure 16-65 and Figure 16-66. Maps for all six flood scenarios are shown in Chapter 9 – Surface Water, Figure 9-81 to Figure 9-86.

Table 16-48 Selected Key Location Details

Location	Longitude	Latitude	Surface Elevation (m AHD)
1-Conveyor	149.655942	-22.705865	30.50
2-Haul Road Culvert 1	149.686984	-22.705121	21.77
3-Haul Road Culvert 2	149.684908	-22.705718	26.42
4- Haul Road Culvert 3	149.688181	-22.703543	25.58
5-Upstream Dam1	149.663625	-22.681432	20.37
6-1st order Deep Creek tributary	149.685178	-22.709398	24.31
7- Deep Creek Bridge	149.674064	-22.714533	26.55
8- P1DD-1 outlet	149.664627	-22.723608	34.60
9- P3DD outlet	149.642601	-22.694613	30.25
10- South Levee	149.665164	-22.720689	35.55
11-Styx River	149.661623	-22.639043	4.84
12- Tooloombah Creek Bridge	149.629877	-22.689383	19.04

Table 16-49 Peak water depths and velocities at selected key locations

Design storm event	Location	Peak water depth (m)		afflux (m)	Peak water levels (m AHD)		Peak water velocity (m/s)	
		Existing Case	Developed Case		Existing Case	Developed Case	Existing Case	Developed Case
9.5% AEP 24 hr duration	1-Conveyor	1.4	2.7	1.3	31.9	33.2	0.4	0.1
	2-Haul Road Culvert 1	5.7	5.5	-0.2	27.5	27.2	0.8	0.2
	3-Haul Road Culvert 2	5.3	5.2	-0.1	31.8	31.6	0.9	1.1
	4- Haul Road Culvert 3	3.2	3.0	-0.2	28.8	28.5	0.3	0.3
	5-Upstream Dam1	1.8	0.0	-1.8	22.2	20.4	0.9	0.0
	6-1st order Deep Creek tributary	5.0	4.9	-0.1	29.3	29.2	0.3	0.3
	7- Deep Creek Bridge	6.0	6.0	0.0	32.5	32.5	1.5	1.6
	8- P1DD-1 outlet	0.3	0.4	0.1	35.0	35.0	0.0	0.0
	9- P3DD outlet	0.7	0.6	0.1	30.9	30.9	0.2	0.2
	10- South Levee	0.0	0.0	0.0	35.6	35.6	0.0	0.0
	11-Styx River	9.4	9.2	-0.2	14.2	14.1	2.0	1.9
	12- Tooloombah Creek Bridge	5.9	5.9	0.0	25.0	25.0	1.2	1.3
4.9% AEP 24 hr duration	1-Conveyor	1.4	2.8	1.4	31.9	33.3	0.4	0.0
	2-Haul Road Culvert 1	5.9	5.7	-0.2	27.6	27.5	0.7	0.2
	3-Haul Road Culvert 2	5.4	5.4	0.0	31.8	31.9	0.9	1.2

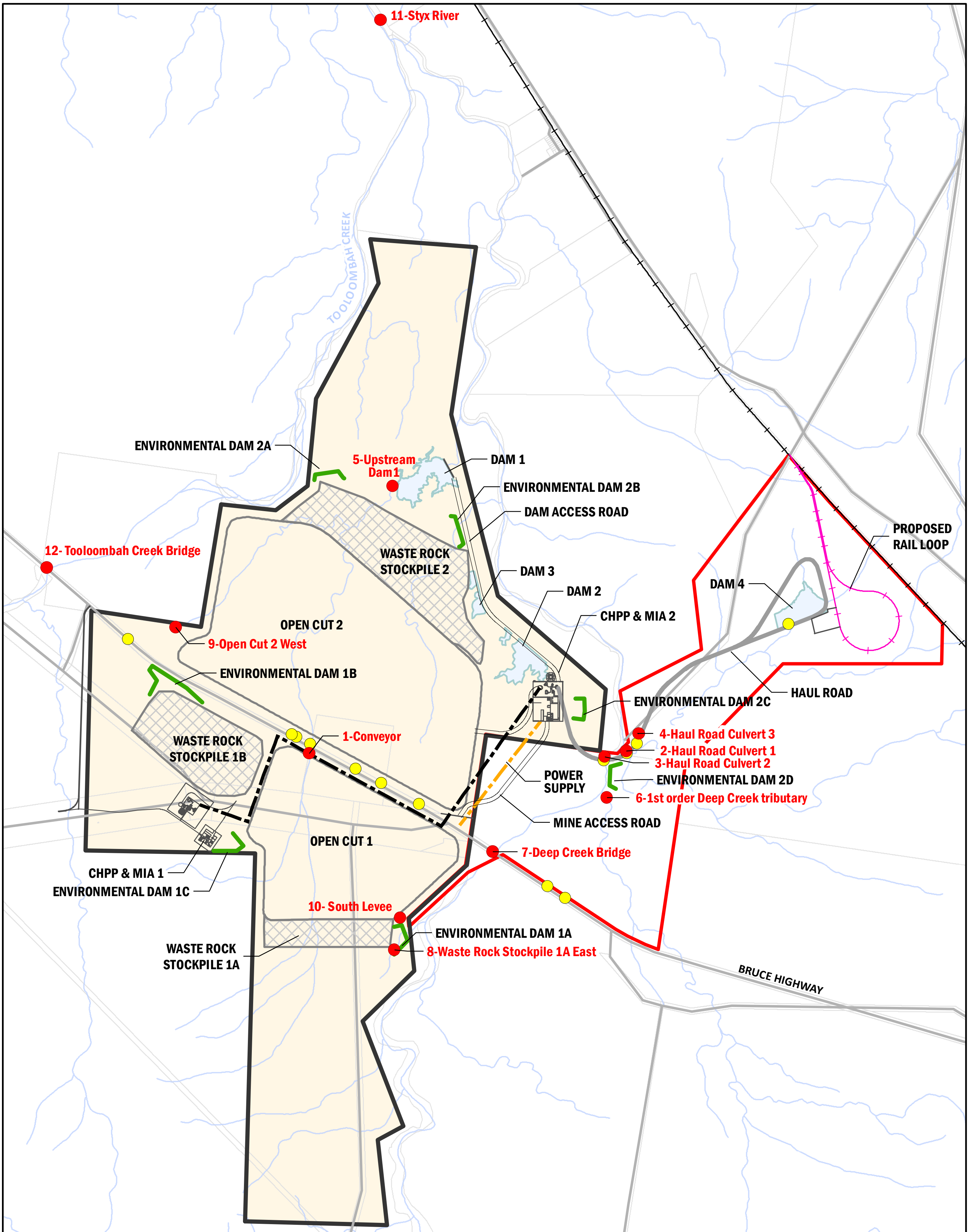
Design storm event	Location	Peak water depth (m)		afflux (m)	Peak water levels (m AHD)		Peak water velocity (m/s)	
		Existing Case	Developed Case		Existing Case	Developed Case	Existing Case	Developed Case
	4- Haul Road Culvert 3	3.3	3.2	-0.1	28.9	28.8	0.2	0.3
	5-Upstream Dam1	2.0	0.0	0.0	22.3	20.4	0.8	0.0
	6-1st order Deep Creek tributary	5.0	5.1	0.1	29.3	29.5	0.3	0.3
	7- Deep Creek Bridge	6.0	6.3	0.3	32.5	32.8	1.6	1.7
	8- P1DD-1 outlet	0.4	0.2	0.2	35.0	34.8	0.0	0.0
	9- P3DD outlet	0.7	0.7	0.0	31.0	30.9	0.2	0.2
	10- South Levee	0.0	0.0	0.0	35.6	35.6	0.0	0.0
	11-Styx River	9.5	9.5	0.0	14.3	14.3	2.0	2.1
	12- Tooloombah Creek Bridge	5.9	6.8	0.9	24.9	25.8	1.2	1.3
2% AEP 24 hr duration	1-Conveyor	1.5	2.9	1.4	32.0	33.4	0.4	0.2
	2-Haul Road Culvert 1	6.4	6.1	-0.3	28.2	27.9	0.8	0.2
	3-Haul Road Culvert 2	5.9	5.8	-0.1	32.3	32.2	1.0	1.2
	4-Haul Road Culvert 3	3.9	3.6	-0.3	29.4	29.2	0.4	0.3
	5-Upstream Dam1	2.5	0.0	0.0	22.9	20.4	0.9	0.0
	6-1st order Deep Creek tributary	5.5	5.5	0.0	29.8	29.8	0.4	0.3
	7- Deep Creek Bridge	6.8	6.8	0.0	33.4	33.4	1.9	2.0
	8- P1DD-1 outlet	0.7	0.7	0.0	35.3	35.3	0.0	0.1
	9- P3DD outlet	0.8	0.7	-0.1	31.1	31.0	0.2	0.2
	10- South Levee	0.1	0.0	0.0	35.6	35.6	0.0	0.0
	11-Styx River	10.2	10.0	-0.2	15.0	14.8	2.2	2.2
	12- Tooloombah Creek Bridge	7.9	7.9	0.0	26.9	27.0	1.3	1.4
1% AEP 24 hr duration	1-Conveyor	1.3	3.0	1.7	31.8	33.5	0.4	0.1
	2-Haul Road Culvert 1	6.8	6.4	-0.4	28.6	28.2	0.6	0.2
	3-Haul Road Culvert 2	6.3	6.0	-0.3	32.7	32.4	0.9	1.3
	4- Haul Road Culvert 3	4.3	3.9	-0.4	29.9	29.5	0.2	0.3
	5-Upstream Dam1	2.8	0.0	-2.8	23.2	20.4	0.9	0.0
	6-1st order Deep Creek tributary	5.9	5.7	-0.2	30.2	30.0	0.3	0.4
	7- Deep Creek Bridge	7.2	7.2	0.0	33.8	33.7	2.1	2.1
	8- P1DD-1 outlet	1.2	1.1	-0.1	35.8	35.7	0.0	0.2
	9- P3DD outlet	0.5	0.7	0.2	30.7	31.0	0.1	0.2
	10- South Levee	0.1	0.2	0.1	35.6	35.8	0.4	0.1
	11-Styx River	10.6	10.3	-0.3	15.5	15.2	2.2	2.2
	12- Tooloombah Creek Bridge	8.7	8.7	0.0	27.8	27.8	1.4	1.5
0.1% AEP	1-Conveyor	2.0	3.2	1.2	32.5	33.7	0.8	0.3

Design storm event	Location	Peak water depth (m)		afflux (m)	Peak water levels (m AHD)		Peak water velocity (m/s)	
		Existing Case	Developed Case		Existing Case	Developed Case	Existing Case	Developed Case
24 hr duration	2-Haul Road Culvert 1	7.4	7.5	0.1	29.1	29.2	0.8	0.4
	3-Haul Road Culvert 2	6.8	6.9	0.1	33.2	33.3	1.0	1.2
	4- Haul Road Culvert 3	4.9	5.0	0.1	30.4	30.5	0.4	0.4
	5-Upstream Dam1	4.2	3.0	-1.2	23.6	23.3	1.0	0.1
	6-1st order Deep Creek tributary	6.4	6.5	0.1	30.7	30.8	0.5	0.4
	7- Deep Creek Bridge	8.0	8.4	0.4	34.5	34.9	2.4	2.6
	8- P1DD-1 outlet	1.9	2.3	0.4	36.5	36.9	0.4	1.2
	9- P3DD outlet	0.9	0.8	-0.1	31.2	31.1	0.3	0.2
	10- South Levee	0.9	1.4	0.5	36.43	36.9	1.2	0.4
	11-Styx River	11.7	11.6	-0.1	16.4	16.4	2.3	2.3
	12- Tooloombah Creek Bridge	10.9	11.5	0.6	29.9	30.5	1.6	1.9
PMF 24 hr duration	1-Conveyor	2.6	3.2	0.4	32.1	33.7	1.2	0.3
	2-Haul Road Culvert 1	8.3	8.2	-0.1	30.1	30.0	0.9	0.4
	3-Haul Road Culvert 2	7.7	7.6	-0.1	34.1	34.0	1.0	1.5
	4- Haul Road Culvert 3	5.8	5.7	-0.1	31.4	31.3	0.6	0.6
	5-Upstream Dam1	6.2	6.8	0.6	26.6	27.2	1.3	0.7
	6-1st order Deep Creek tributary	7.2	7.2	0.0	31.5	31.5	0.5	0.6
	7- Deep Creek Bridge	8.6	9.0	0.6	35.2	35.6	2.5	2.8
	8- P1DD-1 outlet	2.6	3.1	0.5	37.2	37.7	0.9	1.9
	9- P3DD outlet	1.4	1.4	-0.0	31.4	31.6	0.5	0.5
	10- South Levee	1.3	2.2	0.9	36.8	37.8	1.8	0.7
	11-Styx River	13.9	13.0	-0.9	18.7	17.9	2.5	2.5
	12- Tooloombah Creek Bridge	14.1	14.1	0.0	33.1	33.1	2.2	2.3

Flooding of Pits and Subsequent Levee Heights

The developed case flood maps demonstrate no flooding of the open pit areas for up to and including the 0.1% AEP event, due to the inclusion of levees and the raising of the access road (refer to developed flood figures in Chapter 9). Open Cut 1 and Open Cut 2 both have Probable Maximum Flood (PMF) immunity with the inclusion of levees.

The levees and localised raising of road embankments are situated in areas where breakout flows and backwater effects were predicted to occur during extreme flood events (i.e. above 1% AEP). The levee along the Open Cut 1 boundary is not overtopped during any scenario. To achieve this, the levee is required to vary in height from 1 m to 3 m above natural ground level, with an estimated total fill quantity of 20,000 m^3 to achieve 0.1% AEP immunity.



N

0 0.5 1 km

Scale @ A4 1:50,000
Date: 15/11/18
Drawn: Gayle B.

Legend

- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Cadastral boundary
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Watercourse
- Dam
- Key Locations
- Culverts

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

Figure 16-67
Selected key locations

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Key Locations__9-83.mxd 11/15/2018

To achieve PMF immunity for Open Cut 1 a levee height of 2.6 m to 4.0 m above natural ground level would be required, with an estimated total fill quantity of 45,000 m^3. A levee of height 1.8 m will be required along the eastern boundary of Open Cut 2 to prevent the breakout flow from Deep Creek inundating the pit area.

The isolation of the open pits from the available floodplain has an impact on the peak flood depths within Tooloombah and Deep Creek. As the developed case assumes a 19 year planned mining scenario - flow within the tributaries located within Open Cut 1 and Open Cut 2 are completely cut-off in the model. This leads to lower depths and velocities within tributaries located downstream of the pits. The downstream end of the 2nd order minor tributary that runs through Open Pit 1 and Open Cut 2 now reports to Dam 1, bunding water below 36.4 m AHD into the local contours of the area.

This results in a decrease in the peak depths within Deep Creek and Tooloombah Creek by 0.07 m and 0.03 m, respectively. The decrease is considered minor and will unlikely affect the aquatic ecology EVs.

Flooding of Dam 1 access road

The Dam 1 access road links the MIA and CHPP 2 with Dam 1. The Dam 1 access road is at an elevation that prevents backwater inundation from Deep Creek. A corresponding fill volume of approximately 250 m^3 would be required. Filling in these backwater locations results in an afflux of 1.8 m during the 9.5% AEP event along the road alignment near Waste Rock Stockpile 2.

Diversion Drains

The two diversion drains cause localised higher depths and velocities within Tooloombah and Deep Creek. This causes localised increases in peak flood depths at the diversion drain outlet. The diversion of Open Cut 1 upstream catchment to Deep Creek results in an increase in peak depths and velocities. Measured at Deep Creek Bridge, an increase in depth of 0.38 m was predicted for the 0.1% AEP event.

Overall, the impact of the two diversion drains is considered minor. Although they cause localised increases in flood depths and velocities, changes are limited to the immediate area and do not propagate any great distance upstream or downstream.

Flooding to Critical Infrastructure

MIA and CHPP 2 are located within the floodplain of Deep Creek and have been represented in the model by a raised area corresponding to the fill pad upon which this infrastructure will sit. The pad elevation of 31.5 m AHD was selected to ensure that infrastructure is not inundated under any scenarios up to the 0.1% AEP event. The pad would be inundated under the PMF event, as indicated in Figure 9-74 in Chapter 9. In general, the addition of a fill pad to the flood plain was found to cause a water level afflux of up to 0.6 m in the immediate area, and a decrease in peak flood velocity of approximately 0.67 m/s.

The location of MIA and CHPP 1 is not affected by flooding, as it is located at the top of a ridge, and the nearby CHPP environmental dam drains away from this infrastructure, with the result that even if the dam is overtopped, the infrastructure areas remain unaffected.

Flooding to Hazardous Dams

Flood modelling confirms that all environment dams can contain the surface runoff generated by the 9.5% AEP event without overtopping.

Flood Impact of Conveyor

Transport of ROM coal from Open Cut 1 to the product coal stockpiles located on the eastern side of the Bruce Highway via a conveyor under the Bruce Highway via a new culvert arrangement was assessed for hydrological and flood impacts. As the conveyor will not be required until 2028 at the earliest, the design of the culvert and conveyor arrangement has not been finalised; however, an indicative conveyor culvert design is shown in Figure 16-13. The final location of the culvert will be determined in consultation with the DTMR.

The conveyor was originally proposed to be located under the existing Deep Creek road bridge; however, because of concerns regarding potential impacts to water quality during periods of flood, the conveyor has been repositioned away from Deep Creek and the Deep Creek flood inundation areas. Final design of the culvert for the conveyor will be undertaken in consultation with DTMR. Changes to flood depths as a result of the conveyor culvert are considered minor and have no impact on the flooding experienced in the Project area, as the culvert is located outside of the flood zone flow path.

Flood Impact of Deep Creek Culverts

Culverts are required at three locations to enable watercourses to drain freely beneath the haul road. Installation of the culverts, and the embankment in which they sit, is predicted to cause increases to peak water levels on the upstream side.

The following changes to the peak flood depths and velocities were predicted:

- Culvert location 1:
  - Flood depth varies between a decrease of 0.25 m and an increase of 0.3 m
  - Flood velocity varies between a decrease of 0.73 m/s and an increase of 0.32 m/s
- Culvert location 2:
  - Flood depth varies between a decrease of 0.25 m and an increase of 0.24 m
  - Flood velocity varies between a decrease of 0.67 m/s and an increase of 0.42 m/s
- Culvert location 3:
  - Flood depth varies between a decrease of 0.41 m and an increase of 0.22 m
  - Flood velocity does not vary significantly.

Changes to flood depths are considered minor and have no impact on the flooding experienced in the Project area. The increase in velocities is caused by flow contraction through the culverts. This will be addressed by the provision of scour protection (such as concrete aprons, rip-rap or rock mattresses) at culvert outlets.

The analyses have shown that the project is unlikely to alter the hydrologic and hydraulic regimes in any material fashion (ie. run-off volumes and water levels are not greatly different from the existing scenario). Absent any such alteration, it is reasonable to conclude that there will not be any material impacts upon the downstream water values of the Styx River or Broad Sound as a result of flooding events.

16.10.3.3 Mine Site Drainage

The Project's impact on riverine flooding in Tooloombah Creek and Deep Creek, as well as the change in flood hydraulics in the minor drainage gullies that transect the MLA are discussed in Section 16.10.3.1 and 16.10.3.2. The method for assessing these impacts is not as appropriate for the design of the mine site stormwater drainage for the following reasons:

- The rainfall runoff hydrologic model detailed in Section 16.10.3.1 has been developed for critical storm durations of Tooloombah Creek and Deep Creek catchments. Local catchments that contribute to mine stormwater culverts and drains are much smaller and hence have a much-reduced critical storm duration. In all cases, stormwater systems are designed to the critical storm duration at the location of the stormwater drain or structure;
- The hydrologic model outputting hydrographs, when only peak flows are required to size the stormwater system;
- The hydraulic model detailed in Section 16.10.3.2 being simulated on a 10 m grid, which is insufficient to capture the detail of small scale drains and culvert structures, which would in any case be modelled in 1D within the two-dimensional model domain; and
- Empirical formulae representing a more practicable approach to sizing the stormwater system for the nominated AEP design event.

The mine site drainage assessment detailed herein therefore utilises empirical methods to size the following stormwater elements:

- Haul road culvert crossings;
- Dirty water diversion drains;
- Clean water diversion drains; and
- Clean water diversion bunds.

Stormwater Management Overview

Stormwater runoff containment devices, namely environmental dams and drainage sumps, function to capture dirty water runoff generated from disturbed areas such as stockpiles and workshops. The indicative mine drainage general arrangement is shown at Figure 16-21. Environmental dams are sized based on the 9.5% AEP, 24 hour rainfall event in keeping with the DES *Stormwater Guideline* (EHP 2014b). Water captured in the environmental dams will be preferentially used in the mine operations, at the MIA, CHPP and for dust suppression. Excess water from the environmental dams will be directed to Dam 2. Environmental Dams 1b, 2a and 3 will have a low flow perforated riser-pipe decant outlet to discharge treated water to the receiving environment as controlled discharges under conditions licensed by the Environmental Authority. Environmental dams are located at both MIAs, overburden stockpiles and the TLF. MIA drainage sumps and proprietary oil removal devices are proposed to capture runoff from truck wash and workshop areas for treatment and reuse or disposal.

Runoff intercepted by or generated from haul roads will be captured in table drains and conveyed longitudinally towards culvert structures. In areas of steeper grade, sediment transport can be effectively managed using check-dam structures within the drain. Where haul roads cross drainage gullies or the Deep Creek watercourse, an appropriately sized culvert will be provided, allowing for fish passage where relevant.

Clean water runoff from local catchments will be diverted around open pit mining areas for events up to and including the 0.1% AEP (1:1,000 year ARI) design flood. The volume of stormwater entering open mine pits and becoming mine affected water is therefore effectively limited to that rain which falls directly on the open pit area. Precipitation received in the open pits will be dewatered to Dam 2 storage for reuse.

Clean Water Diversions

Diversion drains and bunds are proposed to divert clean water runoff around the mine affected areas, including the open pits and waste areas (Figure 16-68). This clean water is diverted away from mine-affected water which is captured in environmental dams. The clean water is conveyed to Dam 2 for mine use. The diversion drains located around the western perimeter of Open Cut 1 and have been sized to convey the 100 year ARI (0.1% AEP) event.

In the developed case, the small headwater of the 1st order drainage feature within the Open Cut 2 footprint is diverted downstream at Open Cut 2 into Tooloombah Creek via P2DD. A diversion bund is proposed on the open pit side of the diversion drain to increase the pit immunity to a 0.1%AEP event. The drains will be cut into the existing ground, with competent open cut overburden material used to construct a bund on the open pit side (Figure 16-68) following appropriate geotechnical stability design criteria.

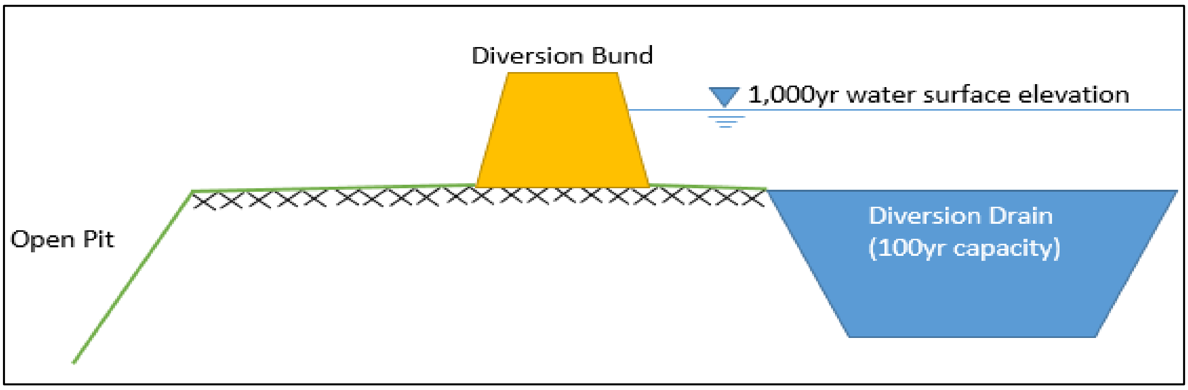
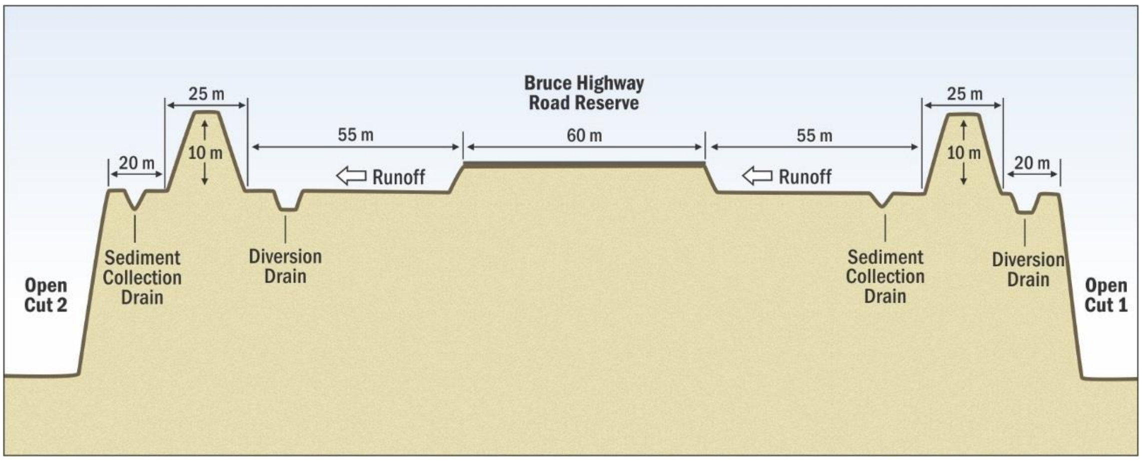


Figure 16-68 Diversion drain and bund concept

Dirty Water Drains

Dirty water drains collect runoff from waste rock stockpiles and processing facilities within the vicinity of the CHPP, ROM and MIA, and discharge to the CHPP environmental dams and waste area environmental dams. These dirty water collector drains have been sized to capture runoff generated from a 9.5% AEP event, which represents the design capacity of the environmental dam for which they discharge to. Similarly, the waste areas have a series of perimeter collector drains, with a design capacity of 9.5% AEP, that discharge to the Waste Rock Stockpiles 1b and 1b environmental dams.

There will be bunds that run on either side of the Bruce Highway that separates Open Cut 1 and Open Cut 2. In addition to preventing runoff from entering the pits, the bunds will act as a barrier to minimise visual impacts from the road, and to reduce driver distraction. On either side of the bund will be a sediment collection drain and a diversion drain that redirects the flow to the main culvert along the Bruce Highway (see Figure 16-69). Both the collection drain and diversion drain will have a minimal catchment and have been sized based on 9.5% AEP event. Check dams will be installed in the sediment catchment drain to drop out sediment prior to entering the existing tributary and Bruce Highway culvert crossings. The drains will require periodic cleaning of sediment to maintain their efficacy.



Note: Schematic for illustration purpose only. At no point will there be open excavations on both sides of the Bruce Highway at the same time.

Figure 16-69 Bruce Highway catch drain arrangement

Culvert Crossings

The proposed haul road connecting the MIA and CHPP 2 with the TLF crosses several drainage gullies, therefore requiring cross-drainage culvert infrastructure. The location of these structures is shown in Figure 16-21. The crossings are conceptualised as box culvert crossings with capacity to pass a minimum 9.5% AEP design discharge. Discharges above the design event will pass over the box culvert as a floodway-type arrangement. The floodway arrangement efficiently passes flows over the road, therefore reducing impacts on localised flood depths and velocities, as well as impacts associated with rising headwaters upstream of the culvert crossing. The use of box culverts removes the need to place cover fill material and hence reduces the migration of sediments where potential scour velocities develop around the culvert structure. The box culvert and floodway concept is illustrated in Figure 16-70. The figure also shows the approach to using circular low flow culverts on overbank regions, if required, including the implementation of a rock armoured floodway.

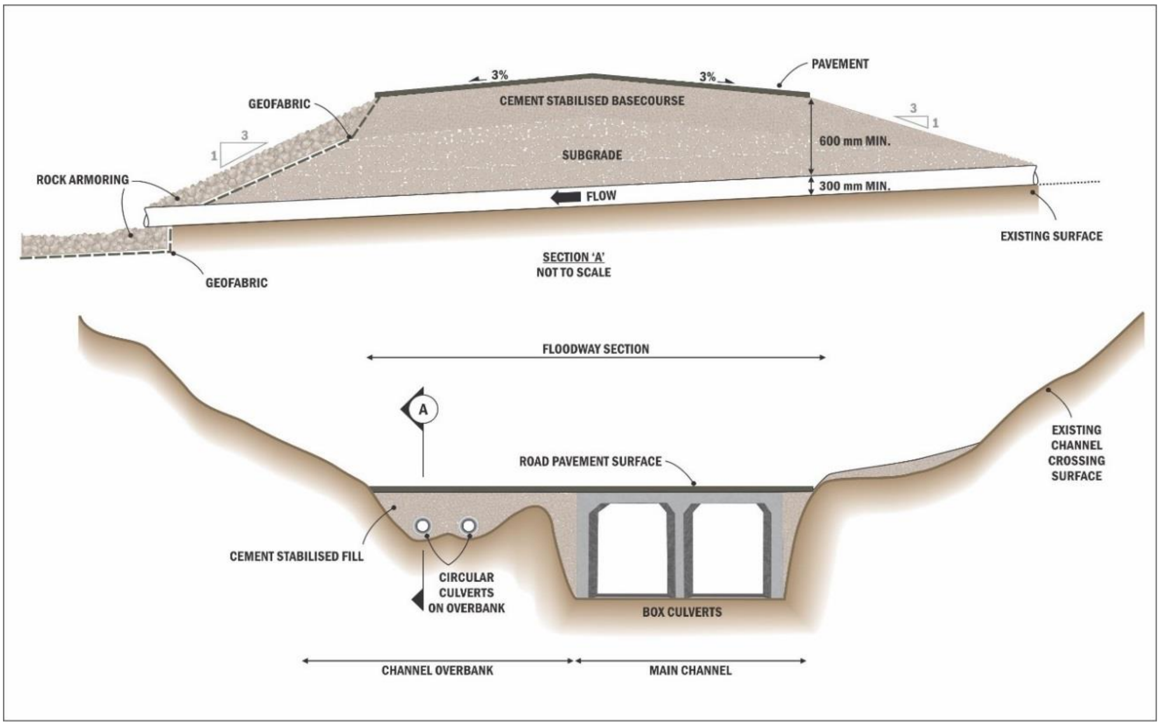


Figure 16-70 Box culvert and circular culvert and floodway arrangement

Consideration has been given to the requirements of Queensland's State Code 18: Constructing or raising waterway barrier works in fish habitats Version 2.4 (Department of State Development, Manufacturing, Infrastructure and Planning, 2018). All culverts that are required in Deep Creek comply with State Code 18. All other culvert crossings not required to comply with State Code 18 will adhere to best-practise design for fish passage and "Accepted development requirements for operational work that is constructing or raising waterway barrier works".

Stormwater Culvert and Drain Peak Design Flow Estimates

To establish the sizing of stormwater infrastructure, the local catchments reporting structures and drains was determined and the likely peak flow was estimated for a nominated design AEP event. The peak flows were initially determined using the RFFE (ARR16). However, the RFFE formulae were derived from catchments much larger than those associated with the Project stormwater system and produced peak flow estimates that were extremely high and unrepresentative of the Project catchments. It was therefore determined that the rational method would be used in the sizing of these drainage infrastructures.

Catchment analysis was undertaken in ArcGIS to delineate the various local catchments reporting to the diversion drains and haul road culvert crossings. The corresponding catchments to each crossing, diversion drain and catch drain are shown in Table 16-50. The diversion drains and haul road crossings are assumed to be constructed in Year 1 of the mine life (2019) and therefore representative of conditions where the greatest peak flow will report to the structures throughout the mine life. As mining develops, the contributing catchments to some structures and drains is reduced and the structures and drains will essentially be oversized from that point forward.

Table 16-50 Local catchment areas

Catchment name	Area (ha)
P1DD-1	452
WRS1BCD-1	86
WRS1ACD-1	32
P2DD-2	30
WRS2CD-1	7
WRS2CD-2	16
WRS2CD-3	6
MIA1CD	23
MIA2CD-1	15
TLOCD-1	13
HR1CD-1	9

The Coefficient of Runoff 'C' and rainfall intensity 'I' were calculated following the guidance provided in the *Queensland Urban Drainage Manual* (DEWS 2013). The Coefficient of Runoff is a dimensionless factor designed to account for the various natural processes that intercept or otherwise prevent precipitation from turning into runoff. It considers the degree of pervious surfaces in the catchment, the type of ground cover, and an estimate of the soil porosity.

Coefficients of Runoff adopted for this analysis are presented in Table 16-51. The result peak flow predictions for each catchment, for a range of standard ARI events, is presented in Table 16-52 and Table 16-53 for diversion drains and haul road culverts, respectively.

The diversion drains estimated peak flows in Table 16-52 are the peak flows at 2019 when the contributing catchment areas to the diversion drains are at their largest. The haul road crossing peak flows presented in Table 16-53 are calculated in accordance with catchment areas as of 2019. As the mining progresses, the contributing catchments to the diversion drains and haul road crossings will decrease, therefore decreasing the estimated peak flow and increasing the design immunity of the system.

Table 16-51 Coefficients of runoff

ARI	F_y	C_{10}	C_y
9.5% AEP	1.00	0.7	0.70
4.9% AEP	1.05	0.7	0.74
2% AEP	1.15	0.7	0.81
1% AEP	1.20	0.7	0.84

Table 16-52 Rational method peak flow – diversion and catch drains

Diversion name	Peak flow at outlet (m^3/s)			
	9.5% AEP	4.9% AEP	2 % AEP	1% AEP
P1DD-1	70.1	76.5	80.7	84.3
WRS1BCD-1	11.9	13.0	13.6	14.2
WRS1ACD-1	5.6	6.1	6.5	6.8
P2DD-1	10.693	11.752	12.452	13.078
P2DD-2	6.1	6.7	7.2	7.6
WRS2CD-1	2.5	2.7	2.8	2.9
WRS2CD-2	7.1	7.9	8.5	9.0
WRS2CD-3	0.9	1.0	1.0	1.1
MIA1CD	2.8	3.0	3.1	3.3
MIA2CD-1	1.4	1.6	1.6	1.7
TLOCD-1	1.4	1.5	1.6	1.7
HR1CD-1	1.1	1.2	1.3	1.4

Table 16-53 Rational method peak flow – haul road culverts

Haul road crossing	Peak flow at outlet (m^3/s)			
	9.5% AEP	4.9% AEP	2 % AEP	1% AEP
Haul Road Crossing 1 (based on hydraulic modelling)	2,779	3,025	3,135	3,678
Haul Road Crossing 2 (based on hydraulic modelling)	767	816	840	965
Haul Road Crossing 3 (based on hydraulic modelling)	134	147	150	178

Stormwater Culvert and Drain Sizing

The culvert arrangement has been conceptualised to pass the 9.5% AEP peak flows through the culvert, with greater flows passing over a floodway arrangement. The culvert locations are illustrated in Figure 16-21. The low flow culvert and floodway arrangement reduces filling within the drainage gullies and reduces flood afflux for rare and extreme flood events by more efficiently passing flows over the floodway. A greater flood immunity may be adopted; however, due to the small critical times of concentration of the contributing catchments, road overtopping events are not likely to significantly hinder mine operations or access for extended periods.

The culvert sizing results are summarised in Table 16-54. The sizing is based on reinforced concrete box culverts. The use of box culverts allows for fish passage at low and high flows and reduces the velocity through the structure. Furthermore, open bottom box culverts are preferred for fish passage over the use base slabs; however, box culverts along the haul road will likely require at least a concrete footing. Deep Creek and tributary crossing was sized in the hydraulic assessment by constructing a 1D culvert within the 2D model domain.

Table 16-54 Culvert sizing

Crossing	Headwater depth (m)	Peak flow (m^3/s)	Number of Units	Span x Height (mm)	Type
Haul Road Crossing 1 (based on hydraulic modelling)	6.47	2780	5	3600x3600	RCBC
Haul Road Crossing 2 (based on hydraulic modelling)	5.72	767	5	3600x3600	RCBC
Haul Road Crossing 3 (based on hydraulic modelling)	4.39	134	5	3600x3600	RCBC

Note: RCBC= reinforced concrete box culvert, size in mm diameter

Diversion drain dimensions are summarised in Table 16-55 for the specified design events and corresponding peak flow estimates.

Table 16-55 Rational method peak flow – diversion drains

Diversion drain	Design event (AEP)	Design flow (m^3/s)
P1DD-1	1%	84.3
P2DD-1	1%	13.1
P2DD-2	1%	7.6

The diversion drains around the Open Cut 1 pit will incorporate a diversion bund on the pit side of the drain to provide a combined 0.1% AEP flood immunity from runoff generated by local upstream catchments. This concept is shown in Figure 16-68 and is tested hydraulically in flood modelling covered under Section 16.10.3.2.

Catch drains that report to the waste rock stockpile environmental dams cater for smaller catchments compared to those of the diversion drains. The peak discharge in catch drains will also likely be attenuated by storage and attenuation within the waste rock pore space. Notwithstanding, the catch drains have been conceptualised to be consistent with the sizing of the diversion drains and are therefore likely conservative in their capacity. To further ensure adequate capacity, material removed from the catch drain can be formed into a diversion bund downgradient of the overburden stockpiles and in a similar arrangement to that shown in Figure 16-68. Optimisation of the catch drain design will occur during detailed design of the water management system. The size of the catch drains is outlined in Table 16-56.

Table 16-56 Rational method peak flow – catch drains

Diversion drain	Design event (AEP)	Design flow (m^3/s)
WRS1BCD-1	9.5%	11.9
WRS1ACD-1	9.5%	5.6
WRS2CD-1	9.5%	2.5
WRS2CD-2	9.5%	7.1
WRS2CD-3	9.5%	0.9
MIA1CD	9.5%	2.8
MIA2CD-1	9.5%	1.4
TLOCD-1	9.5%	1.4
HR1CD-1	9.5%	1.1

16.10.4 Water Resource Management

A schematic of the proposed water management network for the Project is shown in Figure 16-16, with engineering drawings provided at Appendix A16. The breakdown of the mine water demands which must be satisfied by the water supply system is summarised in Table 16-14. The maximum total annual demand excluding water re-use is calculated at 804 Megalitres (ML) at 2030 and mining 10 Mtpa ROM.

The water demand for rehabilitation and mine closure during years 2036 to 2038 will likely be significantly lower than the demands during the operations of the mine. Water demands during rehabilitation stages is assumed to be 20 ML sourced from environmental dams and pit dewatering and will be finalised during detailed design.

Dams 1, 2 and 3 are on the eastern side of Open Cut Two. Dam 1 will also capture water from Open Cut 1, which will be pumped via the conveyor culvert when operational. Dam 4 will capture run-off from the TLF area. Dam 3 and Dam 2 report to Dam 1; however, the transfer arrangement will facilitate the transfer of water between Dams 1, 2 and 3 as necessary. Dam 1 will be the main water source for potable, CHPP and washdown water.

A 700 ML Dam 1 is proposed to provide a secure water supply for both construction and operational phases and involves impounding a tributary drainage feature of Deep Creek to provide a reliable water supply over the life of the mine.

The Dam 1 will supply water for potable use (after first undergoing treatment), and raw water for plant washdown and makeup water for the CHPP. The makeup water demand is determined by the balance between incoming and outgoing coal and rejects moisture content, water required for coal washing, and decant water return from the CHPP decant ponds. The wet fines from coal washing will pass a filter press with an estimated 40 to 60% moisture recovery rate. The MIA environmental dam will provide dust suppression.

In general, reuse of water captured on site in environmental dams and mine dewatering to Dam 2 will take preference over raw water use. Suitable applications for reuse water include CHPP makeup water, dust suppression and stockpile sprays, and vehicle washdown. The water will be sourced from the dam location and / or transferred to the MIA process water dams (MIA Dams) for coal washing use within the CHPP. A simple water balance for the 5 Mtpa scenario is shown in Figure 16-71.

Environmental dams are proposed to capture rainfall runoff from the CHPPs, TLF and waste rock stockpile areas. The primary function of the environmental dams is to capture sediment laden runoff for sediment removal. Captured water in environmental dams will be prioritised for CHPP and MIA use (MIA and waste rock stockpile environmental dams) and for dust suppression, stockpile spray and supplementary fire supply (TLF environmental dam).

Oil / water separators are proposed for vehicle wash and workshop areas to treat hydrocarbon contaminated runoff prior to release or containment in environmental dams.

A potable water demand of approximately 6.3 ML/annum is estimated for the life of the mine. The potable supply will comply with standards outlined in the *Australian Drinking Water Standard Guidelines* (NHMRC and NRMMC 2011). The likely treatment of raw water from Dam 1 required to meet the standards would include sand filtration and chlorine dosing. A polyethylene potable use water tank will be required at the MIA for the storage of treated water.

Fire water supply provisions are incorporated into Dam 1 storage capacity. A total of 5 ML has provisionally been included in Dam 1 for this water resources assessment. It is anticipated that these stores be replenished post use and that the total volume is available for firefighting activities during operations. Additional fire water supply will be provided at the TLF in closed storage tanks primarily designated for dust suppression supply.

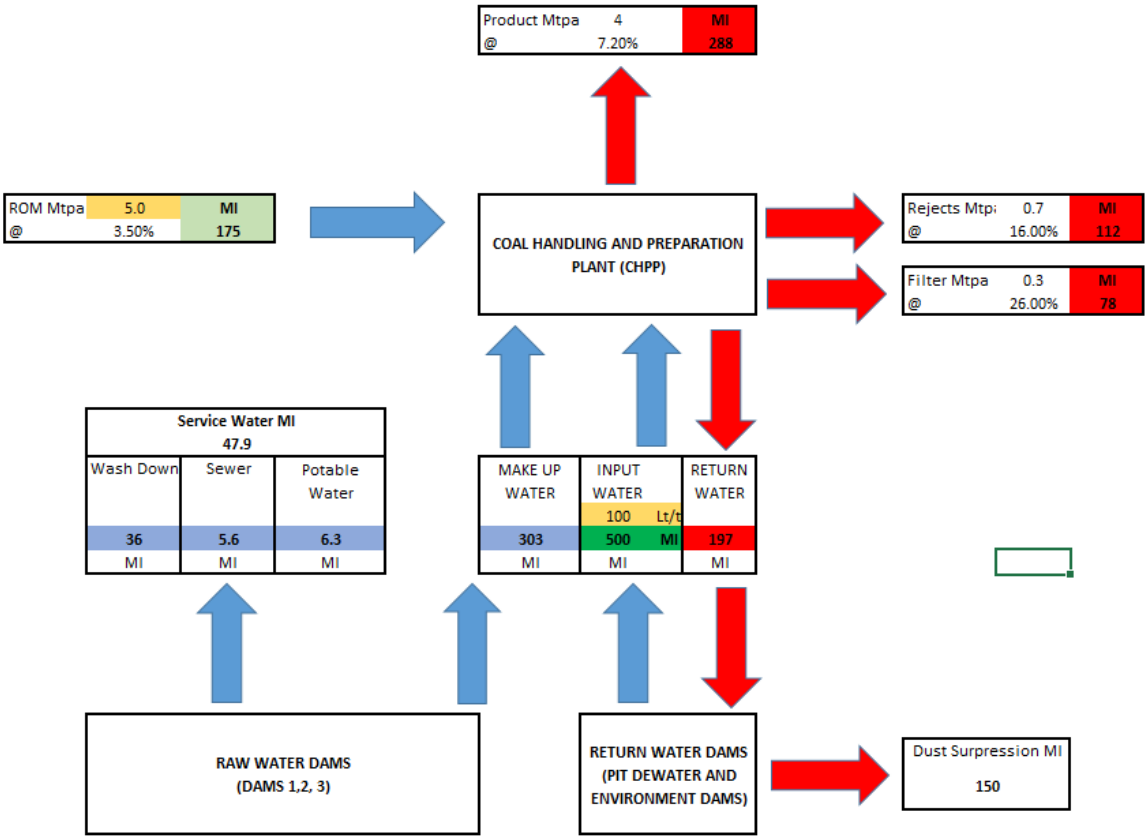


Figure 16-71 Water balance calculations for 5Mpta Throughput

16.10.4.1 Mine Water Balance

A water balance of the water management network was simulated in GoldSim. The primary objectives of the water balance were to determine the net annual balance of water to be held in storages, reliability of supply, the water reuse potential and raw water requirements. The main elements of the model are summarised in Table 16-57. The CHPP water balance, including decant water return and coal moisture input and rejects moisture outputs, was not simulated in the model; however, the overall CHPP make-up water demand from reuse water and raw water sources was included to obtain the net water balance.

Table 16-57 Water balance model elements

Model element	Inputs	Outputs	Comments/assumptions
MIA Dams 1 and 2 (Process Water Dams)	- Direct rainfall - Pump transfer from pit dewatering and Dam 1 - Transfer from Environmental Dam 1a - Transfer from Environmental Dam 1b - Transfer from Environmental Dam 2c	- Evaporation - CHPP demand	The process water dams are each turkey's nest storage of 30 ML capacity, located at each of the MIA locations and supplies water to the CHPP. The MIA dams each hold a 14-day CHPP demand volume to buffer against water supply maintenance and breakdown. The MIA dams are kept full from transfers from the Dam 2 transfers from environmental dams (priority 1) and Dam 1 (priority 2). The MIA dams do not discharge to the environment and have a design storage allowance to ensure overtopping does not occur.
Open cut mine pits	- Direct Rainfall; - Groundwater inflow - In-pit Runoff	- Evaporation - Pump transfer to ex-pit Dam 2	Open cut pits contain a sump (nominally 5 ML) from which groundwater inflow and rainfall runoff volumes are stored. Water is transferred from the pit sump to Dam 2 at a nominal rate of 100 l/s.
Dam 1 (700 ML)	- Direct Rainfall - Catchment runoff - Transfers with Dam 3	- Evaporation - Potable use - Pump transfer PWD for CHPP use, - Washdown - Spillway release	The dam 1 is located near Waste Rock Stockpile 2 and Open Cut 2, which forms the raw water demand source. Demand for raw water depends on the available and suitability of mine affected water for use in the CHPP and for washdown use. Dam 1 is the only source for potable water supply.
Dam 2 (600 ML)	- Direct Rainfall - Catchment runoff - Diversions - Open cut mine pits dewatering - Transfer from Environmental Dam 1b - Transfer from Environmental Dam 2c	- Evaporation - Transfer to Dam 3	Dam 2 is located near the CHPP and MIA2
Dam 3 (150 ML)	- Direct Rainfall - Catchment runoff - Transfers with Dam 2	- Evaporation - Transfer to Dam 1	Dam 3 is located near Waste Rock Stockpile 2 and Open Cut 2.
Dam 4	- Direct Rainfall - Catchment runoff	- Evaporation - Train Loadout water demand	Dam 4 is located near the Train Loadout
Environmental Dams	- Direct Rainfall - Catchment runoff	- Dust suppression - Transfer to Dam 2	There are six environmental dams around the Project that collect catchment runoff and transfer water to the MIA Dams to minimise the Project's reliance on Dam 1. Each of the CHPP and MIA's, waste rock stockpile areas and TLF (Dam 4) have an environmental dam.

Following the methodology described in the *Water Accounting Framework for the Minerals Industry User Guide* (Minerals Council of Australia, 2014), the main water accounting input and output elements at the mine are summarised in Table 16-58 for the dry season, and Table 16-59 for the wet season.

Table 16-58 Water inputs and outputs – Dry season

Input-Output	Source / Destination	Inputs/ Outputs	Volume of Water in Quality Category Number			Total (ML)	Accuracy	Notes
			1 (ML)	2 (ML)	3 (ML)			
Input	Surface Water	*Precipitation and Runoff*	406	-	-	406	Medium - Simulated	
		Rivers and Creeks	-	-	-	-		No water taken
		External Surface Water Storages	-	-	-	-		
	Groundwater	*Aquifer Interception*	-	-	154	154	Medium - Simulated	
		Bore Fields	-	-	-	-		
		Entrainment	-	-	88	88	Medium – Estimated	
	TOTAL INPUTS		406	-	242	648		
Output	Surface Water	*Discharge*	-	-	-	-		
		Supplementation/ Environmental Flows	-	-	-	-		
	Groundwater	*Seepage*	-	-	-	-		
		Reinjection	-	-	-	-		
	Other	*Entrainment Product*	-	-	144	144	Medium – Estimated	
		Entrainment Rejects and Filter	-	-	95	95	Medium – Estimated	
		Evaporation	304	-	-	304		
	TOTAL OUTPUTS		304	-	239	543		

Table 16-59 Water inputs and outputs – Wet season

Input-Output	Source/ Destination	Inputs/ Outputs	Volume of Water in Quality Category Number			Total (ML)	Accuracy	Notes
			1 (ML)	2 (ML)	3 (ML)			
Input	Surface Water	*Precipitation and Runoff*	2,504	-	-	**2,504**	Medium - Simulated	
		Rivers and Creeks	-	-	-	**-**		No water taken
		External Surface Water Storages	-	-	-	**-**		
	Groundwater	*Aquifer Interception*	-	-	154	**154**	Medium - Simulated	
		Bore Fields	-	-	-	**-**		
		Entrainment	-	-	88	**-**	Medium – Estimated	
	TOTAL INPUTS		**2,504**	**-**	**242**	**2,746**		
Output	Surface Water	*Discharge*	-	-	-	**-**		
		Supplementation / Environmental Flows	-	-	-	**-**		
	Groundwater	*Seepage*	-	-	-	**-**		
		Reinjection	-	-	-	**-**		
	Other	*Entrainment Product*	-	-	144	**144**	Medium – Estimated	
		Entrainment Rejects and Filter	-	-	95	**95**	Medium – Estimated	
		Evaporation	441	-	-	**441**		
	TOTAL OUTPUTS		**441**	**-**	**239**	**680**		

16.10.4.2 Climate Data

A total of 127 years (1889 to 2017) of SILO historical climate data (DSITIA 2017) was used to simulate climate variability within the water balance model (see Section 16.10.1.1 for a climate data and variability discussion). By running multiple simulations of the 18-year operational mine plan and by stepping through the full 127 years of available historical climate data, the net water balance in the driest and wettest years were analysed.

During the driest years, there is more reliance on raw water supply, whereas during the wettest years there is more opportunity for water reuse. Moreover, during the wetter years there is a greater net storage requirement to contain open pit mine dewater volumes as well as catchment runoff volumes and direct rainfall falling on the storage areas. Morton's Lake evaporation was used to simulate evaporation from storages; whereas Morton's Wet evapotranspiration rates were used to estimate evaporation from soil moisture stores.

16.10.4.3 Groundwater Inflow and Licenced Discharges

The water demands and sources for the Central Queensland mine is presented in Table 16-14. It should be noted that groundwater inflows also represent a water source that is collected in open cut pit sumps and transferred to Dam 2. Groundwater inflow volumes predicted for the Project are estimated in Chapter 10 - Groundwater and summarised in Table 16-60.

Table 16-60 Predicted groundwater inflow rates and volumes

Mining year	Year	Average inflow rate (ML/day)	Period inflow volume (ML)	Cumulative Volume (ML)
		Open cut	Open cut	Open cut
1	2019	0.9	343	343
2	2020	1.1	406	750
3	2021	0.9	346	1,095
4	2022	0.8	279	1,375
5	2023	1.0	381	1,756
6	2024	1.1	396	2,151
7	2025	1.0	381	2,532
8	2026	1.0	380	2,912
9	2027	0.9	342	3,254
10	2028	1.7	637	3,891
11	2029	1.0	362	4,253
12	2030	1.7	607	4,860
13	2031	0.5	190	5,050
14	2032	0.4	157	5,207
15	2033	0.5	168	5,375
16	2034	0.3	95	5,470
17	2035	0.2	60	5,530
18	2036	0.0	11	5,540

Licenced discharges will also be permitted under EA conditions, allowing for better quality water to be released during natural flow events in the receiving waters. The release limits proposed for the Project are presented in Section 16.10.2.4 and based on WQOs for the Styx Basin and an adopted instream dilution rate for electrical conductivity. For the water balance assessment, and in the absence of licence conditions to simulate the environmental dams were assumed to discharge to Deep Creek at a rate of 1 m^3/s when discharge within Deep Creek exceeded 2 m^3/s.

16.10.4.4 Tooloombah Creek and Deep Creek Flow Characteristics

No gauge data exists for Tooloombah or Deep Creek from which to estimate how frequently and to what magnitude licenced discharges could operate. A rainfall-runoff model was therefore established for the Tooloombah and Deep Creek catchments through implementation of Boughton's Australian Water Balance Model, which is a catchment water balance model that relates daily rainfall and evapotranspiration to runoff. The Australian Water Balance Model (AWBM) schematic is illustrated in Chapter 9 – Surface Water, Figure 9-97.

The adopted AWBM parameters are presented in Table 16-61, and are described as follows:

- BFI - The baseflow index, or ratio of baseflow to total flow;
- KBase - The baseflow recession constant where (1-KBase) multiplied by the baseflow store gives the rate of depletion from the store contributing to total runoff;
- KSurf- The surface recession constant, where (1-KSurf) multiplied by the surface store gives the rate of depletion from the store contributing to total runoff;
- C1-C3 - Surface storage capacities; and
- A1-A3 - Partial areas of the C1-C3 storage capacities.

Table 16-61 Australian water balance model parameters – adopted values

AWBM Parameter	Adopted Value	Default Value
Baseflow Index, BFI	0.17	0.35
Baseflow recession constant, Kb	0.95	0.95
Surface flow recession constant, Ks	0.10	0.35
Surface store capacity, C1	20 mm	7 mm
Surface store capacity, C2	50 mm	70 mm
Surface store capacity, C3	120 mm	150 mm
Partial Area, A1	0.134	0.134
Partial Area, A2	0.433	0.433
Partial Area, A3	0.433	0.433

Note: These parameter values are average values for Queensland catchments (Boughton W. 2009)

In the absence of site-specific data to calibrate the AWBM model, representative values from literature were used. These literature values were based on a study (Boughton, 2009) which investigated 70 catchments within Queensland in varying size from 51 km^2 to 1870 km^2. The rainfall over these catchments varied in quantity between 583-2289 mm/yr. By comparison, the catchments are for Tooloombah and Deep Creek are 370 km^2 and 298 km^2 respectively, with an average annual rainfall of 711 mm. As an additional check, calibration of the AWBM model daily and annual responses was conducted to assess runoff quantities against the closest coastal gauged catchment, Water Park Creek at Byfield, Station 129001A, with catchment area of 212 km^2.

Since Tooloombah and Deep Creek have catchments sizes within the study range it is considered acceptable to use the parameter values established by Boughton's (2009) study for this water balance.

16.10.4.5 Water Balance Results

The primary objective of the water balance model was to determine the net water balance and the required storage sizes for the mine dams based on the life-of-mine water demand. The storage requirements to meet mine demand are presented in Table 16-62. The combined dam storage volumes were sized based on mine affected catchments and estimated mine demand, considering reuse and licenced controlled discharges. Dams 1, 2, and 3 capacities consider the extent of topographical constraints to provide reliable supply to the MIAs and CHPPs. The MIA 1 and MIA 2 were sized to have a demand storage capacity to account for maintenance and down-time of the water management network.

Table 16-62 Water storage requirement

Storage	Design capacity (ML)
Dam 1	700
Dam 2	600
Dam 3	150
Dam 4	200
Environmental combined	150
MIA 1 Process Water Dam	30
MIA 2 Process Water Dam	30

Water reuse potential is high for the mine due to the predicted groundwater inflow volumes and runoff volumes collected in open pits, relative to mine water demands. The data presented at Figure 16-72 and Figure 16-75 show the mean and 99th percentile storage results for the MIA 1 Environmental Dam and Dam 1. The statistics are derived by assessing the climate variability over the historical rainfall and evaporation data record (1889 through 2017). The dates shown on the x-axis are not significant. They signify the arbitrary start date of the simulation, which is set to 1889 as this is the first year of historical climate data.

The following conclusions can be made from the results:

- For MIA 1 and MIA2 Process Dams, the inflows and water transfers were able to meet the CHPP demand; and
- For Dam 1, the maximum storage capacities reached 700 ML, and was able to supply the mine demand for the majority of historical climate simulations.

It is important to note the results contained herein are influenced by the predicted groundwater inflow volumes, assumptions surrounding reuse (see Table 16-57) and the eventual release conditions imposed for mine affected water (see Section 16.10.5 for proposed strategy). On commencement of mine construction, detailed water balance models will be constructed, continually updated with new data and validated to reflect the conditions encountered.

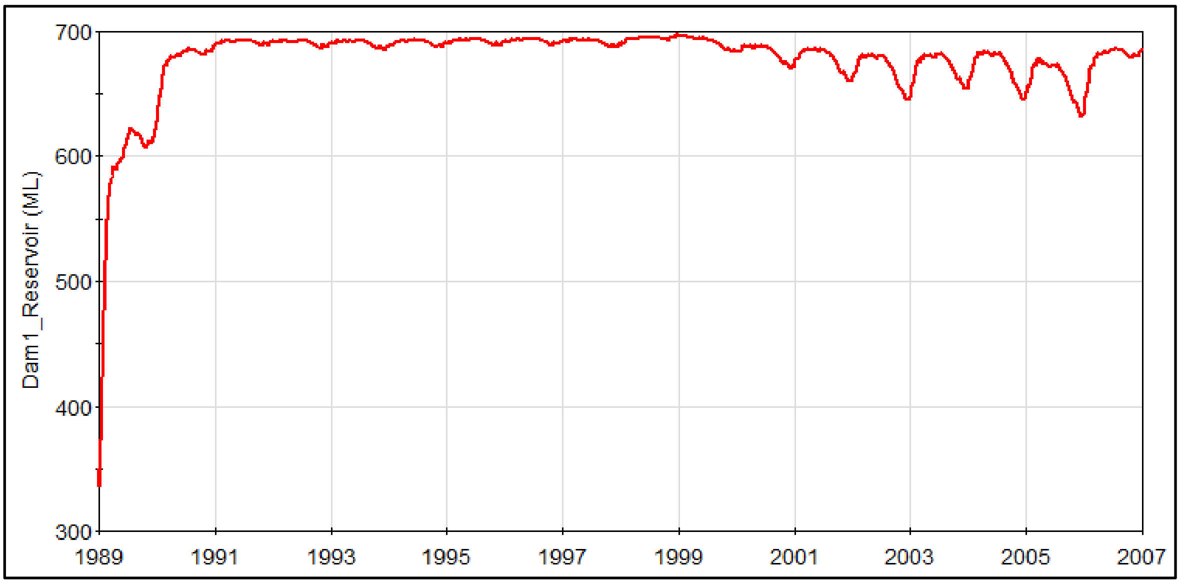


Figure 16-72 Dam 1 – mean storage history

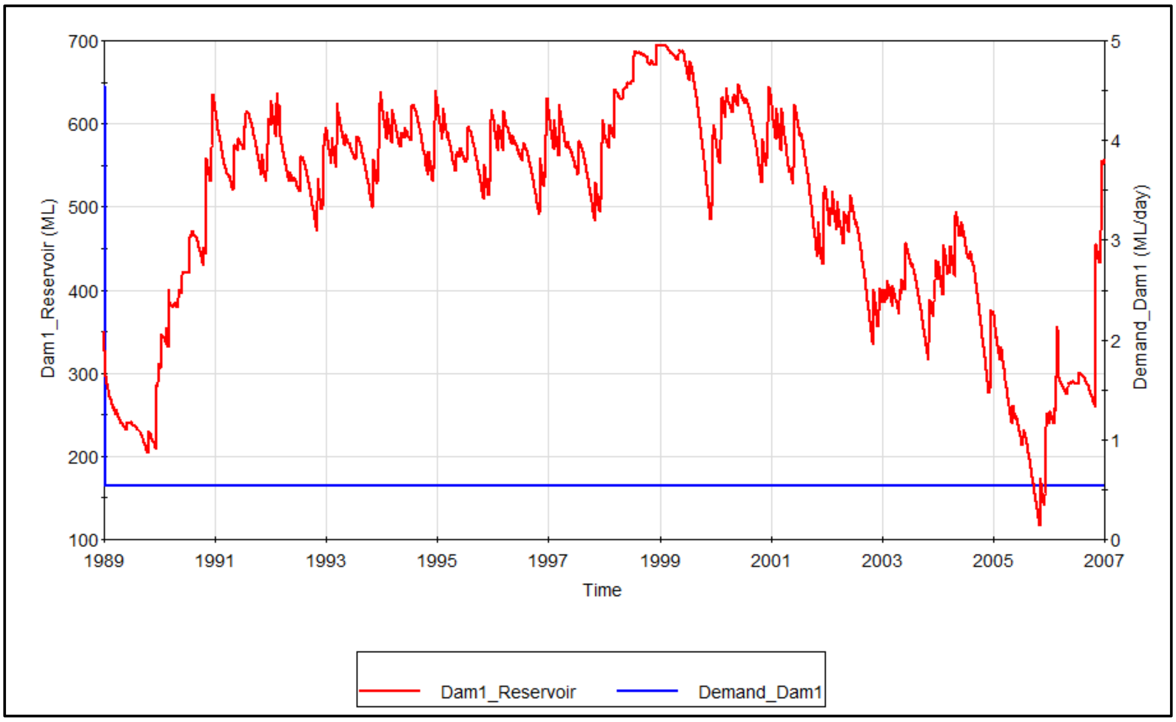


Figure 16-73 Dam 1 - 99th percentile storage history with demand

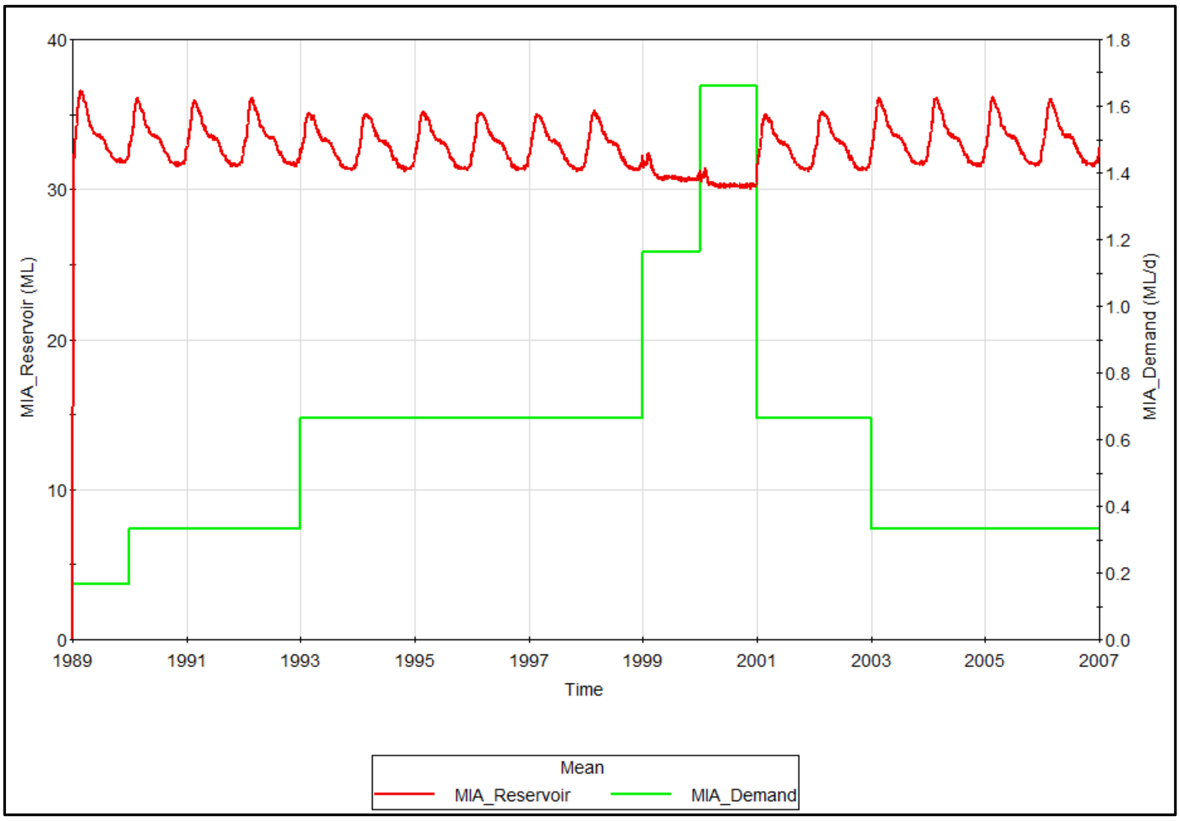


Figure 16-74 MIA Process Dams – mean storage history

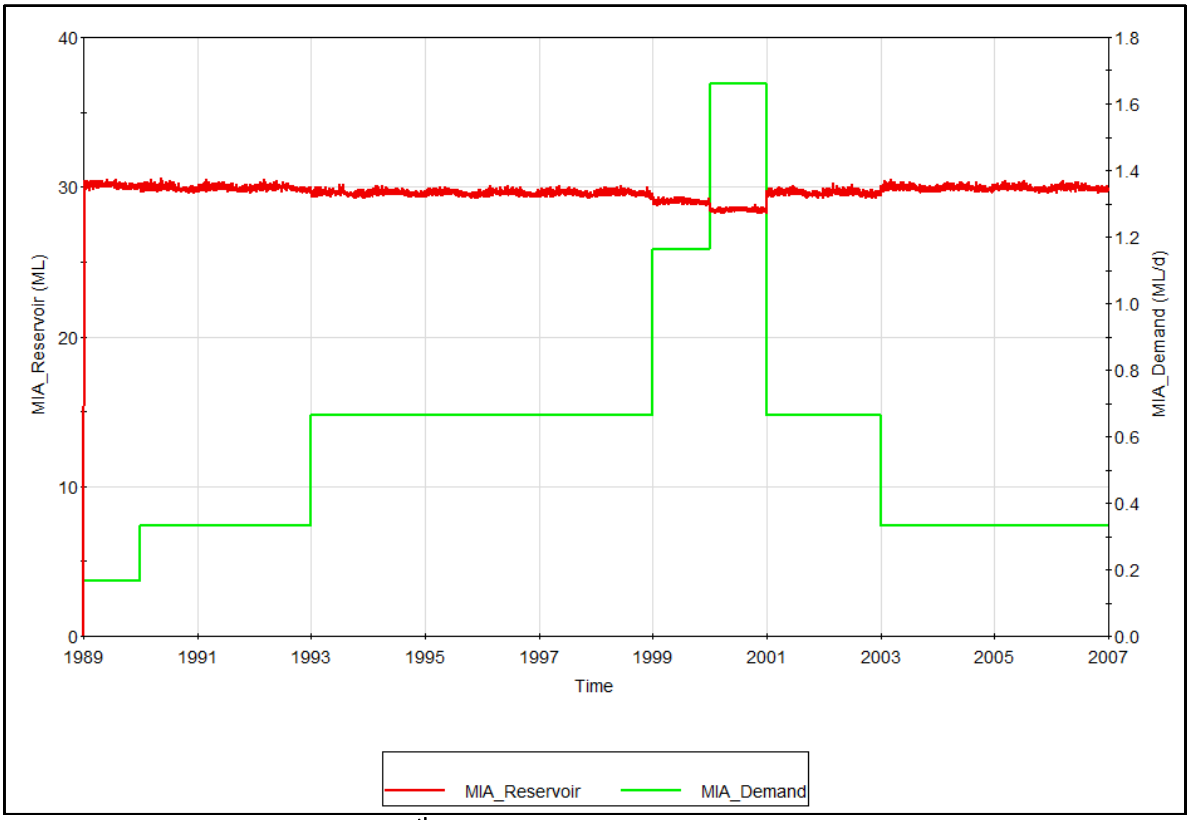


Figure 16-75 MIA Process Dams - 99th percentile storage history

The water deficit over the duration of mining operations is predicted to be minimal, with any deficit most likely to occur during peak production years. Figure 16-76 demonstrates the demand over the 18-year mining simulation; no deficits were observed for a reliability of supply greater than 99%.

Dam 1 does not dry out and the combined system of water storages are able to provide a reliability of greater than 99% over the life of mine.

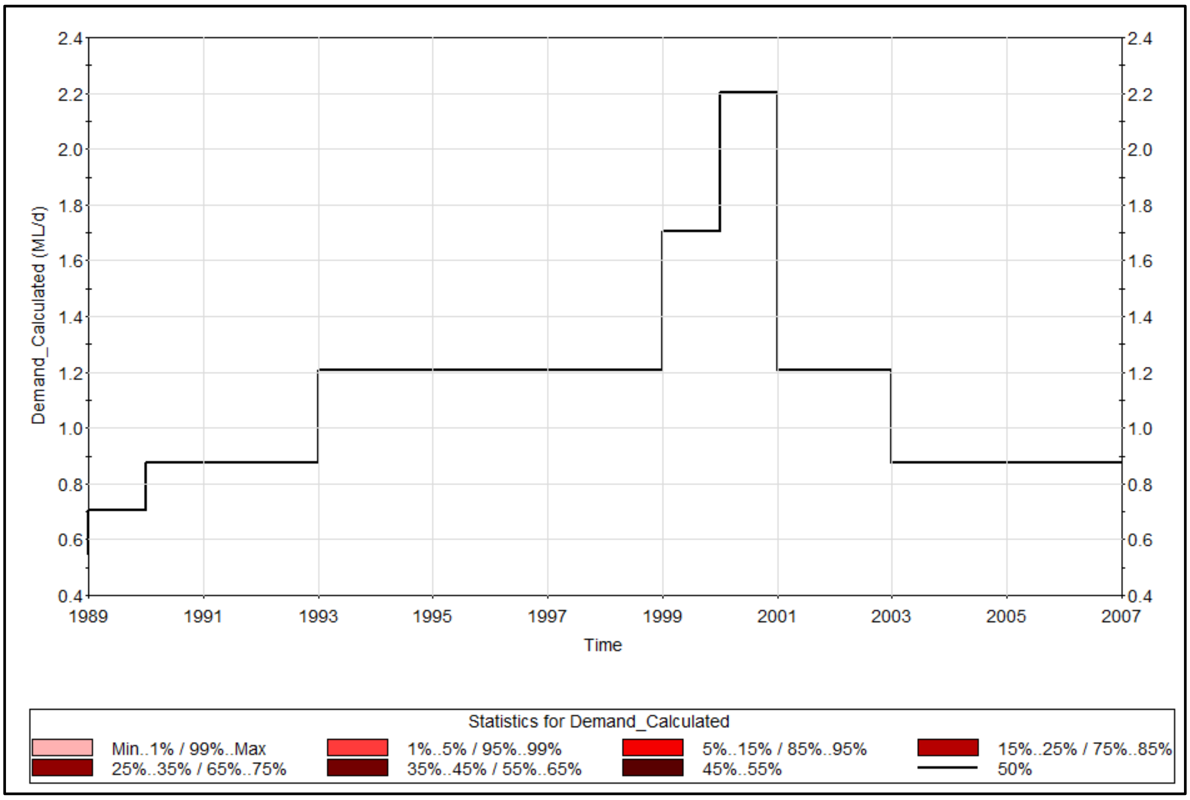


Figure 16-76 Whole mine water demand

16.10.4.6 Regulated Structures Assessment

All proposed storages and levees have undergone preliminary assessment to determine the minimum hydraulic performance requirements under the Queensland Government guidelines: *Structures which are Dams or Levees Constructed as part of Environmentally Relevant Activities* (ESR/2016/1934, Version 8.01, 2017) (EHP 2017b) and the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (*ESR/2016/1933 Version 5.01, 2016) (EHP 2016). This assessment has considered each of the following failure event scenarios:

- 'Failure to contain – seepage' – spills or releases to ground and/or groundwater via seepage from the floor and/or sides of the structure;
- 'Failure to contain – overtopping' – spills or releases from the structure that result from loss of containment due to overtopping of the structure; and
- 'Dam break' – collapse of the structure due to any possible cause.

A summary of the consequence assessment is shown in Table 16-15. Dam 1, Dam 2, Dam 3, Dam 4, MIA 1 and MIA 2 were classified under the "significant" consequence category for the "failure to contain-overtopping" and "dam break" scenarios. Levees were determined to be regulated structures and hence must have a crest elevation higher than the peak 0.1% AEP flood level.

The "failure to contain – seepage" scenario has a minimum classification of "significant" in the consequence manual. Leak detection and monitoring may be imposed through EA conditions for regulated dams containing contaminants, such as the MIA dams, Dam 4 at the TLF, and Dam 2 receiving the pit dewatering. Design provisions for these dams include the use of, where practicable, low permeability clay as the dam foundation or liner to prevent the migration of contaminants.

Only dams with an embankment height of greater than 10 m may be categorised as "referrable", thus requiring a Failure Impact Assessment (FIA). Dam 1 could possibly fall within this category, pending the outcomes of further assessment and final detailed design. The dam FIA, if required, will be undertaken as outlined in the *Guidelines for Failure Impact Assessment of Water Dams* (DNRME 2018). The population at risk (PAR) determined by the FIA will inform the failure impact category that applies to the dam and subsequently the minimum design requirements outlined in applicable Australian National Committee on Large Dams guidelines. The chief executive will then impose dam safety conditions, which are likely to include the following:

- The provision of design and construction reports;
- The preparation of an Emergency Response Plan as prescribed by the DEWS guideline for referable dams;
- The production of Operation and Maintenance Manual procedures in accordance with DNRME guidelines; and
- Development of standard operating procedures.

It is not anticipated that any of the dams conceptualised herein will create a PAR due to the sparse population density and small containment volume of the dams. Furthermore, except for environmental dams, no other storages have external contributing catchments, and therefore can only overtop if the pumps that feed water to the storages fail to shut off at full supply level, or in the unlikely case of extremely intense rain falling directly on to the storage. The spillways will therefore be designed to pass the maximum pump rate that supplies each storage to mitigate against dam break due to overtopping failures.

The storage assessment for the Project dams has been provided earlier in this chapter in Section 16.7.3.7 (pp. 16-59). A summary of the storage sizing assessment is at Table 16-16 and the locations are shown at Figure 16-67.

16.10.5 Mine Affected Water Release Strategy

This section details a water release strategy for mine affected water. The release of mine affected water is proposed as a contingency measure after water reuse within mine operations. Notwithstanding this, it is considered prudent to have a release strategy to minimise the risk of non-compliant discharges through effective balance of the mine water inventory and by discharging better quality water when possible instead of allowing contaminants to concentrate in storages. Releases of mine affected water may occur as "controlled" release through a piped transfer to Tooloombah or Deep Creek in accordance with EA conditions or as an "uncontrolled" release via flow over a designated spillway during extreme wet weather events. Controlled and uncontrolled releases may occur at the same time, for example, during emergency situations.

16.10.5.1 Release Points and Gauging Stations

Release points (RPs) have been designated for storages containing pit dewater volumes, overburden stockpile runoff and mine process water (see Table 16-63). Mine affected water dams have piped outlets that transfer water to RPs within Tooloombah Creek, where instream dilution is possible. Environmental dams located within the Deep Creek catchment have piped transfers to RPs within Deep Creek. The mine affected water RPs, sources and receiving waters are summarised in Table

16-63 and shown at Figure 16-77. RPs will also be located at the environmental dams at the MIA, TLF overburden stockpile areas.

Table 16-63 Mine affected water release points, sources and receiving waters

Release point	Latitude (Decimal Degrees,)	Longitude (Decimal Degrees,)	Mine affected water source and location	Monitoring point	Receiving water description
Mine water dam release points					
RP 3	-22.693928	149.704268	Dam 4	Sampling tap on outlet pipe	Deep Creek tributary
RP 4	-22.680420	149.669604	Dam 1 release point and spillway overflow	Dam spillway and sampling tap on outlet pipe	Deep Creek
Environmental dam release points					
RP 1	-22.722026	149.665554	Waste Rock Stockpile Environmental Dam 1a riser pipe outlet	Sampling tap on riser pipe outlet	Deep Creek
RP 2	-22.707601	149.684239	Waste Rock Stockpile Environmental Dam 2d riser pipe outlet	Sampling tap on riser pipe outlet	Deep Creek
RP 5	-22.678520	149.656474	Waste Rock Stockpile Environmental Dam 2a and piped transfer to diversion drain to Tooloombah Creek	Sampling tap on riser pipe outlet	Tooloombah Creek

There are presently no gauging stations in the vicinity of the mine. Two gauging stations, one on Tooloombah Creek and the second on Deep Creek, will be installed prior to the commencement of construction. The gauging station will be used to support the implementation of the Project's mine affected water release strategy. The location of each gauging station is provided at Figure 16-77.

16.10.5.2 Release Strategy

The proposed release conditions presented herein have been developed based on EHP's *Model Water Conditions for Coal Mines in the Fitzroy Basin* (EHP 2013). The proposed releases reside within the adjoining Styx Basin; however, the guidelines for the Fitzroy Basin form current regulatory expectations for mine water management and thus have been adopted as the basis of the release strategy.

Water quality release limits for mine affected water include electrical conductivity (µS/cm), pH, suspended solids (mg/L) and sulphate (mg/L). In addition to the release limits, release contaminant trigger investigation levels also apply. Should the contaminant trigger level be exceeded, further investigation of background levels would be required. Should the release contaminant levels be shown to exceed the background monitoring level, Central Queensland Coal is required to investigate the potential environmental harm and provide reporting to the administering authority outlining the actions taken to prevent environmental harm.

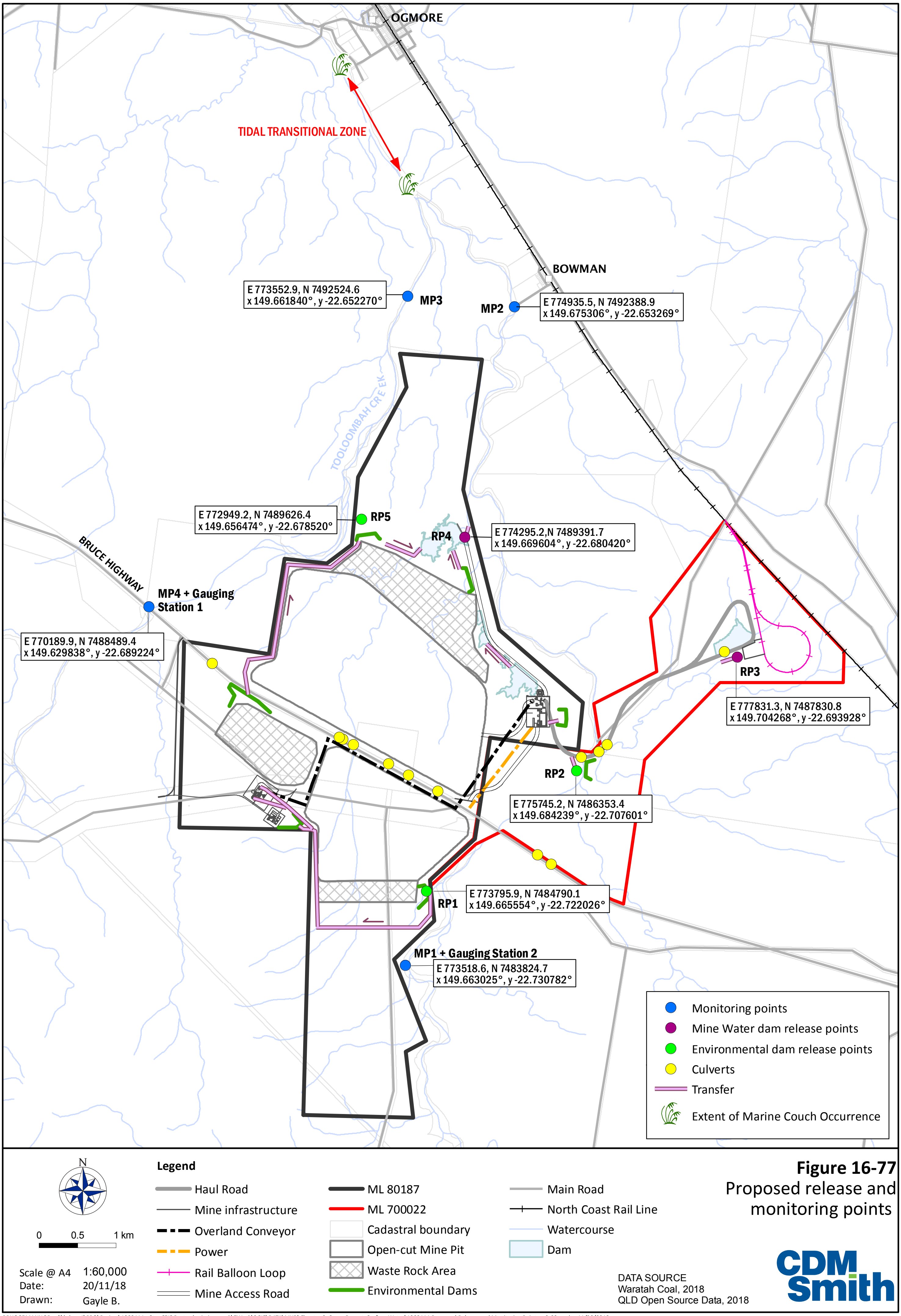


Figure 16-77
Proposed release and monitoring points

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Proposed Release and Monitoring Points__9-99.mxd 11/20/2018

Monitoring of Mine Affected Water Release

Water monitoring will be undertaken at the discharge locations of the environmental dams and mine-affected water dams, and at reference locations both upstream and downstream of the Project area. If water quality levels exceed the WQOs set out in Central Queensland Coal's EA, upstream (control) values will be compared to the water quality within and downstream of the Project area to determine if the exceedance is site-specific, and thus likely to be a result of Project activities, or if it is likely to be natural (similar to water quality levels upstream). The proposed upstream and downstream monitoring points are shown in Figure 16-77 and listed in Table 16-64.

Table 16-64 Proposed monitoring points and receiving waters

Monitoring points	Receiving waters location description	Latitude (Decimal Degrees, GDA94)	Longitude (Decimal Degrees, GDA94)
Upstream background monitoring points			
Monitoring Point 1 (MP1) (and Gauging Station 2)	Deep Creek, located outside the proposed mine lease boundary, upstream of mine releases.	-22. 730782	149. 663025
Monitoring Point 4 (MP4) (and Gauging Station 1)	Tooloombah Creek located outside the proposed mine lease boundary, upstream of mine releases.	-22. 689224	149. 629838
Downstream monitoring points			
Monitoring Point 2 (MP2)	Deep Creek located outside the proposed mine lease boundary downstream of mine releases.	-22. 653269	149. 675306
Monitoring Point 3 (MP3)	Tooloombah Creek located outside the proposed mine lease boundary, downstream of mine releases.	-22. 652270	149. 661840

Flow Triggers and Electrical Conductivity Quality Criteria

There are no flow gauges within the Styx Basin by which to define the hydrologic regime and determine appropriate flow triggers for release of mine affected water. A catchment hydrology model (see Section 16.10.4.4) was constructed to estimate the historical daily runoff volumes in Tooloombah Creek and Deep Creek at the proposed monitoring locations (with a catchment area of approximately 369.7 km^2 and 298.0 km^2 respectively). A simulation was run across the 128 years of historical rainfall and evaporation data to produce the daily flow statistics presented in Table 16-65 and Table 16-66 for Tooloombah Creek and Deep Creek respectively.

To derive the flow statistics, values of runoff lower than 0.01 m^3/s (1 ML/d) were filtered from the data and a percentiles function applied to determine the percentage exceedance probability for stormwater flow events. For example, when a flow event occurs, there is a greater than 80% chance that the flow will exceed 68 ML/d.

Table 16-65 Tooloombah Creek monitoring point - flow statistics for stormwater runoff events

Percentage exceedance probability (%)	Daily flow volume (ML/d)*	Flow rate (m^3/s)*	Percentage of Days with greater than flow (%)
95	0.1	0.00	80.1
80	0.8	0.01	64.0
50	4.2	0.05	43.5
30	14.7	0.17	28.1
20	25.7	0.30	22.1
10	74.7	0.86	12.4
5	175.9	2.04	7.4
1	1,005.0	11.63	2.2

*Simulations were run on a daily timestep. Flow volume (ML/d) represents the average recorded flow rate (in m^3/s) applied across the entire duration for any given day.

Table 16-66 Deep Creek monitoring point - flow statistics for stormwater runoff events

Percentage exceedance probability (%)	Daily flow volume (ML/d)*	Flow rate (m^3/s)*	Percentage of Days with greater than flow (%)
95	0.0	0.00	84.3
80	0.3	0.00	71.0
50	3.3	0.04	44.3
30	13.9	0.16	26.6
20	32.7	0.38	17.7
10	108.9	1.26	8.9
5	307.8	3.56	4.4
1	3,513.0	40.66	0.9

*Simulations were run on a daily timestep. Flow volume (ML/d) represents the average recorded flow rate (in m^3/s) applied across the entire duration for any given day.

The flow duration curves for Tooloombah Creek and Deep Creek, derived from AWBM runoff estimates, are presented at Figure 9-104 in Chapter 9. Unlike in Table 16-65 and Table 16-66 there has been no filtering of the data (i.e. days of zero and low flow are included). Although the two catchments have a different area and slightly different hydrological response, the flow duration curves show that there is greater than approximately 75 ML/day flow in Tooloombah Creek, and 109 ML/day in Deep Creek at the proposed monitoring locations on 10% of days and flows above 0.8 ML/day and 0.2 ML/day on 80% of days for each of the creeks, respectively.

Two streamflow gauging stations are intended to be installed; one on lower Tooloombah Creek and one on lower Deep Creek. Each of the gauging stations will be located a short distance downstream of the northern boundary of the ML 80187. These stations, along with rating curve development and regular readings, are intended to provide streamflow data to regularly update the hydrological understanding, as well as to provide reference points to assist in triggering flow releases.

Flow triggers for release of mine affected water are separated into the following conditions and general principals. Sulphate release conditions will be determined prior to release and in consideration of the release water and receiving water concentrations to not exceed the Model Conditions of 250 mg/L SO_4. This will be calculated using $C_1V_1 = C_2V_2$ where C_1 and V_2 are the concentration and volume of source water and C_2 and V_2 are the concentration and volume or the receiving water.

Flow and EC release conditions for electrical conductivity for the below conditions are summarised in Table 16-67 and Table 16-68. It is proposed that the release conditions be updated as additional Creek water quality data is obtained and once sufficient stream gauging and water quality data has been collected to derive site specific flow triggers. The maximum combined mine discharge flow rates are based on the lowest creek flow rate for each flow condition category to provide the most conservative release conditions. Actual discharge flow rates will be calculated based on the nominated water quality objectives and creek flow data relevant to each discharge event.

- No / low flow stream conditions (low EC mine affected water):
  - End-of-pipe water quality water that meets or exceeds water quality objectives
  - Discharge four weeks after flow event ceases for ephemeral systems where duration of release is limited
  - Low flow trigger determined by the 30th percentile probability of exceedance, occurring on ~28.1% of days for Tooloombah Creek and ~26.6% of days for Deep Creek
  - Mine discharge rate set to equal the trigger flow
- Moderate flow stream conditions (medium quality mine affected water):
  - Requires the use of a flow trigger above which release can occur
  - End-of-pipe EC <3,500 µS/cm or <2,500 µS/cm, with corresponding volumetric limits imposed on each contaminant release limit
  - Discharge rate based on the instream diluted EC limit defined initially by MMC and then by site specific WQOs once sufficient baseline data is obtained
  - Medium flow trigger determined by the 20th percentile probability of exceedance, occurring on ~22.1% of days for Tooloombah Creek and ~17.7% of days for Deep Creek
- High flow stream conditions (poorer quality water):
  - Requires the use of a flow trigger above which release can occur
  - End-of-pipe EC <4,500 µS/cm or 3,500 µS/cm, with corresponding volumetric limits imposed on each contaminant release limit
  - Discharge rate based on the instream diluted EC limit defined initially by MMC and then by site specific WQOs once sufficient baseline data is obtained
  - High flow trigger determined by the 10th percentile probability of exceedance, occurring on ~12.4% of days for Tooloombah Creek and ~8.9% of days for Deep Creek
- Very high flow event stream conditions (poor quality water):
  - Requires the use of a flow trigger above which release can occur
  - End-of-pipe EC <5,500 µS/cm or 4,500 µS/cm, with corresponding volumetric limits imposed on each contaminant release limit
  - Discharge rate based on the instream diluted EC limit defined initially by MMC and then by site specific WQOs once sufficient baseline data is obtained
  - Very high flow trigger determined by the 5th percentile probability of exceedance, occurring on ~7.4% of days for Tooloombah Creek and ~4.4% of days for Deep Creek
- Flood event stream conditions (poor quality water and uncontrolled spill prevention):
  - Requires the use of a flow trigger above which release can occur
  - End-of-pipe EC <6,500 µS/cm or 5,500 µS/cm, with corresponding volumetric limits imposed on each contaminant release limit
  - Discharge rate based on the instream diluted EC limit defined initially by MMC and then by site specific WQOs once sufficient baseline data is obtained
  - Flood flow trigger determine by the 1 percentile probability of exceedance, occurring on ~2.2% of days for Tooloombah Creek and ~0.9% of days for Deep Creek.

Table 16-67 Tooloombah Creek release conditions

Flow condition	Receiving water flow trigger (m^3/s)	Maximum combined mine discharge (m^3/s)	End-of-pipe EC limit (µS/cm)	Tooloombah Creek EC at monitoring point (µS/cm)
No/Low Flow	0.17<[1]	0.17	1,320[2]	1,320[2]
Medium Flow	0.17-0.30	0.113	1,500[3]	1,000[3]
	0.17-0.30	0.049	3,500[3]	
High Flow	0.30-0.86	0.086	3,500[3]	
	0.30-0.86	0.067	4,500[3]	
Very High Flow	0.86-2.04	0.191	4,500[3]	
	0.86-2.04	0.156	5,500[3]	
Flood	>2.04	0.371	5,500[3]	
	>2.04	0.314	6,500[3]	

[1]Following a flow event exceeding 0.17 m^3/s, release of high quality water is permitted for a period of up to 28 days after flow recedes below 0.17 m^3/s

[2]Adopted based on the Model water conditions for coal mines in the Fitzroy Basin for low-flow conditions and the 75th percentile of existing Tooloombah Creek database consisting of 95 data points collected between 2011 and 2018[3]Adopted based on the Model water conditions for coal mines in the Fitzroy Basin for mines in Zone 1 Catchments.

[3]Adopted based on the Model water conditions for coal mines in the Fitzroy Basin for mines in Zone 1 Catchments.

Table 16-68 Deep Creek release conditions

Flow condition	Receiving water flow trigger (m^3/s)	Maximum combined mine discharge (m^3/s)	End-of-pipe EC limit (µS/cm)	Deep Creek EC at monitoring point (µS/cm)
No/Low Flow	0.16[1]	0.16	495.5	495.5[3]
Medium Flow	0.16-0.38	0.107	1,500[3]	1,000^
	0.16-0.38	0.046	3,500[3]	
High Flow	0.38-1.26	0.109	3,500[3]	
	0.38-1.26	0.084	4,500[3]	
Very High Flow	1.26-3.56	0.280	4,500[3]	
	1.26-3.56	0.229	5,500[3]	
Flood	>3.56	0.647	5,500[3]	
	>3.56	0.548	6,500[3]	

[1]Following a flow event exceeding 0.16 m^3/s, release of high quality water is permitted for a period of up to 28 days after flow recedes below 0.16 m^3/s

[2]Adopted based on the Model water conditions for coal mines in the Fitzroy Basin for low-flow conditions and the 75th percentile of existing Deep Creek database consisting of 110 data points collected between 2011 and 2018

[3]Adopted based on the Model water conditions for coal mines in the Fitzroy Basin for mines in Zone 1 Catchments.

16.10.6 Potential Impacts

Mining activities and proposed works that have the potential to impact on surface water conditions and EVs are outlined below for the different Project phases. Potential impacts are discussed and management measures aimed at mitigating those impacts are provided. Potential impacts on water quality as they relate to the Great Barrier Reef World Heritage Area are addressed in Section 16.14.3.

The main construction activities that could impact on surface water EVs are:

- Excavations and earthmoving including topsoil removal and stockpiling for the construction of the mine infrastructure including site access roads, bunds, dams, CHPP and MIA. This may potentially lead to erosion and sedimentation, deterioration of water quality, and changes to water flows; and
- The use of fuels and chemicals for vehicles and construction equipment, potentially resulting in water contamination because of spills, leaks, or other uncontrolled releases.

Operational impacts are in relation to:

- Altered catchment conditions on the hydrology of waterways and drainage lines due to excavations, buildings and infrastructure, water dams, sediment dams and waste rock stockpile areas;
- Altered flooding response due to the reduction in available floodplain due to bunds, levee, sediment dams and mine infrastructure; and
- Stormwater runoff, erosion and contamination from either CHPP or MIA areas.

16.10.6.1 Increased Sedimentation of Waterways and Sediment Runoff

During construction and operation, sediment can be mobilised and transported by surface water during rainfall events, ultimately discharging into Deep Creek drainage lines. This may result in negative impacts on water quality and aquatic habitats. Specifically, increased quantities of suspended sediments can reduce light penetration, decreasing the photosynthesis of aquatic flora and lowering dissolved oxygen concentrations. Due to the ephemeral nature of the drainage features and watercourses, this is unlikely to be an impact in the immediate area but would more likely cause impacts downstream and in the Styx River where more permanent refugial pools exist. Suspended sediments from runoff will likely contain elevated nitrogen and phosphorus levels due to the agricultural activities on the Mamelon property. Increased nutrients can promote algal growth and in extreme cases result in blooms and surface water deoxygenation during low flow situations. Due to proximity to the MIA, Deep Creek is considered the watercourse most at risk from increased sedimentation.

Erosion and sedimentation during the operation phases is most likely to occur from stormwater runoff from the coal stockpile, MIA and from ongoing minor earthworks associated with the maintenance of roads and dams. If stormwater runoff is not adequately contained, there is a potential for increased sedimentation and contamination to adversely impact surface water receiving environments, particularly Deep Creek. Surface water observations taken during no flow periods during the surface water monitoring program undertaken in 2017 and 2018 recorded naturally high turbidity levels in Deep Creek sites.

Impacts to Tooloombah Creek are unlikely, as most of the Project area drains towards Deep Creek with only 15% draining towards Tooloombah Creek. The catchment is isolated from most of the Project infrastructure components. The diversion of clean stormwater run-off from upstream of Open Cut 1 western section may mobilise sediments during the operational period.

Baseline water quality monitoring results indicated that existing waterways generally have low to moderate turbidity and suspended sediment loads during and following flow periods. During extended dry periods with no flow (as sampled in February 2017, and November 2017 to April 2018) when the waterways are reduced to isolated pools, high levels of turbidity and suspended sediment loads were recorded predominantly (but not solely) in Deep Creek sites.

The potential impacts of erosion and sedimentation from surface runoff, if not adequately mitigated, could produce moderate impacts on local downstream water quality, and on aquatic ecosystems EVs, including the marine environment (and associated recreational fishing values).

16.10.6.2 Direct Disturbance of Waterways

The Project MIA, open cut pit and stockpiles are unlikely to directly disturb the watercourses. However, the abovementioned Project components and infrastructure will cut-off the two drainage features that traverse the open pit locations. This will result in lower flows in the reaches downstream of the open pits.

Most of the waterway disturbance will occur at the haul road crossings of Deep Creek, Barrack Creek and an unnamed tributary of Deep Creek. Both Deep Creek and Barrack Creek are incised with channel depths in the range of 6.5 m to 7.8 m. The unnamed tributary of Deep Creek is significantly shallower with a channel depth of around 3.5 m.

At these crossings, impacts may include: riparian vegetation clearing, direct deformation of the bed and banks, and alteration of hydrological flows. Consequential impacts may include: decreased habitat, increased potential for erosion and an increase in runoff velocity due to effective increase in bed slope that can result from the construction of cross-drainage structures.

16.10.6.3 Accidental Release of Pollutants

During general Project construction activities, the refuelling of vehicles and maintenance of equipment has the potential to release fuels and chemicals into the two watercourses on either side of the Project area. This source of potential contamination is continued during the operations of the mine. Accidental release of pollutants may adversely impact Deep Creek as the majority of the Project footprint majority lies within the Deep Creek catchment. Impact on Tooloombah Creek is less likely as the local Environmental Dams 1a, 2a and 2b are the only infrastructure to potentially discharge into the creek. Several items of infrastructure have the potential to accidentally release contaminants to either Deep Creek or Tooloombah Creek, owing to their proximity. These include:

- The waste rock stockpile areas (1a and 1b) located to the south and west of Open Cut 1 have potential to release contaminated run-off into Deep Creek and Tooloombah Creek respectively. Waste Rock Stockpile 1a is located approximately 250 m west of Deep Creek. Waste Rock Stockpile 2 has the potential of releasing contaminated run-off into Tooloombah Creek and potentially Deep Creek. However, it is noted that analysis of the waste rock properties show very little likelihood of acid and / or saline mine drainage occurring. The likelihood of elevated metals leaching from the waste rock stockpiles is also considered to be unlikely – these are discussed in Section 16.7.3.6 and 16.9 and in detail in Chapter 8 – Waste Rock;
- The MIA / CHPP areas have potential to accidentally release industrial pollutants, particularly MIA / CHPP 2 which is located approximately 500 m from Deep Creek; and
- Dam 1 is located onstream, which during the construction of the dam wall has the potential to release construction related contaminants into Deep Creek (refer Figure 16-67).

Without mitigation, potential exists for aqueous waste streams to potentially enter waterways. This includes such things as:

- Oily waste water (from heavy equipment cleaning);
- Contaminated runoff from chemical storage areas;
- Contaminated drainage from fuel oil storage areas; and
- General washdown water.

The accidental release of pollutants can result in adverse impacts of flora and fauna (i.e. through coating) or may manifest itself as chronic illness and mortality, via slow and long term release of contaminants.

The EVs for the receiving waters include irrigation, stock watering and human consumption. Accidental release of pollutants and contaminants may adversely impact downstream agricultural operations and prevent use of the water for human consumption.

Potential impacts of accidental pollutant and contaminant releases, if not adequately mitigated, have potential to produce moderate impacts on local and downstream water quality and aquatic ecology, (including downstream impact on the waters of Broad Sound and the Great Barrier Reef World Heritage Area), irrigation, farm supply, stock water.

16.10.6.4 Hydrology and Water Flows

The major changes in catchment hydrology relates to the addition of drains to divert the catchments upstream of the mine pits. This will result in increased volumes of runoff presenting at the Deep Creek Bridge. All catchments to the west of MIA 1 will be diverted around Waste Rock Stockpile 1b into an environmental dam that reports into Tooloombah Creek under extreme circumstances, where the additional contributing catchment may also result in increased runoff volumes with respect to the current situation.

The addition of hardstand areas such as the MIA, haul roads and access roads will also change hydrologic characteristics, as these surfaces are relatively impervious and transform a higher proportion of rainfall into run-off, increasing peak runoff rates. Waste rock areas; however, are generally comprised of loose spoil and have a high capacity to absorb rainfall. Incident precipitation slowly percolates through the spoil before discharging to the environmental dam. This process has the effect of reducing peak runoff.

Hydraulic modelling indicates that a general reduction in peak flows is likely downstream of the site boundary, because of the reduction in contributing catchment area caused by the construction of the open cut pits.

The overall impact is relatively minor – for example, under the 0.1% AEP design flood event a reduction in peak flood level of approximately 0.02 m is predicted at the Styx River confluence of Deep Creek and Tooloombah Creek. In Deep Creek, a decrease in peak flood levels of about 0.07 m is predicted. Tooloombah Creek flood levels are predicted to decrease by about 0.03 m. As would be expected, peak velocities are predicted to decrease commensurately. Given the very minor predicted change in peak flow characteristics it is considered to have only have a very minor impact (if at all) on aquatic ecology EVs.

16.10.7 Mitigation and Management Measures

The following sections provides the mitigation measures proposed to be applied to Project activities to manage the potential impacts to surface water values identified in the previous Section (also refer Section 16.14.3 and 16.15.3).

16.10.7.1 Control of Erosion and Sediment

Section 16.9.4 provides a detailed assessment of the potential for erosion and sediment impacts from the Project and the required control measures / infrastructure under a detailed ESCP. The major points of this assessment are summarised here. For more information refer back to Section 16.9.4.

Land Management – Stock Removal

The Project is located on the Mamelon property. Mamelon encompasses a total area of 6,478 ha of which the Project disturbance footprint covers approximately 1,124.8 ha. Central Queensland Coal have proposed destocking the majority of the property and restricting cattle access to already cleared habitat in the south-west and south of the property, outside of the ML. This area encompasses approximately 1,000 ha. The remaining area, including the creek lines which lie adjacent to the mine area, will be managed and allowed to regenerate. In the longer term this measure will contribute to localised water quality improvements, and contribute to improving the water quality entering Broad Sound and the GBRWHA through the following:

- The long-term restoration of this habitat, and in particular allowing vegetation to regrow along the riparian zones along Deep Creek and Tooloombah Creek (which are presently mostly cleared), will capture / entrain sediment and nutrient run-off from the property;
- The restoration of cleared areas will also reduce soil erosion on cleared areas of the property, thereby reducing the entrainment of sediments entering creek lines during bouts of heavy rainfall; and
- The removal of cattle from much of the property will also remove a source of long-term nutrient input into creek lines following rainfall.

The mobilisation of sediments from grazed environments occurs through different mechanisms and at differing scales. Within the Project area the typical mechanisms that exist within the more frequently grazed areas are sheet erosion, gully erosion and stream bank erosion. Hillslope erosion is also a contributing mechanism within the Project area although these areas are not grazed to the same extent as the more productive undulating to gently undulating country.

In the absence of specific data for the Styx catchment, erosion estimations for land under grazing were undertaken using the HowLeaky? model developed for the Eden Bann Weir EIS (refer Section 16.9.3 for more information). The results of the assessment show that for areas of 1% slope under the grazing regimes described at Table 16-17, the estimated annual sediment generation potential ranges between 595 to 2,797 t/ha and 182 to 856 t/ha for ML 80187 and ML 700022 respectively. For areas of 3% slope under grazing regime C as described at Table 16-17, the estimated annual sediment generation is 230 t/ha and 99 t/ha for ML 80187 and ML 700022 respectively.

Central Queensland Coal has committed to the destocking the majority of the Mamelon property to allow for the natural regeneration of vegetation across the property. The small portion of the property that is not proposed to be destocked is on land of >3% slope and was not considered in the assessment at Table 16-18. The destocking of Mamelon will allow for the natural regeneration of land undisturbed by the mine and allow for the continued progressive rehabilitation of land disturbed by the mine. Noting the Project will be implementing a wide range of specifically engineered and designed sediment control measures to prevent sediment from leaving the site, there is expected to be a significant reduction in mobilised sediments compared to that of the current grazing regime.

Engineered Erosion and Sediment Controls

An effective ESC strategy considers the interrelated processes of drainage control (minimising water flows through erosion prone areas), erosion control (minimising the detachment of sediment), and sediment control (capturing sediment displaced by up-slope erosion processes). Therefore, the key strategies adopted in the ESCP will involve diversion of water flowing into disturbance areas, minimising erosion within the disturbance areas, and trapping the majority of sediment that is generated before it is mobilised off site.

The following steps will be taken to minimise sedimentation during the active phase of the site:

- The Project has been designed to ensure surface water flows into creeks are maintained as close as possible to natural conditions;
- Diversion drains and banks will be used to redirect any "clean" surface water flows around the main site areas. This minimises the potential for erosion by limiting the amount of water flowing through the disturbance areas and protects infrastructure from flooding during extreme events. Design and sizing of diversion drains, banks and culverts is discussed further in Chapter 9 – Surface Water;
- Exposed soil surfaces will be engineered to minimise erosion potential. This will be achieved through careful material selection, slope grading, and other surface treatments; and
- Any sediment-laden water within the disturbance areas will be captured and treated in a manner which minimises amount of sediment released into the surrounding environment.

Stormwater runoff containment devices, namely environmental dams, function to capture dirty water runoff generated from disturbed areas such as stockpiles and the MIA and CHPP areas. Environmental dams are sized based on the 10-year ARI, 24-hour rainfall event in keeping with the DES Stormwater Guideline (EHP 2014b). Environmental dams will have a low flow perforated riser-pipe outlet to discharge treated water to the receiving environment. Environmental dams are located at both MIAs, overburden stockpiles and the TLF. MIA drainage sumps and proprietary oil removal devices are proposed to capture runoff from truck wash and workshop areas for treatment and reuse or disposal.

Runoff intercepted by or generated from haul roads will be captured in table drains and conveyed longitudinally towards culvert structures. In areas of steeper grade, sediment transport can be effectively managed using check-dam structures within the drain. Where haul roads cross drainage gullies or the Deep Creek watercourse, an appropriately sized culvert will be provided, allowing for fish passage where relevant.

Clean water runoff from local catchments will be diverted around open pit mining areas for events up to and including the 0.1% AEP (1: 1,000-year ARI) design flood. The volume of stormwater entering open mine pits and becoming mine affected water is therefore effectively limited to that rain which falls directly on the open pit area. Precipitation received in the open pits will be dewatered to an ex-pit storage for reuse or discharged to receiving waters as controlled discharges under conditions licensed by the State's Environmental Authority issued for the Project.

The key ESC infrastructure proposed for the site includes:

- Clean water diversions - Diversion drains and bunds are proposed to divert clean water runoff around the mine affected areas, including the open pits and waste areas;
- Dirty water diversions - Dirty water drains collect runoff from waste rock stockpiles and processing facilities within the vicinity of the CHPP, ROM and MIA, and discharge to the CHPP Environmental dams and waste area environmental dams. These dirty water drains will be sized to capture runoff generated from a 24 hour 1 in 10-year ARI event;
- Environmental dams - Environmental dams (sediment basins) around the Project collect catchment runoff and transfer water to the MIA Dams. Each of the CHPP and MIA's, waste areas and TLF have an environmental dam. Environmental Dams are sized to capture the 1 in 10-year

ARI 24 hr duration storm event in accordance with The DES Stormwater Guideline (EHP 2014b); and

- Culvert crossings - The proposed haul road connecting the MIA and CHPP 2 with the TLF crosses several drainage gullies, therefore requiring cross-drainage culvert infrastructure. The crossings are conceptualised as box culvert crossings with capacity to pass a minimum 1 in 10-year ARI design discharge. Discharges above the design event will pass over the box culvert as a floodway-type arrangement.

Temporary ESC diversion drains will be designed with capacity to convey a 1:100-yr peak flow event. This level of protection is above and beyond the 1:10-yr design standard recommended in the ESCP guidelines (IECA 2008) and has been adopted to ensure that more than adequate protection is provided throughout the life of mine. Temporary structures include all diversion drains and sediment traps that will be removed at mine closure, such as those installed around the plant area.

All permanent ESC structures (i.e. the main site diversion banks around open cut mine areas) will be designed to withstand a 1:1,000-yr peak flow event in keeping with the EHP Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (2016). All environmental dams will be designed as Type 1 sediment basins. These are flow-through type basins, designed to remove 90 % of material > 0.045 mm in diameter (silts), and with a sediment storage zone that is 50% of the volume of the water settling zone.

The installation of all ESC measures has been scheduled to maximise protection throughout all phases of site development. Control measures will be put in place prior to soil disturbance wherever practical and will remain in place for the duration of the expected disturbance. Land clearing will be scheduled for the dry season to minimise exposure to rainfall, where practical.

The main site diversion banks in particular will be designed to be installed in stages. The main diversion banks will be installed progressively as the pits are developed. These features will remain in place after site closure. The smaller diversion drains associated with each of the infrastructure areas will be installed shortly after the areas are cleared and reshaped for construction. These features will be removed after the infrastructure areas are decommissioned and the areas are ready for rehabilitation.

Flow diversion banks and drains will be constructed to divert all clean water surface flows around the main work areas to minimise the potential volume water that will need to be managed within the site. The critical design factor for surface water diversions is the expected peak flow rate. Peak flow rates typically occur during short, intense storms (e.g. a 1:100-yr, 10 min event at 246 mm/hr) rather than during longer storm events (e.g. 1:100-yr, 72 hr event averaging 7.16 mm/hr). The main site diversion banks will be designed to convey a 1:1,000-yr peak flow event, and all temporary drains will be designed for a 1:100-yr peak flow event, and critical rainfall durations ranged from approximately 5-70 min. All diversion banks and drains will be constructed from compacted native soil materials.

All diversion banks will be designed assuming a 10:1 gradient (0.10 m/m slope) on the upslope side, and a 3:1 gradient (0.33 m/m slope) for the constructed bank. All diversion drains will be designed assuming an 8:1 gradient (0.13 mm/m slope) on both sides of the drain. Gentler construction angles will increase the design capacity of these features so long as the design flow depth is maintained. Discharge from each diversion structure will be via a level spreader or rock chute, to ensure that the concentrated surface flow is transitioned back to sheet flow in a way that minimises erosion downslope of the outlet.

Further information and detail on erosion and sediment control measures are provided in Section 16.9.4.4 including 'Minimising erosion on disturbed surfaces' and 'Sediment and drainage controls'.

16.10.7.2 Control of Pollutants and Contaminants

All contaminated water on-site will be collected using site environmental dams, preventing the water from entering local waterways. The Project will include six environmental dams. These dams will collect water from the MIA, CHPP, waste rock storage, coal stockpile and the TLF and store contaminated rainfall runoff across the site. This water will be used to supplement the demands for stockpile dust suppression, washdown and CHPP demand.

In addition to the installation of environmental dams, the following management measures will be implemented to minimise the risk of pollutants and contaminants entering local water ways:

- Appropriate spill control materials including booms and absorbent materials will be onsite at refuelling facilities at all times. These will be used for mitigating and managing events where a substance is spilled into the surrounding waters;
- All refuelling facilities and the storage and handling of oil and chemicals will comply with relevant Australian Standards (management and mitigation measures for wastewater is discussed in Chapter 7 – Waste Management);
- Procedures will be established at the mine for safe and effective fuel, oil and chemical storage and handling. This includes storing these materials within roofed, bunded areas with a storage capacity of 100% of the largest vessel and 10% of the second largest vessel. The bunding will have floors and walls that are lined with an impermeable material to prevent leaching and spills; and
- Wash-down areas for plant and equipment will be clearly marked to prevent contaminated water from leaching into soils or flowing into nearby watercourses.

16.10.7.3 Monitoring for Seepage

The detailed design of the environmental and water dams on site will consider and make provision for the detection and management of seepage where it may result in safety and / or water quality impacts to the receiving environment. In general, the site water management strategy indicates that mine-impacted water will be of good to moderate quality, having been in contact with coal and / or sediment. The largest amount of seepage is likely to occur within the floor of the environmental and water dams, resulting in in-detectable to minor increases in contribution to shallow aquifer groundwater. The magnitude of seepage through the floor is difficult to measure but can be modelled in the site-wide water balance model. Seepage via the dam wall / embankments is also likely to be filtered and of good to moderate quality. Seepage has been considered in the consequence category of the dams. The site water management plan will address monitoring, including visual inspections for seepage from embankments, along with trigger and action plans based on the volume, rate and quality detected.

16.10.7.4 Ongoing Water Quality Management and Monitoring

Water Release Points and Monitoring

The Project has five proposed mine affected water release points (see Table 16-63). Water monitoring will be undertaken at the environmental dams, mine-affected water dams, discharge locations and locations both upstream and downstream of the Project area (Figure 16-77). In addition, ongoing monitoring will be undertaken at the sample locations identified in Table 16-64 to assess water quality impacts on waterway flows. This will enable Central Queensland Coal to continually monitor water quality within the waterways (upstream of the Project area at the control sites) and the potentially impacted watercourses (within the Project area and downstream of the Project area at the impact and monitoring sites).

Receiving Environment Monitoring Program

Monitoring will complement the water management strategy to confirm that any potential uncontrolled discharges (overflows from the environmental dams) or controlled discharges do not adversely impact on downstream water quality. Monitoring will also serve as a continual improvement mechanism for the ongoing management of stormwater including operational calibration of the water balance model.

A Project Receiving Environment Monitoring Program (REMP) will be developed in accordance with Guidelines, including the technical guideline - Wastewater Release to Queensland Waters (EHP 2016a), and will be periodically updated as required throughout the life of the Project. The REMP will encompass both surface water and groundwater elements.

The REMP will incorporate the following elements pertaining to surface water:

- Development of Final WQOs, with trigger values set at the 20th and 80th percentiles and in accordance with the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives. Percentiles will be identified through ongoing baseline investigations undertaken prior to construction (responses to trigger values are explained below). Baseline water quality monitoring to determine locally derived WQOs for the Project. If DES deems that insufficient data has been collected prior to construction to determine baseline trigger values, interim WQO trigger values will be applied as per Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives;
- An ongoing baseline assessment and interpretation of water quality data, undertaken in accordance with relevant guidelines, including the Monitoring and Sampling Manual 2009 (EHP 2010), QWQG (EHP 2009), and ANZECC guidelines. The monitoring program will outline, as a minimum:
  - Measures to further derive local WQOs from data collected from reference sites, chosen in accordance with the QWQG (EHP 2009)
  - Frequency and locations for sampling
  - Relevant water quality parameters, including physico-chemical and estimation of local stream flow
  - Water quality sampling methods
- A plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate;
- The recording of all data used to determine locally-derived WQOs. Data shall be recorded in an electronic format for review by the administering authority if requested;
- Monitoring that includes inspections of construction areas and surrounding waters for visual changes to water quality. Specifically, the programme will include:
  - Event based monitoring throughout the life of the Project, carried out at a minimum of six sampling locations (one location upstream and one location downstream of release points, for each for Deep Creek, Tooloombah Creek and tributary of Deep Creek)

  - Ongoing quarterly monitoring of water quality, to be carried out on the mine affected water dams, when standing water is present

- Physical and chemical water quality monitoring, both up and down stream of work sites, and in all Project affected water dams and defined watercourses within the Project area;
- A plan that includes the actions required if a trigger level is exceeded. Specific actions will include:
  - A comparison of upstream and downstream results to determine if the pollutant source is likely to have come from the Project
  - A review of construction methods to determine ways of improving works to minimise the risk of further contamination
  - The identification of corrective actions to prevent any future exceedances.

The incident reporting processes to DES will be completed as per EA conditions set by the State.

Trigger Action Response Plans

Trigger Action Response Plans (TARPs) will outline actions and responses necessary should monitoring identify exceedances in the Project water quality criteria (trigger levels). In addition, the TARP will outline the criteria, monitoring and reporting measures for environmental incidents, unplanned events or cases of unauthorised discharge. The draft TARPs will be finalised once EA conditions are finalised and form part of the REMP response to the ongoing monitoring program and actions required to address exceedances. The criteria, monitoring and reporting measures for ongoing Project surface water monitoring, reductions in baseflow and for unforeseen events / unplanned discharges are presented at Table 16-69 to Table 16-71.

Water Management Plan

In addition to the REMP, a Water Management Plan (WMP) will be prepared for the Project. Both documents together form the approach to management onsite water usage and storage, and the monitoring of EV in relation to water usage (including groundwater drawdown) and water release. It is assumed that the WMP will be a requirement of the Project's EA.

The WMP be developed to minimise the risk of adverse impacts on surface and groundwater systems. The WMP will describe the mine water balance, key water infrastructure (i.e. water storages, pipe network, drainage system), flood immunity infrastructure and will be split to describe the water management requirements for the construction and operational phases of the Project. In addition, the WMP will also:

- Specify the water source for each water storage;
- Identify the likely water quality of each water storage and the worst possible water quality that could occur under extreme climate conditions;
- Identify the flood and extreme rainfall events that each water storage is designed to contain before an uncontrolled release occurs; and
- Identify design parameters such as the amount of freeboard that will be maintained.

The WMP will be provided to DES for review prior to the commencement of construction and mining activities.

Table 16-69 Trigger Action Response Plan - surface waters (RP1 to RP5)

Monitoring Type	Parameters	Frequency	Criteria	Trigger	Action	Response	Plan
Discharge monitoring of surface waters	Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Zn, B, Co, Mn, Mo, Se, Ag, U, V, NH3, NO3, TPH, F, Na, So4	Commencement of release then weekly during release	TBC – post-EA	Single exceedance of EA parameters	Notify dept (DES) Investigation by Environment Officer and Engineering team	Develop remedial action plan to address investigation findings	Follow up information provided to Department if required Results included in the Annual Environment Report Incident Reporting Requirements completed
Discharge monitoring of surface waters	Electrical conductivity (µS/cm) pH (pH units) Turbidity (NTU) Sulphate (SO_4^{2-}) (mg/L) TSS	Daily during release	1,000 (µS/cm) 6.5-9 pH TBC – post-EA 250 (SO_4^{2-}) (mg/L) TBC – post EA	Single exceedance of EA parameters	Notify dept (DES) Investigation by Environment Officer and Engineering team	Develop remedial action plan to address investigation findings	Follow up information provided to Department if required Results included in the Annual Environment Report Incident Reporting Requirements completed

Table 16-70 Trigger Action Response Plan - surface waters (unplanned events or unauthorised discharge)

Event	Criteria	Compliance Criteria (Exceedance)	Trigger	Action	Responses	Plan
Environmental Incident: Unforeseen Hazard, Unplanned Event or Unauthorised Discharge event is defined as: Loss of mine water or sediment laden waters from an onsite water containment structure, including water management dam, sediment dam, catch drains, pipelines and pumping stations released into creeks and drainage lines; the event threatens or causes material harm and the discharge may or may not flow offsite	Breach of EA condition	Yes	Breach occurs	A. Management of an incident is in accordance with CQC Incident Response – Site Supervisors review and escalate notifications to departments, managers and the senior management team as required (determined by incident risk). IF The incident is determined to be 'an incident or set of circumstances, during or as a consequence of which there is or is likely to be a leak, spill or other escape or deposit of a substance, as a result of which pollution to land, water or air, has occurred, is occurring or is likely to occur' a member of the CQC senior management (or delegate) will be notified. B. If determined the incident has caused, or threatens to cause environmental hard CQC will notify DES	A. Incident is investigated and reported internally; corrective actions are applied where appropriate. Key personnel are involved in incident investigation and mitigation processes. B. Incident Management process will be completed until the incident closed AND Monitoring programs consistent with the EA and / or REMP will be implemented following the discharge event, which is to include: monitoring of the discharge water in accordance with the EA; monitoring upstream and downstream of the discharge point for the prescribed EA parameters; a stream health survey downstream of the discharge point following cessation of the discharge; and AND CQC will develop and implement a remedial action plan (short-term focus) for immediate Response.	A. A summary of environmental incidents are provided within the Annual Environmental Report. B. Internal and External Reporting requirements are completed in accordance with EA conditions

Table 16-71 Trigger Action Response Plan - Base Flow Loss for Deep Creek and Tooloombah Creek

Event	Criteria	Compliance Criteria (Exceedance)	Trigger	Action	Responses	Plan
Base Flow Loss for Deep Creek and Tooloombah Creek	Other than predicted loss in base flow Deep Creek and Tooloombah Creek systems (accounting for seasonal variability)	Yes	A. Annual assessment of baseflow data (trend analysis) displays two consecutive years of baseflow loss above EA predictions. OR A single Complaint received from private landholder regarding base flow loss B. Annual assessment of baseflow data (trend analysis) displays three consecutive years of baseflow loss above EA predictions. OR Reported or observed instantaneous baseflow loss that is uncharacteristic of baseline conditions. OR Mining Impacts cause change in base flow and adversely affects private landholders OR Complaint received from more than one private landholder regarding base-flow loss	A. Investigation completed by reviewing monitoring data, historical averages and operational activities. B. Investigation completed by CQC, reviewing monitoring data, historical averages and operational activities AND CQC assesses impact to private landholders	A. A remedial action plan is developed and implemented to address the Investigation findings B. The remedial action plan (three consecutive) is re-assessed AND DES are notified of the continued elevated criteria AND CQC develops engagement and consultation strategy for affected private landholders	A. A summary of monitoring results, investigations and remedial action plans is provided within the Annual Environmental Reporting to DES. B. Follow up information is provided to DES where requested

16.10.8 Cumulative Impacts

The Project is wholly contained within the Styx River Basin, and the two catchments for the Project area are Tooloombah and Deep Creek. Tooloombah Creek catchment comprises approximately 36,000 ha and Deep Creek comprises a further 29,000 ha. Only 15% of the Project area drains towards Tooloombah Creek with the majority of surface water draining into Deep Creek. Both Deep Creek and Tooloombah Creek meet at a confluence downstream of the Project area to form the Styx River.

For this cumulative assessment, we have chosen to restrict the assessment to the overall Styx River, as it is unlikely that the Project will impact area beyond this extent. The Styx River is dominated by cattle grazing with most of the catchment rural with minimal developments.

There are three surface water entitlements in Tooloombah and Deep Creek. The existing water entitlements are small with extraction requirements of 18 ML and 8 ha. The combined existing water extraction is unlikely to impact the water flow within Tooloombah Creek as the Project is not planning to extract water from the creeks.

Overland flows are presently directed away from Deep Creek and Tooloombah Creek to several water storages constructed to support the existing grazing activity on Mamelon property. Prior to the commencement of operations, water diversions will be established to divert overland flows back to Deep Creek and Tooloombah Creek prior to entering the mine disturbance area. This water will be in addition to what currently reports to Deep Creek and Tooloombah Creeks, and is considered beneficial in terms of providing additional water to support environmental flows and lessen environmental impacts associated with the water abstraction by the existing licence holders.

The Project resides within the middle region of Styx Basin in which there are numerous proposed mines and developments. Many the exploration permits within the basin are dominated by mineral and coal exploration permits The Styx River is currently undeveloped which effectively minimises surface water cumulative impacts associated with the Project as there are no developments which are likely to increase the impacts.

16.11 Environmental Context – Groundwater

Many of the potential impacts on the relevant MNES are indirect impacts that arise due to direct impacts on intermediary receptors of the environment. To assess the potential impacts on MNES it is therefore necessary to assess the impacts on these intermediaries first. This section provides an overview of key aspects of the environmental context associated with groundwater that are relevant to the Project.

16.11.1 Existing Environment

The following sections summarise the existing environmental values as appropriate to groundwater values. Description of local Topography is provided in Section 16.9.1.1, Climate is located in Section 16.10.1.1, and Hydrology in Section 16.10.1.2.

16.11.1.1 Geology

Styx Basin

The Project lies within, and targets the coal reserves of, the Styx geological basin (Styx Basin), which is described by GeoScience Australia (2017a) and Malone et al (1969) as a small, elongate, early-

Cretaceous, intracratonic sag basin comprising up to 1,000 m of siliciclastic sediments and coal measures. Intracratonic sag basins are typically 'saucer-like' in geometry and are developed by depositional infill of a sag in the Earth's crust, which generally forms by gradual subsidence due to downwelling of the mantle. The infill sediments of Styx Basin are known collectively as the Styx Coal Measures.

In total, the Styx Basin covers an area of approximately 2,000 km^2 and extends offshore to depths of up to 100 m below sea level. It is thought to have developed by subsidence of the Strathmuir Synclinorium, an older (deeper) feature containing Permian strata of the Bowen Basin.

The regional geology of the Styx River Basin is shown in cross section presented in Figure 16-78. The maximum known thickness of sedimentary rocks within the Basin is 387 m (observed in an onshore coal exploration drillhole; Malone et al 1969) but geophysical surveys suggest the Basin thickens offshore to the north (Malone et al 1969). The general dip of the Styx Coal Measures is to the east, with outcrop and sub-crop beneath surface Cenozoic deposits occurring along the west and central portion of the basin. The southern part of Styx Basin, where the Project is located, is bounded to the east by a post-depositional, high-angle reverse fault. Either side of the fault, the Cretaceous and Permian units are folded and faulted.

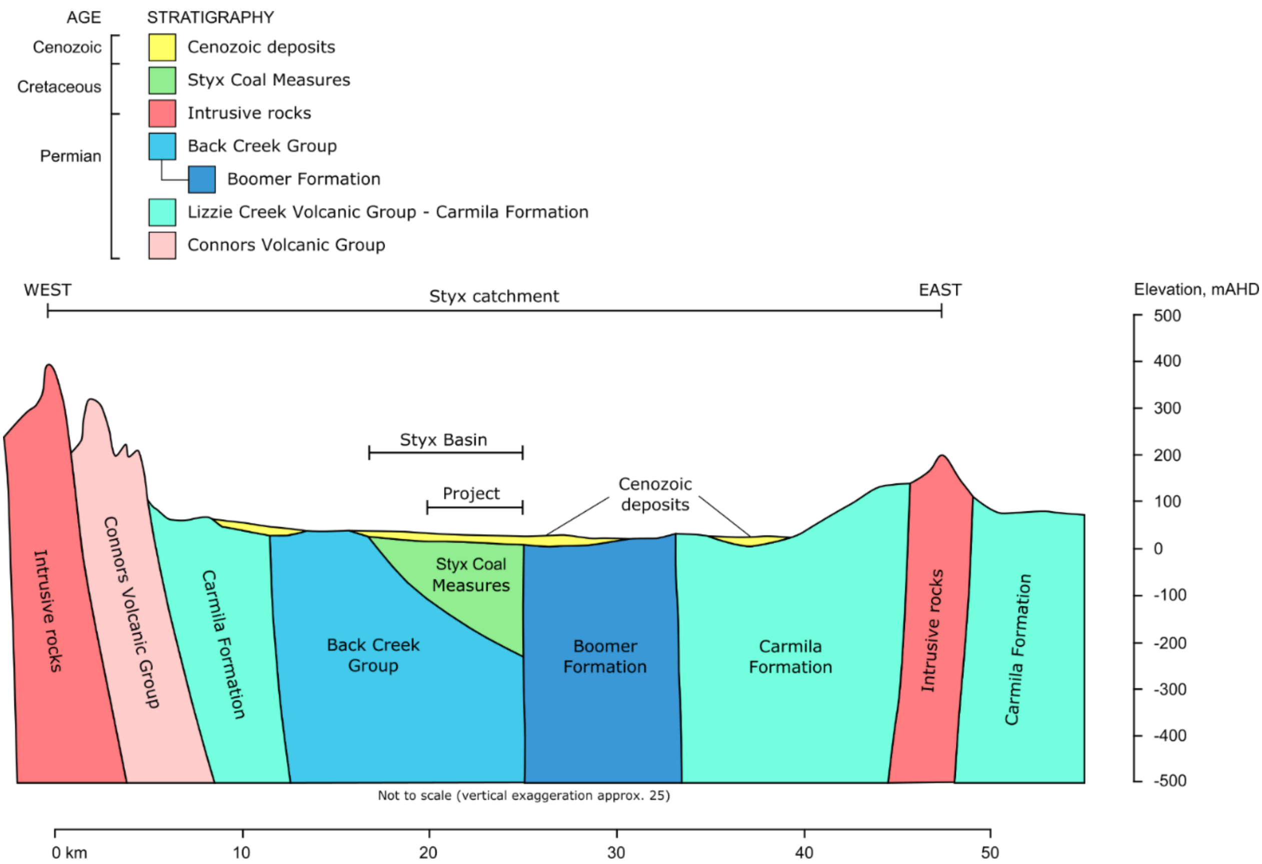


Figure 16-78 Schematic geological cross-section

Stratigraphy

Brief details of the important stratigraphy present within and bounding the Styx Basin are presented below, from oldest to youngest. A detailed discussion is provided in Chapter 5 – Land and Table 16-72 presents summary details concerning age and stratigraphic relationships.

Table 16-72 Stratigraphy of Styx River Basin

Age (Ma)	Group	Formation	Description[1]
Cenozoic (0 to 66)	-	Cenozoic deposits	Alluvium, colluvium, soils, estuarine deposits, etc.
			Unconformity
Early Cretaceous (100 to 145)	-	Styx Coal Measures	Quartzose sandstone, mudstone, conglomerate and coal
			Unconformity
Late to Early Permian (251 to 268)	Back Creek Group	Boomer Formation	Lithic sandstone, siltstone, mudstone, rare conglomerate
			Quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite
Early Permian (284 ± 7)	Lizzie Creek Volcanic Group	Carmila Beds	Siltstone and mudstone, volcanilithic sandstone and conglomerate and minor altered basalt; local rhyolitic to dacitic ignimbrite and volcaniclastic rocks
			Unconformity
Early Permian to Late Carboniferous (300 to 306.5 ± 1.6)	Connors Volcanic Group		Felsic to mafic volcanic rocks; rhyolitic to andesitic flows, high-level intrusives, and volcaniclastic rocks including ignimbrite

[1] Australian Stratigraphic Units Database; http://www.ga.gov.au/data-pubs/data-standards/reference-databases/stratigraphic-units

Connors Volcanic Group

The Connors Volcanic Group consists mainly of Carboniferous to Early Permian massive volcanics that unconformably underlie the Lizzie Creek Volcanic Group. The Connors Volcanics formed islands in the Lower Permian sea and have greatly influenced the subsequent deformation of the Lower Permian sediments (Malone et al, 1969). The rocks of Connors Volcanic Group outcrop in a linear zone, the Connors Arch, to the west of Styx Basin and largely control the Broad Sound Range.

Lizzie Creek Volcanic Group - Carmila Beds

Permian sediments of the Carmila Beds underlie the Back Creek Group and unconformably overlie the Connors Volcanic Group. The Carmila Beds were deposited initially as terrestrial volcanics with some freshwater sediments followed by a marine depositional environment. On the eastern margin of Styx Basin, the Carmila Beds outcrop on and east of Connors Range, in a large area north of Marlborough, and on both sides of the southern end of Broad Sound Range (Malone et al. 1969). Near Tooloombah homestead and farther south (near the Project area), the Carmila Beds have been described by Malone et al. (1969) as comprising mainly of volcanolithic sediments, with primary volcanics constituting only about 20%.

Back Creek Group and Boomer Formation

Following the marine depositional period when the Carmila Beds were deposited, the sea transgressed and deposition of the Permian Back Creek Group commenced. The different rock types of the Back Creek Group are thought to reflect marine transgression and regression periods. Locally, the Back Creek Group overlies the Lizzie Creek Volcanic Group (Carmila Beds) and underlie the Styx Coal Measures. In the Project area, the Back Creek Group extends north to south approximately sub-parallel to, beneath and to the west of Styx Basin. On the eastern side of the Styx Basin, the Back Creek Group is represented by Boomer Formation, which comprises of marine sediments that have undergone varying degrees of faulting and folding.

Styx Coal Measures

The Lower Cretaceous Styx Coal Measures are thought to have originally been deposited over a larger area but are now only present in the fault-bounded Styx Basin and in a few outlier areas. The Styx Coal Measures outcrop in a north-trending belt, extending south from Saint Lawrence township on the coast to near the headwaters of Tooloombah Creek. The depositional environments were freshwater, deltaic to paludal (marsh) with occasional marine incursions.

The coal measures dip generally eastwards at around 5°, unconformably overlie the undifferentiated Back Creek Group and are faulted against the Boomer Formation along the eastern boundary of the measures. Historical drilling records identify a pebble conglomerate at the base of the Styx Coal Measures. The Styx Coal Measures comprise:

- overburden materials typically comprising of variably weathered interbedded quartzose sandstone (dominant) and siltstone/mudstone, and traces of coal;
- the coal seams and interburden materials typically comprising of coal seams, and variably weathered interbedded siltstone/mudstone (dominant) and sandstone; and
- underburden materials typically comprising of interbedded sandstone (dominant) and siltstone/mudstone.

Tertiary Deposits

To the southeast of the Project, Tertiary sediments outcrop and form tablelands at an elevation of around 100 m AHD. The tablelands are capped with laterised sediments that form rocky cliffs. The lower slopes of the tablelands are scree-covered and commonly blanketed with thick vegetation (mature trees). The Tertiary sediments include sandstone, siltstone, claystone, diatomite, oil shale, conglomerate and some basalt (Malone et al, 1969). Malone et al (1969) describes the Tertiary sediments as unconformably overlying Permian rocks (likely the Back Creek Group).

Cenozoic Deposits

Cenozoic sediments cover a majority of the Project area and consist of sand, alluvium, lateritic gravel and reworked Tertiary and Permian sediments. Mangrove swamps and alluvial flats are developed along the coast. Within the Project area, the Cenozoic sediments overlie the Styx Coal Measures and Back Creek Group Formation to thickness of up to 18 m.

Project Geochemistry

Waste rock characterisation has been undertaken by RGS Environmental and is detailed in Chapter 8 – Waste Rock and Rejects. A total of 195 samples (including overburden, potential rejects, and fine coal reject samples) were collected from 15 bore holes covering a range of depths from 11.6 metres below ground level (mbgl) to 147 mbgl in various lithologies. Rock samples were subjected to an Acid Base Accounting (ABA) assessment, allowing sampled lithologies to be classified into non-acid forming (NAF), potentially acid forming (PAF) and uncertain categories. Overall, the risk of acid generation from waste rock and coal reject materials is considered low, with over 98% of samples analysed classified as NAF (RGS Environmental 2012).

A kinetic leach study was also undertaken to provide confirmation or not that waste materials have a low acid generation potential. Although no visual indicators were noted for presence of pyrite, the oxidation of composite materials showed no indication of acidification during the study. Previous experience has shown that when a small amount of acid generating materials is mixed with non-acid forming materials (with acid neutralisation potential), the net acid generation potential of the overall mixture may be effectively buffered. The data collected to date is considered sufficient to support the conclusion that the risk of acid generation from waste rock is low.

There was no discernible trend for which type of materials (waste rock or potential coal reject) would be more likely to contain PAF. As such fine coal rejects (21 samples) were also analysed to provide an indication of the acid potential and composition of the coal processing waste stream. The fine rejects were largely classifiable as NAF with Acid Neutralising Capacity (ANC) / Maximum Potential Acidity (MPA) ratios indicative of negligible risk.

An assessment of the potential to generate acidic leachate from waste rock and coal reject material has also been undertaken (RGS Environmental 2012). The assessment found metal / metalloid concentrations in water extracts were within the same order of magnitude as the assessment criteria, generally consistent across composition samples and, therefore, likely to be consistent with existing concentrations within the regional geology.

Although the waste rock is expected to have a low capacity to generate acidity it does have moderate saline drainage potential and kinetic leach column results indicate that leachate may contain elevated concentrations of dissolved arsenic (As), molybdenum (Mo), selenium (Se) and vanadium (V) when compared to WQO and EVs.

Waste rock and fine rejects has been classified as:

- Acid consuming:
  - Will likely remain pH neutral to alkaline following excavation (composite waste rock and potential coal reject samples were alkaline, with pH ranging from 8.6 to 10)
  - Dissolution of heavy metals in an acidic environment is unlikely
- Having low potential to be potentially acid forming;
- Having moderate saline drainage potential (salinity of the samples ranged from 440 to 660 µS/cm); and
- Potential to be highly sodic.

The geochemical assessment for waste materials indicates the potential for generation of acidic leachate is low to negligible. A deterioration of groundwater quality in response to waste materials management is considered very unlikely to occur.

Geological Model

A regional geological model covering an area of around 30,000 km^2 has been developed for the purpose of developing the groundwater model presented in this SEIS and is presented in Appendix A6 – Groundwater Technical Report. A more detailed local-scale geological model developed by Central Queensland Coal for resource assessment covers a smaller area of around 50 km^2 in the immediate Project area is incorporated into the regional scale model.

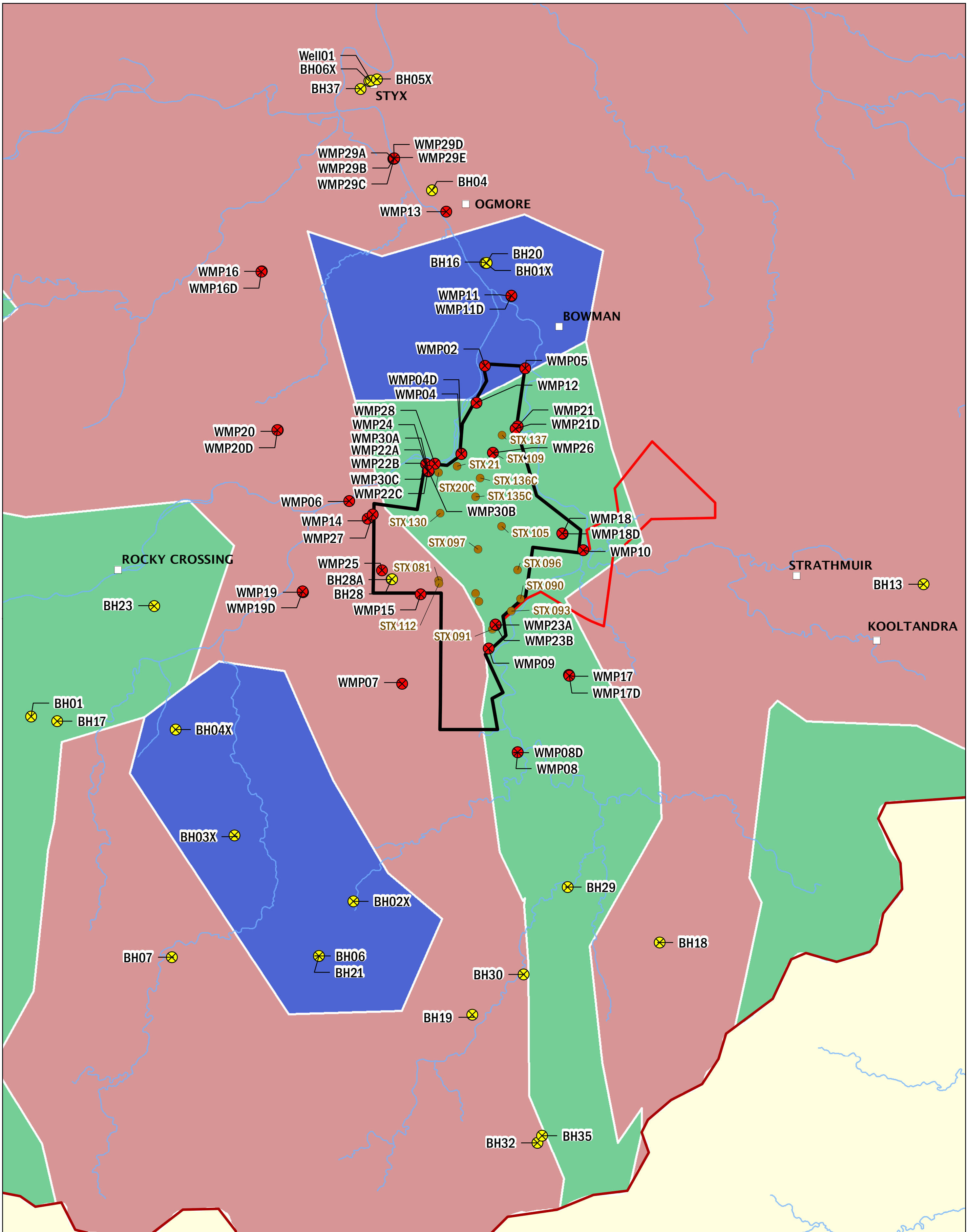
The local geological model contains interpreted elevations and thicknesses of coal seams/interburden strata within the Styx Coal Measures as intersected by the resource drilling program. The two models have been merged for the purpose of developing the groundwater model to assist in assessing the effects of mining on groundwater and connected systems (see Appendix A6 – Groundwater Technical Report for detail).

16.11.1.2 Hydrogeology

The Bureau of Meteorology's (BoM's) National Groundwater Information System reports that Styx River Basin lies outside of declared groundwater management areas, including alluvial aquifer boundaries declared by the DNRME. The BoM database lists the purposes of all bores located within Styx catchment as "unknown". The bore census conducted for the Project in 2011 and 2017 found that most bores are used for stock watering and only some are used for domestic purposes (Central Queensland Coal and Fairway Coal, 2012, CDM Smith, 2017).

Figure 16-79 and Figure 16-80 present locality plans showing the location of different types of bores and drillholes in the Styx River Basin, including landholder bores, Project groundwater monitoring bores and drillholes, and registered bores.

Central Queensland Coal has installed 46 monitoring bores between late 2017 and late 2018 ("Styx Project WMP bores"), and a summary of the installations is provided in Table 16-73, with composite bore logs presented as Attachment 1 to Appendix A6 – Groundwater Technical Report. These bores have been installed to provide greater coverage around the Project (for groundwater heads and quality), especially near to watercourses to assess the potential for groundwater and surface water interactions and vertical hydraulic gradients between shallow and deeper hydrostratigraphy. Of the 46 Styx Project WMP bores installed, 15% of the bores have been screened across multiple units. Where this occurs, the hydrogeological interpretations have been based on the dominant unit.



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Legend

- Landholder bore (census 2017)
- Styx WMP bore (drilled 2017/18)
- Styx drillhole
- Styx River Basin
- Watercourse
- ML 80187
- ML 700022

Groundwater Zone

- Bison
- Styx
- Uplands

Figure 16-79
Groundwater bores and data availability – landholder and Project bores

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018

CDM Smith

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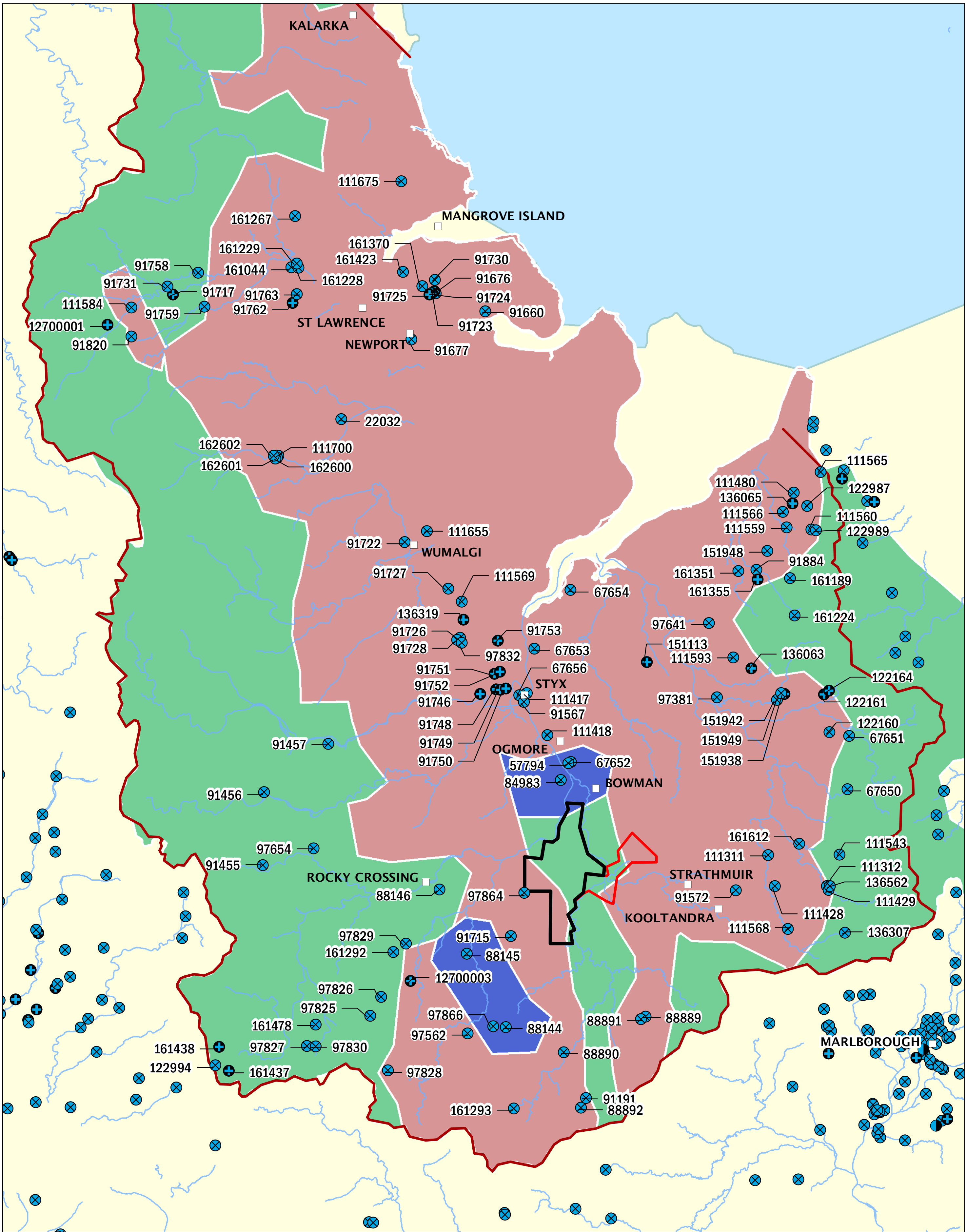

Legend

Styx River Basin
Watercourse
ML 80187
ML 700022

Registered bore (GWDBQ)
Existing
Abandoned and destroyed
Abandoned but useable
Unknown

Groundwater Zone
Bison
Styx
Uplands

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Kilometres

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Figure 16-80
Groundwater bores and data availability – GWDBQ registered bores

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018

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Table 16-73 Recently installed Project groundwater monitoring bores ("Styx Project WMP bores")

ID	Date drilled	Casing Diameter (m)	Slotted Interval (mbgl)	Total depth (mbgl)	Inferred HSU*
WMP02	1-Oct-17	0.125	12 – 18	18.4	Alluvium
WMP04	11-Oct-17	0.125	12 – 18	18.4	Alluvium
WMP04D	29-Sep-17	0.125	18.5 – 36.3	36.5	Alluvium and Styx Coal Measures (overburden)
WMP05	30-Sep-17	0.125	9 – 12	12.4	Alluvium
WMP06	3-Nov-17	0.125	12 – 18	18.4	Alluvium and Styx Coal Measures (underburden)
WMP07	16-Oct-17	0.125	48 – 60	60	Styx Coal Measures (underburden)
WMP08	2-Nov-17	0.125	10 – 16	16	Alluvium
WMP08D	2-Nov-17	0.125	24 – 36	36	Styx Coal Measures (underburden)
WMP09	14-Oct-17	0.125	7.1 – 15	15.4	Alluvium
WMP10	13-Oct-17	0.125	12 – 18	18.4	Styx Coal Measures (overburden)
WMP11	18-Mar-18	0.125	18 – 24	24	Styx Coal Measures (overburden)
WMP11D	17-Mar-18	0.125	30 – 36	36	Styx Coal Measures (overburden)
WMP12	6-Nov-17	0.125	11 – 17	18	Alluvium and Styx Coal Measures (overburden)
WMP13	12-Jan-18	0.125	12.7 – 19.7	19.7	Alluvium and Styx Coal Measures (overburden)
WMP14	19-Mar-18	0.125	9 – 18	18	Alluvium and Styx Coal Measures (overburden)
WMP15	20-Mar-18	0.125	9 - 21	21	Alluvium and Styx Coal Measures (underburden)
WMP16	20-Oct-18	0.05	25.5 – 31.5	31.5	Styx Coal Measures (overburden)
WMP16D	21-Oct-18	0.05	35.7 – 41.7	42	Styx Coal Measures (coal seams/interburden)
WMP17	3-Oct-18	0.05	9 - 12	12	Alluvium
WMP17D	2-Oct-18	0.05	21 - 24	24	Styx Coal Measures (overburden)
WMP18	13-Sep-18	0.05	9.2 - 12.2	12.2	Alluvium
WMP18D	12-Sep-18	0.05	18.5 - 23.5	23.5	Styx Coal Measures (overburden)
WMP19	6-Sep-18	0.05	13.1 - 16.1	16.1	Weathered Basement
WMP19D	7-Sep-18	0.05	24.9 - 27.9	28	Weathered Basement
WMP20	20-Oct-18	0.05	14.5 – 20.5	20.5	Styx Coal Measures (overburden)
WMP20D	20-Oct-18	0.05	24 – 30	30	Styx Coal Measures (overburden)
WMP21	10-Sep-18	0.05	6.9 - 9.9	9.9	Alluvium
WMP21D	10-Sep-18	0.05	14 - 20	22	Alluvium and Styx Coal Measures (overburden)
WMP22A	19-Oct-18	0.78	27 – 30	30	Styx Coal Measures (overburden)
WMP22B	19-Oct-18	0.1	50 – 56	56	Styx Coal Measures (coal seams/interburden)
WMP22C	19-Oct-18	0.1	200 - 206	206	Styx Coal Measures (underburden)
WMP23A	6-Oct-18	0.9	48.5 - 54.5	56.5	Styx Coal Measures (coal seams/interburden)
WMP23B	6-Oct-18	0.9	187 - 193	194	Styx Coal Measures (underburden)
WMP24	11-Sep-18	0.05	23.4 - 26.4	26.4	Styx Coal Measures (overburden)

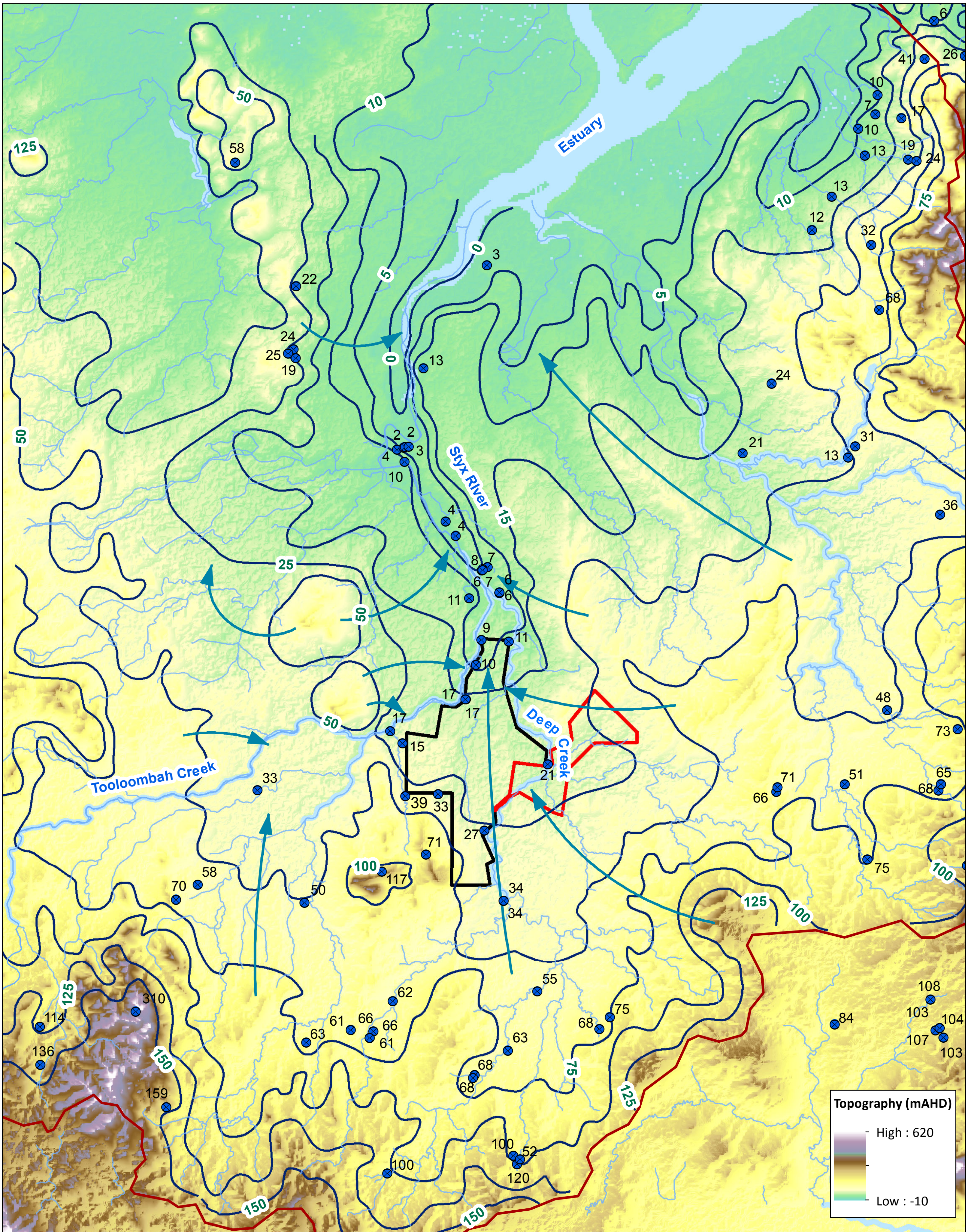
ID	Date drilled	Casing Diameter (m)	Slotted Interval (mbgl)	Total depth (mbgl)	Inferred HSU*
WMP25	8-Sep-18	0.05	10.1 - 13.1	13.2	Alluvium
WMP26	9-Sep-18	0.05	11.5 - 20.5	20.5	Alluvium
WMP27	8-Sep-18	0.05	14.5 - 20.5	20.5	Styx Coal Measures (overburden) and minor alluvium
WMP28	11-Sep-18	0.05	8.9 - 11.9	12	Styx Coal Measures (overburden)
WMP29A	28-Oct-18	0.1	6.5 – 12.5	12.5	Alluvium
WMP29B	28-Oct-18	0.1	16 – 20	20	Alluvium
WMP29C	27-Oct-18	0.1	52 – 58	58	Styx Coal Measures (overburden)
WMP29D	1-Nov-18	0.1	115 – 121	121	Styx Coal Measures (coal seams/interburden)
WMP29E	31-Oct-18	0.1	222.5 – 228.5	228.5	Styx Coal Measures (underburden)
WMP30A	19-Oct-18	0.05	27 – 30	30	Styx Coal Measures (overburden)
WMP30B	19-Oct-18	0.05	50 – 56	56	Styx Coal Measures (coal seams/interburden)
WMP30C	19-Oct-18	0.05	200 – 206	206	Styx Coal Measures (underburden)

* Where bore is screened across two units, the dominant HSU is underlined

Groundwater Heads and Flow

The general direction of catchment-scale groundwater flow is toward Styx River and the coast. However, groundwater flow patterns vary across the catchment in response to local-scale recharge and discharge mechanisms. Figure 16-81 presents the 2017/2018 wet season water table elevation contour plan for the Styx River catchment. The contours have been inferred from data sourced from GWDBQ, Project exploration drillholes and Styx Project WMP bores. The plan shows the water table surface is likely a subdued reflection of topography, and that it generally occurs within 15 m of the ground surface in the less elevated parts of the Basin, and is very shallow in lower areas close to Styx River and Broad Sound (Figure 16-81). The inferred contours show groundwater flowlines from the upper catchment (the Tooloombah and Deep Creek sub-catchments) converge on the lower reaches of the creeks, whilst lower in the catchment the flowlines converge on Styx River and the Broad Sound estuary.

Relatively steep water table gradients are observed in Figure 16-82 in areas of the catchment where steep topography occurs and / or lower hydraulic conductivity (K) materials are likely to predominate, e.g. where there is surface exposure of basement rocks. Flatter water table gradients are observed where alluvium is extensive, likely due to higher K materials and / or relatively higher rates of evapotranspiration (from shallow water tables and / or phreatophytic vegetation). The pattern of water table contours around the major watercourses suggest that alluvial aquifer Ks are higher nearer to the watercourses.



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Legend

- Groundwater elevation (mAHD)
- Styx River Basin
- Watercourse
- Inferred water table contour (mAHD)
- Inferred groundwater flow
- ML 80187
- ML 700022

Figure 16-81

Inferred water table elevation and groundwater flow

DATA SOURCE
QLD Open Source Data, 2018;
1 Second SRTM v1.0 © Commonwealth of Australia (Geoscience Australia) 2011;
Central Queensland Coal, 2017

CDM Smith

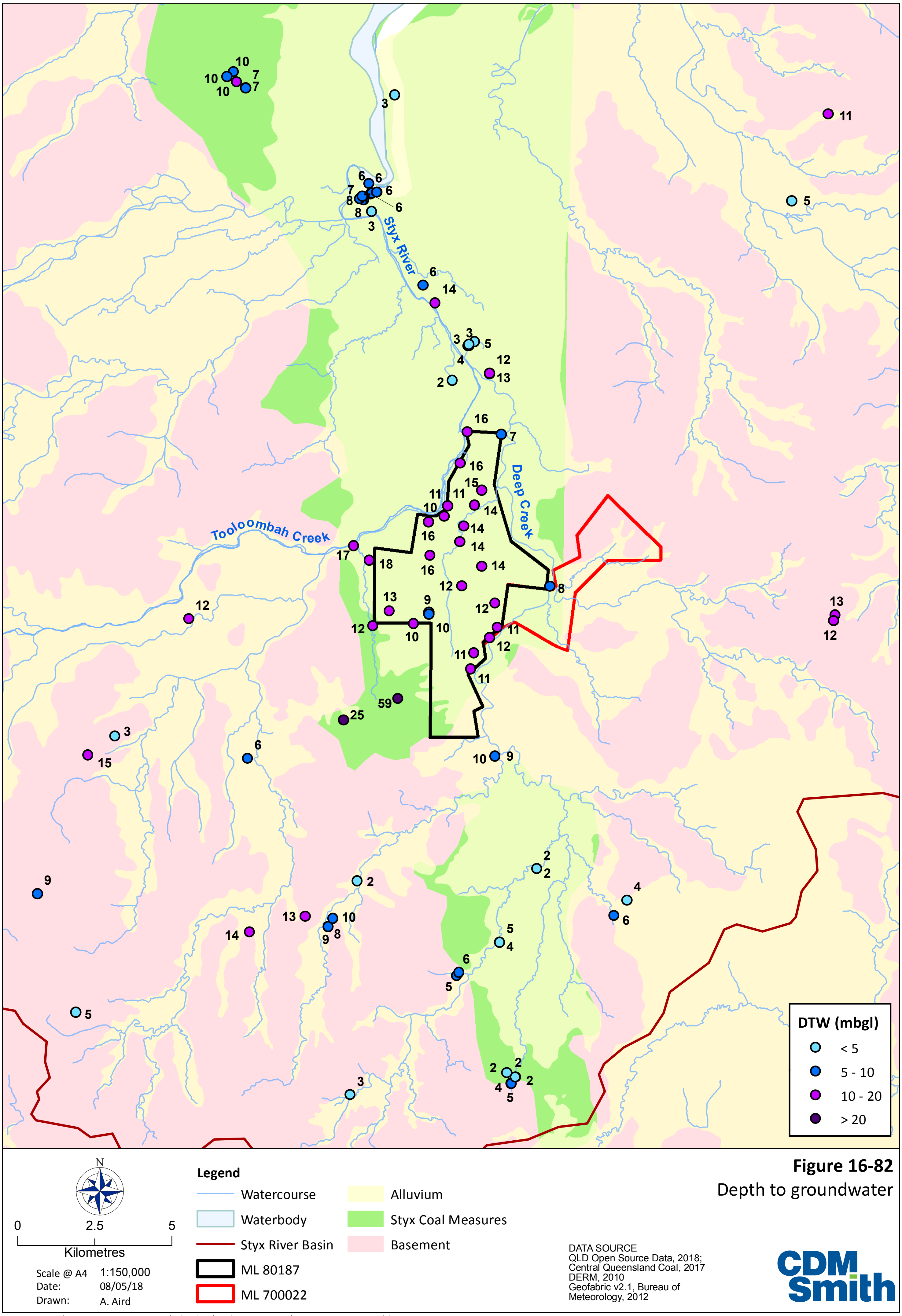

Figure 16-82
Depth to groundwater

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The only timeseries groundwater elevations within the Styx River Basin are from unregistered third party bores identified during the bore census and from some of the Styx Project WMP bores. There are no timeseries groundwater levels from registered bores within the Styx River catchment. Hydrographs showing all available timeseries data, categorised by screened (hydro-)stratigraphic unit are presented along with Rockhampton Aero climate station 039083 rainfall data in Figure 10-22 to Figure 10-26 in Chapter 10. The following observations are made:

- Generally little seasonal variation in Basement and Styx Coal Measures groundwater elevations is observed; and
- Some variation in alluvium groundwater elevations is observed (e.g. bores WMP08, WMP05 and BH01X) with up to 3 m difference in heads between the wet and dry seasons, but a strong seasonal response is not evident across the monitoring network.

Recently constructed nested Styx Project WMP bores (locations shown on Figure 16-79) provide information by which to assess vertical hydraulic gradients in the immediate area of the Project during the wet and dry seasons, depending on time of installation. The available time series groundwater elevation data (corrected for density variations related to salinity) at the nested sites are presented on Figure 16-83. The following describes the relationships observed:

- At the location of WMP04 (alluvium) and WMP04D (Styx Coal Measures overburden), located near Tooloombah Creek at the northwestern boundary of the ML, the hydraulic head within the Styx Coal Measures overburden is higher than the hydraulic head within the alluvium, indicating the potential for groundwater flow from the coal measures to the alluvium, and possibly to the creek (as baseflow) in this area;
- At the location of WMP08 (alluvium) and WMP08D (Styx Coal Measures underburden), located near Deep Creek immediately upstream of the ML, the hydraulic head in the alluvium is lower than the hydraulic head of the deeper coal measures. The gradient between the units appears to increase in the dry season, due to a decline in head within the alluvium. The observed upward hydraulic gradient from the coal measures to the alluvium indicates possible discharge to the creek via the alluvium in this area;
- Only dry season gauging has occurred at the location of WMP11 (Styx Coal Measures overburden) and WMP11D (deeper Styx Coal Measures overburden), which are located above the confluence of Deep Creek and Tooloombah Creek downstream of the ML. The available data suggest groundwater from the coal measures has the potential to discharge to the creeks via the alluvium in the area of the confluence;
- At the location of WMP18 (alluvium) and WMP18D (Styx Coal Measures overburden), located around 1 km west of Deep Creek in the eastern area of the ML, only one gauging has been undertaken (in the dry season). The hydraulic head within the alluvium at this location is higher than the hydraulic head in the Styx Coal measures, indicating a downward gradient between the units;
- The monitoring sites WMP22A (Styx Coal Measures overburden), WMP22B (Styx Coal Measures coal seams/interburden) and WMP22C (Styx Coal Measures underburden) are located near Tooloombah Creek and around 1 km southwest of WMP04/WMP04D. Only one gauging has been undertaken at this site and suggests that there is an upward gradient between Styx Coal Measures units to the alluvium and possibly the creek. This supports the observation at WMP04/WMP04D; and
- Five bores have been installed at WMP29A (shallow alluvium), WMP29B (deeper alluvium), WMP29C (Styx Coal Measures overburden), WMP29D (Styx Coal Measures coal seams/interburden) and WMP29E (Styx Coal Measures underburden) which is located around

4 km north of the Tooloombah and Deep Creek confluence and within around 1 km south of the estuary. As the bores were installed in October 2018, only one gauging has been undertaken at this site, which shows upward gradient from the Styx Coal Measures to the alluvium and possibly the Styx River at this location.

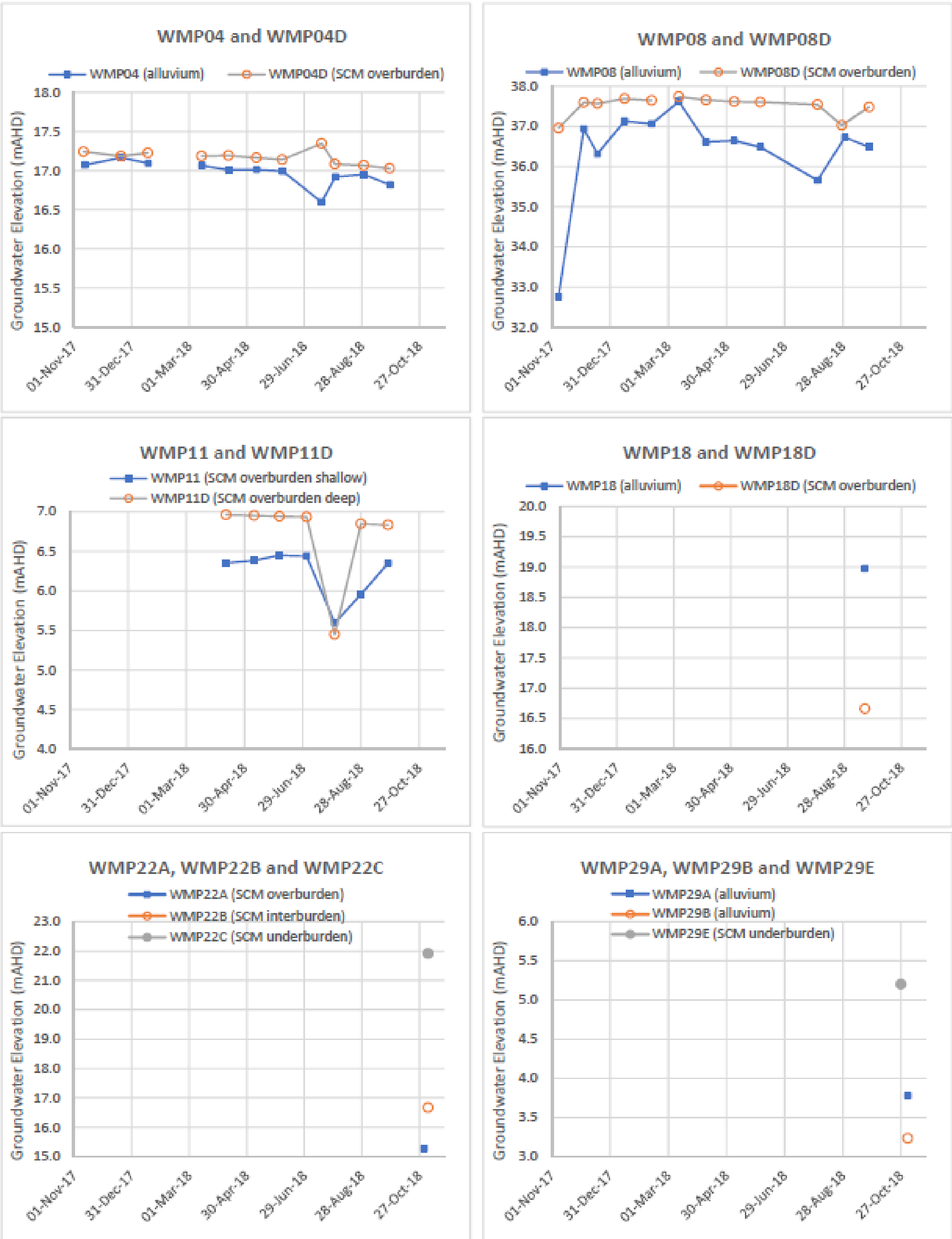

Figure 16-83 Groundwater hydrographs - nested

It is expected a saltwater interface occurs beneath coastal areas of the Styx River Basin, but its exact location is unknown as there are no known measurements of groundwater pressures or salinity profiling near to the coast. The location of the interface will be dependent on groundwater heads near the coast as well as features such as Broad Sound estuary relative to sea level and tidal fluctuations. It is unlikely there is a sharp interface between groundwater and seawater across the broader Study Area downstream of the confluence of Tooloombah and Deep Creeks. The available hydraulic head data shows it is unlikely there is seepage of estuarine / sea water to the Styx Coal Measures from the area where Styx River discharges to Broad Sound estuary.

Summary

The available data show there is little evidence of a distinct seasonal response to rainfall and stream flow events in any of the stratigraphic units, particularly the Styx Coal Measures and Basement. The groundwater elevation data show the lower reaches of Tooloombah and Deep Creeks, and both Styx River and Broad Sound are zones of nett groundwater discharge. An assessment of the vertical hydraulic gradients typically shows upward gradients and potential for flow. This is observed at Styx River near Broad Sound, and further upstream near to both Deep and Tooloombah Creeks.

Hydrogeological Properties

Groundwater Yields

Airlift yields measured during drilling or development of 82 Styx River catchment groundwater bores that have been recorded in the GWDBQ are summarised in Table 16-74 (frequency distribution). Bore yields are reported to range from 0.01 L/s (less than 1 kL/d) up to 6.3 L/s (approximately 550 kL/d). The data show that bore yields are typically low, with more than 75% of bores reporting yields of less than 2 L/s and only 1% of bores reporting yields greater than 6 L/s. Note that bore yield data is not necessarily a good indication of sustainable bore yields under pumping.

Table 16-74 Frequency distribution of bore yields

Bore yield (L/s)	Number of bores	Percent of bores (%)
< 1	43	52
1 to 2	20	24
2 to 3	8	10
3 to 4	4	5
4 to 5	2	2
5 to 6	4	5
6 to 7	1	1
Total	**82**	**100**

Project Area Aquifer Testing Results

The GWDBQ reports aquifer transmissivity values for five bores in the Styx River catchment. Based on their location, the bores are inferred to intersect alluvium and alluvium / weathered / fractured Basement. A summary of these data is presented in Table 16-75, showing moderate to high permeability values from relatively small aquifer intervals.

Table 16-75 Results from aquifer pumping tests recorded in the GWDBQ

GWBDQ RN	Lithology	Duration (hrs)	Interval (m)	T (m^2/d)	K (m/d)
57794	Alluvium	24	3.4	412	121
84983	Alluvium	4.5	0.7	107	153
88144	Alluvium / Basement	2	1.8	59	33
88145	Alluvium / Basement	120	4.6	60	13
88146	Alluvium / Basement	2.6	1.9	6	3

GWDBQ – Groundwater Database - Queensland; T – Aquifer transmissivity; K – Hydraulic conductivity

Where possible, slug (falling head) tests have been undertaken on the newly installed Project WMP bores to obtain head response data for estimating the K of the strata directly adjacent the bores, which are screened across the Alluvium, Styx Coal Measures, Basement or straddling the Alluvium and shallow portions of the Styx Coal Measures. Three slug test methods were used; a near-instantaneous injection of potable water was added to a bore to displace the water column (falling head test); a volume of water was removed from the bore instantaneously (using a bailer) (rising head test); or a volume of water was removed from the bore using drilling rig to airlift the bore dry (rising head test). For bores that exhibited a quick recovery during testing that made analysis of the recovery data impracticable, a constant rate recovery test analysis was undertaken. In each method the water level recovery was monitored back to static. Details on methods used is provided as Appendix A6 – Groundwater Technical Report.

A summary of the slug analyses is provided in Table 16-76 for the project bores. Table 16-77 presents statistics for all Project area aquifer testing results. Figure 16-83 presents frequency distribution plots for estimated K data for each HSU, showing all HSUs to be heterogeneous (with K estimates varying across two to five orders of magnitude). In general terms, Table 16-77 and Figure 16-84 show only the alluvial and weathered basement HSUs, and possibly the shallower Styx Coal Measures overburden, might be considered aquifers. The Styx Coal Measures coal seams / interburden and underburden units are considered to be aquitards.

Figure 16-85 presents the available estimates of transmissivity from GWDBQ records and from the testing of Project WMP bores.

Table 16-76 Summary of derived hydraulic property estimates from aquifer tests

Bore ID	Test type	Screened Stratigraphy [1]	Solution	K (m/d) [2]	D (m) [2]	T (m^2/d) [2]
WMP02	Recovery	Alluvium	Theis Recovery	5	8.5	43
WMP04	FHT	Alluvium	Bouwer-Rice	0.01	3.9	0.04
			Hvorslev	0.02		0.08
WMP04D	FHT	Alluvium / SCM Overburden	Bouwer-Rice	0.02	23.2	0.5
			Hvorslev	0.03		0.7
WMP05	FHT	Alluvium	Bouwer-Rice	0.03	4.9	0.1
			Hvorslev	0.07		0.3
WMP06	FHT	Alluvium / SCM Underburden	Bouwer-Rice	0.01	1.5	0.02
WMP08	FHT	Alluvium	Bouwer-Rice	0.0005	3.9	0.002
WMP08D	FHT	SCM Underburden	Bouwer-Rice	0.03	26.5	0.8
WMP09	FHT	Alluvium	Bouwer-Rice	0.1	4.2	0.5
			Hvorslev	0.2		0.9
WMP10	FHT	SCM Overburden	Bouwer-Rice	0.004	10.7	0.04
WMP12	Recovery	Alluvium / SCM Overburden	Theis Recovery	2	8.5	17
WMP13	FHT	Alluvium / SCM Overburden	Bouwer-Rice	0.3	5.4	2
WMP16	FHT	SCM Overburden	Bouwer- - Mid	0.3	18.3	5
			Bouwer-Rice – Late	0.2		4
	RHT		Bouwer-Rice - Early	0.2		4
			Bouwer-Rice – Mid	0.04		0.7
			Bouwer-Rice – Late	0.007		0.1
WMP16D	FHT	SCM Coal seams / Interburden	Bouwer-Rice - Early	0.02	28.6	0.6
			Bouwer-Rice – Mid	0.003		0.1
			Bouwer-Rice – Late	0.001		0.03
	RHT		Bouwer-Rice – Early	0.01		0.3
			Bouwer-Rice – Mid	0.01		0.3

Bore ID	Test type	Screened Stratigraphy [1]	Solution	K (m/d) [2]	D (m) [2]	T (m^2/d) [2]
			Bouwer-Rice – Late	0.03		0.9
WMP17D	FHT	SCM Overburden	Bouwer-Rice – Mid	0.08	11.4	0.9
			Bouwer-Rice – Late	0.01		0.1
	RHT		Bouwer-Rice – Early	0.3		3
			Bouwer-Rice – Mid	0.06		0.7
WMP18D	FHT	SCM Overburden	Bouwer-Rice – Early	0.7	9.4	7
			Bouwer-Rice - Mid/late	0.02		0.2
WMP19	FHT	Weathered Basement	Bouwer-Rice	0.006	3.1	0.02
WMP19D	FHT	Weathered Basement	Bouwer-Rice – Early	0.6	15	9
			Bouwer-Rice – Mid/late	0.3		5
WMP20	FHT	SCM Overburden	Bouwer-Rice – Early	0.1	9.5	0.9
			Bouwer-Rice – Late	0.0004		0.004
	RHT		Bouwer-Rice – Early	0.3		3
			Bouwer-Rice – Mid	0.2		2
			Bouwer-Rice – Late	0.04		0.4
WMP20D	FHT	SCM Overburden	Bouwer-Rice – Mid	0.06	18.1	1
			Bouwer-Rice – Late	0.003		0.05
	RHT		Bouwer-Rice – Early	0.09		2
			Bouwer-Rice – Mid	0.02		0.4
WMP21D	FHT	Alluvium / <u>SCM Overburden</u>	Bouwer-Rice	0.1	7	0.7
WMP22A	RHT	SCM Overburden	Bouwer-Rice	0.05	15.33	0.8
WMP22B	FHT	SCM Coal seams / Interburden	Bouwer-Rice – Early	0.02	43.82	0.9
			Bouwer-Rice – Late	0.01		0.4
	RHT		Bouwer-Rice – Early	0.009		0.4
			Bouwer-Rice – Mid	0.005		0.2
			Bouwer-Rice – Late	0.01		0.4
	Recovery		Cooper-Jacob	0.005	6	0.03

Notes:
1. Screened across multiple stratigraphic units, underlined unit is interpreted as dominant unit
2. K = hydraulic conductivity, D = aquifer thickness, T = transmissivity
3. K and T are qualitatively estimated from gauged recovery post-development. Bores recovered approximately 15 % in 5 days post-development, so a low K and T has been assigned

Table 16-77 Project area aquifer testing statistics

Screened Stratigraphy	No. bores	Measure	Estimated K, m/d [1]
Alluvium	11	Minimum	1.0×10^{-3}
		Maximum	7.3×10^{0}
		Geomean	6.3×10^{-2}
		Median	3.0×10^{-2}
Styx Coal Measures (bulk estimates for all sequences – overburden, coal seams / interburden and underburden)	19	Minimum [2]	7.0×10^{-4}
		Maximum [3]	3.0×10^{-1}
		Geomean	1.2×10^{-2}
		Median	1.4×10^{-2}

Styx Coal Measures			
Overburden	12	Minimum Maximum Geomean Median	$1.0x10^{-3}$ $3.0x10^{-1}$ $2.0x10^{-2}$ $2.0x10^{-2}$
Coal seams and interburden	4	Minimum Maximum Geomean Median	$7.0x10^{-4}$ $7.5x10^{-3}$ $2.3x10^{-3}$ $3.0x10^{-3}$
Underburden	3	Minimum Maximum Geomean Median	$1.0x10^{-3}$ $3.0x10^{-2}$ $5.4x10^{-3}$ $5.2x10^{-3}$
Weathered / Fractured Basement	2	Minimum Maximum Average	$6.0x10^{-3}$ $3.0x10^{-1}$ $1.5x10^{-1}$

1. K = hydraulic conductivity
2. Consistent between all units within Styx Coal Measures
3. Maximum estimate derived from overburden unit, c.f. maximum measured in coal seams/interburden, and underburden of approximately one order of magnitude less (0.12 m/d)

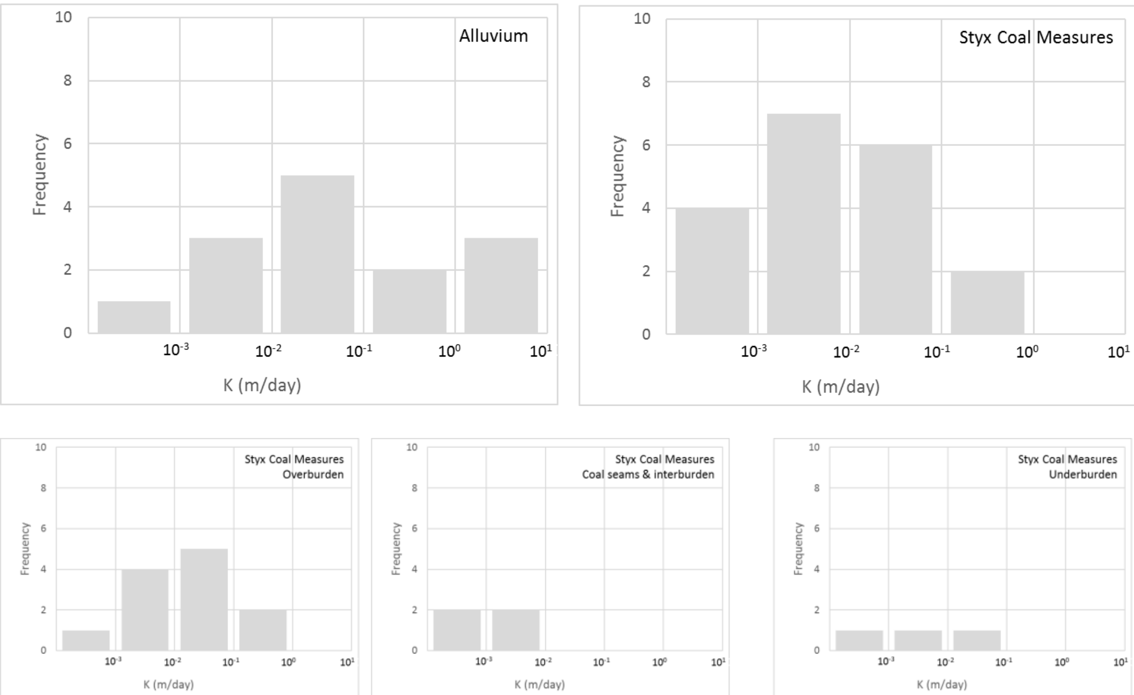

Figure 16-84 HSU hydraulic conductivity frequency distribution plots (note: x-axis logarithmic scale)

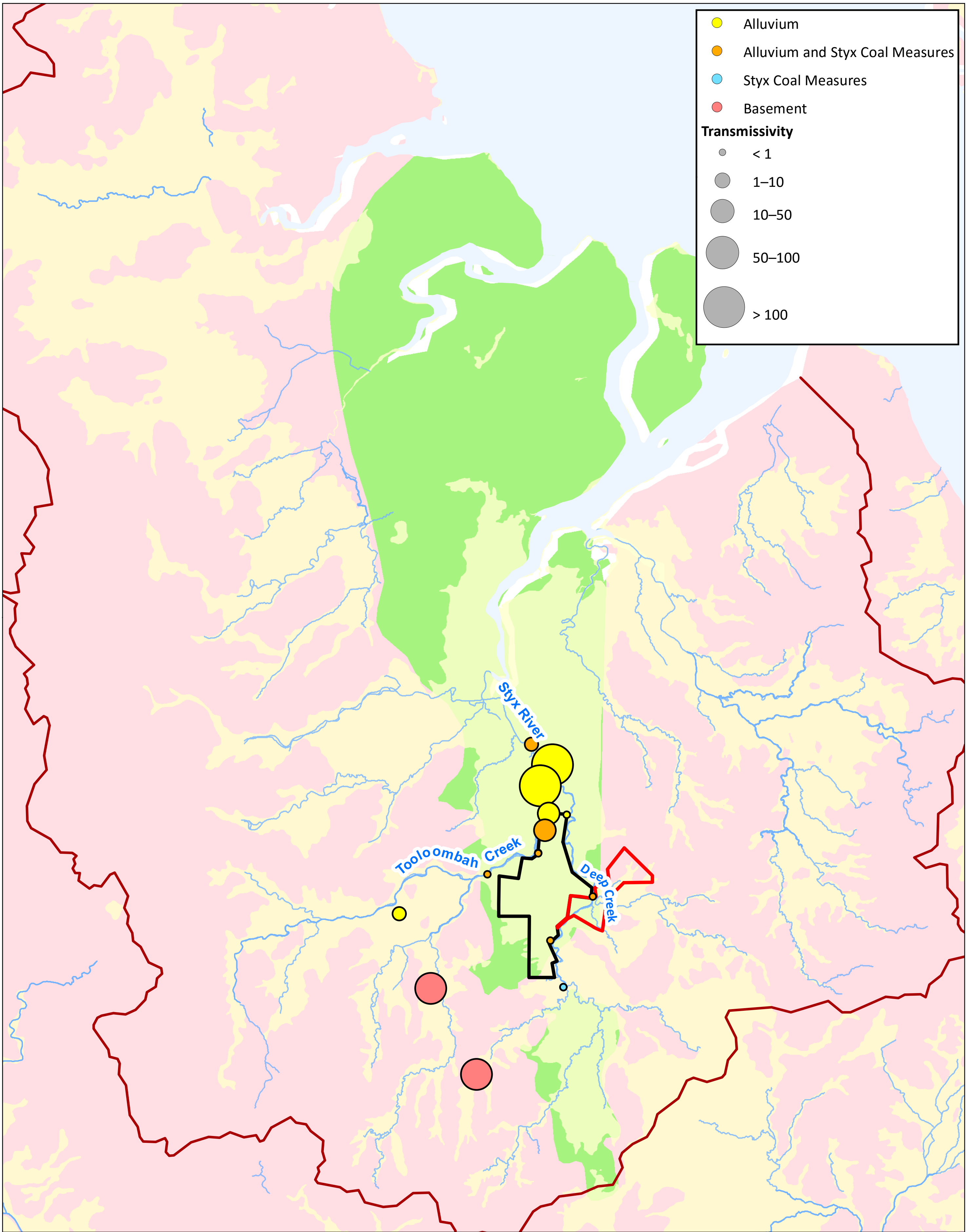

Figure 16-85
Reported transmissivity values

DATA SOURCE
QLD Open Source Data, 2018;
Central Queensland Coal, 2017;
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

Testing Results from Other Relevant Areas and Literature Review

The results of a review of hydrogeological property information from outside the Project area relating to geological units similar to or the same as those found within the Project area are presented in Table 16-78. Apart from the studies completed for the Project, very little of the information available for review is derived from investigations or studies conducted within the Styx River Basin. Where relevant information has not been identified, the values presented are sourced from the literature.

Estimates of hydrogeological properties for Cretaceous coal measures in Queensland are not widely available. Some information has been reported for the Maryborough Basin, which has a similar setting to Styx Basin being located to the southeast (north of Brisbane) and straddling the coast with onshore and offshore extents.

There is more public information available concerning the hydrogeological properties of older and deeper Permian coal measures within Bowen Basin but the relevance to Cretaceous coal measures in the Styx Basin has not been established. In general, based on experience of Permian coal measures, there is an expectation that coal measures (including coal seams/interburden) are more permeable than the overburden and underburden sediments that do not contain coal seams (i.e. the coal seams typically have the higher permeability then bounding sediments). There is also an expectation the permeability of coal measures diminishes with burial depth due to compaction.

Information concerning the hydrogeological properties of the Back Creek Group is derived entirely from studies in the Bowen Basin. No examples from the Styx Basin have been found. There is almost no information about the hydrogeological properties of the Lizzie Creek Volcanic Group and Connors Volcanic Group, potentially because neither of these stratigraphic units are recognised as aquifers. In general, they contain sediments and rocks that are expected to exhibit hydrogeological properties consistent with very poor aquifers and aquitards.

The largest estimates of K are for alluvial sediments and the fractured / weathered (residual) basement rocks that outcrop or sub-crop in the Project area. These aquifers correspond to the shallow water-table aquifer targeted by farm and pastoral bores.

The available information suggests the alluvium and residual basement could have specific yield values around 0.5, whilst the Styx Coal Measures could have specific yield values ranging around 0.01.

Summary

The available aquifer testing data and results of analysis show the alluvium is typically more permeable than the underlying coal measures, generally by more than two orders of magnitude. Residual basement may have permeabilities ranging around the maximums observed for the alluvium, but unweathered basement can typically be expected to have permeabilities lower than either of the alluvium or coal measures. Significant heterogeneity exists in the Study Area groundwater system.

It is considered that sufficient aquifer testing results (local and more regional) are available to assist with characterisation of the hydrogeology of the four HSUs present in the Project area.

Table 16-78 Summary hydrogeological properties from outside Project area

Stratigraphic unit	K_h, m/d	K_v, m/d	Sy	Ss, 1/m	Location	Method (Reference)
Alluvium	Min. 10^{-4} Max. 10^{1}	$2.5x10^{-2}$	$5x10^{-2}$	$1x10^{-4}$	Styx River Basin Maryborough Basin General (literature)	Testing (1) Literature (7) Modelling (2)
Cretaceous coal measures - overburden	$7.5x10^{-3}$	$7.5x10^{-4}$	10^{-2}	$1x10^{-5}$	Maryborough Basin	Modelling (2)
Cretaceous coal measures – coal	Min. 10^{-4} Max. $2.2x10^{-1}$	Min. 10^{-5} Max. $2.2x10^{-2}$	10^{-2}	$1x10^{-5}$	Maryborough Basin	Modelling (2)
Cretaceous coal measures - underburden	$5x10^{-3}$	$5x10^{-4}$	10^{-2}	$1x10^{-5}$	Maryborough Basin	Modelling (2)
Cretaceous coal measures - bulk	Min. $5x10^{-4}$ Max. $4.6x10^{1}$				Maryborough Basin	Testing (2) Modelling (2)
Residual basement (weathered Boomer Formation, Back Creek Group, Carmila Beds, Lizzie Creek Group and Colman Group)	Min. 10^{-3} Max. $3.3x10^{1}$	$2.5x10^{-2}$	$5x10^{-2}$	10^{-4}	Maryborough Basin General (literature)	Literature (7) Modelling (2)
Boomer Formation (siltstone, mudstone, sandstone)	Min. 10^{-5} Max. 10^{-1}				General (literature)	Literature (7)
Back Creek Group	Min. $4x10^{-4}$ Max. 10^{-1}	Min. 10^{-5} Max. $3x10^{-3}$	Min. $5x10^{-4}$ Max. $2x10^{-1}$	Min. $6x10^{-6}$ Max. $5x10^{-4}$	Bowen Basin	Modelling (3, 4, 5)
Carmila Beds (siltstone, mudstone, sandstone)	Min. 10^{-5} Max. 10^{-1}				General (literature)	Literature (7)
Lizzie Creek Volcanic Group	10^{-7}	10^{-6}	10^{-4}	10^{-6}	Bowen Basin	Modelling (6)
Connors Volcanic Group	10^{-5}				General (literature)	Literature (7)

Key: Kh – Horizontal hydraulic conductivity; Kv – Vertical hydraulic conductivity; Sy – Specific yield; Ss – Specific storativity

References: 1. Groundwater Database - Queensland (GWDBQ); 2. AGE (2010); 3. URS (2012); 4. URS (2013); 5. AGE (2014); 6. Drake Coal (2014); 7. The literature (Bear 1972, Bouwer 1978, Freeze and Cherry 1979)

Hydrostratigraphy

Hydrostratigraphic units (HSUs) are zones within a geological system that have similar hydrogeological properties with respect to their influence on groundwater occurrence and flow. While HSUs are often chosen based on geology, the type of rock is less important than the properties of the rock that control resistance to groundwater flow and groundwater storage. At the broadest level, HSUs are categorised as aquifers and aquitards; where aquifers consist of stratigraphic units (or sequence of units) that store and transmit useful amounts of groundwater, and aquitards consist of stratigraphic units (or sequence of units) that generally act as barriers to groundwater flow and do not transmit useful amounts of water.

Based on the observations presented in this Section the HSUs relevant to the Project are considered to be:

- HSU1- Alluvium (aquifer);
- HSU2- Styx Coal Measures (typically an aquifer);
- HSU3- Weathered (residual) and fractured basement (aquifer); and
- HSU4- Unweathered (possibly fractured) basement (aquitard).

Brief descriptions of the HSUs defined as aquifers are outlined below, and general details are presented in Table 16-79. Figure 16-86 presents a schematic cross-sectional profile of the HSUs and Figure 16-87 presents a map showing surface expression of the HSUs.

Table 16-79 Interpreted Project area hydrostratigraphic units

HSU	Geological Units	General geological description	Unit type	Unit description
HSU1: Alluvium	Cenozoic deposits	Unconsolidated alluvium, colluvium, soils, estuarine deposits etc.	Unconfined	Local unconsolidated aquifer of low to high productivity depending on thickness and depth
HSU2: Styx Coal Measures	Styx Coal Measures	Interbedded quartzose sandstone, mudstone, conglomerate and coal	Typically confined aquifer (when considered as an entire unit), variable aquifer and aquitard in reality	Porous extensive aquifers of generally low productivity[1]
HSU3: Weathered / fractured basement	Outcropping and sub-cropping basement (Back Creek Group, Lizzie Creek Volcanic Group and Connors Volcanic Group)	Weathered sandstone, siltstone, mudstone, shale and volcanic rocks	Unconfined / confined	Local weakly to moderately consolidated aquifer of low to moderate productivity
HSU4: Basement	Back Creek Group (including Boomer Formation), Lizzie Creek Volcanic Group (including Carmila beds) and Connors Volcanic Group	Fractured/altered sandstone, siltstone, mudstone, shale, conglomerate and volcanic rocks	Aquitard	Typically massive, variably fractured or fissured

1. Based on analysis of drilling and testing data obtained from Styx WMP bores

Alluvium (HSU1)

The Alluvium comprises unconsolidated Cenozoic sediments associated with watercourses and floodouts/plains (higher in the catchment), and watercourses and swamp deposits (in the coastal and estuarine parts of the lower catchment). These sediments have a thickness of up to 18 m (or more) across the Project area. Yeats (2011) reports groundwater was encountered during resource drilling in most boreholes between ground level and up to 30 m below ground with an inferred average water table depth of 16 m across Project area.

Based on the distribution of identified landholder bores, it is likely the alluvium forms a useful aquifer upstream of Styx township but lower in the catchment it does not, due most likely to the presence of very brackish to saline groundwater. During recent drilling of Project bores installed into the Alluvium (Table 16-73), airlift yields of less than 0.03 L/s have been encountered (the low airlift yields may be reflective of a lack of airline submergence rather than low K).

Styx Coal Measures (HSU2)

The Styx Coal Measures comprises all consolidated sedimentary rocks associated with the Styx Basin, including the coal seams and the overlying, interbedded and underlying sandstone and mudstone units. The units are described as:

- Overburden – consisting of the portion of the Styx Coal Measures above the upper-most coal seam delineated in the Proponent's local-scale geological model;
- Coal seams / interburden – consisting of the portion of the Styx Coal Measures between the upper and lower coal seams as delineated in the Proponent's local-scale geological model; and
- Underburden – consisting of the portion of the Styx Coal Measures below the lower-most coal seam delineated in the Proponent's local-scale geological model.

Coal seams are not generally classified as aquifers because of typically low K values. However, within a sequence of coal seams and typical interburden rocks (such as claystone and shale), the coal seams are sometimes referred to as 'aquifers' because they are more permeable than the much less-permeable interburden layers (IESC 2014).

The Styx Baseline Study (Yeates 2011), which presented the results of resource drilling programs, reported "there has been very little mention of water coming from the coals, though there have been some reports of salty water flows from the alluvium in the upper 50 m". Based on the observations of Yeates and other Central Queensland Coal personnel, the Styx Coal Measures can be considered a poor aquifer.

During recent drilling of Project WMP bores installed into the Styx Coal Measures (Table 16-73), very low airlift yields of between 0.01 and 0.15 L/s were observed to depths up to around 40 m. Typically, below 40 m no airlift yields were observed. At the tested depths, the low to negligible airlift yields cannot be attributed to lack of airline submergence and are considered to be representative of low K.

Weathered / fractured (residual) Basement (HSU3)

Based on a review of the available literature, which shows the highest K's in basement rocks are encountered within shallow intersections, and experience elsewhere, it is likely a thin weathered section of basement (residual basement) could be extensive across the Styx Basin where their basement rocks outcrop or subcrop.

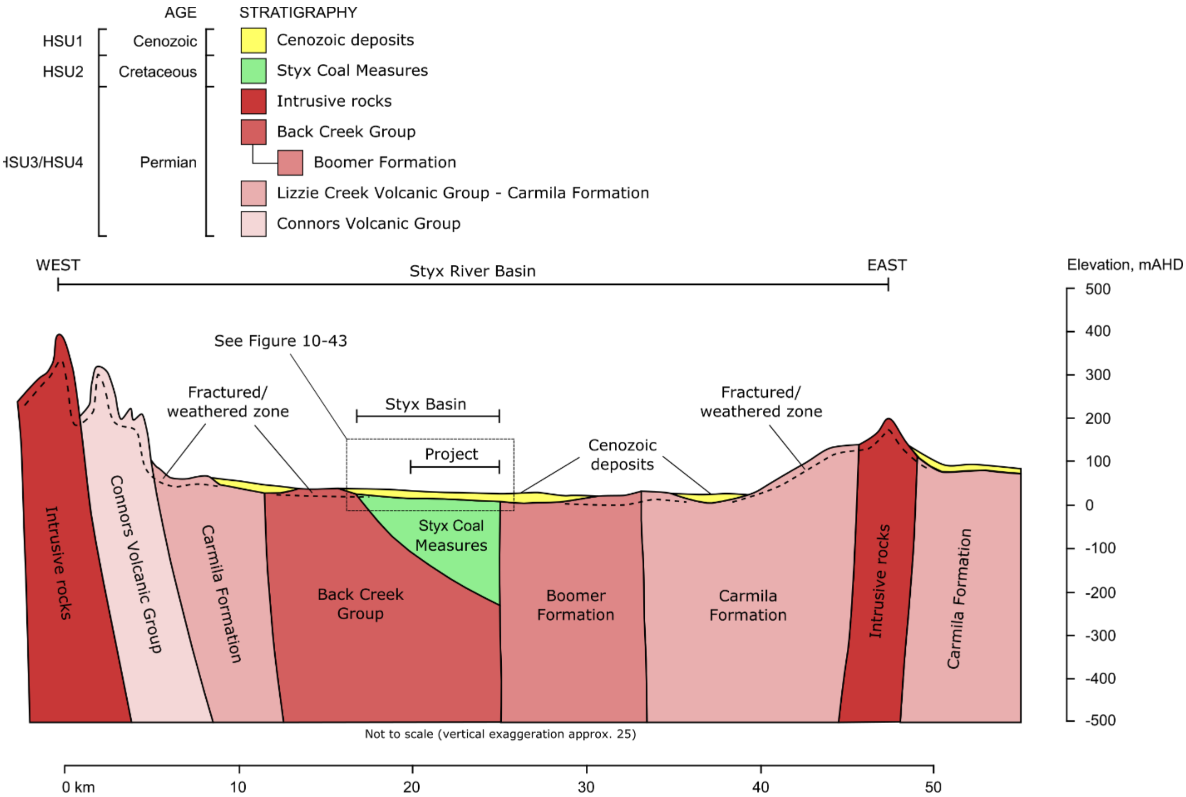

Figure 16-86 Cross-sectional diagram of HSUs associated with the Project area and surrounds

Summary

There are four HSUs present in the Project area – Alluvium, Styx Coal Measures, Weathered Basement, Unweathered Basement. Of these HSUs, only the Alluvium presents as what would normally be referred to as an aquifer. The Styx Coal Measures can at best be described as a poor aquifer, whilst the Weathered Basement may form an aquifer in places. Unweathered Basement forms a basal aquitard to regional the groundwater system.

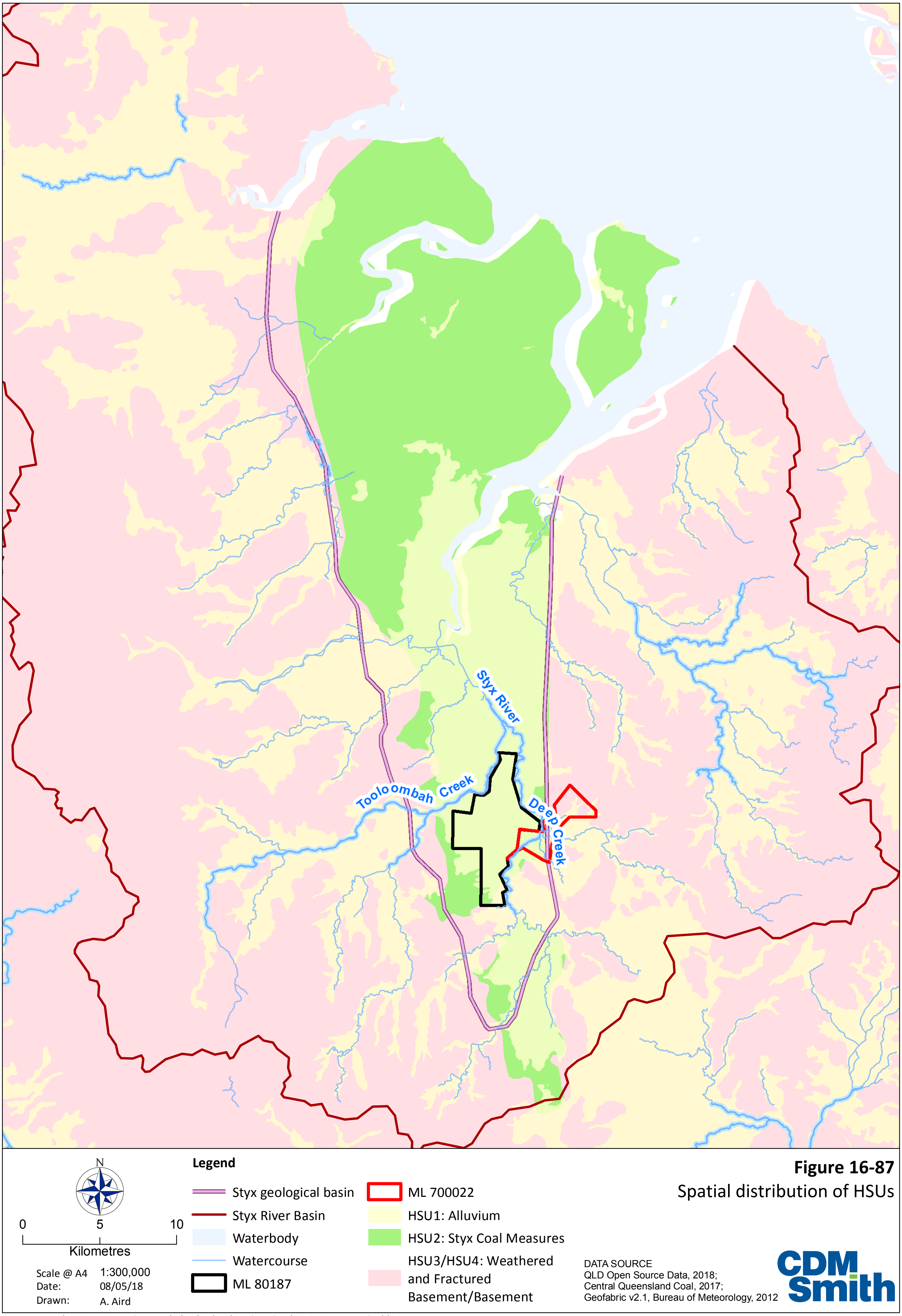

Figure 16-87
Spatial distribution of HSUs

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Groundwater Chemistry

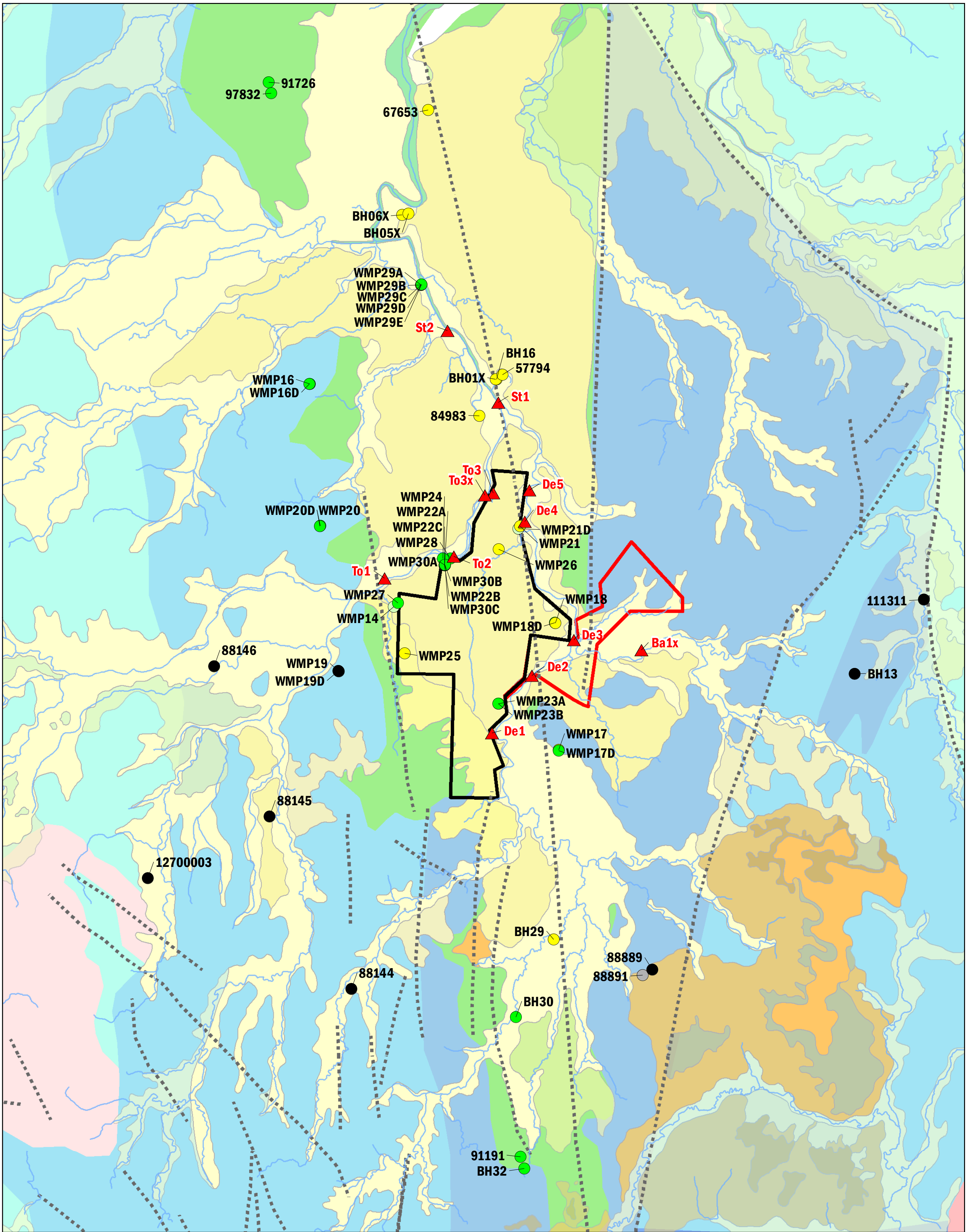
Overview

Groundwater chemistry information collated prior to water affecting activities commencing provides the basis for understanding the pre-mine baseline groundwater resource condition and assists in the interpretation of groundwater flow systems and interactions with surface water and connected systems. Groundwater chemistry is influenced by multiple factors including hydrogeological and mineralogical properties of aquifers and aquitards, sources of recharge, locations and form of discharge, groundwater flow rates and age, and anthropogenic effects. The data presented in this section is used to describe the baseline groundwater chemistry. Additional water chemistry data are presented in Section 16.11.2.1, which is used separately to assess the water requirements of potential groundwater dependent ecosystems.

Groundwater samples have been collected periodically during 2017 and 2018 from privately owned bores identified in the 2017 census, as well as Project WMP bores. Figure 16-88 presents surface water and groundwater sample locations. The number of baseline sampling events at privately owned bores and Project WMP bores is presented in Table 16-80.

In this assessment, groundwater chemistry data (laboratory reported concentrations) are compared against:

- The Australian and New Zealand Guidelines (ANZECC) Guidelines (ANZECC and ARMCANZ, 2000) that are relevant to protection of freshwater aquatic ecosystems, irrigation and stock drinking water;
- The ADWG (NHMRC, NRMMC 2011); and
- WQOs set for the three Groundwater Chemistry Zones (GCZs) within the area that may be impacted by the Project.



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Legend

- Surface water sampling location

HSU

- Alluvium
- Alluvium and Styx Coal Measures
- Styx Coal Measures
- Tertiary sediments
- Other / basement

- ML 80187
- ML 700022
- Watercourse/waterbody

Figure 16-88

Surface water and groundwater baseline water chemistry sampling locations

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018;
Geofabric Product Suite V2.1.1
Bureau of Meteorology (BoM) 2011

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 baseline water chem sampling locations__10-29.mxd 11/7/2018

Table 16-80 Styx Project groundwater sampling summary

Bore ID	Sampling period		Sampling events	samples collected [1]	Dry / damaged
	Earliest	Most recent(2)			
BH01X	Apr-2017	Sep-2018	12	12	
BH05X	Feb-2017	Feb-2017	2	1	1
BH06X	May-2017	Mar-2018	6	6	
BH13	May-2017	Mar-2018	6	6	
BH16	Apr-2017	Sep-2018	12	12	
BH29	May-2017	Nov-2017	5	5	
BH30	May-2017	Nov-2017	5	5	
BH32	Feb-2017	Nov-2017	5	5	
WMP02	Dec-2017	Sep-2018	11	10	
WMP04	Nov-2017	Sep-2018	12	11	
WMP04D	Nov-2017	Sep-2018	12	11	
WMP05	Nov-2017	Sep-2018	12	11	
WMP06	Dec-2017	Sep-2018	11	11	
WMP07	Dec-2017	Sep-2018	11	0	11
WMP08	Nov-2017	Sep-2018	13	13	
WMP08D	Nov-2017	Sep-2018	13	13	
WMP09	Nov-2017	Sep-2018	13	13	
WMP10	Nov-2017	Sep-2018	12	11	
WMP11	Apr-2018	Sep-2018	7	7	
WMP11D	Apr-2018	Sep-2018	7	7	
WMP12	Dec-2017	Sep-2018	11	5	6
WMP13	Jan-2018	Sep-2018	10	10	
WMP14	Apr-2018	Sep-2018	7	0	7
WMP15	Apr-2018	Sep-2018	7	7	
WMP16	Oct-2018	Oct-2018	1		
WMP16D	Oct-2018	Oct-2018	1		
WMP17	Oct-2018	Oct-2018	1		
WMP17D	Oct-2018	Oct-2018	1		
WMP18	Sep-2018	Sep-2018	1	1	
WMP18D	Sep-2018	Sep-2018	1	1	
WMP19	Sep-2018	Sep-2018	1	1	
WMP19D	Sep-2018	Sep-2018	1	1	
WMP20	Oct-2018	Oct-2018	1		
WMP20D	Oct-2018	Oct-2018	1		
WMP21	Sep-2018	Sep-2018	1	0	1
WMP21D	Sep-2018	Sep-2018	1	1	
WMP22A	Oct-2018	Oct-2018	1	1	
WMP22B	Oct-2018	Oct-2018	1	1	
WMP22C	Oct-2018	Oct-2018	1	1	
WMP23A	Oct-2018	Oct-2018	1	1	
WMP23B	Oct-2018	Oct-2018	1	1	
WMP24	Sep-2018	Sep-2018	1	1	
WMP25	Sep-2018	Sep-2018	1	1	
WMP26	Sep-2018	Sep-2018	1	1	
WMP27	Sep-2018	Sep-2018	1	0	1
WMP28	Sep-2018	Sep-2018	1	1	
WMP29A	Oct-2018	Oct-2018	1	1	
WMP29B	Oct-2018	Oct-2018	1	1	
WMP29C	Oct-2018	Oct-2018	1	1	
WMP29D	Nov-2018	Nov-2018	1	1	
WMP29E	Oct-2018	Oct-2018	1	1	
WMP30A	n/a	n/a	n/a	n/a	
WMP30B	n/a	n/a	n/a	n/a	
WMP30C	n/a	n/a	n/a	n/a	

1. Samples sometimes could not be collected due to dry or damaged well, or lack of access; n/a Not sampled
2. Most recent represents the most current data that has been included in the groundwater modelling. Samples have been collected for November and December 2018 and will be added into the database to assist with the development of site specific trigger vlues for the Environmental Authority.

Salinity and Major Ions

The results of a review of groundwater salinity data recorded in the GWDBQ, privately owned bores and Styx Project WMP bores are summarised in Table 16-81. Figure 16-89 presents the spatial distribution of groundwater salinity for each HSU, based on the data presented in Table 16-81.

Table 16-81 Measured groundwater salinity and pH

ID / RN	Inferred HSU	GCZ	TDS (mg/L) [1]	ADWG Palatability [2]	ANZECC stock suitability	pH [4]
GWDQB Data						
57794	Alluvium	Bison	250	Good	Acceptable	7.6
67653	Alluvium	Styx	3,576	Unacceptable	Acceptable	7.5
67654	Alluvium	Styx	8,487	Unacceptable	Acceptable	7.2
84983	Alluvium	Bison	757	Fair	Acceptable	7.6
88144	Basement (Back Creek Group)	Bison	2,863	Unacceptable	Acceptable	6.8
88145	Basement (Back Creek Group)	Bison	1,621	Unacceptable	Acceptable	6.8
88146	Basement (Back Creek Group)	Uplands	529	Good	Acceptable	6.8
88889	Not known	Styx	4,684	Unacceptable	Acceptable	7.6
88891	Tertiary sediments	Styx	5,370	Unacceptable	Unacceptable	7.2
91191	Styx Coal Measures	Styx	4,151	Unacceptable	Acceptable	8
91457	Basement (Carmila Beds)	Uplands	777	Fair	Acceptable	8
91726	Styx Coal Measures	Styx	4,587	Unacceptable	Acceptable	7.8
97832	Styx Coal Measures	Styx	4,294	Unacceptable	Acceptable	7.4
111311	Basement (Boomer Formation)	Styx	8,487	Unacceptable	Unacceptable	7.8
111312	Basement (Carmila Beds)	Styx	2,822	Unacceptable	Acceptable	8.2
12700003	Basement (Rhyolite)	Styx	3,815	Unacceptable	Acceptable	7.5
Private bores (census data)						
BH01X	Alluvium	Bison	270 – 718	Good-Fair	Acceptable	6.1-7.5
BH05X	Alluvium	Styx	8,920	Unacceptable	Unacceptable	7.2
BH06X	Alluvium	Styx	577 – 962	Good-Fair	Acceptable	7.1-7.8
BH13	Basement (Boomer Formation)	Styx	2,110 – 5,480	Unacceptable	Acceptable-unacceptable	6.5-7.1
BH16	Alluvium	Bison	221 - 424	Good	Acceptable	6.1-7.9
BH29	Alluvium	Uplands	190 - 216	Good	Acceptable	6.3-6.6
BH30	Styx Coal Measures	Styx	6,530 – 16,700	Unacceptable	Unacceptable	6.4-7.7
BH32	Styx Coal Measures	Styx	2,630 – 3,490	Unacceptable	Acceptable	6.8-7.1
Styx Project WMP bores						
WMP02	Alluvium	Bison	8,750 – 11,900	Unacceptable	Unacceptable	6.1-7.1
WMP04	Alluvium	Uplands	5,760 – 17,000	Unacceptable	Unacceptable	7.3-9.3
WMP04D	Alluvium and Styx Coal Measures (overburden)	Uplands	14,200 – 17,600	Unacceptable	Unacceptable	6.5-7.4
WMP05	Alluvium	Bison	1,260 – 2,310	Unacceptable	Acceptable	6.8-7.5
WMP06	Alluvium and Styx Coal Measures (underburden)	Styx	1,170 – 4,400	Poor-Unacceptable	Acceptable	6.3-7.4
WMP07	Styx Coal Measures (underburden)	Styx	8,870	Unacceptable	Unacceptable	-
WMP08	Alluvium	Uplands	8,870 - 19,200	Unacceptable	Unacceptable	6.5-7.5
WMP08D	Styx Coal Measures (underburden)	Uplands	8,180 - 8,870	Unacceptable	Unacceptable	6.98-7.7

ID / RN	Inferred HSU	GCZ	TDS (mg/L) [1]	ADWG Palatability [2]	ANZECC stock suitability	pH [4]
WMP09	Alluvium	Uplands	9,650 - 14,800	Unacceptable	Unacceptable	6.5-7.3
WMP10	Styx Coal Measures (overburden)	Uplands	9,410 - 11,400	Unacceptable	Unacceptable	6.6-7.7
WMP11	Styx Coal Measures (overburden)	Bison	17,700 - 22,300	Unacceptable	Unacceptable	6.3-7.3
WMP11D	Styx Coal Measures (overburden)	Bison	20,500 - 21,900	Unacceptable	Unacceptable	6.3-7.3
WMP12	Alluvium and Styx Coal Measures (overburden)	Uplands	1,440 – 5,960	Unacceptable	Acceptable - Unacceptable	6.8-8.6
WMP13	Alluvium and Styx Coal Measures (overburden)	Styx	22,300 – 37,400	Unacceptable	Unacceptable	5.6-7.6
WMP14	Alluvium and Styx Coal Measures (overburden)	Styx	Dry			
WMP15	Alluvium and Styx Coal Measures (underburden)	Styx	2,200 – 4,600	Unacceptable	Acceptable	6.7-7.9
WMP16 5	Styx Coal Measures (overburden)	Styx	5,820	Unacceptable	Unacceptable	7.9
WMP16D [5]	Styx Coal Measures (coal seams/interburden)	Styx	5,055	Unacceptable	Unacceptable	7.9
WMP17 [5]	Alluvium	Uplands	4,490	Unacceptable	Acceptable	7.5
WMP17D [5]	Styx Coal Measures (overburden)	Uplands	27,490	Unacceptable	Unacceptable	-
WMP18 [5]	Alluvium	Uplands	6,930	Unacceptable	Unacceptable	-
WMP18D [5]	Styx Coal Measures (overburden)	Uplands	19,760	Unacceptable	Unacceptable	7.8
WMP19 [5]	Basement	Styx	1,030	Poor	Acceptable	7.7
WMP19D [5]	Basement	Styx	1,110	Poor	Acceptable	7.7
WMP20 [5]	Styx Coal Measures (overburden)	Styx	1,155	Poor	Acceptable	-
WMP20D [5]	Styx Coal Measures (overburden)	Styx	1,155	Poor	Acceptable	8
WMP21	Alluvium	Uplands	Dry			
WMP21D [5]	Alluvium and Styx Coal Measures (overburden)	Uplands	27,320	Unacceptable	Unacceptable	7.7
WMP22A [5]	Styx Coal Measures (overburden)	Uplands	15,615	Unacceptable	Unacceptable	-
WMP22B [5]	Styx Coal Measures (coal seams/interburden)	Uplands	39,420	Unacceptable	Unacceptable	-
WMP22C [5]	Styx Coal Measures (underburden)	Uplands	13,375	Unacceptable	Unacceptable	-
WMP23A [5]	Styx Coal Measures (coal seams/interburden)	Uplands	16,320	Unacceptable	Unacceptable	-
WMP23B [5]	Styx Coal Measures (underburden)	Uplands	14,465	Unacceptable	Unacceptable	-
WMP24 [5]	Styx Coal Measures (overburden)	Uplands	14,870	Unacceptable	Unacceptable	7.9
WMP25 [5]	Alluvium	Styx	590	Good	Acceptable	7.8
WMP26 [5]	Alluvium	Uplands	33,290	Unacceptable	Unacceptable	7.6
WMP27 [5]	Styx Coal Measures (overburden)	Styx	1,855	Unacceptable	Acceptable	-
WMP28 [5]	Styx Coal Measures (overburden)	Uplands	2,050	Unacceptable	Acceptable	8.1
WMP29A [5]	Alluvium	Styx	2,368	Unacceptable	Acceptable	-
WMP29B [5]	Alluvium	Styx	17,600	Unacceptable	Unacceptable	-
WMP29C [5]	Styx Coal Measures (overburden)	Styx	7,610	Unacceptable	Unacceptable	-
WMP29D	Styx Coal Measures (coal seams/interburden)	Styx	No data			

ID / RN	Inferred HSU	GCZ	TDS (mg/L) [1]	ADWG Palatability [2]	ANZECC stock suitability	pH [4]
WMP29E [5]	Styx Coal Measures (underburden)	Styx	13,180	Unacceptable	Unacceptable	-
WMP30A	Styx Coal Measures (overburden)	Uplands	No data			
WMP30B	Styx Coal Measures (coal seams/interburden)	Uplands	No data			
WMP30C	Styx Coal Measures (underburden)	Uplands	No data			

1. TDS – Total dissolved solids concentration, analysed in laboratory

2. ADWG palatability - Australian Drinking Water Quality Guidelines (NHMRC, NRMMC 2011): Good (TDS 0 – 600 mg/L), Fair (TDS 600 - 900 mg/L); Poor (TDS 900 – 1,200 mg/L), Unacceptable (TDS >1,200 mg/L)

3. ANZECC stock suitability - Australian and New Zealand Guidelines (ANZECC and ARMCANZ 2000): Acceptable (TDS 2,000 – 5,000 mg/L), Unacceptable (TDS >5,000 mg/L)

4. Measured in field

5. Bores have TDS values calculated from field EC values using a factor of 0.64 (based on relationship between EC and TDS estimated from historic data in the area)

The data presented in Table 16-81 and Figure16-89 show groundwater salinity (as total dissolved solids; TDS) is variable across the Styx River Basin, ranging from drinking water quality (TDS less than 600 mg/L) to water quality unacceptable for drinking or livestock (TDS greater than 1,200 and 5,000 mg/L, respectively):

- Alluvium aquifer (HSU1) groundwater salinity ranges from 190 to 33,290 mg/L, notably with the higher salinities reported for alluvial groundwaters in the Project area (e.g. WMP02, WMP04, WMP08, WMP09 and WMP26) compared to those closer to Broad Sound and the coast;
- Groundwater sampled from the Styx Coal Measures (HSU2) is generally more saline than groundwater in the other HSUs with salinity ranging from 1,170 to 37,400 mg/L, notably there is no apparent trend in high salinity groundwaters across the Project area and beyond;
- Basement (HSU3/HSU4) groundwater salinity (Back Creek Group or Carmila Beds) ranges from 530 to 8,500 mg/L;
- Of the available data, approximately 60% of samples report TDS concentrations within the acceptable salinity tolerance of most livestock (2,000 to 5,000 mg/L TDS);
- There is no evidence of a seawater – freshwater interface in the deep 'aquifer' units located near Broad Sound (the nested WMP29 wells), with the most saline groundwater sampled from the deeper alluvial sequence (WMP29B; screened between 16 and 20 mbgl – the deepest bore, WMP29E, is screened between 220 and 228.5 mbgl and groundwater sampled from this bore reports a salinity that is 75% of WMP29B groundwater).

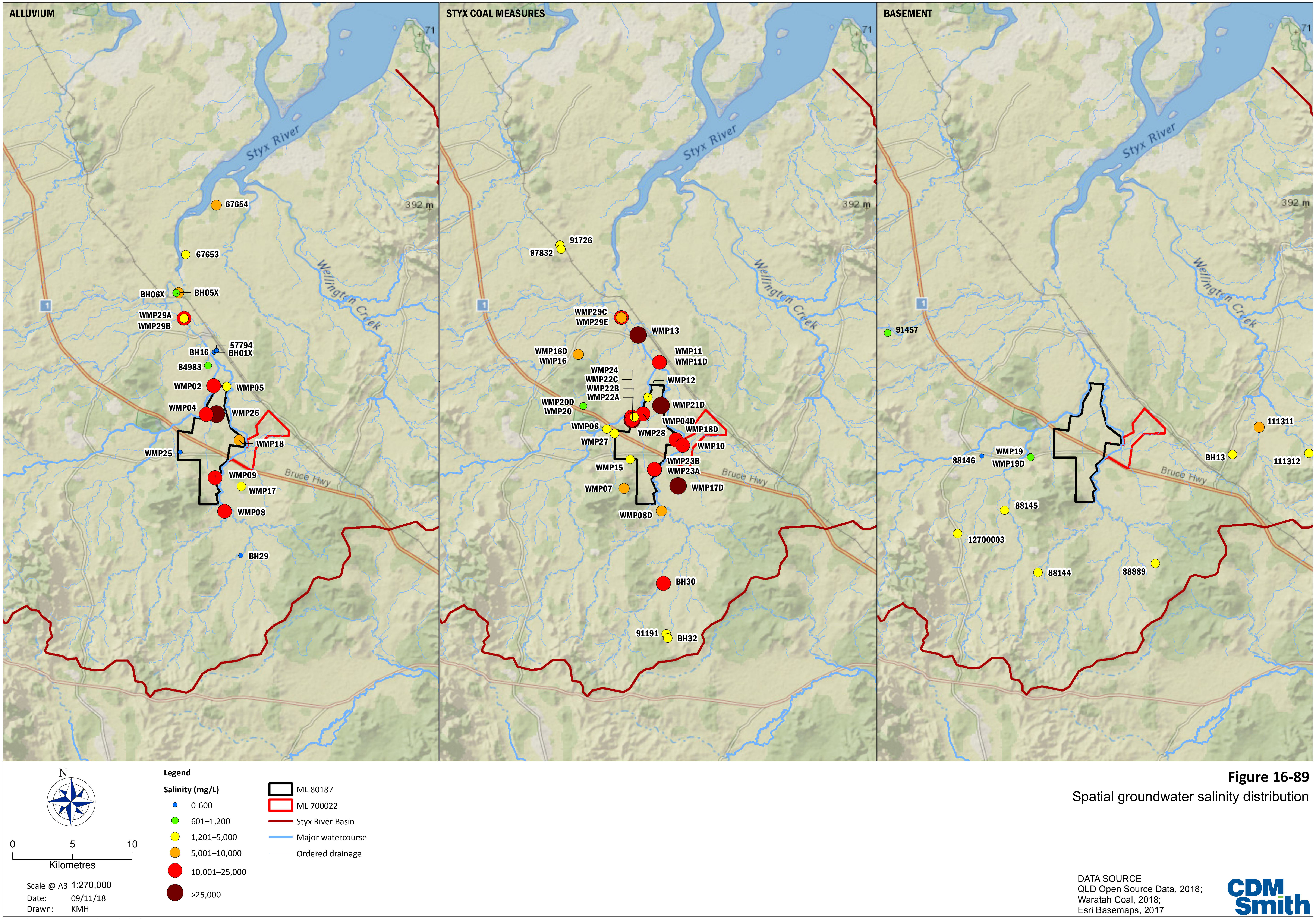

Figure 16-89
Spatial groundwater salinity distribution

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018;
Esri Basemaps, 2017

CDM Smith

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Box and Whisker plots of laboratory reported major ion concentrations, selected dissolved metal concentrations, as well as EC, TDS and field recorded pH are presented in Figure 10-35 to Figure 10-37 (refer Chapter 10 – Groundwater). The water chemistry data presented on the Box and Whisker plots are grouped by HSU and GCZ. As most of the sample locations have fewer than 10 sampling events, and some have only a few sample events, it is not practical to present statistical results for individual locations.

Laboratory reported major ion concentrations in groundwater samples are presented as a Piper plot in Figure 10-38 (refer Chapter 10 – groundwater), along with major ion concentrations for seawater and rainfall (Rockhampton). At locations where the bores are screened across multiple HSUs, the dominant unit was identified based on comparison with the results for other bore locations. The Piper plot shows:

- Alluvium groundwater varies from being similar to Rockhampton rainfall to almost seawater (sodium (Na)-chloride (Cl) dominant), consistent with ocean derived salts mixed with rainfall recharge, or mixing of terrestrial groundwater and marine groundwater in areas where this is likely to occur (e.g. near the coast or near estuaries);
- Concentrations of major ions in Styx Coal Measures groundwaters also vary widely but is typically Na-Cl dominant, which may be representative of depositional environment; and
- Concentrations of major ions in Basement groundwater typically do not display a dominant water type but is generally calcium (Ca)-Cl dominant, which likely indicates reverse ion exchange processes where Na in groundwater is exchanged with Ca in the lithology, resulting in the Ca-Cl dominance.

For comparison, reported groundwater major ion data collected in the November/ December 2017 (representing end of dry season), March 2018 (representing end of wet season) and September 2018 (representing dry season) sampling events are also presented spatially as Stiff patterns on Figure 10-39 to Figure 10-46 (seawater and Rockhampton rainfall are also presented for comparison) (refer Chapter 10 – Groundwater).

The November/ December 2017 (end of dry season/ early wet season) Stiff patterns show:

- Groundwater chemistry signatures of bores completed in the alluvium varies between sites (Figure 10-39 to Figure 10-40 in Chapter 10 - Groundwater);
- Some are more similar to rainwater and less like seawater, as evidenced by the higher concentrations of Ca and HCO_3 in the groundwater samples. The groundwater samples also report a generally lower salinity than would be expected if seawater interaction with groundwater were a dominant process;
- The groundwater chemistry signature of the Styx Coal Measures varies slightly between sites (Figure 10-41 and Figure 10-42 in Chapter 10 - Groundwater). However, all are Na-Cl dominant, which could reflect the shallow marine / estuarine depositional environment of the Styx Coal Measures, or long residence time, or a combination of these processes;
- The groundwater chemistry signature for alluvium bores in close proximity to the Styx Project WMP bores is either similar to the Styx Coal Measures (refer Figure 10-39 and Figure 10-41 in Chapter 10) or to recharge from rainfall or stream flow events (refer Figure 10-9, Figure 10-11 and Figure 10-39 in Chapter 10); and

- The groundwater chemistry signature at WMP13 (screening the alluvium and coal measures near Styx River, downstream of the Deep Creek and Tooloombah Creek confluence) is similar to other Styx Coal Measures groundwater samples.

The Stiff patterns from the March 2018 (end of wet season) sampling event show:

- Alluvial groundwaters typically demonstrate a shift toward a rainwater signature toward the end of the wet season (Figure 10-43 in Chapter 10 - Groundwater), as would be expected in response to streamflow and rainfall recharge. This is most evident at WMP05 and WMP06; and
- Styx Coal Measures groundwater does not show significant seasonal variability (Figure 10-44 in Chapter 10).

The Stiff patterns from the September 2018 (dry season) sampling event show groundwater chemistry similar to that observed in November / December 2017:

- Groundwater chemistry signatures for bores completed in the alluvium varies between sites, with observed similarity to rainwater and less like seawater (Figure 10-45 in Chapter 10), as evidenced by the higher concentrations of Ca and HCO3 in the groundwater samples; and
- Styx Coal Measures groundwater are Na-Cl dominant and do not show significant seasonal variability (Figure 10-46 in Chapter 10).

Laboratory reported major ion concentration and physico-chemical data for groundwater samples collected between 2017 and July 2018 are presented in Chapter 10 (Table 10-16 through Table 10-37) and Appendix A5a (Surface and Groundwater Quality Results). The major ion concentrations have been compared against the WQOs set for the three GCZs within the area that may be impacted by the proposed mine and the ANZECC (2000) stock drinking water guideline values. All other groundwater chemistry data have been taken from the GWDBQ.

Comparison of the major ion and physico-chemical data with the WQOs and ANZECC (2000) stock drinking water guidelines shows that across the sampling sites:

- Baseline sulphate (SO_4) concentrations are above the stock drinking water guideline (ANZECC, 2000) at three locations across the Project area (BH30, WMP08, WMP13, WMP21D and WMP26; see Figure 16-79);
- Ca concentrations are above the stock drinking water guideline (ANZECC, 2000) at one location downstream of the proposed mine (WMP13; see Figure 16-79); and
- Reported major ion concentrations and physico-chemical data typically exceed the WQOs for the three GCZs in the Project area for all monitoring locations and events.

In summary, the available major ion data from the sampled Styx Coal Measures groundwater do not show a distinctly seawater signature, but do show evidence of direct recharge from rainfall and / or interaction with surface water. Seasonal variability in water quality is also not evident in these groundwaters.

Hydro-chemical signatures for alluvial groundwater also show evidence of direct recharge from rainfall or interaction with surface water, and also interaction with Styx Coal Measures groundwater. Seasonal variability in water quality is evident in these groundwaters.

Dissolved Metals, Nutrients and Hydrocarbons

Groundwater samples collected during sampling events for the Project in 2017 and 2018 have been analysed for dissolved metals, nutrients and hydrocarbons and are presented in Chapter 10 (Table 10-46 to Table 10-67) and Appendix A5a (Surface and Groundwater Quality Results). The reported concentrations have been compared against the WQOs set for the three GCZs within the area that may be impacted by the proposed mine, as well as NHMRC (2011) drinking water and relevant ANZECC (2000) guidelines, including 95% level of protection for freshwater aquatic ecosystems, long-term trigger values for irrigation water and livestock drinking water guidelines, respectively.

The laboratory reported dissolved metals, nutrients and hydrocarbon results show that across the sampling sites:

- Concentrations of aluminium (Al), arsenic (As), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), molybdenum (Mo), iron (Fe), fluoride (F), zinc (Zn), chromium (Cr), barium (Ba), nickel (Ni), (Se), silver (Ag), uranium (U) and vanadium (V) reported are generally above the WQOs and guidelines values across multiple sites and monitoring events;
- BTEXN hydrocarbon baseline concentrations are below detection limits, with the exception of detectable toluene concentrations at three locations (BH01X, BH16 and WMP08D). The toluene concentrations reported at BH01X exceeded the NHMRC (2011) drinking water guidelines but the remaining detectable concentrations are below the guideline values;
- Total Petroleum Hydrocarbons (TPH) and Total Recoverable Hydrocarbons (TRH) concentrations are above detection limits at a large number of sample locations (BH01X, BH05X, BH06X, BH13, BH16, WMP02, WMP04, WMP04D, WMP05, WMP06, WMP08, WMP08D, WMP09, WMP10, WMP11, WMP11D, WMP12, WMP13 and WMP15), and are likely representative of groundwater that is in contact with coal bearing strata; and
- Ammonia as N concentrations consistently exceeded the NHMRC (2011) drinking water guidelines at a number of locations (BH01X, BH06X, BH13, BH32, WMP08D, WMP11 and WMP11D) throughout the monitoring events. It should be noted, one Ammonia as N concentration reported at BH16 from the September 2017 monitoring event exceeded the NHMRC (2011) drinking water guidelines and was an order of magnitude higher than concentrations reported from other monitoring events at BH16. The remaining concentrations reported at BH16 were less than the guideline values.

In summary, aluminium, arsenic, cobalt copper, lead, manganese, molybdenum, iron, fluoride, zinc, chromium, barium, nickel, silver, uranium and vanadium occur above the WQOs defined for each of the GCZs within which the Project area. Hydrocarbons are reported in laboratory analyses, particularly for groundwaters sampled from the Styx Coal Measures.

Groundwater Recharge and Discharge Mechanisms

Recharge

There are a number of recharge mechanisms that are active within the Styx River catchment, including diffuse rainfall recharge over much of the catchment and episodic local-scale recharge along the major watercourses (at least) associated with stream losses during and following streamflow events.

A review of the literature has not identified any references that can assist in providing estimates of recharge rates specific to the Styx River catchment. Crosbie et al. (2010) found there have been comparatively few published recharge studies in the region. The national map of groundwater recharge produced by Leaney et al. (2011) utilises the Method of Last Resort (MOLR) approach for estimating recharge rates in data poor areas and suggests recharge rates within the Styx River catchment are in the range of 1 to 5 mm/yr (0.1% to 0.7% of mean annual rainfall; 759 mm/yr, see Section 16.11.2.1). However, it can be expected that higher rates of recharge might occur along watercourses during flow events due to stream losses, and that recharge over those parts of the catchment characterised by alluvial soils will be higher than elsewhere in the catchment where basement rocks and Styx Coal Measures outcrop or sub-crop, or in steep sloping locations.

The Chloride Mass Balance method has been used to estimate recharge rates over different parts of the Styx River catchment. The method assumes Cl concentrations in groundwater arise from dry fall and precipitation, and that there are negligible contributions from rock weathering and anthropogenic sources. The (steady state) chloride mass balance is described by Equation 1 (Cook 2003).

$$C_P P = C_R R + C_Q Q \qquad \textit{Eq. 1}$$

Where C_P= Chloride concentration in precipitation
P= Precipitation rate
C_R= Chloride concentration in recharge
R= Recharge rate
C_Q= Chloride concentration in surface water runoff
Q= Surface water runoff rate

In simple terms, for estimates of groundwater recharge the surface runoff component can be ignored and Equation 1 becomes Equation 2.

$$R = \frac{C_P P}{C_R} \qquad \textit{Eq. 2}$$

Using this method, Table 16-82 presents recharge estimates for the Styx River catchment based on the following criteria:

- Average precipitation rate 759 mm/yr
- Rainfall Cl concentration 2.59 mg/L (Crosbie et al, 2012)
- Groundwater Cl concentrations (adopting the lowest concentration reported)
  - Alluvium 64 to 8,560 mg/L
  - Styx Coal Measures 110 to 5,063 mg/L
  - Basement rocks 290 to 4,608 mg/L

Table 16-82 Estimated rainfall recharge rates

HSU	% of rainfall	mm/yr
Alluvium (HSU1)	<0.1 to 4	<0.5 to 31
Styx Coal Measures (HSU2)	<0.1 to 2.5	<0.5 to 18
Basement (HSU3 / HSU4)	<0.1 to 0.9	<0.5 to 7

In a groundwater modelling sense, climate, vegetative cover, soil type and degree of weathering of out-cropping and sub-cropping rocks are probably the greatest constraints on recharge rates. However, a number of other factors will also affect the potential for recharge to occur and, when it occurs and at what rate.

For example:

- Topographic relief – recharge potential will be greatest in 'flat' areas where rainfall runoff potential is lower than areas where steep topography occurs;
- Depth to water table – recharge potential may be lower in areas where the water table is close to the surface, e.g. in groundwater discharge areas, but this will also depend on the K of the sub-surface and hydraulic gradients; and
- The degree to which the soil water reservoir is depleted.

Discharge

Groundwater discharge occurs from the catchment via evapotranspirative losses from shallow water tables (direct evaporation) and riparian vegetation (transpiration), and discharge to surface water bodies (including permanent pools and baseflow fed streams).

Groundwater – Surface Water Interactions

A conceptual understanding of surface water – groundwater interactions in the Styx River catchment has been developed from the information summarised in this Section (and detailed in Chapter 10 – Groundwater):

- Surface elevations of the landscape and stream beds obtained from a recent Lidar survey [supplemented with Shuttle Radar Topography Mission (SRTM) for areas not covered by the survey];
- Measured, interpreted and inferred groundwater heads collected from third party and newly installed Project WMP bores (Figure 16-79 and 'Groundwater Heads and Flow in this Section);
- Mapping of groundwater dependent ecosystems (GDEs) (Section 16.11.2.1);
- Field observations of watercourse pools (Table 16-83), streambed morphology and geology (Section 16.11.1.1), vegetation (Section 16.10.1.4, 16.11.2.1, and 16.13.3);
- Water quality monitoring results (see 'Groundwater Chemistry' in this Section);
- Interpreted extents of HSUs (Figure 16-87 and 'Hydrogeological Properties' in this Section); and
- Analysis of radon isotopes (^{222}Rn) and stable isotopes of water (^{2}H and ^{18}O), see Section 16.11.2.1.

Figure 16-90 presents the alignments of the hydrogeological cross-sections presented in Figure 16-91 to Figure 16-95 that are used to provide conceptualisations of groundwater and surface water interactions in the area of the proposed mine, i.e.:

- Figure 16-91 and Figure 16-92 along the streambed thalwegs of Tooloombah and Deep Creeks;
- Figure 16-93 (cross-section 1, west-east) and Figure 16-94 (cross-section 2, north-south) through the Project area; and
- Figure 16-95 (cross-section 3, west-east) around 2 km above the confluence of Tooloombah and Deep Creeks.

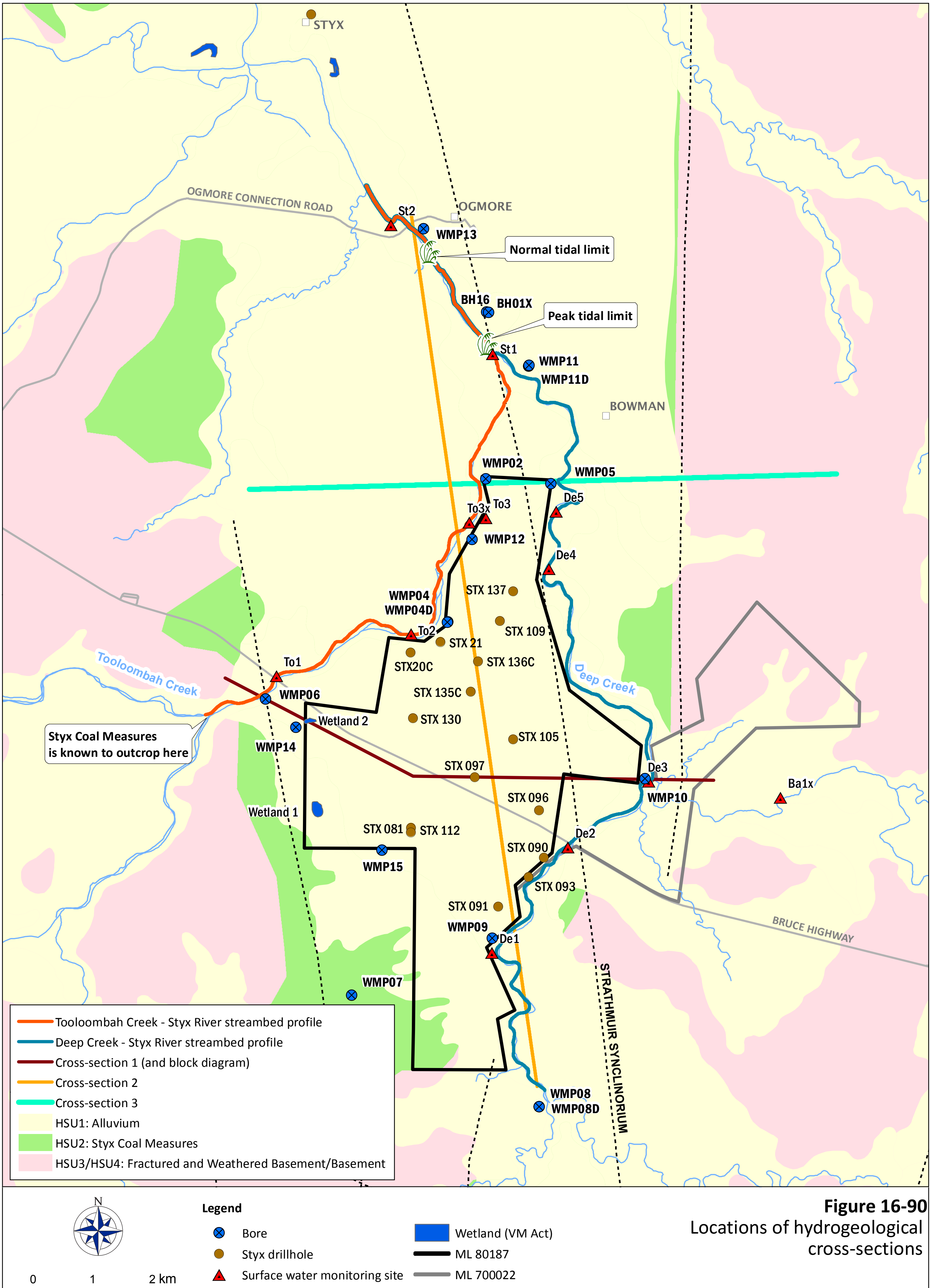
Table 16-83 Field observations of watercourse pools

Days since last rainfall	Monitoring event	Deep Creek					Tooloombah Creek			Styx River	
		De1	De2	De3	De4	De5	T01	T02	T03	St1	St2
9	Feb-17	Dry	Partly wet, brown, very turbid	Partly wet, green, turbid	Partly wet, green/brown, turbid	Not visited	Wet, green-brown, slightly turbid, algae	Wet, low turbidity, algae	Not visited	Wet, green, low turbidity, significant algae	Not visited
32	May-17	Wet, slightly turbid	Wet, slightly turbid	Wet, slightly turbid	Wet, slightly turbid	Not visited	Wet, green-brown, slightly turbid	Wet, green-brown, slightly turbid	Not visited	Wet, green, low turbidity	Not visited
23	Jun-17	Wet, slightly turbid	Wet, slightly turbid	Wet, slightly turbid	Wet, slightly turbid	Not visited	Wet, green-brown, low turbidity	Wet, green-brown, low turbidity	Wet, very low turbidity	Wet, green, low turbidity	Not visited
4	Aug-17	Wet	Wet	Wet	Wet	Not visited	Wet	Wet	Wet	Wet	Not visited
53	Sep-17	Wet	Wet	Wet	Wet	Not visited	Wet	Wet	Wet	Wet	Not visited
3	Nov-17	Wet	Wet	Wet	Wet	Not visited	Wet	Wet	Wet	Wet	Not visited
0	Jan-18	Wet, brown turbid	Wet, very turbid	Wet, very turbid	Wet, very turbid	Wet, very turbid	Wet, turbid	Wet, turbid	Wet	Wet, green, low turbidity, significant algae	Not visited
6	Feb-18	Partly wet, brown, turbid	Wet, very turbid	Wet, very turbid	Wet	Wet	Wet	Wet	Wet	Wet	Not visited

Days since last rainfall	Monitoring event	Deep Creek					Tooloombah Creek			Styx River	
		De1	De2	De3	De4	De5	T01	T02	T03	St1	St2
N/A	Mar-18	Partly wet, brown, turbid	Wet, very turbid	Wet, very turbid	Wet, very turbid	Wet, very turbid	Wet, brown, turbid	Wet, green-brown low turbidity	Wet, low turbidity, aquatic vegetation present	Not visited due to access issues associated with recent rain	Wet, green, low turbidity
N/A	Apr-18	Dry	Wet, very turbid	Dry	Wet, very turbid	Wet, very turbid	Wet, green-brown, slightly turbid	Wet, green-brown, slightly turbid	Wet, very low turbidity	Wet, green, low turbidity	Wet
N/A	May-18	Dry	Dry	Dry	Wet, very turbid	Wet, very turbid	Wet, green-brown, low turbidity	Wet, low turbidity, aquatic vegetation present	Wet, low turbidity, aquatic vegetation present	Wet, green, low turbidity	Wet, green, low turbidity
N/A	Jun-18	Dry	Partly wet	Dry	Partly wet	Partly wet	Wet, green-brown, low turbidity, algae	Wet, green-brown, low turbidity, algae	Wet, low turbidity, aquatic vegetation and algae present	Wet	Wet
N/A	Jul-18	Dry	Partly wet, very small pool	Partly wet	Partly wet, turbid	Partly wet, turbid	Wet, low turbidity	Wet, very low turbidity, aquatic vegetation present	Wet, very low turbidity, aquatic vegetation present	Wet, aquatic vegetation present	Wet (low tide)
	Aug-18	Dry	Dry	Partly wet	Partly wet	Wet, very turbid	Wet, low turbidity	Wet, slightly turbid	Wet, low turbidity	Wet	Wet (low tide), low turbidity

Days since last rainfall	Monitoring event	Deep Creek					Tooloombah Creek			Styx River	
		De1	De2	De3	De4	De5	T01	T02	T03	St1	St2
	Early Sep-18	Dry	Dry	Dry	Partly wet	Wet, turbid	Wet, low turbidity	Wet, low turbidity, aquatic vegetation present	Wet, very low turbidity, aquatic vegetation present	Wet	Wet
	Late Sep-18	Dry	Dry	Dry	Wet, very turbid	Partly wet, slightly turbid	Wet, low turbidity, algae	Wet, flow turbidity	Wet, very low turbidity, aquatic vegetation present	Wet, aquatic vegetation present	Wet (low tide), low turbidity
	Late Oct 18	Dry	Dry	Dry	Dry	Partly wet, slightly turbid	Wet, low turbidity, algae	Wet, low turbidity	Wet, very low turbidity, aquatic vegetation present	Wet, aquatic vegetation present	Wet (low tide), low turbidity

Wet =	Large/continuous pool that extends beyond view
Partly wet =	Small/isolated ponded pool
Dry =	No water present



Scale @ A4 1:80,000
Date: 14/11/18
Drawn: Gayle B.

Legend

- Bore
- Styx drillhole
- Surface water monitoring site
- Inferred tidal limit
- Geological structure
- Wetland (VM Act)
- ML 80187
- ML 700022
- Main road
- Major watercourse
- Waterbody

Figure 16-90
Locations of hydrogeological cross-sections

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018;
St. Lawrence 1:250k geological map, BoMN, 1970

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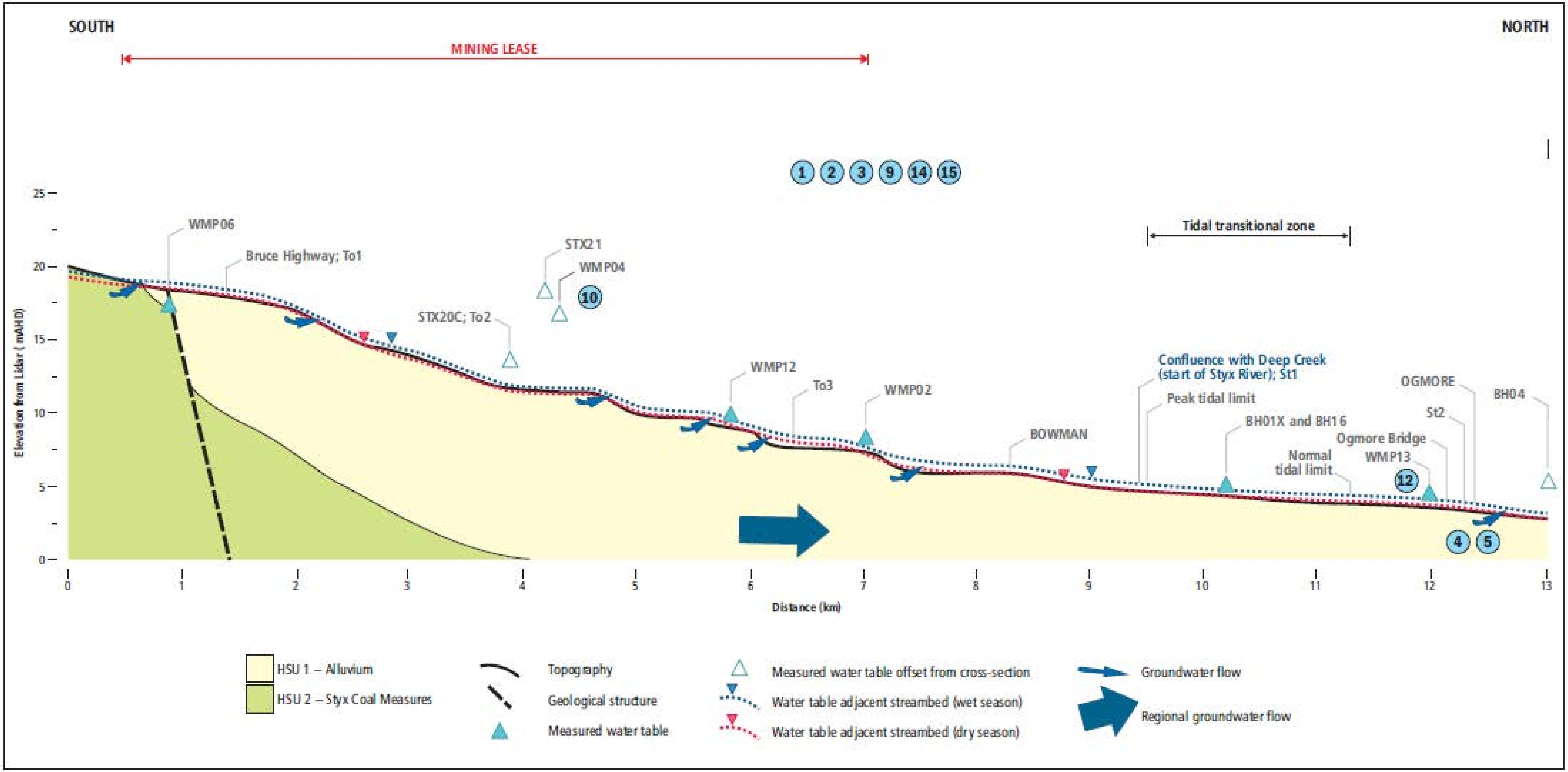

Figure 16-91

Cross-section along Tooloombah Creek streambed

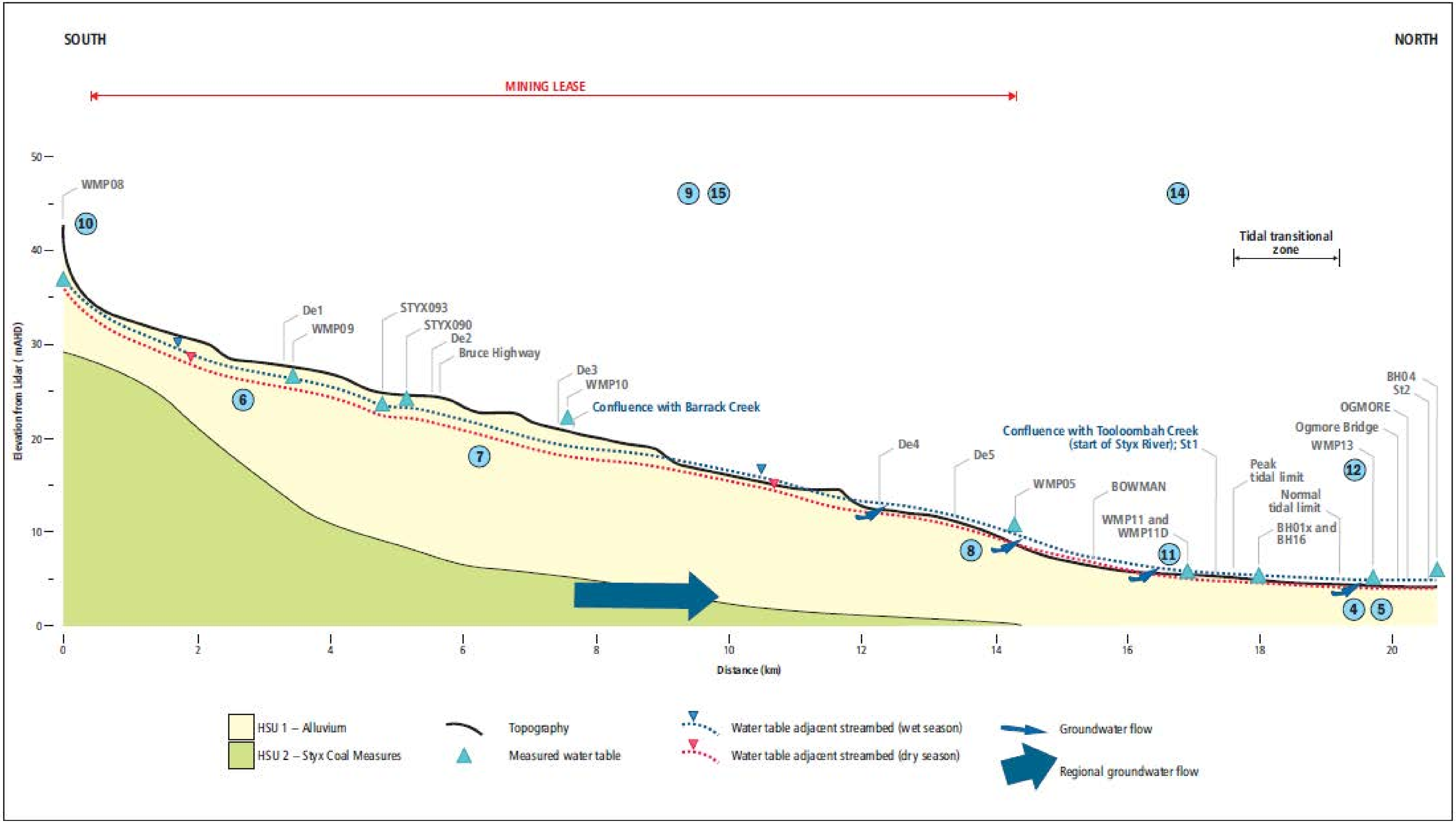

Figure 16-92

Cross-section along Deep Creek streambed

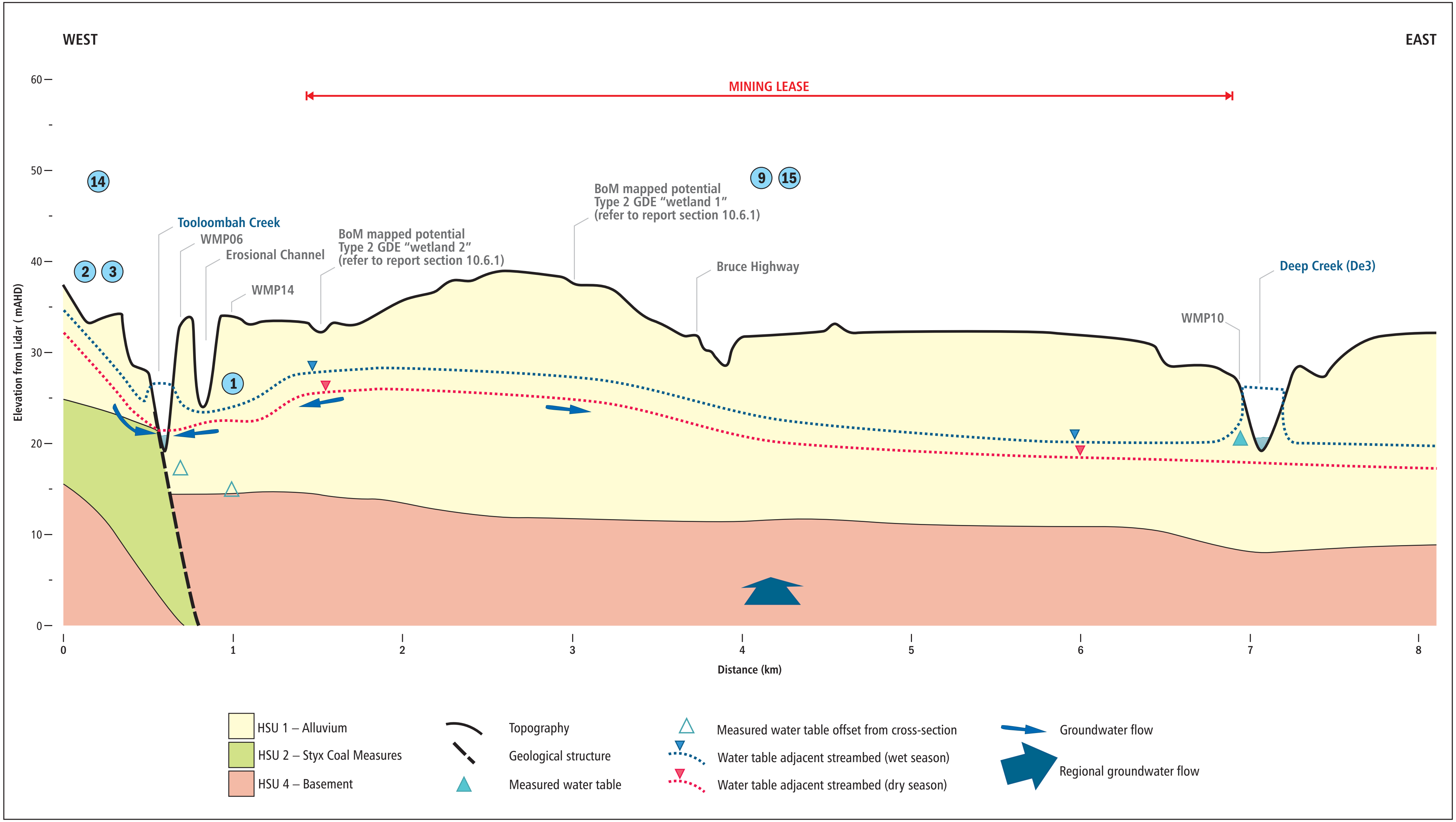

Figure 16-93

Cross-section 1 (Project area bordered by Tooloombah Creek and Deep Creek)

CDM Smith

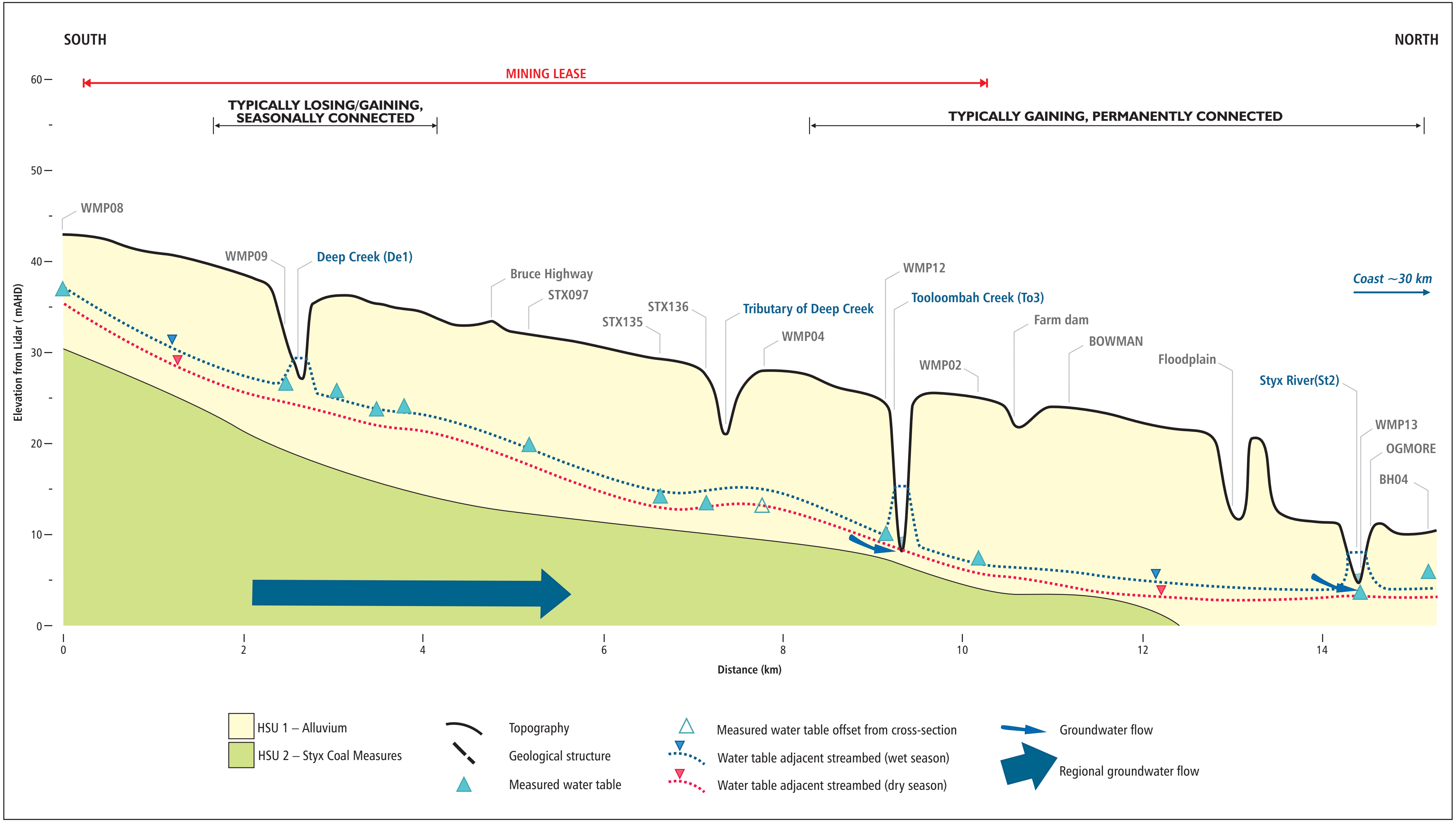

Figure 16-94
Cross-section 2 (Project area north to south)

CDM Smith

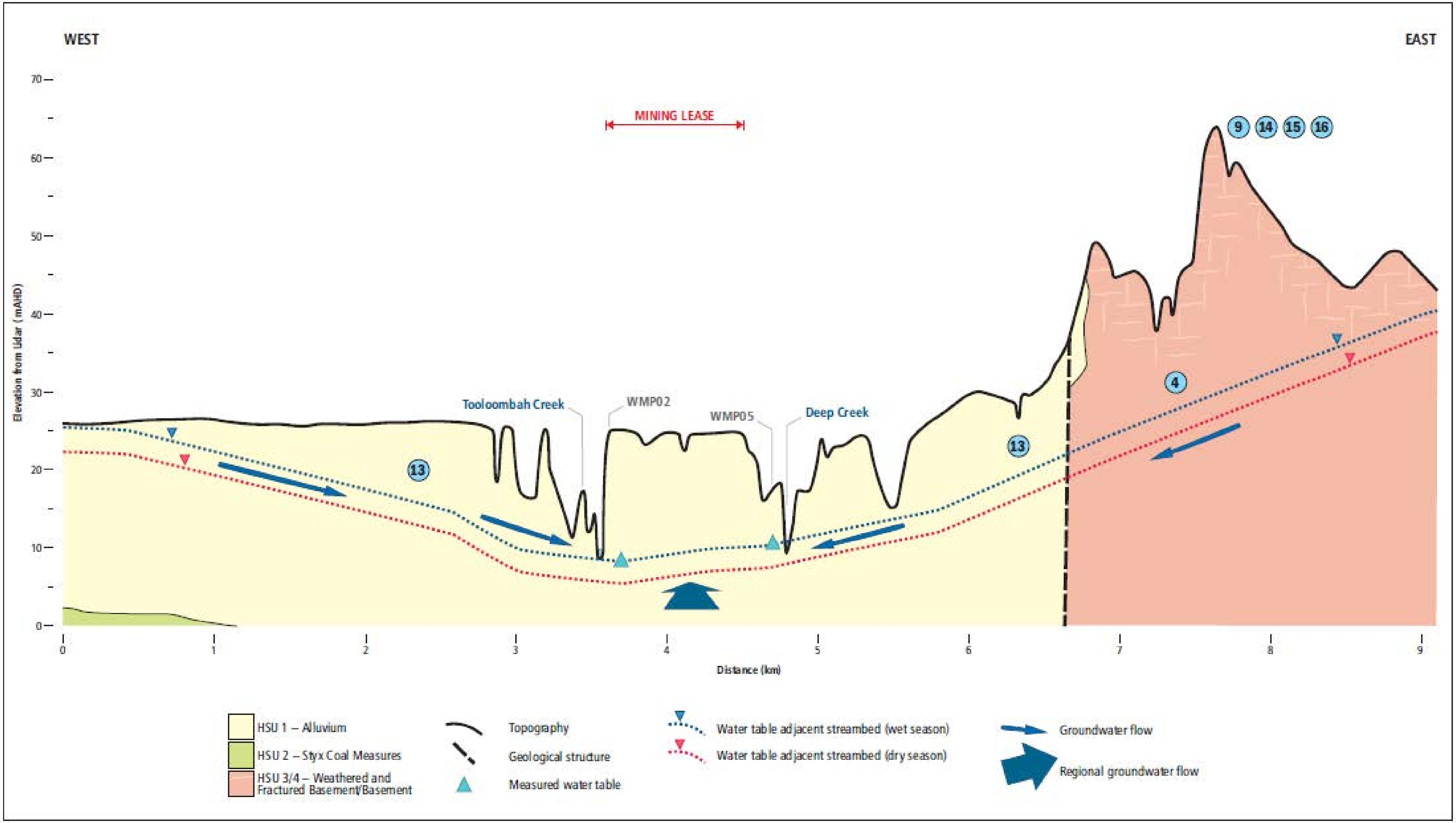

Figure 16-95

Cross-section 3 (west to east at confluence of Tooloombah Creek and Deep Creek)

CDM Smith

The cross-sections present the key elements of the conceptualisation that are relevant to surface water – groundwater interactions, with the following aligning with the numbering in each of the cross-sections:

- Figure 16-91 and Figure 16-93:
  - The hydraulic gradient is relatively steeply dipping (laterally) towards Tooloombah Creek along most of its length (see 'Groundwater Heads and Flow' in this Section for more detail). This gradient drives local groundwater flow toward and discharge to Tooloombah Creek and possibly Styx River
  - Field observations (Table 16-83) show large or continuous pools occur along Tooloombah Creek that appear to be sustained throughout dry periods (up to 53 days without rainfall), likely indicating continuous access to groundwater
  - All Tooloombah Creek surface water samples (To1, To2, To3) show a groundwater influence, i.e. plot similarly on Na / Cl vs Cl ratio plots to nearby dry season groundwaters sampled from WMP06 and WMP12 (refer Figure 16-96)
- Figure 16-91, Figure 16-92, and Figure 16-95:
  - The hydraulic gradient is relatively steeply dipping (laterally) towards lower reaches of Deep Creek and possibly less so toward Styx River downstream of the confluence (particularly between slack water and low tide). This gradient drives local groundwater flow towards, and discharges to Deep Creek and possibly Styx River
- Figure 16-91 and Figure 16-92:
  - Water samples collected at Styx River (St1, St2) show seasonal variation in water chemistry - at times showing possible estuarine water influence and, following periods of high rainfall and / or streamflow, evidence of dilution and stronger stream water / rainwater influence. The water chemistry data strongly indicate the dominant source of water in the Styx River is from the estuary (tidal) or from runoff, and a strong groundwater signature is not evident although groundwater contours (Figure 16-81) suggest groundwater discharges to the river
- Figure 16-92:
  - The hydraulic gradient is relatively flat in the mid to upper reaches of Deep Creek. Table 16-83 shows the pools in the upper reaches of Deep Creek (e.g. De1, De2, De3) persisted through the 2017 dry season but dried out in the 2018 dry season, indicating an intermittent supply of water (including groundwater; see 'Groundwater Heads and Flow' in this Section for more detail)
  - In the mid and upper reaches of Deep Creek (De1, De2, De3, De4), surface water shows a similar signature to rainfall, more so than groundwater sourced from the Styx Coal Measures (see 'Groundwater Chemistry' in this Section for more detail)
  - Measured hydraulic heads for the dry season (at WMP11/WMP11D) indicate an upwards hydraulic gradient within the Styx Coal Measures (HSU2) as discussed in 'Groundwater Heads and Flow' (in this Section) which suggests that HSU1 may receive inflow from HSU2 at least when rainfall and streamflow recharge is not occurring. The upward groundwater head / pressure beneath the streambed possibly 'holds up' the pools during the dry season, particularly along Tooloombah Creek

- Figure 16-92 and Figure 16-95:
  - In the downstream reach of Deep Creek (De5), the hydraulic gradient toward the stream is steeper and dry season surface water samples show a similarity to nearby groundwater (WMP05) (refer Figure 16-97). In addition, this pool persisted through the 2018 dry season, indicating that groundwater may be a source of water to sustain the pool
- Figure 16-91 to Figure 16-95 (inclusive):
  - Following the wet season and either during or following stream flow events, all surface water samples show a reduced groundwater influence and a stronger rainfall signature (refer Stiff patterns presented in 'Groundwater Chemistry' in this Section)
  - Tooloombah Creek and the lower reaches of Deep Creek have thick stands of riparian vegetation (see Section 16.11.2), as well as algae and aquatic vegetation in Tooloombah Creek pools and in Styx River (see Table 16-83), indicating permanence of water availability (soil water, surface water or groundwater, or a combination of two or more of these sources)
  - In both creeks, field observations (see Table 16-83) indicate that pools tend to be turbid in the wet season (due to sediment load and erosion) and less turbid in the dry season (potentially due to sediment load settling, groundwater discharges, which is filtered, or both). Additionally, the less turbid pools could be a result of the high salinity (from groundwater inflow and concentration) causing suspended clays to flocculate and settle. Generally, the pools of Tooloombah Creek are less turbid than Deep Creek, which might be the result of less access by stock or relatively more interaction with groundwater (see Section 16.11.2.2)
- Figure 16-91, Figure 16-92 and Figure 16-94:
  - Measured hydraulic heads (corrected for density variations related to salinity) near both creeks (at WMP04/WMP04D and WMP08/WMP08D) indicate an upward vertical hydraulic gradient in both the wet and dry seasons from Styx Coal Measures (HSU2) to Alluvium (HSU1), as discussed in 'Groundwater Heads and Flow' (in this Section)
  - WMP13 groundwater quality consistently plots similarly to seawater / estuary on Stiff patterns but with an apparent streamflow or groundwater Ca signature, suggesting mixing of different water sources at this location (see 'Hydrogeological Properties' in this Section and Figure 16-20)
- Figure 16-95:
  - Steep lateral gradients exist towards typically gaining stream reaches (e.g. lower Deep Creek, Tooloombah Creek and Styx River), although the gradient between the thalwegs is relatively flat, suggesting a concentration of groundwater discharge to surface water further north of this cross-section
- Figure 16-93:
  - The water table is elevated in the central parts of the Project area and a hydraulic gradient between these areas and the creeks drives groundwater discharge toward the creeks

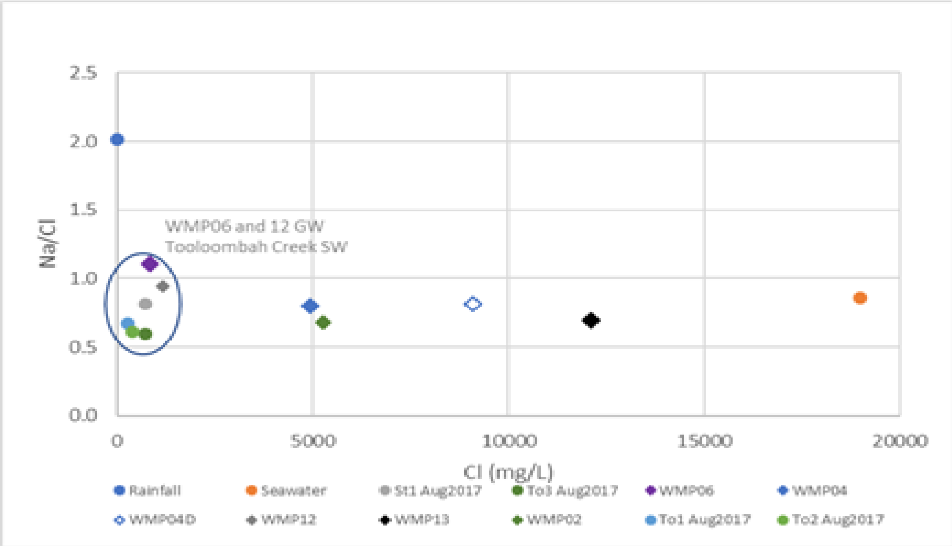

Figure 16-96 Tooloombah Creek Na/Cl vs Cl ratio plot – August 2017 surface water sampling event

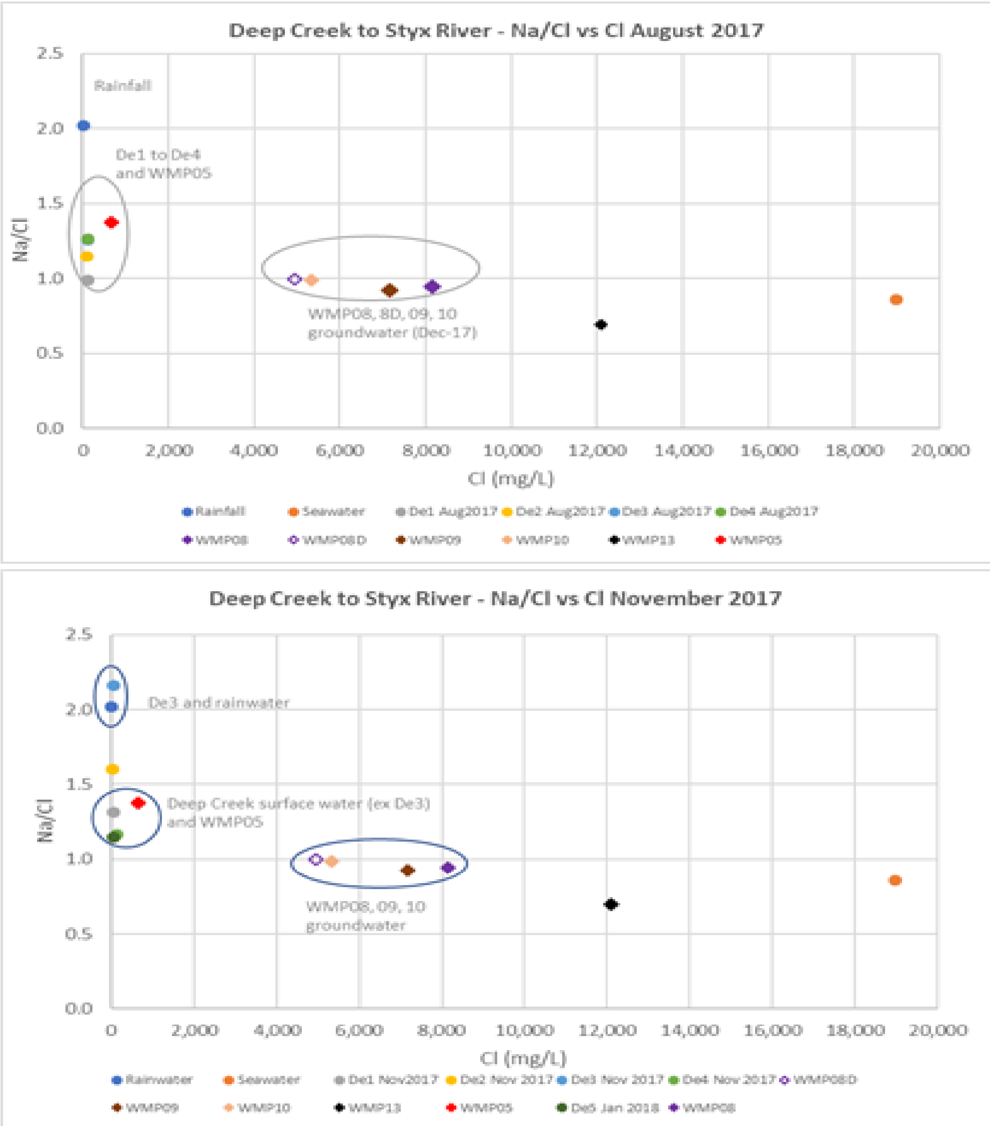

Figure 16-97 Deep Creek Na/Cl vs Cl ratio plot – August and November 2017 surface water sampling event

Summary

Analysis of available hydraulic head, topographical and hydrochemical data shows the main sources of water present in Styx River are derived from tidal (estuarine) waters or surface water runoff.

Groundwater baseflow to Styx River, whilst likely occurring, is not significant compared to these other sources. Groundwater interaction with Tooloombah Creek is likely more sustained over the dry season than is the case along Deep Creek.

Ecological reliance on groundwater (either as baseflow or as a shallow water table) is possible toward the northern extents of the Tooloombah and Deep Creek catchments.

Conceptual Hydrogeological Model

The conceptual processes driving interactions between surface water and groundwater in the Styx River catchment are depicted in Figure 16-98. The following provides a general description:

- General;

  The Project area is characterised by local to intermediate groundwater flow systems (i.e. the distance between recharge and discharge zones ranges between less than a few kilometres up to 20 km). Groundwater flow lines presented in Figure 16-81 show groundwater discharges locally to the major tributaries of Styx River (Tooloombah and Deep Creeks), as well as Styx River itself and the Broad Sound estuary. Groundwater discharge is also expected to low lying areas closer to the coast (beyond the confluence of Styx River with the Broad Sound estuary) via evaporation. Significant amounts of groundwater are expected to be lost via evapotranspiration (ET), either directly from the water table or from plant transpiration, across the broader study area

- Losing stream conditions;

  When stream water levels are above the adjacent water table, a hydraulic gradient is generated away from the watercourse, resulting in stream losses to groundwater (i.e. the stream is losing). As well as recharging the water table aquifer, these stream losses potentially replenish storage in the stream banks (bank storage). In disconnected stream reaches, bank storage will drain away to the water table or back to the stream as flood heights decline.

  All watercourses in the tributary Tooloombah and Deep Creek catchments of Styx River are likely to experience losing conditions during and following high streamflow events. Given there is no streamflow gauging in the Styx River catchment, the frequency and magnitude of flows are not known but it is inferred that losing conditions will sometimes occur during and following high intensity rainfall and runoff events from tributary catchments.

  Downstream of the confluence of Tooloombah and Deep Creeks, Styx River will likely be a losing stream during hide tide periods when the river pool level is higher than the adjacent water table.

- Gaining stream conditions;

  Gaining conditions occur in ‘connected’ stream reaches as the stream water levels recede and the hydraulic gradient reverts back towards the stream, i.e. the water table elevation adjacent to the watercourses is higher than the stream height. Once bank storage is depleted, gaining conditions can be sustained where a local groundwater flow system drives flow to the stream, or where shallow water tables are intersected by the streambed (providing a “window to the water table”).

Tooloombah Creek and the lower portion of Deep Creek (downstream of De4; refer Figure 16-22) are likely to be permanently connected to groundwater and receive inputs from a combination of bank storage return following stream flow events and local groundwater flow systems in drier periods. Watercourse pools that persist for long periods after stream flow events are likely maintained by groundwater discharge.

Below the confluence of Tooloombah and Deep Creeks, Styx River is, on average, a nett gaining stream, i.e. even though stream losses to groundwater may occur during high tide periods the overall water balance is dominated by groundwater discharge to the river.

All of the information and conceptualisations presented in this Section provides the basis for developing a conceptual hydrogeological model for the Project area and more broadly. Figure 16-99 presents a schematic of the conceptual model. The following describes the key elements of the model that are important in consideration of the potential effects of mining on the Styx River catchment groundwater resources and connected systems, with the following aligning with the numbering in each schematic.

1. The water table is typically hosted in unconsolidated alluvial deposits (HSU1) and also within fractured and weathered (residual) zones of outcropping and sub-cropping basement rocks (HSU3), and is generally a subdued reflection of topography, with depth to water table typically less than 15 metres below the surface. The water table varies by up to around 3 m seasonally in unconsolidated alluvial deposits (see ‘Groundwater Heads and Flow’ in this Section and Figure 16-81 and Figure 16-82).

2. Regional groundwater flow is generally to the north, towards Styx River and the coast. The head and salinity data for the nested WMP29 monitoring bores (Figure 16-83 and Table 16-81) indicates underflow toward the coast. Locally, within the Tooloombah and Deep Creek tributary catchments of Styx River, groundwater flow within the water table aquifers is generally toward the creeks and more dominantly toward the confluence of the creeks (see Figure 16-81).

3. Diffuse rainfall recharge occurs across the Styx River Basin, with higher rates of recharge expected over those parts of the catchments covered by cleared alluvial sediments (as detailed in ‘Groundwater Recharge and Discharge Mechanisms’ in this Section).

4. Episodic local groundwater recharge (to bank storage and the underlying / adjacent aquifer) occurs from stream losses during large and sustained streamflow events (generally associated with the wet season, see Figure 16-99), as evidenced by the trend in groundwater chemistry towards a rainfall/streamflow signature (see Figure 10-46 in Chapter 10 - Groundwater).

5. Groundwater discharge via evapotranspiration occurs from:

    - capillary fringe, typically occurring along the riparian zone of watercourses but also in terrestrial environments where the water table is sufficiently close to the surface (vegetation with rooting zones that access only the vadose zone deplete the soil water reservoir);
    - watercourse pools where the streambed intersects the water table;
    - bank storage return, following streamflow events (see Figure 16-98); and
    - in lower lying areas below the confluence of Tooloombah and Deep Creeks, particularly below Styx township.

6. Watercourse pools are likely to be supported at least partly by bank storage return following high streamflow periods, combined with shallow water tables along mid- to lower-reaches of Tooloombah Creek, and lower reaches of Deep Creek. The pools may be seasonally (mid-reaches) or permanently (mid- to lower-reaches) connected to the water table (see Table 16-83).

7. The occurrence of Marine Couch is an indicator of the tidally influenced zone of Styx River. Marine Couch has been observed along the river banks to an in-stream elevation of approximately 6.5 m AHD, below the confluence of Tooloombah and Deep creeks (see Figure 16-20). Groundwater discharge occurs to Styx River and the Broad Sound estuary, although at times during high tides this discharge may be interrupted by leakage for these surface water features (see Figure 16-81 and Stiff patterns presented in Chapter 10 - Groundwater).

8. In the central parts of the Tooloombah and Deep Creek catchments, the Styx Coal Measures (HSU2) discharge upwards to the alluvium (HSU1) except for those periods when local groundwater recharge (from streamflows or seasonal diffuse recharge) might reverse the hydraulic gradient (see Figure 16-83).

9. A mixing zone occurs along Styx River and Broad Sound estuary, where groundwater and surface water interact seasonally (rising and falling water tables, stream flow events) and diurnally (due to tidal effects).

10. Little is known about the dynamics of deeper groundwater systems associated with HSU3 and HSU4. However, residual bedrock (HSU3) will likely be important in moving groundwater from the basement rocks to overlying aquifers or to watercourses.

11. The proposed mine will be progressively mined and backfilled, with voids remaining open for up to around three years (this is discussed further in Section 16.11.4). No voids will remain open at the end of the mining and processing operation. The mine pits will be dewatered by dedicated ex-pit dewatering bores or in-pit sumps, or a combination of both.

Figure 16-98 Mechanisms of surface water – groundwater interactions

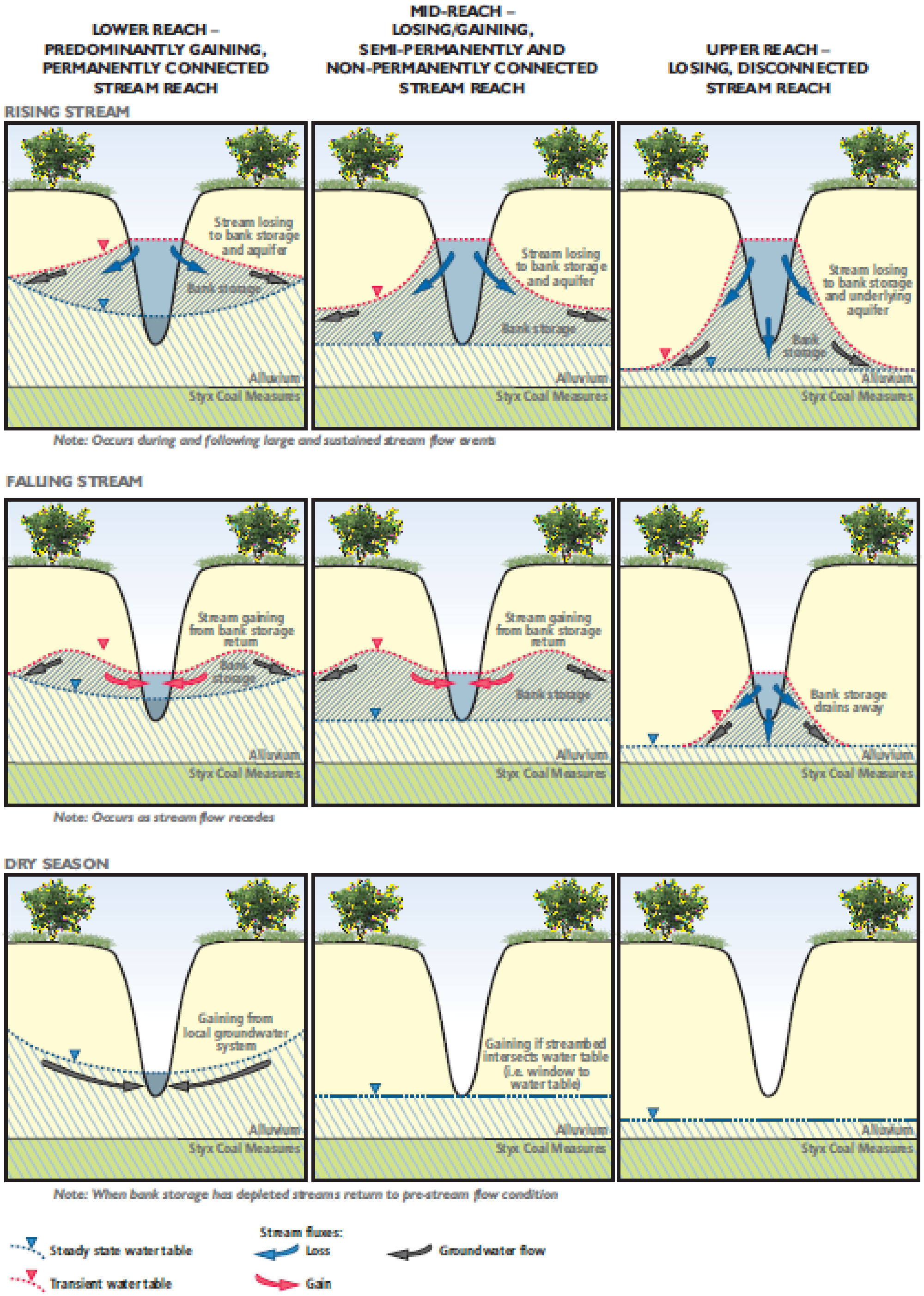

Figure 16-98

Mechanisms of surface water – groundwater interactions

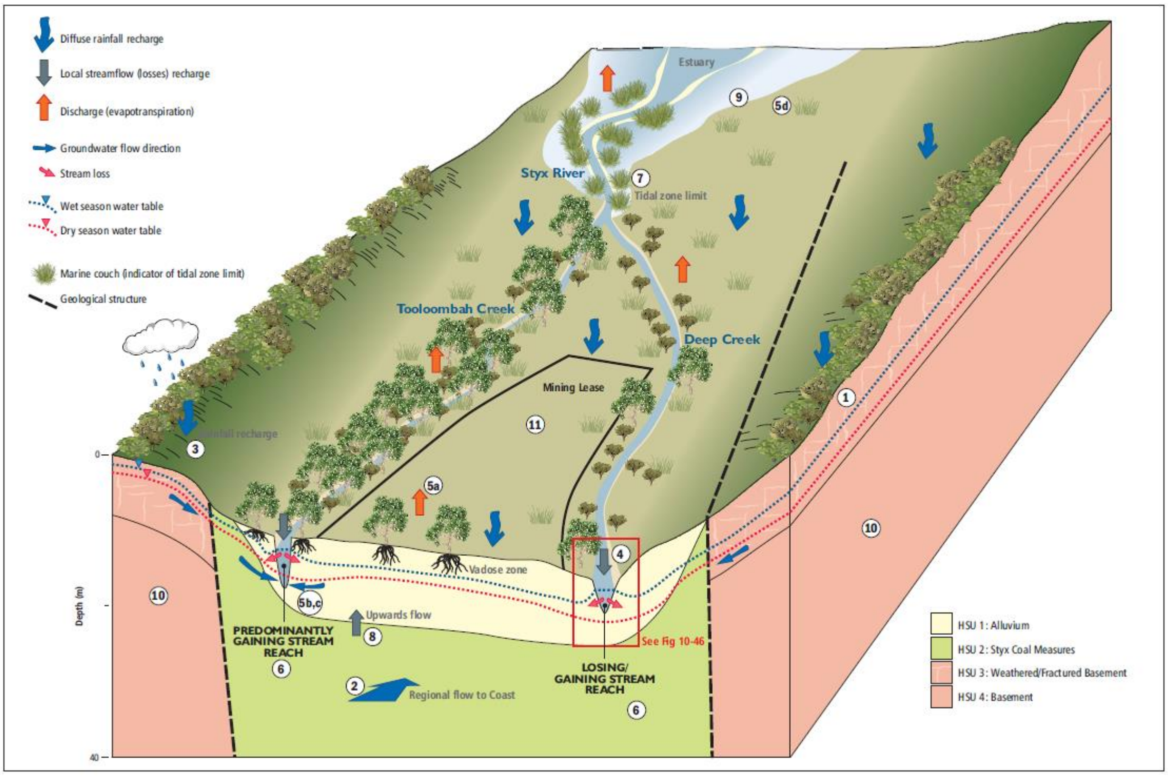

Figure 16-99 Project conceptual hydrogeological model

16.11.2 Potential Sensitive Groundwater Receptors

16.11.2.1 Groundwater Dependent Ecosystems

Figure 16-24 presents rainfall data in a manner that shows the temporal scale over which below average (dry) and above average (wet) rainfall periods. 'Dry' periods are shown to typically occur over decades, whereas 'wet' periods typically occur over just a few years. Vegetation that is found in the study area has physical attributes that allows resilience and resistance to climate variability, such as being able to cope with low soil moisture levels, reduce water loss during dry periods or being able to access groundwater when the soil water reservoir is depleted.

Whilst regional groundwater systems provide water sources for pastoral and other anthropogenic uses, groundwater also supports surface (above ground) and subsurface (below ground) ecosystems that are assessed as beneficial users of groundwater. The Australian GDE toolbox (Richardson et al. 2011) provides a framework to assist with the identification of GDEs and the management of their water requirements. The toolbox adopts the approach of Eamus et al. (2006) by classifying GDEs based on the role groundwater plays in maintaining biodiversity and ecological condition.

Three types of GDEs are defined by the GDE toolbox:

- Subterranean ecosystems dependent on water held in aquifers (e.g. stygofauna) or inundated caves (Type 1 GDEs). These ecosystems typically include karst aquifer systems, sedimentary aquifers and fractured rock groundwater environments;
- Ecosystems dependent on the surface expression of groundwater (Type 2 GDEs), including wetlands, lakes, seeps, springs, and river baseflow systems. In these cases, surface expression of groundwater exists to provide water that can support aquatic biodiversity through access to

habitat (especially when surface run-off is low or non-existent), as well as regulation of water quality and temperature; and

- Ecosystems dependent on subsurface presence of groundwater (Type 3 GDEs), including terrestrial and riparian vegetation that depends on groundwater either seasonally, episodically or permanently to prevent water stress and avoid adverse impacts to their condition. Groundwater that Type 3 GDEs depend on is not visible from the surface. Type 3 GDEs can exist wherever the water table and capillary fringe is within the root zone of the plants, either permanently or episodically. The capillary fringe is the semi-saturated zone of soil above the water table.

There are two sources of information pertaining to the presence of GDEs:

- Queensland Wetland GDE layer providing information regarding Type 2 and 3 GDEs; and
- The National Atlas of GDEs (GDE Atlas) presents the current knowledge of ecosystems that may depend on groundwater across Australia. At the beginning of 2017, the GDE Atlas was updated with the latest information pertaining to GDEs from the Queensland Wetland GDE Layer, and therefore the GDE Atlas can be considered as the primary data source for this assessment.

Information pertaining to Type 1 GDEs is sourced from field surveys undertaken for the Project. Locations sampled for Type 1 GDEs (stygofauna) are shown on Figure 16-100, whilst Figure 16-101 presents the spatial distribution of potential Type 2 and 3 GDEs.

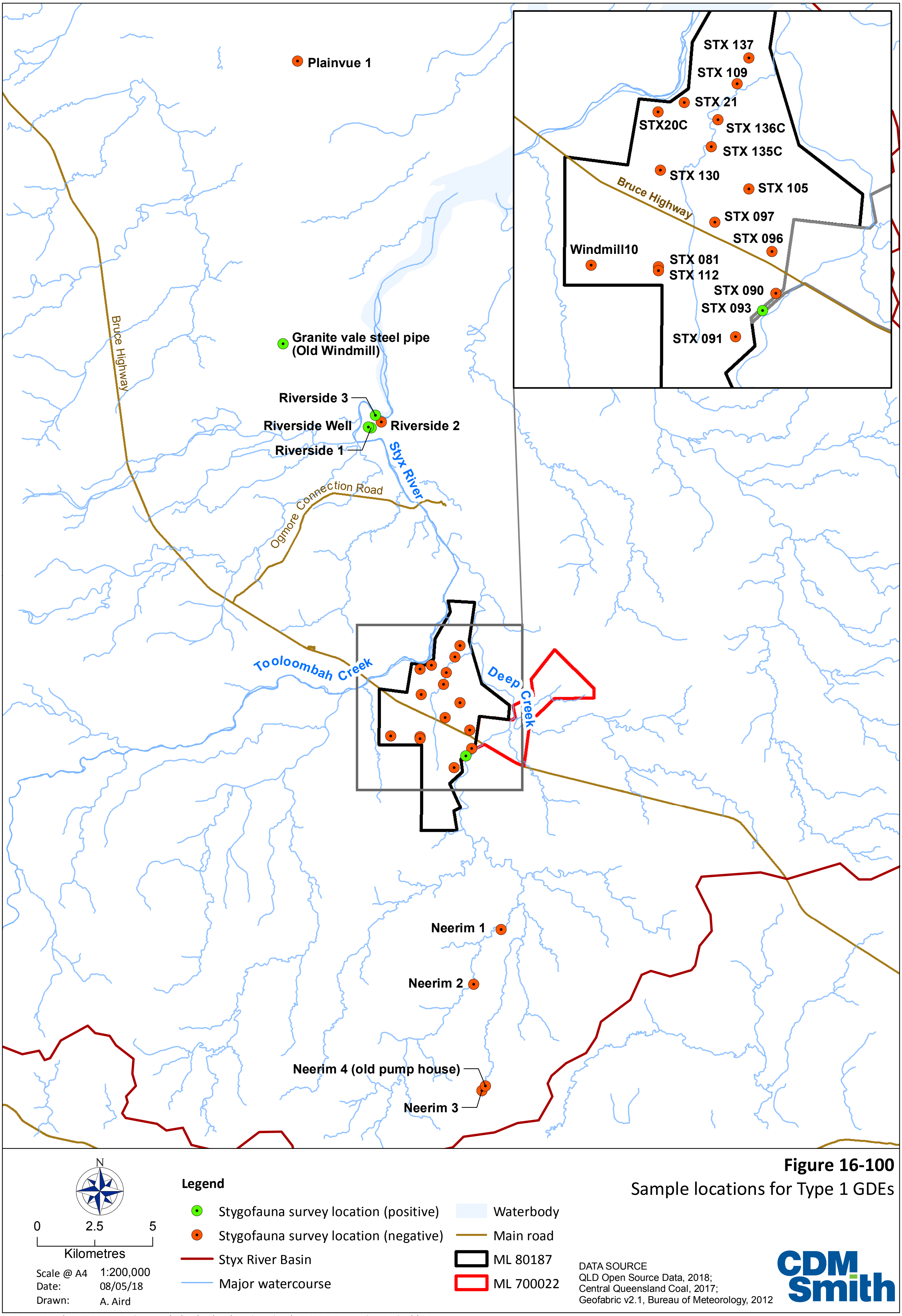

Figure 16-100
Sample locations for Type 1 GDEs

DATA SOURCE
QLD Open Source Data, 2018;
Central Queensland Coal, 2017;
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

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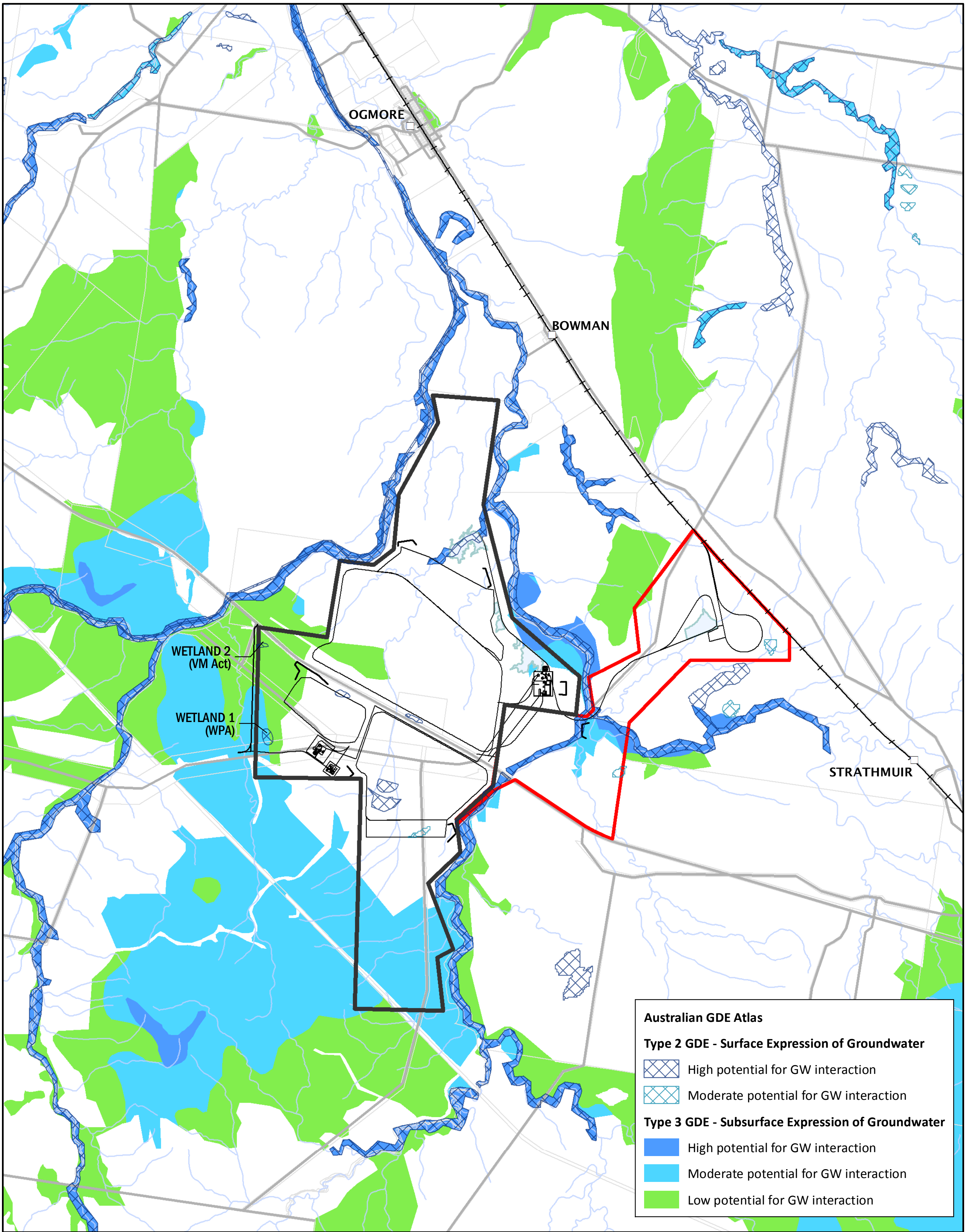

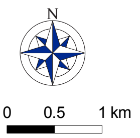

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Date: 01/11/18
Drawn: Gayle B.

Legend

- ML 80187
- ML 700022
- Mine infrastructure
- Cadastral boundary
- Main Road
- North Coast Rail Line
- Watercourse
- Dam

Figure 16-101
Groundwater dependent ecosystems - Australian GDE atlas mapping

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 16_Supp_Report_MNES\1000111 australian GDE mapping__16-23.mxd 11/1/2018

Several ecological field surveys, including recent studies specifically targeting GDEs, have been undertaken for the Project to ground-truth desktop information and identify additional flora and fauna values, and values associated with potential GDEs (refer Section 16.12.2). The surface water and groundwater monitoring network has been expanded by the construction of 16 new bores since the submission of the SEIS (locations shown in Figure 16-79). As the understanding of GDEs develops, it may be necessary to expand or consolidate the network in the future.

Eco-hydrological studies have been carried out to build on the baseline understanding of GDE interactions with groundwater, including stable isotopes of water analyses, water potential measurements and groundwater heads (refer Section 16.12.6.1 for methods; Figure 16-100 for sampling locations).

GDEs Reliant on the Subterranean Water (Type 1)

Information relating to Type 1 GDEs has been sourced from field surveys conducted by Yeats (2012) and ALS Water Sciences, who undertook two seasonal surveys in November 2011 and March 2012. The ALS Water Sciences surveys comprised collection of 21 (2011) and 19 (2012) borewater samples for examination of the presence of stygofauna. Overall, 30 bores within the Project area and surrounds have been assessed for stygofauna presence (see Figure 16-100), including 20 bores established specifically for the Project and 10 landholder bores,

During the field surveys, five sites (STX 093, 'Granite vale steel pipe (Old Windmill)', 'Riverside Well', 'Riverside 1' and 'Riverside 3', as shown in Figure 16-100) recorded the presence of subterranean fauna with four sites recording subsurface species that can be classified as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments. In total, six taxa classified as stygofauna were collected from the five sites - one species belonging to the Order Bathynellacea (Syncarid crustacean), three Families of Oligochaeta (segmented worms), and one species each from the Subclasses Copepoda and Acari.

The results of the two surveys show most of the identified stygofauna communities were recorded in the alluvial aquifer associated with the Styx River more than 8 km downstream of the boundary of the Project area. A single taxon (five individuals) was identified in samples collected from a bore adjacent to the Project boundary (STX093; Figure 16-100). However, it is very unlikely the taxa will be restricted to the sample points where presence has been recorded.

The shallow groundwater levels (i.e. generally less than 20 mbgl) gauged within bores constructed in alluvial sediments within or close to the riparian zone and the taxa present suggests a fine to moderate grained and unconsolidated alluvial aquifer with direct association / connectivity with the river system with an interconnected hyporheic zone (Hancock and Boulton 2008) and fresh to brackish water quality.

The absence of stygofauna from the remaining sampled locations does not indicate stygofauna are not present in the aquifers sampled. However, absence of stygofauna can be attributed to a number of factors, e.g. unsuitable geological conditions (low porosity, low hydraulic conductivity), poor water quality (e.g. high EC or presence of other toxicants) or sampling from a recently drilled bore that has yet to stabilise and attract stygofauna (reduced likelihood of collection).

GDEs Reliant on the Surface Expression of Groundwater (Type 2)

The GDE Atlas identifies potential GDEs that are reliant on the surface expression of groundwater (Type 2 GDEs) along extensive reaches of watercourses, both within and marginal to the Project area (i.e. Styx River, Tooloombah Creek and Deep Creek) as well as several small isolated areas away from riparian zones (Figure 16-101), including:

- Two wetlands which are also identified under Queensland vegetation mapping:
  - 'wetland 1' (UFI 3797128), identified as an artificial/highly modified wetland reliant on surface expression of groundwater and
  - 'wetland 2' (UFI3797178) identified as a coastal/sub-coastal floodplain swamp reliant on surface expression of groundwater
- Other artificially created water reservoirs (Figure 16-101).

Most of these potential Type 2 GDEs are classified as having high potential for interaction with groundwater including Wetland 1 and Wetland 2. However, the water table at these locations is inferred to be around 10 mbgl, so it is unlikely that these features are supported by groundwater entirely.

Watercourse Pools

Field investigations have identified the presence of surface pools along the ephemeral watercourses (Tooloombah and Deep Creeks) that have persisted throughout dry periods (refer Table 16-83 and Section 16.12.6 for details). The observations indicate a potential seasonal reliance of surface expression of groundwater, which is supported by available data (e.g. as presented in Section 10.5.6.7) including:

- Groundwater elevation contours and flow lines which show relatively steep horizontal hydraulic gradients and local groundwater flow along the length of Tooloombah Creek, the down-catchment reach of Deep Creek near the confluence with Tooloombah Creek, and along Styx River (Figure 16-81);
- Water table mapping, which shows depth to water table along riparian zones is typically between 10 and 15 mbgl (Figure 16-82); note that the monitoring bores used to develop the water table mapping are typically installed on ground adjacent to steeply incised creeks meaning the water table beneath the creek beds is shallower than these data suggest). The incised streambeds (to depths of up to around 10 m) likely intersect the water table in places and at different times, e.g. in response to water table fluctuations due to recharge (Figure 10-22 to Figure 10-26 in Chapter 10);
- Measured water levels at nested monitoring bores show upward vertical hydraulic gradients (Figure 16-83), which possibly supports groundwater discharge to the surface and prevents drainage of pools;
- Water chemistry data, which shows similarities between surface waters and nearby groundwaters, indicating that watercourse pools are likely to be sourced at least partly by groundwater;
- Analysis of surface water samples for radon isotopes reported concentrations of ^{222}Rn in Tooloombah Creek pools that are indicative of groundwater discharge. However, reported concentrations of ^{222}Rn at Deep Creek pools indicated low connectivity during the time of sampling (July 2018, dry season). Figure 16-102a plots ^{222}Rn against chloride concentrations and Figure 16-102b plots ^{222}Rn against bicarbonate/chloride ratios:
  - Figure 16-102a indicates groundwater contributes only a limited amount of water to Deep Creek (very low chloride and 222Rn) while Tooloombah Creek possibly receives a comparatively higher amount of groundwater inflow (higher amounts of chloride and 222Rn). The lower 222Rn values encountered at Deep Creek suggest that the pools along Deep Creek have a longer residence time relative to Tooloombah Creek

– Figure 16-102b indicates that groundwater baseflow to some extent contributes to water sampled from pools in both creeks (medium values for the bicarbonate/chloride ratio, see Appendix A6 – Groundwater Technical Report for details) at the time of sampling. The isotope analysis indicates that, overall, both creeks are connected to groundwater to some extent and undergo evaporation.

- Observations of thick stands of potentially groundwater dependent vegetation along riparian zones, as well as algae and aquatic vegetation in areas where pools are permanent, indicating permanence of water that is likely supported by a shallow water table; and
- Observed watercourse pools are broadly consistent with the mapped Type 2 GDEs along riparian zones.

The nature of surface water – groundwater interactions supporting Type 2 (baseflow) GDEs in the area have been classified based on the two typical stream reach types that can be inferred from the available data. These stream reach types are described by the temporal nature of connection and flow dynamics, as outlined in Table 16-84 (see Figure 16-98 for reference). Both stream reach types are interpreted to have a period of losing conditions during high flows but differ according to the degree of sustained connection with groundwater during low / no flow periods.

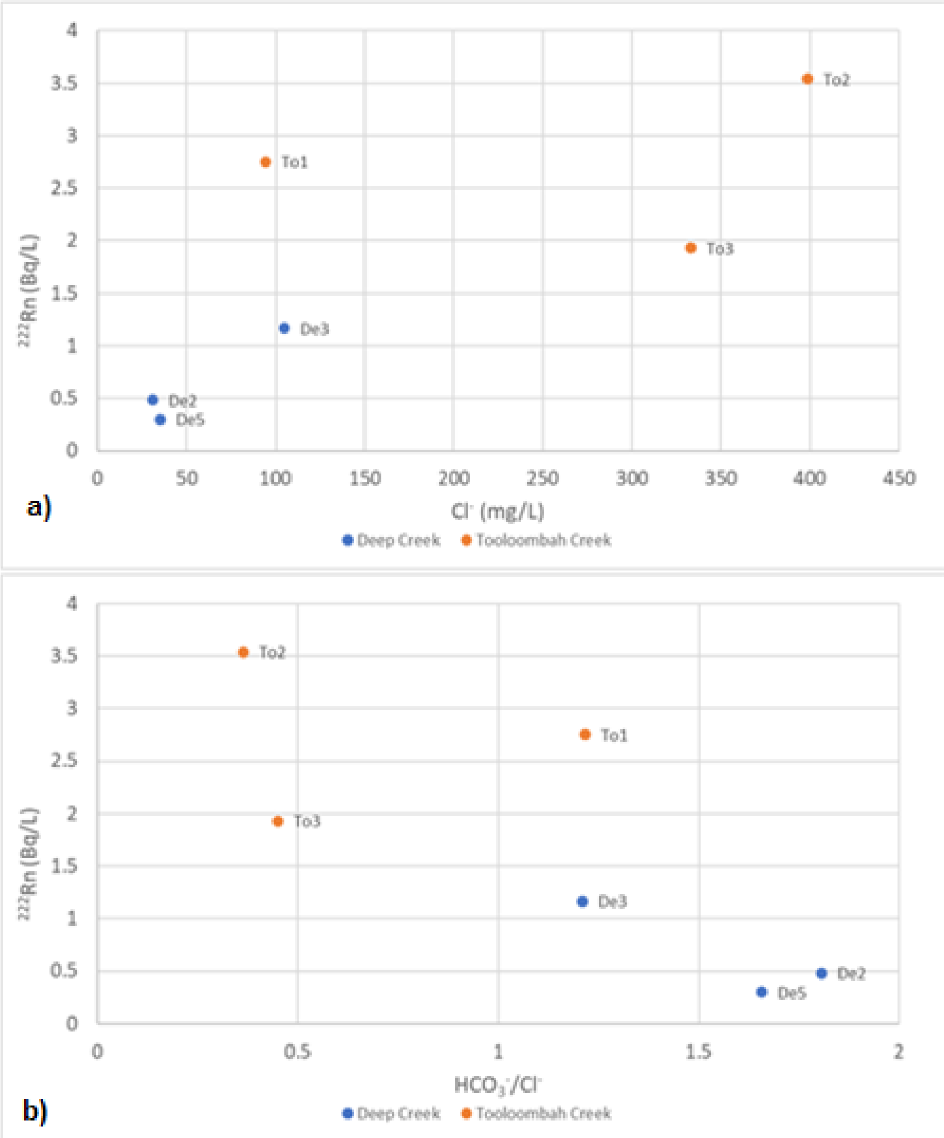


Figure 16-102 Radon vs chloride (a) and radon vs bicarbonate/chloride ratios (b)

Table 16-84 Classification of Type 2 GDEs by stream reach type

Stream reach type	Temporal nature of GDE reliance on groundwater	Streamflow period	Flow dynamics
Typically losing / gaining, seasonally connected to groundwater	Stream flow critically important for meeting environmental water requirements of ecosystem	High flow	Streamflow recharges bank storage and adjacent water table aquifer (i.e. losing conditions)
		Low / no flow	Groundwater baseflow (discharge) to stream from shallow water table and / or bank storage return (i.e. gaining conditions), baseflow may or may not persist between rainfall runoff generated stream flow events
Typically gaining, permanently connected to groundwater	Groundwater baseflow likely to be critically important for meeting environmental water requirements	High flow	Streamflow recharges bank storage (i.e. losing conditions)
		Low / no flow (non-tidal)	Groundwater baseflow (discharge) to stream from shallow water table and / or bank storage return (i.e. gaining conditions), baseflow persists between rainfall runoff generated stream flow events
		Low / no-flow (tidally influenced)	Groundwater discharge can occur during ebb from and flow to high tide, when the hydraulic gradient is towards the stream (i.e. gaining conditions)

Off-stream Wetlands

Wetland 1 and Wetland 2 are formed in shallow depressions of less than around 1 m depth (see Figure 10-50) that become inundated after large rainfall runoff events, as evidenced during two field surveys in early-2017 (see Plate 16-10 and Plate 16-11), which likely serve to maintain the soil water reservoir at these locations.

Based on depth to water table data (see bores WMP25 and WMP27; Figure 16-79 and Figure 16-82), mapped potential Type 2 GDEs located away from riparian zones (i.e. Wetland 1 and Wetland 2) are unlikely to be supported by surface expression of groundwater. Depth to water table at these locations is more than 10 mbgl and observed seasonal variation of the water table is around 3 m (refer Figure 10-22 and Figure 10-23 in Chapter 10). These wetlands are unlikely to interact with groundwater, except as a recharge source for the local aquifer.

Figure 16-103 presents those areas mapped as potential GDEs based on available Project-specific data (i.e. they have been ground-truthed). The presence of Type 2 GDEs is confined to the riparian environments, but not to the identified wetlands (1 and 2; refer Figure 16-101). Type 2 GDEs are likely to have year-round access to groundwater in the lower catchment (i.e. Styx River and lower reach of Deep Creek, near the confluence) and along the mid- to lower-reach of Tooloombah Creek (at least from the confluence up to Bruce Highway). Elsewhere (e.g. middle and upper reaches of Deep Creek), Type 2 GDEs, if present, are likely to only be seasonally connected to groundwater. The dominant source of groundwater supporting Type 2 GDEs in the area is likely to be discharge from the shallow alluvial aquifer, whilst bank storage return after streamflow events will contribute some water back to the watercourses.

Plate 16-10 Wetland 2 prior to Cyclone Debbie (February 2017)

Plate 16-11 Wetland 2 after Cyclone Debbie (May 2017)

GDEs Reliant on the Subsurface Expression of Groundwater (Type 3)

The GDE Atlas identifies potential GDEs that are reliant on the subsurface expression of groundwater (Type 3 GDEs) along the drainage lines (i.e. riparian zones) associated with Styx River, Deep Creek and Tooloombah Creek. Deep Creek and Tooloombah Creek, and areas of low to moderate potential Type 3 GDEs on the southwestern and southeastern margins of the Project area

(Figure 16-101). A number of the vegetation communities mapped in these areas during field surveys (refer Section 16.13.8) have the potential for incorporating some component of groundwater in their water requirements including:

- Forest Red Gum woodland fringing drainage lines (RE 11.3.25):
  - Occur along riparian areas of drainage lines. Vegetation is dominated by Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea Tree (*Melaleuca leucadendra*)
- Forest Red Gum woodland on alluvial plains (RE 11.3.4):
  - Occurs in patches across the eastern side of the Project area where it is associated with the alluvial plains adjacent Deep Creek. Vegetation is dominated by Forest Red Gum, Poplar Gum (*E. platyphylla*) with Carbeen (*Corymbia tessellaris*)
- Broad-leaved Paperbark (*M. viridiflora*) on alluvial plains (RE 11.3.12):
  - This is an isolated community occurring on a natural depression on the western side of the Project area (i.e. wetland 2). The wetland is characterised by a centralised patch of Broad-leaved Paperbark with a ground layer of low sedges and forbs underneath and around the wetland margin. Hydrophytes are present where there is surface water
- Areas of SEVT (RE 11.13.11) along Tooloombah Creek and the downstream portion of Deep Creek.

In riparian areas, the depth to water varies from around 10 m along floodplain terraces (Figure 16-82), to being very shallow in areas adjacent to the watercourses themselves. Vegetation communities in areas of shallow water table are likely to use groundwater during dry periods when the soil water reservoir becomes depleted (i.e. seasonally), but groundwater use is expected to be less where the water table is deeper.

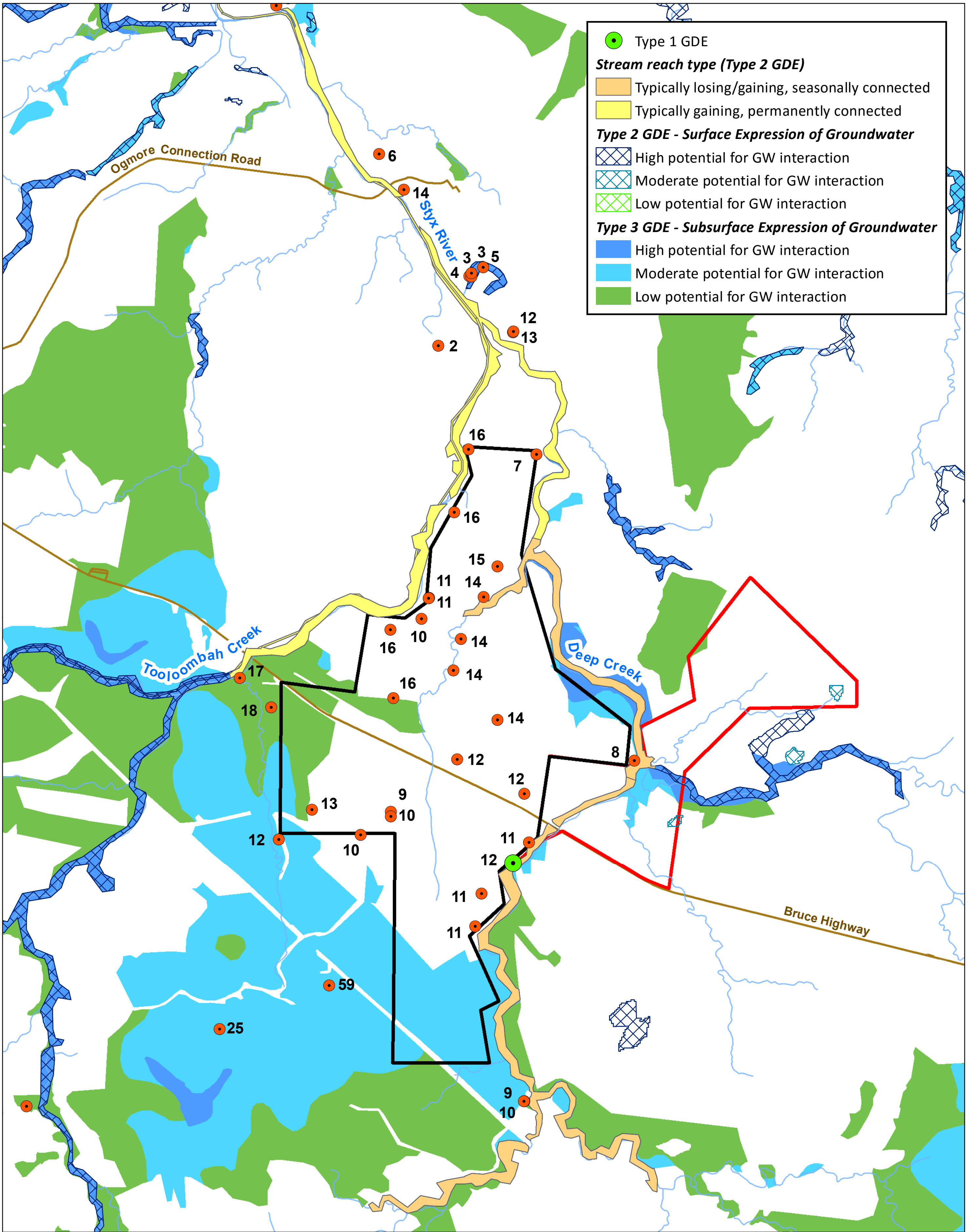
A targeted GDE investigation was carried out in September 2018 in the area of Semi-Evergreen Vine Thicket along Tooloombah Creek, and in the areas of Wetland 1 and 2 to better understand plant water use in these ecological community. The following presents a summary of the findings of the investigations, and Appendix A6 - Groundwater Technical Report presents the details:

- Semi-Evergreen Vine Thicket:
  - Soil and plant material were sampled and analysed to provide stable isotopes of water data, and at the same time measurements were made of soil water and leaf water potentials
  - Groundwater was not encountered during sampling as the water table was beyond the limit of sampling (drilling refusal), which was 10 m
  - The soil and leaf water potentials together with the isotope measurements, strongly indicate a shallow vadose zone (soil water) source of water for the plants sampled, which is well above the water table
- Wetland 1 (Plate 16-10 and Plate 16-11):
  - Soil and plant material were sampled and analysed to provide stable isotopes of water data, and at the same time measurements were made of soil water and leaf water potentials
  - The water table was 10.2 m deep at the time of sampling (bore WMP25)

- Stable isotopes of water data indicate vegetation is sourcing almost all of its water from the near surface (well above the water table)
- Leaf water potentials were equilibrated to a zone of moist soil immediately above the water table (between 8 and 10.2 m deep)

- Wetland 2:
  - Soil and plant material were sampled and analysed to provide stable isotopes of water data, and at the same time measurements were made of soil water and leaf water potentials
  - The water table was 20.5 m deep at the time of sampling (bore WMP27)
  - Both stable isotopes of water data and the water potential measurements indicate no interaction with groundwater, meaning the vegetation is solely supported by the soil water reservoir.

Figure 16-103 presents those areas mapped as potential GDEs based on available Project-specific data (i.e. they have been ground-truthed). The following presents key outcomes arising from the GDE investigations undertaken.



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Kilometres

Scale @ A4 1:80,000
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Legend

- Bore (DTW mbgl)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 16-103
Ground-thruthed GDEs

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\BES170353.01 - Styx Supplementary EIS\GIS\DATA\MXD\FINAL\Groundwater Chapter\BES170353.04_Ground-truthed_GDEs_R4.mxd 8/05/2018

Summary

There is no indication of groundwater use by the riparian Semi-Evergreen Vine Thicket vegetation (RE 11.13.11), with sampled vegetation accessing the soil water reservoir at depths well above the water table measured in this area.

During dry periods, although the results of the study are inconclusive, there is some potential for groundwater to support the Broad-leaved Paperbark trees on Wetland 1 (RE 11.5.3b / UFI 379 7128), Forest Red Gum woodland fringing drainage lines (RE 11.3.25), and Forest Red Gum woodland on alluvial plains (RE 11.3.4), where water tables are less than 10 mbgl.

There is no indication the coastal/sub-coastal floodplain swamp (UFI 379 7178; Wetland 2) and other terrestrial areas are reliant on groundwater, particularly where depths to water table are more than 10 mbgl.

In all instances, the results of the GDE assessment indicates that maintenance of the surface hydrological regime (stream flows and run-off to wetlands) will be critically important for maintenance of environmental water requirements for all identified GDEs.

16.11.2.2 Third Party Groundwater Users

Third party bores have been identified through a search of the GWDBQ as well as a bore census, undertaken by CDM Smith in 2017. Details of third party bores identified are discussed in the following sections.

A search of the GWDBQ (February 2018) identified 447 bores within a 50 km radius of the Project, of which, 118 are within the Styx River Basin (Figure 16-104 and Table 16-85). Of the bores located within the portion of Styx River catchment, 94 (80%) are listed as existing and the remaining 24 (20%) are listed as abandoned and destroyed. DNRME is listed as the owner of 24 bores (20%), and the remainder have unspecified ownership but are likely to be privately owned. Table 16-85 presents statistics sourced from the GWDBQ concerning the purpose of these bores.

Most bores are located within or at the fringes of the mapped Cenozoic deposits (Figure 16-104), which suggests the alluvium and, possibly, geological structure that controls the occurrence and alignment of water courses have been targeted for local groundwater supplies by third-party users.

Table 16-85 Styx River Basin bore purposes

Registered purpose	Count	%age
Stock water supply	105	89
Mineral exploration (incl. coal)	7	6
Water resources investigation	2	2
Sub-artesian monitoring	3	3
Not specified	1	1
	118	**100**

Bore Census

A census of third party groundwater bores within an approximate 10 km radius of the Project was conducted by CDM Smith in February 2017. The census plan included 27 bores, identified from the GWDBQ or previous studies. Of these locations, 20 could be visited and verified, four could not be accessed and three could not be found (expected to be abandoned/destroyed). An additional six bores were identified during the census, which are expected to be unregistered or location details in the GWDBQ inaccurate. Table 16-86 summarises the census results.

Depth to standing water levels were able to be measured at 17 bores and the collection of water samples was possible from eight. The following general observations are made:

- Several bores identified from the GWDBQ were either found in different locations or could not be found;
- Bores that were not in use are generally in poor condition;
- Pumping equipment present within some bores prevented access for measurement of water levels and collection of water samples;
- Bores that were operational are used for stock watering, domestic or industrial / farm use; and
- Bores are constructed to between 6 and 31 m deep, and measured standing water levels are inferred to be representative of the water table elevation.

Table 16-86 Details of third party bores identified during the February 2017 bore census – HSU screened, depth to water and condition assessment

Actual ID	Casing Diameter (m)	Total depth (m bgl)	Inferred HSU	Depth to water (mbgl)	Date	Water Sampled	Condition
BH01X	0.124	10.5	Alluvium	3.80	26-Sep-17	Yes	Poor
BH02X	0.125	13.3	Alluvium	1.90	21-Feb-17	No	Poor
BH03X	0.150	N/A	Alluvium	N/A	21-Feb-17	No	Good
BH04X	0.155	N/A	Basement (Back Creek Group)	N/A	21-Feb-17	No	Good
BH06X	0.140	8.9	Alluvium	6.42	9-Nov-17	Yes	Poor
Well01	0.130	7.6	Alluvium	6.16	23-Feb-17	No	Fair
BH01	N/A	N/A	Basement (Carmila Beds)	N/A	21-Feb-17	No	Poor
BH05X	0.140	10.6	Alluvium	6.41	24-Feb-17	Yes	Fair
BH04	0.125	10.2	Alluvium	6.03	20-Feb-17	No	Poor
BH28	0.125	N/A	Basement (Boomer Form'n)	N/A	21-Jan-17	No	Poor
BH06	0.125	20.5	Basement (Back Creek Group)	8.89	21-Feb-17	No	Fair
BH07	0.160	N/A	Basement (Back Creek Group)	N/A	21-Feb-17	Yes	Good
BH13	0.140	30.8	Basement (Boomer Form'n)	12.61	23-Feb-17	Yes	Poor
BH37	0.140	6.8	Alluvium	Dry	24-Feb-17	No	
BH16	0.147	9.1	Alluvium	3.03	12-Jun-17	Yes	Poor
BH17	N/A	N/A	Basement (Carmila Beds)	N/A	21-Jan-17	No	Fair
BH18	0.140	14.1	Alluvium	5.82	23-Feb-17	No	Poor
BH19	0.140	17.3	Styx Coal Measures	5.26	23-Feb-17	No	Poor
BH20	N/A	N/A	Alluvium	N/A	20-Feb-17	No	Fair
BH21	0.135	14.4	Basement (Back Creek Group)	8.40	21-Feb-17	No	Fair
BH23	N/A	N/A	Basement (Back Creek Group)	N/A	21-Feb-17	No	Poor
BH28A	N/A	N/A	Basement (Boomer Form'n)	N/A	21-Jan-17	No	Fair
BH29	0.140	9.0	Alluvium	2.11	23-Feb-17	Yes	Poor
BH30	0.140	30.0	Styx Coal Measures	4.82	23-Feb-17	No	Poor
BH32	0.130	16.8	Basement (Boomer Form'n)	5.07	23-Feb-17	Yes	Poor
BH35	0.140	11.8	Styx Coal Measures	2.27	23-Feb-17	No	Poor

Notes: Bores that could not be accessed or have been destroyed were not assessed

Water chemistry baseline data for those bores able to be sampled are presented in Appendix A5a and Section 10.5.6.5 in Chapter 10. Only one landholder bore is located on the MLs (BH28A). The well is not currently in use and likely screens the basement aquifer.

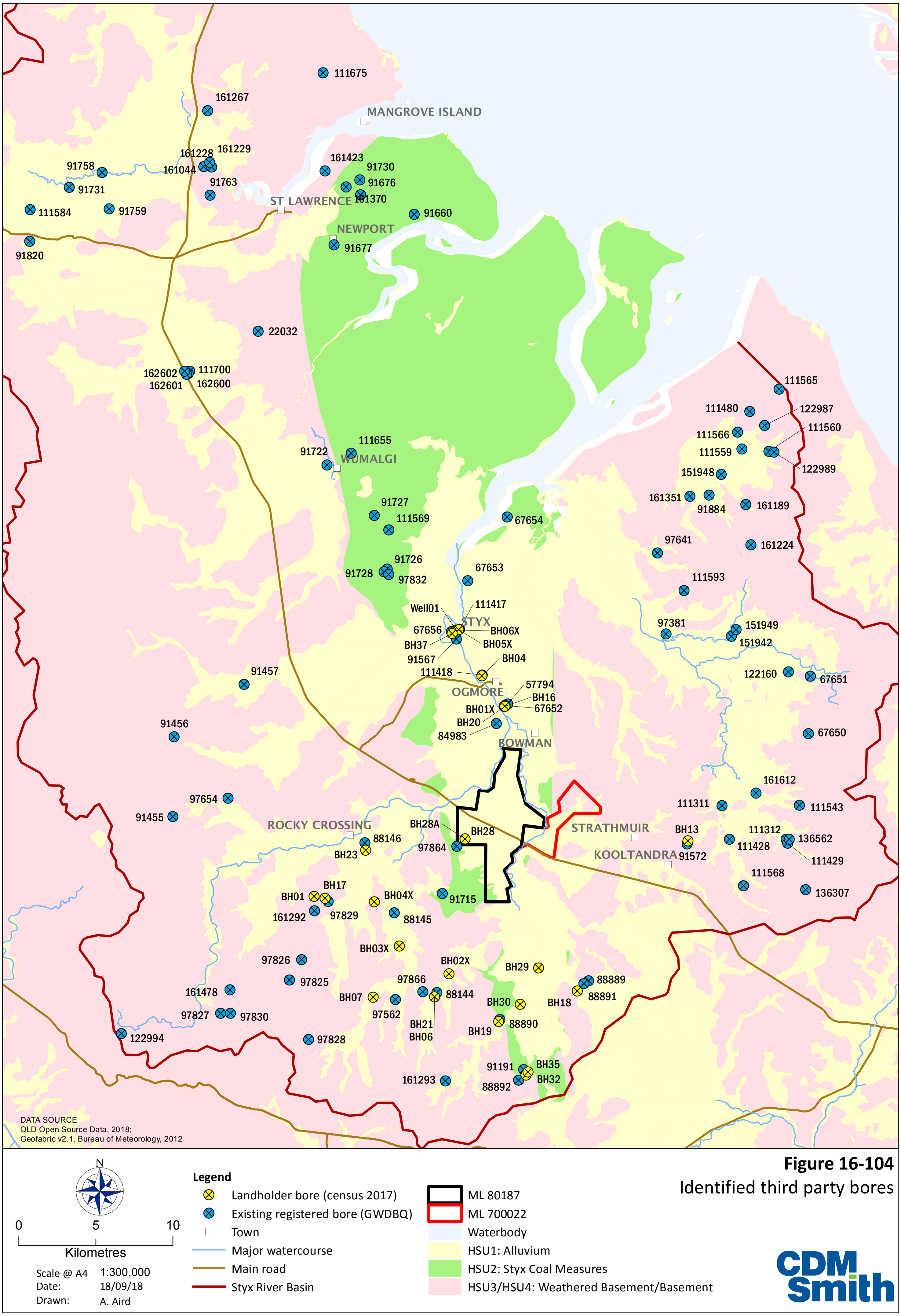


Figure 16-104
Identified third party bores

16.11.3 Impact Assessment

16.11.3.1 Background

The National Water Commission (NWC) mining risk framework (Howe 2011) has been adopted for the groundwater impacts assessment. Figure 16-105 presents the framework, which incorporates seven steps:

- Impact assessment starts with Step 1, which involves setting the context for assessing potential water-related impacts arising from a proposed mining operation (see Section 16.9.1, 16.10.1 and 16.11.1 for details), and Step 2, which involves the setting of management objectives.
- Steps 3 to 4 cover the effects assessment, essentially following a *source-receptor-pathway* analysis that describe how water affecting activities (this Section) might impact on sensitive groundwater receptors (see Sections 16.11.2, 16.11.3.3 and 16.11.3.4). For an effect to occur to a sensitive groundwater receptor an exposure pathway must exist between a mine water affecting activity and a receptor.
- Step 5 brings together the outcomes of Steps 3 and 4 (see Section 16.11.3.4, and Table 16-92 to Table 16-95) to identify threats posed to receptors identified as being at risk from mine water affecting activities (where an exposure pathway exists between the water affecting activity and sensitive receptors). Threat assessment is central to the typical environmental approvals process (Moran et al. 2010), serving to assess the actual consequences arising from mine water affecting activities - not just in terms of direct effects (altered water resource condition) but more importantly in terms of possible receptor response (such as loss of biodiversity or reduced water access for other users and engagement with stakeholders).
- Step 6 (risk characterisation) involves making an informed decision as to the potential for adverse effects to arise to sensitive groundwater receptors as a result of mine development, and is where the task of communicating risk management strategies to stakeholders commences. The nature of water resources, in particular groundwater, does not always lend complete certainty to risk characterisation in regard to understanding the way the system works and how it will respond to mine water affecting activities.
- Monitoring activities that are supported by data evaluation and analysis (Step 7) is a fundamental component of any impact assessment process, i.e. the assessment of risk posed to sensitive groundwater receptors is ongoing during mining and for some time after closure. If necessary, based on the monitoring and evaluation program, it may be that management objectives need to change or the effects assessment needs to be revisited during the life of the mine (see Section 16.10.7).

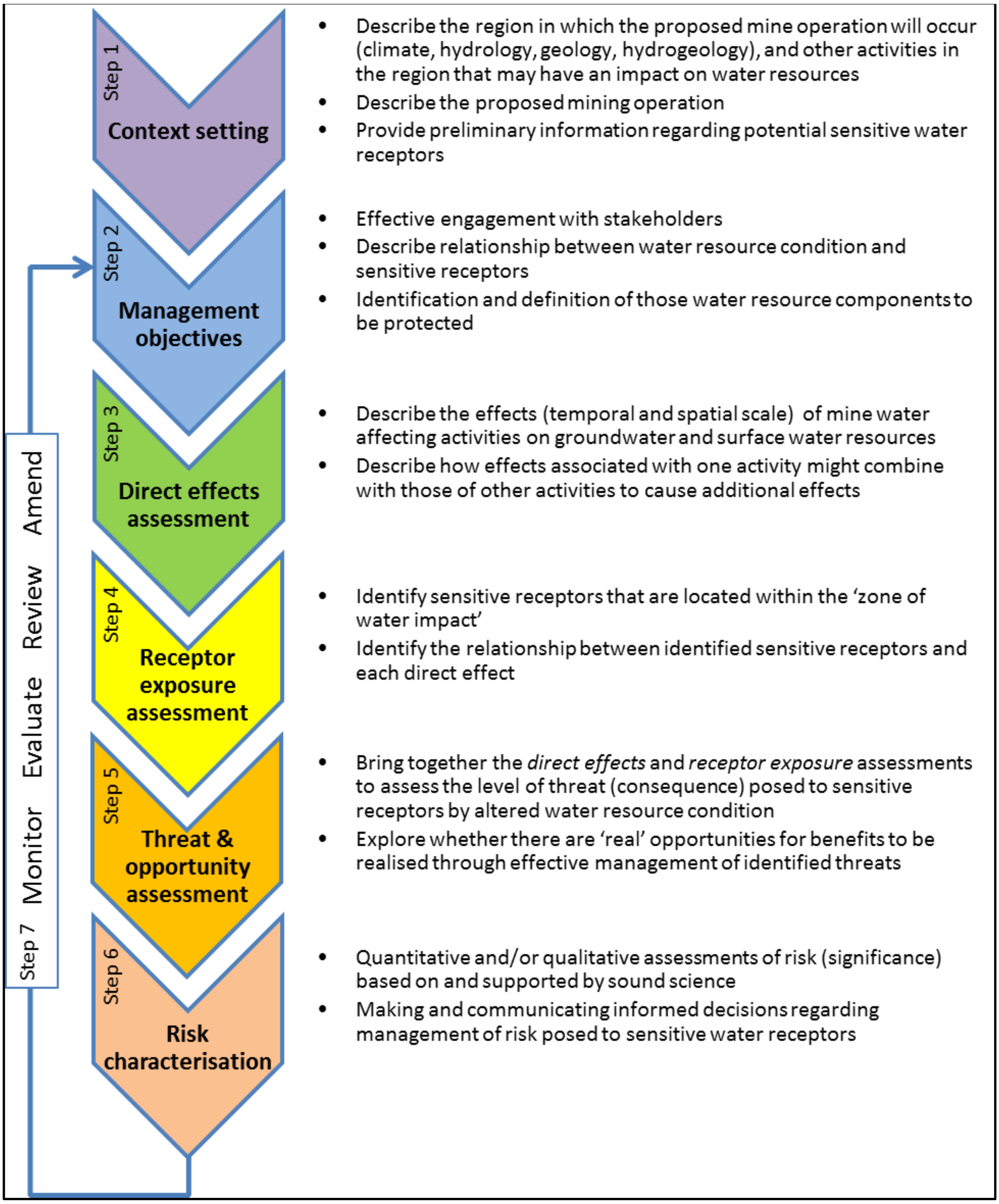


Figure 16-105 Flowchart for assessing the effects of mining on water resources
(adapted from Moran et al. 2010)

16.11.3.2 Direct Effects of Mining on Groundwater

The NWC framework defines the following four direct groundwater effects arising from mining:

- altered groundwater quantity;
- altered groundwater quality;
- altered surface water – groundwater interaction; and
- physical disruption of aquifers.

Direct effects encompass the changes to physical and/or quality aspects of groundwater as a consequence of mining activities, or the changes to the physical characteristics of aquifers affected by mining activities. Examples include changes in water levels, changes in groundwater chemistry or changes in hydraulic properties of aquifers (Moran et al., 2010).

Table 16-87 presents a brief description of water affecting activities (hazards) typically associated with a mining project and how they might arise - the entries rely on descriptions provided by deliverables for the NWC *Framework for assessing local and cumulative effects of mining on groundwater and connected systems* (Howe, 2011) and the Dept. of Energy / CSIRO / Geoscience Australia *Bioregional assessments* (Ford et al. 2016). Further description of the hazards, specifically in relation to the Project, is provided below. Table 16-88 presents summary details of the key mine water affecting activities (hazards) associated with the Project.

Table 16-87 Possible direct effects and key mine water affecting activities (hazards)[1]

Direct effect	Water affecting activity / hazard	Direct effect	Present for Styx Project
Quantity	▪ Mine dewatering ▪ Groundwater supply development ▪ Open pit post-closure ▪ Stockpiling & waste storages ▪ Water storages ▪ Backfilling ▪ Containment and pipeline failure	▪ Depletion of groundwater storage, depressurisation of HSUs[2] (resulting in inter-HSU water transfer, mobilisation of seawater-freshwater interface) ▪ Depletion of groundwater storage, interconnection between aquifers ▪ Evaporative losses from open voids, depletion of groundwater storage ▪ Perched water tables, seepage, altered hydraulic properties ▪ Seepage, water table draw up ▪ Altered hydraulic properties (backfill materials) ▪ Short-term recharge enhancement	▪ Yes, full recovery after mining due to backfilling of pits ▪ No ▪ No, backfilling of pits takes place as mining advances ▪ Yes, but limited due to backfilling of pits ▪ Yes, low potential as close to mine pits ▪ Yes, likely to have similar hydraulic properties to in-situ materials ▪ Potentially, will rely on sound engineering design and management practises
Quality	▪ Mine dewatering ▪ Mine dewatering, HSU depressurisation ▪ Mine waste management ▪ Equipment & containment failure ▪ Open pits during mining and post-closure ▪ Interconnection of aquifers by poor well completion	▪ Mobilisation of salts from poorer water quality stores (aquifers, aquitards, surface water), ASS exposure ▪ Mobilisation of 'seawater-freshwater' interface ▪ Leaching of solutes and potential AMD ▪ Short-term source of potential contaminants ▪ Evaporative concentration of salts within mine voids ▪ Mobilisation of salts from poorer water quality stores (aquifers, aquitards, surface water)	▪ Yes, limited potential for ASS, all HSUs (except alluvial) typically saline ▪ Yes, interface likely occurs east of Styx River and Broad Sound confluence ▪ Yes, restricted potential for AMD ▪ Potential, will rely on sound engineering design and management practices ▪ Limited, during mining limited due to dewatering and after due to backfilling as mining advances ▪ Yes, limited potential as bore completions undertaken in accordance with National Guidelines
Groundwater – surface water interaction	▪ Mine dewatering ▪ Groundwater supply development ▪ Water storages ▪ Mine waste management ▪ Disruption / diversion of surface drainages	▪ Depletion of storage, reduction of baseflow ▪ Depletion of storage, reduction of baseflow ▪ Recharge and water table rise, higher baseflow ▪ Hydraulic loading, water table rise, higher baseflow ▪ Altered recharge mechanisms, water table rise/fall (depending)	▪ Yes, full recovery after mining due to backfilling ▪ No ▪ Yes, low potential as close to mine pits ▪ Yes, but limited due to backfilling ▪ No, no diversions proposed

Table 16-88 Summary details – mine water affecting activities

Water affecting activity	Description [1]
Mine pits and dewatering	▪ All groundwater inflow reporting to active areas of pits will be collected in sumps and pumped from the pits for use in mine water circuit or released to the environment if water in excess of mine requirements exists ▪ No voids present at mine closure and no ongoing dewatering due to evaporative losses, allowing groundwater heads to recover back toward the pre-mine condition
Pit backfill	▪ Simulated backfill hydraulic properties may or may not be consistent with compacted materials ▪ Groundwater recovery in backfilled materials occurs as mining progresses, limited by ongoing dewatering of pits as they open
Water storages	▪ Storages operated for life of mine only ▪ The storages are not planned to be lined and so will leak at a rate determined by permeability of storage bed materials and hydraulic gradient between storage and underlying aquifer
Waste Rock Stockpile	▪ Waste Rock Stockpile could be a source of water recharge to the underlying groundwater system during and following mining ▪ Recharge rates determined by permeability of waste materials ▪ Hydraulic loading of underlying aquifer could reduce transmissivity of alluvium, a post-mine issue following recovery of groundwater system

Notes: 1. For details see Appendix A6 – Groundwater Technical Report

Groundwater Quantity

Potential for inter-HSU transfers of water

Water affecting activities – mine dewatering and depressurisation

Open cut mining will extend below the water table within the proposed mine lease. As overburden sediments and coal seams below the water table are removed, groundwater will seep into the mine void from the intersected saturated strata. Collection of this water to facilitate dry and safe mining conditions, either via ex-pit dewatering bores or in-pit sumps, will depress groundwater heads immediately surrounding the pit to the approximate elevation of the pit floor and a cone of depression (groundwater drawdown / depressurisation) will extend outwards from the pit void within the surrounding HSUs, decreasing in magnitude with increasing distance from the pit void. The zone of depressurisation represents depletion of groundwater storage (unconfined and confined). The degree to which inter-HSU (aquifer and aquitard) transfers of groundwater will depend substantially on K and hydraulic gradients.

Once backfilling commences and active dewatering ceases, groundwater storage (and groundwater heads) will commence recovery back toward the pre-mine condition.

Potential for raised water tables

Water affecting activities – mine waste management, water storages

Water storages (dams) have the potential to seep water to the underlying water table aquifer. In addition, rainfall infiltration to waste landforms has the potential to give rise to perched water tables within the landforms (depending on K of the different materials) and subsequent seepage to the underlying water table aquifer. This seepage may result in raised water table surfaces beneath the facilities. However, development of drawdown local to the mine pits will reduce the potential for significant water table rise.

The waste storages also have the potential to hydraulically load the water table aquifer (predominantly the alluvials, HSU1), which may reduce the K and Sy of this aquifer. In the event this occurs, the water table may 'bank up' upstream of the facilities and water table aquifer groundwater flowpaths may diverge from the baseline.

Backfilling of the mine fits has the potential for differing hydraulic properties between the backfill and in-situ (pre-mine) materials. This has the potential to contribute to water table rise, but the offset of possible higher K by higher Sy will likely mitigate this.

Potential for mobilisation of the seawater – fresh water interface

Water affecting activities – mine dewatering and depressurisation

Groundwater flowlines within the deeper Styx Basin sediments and basement rocks are also expected beneath the shallower groundwater system, with discharge occurring near to the coast or via ET from low lying coastal areas. Vertical hydraulic gradients near to Broad Sound (Figure 16-83) show the deep coal seams and interburden as well as the underburden have a higher head than the shallow Styx River alluvials, indicating the potential for upward leakage and deeper throughflow toward the coast. The head in the deeper units of the Coal Measures HSU would need to decline by around 1.5 m in response to mine dewatering to induce downward seepage of more saline shallower alluvial groundwaters to the Coal Measures.

Potential for accidental release / containment failure

Water affecting activities –water storages / pipelines

Water storages (dams) and water transfer pipelines have the potential to fail and provide temporary potential for local recharge enhancement. However, development of drawdown local to the mine pits will reduce the potential for significant water table rise in response to accidental release and containment failure.

Appropriate engineering design and management practices (including audits, stock takes and training) will be important in removing or mitigating these risks.

Groundwater Quality

Potential for groundwater quality degradation

Water affecting activities – mine dewatering and depressurisation, evaporative losses from open mine pits, installation of monitoring wells

Mine dewatering will result in altered vertical and lateral hydraulic gradients within and between HSUs, which may have the effect of inducing flow of water of different quality (groundwater and surface water) towards depressurised parts of the groundwater system.

Dewatering of the alluvial aquifer (HSU1) and the Coal Measures' (HSU2) overburden and coal seams / interburden is required for mining to proceed. As such, evaporative loss of water from the pits will have limited potential to result in the evaporative concentration of salts in groundwater. Backfilling of the pits as mining progresses will also give rise to limited potential for salinisation of groundwater due to evaporative concentration of salts.

The installation of monitoring bores requires the isolation of screened intervals from other parts of the groundwater system using the placement of cement grout within the well annulus immediately above the screened lithology. Construction of monitoring bores in accordance with best industry practice (NUDLC, 2012) will mitigate the potential for inter-aquifer/aquitard transfer of waters of different quality due to poor bore construction methodologies.

Potential for ASS

Water affecting activities – mine dewatering

The Styx River catchment, including Tooloombah and Deep Creeks, is classified as largely having low to extremely low probability of ASS generation potential (see Section 10.5.6.5), with only a small pocket of high probability of ASS occurrence around 7 km downstream of the Project, near Broad Sound.

Potential for inland mobilisation of the seawater-freshwater interface

Water affecting activities – mine dewatering and depressurisation of HSUs

Hydraulic head and groundwater salinity data for the WMP29 nested monitoring site (Figure 16-83 and Table 16-81) indicate the 'seawater-freshwater' interface is not located near the confluence of Styx River and the Broad Sound estuary, and must be located further toward the coast (i.e. further from the proposed mine). The potential for mobilisation of the 'seawater-freshwater' interface at the coast, or along tidal reaches of Styx River and Broad Sound estuary, will depend on extent of depressurisation (vertical and lateral) of groundwater system in response to mine dewatering.

Potential for acidic metalliferous drainage (AMD)

As summarised in Section 16.7.3.6 (detailed in Chapter 8 – Waste Rock and Rejects) waste rock characterisation has been undertaken for the Project by RGS Environmental (2012). Waste rock and fine rejects were classified as:

- Acid consuming:
  - Will likely remain pH neutral to alkaline following excavation (composite waste rock and potential coal reject samples are alkaline, with pH ranging from 8.6 to 10)
  - Dissolution of heavy metals in an acidic environment is unlikely
- Having low potential to be potentially acid forming;
- Having moderate saline drainage potential (salinity of the samples ranged from 440 to 660 µS/cm, falling within baseline range; see 'Groundwater Chemistry' in Section 16.11.1.2); and
- Potential to be highly sodic.

Based on works to date, the waste rock and coarse/ fine rejects generated during the extraction and processing of the resource have limited potential to impact upon the EVs.

Without appropriate management, there is the potential for leachate from extracted waste rock and fine rejects to enter local waterways and degrade water quality. Although the waste rock is expected to have a low capacity to generate acidity, it does have moderate saline drainage potential (although salinity concentrations are expected at the low end of the baseline range) and the kinetic leach column results indicate that leachate may contain elevated concentrations of dissolved As, Mo, Se and V when compared to WQO and aquatic ecosystem criteria. The leachate derived from the kinetic leach study generally shows an initial flush of soluble metals / metalloids and salts which decreased after the first two to three flushes. This initial flush is likely related to the particle size; the fine materials with smaller particle size have a larger surface area for chemical reactions to occur and thus tend to yield higher leached metals / metalloids and salt concentrations. The kinetic leach study, although a short-term study, indicates a reduction in leached concentrations of most species with time. The study indicates the release of As, Mo, Se and V are not controlled by pyrite oxidation, which is indicated by the steady decline in leached concentrations.

In summary, leach testing demonstrates there is low potential for generation of acid from waste materials (including coal rejects), and that leachate generated from waste materials is expected to be less saline than baseline surface water and groundwater. However, there is the potential for some metals / metalloids (such as As, Mo, Se and V) to be elevated above aquatic ecosystem criteria (e.g. ANZECC 2000) although many metals / metalloids occur naturally above these criteria.

Accidental release / equipment failure / containment failure

Water affecting activities – mine waste management

As with any industrial activity, the risk of accidental release of chemicals or mine impacted waters and materials (such as unintended fuel spill, leakage of sewage effluent, infiltration of stormwater from mine 'contact' areas, failure of water storage dams) will be present on the ML 80187 and ML 700022. Appropriate engineering design and management practices (including audits, stock takes and training) will be important in removing or mitigating these risks.

Surface Water and Groundwater Interaction

Potential for reduced water tables

Water affecting activities – mine dewatering and depressurisation

The Project area is characterised by local to intermediate groundwater flow systems (see 'Conceptual Hydrogeological Model' in Section 16.11.1.2). Groundwater flow lines presented in Figure 16-81 show that groundwater likely discharges locally (as baseflow) to the mid-lower reaches of the major tributaries of Styx River (Tooloombah and Deep Creeks), as well as Styx River itself and the Broad Sound estuary.

Mine dewatering and depressurisation will give rise to local depletion of groundwater storage, resulting in lower water tables especially near to the proposed mine. As a consequence it is expected in some areas close to watercourses water table decline will result in reduced baseflow to the watercourses during mining and for some time after mining is completed. A detailed water balance model examining the potential extent of impacts on waterholes in Tooloombah Creek and Deep Creek due to the Project is located in Section 4 of Appendix A6.

Groundwater often discharges as baseflow to surface water features (streams and wetlands), and via evapotranspiration when the water table surface lies close to the ground surface, often in low parts of the landscape such as wetlands and along riparian zones. Discharge to surface water features and connected systems forms the basis of the assessment of impacts associated with groundwater and surface water interactions. Impacts associated with receptors reliant on shallow water tables are addressed as part of groundwater quantity.

The capture of groundwater during mining (to meet Project water demands, where this is necessary, and provide dry and safe mining conditions) can alter the degree and form of interaction between groundwater and surface water, and connected systems. For example:

- If baseflow fed water courses are located within the zone of drawdown influence of mine pits or borefields, it is probable the rate and timing of baseflow will diminish or cease until post-mine recovery occurs;
- If wetlands relying on shallow water tables or surface expression of groundwater are located within the zone of drawdown influence of mine pits or borefields, the wetlands may become disconnected from groundwater until post-mine recovery occurs;
- Water storages and environmental dams may leak and cause water table mounding beneath the facilities, which may raise water tables near wetlands and terrestrial vegetation to cause water logging, or increase rates of baseflow to nearby water courses; and
- Placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers or mounding of the water table beneath the facilities, which can give rise to displacement of water away from waste rock stockpiles, potentially increasing baseflow discharge to watercourses and wetlands.

Potential for seepage between above ground infrastructure and groundwater

Water affecting activities – mine waste management, water storages

Water storages (dams) have the potential to seep water to the underlying water table aquifer. In addition, rainfall infiltration to waste landforms has the potential to give rise to perched water tables within the landforms (depending on K of the different materials) and subsequent seepage to the underlying water table aquifer. This seepage may result in raised water table surfaces beneath the facilities. However, development of drawdown local to the mine pits will reduce the potential for significant water table rise.

These effects do not impact on existing surface water features. In terms of long-term effects, the waste management facilities (e.g. waste landforms) can provide an ongoing source of enhanced recharge but at a very local scale, and depending on landform closure works.

Potential for altered recharge regimes

Water affecting activities – Disruption and diversion of surface drainages

The only disruptions planned for sub-catchments occur within the mine pit footprint, via excavation of the pits and construction of water storage dams. There are no other plans to alter other sub-catchments. As a result, any effect on spatial recharge regimes will only be very local.

Physical Disruption of Aquifers

Potential for long-term disruption of groundwater system

Water affecting activities – mining (excavation), backfilling

Open cut mining involves removal and translocation of coal, overburden and interburden strata to create mine-pit voids. Disruption of the groundwater system by mining will only be temporary for this Project as all voids will be progressively backfilled and rehabilitated. The hydraulic properties of the backfilled materials may not be consistent with those occurring prior to mine depending on the degree of compaction, but this change is unlikely to be significant as the effect is restricted to the mine voids themselves.

Potential for long-term disruption of groundwater system

Water affecting activities – hydraulic loading

Placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers, in particular, which can give rise to compaction and reduction in transmissivity and storage capacity of these aquifers (where they occur) possibly resulting in displacement of groundwater away from waste rock stockpiles and potentially increasing baseflow discharge to watercourses and wetlands. This effect, if it occurs, will only become apparent once the groundwater system recovers post-mining.

16.11.3.3 Indirect Effects of Mining on Groundwater

Indirect effects of mine-water affecting activities are those that arise in response to direct effects (Moran et al., 2010) and typically relate to the potential for impact on sensitive receptors. The assessment of potential receptor exposure to adverse changes in the groundwater regime (quantity, quality, groundwater and surface water interactions and physical disruption of aquifers) requires the following:

- Knowledge of the position of sensitive receptors within the landscape, particularly in relation to the location and area of influence of mine water affecting activities;
- An understanding of response pathways (connections) between groundwater and potential receptors, in other words the form of receptor reliance on groundwater (e.g. depth to water table, groundwater flux to baseflow fed streams, groundwater quality to meet beneficial purposes);
- An understanding of the capacity for receptors to adapt to altered groundwater regimes (resilience and resistance); and

- An understanding of the spatial and temporal scale of direct groundwater effects at the location of sensitive receptors.

EVs that have been identified for the Project area provide a basis for assessing receptors that may be sensitive to altered groundwater resource condition (i.e. direct effects). Table 16-89 presents a summary of direct effects against relevant EVs, existence of an exposure pathway, and possible scale of effect.

Table 16-89 Linkage between direct effects and EVs

Direct effect	EVs that can be impacted	Potential effect
Quantity	▪ Aquatic ecosystems	▪ Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream (potentially extending as far as estuary) Potential sensitive receptors associated with Project area includes: ▪ Baseflow-fed stream reaches of Tooloombah and Deep Creeks, incl. permanent and semi-permanent pools ▪ Baseflow-fed stream reaches of Styx River and Broad Sound estuary ▪ Coastal marine ecosystems
	▪ Irrigation	▪ Potential reduction in pumping rates due to deeper pumping water levels as a result of drawdown ▪ Potential failure of bores if drawdowns exceed aquifer thickness or screen sections
	▪ Farm supply	
	▪ Stock supply	
	▪ Cultural / spiritual	▪ Largely associated with 'aquatic ecosystems EV'
Quality	▪ Aquatic ecosystems	▪ Limited in association with evaporative salinisation as mine voids will be open for short periods (around three years) prior to backfilling ▪ Limited in association with AMD due to coal measures being typically NAF ▪ Potential impact to estuarine ecosystems if ASS is allowed to become exposed due to altered groundwater flow conditions and drawdown
	▪ Irrigation	
	▪ Farm supply	
	▪ Stock supply	
	▪ Cultural / spiritual	
Groundwater – surface water interaction	▪ Aquatic ecosystems	▪ Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream ▪ Possible significant effect to estuarine and marine (aquatic) ecosystems if surface water discharges from Styx River catchment due to substantial baseflow reduction (combined with reduced stormwater discharge) is sustained in the mid- to long-term
	▪ Irrigation	▪ None (and no sensitive receptors identified in area)
	▪ Farm supply	▪ None (and no sensitive receptors identified in area)
	▪ Stock supply	▪ None (possibly 105 bores within Styx Basin)
	▪ Cultural / spiritual	▪ Largely associated with 'aquatic ecosystems EV'
Aquifer disruption	▪ Aquatic ecosystems	Limited to the mine pits. Potential sensitive receptors associated with Project area includes: ▪ Tooloombah and Deep Creeks riparian vegetation ▪ Terrestrial vegetationj outside riparian zones ▪ Stygofauna
	▪ Irrigation	▪ Limited as there are no bores within the mine pit area
	▪ Farm supply	
	▪ Stock supply	
	▪ Cultural / spiritual	▪ Limited

16.11.3.4 Assessment of Effects

Numerical Model for Effects Assessment

Mine water affecting activities give rise to direct groundwater effects which in turn have the potential to give rise to indirect groundwater (receptor) effects. Groundwater modelling is the only practical way to simulate and predict groundwater system response to mine water affecting activities associated with the Project. In this assessment, the primary objectives of groundwater modelling are to predict potential rates of mine dewatering, to facilitate planning for operational mine water management, and to predict associated effects on groundwater quantity (drawdown and flux) at the Project and surrounding areas during and after mining.

The industry standard model code MODFLOW USG (Panday et al, 2013) has been used to simulate the groundwater system and groundwater affecting activities associated with the Project. Pre- and post-processing of model files has been undertaken using Groundwater Vistas (ESI 2011). Details of the numerical groundwater modelling are provided as Appendix A6 – Groundwater Technical Report, including guidelines, calibration, prediction, sensitivity and uncertainty analysis, model confidence and model limitations.

The hydrogeological conceptualisation presented in Section 16.11.1.2 is represented by the numerical model.

The water affecting activities simulated by the groundwater model include pit excavation / dewatering and pit backfill (Figure 16-10 presents a mine layout plan for the Project). The groundwater model has also been used to simulate possible management strategies to offset unacceptable effects of water affecting activities, and this is discussed further in Section 16.11.4. Table 16-88 presents summary details of the water affecting activities that have the potential to give rise to the direct effects presented in Table 16-87.

The numerical groundwater flow modelling does not directly address the issue of potential groundwater quality change in response to mining. However, model predictions of groundwater quantity change (drawdown / depressurisation) provide a basis from which to assess the potential for changes to water quality associated with the primary water affecting activities (see Table 16-87) to impact on catchment scale groundwater and surface water resources, including the potential for inland mobilisation of the 'seawater-freshwater' interface.

Calibrated Hydraulic Properties

The calibrated hydraulic parameters for each of the simulated HSUs are summarised in Table 16-90, along with the geometric mean value of field measured Ks. Appendix A6 – Groundwater Technical Report presents details of the model calibration process.

Table 16-90 Field measured and adopted (calibrated) hydraulic properties for the Styx groundwater model

HSU	K (m/d)		Sy	S	Recharge (mm/yr)		
	Measured [1]	Modelled	Modelled		Alluvium	Flood zone	Basement
Alluvium	$6.3x10^{-1}$	$4.1x10^{0}$	$1x10^{-2}$	$5x10^{-6}$	4.5	15	3
Styx Coal Measures							
Overburden	$2.0x10^{-2}$	$2.0x10^{-2}$	$5x10^{-3}$	$5x10^{-6}$			
Coal seams/interburden	$2.3x10^{-3}$	$3.0x10^{-3}$					
Underburden	$5.4x10^{-3}$	$4.0x10^{-3}$					
Weathered Basement	$4.2x10^{-2}$	$1.0x10^{0}$	$5x10^{-3}$	$5x10^{-6}$			
Basement	n/a	$4.0x10^{-4}$					

Notes: 1. Geometric mean or average, depending on number of available data points (see Table 16-77). Basement not tested.

The model mass balance is smaller than 0.002%, which demonstrates the model is numerically stable and accurate.

Groundwater Heads

The following presents a summary of predictive results of the calibrated groundwater model. The model incorporates the proposed mining schedule and mine plan that has been provided by Central Queensland Coal (Figure 16-14). Model predicted pre-mine, during mining and post-mine groundwater level and drawdown data are presented in part in Figure 16-10 to Figure 16-109. The full range of modelled scenarios is presented in Appendix A6 – Groundwater Technical Report (Figure 3-19 to Figure 3-36). The following provides discussion around the changes predicted for the water table surface and shallow groundwater flow directions depicted in Figure 16-106 to Figure 16-109 (refer Figure 3-19 to Figure 3-25 in Appendix A6) in response to mining activities:

- The predicted pre-mine water table elevation contours are a reasonable representation of the inferred water table elevation contours presented in Figure 16-81;
- Between mining year 5 and end of mining (year 18) pit dewatering is predicted to capture groundwater from within the proposed lease area and to some extent from the mid- to lower catchment areas of Tooloombah and Deep Creeks. Away from the proposed mine lease area, water table elevation contours are predicted to remain consistent the pre-mine condition;
- During the early recovery phase, the year 10 post-mining water table elevation contours are predicted to remain much the same as the end of mining contours, but by year 25 post-mining the effects of recovery can begin to be seen. During the post-mining recovery phase, water table elevation contours outside the proposed mine lease area are predicted to remain relatively consistent with the pre-mine condition; and
- At all times during the simulated mining and recovery phases the water table contours downstream of the Tooloombah and Deep Creek confluence remain very consistent with the pre-mine condition, indicating the water affecting activities of the proposed mine will not impact on groundwater quantity or groundwater-surface water interactions below the confluence (groundwater quality downstream of the confluence is predicted to remain consistent with pre-mine conditions, by default).

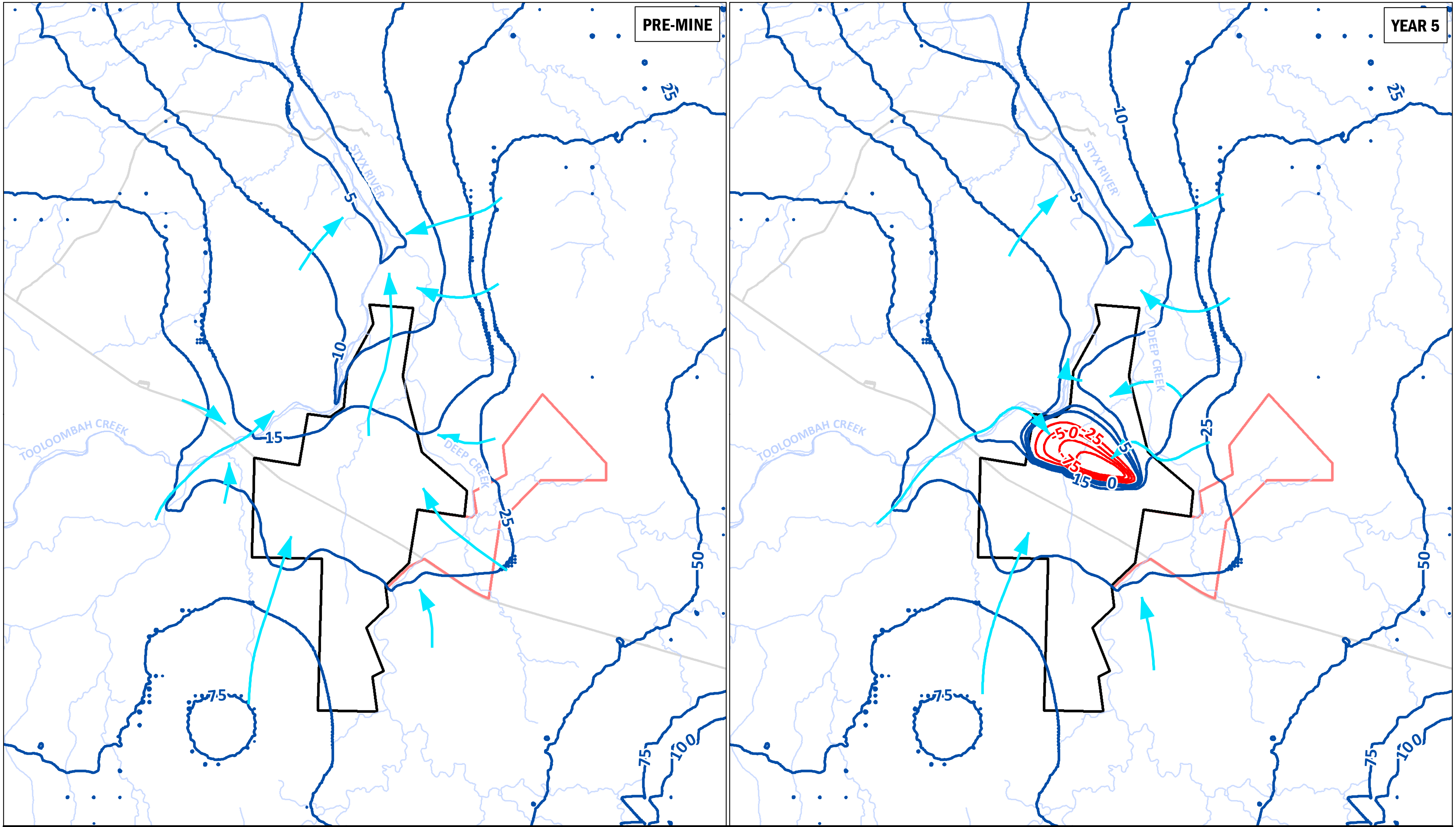


Figure 16-106

Predicted water table elevation contours – pre-mine and year 5

Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

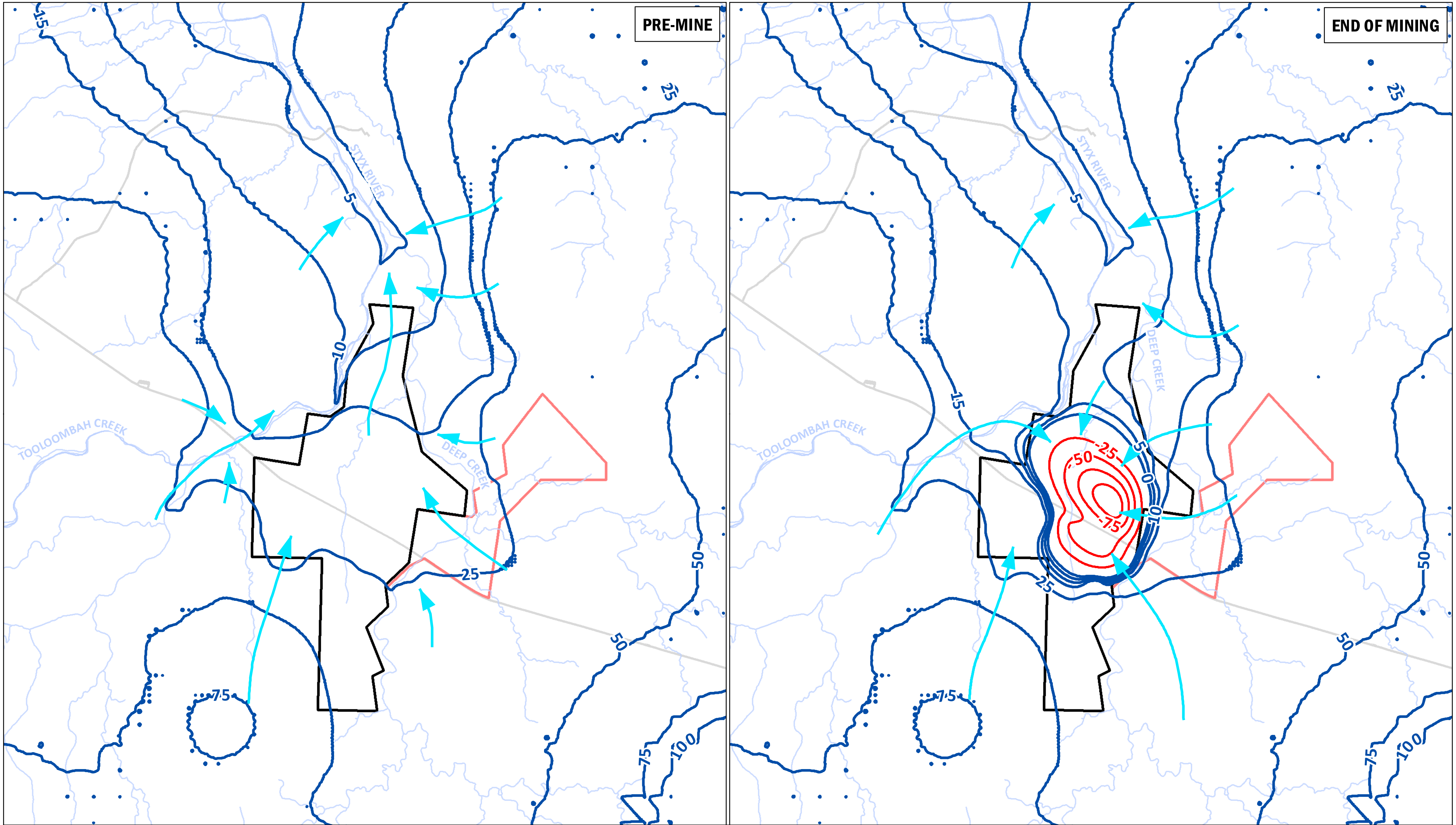
0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__LOM yr 5.mxd 12/20/2018



Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

N

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

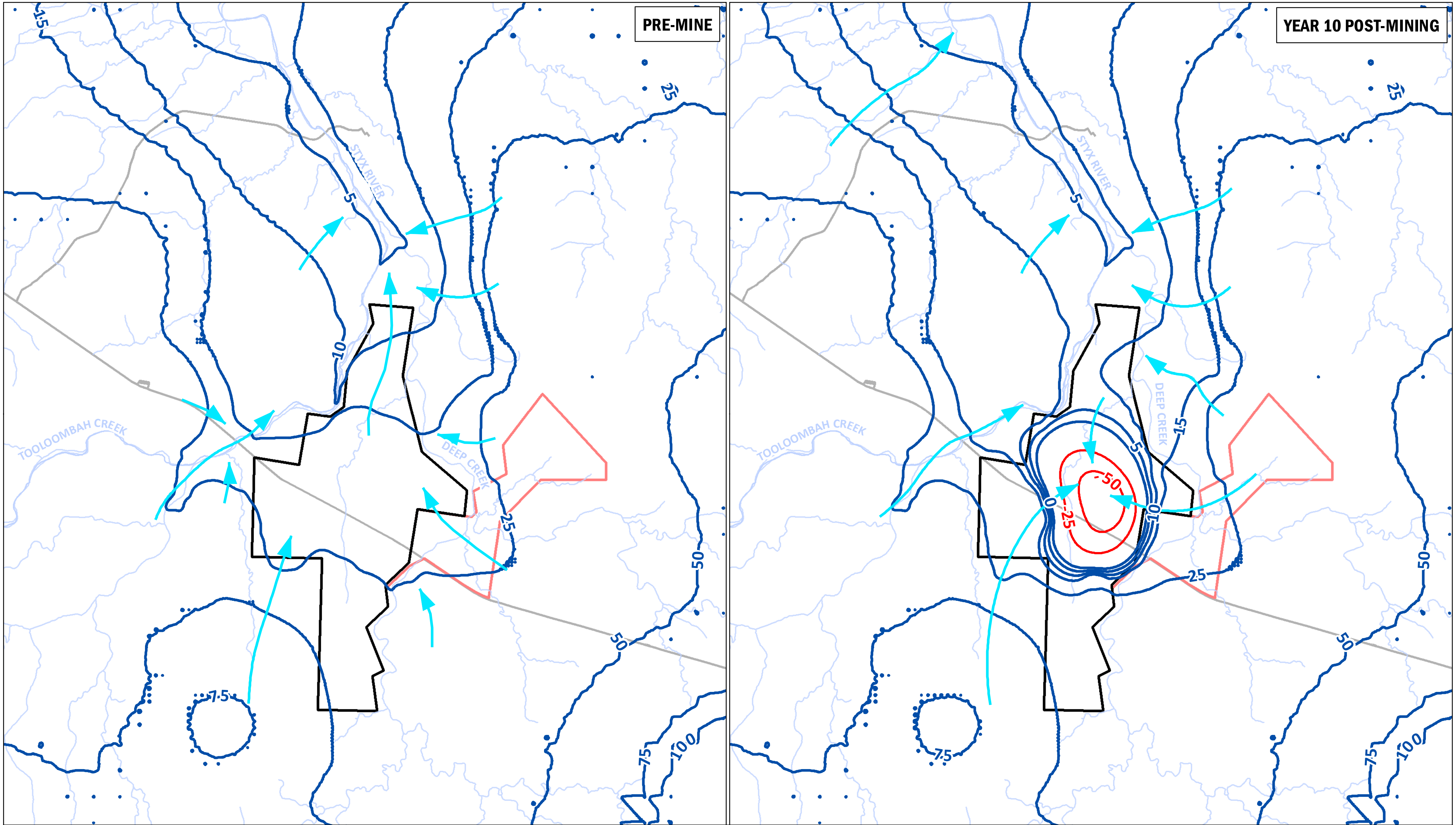
Figure 16-107

Predicted water table elevation contours – pre-mine and end of mining

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__LOM yr 18.mxd 12/20/2018



Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

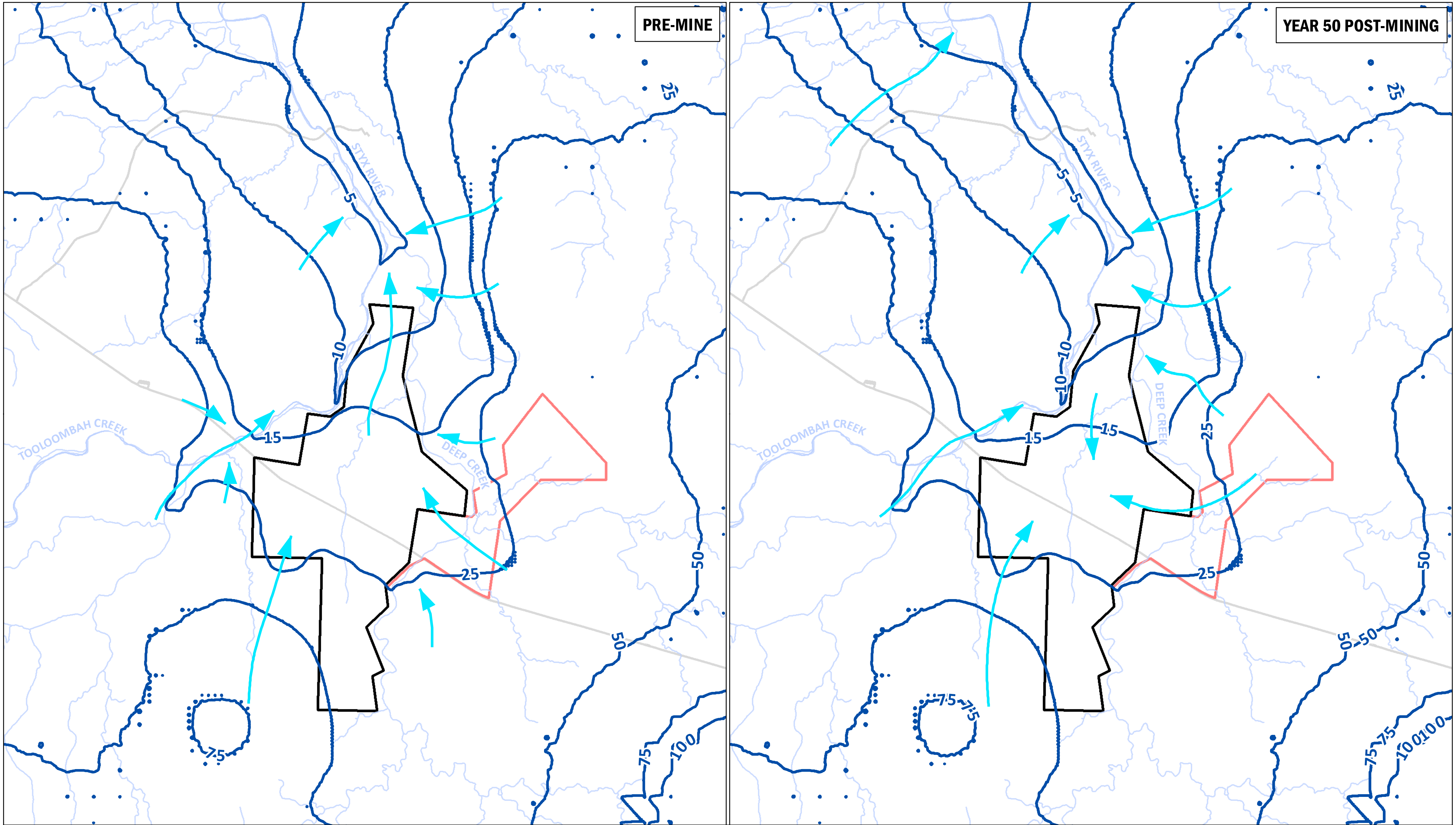
Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Figure 16-108
Predicted water table elevation contours – pre-mine and year 10 post-mining

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__10yrs post-mining.mxd 12/20/2018



Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Figure 16-109
Predicted water table elevation contours – pre-mine and year 50 post-mining

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__50yrs post-mining.mxd 12/20/2018

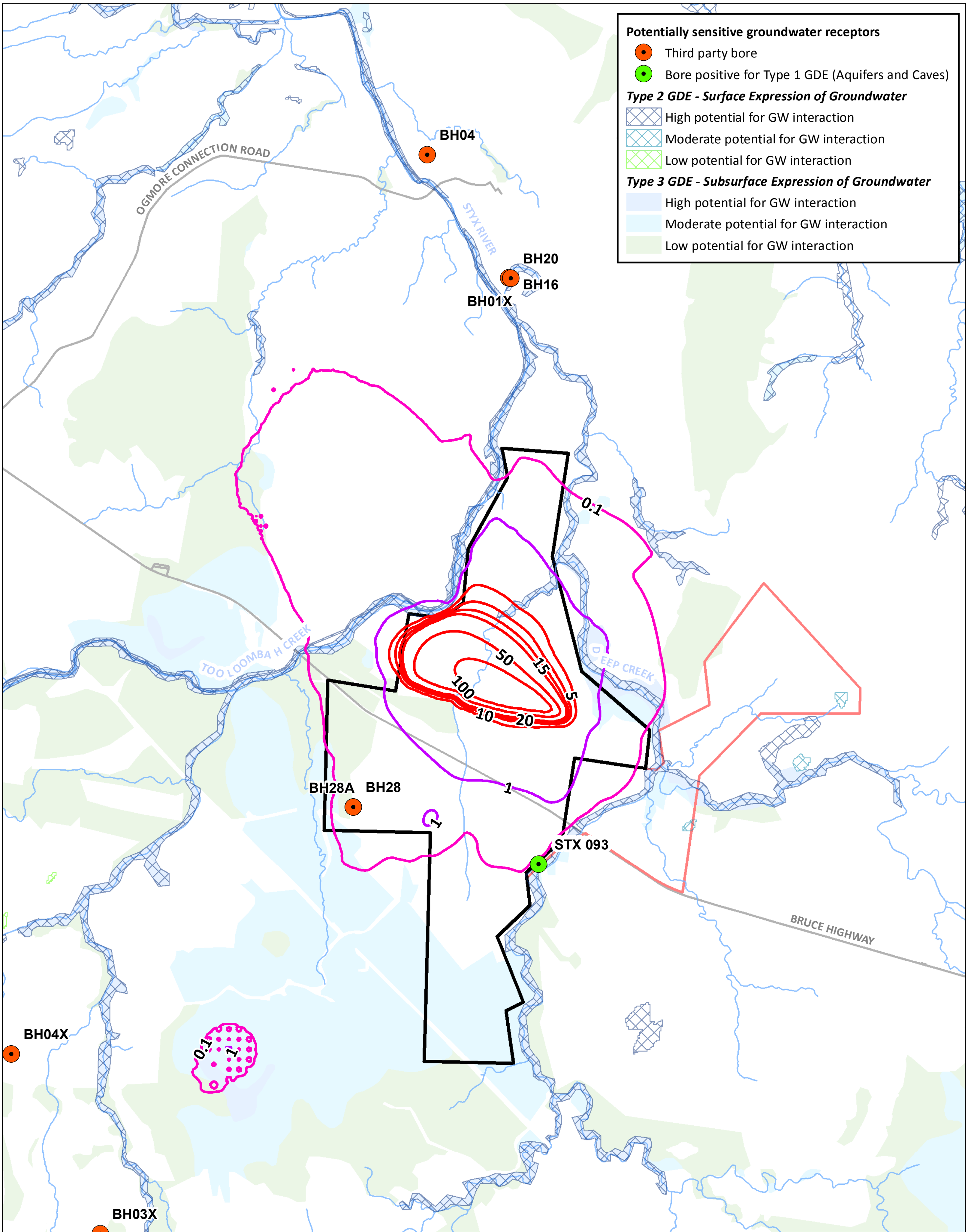
The following provides a discussion of the changes predicted for the potentiometric surface (presented in Figure 16-110 to Figure 16-115) and the saturated extent of HSU1 (alluvium) and HSU2 (the over-, inter- and under-burden units of the Styx Coal Measures) (presented in Figure 3-33 to Figure 3-37 in Appendix A6) in response to mining activities including mining and closure:

- Mining at the 'Open Cut 2' pit, by year 5 (Figure 16-110):
  - 1 m drawdown contour extends to Tooloombah and Deep Creeks on the western and eastern boundaries of ML80187
  - 0.1 m drawdown contour (adopted as the zone of influence) extends beyond Tooloombah Creek to the northeast, but not to the confluence of the two creeks
- Mining at both the 'Open Cut 1' and 'Open Cut 2' pits, by year 10 (Figure 16-111) through to end of mining (Figure 16-112, and Figure 3-33 to Figure 3-37 in Appendix A6):
  - 1 m drawdown contour extends to and beyond Tooloombah and Deep Creeks on the western and eastern boundaries of ML80187, as well as further to the south and north of the ML, to intersect stream reaches of the mid- to lower Deep Creek and mid-Tooloombah Creek
  - 0.1 m drawdown contour extends further beyond Tooloombah Creek to the northeast and within around 1,500 to 2,000 m of Styx River, but not to the confluence of the two creeks
  - alluvium (HSU1) is dewatered over much of the central portion of ML 80187, with small areas outside the ML also dewatered (Figure 3-33 in Appendix A6)
  - overburden coal measures (HSU2) is dewatered over the central portion of ML 80187 (Figure 3-34 in Appendix A6)
  - coal seams/interburden coal measures (HSU2) is dewatered in the areas of 'Open Cut 1' and 'Open Cut 2' (Figure 3-35 in Appendix A6)
  - underburden coal measures (HSU2) remains saturated beneath ML 80187 (Figure 3-36 in Appendix A6)

By year 10 through 25 into closure (with all voids backfilled; Figure 16-113 and Figure 16-114 respectively) the predicted extent of the

  - 1 m drawdown contour remains similar to the contour predicted at end of mining, but extends further east into the Deep Creek catchment and south into both the Deep and Tooloombah Creek catchments
  - 0.1 m drawdown contour extent remains similar to the contour predicted at end of mining

- By year 50 into closure (Figure 16-115) the predicted extent of the 0.1 and 1 m drawdown contours have begun to shrink back towards the decommissioned and back filled pits, and by year 100 into closure (Figure 3-32 in Appendix A6) the groundwater system is predicted to have fully recovered.



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

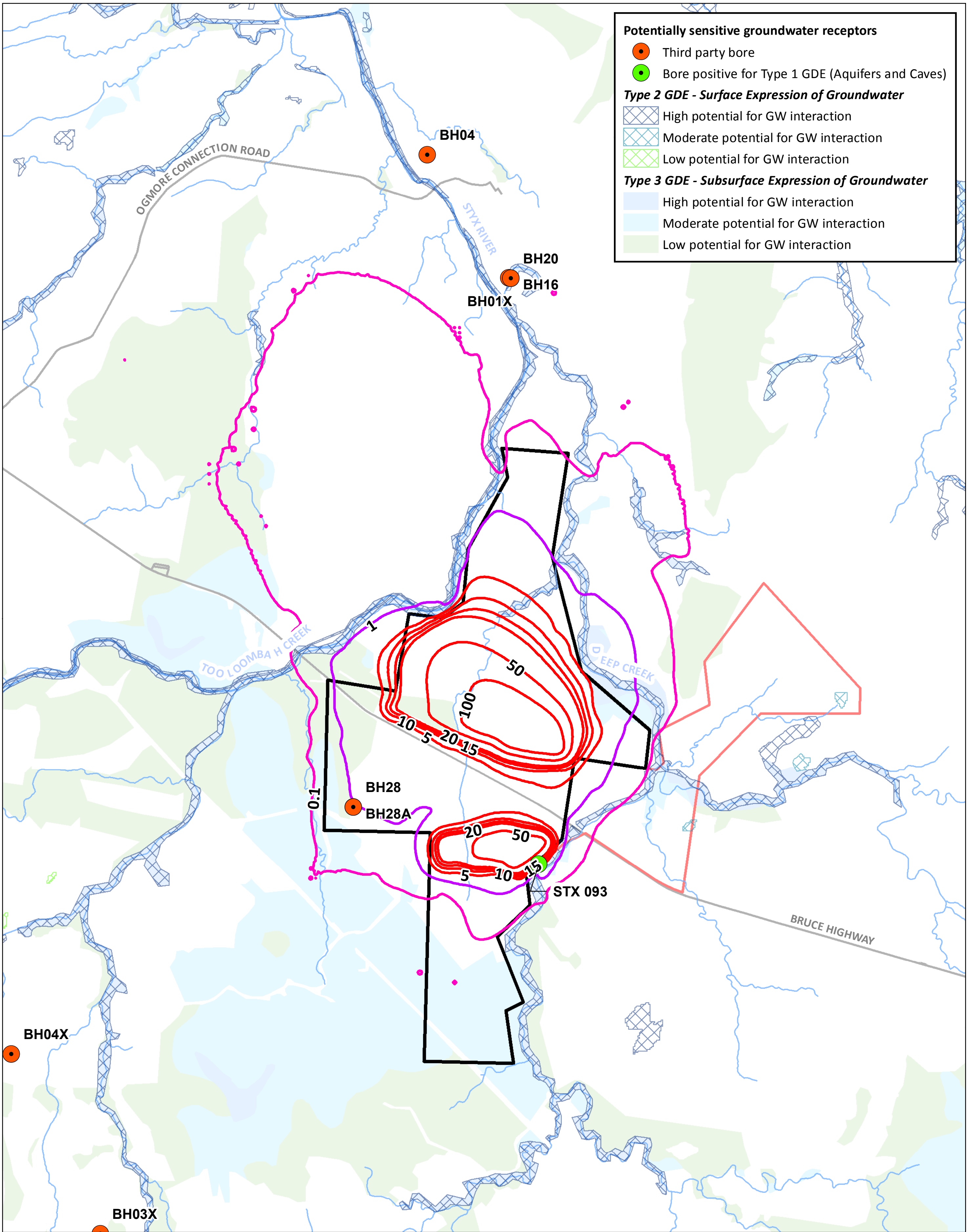
Figure 16-110

Predicted potentiometric surface drawdown contours for all HSUs – year 5

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__LOM yr 5.mxd 12/20/2018



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

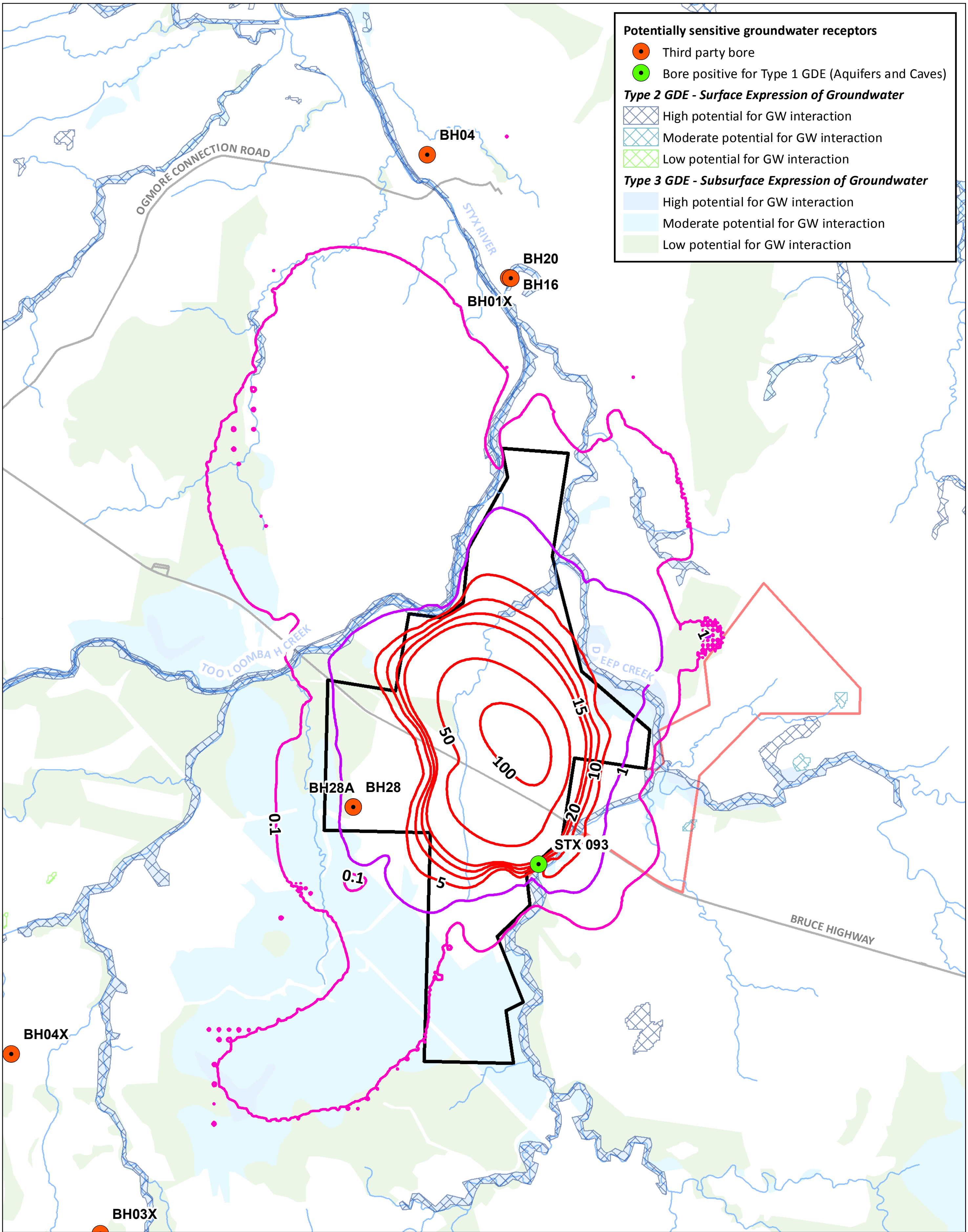
Figure 16-111

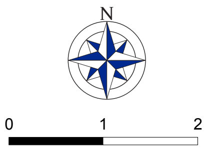
Predicted potentiometric surface drawdown contours for all HSUs – year 10

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__LOM yr 10.mxd 12/20/2018





Legend

Predicted drawdown contour (m)	ML 80187
Major watercourse	ML 700022
Main road	

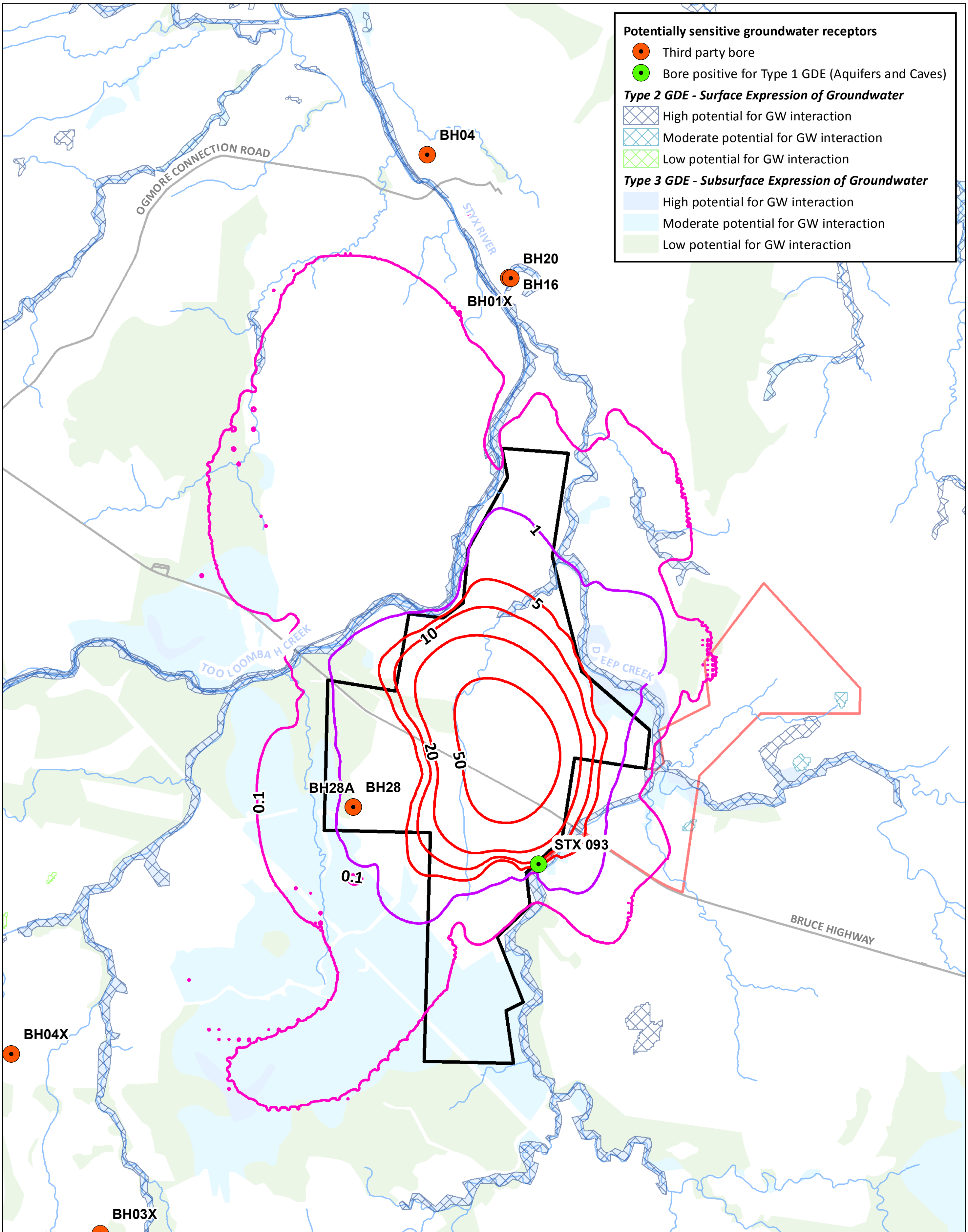
Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Figure 16-112
Predicted potentiometric surface drawdown contours – end of mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__LOM yr 18.mxd 12/20/2018



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 16-113

Predicted potentiometric surface drawdown contours for all HSUs – year 10 post-mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__10yrs post-mining.mxd 12/20/2018

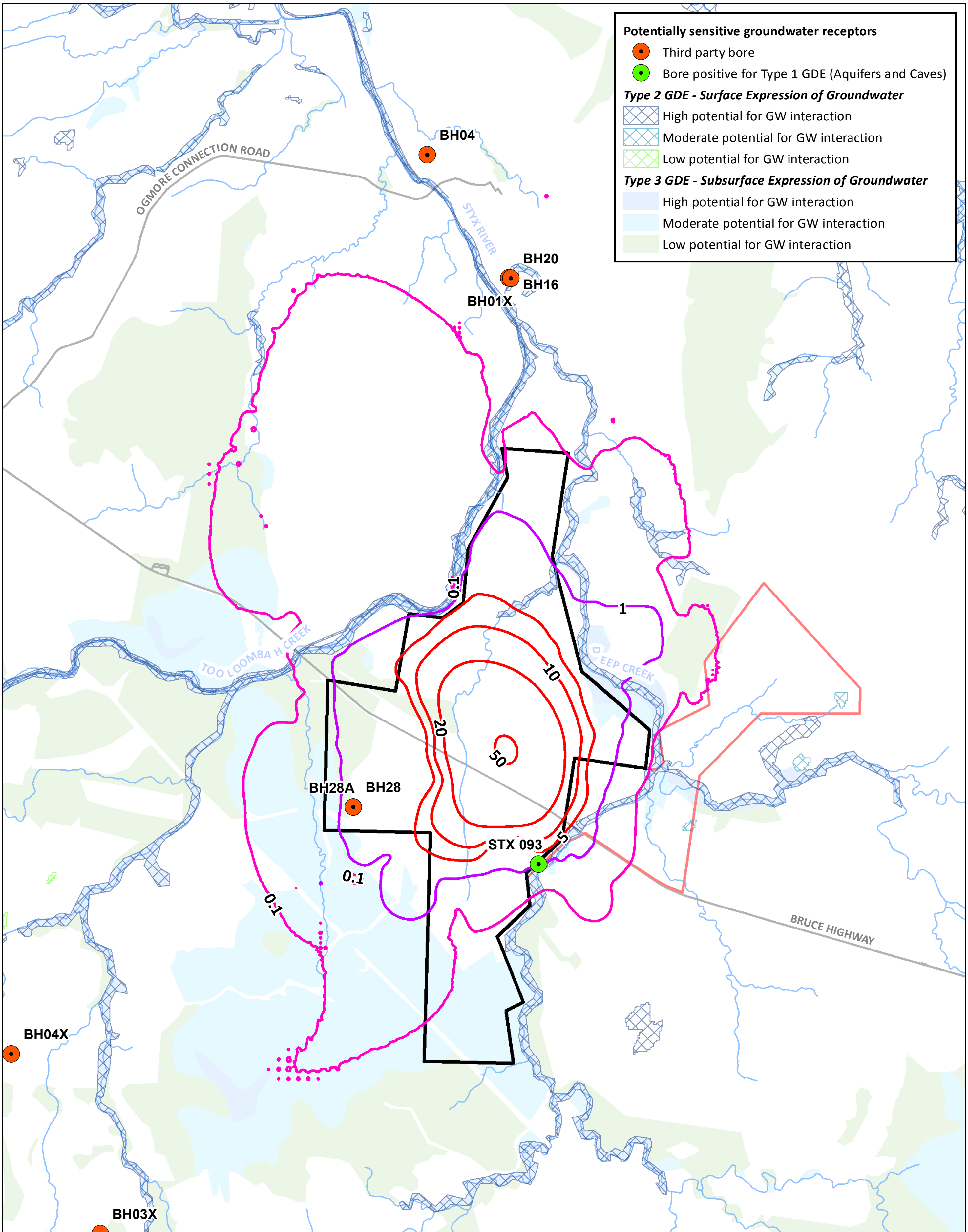


Figure 16-114

Predicted potentiometric surface drawdown contours for all HSUs – year 25 post-mining

N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

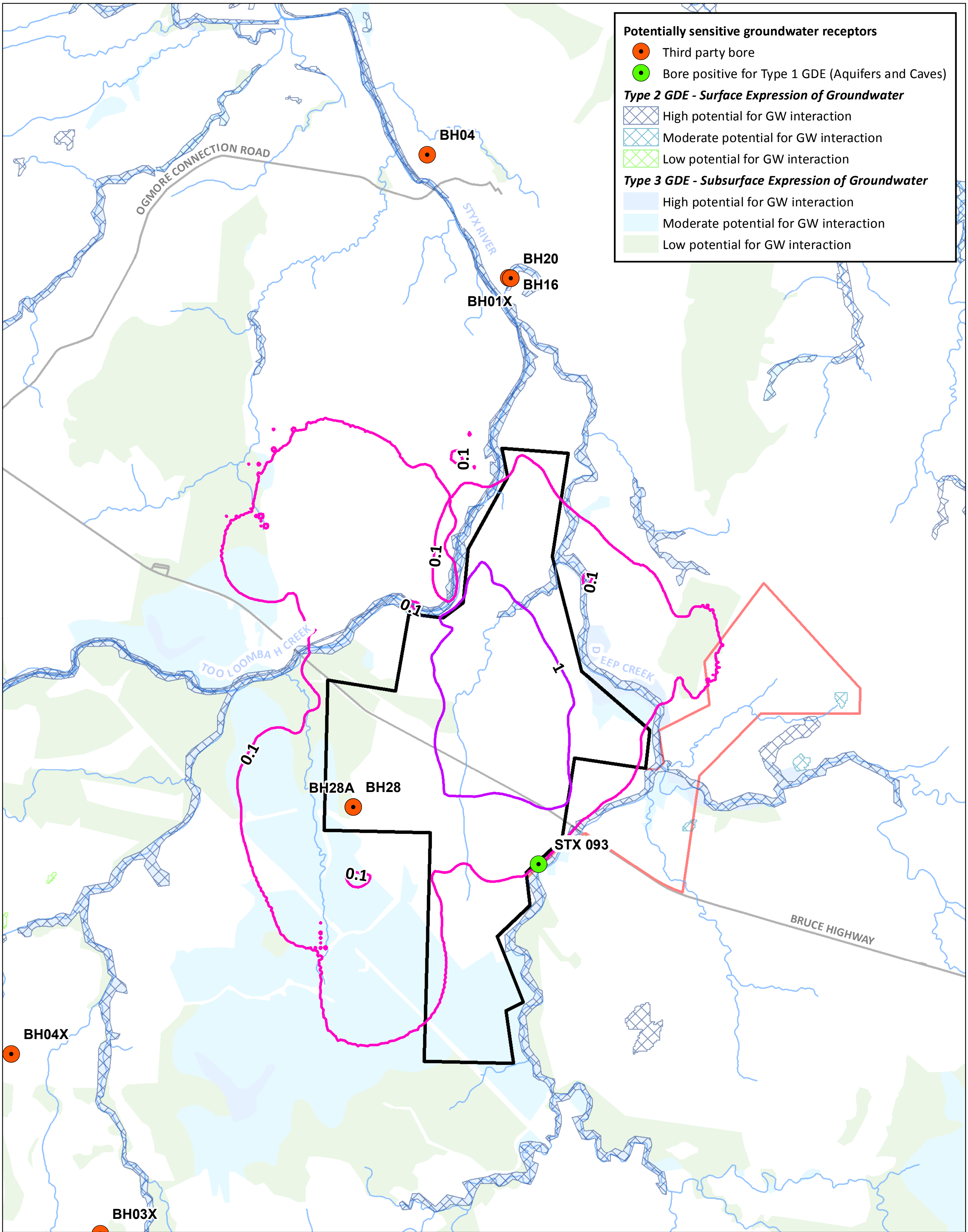
Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__25yrs post-mining.mxd 12/20/2018



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 16-115

Predicted potentiometric surface drawdown contours for all HSUs – year 50 post-mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__50yrs post-mining.mxd 12/20/2018

A key direct effect of mining on groundwater is drawdown associated with dewatering and the associated indirect effects of water table drawdown to support groundwater access by potential riparian GDEs and reduced baseflow to support in-stream GDEs. The quantification of interactions between groundwater and surface water is often constrained by the available topographic data used to represent the ground surface and stream beds in a numerical model, as well as adopted values of stream bed conductance. In this assessment, changes to baseflow (and evapotranspiration) in response to mining have been semi-quantified, i.e. they are presented as relative changes from the predicted pre-mine (baseline) condition.

Figure 16-116 and Figure 16-117 present model predicted changes in flux (baseflow and ET) to the riparian zones of Tooloombah and Deep Creeks in response to mining activities as a proportion of the predicted (no mine) basecase, showing:

- Tooloombah Creek:
  - little to no change in flux between the 'no mine' and 'mining' scenario for the upper reach (above Bruce Highway)
  - upwards of 40% reduction in flux between the 'no mine' and 'mining' scenario for the lower reach (below Bruce Highway), with flux slowly returning to background after closure (~50% recovery by around 65 years after closure, and the remaining ~50% occurring within another 20 years or so)
- Deep Creek:
  - less than 15% reduction in flux between the 'no mine' and 'mining' scenario for the upper reach (above WMP10; Figure 16-79), with flux slowly returning to background within around 75 years after closure
  - 60% reduction in flux between the 'no mine' and 'mining' scenario for the middle reach (between WMP10 and the confluence with the tributary creek that runs through ML 80187; Figure 16-79), with flux slowly returning to background after closure (~25% recovery by around 60 years after closure, and the remaining ~75% occurring within another 20 years or so)
  - less than 15% reduction in flux between the 'no mine' and 'mining' scenario for the lower reach (from the confluence with the tributary creek that runs through ML 80187and the confluence of Deep and Tooloombah Creeks; Figure 16-79), with flux slowly returning to background within around 75 years after closure

Model predicted hydrographs at selected locations where potential GDEs occur are presented in Figure 16-118 and Figure 16-119, and show:

- Drawdown at the location where stygofauna have been identified in Deep Creek catchment alluvium (bore STX093; Figure 16-79 and Figure 16-118) in response to mining activities is predicted to result in an almost 90% loss of vertical habitat over life of mine after which full recovery is predicted to occur by around 50 years after closure (50% recovery occurring by around 15 years after closure); and
- Drawdown at the location of a potential Type 3 GDE (WMP25 and WMP27; Figure 16-79 and Figure 16-119) in response to mining activities is predicted to be less than 2 m in an area where the water table has been gauged at around 10 m or more.

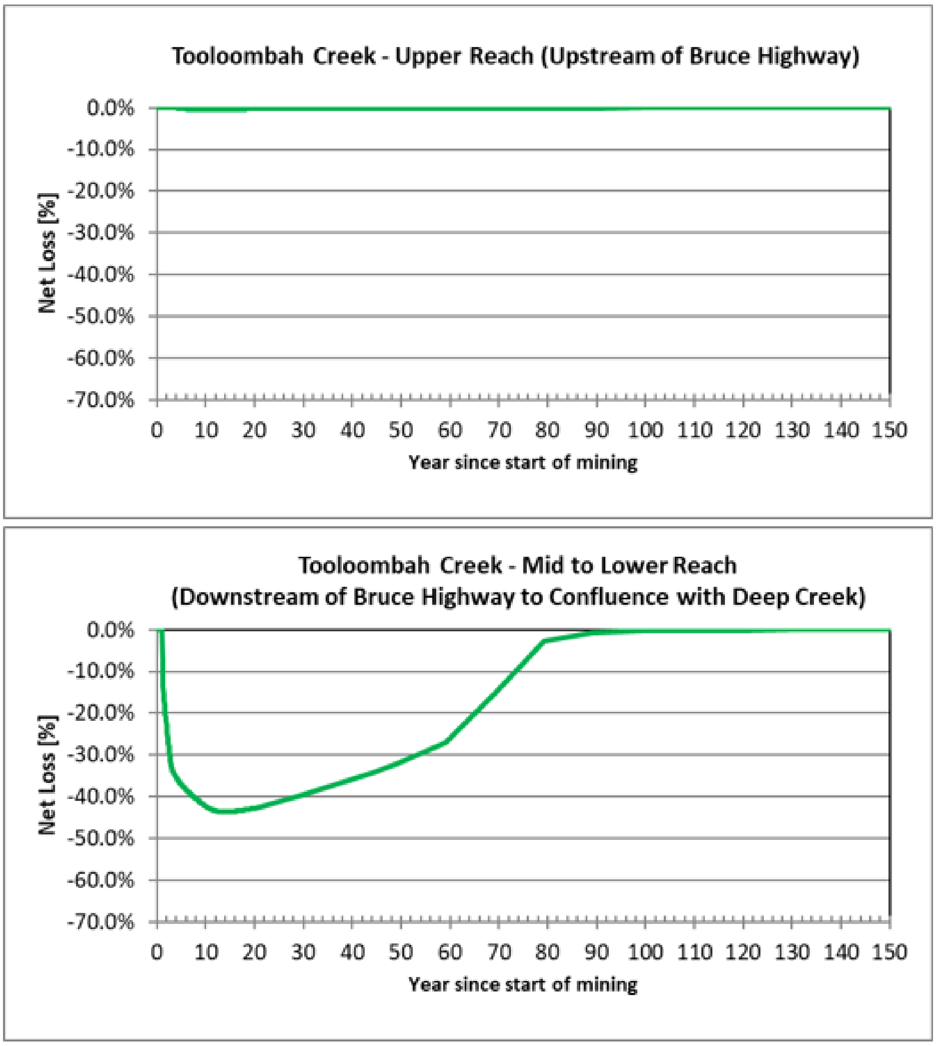


Figure 16-116 Predicted impact on baseflow and evapotranspiration (Tooloombah Creek)

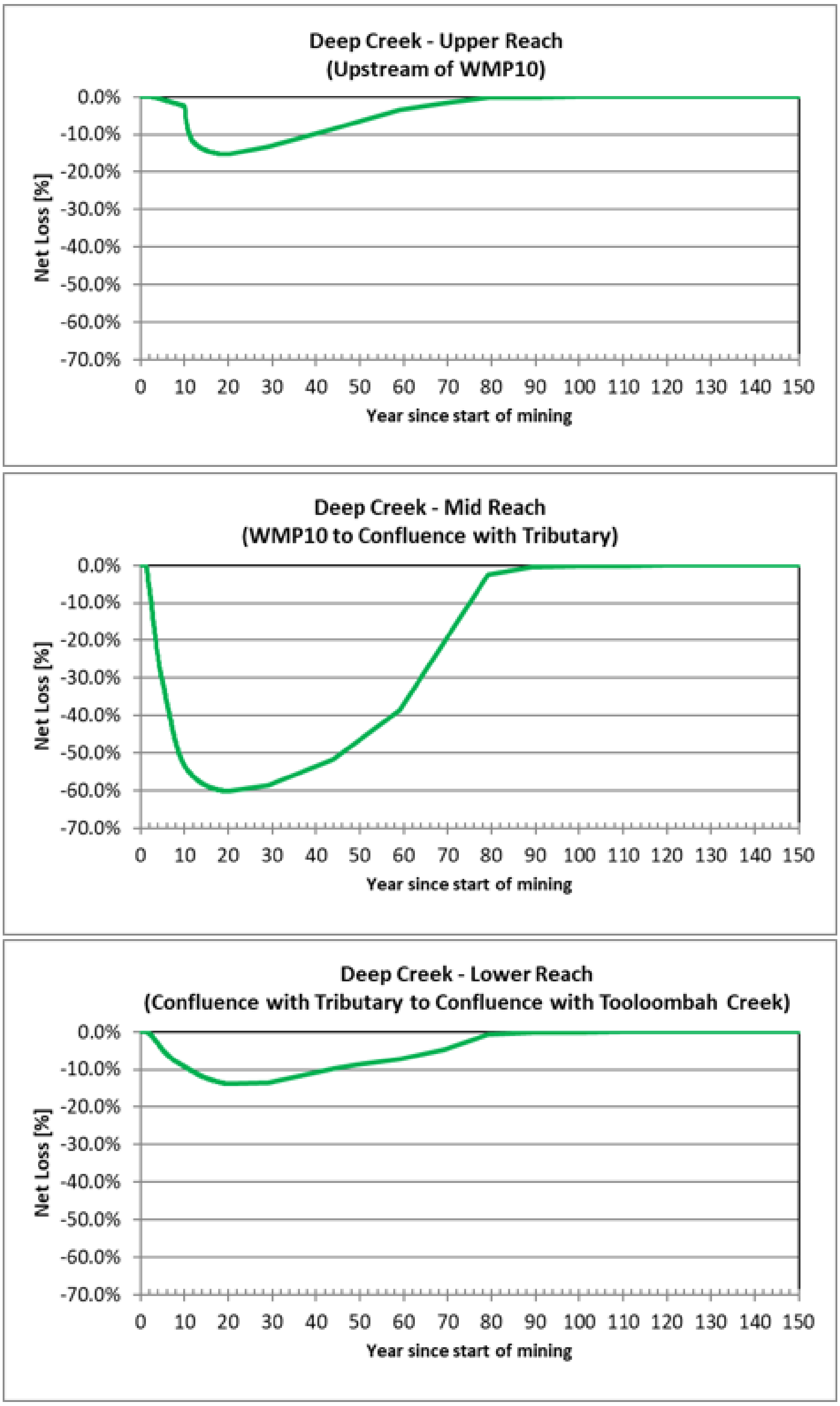


Figure 16-117 Predicted impact on baseflow and evapotranspiration (Deep Creek)

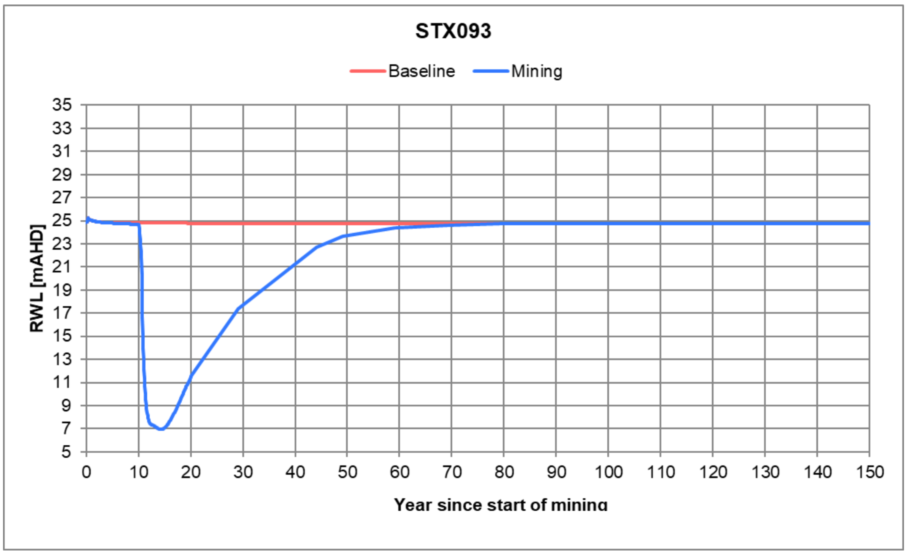


Figure 16-118 Hydrograph showing predicted transient water table response to mine water affecting activities at STX 093 (stygofauna bore, Type 1 GDE)

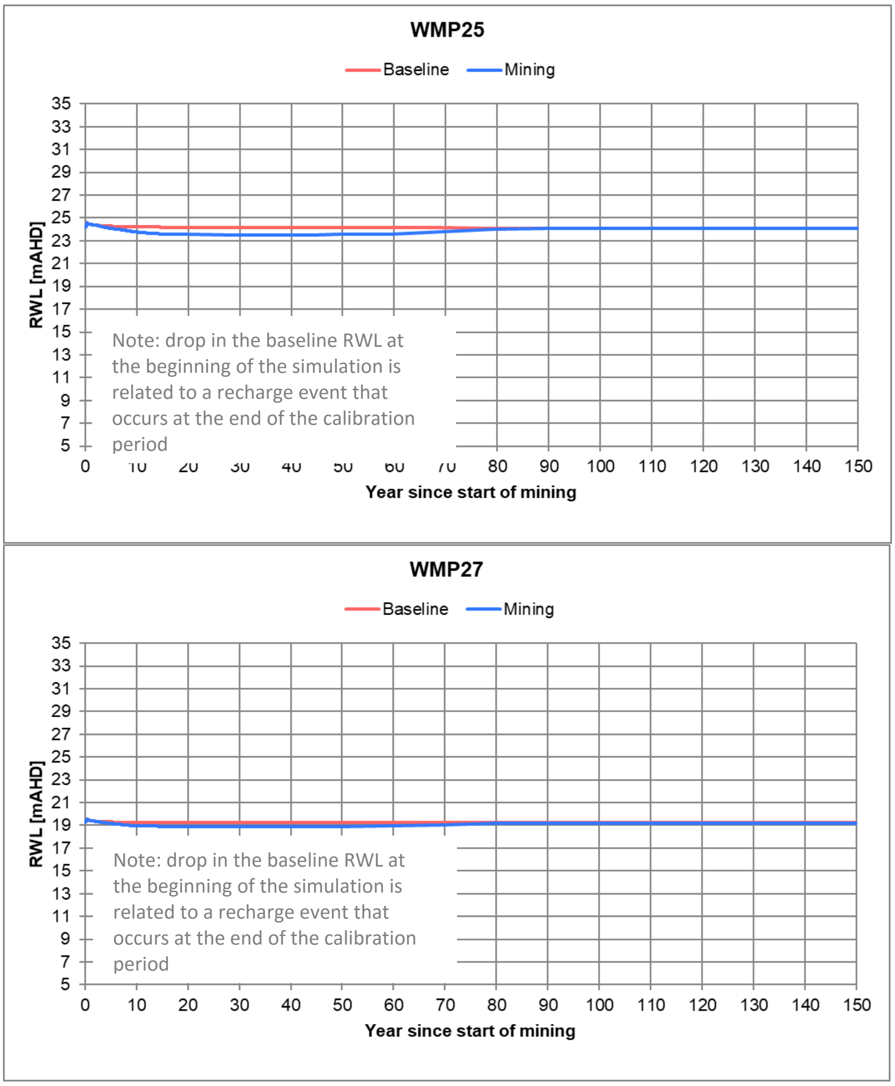


Figure 16-119 Hydrograph showing predicted transient water table response to mine water affecting activities at potential Type 3 GDEs on western ML 80187 boundary (WMP25 and WMP27)

Model predicted hydrographs at third-party bores (Figure 16-104) located in the Project area are presented in Figure 16-120 to Figure 16-122, and show:

- Drawdown in response to mining activities at the location of BH28 and BH28a of up to around 2 m is predicted over the life of mine and out to 70 years after closure; and
- Drawdown in response to mining activities is unlikely to occur at other third-party bores in the area.

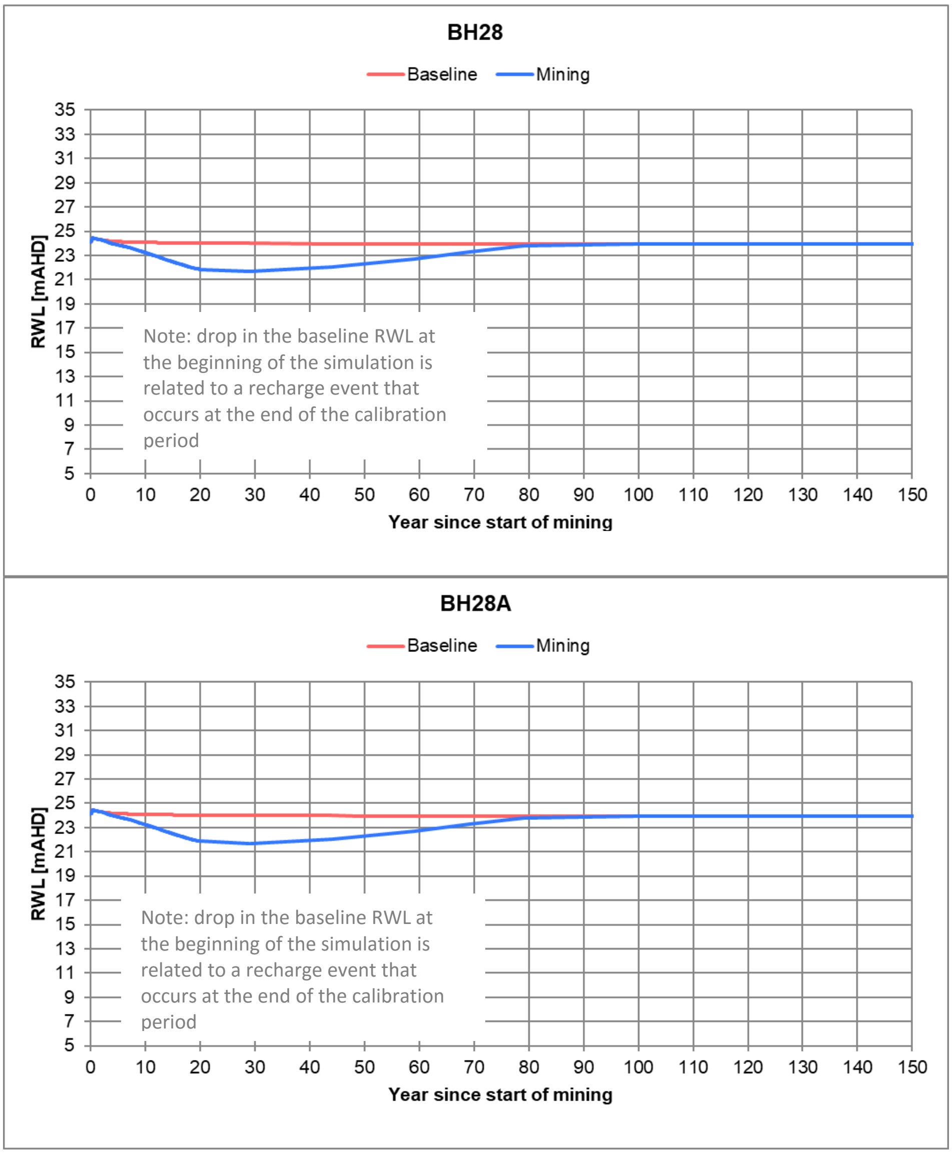


Figure 16-120 Hydrograph showing predicted transient water table response to mine water affecting activities at BH28A and BH28 (third party water user bores, inferred to target the Basement)

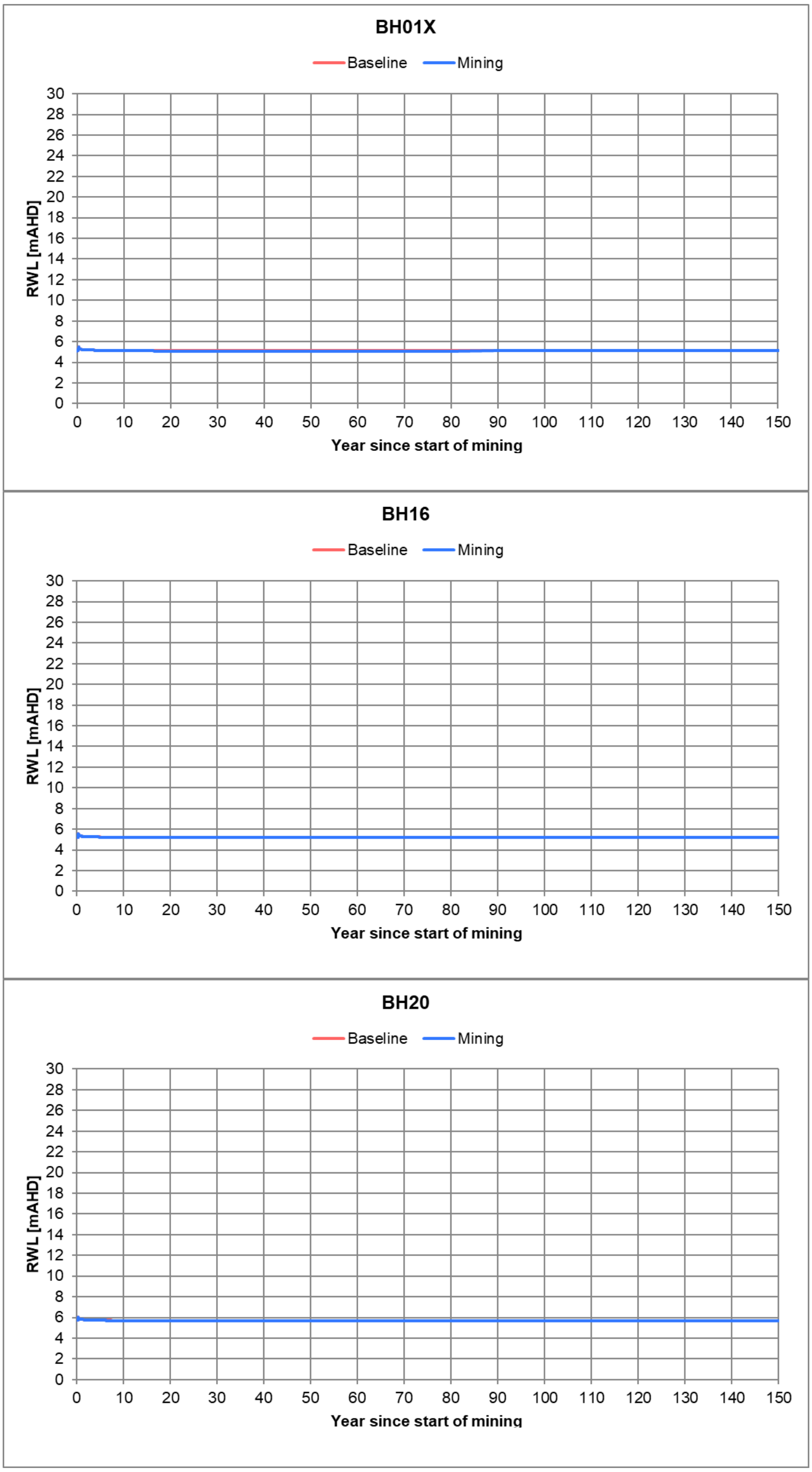


Figure 16-121 Hydrograph showing predicted transient water table response to mine water affecting activities at BH01X, BH16 and BH20 (third party water user bores)

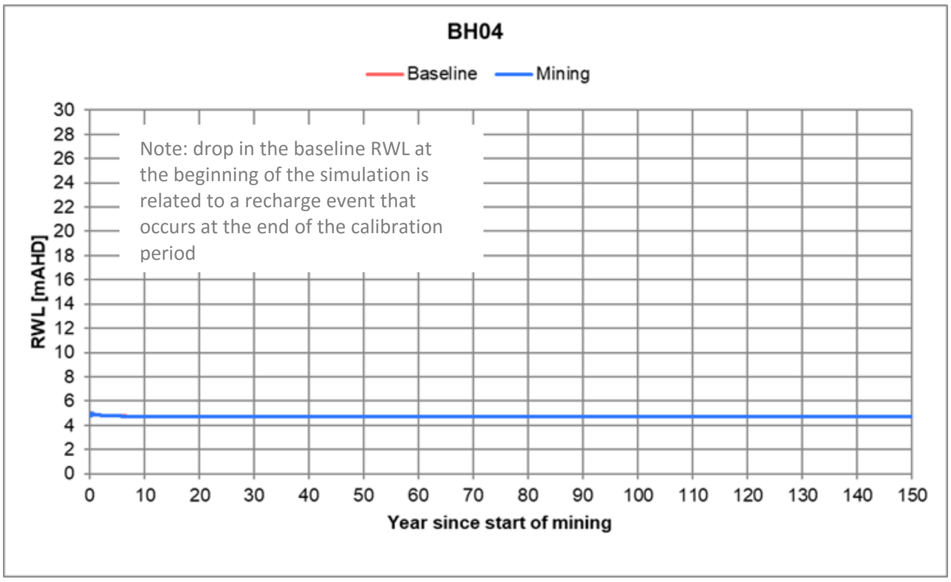


Figure 16-122 Hydrograph showing predicted transient water table response to mine water affecting activities at BH04 (third party water user bores)

Figure 3-51 through 3-53 in Appendix A6 present a west-east aligned cross-section through ML 801887 showing the model predicted pre-mine, year 12 and end of mining, potentiometric surfaces. Figure 3-54 to Figure 3-56 present the same information for a south-north aligned cross-section through ML 801887. The cross-sections and predicted potentiometric surfaces show:

- The pre-mine potentiometric surfaces for each HSU are essentially the same, with the potential for slightly higher heads in the Styx Coal Measures where they subcrop or outcrop on the western side of the geological basin;
- During mining, with the exception of the alluvium (HSU1) and the overburden coal measures (HSU2) that become unsaturated around the mine pits;
  - the lateral extent of the drawn-down potentiometric surfaces are similar, with the basement (HSU3) zone of influence being slightly larger (likely the result of a lower storage coefficient); and
  - the vertical depths differ by many 10s of metres toward the end of mining, as would be expected because of targeted dewatering depths and recovery occurring from bottom up.
- The basement is not dewatered during mining but is depressurised.

Dewatering and Depressurisation

Model predicted dewatering rates presented on Figure 16-123 indicate the peak dewatering rate of around 640 ML/yr will be reached in year 10, rising from around 340 ML/yr at commencement of mining and declining to less than 50 ML/yr at completion of mining. The cumulative abstraction over the life of mine is predicted to be around 5,500 ML.

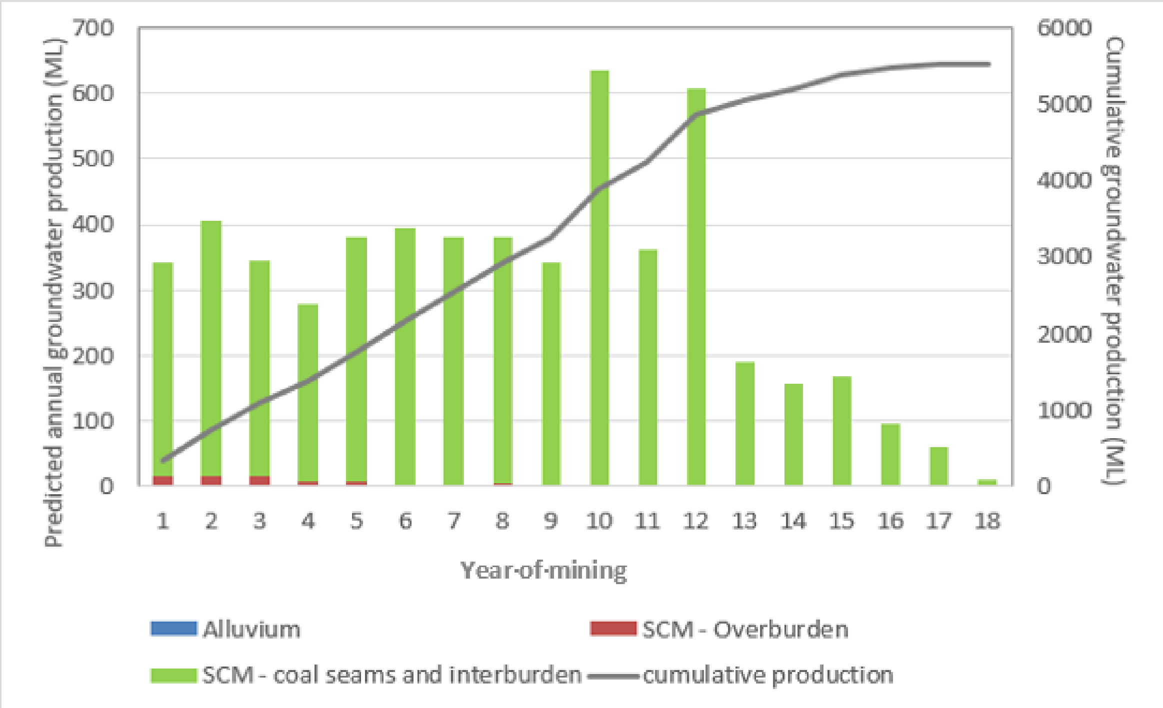


Figure 16-123 Predicted groundwater abstractions (North and South Pits)

Active dewatering of the mine pits is designed to ensure the pits are 'dry' to assist in efficient recovery of coal. However, dewatering results in depressurisation of the local to sub-regional groundwater system - Figure 16-112 presents the predicted zone of a depressurisation / drawdown arising from dewatering (the 0.1 drawdown contour). This zone of depressurisation and dewatering effectively represents the predicted 3,800 ML of water abstracted from the groundwater system over the life of mine.

GDES

Type 1 (subterranean)

Stygofauna have only been identified at one location within the predicted 1 m drawdown contour resulting from active dewatering of the mine (bore STX093; Figure 16-100), but it is expected there are other locations along Tooloombah and Deep Creek where stygofauna may be present. At this location, and other locations where more than 10 m drawdown is predicted for watercourse alluvial aquifers (see Figure 16-107), it is predicted that up to 90% or more of potential stygofaunal habitat will be lost during mining and for some time after closure. However, streamflow recharge can be expected to mitigate this loss of habitat to some extent.

Mine dewatering has the potential to adversely impact on stygofauna habitat in those areas where watercourse alluvial aquifers experience drawdown of 10 m or more. However after mining is completed stygofanal habitat will recover as the groundwater system recovers. Figure 16-125 presents a schematic of the potentiometric surface profile for each HSU at the time when both pits 1 and 2 are at their maximum mined depth and dewatered, and the backfilled pits are beginning to recover but remained dewatered to some extent. Adjacent to the mine pits the basement, and all but the overburden sequence of the Styx Coal Measures are depressurised, i.e. they remain almost to fully saturated but pressures are lower than the pre-mine condition.

Type 2 (surface expression of groundwater)

Where drawdown occurs near to watercourses and wetlands that rely on surface expression of groundwater there is the potential for impact on the capacity of potential Type 2 GDEs to meet environmental water requirements. In the Project area, the only Type 2 GDEs that have been identified are aquatic baseflow fed Tooloombah and Deep Creek pools and the upper reach of Styx River, and to a lesser extent the estuarine lower reach of Styx River and Broad Sound.

The numerical model predicts groundwater interactions with Styx River and Broad Sound are unlikely to be adversely impacted by mine dewatering. However, it is predicted the mid- to lower-reaches of Tooloombah and Deep Creeks will experience lower rates of baseflow (seasonally and annually), as described under 'Groundwater Heads' in this Section.

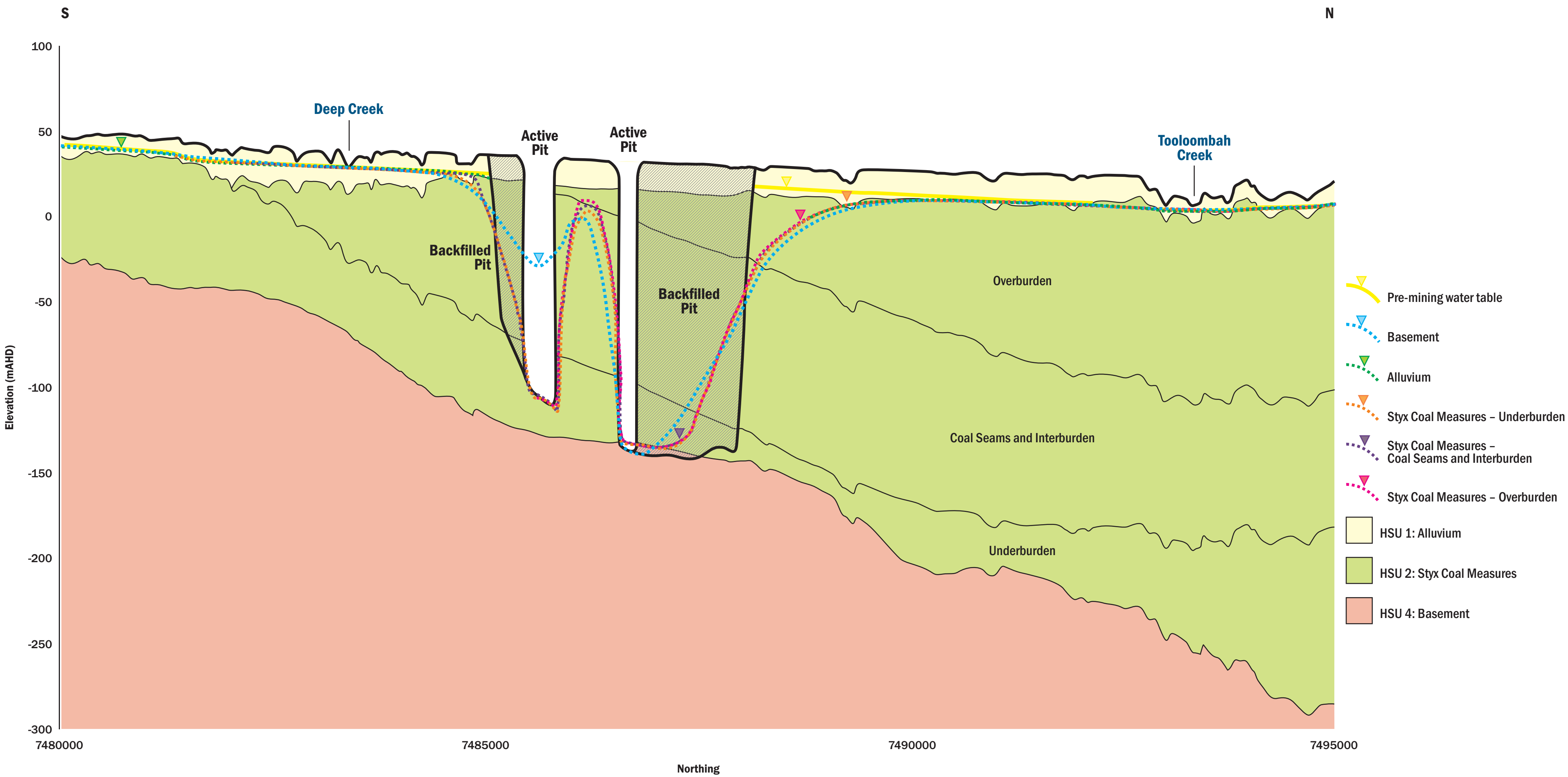
Hydrogeological conceptualisations, GDE-related studies for the Project area and model predictions (Sections 16.11.1.2, 16.11.2.1 and 'Groundwater Heads' in this Section) indicate stream pools, where they occur, may be supported between wet seasons by baseflow. A water balance model has been developed for these pools to estimate the average rate of water consumption by a pool located near the northwestern boundary of ML 80187 (sample point To2; Figure 16-22). The model is presented in detail in Appendix A6 – Groundwater Technical Report.

The water balance model indicates the amount of water required to sustain in-stream pools during the dry season is around 4 mm/d.

Type 3 (subsurface expression of groundwater)

Type 3 GDEs have been identified in the Project area, including riparian and wetland ecosystems. Studies undertaken (see Section 16.11.2.1, 16.12.6.1 and Appendix A6 – Groundwater Technical Report) indicate these GDEs rely on the soil water reservoir (vadose zone) to meet what might be regarded as their typical water requirements. However, in areas where the water table is less than 10 m from the ground surface there is an indication of potential groundwater dependence, possibly during extended dry periods when the soil water reservoir becomes depleted. Figure 16-125 presents a map showing ranges of pre-mine and life of mine water table depth overlain on potential GDE type occurrences, which can be used to identify likelihood of impact arising from mine-related drawdowns.

Apart from existing pre-mine areas where the depth to water table is greater than 20 mbgl (Figure 16-125), the predicted additional area where the depth to water is greater than 20 mbgl due to mine water affecting activities is largely constrained to ML 80187 and ML 700022. This is also the case for areas where the depth to water is greater than 10 mbgl.



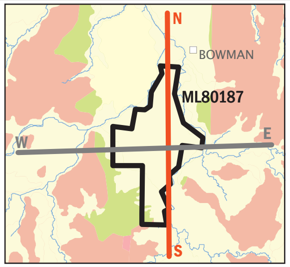
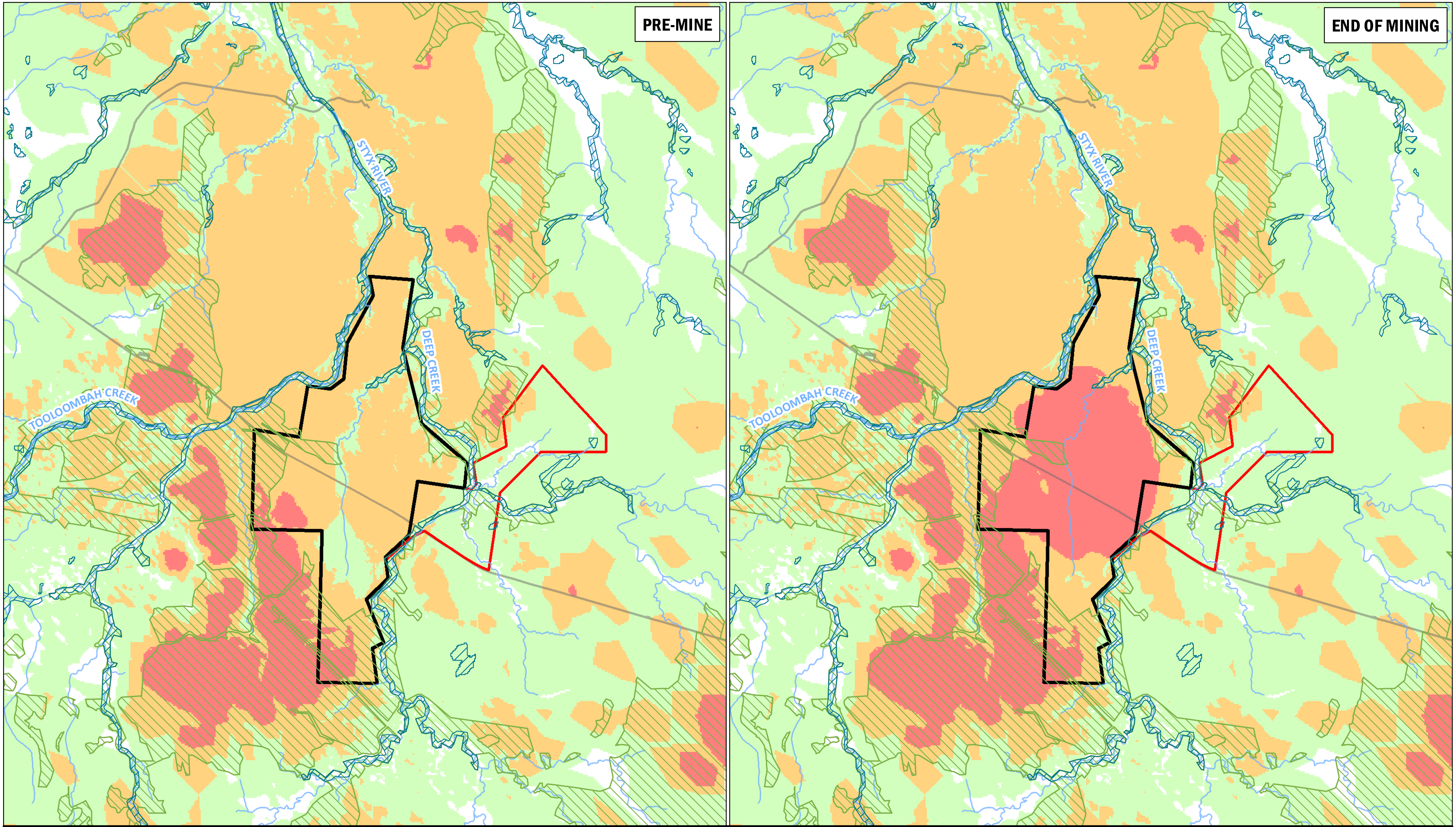


Figure 16-124

Cross-section showing model predicted drawdown (south to north through ML) – year 12 (maximum pit depth)



Legend

Depth to water table

- <5 m
- 5–10 m
- 10–20 m
- >20 m
- Type 2 GDE – Surface Expression of Groundwater
- Type 3 GDE – Subsurface Expression of Groundwater
- ML 80187
- ML 700022
- Major watercourse
- Main road

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Figure 16-125
Comparison between depth to water table pre-mine and at end of mining

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

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Acid Sulphate Soil Interactions

Figure 16-126 presents a map identifying the spatial distribution of potential ASS potential and in the Project area and the predicted maximum drawdown contours (0.1 and 1 m). Mineral exploration holes where the potential for acid generation from encountered geological materials has been tested (sample depth range and depth where Potentially Acid Forming (PAF) materials have been identified.

Geochemical testing indicates predominantly Non-acid Forming (NAF) materials (less than 10% PAF materials) have been identified, which is consistent with the mapping undertaken by Fitzpatrick et al. (2011). Note that the predominantly NAF materials are logged as occurring more than 15 m below ground surface within the Styx Coal Measures. The testing also indicates the waste rock has some neutralising capacity (see Section 16.11.1.1).

The hydrographs presented on Figure 16-126 show the depth intersection of largely NAF materials as well as:

- Outside the ML (one location) PAF materials occur more than 40 m below the water table at all times during and following mining, which is more than 40 m below predicted drawdown depth;
- The full drawdown intersection at one location (STX145C, within Open Cut 2) might expose some material having a low probability of PAF material, although this will be mined; and
- Some exposure of low probability of PAF material may occur very close to the northern limit of Open Cut 2 pit (STX136C) due to drawdown, although this will also be mined.

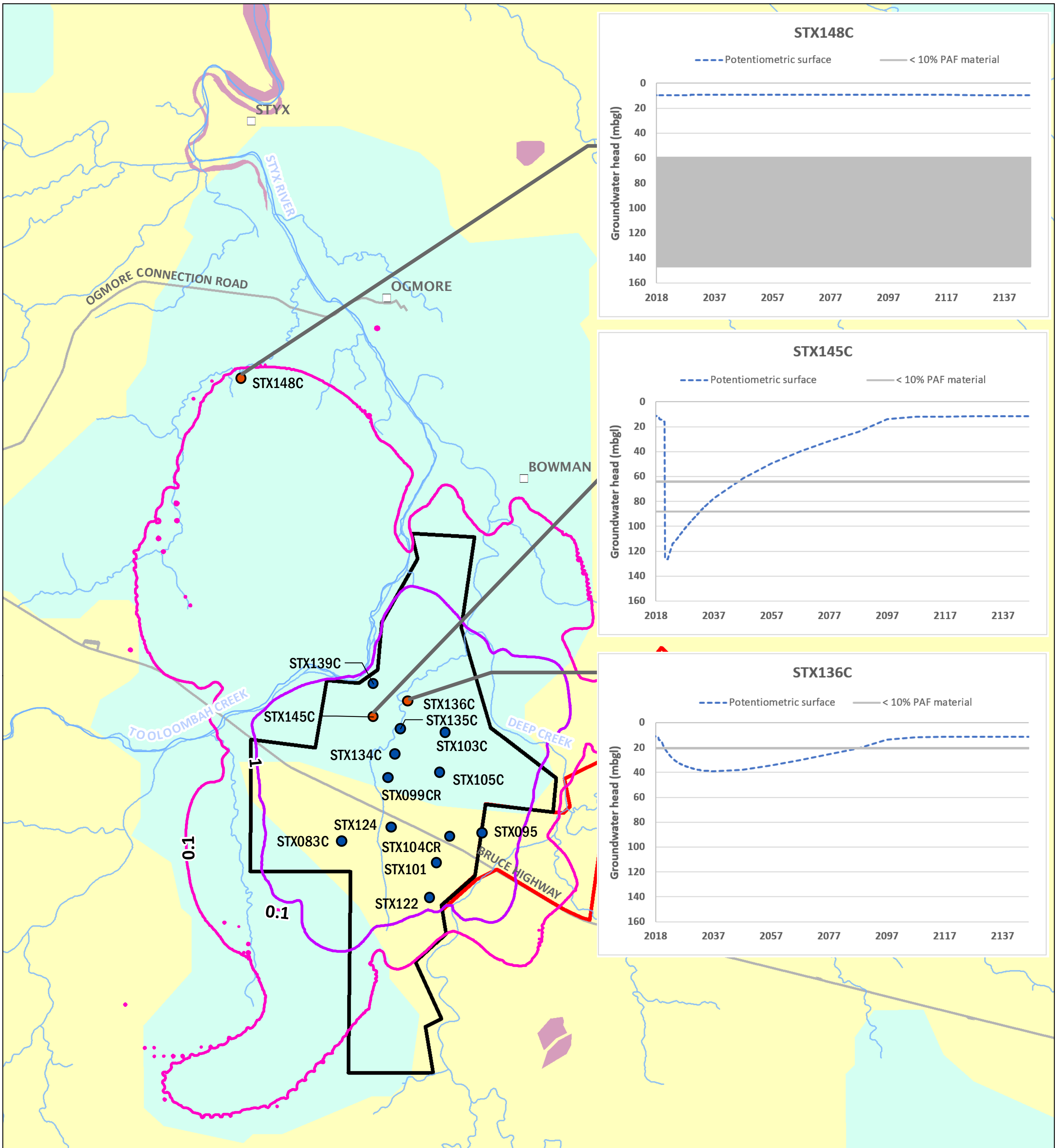
The analysis indicates the potential for ASS exposure in response to mine dewatering is low. The areas most at risk of exposure of ASS occurs within the ML where drawdowns of more than 10 m are predicted, and any development of acid drainage in this area will drain toward the mine pits during mining and post-mining recovery. Back filling of mine pits with materials having neutralising capacity will provide adequate management of this risk.

Seawater-Freshwater Interface Interaction

Hydraulic head and salinity data for the nested WMP29 monitoring bores (Figure 16-83 and Table 16-81), located near Ogmore on Styx River close to Broad Sound indicates underflow toward the coast, and no presence of the seawater-freshwater interface at this location (which must be located closer to the coast).

Regardless, in terms of potential mobilisation of the seawater-freshwater interface due to mine dewatering and associated drawdown, the predicted drawdown data do not indicate this is a likely outcome. Figure 16-86 presents a south-north aligned cross-section through ML 80187 (see also Figure 3-54 in Appendix A6) that show the HSUs and the model predicted potentiometric surfaces for each of the HSUs at end of mining. Also, overlain on the cross-section is the model predicted pre-mine water table surface. The cross-section shows that at the most northerly extent (around the upper reach of Styx River) there is unlikely to be any measurable drawdown in response to mine dewatering that can induce inland mobilisation of the seawater-'freshwater' interface, whether it be located near the point of discharge of Styx River into the Broad Sound estuary or closer to the coast at Broad Sound.

The predicted zone of drawdown is restricted to the southern and western side of Styx River. Vertical hydraulic gradient data for the WMP29 nested monitoring bore site show no indication of a seawater-freshwater interface in this location. As such, the potential for seawater intrusion in response to mine dewatering is considered low to negligible.



Styx drillhole geochemical characterisation

- 0% PAF (NAF)
- <10% PAF

CSIRO Probable ASS Class

- High probability of ASS occurrence
- Low probability of ASS occurrence
- Extremely low probability of ASS occurrence

Borehole	No. of samples	Sample depth range (m)	Lithology of PAF samples	Sample classification
STX136C	11	14 - 74.6	Sandstone (Pyritic) (20.35 - 20.6 m)	91% NAF and 9% PAF
STX145C	17	14 - 128.6	Mudstone/Siltstone (64 - 64.5 m) and Siltstone (87.8 - 88.2 m)	94% NAF and 6% PAF
STX148C	11	59.6 - 147	Sandstone (Pyritic)	79% NAF, 14% uncertain and 7% PAF (low capacity)

N

0 1 2 km

Scale @ A4 1:100,000
Date: 28/11/18
Drawn: A. Aird

Legend

- 0.1m predicted drawdown
- 1m predicted drawdown
- Watercourse
- Main road
- ML 80187
- ML 700022

Figure 16-126
Maximum predicted water table drawdown extent and potential occurrence of ASS

DATA SOURCE
QLD Open Source Data, 2018;
CSIRO, 2011;
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 max WT DD & potential ASS.mxd 11/28/2018

16.11.3.5 Numerical model sensitivity and uncertainty testing

Models are simplified representations of reality, consequently their predictions are always uncertain. A conservative approach to modelling involves adopting parameters that will provide an overestimation of predicted impacts. In the Styx mine environment, the key impacts to existing users (environmental, social and economic) will arise in response to water table drawdown, depressurisation of deeper (confined) HSUs, and reduced baseflow to water courses (quantity and temporal) in response to mine water management. Conservatism in the case of the Styx model is a bias toward an overestimation of the expected 'cone' of drawdown in response to mining activities.

Overly simplistic models fail to capture the signal (i.e. they underfit the data and provide poor prediction). Overly complex models can hide the noise from the regional signal and, by overfitting, the data can provide for poor predictions. A decent parsimony model should derive a good fit with observation and achieve an unbiased normally distributed residual (i.e. the difference between observed and calculated values) of around zero, with a spatially randomly distributed residual. This is what is observed for the Styx model.

With an over-parameterized approach, a better calibration (at the cost of a more important computational effort) can be achieved as locally defined parameters can adjust to local observations. However, a better calibrated model doesn't make a better predictor as many parameters remain indeterminate. The uncertainty analysis for a parsimony approach can be designed to encompass the uncertainty that would be revealed in the over-parameterized approach. In other words, with conservative criteria such as those applied for the Styx model (i.e. "stretching" regional parameters to conservatively high values) the range of predictions (from minimum to maximum drawdown) are wider than the range of predictions that would arise from the null space uncertainty analysis.

A thorough sensitivity and uncertainty analysis of the Styx model is provided in Section 3.7 in Appendix A6 – Groundwater Technical Report and is summarised in the following sections.

Model parameter sensitivity

Model parameterisation

Model calibration sensitivity to hydraulic properties has been tested using parameter estimation software. Details of the analysis are provided in Appendix A6 – Groundwater Technical Report and show the numerical groundwater model is most sensitive to the hydraulic conductivity (K) of the Styx Coal Measures underburden and the alluvium, and recharge rate. The model is least sensitive to specific yield (Sy) of the basement and alluvium and the K of the Styx Coal Measures coal seams/interburden.

In terms of the hydraulic properties the calibration is least sensitive to HSU properties having the least number of observation points. The original model was shown to be least sensitive to the adopted values of Sy of the Basement and Alluvium, and to the K of the Coal Measures coal seams/interburden. Subsequently, additional bores (including nested completions) were installed within the Coal Measures coal seams/interburden and other Coal Measures units to address this issue. Sy has been conservatively represented as 0.01 (alluvium) and 0.005 (Coal Measures and basement), and S has been conservatively represented as 5x10-6. Sy and S have not been not adjusted for any model runs.

Climate Variability

The calibrated model assumes average recharge conditions over the 20 years of mining and 100 year post closure recovery period, including pre-mine initial conditions. It is recognised that climate variability is 'normal' for the Project area, as it is for many parts of Australia, e.g. the number and intensity of cyclones that develop off northeastern Australia is widely variable between years and decades.

Figure 16-24 presents monthly CDFM rainfall data for Strathmuir (BoM Station 033189) and Rockhampton Aero (BoM Station 039083) for the period January 1941 to February 2018 (77 years). The plot shows intra-decadal trends of above average rainfall are typical and, significantly, inter-decadal trends of below average rainfall are not uncommon. Modelling of an extended drought period during the course of mining (20 years) has been undertaken to conservatively test model sensitivity to lower rates of recharge that would be expected under drought conditions (flood recharge as well as diffuse recharge to the alluvium and outcropping basement, where it occurs). Also, a limited above average rainfall period (over 5-years from start of mining) was simulated to assess groundwater system response to a temporarily wetter climate.

The results show:

- Under drier climate conditions (see Appendix A6 – Groundwater Technical Report), there is a predicted 'general' drawdown across the entire model domain of between 0.1 to more than 2 m that is attributable to lower rates of recharge with progressively more drawdown predicted for progressively drier conditions (i.e. moving from 15% less recharge through to 30% and 60% less recharge), as would be expected. However, the model predicted 5 m drawdown remains relatively unchanged between the different drought scenarios when compared against the base case mining / average rainfall scenario, indicating the additional 'cumulative' effect of mine dewatering is negligible; and

- For above average recharge conditions (see Appendix A6 – Groundwater Technical Report), there is basically no change predicted from basecase mining average recharge scenario, except isolated areas where drawup is predicted.

Backfill material hydraulic properties and Hydraulic loading of shallow sediments

Backfilling of mine pits with coal rejects and waste rock may mean the backfilled materials has hydraulic properties that differ from in-situ materials. If this is the case, it is likely that K and S values will be higher than in-situ values but not significantly different due to compaction occurring as the backfill materials are placed back into the pits as well as mixing of materials during mining and backfilling. To assess the possible effects of this outcome, a simulation has been undertaken where the K of backfilled materials is twice that of the overburden ($4x10^{-2}$ cf. $2x10^{-2}$ m/d) and Sy is an order of magnitude higher ($5x10^{-2}$ cf. $5x10^{-3}$).

Along with the assessment of the effects of backfilled materials having different hydraulic properties compared to in-situ materials, an assessment of the potential for stockpiling and waste storage hydraulic loading of shallow sediments has also been undertaken. If hydraulic loading occurs, there will likely be a reduction in hydraulic properties and, to assess the possible effects, the K and Sy of alluvium beneath these storages have been simulated as half that of the basecase ($2x10^{0}$ cf. $4.1x10^{0}$ m/d, and $5x10^{-3}$ cf. $1x10^{-2}$, respectively).

The combined spatial distributions of and changes to hydraulic properties of stockpiles, waste landforms and backfill materials result in a subtle NW-SE elongation of the predicted zone of drawdown, with the 1m drawdown contour passing through Tooloombah Creek (which would have additional effect on Type 2 and Type 3 GDES located in this area; Figure 3-72 in Appendix A6). However, the extent of drawdown (as indicated by the 0.1m contour) remains similar to the base case (which simulates no backfill or hydraulic loading) and emphasises the extent of the drawdown cone is mainly controlled by the properties of the coal seams and interburden.

This assessment can be considered conservative, as it assumes the backfill material is dry when it returns to the pit, although in reality the backfill material will be wet.

Model Uncertainty

As there is often non-uniqueness in relation to combinations of simulated hydraulic properties that achieve an acceptable calibration, the model has been tested for predictive uncertainty relating to this issue, where different combinations of hydraulic properties have been varied within acceptable ranges based on observations of the groundwater system, results of aquifer testing and the literature. A total of 190 predictive uncertainty scenarios have been simulated including models that assess an extended range of hydraulic properties (essentially representing alternative hydrogeological conceptualisations) whilst maintaining an acceptable calibration. In addition, an alternative mining schedule (that generally advances south to north rather than east to west (see Appendix A6 – Groundwater Technical Report, Table 3-9 and Figure 3-63 for the modelled alternative mining schedule) was tested to ascertain if different mine plans & schedules having the same tonnages might impact model predictions.

Details of the assessment of predictive uncertainty are detailed in Appendix A6 - Groundwater Technical Report. The following presents a summary of the outcomes:

- 190 alternative predictive simulations have been simulated to identify possible parameter combinations that maintain an acceptable calibration, and a strong correlation between hydraulic heads and recharge rates was observed, as would be expected;
- Analysis of the effect of varying the K of different HSUs across a broad and conservative range of values has on model calibration and the related extent of drawdown has been undertaken. 106 simulations have been undertaken to test this effect;
- Compared to the basecase calibrated model, peak mine dewatering rates might range between 180 and 1,300 ML/yr:
  - the highest predicted dewatering rate requires K values of all HSUs and recharge rates to be more than half an order of magnitude higher than the adopted values (Table 16-90), which is considered unrealistic
  - the lowest predicted dewatering rate requires K values of all HSUs and recharge rates to be more than half an order of magnitude lower than the adopted values (Table 16-90), which is also considered unrealistic
- Compared to the basecase calibrated model, the spatial extent of drawdown is shown to not be particularly sensitive to the ratio of Kh/Kv, where a ratio of 10 and 100 for the Styx Coal Measures was assessed, and tends to show the isotropic condition (Kh/Kv =1) offers a more conservative outcome;
- Compared to the basecase calibrated model, all predictive uncertainty analyses indicate drawdown associated with mine water affecting activities will not extend to areas where potential ASS might be exposed;
- Compared to the basecase calibrated model, the simulated mining schedule and plan predicts a slightly more conservative outcome than the alternative plan and schedule described above;
- In terms of the hydrogeological conceptualisation adopted for the model:
  - the predictive uncertainty analysis supports the conceptualisation that the combined Tooloombah Creek and Deep Creek catchment is essentially a closed groundwater catchment

– the calibrated model is representative of the simulated groundwater system.

The uncertainty analysis detailed in Appendix A6 – Groundwater Technical Report explores various combinations of parameters that maintain model calibration. Uncertainty testing in relation to combinations of modelled hydraulic properties has shown there are no parameter sets that trigger significant drawdown near the coast or at the confluence of Tooloombah and Deep Creeks.

Alternative Conceptualisations (further uncertainty testing)

To complement the uncertainty analysis, an assessment of alternative conceptualisations that might result in significant impact on the study area groundwater system(s) has been undertaken (essentially a "breaking point" assessment). This assessment explores the conditions necessary to trigger significant drawdown to impact on the receiving environment downstream of the confluence of Tooloombah and Deep Creeks (to Styx River, Broad Sound and the coast, potentially triggering sea water intrusion and exposure of ASS). The assessment is based on model predictions at two locations – the confluence of Tooloombah and Deep Creeks, and where Styx River discharges to Broad Sound. The alternative conceptualisation assessment also assumes recharge rates over the model domain remain unchanged from the basecase calibrated model (providing a very conservative basis for predicting impact where K for the various HSUs increases), and that storativity (S; and important constraint on the extent of drawdown at any point in time) remains the same (i.e. the lowest conceivably possible value of 5×10^{-6}).

Seven scenarios were tested and are detailed in Appendix A6. The following presents a summary of the outcomes:

- The K of the Alluvium, Coal Measures over- and underburden, and Basement provides negligible predictive uncertainty for the model;
- The K of the Coal Measures coal seams/interburden provides the greatest predictive uncertainty for the model;
- Near the coast (where Styx River discharges to Broad Sound) a predicted drawdown of more than 0.5 and 2 m is triggered when the coal seams/interburden K exceeds 0.5 and 2 m/d, respectively - this is true whether coal seams/interburden hydraulic conductivity is increased alone or in conjunction with other units; and
- At the confluence of Deep and Tooloombah Creeks a drawdown of more than 5 m and 25 m is triggered when coal seams/interburden K exceeds 0.5 and 2 m/d, respectively - this is true whether only the coal seams/interburden hydraulic conductivity is increased or when it is in conjunction with other units.

The following summary conclusions remarks can be derived from the alternative conceptualisation assessment:

- Under- or over-estimation, by association, of alluvium, overburden, underburden and basement K has only limited predictive consequence regarding the predicted extent of drawdown arising from mine dewatering;
- The predicted extent of drawdown within the Styx Basin is mainly controlled by Coal Measures coal seams/interburden K;
- Where the Coal Measures coal seams/interburden K values are simulated above 1×10^{-2} m/d, model calibration deteriorates progressively to a point where K values above 2×10^{-1} m/d would be considered unrepresentative (see Figure 3-71 in Appendix A6 – Groundwater Technical Report); and

- A regional Coal Measures coal seams/interburden K value of 1×10^{-2} m/d or less would be considered representative[3]. For this range of coal seams/interburden hydraulic conductivity, the cone of drawdown remains within the vicinity of the mine as predicted by the basecase calibrated model, with drawdown at the confluence of the two creeks only likely to ever be less than 0.5 m and much less than 0.01 m where Styx River discharges Broad Sound.

In summary, Sensitivity testing and uncertainty testing of the model has revealed Coal Measures coal seams/interburden K is the most critical of the modelled hydraulic properties for impact assessment. It carries most of the predictive uncertainty in terms of the extent of the predicted drawdown. To maintain reasonable calibration though, a representative regional value of Coal Measures coal seams/interburden K ought to be lower than 0.01 m/d, which is predicted to result in the spatial and vertical extent of drawdown remaining consistent with that predicted by the basecase model.

The alternative conceptualisation assessment shows the values of Coal Measures coal seams/interburden K required for a significant impact to occur downstream of the Project are not supported by field observations or the general understanding of coal bed hydrogeological characterisation (see 'Hydrogeological Properties' in Section 16.11.1.2 for further discussion).

16.11.3.6 Receptor Exposure and Threat Assessment

The assessment of receptor exposure to altered groundwater conditions and the threat posed to those receptors is based on the analysis and findings described previously in this Section. An overview of the linkages between the potential direct groundwater effects of mining and EVs is summarised in Table 16-89. The EVs identified in Table 16-89 and carried through to the assessment presented in this Section are stock groundwater supplies, aquatic ecosystems (Type 2 GDEs), and 'other' (stygofauna, wetlands, and terrestrial and riparian vegetation; Type 1, 2 and 3 GDEs).

Altered groundwater quantity (drawdown, head, flux) and altered interactions between groundwater and surface water (and connected systems) are considered the primary threatening processes for all receptors, whereas altered groundwater quality and aquifer disruption are considered secondary threatening processes. For all indirect effects, however, a threat assessment needs to consider the following:

- Scale of direct effect:
  - Spatially, e.g. the extent an 'at risk' ecosystem is exposed to an adverse impact
  - Temporally, e.g. will any adverse impact be realised for only a limited period, or will it be permanent
- Capacity for adaptation to altered conditions:
  - Resistance describes the ability of ecosystem components to resist impact by, for example by switching to an alternate water source (vegetation), translocating (stygofauna moving deeper into an aquifer) or via a physiological adaptation (stomatal control in plants)
  - Resilience describes the degree to which groundwater is relied upon to maintain ecosystem function. Stygofauna and most baseflow maintained aquatic ecosystems, for

[3] But any change to the range presented for the basecase calibrated model would require an adjustment of recharge rates (by approximately the same range)

example, will have an obligate reliance whereby removal of access to groundwater will be detrimental. Terrestrial vegetation, though, typically have a facultative reliance, relying on the soil reservoir and only use groundwater when the soil reservoir is depleted.

Table 16-91 presents a summary of direct effects (hazards) carried through to the receptor exposure and threat assessment. The selection is based on whether or not there are engineered controls or management approaches that can be employed to mitigate / remove exposure of receptors to threatening processes, if there are then the applicable direct effects are not addressed further.

Table 16-91 Direct effects carried through to the receptor exposure and threat assessment

Direct effect	Included / excluded from assessment
▪ Open pit mining / excavation	☑ Dictated by the extent of the mineable resource
▪ Backfilling	☑ Has potential issues associated with geochemistry
▪ Mine dewatering / depressurisation	☑ Dewatering required to allow access for mining
▪ Groundwater supply development	☐ No groundwater supply, other dewatering, proposed
▪ Open pit (post-closure)	☐ Pits progressively backfilled during mining
▪ Stockpiling & waste storages	☑ Facilities required for materials management
▪ Water storages	☑ Facilities required for water management
▪ Equipment, containment and pipeline failure	☐ Controlled management through engineering design and management plans
▪ Interconnection of aquifers (bores)	☐ Controlled management through application of National guidance
▪ Disruption / diversion of surface drainages	☐ No major diversions or disruptions to major drainages proposed

Notes: ☑ Included ☐ Excluded

The following tables provide summary details of predicted direct effects and the associated receptor exposure (pathways) and threat assessments for the Project - Table 16-92 (groundwater quantity), Table 16-93(groundwater quantity), Table 16-94 (groundwater and surface water interactions) and Table 16-95 (physical disruption of aquifers).

Table 16-92 Summary details effects, receptor exposure assessment and threat assessment - groundwater quantity

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
WATER TABLE SURFACE AND GROUNDWATER FLOW DIRECTION ▪ Pre-mine - Predicted pre-mine steady state water table contours are consistent with inferred water table contours (Figure 16-81), with regional groundwater flow to the north (toward coast), and a large component of local groundwater flow occurring toward watercourses (baseflow and ET) ▪ During mining - Mid-catchment of Tooloombah and Deep Creeks - Predicted water table contours during mining show groundwater flow is diverted to the mine pit (due to dewatering / depressurisation) (Figure 16-106 and Figure 16-107) - Lower catchment of Tooloombah and Deep Creeks, Styx River and Broad Sound estuary - Predicted water table contours downstream of ML 80187 remain similar to the pre-mine condition (Figure 16-106 and Figure 16-107) - The limited predicted extent of drawdown effect, if any, on groundwater flow fields in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks indicates the potential for seawater intrusion is negligible (see 16.11.3.4) ▪ Post-mine - Mid-catchment of Tooloombah and Deep Creeks - Predicted water table contours show continued recovery of groundwater storage in Project area up to 50 years post-mining, full recovery occurs between 50 and 100 years post-mining (Figure 16-108 and Figure 16-109). - Lower catchment of Tooloombah and Deep Creeks, Styx River and Broad Sound estuary - Predicted water table contours downstream of ML 80187 remain similar to the pre-mine condition (Figure 16-108 and Figure 16-109) - Placement of backfill materials assumes dry materials, a very conservative assumption as full recovery will be aided by fact that materials returned to pits will be partially saturated (above zero) **DRAWDOWN AND DEPRESSURISATION** ▪ During mining - The maximum predicted potentiometric surface drawdown exceeds 100m, but is restricted to ML 80187 immediately surrounding the pits - The 10m potentiometric surface drawdown contour largely remains within ML 80187 and does not extend to Tooloombah Creek or Deep Creek - The 1m potentiometric surface drawdown contour intercepts the mid portion of Tooloombah Creek and Deep Creek - The 0.1m potentiometric surface drawdown contour extends to a maximum of approximately 4.5 km northwest and 1 km southeast of ML 80187 (or a total 'elliptical' diameter of around 10 km) occurring at some time between 10 years of mining and the end of mining (as shown in Figure 16-111 and Figure 16-112) but does not intercept Styx River - The lack of drawdown in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks indicates the potential for seawater intrusion and ASS beyond the ML 80187 boundary is negligible ▪ Post-mine - The maximum extent of the zone of influence occurs around 10 years post-mining (Figure 16-113) - The maximum predicted potentiometric surface drawdown ranges up to 100m until some time after 25 years post-mining immediately surround the backfilled mine pits, but by 50 years post-mining predicted drawdown is less than 50m and by 100 years post-mining full recovery is predicted - The predicted 10m potentiometric surface drawdown contour largely remains within ML 80187 and does not extend to Tooloombah Creek but intercepts a relatively small portion of the mid to upper reach of Deep Creek, adjacent to Open Cut Pit 1, until 50 years post mining - The predicted 1m potentiometric surface drawdown contour intercepts the mid reach of Tooloombah Creek and Deep Creek until 50 years post mining - The 0.1m potentiometric surface drawdown contour extends to a maximum of approximately 4.5 km northwest of the of the ML 80187 boundary, but does not extend to within 1 km of Styx River, at some time between the end of mining and 10 years post-mining (Figure 16-112 and Figure 16-113)	GDEs *Type 1* *Type 2* *Type 3*	 NI Aquatic ecosystems NI	▪ Type 1 GDEs - Drawdown has potential to impact on vertical extent of stygofauna habitat - A maximum drawdown of around 13 m is predicted at the location of the bore where stygofauna have been identified (STX 093, Figure 16-100) between end of mining and 10 years post-mine - Predicted rate of drawdown at this location is around 1.5 m/yr (Figure 16-118). Water is not suddenly removed, possibly allowing stygofauna to move deeper into the alluvium water column - At this location the alluvial aquifer is estimated to have a saturated thickness of around 15 m, corresponding to an approximate maximum 90% loss of vertical habitat over a relatively short reach of Deep Creek - No other locations where stygofauna have been detected are likely to be impacted (locations over 5 km away from nearest predicted drawdown contour) ▪ Type 2 GDEs - Drawdown has potential to impact on baseflow rates (flux) to streams and, consequently, aquatic ecosystem function - 1 to 5 m drawdown predicted along reaches of Tooloombah Creek (mid-reach) until around 50 years post-mine (maximum predicted drawdown occurs around 10 years post-mine) - 1 to 15 m drawdown predicted along reaches of Deep Creek (mid-reach) until around 50 years post-mine (maximum predicted drawdown occurs around 10 years post-mine) - Negligible drawdown predicted along lower reaches of Tooloombah and Deep Creeks (immediately upstream of their confluence), Styx River and Broad Sound estuary ▪ Type 3 GDEs - Drawdown has potential to impact on transpiration rates (and photosynthesis) and, consequently, riparian and terrestrial ecosystem function - Depending on location, between 0.1 and more than 10 m (limited occurrence) drawdown predicted beneath riparian GDEs, typically near to Project e.g. Forest Red Gum woodlands on drainage lines and alluvial plains (RE 11.3.4), Semi-evergreen Vine Thicket on drainage lines (RE 11.13.11, determined as not being a GDE) – the rate of drawdown along mid-reaches of both creeks is predicted to be up to around 1 m/yr (Figure 16-119), possibly allowing vegetation to adapt to the lowering water table if surface flow (and stream loss) regime is maintained - Depending on location, between 0.1 and more than 50 m drawdown predicted beneath terrestrial GDEs, typically near to Project e.g. Forest Red Gum woodlands on alluvial plains (11.3.4) – rate of drawdown at western boundary of ML is predicted to be around 0.2 m/yr, possibly allowing vegetation to adapt to the lowering water table - No drawdown predicted along lower reaches of Tooloombah and Deep Creeks (immediately upstream of their confluence), Styx River and Broad Sound estuary - Either side of Tooloombah and Deep Creeks (west and east, respectively) less than 1 m drawdown is typically predicted	▪ Type 1 GDEs - **High** threat of adverse effects expected at location of bore STX 093, until around 25 years post-mine - **Negligible** threat of adverse impact at other locations where stygofauna have been reported ▪ Type 2 GDEs - **Low** threat of adverse effects expected along stream reaches supporting permanent pools, within the predicted 0.1 to 0.5 m drawdown contours (Figure 16-113) - along a reach length of 3.4 km (Tooloombah Creek) and 3.3 km (Deep Creek) - **Moderate** to **high** threat of adverse effects expected along stream reaches supporting permanent pools, where predicted drawdown of more than 0.5 m occurs (Figure 16-113) – along a reach of 2.4 km (Tooloombah Creek) and 3.9 km (Deep Creek) - **Note: watercourse pools have only been observed along isolated sections of the creeks/BoM mapped potential Type 2 GDE areas, therefore the actual predicted impacted stream length will likely be less** ▪ Type 3 GDEs - Riparian - **Low** threat of adverse effects expected for riparian zones where predicted drawdown of between 0.1 and 1 m occurs (Figure 16-113) – an area of 70 ha (Tooloombah Creek) and 65 ha (Deep Creek) - **Moderate** to **high** threat of adverse effects expected for riparian zones where predicted drawdown of more than 1 m occurs (Figure 16-113) - an area of 3 ha (Tooloombah Creek) and 35 ha (Deep Creek) - **Note: Ground-truthed vegetation mapping (refer Figure 16-143) of vegetation listed as habitat for MNES (RE 11.3.25) indicates a predicted low threat to 40.3 Ha (Tooloombah Creek) and 62.4 ha (Deep Creek) and a moderate to high threat to 8.3 ha (Tooloombah Creek) and 34.2 ha (Deep Creek)** - Terrestrial, where predicted pre-mine water table <10m - **Low** threat of adverse effects for terrestrial GDEs within the predicted 0.1 to 5 m drawdown contour (Figure 16-113), covering an area of 97 ha - **Moderate** to **high** threat of adverse effects expected for terrestrial GDEs where predicted drawdown of more than 5 m occurs (Figure 16-113), covering an area of 3 ha. - **Note: Ground-truthed vegetation mapping (refer Figure 16-143) of vegetation listed as habitat for MNES (RE**

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
- The lack of drawdown in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks indicates the potential for seawater intrusion and ASS beyond the ML 80187 boundary is negligible **PERCHED WATER TABLES / RAISED WATER TABLES** ▪ Seepage from waste management facilities - Potential for perched water tables to form unlikely due to permeability difference between waste materials and alluvials ▪ Hydraulic loading from waste management facilities / stockpiles - Hydraulic loading is predicted to have negligible effect on water table elevation **SEEPAGE RELATED DRAWUP** ▪ During mining - Around the mine pits, the maximum predicted potentiometric surface drawdown beneath water storages exceeds 10m, which reduces the potential for water table drawup				**11.3.4) indicates a predicted low threat to 14.25 Ha an and no areas of predicted moderate to high threat.** - Terrestrial, where predicted pre-mine water table >10m - **Low** threat of adverse effects for terrestrial GDEs within the predicted 5 to 10 m drawdown contour (Figure 16-113), covering an area of 8 ha - **Moderate** to **high** threat of adverse effects expected for terrestrial GDEs where predicted drawdown of more than 10 m occurs (Figure 16-113), covering an area of 18 ha - **Note: Ground-truthed vegetation mapping (Chapter 14 – Terrestrial Ecology) of terrestrial ecosystems listed under the MNES (RE 11.3.4) indicates no areas of predicted threat.**
	Third party users	▪ Stockwater ▪ Irrigation ▪ Farm supply use	▪ Drawdown at (census) identified third party user bores used to assess threat, with six bores identified within the potential zone of effect ▪ At BH28 / BH28A predicted drawdown is around 1.5 m (Figure 16-120) at 10 years post-mine ▪ At BH28 / BH28A the pre-mine available drawdown is around 12 to 15 m, based on WMP15 data (refer Table 16-73, Figure 16-82), indicating around 10% loss of available drawdown ▪ At remaining bores (BH04, BH01X, BH16, BH20; along Styx River reach) drawdown is predicted to be negligible	▪ BH28/28A - **Low** threat of adverse effect expected in regard to continued operation (currently not in use), and the owner of the bores is Central Queensland Coal ▪ Other bores - **Negligible** threat of adverse effect expected in regard to continued operation
	Other	▪ Cultural and Spiritual	▪ Receptor exposure assessment likely corresponds to GDE exposure assessment	▪ Threat likely corresponds to GDE threat assessment

Notes: NI – not (specifically) identified as an EV for the Styx River Basin

Table 16-93 Summary details effects, receptor exposure assessment and threat assessment - groundwater quality

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
GROUNDWATER SALINISATION ▪ Mining - Pit voids will not remain after mining, as progressive backfilling will occur during mining - During mining, when mine pits are open, some evaporation of groundwater seepage to the pits will occur, which will result in concentration of salts in the pits but to a limited degree, some of which will be removed with the coal and some of which will remain in the pit prior to backfilling - Because baseline groundwater salinity of the Styx Coal Measures in the vicinity of the mine pits is shown to be brackish to saline (e.g. WMP04, Figure 16-89), it is not expected salts remaining in the pit prior to backfilling will cause a significant increase in the salinity of recovering groundwater in the backfill materials - Movement of groundwater toward pits during mining and after closure (until recovery is complete) is unlikely to result in adverse water quality change as salinity and other analyte concentrations for Coal Measures, except alluvium, is consistent although widely varying ▪ Water storages - Possible leakage from water storages can be expected to be of similar quality as the water source used to fill the storages, which arises from dewatering - Residence time of water in the storages will not be significant and so the potential for evaporation to cause significant salinisation of stored water is considered low **ACID MINE DRAINAGE (AMD)** ▪ Mining - The available geochemistry data indicate there is little potential for generation of AMD from pit wall materials (refer Section 16.11.1.1) - Leaching of metals / metalloids from pit walls will likely have minimal impact on surface and groundwater quality, if any ▪ Waste materials - The available geochemistry data indicate there is little potential for generation of AMD from waste materials (refer Section 16.11.1.1) - Leaching of metals / metalloids from waste rock (e.g. aluminium (Al), arsenic (As), selenium (Se) and vanadium (V)), where it occurs, will likely have minimal impact on surface water and groundwater quality, if any **ACID SULPHATE SOILS (ASS)** ▪ Mapping - ASS mapping for the Styx River catchment (Figure 16-20) shows the catchment is classified as largely having low to extremely low probability of ASS potential - Only small pockets of high probability ASS occur (i.e., below Ogmore near to Styx River and the Broad Sound estuary, more than 7 km downstream of the Project) - Predicted contours of water table elevation (Figure 16-106 to Figure 16-109) and drawdown (Figure 16-110 to Figure 16-115) show there will be little, if any, change to average water table elevations below Ogmore and beyond the boundaries of ML 80187, and so there is little to no risk of the Project causing onset of ASS conditions **SEAWATER – FRESH WATER INTERFACE** ▪ Predicted contours of water table elevation (Figure 16-106 to Figure 16-109) and drawdown (Figure 16-110 to Figure 16-115) show there will be little, if any, change to average water table elevations along Styx River or below Ogmore, indicating the potential for mobilisation of the seawater-fresh water interface (which has not been observed at confluence of Styx River and Broad Sound estuary) is negligible	GDEs *Type 1* *Type 2* *Type 3*	 NI Aquatic ecosystems NI	▪ GDEs - Little potential exists for salinisation of groundwater resources supporting GDEs, including possible mobilisation of the seawater-freshwater interface - Little potential exists for GDEs to be impacted by AMD or ASS ▪ Third party groundwater users - Little potential exists for salinisation of groundwater resources supporting third party users, including possible mobilisation of the seawater-freshwater interface - Little potential exists for third party users to be impacted by AMD or ASS ▪ Cultural and spiritual - Little potential for groundwater quality change exists to impact on cultural or spiritual values	▪ **Low** to **moderate** threat of adverse impact associated with water quality change
	Third party users	▪ Stockwater ▪ Irrigation ▪ Farm supply use		▪ **Low** to **moderate** threat of adverse impact associated with water quality change
	Other	▪ Cultural and Spiritual		▪ **Low** to **moderate** threat of adverse impact associated with water quality change

Table 16-94 Summary details effects, receptor exposure assessment and threat assessment - groundwater and surface water interaction

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
BASEFLOW ▪ Pre-mine - Predicted pre-mine steady state water table contours are consistent with inferred water table contours (Figure 16-81), with regional groundwater flow to the north (toward coast), and a component of local groundwater flow occurring toward watercourses (baseflow and ET) ▪ Mine - Model-generated hydrographs (see Figure 16-116) show baseflow / ET along the upper reach of Tooloombah Creek and tributaries is predicted to remain unchanged from the pre-mine condition, but there is a predicted reduction along the mid to lower reach of up to around 37% - Model-generated hydrographs (see Figure 16-117) show baseflow / ET along the upper (and tributaries) and lower reaches of Deep Creek is predicted to decline by less than 10% from the pre-mine condition, with a predicted reduction along the mid (and tributaries) of Deep Creek of more than 40% - Predicted water table elevation and drawdown contours indicate there is negligible, if any, baseflow decline to Styx River and Broad Sound estuary ▪ Post-mine - Model-generated hydrographs (see Figure 16-116) show baseflow / ET recovery commences along the mid to lower reach of Tooloombah Creek prior to completion of mining (from around year 12) - Model-generated hydrographs (see Figure 16-117) show baseflow / ET recovery along the affected reaches of Deep Creek commences after mining (and dewatering / depressurisation) is completed **PERCHED WATER TABLES / RAISED WATER TABLES** ▪ Seepage from waste management facilities - Potential for perched water tables to form unlikely due to permeability difference between waste materials and alluvials, so little opportunity for perched water tables to interact with drainages ▪ Hydraulic loading from waste management facilities / stockpiles - Hydraulic loading is predicted to have negligible effect on long-term water table elevation and baseflow conditions **SEEPAGE RELATED DRAWUP** ▪ During mining - Around the mine pits, the maximum predicted potentiometric surface drawdown beneath water storages exceeds 10m, which reduces the potential for water table drawup	GDEs *Type 1* *Type 2* *Type 3*	 NI Aquatic ecosystems NI	▪ Baseflow reduction will likely occur along the mid-lower reaches of Tooloombah Creek and tributaries during mining, and this will persist for up to 80 years post-mining, with recovery to around 90% of the baseline not occurring until around 50 years post-mine ▪ Baseflow reduction will likely occur along the entire modelled reach of Deep Creek and tributaries during mining. This effect will persist for up to 80 years post-mining, with recovery to 90% of baseline flow in the mid-reach not occurring until around 60 years post-mine. ▪ The reaches adjacent to the mine (i.e. the mid-reach of both creeks) are predicted to experience a substantially larger baseflow reduction than the upper or lower reaches.	▪ Type 1 GDEs - Unaffected by potential baseflow reduction / groundwater - surface water interactions ▪ Type 2 GDEs - Tooloombah Creek - **High** threat of adverse impact along the mid-lower reach - **Low** threat of adverse impact along the upper reach - Deep Creek - **High** threat of adverse impact along the mid reach - **Moderate** threat of adverse impact along the upper and lower reaches
	Third party users	▪ Stockwater ▪ Irrigation ▪ Farm supply use	▪ Reduction in base flow is unlikely to directly impact on third party users	▪ Negligible threat posed to third party users as a result of baseflow impacts
	Other	▪ Cultural and Spiritual	▪ Receptor exposure assessment likely corresponds to GDE exposure assessment	▪ Threat likely corresponds to GDE threat assessment

Table 16-95 Summary details effects, receptor exposure assessment and threat assessment – physical disruption of aquifers

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
MINE PITS ▪ Mine - Mining involves excavating / removal of ore and waste (barren) materials - Mine pit development does not require removal of Type 1, Type 2 or Type 3 habitat (refer Figure 16-103) - From a hydrogeological perspective, mining intersects and removes HSUs (aquifer and aquitards), thereby disrupting the baseline hydrogeological setting - As mining progresses, the pits will be backfilled, with backfilled materials compacted using trucks, potential exists for materials to have higher K and S values cf. in-situ materials - Coal measures coal seams/interburden and overburden materials will be backfilled first, followed by alluvium to reimpose to the extent possible baseline hydrostratigraphy ▪ Post-mining - Backfilling of mine pits will allow the groundwater system (quantity and quality) to recover toward pre-mine (baseline) conditions **WASTE ROCK STOCKPILES** ▪ Mine - Waste stockpiling does not require removal of Type 1, Type 2 or Type 3 habitat (ref Figure 16-99) - Waste materials (coal measures coal seams/interburden and overburden) and alluvium materials will be kept separate and stockpiled (see Figure 16-12 for general arrangement of stockpiles) - The stockpiles have the potential to load the unconsolidated sediments on which they are placed, and possibly cause subtle changes (reduction) to alluvium HSU hydraulic properties (e.g. hydraulic conductivity, porosity and storativity) - The effects of loading of the sediments could result in backing up of hydraulic gradients upstream of the stockpiles (possibly reducing impacts to Type 2 and 3 GDEs), and reducing groundwater discharge to the dewatered pits, although modelling suggests this effect is unlikely to be significant - If water tables were to rise due to hydraulic loading, it is considered unlikely they will rise close to ground surface (see Figure 16-82 for baseline depth to water table upstream of the mine) - As pits will be progressively backfilled during mining, the effect of loading effect will be less than would be the case if backfilling did not occur or was delayed until after mining is completed ▪ Post-mine - Due to bulking, it is expected that small waste storages will need to remain in place after closure - Any effect of loading will persist through to the post-mine period, although this is likely to be negligible	GDEs *Type 1* *Type 2* *Type 3*	 NI Aquatic ecosystems NI	▪ Mine pits - During mining, the development of mine pits will temporarily interfere with the local-scale alluvium and coal measures HSUs, resulting in dewatering and depressurisation of adjacent stratigraphy, which will alter access to groundwater by GDEs - Backfilling of the mine pits will allow GDEs to regain access to groundwater at some time after mining and, if impacted, re-establish, i.e. the interference is not permanent, with recovery commencing from year 10 post-mine ▪ Waste storages and stockpiles - Due to progressive backfilling of mine pits, the impact of loading of hydraulic HSUs by waste storages and stockpiles is expected to be limited, and may assist in reducing effects on nearby GDEs - Effect is predicted to be limited / negligible	▪ GDEs - **Low** threat of adverse impact in response to mine pit development and backfilling - **Low** threat of adverse impact in response to waste storages and stockpiling
	Third party users	▪ Stockwater ▪ Irrigation ▪ Farm supply use	▪ Mine pits - The development of mine pits is unlikely to significantly impact on third party groundwater users, as the pits will occur some distance (~1 km) from the nearest identified bore (BH28/28A), where available drawdown is predicted to not be critically impacted ▪ Waste storages and stockpiles - The development of waste storages and stockpiles is also unlikely to significantly impact on third party groundwater users for reasons outlined above	▪ Third party users - **Low** threat of adverse impact in response to mine pit development and backfilling - **Low** threat of adverse impact in response to waste storages and stockpiling
	Other	▪ Cultural and Spiritual	▪ Aesthetic impact is likely, but only in relation to the infrastructure and not due to groundwater effects	▪ Threat likely corresponds to GDE threat assessment