Central Queensland Coal Project

Chapter 9 – Surface Water

Supplementary Environmental Impact Statement

CDM Smith

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Central Queensland Coal Project

Chapter 9 – Surface Water

20 December 2018

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9 Surface Water

This chapter describes the Environmental Values (EVs) of surface water resources that may be affected by the Central Queensland Coal Project (the Project). Existing water quality conditions for surface waters upstream, downstream and within the Project area and potential changes to the hydrological regime, flooding and surface drainage because of the proposed activities are discussed. Potential impacts of the Project on the existing water quality EVs are outlined and appropriate mitigation measures are proposed to manage any impacts.

This chapter has been updated to include further surface water baseline data obtained from ongoing monitoring programs between February 2017 and October 2018. The baseline water quality description has been updated reflecting the additional data. The chapter has also been updated to address comments received in submissions to the EIS. This chapter should be read in conjunction with the following chapters, where comments received in submissions in respect of surface water and water quality have addressed:

- Chapter 4 – Climate (climate change adaption);
- Chapter 5 – Land (erosion and sediment control management, acid sulphate soils management);
- Chapter 10 – Groundwater (surface water and groundwater interaction, saline water ingress, Groundwater Dependent Ecosystems (GDE));
- Chapter 14 – Terrestrial Ecology (GDE functioning);
- Chapter 15 – Aquatic Ecology (ecological functioning in the aquatic environment); and
- Chapter 21 – Hazard and Risk.

Appendix A5a – Surface Water and Groundwater Quality Results and Appendix A5b – Historical Surface Water Quality Results present the laboratory data used in this assessment. Note that Appendix A5b – Historical Surface Water Quality Results references the original proponent; Styx Coal Pty Ltd, and the original Project name, Styx Coal Mine Project; however, the Central Queensland Coal Pty Ltd is the new proponent for the Project and the Project has been renamed as Central Queensland Coal Project to better reflect the change of Proponent. This proponent and title change does not affect the technical studies.

9.1 Project Overview

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 train loadout facility (TLF).

The Project is located 130 km northwest of Rockhampton in the Styx Coal Basin in Central Queensland. 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 million tonnes per annum (Mtpa) of semi-soft coking coal (SSCC) and high grade thermal coal (HGTC). 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. It is intended that all aspects of the Project will be authorised by a site specific environmental authority (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. 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 and 2038.

A new 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 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.

This SEIS supports the original EIS by including responses to submissions that were made during the public notification period regarding the original EIS. Material changes to the Project since the release of the EIS are also discussed.

9.2 Relevant Legislation, Plans and Guidelines

Chapter 1 - Introduction presents the regulatory framework relevant to the Project. Those that relate to water are:

- *Environmental Protection Act 1994* (EP Act);
- *Environmental Protection (Water) Policy 2009* (EPP Water);
- *EP Act Guideline: Application Requirements for Activities with Impacts to Water version 2* (EHP 2014);
- *Water Act 2000* (Water Act);
- *Fisheries Act 1994;*
- Department of Environment and Heritage Protection (EHP) Queensland Water Quality Guidelines 2009 (QWQG); and

- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000) (herein referred to as the ANZECC guidelines).

The following Codes and Manuals apply to the Project in the context of flooding, drainage structure design and regulated structure assessment:

- Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EHP 2016);
- State Development Assessment Provisions (DILGP 2013), 5.2 Constructing or raising waterway barrier works in fish habitats state code, and
- State Development Assessment Provisions: State Code 18: Constructing or raising waterway barrier works in fish habitats (DSDMIP 2018).

This assessment has been prepared to address the requirements of the Terms of Reference (ToR) by establishing the existing surface water EVs under the relevant legislation, plans and guidelines and assessing the potential impacts on the EVs by the Project.

9.2.1 Environmental Protection Act 1994

The EP Act provides the key legislative framework for environmental management and protection in Queensland. The object of the EP Act is to 'Protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes on which life depends' (s3).

The EP Act has a range of subordinate legislation which assists in achieving the object, including the EP Regulation and EPP Water. Among certain aspects, the EP Regulation controls activities with potential to release contaminants into the environment (Environmentally Relevant Activities [ERAs]); contains referrable wetland requirements, prescribes water contaminants (Schedule 9) and sets EVs for wetlands (s 81A). The EP Act and EP Regulation regulate mining and associated ERAs through EA conditions. These conditions provide a means to regulate surface water management for the Project.

9.2.2 Environmental Protection (Water) Policy 2009

The EPP (Water) seeks to achieve the objectives set within the EP Act in relation to Queensland waterways. That is, it seeks to: 'Protect Queensland's waters while allowing for development that is ecologically sustainable' (s3 EP Act).

This purpose of this policy is achieved by:

- Identifying EVs and management goals for Queensland waters;
- Stating water quality guidelines and water quality objectives to enhance or protect the EVs;
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- Monitoring and reporting on the condition of Queensland waters.

Schedule 1 of the EPP (Water) defines EVs for waters within Queensland. EVs and water quality objectives (WQOs) are prepared for drainage basins (at the sub-basin level); however, the setting of values and objectives is at different stages of development throughout Queensland. These EVs and WQOs are set under the EP Act, and its subordinate legislation, while basin resource plans are set under the Water Act.

9.2.3 Sub-basin EVs and WQOs

The Project is wholly contained within the Styx River Basin (Figure 9-1). Specific EVs and WQOs for the Styx River Basin were released in 2014 as part of the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014a).

9.2.4 Water Act 2000

The Water Act provides a structured system for the planning, protection, allocation and use of Queensland's surface waters and groundwater. Under section 808 of the Water Act, a person must not take, supply or interfere with water unless authorised. Authorisation under the Water Act for the taking of water from overland flow, groundwater, a watercourse, lake or spring comes via a water entitlement and a development application.

The Water Act provides for the protection of natural ecosystems and security of supply to water users through the development of water resource plans (WRPs), and other activities. Each managed catchment in Queensland has a separate WRP and associated Resource Operations Plan (ROP) to provide a framework to apply (under the Water Act, Chapter 2 Part 6) and regulate water extractions to ensure that they are maintained as a sustainable resource. The Project is located within the Styx River Basin, which is not covered by any WRP or ROP.

Tooloombah Creek and Deep Creek are both defined as watercourses under the Water Act and border the MLA area to the east and west, respectively. Deep Creek is traversed by the haul road to the TLF and several first and second order drainage features are traversed by the haul road connecting Open Cut 1 to the MIA or diverted around mine pits. Water storage dams are also proposed to be located on first and second order drainage features (see Figure 9-2).

The following approval could potentially be required under the Water Act:

- Placing fill or excavating in a watercourse, as required for works associated with construction of haul roads, bridges and culverts under a Riverine Protection Permit (RPP) described in section 266 of the Water Act (if the works do not comply with the guidelines in 'Riverine protection permit exemption requirements' WSS/2013/726, Version 2.00' (DNRME 2018)).

As the proposed water related operational works will be located within a Mining Lease area, they are an authorised activity under the *Mineral Resources Act 1989* and EP Act. The Project has no requirement for an authorisation to divert the flow of water under the Water Act authorised under an EA; however, this does not exempt the Project from requiring an RPP where the activity does not meet the exemption requirements under the Water Act.

9.2.5 Planning Act 2017

Placing fill in a waterway or constructing waterway barrier works (as defined under the Fisheries Act) associated with the construction of haul road, bridges, culverts and any other waterway crossings outside the boundaries of the mining leases will be required to obtain development approval under the *Planning Act 2017* (Planning Act) where they do not comply with the requirements of a self-assessable code (DAFF 2013).

9.2.6 Fisheries Act 1994

The main purpose of the *Fisheries Act 1994* (Fisheries Act) is to provide for the use, conservation and enhancement of the fish resources and habitats to apply and promote the principles of Ecologically Sustainable Development (ESD). It regulates the taking and possession of specific fish, removal of marine vegetation, the control of development in areas of fish habitat and listed noxious fish species. Approvals for waterway barrier works within waterways are not required for works within a ML area. The *Mineral Resources Act* 1989 states that the Planning Act does not apply to development authorised under the *Mineral Resources Act 1989.* The Fisheries Act is administered for development in a waterway through the Planning Act. An approval is not required for waterway barrier works within the mining lease area. Mining activities within lease boundaries are exempt from approvals under the Planning Act. Approval under the Planning Act is required for waterway barrier works that are off-lease.

All waters of the state are protected against degradation by direct or indirect impact under s125 of the EP Act. If litter, soil, a noxious substance, refuse or other polluting matter is on land, in waters or in a fish habitat and the polluting adversely affects fisheries resources or habitat then penalties apply. There is no mapped fish habitat area within the Project area.

9.2.7 Environmental Offsets Act 2014

The *Environmental Offsets Act 2014* (EO Act), Environmental Offsets Regulation 2014 and the Queensland Government Environmental Offsets Policy provides a streamlined framework for environmental offset requirements. Offsets are required where there is an unavoidable impact on significant EVs. A fish habitat area declared under the Fisheries Act is a matter of environmental significance under the EO Act. Also, if the modification of a waterway barrier works will limit the passage of fish then the waterway providing for the passage of fish is a matter of State environmental significance under the Environmental Offsets Regulation 2014.

In addition, an environmental offset can only be required if impacts from a prescribed activity constitute a significant residual impact as identified through the following guidelines:

- The State guideline that provides guidance on what constitutes a significant residual impact for MSES;
- The Commonwealth Significant Impact Guidelines for what constitutes a significant residual impact on MNES; and
- Any relevant local government significant impact guideline for Matters of Local Environmental Significance (MLES).

To avoid duplication with offsets required under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the policy provides that the administering agency must consider other relevant offset conditions which are for the same or substantially the same prescribed impact. If duplicating conditions are imposed, it allows the proponent to remove the duplication.

9.2.8 Queensland Water Quality Guidelines 2009

The Queensland Water Quality Guidelines (EHP 2009) (QWQG) provide tailored guideline values for Queensland water types and regions. The QWQG also provide a framework for deriving and applying specific guidelines that are local to the waterways in Queensland. Where more locally relevant guidelines are appropriately developed and meet relevant technical requirements (such as those identified in QWQG), then they would in turn take precedence. Locally accepted WQOs are listed under Schedule 1 of the EPP (Water). The Project is wholly contained within the Styx River Basin, which has specific WQOs under Schedule 1 of EPP (Water) that take precedence over the QWQGs.

9.2.9 Australian and New Zealand Guidelines for Water Quality 2000

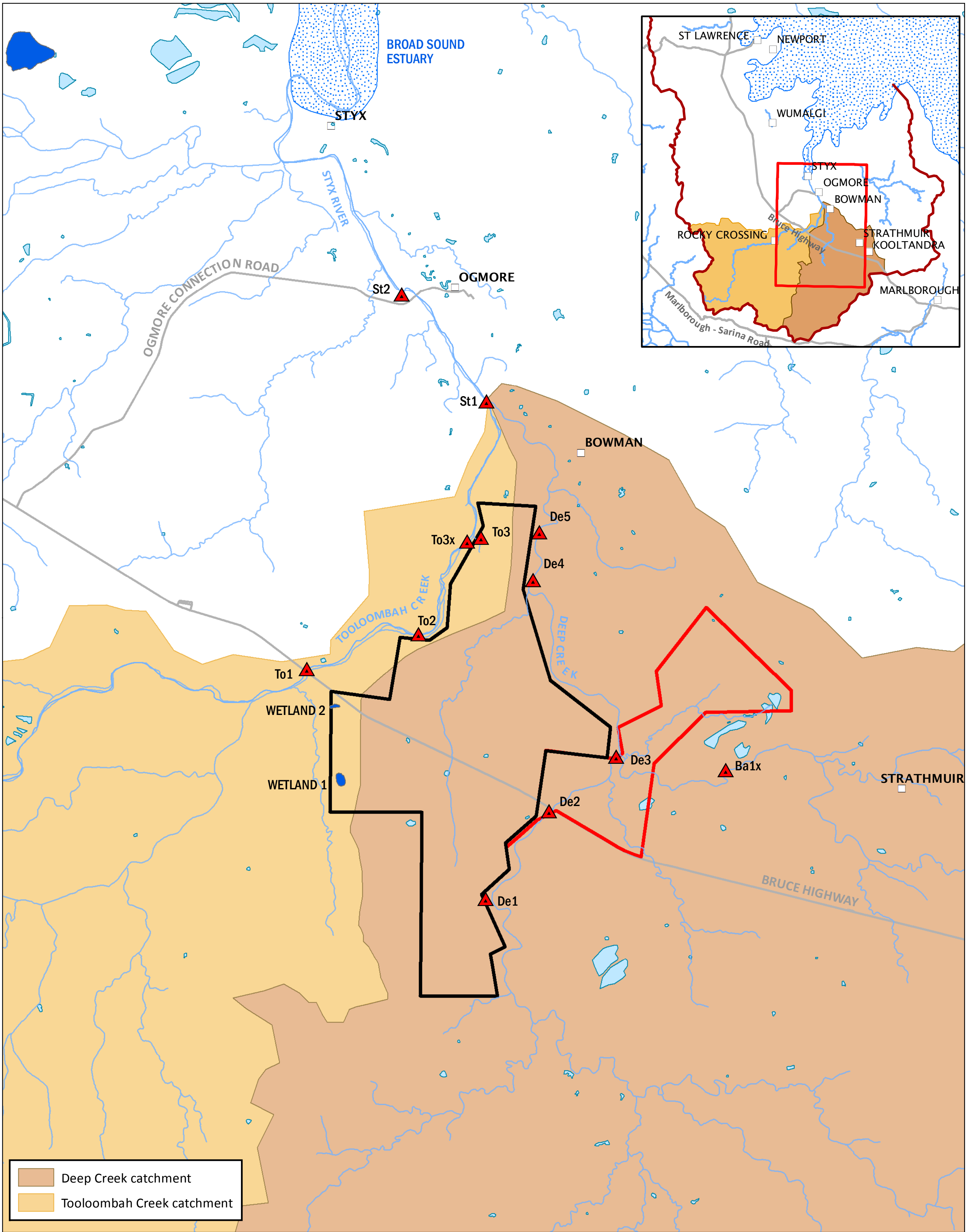
The ANZECC fresh and marine water quality guidelines provide a baseline for monitoring and measuring surface water quality for different ecosystems within Australia and New Zealand. The ANZECC guidelines provide threshold values that identify water quality levels based on multiple chemical and physical parameters. For example, the level of water quality at a certain site can be determined by comparing a range of parameters (e.g. pH, turbidity and conductivity) against threshold values outlined by the ANZECC guidelines. For this section, WQOs for toxicants (metals, inorganics etc.) have been based on the ANZECC guidelines, as per the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014a) (see Section 9.3).

Sediments can act as a source or sink for contaminants, thereby directly affecting the quality of surface waters. For this section, this Guideline will also be used to compare sediment quality data obtained from on-site sampling (for the Project baseline study) against the Interim Sediment Quality Guidelines for toxicants in sediment (Section 3.5 ANZECC guidelines).

9.2.10 Other Guidelines

The following Codes and Manuals apply to the Project in the context of flooding, drainage structure design and regulated structure assessment:

- Guideline; Model mining conditions (ESR/2016/1936) (DES 2017);
- Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933) (EHP 2016);
- EIS Information Guideline – Regulated Structures;
- Guideline on structures which are dams or levees constructed as part of environmentally relevant activities (ESR/2016/1934) (EHP 2017a);
- State Development Assessment Provisions (DILGP 2013), 5.2 constructing or raising waterway barrier works in fish habitats state code; and
- State Development Assessment Provisions: State Code 18: Constructing or raising waterway barrier works in fish habitats (DSDMIP 2018).



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Legend

- Surface water monitoring site
- Styx River Basin
- Wetland (VM Act)
- Wetland (DIWA)
- Reservoirs
- ML 80187
- ML 700022
- Main road
- Major watercourse

Figure 9-1
Surface water catchments and monitoring locations

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

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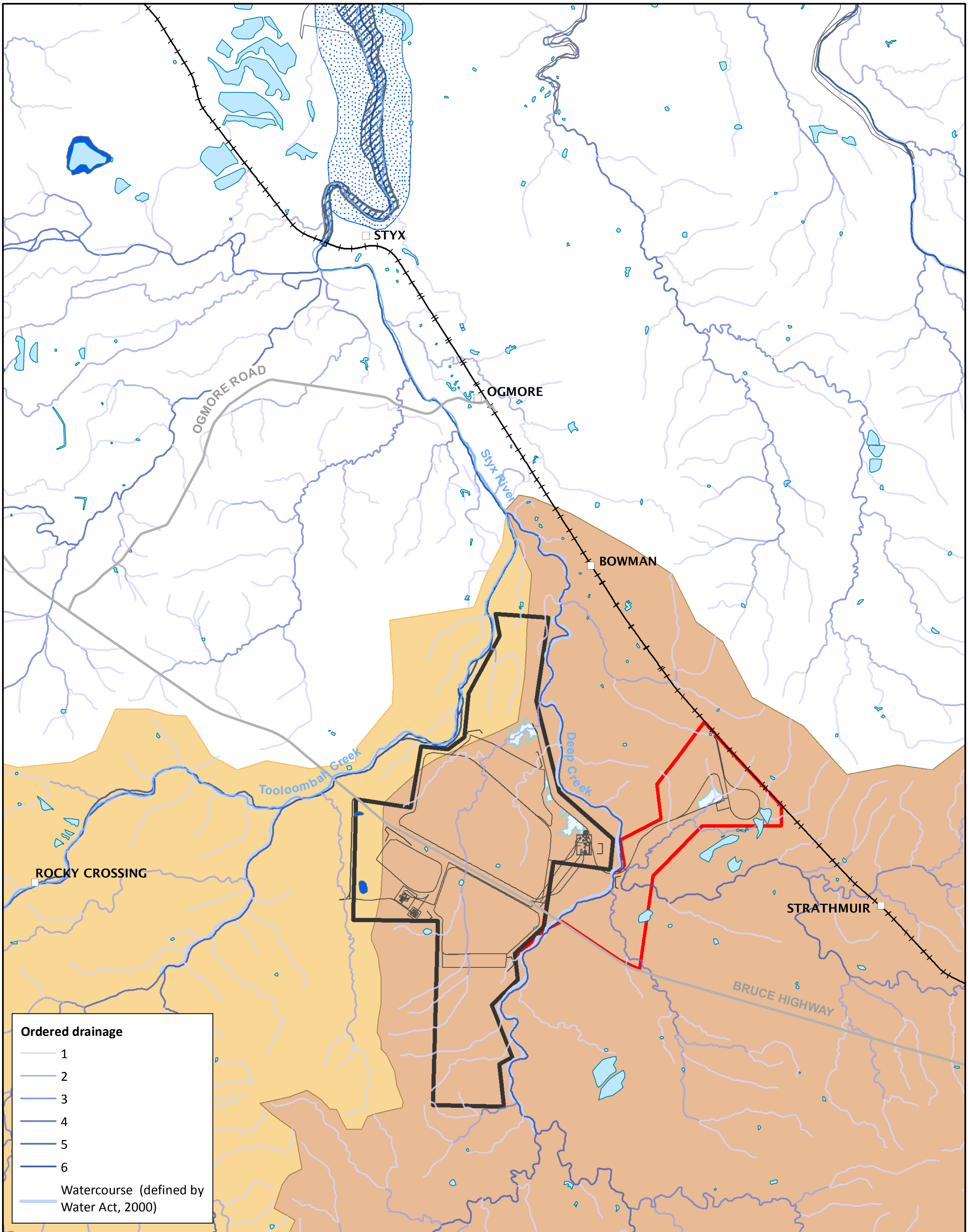
BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Surface_catchments&monitoring_locations_9-1.mxd 11/29/2018



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

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Figure 9-2

Local watercourses, drainage features, wetlands, dams and catchments

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

CDM Smith

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9.3 Environmental Objectives and Performance Outcomes

9.3.1 Environmental Objective

The environmental objectives relevant to surface water provided in Schedule 5 of the EP Regulation is to:

- Operate in a way that protects the EVs of water and wetlands;
- Locate operational activities in such a way that minimises serious environmental harm on areas of high conservation value and special significance and sensitive land uses; and
- Design the water management infrastructure and facilities in such a way that permits operation of the site in accordance with best practice environmental management.

9.3.2 Performance Outcomes

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

- The activity will be managed so that adverse effects on EVs are prevented or minimised;
- The activity will be managed in a way that prevents or minimises adverse effects on wetlands;
- Regulated structures will comply with the 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures' (EHP, 2016);
- Infrastructure will be designed with sufficient flood immunity as to prevent the contamination of otherwise clean water runoff from external contributing catchments;
- Infrastructure will be located outside of flood storage and flood conveyance areas to the extent possible and with the aim of minimising the impact of any activity on existing flood behaviour;
- The storage and handling of contaminants will include effective means of secondary containment to prevent or minimise releases to the environment from spillage or leaks;
- Contingency measures will prevent or minimise adverse effects on the environment due to unplanned releases or discharges of contaminants to water;
- The activity will be managed so that stormwater contaminated by the Project that may cause an adverse effect on an EV will not leave the site without prior treatment;
- Infrastructure and waterway crossings constructed using best practise design features to facilitate the passage of all fish species, on all flows as per consultation with Fisheries Queensland; and
- Stormwater drains and hydraulic structures such as spillways, culverts and floodways, will be designed with appropriate scour protection measures to reduce the migration of sediments to receiving waters.

9.4 Description of Environmental Values

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

The following terms for water are used herein:

- Watercourse – A significant / high order defined drainage feature of watercourse as classified by Department of Natural Resources, Mines and Energy(DNRME) (see Section 9.4.5);
- Drainage feature – A minor tributary that flows only intermittently and for the duration of rainfall events;
- Waterway – A creek or drainage feature with a defined bank, usually used in the context of defining impacts due to changes in water quality; and
- Waters – General term for a receiving body of water (creek, dam, pool etc.), usually used in the context of defining impacts due to changes in water quality.

9.4.1 Data Availability

The sources of available data used to inform this study are summarised in Table 9-1.

Table 9-1 Summary of data availability

Source	Data type(s)	Data period(s)
Bureau of Meteorology (BoM), 2018	▪ Temperature ▪ Rainfall (Strathmuir station 033189)	▪ 1941 - 2018
	▪ Evaporation (Rockhampton Aero station 39083)	▪ 1951 – 2017
	▪ Temperature (Rockhampton Aero station 39083)	▪ 1939 - 2017
Commonwealth of Australia (Geoscience Australia) 2011 1 Second SRTM v1.0	▪ Topography mapping products	▪ 2011
Styx Coal Project Lidar survey, 2017	▪ Surface elevation	▪ 2017
BoM Surface Cartography product of the Australian Hydrological Geospatial Fabric (Geofabric), 2017	▪ Hydrological mapping products	▪ Not applicable
ASRIS, 2011	▪ Soils mapping	▪ Not applicable
CSIRO, 2011	▪ Acid sulphate soil potential	▪ Not applicable
Queensland Government Groundwater Database (GWDBQ), 2018[1]	▪ Groundwater levels	▪ Single point data (assumed at time of drilling), no timeseries within Styx River catchment
	▪ Field measured groundwater quality (physico-chemical)	
	▪ Laboratory reported groundwater chemistry	
	▪ Groundwater yields	
	▪ Stratigraphy and hydrostratigraphy	▪ Not applicable
	▪ Hydrogeological properties	

Source	Data type(s)	Data period(s)
	Facility status	As at February 2018
Third party bore census[2]	Groundwater levels Field measured groundwater quality (physico-chemical) Laboratory reported groundwater chemistry	February 2017 – April 2018
	Bore purpose and use status	Anecdotal, where available
Styx Coal Project WMP bore (installed 2017 and 2018) drilling, testing and monitoring data[3]	Groundwater levels Field measured groundwater quality (physico-chemical) Laboratory reported groundwater chemistry	September 2017 – September 2018 2018
	Lithology (and inferred stratigraphy) Hydrogeological properties	Not applicable
Styx Coal Project exploration drillhole data	Groundwater levels	Unknown (assumed at time of drilling)
	Lithology (and inferred stratigraphy)	Not applicable
Styx Coal Project surface water monitoring data	Field measured water quality	June 2011 to October 2012 February 2017 to October 2018
	Laboratory reported water chemistry	June 2011 to October 2012 February 2017 to October 2018
Field observations and discussions with landholders/care takers	Streamflow frequency and magnitude	Anecdotal
	Occurrence of potentially groundwater dependent pools	2011; 2017 – October 2018
	Occurrence of vegetation communities	February 2017 January 2018
BoM GDE Atlas, 2017	Mapped potential Groundwater Dependent Ecosystems	Incorporating regional scale mapping up to 2017
Bureau of Mineral Resources Saint Lawrence 1:250,000 Geological Series map sheet, 1970	Contextual information	Not applicable
Geoscience Australia Hydrogeology map of Australia 1:5,000,000	Contextual information	Not applicable
BoM National Groundwater Information System	Contextual information	Not applicable
BoM Groundwater Cartography product of the Australian Hydrological Geospatial Fabric (Geofabric), 2017	Contextual information	Not applicable

Notes:
1. A total of 447 bores are identified within a 50 km radius of the Project, 118 of which are within the Styx River Catchment and have been used to inform the hydrogeological conceptualisation.
2. A total of 31 locations were visited, of which 26 are existing and have been used to inform the hydrogeological conceptualisation.
3. A total of 16 monitoring bores were installed for the Project in late 2017 and early 2018.

9.4.2 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 9-3. 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 the Rockhampton Aero, approximately 112 km from the Project, with records dating back to 1939 (no temperature data are available for the Strathmuir station).

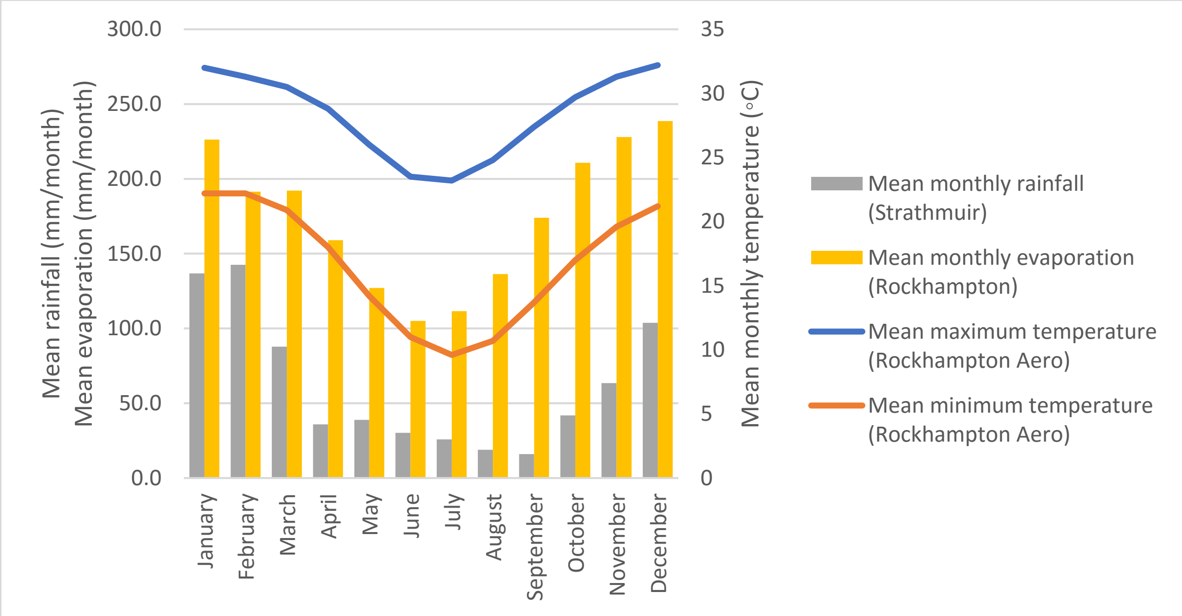


Figure 9-3 Mean climatic conditions

The Project region experiences a sub-tropical climate, with cool winters and hot summers. Mean winter (July) temperatures range between around 8 and 25°C, whilst mean summer (December-January) temperatures range between around 23 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 9-3). 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 plot of monthly rainfall at Strathmuir (BoM Station 033189) from January 1941 to October 2018 is presented in Figure 9-4.

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, and from 2010 to 2013;
- Below average rainfall occurring from approximately 1957 to 1971 and from 1991 to 2009; and

- Around average rainfall occurring from 1940 to 1950, from 1978 to 1990 and from 2014 to present.

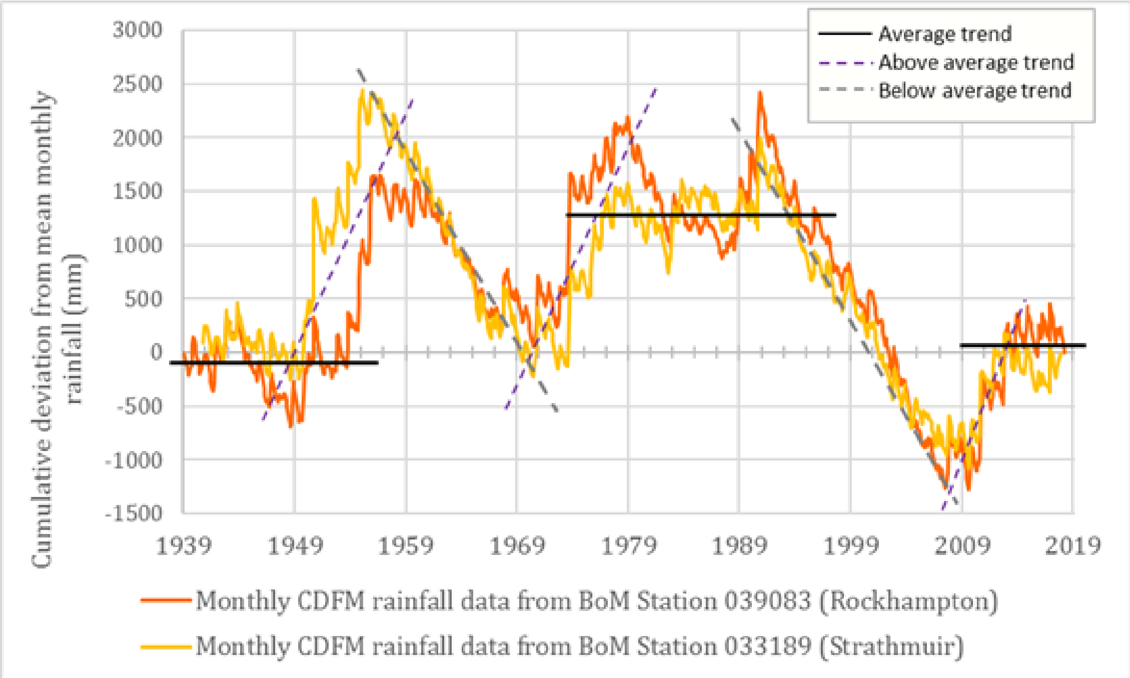


Figure 9-4 Cumulative deviation from mean monthly rainfall from BoM Station 033189 (Strathmuir) and 039083 (Rockhampton Aero)

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/month in the summer months to a minimum of around 105 mm/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 9-3).

9.4.2.1 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:

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

These coordinates represent the approximate location of the Project.

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. Table 9-2 and Figure 9-5 summarise monthly averages of the SILO long-term data.

Table 9-2 Data drill average monthly rainfall and evaporation

Month	Rainfall (mm)	Evaporation (mm)
January	159.7	199.6
February	140.0	165.9
March	91.3	177.7
April	36.8	141.0
May	33.5	115.1
June	38.1	96.6
July	25.2	103.3
August	20.0	125.9
September	18.3	156.1
October	46.2	205.2
November	62.7	217.5
December	108.0	223.3
Annual Average Total	779.8	1927.2

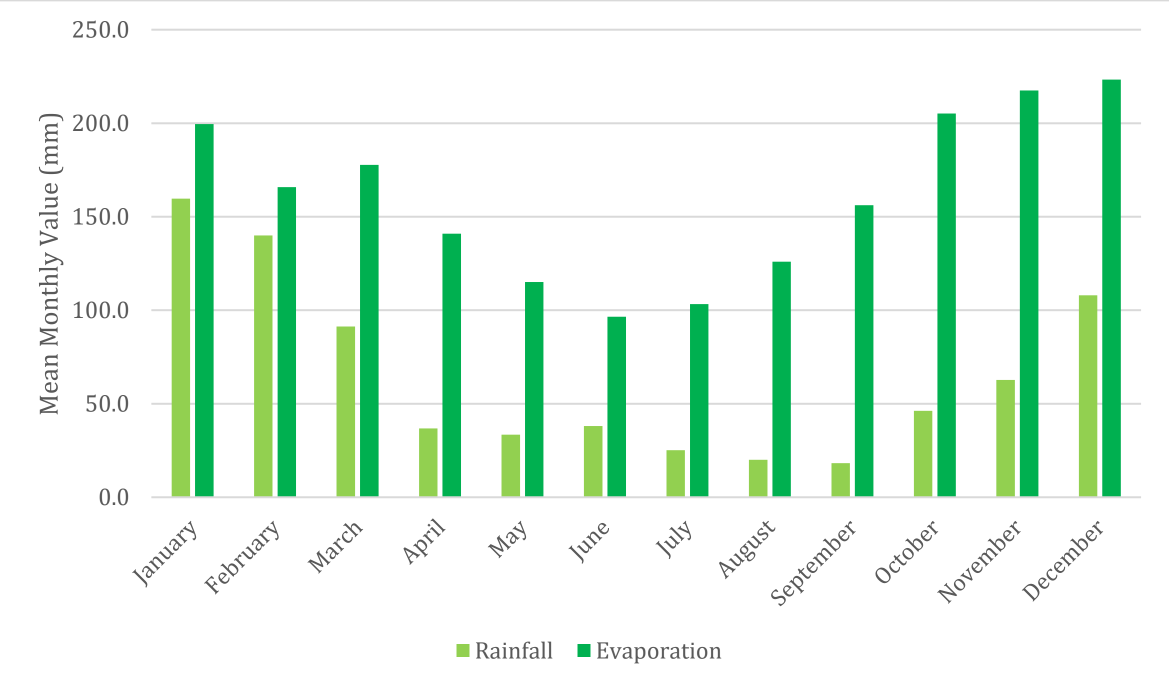


Figure 9-5 Graph of average monthly rainfall and evaporation from SILO

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.

9.4.2.2 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 9-6. The graph indicates good agreement between gauge records and data acquired through SILO.

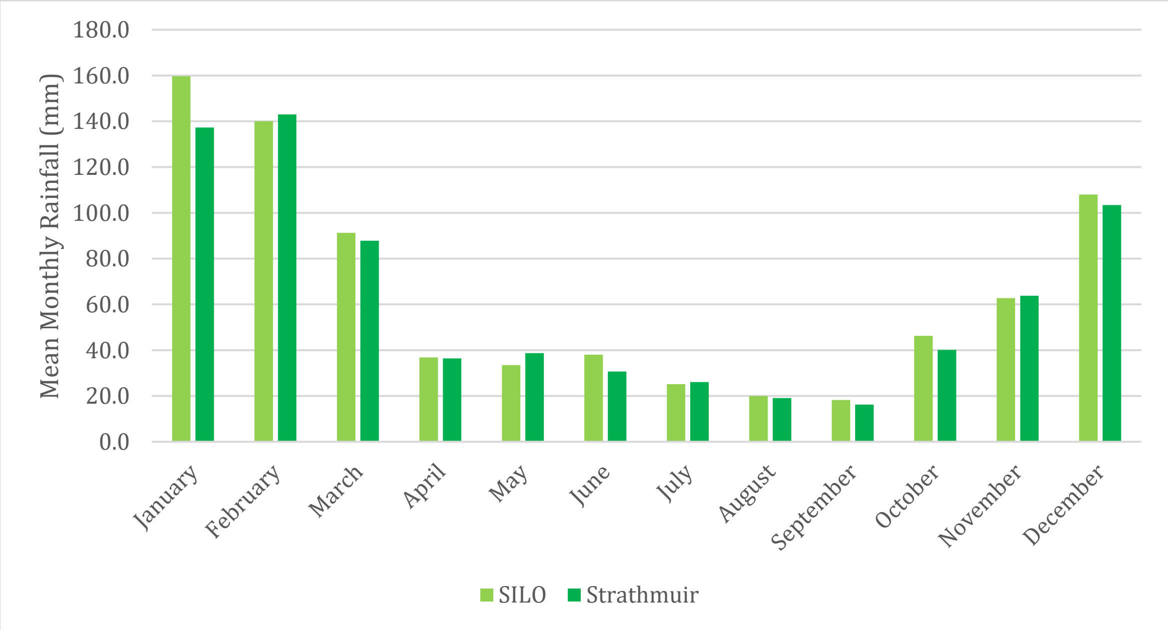


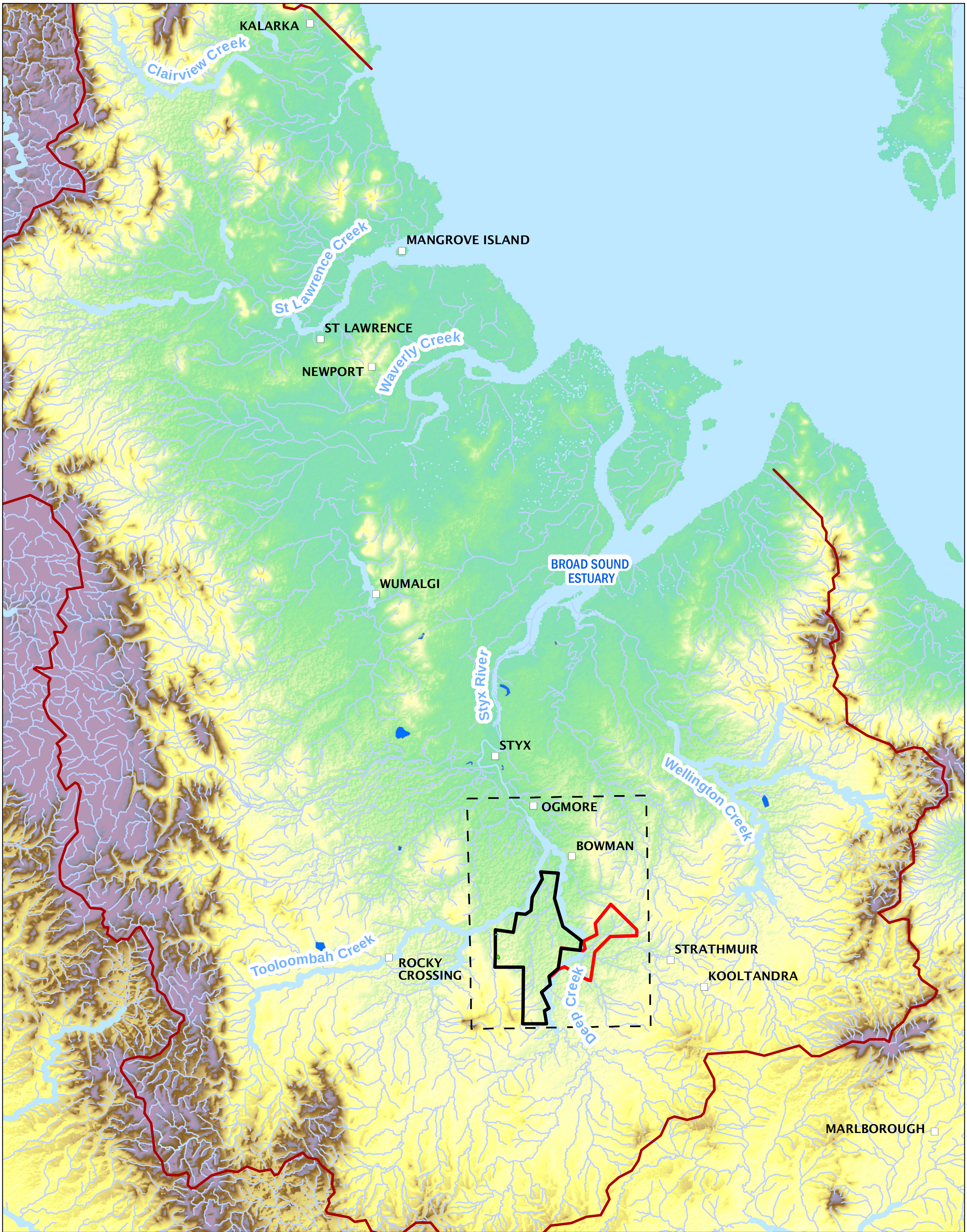
Figure 9-6 Comparison of SILO data to gauge data

9.4.3 Topography

A detailed description of the topographic setting of the Project is provided in EIS Chapter 5 – Land.

The Project lies within the Styx River catchment of the larger Styx River Basin, which has elevations ranging from 540 mAHD along the western catchment boundary to sea level at the coast (see Figure 9-7). Topography at the Project predominantly comprises flat or undulating lands ranging between around 10 and 155 mAHD. The area is drained by several tributary creeks to the Styx River and estuary, including Deep and Tooloombah Creeks (see Figure 9-7).

Acid sulphate soils (ASS) contain iron sulphides that have the potential to produce acid when exposed to oxygen, e.g. when drained or excavated. CSIRO National ASS mapping for the Styx River catchment is shown in Figure 9-8 and shows the catchment is classified as largely having low to extremely low probability of ASS, with only small pockets of high probability of ASS occurrence (e.g. around 7 km downstream of the Project, below Ogmore). ASS are discussed in detail in Chapter 5 – Land.



N

0 2.5 5 km

Scale @ A4 1:325,000
Date: 14/11/18
Drawn: Gayle B.

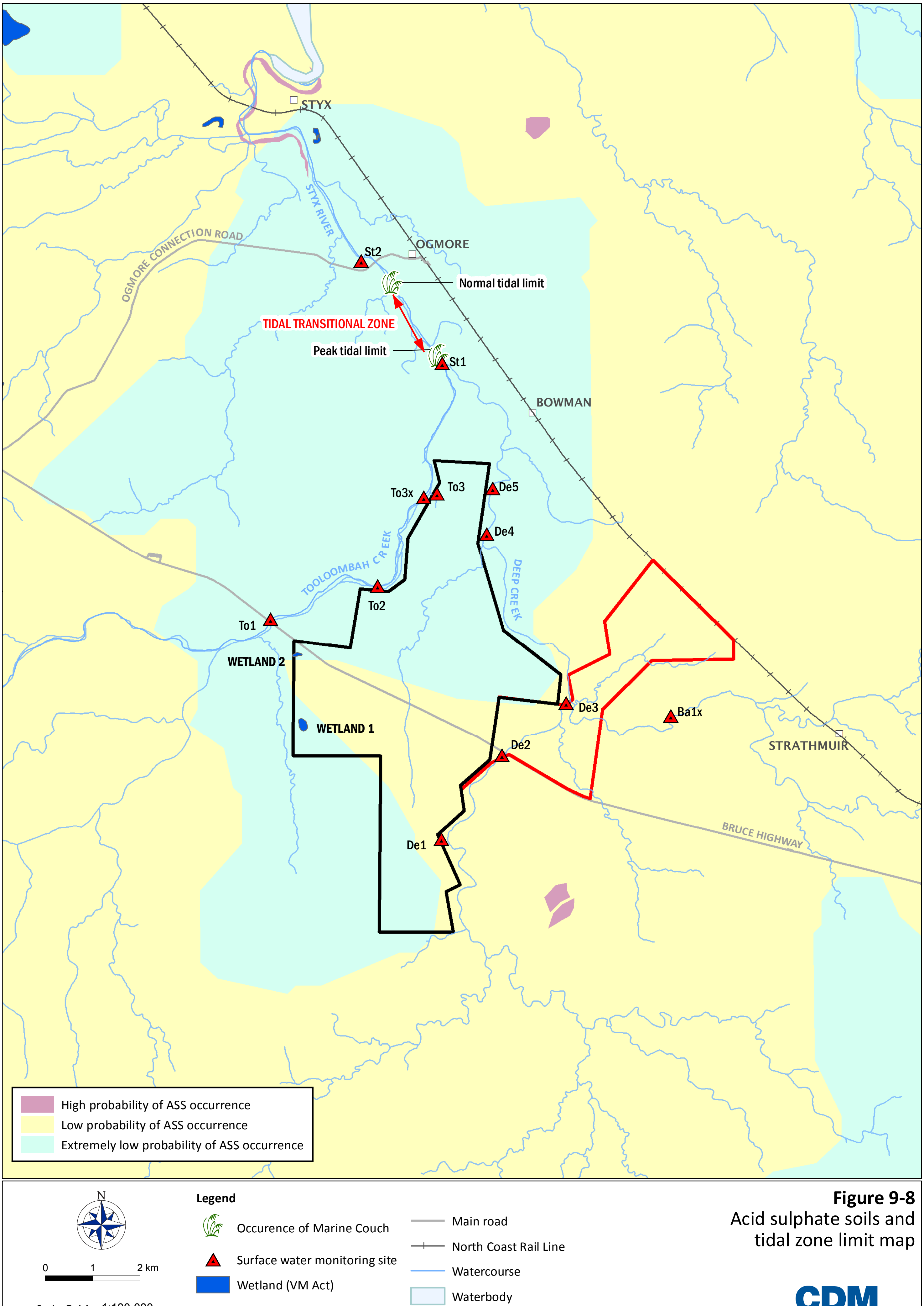
Legend

- Styx River Basin
- Watercourse/waterbody
- Wetland Protection Area
- Wetland (VM Act)
- Lidar survey extent
- ML 80187
- ML 700022

Surface Elevation (mAHD)
High : 620
Low : -10

Figure 9-7
Topography and hydrology

DATA SOURCE
QLD Open Source Data, 2018;
1 Second SRTM v1.0 © Commonwealth of Australia (Geoscience Australia) 2011;
Styx Basin modified from Waratah Coal and QLD Open source data, 2018
Waratah Coal, 2018



Scale @ A4 1:100,000
Date: 29/11/18
Drawn: Gayle B.

Figure 9-8
Acid sulphate soils and tidal zone limit map

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

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 acid sulphate soils_tidal zone limit__9-8.mxd 11/29/2018

9.4.4 Hydrology

The Styx River Basin comprises a number of distinct surface water catchments, including:

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

9.4.4.1 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 (see Figure 9-1). The Broad Sound estuary is listed in the Directory of Important Wetlands of Australia (DIWA).

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 9-8 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 9-8)
  - 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 9-8).

The Styx River discharges to the Great Barrier Reef Marine Park (see Figure 9-9), 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 2017). These wetland areas provide a diverse range of habitats for different wildlife and have been decreasing in size since 2001.

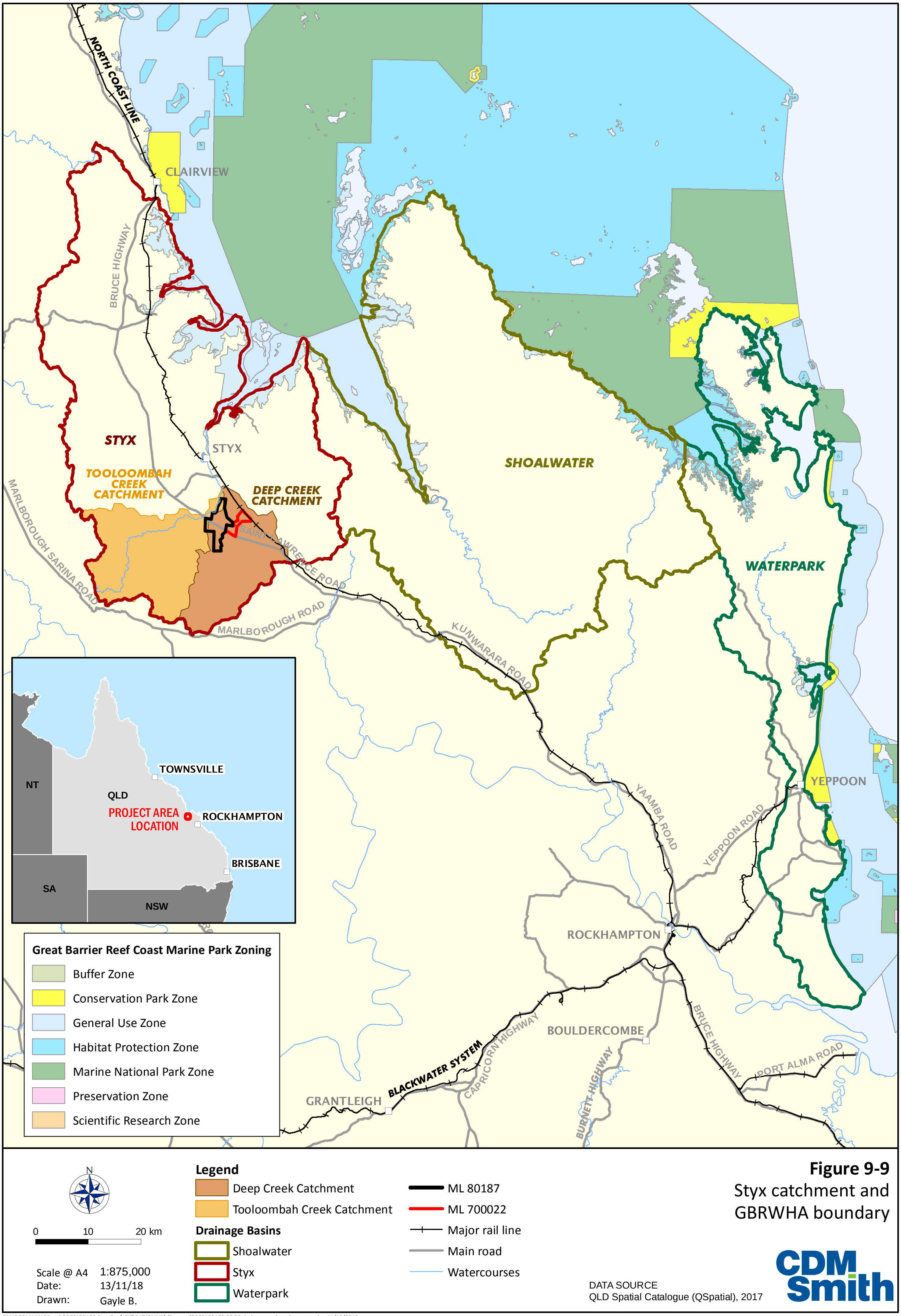


Figure 9-9
Styx catchment and GBRWHA boundary

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9.4.4.2 Deep Creek and Tooloombah Creek Sub-catchments

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.

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 to 3 m wide upstream and 5 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 and possibly erosion and stock having access to the pools. Surface water erosion (sheet and rill) is evident within the southern section of the Project Area where the local landowner has attempted to ameliorate the land 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 can persist for several days only. During high stream flow 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, possibly supported by creek gouge to the water table, is expected to sustain isolated pools along the creek bed between flow events. This interaction between surface water and groundwater is discussed further in Section 9.4.4.4.

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 9-1). Water salinity data (as electrical conductivity, EC) are presented at Figure 9-10 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. 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 on Figure 9-12 and Figure 9-13. As expected, the Piper plot and Stiff patterns shows Deep Creek water chemistry is more similar to Rockhampton rainfall than it is to seawater. The Stiff patterns (Figure 9-12 and Figure 9-13) 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 Section 9.4.4.4.

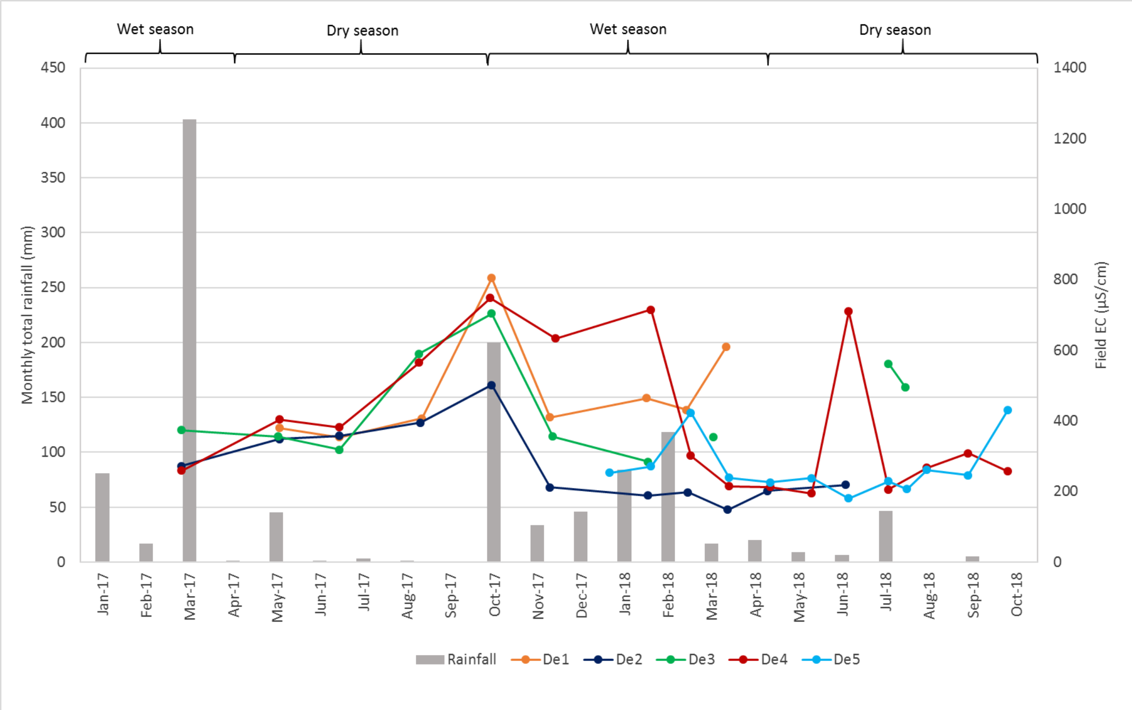


Figure 9-10 Deep Creek field EC - 2017 and 2018

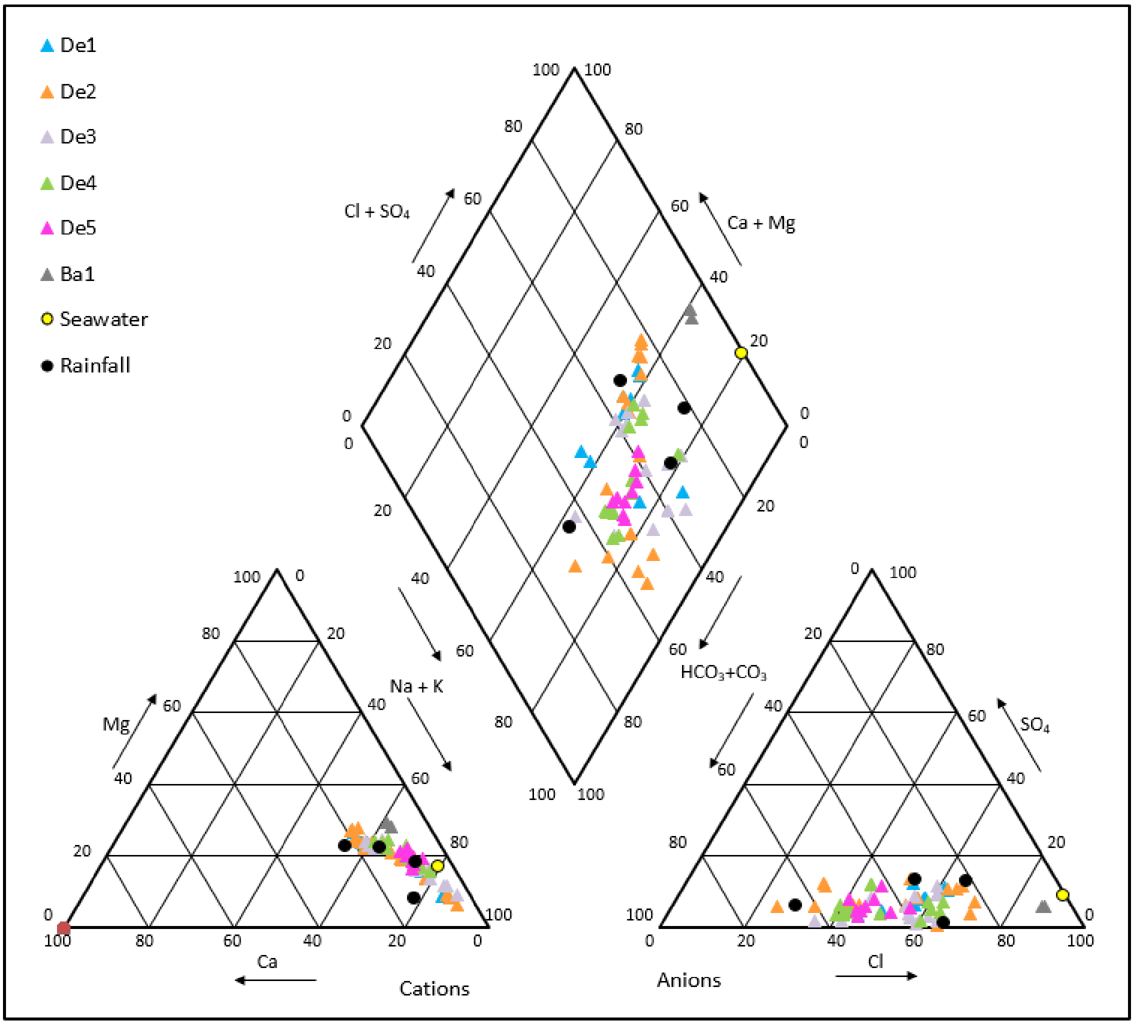


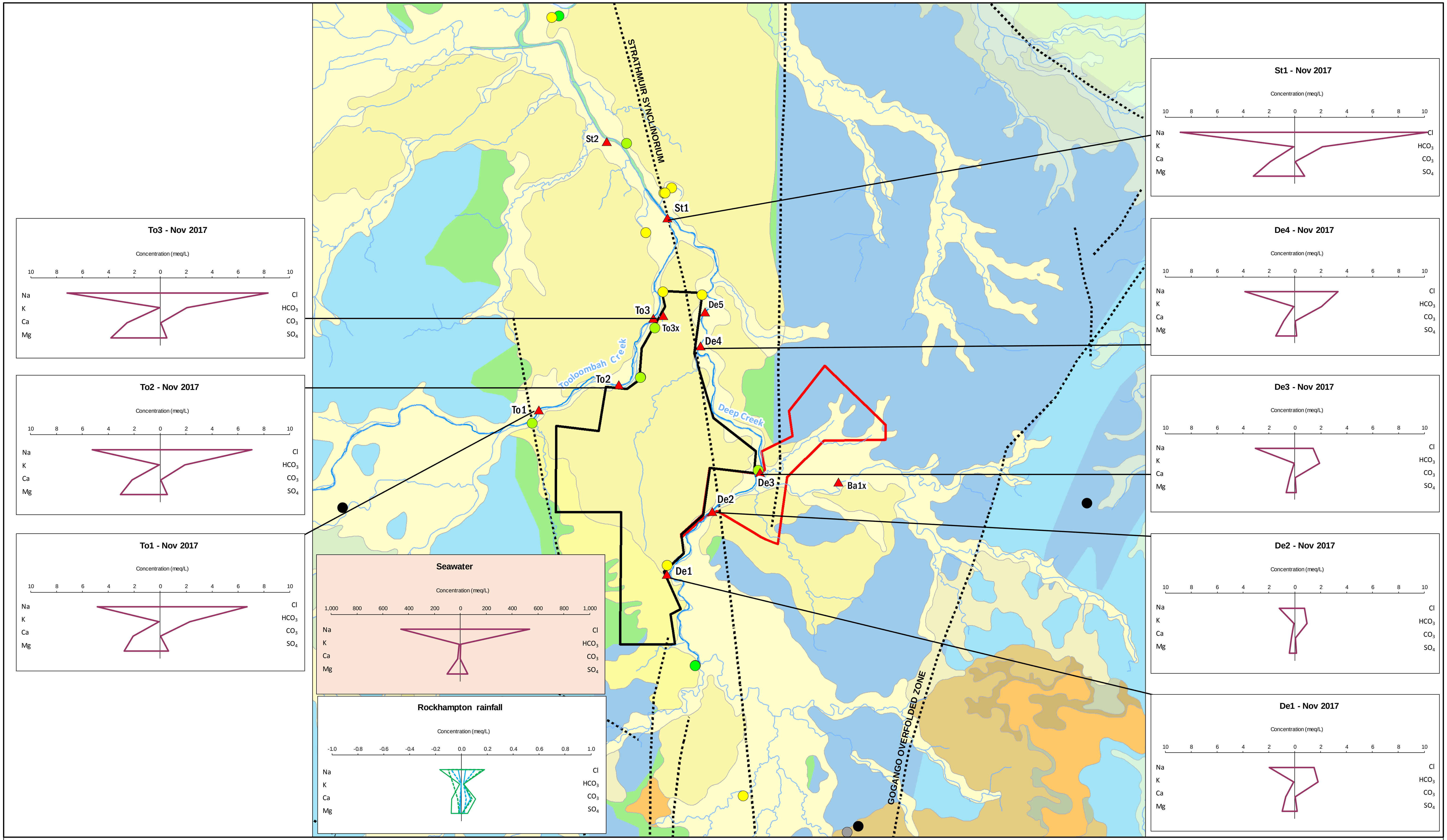
Figure 9-11 Deep Creek water quality Piper Diagram

Tooloombah Creek

The tributary headwaters of Tooloombah Creek rise to the southwest of the Project area, where elevations of around 360 mAHD occur. The creek runs in a general north easterly direction adjacent to western Project boundary before joining Deep Creek around 2 km downstream. 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; see Figure 9-1).

In an 'average year', Tooloombah Creek may have around three flow events, 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 short catchment. During extreme rainfall events, such as Cyclone Debbie during 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.



Legend

Groundwater quality sample locations

Aquifer

- Alluvium
- Alluvium and Styx Coal Measures
- Tertiary
- Styx Coal Measures
- Other

- Surface water sampling location
- Watercourse/waterbody
- ML 80187
- ML 700022

Refer Figure 10-16 for geology legend

0 1 2 km

Scale @ A3 1:100,000
Date: 14/11/18
Drawn: KMH

Figure 9-12

Surface water Stiff patterns – November 2017 sampling

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018;
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

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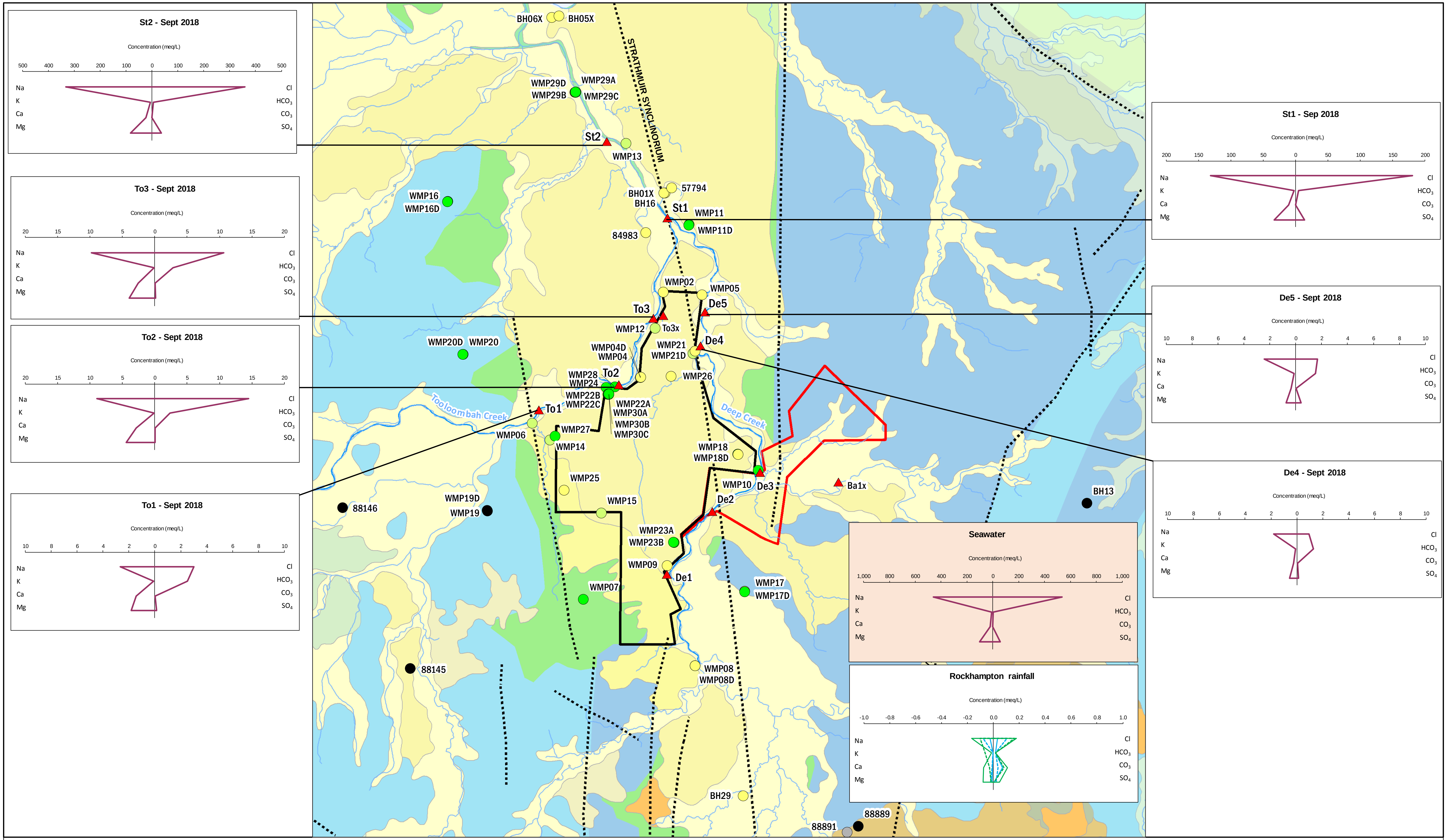

N

Legend

Groundwater quality sample locations

Aquifer

- Alluvium
- Alluvium and Styx Coal Measures
- Styx Coal Measures
- Tertiary sediments
- Basement / other

- Surface water sampling location
- Watercourse/waterbody
- ML 80187
- ML 700022

Refer Figure 12 for geology legend

0 1 2 km

Scale @ A3 1:100,000

Date: 14/11/18

Drawn: KMH

Figure 9-13

Surface water Stiff Patterns – September 2018 sampling

DATA SOURCE

QLD Open Source Data, 2018;

Waratah Coal, 2018

Styx basin modified from Central Queensland Coal and Qld Open Source Data, 2018;

St. Lawrence 1:250k geological map, BoMN, 1970;

Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

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Surface water samples have been periodically collected from monitoring locations along Tooloombah Creek adjacent the western boundary of ML 80187 in 2011, 2012, 2017 and 2018 (refer Figure 9-1 for locations). Water salinity (as EC) is presented on Figure 9-14 for 2017 and 2018 sampling events (there is insufficient data to present 2011 and 2012 data), and shows that the salinity is generally higher than Deep Creek, ranging from around 170 to 2,700 µS/cm EC.

A seasonal influence is evident, with salinity generally increasing during periods of dry / no flow and following the first flush of salts and nutrients experienced at the beginning of the wet season. The higher water salinity concentrations are possibly evidence of a greater degree of groundwater – surface water interaction along Tooloombah Creek than is evident along Deep Creek or a possibly more saline catchment.

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. 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. 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 9.4.4.4 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.

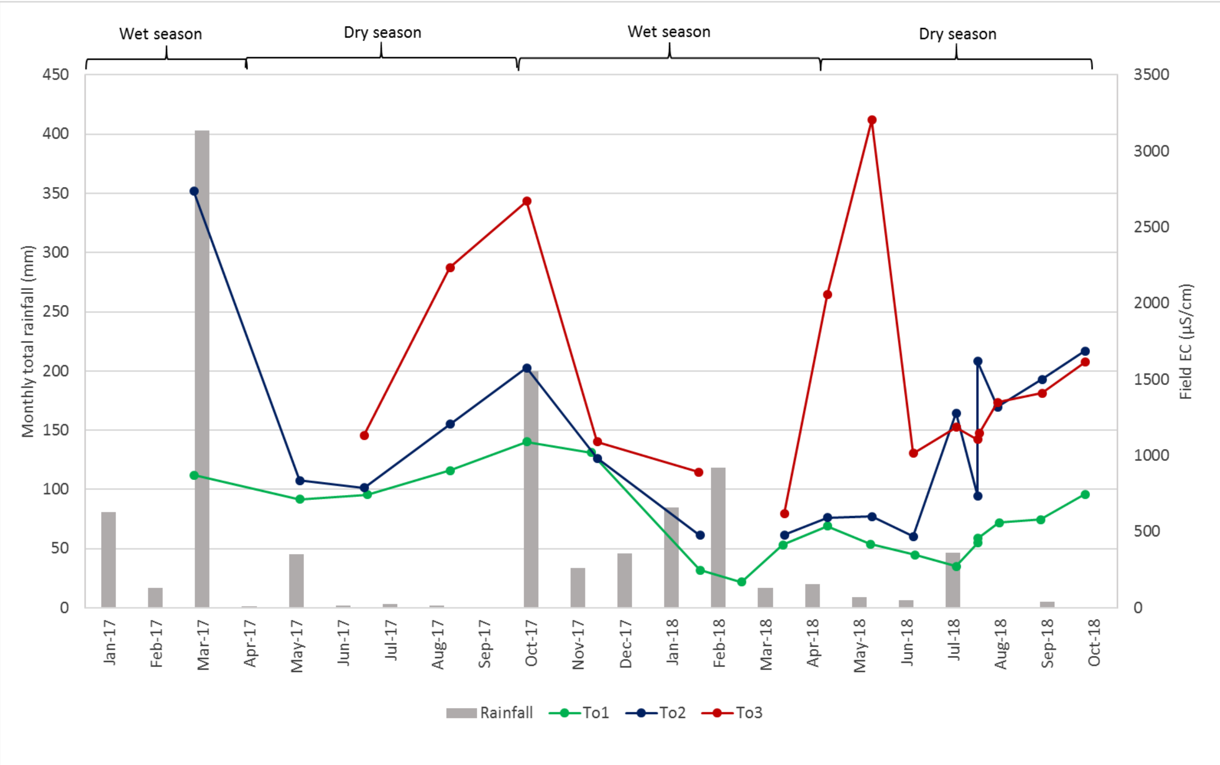


Figure 9-14 Tooloombah Creek field EC – 2017 and 2018

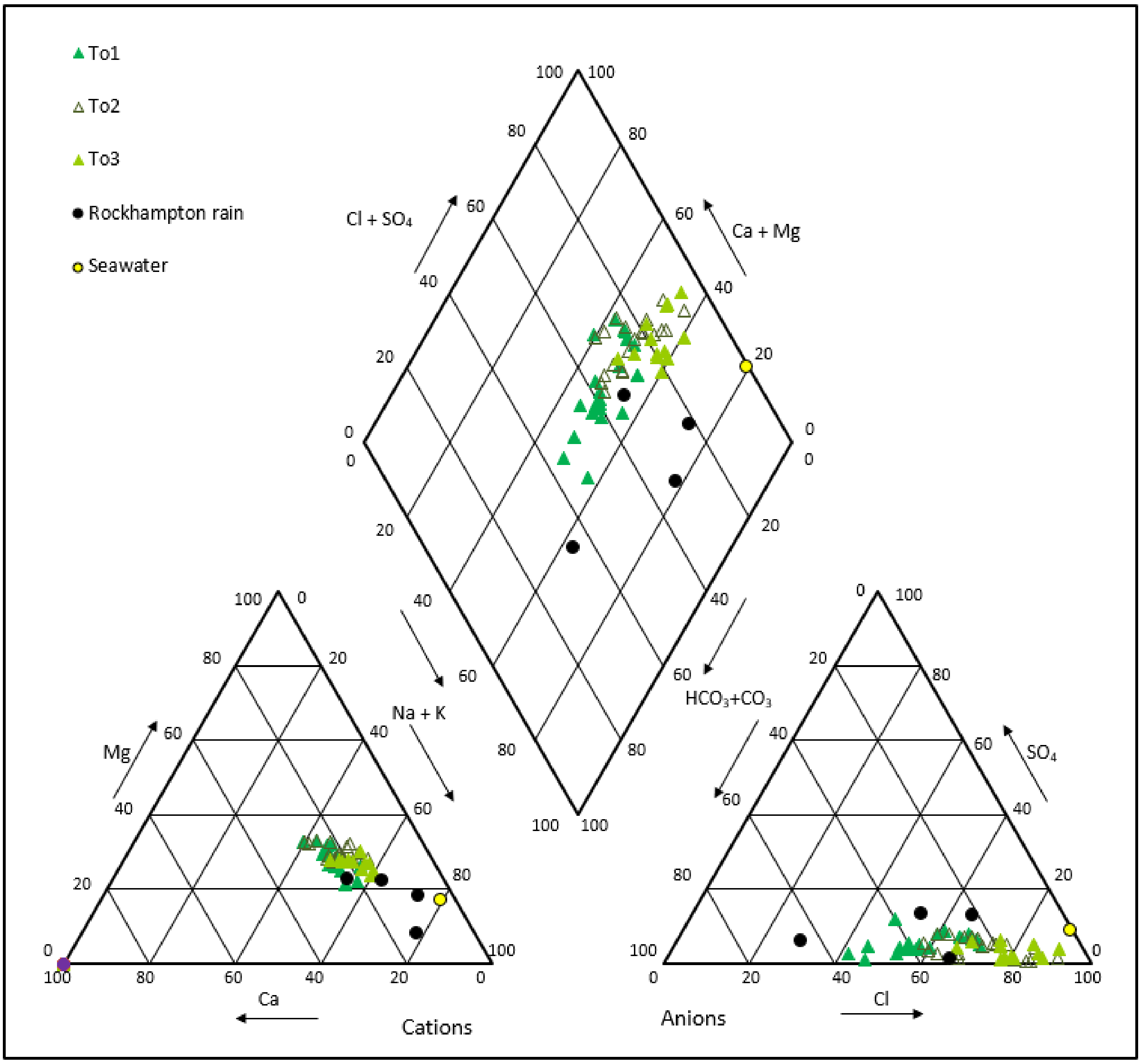


Figure 9-15 Tooloombah Creek water quality Piper Diagram

Large pools of water have been observed within the creek during all sampling events in 2011, 2012, 2017 and 2018. 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 Section 9.4.4.4 and EIS Chapter 10 – Groundwater and Chapter 15 - Aquatic Ecology.

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 9-1). 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 9.4.6 and EIS Chapter 15 – Aquatic Ecology.

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.

9.4.4.3 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 marine 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 to12 m wide. Downstream, near Ogmore Bridge, the channel narrows to around 6 or 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 (St1, located at the confluence of Deep and Tooloombah Creeks and St2, located near Ogmore Bridge) in 2011, 2012, 2017 and Q1 – Q3 2018. As the 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 at Figure 9-16, 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.

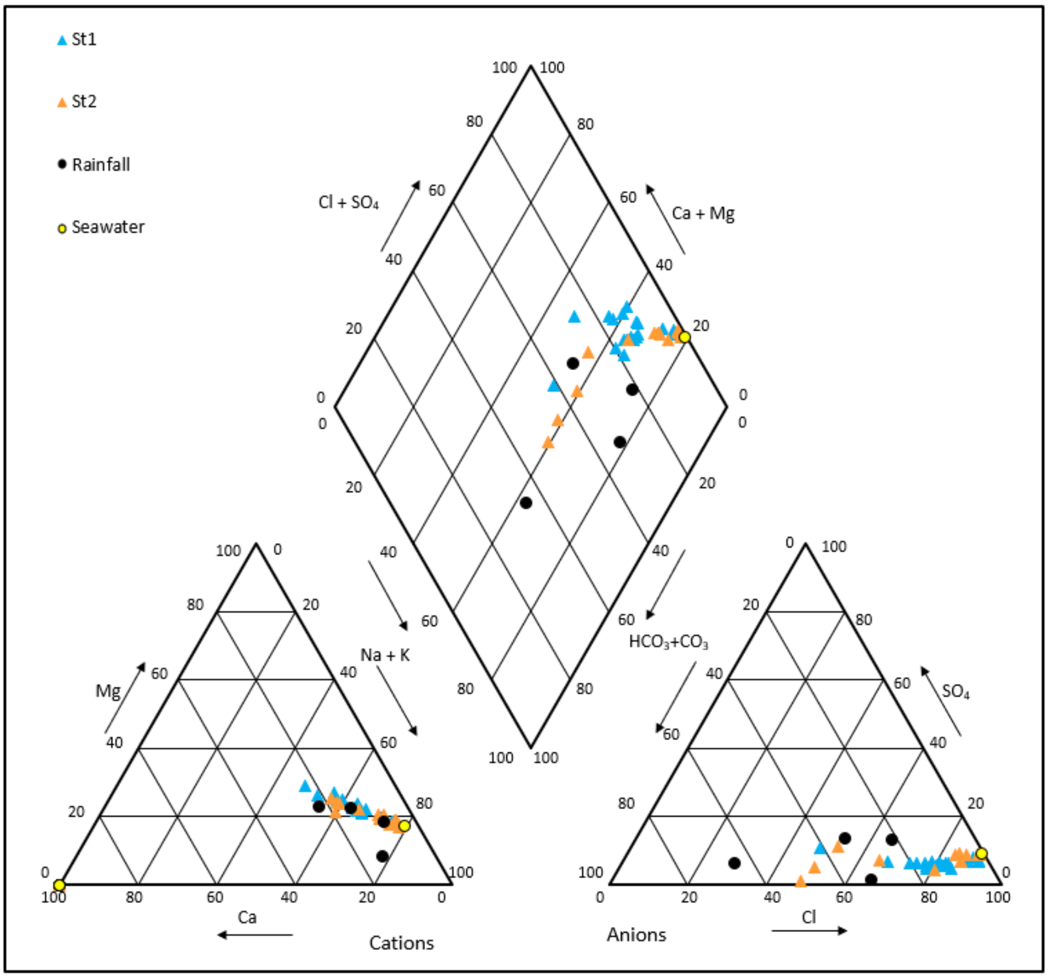


Figure 9-16 Styx River water quality Piper diagram

Water quality results for St1 and St2 in July 2018 (representative of dry season) are presented with Rockhampton rainfall and seawater chemistry on a Stiff pattern on Figure 9-17. 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.

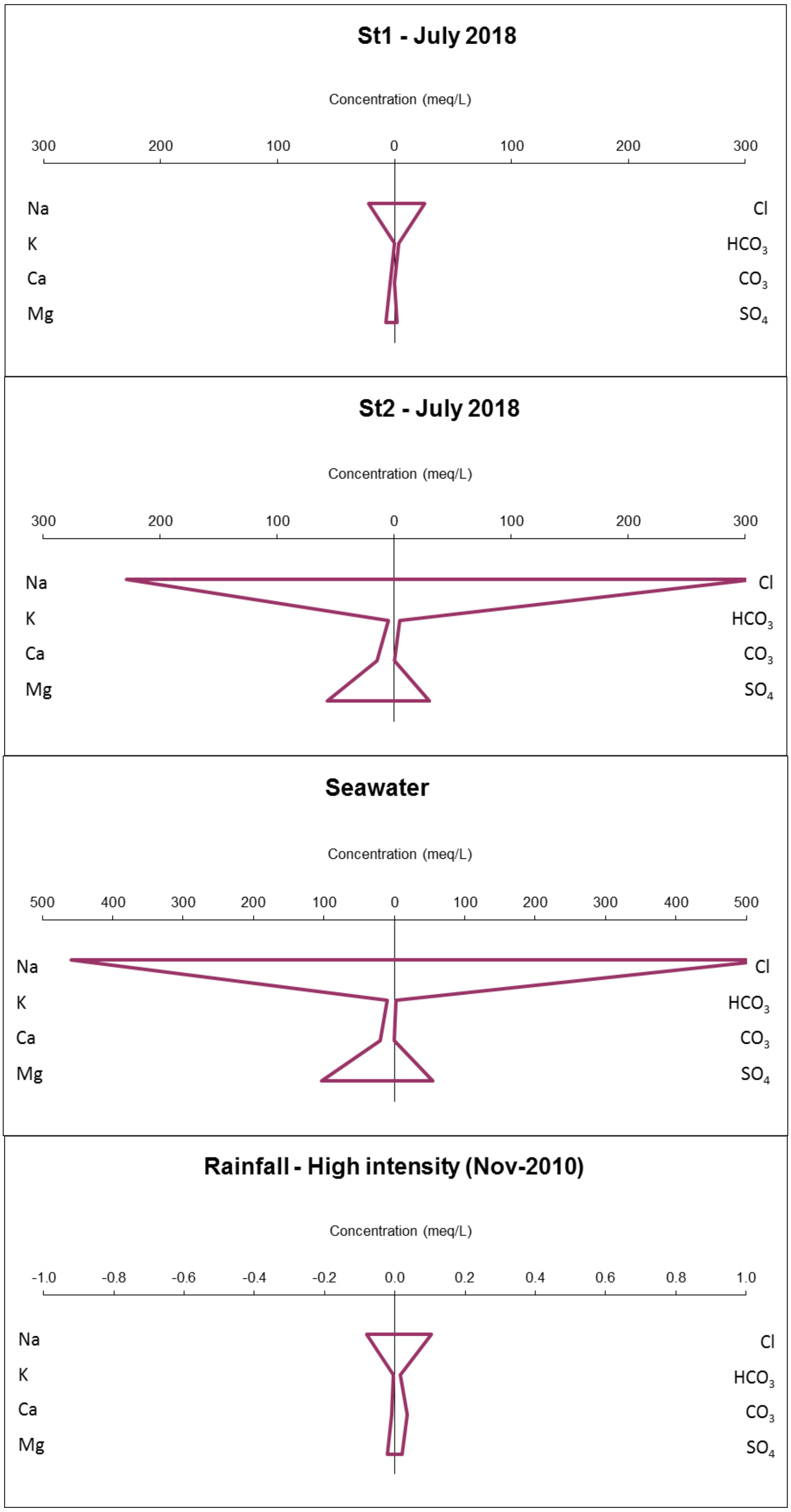


Figure 9-17 Styx River (July 2018), seawater and Rockhampton rainfall Stiff patterns

9.4.4.4 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 probable toward the northern extents of the Tooloombah and Deep Creek catchments.

A conceptual understanding of surface water – groundwater interactions in the Styx River catchment has been developed from the following information:

- 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 (see Figure 10-20 and Section 10.5.6.2 of Chapter 10 - Groundwater);
- Mapping of groundwater dependent ecosystems (GDEs), see Section 10.6 of Chapter 10 – Groundwater;
- Field observations of watercourse pools (Table 9-3), streambed morphology and geology (see Chapter 5 - Land), vegetation (Chapter 14 – Terrestrial Ecology and Chapter 15 – Aquatic Ecology);
- Water quality monitoring results (Sections 9.5 and Section 10.5.6.5 of the Chapter 10 – Groundwater);
- Interpreted extents of HSUs (Figure 10-32 and Section 10.5.6.3 of Chapter 10 - Groundwater); and
- Analysis of radon isotopes (222Rn) and stable isotopes of water (2H and ^{18}O), see Section 10.6 of Chapter 10 - Groundwater.

Figure 9-18 presents the alignments of hydrogeological cross-sections presented in Figure 9-19 to Figure 9-23 that are used to provide conceptualisations of groundwater and surface water interactions in the area of the proposed mine, i.e.:

- Figure 9-19 and Figure 9-20 along the streambed thalwegs of Tooloombah and Deep Creeks;
- Figure 9-21 and Figure 9-22 through the Project area; and
- Figure 9-23 through the confluence of Tooloombah and Deep Creeks.

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 9-19 and Figure 9-21 - The hydraulic gradient is relatively steeply dipping (laterally) towards Tooloombah Creek along most of its length (see Section 9.4.4.2 and Sections 10.5.4.2 and 10.5.6.2 of Chapter 10 – Groundwater for more detail). This gradient drives local groundwater flow toward and discharge to Tooloombah Creek and possibly Styx River;

- Figure 9-19 and Figure 9-21 - Field observations (Table 9-3) 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;
- Figure 9-19 and Figure 9-21 - 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 9-24 and Stiff patterns presented in Figure 9-12 and Figure 9-13);
- Figure 9-19, Figure 9-20 and Figure 9-23 - 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 toward and discharge to Deep Creek and possibly Styx River;
- Figure 9-19 and Figure 9-20 - 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 (refer to Stiff patterns presented in Figure 9-12 and Figure 9-13). The water chemistry strongly indicates 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 (see Figure 10-20 in Chapter 10 - Groundwater) suggest groundwater discharges to the river;
- Figure 9-20 - The hydraulic gradient is relatively flat in the mid to upper reaches of Deep Creek. Table 9-3 shows the pools in the upper reaches of Deep Creek (e.g. De1, De2, De3) have persisted through dry periods but they change in size over time (ranging from large or continuous to small and isolated) and occasionally dry out, indicating an intermittent supply of water (including groundwater; see Sections 9.4.4.2 and Sections 10.5.4.2 and 10.5.6.2 in Chapter 10 – Groundwater for more detail);
- Figure 9-20 - In the mid and upper reaches of Deep Creek (De1, De2, De3, De4), surface water samples do show a similar signature to rainfall, more so than groundwater sourced from the Styx Coal Measures (see Sections 9.4.4.2 and Section 10.5.4.2 in Chapter 10 – Groundwater for more detail);
- Figure 9-20 and Figure 9-23 - In the downstream reach of Deep Creek (De5), the hydraulic gradient towards the stream is steeper and dry season surface water samples show a strong resemblance to nearby groundwater (WMP05), refer Figure 9-25 and Stiff patterns presented in Figure 9-12 and Figure 9-13;
- Figure 9-19 to Figure 9-23 - 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 presented in Figure 9-12 and Figure 9-13);
- Figure 9-19, Figure 9-20 and Figure 9-22 - 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 Section 10.5.6.2 of Chapter 10 - Groundwater;
- Figure 9-20 - Measured hydraulic heads for the dry season (at WMP11/WMP11D) indicate an upwards hydraulic gradient within the Styx Coal Measures (HSU2) as discussed in Section 10.5.6.2 of the Chapter 10 - Groundwater, 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 9-19, Figure 9-20 and Figure 9-22 - 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 (Section 9.4.4.3 and Figure 9-8);
- Figure 9-23 - 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 9-19 to Figure 9-23 - Tooloombah Creek and the lower reaches of Deep Creek have thick stands of potentially groundwater dependent vegetation (see Section 10.6 in Chapter 10 - Groundwater), as well as algae and aquatic vegetation in Tooloombah Creek pools and in Styx River (see Table 9-3), indicating permanence of water;
- Figure 9-19 to Figure 9-23 - In both creeks, field observations (see Table 9-3) 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 precipitating, 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 9.4.4.2); and
- Figure 9-21 - The water table is elevated in the central parts of the Project area and a hydraulic gradient that drives groundwater discharge toward the creeks exists.

Table 9-3 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

Days since last rainfall	Monitoring event	Deep Creek					Tooloombah Creek			Styx River	
		De1	De2	De3	De4	De5	T01	T02	T03	St1	St2
6	Feb-18	Partly wet, brown, turbid	Wet, very turbid	Wet, very turbid	Wet	Wet	Wet	Wet	Wet	Wet	Not visited
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)

Days since last rainfall	Monitoring event	Deep Creek					Tooloombah Creek			Styx River	
		De1	De2	De3	De4	De5	T01	T02	T03	St1	St2
	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
	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

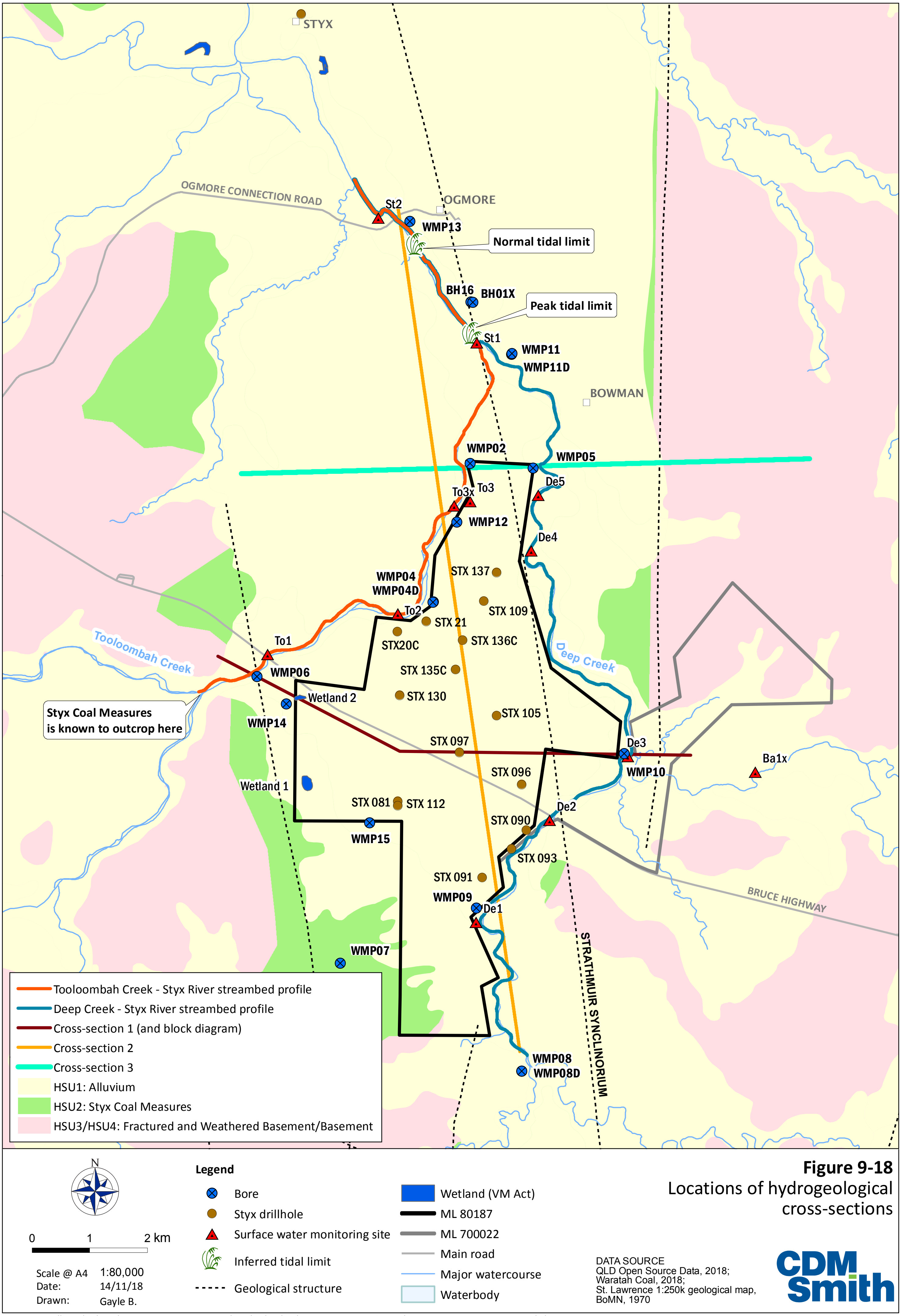


Figure 9-18
Locations of hydrogeological cross-sections

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 HSUs & XsectionLines__9-18.mxd 11/14/2018

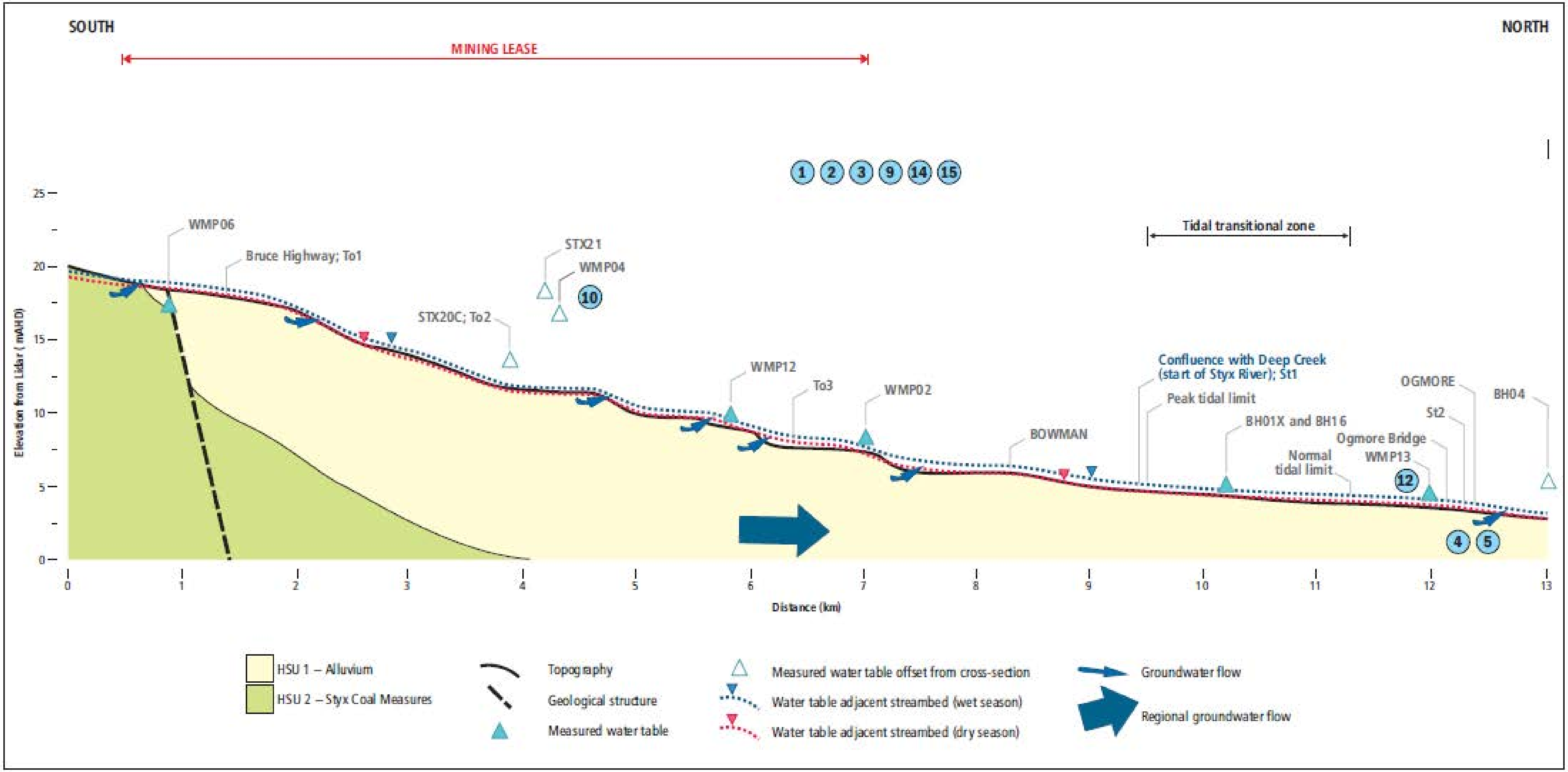


Figure 9-19

Cross-section along Tooloombah Creek streambed

CDM Smith

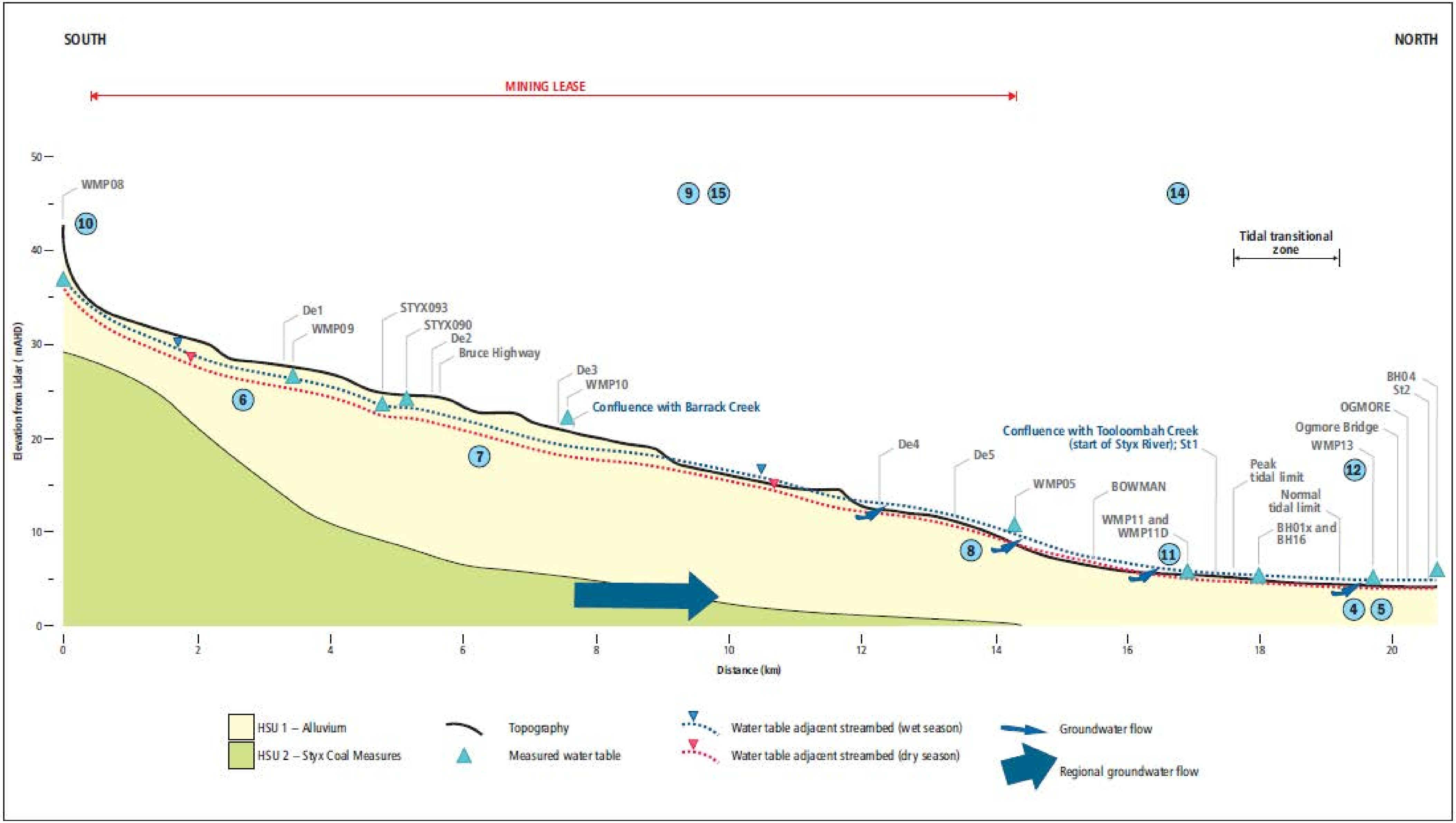


Figure 9-20

Cross-section along Deep Creek streambed

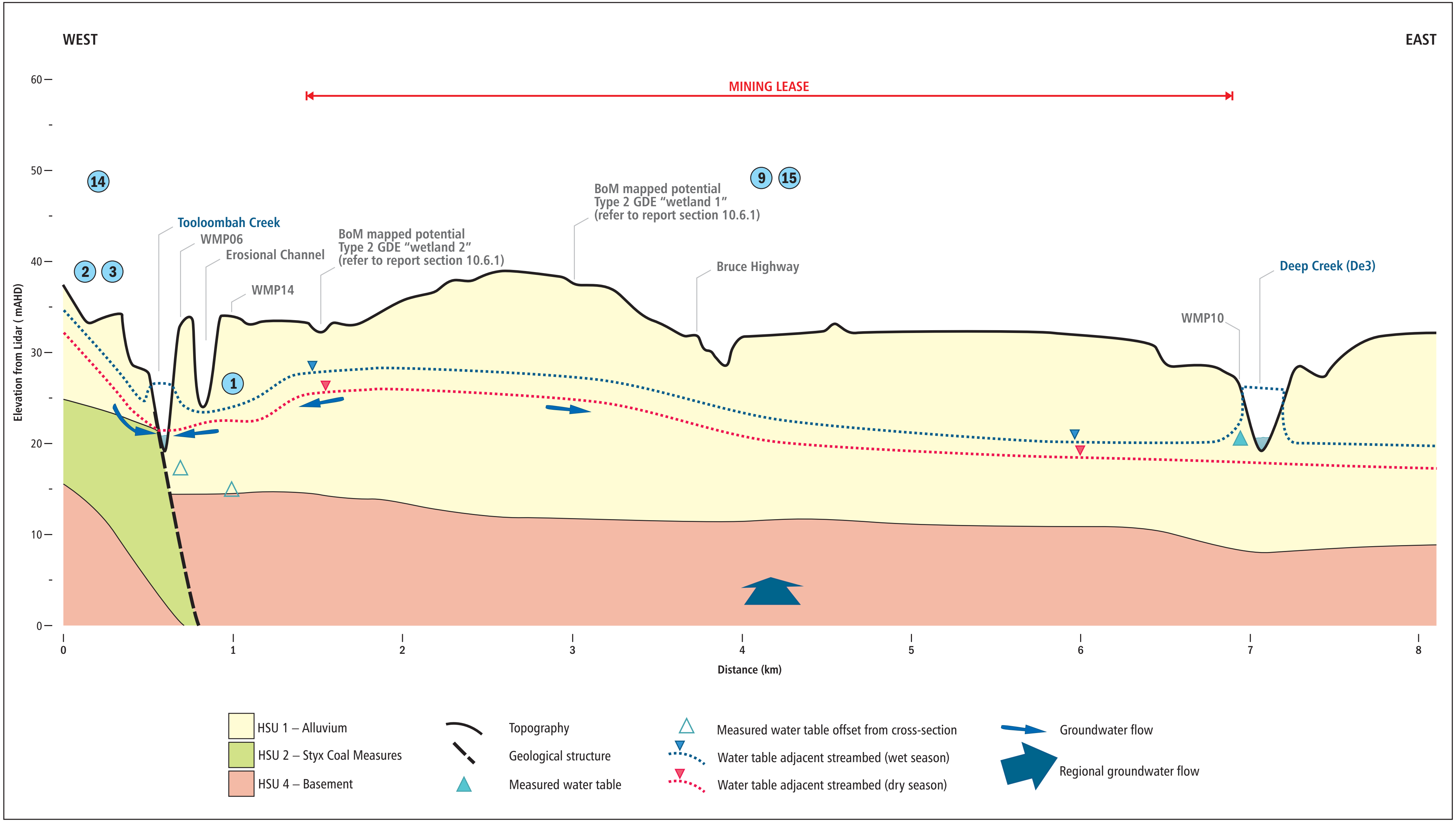


Figure 9-21

Cross-section 1 (Project area bordered by Tooloombah Creek and Deep Creek)

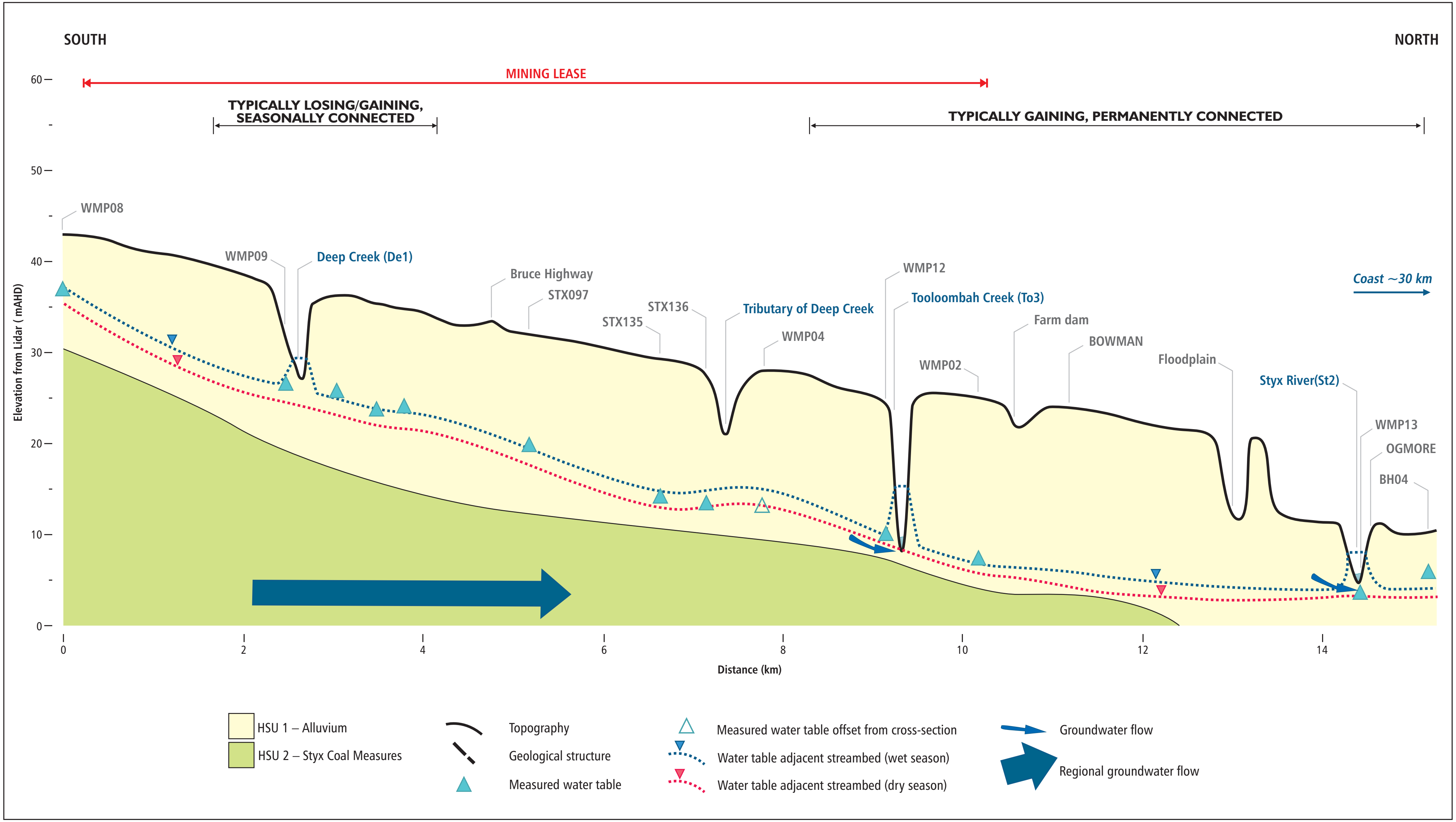


Figure 9-22

Cross-section 2 (Project area north to south)

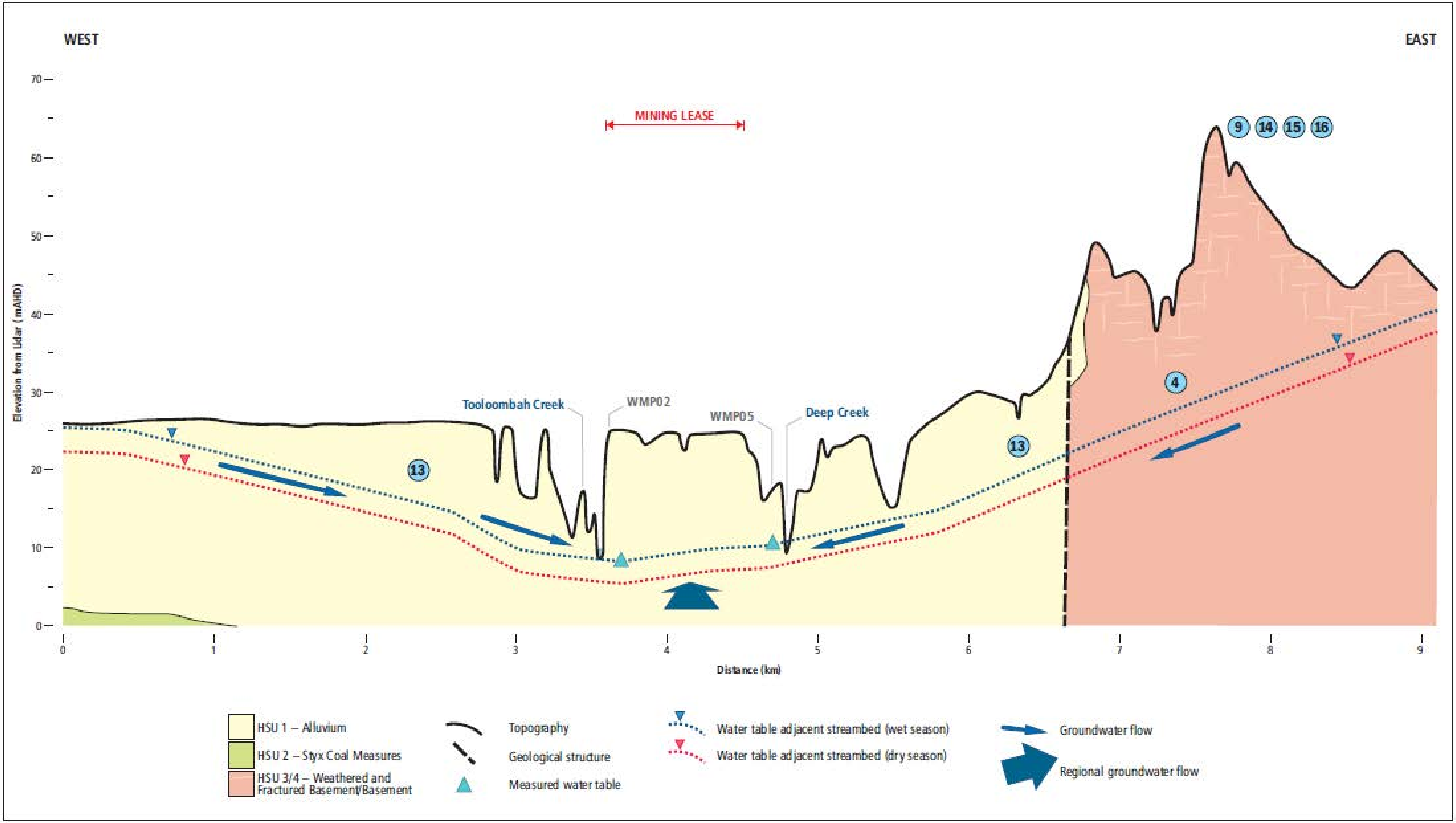


Figure 9-23

Cross-section 3 (west to east at confluence of Tooloombah Creek and Deep Creek)

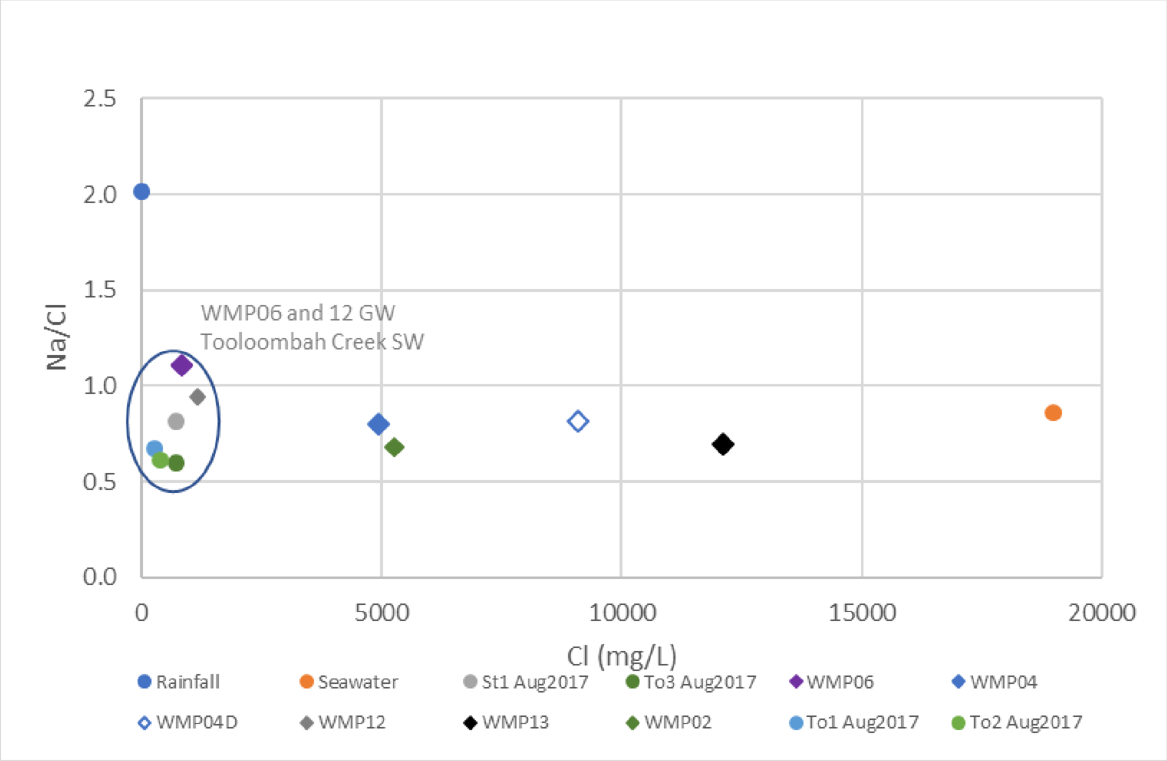


Figure 9-24 Tooloombah Creek Na/Cl vs Cl ratio plot – August 2017 surface water sampling event

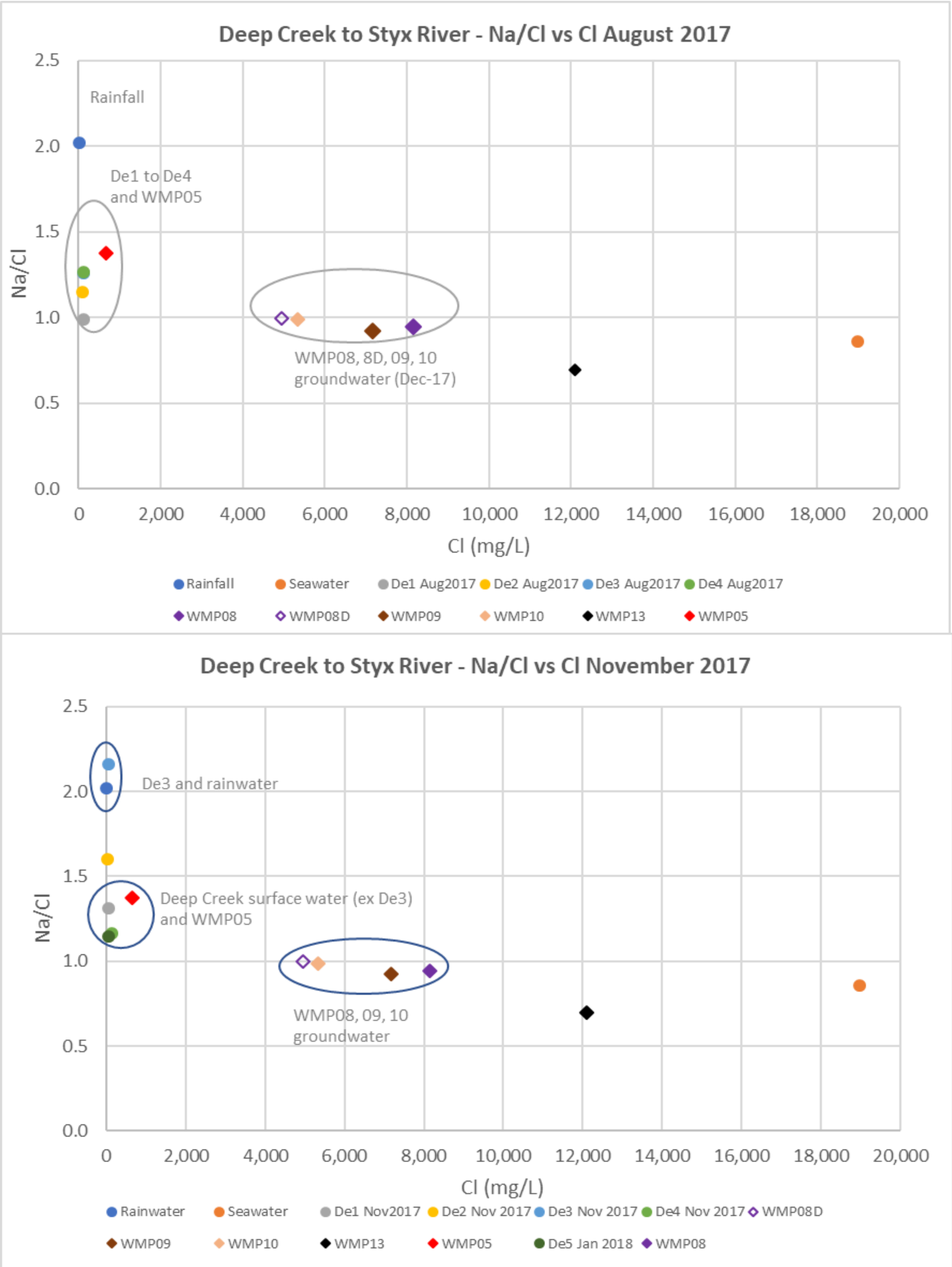


Figure 9-25 Deep Creek Na/Cl vs Cl ratio plot – August and November 2017 surface water sampling event

9.4.4.5 Conceptual Hydrogeological Models

The conceptual processes driving interactions between surface water and groundwater in the Styx River catchment are presented at Figure 9-26. The following provides a general description of the conceptual hydrogeological model.

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 only 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) are likely to be permanently connected to groundwater and receive inputs from a combination of bank storage return and local groundwater flow systems in drier periods. Watercourse pools in these areas 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.

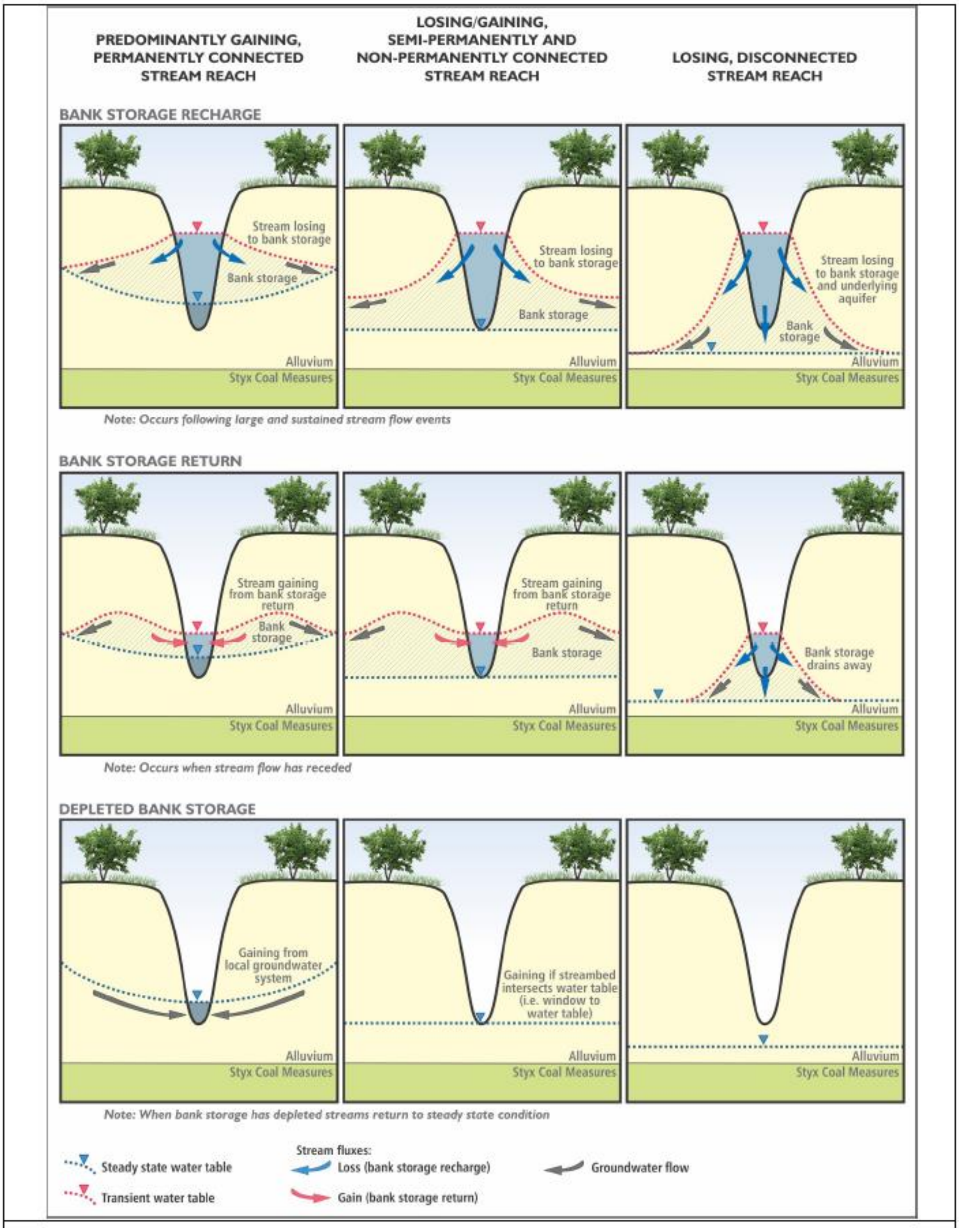


Figure 9-26 Mechanisms of surface water – groundwater interactions

The information and conceptualisations presented in Section 9.4 provide the basis for developing a conceptual hydrogeological model for the Project area and more broadly. Figure 9-27 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:

- The water table is typically hosted in unconsolidated alluvial deposits (HSU1 – see Chapter 10 - Groundwater) and also within fractured and weathered (residual) zones of outcropping and sub-cropping basement rocks (HSU3 – see Chapter 10 - Groundwater) and is generally a subdued reflection of topography, with depth to water table typically less than 15 m below the surface. The water table varies by up to around 3 m seasonally in unconsolidated alluvial deposits;
- 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 (see Figure 10-34 and Table 10 15 in Chapter 10 - Groundwater) 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 10-17);
- 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;
- 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);
- 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 9-26)
  - in lower lying areas below the confluence of Tooloombah and Deep Creeks, particularly closer to Ogmore;
- 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;
- 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. Groundwater discharge occurs to Styx River and the Broad Sound estuary, although at times during high tides this discharge may be interrupted by discharge for these surface water features;
- In the central parts of the Tooloombah and Deep Creek catchments, the Styx Coal Measures (HSU2 – see Chapter 10 - Groundwater) discharge upwards to the alluvium (HSU1 – see Chapter

10 - Groundwater) except for those periods when local groundwater recharge (from streamflows or seasonal diffuse recharge) might reverse the hydraulic gradient. At the outer edges of these catchments hydraulic gradients will typically always be downward;

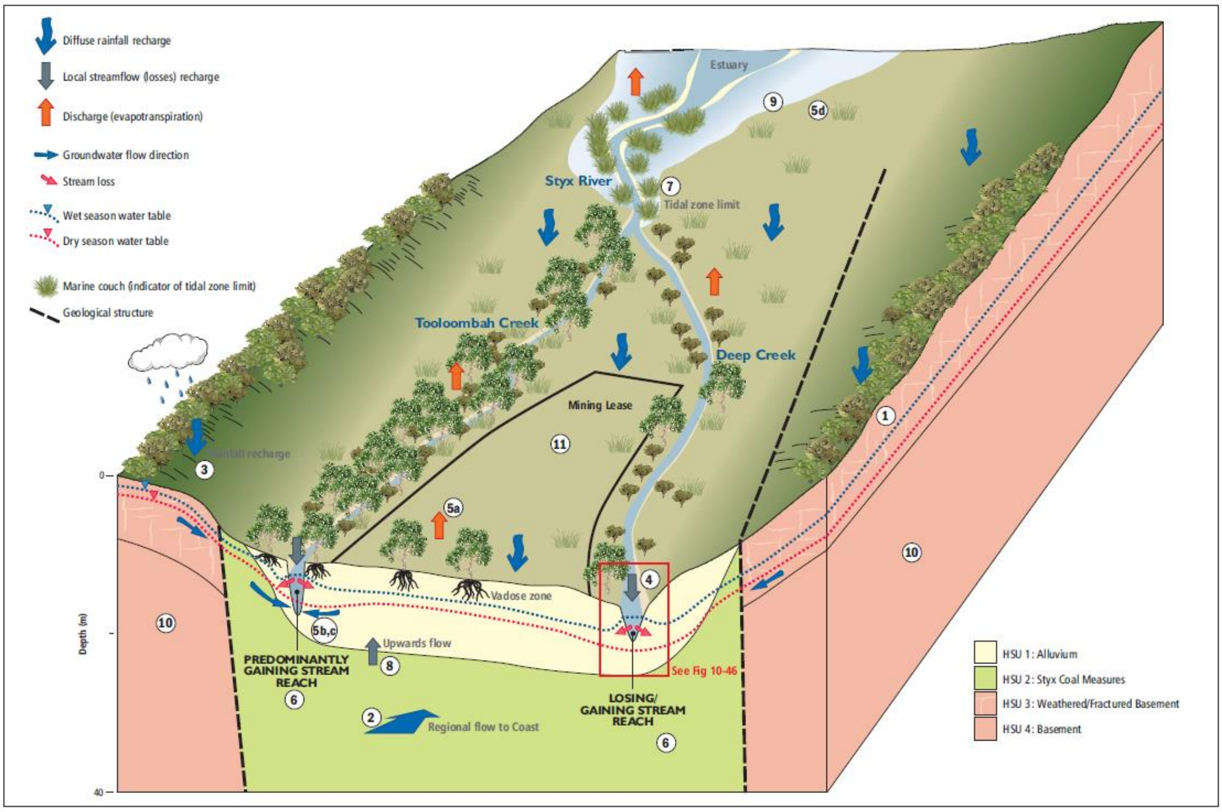


Figure 9-27 Project conceptual hydrogeological model

- A mixing zone occurs along Styx River and Broad Sound estuary, where groundwater and surface water interacts seasonally (rising and falling water tables, stream flow events) and diurnally (due to tidal effects);
- Little is known about the dynamics of deeper groundwater systems associated with HSU3 and HSU4 (see Chapter 10 – Groundwater). However, residual bedrock (HSU3) will likely be important in moving groundwater from the basement rocks to overlying aquifers or to watercourses; and
- The proposed mine will be progressively mined and backfilled. 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.

9.4.5 Existing Waterways and Local Catchments

Two water features surround the Project area which are defined as watercourses by DNRME (see Figure 9-2), in accordance with the definition of a watercourse provided in the Water Act. These are:

- Deep Creek; and
- Tooloombah Creek.

Both watercourses are located outside the Project area; however, several of their tributary 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. This implies that the drainage features do not continually contain water and the stream flow is seasonal in nature and directly following rainfall events.

The Project surface infrastructure is predominantly located within the Deep Creek catchment as shown Figure 9-9, except for the environmental dams 1b and 2a which are located within the Tooloombah Creek catchment. Clean water diversions of existing drainage lines are proposed to prevent contamination through contact with stockpiling, processing and mine pit areas. The diversions direct water to the same watercourse in which they would otherwise discharge to. The proposed diversions are discussed in detail in Section 9.6.3.

Surface water features within the Project area include (see Figure 9-2):

- 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.

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.

9.4.5.1 Deep Creek - February 2017 Assessment

Deep Creek borders the Project area to the east, outside of the MLA, and will be traversed by the proposed haul road that connects the MIA 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 9-1).

Most locations inspected during February 2017 were dry with some pools identified at localised depressions. The channel was identified as having short grass growing along the channel floor, and with trees and short grasses established along the banks (see Plate 9-2).

The channel bed comprised of silty sand 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 the force of gravity.

Plate 9-1: Deep Creek downstream, Bruce Highway bridge along the southern boundary of the Project area, turbid pooled water (Feb 2017)

Plate 9-2: Deep Creek beneath Bruce Highway along the southern boundary area, showing a dry, silty sand substrate (Feb 2017)

9.4.5.2 Tooloombah Creek - February 2017 Assessment

Tooloombah Creek borders the Project area to the west, outside of the MLA. Tooloombah Creek was observed in February 2017 with depths of water accumulated within the creek banks greater than 0.5 m. The creek 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, including full-grown trees (see Plate 9-3), creating a stable bank that appeared resistant to scour. The water within the creek was brackish, most likely a combination of the saline tidal wedge and freshwater runoff, as demonstrated by the varying electric conductivity measurements taken in

Tooloombah Creek of 87.2 µs/cm and 2,737 µs/cm. The rocky substrate produces less silt and therefore lower turbidity than observed in Deep Creek (see Section 9.5 for details).

No water was observed in Tooloombah Creek past the transition from a rocky substrate to a sandy substrate, which occurs upstream of the Bruce Highway bridge that crosses Tooloombah Creek. This suggests that:

- Tooloombah Creek is tidal up to the point of the Bruce Highway;
- The rock substrate creates less pervious substrate that holds pooled water for longer periods;
- Water flows through the sandy substrate further upstream of the Bruce Highway and surfaces at the rocky substrate sections further downstream;
- There is groundwater connectivity in the lower reaches of Tooloombah Creek; or
- Some combination of the above factors.

Plate 9-3: Tooloombah Creek downstream of Bruce Highway bridge, western boundary (Feb 2017)

Plate 9-4: Tooloombah Creek upstream of Bruce Highway bridge, western boundary (Feb 2017)

9.4.5.3 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 was observed to be tidally influenced, with the water surface level rising significantly on two occasions over the day. The tidal nature of the Styx River supports well established vegetation on the river banks, making the banks stable and resistant to scour (see Plate 9-5). 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 9.5 for details).

Plate 9-5: Styx River, downstream confluence between Deep Creek and Tooloombah Creek (Feb 2017)

9.4.5.4 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.

9.4.6 Wetlands and Farm Dams

Wetlands are defined by DES 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 and DES 2015).

There are three types of wetlands that have been identified within the Project area and surrounding areas:

- 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 in the west of the site. The other wetland (Ref 688938) (Wetland 1) is located to the south west of Open Pit 1 (see Plate 9-6). 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 9-4.

Table 9-4 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

Plate 9-6: Wetland of high ecological significance (ref. 688938)

There are four existing farm dams of varying size within the Project area (see Figure 9-2), all dams are located adjacent to the Bruce Highway. These dams are predominantly used for stock water, are highly disturbed and do not support vegetation communities. The two rural water storages located on the southern side of the Bruce Highway (plan MC493) are shown in Plate 9-7 and Plate 9-8. 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.

Plate 9-7: Rural water storage (ref.696686)

Plate 9-8: Rural water storage (Open Cut 1)

9.4.7 Water Supply within the Broader Catchment Area

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 (see Section 9.4.8 for additional information).

9.4.8 Existing Water Users

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 Chapter 10 - Groundwater 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. These entitlements are summarised in Table 9-5. 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 located on parcel of land adjacent to the Mamelon property, separated by Deep Creek, and approximately 3 km downstream of mine infrastructure and environmental dam release point locations on Deep Creek;
- 1/RP616700 - Domestic / stock supply entitlement located on parcel of land adjacent to the Mamelon property and straddling 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 on parcel of land directly bordering the Project to the north and extracting approximately 6 km downstream of the Bruce Highway on Tooloombah Creek.

Table 9-5 Water entitlements for waters associated with the Project

Water Source	Location	Authorised Use	Entitlement Per Water Year	Maximum Extraction Rate	Water Name / Type
Tooloombah Creek	1/RP616700	Domestic Supply; Stock	18 ML	-	Tooloombah Creek / Watercourse (Surface Water)
Deep Creek	119/CP900367	Irrigation	20 ha	-	Deep Creek / Watercourse (Surface Water)
Tooloombah Creek	45/MPH26062	Irrigation	8 ha	-	Tooloombah Creek / Watercourse (Surface Water)

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 10.7 and Section 10.8 of Chapter 10 – Groundwater. 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.

9.5 Water Quality Assessment

9.5.1 Environmental Values and 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 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 9-6. Water quality objectives associated with the Project for the protection of aquatic ecosystem EVs are summarised in Table 9-7 and Table 9-8.

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[1]. 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 9-6 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	✓

Notes: ✓ - river basin is suitable for the environmental value; X - river basin is not suitable for the environmental value.

Table 9-7 Water quality objectives for waters associated with the Project (EPP Water)

Criteria source (EV)	Parameter	WQO
Physico-chemical		
	Ammonia nitrogen	<20 µg/L
	Oxidised nitrogen	<60 µg/L

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

Criteria source (EV)	Parameter	WQO
Aquatic ecosystem – Deep Creek and Tooloombah Creek	Total nitrogen	<500 µg/L
	Filterable reactive phosphorus	<20 µg/L
	Total phosphorus	<50 µg/L
	Chlorophyll a	<5 µg/L
	Dissolved oxygen	85% - 110% saturation
	Turbidity	<50 NTU
	Suspended solids	<10 mg/L
	pH	6.5 - 8.0
	Toxicants (metals, inorganics etc.)	See Table 9-8
Aquatic ecosystem – Styx River	Ammonia nitrogen	<10 µg/L
	Oxidised nitrogen	<10 µg/L
	Total nitrogen	<300 µg/L
	Filterable reactive phosphorus	<8 µg/L
	Total phosphorus	<25 µg/L
	Chlorophyll a	<4 µg/L
	Dissolved oxygen	85% - 100% saturation
	Turbidity	Not Determined
	Suspended solids	Not Determined
	pH	7.0 - 8.4
	Toxicants (metals, inorganics etc.)	See Table 9-8
Stock watering – Total Dissolved Solids	Total Dissolved Solids	
	Beef	4,000 mg/L
	Dairy cattle	2,500 mg/L
	Sheep	5,000 mg/L
	Horses	4,000 mg/L
	Pigs	4,000 mg/L
	Poultry	2,000 mg/L
	Aluminium	5 mg/L
	Metal or metalloids	
	Arsenic	0.5 mg/L
	Beryllium	Not Determined
	Boron	5 mg/L
	Cadmium	0.01 mg/L
	Chromium	1 mg/L
	Cobalt	1 mg/L
	Copper	0.4 mg/L (sheep), 1 mg/L (cattle), 5 mg/L (pigs and poultry)
	Fluoride	2 mg/L
	Iron	Not sufficiently toxic
	Lead	0.1 mg/L
	Manganese	Not sufficiently toxic
	Mercury	0.002 mg/L
	Molybdenum	0.15 mg/L

Criteria source (EV)	Parameter	WQO		
	Nickel	1 mg/L		
	Selenium	0.02 mg/L		
	Sulphate	1,000 mg/L		
	Uranium	0.2 mg/L		
	Vanadium	Not Determined		
	Zinc	20 mg/L		
Human consumer	Sodium	20 mg/L		
	Total dissolved solids (prior to treatment)	<600 mg/l		
Primary recreation	Temperature	16 - 34°C		
	Dissolved oxygen	>80%		
Heavy metals and metalloid long-term trigger level				
		Soil cumulative contaminant loading limit (CCL) (kg/ha)	**Long-term trigger value (LTV) in irrigation water (up to 100 years) (mg/L)**	**Short-term trigger value (STV) in irrigation water (up to 20 years) (mg/L)**
Irrigation	Aluminium	Not Determined	5.000	20.000
	Arsenic	20	0.100	2.000
	Beryllium	Not Determined	0.100	0.500
	Boron	Not Determined	0.500	Table 9.2.18 of ANZECC
	Cadmium	2	0.010	0.050
	Chromium (CRVI)	Not Determined	0.100	1.000
	Cobalt	Not Determined	0.050	0.100
	Copper	140	0.200	5.000
	Fluoride	Not Determined	1.000	2.000
	Iron	Not Determined	0.200	10.000
	Lead	260	2.000	5.000
	Lithium	Not Determined	2.500	2.500
	Manganese	Not Determined	0.200	10.000
	Mercury	2	0.002	0.002
	Molybdenum	Not Determined	0.010	0.050
	Nickel	85	0.200	2.000
	Selenium	10	0.020	0.050
	Uranium	Not Determined	0.010	0.100
	Vanadium	Not Determined	0.100	0.500
	Zinc	300	2.00	5.000
Biological				
Human consumer	Giardia	0 cysts		
	Cryptosporidium	0 cysts		
	Blue–green algae (cyanobacteria)	<100 cells/mL		
	pH	6.5 -8.5		
	Total Dissolved Solids (TDS)	600 mL		

Criteria source (EV)	Parameter	WQO
	Sodium	180 mg/L
	Sulphate	250 mg/L
	Dissolved oxygen	>85% saturate

Table 9-8 Water quality objectives for toxicants (ANZECC)

Criteria source (EV)	Parameter	WQO (mg/L)
Aquatic Ecosystems	Aluminium	0.055
	Arsenic	0.024
	Beryllium	ND
	Boron	0.370[1]
	Cadmium	0.0002
	Chromium (CRVI)	0.001
	Cobalt	0.0014[1]
	Copper	0.0014[1]
	Fluoride	2.4[1]
	Iron	0.35[1]
	Lead	0.0034
	Lithium	ND
	Manganese	1.9
	Mercury	0.0006
	Molybdenum	0.034[1]
	Nickel	0.011
	Selenium	0.005
	Uranium	ND
	Vanadium	0.006[1]
	Zinc	0.008[1]

[1] WQO will be updated when the revised ANZECC Guidelines are published

9.5.2 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 9-1. The relevant scope of each of the sampling locations is shown in Table 9-9. The results from these sampling events are presented in Table 9-15 to Table 9-23 and are discussed in the following sections.

Table 9-9 Current and historical sampling sites

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

Site ID	Current Sampling Scope	Historical Sampling Scope
De2	✓	✓
De3	✓	✓
De4	✓	✗
De5	✓	✗

9.5.2.1 Historical (2011) Water Quality Sampling Method

Water quality was measured as follows (i) *in-situ* measurements taken while on site and (ii) water quality samples collected for laboratory analysis.

In-situ measurements were recorded using a YSI 556 multi-parameter water quality meter and measurements included water temperature (°C), pH, conductivity (µS/cm) and dissolved oxygen (% saturation and mg/L). A TPS multi-parameter meter was also used on several occasions when readings from the YSI meter were being cross-checked. Both meters were calibrated in the laboratory and in the field prior to use. Turbidity was measured separately using a hand held HACH 2100P turbidity meter, while alkalinity (a measure of calcium carbonate concentration that is highly relevant to macroinvertebrate community composition) was measured using Chemetrics titration kits.

Water samples were collected according to procedures outlined in the EHP (2009a) guidelines. Samples were kept chilled in an esky and set to the ALS laboratory in Brisbane within 24 hours of collection to ensure that they were received within sample holding times. Samples were tested for the following using appropriate methods and levels of reporting (LOR):

- Aluminium;
- Arsenic;
- Boron;
- Cobalt;
- Iron;
- Lead;
- Manganese;
- Molybdenum;
- Nickel;
- Selenium;
- Vanadium;
- Cadmium;
- Chromium;
- Copper;
- Silver;
- Uranium;

- Zinc;
- Mercury; and
- Escherichia coli.

Flow velocities were assessed to assist with the interpretation of water quality. Cross-channel flow measurements were originally planned to be taken in the main channel of the creeks sampled, but this was impractical due to a number of conditions including time available, low flow conditions, estuarine crocodiles and overhanging vegetation. Instead, flow measurements were taken where macroinvertebrates or fish were collected and not necessarily where water measurements were taken. Nonetheless, this process provided some indication of the relative nature of flow conditions experienced at the time of sampling.

9.5.2.2 Monitoring Results

Stream Conditions

The stream/waterway conditions during each sampling event is presented in Table 9-10. 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 9-10 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.

9.5.2.3 Comparison of Results with Guidelines

Protection of Aquatic Ecosystems

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

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).

Table 9-11 Summary of compliance with WQOs – Deep Creek (June 2011 – October 2018)

<table>
<tr><th rowspan="2">Creek System</th><th colspan="4">Phys-chem</th><th colspan="4">Turbidity/SS</th><th colspan="5">Nutrients</th><th colspan="6">Metals (dissolved)</th></tr>
<tr><th>Param</th><th>n</th><th>Median</th><th>WQO</th><th>Param</th><th>n</th><th>Median</th><th>WQO</th><th>Param</th><th>n</th><th>% Detects</th><th>Median</th><th>WQO</th><th>Param [5]</th><th>n</th><th>% Detects</th><th>Median</th><th>95th %ile</th><th>WQO</th></tr>
<tr><td rowspan="8">Deep Creek (De1, De2, De3, De4, De5)</td><td>DO (mg/L)</td><td>58</td><td>5.22</td><td>6.77 – 8.76[2]</td><td>Turbidity (NTU)</td><td>71</td><td>67.0</td><td>50</td><td>Ammonia N (µg/L)</td><td>75</td><td>82.7</td><td>40</td><td>20[1]/900</td><td>Al (µg/L)</td><td>73</td><td>54.8</td><td>40.0</td><td>4,418.0</td><td>55[4]</td></tr>
<tr><td>EC (µS/cm)</td><td>98</td><td>356.95</td><td>375[1]/1000</td><td>SS (mg/L)</td><td>61</td><td>25.0</td><td>10</td><td>Nitrate N (µg/L)</td><td>75</td><td>41.3</td><td><10</td><td>1,100</td><td>Fe (µg/L)</td><td>73</td><td>43.8</td><td>50.0</td><td>2,652.0</td><td>NA</td></tr>
<tr><td>pH (units)</td><td>85</td><td>7.69</td><td>6.5-8.0</td><td colspan="4" rowspan="6">Turbidity and suspended solids above QWQG during wet periods.</td><td>NO_x (µg/L)</td><td>75</td><td>42.7</td><td><10</td><td>60</td><td>Pb (µg/L)</td><td>73</td><td>5.5</td><td>1.0</td><td>10.0</td><td>3.4</td></tr>
<tr><td colspan="4" rowspan="5">DO moderately below QWQG except during flow periods. Conductivity below QWQG (below EHP 2011 except Nov-11 at De1). pH generally good, but elevated during late dry, and low after wet.</td><td>Org N (µg/L)</td><td>75</td><td>98.7</td><td>1,000</td><td>420</td><td>Se (µg/L)</td><td>73</td><td>2.7</td><td>10.0</td><td>10.0</td><td>11</td></tr>
<tr><td>TN (µg/L)</td><td>75</td><td>98.7</td><td>1,000</td><td>500/3,400[3]</td><td>V (µg/L)</td><td>73</td><td>4.1</td><td>10.0</td><td>14.0</td><td>6/10</td></tr>
<tr><td>TP (µg/L)</td><td>75</td><td>96</td><td>150</td><td>50/2,000[3]</td><td>Zn (µg/L)</td><td>73</td><td>13.7</td><td>5.0</td><td>11.4</td><td>8</td></tr>
<tr><td>FRP (µg/L)</td><td>73</td><td>20.5</td><td><10</td><td>20</td><td>Cu (µg/L)</td><td>73</td><td>68.5</td><td>2.0</td><td>3.0</td><td>1.4/2</td></tr>
<tr><td colspan="5">Nutrients generally showed exceedances for NH_4-N, Org N, TN, TP at all times but exceedances were more pronounced during the wet post December period. FRP exceeded the guidelines post December only.</td><td colspan="6">Metals detected above the trigger levels were Al, Fe, Pb, V, Zn, Cr, Cu and Ag. As, Ba, Bo, Mn, Sr, and Ti were also detected, but without any exceedances.</td></tr>
</table>

1. Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2. WQO for DO based on EPP (Water) 'Aquatic Ecosystem' – the WQO for dissolved oxygen is based on a conversion from the % saturation to mg/L applying insitu temperature and altitude of 300 mAHD.
3. EHP (2011) – Fitzroy River Sub-basin Environmental Values and Water Quality Objectives.
4. for pH >6.5.
5. Al - Aluminium, Sb - Antimony, Fe - Iron, Pb - Lead, Se - Selenium, V - Vanadium, Zn - Zinc, Cr - Chromium, Cu - Cooper, Ag - Silver, As - Arsenic, Ba - Barium, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 9-12 Summary of compliance with WQOs – Tooloombah Creek (June 2011 – October 2018)

Creek System	Phys-chem				Turbidity/SS				Nutrients					Metals (dissolved)					
	Param	n	Median	WQO	Param	n	Median	WQO	Param	n	% Detect	Median	WQO	Param[5]	n	% Detect	Median	95th %ile	WQO
Tooloombah Creek (To1, To2, To3)	DO (mg/L)	47	6.16	6.77 – 8.76[2]	Turbidity (NTU)	61	5.93	50	Ammonia (µg/L)	61	85.2	30	20[1]/900	Al (µg/L)	61	44.3	10	210	55[4]
	EC (µS/cm)	94	974	375[1]/1000	SS (mg/L)	60	8.5	10	Nitrate N (µg/L)	61	26.2	10	1,100	Fe (µg/L)	61	29.5	50	160	350/300
	pH (units)	67	7.92	6.5-8.0	Turbidity was above QWQG during the Jan 12 and Mar 12 rainfall peaks and again in Jan 18 (396). SS generally exceeded the QWQG during the wet season.				NO_x (µg/L)	61	26.2	10	60	Se (µg/L)	59	1.7	10	10	11
	Dissolved oxygen predominantly reports within the QWQG although showed exceedances above and below the QWQG, with EC generally above. During the wet season pH can rise above the WQO and on one occasion reported very low (5.9) in Jan 12.								Org N (µg/L)	61	100	400	420	Vn (µg/L)	61	1.6	10	10	6/10[2]
									TN (µg/L)	61	100	400	500/3,400[3]	Cr (µg/L)	61	6.6	1.0	1.0	1.0
									TP (µg/L)	61	91.8	30	50/2,000[3]	Cu (µg/L)	61	27.9	1.0	50	1.4/2[2]
									FRP (µg/L)	59	6.8	<10	20	Ag (µg/L)	49	0	1.0	1.0	0.05/1.0
									Ammonia, Org N, and TN were above the QWQG, with TP and FRP above during rainfall periods.					U (µg/L)	27		1.0	1.0	1.0
														Metals detected above the trigger levels were Al, Sb, Fe, Se, Sn, V, Cr, Cu, Ag and U. As, Ba, Mn, Sr and Ti were also detected, but without any exceedances.					

1. Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2. WQO for DO based on EPP (Water) 'Aquatic Ecosystem' – the WQO for dissolved oxygen is based on a conversion from the % saturation to mg/L applying insitu temperature and altitude of 300 mAHD.
3. EHP (2011) – Fitzroy River Sub-basin Environmental Values and Water Quality Objectives.
4. for pH >6.5.
5. Al - Aluminium, Sb - Antimony, Fe - Iron, Pb - Lead, Se - Selenium, V - Vanadium, Zn - Zinc, Cr - Chromium, Cu - Cooper, Ag - Silver, As - Arsenic, Ba - Barium, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 9-13 Summary of compliance with WQOs – Styx River (St1) (June 2011 – October 2018)

Creek System	Phys-chem				Turbidity/SS				Nutrients					Metals (dissolved)					
	Param	n	Median	WQO	Param	n	Median	WQO	Param	n	% Detects	Median	WQO	Param[6]	n	% Detects	Median	95th %ile	WQO
Styx River (St1)	DO (mg/L)	17	6.07	6.77 – 8.76[2]	Turbidity (NTU)	22	10.1	50	Ammonia (µg/L)	22	86.4	40	20[1]/900	Al (µg/L)	22	13.6	100	9,410	55[5]
	EC (µS/cm)	33	2830	375[1]/1000	SS (mg/L)	22	11	10	Nitrate N (µg/L)	22	36.4	<10	1,100	Fe (µg/L)	22	4.5	50	4,340	350/300[4]
	pH (units)	25	7.80	6.5-8.0	Turbidity and suspended solids were elevated during wet season but otherwise generally within the WQO.				NO_x (µg/L)	22	36.4	<10	60	Zn (µg/L)	22	31.8	5.0	30	8
	Dissolved oxygen shows a broad range sometimes exceeding the WQO pending flow conditions. Conductivity remained above at all times. pH tends to be circum-neutral to slightly alkaline.								Org N (µg/L)	22	100	400	420	Cu (µg/L)	22	50	1.0	6.0	1.4/2
									TN (µg/L)	22	100	450	500/3,400[3]	Vn (µg/L)	22	4.5	10	20	10/6[4]
									TP (µg/L)	22	81.8	30	50/2,000[3]	Cr (µg/L)	22	4.5	1.0	2.0	1
									FRP (µg/L)	22	13.6	<10	20	Metals detected above the trigger levels were Al, Sb, Fe, Se, Sn, V, Cr, Cu, Ag and U. As, Ba, Mn, Sr and Ti were also detected, but without any exceedances.					
									Ammonia was above the QWQG on all occasions, with Org N, TN, TP and FRP above during rainfall periods.										

1. Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2. WQO for DO based on EPP (Water) 'Aquatic Ecosystem' – the WQO for dissolved oxygen is based on a conversion from the % saturation to mg/L applying insitu temperature and altitude of 300 mAHD.
3. EHP (2011) – Fitzroy River Sub-basin Environmental Values and Water Quality Objectives.
4. ANZECC Guidelines low reliability value (for marine waters for St2).
5. for pH >6.5.
6. Al - Aluminum, Sb - Antimony, Fe - Iron, Pb - Lead, Se - Selenium, V - Vanadium, Zn - Zinc, Cr - Chromium, Cu - Cooper, Ag - Silver, As - Arsenic, Ba - Barium, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 9-14 Summary of compliance with WQOs – Styx River (St2) (June 2011 – October 2018)

Creek System	Phys-chem				Turbidity/SS				Nutrients					Metals (dissolved)					
	Param	n	Median	WQO	Param	n	Median	WQO	Param	n	%Detects	Median	WQO	Param[6]	n	%Detects	Median	95th %ile	WQO
Styx River (St2)	DO (mg/L)	9	8.74	6.77 – 8.76[2]	Turbidity (NTU)	18	13.8	50	Ammonia (µg/L)	17	94.1	70	20[1]/900	Al (µg/L)	17	23.5	50	10,800	55[5]
	EC (µS/cm)	27	17,861	375[1]/1000	SS (mg/L)	17	21	10	Nitrate N (µg/L)	17	52.9	10	1,100	Mn (µg/L)	17	58.8	30	190.8	80[4]
	pH (units)	19	7.76	6.5-8.0	Turbidity and suspended solids exceeded the QWQG during rainfall events.				NO_x (µg/L)	17	52.9	10	60	Se (µg/L)	16	31.2	50	1,600	3[4]
	Dissolved oxygen was variable, being mostly above the QWQG though Sep 11 and Nov 11 were below (dry periods). Two low pH readings were found obtained during Sep 11 and Mar 12.								Org N (µg/L)	17	88.2	500	420	Zn (µg/L)	17	23.5	5.0	26.0	15
									TN (µg/L)	17	88.2	500	500/3,400[3]	Cu (µg/L)	17	58.8	2.0	16.0	1.3
									TP (µg/L)	17	64.7	70	50/2,000[3]	Metals detected above the trigger levels were Al, Mn, Se, Zn and Cu. Sb, As, Ba, Bo, Fe, Sr, Ti, V, Cr and U were also detected, but without any exceedances.					
									FRP (µg/L)	17	35.3	<10	20						
									Ammonia, NOx and TP were generally above the guidelines (though less so for TP during the dry), with Org N, TH and FRP above during rainfall periods.										

1. Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2. WQO for DO based on EPP (Water) 'Aquatic Ecosystem' – the WQO for dissolved oxygen is based on a conversion from the % saturation to mg/L applying insitu temperature and altitude of 300 mAHD.
3. EHP (2013) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin. EHP (2011) – Fitzroy River Sub-basin Environmental Values and Water Quality Objectives.
4. ANZECC Guidelines low reliability value (for marine waters for St2).
5. for pH >6.5.
6. Al - Aluminium, Sb - Antimony, Fe - Iron, Pb - Lead, Se - Selenium, V - Vanadium, Zn - Zinc, Cr - Chromium, Cu - Cooper, Ag - Silver, As - Arsenic, Ba - Barium, Mn - Manganese, Sr - Strontium, Ti – Titanium.

Table 9-15 Historical water quality data - physical-chemical characteristics - Deep Creek

Site	Date	Flow Type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb Alk	SO_4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	uS/cm		NTU	°C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
De1	1/6/11	Baseflow	80.4	461	6.92	13.1	15.71	-	536	6	89	29	116	<0.1	20	16	72	3	5.65	5.52
De2	2/6/11	Baseflow	83.4	476	7.06	12.9	16.68	-	562	6	88	28	119	0.1	20	16	73	3	5.7	5.57
De3	3/6/11	Baseflow	85.8	447	7.21	17.2	14.79	-	508	6	100	24	118	0.1	17	16	82	3	5.83	5.81
De3	5/6/11	Baseflow	85.8	447	7.21	17.2	14.79	-	508	6	100	24	118	0.1	17	16	82	3	5.83	5.81
De1	29/9/11	No flow	58.4	849	8.0	7.6	20.7	185	-	-	-	-	-	-	-	-	-	-	-	-
De2	29/9/11	No flow	34.7	795	8.1	7.5	20.6	194	593	13	102	42	171	0.1	28	25	92	4	7.74	7.56
De3	29/9/11	No flow	30	754	7.9	9.8	21.5	242	445	11	173	14	144	0.1	26	22	100	3	7.81	7.53
De3	25/10/11	No flow	78.3	619	8.4	44.0	25.2	171	341	20	121	6	112	0.3	17	16	80	3	5.7	5.72
De1	26/10/11	No flow	73.5	918	7.1	6.5	22.0	135	-	-	-	-	-	-	-	-	-	-	-	-
De2	26/10/11	No flow	26.6	767	7.7	9.2	23.1	190	493	13	100	27	184	0.1	29	25	90	6	7.75	7.57
De1	21/11/11	No flow	63.6	1,254	8.0	7.6	29.2	99	-	-	-	-	-	-	-	-	-	-	-	-
De2	21/11/11	No flow	66	925	8.1	6.0	26.4	141	545	9	132	16	218	-	30	30	108	6	9.12	8.82
De3	21/11/11	No flow	100.6	727	8.3	27.8	26.6	131	465	25	181	4	160	-	25	22	111	4	8.21	7.99
De1	13/12/11	No flow	34.4	355	8.2	Too turbid	29.5	215	-	-	-	-	-	-	-	-	-	-	-	-
De2	13/12/11	No flow	57.1	397	8.0	959	28.3	125	10,600	668	55	26	78	-	<1	<1	89	<1	3.84	3.87
De3	13/12/11	No flow	58.8	523.6	7.5	Too turbid	27.7	134	3,020	472	75	4	84	0.1	5	8	70	2	3.95	4
De1	31/1/12	Storm/ baseflow	120.3	262	4.96	180.5	26.4	214	302	98	44	13	40	<0.1	9	7	29	4	2.28	2.39
De2	31/1/12	Storm/ baseflow	156.6	465	5.53	166.5	29.4	222	307	99	44	14	39	<0.1	9	7	29	4	2.27	2.39
De1	21/2/12	Storm flow	90.1	0.07	7.2	5.0	29.1	160	388	<5	114	34	152	0.1	27	21	90	6	7.27	7.14
De2	21/2/12	Storm flow	81.3	683	7.3	6.8	28.3	144	351	5	92	31	139	0.1	24	19	77	6	6.4	6.26
De2	20/3/12	Storm flow	95.3	268	7.5	179.5	28.5	134	267	170	40	<1	44	<0.1	8	6	28	3	2.04	2.19

Table 9-16 Historical water quality data – nutrients and biological characteristics - Deep Creek

Site	Date	Flow Type	Ammonia A	Nitrite N	Nitrate N	NOx	TKN	TN	TP	FRP	E.coli
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
De1	1/6/11	Baseflow	0.03	<0.01	0.03	0.03	0.7	0.7	0.04	<0.01	~90
De2	2/6/11	Baseflow	0.03	<0.01	0.03	0.03	0.4	0.4	<0.01	<0.01	~30
De3	3/6/11	Baseflow	0.02	<0.01	0.12	0.12	0.5	0.6	0.1	-	-
De3	5/6/11	Baseflow	0.02	<0.01	0.12	0.12	0.5	0.6	0.1	-	-
De2	29/9/11	No flow	0.03	<0.01	0.02	0.02	0.4	0.4	0.04	0.02	-
De3	29/9/11	No flow	0.02	<0.01	0.02	0.02	0.4	0.4	0.04	<0.01	-
De3	25/10/11	No flow	0.01	<0.01	0.02	0.02	0.4	0.4	0.01	<0.01	-
De2	26/10/11	No flow	0.03	<0.01	0.02	0.02	0.6	0.6	0.04	<0.01	-
De2	21/11/11	No flow	0.04	<0.01	0.01	0.01	1	1	0.08	<0.01	-
De3	21/11/11	No flow	0.01	<0.01	<0.01	<0.01	0.7	0.7	0.02	<0.01	-
De2	13/12/11	No flow	0.12	0.03	0.16	0.19	6.2	6.4	2.2	<0.01	-
De3	13/12/11	No flow	0.14	<0.01	<0.01	<0.01	2.8	2.8	0.58	<0.01	-
De1	31/1/12	Storm / baseflow	0.06	<0.01	0.01	0.01	1.2	1.2	0.26	0.11	-
De2	31/1/12	Storm / baseflow	0.31	<0.01	0.01	0.01	1.6	1.6	0.26	0.11	-
De1	21/2/12	Storm flow	0.07	<0.01	<0.01	<0.01	0.5	0.5	0.03	0.02	-
De2	21/2/12	Storm flow	0.08	<0.01	<0.01	<0.01	0.4	0.4	0.04	0.02	-
De2	20/3/12	Storm flow	0.14	<0.01	0.02	0.02	1	1	0.16	0.07	-

Table 9-17 Historical water quality data – dissolved metals - Deep Creek

Site	Date	Flow Type	Al	An	As	Ba	Bo	Cr	Cu	Fe	Pb	Mn	Se	Sr	Ti	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
De1	1/6/11	Baseflow	<0.1	-	<0.01	<0.1	-	<0.001	0.002	<0.05	<0.01	0.08	<0.01	-	-	<0.01	0.029
De2	2/6/11	Baseflow	<0.1	-	<0.01	<0.1	-	<0.001	<0.001	<0.05	<0.01	0.04	<0.01	-	-	<0.01	0.006
De3	3/6/11	Baseflow	<0.1	-	<0.01	<0.1	-	<0.001	<0.001	<0.05	<0.01	0.04	<0.01	-	-	<0.01	<0.005
De3	5/6/11	Baseflow	<0.1	-	<0.01	<0.1	-	<0.001	<0.001	<0.05	<0.01	0.04	<0.01	-	-	<0.01	<0.005
De2	29/9/11	No flow	<0.1	<0.01	<0.01	<0.1	<0.1	<0.001	0.001	0.06	<0.01	0.89	<0.01	0.4	<0.01	<0.01	0.03
De3	29/9/11	No flow	<0.1	<0.01	0.01	0.1	<0.1	<0.001	<0.001	0.09	<0.01	0.82	<0.01	0.4	<0.01	<0.01	<0.005
De3	25/10/11	No flow	<0.1	<0.01	<0.01	<0.1	<0.1	<0.001	<0.001	<0.05	<0.01	0.08	<0.01	<0.1	<0.01	<0.01	<0.005
De2	26/10/11	No flow	<0.1	<0.01	<0.01	<0.1	<0.1	<0.001	<0.001	<0.05	<0.01	1.28	<0.01	0.4	<0.01	<0.01	<0.005
De2	21/11/11	No flow	<0.1	<0.01	<0.01	0.1	<0.1	<0.001	<0.001	0.14	<0.01	0.43	<0.01	0.5	<0.01	<0.01	<0.005
De3	21/11/11	No flow	<0.1	<0.01	<0.01	<0.1	0.1	<0.001	<0.001	<0.05	<0.01	0.34	<0.01	0.4	<0.01	<0.01	<0.005
De3	13/12/11	No flow	<0.1	<0.1	<0.1	<0.1	<0.1	<0.001	0.004	<0.1	<0.1	0.2	<0.1	<1	<0.1	<0.1	0.009
De1	31/1/12	Storm / baseflow	8.72	<0.01	<0.01	<0.1	<0.1	<0.001	0.003	4.17	<0.01	0.04	<0.01	0.1	0.2	0.02	<0.005
De2	31/1/12	Storm / baseflow	8.71	<0.01	<0.01	<0.1	<0.1	<0.001	0.003	4.18	<0.01	0.04	<0.01	0.1	0.2	0.02	<0.005
De1	21/2/12	Storm flow	<0.1	<0.01	<0.01	<0.1	0.1	<0.001	0.001	<0.05	0.01	0.06	0.02	0.4	<0.01	<0.01	<0.005
De2	21/2/12	Storm flow	<0.1	<0.01	<0.01	<0.1	<0.1	<0.001	0.001	<0.05	0.01	<0.01	0.02	0.4	<0.01	<0.01	<0.005
De2	20/3/12	Storm flow	1.96	0.01	<0.01	<0.1	<0.1	0.002	0.003	1.62	<0.01	0.03	<0.01	0.1	0.07	<0.01	<0.005

Table 9-18 Historical water quality data - physical-chemical characteristics - Tooloombah Creek

Site	Date	Flow Type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb Alk	SO_4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	uS/cm		NTU	°C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
To1	3/6/11	Baseflow	94.7	866	7.59	5.93	16.05	-	740	<5	212	42	232	0.2	65	47	104	2	11.6	11.7
To2	4/6/11	Baseflow	92.11	848	7.4	1.67	15.64	-	778	<5	209	41	228	0.2	63	46	104	2	11.5	11.5
To1	29/9/11	Baseflow	70.1	951	8	5.6	22.3	192	-	-	-	-	-	-	-	-	-	-	-	-
To2	29/9/11	Baseflow	88.9	965	7.9	3	23.7	227	676	9	178	39	223	0.2	52	38	91	2	10.7	9.73
To1	25/10/11	Baseflow	76.1	1132	8.1	5.4	24.2	166	669	5	162	40	254	0.2	54	45	105	3	11.2	11
To2	25/10/11	Baseflow	136.6	1146	8.4	7.2	27.1	166	674	8	153	38	250	0.2	53	44	104	3	10.9	10.9
To2	21/11/11	Baseflow	127.5	1407	8.3	4.7	28.8	144	820	9	168	33	366	-	50	52	155	3	14.4	13.6
To1	22/11/11	Baseflow	74.5	1276	8.2	1.2	28.4	180	718	<5	183	39	313	-	53	48	129	2	13.3	12.3
To1	14/12/11	Baseflow	87.7	1225	7.7	15	27.7	148	608	<5	140	24	243	0.2	43	37	98	3	10.2	9.53
To2	14/12/11	Baseflow	108	1320	7.8	18.8	30.1	159	657	12	151	23	270	0.2	45	42	108	3	11.1	10.5
To1	31/01/12	Storm/baseflow	143.4	392	5.86	119.8	29.6	225	247	51	40	10	28	<0.1	9	6	20	3	1.8	1.89
To1	21/02/12	Storm flow	90.1	463	7.8	13.9	28.6	163	240	10	91	10	80	0.1	21	15	43	2	4.28	4.2
To1	20/03/12	Storm flow	98.8	193.7	7.5	125	28.6	139	235	23	41	<1	21	0.2	6	4	18	2	1.41	1.46

Table 9-19 Historical water quality data – nutrients and biological characteristics – Tooloombah Creek

Site	Date	Flow Type	Ammonia A	Nitrite N	Nitrate N	NOx	TKN	TN	TP	FRP	*E.coli*
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
To1	3/6/11	Baseflow	0.02	<0.01	0.03	0.03	0.4	0.4	0.03	-	-
To2	4/6/11	Baseflow	0.02	<0.01	0.02	0.02	0.6	0.6	0.02	-	-
To2	29/9/11	Baseflow	0.03	<0.01	0.01	0.01	0.4	0.4	0.07	<0.01	-
To1	25/10/11	Baseflow	0.02	<0.01	0.02	0.02	0.4	0.4	0.01	<0.01	-
To2	25/10/11	Baseflow	0.02	<0.01	0.02	0.02	0.4	0.4	<0.01	<0.01	-
To2	21/11/11	Baseflow	0.04	<0.01	0.01	0.01	0.7	0.7	0.03	<0.01	-
To1	22/11/11	Baseflow	0.02	<0.01	0.02	0.02	0.5	0.5	0.05	<0.01	-
To1	14/12/11	Baseflow	0.1	<0.01	<0.01	<0.01	0.6	0.6	0.04	<0.01	-
To2	14/12/11	Baseflow	0.06	<0.01	<0.01	<0.01	0.6	0.6	0.08	0.02	-
To1	31/01/12	Storm / baseflow	0.25	<0.01	0.01	0.01	1.2	1.2	0.17	0.06	-
To1	21/02/12	Storm flow	0.06	<0.01	0.02	0.02	0.4	0.4	0.04	0.01	-
To1	20/03/12	Storm flow	0.69	<0.01	0.02	0.02	1.2	1.2	0.15	0.02	-

Table 9-20 Historical water quality data – dissolved metals - Tooloombah Creek

Site	Date	Flow Type	Al	An	As	Ba	Bo	Cr	Cu	Fe	pH	Mn	Se	Sr	Ti	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
To1	3/6/11	Baseflow	<0.10	-	<0.01	<0.1	<0.001	<0.001	<0.05	0.01	<0.01	-	-	-	0.001	<0.01	<0.005
To2	4/6/11	Baseflow	<0.10	-	<0.01	<0.1	<0.001	<0.001	<0.05	0.03	<0.01	-	-	-	0.001	<0.01	<0.005
To2	29/9/11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.04	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	0.01
To1	25/10/11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.02	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To2	25/10/11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.02	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To2	21/11/11	Baseflow	<0.10	<0.01	0.01	0.1	<0.001	<0.001	<0.05	0.04	0.02	0.6	<0.01	<0.01	<0.001	<0.01	<0.005
To1	22/11/11	Baseflow	<0.10	0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.29	<0.01	0.6	<0.01	<0.01	<0.001	<0.01	<0.005
To1	14/12/11	Baseflow	<0.10	<0.01	<0.01	<0.1	0.002	0.001	<0.05	0.05	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To2	14/12/11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	0.001	<0.05	0.12	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To1	31/01/12	Storm / baseflow	7.47	<0.01	<0.01	<0.1	<0.001	0.002	3.18	0.03	<0.01	0.1	<0.01	0.18	<0.001	0.01	<0.005
To1	21/02/12	Storm flow	<0.1	<0.01	<0.01	<0.1	<0.001	<0.001	0.05	0.01	0.01	0.2	<0.01	<0.01	<0.001	<0.01	<0.005
To1	20/03/12	Storm flow	2.89	<0.01	<0.01	<0.1	<0.001	0.002	1.62	0.01	<0.01	<0.1	0.01	0.08	<0.001	<0.01	<0.005

Table 9-21 Historical water quality data - physical-chemical characteristics – Styx River

Site	Date	Flow Type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb Alk	SO_4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	uS/cm		NTU	^oC	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
St2	4/6/11	Baseflow	114.6	1,390	7.63	5.41	18.49	-	1,080	<5	306	68	422	0.4	64	55	227	6	19.4	17.8
St1	5/6/11	Baseflow	90.9	987	9.19	5.63	16.74	-	850	<5	190	42	291	0.2	58	45	139	2	12.9	12.7
St1	27/9/11	Baseflow	-	1,942	6.9	-	23.3	-	-	-	-	-	-	-	-	-	-	-	-	-
St2	27/9/11	Baseflow	-	5,450	6.8	11.8	23.9	125	-	-	-	-	-	-	-	-	-	-	-	-
St1	29/9/11	Baseflow	87.3	1,873	7.8	5.9	22.8	244	1,260	9	192	60	531	0.2	64	58	252	3	20.1	19
St2	29/9/11	Baseflow	49.8	8,200	6.9	9.7	22.4	203	6,400	21	266	379	2,800	0.4	124	192	1,490	47	92.2	88
St1	25/10/11	Baseflow	113.6	2,562	6.8	8.4	28.7	104	1,510	9	177	69	646	0.2	76	74	333	4	23.2	24.5
St2	25/10/11	Baseflow	158.4	5,100	8.0	12.7	27.1	145	3,120	13	208	187	1,340	0.3	85	123	780	25	45.8	48.9
St1	21/11/11	Baseflow	116.4	3,830	7.6	6.8	29.9	98	2,270	13	226	106	998	-	111	107	487	4	34.9	35.6
St2	21/11/11	Baseflow	177.4	5,600	8.2	7.9	28.7	118	4,440	18	214	240	1,650	-	85	147	969	26	56.2	59.2
St1	13/12/11	Baseflow	161	2,264	7.7	67.7	32.3	186	1,050	27	103	37	487	0.1	38	44	224	4	16.6	15.4
St2	13/12/11	Baseflow	163.2	1,445	8.1	109.9	32.2	198	736	33	103	24	324	0.2	27	29	154	7	11.7	10.6
St1	31/1/12	Storm/baseflow	90.6	321.5	7.12	201.4	27.2	196	268	84	44	9	30	<0.1	8	6	21	3	1.91	1.88
St2	31/1/12	Storm/baseflow	125.5	206	7.32	162.1	27.2	213	303	103	41	10	35	<0.1	7	6	26	4	2.01	2.08
St2	22/2/12	Storm flow	81.4	189.9	8.1	177.2	24.3	176	1,110	548	44	4	28	<0.1	6	5	22	2	1.75	1.72
St2	20/3/12	Storm flow	91.9	1,953	6.4	157.2	28.4	140	242	52	40	<1	22	<0.1	6	4	20	2	1.42	1.55

Table 9-22 Historical water quality data – nutrients and biological characteristics – Styx River

Site	Date	Flow Type	Ammonia	Nitrite	Nitrate	NOx	TKN	TN	TP	FRP	*E.coli*
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
St2	4/6/11	Baseflow	0.03	<0.01	0.04	0.04	0.4	0.4	<0.01	<0.01	17
St1	5/6/11	Baseflow	0.02	<0.01	0.04	0.04	0.5	0.5	0.12	<0.01	10
St1	29/9/11	Baseflow	0.02	<0.01	0.03	0.03	0.5	0.5	0.12	<0.01	-
St2	29/9/11	Baseflow	0.03	<0.01	0.02	0.02	0.2	0.2	0.06	<0.01	-
St1	25/10/11	Baseflow	<0.01	<0.01	0.02	0.02	0.3	0.3	<0.01	<0.01	-
St2	25/10/11	Baseflow	0.04	<0.01	0.01	0.01	0.3	0.3	<0.01	<0.01	-
St1	21/11/11	Baseflow	0.04	<0.01	0.03	0.03	0.3	0.3	<0.01	<0.01	-
St2	21/11/11	Baseflow	0.02	<0.01	0.02	0.02	0.3	0.3	0.4	<0.01	-
St1	13/12/11	Baseflow	0.08	<0.01	<0.01	<0.01	1.1	1.1	0.33	0.21	-
St2	13/12/11	Baseflow	0.12	<0.01	<0.01	<0.01	0.9	0.9	0.28	0.2	-
St1	31/1/12	Storm / baseflow	0.06	<0.01	0.01	0.01	1.0	1.0	0.2	0.07	-
St2	31/1/12	Storm / baseflow	0.07	<0.01	<0.01	<0.01	1.4	1.4	0.3	0.09	-
St2	22/2/12	Storm flow	0.05	<0.01	0.02	0.02	1.9	1.9	0.41	<0.01	-
St2	20/3/12	Storm flow	0.08	<0.01	0.02	0.02	0.8	0.8	0.19	0.05	-

Table 9-23 Historical water quality data – dissolved metals – Styx River

Site	Date	Flow Type	Al	As	Ba	Bo	Cd	Cr	Cu	Fe	Mn	Se	Sr	Ti	Ur	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
St2	4/6/11	Baseflow	<0.10	<0.01	<0.1	-	0.0001	<0.001	0.001	<0.05	0.08	<0.01	-	-	<0.001	<0.01	0.026
St1	5/6/11	Baseflow	<0.10	<0.01	<0.1	-	<0.0001	<0.001	<0.001	<0.05	0.19	<0.01	-	-	<0.001	<0.01	0.005
St1	29/9/11	Baseflow	<0.10	<0.01	0.1	<0.1	<0.0001	<0.001	<0.001	<0.05	0.28	<0.01	0.8	<0.01	<0.001	<0.01	0.03
St2	29/9/11	Baseflow	<0.10	0.1	0.2	0.7	<0.0001	<0.001	<0.001	<0.05	0.38	<0.01	1.9	<0.01	0.001	<0.01	0.02
St1	25/10/11	Baseflow	<0.10	<0.01	0.2	0.1	<0.0001	<0.001	<0.001	<0.05	0.55	<0.01	1.0	<0.01	<0.001	<0.01	<0.005
St2	25/10/11	Baseflow	<0.10	<0.01	0.1	0.4	<0.0001	<0.001	<0.001	<0.05	0.03	0.01	1.2	<0.01	<0.001	<0.01	<0.005
St1	21/11/11	Baseflow	<0.10	<0.01	0.3	0.2	<0.0001	<0.001	<0.001	<0.05	0.2	<0.01	1.6	<0.01	<0.001	<0.01	<0.005
St2	21/11/11	Baseflow	<0.10	<0.01	0.1	0.6	<0.0001	<0.001	0.002	<0.05	<0.01	<0.01	1.5	<0.01	<0.001	<0.01	<0.005
St1	13/12/11	Baseflow	<0.10	<0.01	0.1	<0.1	<0.0001	0.002	0.006	<0.05	0.13	<0.01	0.6	<0.01	<0.001	<0.01	0.011
St2	13/12/11	Baseflow	<0.10	<0.01	<0.1	0.1	<0.0001	<0.001	0.002	<0.05	0.18	<0.01	0.4	<0.01	<0.001	<0.01	<0.005
St1	31/1/12	Storm / baseflow	9.41	<0.01	<0.1	<0.1	<0.0001	<0.001	0.002	4.34	0.06	<0.01	0.1	0.26	<0.001	0.02	<0.005
St2	31/1/12	Storm / baseflow	10.8	<0.01	<0.1	<0.1	<0.0001	<0.001	0.003	5.3	0.06	<0.01	0.1	0.3	<0.001	0.02	<0.005
St2	22/2/12	Storm flow	0.51	<0.01	<0.1	<0.1	<0.0001	<0.001	0.002	0.44	0.02	<0.01	<0.1	0.02	<0.001	<0.01	0.006
St2	20/3/12	Storm flow	2.42	<0.01	<0.1	<0.1	<0.0001	0.002	0.003	1.58	0.02	0.03	<0.1	0.07	<0.001	<0.01	<0.005

9.5.3 Field Assessment – February 2017 to October 2018

Surface water assessments were conducted at 11 sites between February 2017 and October 2018. 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).

9.5.3.1 Site Condition

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 22 of October to 25 October 2018.

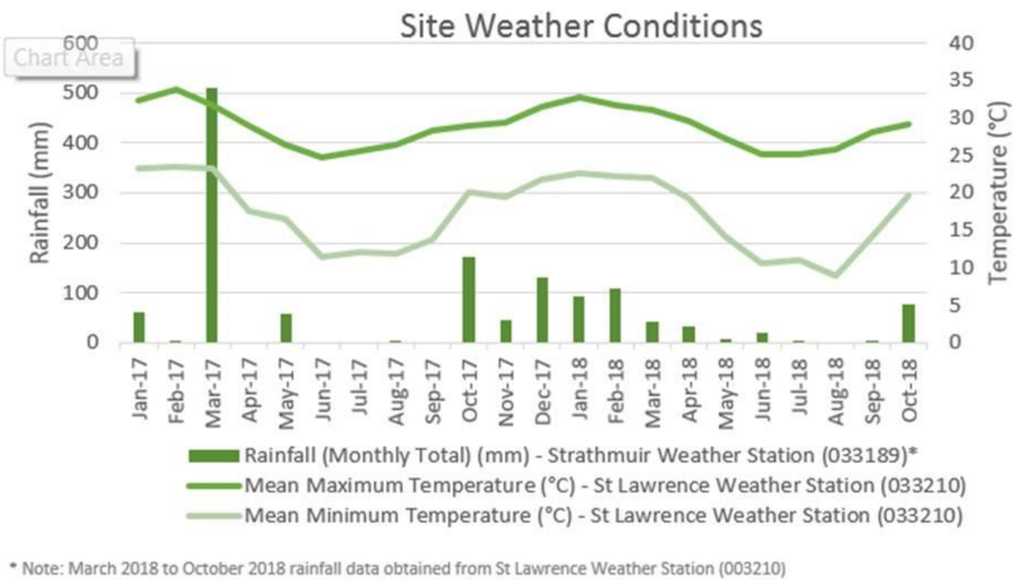


Figure 9-28 Site rainfall and temperature weather data

The vegetation recorded at the sampling locations was described as RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*). A summary of site description including flow conditions and vegetation for each of the survey sites is presented in Table 9-24. Photos have been provided as a visual reference to the various creeks within the Project area. Note that the photos are not intended to represent peak flow conditions during a flood event.

Table 9-24 Surface water survey site descriptions

Deep Creek, Site DE1 (photos taken May 2017)	
Site location	773447 m easting, 7483818 m northing South of the mine area
Flow condition	Slow / minimal flow
Bank and stream bed width	8 m
Maximum water depth (m)	0.2 – 0.3 m
Presence of bank erosion	Minimal
Bank slopes steepness	50°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).
	

Deep Creek, Site DE2 (photos taken May 2017)	
Site location	774660 m easting, 7485560 m northings To the east of the mine area, under the Bruce Highway.
Flow condition	Slow flow
Bank and stream bed width	5 – 10 m
Maximum water depth (m)	0.8 m
Presence of bank erosion	Minimal
Bank slopes steepness	45°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).

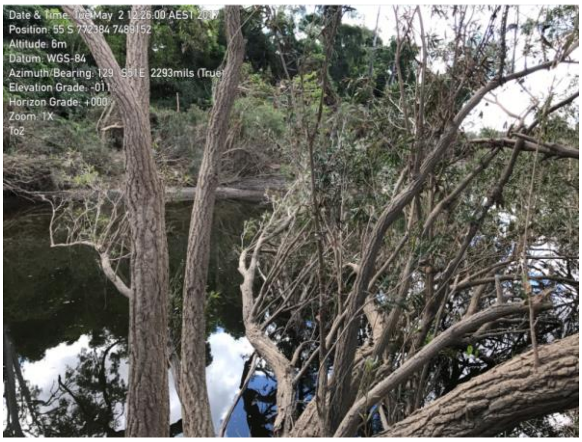
Deep Creek, Site DE3 (photos taken May 2017)	
Site location	775929 m easting, 7486636 m northings To the east of the mine area, close to the proposed haul road.
Flow condition	Flow
Bank and stream bed width	3 – 4 m
Maximum water depth (m)	0.5 m
Presence of bank erosion	Partial
Bank slopes steepness	60°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).

Deep Creek, Site DE4 (photos taken May 2017)	
Site location	774444 m easting, 7490214 m northings To the north of the mine area.
Flow condition	Slow flow
Bank and stream bed width	2 – 3 m
Maximum water depth (m)	0.3 – 0.4 m
Presence of bank erosion	Minimal
Bank slopes steepness	30 – 45°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).

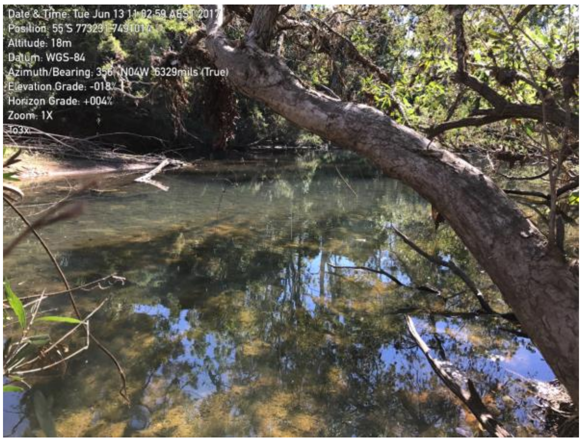
Styx River, Site ST1 (photos taken May 2017)	
Site location	773640 m easting, 7493824 m northings To the north of the Project area, to the west of the North Coast rail line.
Flow condition	Flow
Bank and stream bed width	20 m
Maximum water depth (m)	Deep
Presence of bank erosion	Minimal
Bank slopes steepness	45°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).

Tooloombah Creek, Site TO1 (photos taken May 2017)	
Site location	770196 m easting, 7488498 m northings Located to the west of the Project area.
Flow condition	Slow flow
Bank and stream bed width	5 – 10 m
Maximum water depth (m)	> 1 m
Presence of bank erosion	Minimal
Bank slopes steepness	25 – 45°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).

Tooloombah Creek, Site TO2 (photos taken May 2017)	
Site location	772292 m easting, 7489165 m northings Located to the north of the mine area.
Flow condition	Slow flow
Bank and stream bed width	15 – 20 m
Maximum water depth (m)	Deep
Presence of bank erosion	Minimal
Bank slopes steepness	60°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).



Tooloombah Creek, Site TO3x (photos taken June 2017)	
Site location	773231 m easting, 7491014 m northings Located to the north of the mine area.
Flow condition	Very slow/no flow
Bank and stream bed width	5 – 10 m
Maximum water depth (m)	1 m
Presence of bank erosion	Minimal
Bank slopes steepness	45°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).

	
Barrack Creek, Site BA1x (photos taken May 2017)	
Site location	776563 m easting, 7486323 m northings
Flow condition	Slow flow
Bank and stream bed width	10 m
Maximum water depth (m)	0.3 m
Presence of bank erosion	Minor
Bank slopes steepness	45°
Dominant habitat vegetation	RE 11.3.25 – Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea-tree (*Melaleuca leucadendra*) open forest over a variable understorey but generally including Weeping Bottlebrush (*M. viminalis*).
	

9.5.3.2 Water Quality Sampling Method

During the February 2017 to October 2018 sampling program, eleven survey sites were sampled for surface water quality. Sample sites included four on Deep Creek (De1, De2, De3, De4 and De5), three on Tooloombah Creek (To1, To2, To3), two on Styx River (St1 and St2) and one on Barrack Creek. Field observations for each sampling point are summarised at Table 9-3 and locations are shown at Figure 9-1.

The following physical parameters were tested in-situ using a calibrated hand-held water quality meter:

- Water temperature (°C);
- pH (standard unit);

- Dissolved Oxygen (DO) (% (percent saturation));
- Conductivity (µS/cm (Microsiemens per centimetre)); and
- Turbidity (NTU (Nephelometric Turbidity Units)).

Measurements were taken from streams and pools at a depth at least 0.10 m below the surface and 0.10 m above the watercourse bed using laboratory calibrated equipment. A field duplicate water sample was analysed in order to determine the precision of the analytical program. Field duplicates were within an acceptable range. The results of the internal QA/QC program undertaken by the laboratory has been reviewed to ensure that the data is reliable and complete. Chain of Custody documentation and sample receipt advice slips were signed and dated by the laboratory to confirm that sampled were received in good condition and within acceptable holding times. The analytical methods used for the laboratory's internal QA/QC program are NATA accredited. Time of day was also recorded to assist in interpreting results.

Water samples were also collected at a depth of 0.30 m. Samples were collected within laboratory supplied sample bottles and stored at 4°C, as per National Association of Testing Authorities (NATA) guidelines. Samples were transferred with a chain of custody to a NATA accredited lab for analysis. Water samples were tested for the following parameters:

- Total Dissolved Solids;
- Suspended Solids;
- Total Alkalinity;
- Sulphate;
- Chloride;
- Ammonia;
- Nitrite;
- Nitrate;
- Total Nitrogen;
- Total Phosphorus;
- Reactive Phosphorus;
- Fluoride;
- Dissolved Major Cations;
- Dissolved Metals;
- Ionic Balance;
- Total Petroleum Hydrocarbons; and
- BTEXN (benzene, toluene, ethylbenzene, xylene, naphthalene).

9.5.4 Sediment Sampling

The ANZECC guidelines provide a framework for managing receiving water quality. Those Guidelines recognised that total load and fate of contaminants, particularly to enclosed systems, should also be considered. Sediments are important, both as a source and as a sink of contaminants, and the ANZECC guidelines have established Interim Sediment Quality Guidelines as a basis for sediment quality assessments. These guidelines have subsequently been updated in the Sediment quality assessment: A Practical Handbook by CSIRO (Simpson and Batley 2016).

There are no specific guidelines based on Australian regions or habitat types, with the guidelines noting that: 'There is little reliable data on sediment toxicity for either Australia or New Zealand from which independent sediment quality guidelines might be derived'. Interim values have been set by the ANZECC guidelines until specific sediment guidelines are established for Australia. It is important to note that the upper and lower guideline values are guides only. Where data exceed the low trigger value, the guidelines suggest that the levels recorded are merely higher than occur naturally and if levels exceed the high trigger value, mitigation and management measures may be required.

The decision tree in the ANZECC guidelines for assessment of potentially contaminated sediments notes that where test results are below the lower Interim Sediment Quality Guidelines value, there is low risk and typically no action is necessary. Exceedances of the upper Interim Sediment Quality Guidelines value should require an examination of factors. Those values that lay between the limits should be checked against background concentrations. The purpose of sediment sampling for the Project is to understand the existing environment and set the baseline waterway sediment quality to assist with determining any potential future impacts, should they occur.

Central Queensland Coal commits to assessing sediments at each of the water quality monitoring locations prior to the commencement of construction activities, during the first wet season and at the completion of the first wet season after construction has started. Additional sediment sampling sites downstream of the Project closer to Ogmore will be added to the sites to be monitored. The sediments sampling program will be developed and described in the REMP that will be prepared for the Project prior to the commencement of mining activities. Sediments samples will then be collected annually from each water quality monitoring location prior to and post each wet season. Sediment sampling will also be collected post each severe weather event, (i.e. cyclonic conditions, long duration rain fall events). This approach will provide a relevant assessment of sediment characteristics as a background and in a mobilised setting.

Sediment samples will be collected from the bed of the watercourse at each water quality site. Samples will be collected, recorded, handled and transported according to NATA guidelines and all samples will be analysed at a NATA accredited lab. The quality assurance, sample methods and physico-chemical analytical parameters selected for analysis will be aligned with the DES Monitoring and Sampling Manual 2009 (Version 2, July 2013) and the more recent guidance by CSIRO (Simpson and Batley 2016). All results will be compared against the most recent sediment guidelines which are currently represented in Table A.1 of the CSIRO publication.

9.5.5 Surface Water Quality Assessment

Baseline water quality values for samples captured during the seventeen sampling events in 2017-2018 are presented in Table 9-25 to Table 9-41. The February 2017 survey followed a very dry period and no flow was recorded in the creeks. Heavy rains associated with Cyclone Debbie were experienced in the area in late March and flowing water was recorded during the May 2017 survey. 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 9-42. The samples are compared against the

Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values, Water Quality Objectives 2014, 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 brief assessment of the results for the key parameters.

9.5.5.1 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 9-29). 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 and 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.

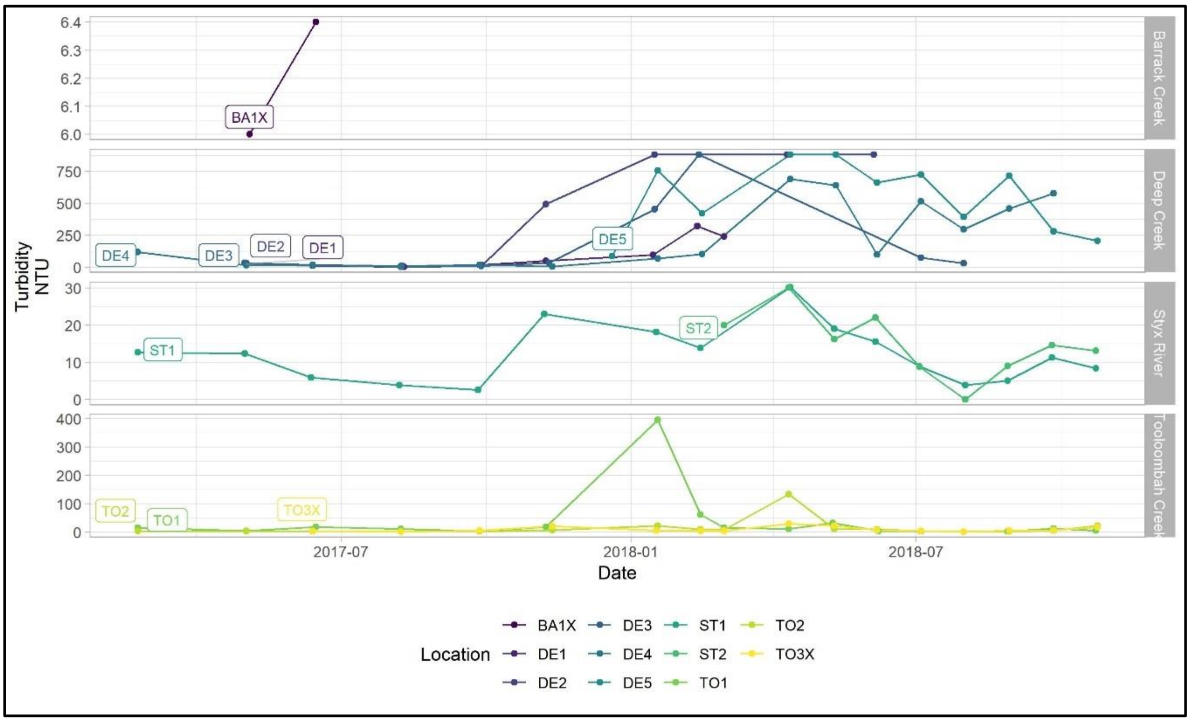


Figure 9-29 2017-2018 turbidity surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

9.5.5.2 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 9-30. 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 9-31).

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).

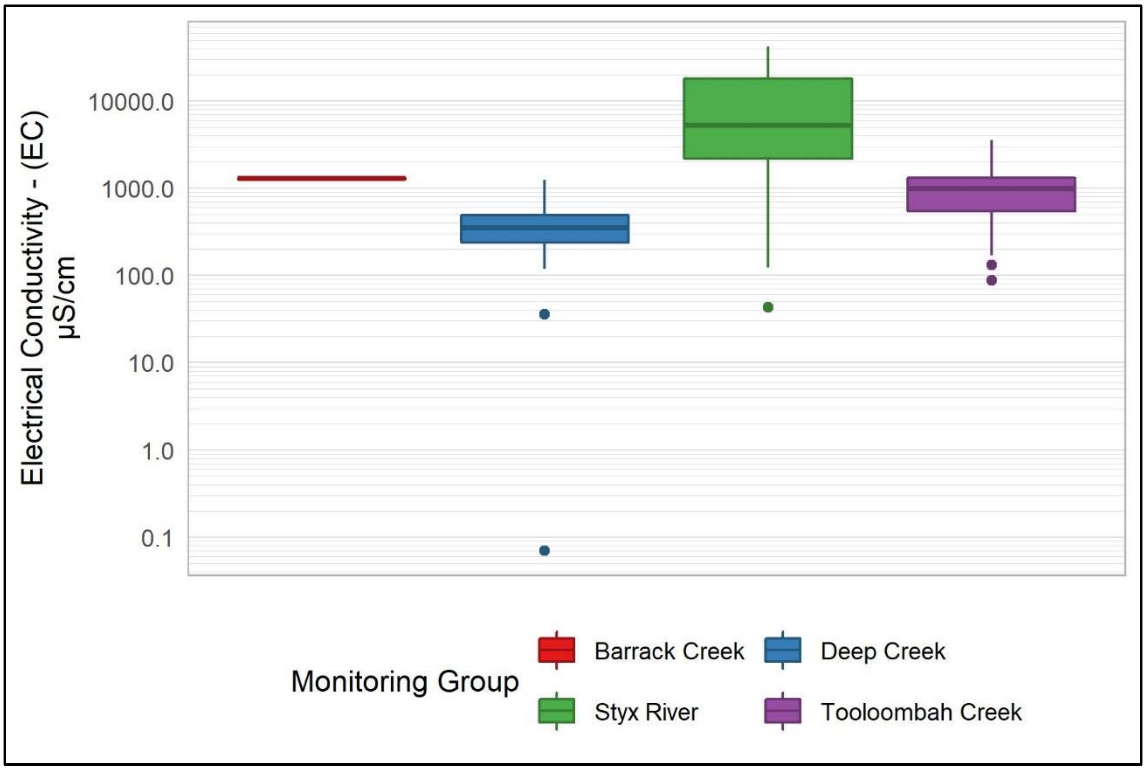


Figure 9-30 2011-2018 electrical conductivity surface water quality box-plot data (log scale) for Barrack, Deep, Tooloombah Creeks and Styx River

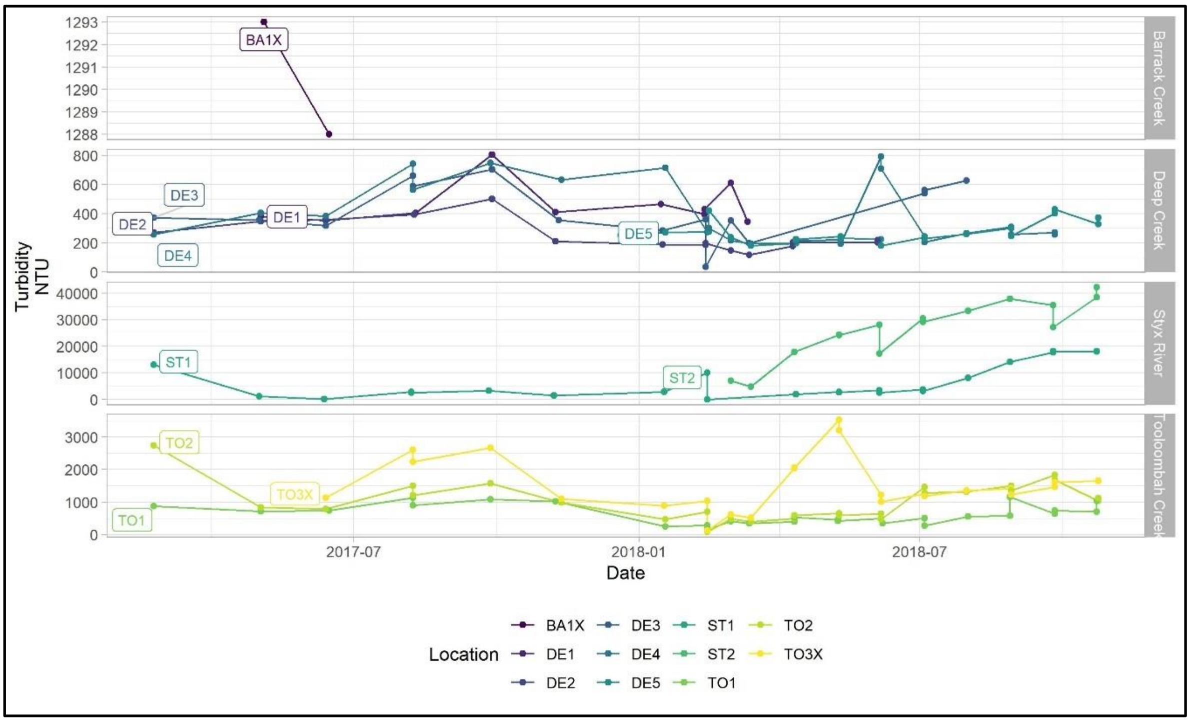


Figure 9-31 2017-2018 electrical conductivity surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

9.5.5.3 pH

Styx River, Deep Creek and Tooloombah Creek show a broad range of pH over time as illustrated in Figure 9-32. The pH typically sits between 7-8 with Tooloombah Creek reporting more alkaline conditions than the other creeks. Figure 9-33 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.

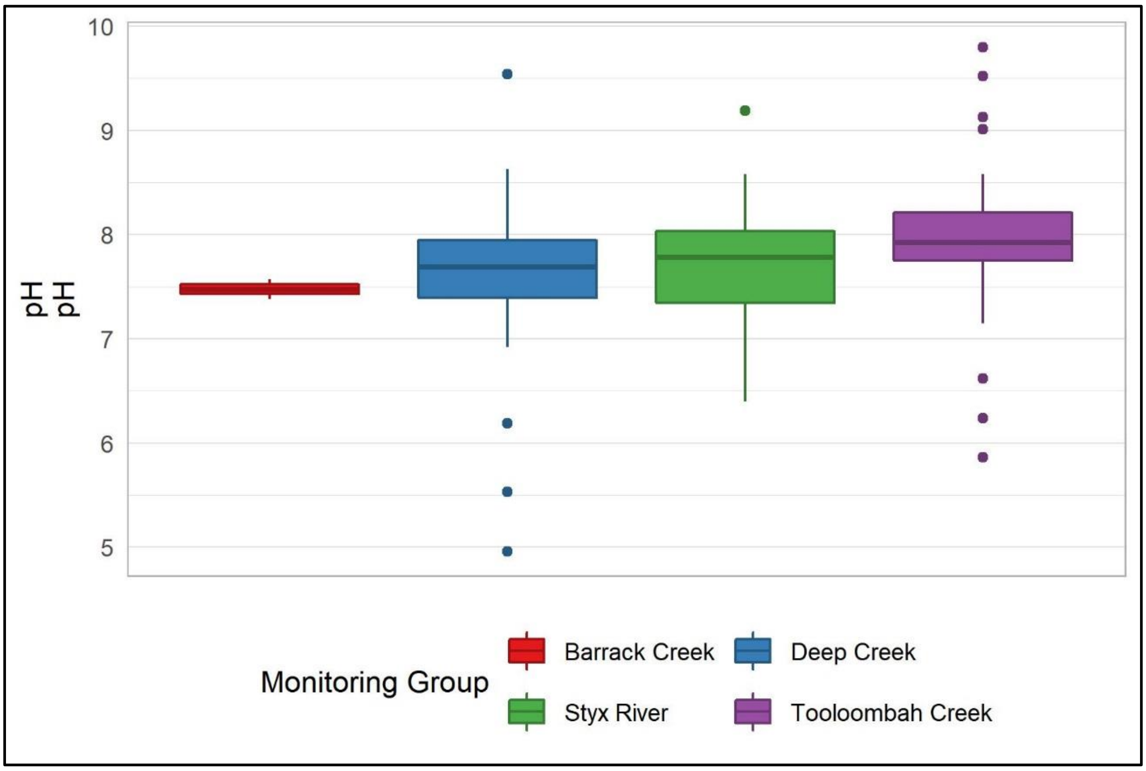


Figure 9-32 2011-2018 pH surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

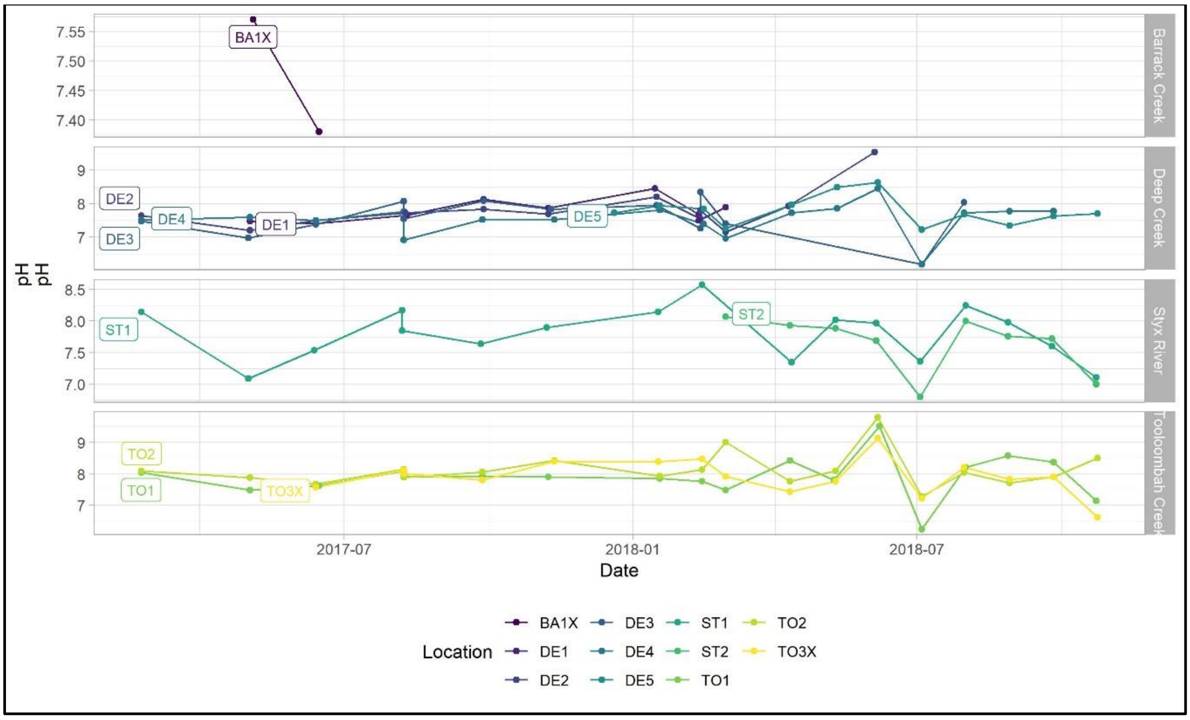


Figure 9-33 2017-2018 pH surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

9.5.5.5 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 9-34). Elevated levels occur during both 2017 and 2018 wet season flows as illustrated in Figure 9-35 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 9-36. The time series data plots (Figure 9-37) 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 9-38). 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 9-39).

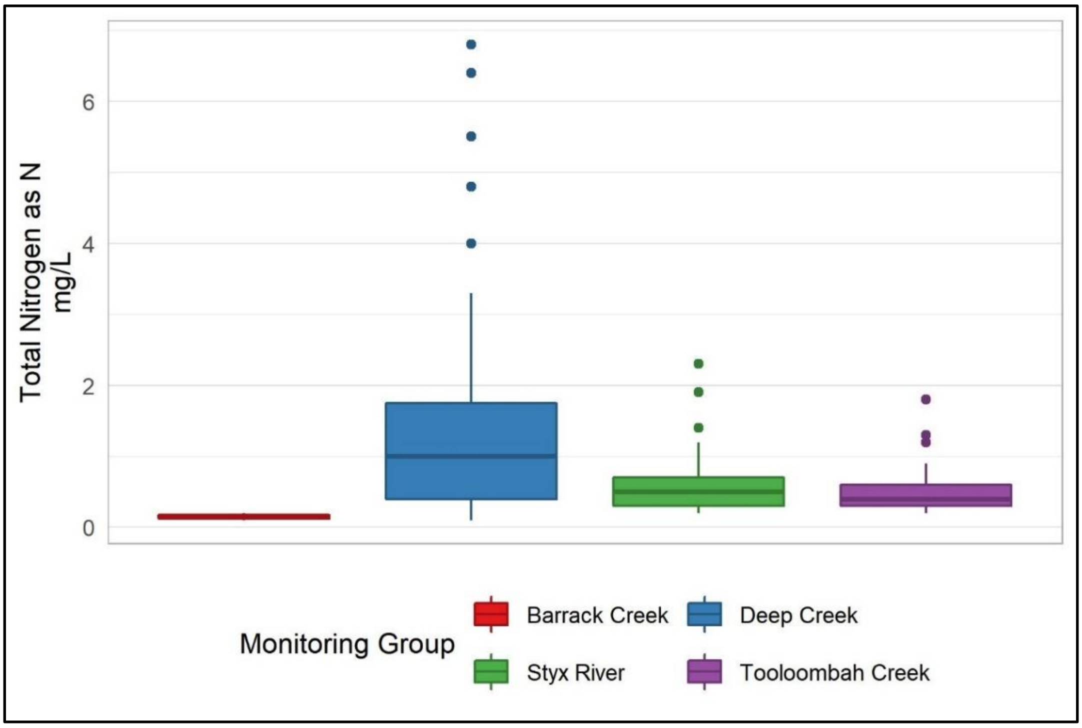


Figure 9-34 2011-2018 total nitrogen surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

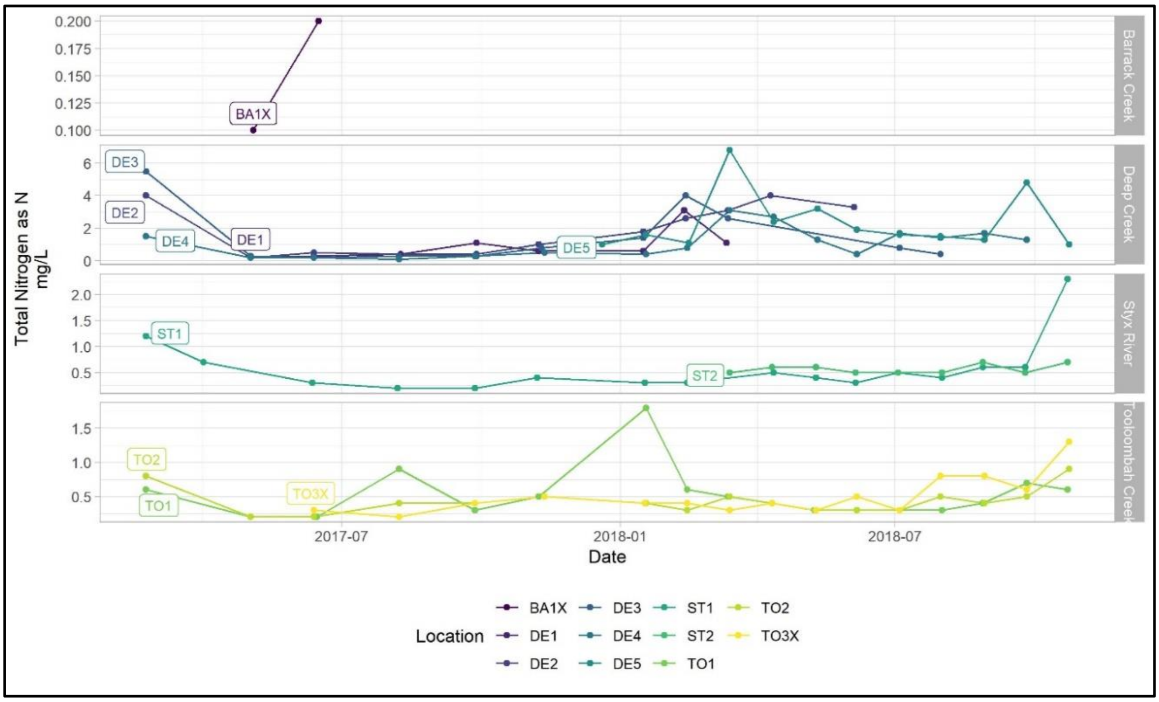


Figure 9-35 2017-2018 total nitrogen surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

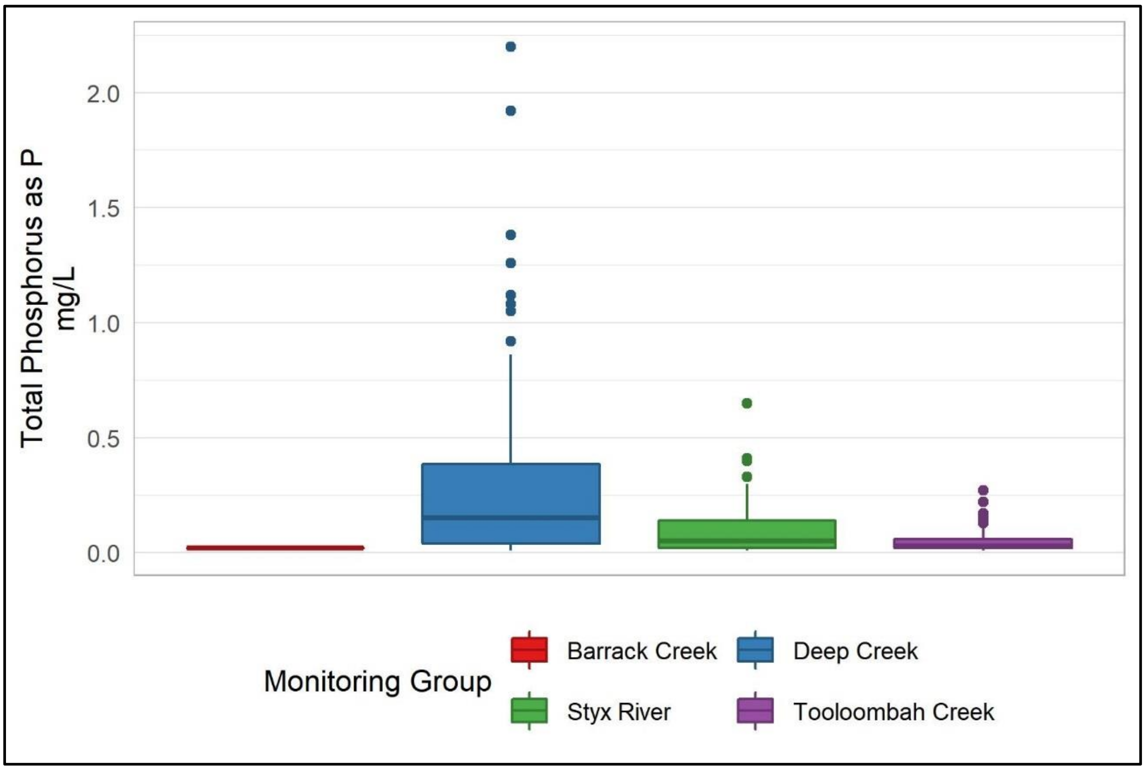


Figure 9-36 2011-2018 total phosphorus surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

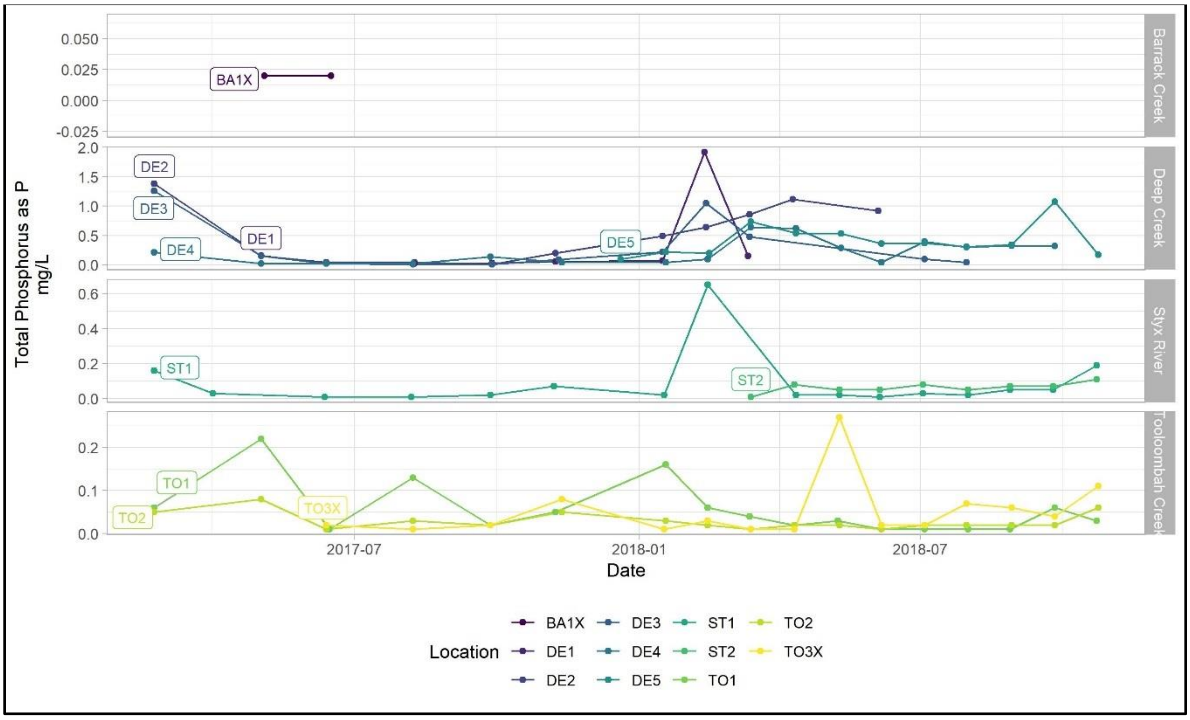


Figure 9-37 2017-2018 total phosphorus surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

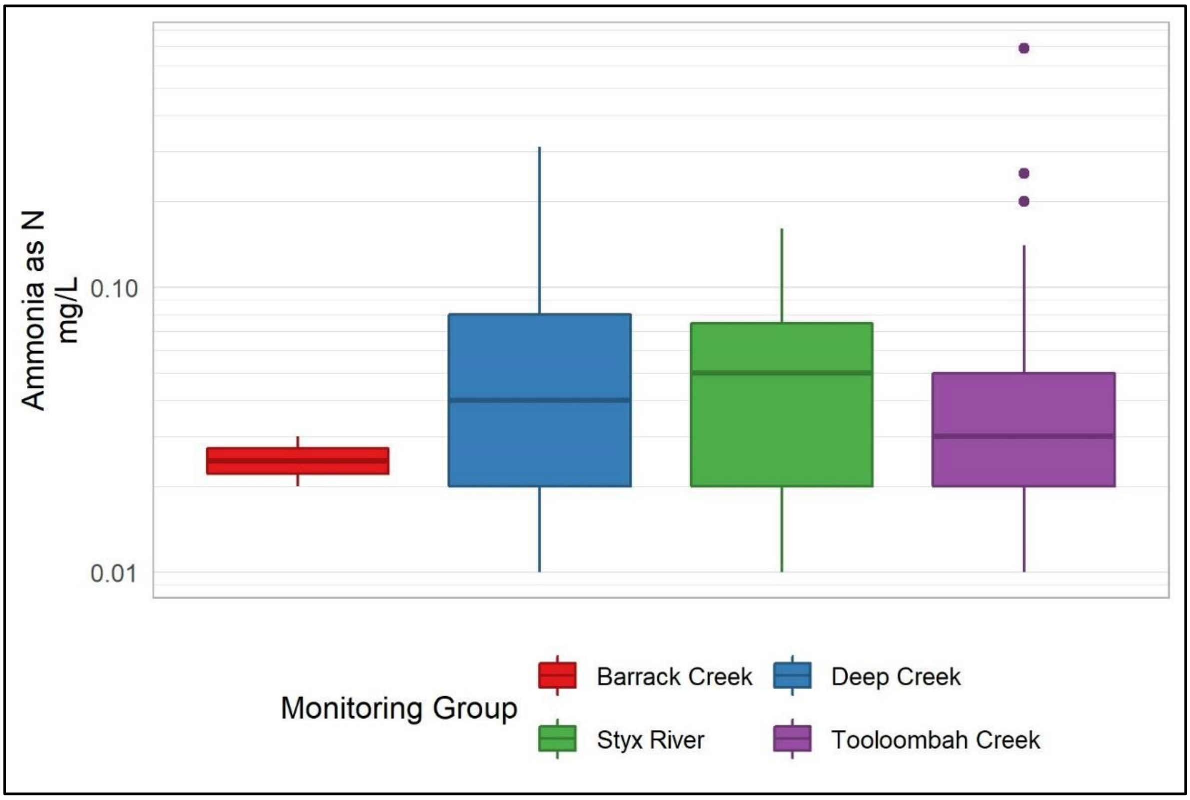


Figure 9-38 2011-2018 ammonia-N surface water quality box-plot data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

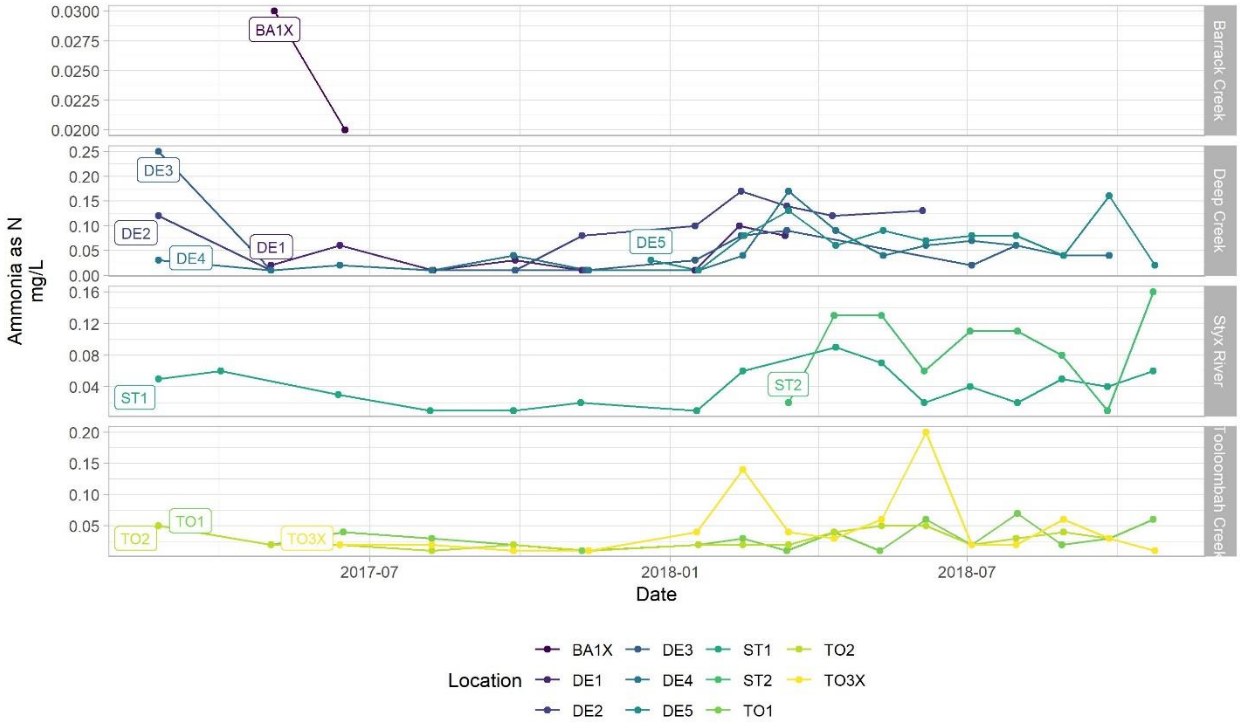


Figure 9-39 2017-2018 ammonia-N surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

9.5.5.6 Dissolved Heavy Metals

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 9-40. The time series plot (Figure 9-41) 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 9-42), 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 9-43). 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 9-44). 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.

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.

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).

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 9-44). 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 9-47) 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.

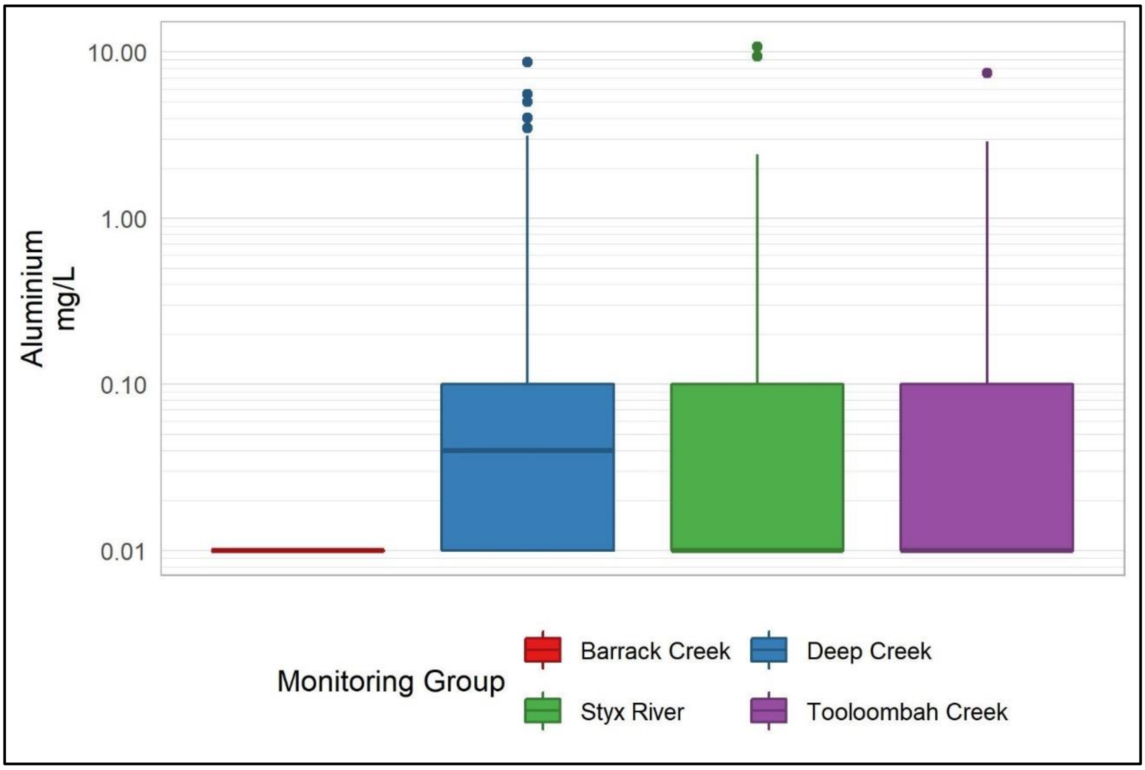


Figure 9-40 2011-2018 dissolved aluminium surface water quality box-plot data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

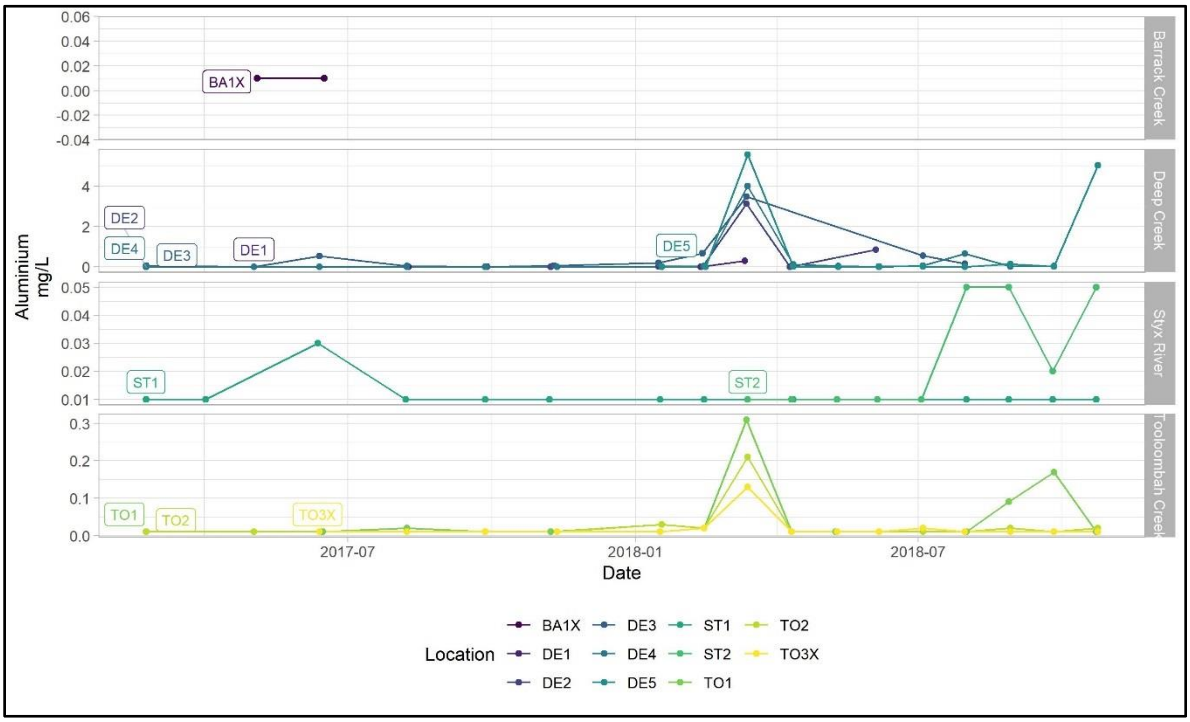


Figure 9-41 2017-2018 dissolved aluminium surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

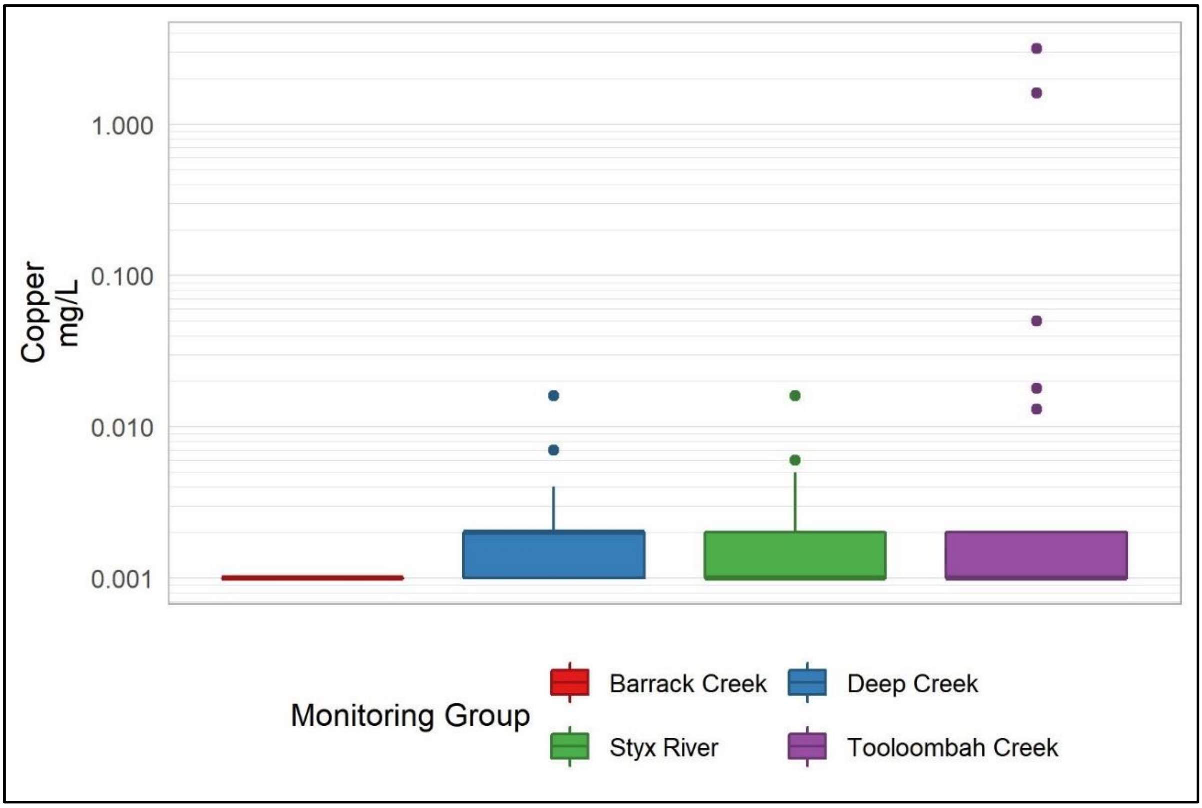


Figure 9-42 2011-2018 dissolved copper surface water quality box-plot data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

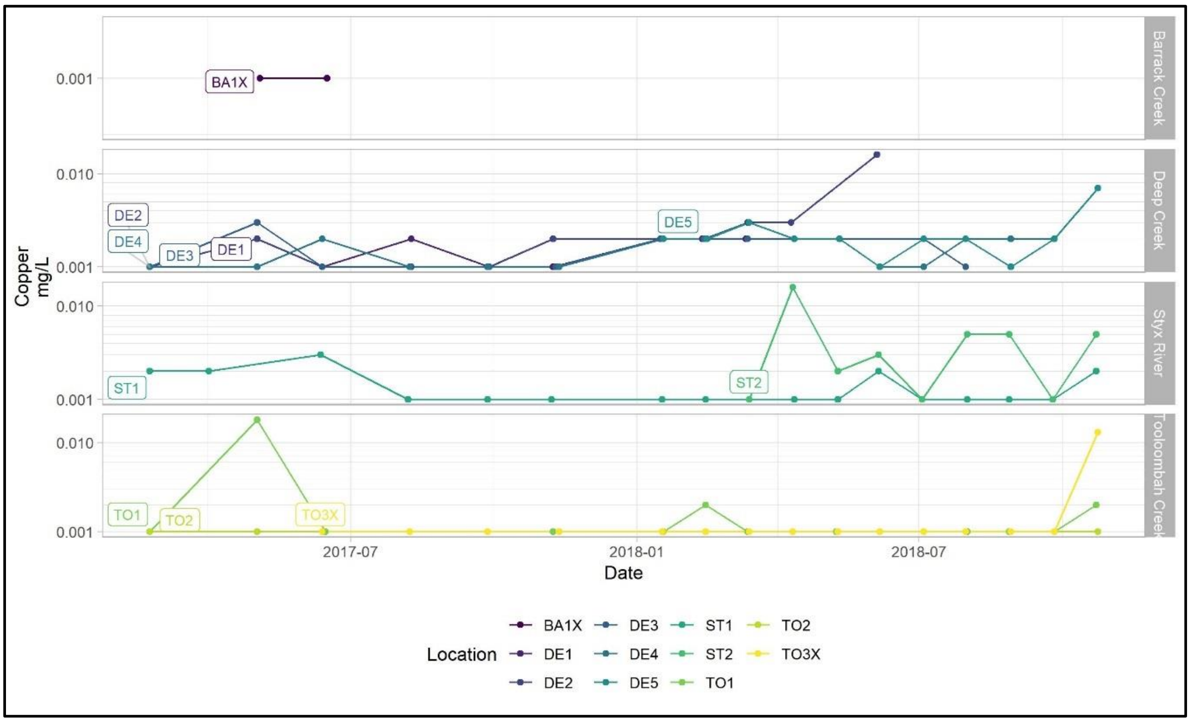


Figure 9-43 2017-2018 dissolved copper surface water quality time-series data (log-scale) for Barrack, Deep, Tooloombah Creeks and Styx River

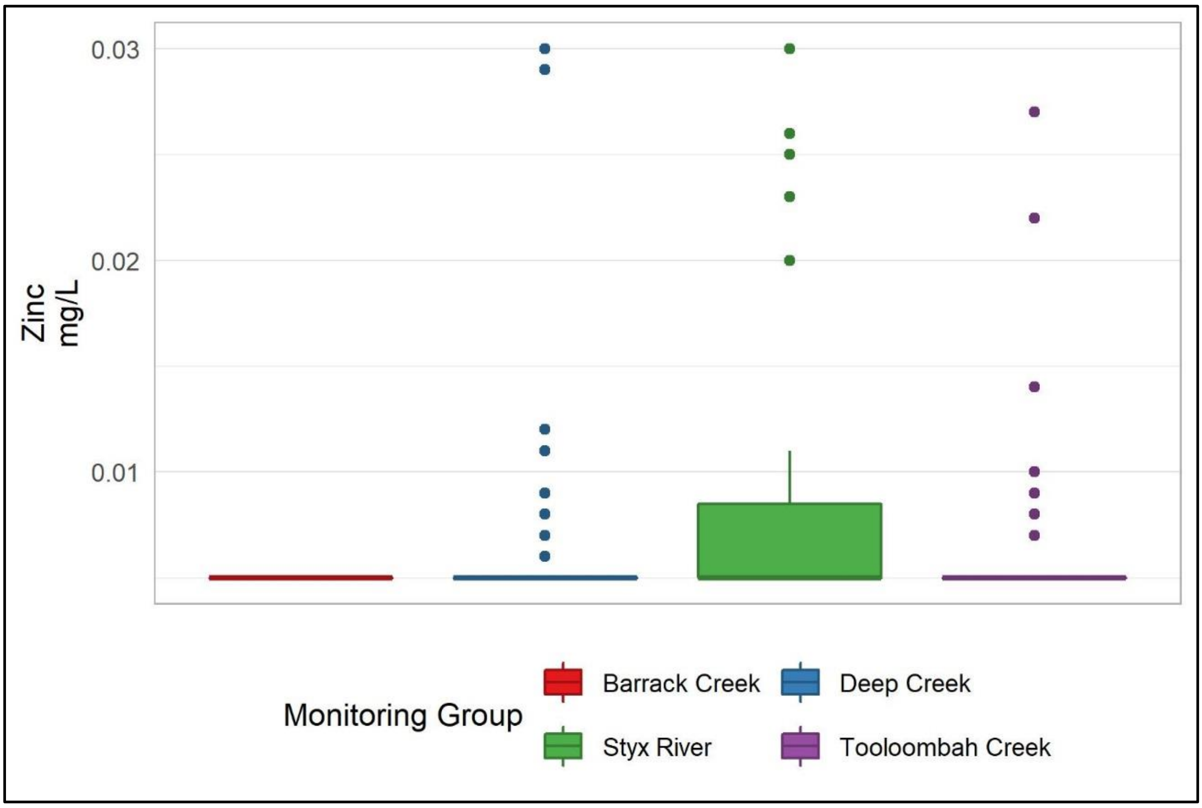


Figure 9-44 2011-2018 dissolved zinc surface water quality box-plot data for Barrack, Deep, Tooloombah Creeks and Styx River

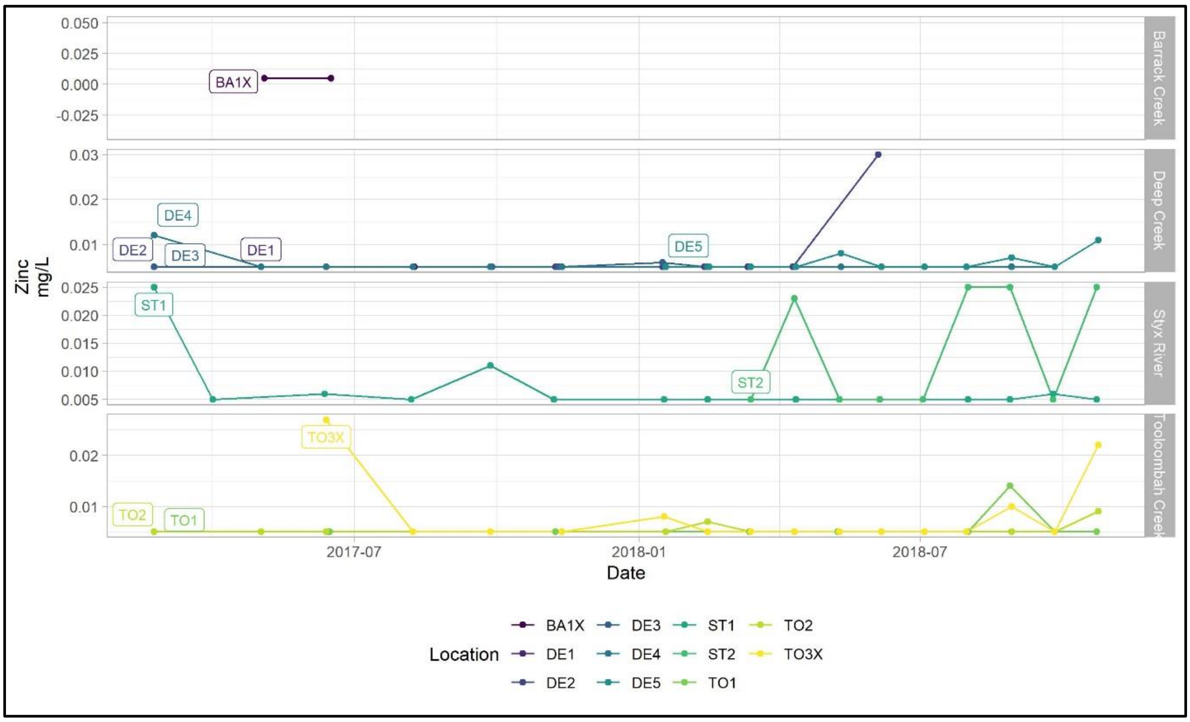


Figure 9-45 2017-2018 dissolved zinc surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

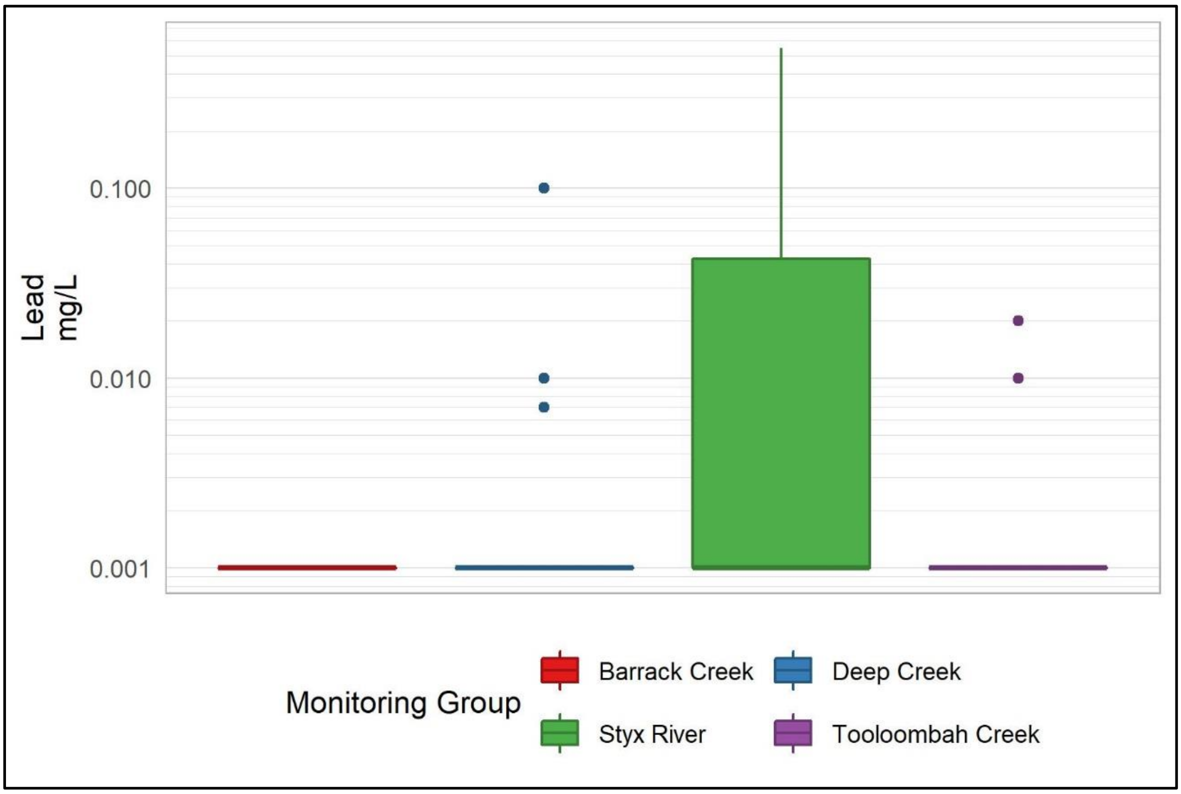


Figure 9-46 2011-2018 dissolved lead surface water quality box-plot data (log scale) for Barrack, Deep, Tooloombah Creeks and Styx River

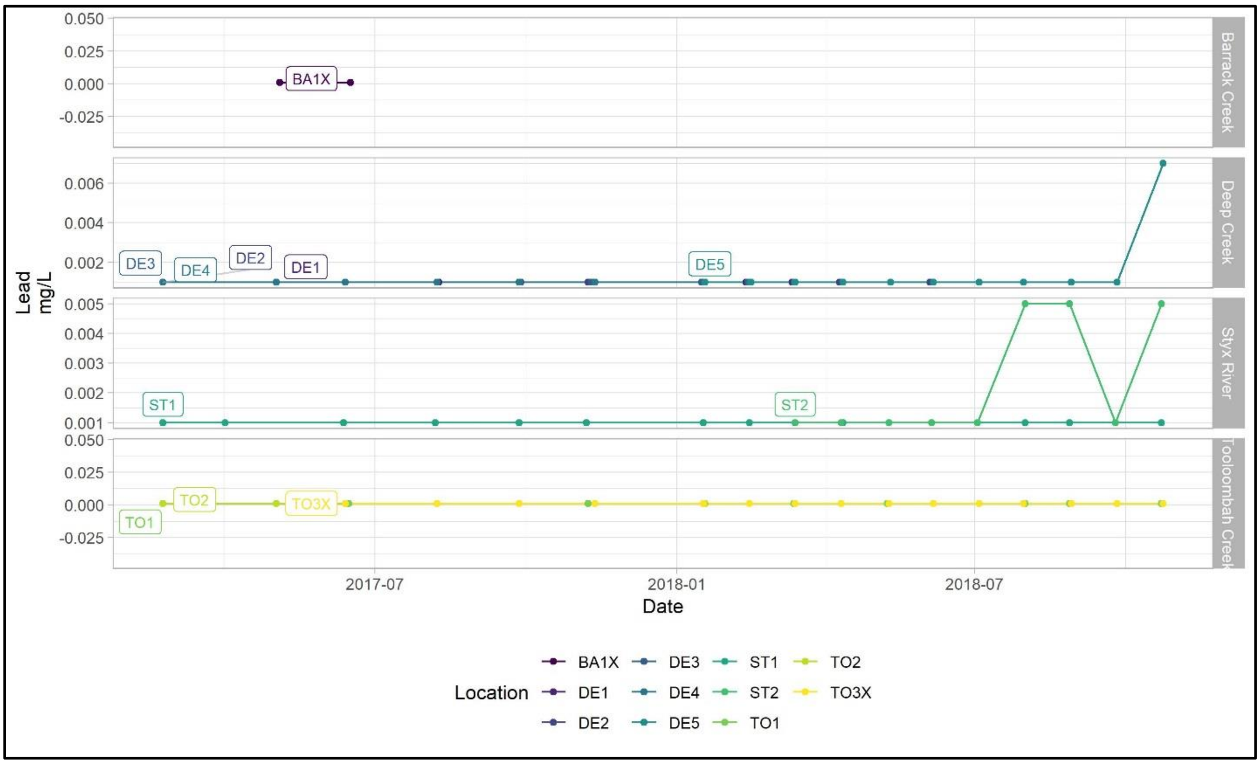


Figure 9-47 2017-2018 dissolved lead surface water quality time-series data for Barrack, Deep, Tooloombah Creeks and Styx River

Table 9-25 Surface water quality results during February 2017 sample events

Parameter	WQOs	Styx River	Barrack Creek	Tooloombah Creek			Deep Creek			
		St1	Ba1	To1	To2	To3	De1	De2	De3	De4
In-situ results										
Water Temperature (°C)	**16 – 34[5]**	29.9	Dry	26.6	29.5	Inaccessible	Dry	27.1	26.2	28.7
Dissolved Oxygen (mg/l)[7]	**6.77 – 8.76[3]**	5.07	Dry	14.5	3.3	Inaccessible	Dry	3.01	1.3	2.8
pH	**6.5 – 8.0[3]**	8.15	Dry	8.04	8.1	Inaccessible	Dry	7.65	7.48	7.51
Conductivity- base flow (µS/cm)	**20-250[1]**	13,103	Dry	872	2,737	Inaccessible	Dry	271.9	373.7	258.8
Turbidity (NTU)	**50[3]**	12.6	Dry	14.5	3.3	Inaccessible	Dry	XXX	XXX	116
Laboratory results										
Total Dissolved Solids (mg/L)	**600[4]**	7,810	Dry	348	1,660	Inaccessible	Dry	1,540	3,570	236
Suspended Solids (mg/L)	**10[3]**	13	Dry	5	5	Inaccessible	Dry	1,100	161	32
Total Alkalinity as $CaCO_3$ (mg/L)	**≥20[1]**	194	Dry	122	115	Inaccessible	Dry	74	80	54
Sulphate (mg/L)	**250[4]**	501	Dry	12	22	Inaccessible	Dry	8	4	12
Chloride (mg/L)	-	4,510	Dry	119	849	Inaccessible	Dry	34	68	31
Ammonia N (mg/L)	**0.02**	0.05	Dry	0.05	0.05	Inaccessible	Dry	0.12	0.25	0.03
Nitrite N (mg/L)	-	<0.01	Dry	<0.01	<0.01	Inaccessible	Dry	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	**0.158[1]**	<0.01	Dry	0.02	0.05	Inaccessible	Dry	0.05	0.03	0.02
Total Nitrogen (mg/L)	**0.5[3]**	1.2	Dry	0.6	0.8	Inaccessible	Dry	4	5.5	1.5
Total Phosphorus as P (mg/L)	**0.05[3]**	0.16	Dry	0.06	0.05	Inaccessible	Dry	1.38	1.26	0.21
Reactive Phosphorus (mg/L)	**0.02[3]**	0.01	Dry	<0.01	<0.01	Inaccessible	Dry	0.01	0.01	<0.01
Fluoride (mg/L)	**2.4[2]**	0.4	Dry	0.3	0.3	Inaccessible	Dry	0.2	0.2	0.2
Dissolved Major Cations										
Calcium (mg/L)	-	128	Dry	20	65	Inaccessible	Dry	4	3	4
Magnesium (mg/L)	-	286	Dry	18	76	Inaccessible	Dry	4	5	5
Sodium (mg/L)	-	2,150	Dry	72	286	Inaccessible	Dry	42	66	32
Potassium (mg/L)	-	68	Dry	2	3	Inaccessible	Dry	3	2	4
Dissolved Metals										
Aluminium (mg/L)	**0.055[1]**	<0.01	Dry	<0.01	<0.01	Inaccessible	Dry	<0.01	0.06	<0.01
Arsenic (mg/L)	**0.024[1]**	0.004	Dry	0.002	0.002	Inaccessible	Dry	0.003	0.002	0.002
Barium (mg/L)	**1.0[1]**	0.271	Dry	0.028	0.15	Inaccessible	Dry	0.022	0.034	0.03
Cadmium (mg/L)	**0.0002[1]**	<0.0001	Dry	<0.0001	<0.0001	Inaccessible	Dry	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	**0.001[1]**	<0.001	Dry	<0.001	<0.001	Inaccessible	Dry	<0.001	<0.001	<0.001
Cobalt (mg/L)	**0.0014[2]**	<0.001	Dry	<0.001	<0.001	Inaccessible	Dry	<0.001	0.001	<0.001

Copper (mg/L)	**0.0014**[1]	0.002	Dry	<0.001	<0.001	Inaccessible	Dry	0.001	<0.001	<0.001
Lead (mg/L)	**0.0034**[1]	<0.001	Dry	<0.001	<0.001	Inaccessible	Dry	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9**[1]	0.006	Dry	0.102	0.153	Inaccessible	Dry	0.382	0.366	0.202
Molybdenum (mg/L)	**0.034**[2]	0.002	Dry	<0.001	<0.001	Inaccessible	Dry	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011**[1]	0.001	Dry	<0.001	<0.001	Inaccessible	Dry	0.003	0.002	0.002
Selenium (mg/L)	**0.005**[1]	<0.01	Dry	<0.01	<0.01	Inaccessible	Dry	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005**[1]	<0.001	Dry	<0.001	<0.001	Inaccessible	Dry	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01**[6]	<0.001	Dry	<0.001	<0.001	Inaccessible	Dry	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006**[2]	<0.01	Dry	<0.01	<0.01	Inaccessible	Dry	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008**[1]	0.025	Dry	<0.005	<0.005	Inaccessible	Dry	<0.005	<0.005	0.012
Iron (mg/L)	**0.35**[2]	<0.05	Dry	<0.05	0.07	Inaccessible	Dry	0.08	0.08	<0.05
Mercury (mg/L)	**0.0006**[1]	<0.0001	Dry	<0.0001	<0.0001	Inaccessible	Dry	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (meq/L)	-	142	Dry	6.04	26.7	Inaccessible	Dry	2.6	3.6	2.2
Total Cations (meq/L)	-	125	Dry	5.66	22	Inaccessible	Dry	2.43	3.48	2.1
Ionic Balance (%)	-	6.13	Dry	3.26	9.62	Inaccessible	Dry	----	1.65	----
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20	Dry	<20	<20	Inaccessible	Dry	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	Dry	<50	<50	Inaccessible	Dry	<50	<50	50
C15 - C28 Fraction (µg/L)	-	<100	Dry	<100	<100	Inaccessible	Dry	200	180	150
C29 - C36 Fraction (µg/L)	-	<50	Dry	<50	<50	Inaccessible	Dry	150	200	70
C10 - C36 Fraction (sum) (µg/L)	-	<50	Dry	<50	<50	Inaccessible	Dry	350	380	270
BTEXN										
Benzene (µg/L)	**950**[1]	<1	Dry	<1	<1	Inaccessible	Dry	<1	<1	<1
Toluene (µg/L)	-	<2	Dry	<2	<2	Inaccessible	Dry	3	<2	<2
Ethylbenzene (µg/L)	-	<2	Dry	<2	<2	Inaccessible	Dry	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2	Dry	<2	<2	Inaccessible	Dry	<2	<2	<2
ortho-Xylene (µg/L)	**350**[1]	<2	Dry	<2	<2	Inaccessible	Dry	<2	<2	<2
Total Xylenes (µg/L)	-	<2	Dry	<2	<2	Inaccessible	Dry	<2	<2	<2
Sum of BTEX (µg/L)	-	<1	Dry	<1	<1	Inaccessible	Dry	3	<1	<1
Naphthalene (µg/L)	**16**[1]	<5	Dry	<5	<5	Inaccessible	Dry	<5	<5	<5

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 $25^{o}C$ 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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory. Note: Turbidity reading XXX = >880 NTU

Table 9-26 Surface water quality results during May 2017 sample events

Parameter	WQOs	Styx River	Barrack Creek	Tooloombah Creek			Deep Creek			
		St1	Ba1	To1	To2	T03	De1	De2	De3	De4
In-situ results										
Water Temperature (°C)	16 – 34[5]	23.7	22.2	22.3	24.1	Inaccessible	19.7	20.0	20.0	20.2
Dissolved Oxygen (mg/l)	6.77 – 8.76[3]	5.57	5.62	4.85	5.70	Inaccessible	5.55	6.03	6.22	6.88
pH	6.5 – 8.0[3]	7.09	7.57	7.49	7.88	Inaccessible	7.48	7.20	6.98	7.60
Conductivity- base flow (µS/cm)	20-250[1]	1,127	1,293	713	839	Inaccessible	380.4	348.9	355.9	404.5
Turbidity (NTU)	50[3]	12.3	6.0	4.0	2.5	Inaccessible	23.5	28.7	32.9	14.0
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	687	906	432	615	Inaccessible	298	274	290	318
Suspended Solids (mg/L)	10[3]	10	6	6	8	Inaccessible	6	<5	15	6
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	148	60	141	140	Inaccessible	86	81	83	87
Sulphate (mg/L)	250[4]	40	41	32	33	Inaccessible	17	15	16	16
Chloride (mg/L)	-	318	434	167	210	Inaccessible	88	76	76	91
Ammonia N (mg/L)	0.02	0.06	0.03	0.02	0.02	Inaccessible	0.02	<0.01	<0.01	0.01
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	Inaccessible	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	0.06	<0.01	<0.01	<0.01	Inaccessible	<0.01	<0.01	0.02	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.7	0.1	0.2	0.2	Inaccessible	0.2	0.2	0.3	0.2
Total Phosphorus as P (mg/L)	0.05[3]	0.03	0.02	0.22	0.08	Inaccessible	0.16	0.15	0.15	0.02
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	Inaccessible	<0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2	0.1	0.2	0.2	Inaccessible	<0.1	<0.1	<0.1	<0.1
Dissolved Major Cations										
Calcium (mg/L)	-	34	25	35	39	Inaccessible	14	12	13	13
Magnesium (mg/L)	-	33	48	26	30	Inaccessible	12	11	11	13
Sodium (mg/L)	-	169	197	85	96	Inaccessible	55	51	52	60
Potassium (mg/L)	-	4	4	3	3	Inaccessible	3	3	3	3
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	<0.01	<0.01	<0.01	<0.01	Inaccessible	<0.01	<0.01	<0.01	<0.01
Arsenic (mg/L)	0.024[1]	0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001
Barium (mg/L)	1.0[1]	0.112	0.201	0.074	0.082	Inaccessible	0.057	0.052	0.058	0.072
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	Inaccessible	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	0.002	<0.001	0.018	<0.001	Inaccessible	0.002	0.002	0.003	<0.001
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.43	0.055	0.009	0.035	Inaccessible	0.078	0.04	0.201	0.169
Molybdenum (mg/L)	**0.034[2]**	<0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	0.001	0.001	0.002	<0.001	Inaccessible	0.001	0.001	0.002	0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	Inaccessible	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	<0.001	<0.001	<0.001	Inaccessible	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	Inaccessible	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.005	<0.005	<0.005	Inaccessible	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	Inaccessible	<0.05	<0.05	<0.05	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	Inaccessible	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (meq/L)	-	12.8	14.3	8.19	9.41	Inaccessible	4.55	4.07	4.14	4.64
Total Cations (meq/L)	-	11.9	13.9	7.66	8.67	Inaccessible	4.16	3.8	3.89	4.4
Ionic Balance (%)	-	3.63	1.51	3.37	4.1	Inaccessible	4.58	3.5	3.02	2.58
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	Inaccessible	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	Inaccessible	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	Inaccessible	<100	<100	<100	<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	Inaccessible	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	Inaccessible	<50	<50	<50	<50
BTEXN										
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	Inaccessible	<1	<1	<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	Inaccessible	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	Inaccessible	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	Inaccessible	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	Inaccessible	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	Inaccessible	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	Inaccessible	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	Inaccessible	<5	<5	<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-27 Surface water quality results during June 2017 sample events

Parameter	WQOs	Styx River	Barrack Creek	Tooloombah Creek			Deep Creek			
		St1	Ba1x	To1	To2	To3x	De1	De2	De3	De4
In-situ results										
Water Temperature (°C)	16 – 34[5]	19.9	20.1	20	19.3	18.3	16	15.6	15.8	16.1
Dissolved Oxygen (mg/l)	6.77 – 8.76[3]	5.96	4.85	5.57	6.01	5.19	4.6	5.41	5.46	5.5
pH	6.5 – 8.0[3]	7.54	7.38	7.62	7.68	7.58	7.41	7.5	7.38	7.5
Conductivity- base flow (µS/cm)	-	1,227	1,288	742	788	1,133	353.9	357.9	318.3	382.3
Turbidity (NTU)	50[3]	5.9*	6.4	18.2	2.2*	3.9*	10.2*	17.7*	18.6*	14.1*
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	869	1,010	620	576	889	261	233	267	295
Suspended Solids (mg/L)	10[3]	6	<5	<5	<5	16	<5	9	<5	7
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	179	56	161	142	167	98	92	104	105
Sulphate (mg/L)	250[4]	48	41	36	35	47	14	12	12	13
Chloride (mg/L)	-	420	455	227	251	404	88	75	85	112
Ammonia N (mg/L)	0.02	0.03	0.02	0.04	0.02	0.02	0.06	0.02	0.02	0.02
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
Total Nitrogen (mg/L)	0.5[3]	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.2
Total Phosphorus as P (mg/L)	0.05[3]	<0.01	0.02	0.01	0.01	0.02	0.02	0.04	0.02	0.02
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2	<0.1	0.2	0.2	0.2	<0.1	<0.1	0.1	0.1
Dissolved Major Cations										
Calcium (mg/L)	-	35	26	41	43	62	16	9	8	13
Magnesium (mg/L)	-	36	48	22	35	49	13	9	10	14
Sodium (mg/L)	-	209	187	106	110	163	62	60	73	74
Potassium (mg/L)	-	3	4	3	3	2	2	3	2	3
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	0.03	<0.01	<0.01	0.010	<0.01	<0.01	<0.01	0.550	<0.01
Arsenic (mg/L)	0.024[1]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Barium (mg/L)	1.0[1]	0.094	0.198	0.072	0.087	0.125	0.055	0.048	0.057	0.056
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.122	0.044	0.064	0.040	0.085	0.034	0.008	0.081	0.144
Molybdenum (mg/L)	**0.034[2]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	0.006	<0.005	<0.005	<0.005	0.027	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.370	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (meq/L)	-	16.4	14.8	10.4	10.6	15.7	4.73	4.2	4.72	5.53
Total Cations (meq/L)	-	13.9	13.5	8.54	9.89	14.3	4.62	3.88	4.45	5.1
Ionic Balance (%)	-	8.4	4.68	9.65	3.69	4.82	1.24	4.05	3.02	4.06
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
BTEXN										
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5	<5	<5	<5	<5

*- Turbidity measured in the laboratory 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 NO3) of 0.7 mg/L is represented as Nitrate N (0.158 mg/L). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-28 Surface water quality results during August 2017 sample events

Parameter	WQOs	Styx River	Barrack Creek	Tooloombah Creek			Deep Creek			
		St1	Ba1	To1	To2	To3	De1	De2	De3	De4
In-situ results										
Water Temperature (°C)	16 – 34[5]	24.4	DRY	19.3	21.0	23.6	14	20.4	23.3	18.0
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	6.33		6.38	9.03	10.66	5.46	6.18	4.16	3.32
pH	6.5 – 8.0[3]	7.85		7.91	7.89	8.01	7.66	7.73	7.55	6.92
Conductivity- base flow (µS/cm)	20-250[1]	2480		902	1205	2235	406.7	395.6	590	565
Turbidity (NTU)	50[3]	3.8		11.0	2.0	0.5	2.8	9.2	2.2	7.8
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	1,600		642	834	1,590	327	284	369	417
Suspended Solids (mg/L)	10[3]	7		30	8	<5	<5	8	<5	<5
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	228		160	149	159	112	97	165	139
Sulphate (mg/L)	250[4]	88		36	35	58	12	11	8	23
Chloride (mg/L)	-	734		258	390	708	109	86	105	137
Ammonia N (mg/L)	0.02	<0.01		0.03	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Nitrite N (mg/L)	-	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.2		0.9	0.4	0.2	0.4	0.4	0.3	<0.1
Total Phosphorus as P (mg/L)	0.05[3]	0.01		0.13	0.03	<0.01	0.02	0.04	0.01	0.02
Reactive Phosphorus (mg/L)	0.02[3]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2		0.2	0.2	0.2	<0.1	<0.1	0.1	0.1
Dissolved Major Cations										
Calcium (mg/L)	-	67		49	58	91	19	14	14	13
Magnesium (mg/L)	-	70		37	49	79	14	11	15	14
Sodium (mg/L)	-	389		113	155	276	70	64	89	112
Potassium (mg/L)	-	4		3	2	3	3	3	3	1
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	<0.01		0.02	0.01	<0.01	<0.01	<0.01	0.04	<0.01
Arsenic (mg/L)	0.024[1]	0.001		<0.001	<0.001	<0.001	<0.001	0.001	0.002	<0.001
Barium (mg/L)	1.0[1]	0.144		0.092	0.112	0.174	0.058	0.042	0.061	0.081
Cadmium (mg/L)	0.0002[1]	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002

Copper (mg/L)	**0.0014[1]**	<0.001		<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001
Lead (mg/L)	**0.0034[1]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.013		0.011	0.006	0.018	0.018	0.003	0.124	1.28
Molybdenum (mg/L)	**0.034[2]**	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002
Selenium (mg/L)	**0.005[1]**	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (meq/L)	-	27.1		11.2	14.7	24.4	5.56	4.59	6.42	7.12
Total Cations (meq/L)	-	26.1		10.5	13.7	23.1	5.22	4.46	5.88	6.7
Ionic Balance (%)	-	1.81		3.42	3.47	2.59	3.16	1.42	4.42	3.06
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20		<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100		<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
BTEXN										
Benzene (µg/L)	**950[1]**	<1		<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2		<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1		<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**	<5		<5	<5	<5	<5	<5	<5	<5

*- Turbidity measured in the laboratory 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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-29 Surface water quality results during September 2017 sample events

Parameter	WQOs	Styx River	Barrack Creek	Tooloombah Creek			Deep Creek			
		St1	Ba1	To1	To2	To3	De1	De2	De3	De4
In-situ results										
Water Temperature (°C)	16 – 34[5]	25.0	Dry	23.8	24.8	24.5	28.6	25.7	25.0	21.0
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	8.37		6.07	8.99	9.13	5.96	4.28	4.21	3.49
pH	6.5 – 8.0[3]	7.64		7.93	8.06	7.81	8.13	7.83	8.09	7.53
Conductivity- base flow (µS/cm)	20-250[1]	3317		1090	1577	2670	805	502	704	748
Turbidity (NTU)	50[3]	2.5		2.1	1.9	4.8	16.0	8.3	7.5	18.5
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	2,130		832	1,290	1,770	446	263	419	483
Suspended Solids (mg/L)	10[3]	9		<5	8	6	14	8	7	9
Total Alkalinity as $CaC0_3$ (mg/L)	≥20[1]	241		144	119	104	163	106	210	158
Sulphate (mg/L)	250[4]	113		38	37	57	10	11	4	19
Chloride (mg/L)	-	1120		318	536	982	171	107	126	192
Ammonia N (mg/L)	0.02	0.01		0.02	0.02	<0.01	0.03	<0.01	<0.01	0.04
Nitrite N (mg/L)	-	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.2		0.3	0.4	0.4	1.1	0.4	0.3	0.3
Total Phosphorus as P (mg/L)	0.05[3]	0.02		0.02	0.02	0.02	0.03	<0.01	<0.01	0.14
Reactive Phosphorus (mg/L)	0.02[3]	<0.01		<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2		0.2	0.2	0.2	0.1	0.1	0.2	0.1
Dissolved Major Cations										
Calcium (mg/L)	-	91		48	57	88	21	13	16	16
Magnesium (mg/L)	-	100		48	66	101	23	14	18	19
Sodium (mg/L)	-	546		132	193	341	106	72	116	132
Potassium (mg/L)	-	4		3	3	3	6	3	3	2
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	<0.01		0.01	<0.01	0.01	0.02	<0.01	0.01	0.01
Arsenic (mg/L)	0.024[1]	0.002		<0.001	<0.001	<0.001	0.002	0.001	0.002	0.001
Barium (mg/L)	1.0[1]	0.195		0.092	0.106	0.153	0.059	0.043	0.058	0.085
Cadmium (mg/L)	0.0002[1]	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003

Copper (mg/L)	**0.0014[1]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (mg/L)	**0.0034[1]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.012		0.03	0.008	0.016	1.74	0.013	0.016	4.02
Molybdenum (mg/L)	**0.034[2]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Nickel (mg/L)	**0.011[1]**	<0.001		<0.001	<0.001	<0.001	0.002	0.001	0.001	0.002
Selenium (mg/L)	**0.005[1]**	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	0.011		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (meq/L)	-	38.8		12.6	18.3	31	8.29	5.36	7.83	8.97
Total Cations (meq/L)	-	36.6		12.2	16.7	27.6	7.7	5.01	7.4	8.15
Ionic Balance (%)	-	2.84		1.91	4.34	5.72	3.65	3.43	2.83	4.75
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20		<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100		<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
BTEXN										
Benzene (µg/L)	**950[1]**	<1		<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2		<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1		<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**	<5		<5	<5	<5	<5	<5	<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-30 Surface water quality results during November 2017 sample events

Parameter	WQOs	Styx River	Barrack Creek	Tooloombah Creek			Deep Creek			
		St1	Ba1	To1	To2	To3	De1	De2	De3	De4
In-situ results										
Water Temperature (°C)	16 – 34[5]	30.8	Dry	23.8			24.7	25.3	21.1	21
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	6.4		6.07			2.98	3.73	6.93	3.49
pH	6.5 – 8.0[3]	7.9		7.93			7.87	7.69	7.83	7.53
Conductivity- base flow (µS/cm)	20-250[1]	1425		1090			410.5	211.5	356	748
Turbidity (NTU)	50[3]	23		2.1			49.1	493	32.4	18.5
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	799		623	560	662	252	567	249	330
Suspended Solids (mg/L)	10[3]	10		14	<5	8	23	50	18	7
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	130		139	117	126	109	56	115	125
Sulphate (mg/L)	250[4]	36		31	26	24	8	6	4	6
Chloride (mg/L)	-	363		237	251	295	53	27	50	118
Ammonia N (mg/L)	0.02	0.02		<0.01	<0.01	<0.01	<0.01	0.08	0.01	<0.01
Nitrite N (mg/L)	-	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.4		0.5	0.5	0.5	0.6	1.0	0.8	0.5
Total Phosphorus as P (mg/L)	0.05[3]	0.07		0.05	0.05	0.08	0.06	0.20	0.09	0.04
Reactive Phosphorus (mg/L)	0.02[3]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2		0.2	0.2	0.2	0.2	0.1	0.1	<0.1
Dissolved Major Cations										
Calcium (mg/L)	-	38		42	43	51	14	5	8	17
Magnesium (mg/L)	-	39		34	37	46	12	5	8	18
Sodium (mg/L)	-	203		112	120	165	45	28	70	89
Potassium (mg/L)	-	3		3	3	2	4	3	2	3
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	<0.01		<0.01	<0.01	0.01	<0.01	<0.01	0.06	<0.01
Arsenic (mg/L)	0.024[1]	0.002		0.002	0.002	0.002	0.002	0.002	0.004	<0.001
Barium (mg/L)	1.0[1]	0.087		0.08	0.07	0.092	0.048	0.028	0.04	0.045
Cadmium (mg/L)	0.0002[1]	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014**[1]	<0.001		<0.001	<0.001	<0.001	0.001	0.002	<0.001	<0.001
Lead (mg/L)	**0.0034**[1]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9**[1]	0.107		0.033	0.019	0.028	0.146	0.063	0.021	0.26
Molybdenum (mg/L)	**0.034**[2]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011**[1]	0.001		<0.001	<0.001	<0.001	0.002	0.002	0.002	0.002
Selenium (mg/L)	**0.005**[1]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005**[1]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01**[6]	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006**[2]	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008**[1]	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35**[2]	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	0.21	<0.05
Mercury (mg/L)	**0.0006**[1]	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (mg/L)	-	13.6		10.1	9.96	11.3	3.84	2	3.79	5.95
Total Cations (mg/L)	-	14		9.84	10.5	13.6	3.74	1.96	4.15	6.28
Ionic Balance (%)	-	1.54		1.33	2.58	8.92	1.23	----	4.56	2.67
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20		<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100		<100	<100	<100	<100	130	<100	<100
C29 - C36 Fraction (µg/L)	-	<50		<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50		<50	<50	<50	<50	130	<50	<50
BTEXN										
Benzene (µg/L)	**950**[1]	<1		<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350**[1]	<2		<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2		<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1		<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16**[1]	<5		<5	<5	<5	<5	<5	<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-31 Surface water quality results during January 2018 sample events

Parameter	WQOs	Styx River	Tooloombah Creek			Deep Creek				
		St1	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results										
Water Temperature (°C)	16 – 34[5]	31.9	26.6			27.6	24.3	25.1	27.2	27
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	6.45	5.08			5.97	4.03	1.05	5.57	4.98
pH	6.5 – 8.0[3]	8.15	7.85			8.46	8.2	7.95	7.81	7.94
Conductivity- base flow (µS/cm)	20-250[1]	2786	246.8			464.7	188.8	284.6	715	270.9
Turbidity (NTU)	50[3]	18.1	396			97	880	452	67	756
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	790	318	250	549	247	1130	506	402	570
Suspended Solids (mg/L)	10[3]	13	62	14	6	18	44	34	36	100
Total Alkalinity as $CaC0_3$ (mg/L)	≥20[1]	123	55	82	116	106	58	76	113	46
Sulphate (mg/L)	250[4]	27	4	6	21	6	4	2	12	5
Chloride (mg/L)	-	333	29	78	186	54	12	25	131	39
Ammonia N (mg/L)	0.02	<0.01	0.02	0.02	0.04	<0.01	0.1	0.03	<0.01	<0.01
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.3	1.8	0.4	0.4	0.6	1.8	1.4	0.4	1.6
Total Phosphorus as P (mg/L)	0.05[3]	0.02	0.16	0.03	0.01	0.07	0.49	0.22	0.04	0.22
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Dissolved Major Cations										
Calcium (mg/L)	-	39	10	20	34	15	4	6	14	4
Magnesium (mg/L)	-	38	7	14	26	12	4	7	18	5
Sodium (mg/L)	-	149	22	46	91	55	27	32	88	29
Potassium (mg/L)	-	4	2	3	3	3	2	3	3	2
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	<0.01	0.03	0.03	<0.01	0.02	0.02	0.21	<0.01	0.03
Arsenic (mg/L)	0.024[1]	0.002	0.002	0.003	0.002	0.002	0.001	0.004	0.001	0.001
Barium (mg/L)	1.0[1]	0.124	0.036	0.035	0.05	0.039	0.019	0.023	0.065	0.021
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	0.001	0.001	<0.001	<0.001	0.002	0.002	0.002	0.002	0.002
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.199	0.017	0.112	0.014	0.013	0.019	0.006	0.276	0.044
Molybdenum (mg/L)	**0.034[2]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.002	0.001	0.002
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	0.006	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	0.23	<0.05	0.07
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (mg/L)	-	12.4	2	3.96	8	3.77	1.58	2.26	6.2	2.12
Total Cations (mg/L)	-	11.6	2.08	4.23	7.87	4.2	1.75	2.34	6.08	1.92
Ionic Balance (%)	-	3.14	----	3.23	0.82	5.51	5.21	----	0.96	----
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100	130	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	130	<50	<50	<50	<50	<50	<50	<50
BTEXN										
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5	<5	<5	<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-32 Surface water quality results during February 2018 sample events

Parameter	WQOs	Styx River	Tooloombah Creek			Deep Creek				
		St1	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results										
Water Temperature (°C)	16 – 34[5]	35.5	28.2			29.7	26.5	25.9	30.7	31.5
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	4.87	8.31			4.48	1.58	7.87	2.43	7.71
pH	6.5 – 8.0[3]	8.58	7.76			7.5	7.8	8.35	7.39	7.85
Conductivity- base flow (µS/cm)	20-250[1]	43.2	169.9			431.2	197.7	35.9	301.7	422.8
Turbidity (NTU)	50[3]	13.8	61.5			322	880	880	102	422
Laboratory results										
Total Dissolved Solids (mg/L)	600[4]	6020	189	404	606	2920	1490	2780	240	483
Suspended Solids (mg/L)	10[3]	17	7	14	<5	205	120	248	27	16
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	203	82	120	127	77	65	72	62	64
Sulphate (mg/L)	250[4]	405	3	6	10	14	5	5	4	5
Chloride (mg/L)	-	3280	36	156	265	77	21	73	39	45
Ammonia N (mg/L)	0.02	0.06	0.03	0.02	0.14	0.10	0.17	0.08	0.04	0.08
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.3	0.6	0.3	0.4	3.1	2.6	4.0	0.8	1.1
Total Phosphorus as P (mg/L)	0.05[3]	0.65	0.06	0.02	0.03	1.92	0.64	1.05	0.1	0.2
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.4	0.2	0.2	0.2	0.5	0.2	0.1	0.2	0.2
Dissolved Major Cations										
Calcium (mg/L)	-	134	14	26	29	5	3	2	5	4
Magnesium (mg/L)	-	249	9	22	31	4	4	4	7	6
Sodium (mg/L)	-	1880	30	73	124	72	33	70	48	40
Potassium (mg/L)	-	55	2	2	3	2	3	2	3	3
Dissolved Metals										
Aluminium (mg/L)	0.055[1]	<0.01	0.02	0.02	0.02	0.01	0.02	0.69	0.04	<0.01
Arsenic (mg/L)	0.024[1]	0.003	0.004	0.002	0.002	0.002	0.002	0.003	0.002	0.003
Barium (mg/L)	1.0[1]	0.261	0.024	0.031	0.048	0.015	0.014	0.016	0.024	0.026
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	0.001	0.002	0.001	<0.001	0.002	0.002	0.002	0.002	0.002
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.110	0.090	0.021	0.007	0.003	0.024	0.014	0.109	0.030
Molybdenum (mg/L)	**0.034[2]**	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.002	0.002	0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.46	0.14	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance										
Total Anions (mg/L)	-	105	2.72	6.92	10.2	4.00	2.00	3.60	2.42	2.65
Total Cations (mg/L)	-	110	2.80	6.33	9.47	3.76	1.99	3.52	2.99	2.51
Ionic Balance (%)	-	2.48	----	4.44	3.82	3.10	----	1.08	----	----
Total Petroleum Hydrocarbons										
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	160	<100	<100	<100	<100	110
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	210	<50	<50	<50	<50	110
BTEXN										
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5	<5	<5	<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-33 Surface water quality results during March 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]		29.4	28.4	29.7	28.1	27.4	24.7	26.3	26.1	26.7
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]		4.49	3.48	4	3.88	5.61	3.09	1.8	1.7	1.43
pH	6.5 – 8.0[3]		8.07	7.49	9.01	7.92	7.89	7.16	7.4	6.96	7.26
Conductivity- base flow (µS/cm)	20-250[1]		7003	414.1	480.1	621	610	148.8	354.3	215.4	239.4
Turbidity (NTU)	50[3]		20	15	7.7	4.4	238.0	>880	>880	>880	>880
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]		2,830	255	286	371	302	2080	1610	1160	1350
Suspended Solids (mg/L)	10[3]		16	12	12	10	61	91	44	147	260
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]		187	75	85	84	84	44	50	59	50
Sulphate (mg/L)	250[4]		158	8	10	10	7	8	7	3	6
Chloride (mg/L)	-		1390	59	78	110	54	15	29	24	23
Ammonia N (mg/L)	0.02		0.02	<0.01	0.02	0.04	0.08	0.14	0.09	0.17	0.13
Nitrite N (mg/L)	-		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]		<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	<0.01	0.01
Total Nitrogen (mg/L)	0.5[3]		0.5	0.5	0.5	0.3	1.1	3.1	2.6	3.1	6.8
Total Phosphorus as P (mg/L)	0.05[3]		<0.01	0.04	0.01	<0.01	0.15	0.86	0.48	0.64	0.74
Reactive Phosphorus (mg/L)	0.02[3]		<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01
Fluoride (mg/L)	2.4[2]		0.2	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1
Dissolved Major Cations											
Calcium (mg/L)	-		83	16	19	24	6	<1	2	3	2
Magnesium (mg/L)	-		108	12	14	17	7	1	3	4	4
Sodium (mg/L)	-		745	40	42	54	62	24	38	31	28
Potassium (mg/L)	-		22	2	2	2	3	1	2	2	2
Dissolved Metals											
Aluminium (mg/L)	0.055[1]		<0.01	0.31	0.21	0.13	0.31	3.14	3.5	4.01	5.57
Arsenic (mg/L)	0.024[1]		0.003	0.002	0.002	0.002	0.002	<0.001	0.001	0.002	0.001
Barium (mg/L)	1.0[1]		0.087	0.033	0.037	0.047	0.028	0.011	0.017	0.028	0.026
Cadmium (mg/L)	0.0002[1]		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]		<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003	0.003	0.004
Cobalt (mg/L)	0.0014[2]		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**		<0.001	0.001	0.001	0.001	0.002	0.003	0.002	0.003	0.003
Lead (mg/L)	**0.0034[1]**		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Manganese (mg/L)	**1.9[1]**		<0.001	0.002	0.002	0.019	0.002	0.037	0.008	0.186	0.016
Molybdenum (mg/L)	**0.034[2]**		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**		<0.001	<0.001	<0.001	<0.001	0.002	0.003	0.003	0.003	0.004
Selenium (mg/L)	**0.005[1]**		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**		<0.05	0.22	0.19	0.16	0.29	1.64	2.05	2.32	3.15
Mercury (mg/L)	**0.0006[1]**		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-		46.2	3.33	4.11	4.99	3.35	1.47	1.96	1.92	1.77
Total Cations (mg/L)	-		46	3.58	3.98	5	3.65	1.59	2.05	1.88	1.7
Ionic Balance (%)	-		0.26	3.59	1.59	0.07	4.31	----	----	----	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-		<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction (µg/L)	-		<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction (µg/L)	-		<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction (µg/L)	-		<50	<50	<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-		<50	<50	<50	<50	<50	<50	<50	<50	<50
BTEXN											
Benzene (µg/L)	**950[1]**		<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene (µg/L)	-		<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene (µg/L)	-		<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene (µg/L)	-		<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene (µg/L)	**350[1]**		<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes (µg/L)	-		<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX (µg/L)	-		<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene (µg/L)	**16[1]**		<5	<5	<5	<5	<5	<5	<5	<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-34 Surface water quality results during April 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]	25.3	25.3	23.3	24.3	23.4		25.2		22.5	23.1
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	4.27	6.29	4.01	2.62	3.87		3.72		3.64	2.46
pH	6.5 – 8.0[3]	7.35	7.93	8.43	7.77	7.43	DRY	7.93	DRY	7.73	7.97
Conductivity- base flow (µS/cm)	20-250[1]	1992	17861	538	592	2057		201.7		213	225.6
Turbidity (NTU)	50[3]	30.2	30.1	10.4	133	28.6		880 *		690	880 *
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]	839	10,100	238	303	1,350		820		631	1,280
Suspended Solids (mg/L)	10[3]	16	72	9	9	7		166		225	116
Total Alkalinity as $CaC0_3$ (mg/L)	≥20[1]	179	274	90	94	130		58		57	56
Sulphate (mg/L)	250[4]	48	711	7	6	13		10		3	4
Chloride (mg/L)	-	542	6,010	70	98	625		20		25	28
Ammonia N (mg/L)	0.02	0.09	0.13	0.04	0.04	0.03		0.12		0.09	0.06
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	0.1	0.05	<0.01	<0.01	<0.01		0.08		0.02	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.5	0.6	0.4	0.4	0.4		4		2.7	2.4
Total Phosphorus as P (mg/L)	0.05[3]	0.02	0.08	0.02	0.02	<0.01		1.12		0.62	0.54
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	<0.01		0.02		<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2	0.5	0.2	0.2	0.2		0.2		0.1	0.1
Dissolved Major Cations											
Calcium (mg/L)	-	52	219	18	24	78		2		3	4
Magnesium (mg/L)	-	50	381	12	17	67		2		4	4
Sodium (mg/L)	-	277	3090	46	52	235		34		33	33
Potassium (mg/L)	-	4	93	2	2	3		2		2	2
Dissolved Metals											
Aluminium (mg/L)	0.055[1]	<0.01	<0.01	0.01	0.01	<0.01		0.01		0.13	0.02
Arsenic (mg/L)	0.024[1]	0.003	0.003	0.002	0.002	0.002		0.002		0.001	0.002
Barium (mg/L)	1.0[1]	0.119	0.182	0.032	0.05	0.11		0.01		0.015	0.02
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001		<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	<0.001	0.016	<0.001	0.001	<0.001		0.003		0.002	0.002
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.206	0.122	0.017	0.038	0.033		0.008		0.039	0.002
Molybdenum (mg/L)	**0.034[2]**	<0.001	0.002	<0.001	<0.001	<0.001		0.002		<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	0.003	<0.001	<0.001	<0.001		0.001		0.001	<0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	0.023	<0.005	<0.005	<0.005		<0.005		<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05		0.15	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001		<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	19.9	190	3.92	4.77	20.5		1.93		1.91	1.99
Total Cations (mg/L)	-	18.9	179	3.94	4.91	19.7		1.79		1.96	2.02
Ionic Balance (%)	-	2.59	2.91	0.24	1.47	1.97		----		----	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20		<20		<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50		<50		<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100		<100		<100	<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50		<50		<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50		<50		<50	<50
BTEXN											
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1		<1		<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2		<2		<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1		<1		<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5		<5		<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-35 Surface water quality results during May 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]	25.9	26.8	22.5	23.0	22.0				20.8	21.2
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	6.18	5.41	5.27	4.1	3.62				3.97	4.09
pH	6.5 – 8.0[3]	8.02	7.89	7.81	8.09	7.76	DRY	DRY	DRY	7.86	8.49
Conductivity- base flow (µS/cm)	20-250[1]	2,715	24,257	418.4	600	3,203				194.9	231.9
Turbidity (NTU)	50[3]	19	16.2	31.6	10.2	22.2				639	880*
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]	1,620	17,100	290	371	2,170				788	1,190
Suspended Solids (mg/L)	10[3]	9	<5	7	6	19				162	562
Total Alkalinity as $CaC0_3$ (mg/L)	≥20[1]	228	278	103	110	227				62	61
Sulphate (mg/L)	250[4]	72	949	8	5	44				4	6
Chloride (mg/L)	-	766	8,280	74	137	1,010				29	33
Ammonia N (mg/L)	0.02	0.07	0.13	<0.01	0.05	0.06				0.04	0.09
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01	0.02	<0.01	<0.01	0.01				0.02	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.4	0.6	0.3	0.3	0.3				1.3	3.2
Total Phosphorus as P (mg/L)	0.05[3]	0.02	<0.05	0.03	0.02	0.27				0.29	0.53
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2	0.5	0.2	0.2	0.2				0.2	0.1
Dissolved Major Cations											
Calcium (mg/L)	-	65	236	20	28	91				4	4
Magnesium (mg/L)	-	68	512	14	20	84				5	5
Sodium (mg/L)	-	392	4,020	47	64	405				34	35
Potassium (mg/L)	-	6	131	2	1	3				2	3
Dissolved Metals											
Aluminium (mg/L)	0.055[1]	<0.01	<0.01	<0.01	<0.01	<0.01				0.05	0.01
Arsenic (mg/L)	0.024[1]	0.003	0.003	0.001	0.001	0.001				0.002	0.001
Barium (mg/L)	1.0[1]	0.148	0.229	0.031	0.059	0.229				0.017	0.022
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001

Copper (mg/L)	**0.0014**[1]	0.001	0.002	<0.001	<0.001	<0.001				0.002	0.002
Lead (mg/L)	**0.0034**[1]	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001
Manganese (mg/L)	**1.9**[1]	0.296	0.138	0.009	0.071	0.229				0.011	0.009
Molybdenum (mg/L)	**0.034**[2]	<0.001	0.003	<0.001	<0.001	<0.001				<0.001	<0.001
Nickel (mg/L)	**0.011**[1]	<0.001	0.009	0.001	<0.001	<0.001				<0.001	0.001
Selenium (mg/L)	**0.005**[1]	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Silver (mg/L)	**0.00005**[1]	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001
Uranium (mg/L)	**0.01**[6]	<0.001	0.002	<0.001	<0.001	<0.001				<0.001	<0.001
Vanadium (mg/L)	**0.006**[2]	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Zinc (mg/L)	**0.008**[1]	<0.005	<0.005	<0.005	<0.005	<0.005				<0.005	0.008
Iron (mg/L)	**0.35**[2]	<0.05	<0.05	<0.05	<0.05	0.05				0.08	<0.05
Mercury (mg/L)	**0.0006**[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	27.7	259	4.31	6.17	33.9				2.14	2.27
Total Cations (mg/L)	-	26	232	4.24	5.85	29.1				2.14	2.21
Ionic Balance (%)	-	3.01	5.45	0.77	2.61	7.6				----	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20				<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50				<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100				<100	360
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50				<50	80
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50				<50	440
BTEXN											
Benzene (µg/L)	**950**[1]	<1	<1	<1	<1	<1				<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
ortho-Xylene (µg/L)	**350**[1]	<2	<2	<2	<2	<2				<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1				<1	<1
Naphthalene (µg/L)	**16**[1]	<5	<5	<5	<5	<5				<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-36 Surface water quality results during June 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]	17.3	11.9	14.2	14.5	19.1		14.3		21.4	16.8
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	8.5	7.4	6.19	7.11	11.95		77.2		10.16	10.15
pH	6.5 – 8.0[3]	7.97	7.69	9.52	9.8	9.13	DRY	9.54	DRY	8.45	8.63
Conductivity- base flow (µS/cm)	20-250[1]	2,534	17,209	347.6	469.2	1015		219		710	181
Turbidity (NTU)	50[3]	15.5	22	3.5	8.8	6.7		880 *		98	662
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]	1,930	18,500	293	382	730		2,490		522	975
Suspended Solids (mg/L)	10[3]	12	15	7	8	8		44		30	44
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	239	266	100	105	123		47		136	52
Sulphate (mg/L)	250[4]	83	1,280	8	7	7		5		27	7
Chloride (mg/L)	-	928	9720	85	138	330		24		168	31
Ammonia N (mg/L)	0.02	0.02	0.06	0.06	0.05	0.20		0.13		0.06	0.07
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		<0.01	0.02
Nitrate N (mg/L)[8]	0.158[1]	<0.01	<0.01	<0.01	<0.01	<0.01		0.13		<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.3	0.5	0.3	0.3	0.5		3.3		0.4	1.9
Total Phosphorus as P (mg/L)	0.05[3]	0.01	<0.05	0.01	0.01	0.02		0.92		0.04	0.36
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	<0.01		0.01		<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.2	0.5	0.2	0.2	0.2		0.2		0.2	0.1
Dissolved Major Cations											
Calcium (mg/L)	-	79	303	21	26	45		2		9	4
Magnesium (mg/L)	-	80	633	15	20	40		2		14	5
Sodium (mg/L)	-	478	5,370	50	69	188		37		132	36
Potassium (mg/L)	-	6	177	2	1	2		2		<1	3
Dissolved Metals											
Aluminium (mg/L)	0.055[1]	<0.01	<0.01	<0.01	<0.01	<0.01		0.85		<0.01	0.02
Arsenic (mg/L)	0.024[1]	0.002	0.003	0.001	<0.001	0.001		<0.001		0.001	0.001
Barium (mg/L)	1.0[1]	0.171	0.218	0.041	0.049	0.092		0.016		0.041	0.021
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001		<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001

Cobalt (mg/L)	**0.0014[2]**	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Copper (mg/L)	**0.0014[1]**	0.002	0.003	<0.001	<0.001	0.001		0.016		<0.001	0.001
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.042	0.143	0.006	0.009	0.012		0.005		0.008	<0.001
Molybdenum (mg/L)	**0.034[2]**	<0.001	0.003	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	0.002	0.002	<0.001	<0.001	<0.001		0.005		<0.001	0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	0.002	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.005	<0.005	<0.005	<0.005		0.030		<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05		0.62		<0.05	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001		<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	32.7	306	4.56	6.14	11.9		1.72		8.02	2.06
Total Cations (mg/L)	-	31.5	305	4.51	5.97	13.8		1.92		7.34	2.25
Ionic Balance (%)	-	1.88	0.14	0.59	1.37	7.22		----		4.40	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20		<20		<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	60	<50	<50		<50		<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100		<100		<100	130
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50		<50		<50	60
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	60	<50	<50		<50		<50	190
BTEXN											
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1		<1		<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2		<2		<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1		<1		<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5		<5		<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-37 Surface water quality results during July 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]	20	25.1	19.1	21.0	20.4			19.2	19.4	22.6
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	8.52	5.74	7.3	6.16	7.38			2.81	48.5	6.27
pH	6.5 – 8.0[3]	7.36	6.8	6.24	7.29	7.22	DRY	DRY	6.19	6.19	7.23
Conductivity- base flow (µS/cm)	20-250[1]	3,214	29,181	273.9	1,278	1,187			562	206.3	229.2
Turbidity (NTU)	50[3]	8.9	8.8	2.1	4.5	4.3			72.5	514	724
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]	2,160	19,900	300	894	801			353	764	782
Suspended Solids (mg/L)	10[3]	<5	<5	65	6	<5			37	160	352
Total Alkalinity as $CaCO_3$ (mg/L)	≥20[1]	243	257	114	151	149			85	69	65
Sulphate (mg/L)	250[4]	98	1,430	9	8	8			27	5	5
Chloride (mg/L)	-	906	10,900	88	402	340			101	32	34
Ammonia N (mg/L)	0.02	0.04	0.11	0.02	0.02	0.02			0.02	0.07	0.08
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	0.01	0.03	<0.01	<0.01	0.01			0.2	0.01	0.02
Total Nitrogen (mg/L)	0.5[3]	0.5	<0.5	0.3	0.3	0.3			0.8	1.7	1.6
Total Phosphorus as P (mg/L)	0.05[3]	0.03	0.08	0.01	0.02	0.02			0.1	0.4	0.37
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.3	0.7	0.2	0.2	0.2			<0.1	0.2	0.2
Dissolved Major Cations											
Calcium (mg/L)	-	72	297	20	44	41			7	4	4
Magnesium (mg/L)	-	91	693	16	41	36			8	6	6
Sodium (mg/L)	-	507	5260	50	145	151			87	36	35
Potassium (mg/L)	-	5	186	2	2	2			4	3	3
Dissolved Metals											
Aluminium (mg/L)	0.055[1]	<0.01	<0.01	<0.01	<0.01	0.02			0.56	0.06	0.02
Arsenic (mg/L)	0.024[1]	0.002	0.002	0.001	<0.001	0.001			0.002	0.002	0.002
Barium (mg/L)	1.0[1]	0.206	0.19	0.041	0.085	0.077			0.025	0.023	0.02
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			<0.0001	<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.001	<0.001	<0.001	<0.001			0.001	<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	0.001	<0.001	<0.001	<0.001	0.001			0.002	0.001	0.002
Lead (mg/L)	**0.0034[1]**	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.018	0.098	0.008	0.031	0.096			0.015	0.017	0.003
Molybdenum (mg/L)	**0.034[2]**	<0.001	0.004	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	0.001	<0.001	<0.001	<0.001			0.002	0.001	0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	0.002	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.005	<0.005	<0.005	<0.005			<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05			0.35	0.09	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			<0.0001	<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	32.4	342	4.95	14.5	12.7			5.11	2.38	2.36
Total Cations (mg/L)	-	33.3	305	4.54	11.9	11.6			4.89	2.34	2.29
Ionic Balance (%)	-	1.23	5.71	4.28	9.81	4.54			2.15	----	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20			<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50			<50	<50	60
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100			110	<100	230
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50			60	<50	100
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50			170	<50	390
BTEXN											
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1		<1		<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2		<2		<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1		<1		<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5		<5		<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-38 Surface water quality results during early-August 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	**16 – 34[5]**	20.69	22.93	17.8	22.6	24.5			15.85	15.4	20.08
Dissolved Oxygen (mg/l)[7]	**6.77 – 8.76[3]**	NR	NR	NR	NR	3.5			4.51	4.81	5.52
pH	**6.5 – 8.0[3]**	8.25	8.00	8.21	8.05	8.21	DRY	DRY	8.04	7.73	7.68
Conductivity- base flow (µS/cm)	**20-250[1]**	8,030	33,400	559	1,320	1,350			628	267	261
Turbidity (NTU)	**50[3]**	3.8	0.0*	*	0.8	1.6			30.3	297	394
Laboratory results											
Total Dissolved Solids (mg/L)	**600[4]**	4,580	22,800	298	766	722			350	605	735
Suspended Solids (mg/L)	**10[3]**	14	22	10	19	30			53	87	81
Total Alkalinity as $CaC0_3$ (mg/L)	**≥20[1]**	257	264	112	132	156			173	72	67
Sulphate (mg/L)	**250[4]**	284	1,580	10	6	8			8	4	4
Chloride (mg/L)	-	2,610	11,500	100	357	352			88	32	34
Ammonia N (mg/L)	**0.02**	0.02	0.11	0.07	0.03	0.02			0.06	0.06	0.08
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Nitrate N (mg/L)[8]	**0.158[1]**	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	0.01
Total Nitrogen (mg/L)	**0.5[3]**	0.4	0.5	0.3	0.5	0.8			0.4	1.4	1.5
Total Phosphorus as P (mg/L)	**0.05[3]**	0.02	<0.05	<0.01	0.02	0.07			0.04	0.3	0.31
Reactive Phosphorus (mg/L)	**0.02[3]**	<0.01	0.02	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Fluoride (mg/L)	**2.4[2]**	0.3	0.6	0.2	0.2	0.2			0.2	0.1	0.2
Dissolved Major Cations											
Calcium (mg/L)	-	114	347	25	48	49			11	5	4
Magnesium (mg/L)	-	167	826	18	39	38			13	6	5
Sodium (mg/L)	-	1140	6480	57	148	174			105	41	37
Potassium (mg/L)	-	25	217	2	2	2			3	3	3
Dissolved Metals											
Aluminium (mg/L)	**0.055[1]**	<0.01	<0.05	<0.01	<0.01	<0.01			0.16	0.67	<0.01
Arsenic (mg/L)	**0.024[1]**	0.002	<0.005	0.001	<0.001	0.001			0.001	0.002	0.002
Barium (mg/L)	**1.0[1]**	0.287	0.209	0.047	0.091	0.108			0.067	0.028	0.024
Cadmium (mg/L)	**0.0002[1]**	<0.0001	<0.0005	<0.0001	<0.0001	<0.0001			<0.0001	<0.0001	<0.0001
Chromium (mg/L)	**0.001[1]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Cobalt (mg/L)	**0.0014[2]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001

Copper (mg/L)	**0.0014[1]**	<0.001	<0.005	<0.001	<0.001	<0.001			0.001	0.002	0.002
Lead (mg/L)	**0.0034[1]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.114	0.146	0.007	0.06	0.076			0.009	0.009	0.002
Molybdenum (mg/L)	**0.034[2]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	0.001	0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.05	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	<0.001	<0.005	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.05	<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.025	<0.005	<0.005	<0.005			<0.005	<0.005	<0.005
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05			0.16	0.41	<0.05
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			<0.0001	<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	84.7	362	5.27	12.8	13.2			6.1	2.42	2.38
Total Cations (mg/L)	-	69.6	373	5.26	12.1	13.2			6.26	2.6	2.3
Ionic Balance (%)	-	9.73	1.38	0.07	2.96	0.08			1.27	----	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20			<20	<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50			<50	<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100			<100	<100	<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50			<50	<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50			<50	<50	<50
BTEXN											
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1		<1		<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2		<2		<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2		<2		<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1		<1		<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5		<5		<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-39 Surface water quality results during late-August 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]	23.8	24.2	18.1	20.3	19.0				16.2	14.4
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	10	7.92	9.85	7.32	7.9				6.82	4.85
pH	6.5 – 8.0[3]	7.98	7.76	8.58	7.72	7.83	DRY	DRY	DRY	7.78	7.35
Conductivity- base flow (µS/cm)	20-250[1]	14,167	37,794	1,163	1,360	1,237				258.8	246.2
Turbidity (NTU)	50[3]	5	9	2.1	2.5	5.6				459.3	713.3
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]	8,800	25,800	319	861	776				600	707
Suspended Solids (mg/L)	10[3]	9	25	<5	17	44				52	54
Total Alkalinity as $CaC0_3$ (mg/L)	≥20[1]	266	276	126	139	168				89	83
Sulphate (mg/L)	250[4]	563	1,880	9	5	9				5	4
Chloride (mg/L)	-	4,930	13,300	98	450	393				39	42
Ammonia N (mg/L)	0.02	0.05	0.08	0.02	0.04	0.06				0.04	0.04
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01	<0.01	<0.01	<0.01	0.03				<0.01	<0.01
Total Nitrogen (mg/L)	0.5[3]	0.6	0.7	0.4	0.4	0.8				1.7	1.3
Total Phosphorus as P (mg/L)	0.05[3]	<0.05	0.07	0.01	0.02	0.06				0.33	0.34
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	0.01	<0.01	<0.01	<0.01				0.01	<0.01
Fluoride (mg/L)	2.4[2]	0.4	0.6	0.2	0.2	0.2				0.2	0.2
Dissolved Major Cations											
Calcium (mg/L)	-	147	383	22	46	48				5	5
Magnesium (mg/L)	-	343	959	22	51	48				9	8
Sodium (mg/L)	-	2240	8020	66	175	188				48	46
Potassium (mg/L)	-	63	246	3	2	3				4	3
Dissolved Metals											
Aluminium (mg/L)	0.055[1]	0.01	<0.05	0.09	0.02	0.01				0.02	0.14
Arsenic (mg/L)	0.024[1]	0.002	<0.005	0.001	<0.001	<0.001				0.002	0.002
Barium (mg/L)	1.0[1]	0.388	0.188	0.049	0.102	0.118				0.031	0.027
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0005	0.0002	<0.0001	<0.0001				<0.0001	<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.005	<0.001	<0.001	<0.001				<0.001	<0.001
Cobalt (mg/L)	0.0014[2]	<0.001	<0.005	0.005	<0.001	<0.001				<0.001	0.002

Copper (mg/L)	**0.0014[1]**	<0.001	<0.005	0.001	<0.001	<0.001				0.002	0.001
Lead (mg/L)	**0.0034[1]**	<0.001	<0.005	<0.001	<0.001	<0.001				<0.001	<0.001
Manganese (mg/L)	**1.9[1]**	0.077	0.242	0.004	0.078	0.016				0.008	0.014
Molybdenum (mg/L)	**0.034[2]**	0.002	<0.005	0.001	<0.001	<0.001				<0.001	<0.001
Nickel (mg/L)	**0.011[1]**	<0.001	<0.005	<0.001	<0.001	<0.001				<0.001	<0.001
Selenium (mg/L)	**0.005[1]**	<0.01	<0.05	<0.01	<0.01	<0.01				<0.01	<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.005	<0.001	<0.001	<0.001				<0.001	<0.001
Uranium (mg/L)	**0.01[6]**	0.001	<0.005	<0.001	<0.001	<0.001				<0.001	<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.05	<0.01	<0.01	<0.01				<0.01	<0.01
Zinc (mg/L)	**0.008[1]**	<0.005	<0.025	0.014	<0.005	0.01				<0.005	0.007
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05				0.05	0.1
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	156	420	5.47	15.6	14.6				2.98	2.93
Total Cations (mg/L)	-	135	453	5.86	14.2	14.6				3.18	2.98
Ionic Balance (%)	-	7.39	3.82	3.41	4.77	0.1				3.21	----
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20				<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50				<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100				<100	<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50				<50	<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50				<50	<50
BTEXN											
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1				<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2				<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1				<1	<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5				<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-40 Surface water quality results during September 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	**16 – 34[5]**	26.5	19.2	21.5	24.3	21.4				23.0	22.9
Dissolved Oxygen (mg/l)[7]	**6.77 – 8.76[3]**	5.1	5.21	8.7	6.06	3.97				4.31	4.1
pH	**6.5 – 8.0[3]**	7.6	7.72	8.37	7.9	7.9	DRY	DRY	DRY	7.77	7.63
Conductivity- base flow (µS/cm)	**20-250[1]**	18,183	27,205	746	1,687	1,614				257.4	431.2
Turbidity (NTU)	**50[3]**	11.3	14.6	11.6	5.3	7.3				576	280
Laboratory results											
Total Dissolved Solids (mg/L)	**600[4]**	12,400	25,100	384	1,210	819				1,000	972
Suspended Solids (mg/L)	**10[3]**	30	66	48	25	9				74	1,320
Total Alkalinity as $CaCO_3$ (mg/L)	**≥20[1]**	272	286	154	145	173				78	93
Sulphate (mg/L)	**250[4]**	678	1,720	7	4	6				7	20
Chloride (mg/L)	-	6,400	12,700	107	515	378				33	60
Ammonia N (mg/L)	**0.02**	0.04	<0.01	0.03	0.03	0.03				0.04	0.16
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Nitrate N (mg/L)[8]	**0.158[1]**	<0.01	<0.01	<0.01	<0.01	<0.01				0.01	0.02
Total Nitrogen (mg/L)	**0.5[3]**	0.6	<0.5	0.7	0.5	0.6				1.3	4.8
Total Phosphorus as P (mg/L)	**0.05[3]**	0.05	0.07	0.06	0.02	0.04				0.32	1.08
Reactive Phosphorus (mg/L)	**0.02[3]**	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Fluoride (mg/L)	**2.4[2]**	0.4	0.6	0.2	0.2	0.2				0.2	0.2
Dissolved Major Cations											
Calcium (mg/L)	-	219	463	29	57	52				5	7
Magnesium (mg/L)	-	400	1,010	22	54	48				7	9
Sodium (mg/L)	-	3,020	7,630	61	205	225				41	56
Potassium (mg/L)	-	84	253	3	4	3				4	5
Dissolved Metals											
Aluminium (mg/L)	**0.055[1]**	<0.01	0.02	0.17	0.01	<0.01				0.04	0.02
Arsenic (mg/L)	**0.024[1]**	0.003	0.004	0.002	0.001	0.001				0.003	0.002
Barium (mg/L)	**1.0[1]**	0.311	0.189	0.062	0.111	0.092				0.024	0.041
Cadmium (mg/L)	**0.0002[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Chromium (mg/L)	**0.001[1]**	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001
Cobalt (mg/L)	**0.0014[2]**	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001

Copper (mg/L)	**0.0014**[1]	<0.001	0.001	<0.001	0.001	<0.001				0.002	0.002
Lead (mg/L)	**0.0034**[1]	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001
Manganese (mg/L)	**1.9**[1]	0.082	0.178	0.052	0.053	0.054				0.002	0.087
Molybdenum (mg/L)	**0.034**[2]	0.002	0.004	<0.001	<0.001	<0.001				<0.001	<0.001
Nickel (mg/L)	**0.011**[1]	0.002	0.001	<0.001	<0.001	0.002				0.001	0.002
Selenium (mg/L)	**0.005**[1]	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Silver (mg/L)	**0.00005**[1]	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001
Uranium (mg/L)	**0.01**[6]	0.003	0.002	<0.001	<0.001	<0.001				<0.001	<0.001
Vanadium (mg/L)	**0.006**[2]	<0.01	<0.01	<0.01	<0.01	<0.01				<0.01	<0.01
Zinc (mg/L)	**0.008**[1]	0.006	<0.005	<0.005	<0.005	<0.005				<0.005	<0.005
Iron (mg/L)	**0.35**[2]	<0.05	<0.05	<0.05	<0.05	<0.05				0.07	0.05
Mercury (mg/L)	**0.0006**[1]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Ionic Balance											
Total Anions (mg/L)	-	200	400	6.24	17.5	14.2				2.64	3.97
Total Cations (mg/L)	-	177	444	5.99	16.3	16.4				2.71	3.65
Ionic Balance (%)	-	6.02	5.31	2.07	3.55	7.06				----	4.11
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20				<20	<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50				<50	<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100				<100	140
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50				<50	110
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50				<50	250
BTEXN											
Benzene (µg/L)	**950**[1]	<1	<1	<1	<1	<1				<1	<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
ortho-Xylene (µg/L)	**350**[1]	<2	<2	<2	<2	<2				<2	<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2				<2	<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1				<1	<1
Naphthalene (µg/L)	**16**[1]	<5	<5	<5	<5	<5				<5	<5

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). Red font = Data above or below trigger values. Note: Values that say '<0.0001' are described as 'undetectable' by the laboratory.

Table 9-41 Surface water quality results during October 2018 sample events

Parameter	WQOs	Styx River		Tooloombah Creek			Deep Creek				
		St1	St2	To1	To2	To3	De1	De2	De3	De4	De5
In-situ results											
Water Temperature (°C)	16 – 34[5]	29.4	31.7	27.2	25.8	25.8					29.1
Dissolved Oxygen (mg/l)[7]	6.77 – 8.76[3]	3.92	66.5*	4.02	4.77	2.33					3.65
pH	6.5 – 8.0[3]	7.11	7	7.15	8.5	6.62	DRY	DRY	DRY	DRY	7.7
Conductivity- base flow (µS/cm)	20-250[1]	18,148	42,250	1,039	1,125	1,659					373.6
Turbidity (NTU)	50[3]	8.4	13.1	5.3	22.3	16					206
Laboratory results											
Total Dissolved Solids (mg/L)	600[4]	12,200	29,100	414	672	1,030					314
Suspended Solids (mg/L)	10[3]	15	14	10	288	243					86
Total Alkalinity as CaC0$_3$ (mg/L)	≥20[1]	228	245	143	96	174					85
Sulphate (mg/L)	250[4]	637	1,870	3	4	3					4
Chloride (mg/L)	-	6,040	13,600	125	285	450					49
Ammonia N (mg/L)	0.02	0.06	0.16	0.06	<0.01	<0.01					0.02
Nitrite N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	<0.01					<0.01
Nitrate N (mg/L)[8]	0.158[1]	<0.01	<0.01	<0.01	<0.01	<0.01					<0.01
Total Nitrogen (mg/L)	0.5[3]	2.3	0.7	0.6	0.9	1.3					1.0
Total Phosphorus as P (mg/L)	0.05[3]	0.19	0.11	0.03	0.06	0.11					0.17
Reactive Phosphorus (mg/L)	0.02[3]	<0.01	0.02	<0.01	<0.01	<0.01					<0.01
Fluoride (mg/L)	2.4[2]	0.4	0.6	0.2	0.2	0.2					0.2
Dissolved Major Cations											
Calcium (mg/L)	-	224	455	35	35	49					11
Magnesium (mg/L)	-	406	1,020	24	36	44					11
Sodium (mg/L)	-	2,670	8,030	69	133	198					42
Potassium (mg/L)	-	79	246	5	2	4					6
Dissolved Metals											
Aluminium (mg/L)	0.055[1]	<0.01	<0.05	0.01	0.02	0.01					5.03
Arsenic (mg/L)	0.024[1]	0.003	0.005	0.003	0.002	0.002					0.004
Barium (mg/L)	1.0[1]	0.464	0.251	0.064	0.061	0.112					0.177
Cadmium (mg/L)	0.0002[1]	<0.0001	<0.0005	<0.0001	<0.0001	<0.0001					<0.0001
Chromium (mg/L)	0.001[1]	<0.001	<0.005	<0.001	<0.001	<0.001					0.004
Cobalt (mg/L)	0.0014[2]	<0.001	<0.005	<0.001	<0.001	<0.001					0.004

Copper (mg/L)	**0.0014[1]**	0.002	<0.005	0.002	<0.001	0.013					0.007
Lead (mg/L)	**0.0034[1]**	<0.001	<0.005	<0.001	<0.001	<0.001					0.007
Manganese (mg/L)	**1.9[1]**	0.119	0.093	0.136	0.011	0.036					0.445
Molybdenum (mg/L)	**0.034[2]**	0.002	0.005	0.001	<0.001	<0.001					<0.001
Nickel (mg/L)	**0.011[1]**	0.001	<0.005	<0.001	<0.001	0.003					0.006
Selenium (mg/L)	**0.005[1]**	<0.01	<0.05	<0.01	<0.01	<0.01					<0.01
Silver (mg/L)	**0.00005[1]**	<0.001	<0.005	<0.001	<0.001	<0.001					<0.001
Uranium (mg/L)	**0.01[6]**	0.001	<0.005	<0.001	<0.001	<0.001					<0.001
Vanadium (mg/L)	**0.006[2]**	<0.01	<0.05	<0.01	<0.01	<0.01					0.02
Zinc (mg/L)	**0.008[1]**	<0.005	<0.025	<0.005	0.009	0.022					0.011
Iron (mg/L)	**0.35[2]**	<0.05	<0.05	<0.05	<0.05	<0.05					6.08
Mercury (mg/L)	**0.0006[1]**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001					<0.0001
Ionic Balance											
Total Anions (mg/L)	-	188	427	6.44	10	16.2					3.16
Total Cations (mg/L)	-	163	462	6.85	10.5	14.8					3.43
Ionic Balance (%)	-	7.25	3.91	3.05	2.45	4.68					4.1
Total Petroleum Hydrocarbons											
C6 - C9 Fraction (µg/L))	-	<20	<20	<20	<20	<20					<20
C10 - C14 Fraction (µg/L)	-	<50	<50	<50	<50	<50					<50
C15 - C28 Fraction (µg/L)	-	<100	<100	<100	<100	<100					<100
C29 - C36 Fraction (µg/L)	-	<50	<50	<50	<50	<50					<50
C10 - C36 Fraction (sum) (µg/L)	-	<50	<50	<50	<50	<50					<50
BTEXN											
Benzene (µg/L)	**950[1]**	<1	<1	<1	<1	<1					<1
Toluene (µg/L)	-	<2	<2	<2	<2	<2					<2
Ethylbenzene (µg/L)	-	<2	<2	<2	<2	<2					<2
meta- & para-Xylene (µg/L)	-	<2	<2	<2	<2	<2					<2
ortho-Xylene (µg/L)	**350[1]**	<2	<2	<2	<2	<2					<2
Total Xylenes (µg/L)	-	<2	<2	<2	<2	<2					<2
Sum of BTEX (µg/L)	-	<1	<1	<1	<1	<1					<1
Naphthalene (µg/L)	**16[1]**	<5	<5	<5	<5	<5					<5

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). Red font = Data above or below trigger values. Note: Values that say ‘<0.0001’ are described as ‘undetectable’ by the laboratory.

Table 9-42 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%	3165.16	683	270.96	1968.6	18169
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 $CaC0_3$ (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	6014.5
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).

9.5.6 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 9-43. 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 9-43 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]	-

Quality Characteristic[3]	Trigger level (µg/L)	Basis	Comment on trigger level
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 Erosion and Sediment Control Plan.

The proposed release limits for pH and Turbidity are presented at Table 9-44. The end of pipe discharges and target in-stream dilution values for EC are presented at Table 9-45 and Table 9-46 for Tooloombah Creek and Deep Creek respectively.

Table 9-44 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 9-45 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	<0.113 m^3/s	1,500

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)
						>0.17 m^3/s	<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 9-46 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

9.6 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.

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).

9.6.1 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.

9.6.1.1 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 9-47.

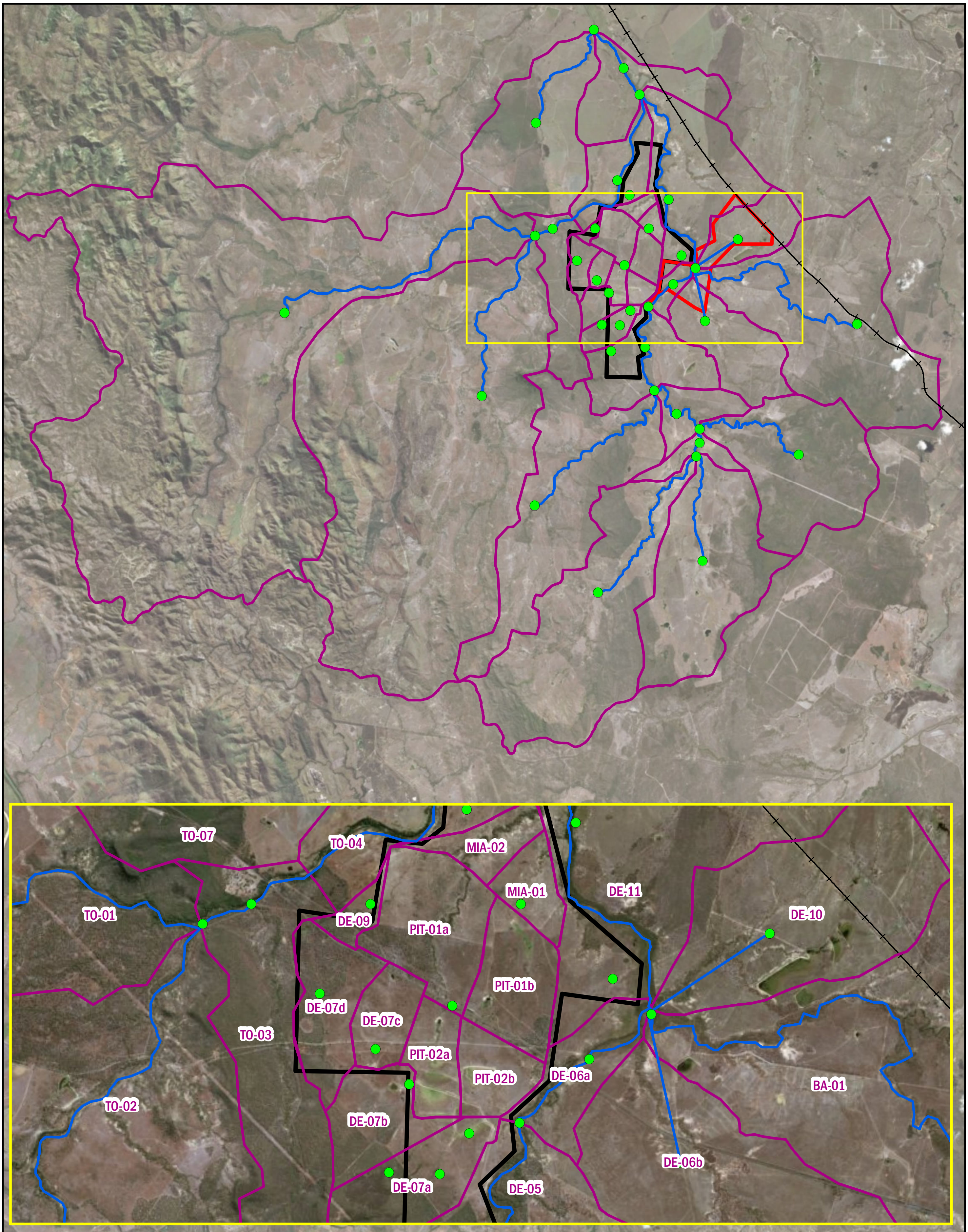
Table 9-47 Design point rainfall intensities (mm/hr)

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

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 9-48) presented in Table 9-48. 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 9-48 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



N

0 2.5 5 km

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Date: 14/11/18
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Legend

- Nodes
- Reaches
- XP-RAFT Catchments
- ML 80187
- ML 700022
- North Coast Rail Line

Figure 9-48

XP-RAFTS catchment delineation – base case

CDM Smith

9.6.1.2 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
- 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 in Section 9.6.1.1 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 9-49.

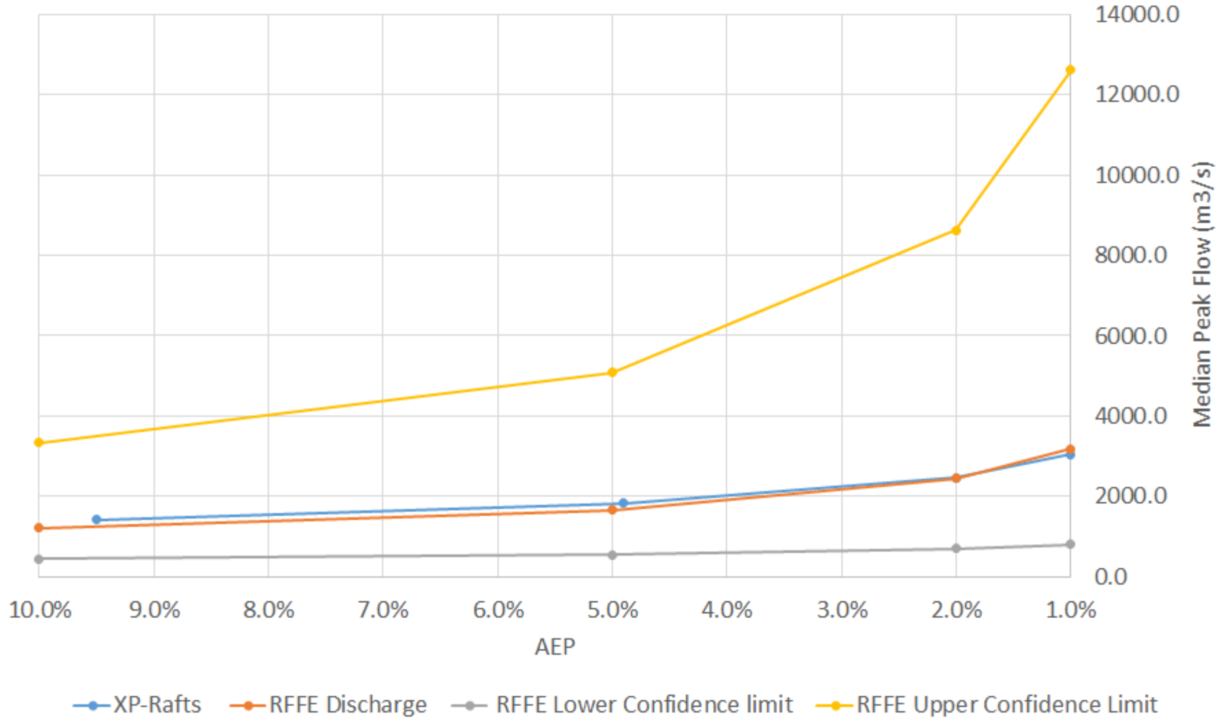

Figure 9-49 Comparison of peak flows of XP-RAFTS and RFFE

It can be seen from Figure 9-49 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 9-49.

Table 9-49 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, shown in green in Figure 9-50, were selected as they represent a reasonable range of high, low and medium rainfall years.

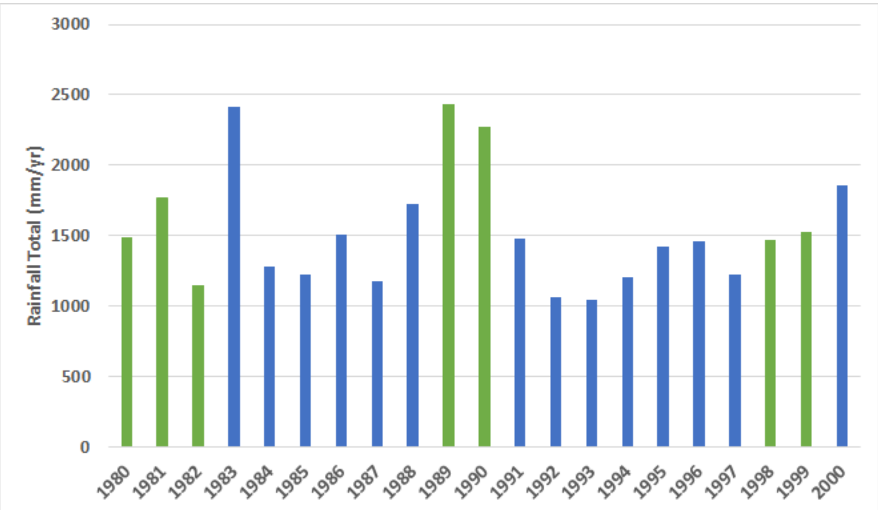

Figure 9-50 Water Park Creek rainfall years (green) used in regional hydrological comparison

The resulting comparison rainfall event sets are plotted in Figure 9-51 and show that the calculated Deep Creek flow rates give results that correlate with the regional surface water gauging data from Water Park Creek.

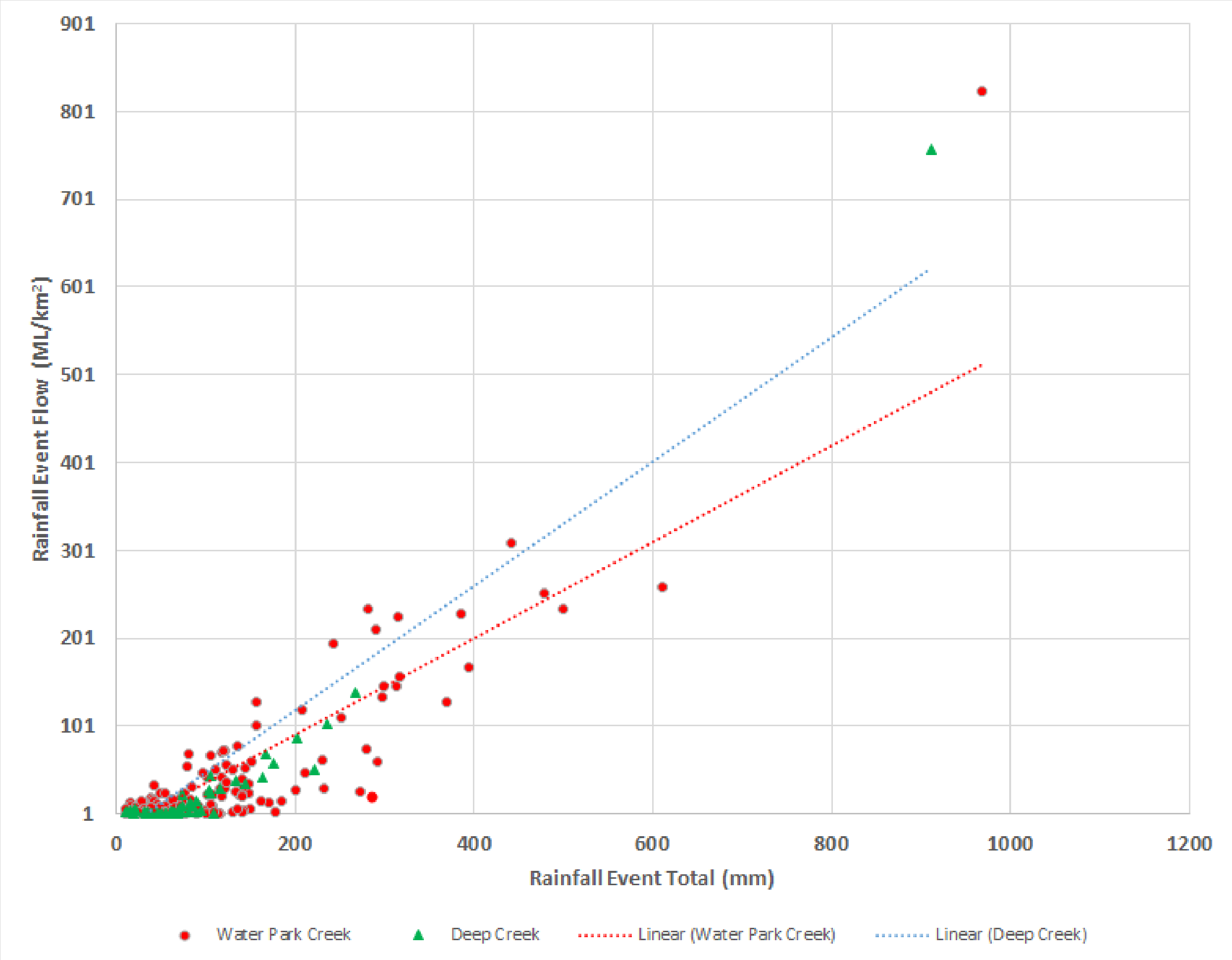

Figure 9-51 Regional rainfall – flow comparison for Water Park Creek and Deep Creek

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 XP-RAFT hydrological 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 and the Storage Coefficient Multiplication Factor Bx value. The currently selected values are shown in Table 9-50.

Table 9-50 Selected XP-RAFTS parameters

Calibration Parameter	Selected Value
Manning's n	0.045
Storage Coefficient Multiplication Factor (Bx)	1.0

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.

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) as indicated in Table 9-51. Including the selected value of 0.045 (minor stream flow, high grass, mature field crops).

Table 9-51 Manning's n values used in sensitivity analysis

Description	Manning's n
Short Grass	0.025
High Grass\ Mature Field Crops	0.045
Light brush and trees in summer	0.06
Medium to dense brush in summer	0.08
Dense brush in summer	0.1

The results are shown in Figure 9-52 and show that the used value of 0.045 is a conservative and reasonable value for manning's n.

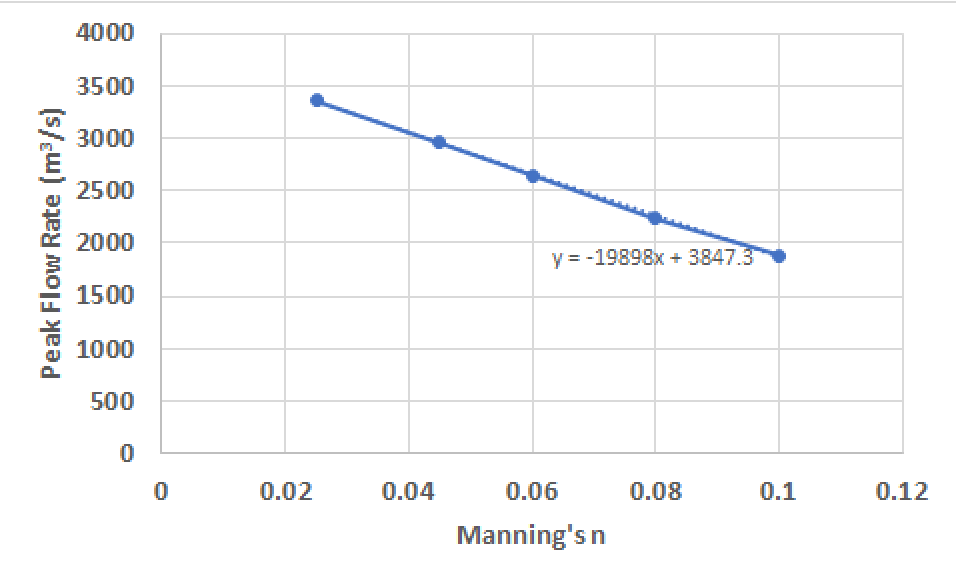

Figure 9-52 XP-RAFTS peak flow sensitivity to Manning's n

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 9-53 and show that the selected value of 1 is a conservative and reasonable value for Bx.

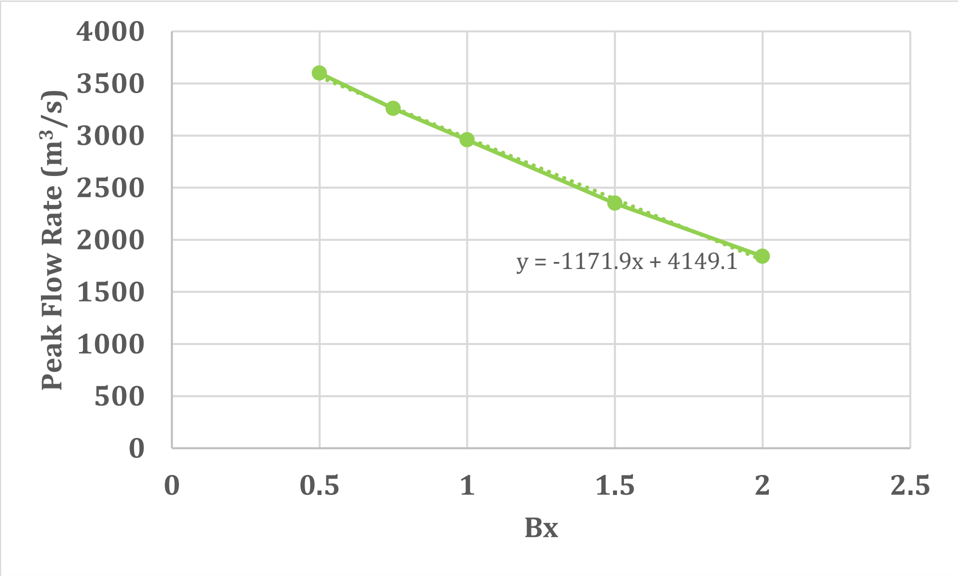

Figure 9-53 XP-RAFTS peak flow sensitivity to the Bx factor

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.

9.6.1.3 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 .

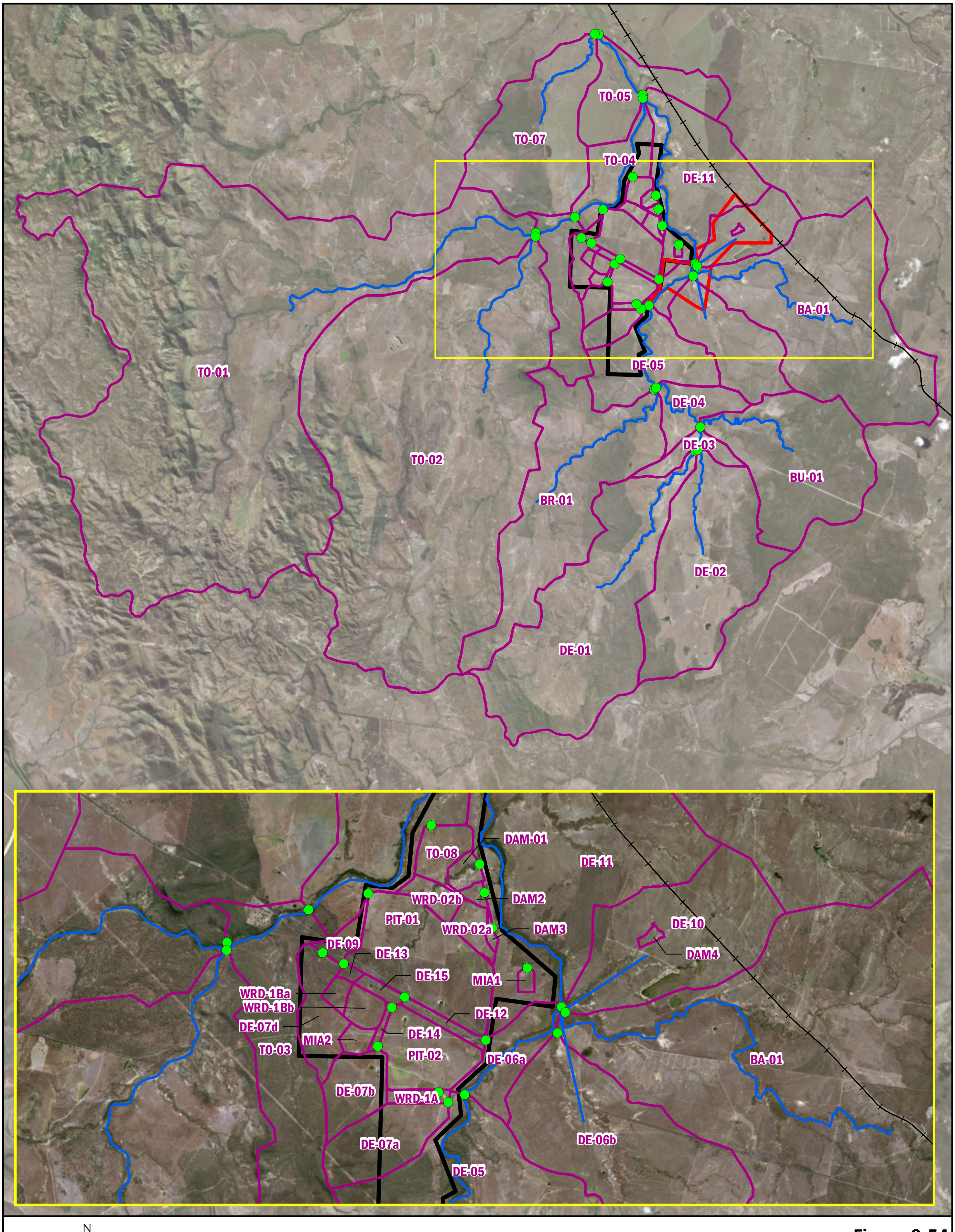

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Figure 9-54
XP-RAFTS catchment delineation – developed case

CDM Smith

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9.6.1.4 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 9-52.

Table 9-52 Peak flows at the Project area boundary (J6) – 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

The corresponding runoff hydrographs are shown in Figure 9-55. 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.

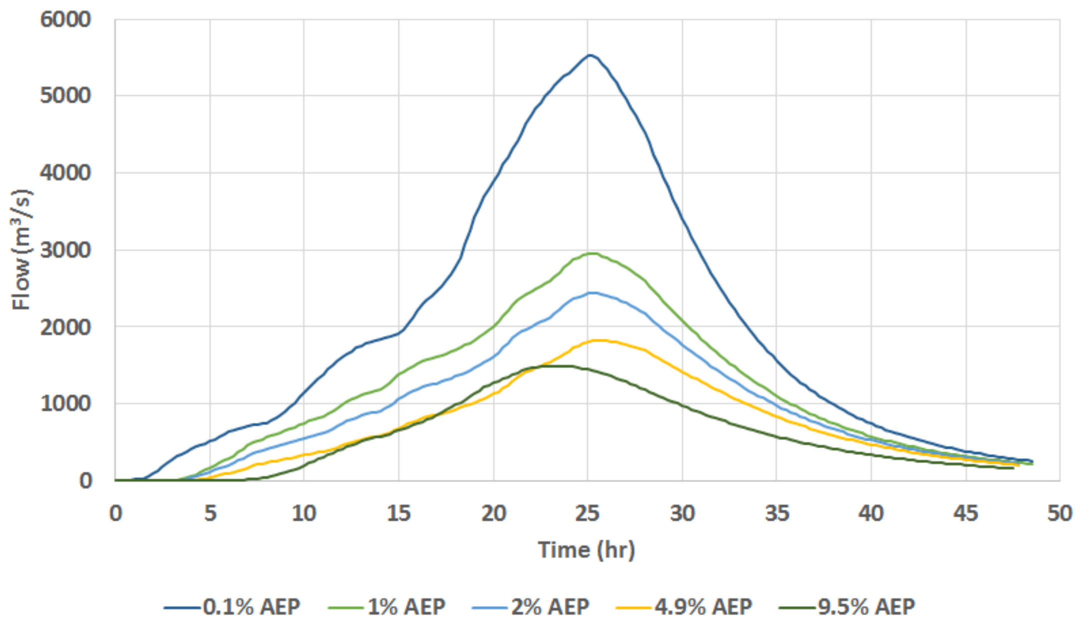

Figure 9-55 Critical storm duration hydrographs – existing case

9.6.1.5 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 detail 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 9-53.

Table 9-53 Peak flows at the Project area boundary (J6) – 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

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.

Developed case runoff hydrographs are presented in Figure 9-56. 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.

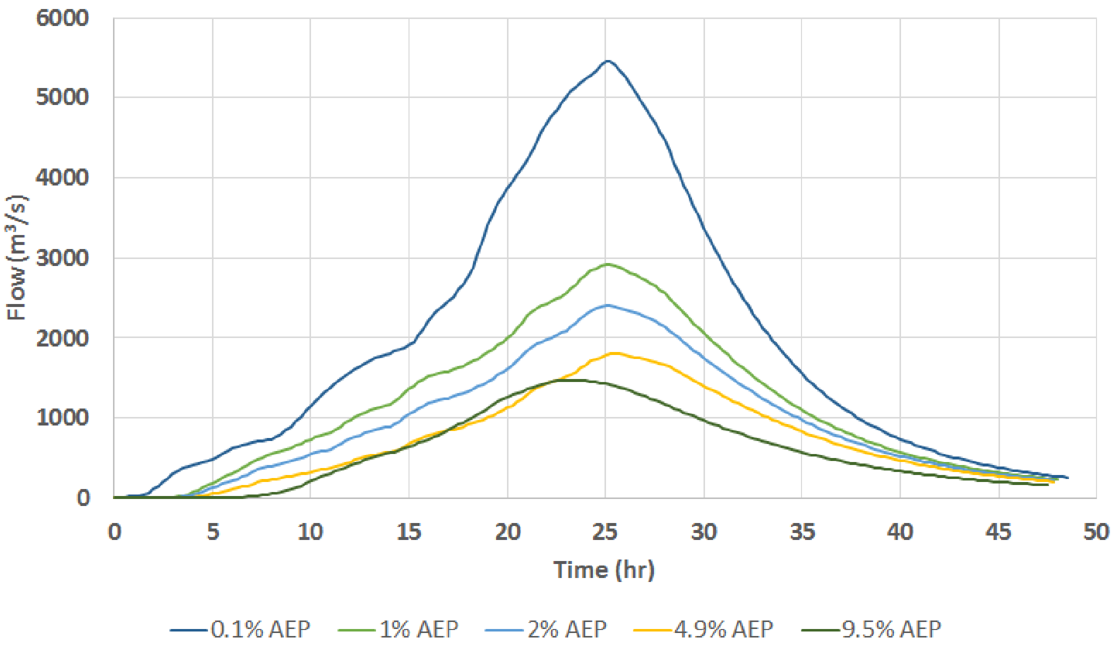

Figure 9-56 Critical storm duration – developed case

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 (refer J4) 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.

9.6.2 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 (see Section 9.6.1).

9.6.2.1 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 (see Section 9.6.1.4) 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 9-54.

Table 9-54 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' values 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 9-57 to Figure 9-68). 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 highresolution 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 9-55.

Table 9-55 Adopted existing Manning's n roughness values

Land Use	Value
Pasture	0.035
Channel	0.03
Light Brush	0.06
Heavy Brush	0.1

9.6.2.2 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; these maps are shown in Figure 9-57 to Figure 9-68.

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.

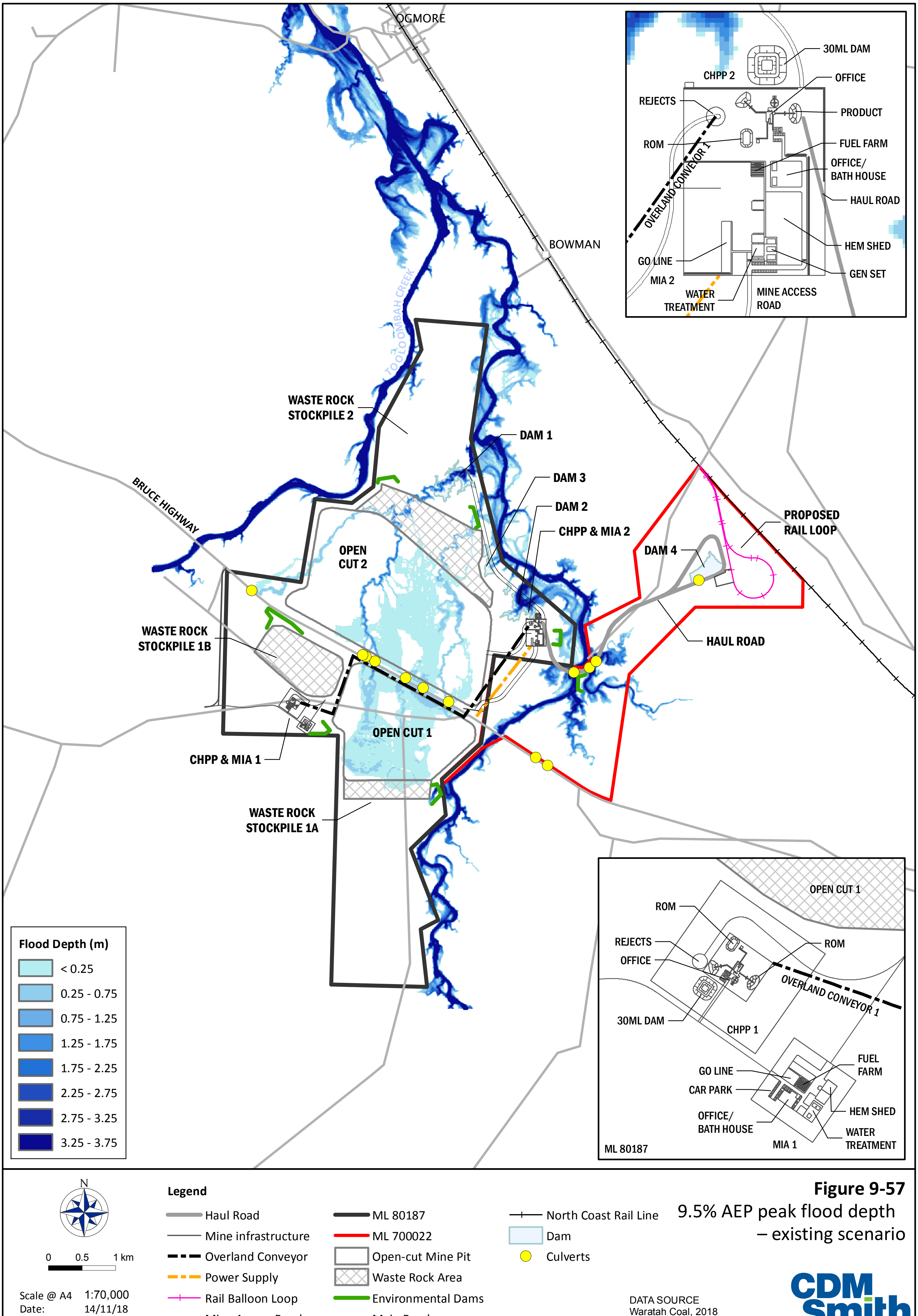

Figure 9-57
9.5% AEP peak flood depth – existing scenario

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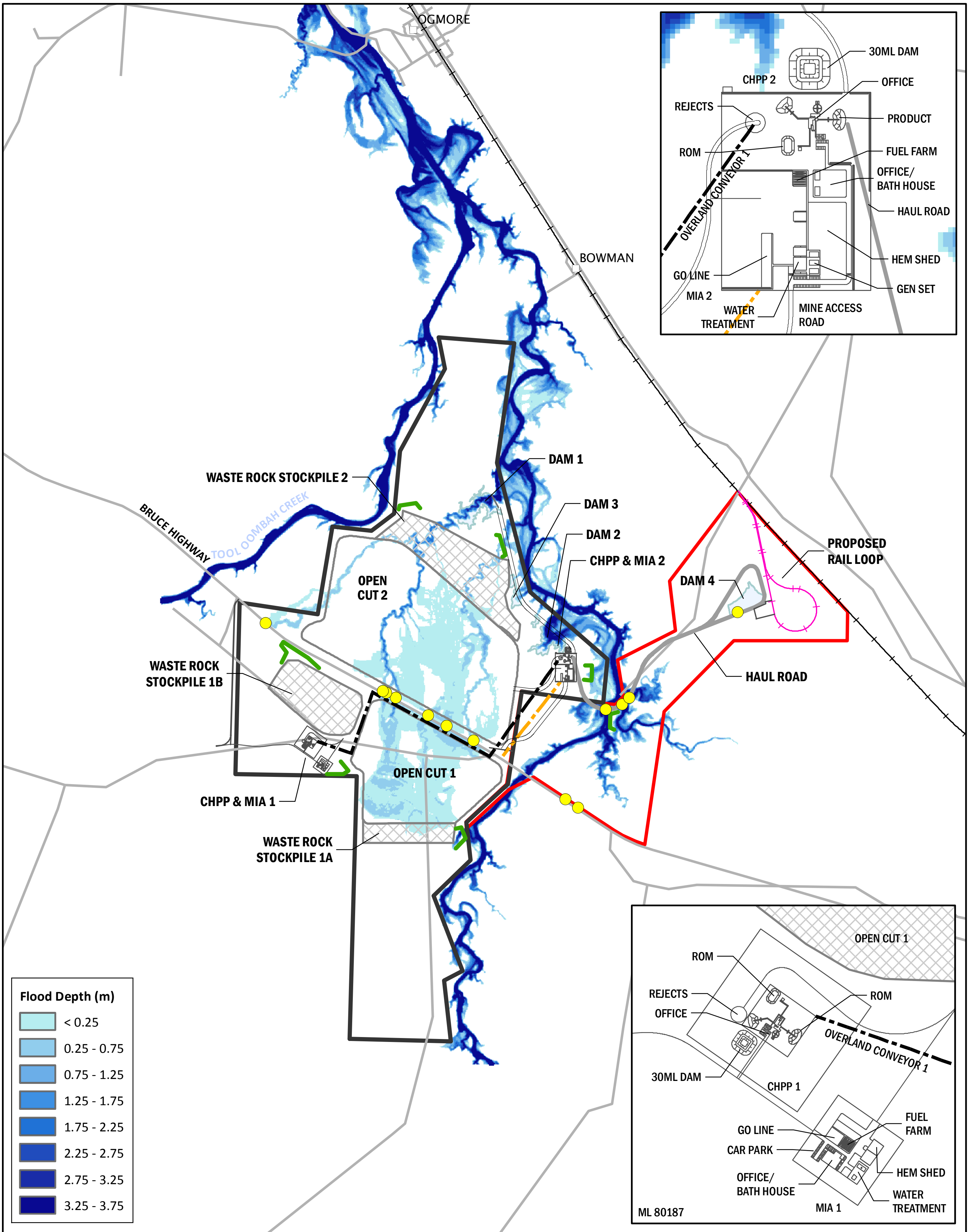

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Legend

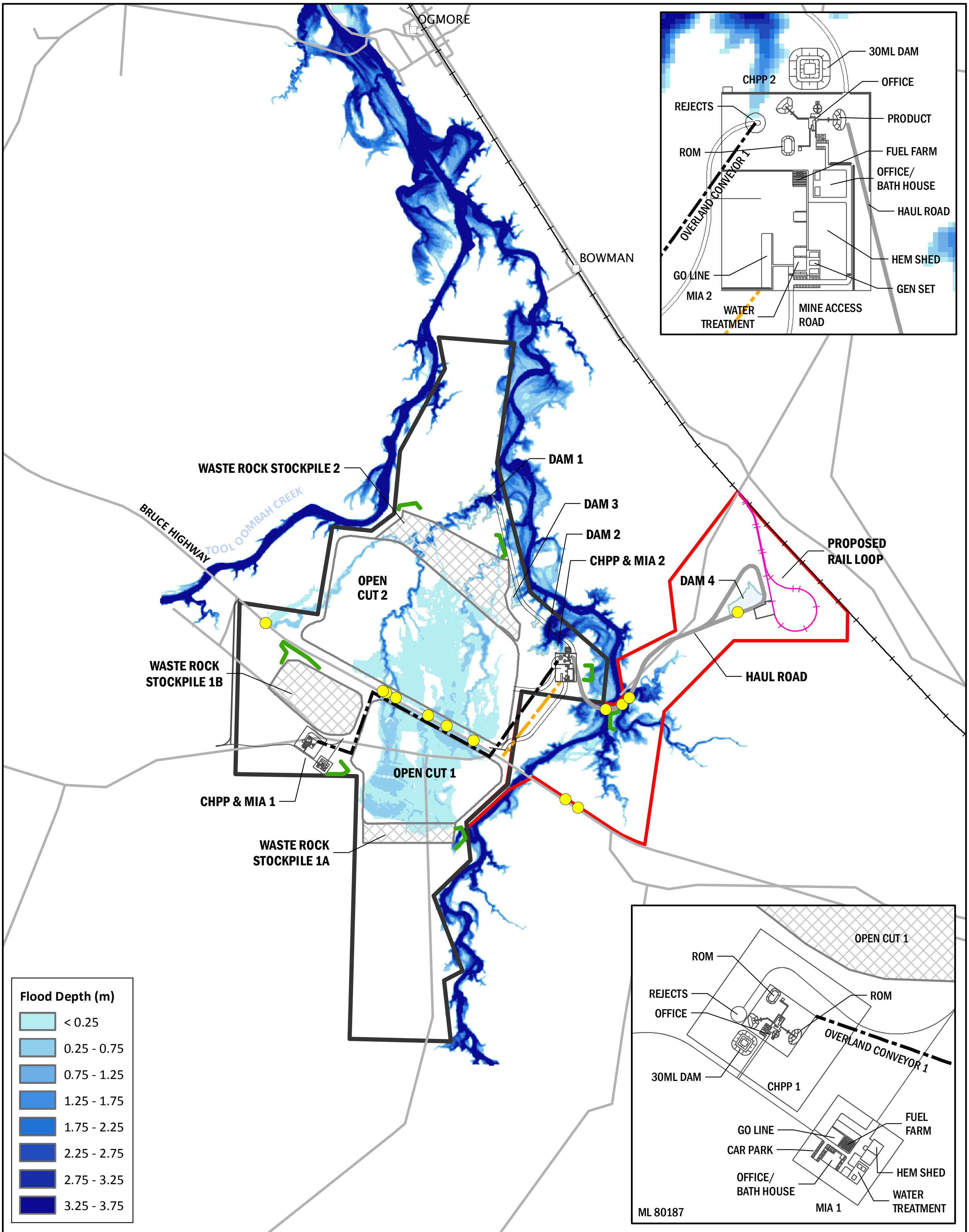
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 9-58
4.9% 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 4p9AEP Depth__9-54.mxd 11/14/2018



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 9-59
2% AEP peak flood depth – existing scenario

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 9_Supp_Report_Surface Water\1000111 Ex 2AEP Depth__9-55.mxd 11/14/2018

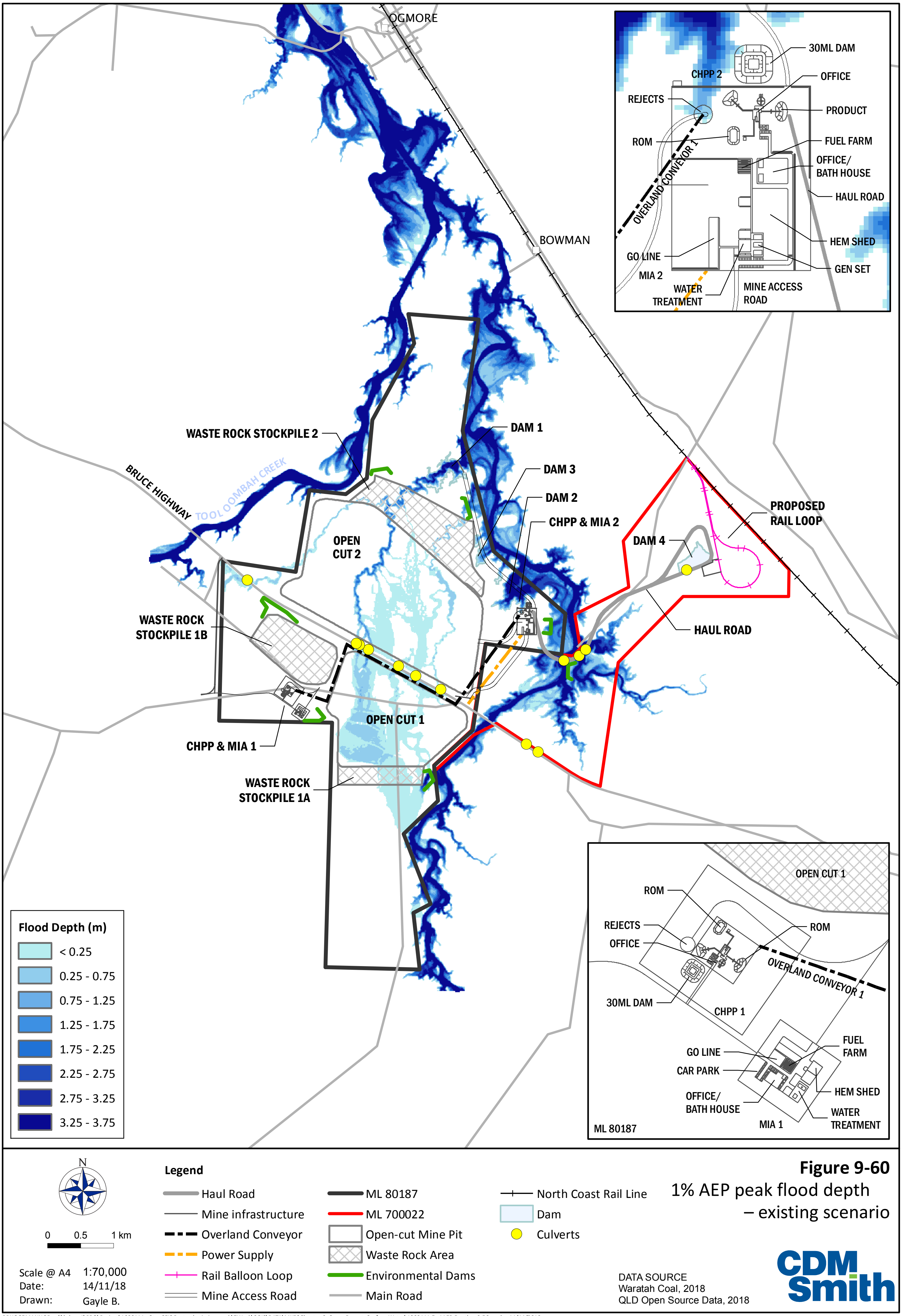
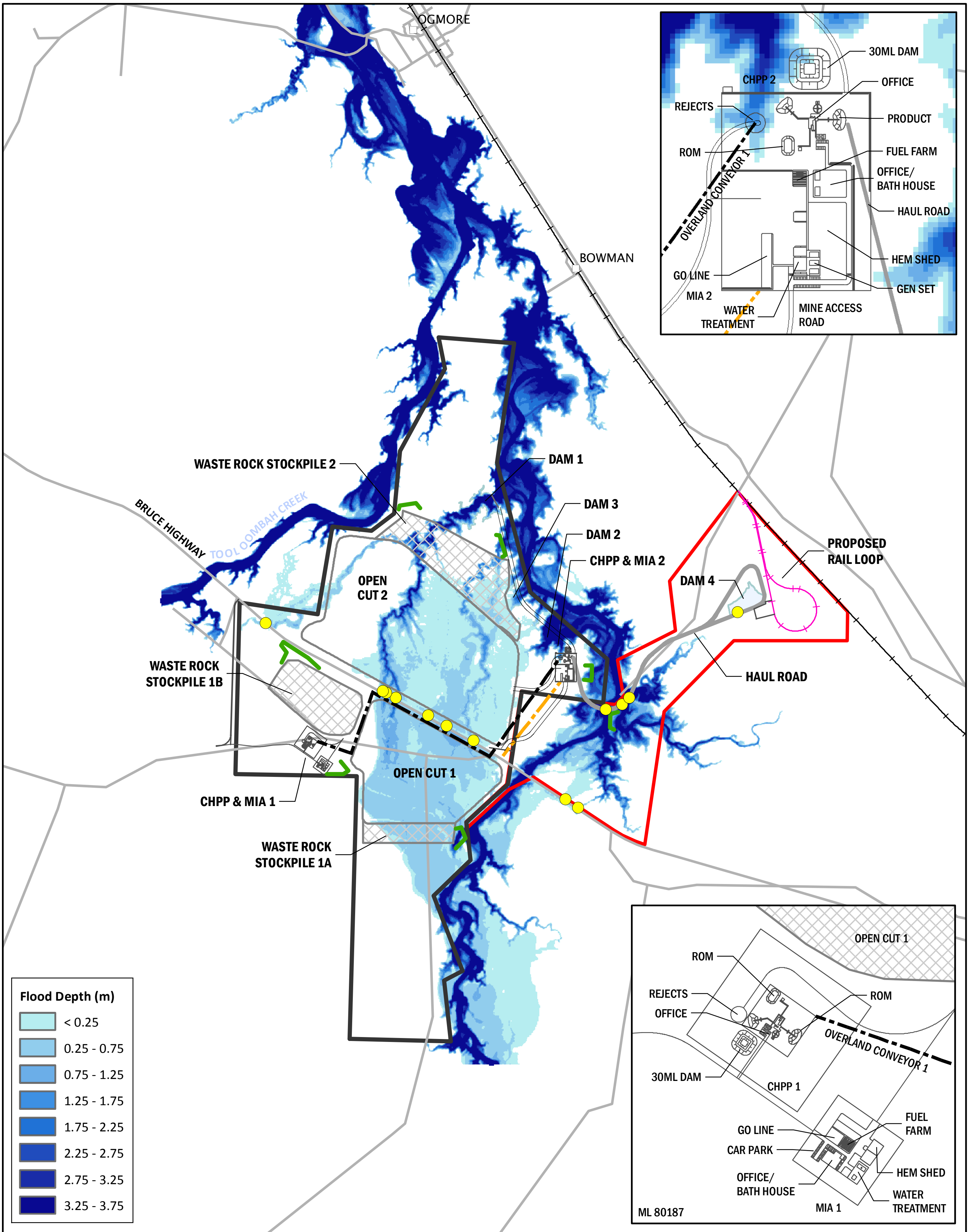


Figure 9-60
1% AEP peak flood depth – existing scenario

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 11/14/2018



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

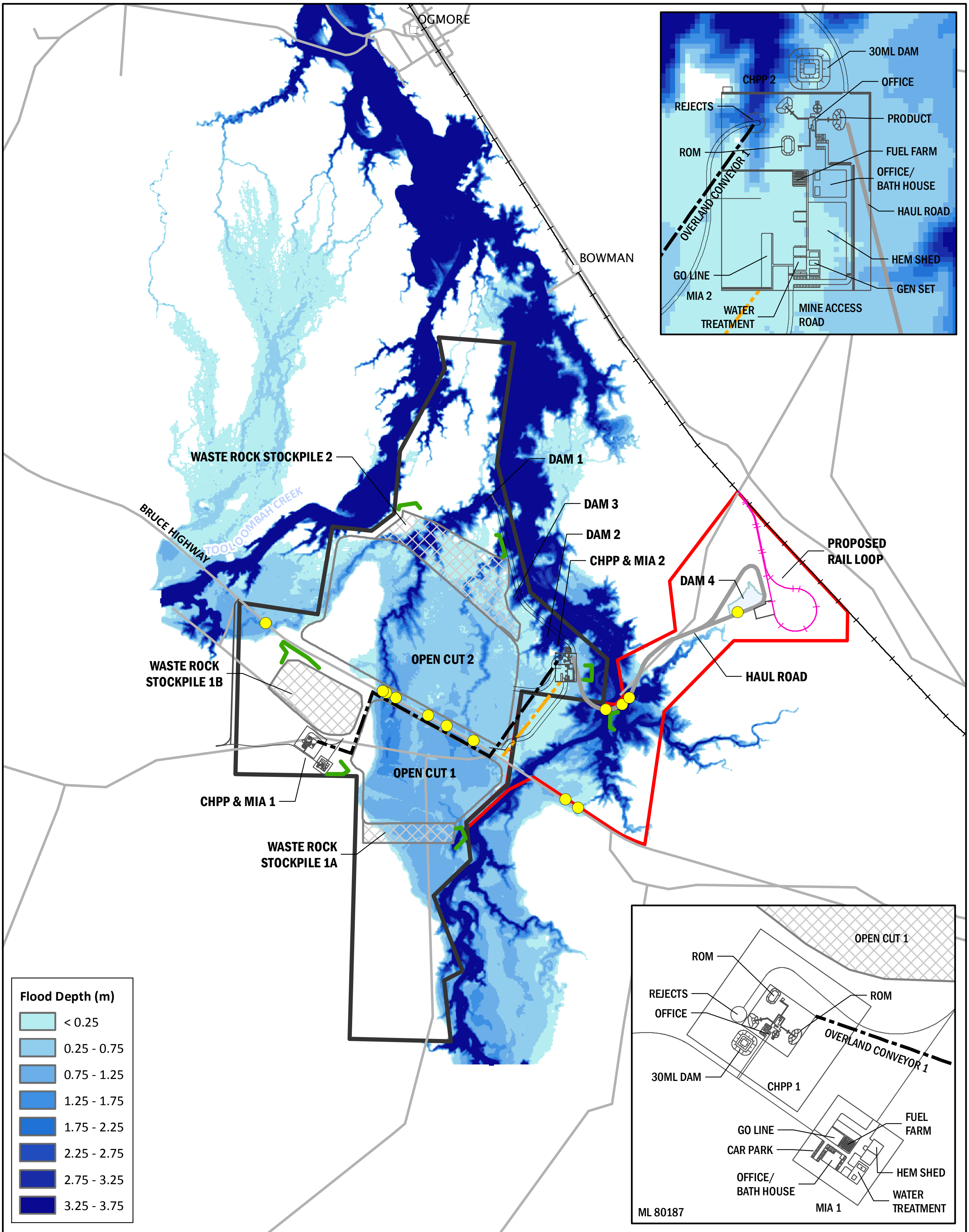
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 9-61 0.1% 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 0p1AEP Depth__9-57.mxd 11/15/2018



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

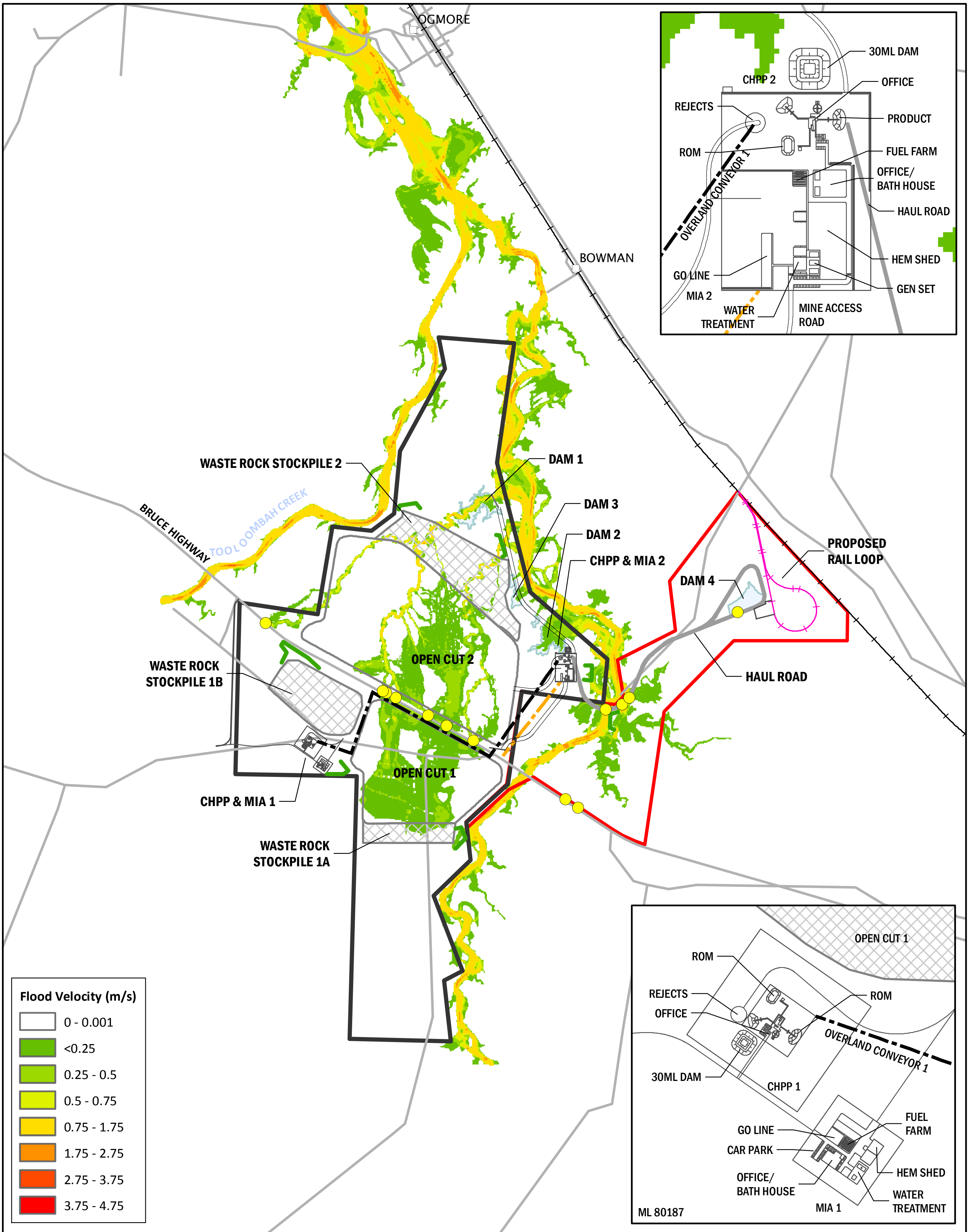
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 9-62
PMF 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 PMF Depth__9-58.mxd 11/15/2018



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

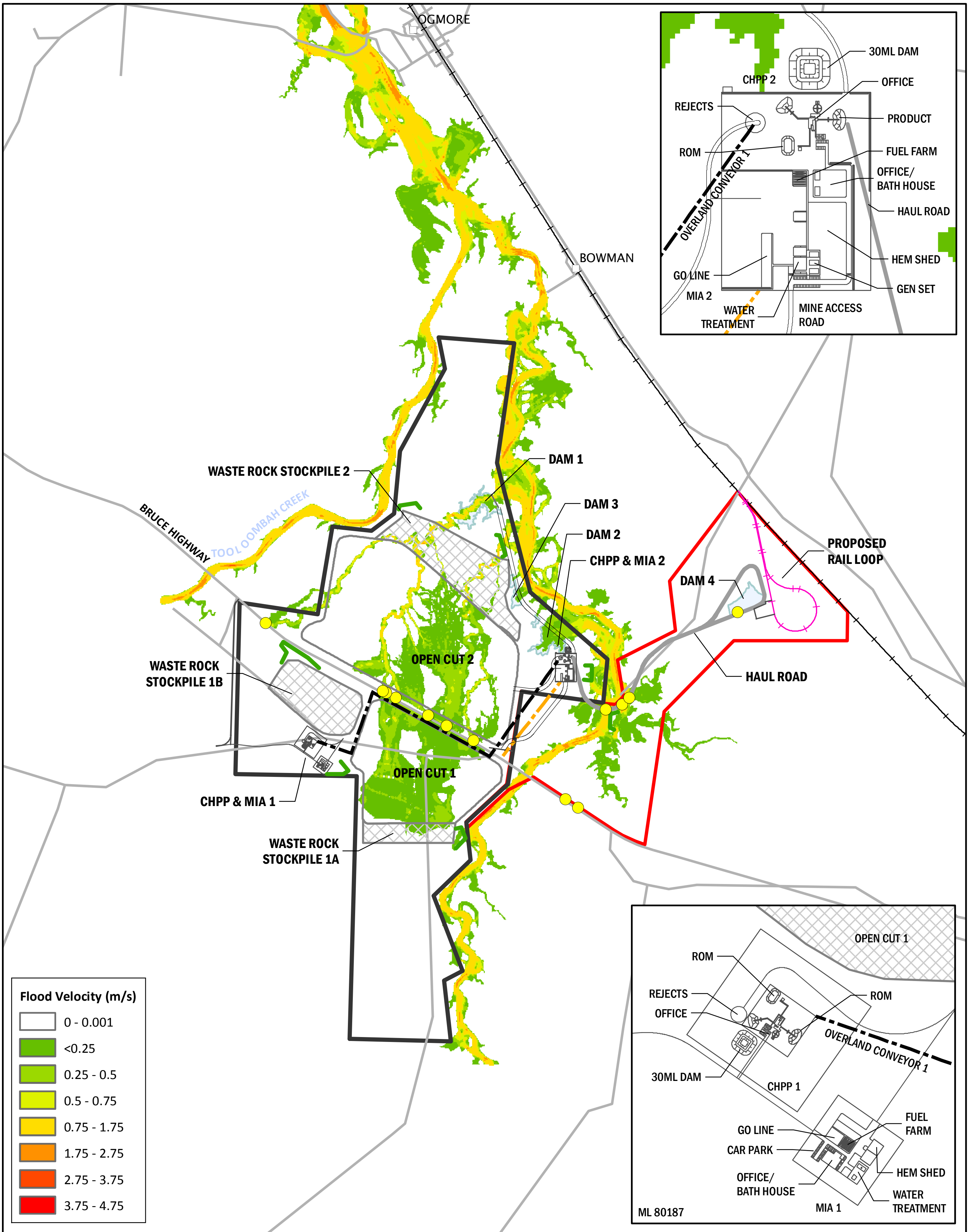
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 9-63
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



N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Legend

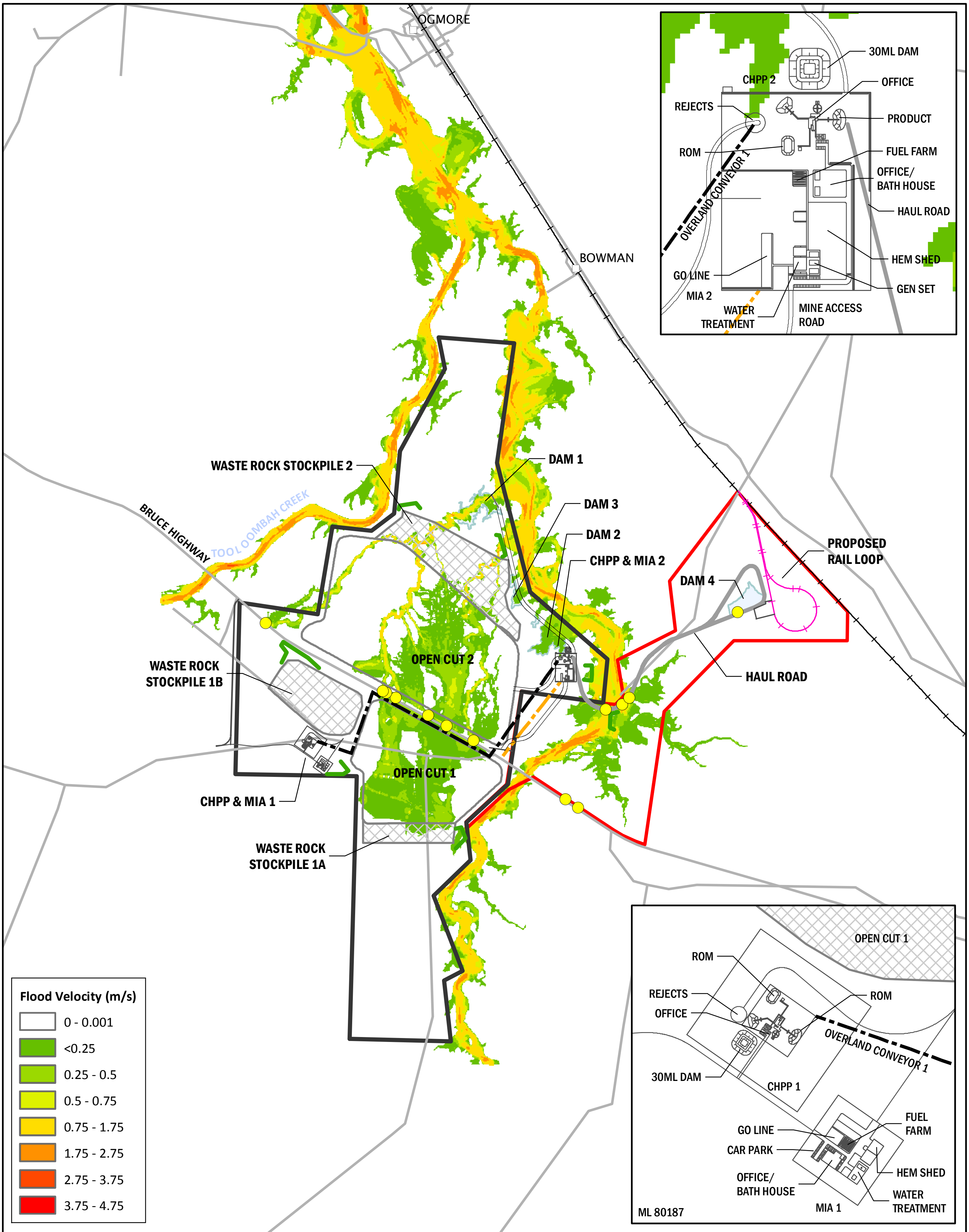
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 9-64
4.9% 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 4p9AEP Vel_9-60.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
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Figure 9-65

2% AEP peak flood velocity – existing scenario

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

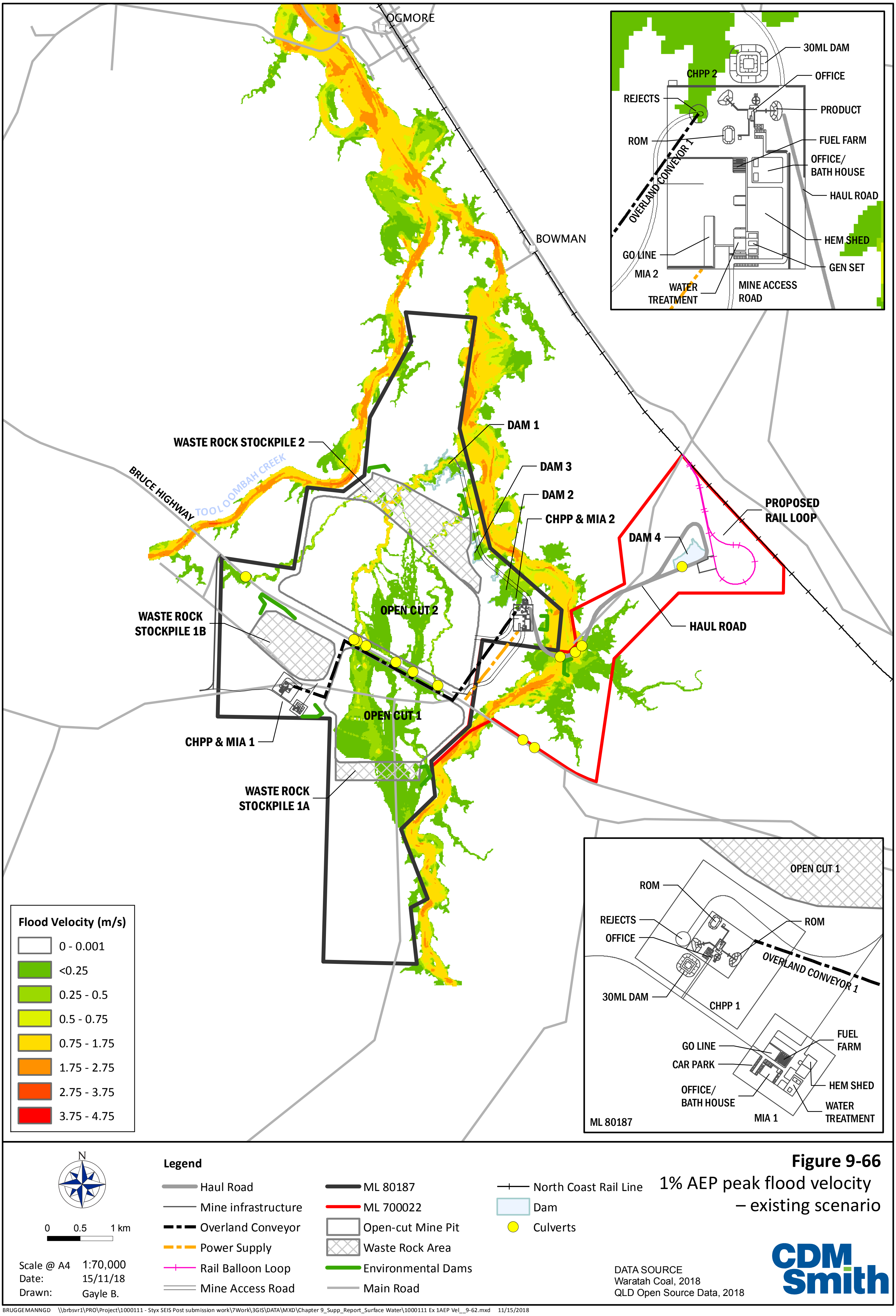
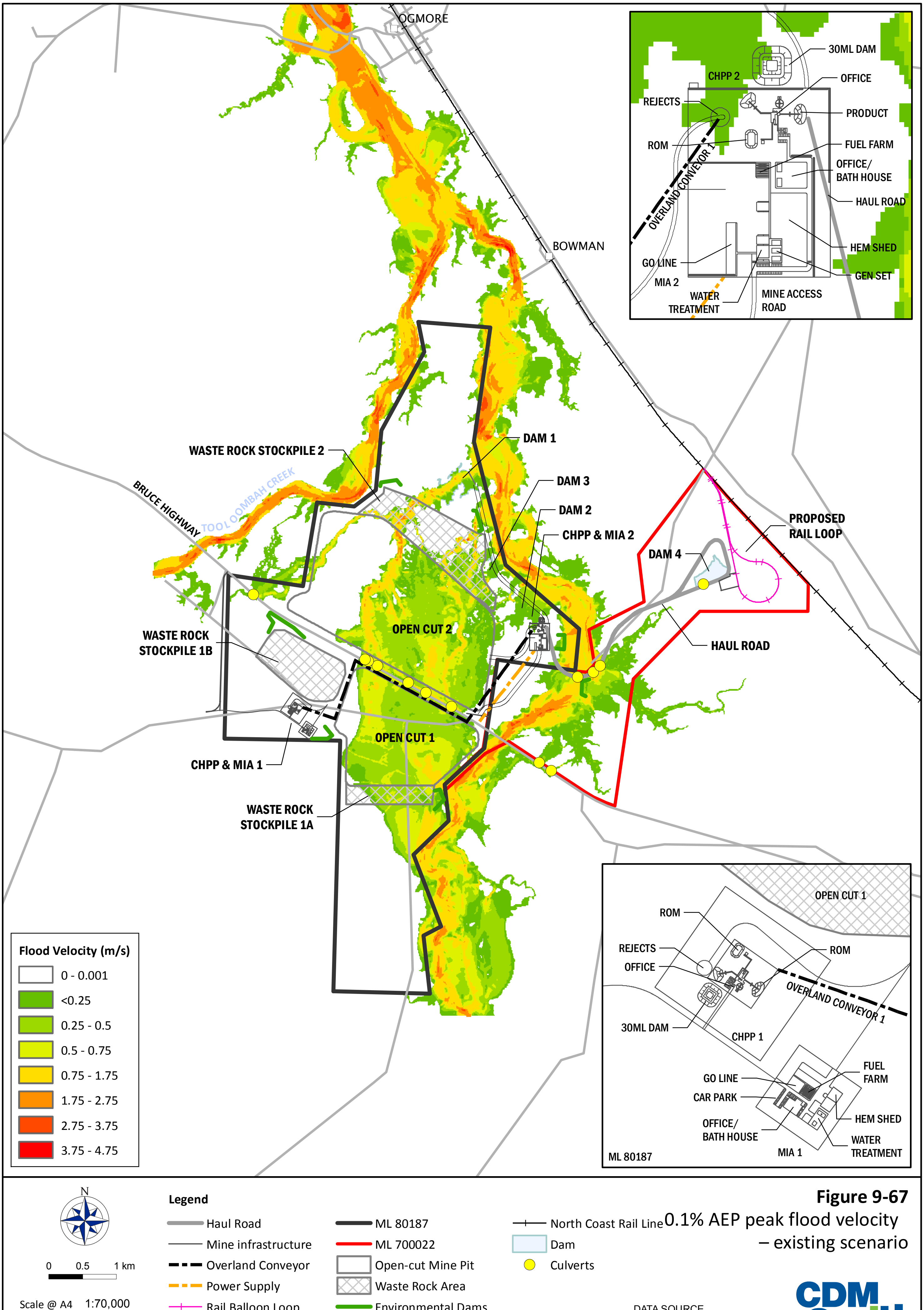


Figure 9-66
1% AEP peak flood velocity – existing scenario



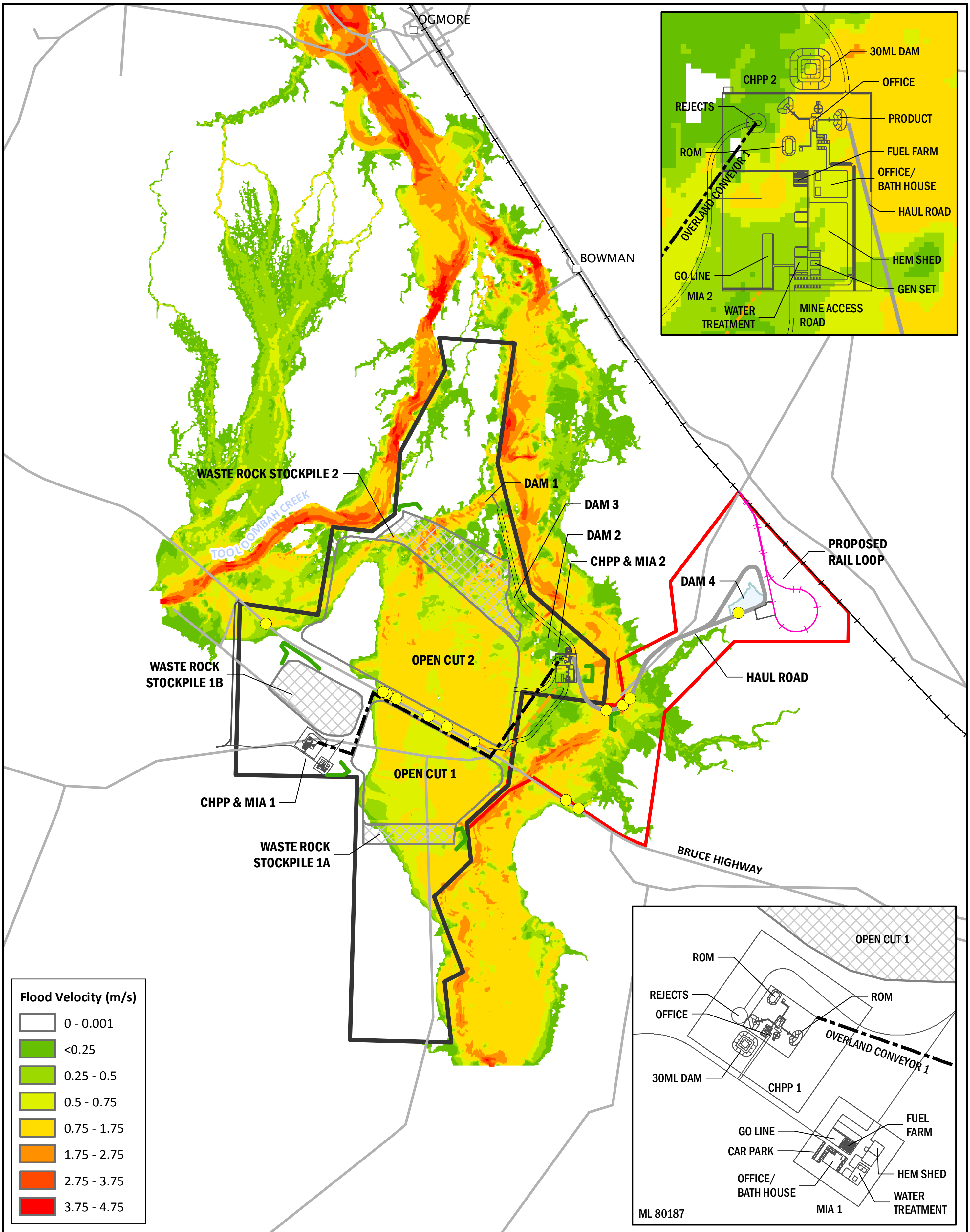
Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Figure 9-67
0.1% 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 0p1AEP Vel__9-63.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	ML 80187	North Coast Rail Line
Mine infrastructure	ML 700022	Dam
Overland Conveyor	Open-cut Mine Pit	Culverts
Power Supply	Waste Rock Area	
Rail Balloon Loop	Environmental Dams	
Mine Access Road	Main Road	

Figure 9-68
PMF 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 PMF Vel__9-64.mxd 11/15/2018

9.6.2.3 Developed Case Model Build

The developed case model was built by applying the hydrographs (see Section 9.6.1.5) 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 Figure 9-69 to Figure 9-79) 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.

9.6.2.4 Developed Case Results

Results were processed to create maps showing depth and velocity maxima; these maps are shown in Figure 9-69 to Figure 9-79.

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 six flood events, are shown in Figure 9-81 to Figure 9-86.

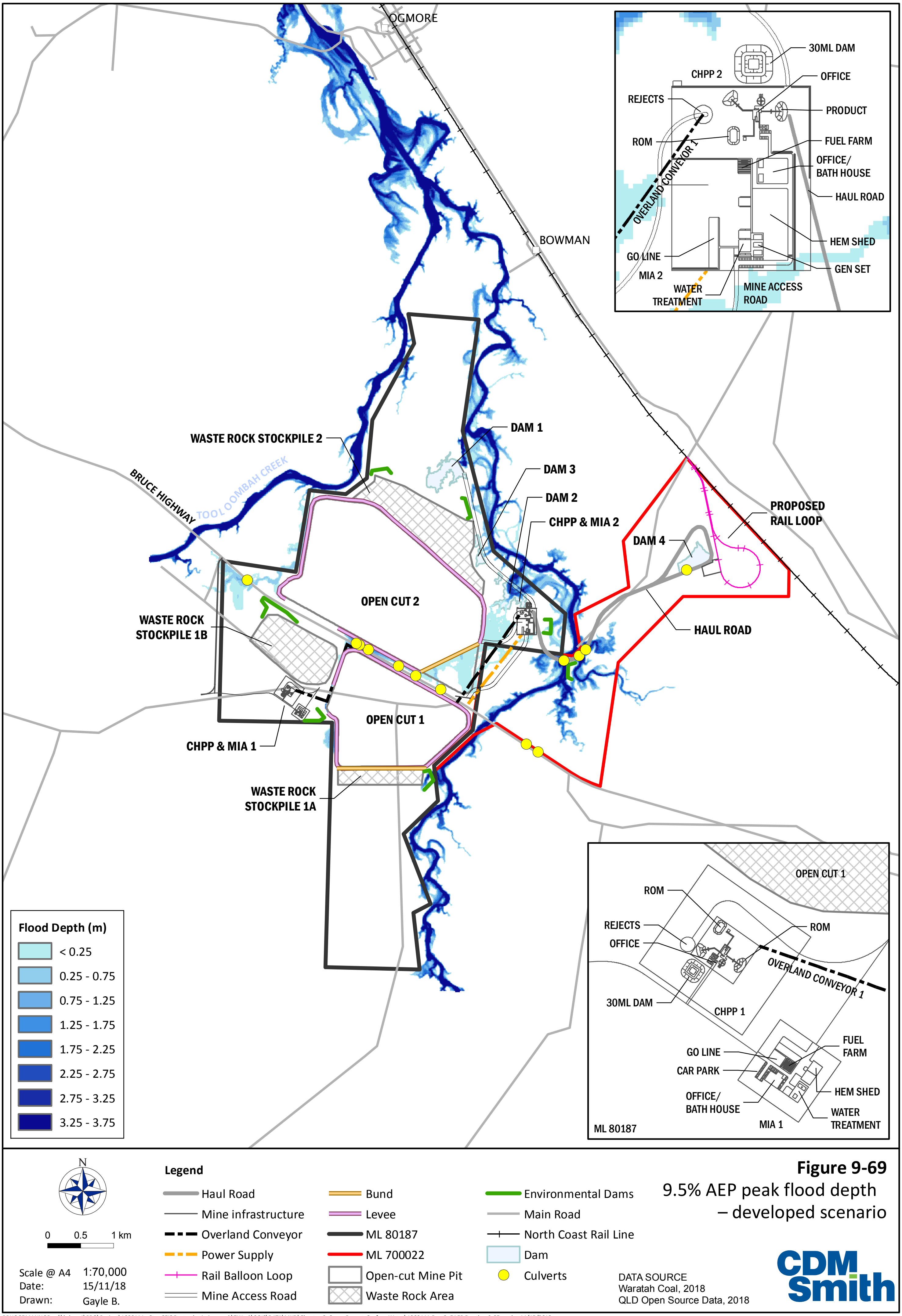


Figure 9-69

9.5% AEP peak flood depth – developed scenario

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

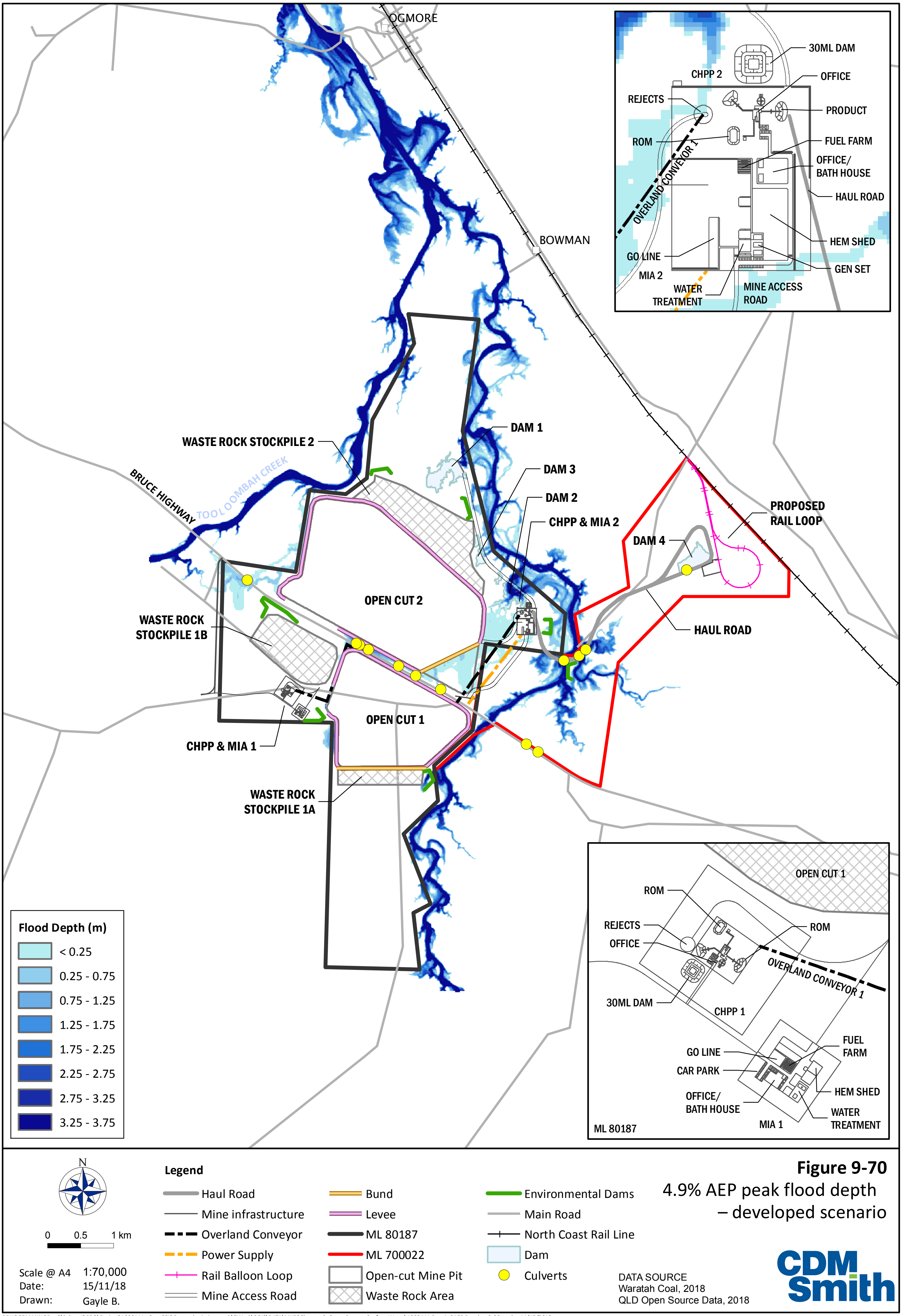


Figure 9-70
4.9% AEP peak flood depth – developed scenario

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 4p9AEP Depth__9-66.mxd 11/15/2018

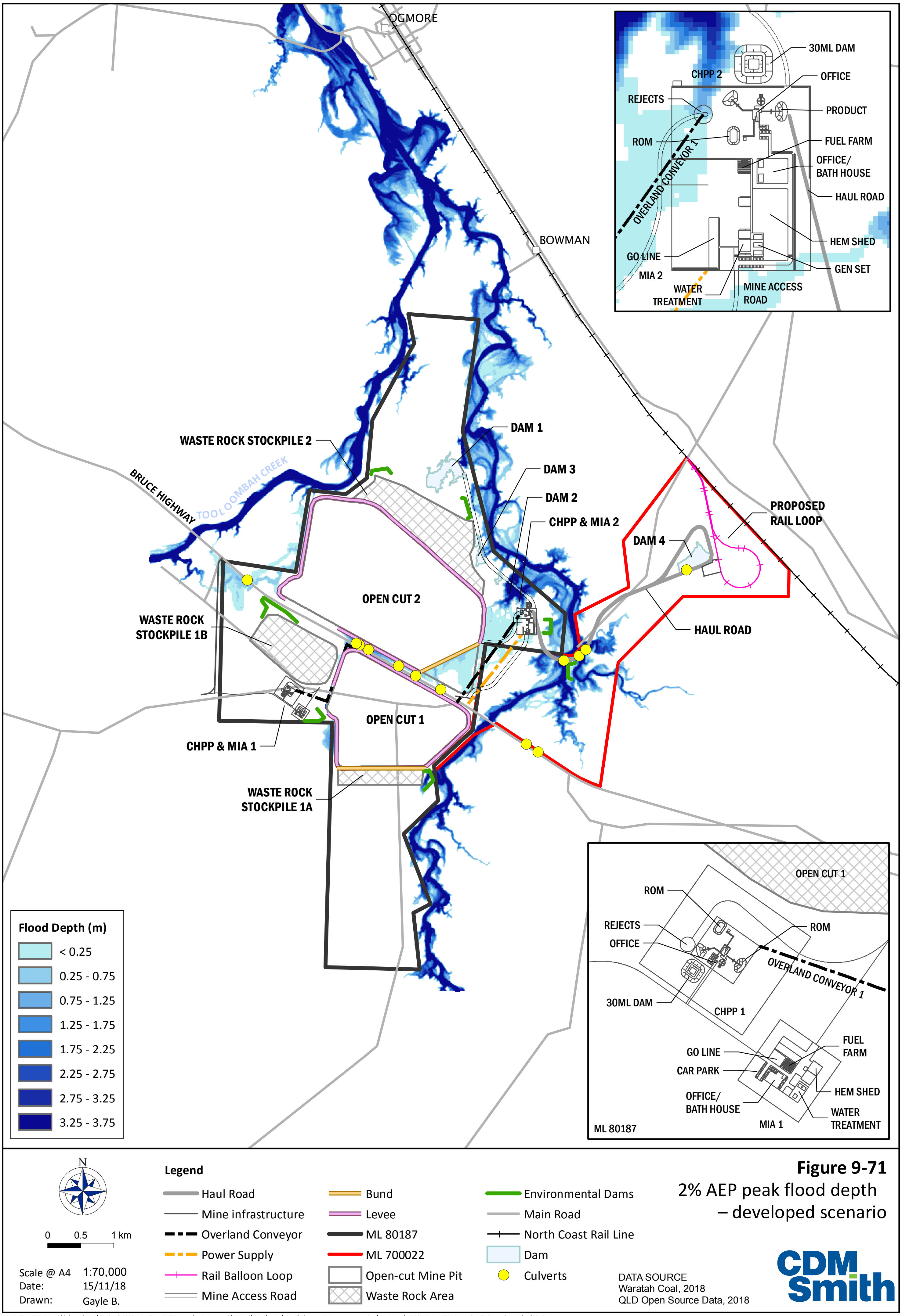


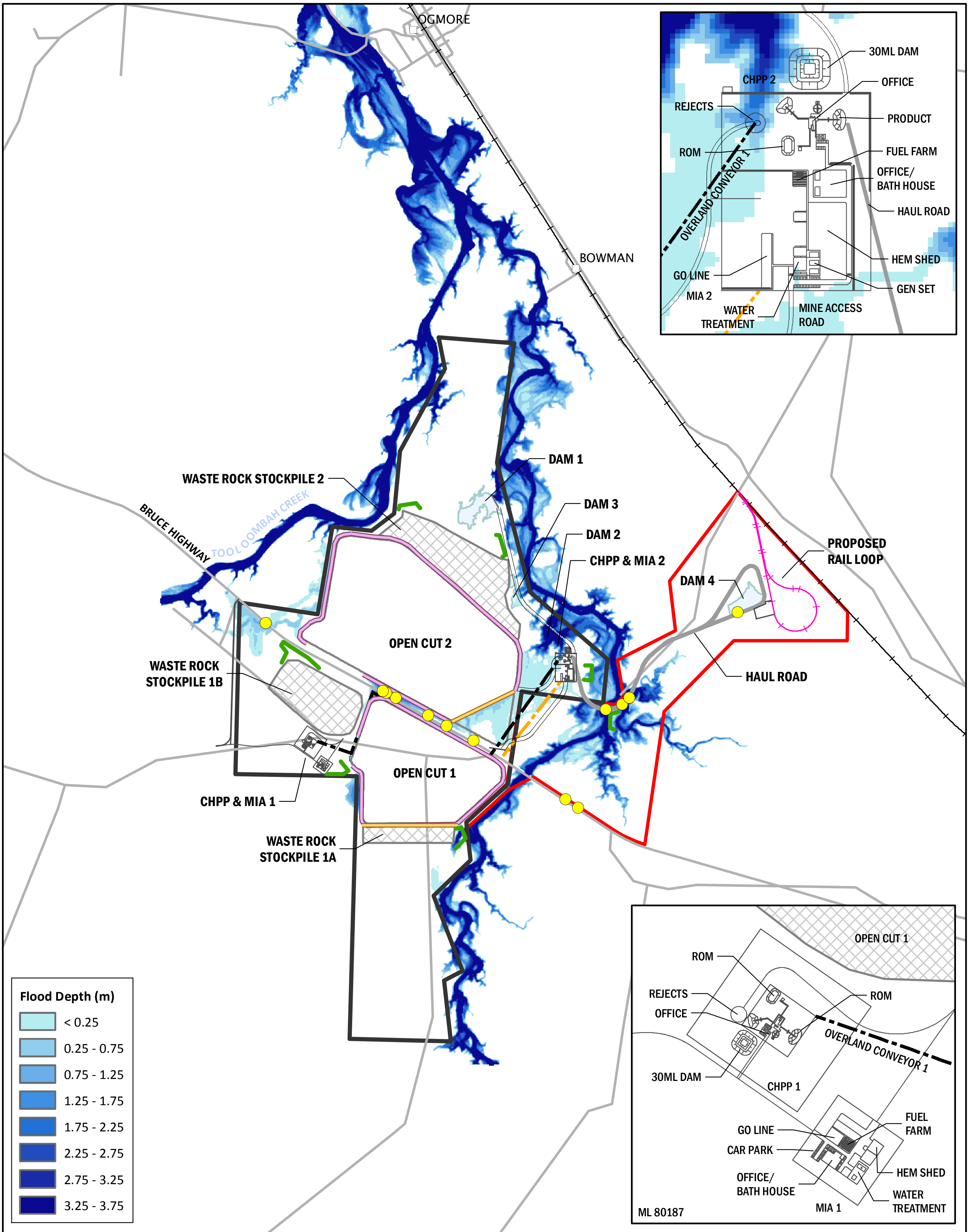
Figure 9-71
2% AEP peak flood depth – developed scenario

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 2AEP Depth__9-67.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 9-72
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

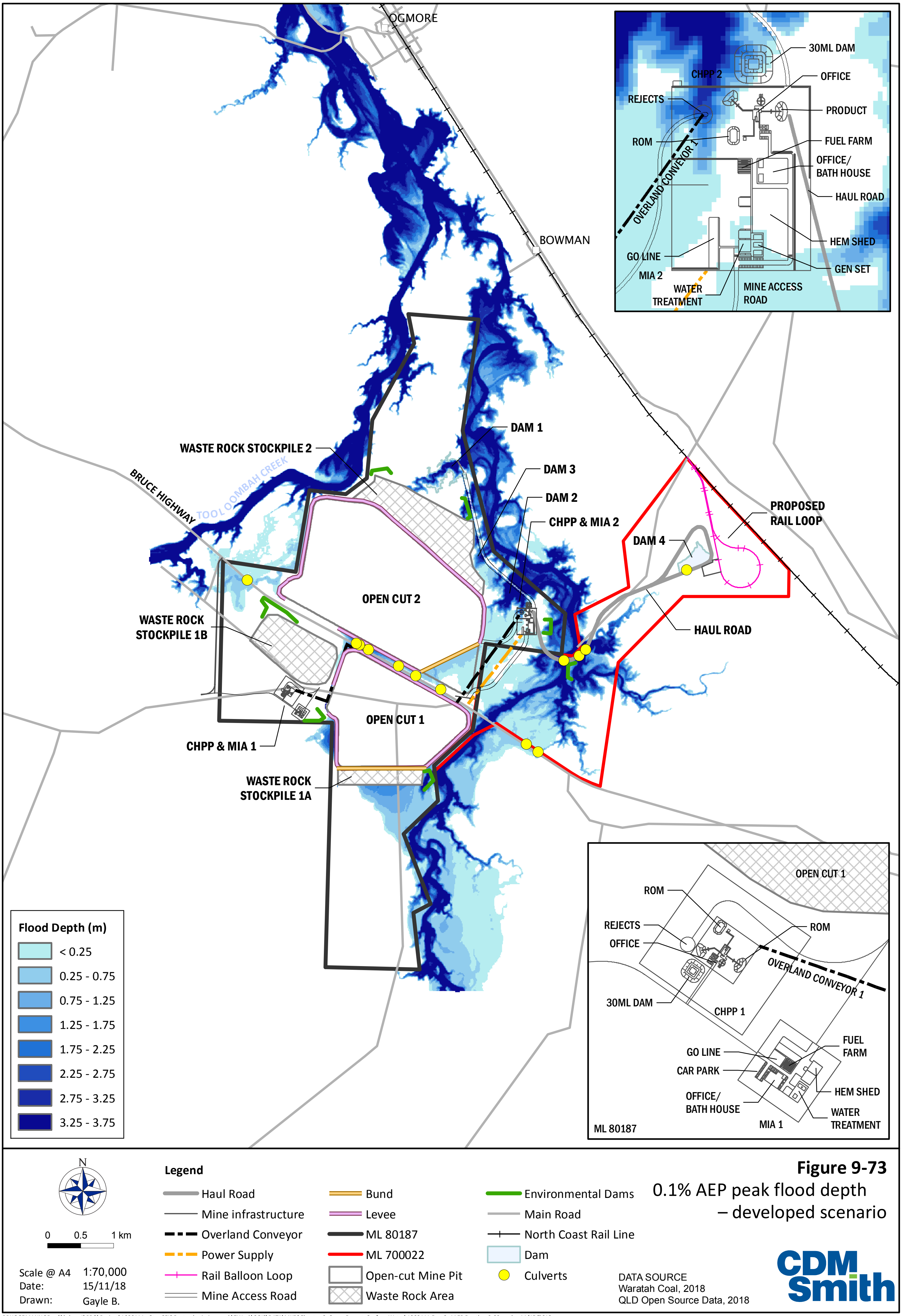
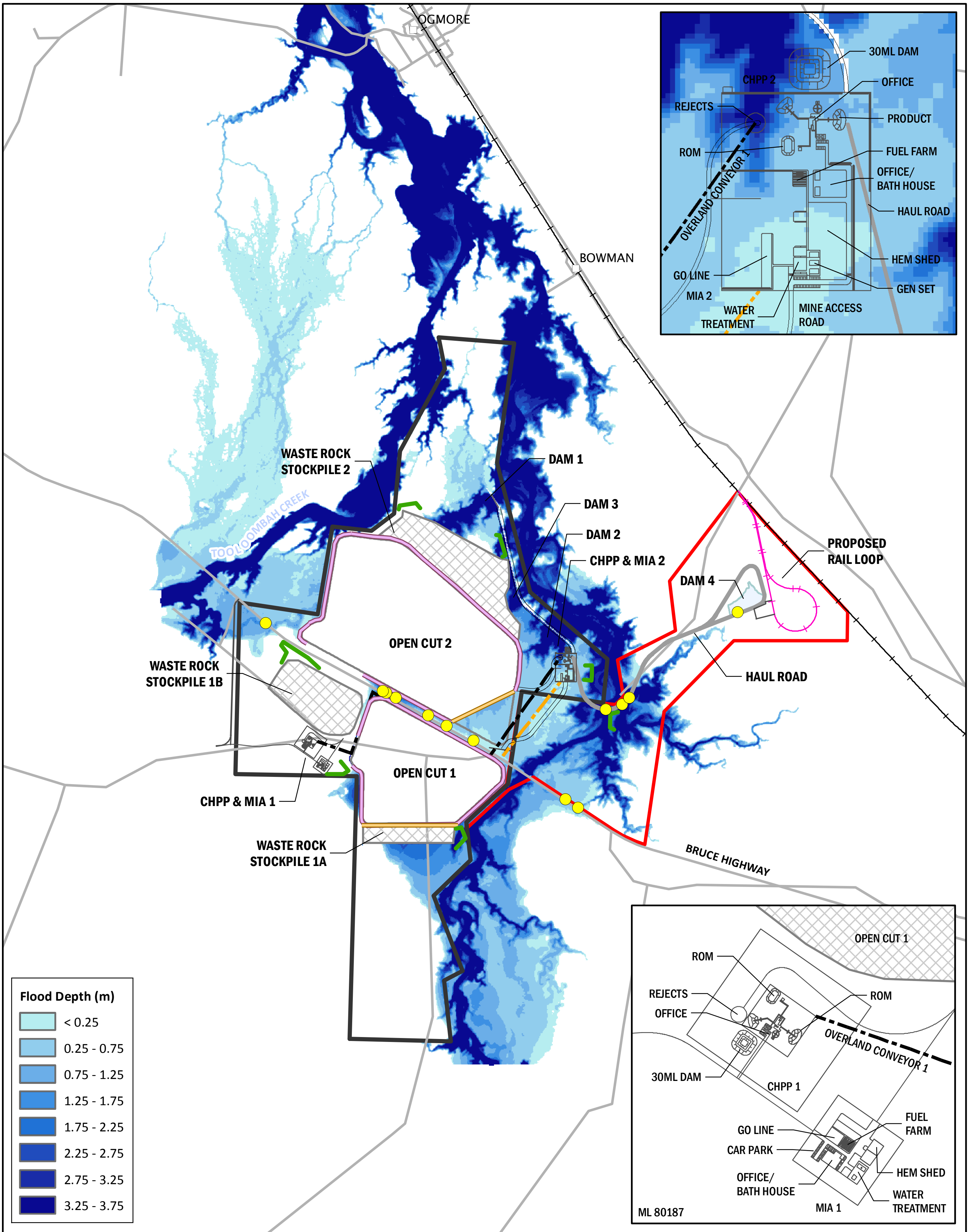


Figure 9-73
0.1% AEP peak flood depth – developed scenario

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Dev 0p1AEP Depth__9-69.mxd 11/15/2018



N
0 0.5 1 km

Legend

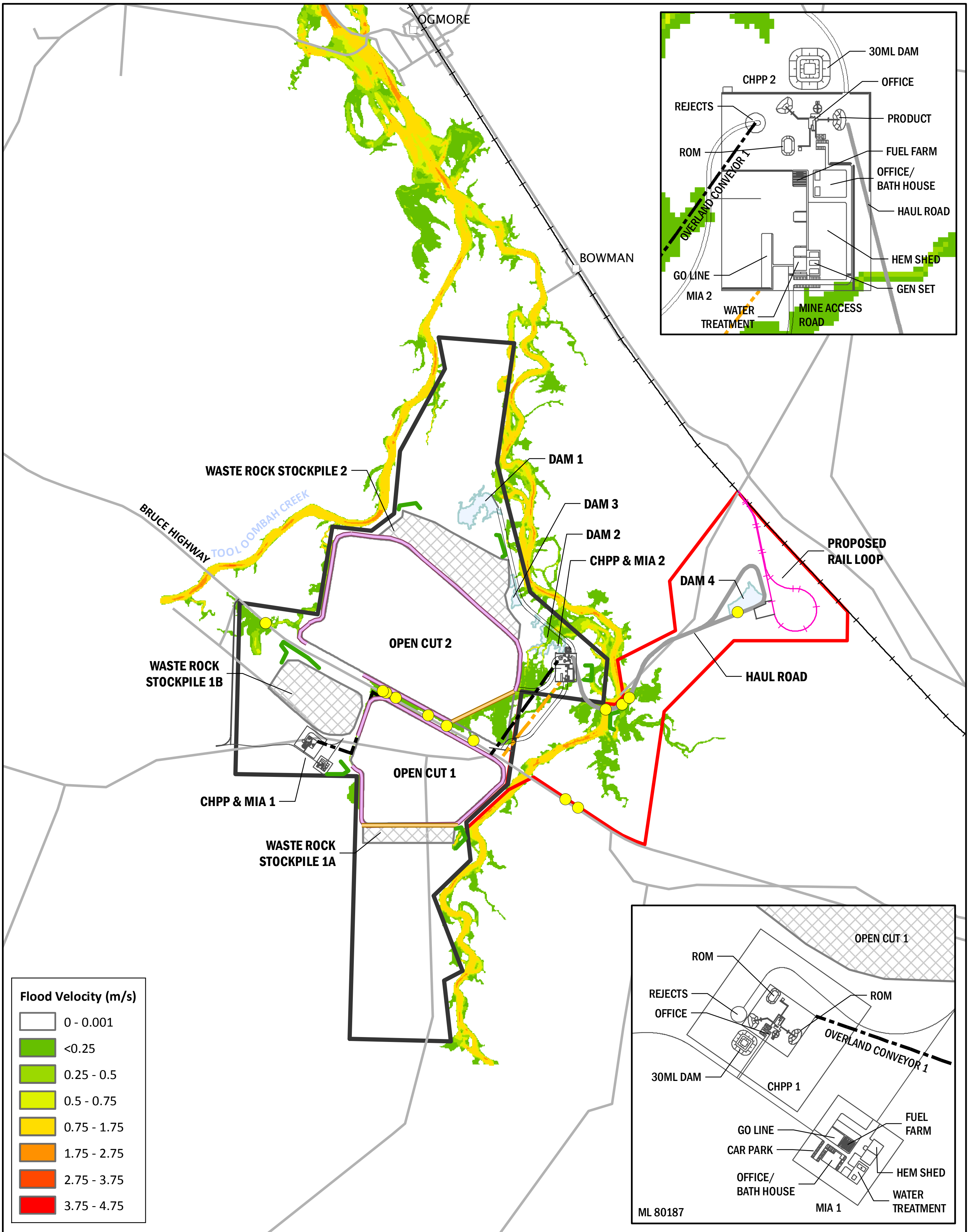
- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power Supply
- Rail Balloon Loop
- Mine Access Road
- Bund
- Levee
- ML 80187
- ML 700022
- Open-cut Mine Pit
- Waste Rock Area
- Environmental Dams
- Main Road
- North Coast Rail Line
- Dam
- Culverts

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Figure 9-74
PMF peak flood depth – developed scenario

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

CDM Smith



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

N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Figure 9-75
9.5% AEP peak flood velocity – developed scenario

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 9_Supp_Report_Surface Water\1000111 Dev 9p5AEP Vel__9-71.mxd 11/15/2018

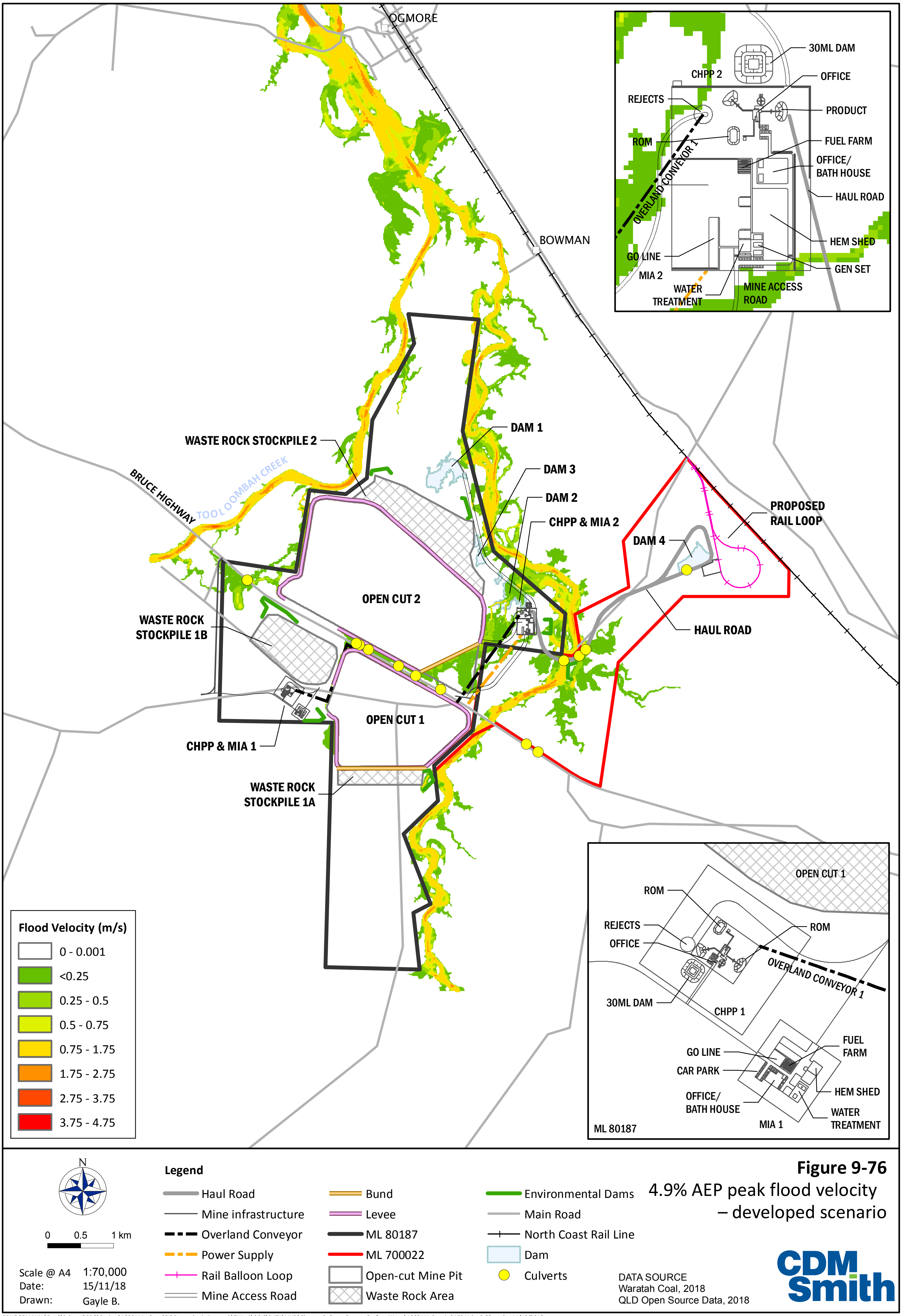
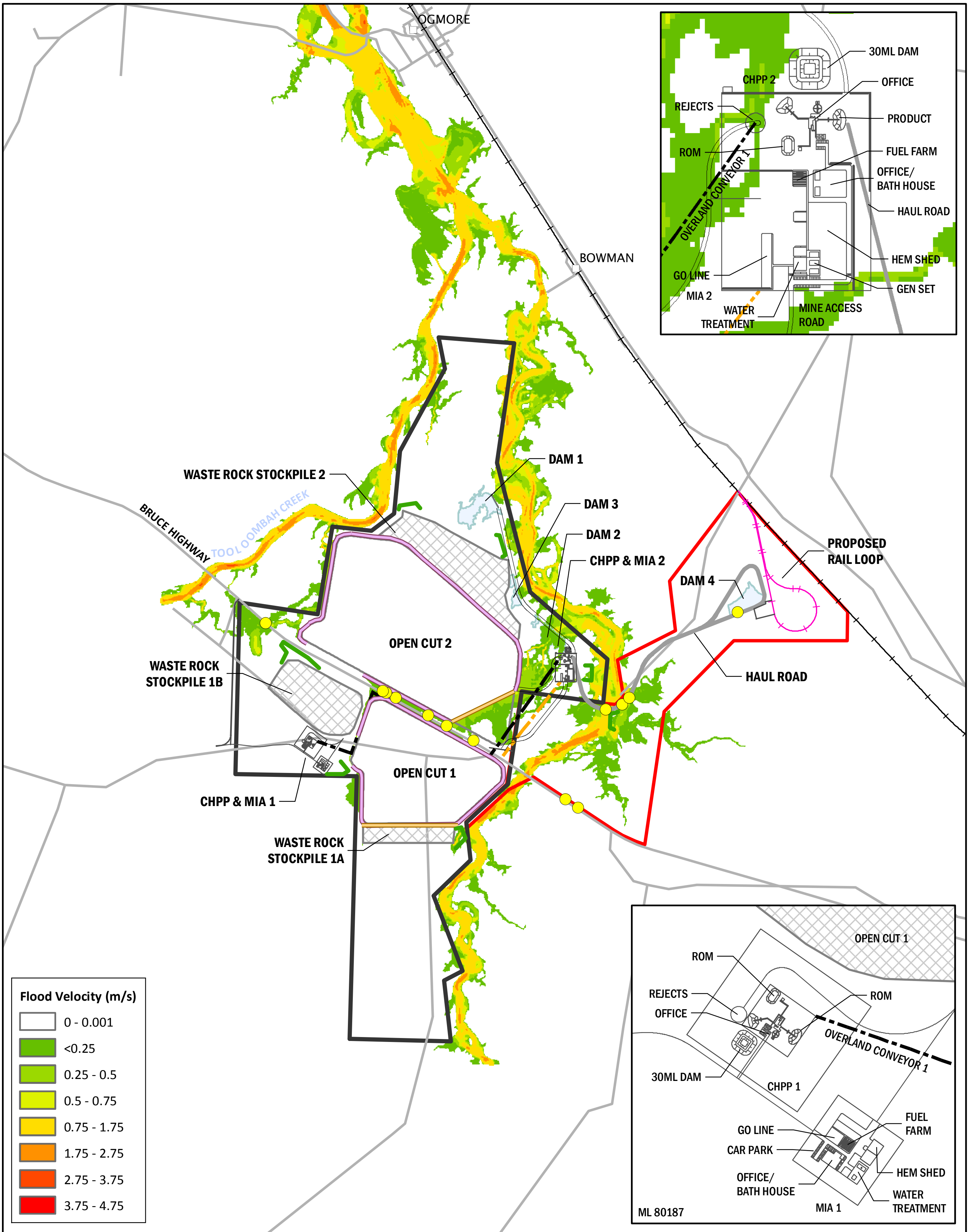


Figure 9-76
4.9% AEP peak flood velocity – developed scenario

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 Dev 4p9AEP Vel__9-72.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	Watercourse
Rail Balloon Loop	Open-cut Mine Pit	Dam
Mine Access Road	Waste Rock Area	Culverts

Figure 9-77
2% AEP peak flood velocity – developed scenario

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 9_Supp_Report_Surface Water\1000111 Dev 2AEP Vel__9-73.mxd 11/15/2018

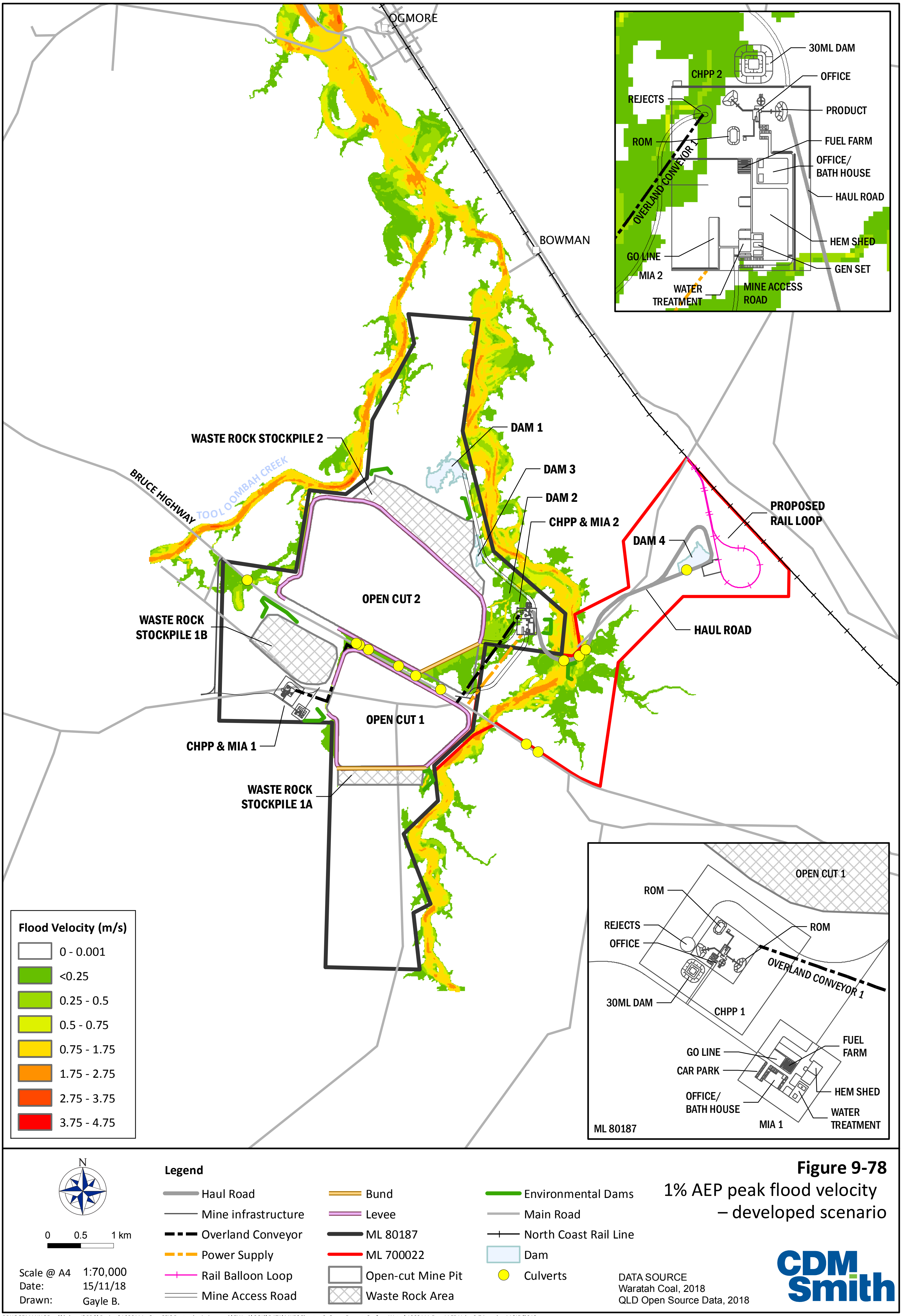
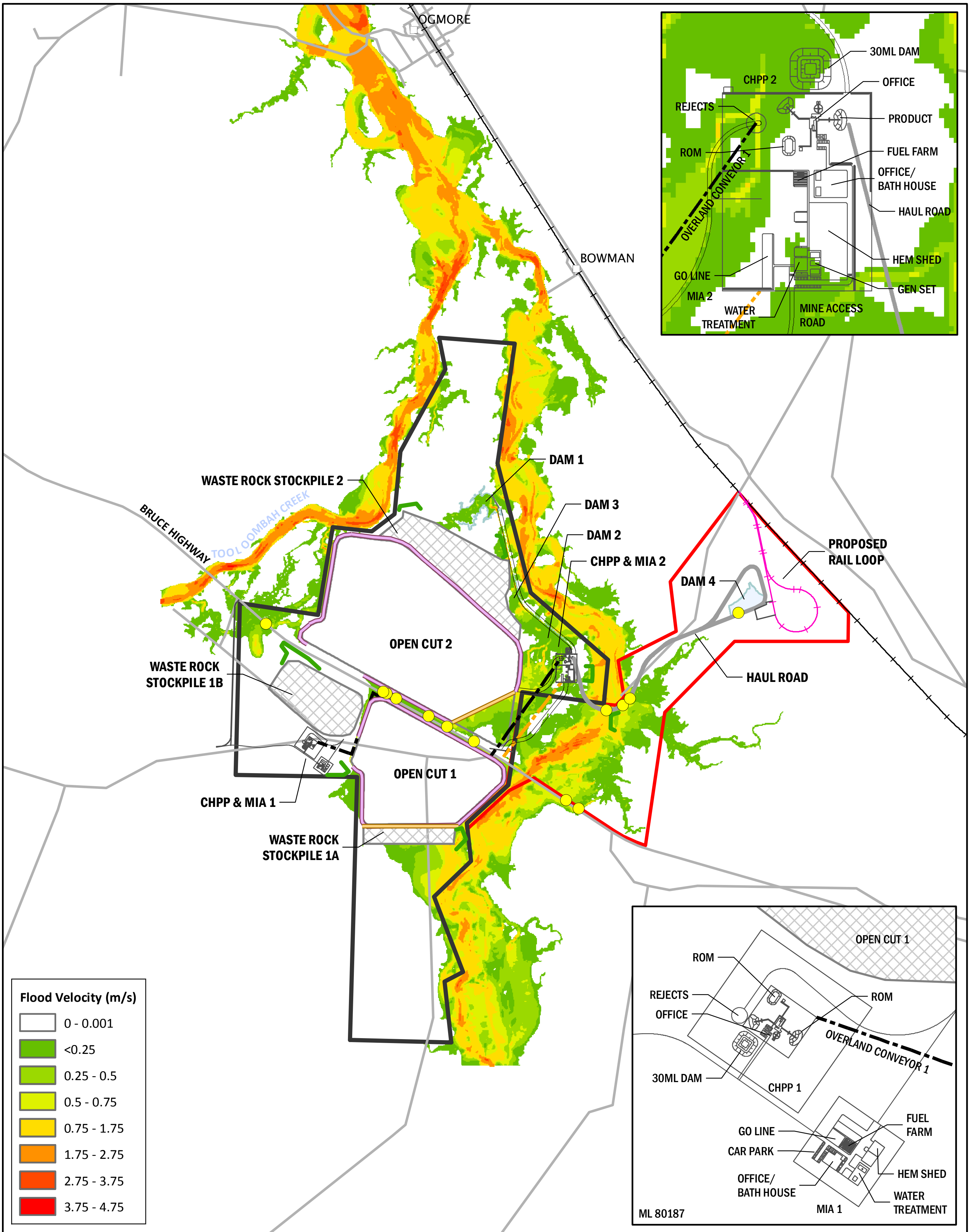


Figure 9-78
1% AEP peak flood velocity – developed scenario

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



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	

N

0 0.5 1 km

Scale @ A4 1:70,000
Date: 15/11/18
Drawn: Gayle B.

Figure 9-79
0.1% 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 0p1AEP Vel__9-75.mxd 11/15/2018

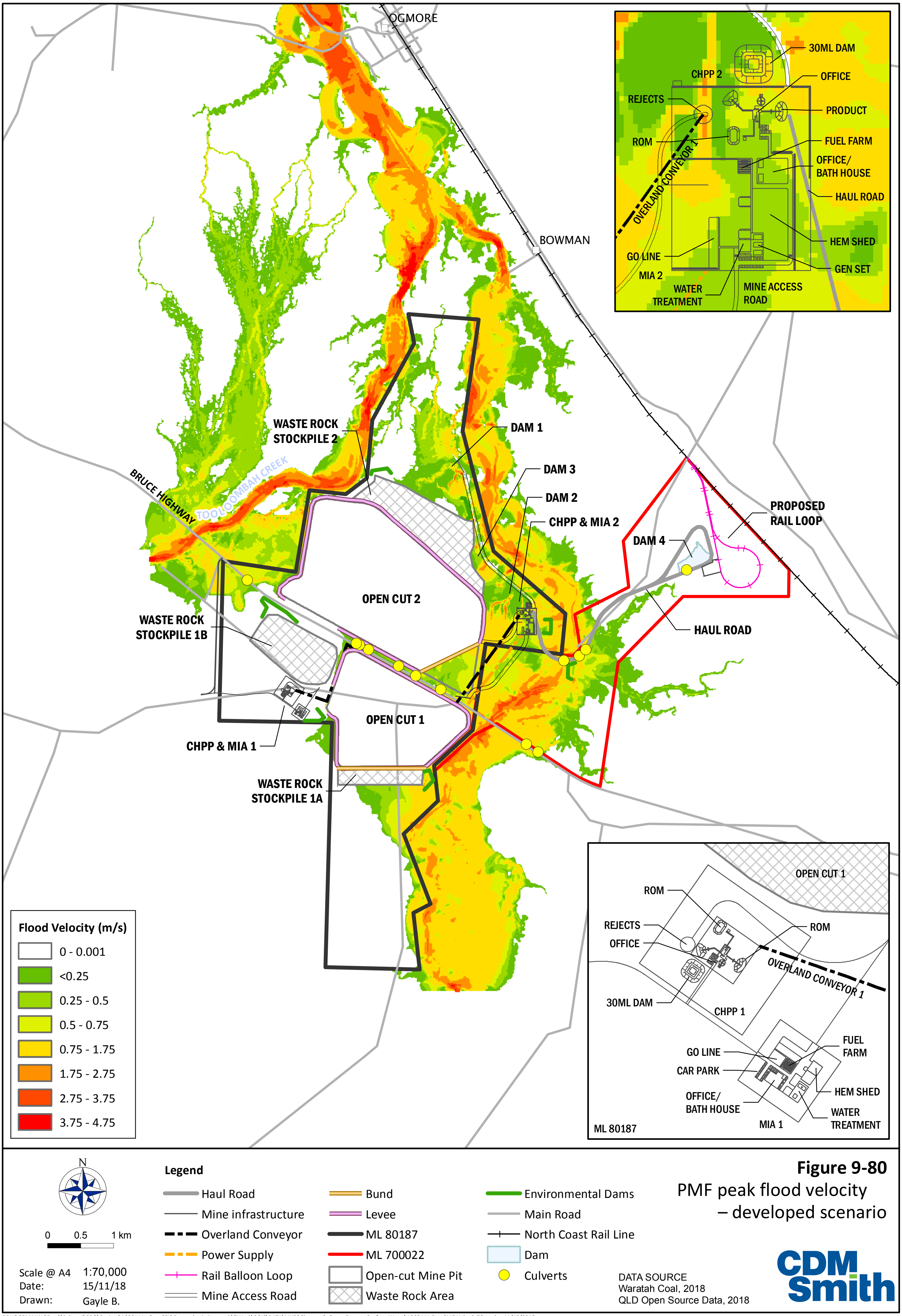


Figure 9-80
PMF peak flood velocity – developed scenario

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 9_Supp_Report_Surface Water\1000111 Dev PMF Vel__9-76.mxd 11/15/2018

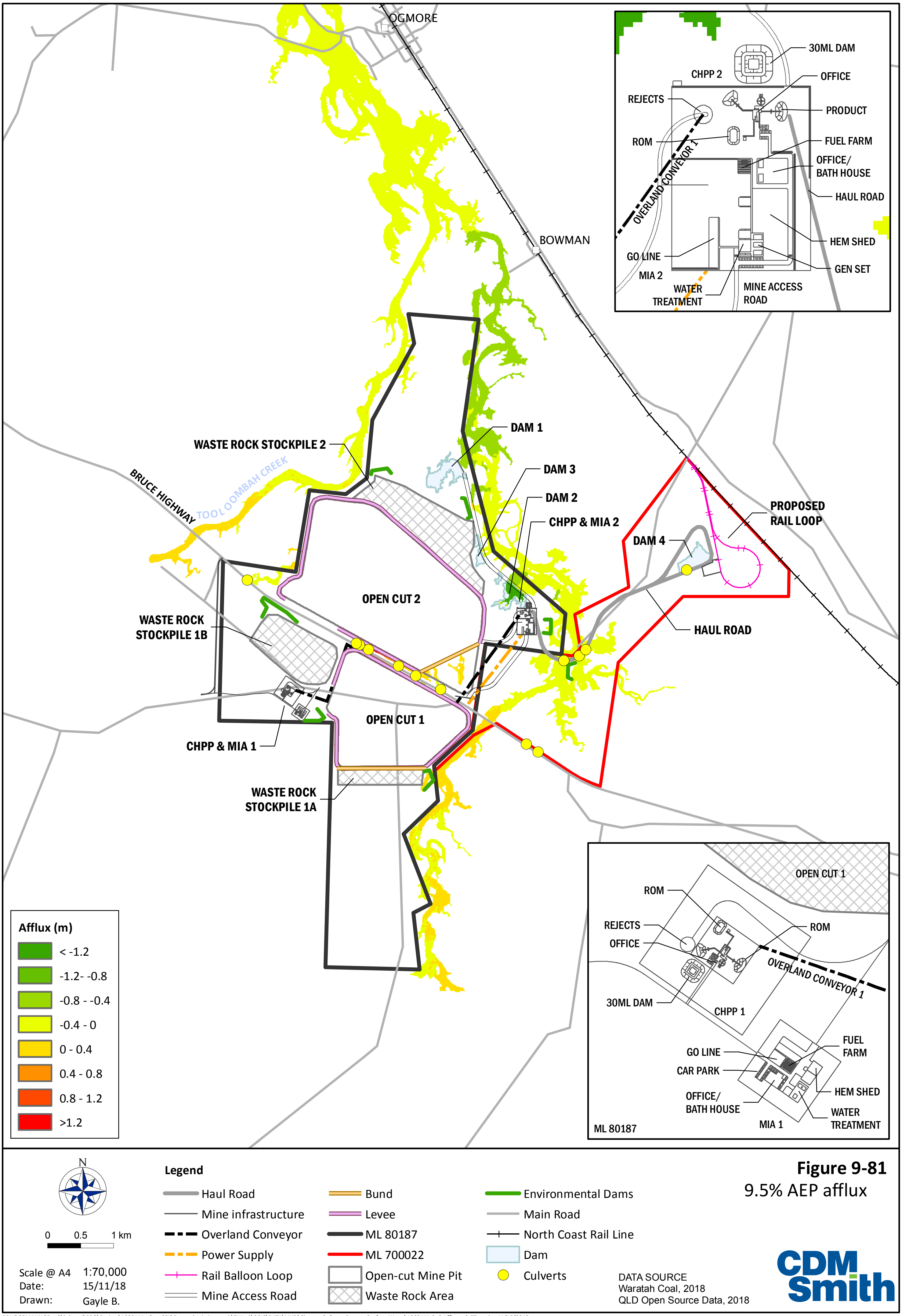


Figure 9-81
9.5% AEP afflux

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

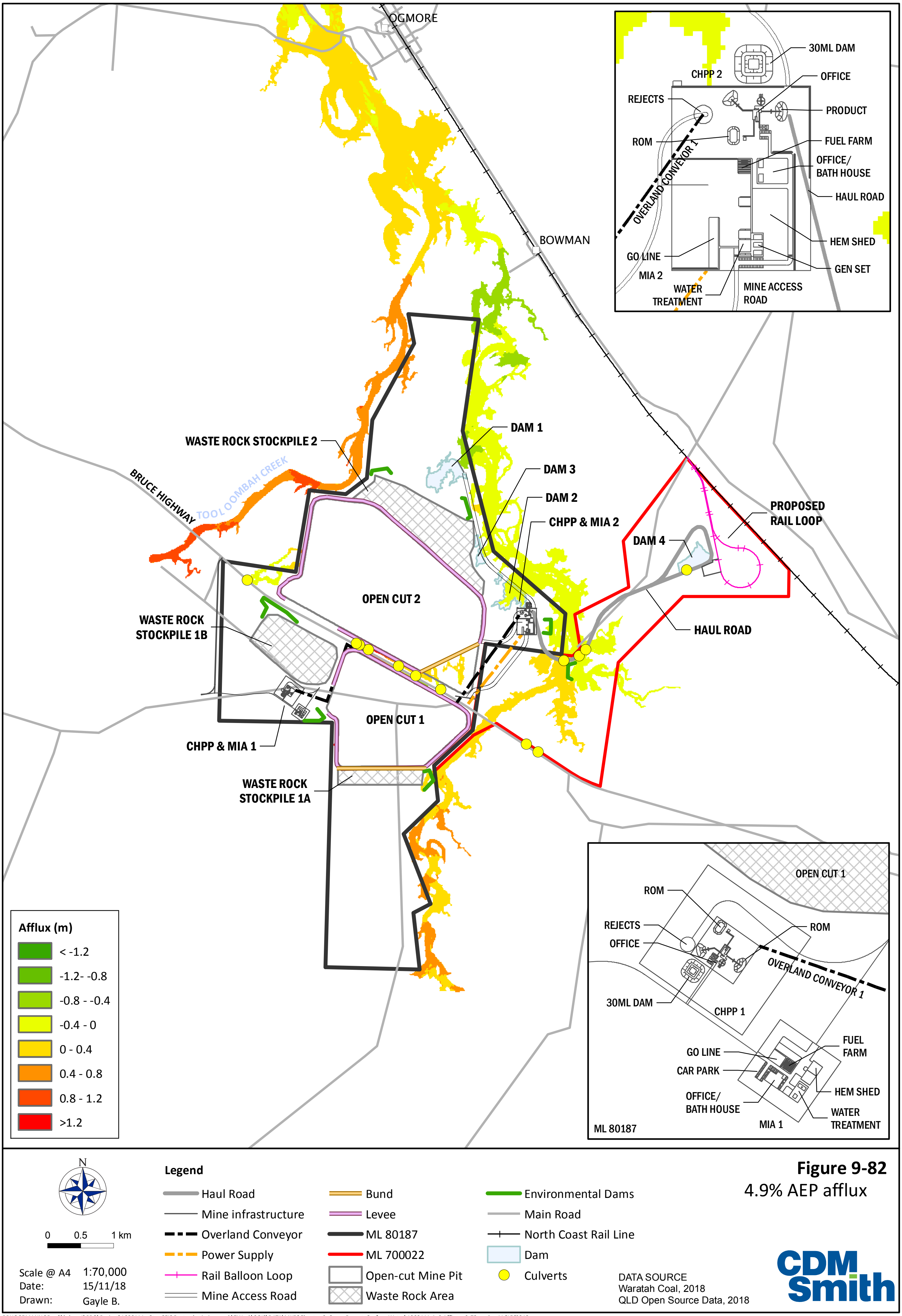


Figure 9-82
4.9% AEP afflux

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 4p9 Afflux__9-78.mxd 11/15/2018

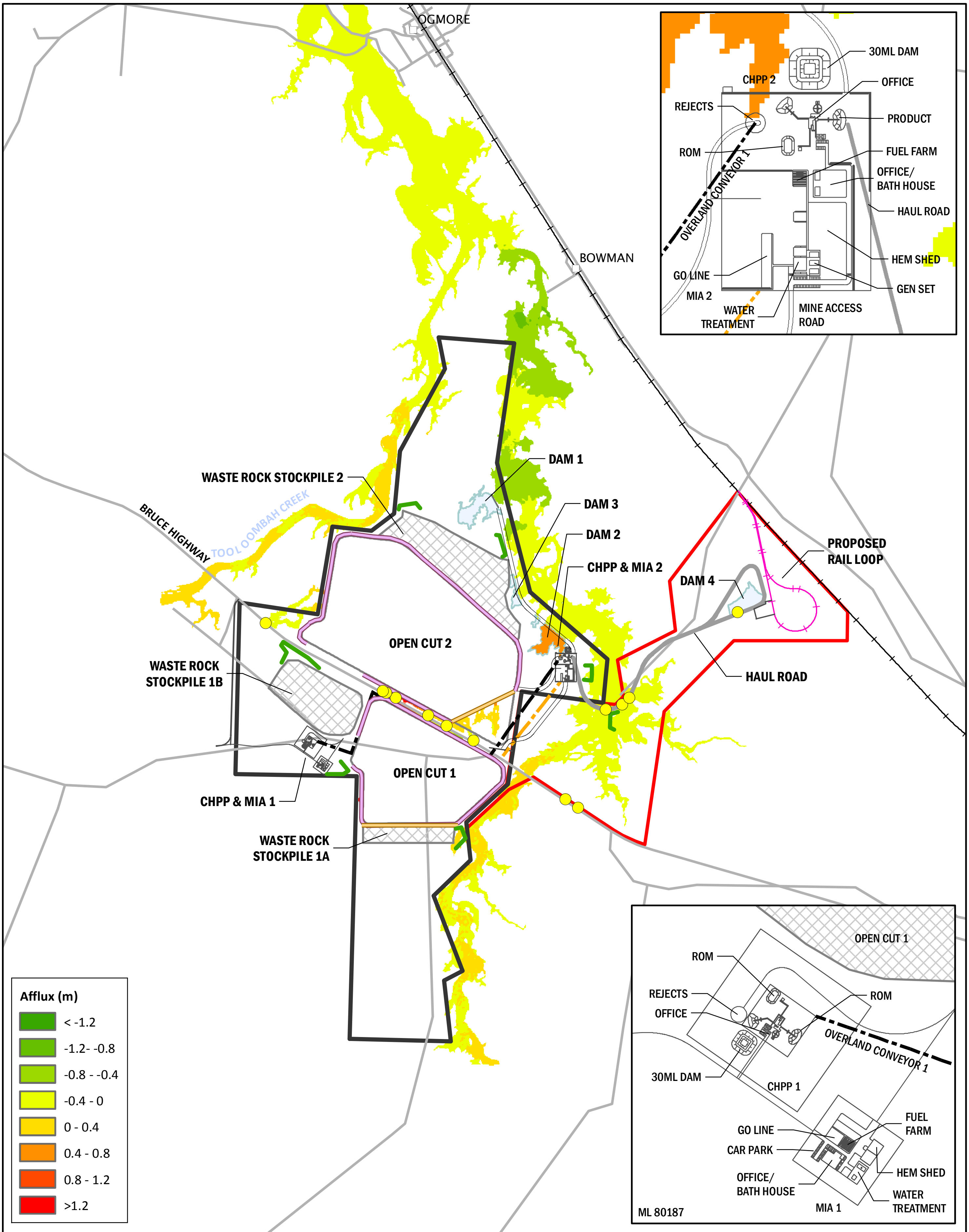


Figure 9-83
2% AEP afflux

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	

N

0 0.5 1 km

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 2AEP Afflux__9-79.mxd 11/15/2018

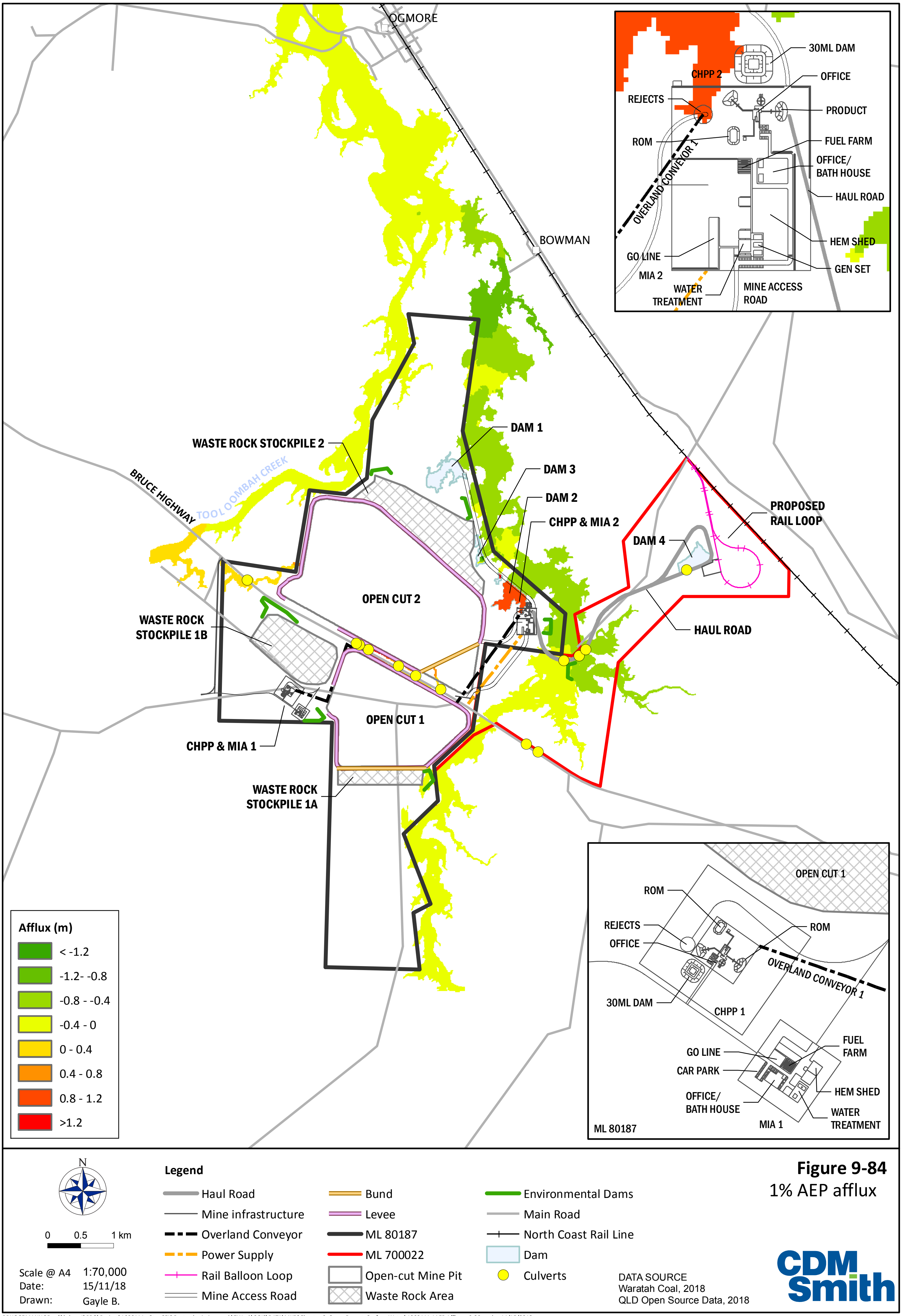


Figure 9-84

1% AEP afflux

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 1AEP Afflux__9-80.mxd 11/15/2018

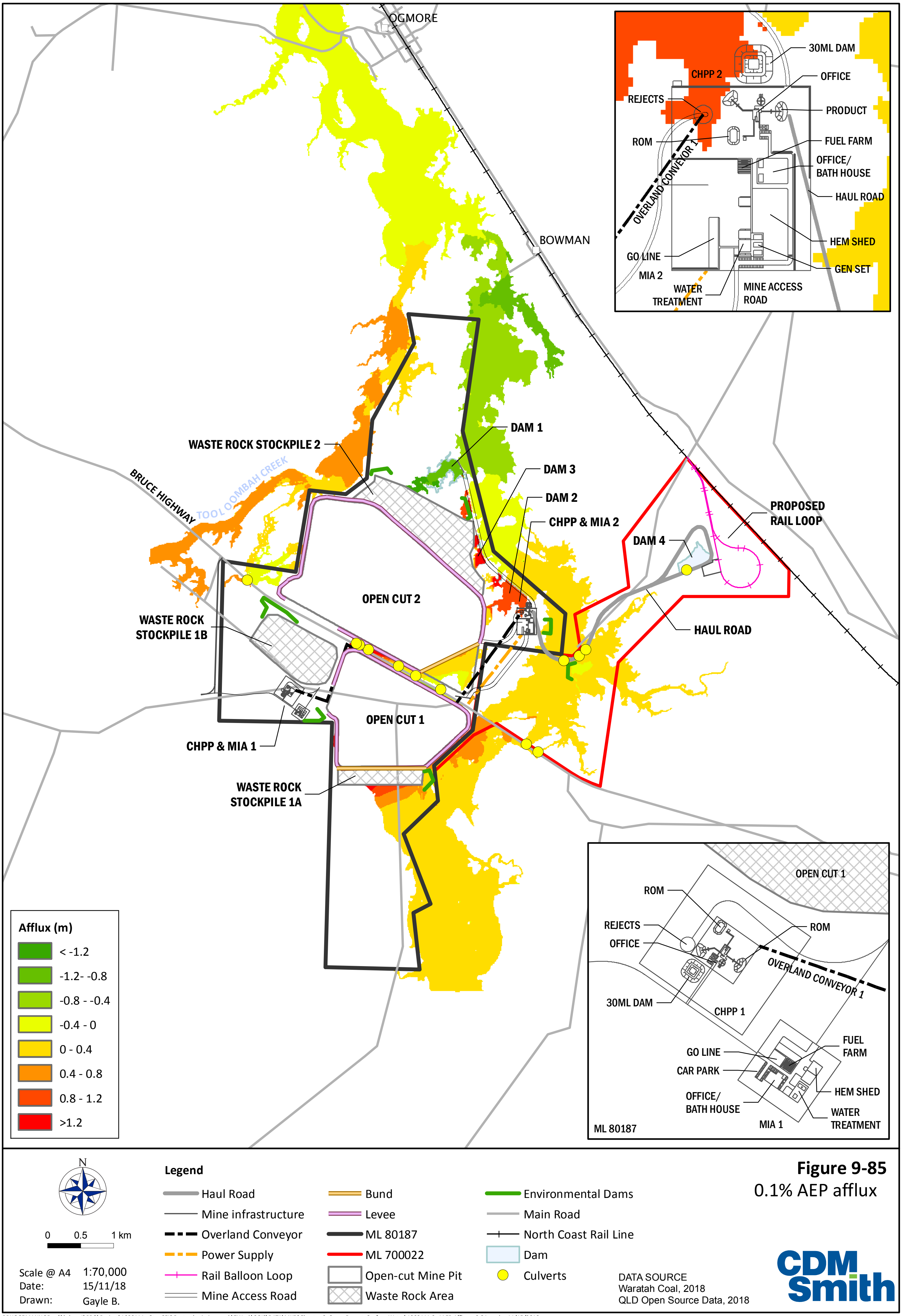
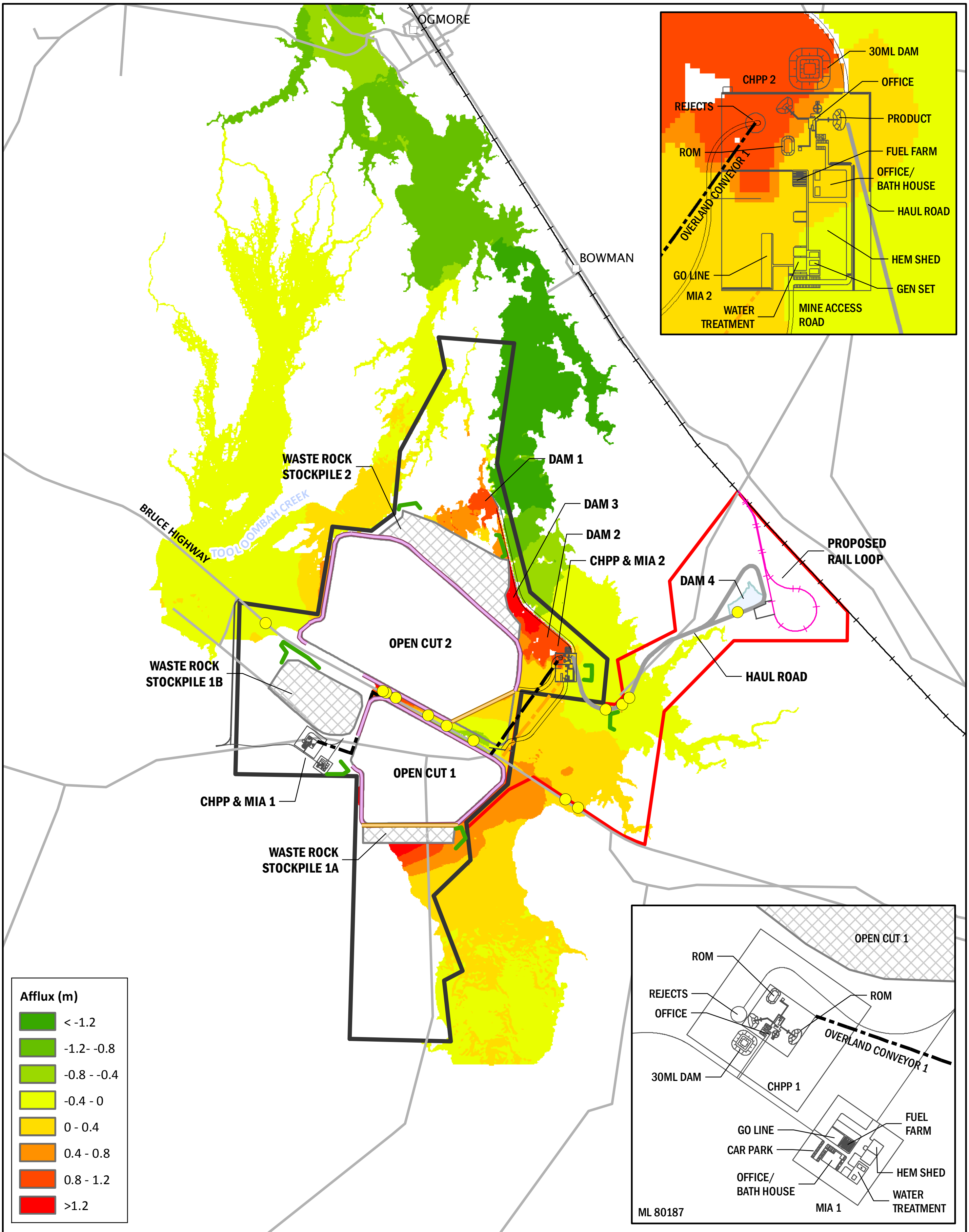


Figure 9-85
0.1% AEP afflux

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 0p1AEP Afflux__9-81.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	

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

Figure 9-86
PMF afflux

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 9_Supp_Report_Surface Water\1000111 PMF Afflux__9-82.mxd 11/15/2018

9.6.2.5 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 9-56 and in Figure 9-87. The results are shown in Table 9-57. Afflux maps for the six flood events are shown in Figure 9-81 to Figure 9-86.

Table 9-56 Selected Key Location Details

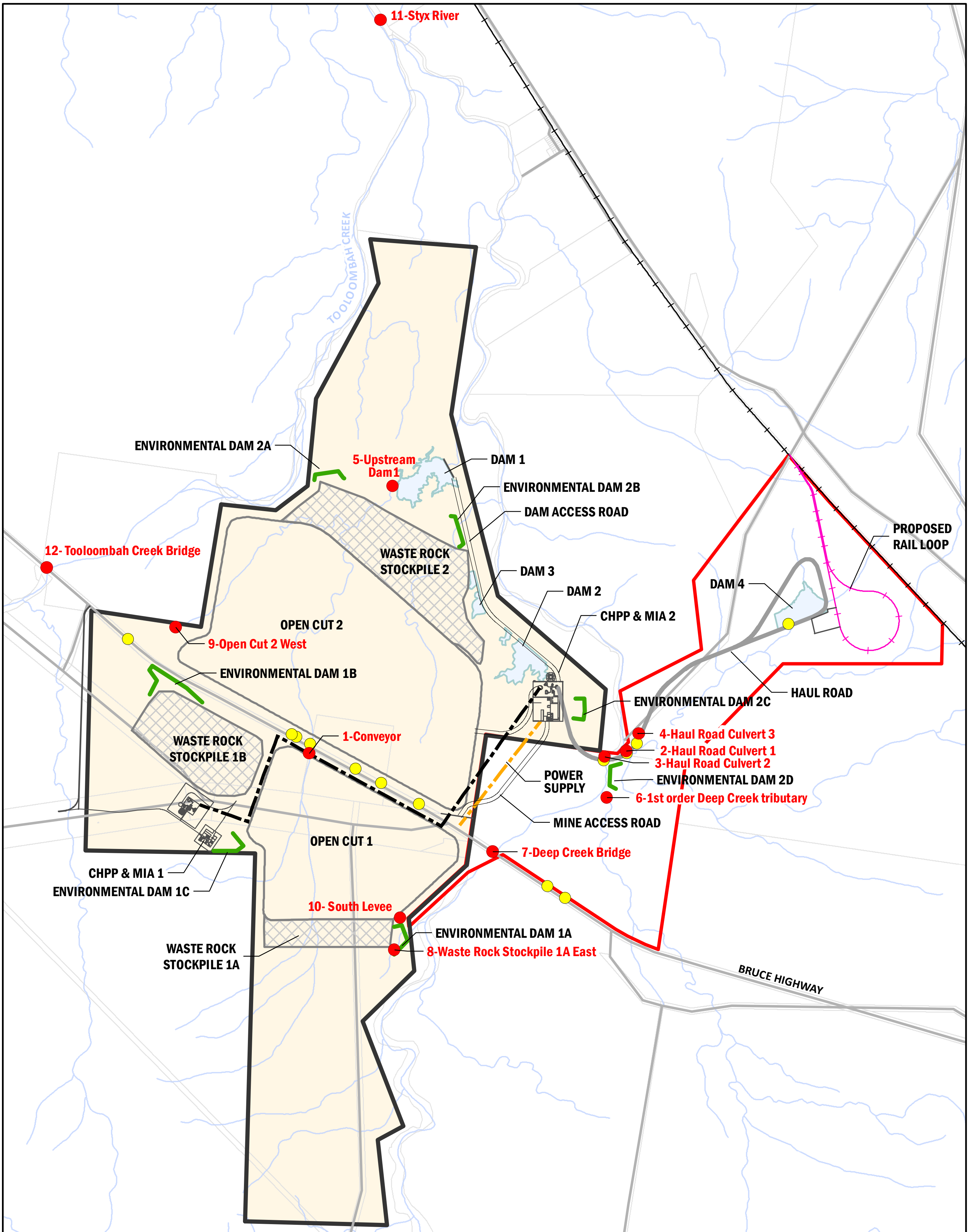
Location	Longitude	Latitude	Surface Elevation (m AHD)
1-Conveyor	149.655942	-22.705865	30.50
2-Haul Road Culvert 1	149.686984	-22.705121	21.77
3-Haul Road Culvert 2	149.684908	-22.705718	26.42
4- Haul Road Culvert 3	149.688181	-22.703543	25.58
5-Upstream Dam1	149.663625	-22.681432	20.37
6-1st order Deep 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 9-57 Peak water depths, levels 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
	4- Haul Road Culvert 3	3.3	3.2	-0.1	28.9	28.8	0.2	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
	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



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Date: 15/11/18
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Legend

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

Figure 16-67
Selected key locations

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 Key Locations__9-83.mxd 11/15/2018

Flooding of Pits and Subsequent Levee Heights

The developed case flood maps demonstrate no flooding of the open pit areas (see Figure 9-69 to Figure 9-79) for up to including the 0.1% AEP event, due to the inclusion of levees and the raising of the access road (refer to developed flood figures). Open Cut 1, Open Cut 2 all have 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.

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 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 environmental 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 9-88. 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.

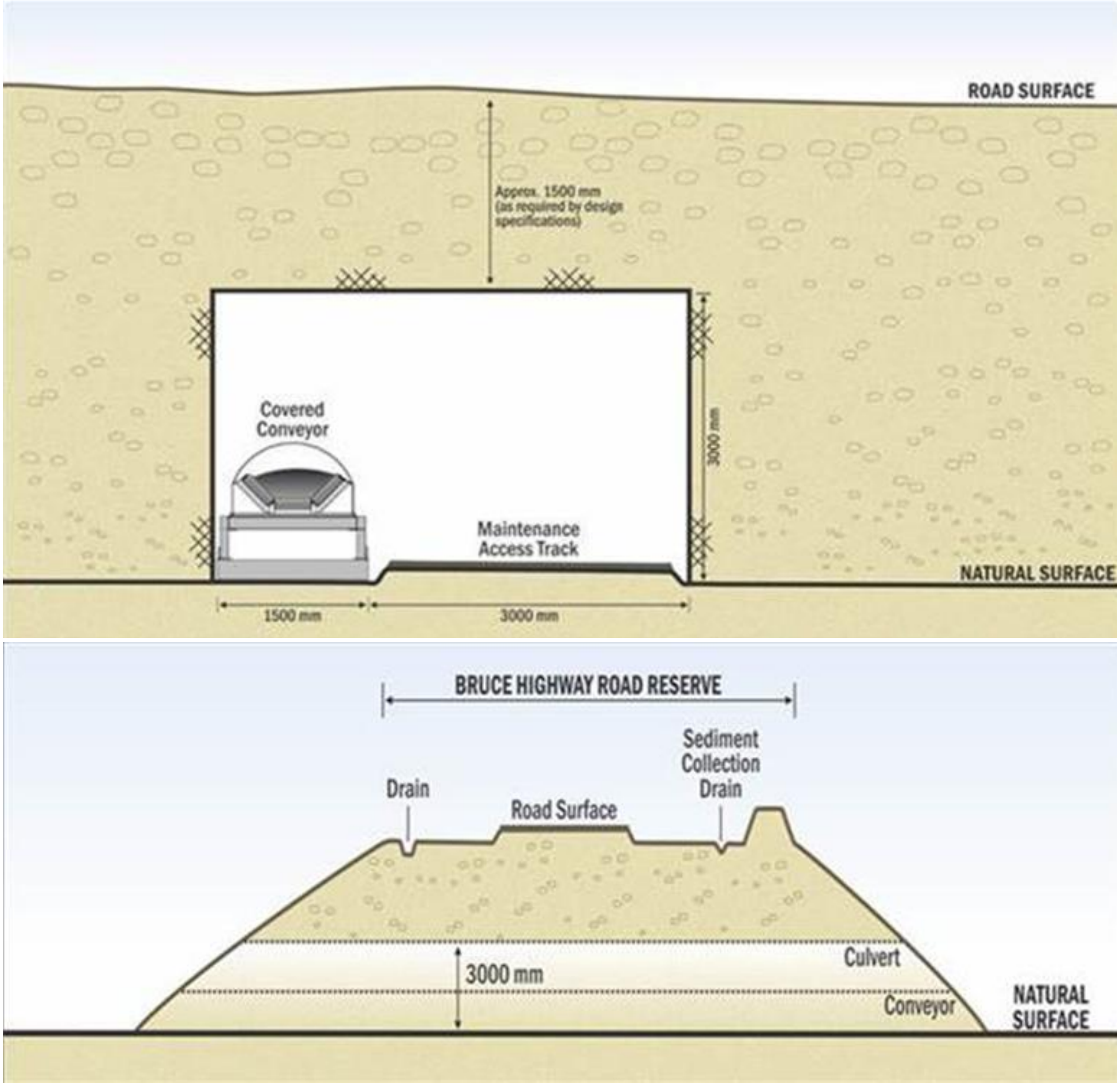


Figure 9-88 New conveyor arrangement under the Bruce Highway (from 2029 onwards)

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.

9.6.3 Mine Site Drainage Assessment

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 9.6.1 and 9.6.2. 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 9.6.1 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 9.6.2 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:

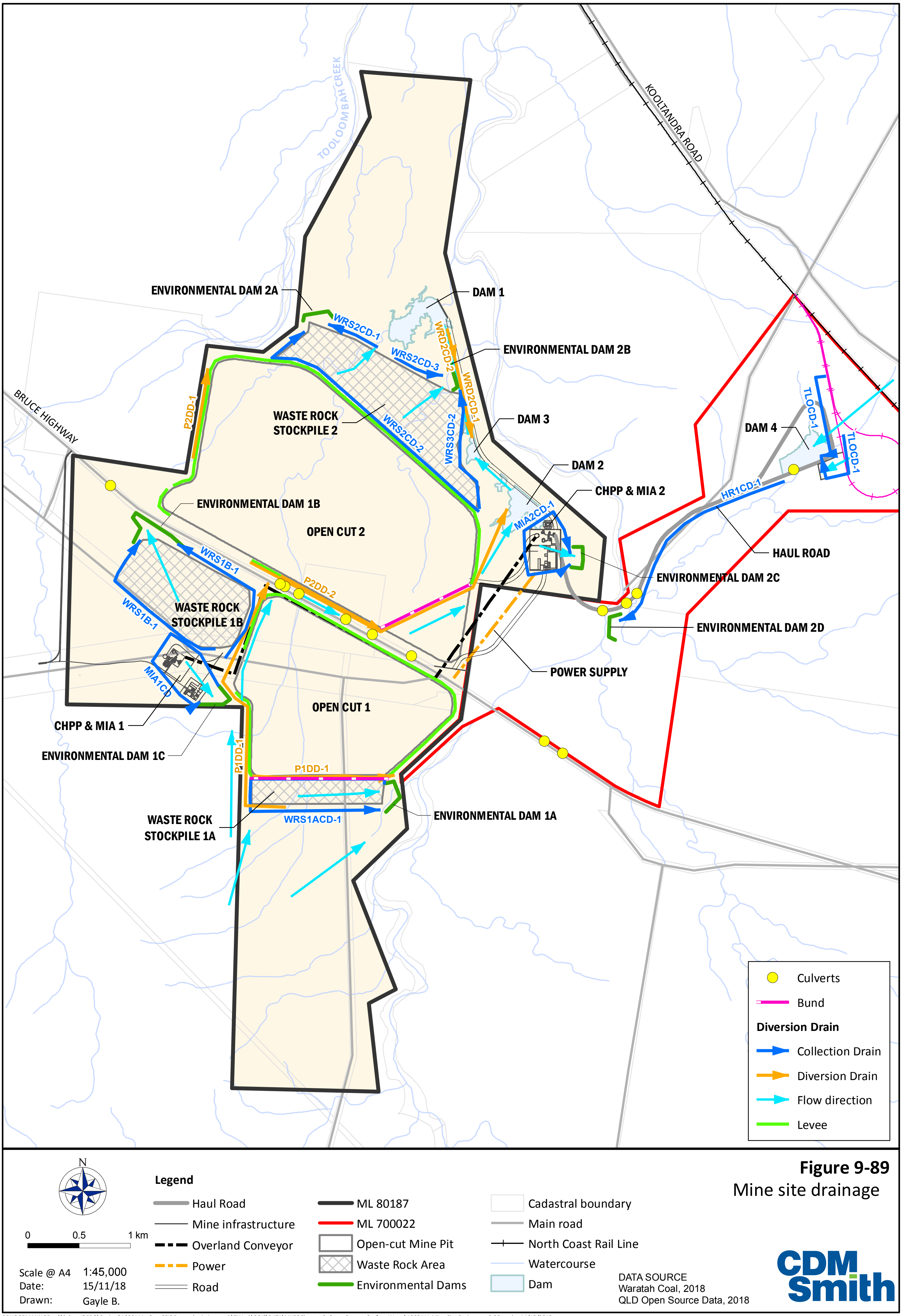
- Haul road culvert crossings;
- Dirty water diversion drains;
- Clean water diversion drains; and
- Clean water diversion bunds.

9.6.3.1 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 9-89. 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. The 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.



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Date: 15/11/18
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Figure 9-89
Mine site drainage

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 Mine Site Drainage__9-85.mxd 11/15/2018

9.6.3.2 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 (see Figure 9-90). 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 (see Figure 9-90) following appropriate geotechnical stability design criteria.

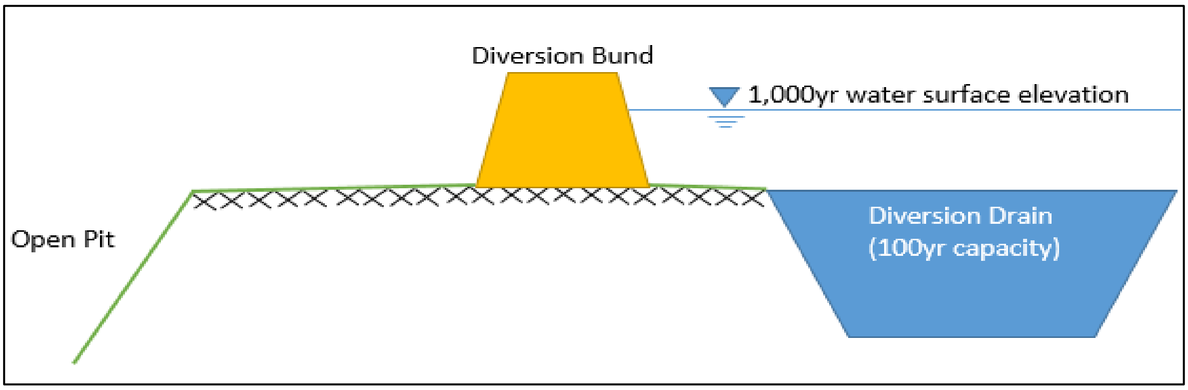
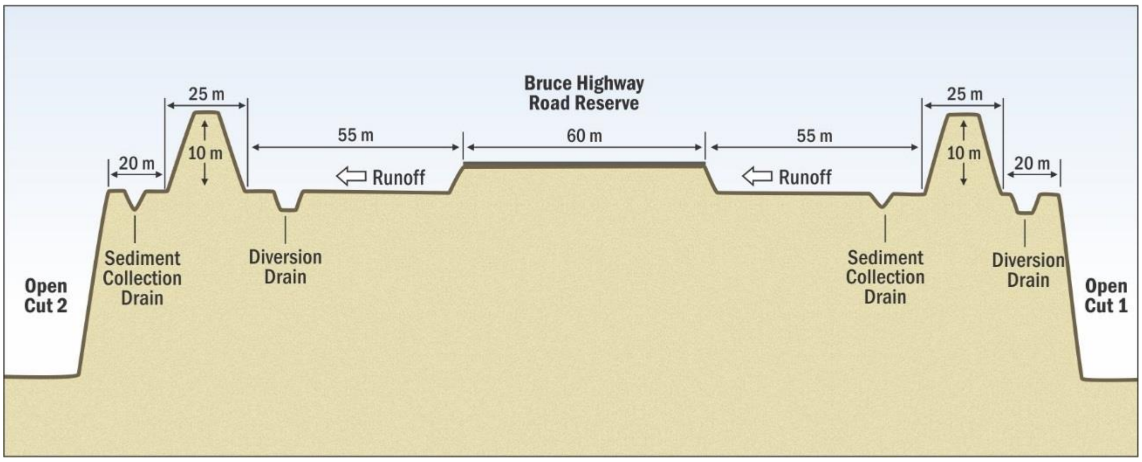


Figure 9-90 Diversion drain and bund concept

9.6.3.3 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 9-91). 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 9-91 Bruce Highway catch drain arrangement

9.6.3.4 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 9-89. 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 9-92. 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.

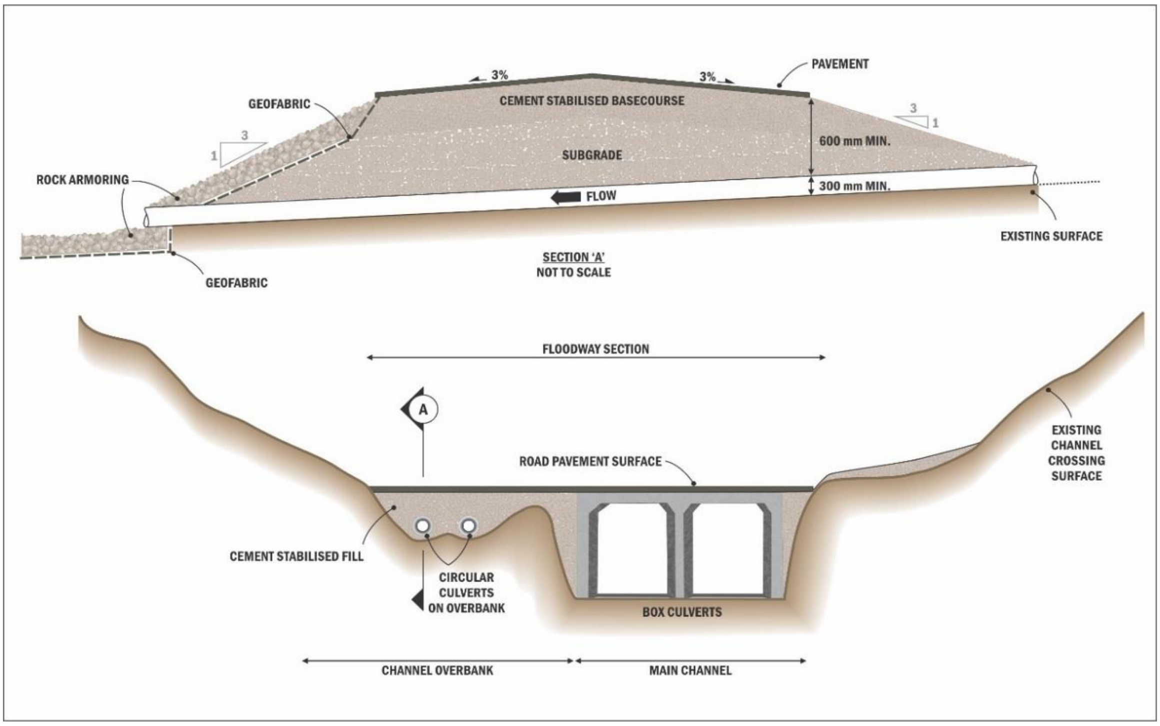


Figure 9-92 Box culvert and circular culvert and floodway arrangement

Fish Passage Design Considerations

Consideration has been given to the requirements of 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 (classified as a major impact waterway, refer to Figure 9-68) will 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”.

State Code 18 contains a number of performance outcomes and associated acceptable outcomes that should be addressed. Those relevant to culvert crossings are presented below.

Performance Outcome (PO4)

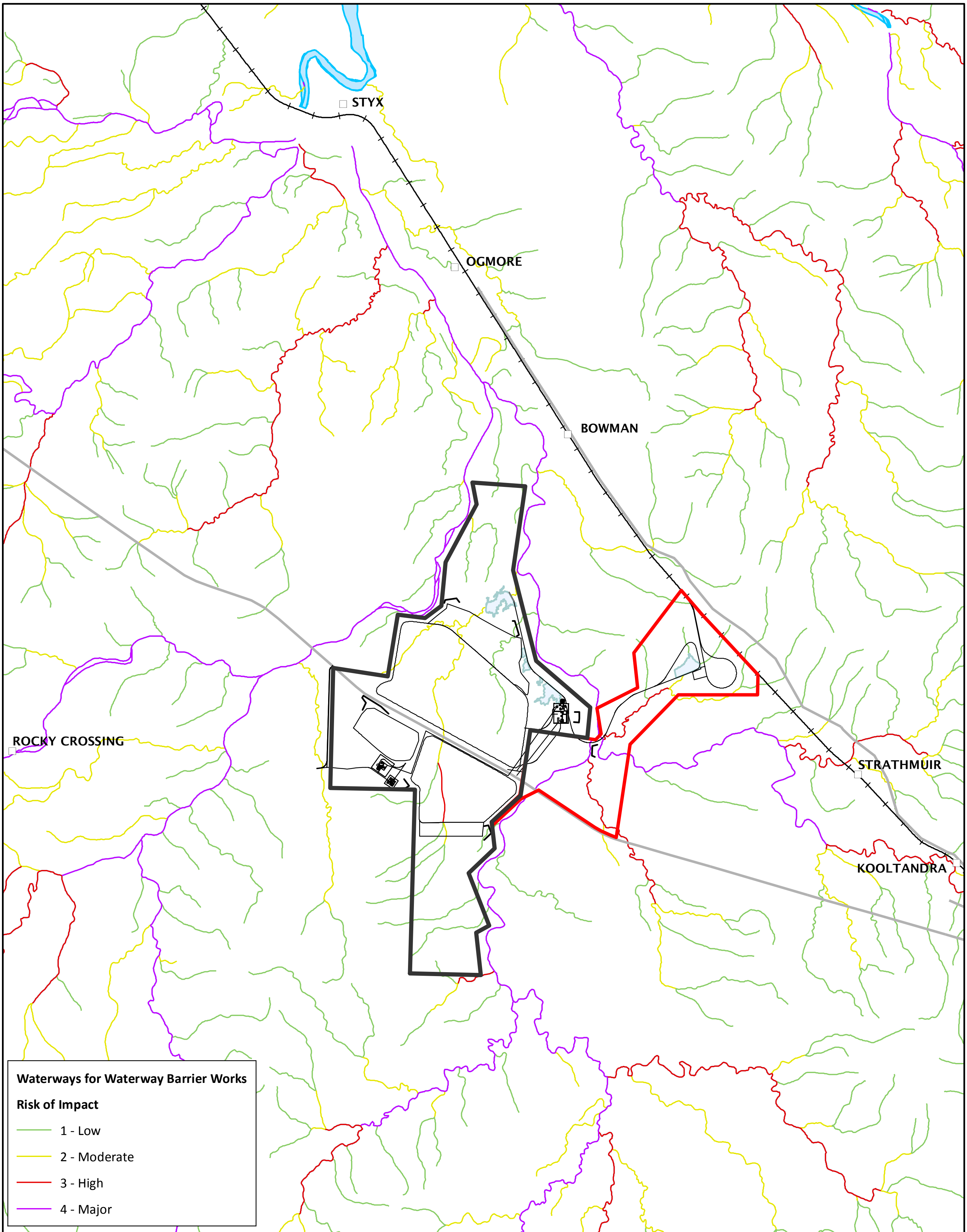
For the life of the barrier, adequate fish passage must be provided and maintained at all waterway barrier works through:

- fishway(s) that adequately provide for the movement of fish; or
- the movement of fish is adequately provided in another way.

Acceptable Outcomes for PO4

- Hydraulic conditions (depth, velocities and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the crossing at all flows up to the drownout of the structure (AO4.1). For the life of the culvert crossing, relative levels of: a bed level crossing or a culvert invert, bed erosion protection, apron scour protection and the stream bed are maintained to avoid drops in elevation at their joins (AO4.2):
  - The profile between scour aprons and culvert inverts will be flush and with no steps that will impede fish passage
- The culvert crossing, and associated erosion protection structures are installed at no steeper gradient than the waterway bed gradient (AO4.3):
  - This is standard design practice and will be applied to this Project
- In-stream scour protection structures are roughened throughout to approximately simulate natural bed conditions (AO4.4):
  - Rock aprons are typically used and are appropriate
- Adequate design (for example, culvert aperture) and maintenance measures are in place for the life of the crossing to keep crossings clear of blockages through a regular inspection program to retain fish passage through the crossing (AO4.5)
- The haul road culvert crossings comply with the acceptable outcomes (AO4.13) of Performance Outcome 4 by installing culverts only where the site conditions do not allow for a bridge:
  - Due to the small and ephemeral nature of the haul road crossings within the MLA, bridge structures are not considered feasible
  - A bridge could be constructed on Deep Creek; however, this does not represent a cost-effective solution where suitable box culvert structures can be installed

- The combined width of the culvert cell apertures is equal to 100 per cent of the main channel width (AO4.14):
  - The crossings are designed to provide low flow passage through the width of main channel and then overtop for out of bank flows
- The base of the culvert is… (AO5.15):
  - Buried a minimum of 300 millimetres to allow bed material to deposit and reform the natural bed on top of the culvert base (This is required for the use of circular culverts or box culverts with a base slab), or
  - The stream bed (This is only permissible for box culverts with footings instead of a base slab. The use of footings must be confirmed through geotechnical analysis during the detailed design phase); or
  - Roughened throughout the culvert floor to approximately simulate natural bed conditions (Culverts will be designed with a brush finish)
- The outermost culvert cells incorporate roughening elements such as baffles on their bankside sidewalls (AO4.16):
  - This condition will be considered for Deep Creek crossing only
- Roughening elements are installed on the upstream wingwalls on both banks to the height of the upstream obvert for full height of the wingwall (AO4.17):
  - This condition will be considered for the Deep Creek crossing only
- Roughening elements provide a contiguous lower velocity zone (no greater than 0.3 metres / second) for at least 100 millimetres width from the wall through the length of the culvert and wingwalls (AO4.18):
  - This condition will be assessed during final design; however, roughening may not be appropriate given high velocity flow already present in the natural stream channel. Furthermore, no design event is listed for this velocity condition to be met in practice
- Culvert alignment to the stream flow minimises water turbulence (AO4.19):
  - Culverts are aligned in the direction of flow
- There is sufficient light at the entrance to and through the culvert so that fish are not discouraged by a sudden descent into darkness (AO4.20)
  - The culvert length is a function of haul road width. The minimum width that allows safe crossing of the haul road vehicles will be applied
- The depth of cover above the culvert is as low as structurally possible, except where culverts have an ARI greater than 50 years (AO4.21):
  - A 9.5% AEP design has been adopted. A box culvert solution will allow for minimal to no depth of cover
- For culvert crossings designed with a flood immunity >ARI 50, fish passage is provided up to culvert capacity (AO4.22):
  - Not applicable



Legend

- ML 80187
- ML 700022
- Mine infrastructure
- Main Road
- North Coast Rail Line
- Dam
- MSES – Declared Fish Habitat Area

N

0 1 2 km

Scale @ A4 1:100,000
Date: 22/11/18
Drawn: Gayle B.

Figure 9-93
Declared fish habitat area and risk of impact

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

9.6.3.5 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.

The probabilistic Rational Method provides an estimate of peak discharge for a given design storm frequency, and is represented as follows:

$$Q_y = (C_y * I_y * A)/360$$

Where:

Q_y = Peak discharge (m^3/s);

C = Coefficient of Runoff;

I = Design Rainfall Intensity (mm/h);

A = Catchment Area (ha); and,

The subscript ‘y’ denotes the particular AEP under consideration.

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 9-58.

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. The locations of the stormwater elements are shown in Table 9-58.

Table 9-58 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. It varies in accordance with storm frequency per the equation below:

$$(C_y = F_y * C_{10})$$

Where:

C = Coefficient of Runoff;

F = Frequency Adjustment Factor;

C10 = Coefficient of Runoff, 10 yr ARI design rainfall event; and

The subscript 'y' denotes the ARI under consideration.

Coefficients of Runoff adopted for this analysis are presented in Table 9-59. The result peak flow predictions for each catchment, for a range of standard ARI events, is presented in Table 9-60 and Table 9-61 for diversion drains and haul road culverts, respectively.

The diversion drains estimated peak flows in Table 9-60 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 9-61 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 9-59 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 9-60 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 9-61 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

9.6.3.6 Stormwater Culvert and Drain Sizing

The culvert arrangement has been conceptualised to pass the 9.5% AEP peak flows (see Section 9.6.3.5) through the culvert, with greater flows passing over a floodway arrangement. The culvert locations are illustrated in Figure 9-99. 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 9-62. 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. Further information regarding the sizing of the culvert is discussed in Section 9.6.2.2.

Table 9-62 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 9-63 for the specified design events and corresponding peak flow estimates. The drains were sized using Manning's Equation, as follows:

$$Q = 1/n * A * R^{2/3} * Se^{1/2}$$

Where:

Q = Design flow (m^3/s);

n = Manning's roughness coefficient;

A = Flow area (m^2)

R = Hydraulic Radius (m)

Se = Channel slope (m/m)

Table 9-63 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 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 9-90 and is tested hydraulically in flood modelling covered under Section 9.6.2.

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 9-90 . 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 9-64.

Table 9-64 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

9.7 Water Resource Management

A schematic of the proposed water management network for the Project is shown in Figure 9-94, 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 9-65. The maximum total annual demand excluding water re-use is calculated at 804 Megalitres (ML) at 2030 and mining 10 Mtpa ROM.

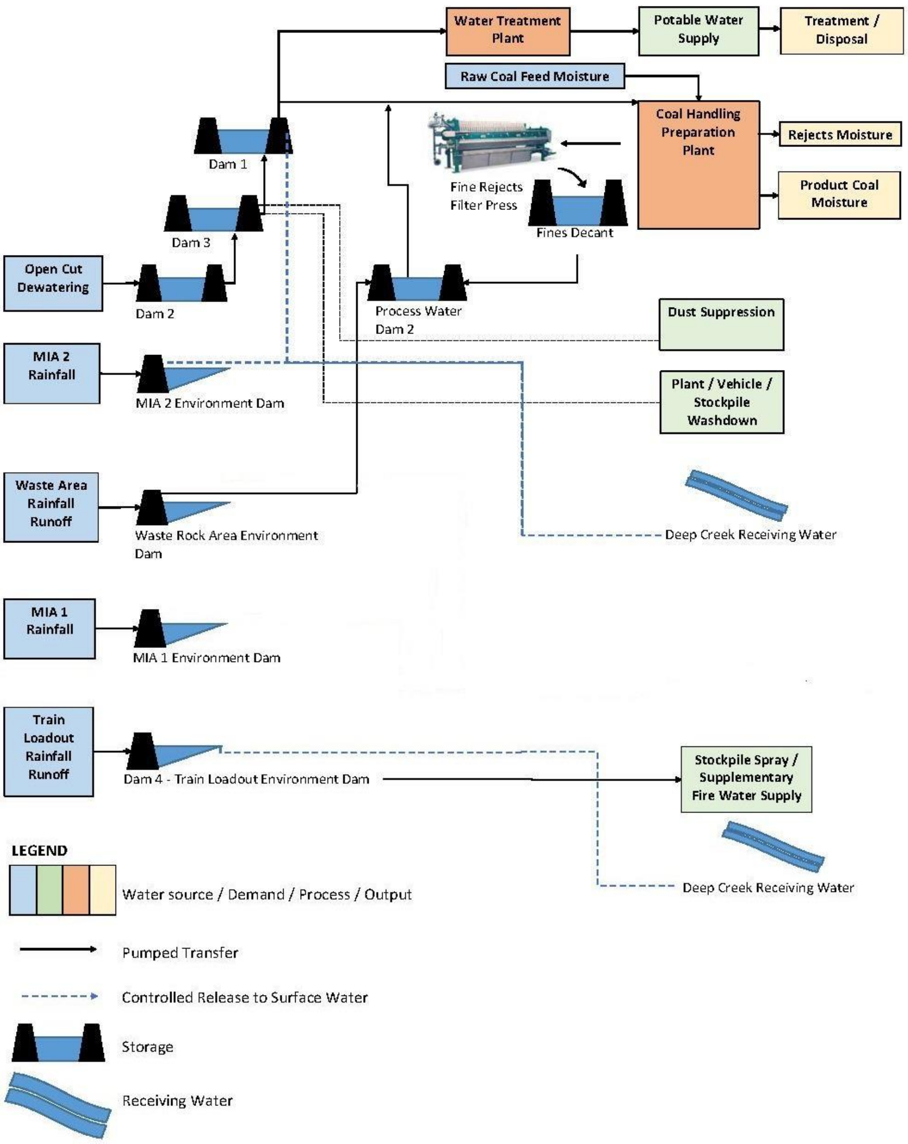


Figure 9-94 Proposed water management network

Table 9-65 Mine water demands (estimated)

Year	ROM (Mt)	Potable Demand	CHPP Demand	Dust Suppression Demand	Washdown Demand	Sewer	Total Water Demand
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 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 9-95.

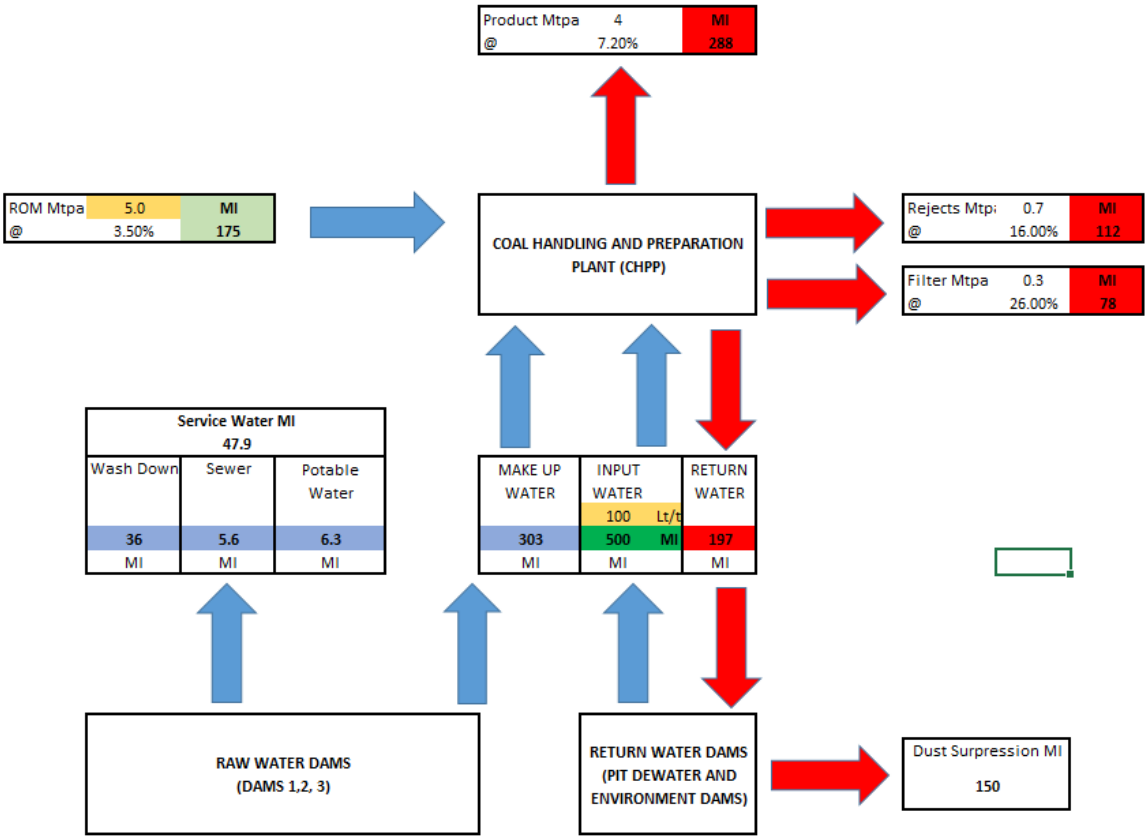


Figure 9-95 Water balance calculations for 5Mpta throughput

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.

9.7.1 Mine Water Balance

A water balance of the water management network described in Section 9.7 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 9-66. 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 9-66 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

Model element	Inputs	Outputs	Comments/assumptions
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 9-67 for the dry season, and Table 9-68 for the wet season.

Table 9-67 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 9-68 Water inputs and outputs – Wet season

Input-Output	Source/ Destination	Inputs/ Outputs	Volume of Water in Quality Category Number 1 (ML)	2 (ML)	3 (ML)	Total (ML)	Accuracy	Notes
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**		

9.7.2 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 9.4.2.2 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.

9.7.3 Groundwater Inflow and Licenced Discharges

The water demands and sources for the Central Queensland mine is presented in Table 9-65, Section 9.7.1. 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 9-69 and Figure 9-96.

Table 9-69 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

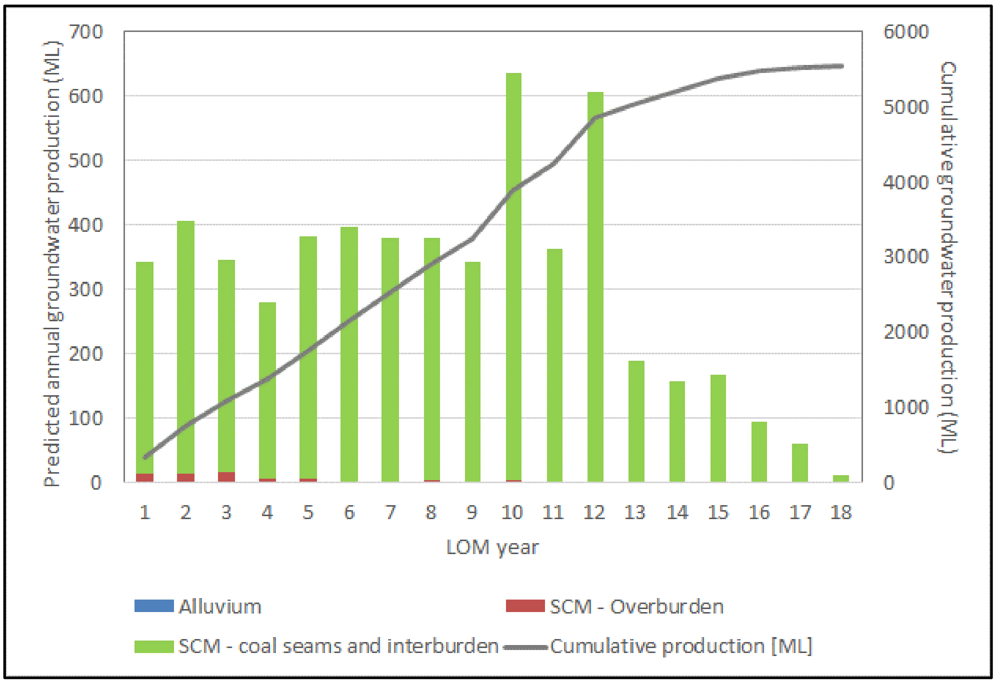


Figure 9-96 Predicted groundwater pit inflow volumes

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 9.5.6 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.

9.7.4 Tooloombah 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 Figure 9-97.

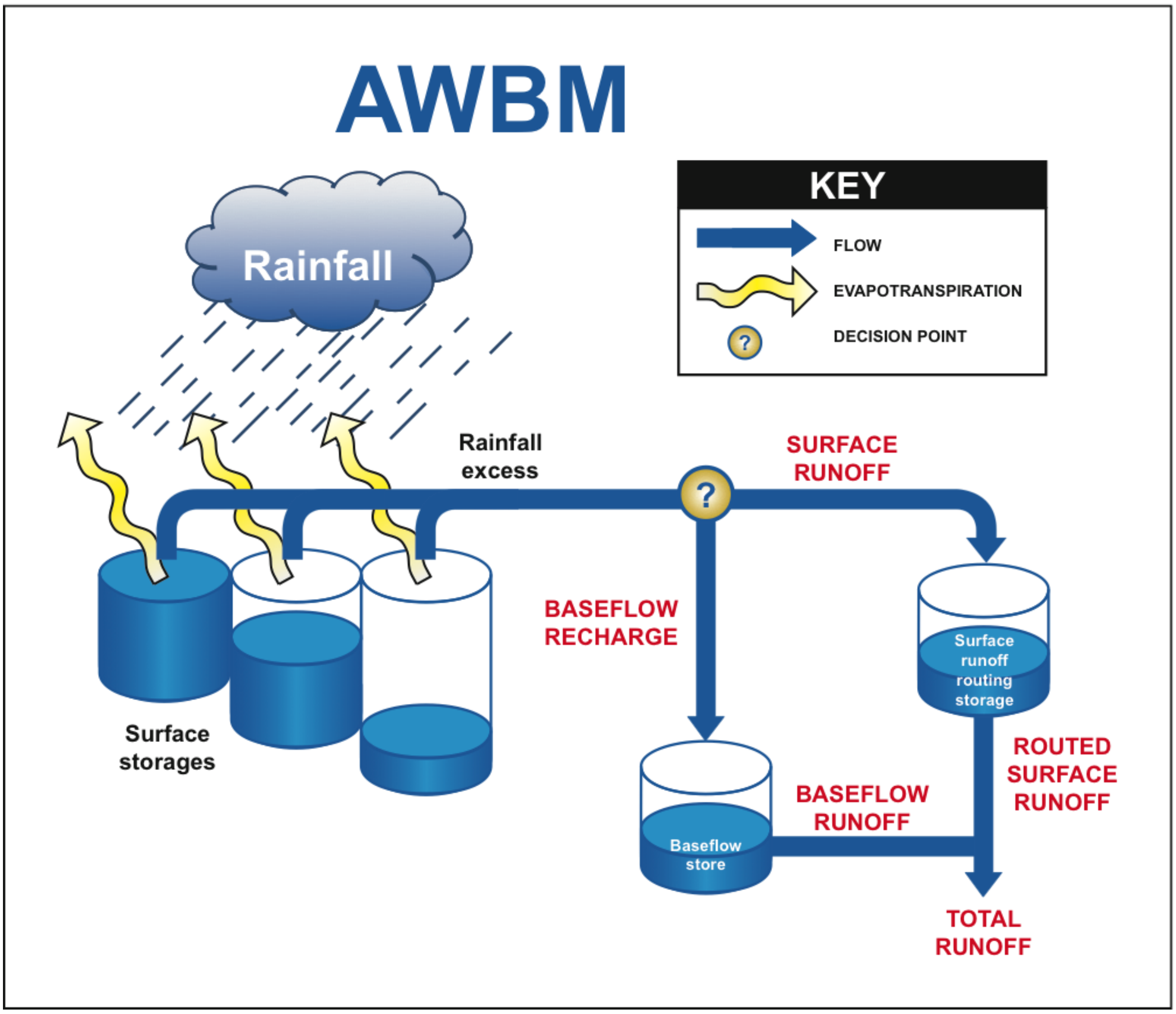


Figure 9-97 Australian Water Balance Model schematic

The adopted AWBM parameters are presented in Table 9-70, 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 9-70 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	20mm	7mm
Surface store capacity, C2	50mm	70mm
Surface store capacity, C3	120mm	150mm
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.

9.7.5 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 9-71. 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 9-71 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 9-98 and Figure 9-101 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 9-66) and the eventual release conditions imposed for mine affected water (see Section 9.9.2 for proposed strategy). On commencement of mine construction, detailed water balance models should be constructed, continually updated with new data and validated to reflect the conditions encountered.

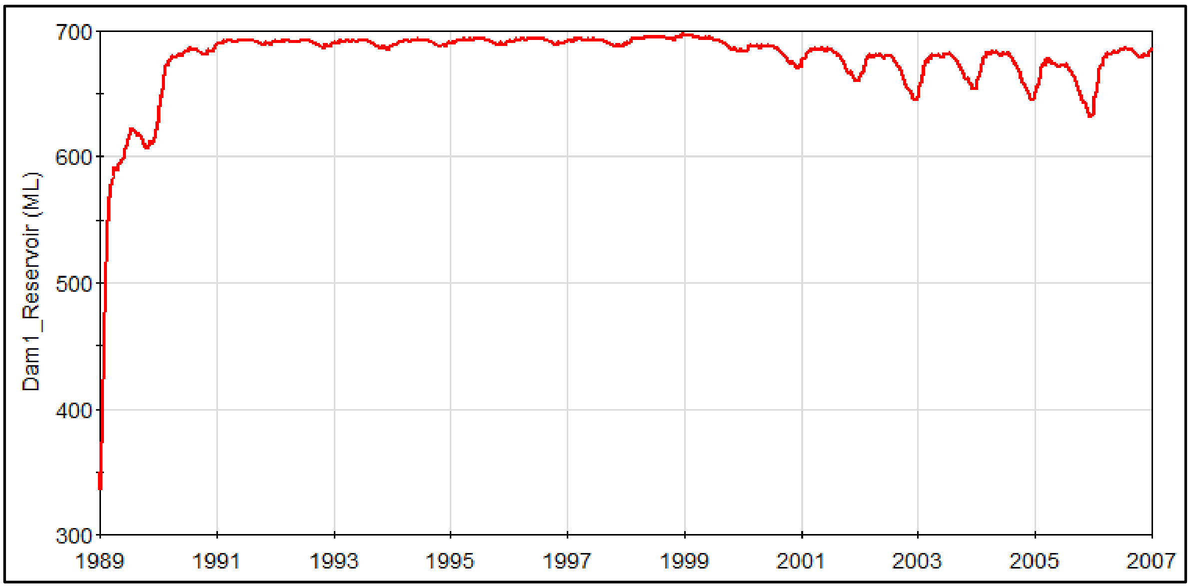


Figure 9-98 Dam 1 – mean storage history

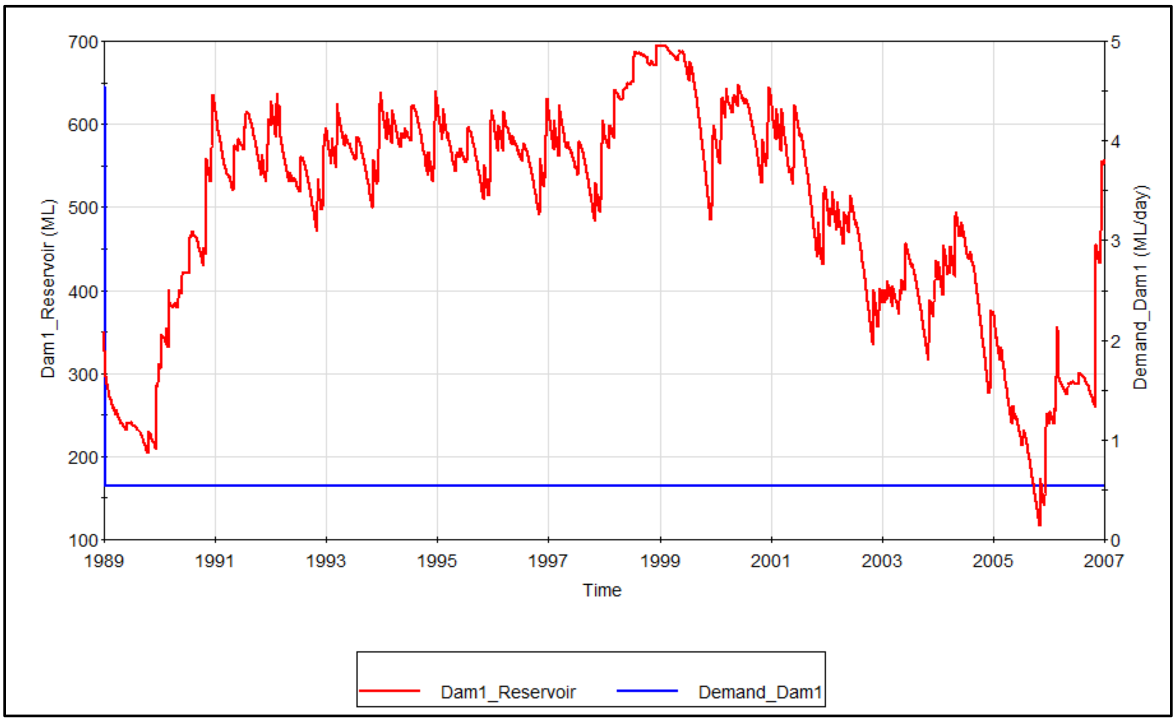


Figure 9-99 Dam 1 - 99th percentile storage history with demand

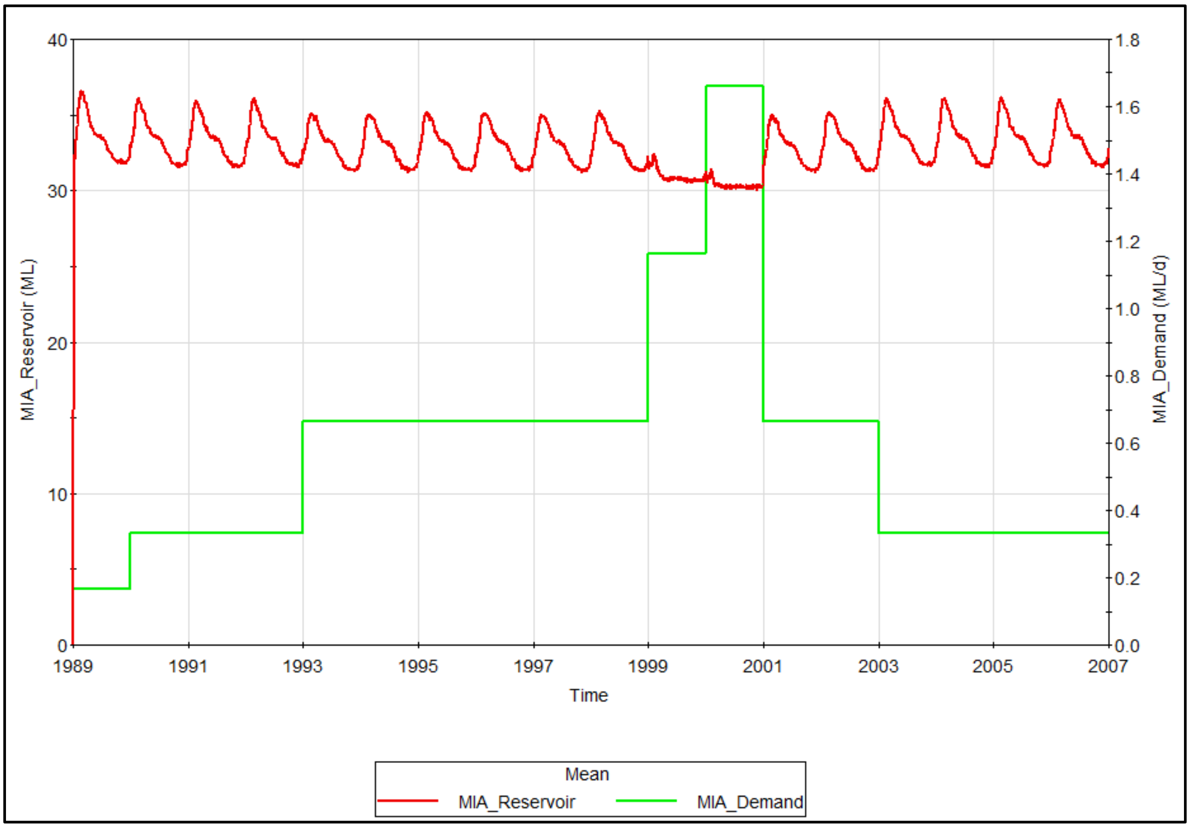


Figure 9-100 MIA Process Dams – mean storage history

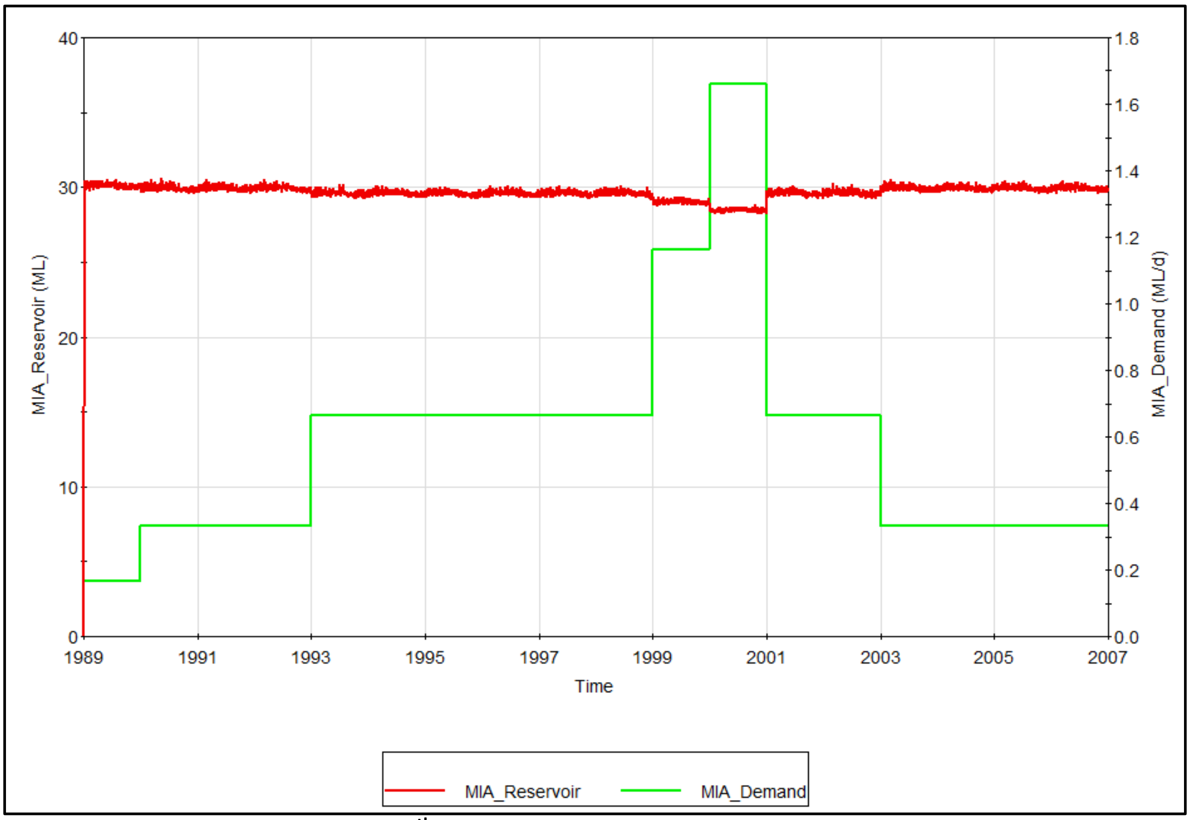


Figure 9-101 MIA Process Dams - 99th percentile storage history

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 9-102 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.

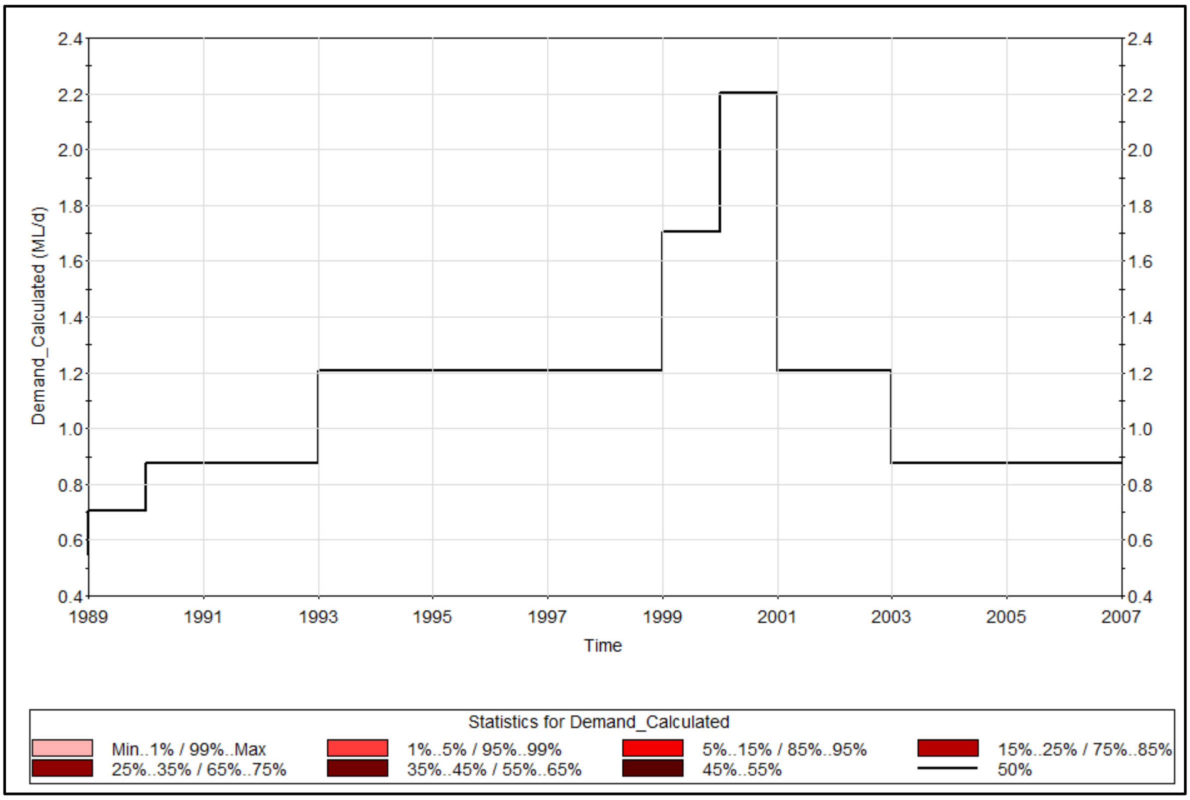


Figure 9-102 Whole mine water demand

9.8 Regulated Structures Assessment

All proposed storages and levees have undergone preliminarily assessment under the *Structures which are Dams or Levees Constructed as part of Environmentally Relevant Activities* (ESR/2016/1934, Version 8.01, 2017) (EHP 2017a) and the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (*ESR/2016/1933 Version 5.01, 2016) (EHP 2016) to determine the minimum hydraulic performance requirements. 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 9-72. 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.

Table 9-72 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.
Environmental 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.

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 2018a). 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.

9.8.1 Storage Assessment

Based on the consequence assessment summarised in Table 9-72 and discussed at Section 9.7, 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% AEP 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.[2]

The MIA1 and MIA 2 dams (PWDs) are designed as turkey's nest storages with no external contributing catchment. Contributing catchments to environmental 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 9.7.1 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;
- Environmental dams – Sized to capture the 9.5% 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 at Table 9-73 and the locations are shown at Figure 9-87.

Table 9-73 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 13.5 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.

[2] 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

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
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 3.6 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 Environmental Dam	30	N	1.7*	N/A	N/A	N/A	1% AEP rainfall#
7	MIA 2 Environmental Dam	30	N	1.7*	N/A	N/A	N/A	1% AEP rainfall#
8	Dam 4 TLF	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 environmental dams that are not regulated structures
*Dam areas calculated on an assumed average depth of 3m

9.9 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.

9.9.1 Release Points and Gauging Stations

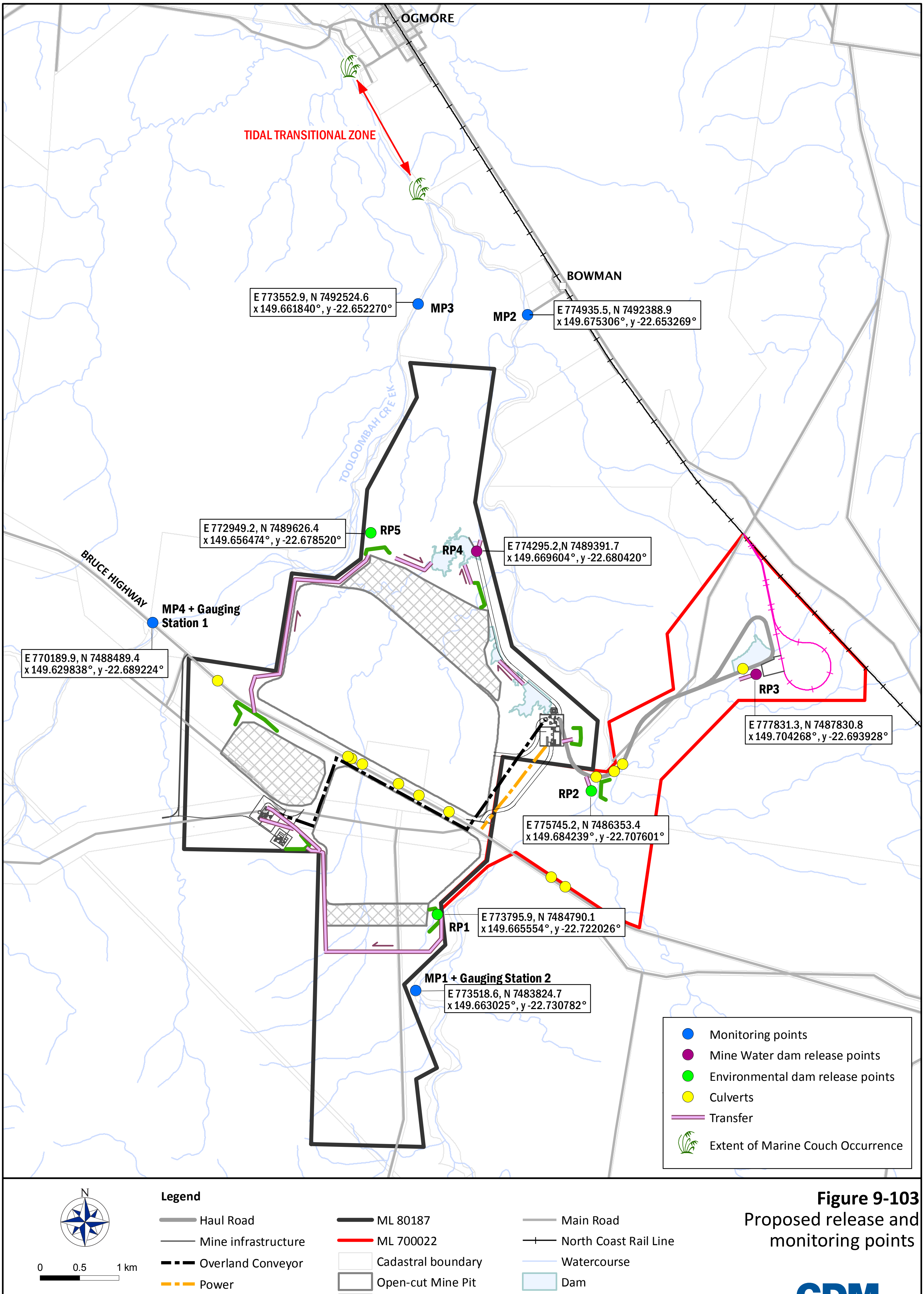
Release points (RPs) have been designated for storages containing pit dewater volumes, overburden stockpile runoff and mine process water (see Table 9-74). Mine affected water dams have piped outlets that transfer water to RPs within Tooloombah Creek, where instream dilution is possible. Environmental 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 9-74 and shown at Figure 9-103. RPs will also be located at the environmental dams at the MIA, TLF overburden stockpile areas.

Table 9-74 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 9-103.



Scale @ A4 1:60,000
Date: 20/11/18
Drawn: Gayle B.

Figure 9-103
Proposed release and monitoring points

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 Proposed Release and Monitoring Points__9-99.mxd 11/20/2018

9.9.2 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.

9.9.2.1 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 9-103 and listed in Table 9-75.

Table 9-75 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

9.9.2.2 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 9.7.4) 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 9-76 and Table 9-77 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 9-76 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 9-77 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. Unlike in Table 9-76 and Table 9-77 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.

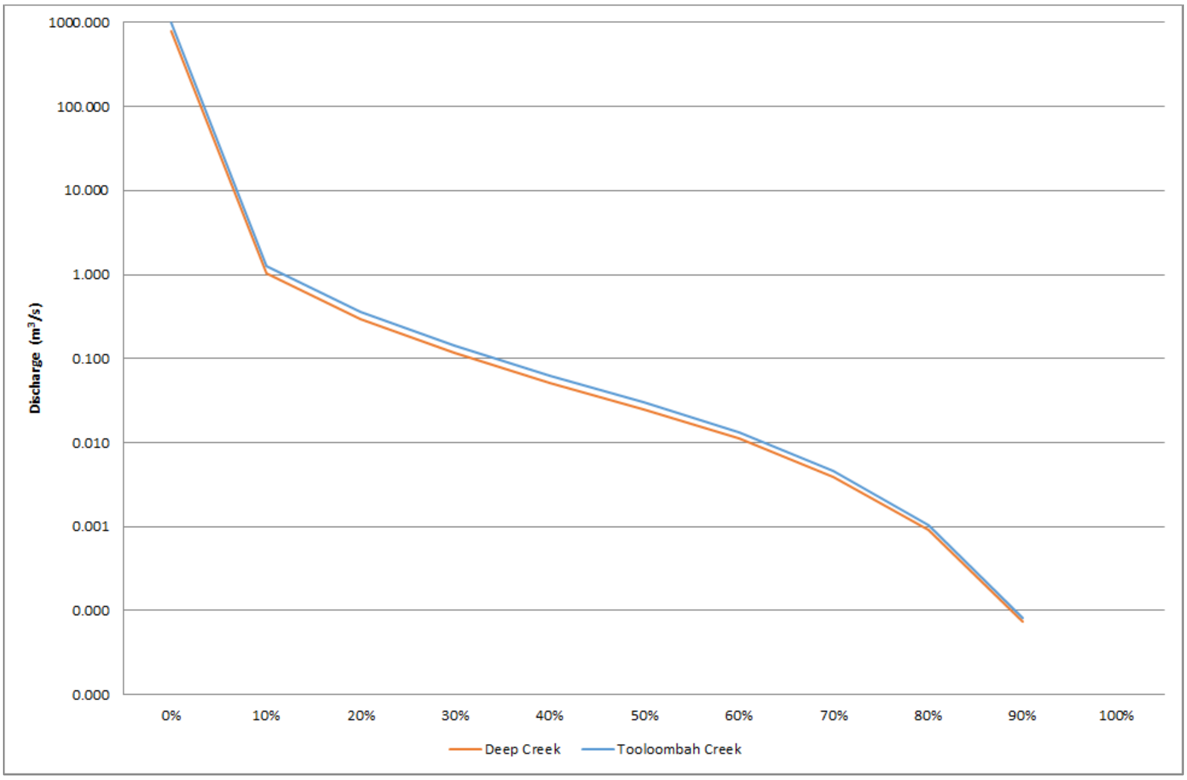


Figure 9-104 Flow duration curves for Tooloombah Creek and Deep Creek proposed monitoring points

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 9-78 and Table 9-79. 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 9-78 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 75^{th} 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 9-79 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 75^{th} 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.

9.10 Potential Impacts on Environmental Values

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 in the Great Barrier Reef World Heritage Area is addressed in Chapter 16 - MNES.

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.

9.10.1 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 within 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).

9.10.2 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.

9.10.3 Accidental Release of Pollutants

Accidental release of pollutants may adversely impact Deep Creek as the Project Area majority lies within the Deep Creek catchment. There is a less likely impact on Tooloombah Creek as the local environmental dams 1a, 2a and 2b are the only infrastructure to potentially discharge into the creek. Potential sources of pollutants include MIA and the CHPP areas, which are located approximately 250 m and 500 m from Deep Creek respectively. Waste Rock Stockpile 1a is located approximately 250 m west of Deep Creek representing another potential source of contaminants (see Figure 9-87).

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 (note 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 form the waste rock stockpiles is also considered to be unlikely – these are discussed in detail in Chapter 8 – Waste Rock);
- Waste Rock Stockpile 2 has the potential of releasing contaminated run-off into Tooloombah Creek and potentially Deep Creek (note 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 form the waste rock stockpiles is also considered to be unlikely – these are discussed in detail in Chapter 8 – Waste Rock); 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.

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, could produce moderate impacts on local and downstream water quality, aquatic ecology, irrigation, farm supply, stock water and cultural / spiritual EVs. It is unlikely to impact human consumer and drinking water EVs due to the distance between the Project area and downstream extraction points.

9.10.4 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 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. Changes to peak flows, levels, and velocities, are likely to have only have a minor impact on aquatic ecology EVs.

9.11 Mitigation and Management Measures

To manage the potential impacts listed in Section 9.10, the following mitigation and management measures are proposed.

9.11.1 Control of Erosion and Sediment

9.11.1.1 Removal of Stock

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. 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 of the assessment show that for areas of 1% slope under the grazing regimes described at Table 5 41, 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 5 41, 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 5 45. 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.

9.11.1.2 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 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 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.

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 EHP Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (2016);
- The EHP Stormwater Guideline for Environmentally Relevant Activities (2014b); and
- Stakeholder requirements.

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 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-yr 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-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.

9.11.1.3 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 native 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 3 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 native 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. the explosive magazine access road, and haul roads between the northern pit and WRD 1) 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 WRD surfaces will be achieved through the placement of waste rock material. Most of the other disturbance areas are to be constructed using compacted native 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.

9.11.1.4 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 sediment 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 ponds 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 is in accordance with the following principles:

- The site has been divided into 18 storm water management sub-catchments;
- Site drainage ditches are designed for a minimum 1 in 10 year Average 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 minimum 1 in 10 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.

Clean Water Diversions

Clean water is defined as run off 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 the transect the ML are to be 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.

Flow Diversion Banks

Diversion banks and berms are earth structures and 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 th3e construction program where appropriate. Diversion banks are particularly important during the clearing stage of construction.

The size of the construction catchments will be broken up using flow diversion banks placed at regular intervals down the slope with the intent of slowing the flow of water and divert surface runoff to the receiving environment. Recommended maximum spacing of drainage systems down exposed, non-vegetated or recently seeded slopes are provided at Table 9-80. 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.

Table 9-80 Maximum flow diversion bank spacing

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

Source: IECA Table 4.3.2

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.

Vegetation Buffers

Buffer strips of vegetation will be left intact, wherever possible, between construction works and wetland and/or creek 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 shall also be established where possible in know sensitive areas.

Central Queensland Coal will destock most of the 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 this measure will contribute to localised water quality improvements through long-term restoration of this habitat and allowing vegetation to regrow along the riparian zones along Deep Creek and Tooloombah Creek (which are presently mostly cleared) will capture sediment 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 sediment entering the creek lines during heavy rainfall 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 exit 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 shall be maintained and cleaned or repaired as necessary to ensure they are working efficiently.

9.11.2 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 stockpiles, 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.

9.11.3 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.

9.11.4 Ongoing Water Quality Management and Monitoring

9.11.4.1 Water Release Points and Monitoring

The Project has five proposed mine affected water release points (see Table 9-74). 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 9-103). In addition, ongoing monitoring will be undertaken at the sample locations identified in Table 9-75 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).

9.11.4.2 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 incorporate the following elements:

- 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 2009a), 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 the EA conditions.

9.11.4.3 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 9-81 to Table 9-83.

Table 9-81 Trigger Action Response Plan - surface waters (RP1 to RP5)

Monitoring Type	Parameters	Frequency	Criteria	Trigger	Action	Response	Plan
Discharge monitoring of surface waters	Electrical conductivity (µS/cm) pH (pH units) Turbidity (NTU)	Daily during release	TBC – post-EA 6.5-9 pH TBC – post-EA	Single exceedance of EA parameters	Notify Department 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

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 Department 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 DES Investigation by Environment Officer	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 9-82 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 Central Queensland Coal 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 Central Queensland Coal senior management (or delegate) will be notified. B. If determined the incident has caused, or threatens to cause environmental hard Central Queensland Coal 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 Central Queensland Coal 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 9-83 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 Central Queensland Coal, reviewing monitoring data, historical averages and operational activities AND Central Queensland Coal 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 Central Queensland Coal 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

9.11.4.4 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.

9.12 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.

9.13 Qualitative Risk Assessment

Potential impacts on ecological values have been assessed utilising the risk assessment framework outlined in Chapter 1 - Introduction.

For the purposes of risk associated with aquatic EVs, risk levels are defined as follows:

- Extreme – Works must not proceed until suitable mitigation measures have been adopted to minimise the risk;
- High – Works should not proceed until suitable mitigation measures have been adopted to minimise the risk;
- Medium – Acceptable with formal review. Documented action plan to manage risk is required; and
- Low - Acceptable with review.

A qualitative risk assessment is outlined in Table 9-84. It outlines: the potential impacts, the initial risk, proposed control measures (as detailed in the previous section), and the residual risk following the implementation of those measures.

Table 9-84 Qualitative risk assessment

Issue	Potential impacts	Potential risk	Mitigation measures	Residual risk
Increased Sedimentation of Waterways and Sediment Runoff	▪ Degradation of instream habitat / water quality including downstream HEV estuarine habitat in the Styx River ▪ Changes flood extent as less storage available for rainfall events	High	▪ Design and implement Project Erosion and Sediment Control Plan ▪ Surface waters managed and monitored under Project Receiving Environment Monitoring Program ▪ Minimise unnecessary disturbance to vegetated lands ▪ Progressive rehabilitation of disturbed areas will be undertaken ▪ Appropriately designed water management system including environmental dams	Low
Direct Disturbance of Waterways	▪ Changes to flow characteristics ▪ Changes in sediment loads ▪ Decrease habitat ▪ Increased erosion and increase in runoff velocity due to the construction of culverts ▪ Causes localised surface water ponded areas	High	▪ Construction of culverts, and watercourse / drainage feature crossings and diversions during no-flow/low-flow conditions; ▪ Implementation of requirements set out in the Erosion and Sediment Control Plan (ESCP); ▪ Vegetation will be preserved with only the minimum amount of land required to operate the Project cleared at any one time; and ▪ Monitor the crossings and Erosion and Sediment Control (ESC) devices to ensure ongoing effectiveness and implement corrective actions should a fault in the crossings or ESC devices be identified.	Low
Accidental release of pollutants	▪ Degradation of instream habitat/water quality including downstream HEV estuarine habitat in the Styx River ▪ Fish mortality events ▪ Decreases in water quality i.e. lower DO levels, higher turbidity	High	▪ Design and implement Project Receiving Environment Monitoring Program and Water Management Plan ▪ Controlled release of better quality water in accordance with licensed EA conditions ▪ Maintenance of Design Storage Allowance on the onset of the wet season to minimise the likelihood of uncontrolled discharges ▪ Pipeline connectivity between storages to allow water transfer to where there is available capacity ▪ Establish measures to minimise/control Project-associated chemical spills ▪ Project design will locate infrastructure to minimise stormwater run-off ▪ All waters discharged into adjacent waterways will be treated in retention basins and similar in quality to receiving waters	Medium
Hydrology and water flows	▪ Reduction of inflows to watercourses and drainage features	High	▪ Design and implement Project Receiving Environment Monitoring Program ▪ Project design to ensure surface water flows into creeks maintained as close to natural conditions as practical	Low

Note: R=Rare, UL= Unlikely, P=Possible, L=Likely, AC=Almost Certain

9.14 Conclusion

This chapter described the EVs of surface water resources that may be affected by the Project, and identified historical and current surface water conditions upstream, downstream and within the Project area. The ephemeral watercourses and wetlands (including farm dams) within the Project area and surrounding region are classified as moderately disturbed, with the background water quality reflecting that the land is largely given over to grazing.

Intermittent flooding is a natural feature of the landscape, reflected in the predominance of ephemeral watercourses. Flood modelling identified that the CHPP and MIA 1 will be outside of the area of flood risk and, with the use of sediment control devices, no impact is anticipated to watercourses within and surrounding the Project site during construction. CHPP and MIA 2 are within the flood risk for events greater than 0.1%, with water ponding on the pad surface. During the PMF AEP event a maximum water depth of 0.99 m was recorded on the pad; this is with the existing surface elevation raised by between 1.0-2.5 m.

A preliminary mine water balance generally shows that the planned mining and processing water demands will be met by water sourced from catchment rainfall, groundwater dewatering from mining activities, and reuse of water around the site. The on-site water storages are not expected to be regulated structures due to the relatively low volume and height / depth required to meet the Project water storage requirements. During the driest years, there is more reliance on catchment and groundwater 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.

A Project REMP will be developed that specifies the threshold and trigger levels for management actions, and identifies the mitigating or reparative actions required to reduce the risk or effect of impacts. A Water Management Plan will be developed prior to construction, to monitor the effects on the waterways which will receive the highest level of disturbance. Although some level of impacts is unavoidable, the assessment has identified that mitigation and management measures can be employed to significantly reduce the potential for adverse impacts on the area's surface water EVs.

9.15 Commitments

In relation to surface water, Central Queensland Coal's commitments are provided in Table 9-85.

Table 9-85 Commitments – surface water

Commitment
Construction of culverts, diversions and watercourse/drainage feature crossings will be undertaken during no-flow/low-flow periods.
Crossing designs in major impact waterways (i.e. Deep Creek) will comply with State Code 18: Constructing or raising waterway barrier works in fish habitats. All other culvert crossings, not required to comply with State Code 18, adhere to best-practise design for fish passage and Accepted development requirements for operation work that is constructing or raising waterway barrier works.
Should the release contaminant levels be shown to exceed the background monitoring level, Central Queensland Coal will investigate the potential environmental harm and provide reporting to the administering authority outlining the actions taken to prevent environmental harm.
Undertake water monitoring 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.
Use monitoring as a continual improvement mechanism for the ongoing management of stormwater including operational calibration of the water balance model.

Commitment
Design and implement a Project Erosion and Sediment Control Plan to be certified by a suitably qualified person, prior to construction.
Develop and implement a Receiving Environment Monitoring Program in accordance with relevant Guidelines and periodically update as required throughout the life of the Project.
Develop an annual and post severe climatic event sediment monitoring program for inclusion in the REMP.
Prepare and implement a Water Management Plan that outlines the monitoring and management measures for surface water and groundwater.
Minimise unnecessary disturbance to vegetated lands.
Undertake progressive rehabilitation of disturbed areas.
Prepare and implement a water management network to manage impact to water resources.
Reuse water captured in environmental dams (onsite) and mine dewatering before using raw water, where practicable.

9.16 IESC Cross-Reference Tables

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) is a statutory body under the EPBC Act. The IESC has developed Information Guidelines that outline what types of information a proposal for a CSG or large coal mining project should include. This information is needed to enable the IESC to provide robust scientific advice to government regulators on the potential water-related impacts of such proposals.

The guidelines were first published in February 2013. The guidelines were reviewed and amended in April 2014, June 2015 and May 2018, to update reference material, cover developments in leading practice and knowledge, take account of the IESC's recent experience and incorporate comments from users. The Guidelines provide both general guidance on IESC information needs and guidance on specific information requirements.

The general guidance requirements are addressed variously throughout the SEIS. The description of the Project is provided at Chapter 1 – Introduction and in greater detail at Chapter 3 – Description of the Project. Risk assessments are provided in each of the technical chapters and in cases, reported in the associated technical reports. The descriptions of impacts to water resources and water-dependent assets are, in addition to this Chapter, discussed in detail in Chapter 10 – Groundwater, Chapter 14 – Terrestrial Ecology, Chapter 15 Aquatic Ecology and Chapter 16 – Matters of National Environmental Significance. Baseline data is included where relevant in each of the technical chapters as are monitoring and management. As there are no projects directly associated with the Styx Basin, cumulative impacts have been assessed as existing land uses (i.e. cattle grazing) and where broader reaching activities are relevant (i.e. social and economic impacts).

Specific information needs relevant to surface water are discussed in Table 9-86 and Table 9-87.

Table 9-86 Surface Water - IESC Compliance Checklist

Question	Yes/No	Comments
Context and conceptualisation		
Describe the hydrological regime of all watercourses, standing waters and springs across the site including: • geomorphology, including drainage patterns, sediment regime and floodplain features; • spatial, temporal and seasonal trends in streamflow and/or standing water levels; • spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides); and, • current stressors on watercourses, including impacts from any currently approved projects.	Yes	Section 9.4 discusses the hydrological regime of all watercourses, standing waters and springs across the site, including Deep Creek, Tooloombah Creek, and the Styx River. In the absence of historical stream gauging of the site watercourses, references, regional assessments and parameter sensitivity have been conducted in hydrological analysis and modelling discussed in Section 9.6. The hydrological modelling has been conducted with XP-RAFTS, AWBM/GoldSim to represent both peak floods and daily variability based on long-term historical rainfall records. Sections 9.4 and 9.5 discusses the water quality sampling and analysis conducted on Deep Creek, Tooloombah Creek, and the Styx River. Seasonal trends in turbidity, salinity, acidity, nitrogen, phosphorus, ammonia-N, dissolved aluminium, dissolved copper, dissolved zinc, and dissolved lead for Barrack, Deep, and Tooloombah Creeks and Styx River are shown in Figures 9-29 to 9-47. The environmental values of surface waters within the Project area, downstream and upstream are discussed in Section 9.4. Section 9.10 discusses the potential impacts on environmental values.
Describe the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	Yes	Section 9.6 discusses the hydrology and flood modelling that has been completed for the existing and developed land uses. The flood volume, depth, duration, extent, velocity and afflux for a range of annual exceedance probabilities has been conducted. Flood hydrographs and maps identifying peak flood extent, depth, velocity and afflux are incorporated in Chapter 9.
Provide an assessment of the frequency, volume, seasonal variability and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.	Yes	Section 9.7 presents the GoldSim water balance inputs and results, and then a specific MCA water accounting framework summary of the average annual volumes, quality and certainty of water inputs and outputs.
Analytical and numerical modelling		
Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Yes	Discussed in detail in Chapter 10 - Groundwater.

Question	Yes/No	Comments
Describe and justify model assumptions and limitations, and calibrate with appropriate surface water monitoring data.	Yes	In the absence of historical stream gauging of the site watercourses, references, regional assessments and parameter sensitivity have been conducted in hydrological analysis and modelling discussed in Section 9.6. The hydrological modelling has been conducted with XP-RAFTS, AWBM/GoldSim to represent both peak floods and daily variability based on long-term historical rainfall records.
Use methods in accordance with the most recent publication of Australian Rainfall and Runoff (Ball et al. 2016).	Yes	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 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.
Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	Yes	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 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.
Develop and describe a program for review and update of the models as more data and information becomes available.	Yes	The absence of historical stream gauging of the site watercourses is noted, and Section 9.7 discusses the program on commencement of mine construction, detailed water balance models should be constructed, continually updated with new data and validated to reflect the conditions encountered.
Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Yes	In the absence of historical stream gauging of the site watercourses, references, regional assessments and parameter sensitivity have been conducted in hydrological analysis and modelling discussed in Section 9.6. The hydrological modelling has been conducted with XP-RAFTS, AWBM/GoldSim to represent both peak floods and daily variability based on long-term historical rainfall records.

Question	Yes/No	Comments
Impacts to water resources and water-dependent assets		
Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider: • impacts on streamflow under the full range of flow conditions. • impacts associated with surface water diversions. • impacts to water quality, including consideration of mixing zones. • the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets. • landscape modifications such as subsidence, voids, post rehabilitation landform collapses, on-site earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water dependent species and communities.	Yes	As the watercourses adjacent to the Project site (Deep Creek and Tooloombah Creek) are ephemeral, the emphasis has been on the linkages between groundwater and water dependent ecosystems. Section 9.10 discusses the potential impacts on environmental values. Impacts to groundwater dependent assets are discussed in detail in Chapter 10 – Groundwater.
Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Yes	Section 9.5 discusses the potential impacts on environmental values. The Project has committed to implementing a program of supplementary flows should monitoring determine potential adverse impacts to ecological communities. The maintenance of environment flows are discussed in Chapter 15 – Aquatic Ecology as is the modelling of stream pool water balances for the permanent pools in Tooloombah Creek. Section 15.6 discusses the assessment. The environmental values of surface waters within the Project area, downstream and upstream are discussed in Section 9.4. Section 9.10 discusses the potential impacts on environmental values.

Question	Yes/No	Comments
Identify processes to determine surface water quality guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets	Yes	Water monitoring to 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. Section 9.9 identifies the processes to determine if the exceedance is site-specific, and thus likely to be a result of Project activities. The proposed upstream and downstream monitoring points are shown in Figure 9-103 and listed in Section 9.11.4.
Propose mitigation actions for each identified significant impact.	Yes	Section 9.11 discusses the mitigation actions proposed to address each identified significant impact on environmental values.
Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	Yes	Sections 9.11 and 9.12 discuss the adequacy of the proposed measures, and methods to evaluate if impacts are or may be occurring. Additional discussion is presented in Chapter 10 - Groundwater.
Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and reasonably foreseeable) are considered in combination.	Yes	The cumulative surface water related impacts that may be associated with the proposed Project are discussed in Section 9.12.
Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	Yes	Section 9.6 presents the assessment of risks of flooding, based on the Project's modelled 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.
Data and monitoring		
Identify monitoring sites representative of the diversity of potentially affected water dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	Yes	Section 9.9 discusses water monitoring to be undertaken reference locations both upstream and downstream of the Project area. A commitment to the preparation of a Receiving Environment Management Plan (REMP) is provided in the Chapter. The REMP will be the overarching management plan that will describe the monitoring programs that will be implemented in respect of surface water quality and flows maintenance throughout the life of the Project and post mining. See Section 9.11.

Question	Yes/No	Comments
Develop and describe a surface water monitoring program that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions, and assess the effectiveness of mitigation and management measures. The program will: • include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals); • comparison of physico-chemical data to national/regional guidelines or to site specific guidelines derived from reference condition monitoring if available; and, • identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.	Yes	Section 9.9 discusses water monitoring to be undertaken reference locations both upstream and downstream of the Project area.
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Yes	Section 9.9 discusses water monitoring to be undertaken reference locations both upstream and downstream of the Project area.
Describe the rationale for selected monitoring parameters, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor largescale impacts.	Yes	Section 9.9 discusses water monitoring to be undertaken reference locations both upstream and downstream of the Project area.
Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and describe data methods, including whether missing data have been patched.	Yes	The description of the environmental values, including climate and hydrology is provided in Section 9.4. Section 9.4 also discusses data availability and a comparison of SILO data and other data sources.
Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate	Yes	A commitment to the preparation of a Receiving Environment Management Plan (REMP) is provided in the Chapter. The REMP will be the overarching management plan that will describe the monitoring programs that will be implemented in respect of surface water quality and flows maintenance throughout the life of the Project and post mining. See section 9.11.
Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	Yes	Section 9.9 discusses water monitoring to be undertaken reference locations both upstream and downstream of the Project area.

Table 9-87 Water Balance - IESC Compliance Checklist

Question	Yes/No	Comments
Is a quantitative site water balance model provided, that describes the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.?	Yes	A site water balance model for mining activities using GoldSim is presented. The key elements of the model include: o stochastic daily rainfall based on daily historical rainfall applied to the Life of Mine (looping with a one year step for the period of record) o surface catchment runoff applied with an in-built AWBM hydrology module (with catchments changing with mine plan development) o mine open cut groundwater dewatering from the groundwater modelling o the site water storages' stage-area-storage volumes from preliminary engineering drawings o mine demands have been provided as annual volumes, evenly distributed to a daily demand.
Are estimates provided of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	Yes	Water accounting framework tables for wet and dry seasons are presented in Tables 9-62 and 9-63 as per the Water Accounting Framework for the Minerals Industry User Guide (Minerals Council of Australia, 2014).
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	Yes	A site water balance model for mining activities using GoldSim is presented. The key elements of the model include: o stochastic daily rainfall based on daily historical rainfall applied to the Life of Mine (looping with a one year step for the period of record) o surface catchment runoff applied with an in-built AWBM hydrology module (with catchments changing with mine plan development) o mine open cut groundwater dewatering from the groundwater modelling o the site water storages' stage-area-storage volumes from preliminary engineering drawings o mine demands have been provided as annual volumes, evenly distributed to a daily demand.
Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation	No	The release limits proposed for the Project are presented in Section 9.5.6 and based on Water Quality Objectives (WQOs) for the Styx Basin and an adopted instream dilution rate for electrical conductivity.

9.17 ToR Cross-reference Table

Table 9-88 ToR cross-reference

Terms of Reference	Section of the EIS
8.3 Water Quality	
The assessment of water quality is considered a critical matter given the proximity of the Great Barrier Reef World Heritage Area, the presence of a wetland of national significance within the protect area, and usage of water resources for grazing purposes in the area. Conduct impact assessment in accordance with the EHP's *EIS information guideline—Water*.	Noted
With reference to the Environmental Protection (Water) Policy 2009 and section 9 the EP Act, identify the environmental values of surface waters within the project area, downstream and upstream that may be affected by the project, including any human uses of the water and any cultural values.	Section 9.4
Define and/or establish the relevant water quality objectives applicable to the environmental values, and demonstrate how these will be met by the project during construction, operation and decommissioning.	Sections 9.5
Quantify sediment and contaminant load increases in streams and to the reef as a result of mining operations.	Section 9.10
Detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the project and at suitable reference locations using sufficient data to define background conditions and natural variation in accordance with appropriate national and state guidelines and policies.	Section 9.5
Describe the quantity, quality, location, duration and timing[3] of all potential and/or proposed releases of contaminants addressing applicable standards from any relevant regional water quality management plans, strategies, or guidelines relating to water quality. Releases may include controlled water discharges to surface water streams, uncontrolled discharges when the design capacity of storages is exceeded, spills of products during loading or transportation, spills of product from the conveyor, contaminated run-off from operational areas of the site (including seepage from waste rock dumps), or run-off from disturbed acid sulphate soils.	Section 9.9
Assess the likely impacts of any releases from point or diffuse sources on all relevant environmental values of the receiving environment, including environmentally sensitive areas; such as the Great Barrier Reef World Heritage Area and Broad Sound Directory of Important Wetlands in Australia (DIWA) nationally important wetland as well as near-field and mid-field locations. The assessment should consider the quality and hydrology of receiving waters and the assimilative capacity of the receiving environment.	Section 9.10
Describe how impacts on water quality objectives and environmental values would be avoided or minimised through the implementation of management strategies that comply with the management hierarchy and management intent of the Environmental Protection (Water) Policy 2009. Appropriate management strategies may include the use of erosion and sediment control practices, and the separation of clean storm water run-off from the run-off from disturbed and operational areas of the site.	Section 9.11

[3] Duration and timing are important aspects of the risk characteristics that affect the impacts of mine and CSG water releases; e.g. for how long will water be released in total and when will it occur with respect to existing 'natural' flows

Terms of Reference	Section of the EIS
Describe how monitoring would be used to demonstrate that objectives were being assessed, audited and met. For example, provide measurable criteria, standards and/or indicators that will be used to assess the condition of the ecological values and health of surface water environments. Propose corrective actions to be used if objectives are not being met.	Section 9.11.4
8.4 Water Resources	
The assessment of surface water and groundwater resources is considered a critical matter given the usage of water resources for grazing purposes in the area. Conduct impact assessment in accordance with the EHP's *EIS Information guidelines – Water*.	Noted
The assessment of surface water and groundwater resources is considered a critical matter given the usage of water resources for grazing purposes in the area. Conduct impact assessment in accordance with the EHP's *EIS information guidelines—Water*. Describe present and potential users and uses of water in areas potentially affected by the project, including municipal, agricultural[4], industrial, recreational and environmental uses of water.	Section 9.4
Provide details of any proposed changes to, or use of, surface water or groundwater	Sections 9.10
Identify any approval or allocation that would be needed under the *Water Act 2000*.	Section 9.2.4
Include maps of suitable scale showing the location of diversions and other water-related infrastructure in relation to mining infrastructure.	Sections 9.6 and 9.7
Detail any significant diversion or interception of overland flow.	Section 9.6
Assess the potential impacts of any new water infrastructure (including diversions, pits, dams, etc.) and any proposed changes to water supply or take, on ground and surface water hydrology, quality and hydrological processes.	Section 9.10
Describe the options for supplying water to the project and assess any potential consequential impacts in relation to the objectives of any water resource plan and resource operations plan that may apply.	Chapter 3 – Project Description
Describe the proposed supply of potable water for the project, including temporary demands during the construction period.	Chapter 3 – Project Description
Also describe on-site storage and treatment requirements for waste water from accommodation and/or offices and workshops.	Section 9.8 and Chapter 3 Project Description
Describe the practices and procedures that would be used to avoid or minimise impacts on water resources.	Section 9.11 and Chapter 3 - Project Description
8.5 Flooding	
The assessment of surface water and groundwater resources is considered a critical matter given the use of the area for cattle grazing and the need to protect the environmental values of water resources.	Noted
Describe current flood risk for a range of annual exceedance probabilities (AEPs) up to the PMF for the project site.	Section 9.6

[4] https://publications.qld.gov.au/dataset/daff-environmental-impact-assessment-companion-guide/resource/7b1825c4-5e42-4cf8-aa2d-7fa55c2f5e4c

Terms of Reference	Section of the EIS
Use flood modelling to assess how the project may potentially change flooding and run-off characteristics on-site and upstream and downstream of the site.	Section 9.6
Maps and plans showing inundated and flooded areas for the full range of AEPs up to the PMF flood should be presented for the site, for the case before construction of the project, and also after mine closure. The assessment should consider all infrastructure associated with the project including levees, roads, and linear infrastructure, and all proposed measures to avoid or minimise impacts.	Section 9.6
Evidence should be provided that the securing of storage containers of hazardous contaminants during flood events meets the requirements of Schedule 5, table 2 of the EP Regulation.	Section 9.11.3
Describe and illustrate where any residual voids and mining features e.g. waste rock dumps would lie in relation to the extent of the PMF. Demonstrate that these features will not impact on the ecological functioning and physical processes of the floodplain and GBR in the longer-term.	Section 9.6.2
Assess the project's vulnerabilities to climate change (e.g. changing patterns of rainfall, hydrology, temperature and extreme weather events).	Chapter 4 – Climate
Describe possible adaptation strategies (preferred and alternative) based on climate change projections for the project.	Chapter 4 – Climate
8.6 Regulated Structures	
Conduct impact assessments on regulated structures in accordance with the EHP's *EIS information guideline—Regulated structures*, EHP's *Guideline on structures which are dams of levees constructed as part of environmentally relevant activities*[5], and EHP's *Manual for assessing hazard categories and hydraulic performance of structures*[6].	Noted
Describe the purpose of all dams or levees proposed on the project site.	Section 9.7.1 and Chapter 3 – Project Description
Show their locations on appropriately scaled maps, and provide plans and cross-sections, illustrating such features as embankment heights, spillways, discharge points, design storage allowances, and maximum volumes.	Section 9.8
Describe how storage structures and other infrastructure would be sited to avoid or minimise risks from flooding.	Section 9.6
Where project infrastructure comprises dams or other structures for storing potentially hazardous materials, undertake a consequence category assessment for each dam or levee, according to the criteria outlined in EHP's *Manual for assessing consequence categories and hydraulic performance of structures*. The assessment must be undertaken for the three different failure event scenarios described in EHP's manual, i.e. for seepage, overtopping and dam break. Regulated structures must comply with the *Manual for assessing consequence categories and hydraulic performance of structures* in accordance with Schedule 5, table 2 of the EP Regulation.	Section 9.8

[5] http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-structures-dams-levees-eras.pdf

[6] https://www.ehp.qld.gov.au/assets/documents/regulation/era-mn-assessing-consequence-hydraulic-performance.pdf

Terms of Reference	Section of the EIS
Following the consequence category assessment, determine the consequence category ('low, significant, or high') according to table 1 of EHP's *Manual for assessing hazard categories and hydraulic performance of structures* and provide certified copies of these the consequence category determination for each of the proposed dams or levees.	Section 9.8. Note; however, the proponent is seeking to have this requirement to provide certified copies of drawings as an EA Condition as this will enable the outcomes of the EIS process to be considered in final design of each dam.
Describe how risks associated with dam or storage failure, seepage through the floor, embankments of the dams, and/or with overtopping of the structures will be avoided, minimised or mitigated to protect people, property and the environment.	Sections 9.8 and 9.11