Central Queensland Coal Project

Chapter 10 – Groundwater

Supplementary Environmental Impact Statement

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Central Queensland Coal Project
Chapter 10 - Groundwater

20 December 2018

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10 Groundwater

This chapter outlines the existing groundwater environment within and surrounding the Central Queensland Coal Project (the Project) area and discusses potential impacts and mitigation measures.

The updated chapter provides additional information to that already included in the Environmental Impact Statement (EIS), in response to the submissions relating to EIS Chapter 10 – Groundwater. Appendix A13 – EIS Submissions includes the full details of all submissions received for the Project.

10.1 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 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 to 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 Dalrymple Bay Coal Terminal (DBCT).

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

Queensland Coal will manage the Project construction and ongoing operations with the assistance of contractors.

This SEIS supports the EIS by responding to the submissions that were made during the public notification period regarding the original EIS and identifies the material changes to the Project.

10.2 Relevant Legislation, Plans and Guidelines

Environmental protection is governed by several legislative Acts, plans and guidelines that are described in Chapter 1 – Introduction. Those with specific relevance to groundwater are:

- *Water Act 2000* (Qld) (Water Act);
- *Environmental Protection Act 1994* (Qld) [EP Act];
- *Environmental Protection (Water) Policy 2009* (Qld) [EPP (Water)];
- Queensland Water Quality Guidelines 2009 (QWQG) (DEHP 2009);
- 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 2000 (herein referred to as the ANZECC guidelines) (ANZECC/ARMCANZ 2000);
- National Health and Medical Research Council (NHMRC) and Medical Research Council and National Resource Management Ministerial Council (NRMMC) Australian Drinking Water Guidelines (ADWG) (NHMRC/NRMMC 2011);
- DES Mining Guideline – Model Mining Conditions; and
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act).

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

10.2.1 Water Act 2000

The *Water Act 2000* (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. The Water Act was amended in 2016 to require all mining activities to be assessed and approved for the take of incidental water extracted during operations. The changes as a result of the water reforms, with respect to the taking or interfering with groundwater, are discussed in this chapter.

Central Queensland Coal will confirm with DNRME and DES prior to the commencement of construction that all authorisations required under the Water Act have been obtained.

10.2.1.1 Water Supply

The Project area lies wholly within the Styx Catchment (Queensland river basin 127), a small catchment forming part of the Fitzroy River Natural Resource Management region that discharges into the Coral Sea adjacent to Rosewood Island (in the vicinity of the Project). No water resource plan is in force over the catchment. As such, no permit is required by the Project to interfere with overland flow.

The Project is not located within a declared sub-artesian area or groundwater management area.

Water for the construction and operation of the Project will be sourced from an external supply and trucked to the site. Once operational, water will be sourced from a number of options (see Chapter 9 – Surface Water and Chapter 10 – Groundwater).

Pursuant to section 376 of the Water Act an Underground Water Impact Report (UWIR) will be prepared prior to exercising its rights to utilise groundwater associated with the mining operations. Under the *Water Reform and Other Legislation Amendment (WROLA) Act 2014* additional matters are required to be addressed as part of the EA process. The UWIR will address the requirements of chapter three, division four, section 376 of the Water Act which stipulates that the UWIR must include:

- Part A: Information about underground water extractions resulting from the exercise of underground water rights:
  - Quantity of water already produced
  - Quantity of water to be produced in the next three years
- Part B: Information about aquifers affected, or likely to be affected:
  - Aquifer descriptions
  - Underground water flow and aquifer interactions
  - Underground water level trend analysis
- Part C: Maps showing the area of the affected aquifer(s) where underground water levels are expected to decline:
  - Maps of affected areas
  - Methods and techniques used in building a computer based hydrogeologic model, and the associated water level maps and predictions
  - Water bores within Immediately Affected Areas
  - Annual review of maps produced
- Part D: Impacts on Environmental Values (EVs):
  - Identification and description of EVs
  - Nature and extent of any impacts on the EVs
  - Impacts to formation integrity and surface subsidence
- Part E: A water monitoring strategy:
  - Rationale behind water monitoring strategy
  - Timetable for the water monitoring strategy
  - Reporting program for the water monitoring strategy

- Part F: A spring impact management strategy:
  - Spring inventory and values
  - Connectivity between the spring and aquifer
  - Management of impacts
  - Timetable for strategy
  - Reporting program.

In accordance with section 370(2), the UWIR must be submitted prior to Central Queensland Coal exercising its underground water rights. Central Queensland Coal will ensure the mandatory consultation and submission period (20 business days) as described in sections 381 and 382 of the Water Act is addressed. The UWIR submitted to the Department of Environment and Science (DES) will be accompanied by a submissions summary which is described in section 383 of the Water Act. A new UWIR will be prepared and submitted to DES generally within 10 business days after each third anniversary of the day the first UWIR took effect.

10.2.1.2 Interfering with a Watercourse

A number of watercourses intersect the Project area and are subject to the provisions of the Water Act if interfered with. Placing fill or excavating in a watercourse, as required for works associated with construction of haul roads, bridges and culverts requires a Riverine Protection Permit (RPP). A general exemption for this permit has been granted for resource holders where the works are authorised by an EA and comply with the guidelines for RPP exemption requirements' WSS/2013/726, Version 1.04 (dated 24 October 2017) (DNRM 2016). Consequently, Central Queensland Coal will be exempt from requiring a RPP.

No diversions are proposed as a result of the Project. Minor waterway diversions or realignments may be required around the open pit areas and are described in Chapter 9 – Surface Water. Watercourse diversions undertaken as part of a mining resource activity are now assessed as part of the issuing of an EA by DES. The guideline for *Works That Interfere With Water In A Watercourse – Watercourse Diversions* (DNRM 2014) outlines the considerations which must be satisfied in the assessment of the EA. As such no additional approvals under the Water Act are required for watercourse diversions or realignments.

10.2.2 Environmental Protection (Water) Policy 2009

The object of the *Environmental Protection Act 1994* (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). Of the five pieces of subordinate legislation under the EP Act the EPP (Water) applies directly to groundwater.

The EPP (Water) provides a framework for:

- Identifying EVs and management goals for Queensland waters;
- Stating water quality guidelines and objectives to protect or enhance 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.

The Project is wholly contained within the Styx River Basin. 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 (DEHP 2014).

10.2.3 Queensland Water Quality Guidelines 2009

The Queensland Water Quality Guidelines (DEHP 2009) (QWQG) are tailored guideline values for Queensland water types and regions. The QWQG also provides a framework for deriving and applying specific guidelines that are local to the water systems in Queensland. The WQOs for a water that is not in Schedule 1 of the EPP (Water) are the set of water quality guidelines (e.g. the QWQG and ANZECC) for all indicators that will protect all EVs for the water.

10.2.4 Australian and New Zealand Guidelines for Water Quality 2000

The ANZECC water quality guidelines provide a baseline for monitoring and measuring 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.

10.2.5 Australian Drinking Water Guidelines 2011

The ADWG has been developed by the NHMRC in collaboration with the Natural Resource Management Ministerial Council (NRMMC). The ADWG is designed to provide an authoritative reference to the Australian community and the water supply industry on what defines safe, good quality water, how it can be achieved and how it can be assured.

10.2.6 Mining Guideline – Model Mining Conditions

The purpose of the Model Mining Conditions is to provide a set of model conditions to form general environmental protection commitments for the mining activities and the EA conditions pursuant to the EP Act. The guideline states that the 'model conditions should be applied to all new mining project applications lodged after the guideline is approved', therefore the Project is subject to the groundwater conditions outlined in this guideline. Schedule E of the Model Mining Conditions provides the regulatory conditions, associated with groundwater, for mining activities.

Refer to Chapter 23 – Draft EA Conditions for the proposed groundwater conditions for the Project.

10.2.7 Environment Protection and Biodiversity Conservation Act 1999

The Project was identified as having the potential to impact on Matters of National Environmental Significance (MNES) and was referred to the Commonwealth Department of the Environment (DotE), now the Department of the Environment and Energy (DotEE). The Project was deemed to be a controlled action requiring approval under the EPBC Act (EPBC ref 2016/7851).

A stand-alone chapter has been prepared and assessed as part of approval under the EPBC Act; refer to Chapter 16 – Matters of National Environmental Significance. The assessment bilateral process allows for the assessment of impacts on MNES to be undertaken as part of the State EIS process, with input from the Department throughout. Assessment of the Project under the EPBC Act in Chapter 16 includes water resources related to coal seam gas and large coal mining developments as a MNES (the 'water trigger').

10.3 Environmental Objectives and Performance Outcomes

10.3.1 Environmental Objective

The environmental objective relevant to groundwater is provided in the *Environmental Protection Regulation 2008* (EP Regulation). In accordance with the EP Regulation, the Project groundwater objective is to operate in a way that protects the EVs of groundwater, and any connected surface ecosystems.

10.3.2 Performance Outcomes

The main aim of the Project is for no change to groundwater quantity that can impact adversely on existing users, or actual or potential discharge to groundwater 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 groundwater:

- There will be no direct or indirect release of contaminants to groundwater from the operation of the activity that will cause an adverse effect on a groundwater EVs;
- There will be no loss of supply caused by drawdown associated with the operations of the mine to beneficial users of groundwater;
- There will be no permanent adverse impact on GDEs; and
- There will be no actual or potential adverse effect on groundwater from the operation of the activity, or, the activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.

10.4 Description of Environmental Values and Water Quality Objectives

The EIS identifies and describes the groundwater EVs that must be protected. EVs are specified in the EP Act, the EP Regulation, environmental protection policies (EPPs) and relevant guidelines.

The Project is wholly contained within Styx River Basin. Specific EVs and WQOs for 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 (DEHP 2014). Existing groundwater users within the Basin include commercial users (e.g. agriculture and stock water supply), social and cultural users (e.g. domestic water supply), and environmental users (e.g. aquatic, riparian, terrestrial and subterranean ecosystems).

This section has been updated with additional detail in respect of EVs, WQOs and environmental performance outcomes.

10.4.1 Groundwater Environmental Values

Groundwater EVs are assessed based on the hydrogeological conceptualisation presented in Section 10.5.6.8 utilising all available information from desktop assessment, onsite groundwater investigations and a comprehensive literature review.

Groundwater EVs are defined by their contribution to the water requirements of ecological systems and/ or anthropogenic water users. The suitability of groundwater for supporting dependant ecosystems and/ or the purposes for which it is abstracted are key indicators of EVs. Groundwater EVs must be protected from pollution, depletion and flow modification such that habitats are maintained and to ensure groundwater continues to meet the requirements of the community both in terms of quantity and quality.

To protect the aquifers of the Project area 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 groundwaters for various beneficial uses and has established EVs and WQOs for a number of Basins including the Styx River Basin. The EVs considered applicable to the Project are outlined in Table 10-1 and Figure 10-1, which also shows the Project is located primarily within the Styx (03) and Uplands (10) Groundwater Chemistry Zones (GCZ), but a small northern part of the Project is located within the Bison (15) GCZ.

The assessment presented in this Chapter also needs to consider the potential zone of influence on the Basin's groundwater system, which is likely to extend across all three GCZs. Table 10-2 presents WQOs for each of the GCZs.

Table 10-1 Environmental values for waters associated with the Project

Environmental Values [1]											
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
✓	✓	✓	✓								✓

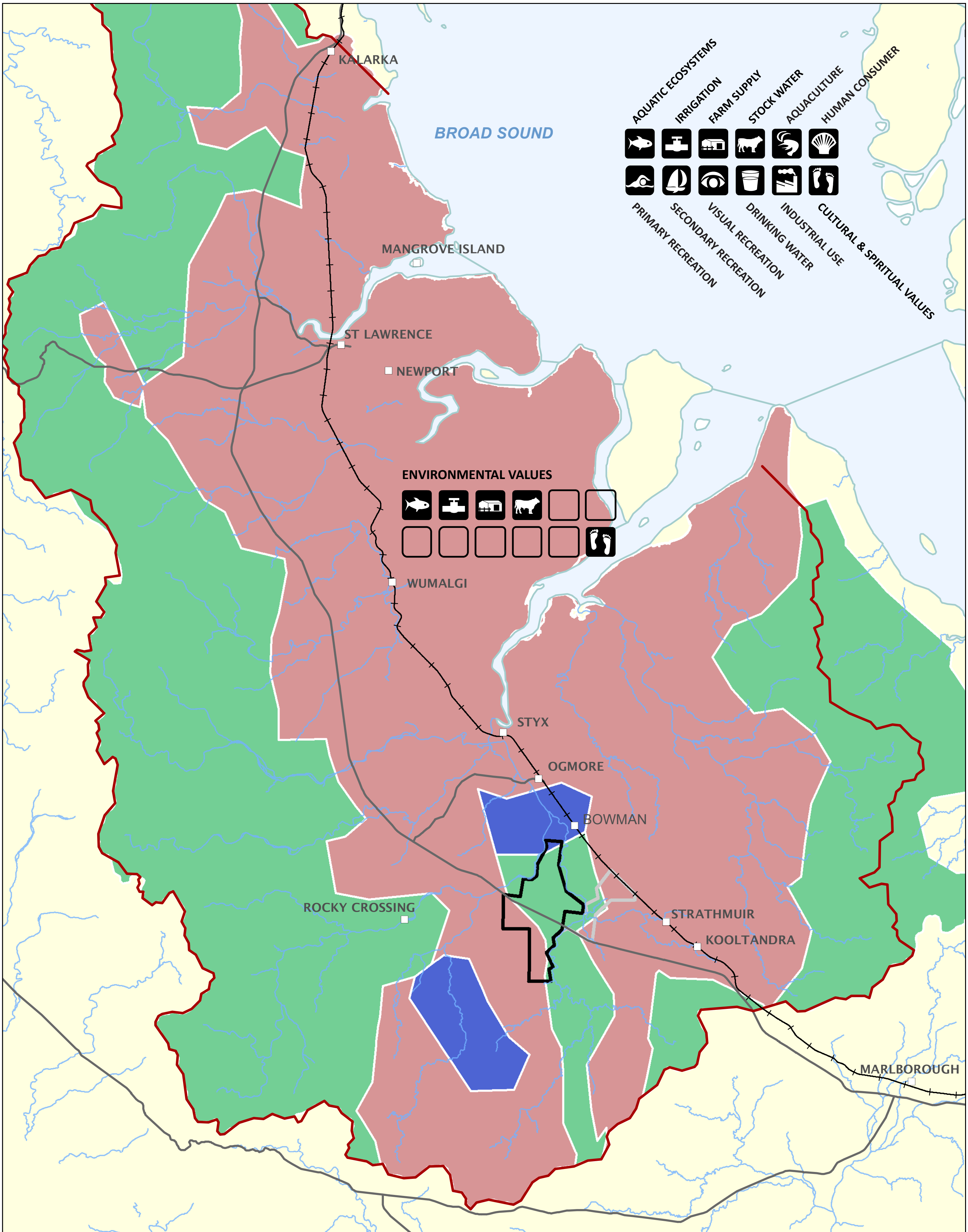
Notes: ✓ indicates groundwater is suitable for the EV, and grey shading indicates groundwater is not suitable for the EV

10.4.2 Water Quality Objectives

The purpose of defining WQOs, which are long-term goals for water quality management, is to support and protect EVs (DEHP 2009). Notably, where groundwater and surface water interaction occurs, it is important that the WQOs of either resource are not compromised by degradation of water quality in either resource. The ANZECC Guidelines recommend that underground aquatic ecosystems are afforded the highest level of protection (DEHP 2009).

As mentioned above, WQOs vary across the Styx Basin and are defined on the basis of GCZs (refer Figure 10-1 and Table 10-2). The applicable GCZs for the Project are:

- Styx (zone 03);
- Uplands (zone 10); and
- Bison (zone 15).



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Legend

Groundwater Zone

- Bison
- Styx
- Uplands
- Styx River Basin
- ML 80187
- ML 700022
- Main road
- Watercourse
- North Coast Rail Line

Figure 10-1

Styx Basin WQ1273 groundwater zones (adapted from QLD Government WQ1273)

DATA SOURCE
QLD Open Source Data, 2018;
Central Queensland Coal, 2017;
Environmental Protection (Water) Policy 2009.

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Table 10-2 WQOs for groundwater resources having the potential to be impacted by the Project

Depth[2]	Percentile	Indicator / WQO[1]																		
		Na	Ca	Mg	HCO3	Cl	SO_4	NO_3	EC (µs/cm)	Hardness	pH (units)	Alkalinity	SiO_2	F	Fe	Mn	Zn	Cu	SAR (unitless)	RAH (meq/L)
GCZ		**Styx**																		
S	20th	781	95	163	326	1,727	164	-	6,445	867	7.5	272.5	23	0.32	-	0.035	0.039	-	7.6	
	50th	1,296	222	209	583	2,342	301	0.00	7,620	1,346	7.7	478.5	30	0.68	-	0.165	0.140	0.010	15.3	
	80th	1,564	315	310	628	3,607	653	3.26	9,887	1,995	8.0	524.5	33	1.07	0.09	0.478	12.67	0.041	22.6	
M	20th	763	35	137	52	1,617	18	0.65	5,457	711	5.1	42.5	30	0.47	-	0.105	0.144	0.071	11.25	
	50th	1,062	70	185	105	2,094	100	2.00	7,380	1,121	7.2	86.0	43	0.60	-	0.330	0.900	0.080	13.90	
	80th	1,650	235	211	793	3,045	278	5.50	9,490	1,302	7.6	653.5	79	1.08	0.34	1.878	1.035	0.476	22.60	
GCZ		**Uplands**																		
VS	20th	38	38	42	328	71	20	0.62	774	330	7.5	275.0	28	0.09	-	-	0.010	0.010	0.87	-
	50th	60	55	17	266	64	22	1.00	680	234	7.8	220.0	30	0.20	0.01	0.010	0.010	0.010	1.70	0.40
	80th	100	84	39	506	97	44	7.00	970	35	8.1	417.6	36	0.50	0.04	0.010	0.045	0.015	2.60	2.31
M	20th	85	56	34	449	49	13	2.25	899	314	7.5	370.9	31	0.35	-	-	0.010	0.010	1.90	0.51
	50th	93	79	38	511	75	33	7.70	1,050	376	7.8	422	35	0.58	0.01	-	0.020	0.020	2.10	1.43
	80th	108	98	64	590	111	38	11.27	1,225	431	8.0	486.2	51	0.60	0.03	0.010	0.068	0.030	2.60	1.84
GCZ		**Bison**																		
S	20th	137	45	31	332	180	29	-	1,060	240	6.8	272.	30	0.20	0.02	-	-	-	2.20	1.31
	50th	245	75	52	560	330	49	-	1,800	401	7.6	465.0	30	0.30	0.02	-	-	-	4.20	1.53
	80th	289	402	106	605	995	153	-	3,675	1,441	8.0	500.0	38	0.50	0.02	-	-	-	5.3	1.74
M	20th	384	542	327	210	2,200	189	12.90	6,570	2,699	7.2	173.0	29	0.23	-	-	-	-	3.10	-
	50th	390	582	344	237	2,337	202	23.55	7,035	2,869	7.4	195.0	31	0.27	-	-	-	-	3.15	-
	80th	396	623	361	263	3,474	215	34.20	7,500	3,038	7.5	217.0	33	0.30	-	-	-	-	3.20	-

Notes:
1. All as mg/L unless otherwise indicated; "-" not designated
2. VS = very shallow (<5 m); S = shallow (5-20 m); M = moderate (20-40 m)

10.5 Existing Environment

The following sections describe the existing environment within the Project area.

10.5.1 Data availability

The sources of available data used to inform this study are summarised in Table 10-3.

Table 10-3 Summary of data availability

Source	Data type(s)	Data period(s)
Bureau of Meteorology (BoM), 2018	Temperature Rainfall (Strathmuir station 033189 and Rockhampton Aero station 039083	1939 - 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
Fitzpatrick et al. 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	
	Facility status	As at February 2018
Third party bore census [2]	Groundwater levels	February 2017 – July 2018
	Field measured groundwater quality (physico-chemical)	
	Laboratory reported groundwater chemistry	
	Bore purpose and use status	Anecdotal, where available
Styx Coal Project WMP bores (installed 2017 and early 2018) drilling, testing and monitoring data [3]	Groundwater levels	September 2017 – September 2018
	Field measured groundwater quality (physico-chemical)	
	Laboratory reported groundwater chemistry	
	Lithology (and inferred stratigraphy)	Not applicable
	Hydrogeological properties	
	Groundwater levels	Point data from post-development
	Field measured groundwater quality (physico-chemical)	

Source	Data type(s)	Data period(s)
Styx Coal Project WMP bores (installed late 2018) drilling, testing and monitoring data [4]	▪ Lithology (and inferred stratigraphy)	▪ Not applicable
	▪ Hydrogeological properties	
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 March 2012 ▪ February 2017 to September 2018
	▪ Laboratory reported water chemistry	▪ June 2011 to March 2012 ▪ February 2017 to September 2018
Field observations and discussions with landholders/care takers	▪ Streamflow frequency and magnitude	▪ Anecdotal
	▪ Occurrence of potentially groundwater dependent pools	▪ 2011; 2017 – September 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
Queensland Herbarium, 2018	▪ Qld Regional Ecosystem (vegetation) mapping - V10.1	▪ Not applicable
Queensland open source spatial data, 2018	▪ Wetland mapping under Vegetation Management Act 1999.	▪ 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
4. A total of 30 monitoring bores were installed for the Project in late 2018

10.5.2 Climate

Chapter 4 – Climate of the SEIS presents a detailed description of the climatic setting of the Project. 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 10-2. The longest and most continuous rainfall record closest to the Project has been obtained from Bureau of Meteorology (BoM) Station 033189 located at Strathmuir, approximately 7 km east of the Project, with records from 1941 to present. Mean temperature data have been obtained from BoM Station 039083, located at Rockhampton Aero, approximately 112 km from the Project, with records dating back to 1939 (no temperature data are available for the Strathmuir weather station).

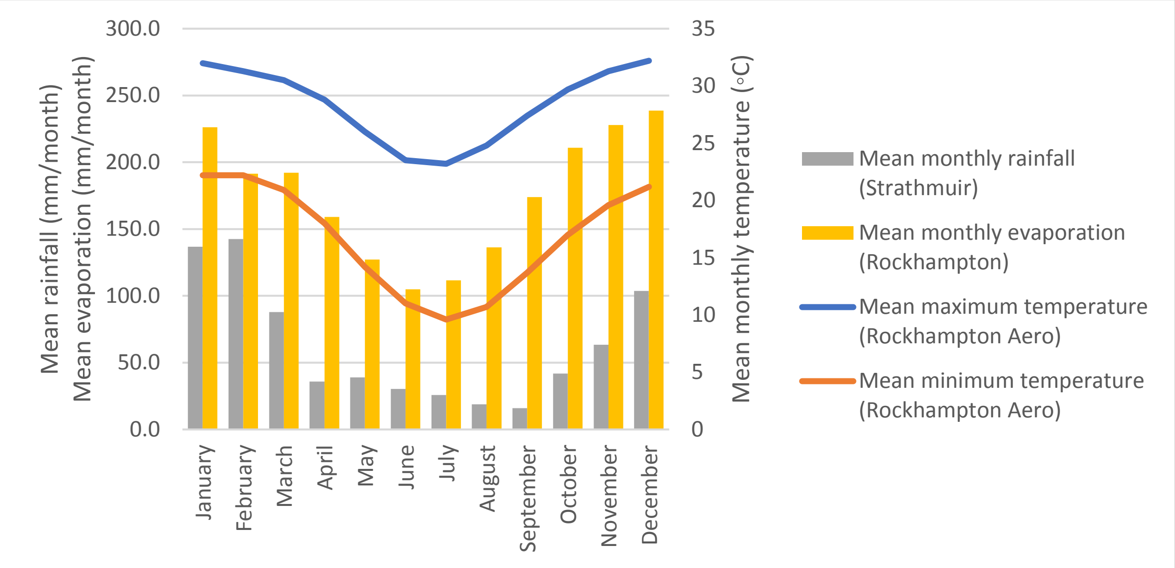


Figure 10-2 Mean climatic conditions

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 10-2).

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

Cumulative deviation from mean rainfall is the accumulated difference between actual rainfall (e.g. in a month or a year) and the long-term mean, providing an indication of the general climatic trend over time as well as general water availability (soil water, surface water and groundwater). A cumulative deviation from mean (CDFM) plot of monthly rainfall at Strathmuir (BoM Station 033189) and Rockhampton Aero (BoM Station 039083) from January 1941 to February 2018 is presented in Figure 10-3. The plot indicates that climate (rainfall) variability is typical of the Project area, with periods of:

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

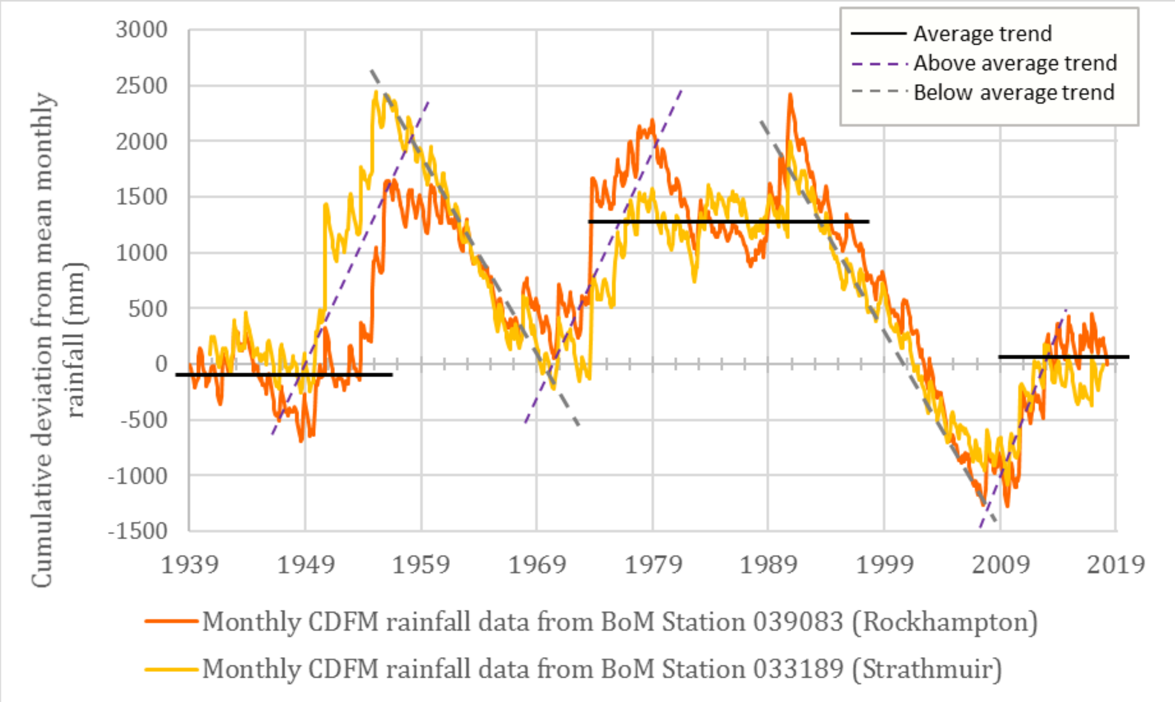


Figure 10-3 Cumulative deviation from mean monthly rainfall from BoM Station 033189 (Strathmuir) and 039083 (Rockhampton Aero)

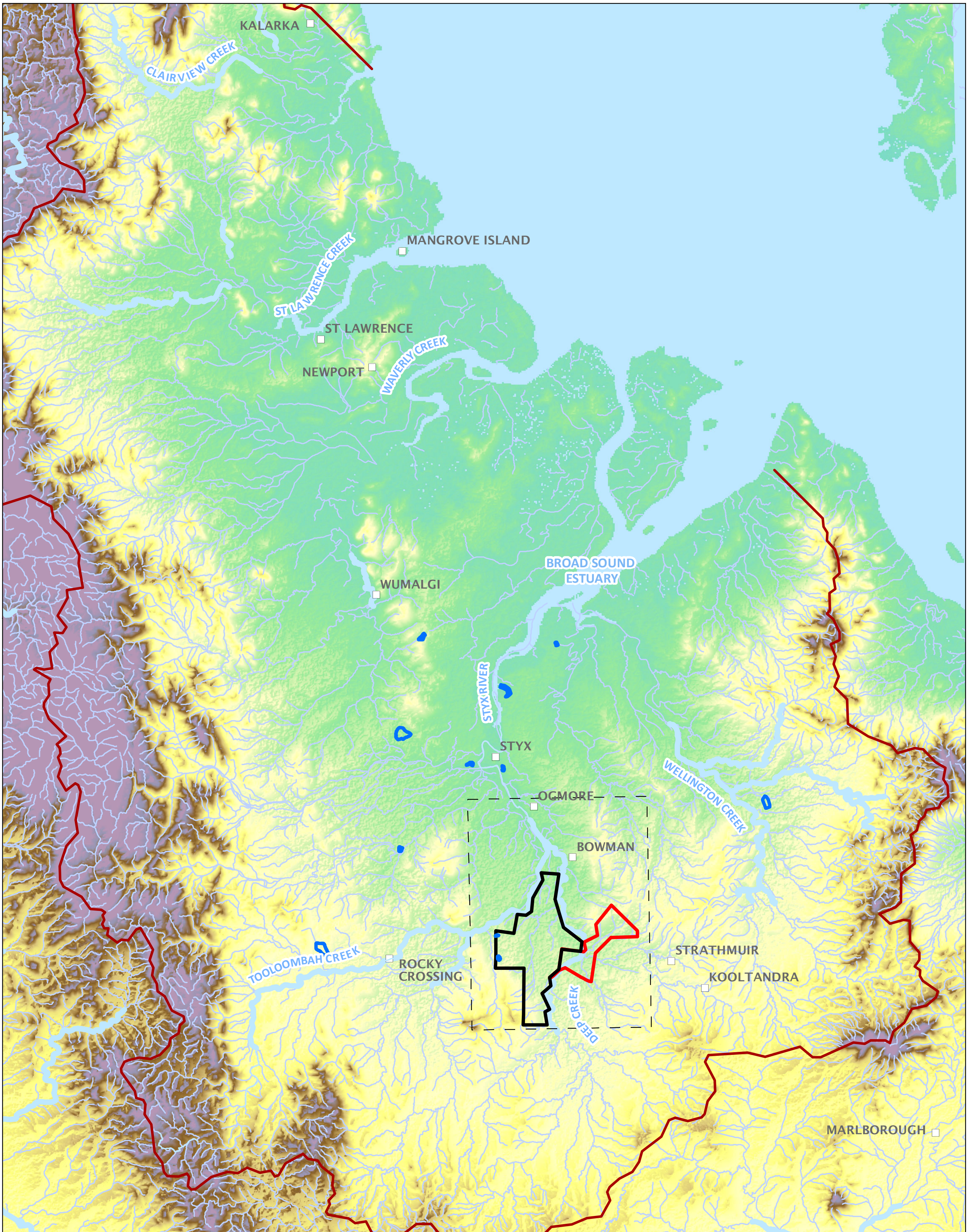
The mean monthly evaporation (calculated from the long-term average daily evaporation at Rockhampton Aero (BoM Station 039083)) ranges from a maximum of around 240 mm per month in the summer months to a minimum of around 105 mm per month in the winter months. Total average annual evaporation (around 2,100 mm) is considerably higher than average annual rainfall, and on average evaporation rates exceed rainfall rates in every month of the year (Figure 10-2).

10.5.3 Topography

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

The Project lies within the Styx River catchment of the larger Styx River Basin, which has elevations ranging from 540 m Australian Height Datum (AHD) along the western catchment boundary to sea level at the coast (see Figure 10-4). Topography at the Project predominantly comprises flat or undulating lands ranging between around 10 and 155 m AHD. The area is drained by several tributary creeks to the Styx River and Broad Sound Estuary, including Deep and Tooloombah Creeks (see Figure 10-4).

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 10-5 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).



Scale @ A4 1:325,000
Date: 29/11/18
Drawn: A. Aird

Legend

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

Surface Elevation (mAHD)

High : 620

Low : -10

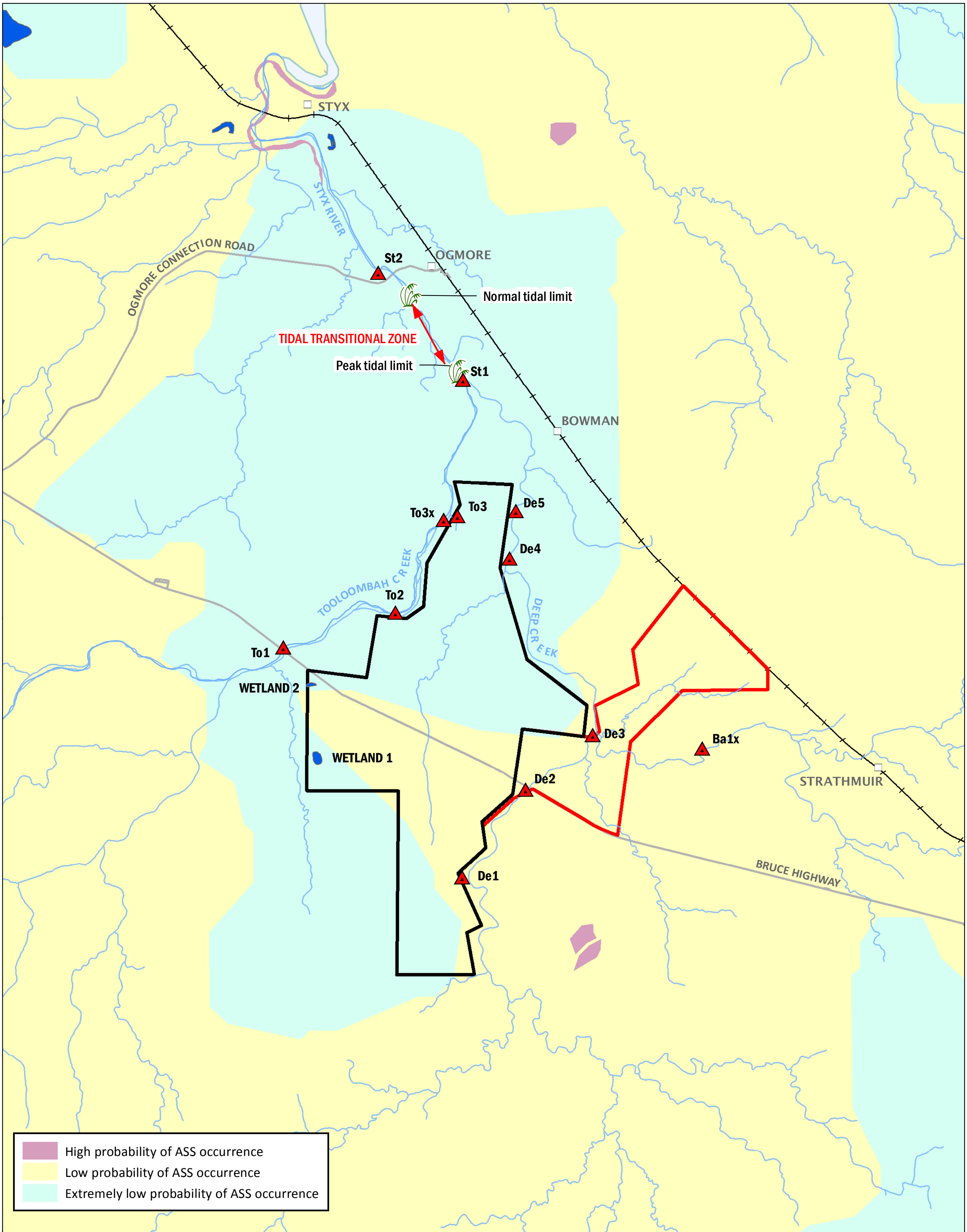
Figure 10-4

Topography and hydrology

DATA SOURCE
QLD Open Source Data, 2018;
1 Second SRTM v1.0 © Commonwealth of Australia (Geoscience Australia) 2011.
Waratah Coal, 2017

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Topography&drainage.mxd 11/29/2018



N

0 1 2 km

Scale @ A4 1:100,000
Date: 29/11/18
Drawn: A. Aird

Legend

- Occurence of Marine Couch
- Surface water monitoring site
- Wetland (VM Act)
- ML 80187
- ML 700022
- Main road
- North Coast Rail Line
- Watercourse
- Waterbody

Figure 10-5
Acid sulphate soils and tidal zone limit map

DATA SOURCE
QLD Open Source Data, 2018;
CSIRO, 2011;
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 acid sulphate soils.mxd 11/29/2018

10.5.4 Hydrology

The Styx River Basin comprises a number of distinct surface water catchments (Figure 10-4), including:

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

Further information on hydrology within the Styx River Basin is presented in Chapter 9 - Surface Water.

10.5.4.1 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 (Figure 10-4). 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 (see Section 10.5.4.3 for more detail, and Figure 10-5) and discharges to the Broad Sound Estuary, which extends from just downstream of Styx township, approximately 8 km downstream (north) of the Project, to the coast, approximately 32 km further downstream (see Figure 10-4). 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 due to 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 10-5 shows an area of high probability of ASS extending up along Styx River, approximately 7 km from the Project, which likely represents the extent of the normal low tide limit where permanently inundated soils are expected to occur. Note: the areas within and around the Project are mapped as having an extremely low or low probability of ASS; and

- 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 and below the confluence of Tooloombah and Deep Creeks, which probably represents the normal high tide limit (Figure 10-5)
  - Sparse occurrences of Marine Couch are observed further upstream, near the confluence of Deep and Tooloombah Creeks (approximately 2.5 km downstream of the Project) at a streambed elevation of approximately 6.5 m AHD, which probably represents the peak tide limit associated with king tides and storm surges (Figure 10-5).

10.5.4.2 Deep Creek and Tooloombah Creek Sub-catchments

Both Deep Creek and Tooloombah Creek are located outside the MLs, but the Project area occurs within their catchments (Figure 10-4). 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 ephemeral.

Deep Creek

The tributary headwaters of Deep Creek occur to the south of the Project, at elevations around 90 to 180 m AHD, 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, ephemeral 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 upstream, and 5 to 10 m downstream, of the Project. The creek bed is comprised of silts, sands and clays, and has a generally smooth channel with little vegetation that would provide resistance to flow.

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

Anecdotal evidence suggests large seasonal flow events are around 4 m deep and persist for several days only. During high streamflow events, Deep Creek is likely to be a local source of recharge to the near-stream shallow alluvial aquifer, most of which will take the form of bank storage that will drain back to the creek as flow declines (bank storage return). This process, supported by creek gouge to the water table, is expected to sustain isolated pools along the creek bed between flow events. This interaction between surface water and groundwater is discussed further in Section 10.5.6.7.

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 Q1-Q3 2018 (refer Figure 10-7). The number of baseline sampling events at surface water monitoring locations is presented in Table 10-4.

Table 10-4 Styx Project surface water baseline sampling summary

Bore ID	Sampling period		Number of sampling events	Number of samples collected[1]	Dry
	Earliest	Most recent			
St1	Jun-11	Jan-12	7	7	
	Feb-17	Sep-18	15	15	
St2	Jun-11	Mar-12	9	9	
	Mar-18	Sep-18	8	8	
To1	Jun-11	Mar-12	8	8	
	Feb-17	Sep-18	18	16	2
To2	Jun-11	Dec-11	5	5	
	Feb-17	Sep-18	18	16	2
To3	Jun-17	Sep-18	16	14	2
De1	Jun-11	Mar-12	8	3	4
	Feb-17	Sep-18	15	8	7
De2	Jun-11	Mar-12	8	8	
	Feb-17	Sep-18	15	11	4
De3	Jun-11	Dec-11	5	5	
	Feb-17	Sep-18	16	11	5
De4	Feb-17	Sep-18	16	16	
De5	Dec-17	Sep-18	12	11	1
Ba1	Feb-17	Jun-17	3	2	1

1. Samples sometimes could not be collected due to dry pool

Water salinity data (as electrical conductivity, EC) are presented at Figure 10-6 for 2017 and 2018 sampling events (there are insufficient data to present 2011 and 2012 data). The water is generally fresh, ranging from 150 to 800 µS/cm EC. A seasonal influence is evident, with a general salinity increase during periods of no flow and following the first flush of salts and nutrients experienced at the beginning of the wet season.

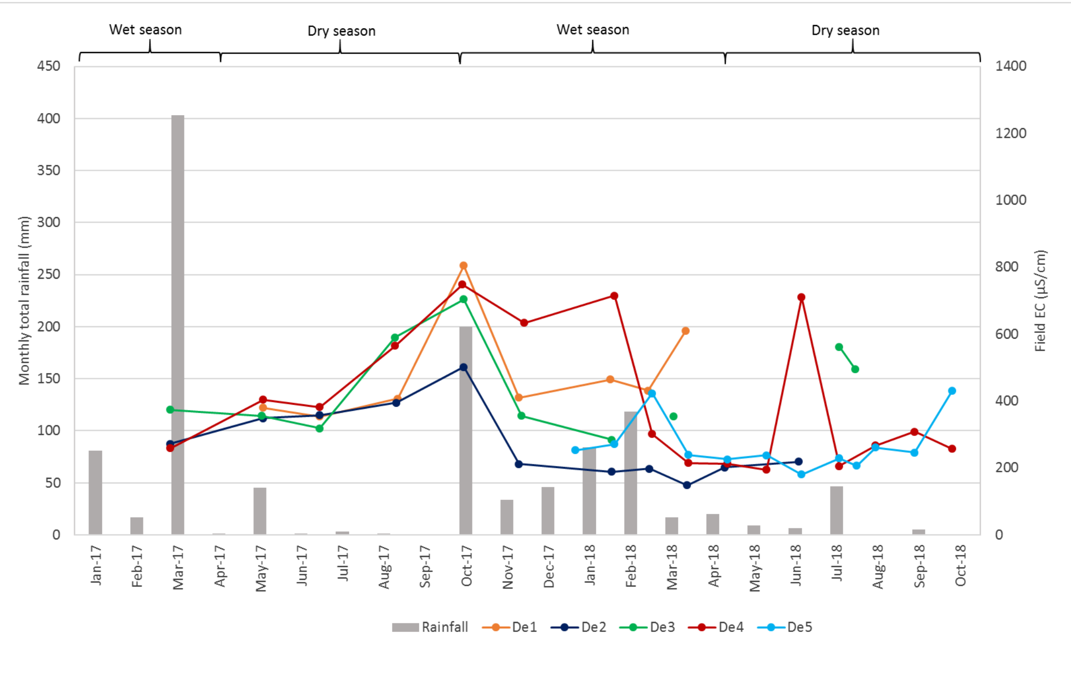
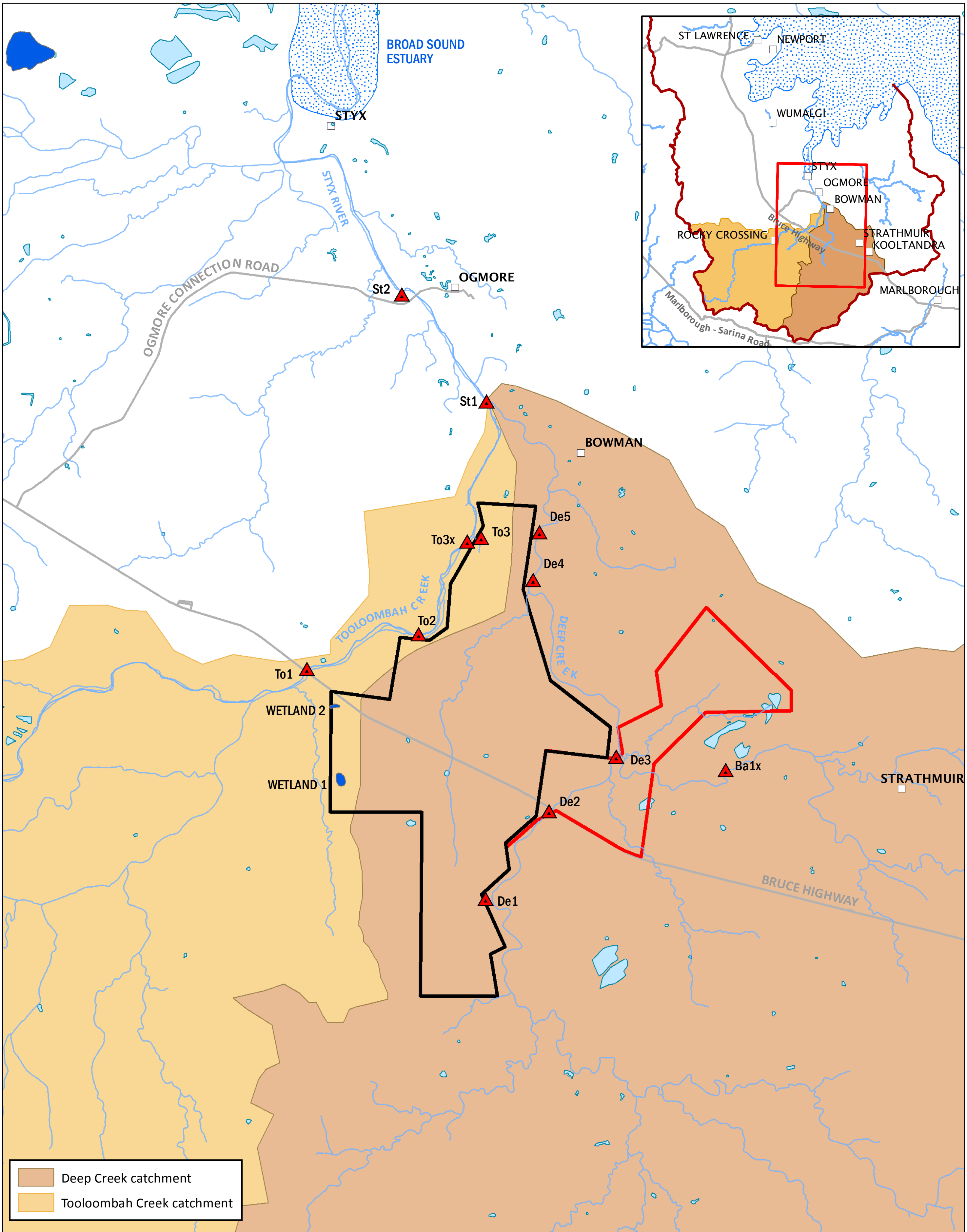


Figure 10-6 Deep Creek field EC - 2017 and 2018



N

0 1 2 km

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

Legend

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

Figure 10-7
Tributary catchments and monitoring locations

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

CDM Smith

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 10-8. The major ion composition of water samples collected from surface water monitoring locations in November 2017, March 2018 and September 2018 are also presented as Stiff patterns on Figure 10-9 to Figure 10-11. As expected, the Piper plot and Stiff patterns show Deep Creek water chemistry is more similar to Rockhampton rainfall than it is to seawater. The Stiff patterns (Figure 10-9 to Figure 10-11) 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. The surface water quality is discussed further in Chapter 9 – Surface Water.

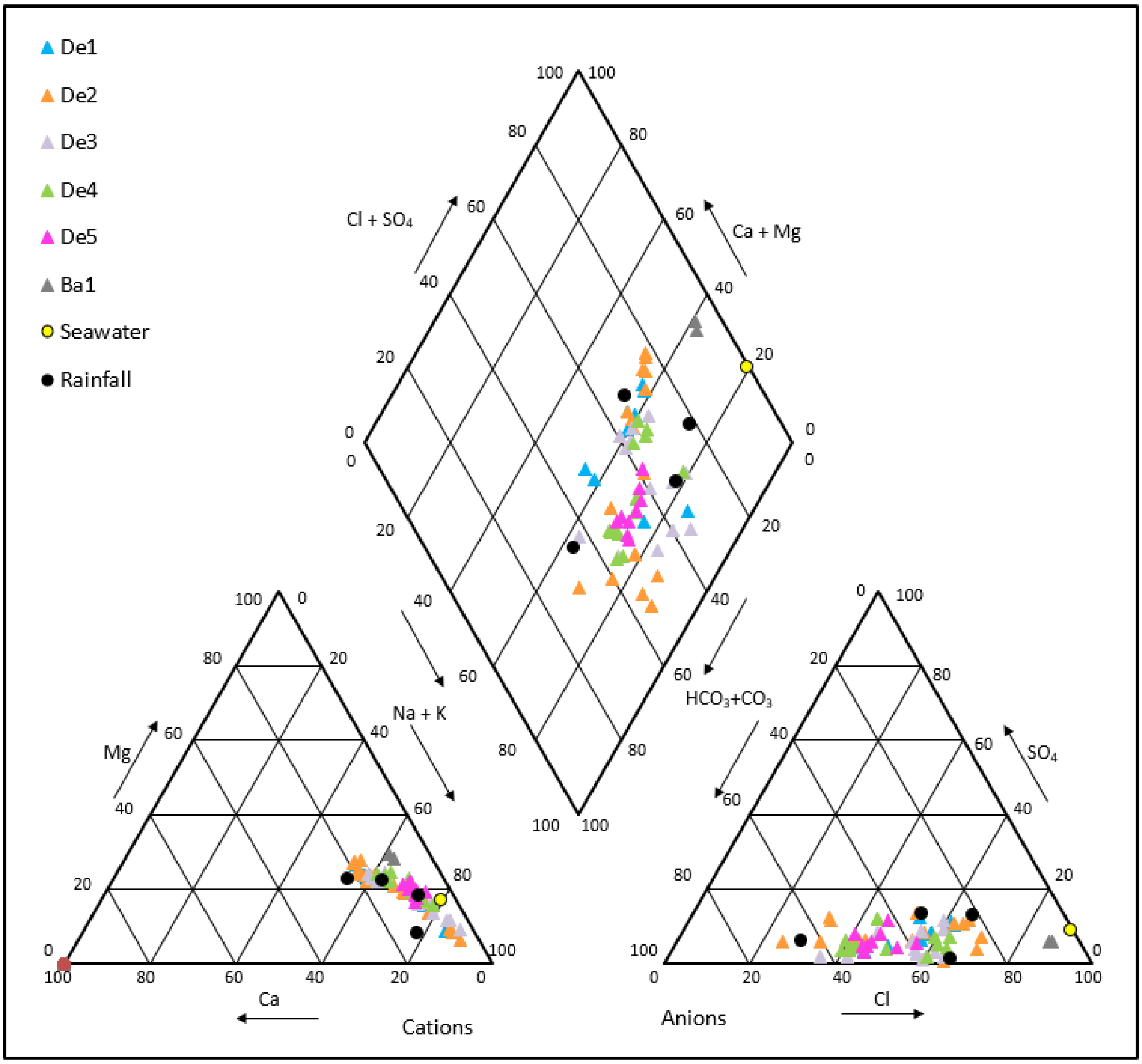
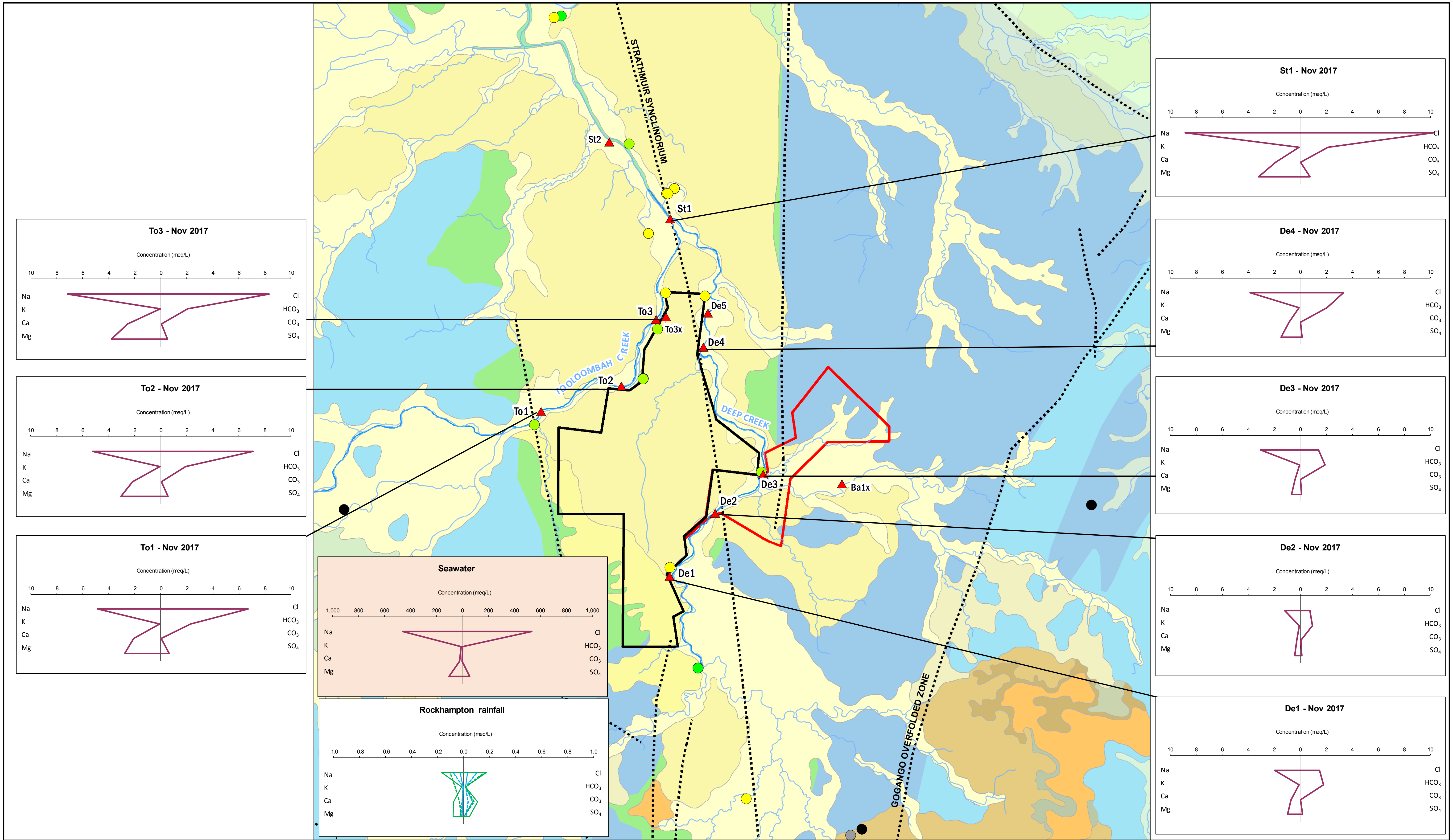


Figure 10-8 Deep Creek water quality Piper diagram



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

N

0 1 2 km

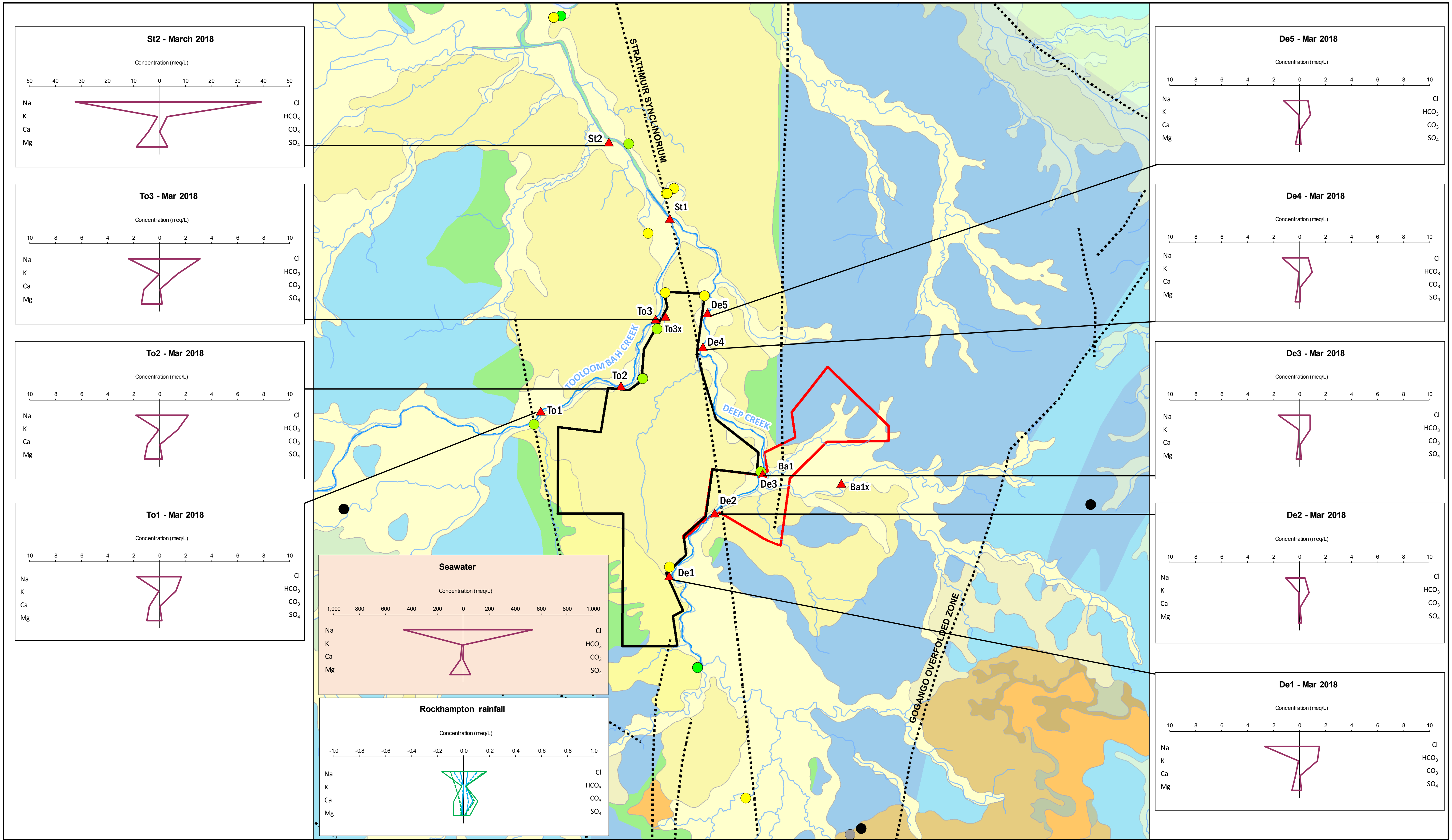
Scale @ A3 1:100,000
Date: 29/11/18
Drawn: KMH

Figure 10-9
Surface water Stiff patterns – November 2017 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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 SW_quality_Stiff_Nov2017_R1.mxd 11/29/2018



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

N

0 1 2 km

Scale @ A3 1:100,000

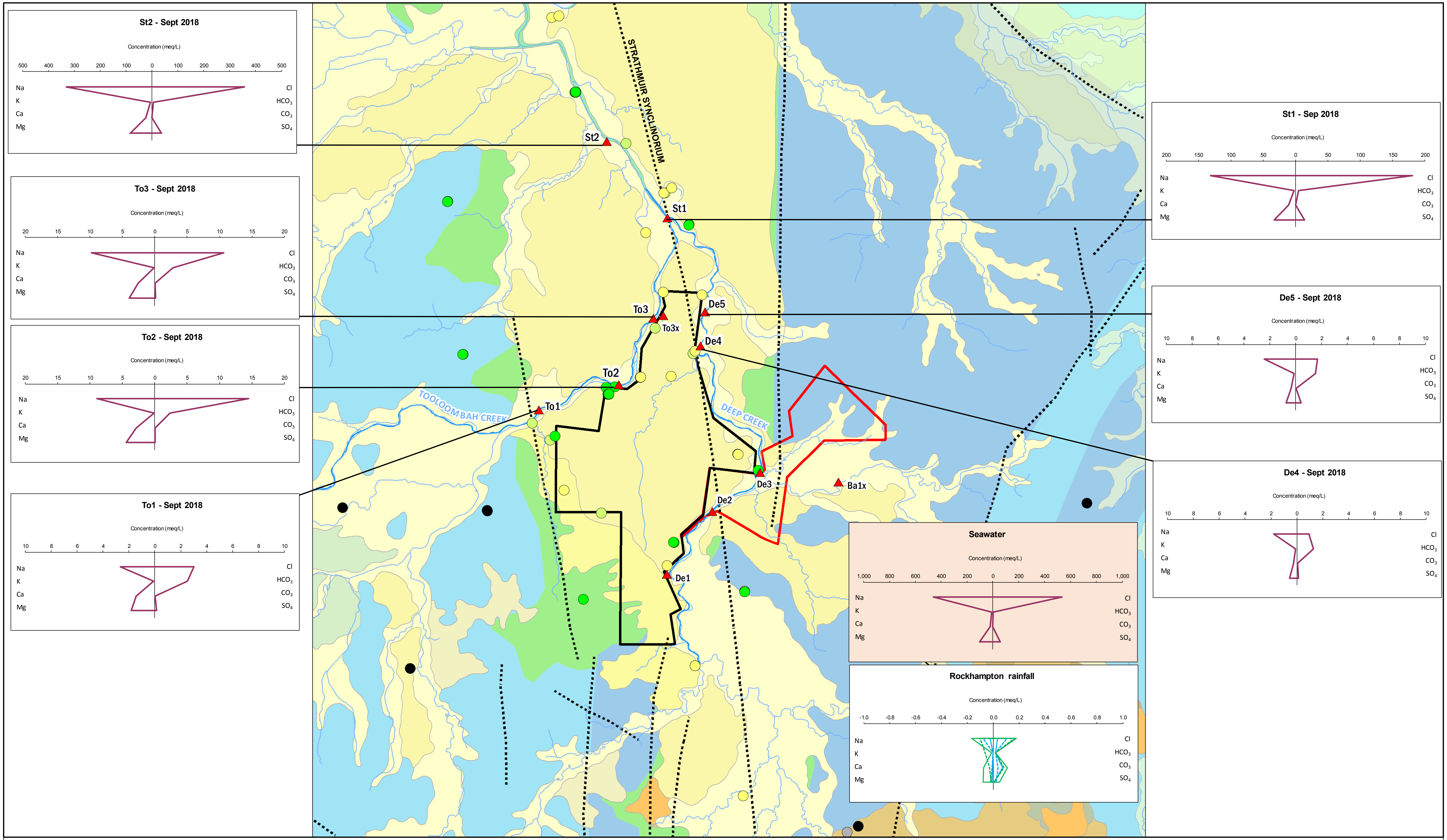
Date: 29/11/18

Drawn: KMH

Figure 10-10
Surface water Stiff patterns – March 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



N

0 1 2 km

Scale @ A3 1:100,000
Date: 29/11/18
Drawn: KMH

Legend

Groundwater 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 10-16 for geology legend

Figure 10-11

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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 SW_quality_Stiff_Sep2018_R1.mxd 11/29/2018

Tooloombah Creek

The tributary headwaters of Tooloombah Creek rise to the southwest of the Project area, where elevations of around 360 m AHD occur. The creek runs in a general northeasterly direction adjacent to the western Project boundary before joining Deep Creek around 2 km downstream of the Project. The total catchment area of Tooloombah Creek is around 370 km^2. There are no streamflow data available for Tooloombah Creek, however, like Deep Creek it is classified as a major, ephemeral 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; Figure 10-7).

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

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 10-7 for locations). Water salinity (as EC) is presented on Figure 10-12 for 2017 to Q3 2018 sampling events (there is insufficient data to present 2011 and 2012 data), and shows salinity is generally higher than Deep Creek, ranging from around 170 to 3,200 µS/cm EC.

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

The results of laboratory analysis of Tooloombah Creek surface water samples are presented, along with seawater and rainfall chemistry from Rockhampton, on a Piper (trilinear) plot on Figure 10-13. The major ion composition of surface water samples collected in November 2017, March 2018 and September 2018 are also presented as Stiff patterns on Figure 10-9 to Figure 10-11. 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. However, water chemistry is more like rainfall than seawater. 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 10.5.6.7 for further discussion). The Stiff patterns also show surface water composition varies between the dry and end of wet season likely due to dilution by surface water runoff.

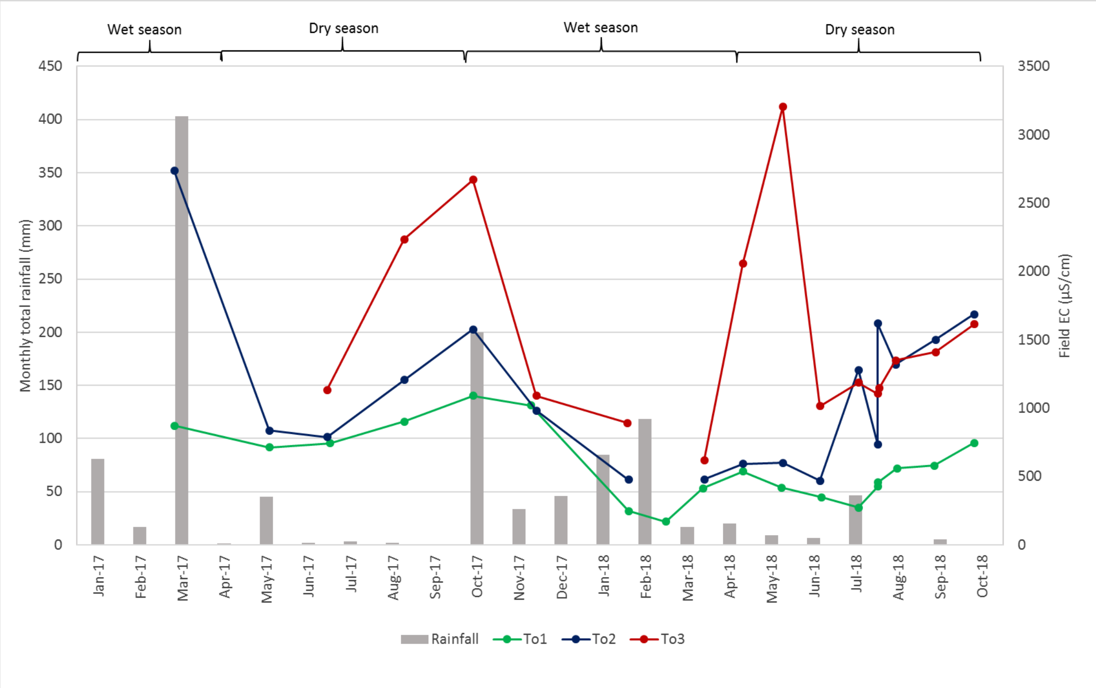


Figure 10-12 Tooloombah Creek field EC – 2017 and 2018

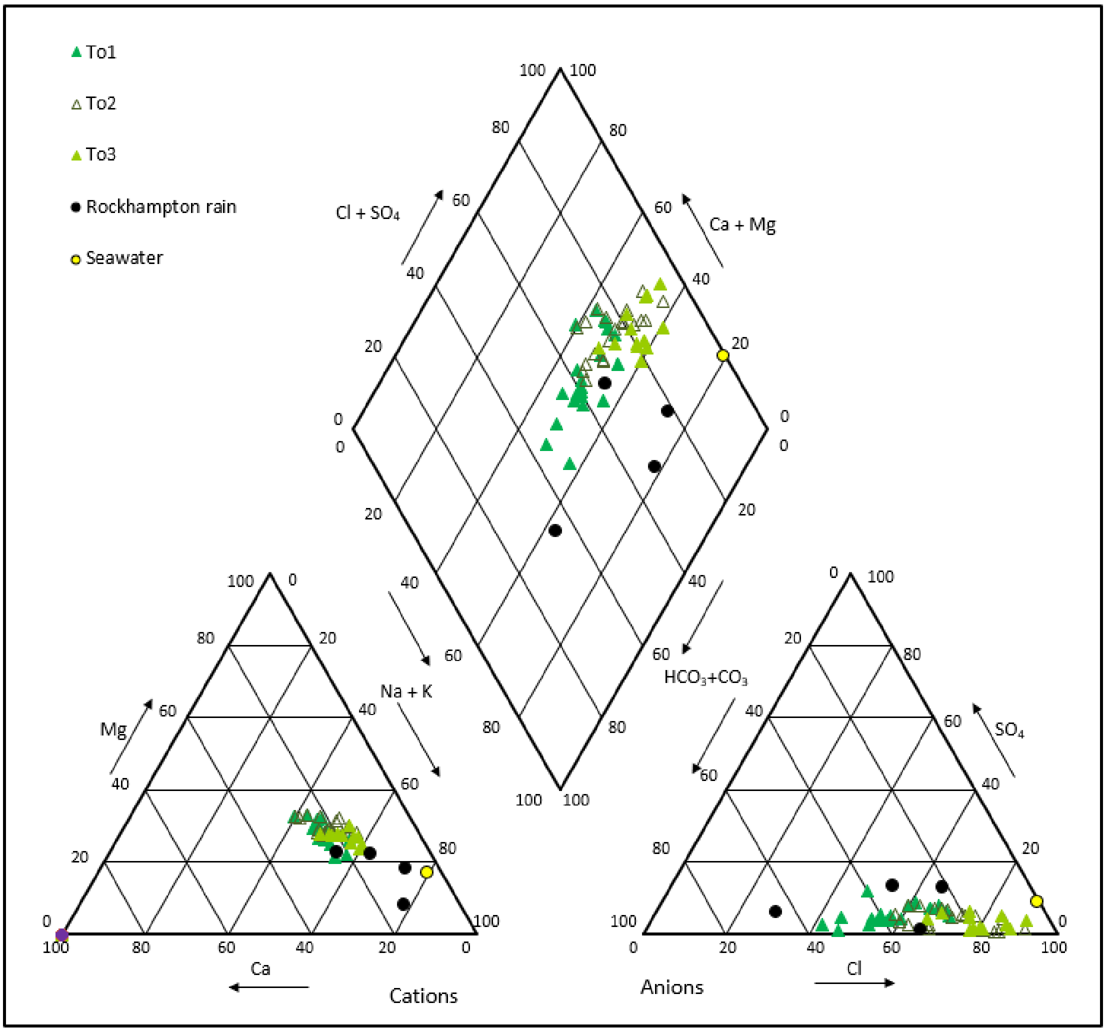


Figure 10-13 Tooloombah Creek water quality Piper Diagram

Large pools of water have been observed within the creek during all sampling events in 2011, 2012, 2017 and 2018 when flow events were not occurring. Water held in these pools appears less turbid than Deep Creek pools, due to a combination of catchment hydrology (less erosion and slower flows), possible reduced stock access and increased residence time of pool water enabling sediments to settle. The presence of these pools is discussed further in Sections 10.5.6.7.

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 10-7). The more southern of the two wetlands ('Wetland 1'), has been mapped as a Wetland Protection Area whilst the wetland located further to the north ('Wetland 2'), has been mapped under the Department of Natural Resources, Mines and Energy (DNRME) vegetation mapping. A detailed description of the wetlands is provided in SEIS Chapter 15 – Aquatic Ecology.

Water quality data 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 a groundwater signature.

10.5.4.3 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 estuarine waters providing brackish to saline conditions that are markedly different from the higher sub-catchments. At the confluence of Deep and Tooloombah Creeks the Styx River channel is approximately 10 to 12 m wide and 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 (refer Figure 10-7). As Styx River is tidally influenced, river water salinity varies from fresh (125 µS/cm) to saline (more than 35,000 µS/cm) depending on timing and location of the sampling. Water quality results are presented on a Piper plot at Figure 10-14 and show Styx River water chemistry ranges from 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.

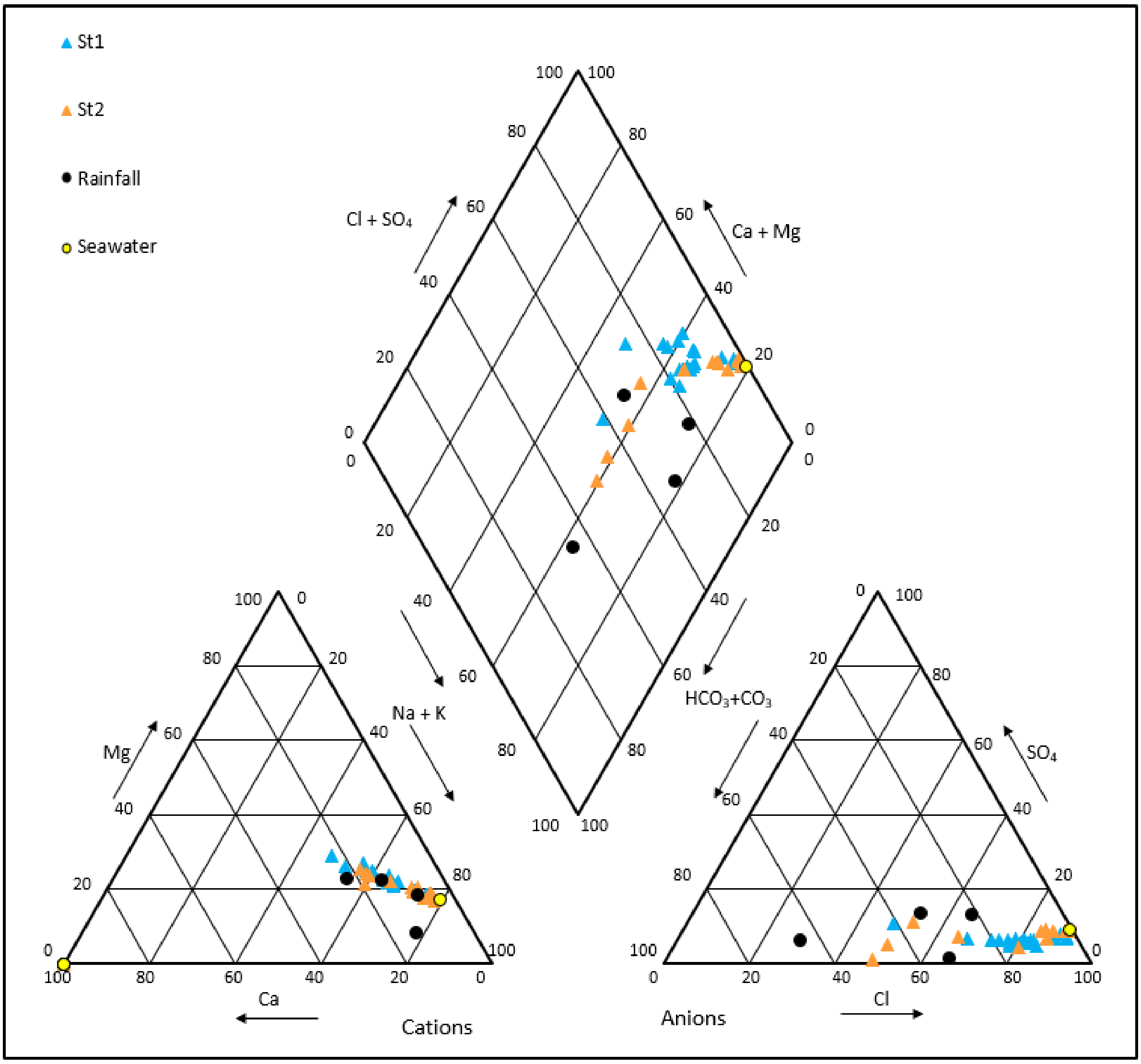


Figure 10-14 Styx River water quality Piper diagram

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 10-15. 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. At the time of sampling, it is evident that a freshwater – seawater mixing zone occurs within Styx River between the locations of St1 and St2.

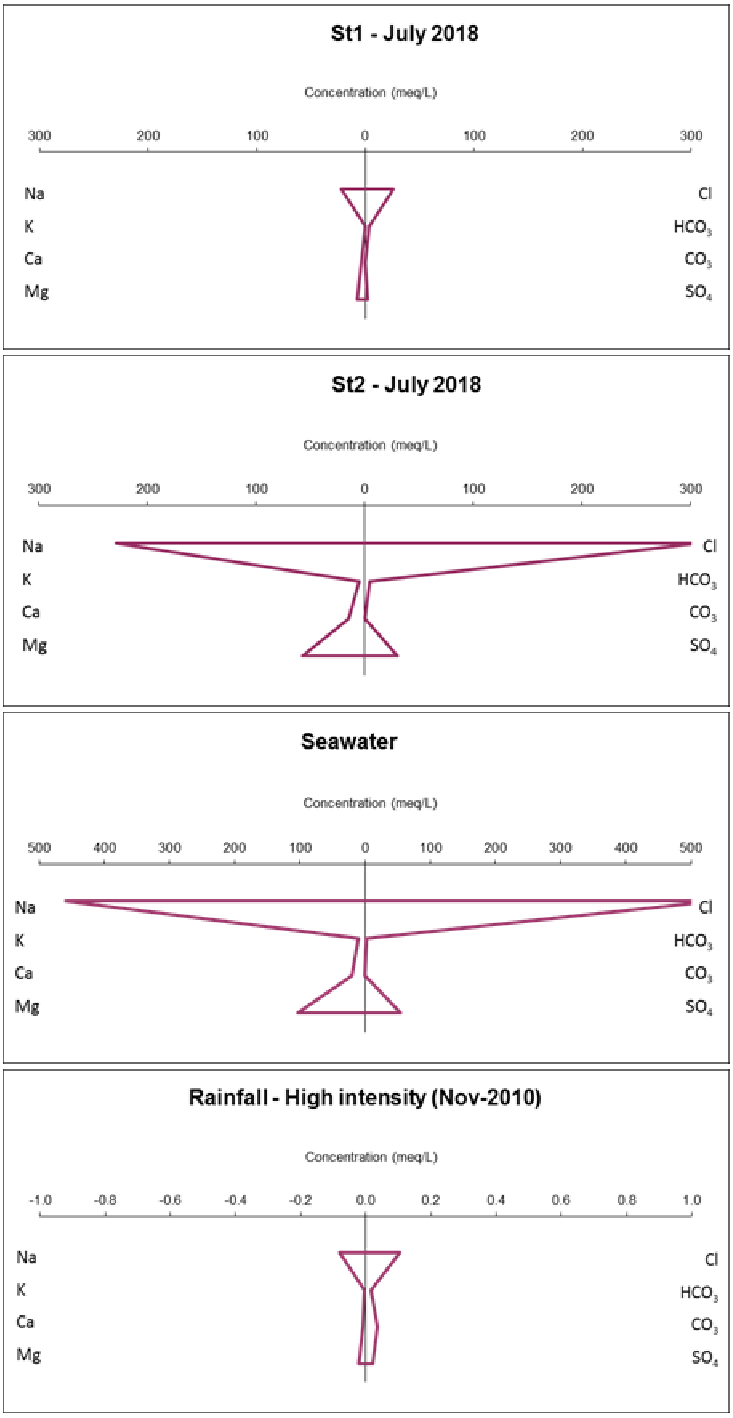


Figure 10-15 Styx River (July 2018), seawater and Rockhampton rainfall Stiff patterns

10.5.5 Geology

10.5.5.1 Styx Basin

The Project lies within, and targets the coal reserves of, the Styx geological basin (Styx Basin), which is described by GeoScience Australia (2017) and Malone et al (1969) as a small, elongate, early-Cretaceous, intracratonic sag basin comprising up to 1,000 m of siliciclastic sediments and coal measures. Intracratonic sag basins are typically 'saucer-like' in geometry and are developed by depositional infill of a sag in the Earth's crust, which generally forms by gradual subsidence due to downwelling of the mantle. The infill sediments of Styx Basin are known collectively as the Styx Coal Measures.

In total, the Styx Basin covers an area of approximately 2,000 km^2 and extends offshore to depths of up to 100 m below sea level. It is thought to have developed by subsidence of the Strathmuir Synclinorium, an older (deeper) feature containing Permian strata of the Bowen Basin.

The regional geology of the Styx River Basin is shown on the geological map and cross section presented in Figure 10-16 and Figure 10-17. The maximum known thickness of sedimentary rocks within the Basin is 387 m (observed in an onshore coal exploration drillhole; Malone et al 1969) but geophysical surveys suggest the Basin thickens offshore to the north (Malone et al 1969). The general dip of the Styx Coal Measures is to the east, with outcrop and sub-crop beneath surface Cenozoic deposits occurring along the west and central portion of the basin. The southern part of Styx Basin, where the Project is located, is bounded to the east by a post-depositional, high-angle reverse fault. Either side of the fault, the Cretaceous and Permian units are folded and faulted.

10.5.5.2 Stratigraphy

Brief details of the important stratigraphy present within and bounding the Styx Basin are presented below, from oldest to youngest. A detailed discussion is provided in Chapter 5 – Land and Table 10-5 presents summary details concerning age and stratigraphic relationships.

Table 10-5 Stratigraphy of Styx River Basin

Age (Ma)	Group	Formation	Description[1]
Cenozoic (0 to 66)	-	Cenozoic deposits	Alluvium, colluvium, soils, estuarine deposits, etc.
		Unconformity	
Early Cretaceous (100 to 145)	-	Styx Coal Measures	Quartzose sandstone, mudstone, conglomerate and coal
		Unconformity	
Late to Early Permian (251 to 268)	Back Creek Group	Boomer Formation	Lithic sandstone, siltstone, mudstone, rare conglomerate
			Quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite
Early Permian (284 ± 7)	Lizzie Creek Volcanic Group	Carmila Beds	Siltstone and mudstone, volcanilithic sandstone and conglomerate and minor altered basalt; local rhyolitic to dacitic ignimbrite and volcaniclastic rocks
		Unconformity	
Early Permian to Late Carboniferous (300 to 306.5 ± 1.6)	Connors Volcanic Group		Felsic to mafic volcanic rocks; rhyolitic to andesitic flows, high-level intrusives, and volcaniclastic rocks including ignimbrite

[1] Australian Stratigraphic Units Database; http://www.ga.gov.au/data-pubs/data-standards/reference-databases/stratigraphic-units

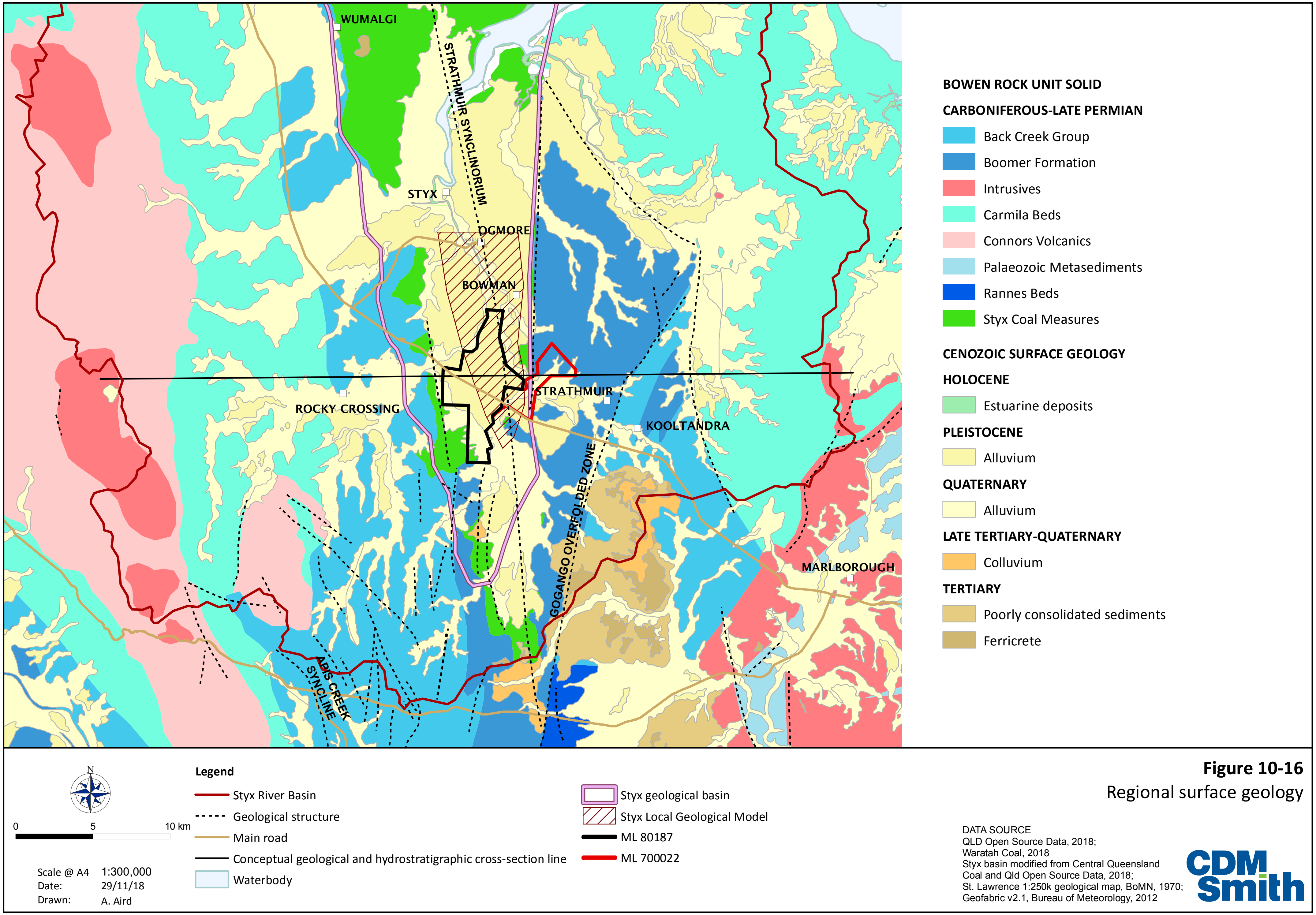


Figure 10-16
Regional surface geology

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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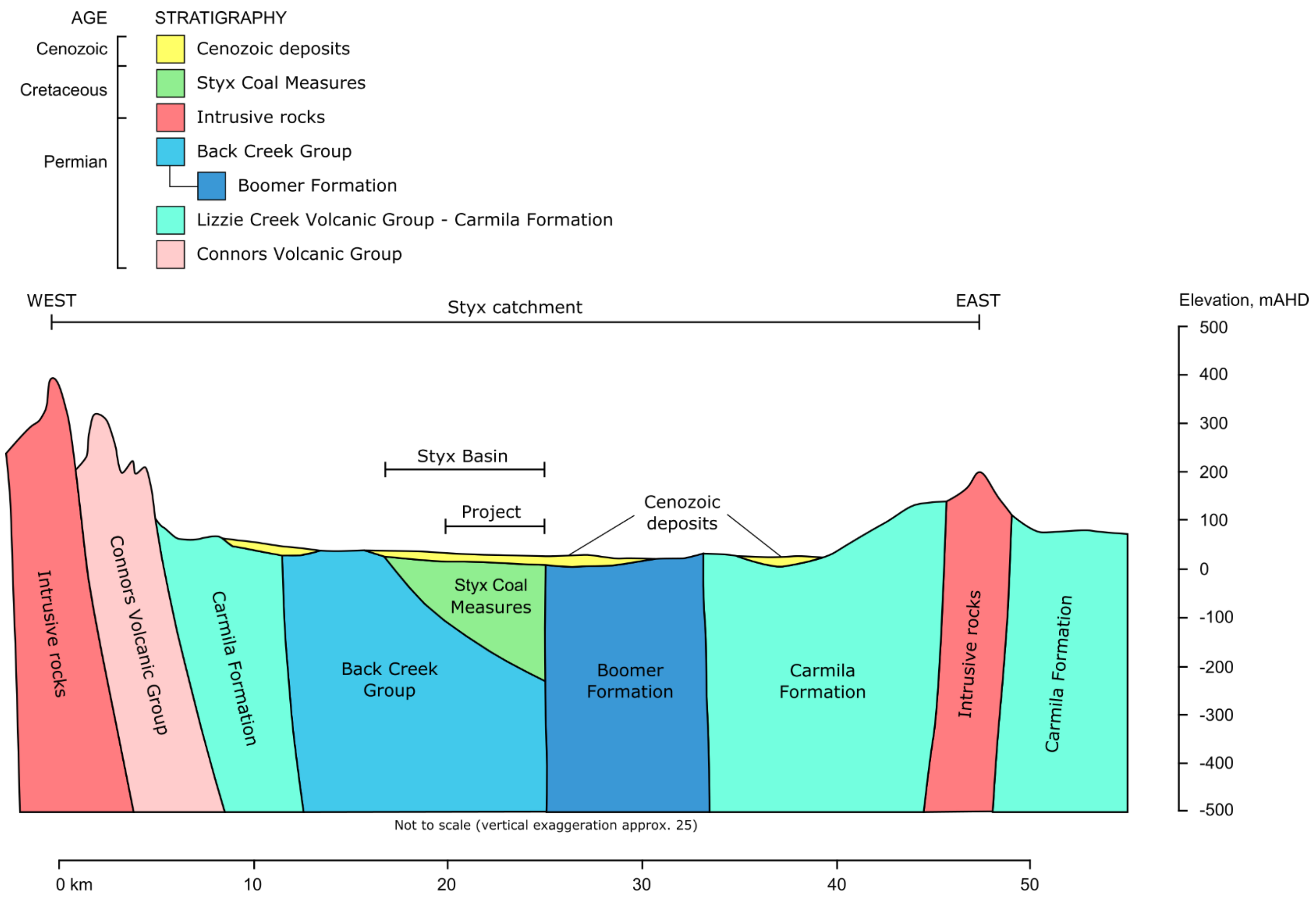

Figure 10-17 Schematic geological cross section

Connors Volcanic Group

The Connors Volcanic Group consists mainly of Carboniferous to Early Permian massive volcanics that unconformably underlie the Lizzie Creek Volcanic Group. The Connors Volcanics formed islands in the Lower Permian sea and have greatly influenced the subsequent deformation of the Lower Permian sediments (Malone et al, 1969). The rocks of Connors Volcanic Group outcrop in a linear zone, the Connors Arch, to the west of Styx Basin and largely control the Broad Sound Range.

Lizzie Creek Volcanic Group - Carmila Beds

Permian sediments of the Carmila Beds underlie the Back Creek Group and unconformably overlie the Connors Volcanic Group. The Carmila Beds were deposited initially as terrestrial volcanics with some freshwater sediments followed by a marine depositional environment. On the eastern margin of Styx Basin, the Carmila Beds outcrop on and east of Connors Range, in a large area north of Marlborough, and on both sides of the southern end of Broad Sound Range (Malone et al. 1969). Near Tooloombah homestead and farther south (near the Project area), the Carmila Beds have been described by Malone et al. (1969) as comprising mainly of volcanolithic sediments, with primary volcanics constituting only about 20%.

Back Creek Group and Boomer Formation

Following the marine depositional period when the Carmila Beds were deposited, the sea transgressed and deposition of the Permian Back Creek Group commenced. The different rock types of the Back Creek Group are thought to reflect marine transgression and regression periods. Locally, the Back Creek Group overlies the Lizzie Creek Volcanic Group (Carmila Beds) and underlie the Styx Coal Measures. In the Project area, the Back Creek Group extends north to south approximately sub-parallel to, beneath and to the west of Styx Basin.

On the eastern side of the Styx Basin, the Back Creek Group is represented by Boomer Formation, which comprises of marine sediments that have undergone varying degrees of faulting and folding.

Styx Coal Measures

The Lower Cretaceous Styx Coal Measures are thought to have originally been deposited over a larger area but are now only present in the fault-bounded Styx Basin and in a few outlier areas. The Styx Coal Measures outcrop in a north-trending belt, extending south from Saint Lawrence township on the coast to near the headwaters of Tooloombah Creek. The depositional environments were freshwater, deltaic to paludal (marsh) with occasional marine incursions.

The coal measures dip generally eastwards at around 5°, unconformably overlie the undifferentiated Back Creek Group and are faulted against the Boomer Formation along the eastern boundary of the measures. Historical drilling records identify a pebble conglomerate at the base of the Styx Coal Measures.

The Styx Coal Measures comprise:

- overburden materials typically comprising of variably weathered interbedded quartzose sandstone (dominant) and siltstone/mudstone, and traces of coal;
- the coal seams and interburden materials typically comprising of coal seams, and variably weathered interbedded siltstone/mudstone (dominant) and sandstone; and
- underburden materials typically comprising of interbedded sandstone (dominant) and siltstone/mudstone.

Tertiary Deposits

To the southeast of the Project, Tertiary sediments outcrop and form tablelands at an elevation of around 100 m AHD. The tablelands are capped with laterised sediments that form rocky cliffs. The lower slopes of the tablelands are scree-covered and commonly blanketed with thick vegetation (mature trees). The Tertiary sediments include sandstone, siltstone, claystone, diatomite, oil shale, conglomerate and some basalt (Malone et al, 1969). Malone et al (1969) describes the Tertiary sediments as unconformably overlying Permian rocks (likely the Back Creek Group).

Cenozoic Deposits

Cenozoic sediments cover a majority of the Project area and consist of sand, alluvium, lateritic gravel and reworked Tertiary and Permian sediments. Mangrove swamps and alluvial flats are developed along the coast. Within the Project area, the Cenozoic sediments overlie the Styx Coal Measures and Back Creek Group Formation to thickness of up to 18 m.

10.5.5.3 Project Geochemistry

Waste rock characterisation has been undertaken by RGS Environmental and is detailed in Chapter 8 – Waste Rock and Rejects. A total of 195 samples (including overburden, potential rejects, and fine coal reject samples) were collected from 15 bore holes covering a range of depths from 11.6 metres below ground level (mbgl) to 147 mbgl in various lithologies. Rock samples were subjected to an Acid Base Accounting (ABA) assessment, allowing sampled lithologies to be classified into non-acid forming (NAF), potentially acid forming (PAF) and uncertain categories. Overall, the risk of acid generation from waste rock and coal reject materials is considered low, with over 98% of samples analysed classified as NAF (RGS Environmental 2012).

A kinetic leach study was also undertaken to provide confirmation or not that waste materials have a low acid generation potential. Although no visual indicators were noted for presence of pyrite, the oxidation of composite materials showed no indication of acidification during the study. Previous experience has shown that when a small amount of acid generating materials is mixed with non-acid forming materials (with acid neutralisation potential), the net acid generation potential of the overall mixture may be effectively buffered. The data collected to date is considered sufficient to support the conclusion that the risk of acid generation from waste rock is low.

There was no discernible trend for which type of materials (waste rock or potential coal reject) would be more likely to contain PAF. As such fine coal rejects (21 samples) were also analysed to provide an indication of the acid potential and composition of the coal processing waste stream. The fine rejects were largely classifiable as NAF with Acid Neutralising Capacity (ANC)/ Maximum Potential Acidity (MPA) ratios indicative of negligible risk.

An assessment of the potential to generate acidic leachate from waste rock and coal reject material has also been undertaken (RGS Environmental 2012). The assessment found metal / metalloid concentrations in water extracts were within the same order of magnitude as the assessment criteria, generally consistent across composition samples and, therefore, likely to be consistent with existing concentrations within the regional geology.

Although the waste rock is expected to have a low capacity to generate acidity it does have moderate saline drainage potential and kinetic leach column results indicate that leachate may contain elevated concentrations of dissolved arsenic (As), molybdenum (Mo), selenium (Se) and vanadium (V) when compared to WQO and EVs.

Waste rock and fine rejects has been classified as:

- Acid consuming:
  - Will likely remain pH neutral to alkaline following excavation (composite waste rock and potential coal reject samples were alkaline, with pH ranging from 8.6 to 10)
  - Dissolution of heavy metals in an acidic environment is unlikely
- Having low potential to be potentially acid forming;
- Having moderate saline drainage potential (salinity of the samples ranged from 440 to 660 µS/cm); and
- Potential to be highly sodic.

The geochemical assessment for waste materials indicates the potential for generation of acidic leachate is low to negligible. A deterioration of groundwater quality in response to waste materials management is considered very unlikely to occur.

10.5.5.4 Geological Models

A regional geological model covering an area of around 30,000 km^2 has been developed for the purpose of developing the groundwater model presented in this SEIS and is presented in Appendix A6 – Groundwater Technical Report. A more detailed local-scale geological model developed by Central Queensland Coal for resource assessment covers a smaller area of around 50 km^2 in the immediate Project area (Figure 10-16) is incorporated into the regional scale model.

The local geological model contains interpreted elevations and thicknesses of coal seams/interburden strata within the Styx Coal Measures as intersected by the resource drilling program. The two models have been merged for the purpose of developing the groundwater model to assist in assessing the effects of mining on groundwater and connected systems (see Appendix A6 – Groundwater Technical Report for detail).

10.5.6 Hydrogeology

10.5.6.1 Overview

The BoM's National Groundwater Information System reports that Styx River Basin lies outside of any declared groundwater management areas, including alluvial aquifer boundaries declared by the DNRME (BoM, nd). The BoM database lists the purposes of all bores located within Styx catchment as "unknown". The bore censuses conducted for the Project in 2011 and 2017 (refer Section 10.6.2) found that most bores are used for stock watering and only some are used for domestic purposes (Central Queensland Coal and Fairway Coal 2012, CDM Smith 2017).

Figure 10-18 and Figure 10-19 present a locality plans showing the location of different types of bores and drillholes in the Styx River Basin, including landholder bores, Project groundwater monitoring bores and drillholes, and registered bores.

Central Queensland Coal has installed 46 monitoring bores between late 2017 and late 2018 ("Styx Project WMP bores"), and a summary of the installations is provided in Table 10-6, with composite bore logs presented as Attachment 1 to Appendix A6 – Groundwater Technical Report. These bores have been installed to provide greater coverage around the Project (for groundwater heads and quality), especially near to watercourses to assess the potential for groundwater and surface water interactions and vertical hydraulic gradients between shallow and deeper hydrostratigraphy. Of the 46 Styx Project WMP bores installed, 15% of the bores have been screened across multiple units. Where this occurs, the hydrogeological interpretations have been based on the dominant unit.

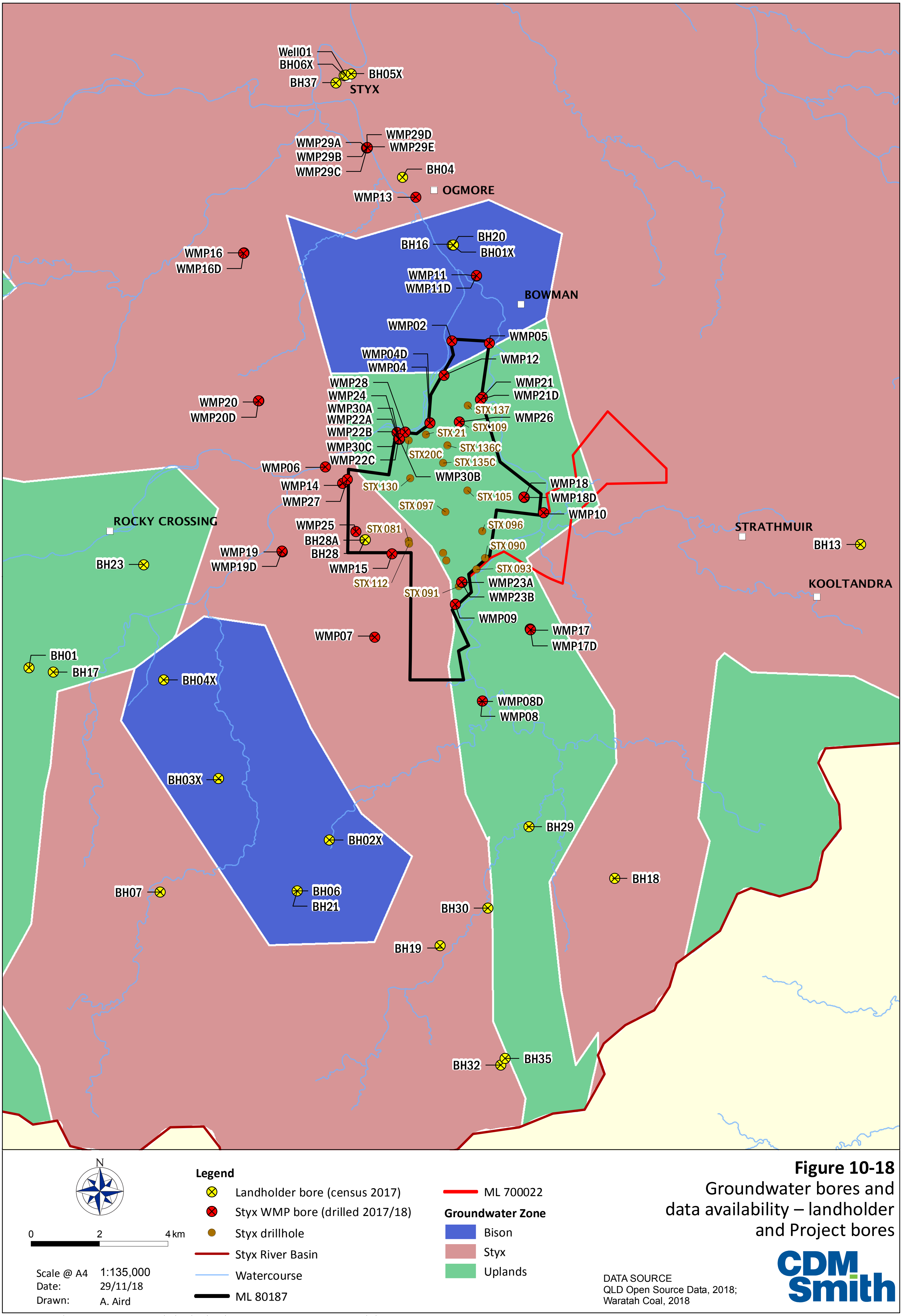

Figure 10-18
Groundwater bores and data availability – landholder and Project bores

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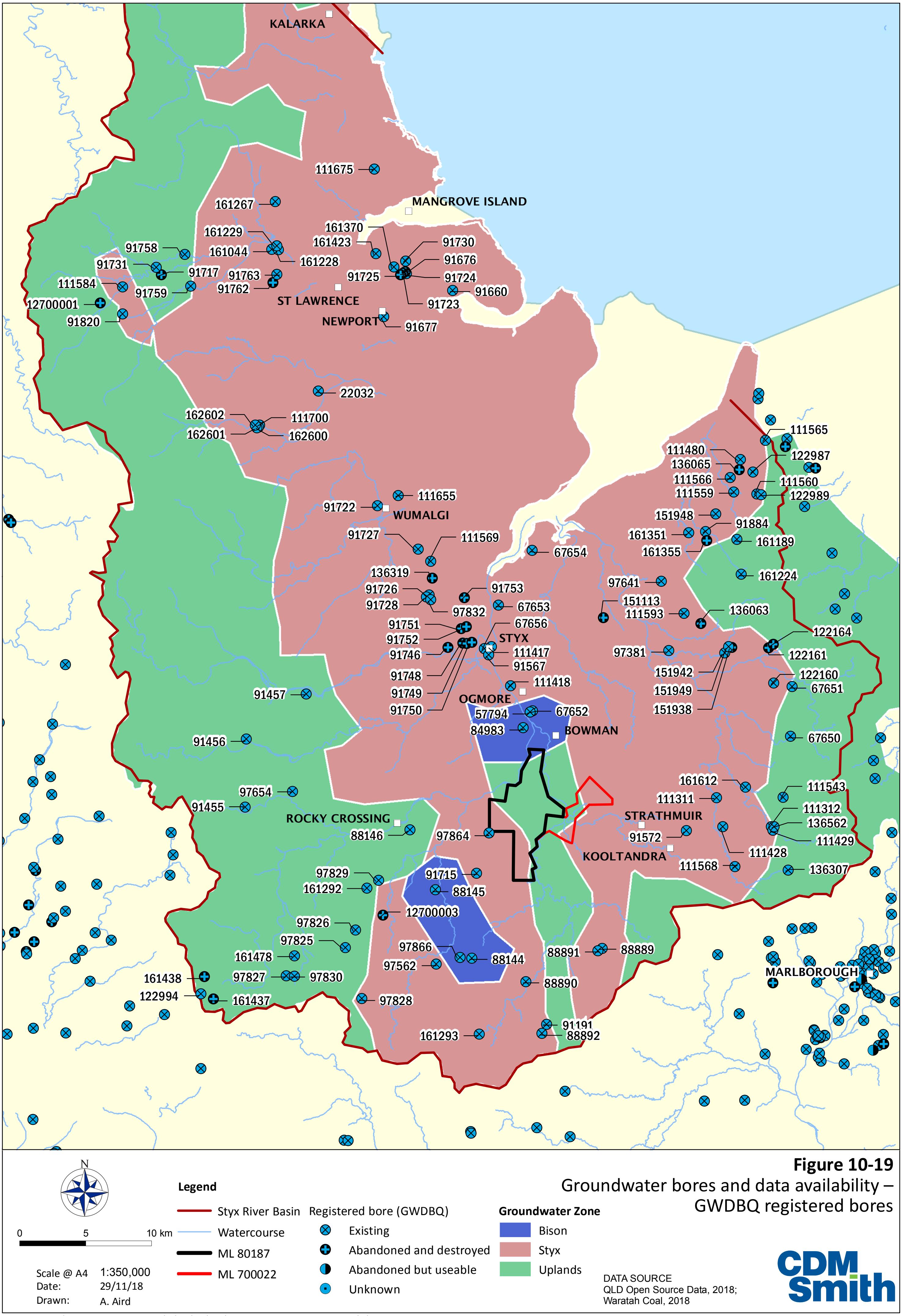

Figure 10-19
Groundwater bores and data availability – GWDBQ registered bores

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Table 10-6 Recently installed Project groundwater monitoring bores ("Styx Project WMP bores")

ID	Date drilled	Casing Diameter (m)	Slotted Interval (mbgl)	Total depth (mbgl)	Inferred HSU
WMP02	1-Oct-17	0.125	12 – 18	18.4	Alluvium
WMP04	11-Oct-17	0.125	12 – 18	18.4	Alluvium
WMP04D	29-Sep-17	0.125	18.5 – 36.3	36.5	Alluvium and Styx Coal Measures (overburden)
WMP05	30-Sep-17	0.125	9 – 12	12.4	Alluvium
WMP06	3-Nov-17	0.125	12 – 18	18.4	Alluvium and Styx Coal Measures (underburden)
WMP07	16-Oct-17	0.125	48 – 60	60	Styx Coal Measures (underburden)
WMP08	2-Nov-17	0.125	10 – 16	16	Alluvium
WMP08D	2-Nov-17	0.125	24 – 36	36	Styx Coal Measures (underburden)
WMP09	14-Oct-17	0.125	7.1 – 15	15.4	Alluvium
WMP10	13-Oct-17	0.125	12 – 18	18.4	Styx Coal Measures (overburden)
WMP11	18-Mar-18	0.125	18 – 24	24	Styx Coal Measures (overburden)
WMP11D	17-Mar-18	0.125	30 – 36	36	Styx Coal Measures (overburden)
WMP12	6-Nov-17	0.125	11 – 17	18	Alluvium and Styx Coal Measures (overburden)
WMP13	12-Jan-18	0.125	12.7 – 19.7	19.7	Alluvium and Styx Coal Measures (overburden)
WMP14	19-Mar-18	0.125	9 – 18	18	Alluvium and Styx Coal Measures (overburden)
WMP15	20-Mar-18	0.125	9 - 21	21	Alluvium and Styx Coal Measures (underburden)
WMP16	20-Oct-18	0.05	25.5 – 31.5	31.5	Styx Coal Measures (overburden)
WMP16D	21-Oct-18	0.05	35.7 – 41.7	42	Styx Coal Measures (coal seams/interburden)
WMP17	3-Oct-18	0.05	9 - 12	12	Alluvium
WMP17D	2-Oct-18	0.05	21 - 24	24	Styx Coal Measures (overburden)
WMP18	13-Sep-18	0.05	9.2 - 12.2	12.2	Alluvium
WMP18D	12-Sep-18	0.05	18.5 - 23.5	23.5	Styx Coal Measures (overburden)
WMP19	6-Sep-18	0.05	13.1 - 16.1	16.1	Weathered Basement
WMP19D	7-Sep-18	0.05	24.9 - 27.9	28	Weathered Basement
WMP20	20-Oct-18	0.05	14.5 – 20.5	20.5	Styx Coal Measures (overburden)
WMP20D	20-Oct-18	0.05	24 – 30	30	Styx Coal Measures (overburden)
WMP21	10-Sep-18	0.05	6.9 - 9.9	9.9	Alluvium
WMP21D	10-Sep-18	0.05	14 - 20	22	Alluvium and Styx Coal Measures (overburden)
WMP22A	19-Oct-18	0.78	27 – 30	30	Styx Coal Measures (overburden)
WMP22B	19-Oct-18	0.1	50 – 56	56	Styx Coal Measures (coal seams/interburden)
WMP22C	19-Oct-18	0.1	200 - 206	206	Styx Coal Measures (underburden)
WMP23A	6-Oct-18	0.9	48.5 - 54.5	56.5	Styx Coal Measures (coal seams/interburden)
WMP23B	6-Oct-18	0.9	187 - 193	194	Styx Coal Measures (underburden)

ID	Date drilled	Casing Diameter (m)	Slotted Interval (mbgl)	Total depth (mbgl)	Inferred HSU
WMP24	11-Sep-18	0.05	23.4 - 26.4	26.4	Styx Coal Measures (overburden)
WMP25	8-Sep-18	0.05	10.1 - 13.1	13.2	Alluvium
WMP26	9-Sep-18	0.05	11.5 - 20.5	20.5	Alluvium
WMP27	8-Sep-18	0.05	14.5 - 20.5	20.5	Styx Coal Measures (overburden) and minor alluvium
WMP28	11-Sep-18	0.05	8.9 - 11.9	12	Styx Coal Measures (overburden)
WMP29A	28-Oct-18	0.1	6.5 – 12.5	12.5	Alluvium
WMP29B	28-Oct-18	0.1	16 – 20	20	Alluvium
WMP29C	27-Oct-18	0.1	52 – 58	58	Styx Coal Measures (overburden)
WMP29D	1-Nov-18	0.1	115 – 121	121	Styx Coal Measures (coal seams/interburden)
WMP29E	31-Oct-18	0.1	222.5 – 228.5	228.5	Styx Coal Measures (underburden)
WMP30A	19-Oct-18	0.05	27 – 30	30	Styx Coal Measures (overburden)
WMP30B	19-Oct-18	0.05	50 – 56	56	Styx Coal Measures (coal seams/interburden)
WMP30C	19-Oct-18	0.05	200 – 206	206	Styx Coal Measures (underburden)

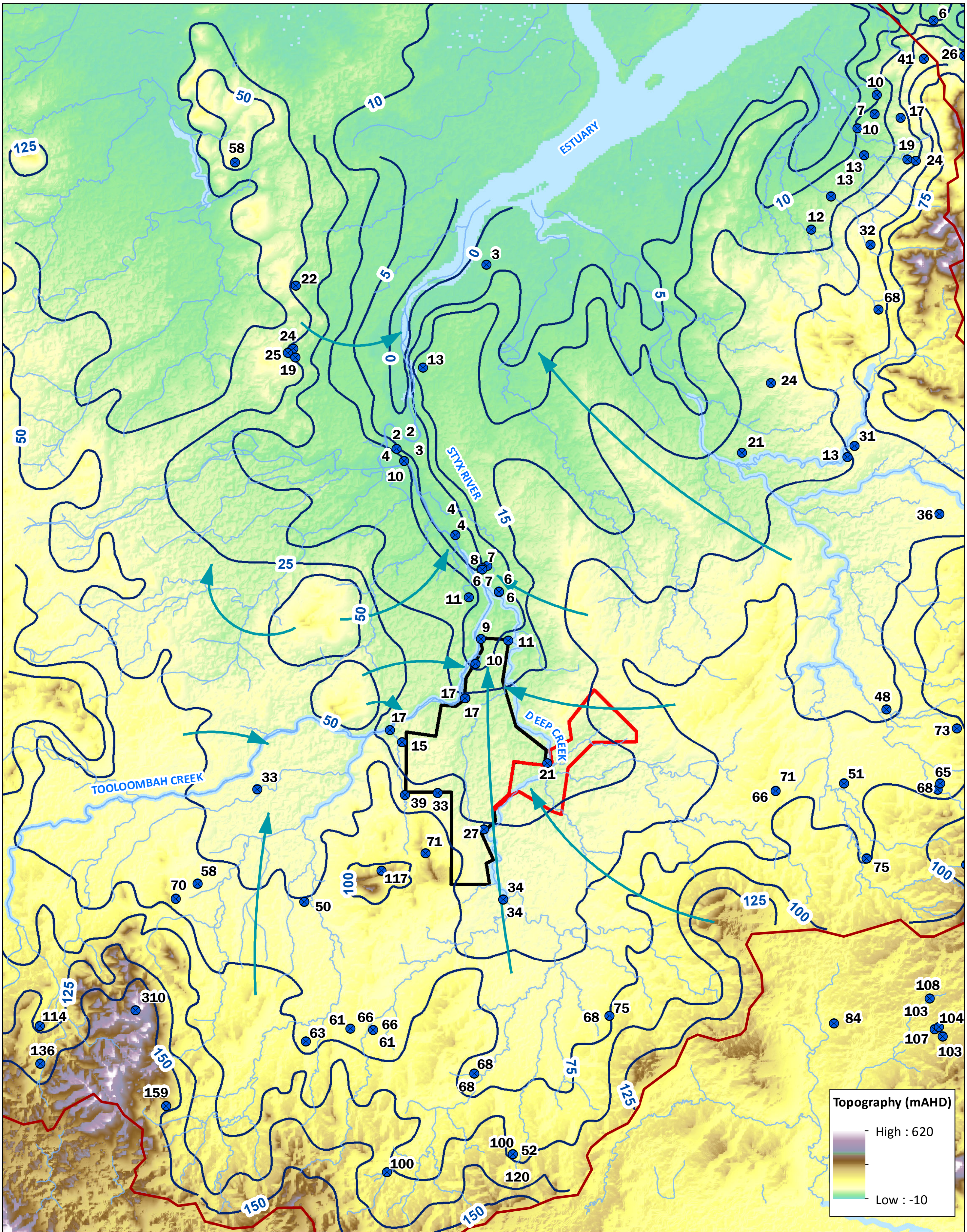
mbgl = metres below ground level

Where bore is screened across two units, the dominant HSU is underlined

10.5.6.2 Groundwater Heads and Flow

The general direction of catchment-scale groundwater flow is toward Styx River and the coast. However, groundwater flow patterns vary across the catchment in response to local-scale recharge and discharge mechanisms. Figure 10-20 presents the 2017/2018 wet season water table elevation contour plan for the Styx River catchment. The contours have been inferred from data sourced from GWDBQ, Project exploration drillholes and Styx Project WMP bores. The plan shows the water table surface is likely a subdued reflection of topography, and that it generally occurs within 15 m of the ground surface in the less elevated parts of the Basin, and is very shallow in lower areas close to Styx River and Broad Sound (Figure 10-21). The inferred contours show groundwater flowlines from the upper catchment (the Tooloombah and Deep Creek sub-catchments) converge on the lower reaches of the creeks, whilst lower in the catchment the flowlines converge on Styx River and the Broad Sound estuary.

Relatively steep water table gradients are observed in Figure 10-20 in areas of the catchment where steep topography occurs and / or lower hydraulic conductivity (K) materials are likely to predominate, e.g. where there is surface exposure of basement rocks. Flatter water table gradients are observed where alluvium is extensive, likely due to higher K materials and / or relatively higher rates of evapotranspiration (from shallow water tables and / or phreatophytic vegetation). The pattern of water table contours around the major watercourses suggest that alluvial aquifer Ks are higher nearer to the watercourses.



Scale @ A4 1:200,000
Date: 13/12/18
Drawn: A. Aird

Figure 10-20
Inferred water table elevation and groundwater flow (wet season 2017/2018)

DATA SOURCE
QLD Open Source Data, 2018;
1 Second SRTM v1.0 © Commonwealth of Australia (Geoscience Australia) 2011

CDM Smith

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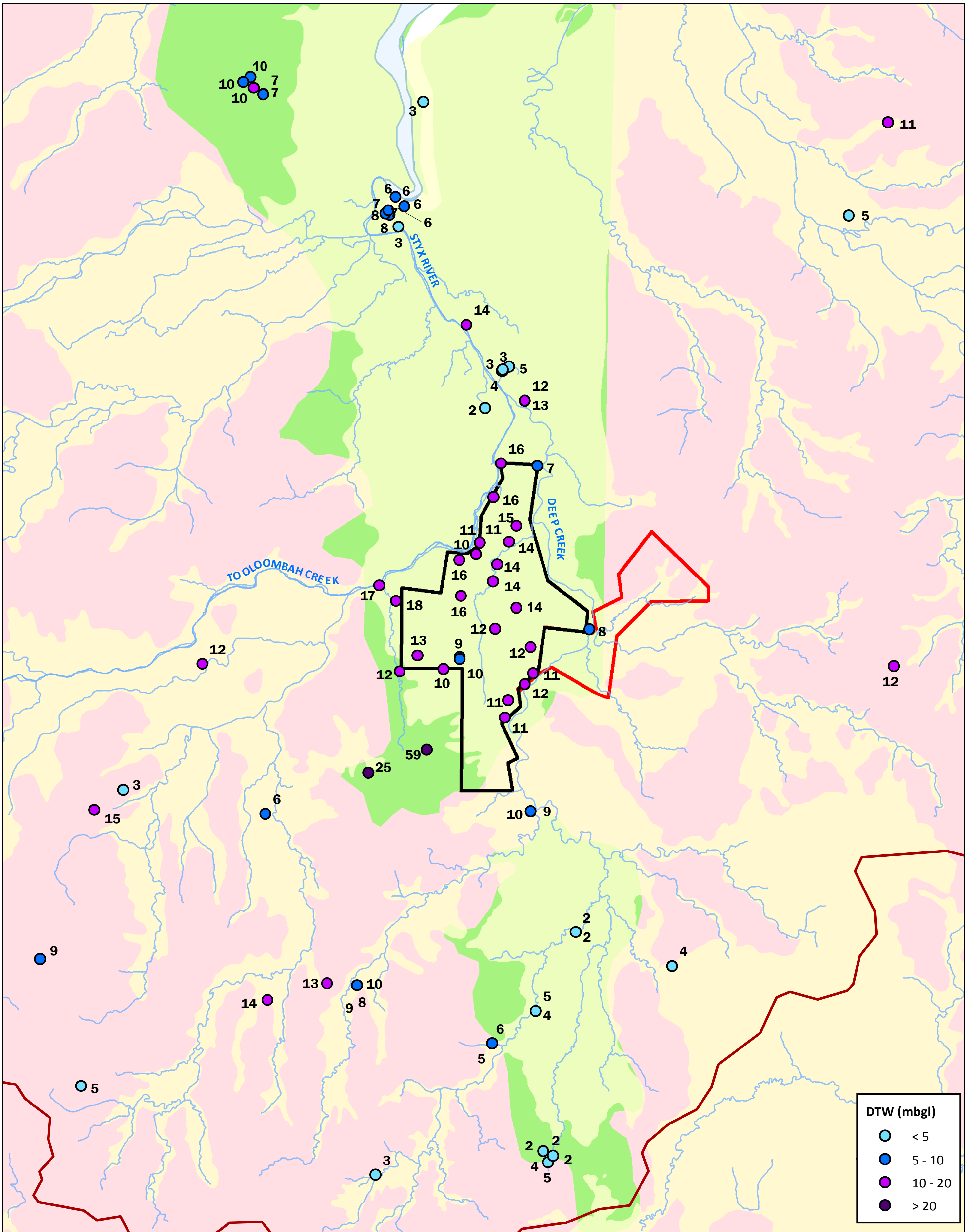


N

0 2.5 5 km

Scale @ A4 1:150,000
Date: 29/11/18
Drawn: A. Aird

Legend

- Styx River Basin
- ML 80187
- ML 700022
- Watercourse
- Waterbody
- Alluvium
- Styx Coal Measures
- Basement

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018
DERM, 2010
Geofabric v2.1, Bureau of Meteorology, 2012

Figure 10-21
Depth to groundwater
(wet season 2017/2018)

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 depth to groundwater.mxd 11/29/2018

The only timeseries groundwater elevations within the Styx River Basin are from unregistered third party bores identified during the bore census and from some of the Styx Project WMP bores. There are no timeseries groundwater levels from registered bores within the Styx River catchment. Hydrographs showing all available timeseries data, categorised by screened (hydro-)stratigraphic unit are presented along with Rockhampton Aero climate station 039083 rainfall data in Figure 10-22 to Figure 10-26. The following observations are made:

- Generally little seasonal variation in Basement and Styx Coal Measures groundwater elevations is observed; and
- Some variation in alluvium groundwater elevations is observed (e.g. bores WMP08, WMP05 and BH01X) with up to 3 m difference in heads between the wet and dry seasons, but a strong seasonal response is not evident across the monitoring network.

Recently constructed nested Styx Project WMP bores (locations shown on Figure 10-18) provide information by which to assess vertical hydraulic gradients in the immediate area of the Project during the wet and dry seasons, depending on time of installation. The available time series groundwater elevation data (corrected for density variations related to salinity) at the nested sites are presented on Figure 10-27. The following describes the relationships observed:

- At the location of WMP04 (alluvium) and WMP04D (Styx Coal Measures overburden), located near Tooloombah Creek at the northwestern boundary of the ML, the hydraulic head within the Styx Coal Measures overburden is higher than the hydraulic head within the alluvium, indicating the potential for groundwater flow from the coal measures to the alluvium, and possibly to the creek (as baseflow) in this area;
- At the location of WMP08 (alluvium) and WMP08D (Styx Coal Measures underburden), located near Deep Creek immediately upstream of the ML, the hydraulic head in the alluvium is lower than the hydraulic head of the deeper coal measures. The gradient between the units appears to increase in the dry season, due to a decline in head within the alluvium. The observed upward hydraulic gradient from the coal measures to the alluvium indicates possible discharge to the creek via the alluvium in this area;
- Only dry season gauging has occurred at the location of WMP11 (Styx Coal Measures overburden) and WMP11D (deeper Styx Coal Measures overburden), which are located above the confluence of Deep Creek and Tooloombah Creek downstream of the ML. The available data suggest groundwater from the coal measures has the potential to discharge to the creeks via the alluvium in the area of the confluence;
- At the location of WMP18 (alluvium) and WMP18D (Styx Coal Measures overburden), located around 1 km west of Deep Creek in the eastern area of the ML, only one gauging has been undertaken (in the dry season). The hydraulic head within the alluvium at this location is higher than the hydraulic head in the Styx Coal measures, indicating a downward gradient between the units;
- The monitoring sites WMP22A (Styx Coal Measures overburden), WMP22B (Styx Coal Measures coal seams/interburden) and WMP22C (Styx Coal Measures underburden) are located near Tooloombah Creek and around 1 km southwest of WMP04/WMP04D. Only one gauging has been undertaken at this site and suggests that there is an upward gradient between Styx Coal Measures units to the alluvium and possibly the creek. This supports the observation at WMP04/WMP04D; and
- Five bores have been installed at WMP29A (shallow alluvium), WMP29B (deeper alluvium), WMP29C (Styx Coal Measures overburden), WMP29D (Styx Coal Measures coal seams/interburden) and WMP29E (Styx Coal Measures underburden) which is located around 4 km north of the Tooloombah and Deep Creek confluence and within around 1 km south of the

estuary. As the bores were installed in October 2018, only one gauging has been undertaken at this site, which shows upward gradient from the Styx Coal Measures to the alluvium and possibly the Styx River at this location.

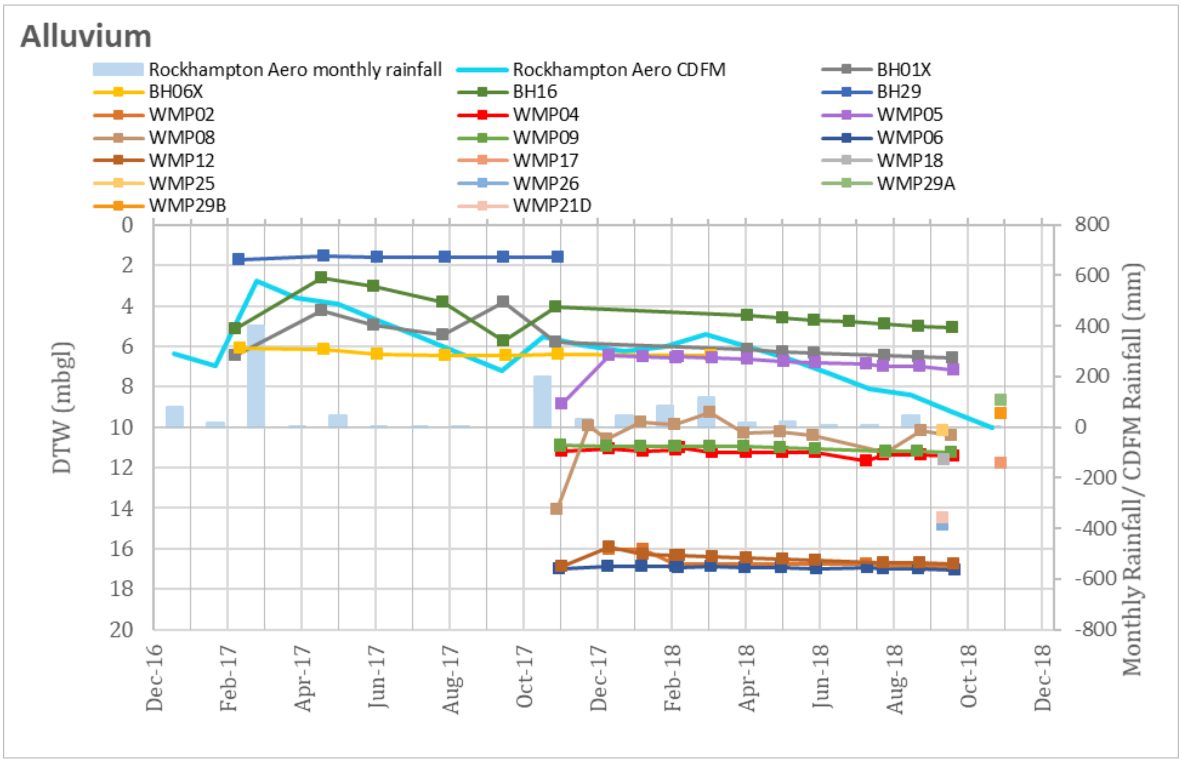


Figure 10-22 Groundwater hydrographs - Alluvium bores

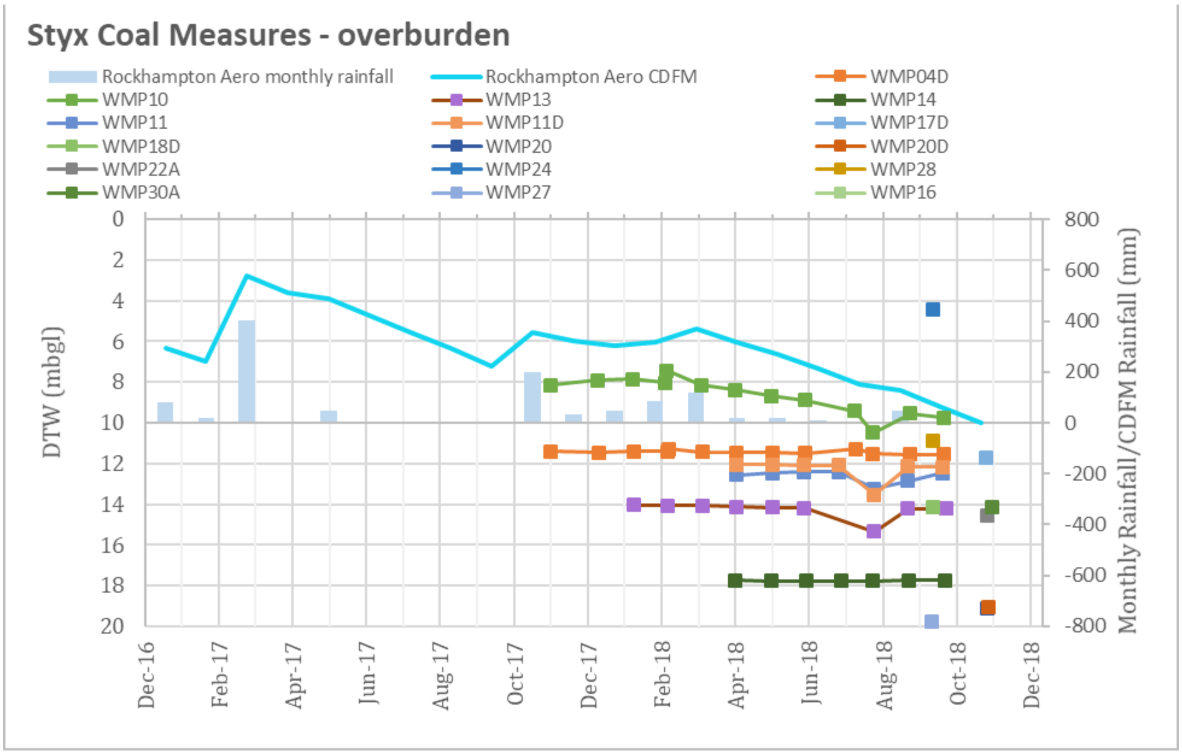


Figure 10-23 Groundwater hydrographs - Styx Coal Measures (overburden) bores

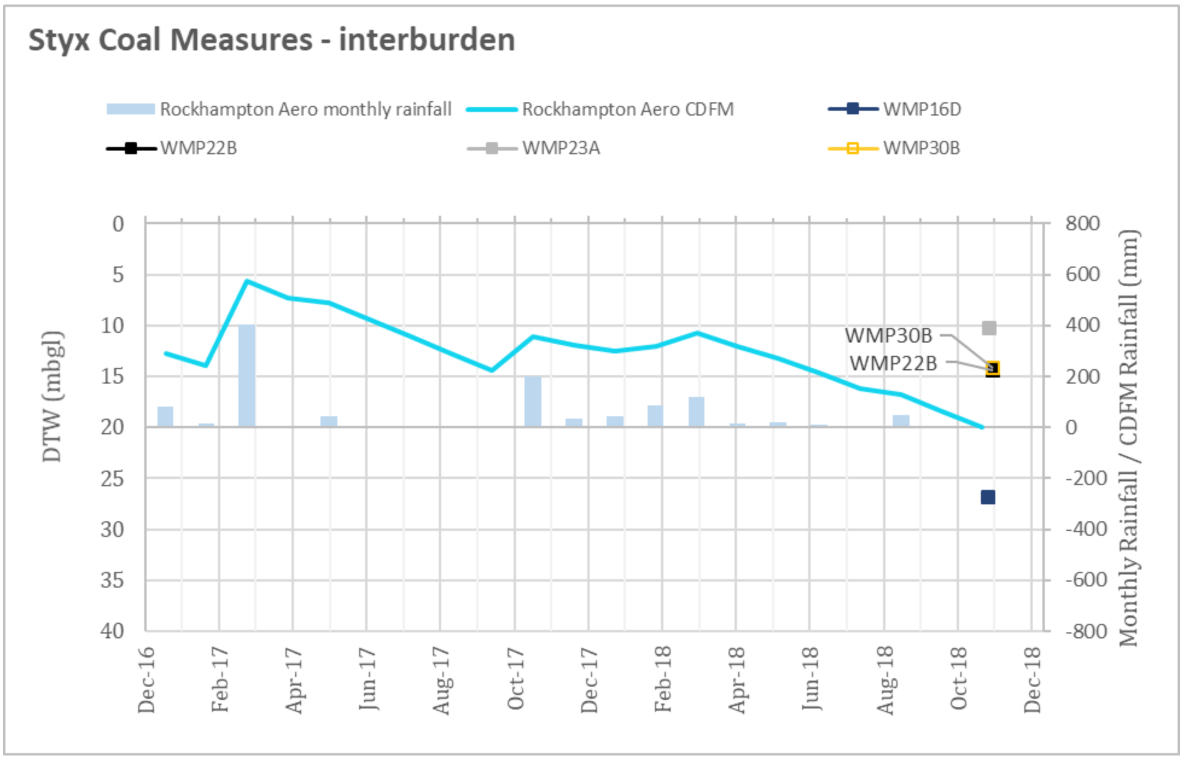


Figure 10-24 Groundwater hydrographs - Styx Coal Measures (coal seams/interburden) bores

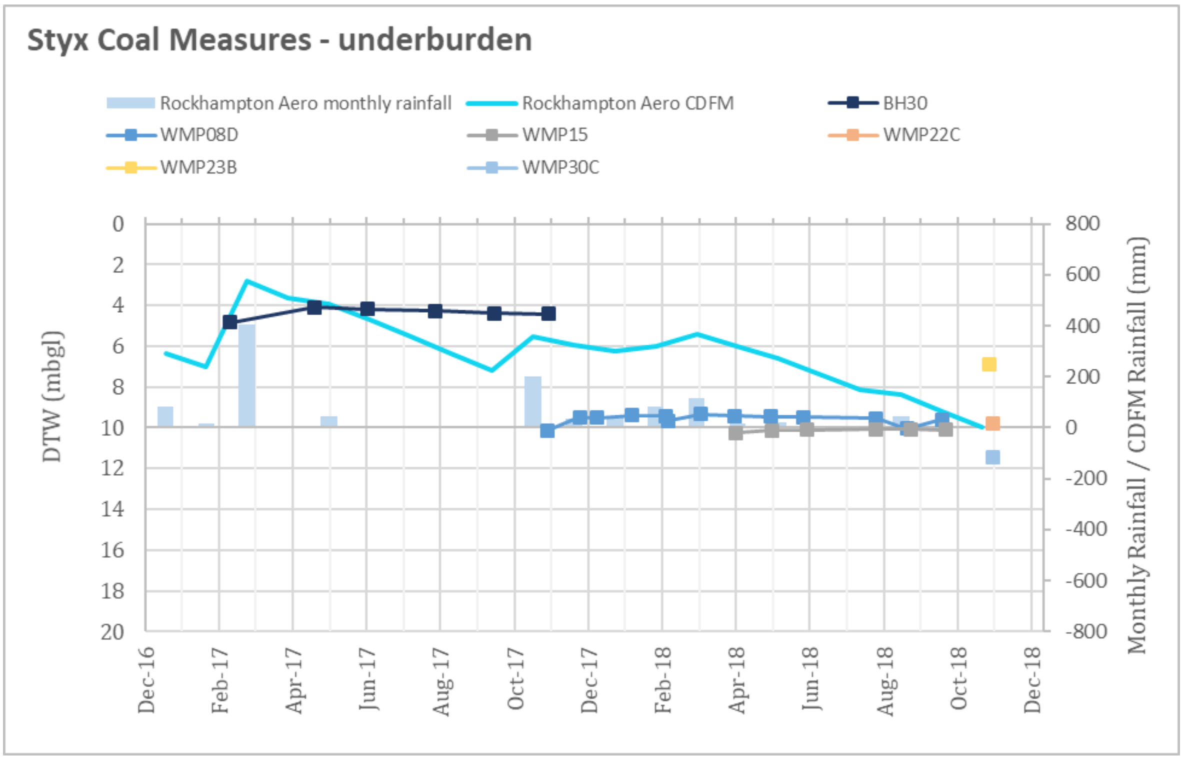


Figure 10-25 Groundwater hydrographs - Styx Coal Measures (underburden) bores

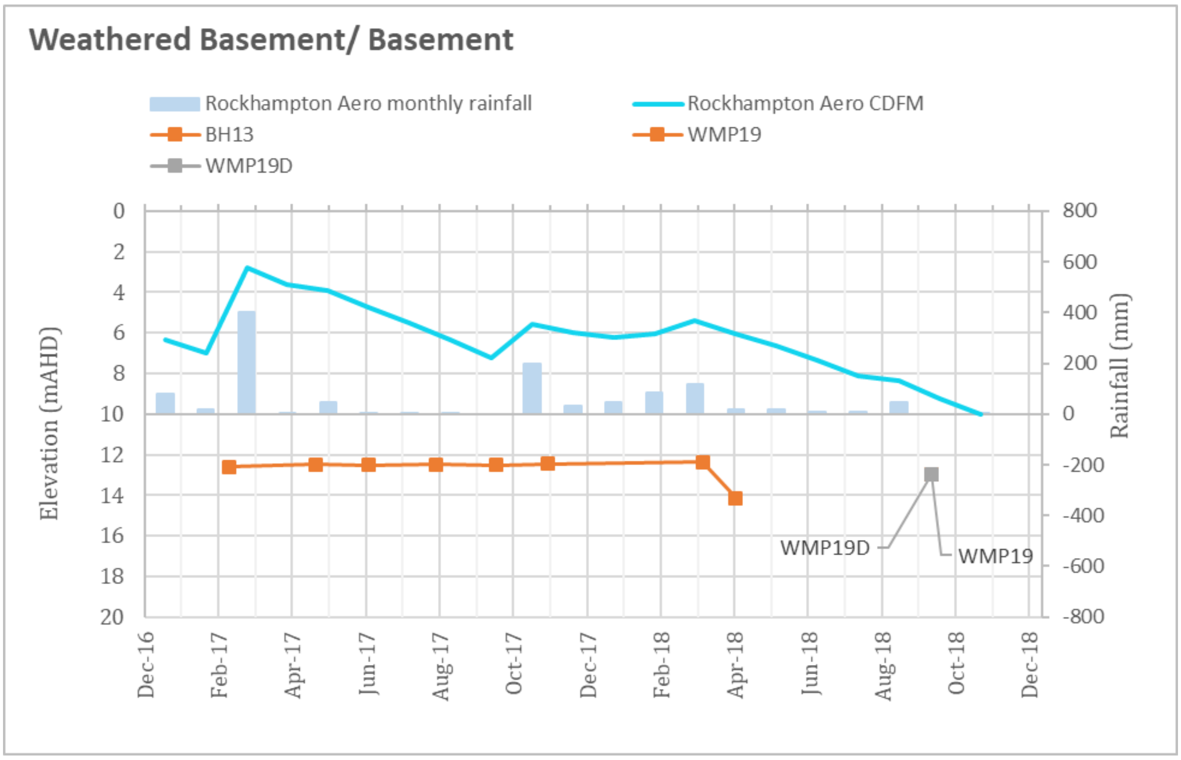


Figure 10-26 Groundwater hydrographs – Weathered Basement/Basement bores

It is expected a saltwater interface occurs beneath coastal areas of the Styx River Basin, but its exact location is unknown as there are no known measurements of groundwater pressures or salinity profiling near to the coast. The location of the interface will be dependent on groundwater heads near the coast as well as features such as Broad Sound estuary relative to sea level and tidal fluctuations. It is unlikely there is a sharp interface between groundwater and seawater across the broader Study Area downstream of the confluence of Tooloombah and Deep Creeks. The available hydraulic head data shows it is unlikely there is seepage of estuarine / sea water to the Styx Coal Measures from the area where Styx River discharges to Broad Sound estuary.

The available data show there is little evidence of a distinct seasonal response to rainfall and stream flow events in any of the stratigraphic units, particularly the Styx Coal Measures and Basement.

The groundwater elevation data show the lower reaches of Tooloombah and Deep Creeks, and both Styx River and Broad Sound are zones of nett groundwater discharge.

An assessment of the vertical hydraulic gradients typically shows upward gradients and potential for flow. This is observed at Styx River near Broad Sound, and further upstream near to both Deep and Tooloombah Creeks.

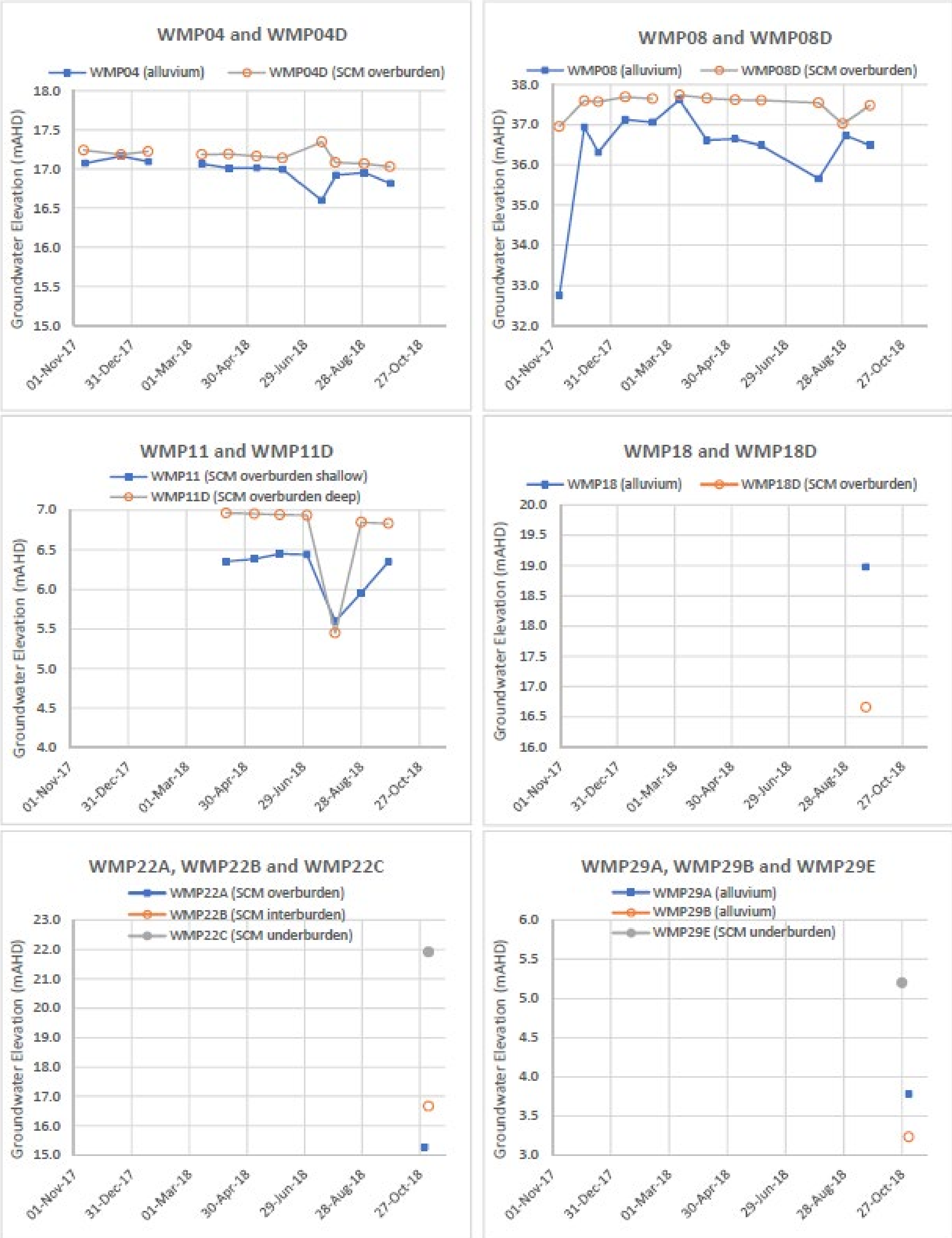


Figure 10-27 Groundwater hydrographs - nested sites

Vertical hydraulic gradients near to Broad Sound (Figure 10-27) show the deep coal seams and interburden, and the underburden have a higher head than the shallow Styx River alluvials, indicating the potential for upward leakage and deeper throughflow toward the coast.

10.5.6.3 Hydrogeological Properties

Groundwater Yields

Airlift yields measured during drilling or development of 82 Styx River catchment groundwater bores that have been recorded in the GWDBQ are shown in Figure 10-28 and summarised in Table 10-7 (frequency distribution). Bore yields are reported to range from 0.01 L/s (less than 1 kL/d) up to 6.3 L/s (approximately 550 kL/d). The data show that bore yields are typically low, with more than 75% of bores reporting yields of less than 2 L/s and only 1% of bores reporting yields greater than 6 L/s. Note that bore yield data is not necessarily a good indication of sustainable bore yields under pumping.

Project Area Aquifer Testing Results

The GWDBQ reports aquifer transmissivity values for five bores in the Styx River catchment. Based on their location, the bores are inferred to intersect alluvium and alluvium / weathered / fractured Basement (see Figure 10-30 for locations). A summary of these data is presented in Table 10-8, showing moderate to high permeability values from relatively small aquifer intervals.

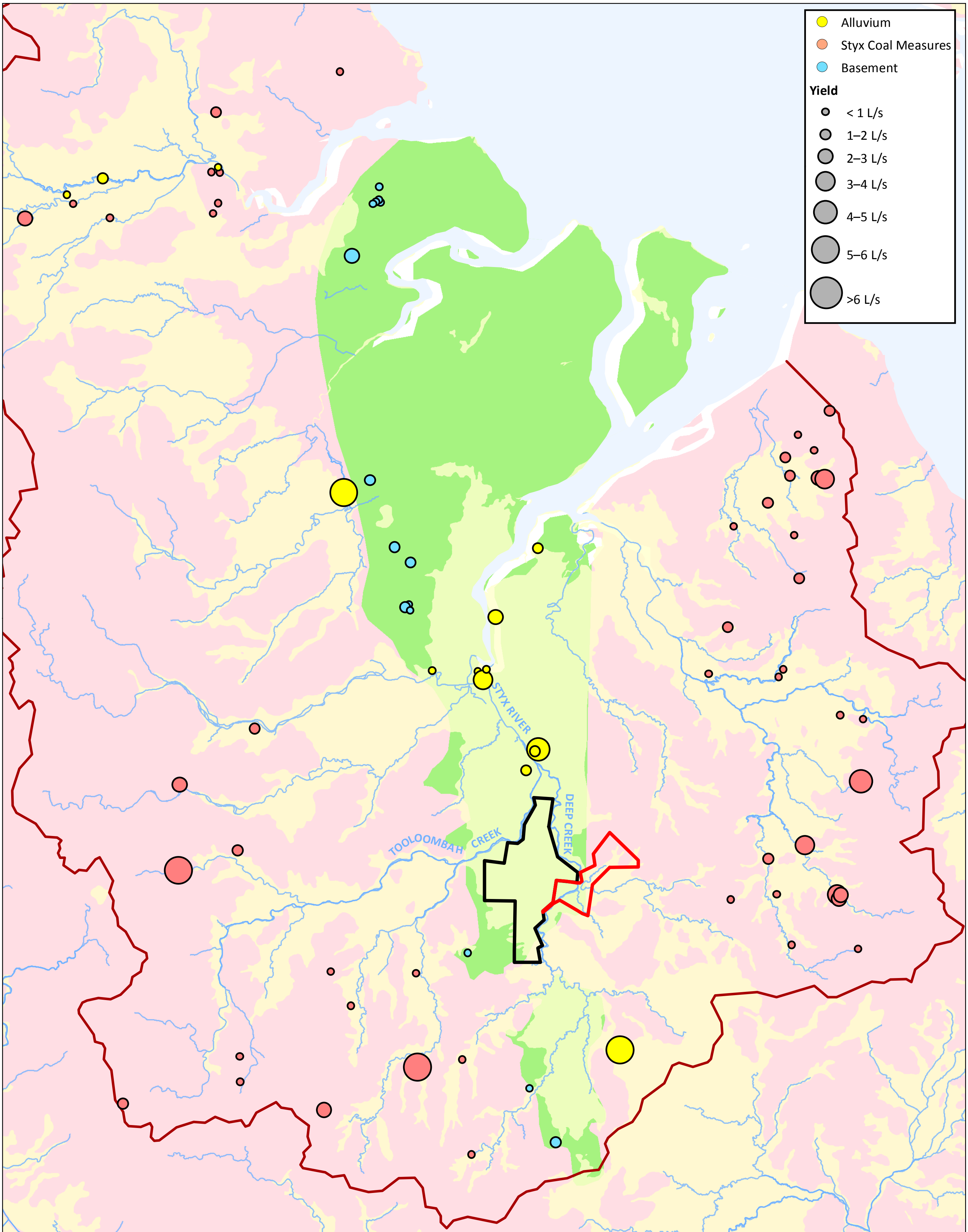
Table 10-7 Frequency distribution of bore yields

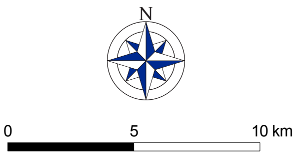
Bore yield (L/s)	Number of bores	Percent of bores (%)
< 1	43	52
1 to 2	20	24
2 to 3	8	10
3 to 4	4	5
4 to 5	2	2
5 to 6	4	5
6 to 7	1	1
Total	**82**	**100**

Table 10-8 Results from aquifer pumping tests recorded in the GWDBQ

GWBDQ RN	Lithology	Duration (hrs)	Interval (m)	T (m^2/d)	K (m/d)
57794	Alluvium	24	3.4	412	121
84983	Alluvium	4.5	0.7	107	153
88144	Alluvium / Basement	2	1.8	59	33
88145	Alluvium / Basement	120	4.6	60	13
88146	Alluvium / Basement	2.6	1.9	6	3
GWDBQ – Groundwater Database - Queensland; T – Aquifer transmissivity; K – Hydraulic conductivity					

Groundwater investigations conducted for the Styx Trial Pit (AMEC 2014) included two airlift pumping tests undertaken at drillholes STX00104 and STX00205 (see Figure 10-18 for locations). However, for various reasons such as difficulties in measuring pumping yield, difficulties in gauging drawdown and interruptions to the tests, the results are possibly compromised. The larger airlift pumping rate sustained from STX00205 is attributed to the presence of a gravel bed at the base of the "weathering profile" located above the coal resource and the presence of a 4 m thick coal seam. The results from the pumping tests are presented at Table 10-9.





Legend

Styx River Basin
ML 80187
ML 700022
Watercourse
Waterbody
Alluvium
Styx Coal Measures
Basement

Scale @ A4 1:300,000
Date: 29/11/18
Drawn: A. Aird

Figure 10-28
Groundwater bore yields

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 groundwater bore yields.mxd 11/29/2018

Table 10-9 Results from aquifer pumping tests for the Styx Trial Pit (AMEC 2014)

Bore ID	Method	Hole depth (m)	Interval (m)	Average airlift rate (L/s)	T (m^2/d)	S
STX00104	Airlift pump	81.5	NR	0.03	<1 to 10	$2x10^{-7}$ to $4.4x10^{-6}$
STX00205	Airlift pump	88.3	NR	0.15	<1	-
NR – Not reported; T – Aquifer transmissivity; S – Aquifer storativity (dimensionless)						

Estimated values of aquifer storativity from the pumping test of STX00205 are close to, or below, the lower limit of practical values expected for compressibility of water and rock, noting that values of specific storativity less than approximately $1.0x10^{-6}$ m^{-1} are generally not anticipated on physical grounds. The small values of storativity indicate the observed responses at the observation bores were most likely caused by depressurisation of confined strata within the sequence intersected by the drillholes rather than drawdown of the water table.

Where possible, slug (falling head) tests have been undertaken on the newly installed Project WMP bores to obtain head response data for estimating the K of the strata directly adjacent the bores, which are screened across the Alluvium, Styx Coal Measures, Basement or straddling the Alluvium and shallow portions of the Styx Coal Measures. Three slug test methods were used; a near-instantaneous injection of potable water was added to a bore to displace the water column (falling head test); a volume of water was removed from the bore instantaneously (using a bailer) (rising head test); or a volume of water was removed from the bore using drilling rig to airlift the bore dry (rising head test). For bores that exhibited a quick recovery during testing that made analysis of the recovery data impracticable, a constant rate recovery test analysis was undertaken. In each method the water level recovery was monitored back to static. Details on methods used is provided as Appendix A6 – Groundwater Technical Report.

A summary of the slug analyses is provided in Table 10-10 for the project bores. Table 10-11 presents statistics for all Project area aquifer testing results. Figure 10-29 presents frequency distribution plots for estimated K data for each HSU, showing all HSUs to be heterogeneous (with K estimates varying across two to five orders of magnitude). In general terms, Table 10-11and Figure 10-29 show only the alluvial and weathered basement HSUs, and possibly the shallower Styx Coal Measures overburden, might be considered aquifers. The Styx Coal Measures coal seams / interburden and underburden units are considered to be aquitards.

Figure 10-30 presents the available estimates of transmissivity from GWDBQ records and from the testing of Project WMP bores.

Testing Results from Other Relevant Areas and Literature Review

The results of a review of hydrogeological property information from outside the Project area relating to geological units similar to or the same as those found within the Project area are presented in Table 10-12. Apart from the studies completed for the Project, very little of the information available for review is derived from investigations or studies conducted within the Styx River Basin. Where relevant information has not been identified, the values presented are sourced from the literature.

Estimates of hydrogeological properties for Cretaceous coal measures in Queensland are not widely available. Some information has been reported for the Maryborough Basin, which has a similar setting to Styx Basin being located to the southeast (north of Brisbane) and straddling the coast with onshore and offshore extents.

Table 10-10 Summary of derived hydraulic property estimates from aquifer tests

Bore ID	Test type	Screened Stratigraphy [1]	Solution	K (m/d) [2]	D (m) [2]	T (m^2/d) [2]
WMP02	Recovery	Alluvium	Theis Recovery	5	8.5	43
WMP04	FHT	Alluvium	Bouwer-Rice	0.01	3.9	0.04
			Hvorslev	0.02		0.08
WMP04D	FHT	Alluvium / SCM Overburden	Bouwer-Rice	0.02	23.2	0.5
			Hvorslev	0.03		0.7
WMP05	FHT	Alluvium	Bouwer-Rice	0.03	4.9	0.1
			Hvorslev	0.07		0.3
WMP06	FHT	Alluvium / SCM Underburden	Bouwer-Rice	0.01	1.5	0.02
WMP08	FHT	Alluvium	Bouwer-Rice	0.0005	3.9	0.002
WMP08D	FHT	SCM Underburden	Bouwer-Rice	0.03	26.5	0.8
WMP09	FHT	Alluvium	Bouwer-Rice	0.1	4.2	0.5
			Hvorslev	0.2		0.9
WMP10	FHT	SCM Overburden	Bouwer-Rice	0.004	10.7	0.04
WMP12	Recovery	Alluvium / SCM Overburden	Theis Recovery	2	8.5	17
WMP13	FHT	Alluvium / SCM Overburden	Bouwer-Rice	0.3	5.4	2
WMP16	FHT	SCM Overburden	Bouwer- - Mid	0.3	18.3	5
			Bouwer-Rice – Late	0.2		4
	RHT		Bouwer-Rice - Early	0.2		4
			Bouwer-Rice – Mid	0.04		0.7
			Bouwer-Rice – Late	0.007		0.1
WMP16D	FHT	SCM Coal seams / Interburden	Bouwer-Rice - Early	0.02	28.6	0.6
			Bouwer-Rice – Mid	0.003		0.1
			Bouwer-Rice – Late	0.001		0.03
	RHT		Bouwer-Rice – Early	0.01		0.3
			Bouwer-Rice – Mid	0.01		0.3
			Bouwer-Rice – Late	0.03		0.9
WMP17D	FHT	SCM Overburden	Bouwer-Rice – Mid	0.08	11.4	0.9
			Bouwer-Rice – Late	0.01		0.1
	RHT		Bouwer-Rice – Early	0.3		3
			Bouwer-Rice – Mid	0.06		0.7
WMP18D	FHT	SCM Overburden	Bouwer-Rice – Early	0.7	9.4	7
			Bouwer-Rice - Mid/late	0.02		0.2
WMP19	FHT	Weathered Basement	Bouwer-Rice	0.006	3.1	0.02
WMP19D	FHT	Weathered Basement	Bouwer-Rice – Early	0.6	15	9
			Bouwer-Rice – Mid/late	0.3		5
WMP20	FHT	SCM Overburden	Bouwer-Rice – Early	0.1	9.5	0.9
			Bouwer-Rice – Late	0.0004		0.004
	RHT		Bouwer-Rice – Early	0.3		3
			Bouwer-Rice – Mid	0.2		2
			Bouwer-Rice – Late	0.04		0.4
WMP20D	FHT	SCM Overburden	Bouwer-Rice – Mid	0.06	18.1	1
			Bouwer-Rice – Late	0.003		0.05
	RHT		Bouwer-Rice – Early	0.09		2
			Bouwer-Rice – Mid	0.02		0.4
WMP21D	FHT	Alluvium / SCM Overburden	Bouwer-Rice	0.1	7	0.7
WMP22A	RHT	SCM Overburden	Bouwer-Rice	0.05	15.33	0.8
WMP22B	FHT	SCM Coal seams / Interburden	Bouwer-Rice – Early	0.02	43.82	0.9
			Bouwer-Rice – Late	0.01		0.4
	RHT		Bouwer-Rice – Early	0.009		0.4
			Bouwer-Rice – Mid	0.005		0.2
			Bouwer-Rice – Late	0.01		0.4
	Recovery		Cooper-Jacob	0.005	6	0.03

Bore ID	Test type	Screened Stratigraphy [1]	Solution	K (m/d) [2]	D (m) [2]	T (m^2/d) [2]
WMP22C	FHT	SCM Underburden	Bouwer-Rice	0.003	193.52	0.6
	RHT		Bouwer-Rice – Early	0.003		0.6
			Bouwer-Rice – Mid	0.002		0.4
			Bouwer-Rice – Late	0.003		0.6
	Recovery		Cooper-Jacob	0.008	6	0.05
WMP23A	FHT	SCM Coal seams / Interburden	Bouwer-Rice	0.0007	44.1	0.03
WMP24	FHT	SCM Overburden	Bouwer-Rice	0.005	18.4	0.09
			Hvorslev	0.006		0.1
WMP25	FHT	Alluvium	Bouwer-Rice	0.006	17.8	0.1
WMP26	FHT	Alluvium	Bouwer-Rice – Early	0.03	5.6	0.2
			Bouwer-Rice – Mid/late	0.009		0.05
WMP27	FHT	Alluvium / SCM Overburden	Bouwer-Rice	0.006	1	0.006
WMP28	FHT	SCM Overburden	Bouwer-Rice	0.002	1	0.002
WMP29A	FHT	Alluvium	Bouwer-Rice - Early	6	0.7	4
			Bouwer-Rice – Late	8		6
	RHT		Bouwer-Rice - Early	7		5
WMP29B	FHT	Alluvium	Bouwer-Rice - Early	0.2	3	0.6
			Bouwer-Rice– Mid	0.02		0.06
	RHT		Bouwer-Rice - Early	0.2		0.6
			Bouwer-Rice – Mid	0.02		0.06
			Bouwer-Rice (1976) – Late	0.1		0.3
WMP29C	Qualitative[3]	SCM Overburden	Qualitative[1]	0.001	6	0.006
WMP29D	Qualitative[3]	SCM Coal seams / Interburden	Qualitative[3]	0.001		0.006
WMP29E	Qualitative[3]	SCM Underburden	Qualitative[3]	0.001		0.006

Notes:
1. Screened across multiple stratigraphic units, underlined unit is interpreted as dominant unit
2. K = hydraulic conductivity, D = aquifer thickness, T = transmissivity
3. K and T are qualitatively estimated from gauged recovery post-development. Bores recovered approximately 15 % in 5 days post-development, so a low K and T has been assigned

Table 10-11 Project area aquifer testing statistics

Screened Stratigraphy	No. bores	Measure	Estimated K, m/d [1]
Alluvium	11	Minimum Maximum Geomean Median	1.0×10^{-3} 7.3×10^{0} 6.3×10^{-2} 3.0×10^{-2}
Styx Coal Measures (bulk estimates for all sequences – overburden, coal seams / interburden and underburden)	19	Minimum [2] Maximum [3] Geomean Median	7.0×10^{-4} 3.0×10^{-1} 1.2×10^{-2} 1.4×10^{-2}
Styx Coal Measures Overburden	12	Minimum Maximum Geomean Median	1.0×10^{-3} 3.0×10^{-1} 2.0×10^{-2} 2.0×10^{-2}
Coal seams and interburden	4	Minimum Maximum Geomean Median	7.0×10^{-4} 7.5×10^{-3} 2.3×10^{-3} 3.0×10^{-3}
Underburden	3	Minimum Maximum Geomean Median	1.0×10^{-3} 3.0×10^{-2} 5.4×10^{-3} 5.2×10^{-3}
Weathered / Fractured Basement	2	Minimum Maximum Average	6.0×10^{-3} 3.0×10^{-1} 1.5×10^{-1}

Notes:
1. K = hydraulic conductivity
2. Consistent between all units within Styx Coal Measures
3. Maximum estimate derived from overburden unit, c.f. maximum measured in coal seams/interburden, and underburden of approximately one order of magnitude less (0.12 m/d)

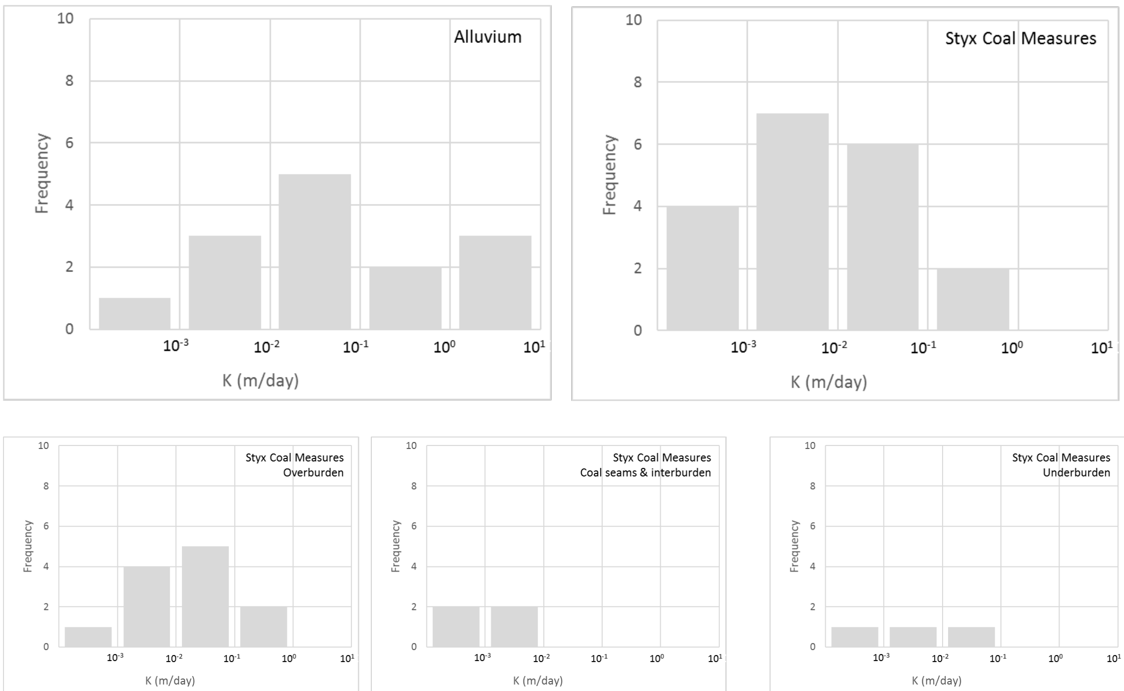


Figure 10-29 HSU hydraulic conductivity frequency distribution plots (note: x-axis logarithmic scale)

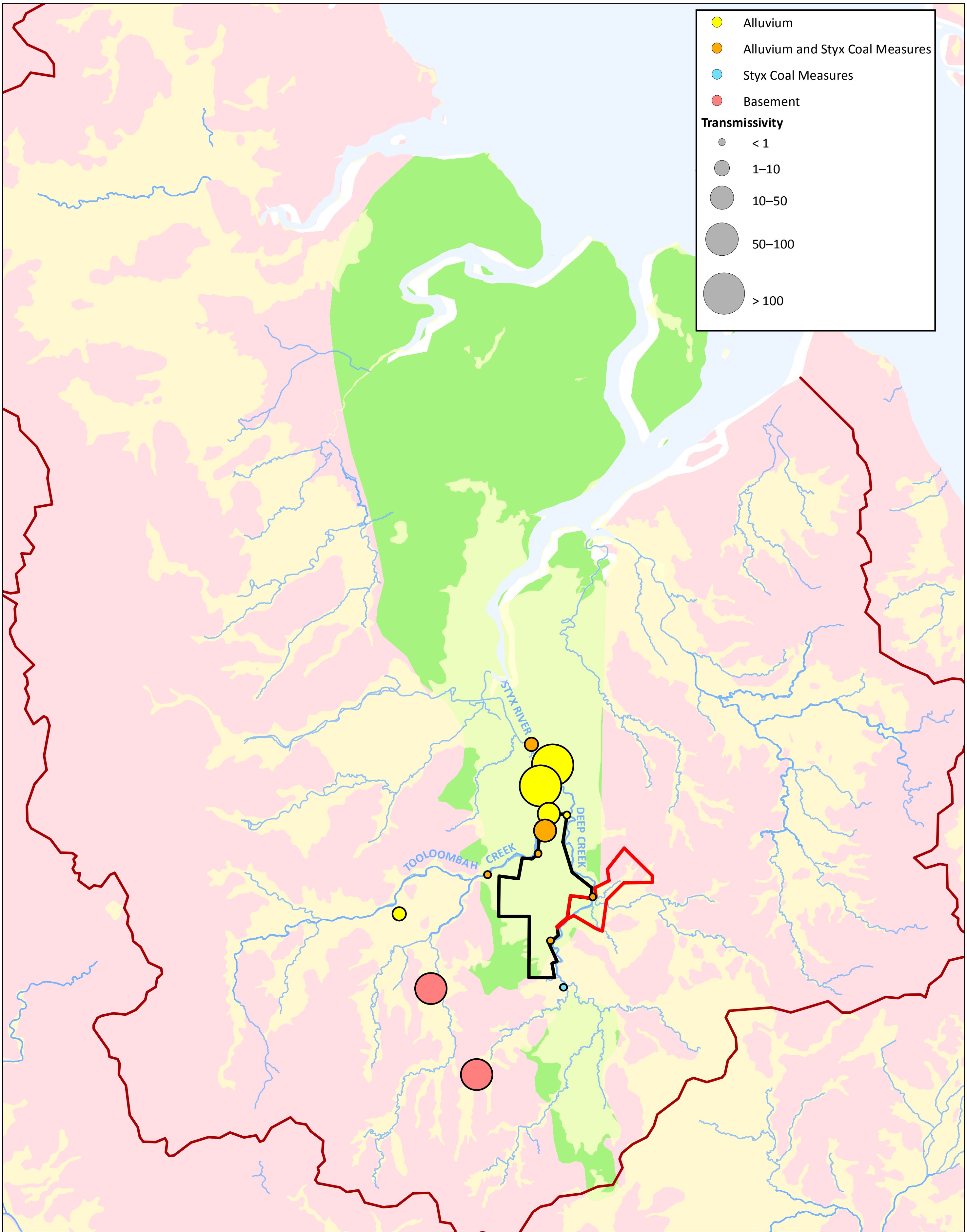


Figure 10-30

Reported transmissivity values

Scale @ A4 1:300,000
Date: 29/11/18
Drawn: A. Aird

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 reported transmissivity values.mxd 11/29/2018

There is more public information available concerning the hydrogeological properties of older and deeper Permian coal measures within Bowen Basin but the relevance to Cretaceous coal measures in the Styx Basin has not been established. In general, based on experience of Permian coal measures, there is an expectation that coal measures (including coal seams/interburden) are more permeable than the overburden and underburden sediments that do not contain coal seams (i.e. the coal seams typically have the higher permeability then bounding sediments). There is also an expectation the permeability of coal measures diminishes with burial depth due to compaction.

Information concerning the hydrogeological properties of the Back Creek Group is derived entirely from studies in the Bowen Basin. No examples from the Styx Basin have been found. There is almost no information about the hydrogeological properties of the Lizzie Creek Volcanic Group and Connors Volcanic Group, potentially because neither of these stratigraphic units are recognised as aquifers. In general, they contain sediments and rocks that are expected to exhibit hydrogeological properties consistent with very poor aquifers and aquitards.

The largest estimates of K are for alluvial sediments and the fractured / weathered (residual) basement rocks that outcrop or sub-crop in the Project area. These aquifers correspond to the shallow water-table aquifer targeted by farm and pastoral bores.

The available information suggests the alluvium and residual basement could have specific yield values around 0.5, whilst the Styx Coal Measures could have specific yield values ranging around 0.01.

The available aquifer testing data and results of analysis show the alluvium is typically more permeable than the underlying coal measures, generally by more than two orders of magnitude. Residual basement may have permeabilities ranging around the maximums observed for the alluvium, but unweathered basement can typically be expected to have permeabilities lower than either of the alluvium or coal measures. Significant heterogeneity exists in the Study Area groundwater system.

It is considered that sufficient aquifer testing results (local and more regional) are available to assist with characterisation of the hydrogeology of the four HSUs present in the Project area.

10.5.6.4 Hydrostratigraphy

Overview

Hydrostratigraphic units (HSUs) are zones within a geological system that have similar hydrogeological properties with respect to their influence on groundwater occurrence and flow. While HSUs are often chosen based on geology, the type of rock is less important than the properties of the rock that control resistance to groundwater flow and groundwater storage. At the broadest level, HSUs are categorised as aquifers and aquitards, where aquifers consist of stratigraphic units (or sequence of units) that store and transmit useful amounts of groundwater, and aquitards consist of stratigraphic units (or sequence of units) that generally restrict groundwater flow and do not transmit useful amounts of water.

Table 10-12 Summary hydrogeological properties from outside Project area

Stratigraphic unit	K_h, m/d	K_v, m/d	Sy	Ss, 1/m	Location	Method (Reference)
Alluvium	Min. 10^{-4} Max. 10^{1}	$2.5x10^{-2}$	$5x10^{-2}$	$1x10^{-4}$	Styx River Basin Maryborough Basin General (literature)	Testing (1) Literature (7) Modelling (2)
Cretaceous coal measures - overburden	$7.5x10^{-3}$	$7.5x10^{-4}$	10^{-2}	$1x10^{-5}$	Maryborough Basin	Modelling (2)
Cretaceous coal measures – coal	Min. 10^{-4} Max. $2.2x10^{-1}$	Min. 10^{-5} Max. $2.2x10^{-2}$	10^{-2}	$1x10^{-5}$	Maryborough Basin	Modelling (2)
Cretaceous coal measures - underburden	$5x10^{-3}$	$5x10^{-4}$	10^{-2}	$1x10^{-5}$	Maryborough Basin	Modelling (2)
Cretaceous coal measures - bulk	Min. $5x10^{-4}$ Max. $4.6x10^{1}$				Maryborough Basin	Testing (2) Modelling (2)
Residual basement (weathered Boomer Formation, Back Creek Group, Carmila Beds, Lizzie Creek Group and Colman Group)	Min. 10^{-3} Max. $3.3x10^{1}$	$2.5x10^{-2}$	$5x10^{-2}$	10^{-4}	Maryborough Basin General (literature)	Literature (7) Modelling (2)
Boomer Formation (siltstone, mudstone, sandstone)	Min. 10^{-5} Max. 10^{-1}				General (literature)	Literature (7)
Back Creek Group	Min. $4x10^{-4}$ Max. 10^{-1}	Min. 10^{-5} Max. $3x10^{-3}$	Min. $5x10^{-4}$ Max. $2x10^{-1}$	Min. $6x10^{-6}$ Max. $5x10^{-4}$	Bowen Basin	Modelling (3, 4, 5)
Carmila Beds (siltstone, mudstone, sandstone)	Min. 10^{-5} Max. 10^{-1}				General (literature)	Literature (7)
Lizzie Creek Volcanic Group	10^{-7}	10^{-6}	10^{-4}	10^{-6}	Bowen Basin	Modelling (6)
Connors Volcanic Group	10^{-5}				General (literature)	Literature (7)

Key: Kh – Horizontal hydraulic conductivity; Kv – Vertical hydraulic conductivity; Sy – Specific yield; Ss – Specific storativity
References: 1. Groundwater Database - Queensland (GWDBQ); 2. AGE (2010); 3. URS (2012); 4. URS (2013); 5. AGE (2014); 6. Drake Coal (2014); 7. The literature (Bear 1972, Bouwer 1978, Freeze and Cherry 1979)

Based on the observations presented in Sections 10.5.5.4 through to this section, the HSUs relevant to the Project are considered to be:

- HSU1- Alluvium (aquifer);
- HSU2- Styx Coal Measures (aquitard);
- HSU3- Weathered (residual) and fractured basement (aquifer); and
- HSU4- Unweathered (possibly fractured) basement (aquitard).

Brief descriptions of the HSUs defined as aquifers are outlined below, and general details are presented in Table 10-13. Figure 10-31 presents a schematic cross-sectional profile of the HSUs, and Figure 10-32 presents a map showing surface expression of the HSUs.

Table 10-13 Interpreted Project area hydrostratigraphic units

HSU	Geological Units	General geological description	Unit type	Unit description
HSU1: Alluvium	Cenozoic deposits	Unconsolidated alluvium, colluvium, soils, estuarine deposits etc.	Unconfined	Local unconsolidated aquifer of low to high productivity depending on thickness and depth
HSU2: Styx Coal Measures	Styx Coal Measures (overburden, coal seams/interburden and underburden)	Interbedded quartzose sandstone, mudstone, conglomerate and coal	Typically confined aquifer (when considered as an entire unit), variable aquifer and aquitard in reality	Porous extensive aquitards of generally low productivity [1]
HSU3: Weathered/ fractured basement	Outcropping and sub-cropping basement (Back Creek Group, Lizzie Creek Volcanic Group and Connors Volcanic Group)	Weathered sandstone, siltstone, mudstone, shale and volcanic rocks	Unconfined / confined	Local weakly to moderately consolidated aquifer of low to moderate productivity
HSU4: Basement	Back Creek Group (including Boomer Formation), Lizzie Creek Volcanic Group (including Carmila beds) and Connors Volcanic Group	Fractured/altered sandstone, siltstone, mudstone, shale, conglomerate and volcanic rocks	Aquitard	Typically massive, variably fractured or fissured

Notes: 1. Based on analysis of drilling and testing data obtained from Styx WMP bores

Descriptions

Alluvium (HSU1)

The alluvium comprises unconsolidated Cenozoic sediments associated with watercourses and floodouts/ plains (higher in the catchment), and watercourses and swamp deposits (in the coastal and estuarine parts of the lower catchment). These sediments have a thickness of up to 18 m (or more) across the Project area. Yeates (2011) reports groundwater being encountered during resource drilling in most boreholes between ground level and up to 30 m below ground with an inferred average water table depth of 16 m across the Project area.

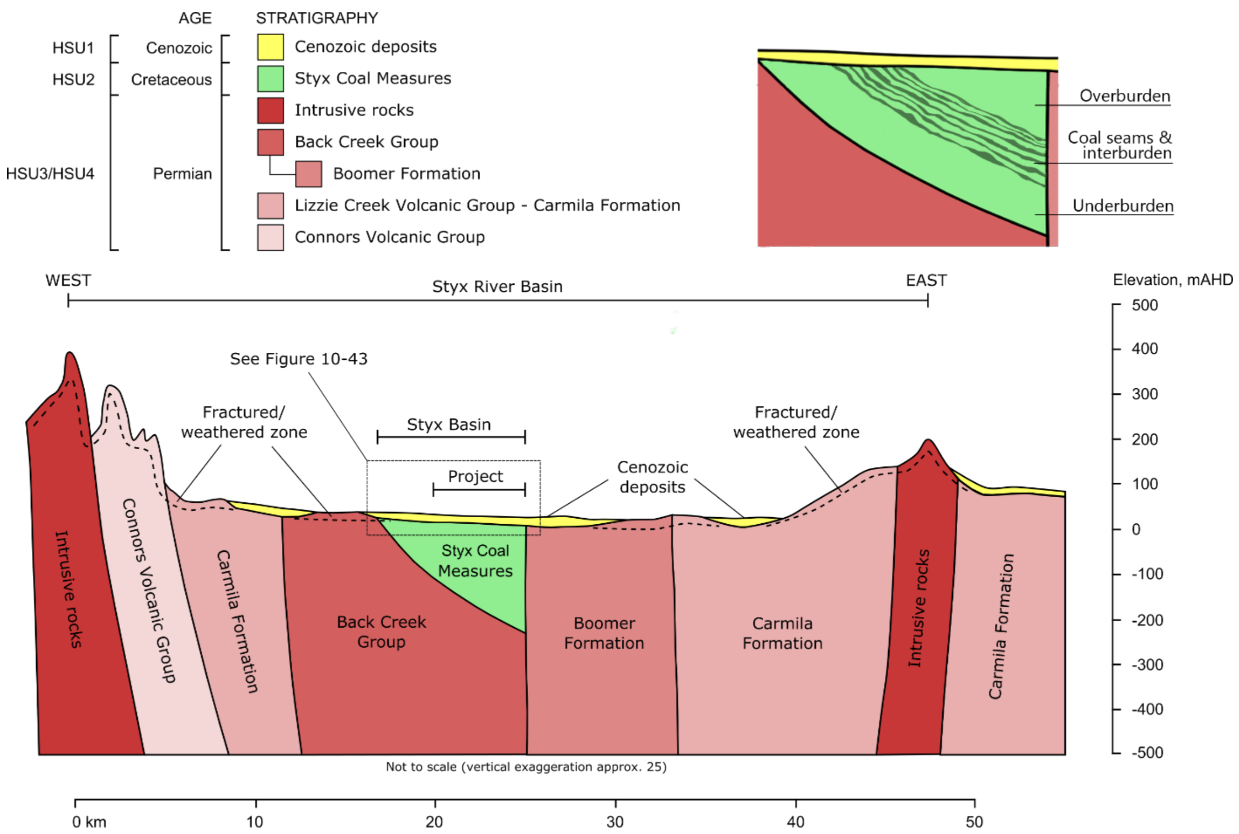


Figure 10-31 HSU cross-section schematic

Based on the distribution of identified landholder bores, it is likely the alluvium forms a useful aquifer upstream of Styx township but lower in the catchment it does not, due most likely to the presence of very brackish to saline groundwater.

During recent drilling of Project bores installed into the Alluvium (Table 10-6), airlift yields of less than 0.03 L/s have been encountered (the low airlift yields may be reflective of a lack of airline submergence rather than low K).

Styx Coal Measures (HSU2)

The Styx Coal Measures comprises all consolidated sedimentary rocks associated with the Styx Basin, including the coal seams and the overlying, interbedded and underlying sandstone and mudstone units. The units are described as:

- Overburden – consisting of the portion of the Styx Coal Measures above the upper-most coal seam delineated in the Proponent's local-scale geological model;
- Coal seams / interburden – consisting of the portion of the Styx Coal Measures between the upper and lower coal seams as delineated in the Proponent's local-scale geological model; and
- Underburden – consisting of the portion of the Styx Coal Measures below the lower-most coal seam delineated in the Proponent's local-scale geological model.

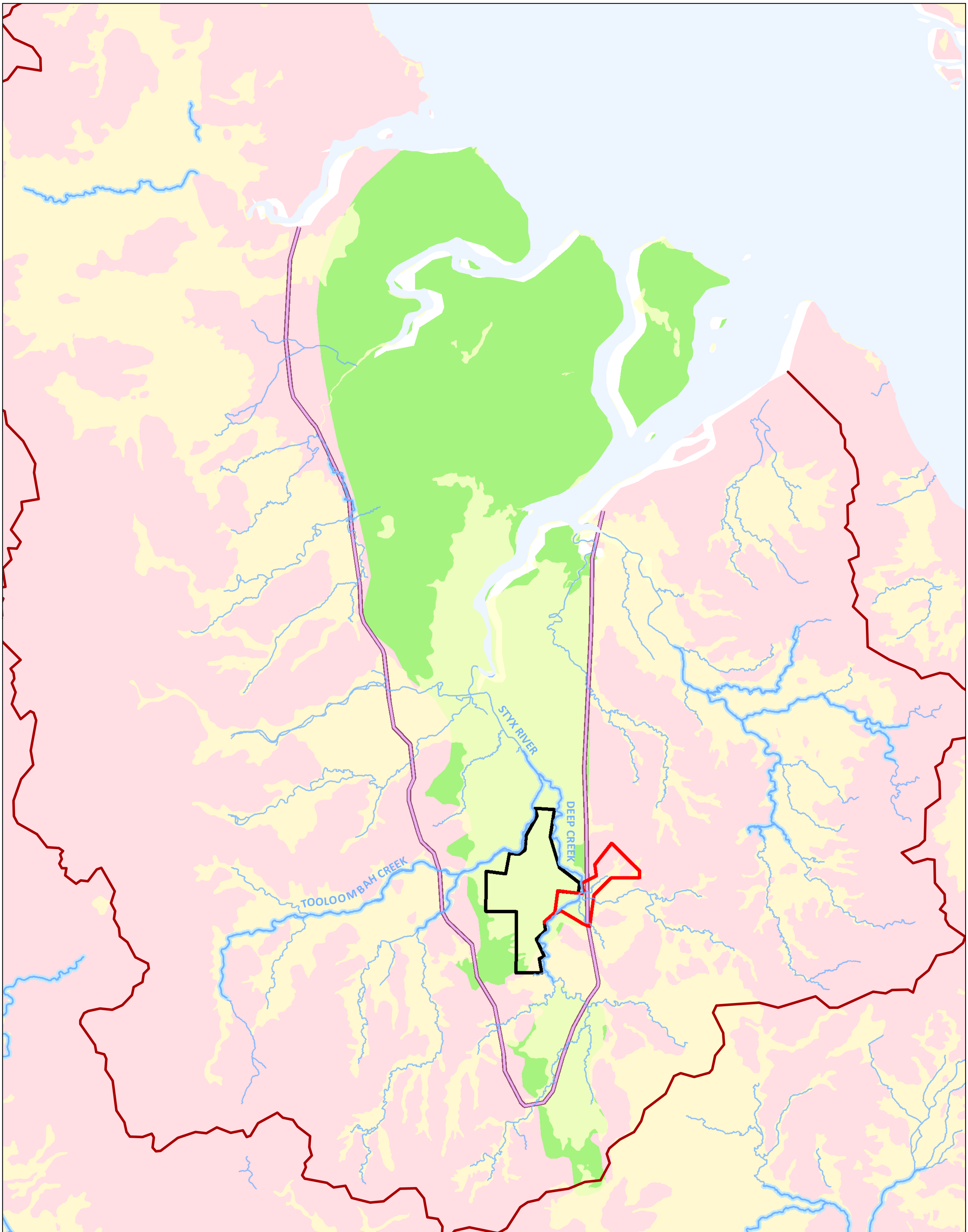


Figure 10-32
Spatial distribution of HSUs

Scale @ A4 1:300,000
Date: 29/11/18
Drawn: A. Aird

DATA SOURCE
QLD Open Source Data, 2018
Waratah Coal, 2018l
Styx basin modified from Central Queensland Coal and QLD Open Source Data, 2018
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 spatial distributioin of HSUs.mxd 11/29/2018

Coal seams are not generally classified as aquifers because of typically low K values. However, within a sequence of coal seams and typical interburden rocks (such as claystone and shale), the coal seams are sometimes referred to as 'aquifers' because they are more permeable than the much less-permeable interburden layers (IESC 2014).

The Styx Baseline Study (Yeates 2011), which presented the results of resource drilling programs, reported "there has been very little mention of water coming from the coals, though there have been some reports of salty water flows from the alluvium in the upper 50 m". Based on the observations of Yeates and other Central Queensland Coal personnel, the Styx Coal Measures can be considered a poor aquifer.

During recent drilling of Project WMP bores installed into the Styx Coal Measures (Table 10-6), very low airlift yields of between 0.01 and 0.15 L/s were observed to depths up to around 40 m. Typically, below 40 m no airlift yields were observed. At the tested depths, the low to negligible airlift yields cannot be attributed to lack of airline submergence and are considered to be representative of low K.

Weathered / fractured (residual) Basement (HSU3) and Unweathered Basement (HSU4)

Based on a review of the available literature, which shows the highest K's in basement rocks are encountered within shallow intersections, and experience elsewhere, it is likely a thin weathered section of basement (residual basement) could be extensive across the Styx Basin where their basement rocks outcrop or subcrop.

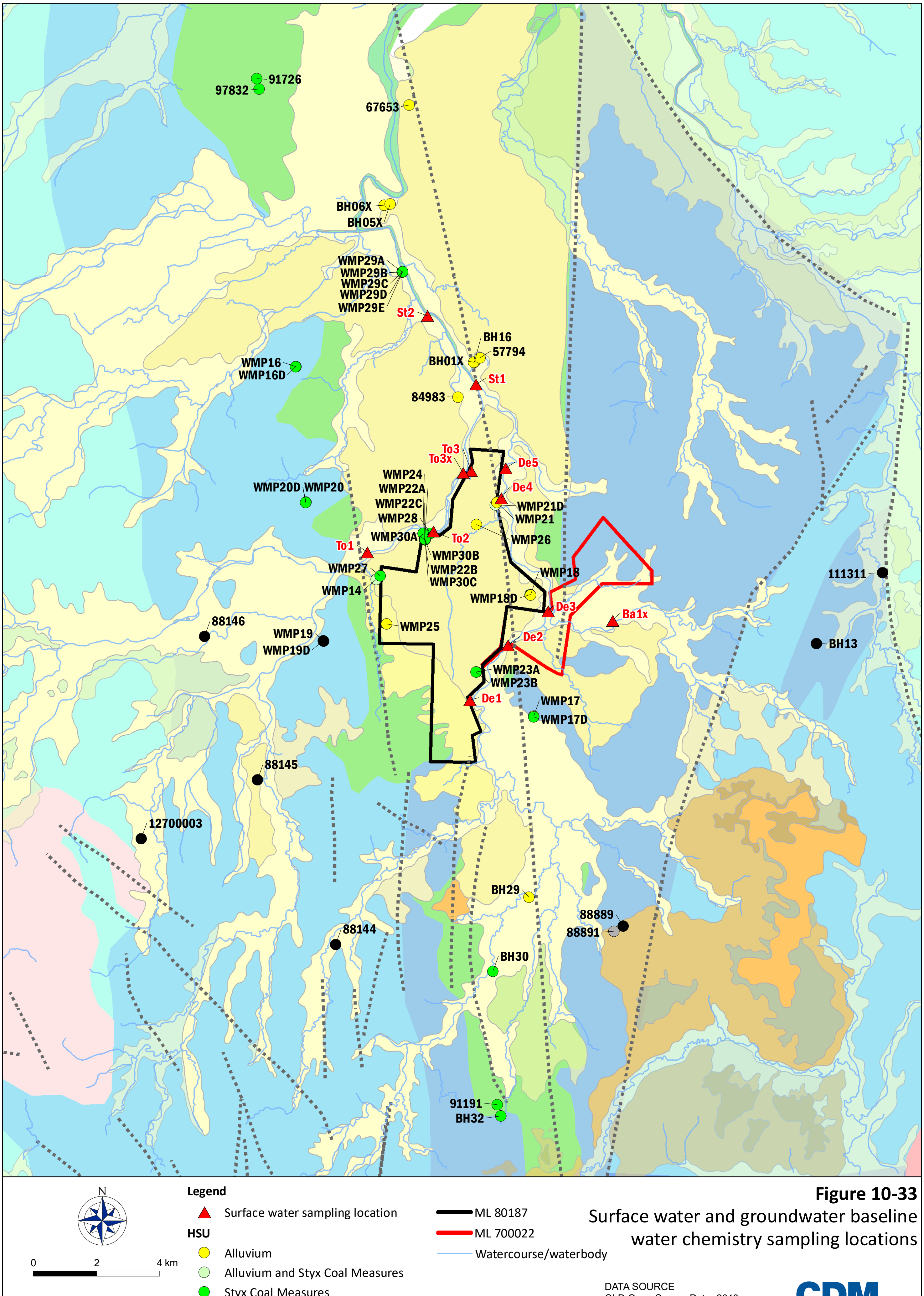
There are four HSUs present in the Project area – Alluvium, Styx Coal Measures, Weathered Basement, Unweathered Basement. Of these HSUs, only the Alluvium presents as what would normally be referred to as an aquifer. The Styx Coal Measures can at best be described as a poor aquifer, whilst the Weathered Basement may form an aquifer in places. Unweathered Basement forms a basal aquitard to regional the groundwater system.

10.5.6.5 Groundwater Chemistry

Overview

Groundwater chemistry information collated prior to water affecting activities commencing provides the basis for understanding the pre-mine baseline groundwater resource condition and assists in the interpretation of groundwater flow systems and interactions with surface water and connected systems. Groundwater chemistry is influenced by multiple factors including hydrogeological and mineralogical properties of aquifers and aquitards, sources of recharge, locations and form of discharge, groundwater flow rates and age, and anthropogenic effects. The data presented in this section is used to describe the baseline groundwater chemistry. Additional water chemistry data are presented in Section 10.6.1, which is used separately to assess the water requirements of potential groundwater dependent ecosystems.

Groundwater samples have been collected periodically during 2017 and 2018 from privately owned bores identified in the 2017 census, as well as Project WMP bores. Figure 10-33 presents surface water and groundwater sample locations. The number of baseline sampling events at privately owned bores and Project WMP bores is presented in Table 10-14.



Legend

- Surface water sampling location

HSU

- Alluvium
- Alluvium and Styx Coal Measures
- Styx Coal Measures
- Tertiary sediments
- Other / basement

- ML 80187
- ML 700022
- Watercourse/waterbody

Scale @ A4 1:150,000
Date: 07/12/18
Drawn: Kate H.

Refer Figure 10-16 for geology legend

Figure 10-33
Surface water and groundwater baseline water chemistry sampling locations

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018;
Geofabric Product Suite V2.1.1
Bureau of Meteorology (BoM) 2011

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 baseline water chem sampling locations.mxd 7/12/2018

Table 10-14 Styx Project groundwater sampling summary

Bore ID	Sampling period		Number of sampling events	Number of samples collected [1]	Dry / damaged
	Earliest	Most recent			
BH01X	Apr-2017	Sep-2018	12	12	
BH05X	Feb-2017	Feb-2017	2	1	1
BH06X	May-2017	Mar-2018	6	6	
BH13	May-2017	Mar-2018	6	6	
BH16	Apr-2017	Sep-2018	12	12	
BH29	May-2017	Nov-2017	5	5	
BH30	May-2017	Nov-2017	5	5	
BH32	Feb-2017	Nov-2017	5	5	
WMP02	Dec-2017	Sep-2018	11	10	
WMP04	Nov-2017	Sep-2018	12	11	
WMP04D	Nov-2017	Sep-2018	12	11	
WMP05	Nov-2017	Sep-2018	12	11	
WMP06	Dec-2017	Sep-2018	11	11	
WMP07	Dec-2017	Sep-2018	11	0	11
WMP08	Nov-2017	Sep-2018	13	13	
WMP08D	Nov-2017	Sep-2018	13	13	
WMP09	Nov-2017	Sep-2018	13	13	
WMP10	Nov-2017	Sep-2018	12	11	
WMP11	Apr-2018	Sep-2018	7	7	
WMP11D	Apr-2018	Sep-2018	7	7	
WMP12	Dec-2017	Sep-2018	11	5	6
WMP13	Jan-2018	Sep-2018	10	10	
WMP14	Apr-2018	Sep-2018	7	0	7
WMP15	Apr-2018	Sep-2018	7	7	
WMP16	Oct-2018	Oct-2018	1		
WMP16D	Oct-2018	Oct-2018	1		
WMP17	Oct-2018	Oct-2018	1		
WMP17D	Oct-2018	Oct-2018	1		
WMP18	Sep-2018	Sep-2018	1	1	
WMP18D	Sep-2018	Sep-2018	1	1	
WMP19	Sep-2018	Sep-2018	1	1	
WMP19D	Sep-2018	Sep-2018	1	1	
WMP20	Oct-2018	Oct-2018	1		
WMP20D	Oct-2018	Oct-2018	1		
WMP21	Sep-2018	Sep-2018	1	0	1
WMP21D	Sep-2018	Sep-2018	1	1	
WMP22A	Oct-2018	Oct-2018	1	1	
WMP22B	Oct-2018	Oct-2018	1	1	
WMP22C	Oct-2018	Oct-2018	1	1	
WMP23A	Oct-2018	Oct-2018	1	1	
WMP23B	Oct-2018	Oct-2018	1	1	
WMP24	Sep-2018	Sep-2018	1	1	
WMP25	Sep-2018	Sep-2018	1	1	
WMP26	Sep-2018	Sep-2018	1	1	
WMP27	Sep-2018	Sep-2018	1	0	1
WMP28	Sep-2018	Sep-2018	1	1	
WMP29A	Oct-2018	Oct-2018	1	1	
WMP29B	Oct-2018	Oct-2018	1	1	
WMP29C	Oct-2018	Oct-2018	1	1	
WMP29D	Nov-2018	Nov-2018	1	1	
WMP29E	Oct-2018	Oct-2018	1	1	
WMP30A	n/a	n/a	n/a	n/a	
WMP30B	n/a	n/a	n/a	n/a	
WMP30C	n/a	n/a	n/a	n/a	

Notes: 1. Samples sometimes could not be collected due to dry or damaged well, or lack of access
n/a Not sampled

In this assessment, groundwater chemistry data (laboratory reported concentrations) are compared against:

- The Australian and New Zealand Guidelines (ANZECC) Guidelines (ANZECC and ARMCANZ, 2000) that are relevant to protection of freshwater aquatic ecosystems, irrigation and stock drinking water;
- The ADWG (NHMRC, NRMMC 2011); and
- WQOs set for the three GCZs within the area that may be impacted by the Project.

Salinity and Major Ions

The results of a review of groundwater salinity data recorded in the GWDBQ, privately owned bores and Styx Project WMP bores are summarised in Table 10-15.

Figure 10-34 presents the spatial distribution of groundwater salinity for each HSU, based on the data presented in Table 10-15.

Table 10-15 Measured groundwater salinity and pH

ID / RN	Inferred HSU	GCZ	TDS (mg/L) [1]	ADWG Palatability [2]	ANZECC stock suitability	pH [4]
GWDQB Data						
57794	Alluvium	Bison	250	Good	Acceptable	7.6
67653	Alluvium	Styx	3,576	Unacceptable	Acceptable	7.5
67654	Alluvium	Styx	8,487	Unacceptable	Acceptable	7.2
84983	Alluvium	Bison	757	Fair	Acceptable	7.6
88144	Basement (Back Creek Group)	Bison	2,863	Unacceptable	Acceptable	6.8
88145	Basement (Back Creek Group)	Bison	1,621	Unacceptable	Acceptable	6.8
88146	Basement (Back Creek Group)	Uplands	529	Good	Acceptable	6.8
88889	Not known	Styx	4,684	Unacceptable	Acceptable	7.6
88891	Tertiary sediments	Styx	5,370	Unacceptable	Unacceptable	7.2
91191	Styx Coal Measures	Styx	4,151	Unacceptable	Acceptable	8
91457	Basement (Carmila Beds)	Uplands	777	Fair	Acceptable	8
91726	Styx Coal Measures	Styx	4,587	Unacceptable	Acceptable	7.8
97832	Styx Coal Measures	Styx	4,294	Unacceptable	Acceptable	7.4
111311	Basement (Boomer Formation)	Styx	8,487	Unacceptable	Unacceptable	7.8
111312	Basement (Carmila Beds)	Styx	2,822	Unacceptable	Acceptable	8.2
12700003	Basement (Rhyolite)	Styx	3,815	Unacceptable	Acceptable	7.5
Private bores (census data)						
BH01X	Alluvium	Bison	270 – 718	Good-Fair	Acceptable	6.1-7.5
BH05X	Alluvium	Styx	8,920	Unacceptable	Unacceptable	7.2
BH06X	Alluvium	Styx	577 – 962	Good-Fair	Acceptable	7.1-7.8
BH13	Basement (Boomer Formation)	Styx	2,110 – 5,480	Unacceptable	Acceptable-unacceptable	6.5-7.1
BH16	Alluvium	Bison	221 - 424	Good	Acceptable	6.1-7.9
BH29	Alluvium	Uplands	190 - 216	Good	Acceptable	6.3-6.6
BH30	Styx Coal Measures	Styx	6,530 – 16,700	Unacceptable	Unacceptable	6.4-7.7
BH32	Styx Coal Measures	Styx	2,630 – 3,490	Unacceptable	Acceptable	6.8-7.1
Styx Project WMP bores						
WMP02	Alluvium	Bison	8,750 – 11,900	Unacceptable	Unacceptable	6.1-7.1

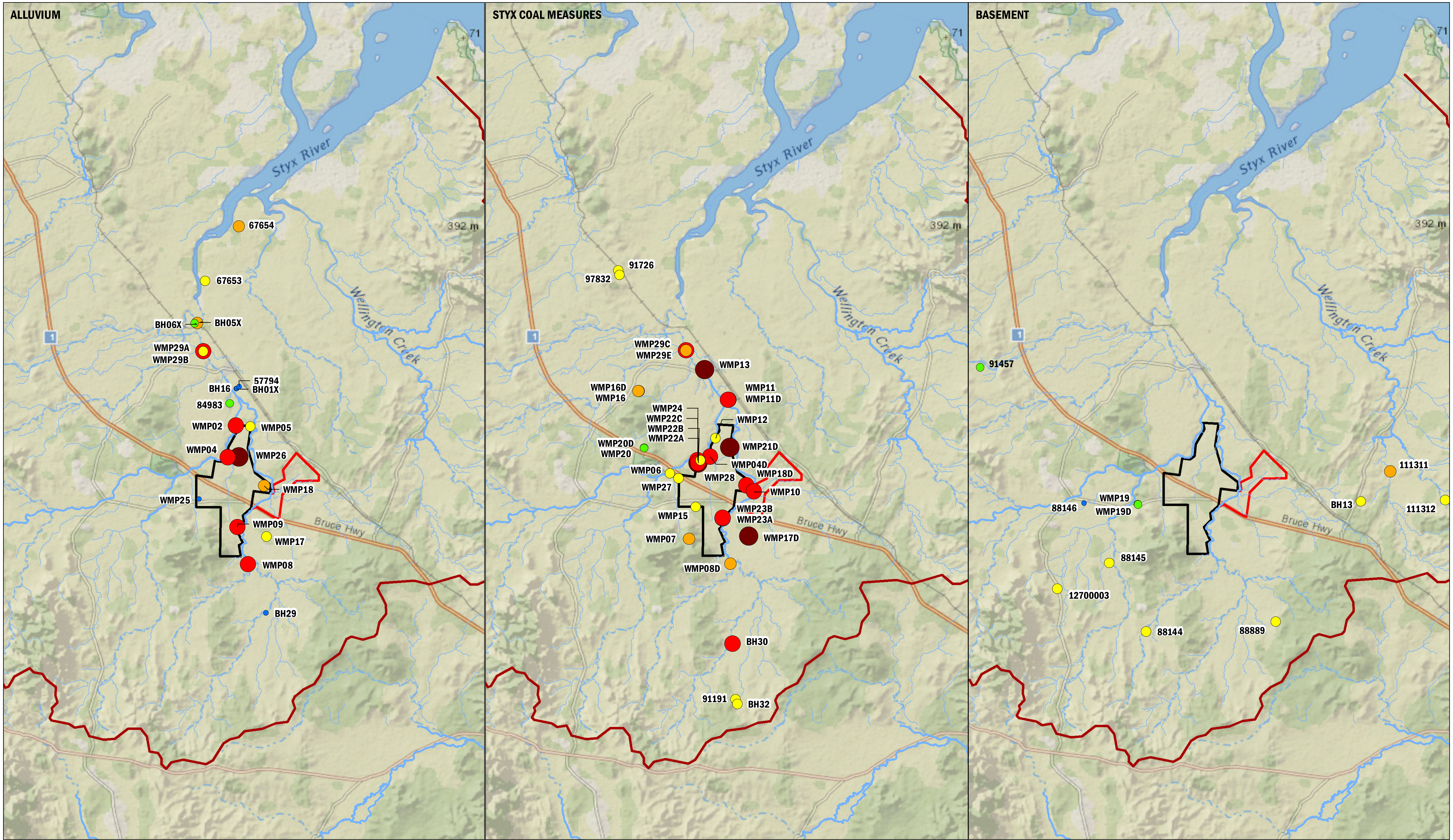
ID / RN	Inferred HSU	GCZ	TDS (mg/L) [1]	ADWG Palatability [2]	ANZECC stock suitability	pH [4]
WMP04	Alluvium	Uplands	5,760 – 17,000	Unacceptable	Unacceptable	7.3-9.3
WMP04D	Alluvium and Styx Coal Measures (overburden)	Uplands	14,200 – 17,600	Unacceptable	Unacceptable	6.5-7.4
WMP05	Alluvium	Bison	1,260 – 2,310	Unacceptable	Acceptable	6.8-7.5
WMP06	Alluvium and Styx Coal Measures (underburden)	Styx	1,170 – 4,400	Poor-Unacceptable	Acceptable	6.3-7.4
WMP07	Styx Coal Measures (underburden)	Styx	8,870	Unacceptable	Unacceptable	-
WMP08	Alluvium	Uplands	8,870 - 19,200	Unacceptable	Unacceptable	6.5-7.5
WMP08D	Styx Coal Measures (underburden)	Uplands	8,180 - 8,870	Unacceptable	Unacceptable	6.98-7.7
WMP09	Alluvium	Uplands	9,650 - 14,800	Unacceptable	Unacceptable	6.5-7.3
WMP10	Styx Coal Measures (overburden)	Uplands	9,410 - 11,400	Unacceptable	Unacceptable	6.6-7.7
WMP11	Styx Coal Measures (overburden)	Bison	17,700 - 22,300	Unacceptable	Unacceptable	6.3-7.3
WMP11D	Styx Coal Measures (overburden)	Bison	20,500 - 21,900	Unacceptable	Unacceptable	6.3-7.3
WMP12	Alluvium and Styx Coal Measures (overburden)	Uplands	1,440 – 5,960	Unacceptable	Acceptable - Unacceptable	6.8-8.6
WMP13	Alluvium and Styx Coal Measures (overburden)	Styx	22,300 – 37,400	Unacceptable	Unacceptable	5.6-7.6
WMP14	Alluvium and Styx Coal Measures (overburden)	Styx	Dry			
WMP15	Alluvium and Styx Coal Measures (underburden)	Styx	2,200 – 4,600	Unacceptable	Acceptable	6.7-7.9
WMP16 5	Styx Coal Measures (overburden)	Styx	5,820	Unacceptable	Unacceptable	7.9
WMP16D [5]	Styx Coal Measures (coal seams/interburden)	Styx	5,055	Unacceptable	Unacceptable	7.9
WMP17 [5]	Alluvium	Uplands	4,490	Unacceptable	Acceptable	7.5
WMP17D [5]	Styx Coal Measures (overburden)	Uplands	27,490	Unacceptable	Unacceptable	-
WMP18 [5]	Alluvium	Uplands	6,930	Unacceptable	Unacceptable	-
WMP18D [5]	Styx Coal Measures (overburden)	Uplands	19,760	Unacceptable	Unacceptable	7.8
WMP19 [5]	Basement	Styx	1,030	Poor	Acceptable	7.7
WMP19D [5]	Basement	Styx	1,110	Poor	Acceptable	7.7
WMP20 [5]	Styx Coal Measures (overburden)	Styx	1,155	Poor	Acceptable	-
WMP20D [5]	Styx Coal Measures (overburden)	Styx	1,155	Poor	Acceptable	8
WMP21	Alluvium	Uplands	Dry			
WMP21D [5]	Alluvium and Styx Coal Measures (overburden)	Uplands	27,320	Unacceptable	Unacceptable	7.7
WMP22A [5]	Styx Coal Measures (overburden)	Uplands	15,615	Unacceptable	Unacceptable	-
WMP22B [5]	Styx Coal Measures (coal seams/interburden)	Uplands	39,420	Unacceptable	Unacceptable	-
WMP22C [5]	Styx Coal Measures (underburden)	Uplands	13,375	Unacceptable	Unacceptable	-
WMP23A [5]	Styx Coal Measures (coal seams/interburden)	Uplands	16,320	Unacceptable	Unacceptable	-

ID / RN	Inferred HSU	GCZ	TDS (mg/L) [1]	ADWG Palatability [2]	ANZECC stock suitability	pH [4]
WMP23B [5]	Styx Coal Measures (underburden)	Uplands	14,465	Unacceptable	Unacceptable	-
WMP24 [5]	Styx Coal Measures (overburden)	Uplands	14,870	Unacceptable	Unacceptable	7.9
WMP25 [5]	Alluvium	Styx	590	Good	Acceptable	7.8
WMP26 [5]	Alluvium	Uplands	33,290	Unacceptable	Unacceptable	7.6
WMP27 [5]	Styx Coal Measures (overburden)	Styx	1,855	Unacceptable	Acceptable	-
WMP28 [5]	Styx Coal Measures (overburden)	Uplands	2,050	Unacceptable	Acceptable	8.1
WMP29A [5]	Alluvium	Styx	2,368	Unacceptable	Acceptable	-
WMP29B [5]	Alluvium	Styx	17,600	Unacceptable	Unacceptable	-
WMP29C [5]	Styx Coal Measures (overburden)	Styx	7,610	Unacceptable	Unacceptable	-
WMP29D	Styx Coal Measures (coal seams/interburden)	Styx	No data			
WMP29E [5]	Styx Coal Measures (underburden)	Styx	13,180	Unacceptable	Unacceptable	-
WMP30A	Styx Coal Measures (overburden)	Uplands	No data			
WMP30B	Styx Coal Measures (coal seams/interburden)	Uplands	No data			
WMP30C	Styx Coal Measures (underburden)	Uplands	No data			

Notes: 1 TDS – Total dissolved solids concentration, analysed in laboratory
2 ADWG palatability - Australian Drinking Water Quality Guidelines (NHMRC, NRMMC 2011): Good (TDS 0 – 600 mg/L), Fair (TDS 600 - 900 mg/L); Poor (TDS 900 – 1,200 mg/L), Unacceptable (TDS >1,200 mg/L)
3 ANZECC stock suitability - Australian and New Zealand Guidelines (ANZECC and ARMCANZ 2000): Acceptable (TDS 2,000 – 5,000 mg/L), Unacceptable (TDS >5,000 mg/L)
4 Measured in field
5 Bores have TDS values calculated from field EC values using a factor of 0.64 (based on relationship between EC and TDS estimated from historic data in the area)

The data presented in Table 10-15 and Figure 10-34 show groundwater salinity (as total dissolved solids; TDS) is variable across the Styx River Basin, ranging from drinking water quality (TDS less than 600 mg/L) to water quality unacceptable for drinking or livestock (TDS greater than 1,200 and 5,000 mg/L, respectively):

- Alluvium aquifer (HSU1) groundwater salinity ranges from 190 to 33,290 mg/L, notably with the higher salinities reported for alluvial groundwaters in the Project area (e.g. WMP02, WMP04, WMP08, WMP09 and WMP26) compared to those closer to Broad Sound and the coast;
- Groundwater sampled from the Styx Coal Measures (HSU2) is generally more saline than groundwater in the other HSUs with salinity ranging from 1,170 to 37,400 mg/L, notably there is no apparent trend in high salinity groundwaters across the Project area and beyond;
- Basement (HSU3/HSU4) groundwater salinity (Back Creek Group or Carmila Beds) ranges from 530 to 8,500 mg/L;
- Of the available data, approximately 60% of samples report TDS concentrations within the acceptable salinity tolerance of most livestock (2,000 to 5,000 mg/L TDS); and
- There is no evidence of a seawater – freshwater interface in the deep 'aquifer' units located near Broad Sound (the nested WMP29 wells), with the most saline groundwater sampled from the deeper alluvial sequence (WMP29B; screened between 16 and 20 mbgl – the deepest bore, WMP29E, is screened between 220 and 228.5 mbgl and groundwater sampled from this bore reports a salinity that is 75% of WMP29B groundwater).



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0 5 10 km

Scale @ A3 1:270,000
Date: 29/11/18
Drawn: KMH

Legend

Salinity (mg/L)

- 0-600
- 601–1,200
- 1,201–5,000
- 5,001–10,000
- 10,001–25,000
- >25,000

- Styx River Basin
- ML 80187
- ML 700022
- Major watercourse
- Ordered drainage

Figure 10-34
Spatial groundwater salinity distribution

DATA SOURCE
QLD Open Source Data, 2018
Waratah Coal, 2018
Styx basin modified from Central Queensland Coal and Qld Open Source Data, 2018
Esri Basemaps, 2017

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Groundwater_salinity_R4.mxd 11/29/2018

Box and Whisker plots of laboratory reported major ion concentrations, selected dissolved metal concentrations, as well as EC, TDS and field recorded pH are presented in Figure 10-35 to Figure 10-37. The water chemistry data presented on the Box and Whisker plots are grouped by HSU and GCZ. As most of the sample locations have fewer than 10 sampling events, and some have only a few sample events, it is not practical to present statistical results for individual locations.

Laboratory reported major ion concentrations in groundwater samples are presented as a Piper plot in Figure 10-38, along with major ion concentrations for seawater and rainfall (Rockhampton). At locations where the bores are screened across multiple HSUs, the dominant unit was identified based on comparison with the results for other bore locations. The Piper plot shows:

- Alluvium groundwater varies from being similar to Rockhampton rainfall to almost seawater (sodium (Na)-chloride (Cl) dominant), consistent with ocean derived salts mixed with rainfall recharge, or mixing of terrestrial groundwater and marine groundwater in areas where this is likely to occur (e.g. near the coast or near estuaries);
- Concentrations of major ions in Styx Coal Measures groundwaters also vary widely but is typically Na-Cl dominant, which may be representative of depositional environment; and
- Concentrations of major ions in Basement groundwater typically do not display a dominant water type but is generally calcium (Ca)-Cl dominant, which likely indicates reverse ion exchange processes where Na in groundwater is exchanged with Ca in the lithology, resulting in the Ca-Cl dominance.

For comparison, reported groundwater major ion data collected in the November/ December 2017 (representing end of dry season), March 2018 (representing end of wet season) and September 2018 (representing dry season) sampling events are also presented spatially as Stiff patterns on Figure 10-39 to Figure 10-46 (seawater and Rockhampton rainfall are also presented for comparison).

The November/ December 2017 (end of dry season/ early wet season) Stiff patterns show:

- Groundwater chemistry signatures of bores completed in the alluvium varies between sites (Figure 10-39 and Figure 10-40);
- Some are more similar to rainwater and less like seawater, as evidenced by the higher concentrations of Ca and HCO_3 in the groundwater samples. The groundwater samples also report a generally lower salinity than would be expected if seawater interaction with groundwater were a dominant process;
- The groundwater chemistry signature of the Styx Coal Measures varies slightly between sites (Figure 10-41 and Figure 10-42). However, all are Na-Cl dominant, which could reflect the shallow marine / estuarine depositional environment of the Styx Coal Measures, or long residence time, or a combination of these processes;
- The groundwater chemistry signature for alluvium bores in close proximity to the Styx Project WMP bores is either similar to the Styx Coal Measures (refer Figure 10-39 and Figure 10-41) or to recharge from rainfall or stream flow events (refer Figure 10-9, Figure 10-11 and Figure 10-39); and
- The groundwater chemistry signature at WMP13 (screening the alluvium and coal measures near Styx River, downstream of the Deep Creek and Tooloombah Creek confluence) is similar to other Styx Coal Measures groundwater samples.

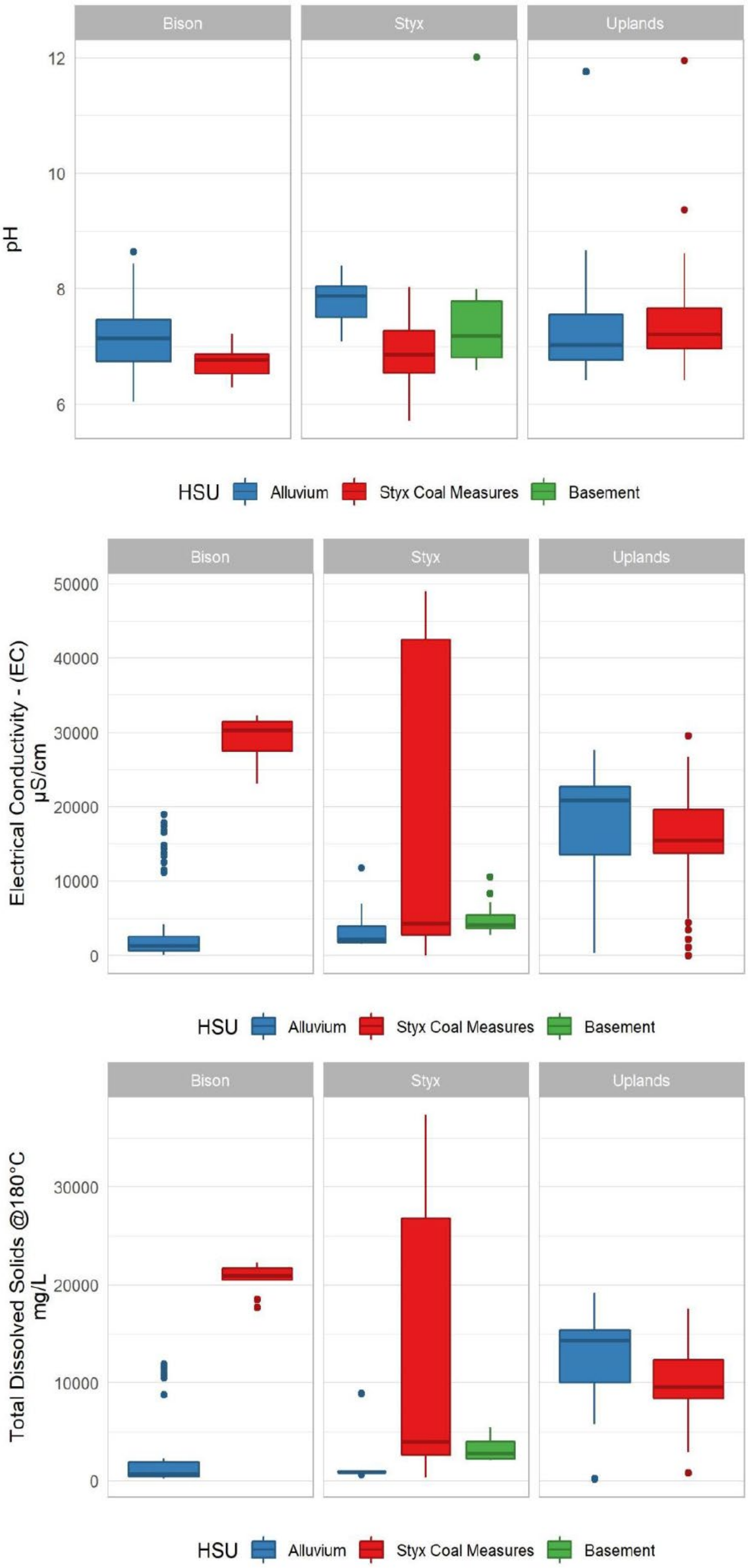


Figure 10-35 Box and Whisker plots – pH, EC and TDS for each GCZ

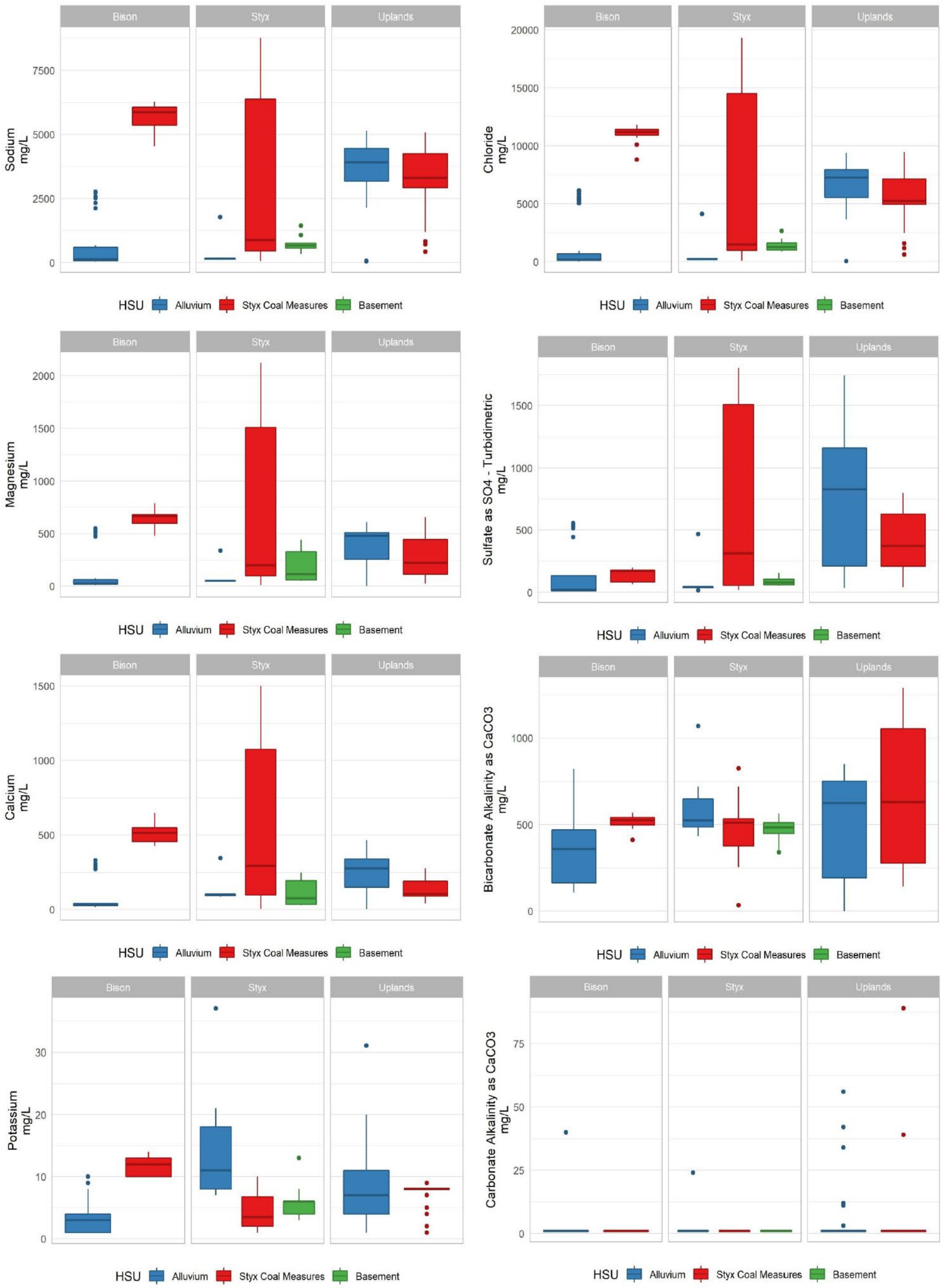


Figure 10-36 Box and Whisker plot –Major Ions for each GCZ

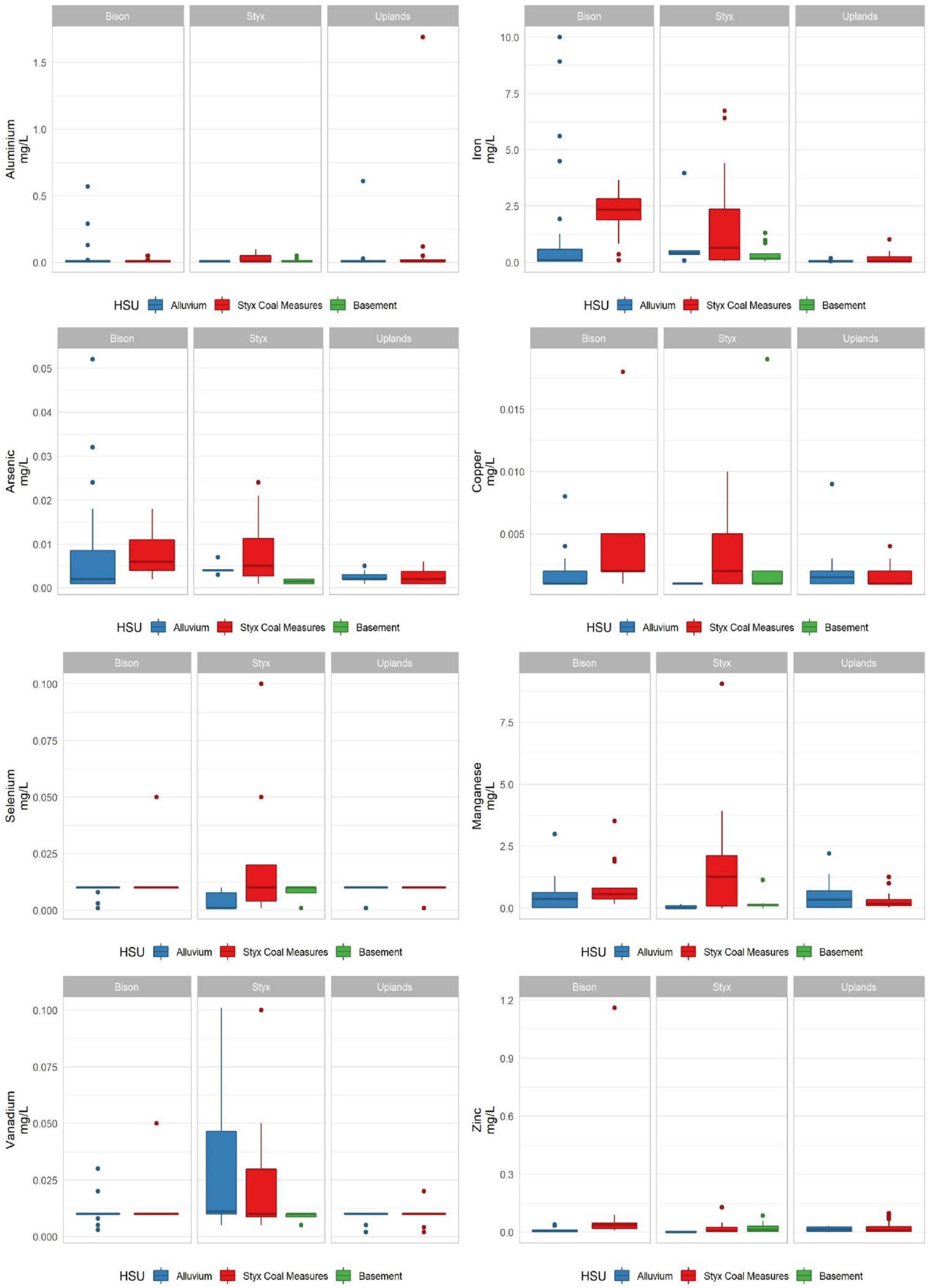


Figure 10-37 Box and Whisker plot – Select Dissolved Metals for each GCZ

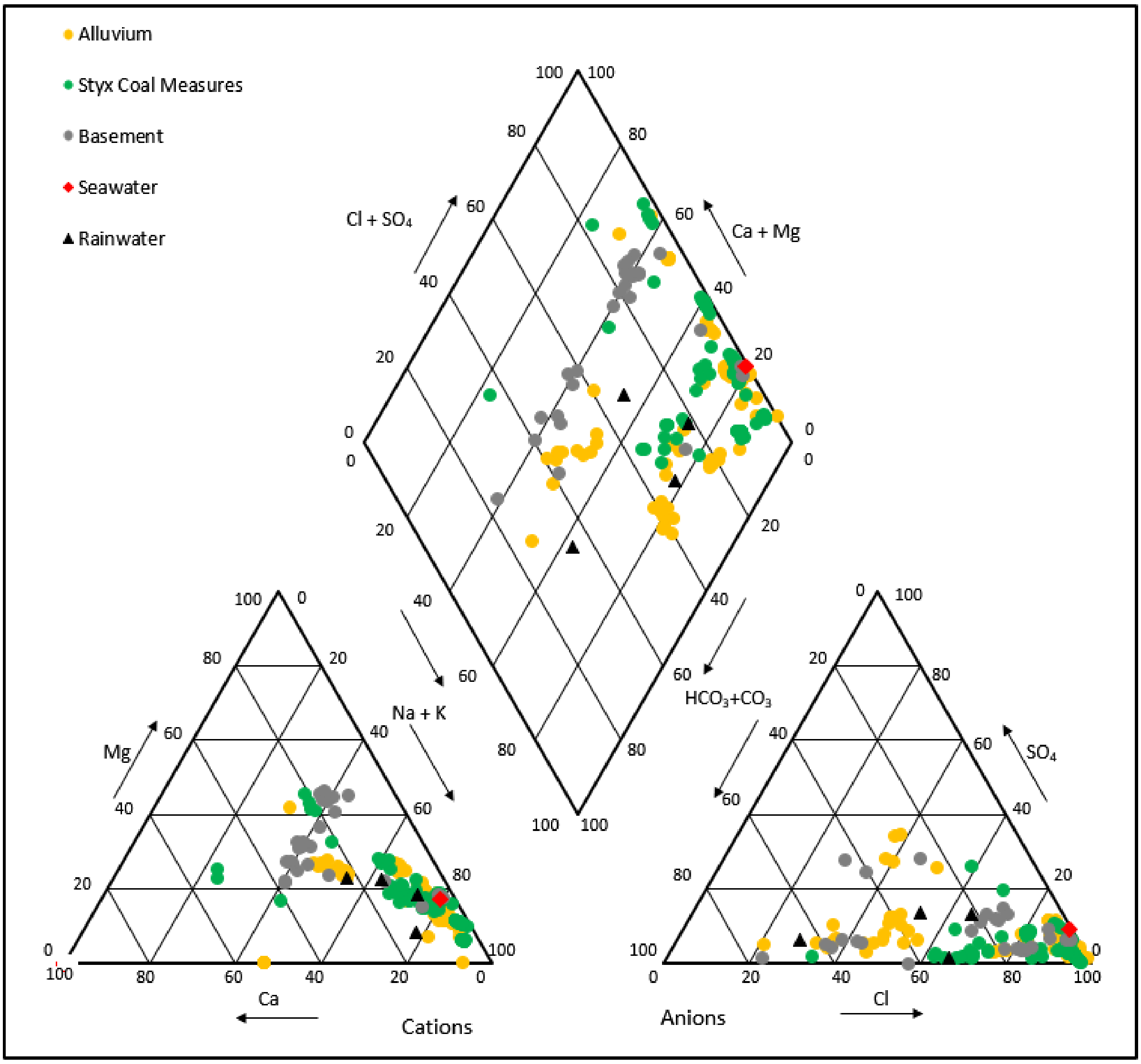
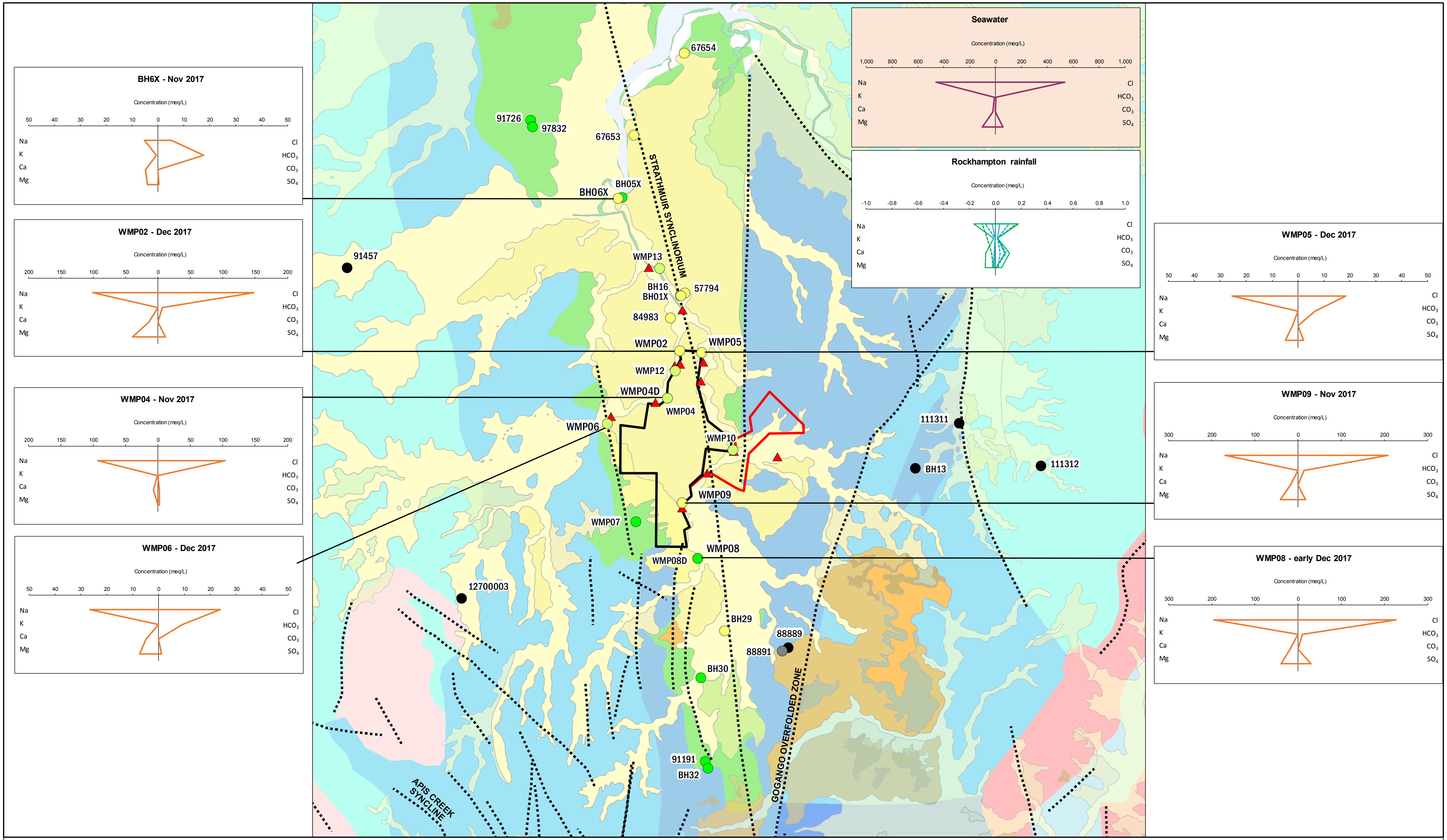


Figure 10-38 Groundwater tri-linear Piper Plot

The Stiff patterns from the March 2018 (end of wet season) sampling event show:

- Alluvial groundwaters typically demonstrate a shift toward a rainwater signature toward the end of the wet season (Figure 10-43), as would be expected in response to streamflow and rainfall recharge. This is most evident at WMP05 and WMP06; and
- Styx Coal Measures groundwater does not show significant seasonal variability (Figure 10-44).



N

0 2.5 5 km

Scale @ A3 1:180,000
Date: 29/11/18
Drawn: NAME

Legend

Groundwater quality sample locations

Aquifer

- Alluvium
- Alluvium and Styx Coal Measures
- Other
- Styx Coal Measures
- Tertiary (undefined)

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

Refer Figure 10-16 for geology legend

Figure 10-39

Alluvium groundwater Stiff patterns – November/December 2017 sampling

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2017
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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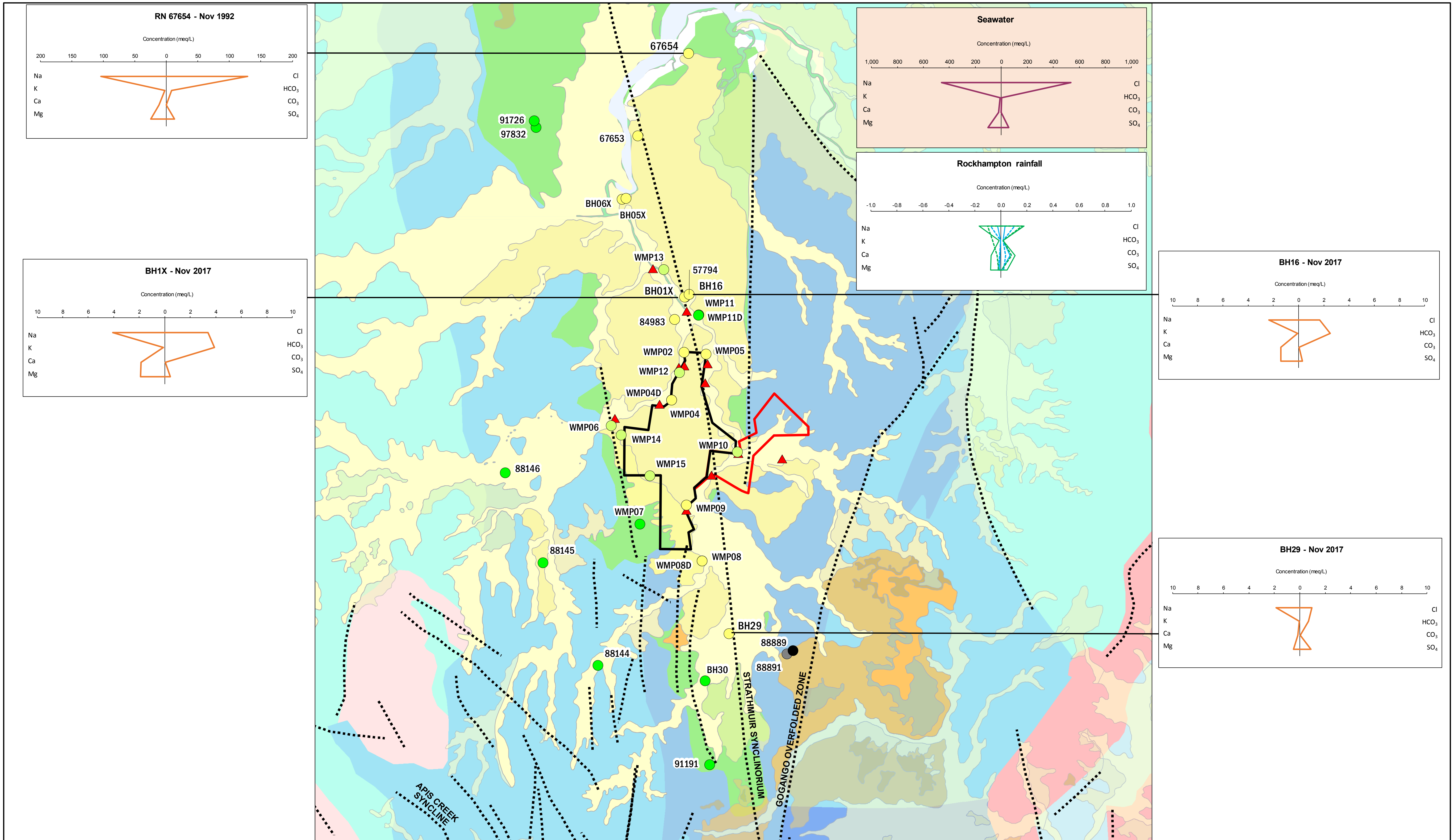

N

0 2.5 5 km

Scale @ A3 1:180,000
Date: 29/11/18
Drawn: Gayle B.

Legend

Groundwater quality sample locations

Aquifer

- Alluvium
- Alluvium and Styx Coal Measures
- Other
- Styx Coal Measures
- Tertiary (undefined)

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

Refer Figure 10-16 for geology legend

Figure 10-40

Alluvium groundwater Stiff patterns – November and December 2017 sampling

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2017
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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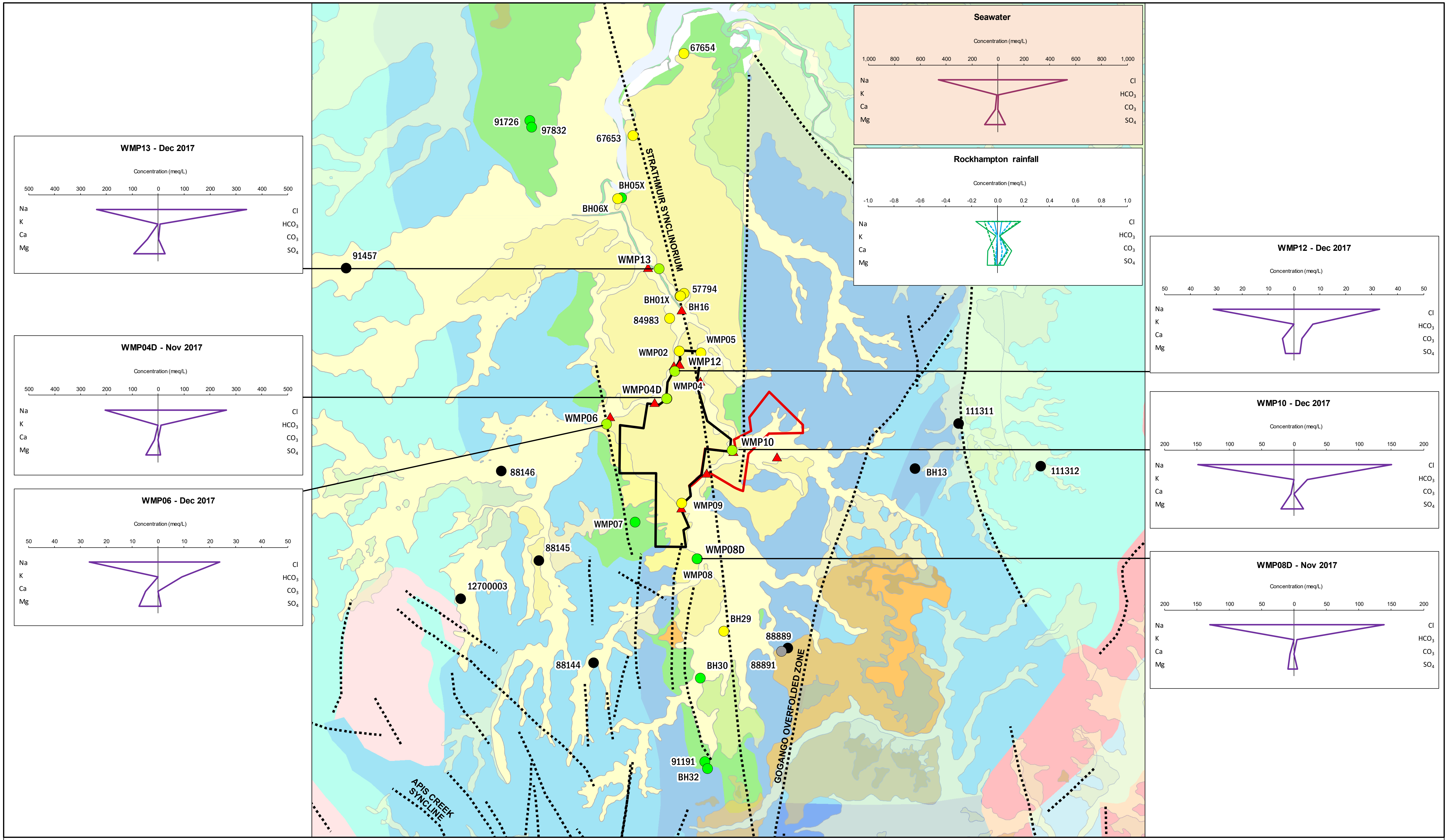


N

0 2.5 5 km

Scale @ A3 1:180,000
Date: 07/12/18
Drawn: KMH

Legend

Groundwater quality sample locations

Aquifer

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

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

Refer Figure 10-16 for geology legend

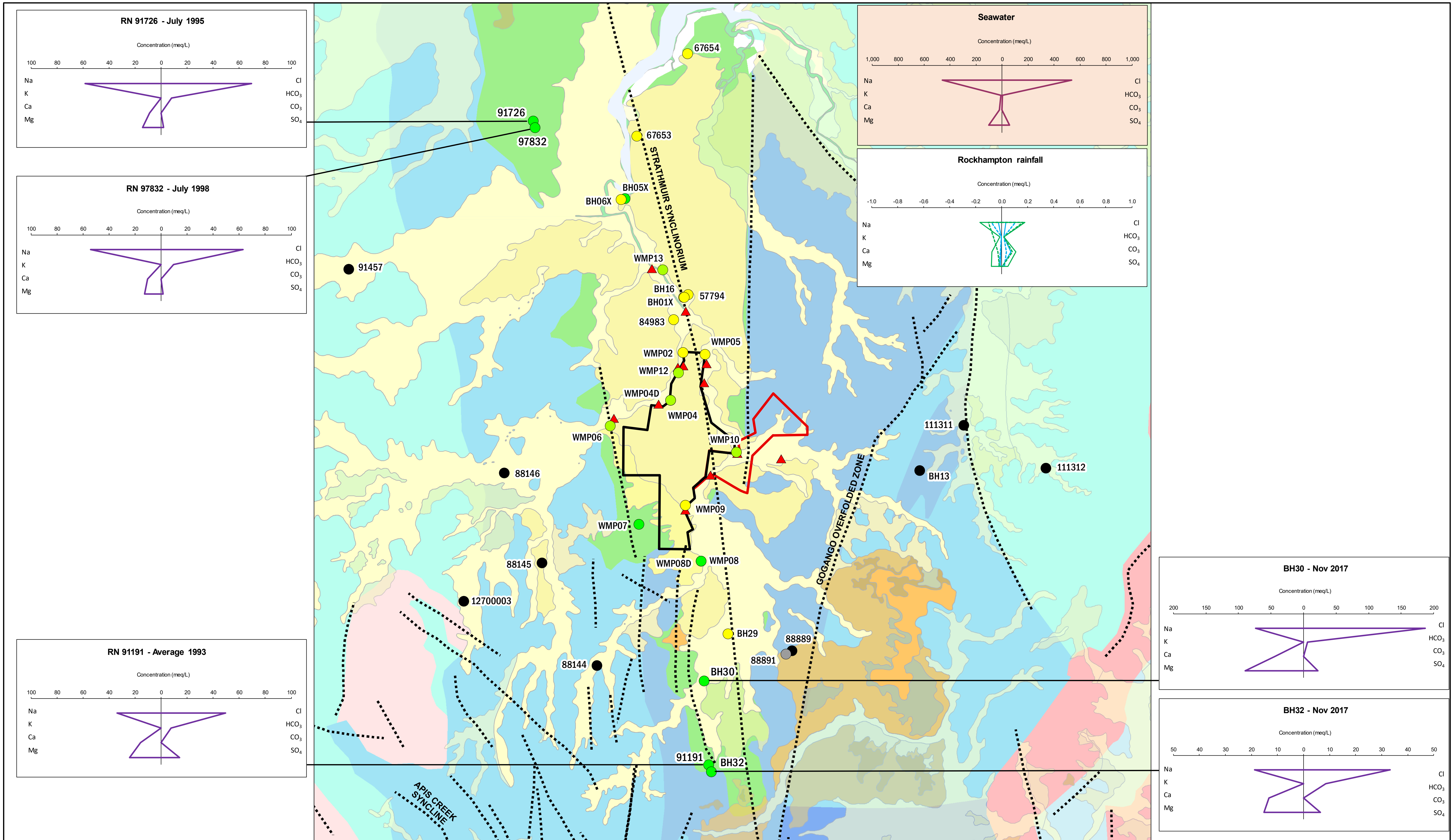
Figure 10-41

Styx Coal Measures groundwater Stiff patterns – November/December 2017 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

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Styx CM GW Stiff NovDec2017_R1a.mxd 7/12/2018



N

0 2.5 5 km

Scale @ A3 1:180,000
Date: 07/12/18
Drawn: KMH

Legend

Groundwater quality sample locations

Aquifer

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

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

Refer Figure 10-16 for geology legend

Figure 10-42

Styx Coal Measures groundwater Stiff patterns – November/December 2017 sampling

DATA SOURCE
QLD Open Source Data, 2018;
Central Queensland Coal, 2017
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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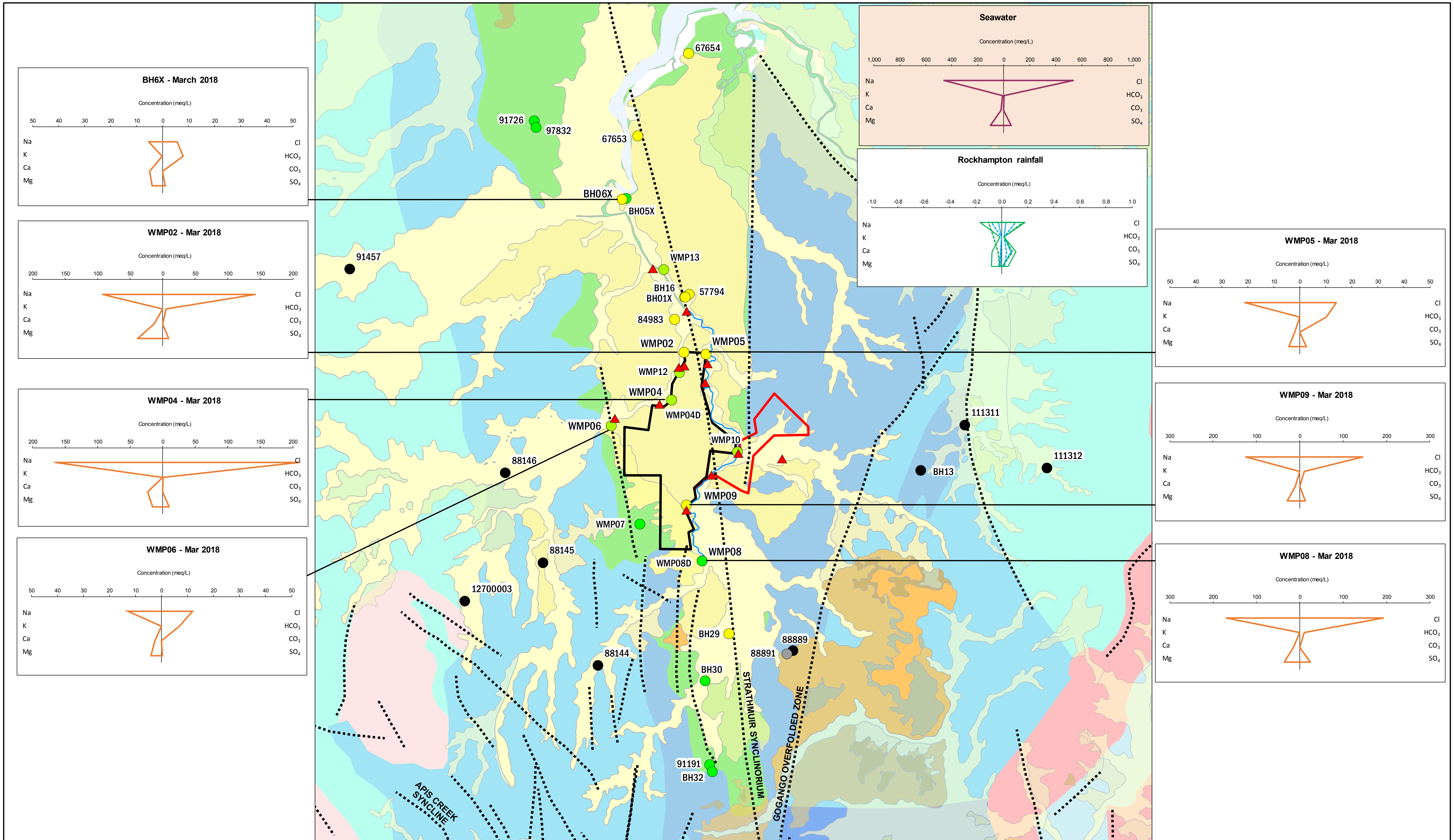

N

Legend

Groundwater quality sample locations

Aquifer

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

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

0 2.5 5 km

Scale @ A3 1:180,000
Date: 29/11/18
Drawn: KMH

Refer Figure 10-16 for geology legend

Figure 10-43
Alluvium groundwater Stiff patterns – March 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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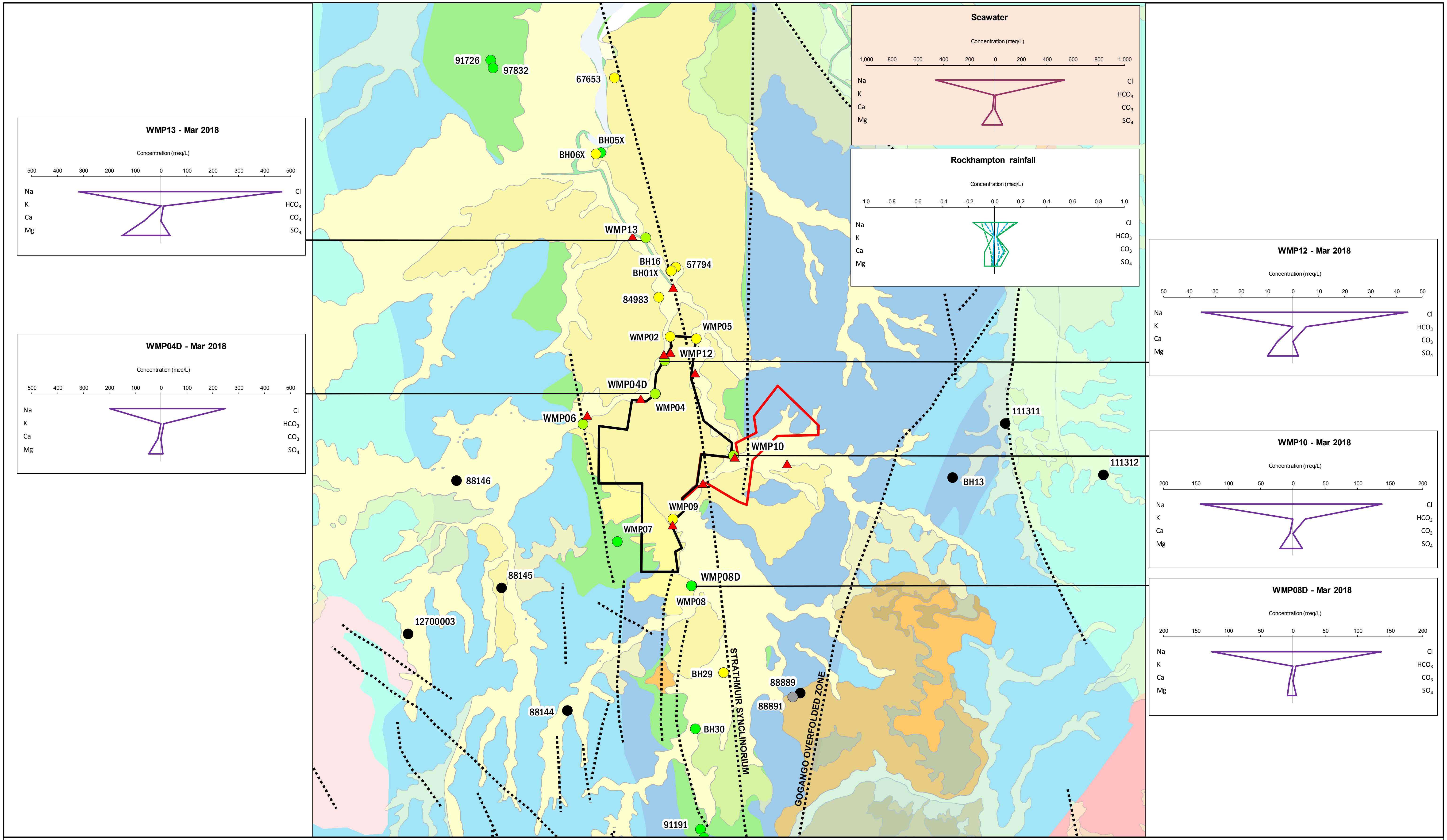


N

0 2 4 km

Scale @ A3 1:150,000
Date: 13/12/18
Drawn: KMH

Legend

Groundwater quality sample locations

Aquifer

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

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

Refer Figure 10-16 for geology legend

Figure 10-44

Styx Coal Measures groundwater Stiff patterns – March 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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Styx CM GW Stiff Mar2018_R2.mxd 12/13/2018

The Stiff patterns from the September 2018 (dry season) sampling event show groundwater chemistry similar to that observed in November / December 2017:

- Groundwater chemistry signatures for bores completed in the alluvium varies between sites, with observed similarity to rainwater and less like seawater (Figure 10-45), as evidenced by the higher concentrations of Ca and HCO3 in the groundwater samples; and
- Styx Coal Measures groundwater are Na-Cl dominant and do not show significant seasonal variability (Figure 10-46).

Laboratory reported major ion concentration and physico-chemical data for groundwater samples collected between 2017 and July2018 are presented in Table 10-16 through Table 10-37. The major ion concentrations have been compared against the WQOs set for the three GCZs within the area that may be impacted by the proposed mine and the ANZECC (2000) stock drinking water guideline values. All other groundwater chemistry data have been taken from the GWDBQ.

Comparison of the major ion and physico-chemical data with the WQOs and ANZECC (2000) stock drinking water guidelines (refer Table 10-16 to Table 10-37) shows:

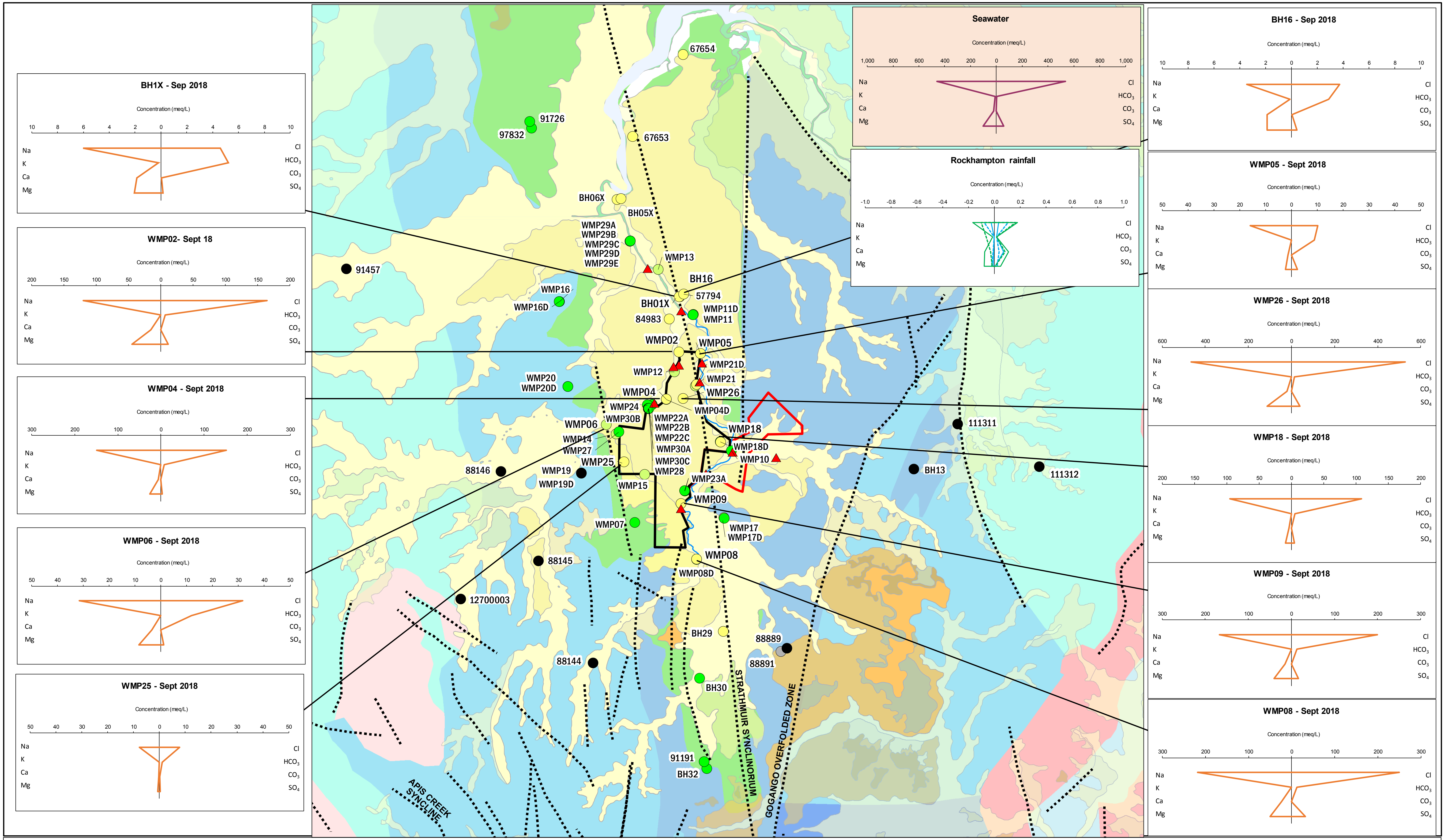
- Baseline sulphate (SO_4) concentrations are above the stock drinking water guideline (ANZECC, 2000) at three locations across the Project area (BH30, WMP08, WMP13, WMP21D and WMP26; see Figure 10-18);
- Ca concentrations are above the stock drinking water guideline (ANZECC, 2000) at one location downstream of the proposed mine (WMP13; see Figure 10-18); and
- Reported major ion concentrations and physico-chemical data typically exceed the WQOs for the three GCZs in the Project area for all monitoring locations and events.

The available major ion data from the sampled Styx Coal Measures groundwater do not show a distinctly seawater signature, but do show evidence of direct recharge from rainfall or interaction with surface water. Seasonal variability in water quality is also not evident in these groundwaters.

Hydro-chemical signatures for alluvial groundwater also show evidence of direct recharge from rainfall or interaction with surface water, and also interaction with Styx Coal Measures groundwater. Seasonal variability in water quality is evident in these groundwaters.

Dissolved Metals, Nutrients and Hydrocarbons

Groundwater samples collected during sampling events for the Project in 2017 and 2018 have been analysed for dissolved metals, nutrients and hydrocarbons (refer Table 10-46 to Table 10-67). The reported concentrations have been compared against the WQOs set for the three GCZs within the area that may be impacted by the proposed mine, as well as NHMRC (2011) drinking water and relevant ANZECC (2000) guidelines, including 95% level of protection for freshwater aquatic ecosystems, long-term trigger values for irrigation water and livestock drinking water guidelines, respectively.



Legend

Groundwater quality sample locations

Aquifer

- Alluvium
- Alluvium and Styx Coal Measures
- Styx Coal Measures
- Tertiary (undefined)
- Basement / Other

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

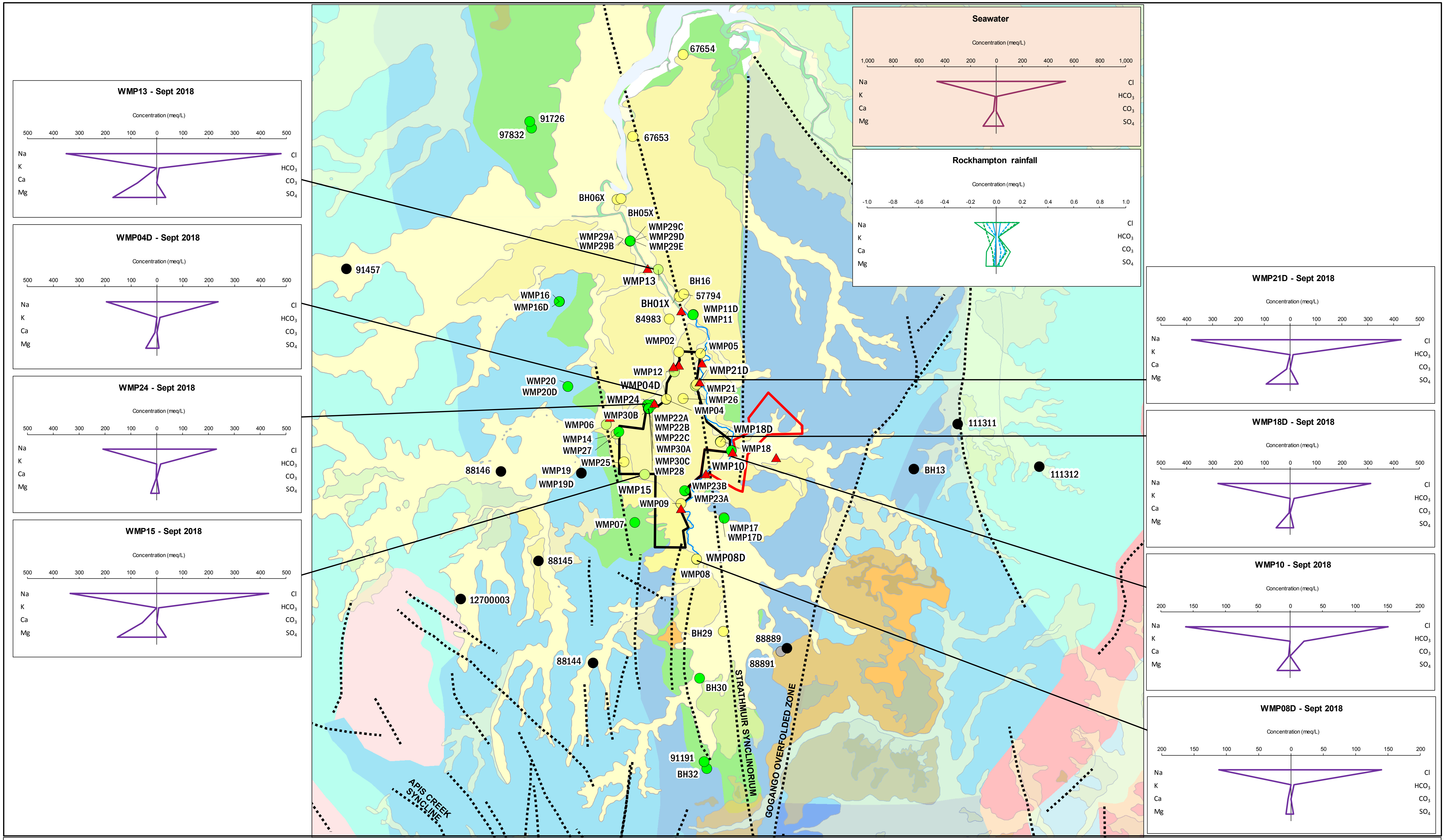
Scale @ A3 1:180,000
Date: 13/12/18
Drawn: KMH

Refer Figure 10-16 for geology legend

Figure 10-45
Alluvium groundwater 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



N

0 2 4 km

Scale @ A3 1:180,000
Date: 13/12/18
Drawn: KMH

Legend

Groundwater quality sample locations

Aquifer

- Alluvium
- Alluvium and Styx Coal Measures
- Styx Coal Measures
- Tertiary (undefined)
- Basement / Other

- Surface water sampling location
- ML 80187
- ML 700022
- Waterbody

Refer Figure 10-16 for geology legend

Figure 10-46

Styx Coal Measures groundwater 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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Styx CM GW Stiff Sep2018_R2.mxd 12/13/2018

Table 10-16 Laboratory reported major ion and physico-chemical data – BH01X

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
EC (field)		3,675	142.5	663	694	408.7	766	1,215	1,131	996	1,187	2,240	1,070	1,062
pH (field)		8	6.3	6.7	6.7	6.5	6.1	6.8	7.1	7.5	6.5	-	7	7
TDS	1		270	408	431	287	439	415	661	447	718	346	494	615
TSS	5		63	253	69	14	128	68	34	61	63	62	78	110
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	605	107	200	196	139	238	374	359	308	396	470	310	318
Total Alkalinity as CaCO3	1	500	107	200	196	139	238	374	359	308	396	470	310	318
Sulphate (SO4)	1	153	15	22	17	11	20	10	7	10	9	8	10	8
Chloride (Cl)	1	995	67	122	109	52	120	135	143	130	136	143	151	163
Calcium (Ca)	1	402	16	31	33	23	37	37	38	29	34	41	36	37
Magnesium (Mg)	1	106	11	21	21	16	23	23	22	17	22	22	27	25
Sodium (Na)	1	289	43	87	90	49	94	100	97	86	101	106	113	138
Potassium (K)	1	-	3	4	4	3	4	10	9	6	10	10	7	8

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-17 Laboratory reported major ion and physico-chemical data – BH05X

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	24-Feb-17
EC (field)		9,887	11,736
pH (field)		8	7.2
TDS	1		8,920
TSS	5		51
Hydroxide Alkalinity as CaCO3	1		<1
Carbonate Alkalinity as CaCO3	1		<1
Bicarbonate Alkalinity as CaCO3	1	628	488
Total Alkalinity as CaCO3	1	524.5	488
Sulphate (SO4)	1	653	468
Chloride (Cl)	1	3,607	4,100
Calcium (Ca)	1	315	345
Magnesium (Mg)	1	310	338
Sodium (Na)	1	1,564	1,770
Potassium (K)	1	-	37

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-18 Laboratory reported major ion and physico-chemical data – BH06X

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date					
			3-May-17	15-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	13-Mar-18
EC (field)		9,887	2,156	1,412	1,333	1,663	2,525	1,619
pH (field)		8	7.83	7.35	7.34	7.7	7.07	7.28
TDS	1		832	962	577	922	866	872
TSS	5		115	332	92	122	408	419
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	24	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	628	719	523	432	577	1,070	483
Total Alkalinity as CaCO3	1	524.5	719	523	456	577	1,070	483
Sulphate (SO4)	1	653	42	46	37	38	16	44
Chloride (Cl)	1	3,607	264	250	214	198	182	196
Calcium (Ca)	1	315	86	89	102	101	98	102
Magnesium (Mg)	1	310	47	48	47	50	50	50
Sodium (Na)	1	1,564	177	143	143	132	119	126
Potassium (K)	1	-	15	8	8	11	21	7

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-19 Laboratory reported major ion and physico-chemical data – BH13

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date					
			4-May-17	16-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	15-Mar-18
EC (field)		9,490	3,103	5,563	6,294	7,190	5,610	6,026
pH (field)		7.6	7.0	6.7	6.7	7.1	6.7	6.5
TDS	1		2,110	4,020	4,150	5,480	3,310	3,370
TSS	5		167	44	44	26	7	50
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	793	354	511	388	563	523	478
Total Alkalinity as CaCO3	1	653.5	354	511	388	563	523	478
Sulphate (SO4)	1	278	62	98	109	116	101	105
Chloride (Cl)	1	3,045	874	1,560	1,620	1,980	1,700	1,580
Calcium (Ca)	1	235	111	213	231	247	179	194
Magnesium (Mg)	1	211	168	333	370	439	326	302
Sodium (Na)	1	1,650	331	508	585	667	558	517
Potassium (K)	1	-	3	4	5	6	4	4

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderate groundwater

Table 10-20 Laboratory reported major ion and physico-chemical data – BH16

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
EC (field)		3,675	341.3	297.7	372.8	733	455	522	471	455	535	490	692	692
pH (field)		8	6.1	6.5	6.5	6.8	6.5	6.7	7.9	7.1	6.4	-	6.53	6.63
TDS	1		286	221	262	424	297	300	308	301	334	403	396	421
TSS	5		32	32	32	50	34	52	22	22	7	57	46	20
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	605	123	151	139	225	154	164	156	148	155	164	182	177
Total Alkalinity as CaCO3	1	500	123	151	139	225	154	164	156	148	155	164	182	177
Sulphate (SO4)	1	153	18	8	8	10	15	12	10	10	12	19	19	20
Chloride (Cl)	1	995	45	25	49	117	59	51	49	55	82	113	117	132
Calcium (Ca)	1	402	23	17	24	33	28	27	25	21	26	36	34	38
Magnesium (Mg)	1	106	14	11	14	23	17	16	14	12	16	21	25	23
Sodium (Na)	1	289	46	43	42	82	54	59	55	51	60	67	75	79
Potassium (K)	1	-	3	2	3	4	3	3	3	3	3	3	4	4

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-21 Laboratory reported major ion and physico-chemical data – BH29

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
EC (field)		970	320.2	244.2	264.4	284.9	288.6
pH (field)		8.1	6.6	6.3	6.3	6.6	6.3
TDS	1		216	196	208	198	190
TSS	5		19	45	20	16	6
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	506	41	52	53	50	42
Total Alkalinity as CaCO3	1	417.6	41	52	53	50	42
Sulphate (SO4)	1	44	36	35	36	47	42
Chloride (Cl)	1	97	52	34	38	37	34
Calcium (Ca)	1	84	4	3	4	4	3
Magnesium (Mg)	1	39	9	6	7	8	6
Sodium (Na)	1	100	57	44	49	50	43
Potassium (K)	1	-	<1	<1	<1	<1	<1

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-22 Laboratory reported major ion and physico-chemical data – BH30

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
EC (field)		9,490	12,311	12,507	15,225	17,861	17,787
pH (field)		7.6	7.7	6.4	6.5	6.5	6.5
TDS	1		6,530	11,400	11,600	12,000	16,700
TSS	5		18	20	8	22	14
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	793	301	331	253	355	371
Total Alkalinity as CaCO3	1	653.5	301	331	253	355	371
Sulphate (SO4)	1	278	729	873	**1,050**	**1,100**	**1,060**
Chloride (Cl)	1	3,045	4,470	5,040	5,480	7,570	6,630
Calcium (Ca)	1	235	616	709	841	970	876
Magnesium (Mg)	1	211	740	818	986	1,260	1,090
Sodium (Na)	1	1,650	1,280	1,360	1,630	1,740	1,690
Potassium (K)	1	-	6	6	7	7	7

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for either Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderate groundwater

Table 10-23 Laboratory reported major ion and physico-chemical data – BH32

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
EC (field)		9,887	-	3,677	3,856	4,424	4,319
pH (field)		8	-	6.9	6.9	7.1	6.8
TDS	1		2,640	2,780	2,630	3,490	2,930
TSS	5		36	<5	7	21	34
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	628	594	527	319	521	521
Total Alkalinity as CaCO3	1	524.5	594	527	319	521	521
Sulphate (SO4)	1	653	178	228	287	315	306
Chloride (Cl)	1	3,607	999	1,040	1,020	1,350	1,180
Calcium (Ca)	1	315	270	278	254	305	265
Magnesium (Mg)	1	310	178	177	180	211	185
Sodium (Na)	1	1,564	424	422	454	456	432
Potassium (K)	1	-	4	3	3	3	3

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-24 Laboratory reported major ion and physico-chemical data – WMP02

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date									
			20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-2018	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
EC (field)		3,675	16,225	14,851	14,059	15,166	15,335	14,780	13,895	23,450	16,569	15,814
pH (field)		8	6.8	6.7	6.6	6.5	7.05	6.9	6.1	6.77	6.6	6.68
TDS	1		11,400	10,800	8,750	11,000	10,500	11,600	11,800	10,900	10,600	10,500
TSS	5		24,500	3,560	2,000	1,420	1,140	1,060	653	1,620	1,320	652
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	605	406	412	336	392	416	398	428	430	440	442
Total Alkalinity as CaCO3	1	500	406	412	336	392	416	398	428	430	440	442
Sulphate (SO4)	1	153	546	514	442	516	544	553	520	546	541	533
Chloride (Cl)	1	995	5,260	5,380	5,040	5,800	6,060	5,820	5,580	6,150	6,120	5,830
Calcium (Ca)	1	402	285	301	272	330	298	278	282	292	266	308
Magnesium (Mg)	1	106	478	540	472	509	514	536	538	526	614	546
Sodium (Na)	1	289	2,320	2,560	2,120	2,570	2,520	2,730	2,510	2,720	2,790	2,760
Potassium (K)	1	-	1	1	1	1	1	1	<1	1	1	<1

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-25 Laboratory reported major ion and physico-chemical data – WMP04

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17 [3]	20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
EC (field)		970	11,973	11,852	18,109	21,684	19,616	19,671	14,583	17,624	33,550	24,966	14,756
pH (field)		8.1	11.8	9.3	8.2	8.95	8.3	8.0	7.8	7.3	8.05	7.33	7.58
TDS	1		5,760	8,440	10,400	15,100	14,400	15,200	10,400	15,000	17,000	16,800	9,200
TSS	5		401	3,010	4,280	16,500	10,700	167	976	6,050	133	227	182
Hydroxide Alkalinity as CaCO3	1		249	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		56	42	34	<1	3	<1	12	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	506	<1	74	244	51	142	544	431	509	506	565	500
Total Alkalinity as CaCO3	1	417.6	305	116	278	51	145	544	442	509	506	565	500
Sulphate (SO4)	1	44	90	192	218	473	358	322	195	280	365	364	163
Chloride (Cl)	1	97	3,660	4,920	5,760	7,440	7,850	8,480	5,680	7,860	9,400	8,730	5,370
Calcium (Ca)	1	84	140	58	107	465	192	199	158	190	233	206	115
Magnesium (Mg)	1	39	<1	87	195	185	402	423	320	422	497	488	313
Sodium (Na)	1	100	2,140	2,550	2,910	3,800	4,110	4,150	3,730	4,000	4,740	4,410	3,430
Potassium (K)	1	-	31	20	14	15	14	14	13	14	14	14	11

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater
3. It is likely that water chemistry results are influenced by insufficient bore development in the November 2017 sampling event

Table 10-26 Laboratory reported major ion and physico-chemical data – WMP04D

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
EC (field)		1,225	24,689	27,804	27,774	27,266	26,181	24,989	22,231	21,646	32,430	25,192	22,918
pH (field)		8	6.9	7.0	6.9	7.1	7.0	7.1	7.4	6.5	7.06	6.88	6.92
TDS	1		17,000	17,200	17,200	15,600	17,600	16,100	16,400	17,200	16,100	15,700	14,200
TSS	5		48	230	187	228	360	128	122	66	194	175	265
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	590	677	645	640	678	686	662	609	670	663	686	694
Total Alkalinity as CaCO3	1	486.2	677	645	640	678	686	662	609	670	663	686	694
Sulphate (SO4)	1	38	413	464	459	377	408	385	367	379	376	394	354
Chloride (Cl)	1	111	9,340	9,080	9,370	8,770	9,240	9,440	8,770	9,030	8,990	8,480	8,390
Calcium (Ca)	1	98	270	200	201	236	278	199	199	200	194	164	162
Magnesium (Mg)	1	64	582	609	654	569	568	567	534	601	550	499	516
Sodium (Na)	1	108	4,720	4,800	5,080	4,580	4,740	4,680	4,730	4,750	4,880	4,400	4,490
Potassium (K)	1	-	9	8	9	9	9	9	8	9	9	8	8

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderate groundwater

Table 10-27 Laboratory reported major ion and physico-chemical data – WMP05

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
EC (field)		3,675	2,690	3,506	3,482	2,696	2,222	2,152	1,988	2,102	2,971	2,121	2,026
pH (field)		8	7.4	7.3	7.1	7.4	7.2	7.4	7.5	6.8	7.46	7.38	7.33
TDS	1		1,640	1,960	2,310	1,520	1,580	1,440	1,260	1,350	1,330	1,310	1,440
TSS	5		838	506	480	34,800	5,280	2,180	708	733	2,510	4,210	3,050
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	40	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	605	657	822	780	622	535	542	493	546	502	512	544
Total Alkalinity as CaCO3	1	500	657	822	820	622	535	542	493	546	502	512	544
Sulphate (SO4)	1	153	72	105	104	114	133	134	136	136	124	127	112
Chloride (Cl)	1	995	500	654	674	498	365	387	372	362	348	351	359
Calcium (Ca)	1	402	44	42	42	39	15	24	27	24	31	30	26
Magnesium (Mg)	1	106	53	60	66	51	37	36	34	34	35	46	28
Sodium (Na)	1	289	482	583	666	486	471	413	447	398	398	442	364
Potassium (K)	1	-	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-28 Laboratory reported major ion and physico-chemical data – WMP06

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			20-Dec-17	16-Jan-18	13-Feb-18	13-Mar-18	10-Apr-18	9-May-18	7-Jun-18	5-Jul-18	31-Jul-18	28-Aug-18	27-Sep-18
EC (field)		9,887	3,901	5,279	5,933	1,489	1,857	2,334	2,516	2,904	5,203	4,280	4,466
pH (field)		8	6.8	6.8	6.8	6.4	6.6	6.8	7.4	6.3	6.72	6.73	6.55
TDS	1		3,380	2,910	4,400	1,230	1,170	1,360	1,750	1,900	2,180	2,360	2,690
TSS	5		27,900	364	3,520	13,000	9,400	3,220	6,220	1,460	3,980	1,970	2,830
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	628	557	716	824	415	373	474	514	589	621	684	719
Total Alkalinity as CaCO3	1	524.5	557	716	824	415	373	474	514	589	621	684	719
Sulphate (SO4)	1	653	58	78	101	20	21	20	21	39	36	48	54
Chloride (Cl)	1	3,607	845	1,380	1,580	419	381	536	659	807	954	1,060	1,120
Calcium (Ca)	1	315	96	105	103	52	55	45	59	67	106	88	70
Magnesium (Mg)	1	310	89	108	125	50	42	42	62	71	95	108	104
Sodium (Na)	1	1,564	609	805	938	297	280	340	448	479	645	665	727
Potassium (K)	1	-	2	2	2	1	1	<1	1	1	2	2	2

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units

2 Water Quality Objectives for shallow groundwater

Table 10-29 Laboratory reported major ion and physico-chemical data – WMP08

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date											
			6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	30-Aug-18	24-Sep-18
EC (field)		970	23,432	26,578	26,389	26,908	21,470	22,360	22,265	21,635	22,992	17,600	27,344	25,825
pH (field)		8.1	6.9	7.1	6.9	6.7	6.8	6.8	7.0	7.1	6.5	7.36	6.79	6.86
TDS	1		15,300	17,600	18,100	19,200	13,600	15,700	15,400	16,500	16,700	17,600	18,700	17,400
TSS	5		532	426	247	283	1,620	299	2,880	1,230	224	9,650	2,620	576
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	506	610	658	674	779	604	625	661	640	664	717	704	734
Total Alkalinity as CaCO3	1	417.6	610	658	674	779	604	625	661	640	664	717	704	734
Sulphate (SO4)	1	44	**1,410**	**1,260**	**1,600**	**1,740**	**1,140**	**1,180**	**1,270**	**1,420**	**1,490**	**1,470**	**1,640**	**1,540**
Chloride (Cl)	1	97	8,020	8,150	8,870	9,270	6,800	7,830	7,700	8,480	8,980	8,360	8,640	8,840
Calcium (Ca)	1	84	379	368	387	422	312	316	344	402	338	378	361	463
Magnesium (Mg)	1	39	474	590	574	607	437	513	480	502	532	600	520	605
Sodium (Na)	1	100	4,480	4,990	5,000	5,140	3,900	4,690	4,580	4,800	4,410	5,110	4,510	5,020
Potassium (K)	1	-	8	8	7	7	6	8	7	7	7	8	7	8

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for either Styx or Bison GCZs; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-30 Laboratory reported major ion and physico-chemical data – WMP08D

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			8-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
EC (field)		1,225	14,253	13,736	15,548	14,707	14,578	14,701	14,560	14,315	13,042	13,209	14,700	14,843	13,590
pH (field)		8	7.5	7.4	7.5	7.4	7.3	7.3	7.4	7.6	7.7	7.0	8	7	7
TDS	1		8,870	8,180	8,320	8,370	8,700	8,330	8,710	8,760	8,690	8,660	8,580	8,480	8,430
TSS	5		24	50	24	34	64	192	126	93	248	199	125	14	222
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	590	281	254	270	270	273	273	263	282	276	272	260	274	284
Total Alkalinity as CaCO3	1	486.2	281	254	270	270	273	273	263	282	276	272	260	274	284
Sulphate (SO4)	1	38	237	254	211	193	216	236	208	215	226	193	210	178	205
Chloride (Cl)	1	111	4,910	5,000	4,940	5,090	5,220	4,850	5,140	5,090	5,170	5,240	4,960	5,150	4,970
Calcium (Ca)	1	98	119	96	101	103	105	112	100	107	110	111	105	86	90
Magnesium (Mg)	1	64	111	100	122	112	111	109	108	112	102	113	112	116	95
Sodium (Na)	1	108	2,980	2,860	3,190	3,020	2,980	2,880	2,950	3,150	3,050	2,920	3,000	2,940	2,560
Potassium (K)	1	-	8	8	8	8	8	8	8	8	8	8	8	8	7

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderate groundwater

Table 10-31 Laboratory reported major ion and physico-chemical data – WMP09

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			11-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	6-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
EC (field)		970	21,502	20,046	22,574	21,589	22,002	12,863	19,778	20,789	19,104	19,508	21,900	21,749	20,144
pH (field)		8.1	6.9	6.9	6.8	6.8	6.8	6.9	6.6	6.9	7.3	6.5	7	6	7
TDS	1		14,400	14,300	14,800	14,600	14,800	9,650	13,700	14,200	14,200	13,400	14,000	13,500	14,200
TSS	5		236	243	303	243	128	725	564	394	296	463	889	204	362
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	506	850	776	802	774	795	610	727	837	714	768	799	797	805
Total Alkalinity as CaCO3	1	417.6	850	776	802	774	795	610	727	837	714	768	799	797	805
Sulphate (SO4)	1	44	834	893	938	743	915	625	828	857	847	853	871	882	760
Chloride (Cl)	1	97	7,400	7,240	7,160	7,250	7,580	5,140	6,900	7,300	7,030	7,610	6,990	7,510	7,050
Calcium (Ca)	1	84	341	257	304	308	280	216	255	292	275	259	275	267	304
Magnesium (Mg)	1	39	500	466	560	514	503	357	488	494	483	491	532	555	485
Sodium (Na)	1	100	3,890	3,920	4,280	4,100	3,910	2,860	3,720	3,910	3,910	3,580	4,000	3,870	3,840
Potassium (K)	1	-	4	4	5	4	4	3	4	4	4	4	4	4	5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-32 Laboratory reported major ion and physico-chemical data – WMP10

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	16-Jan-18	13-Mar-18	10-Apr-18	9-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
EC (field)		970	16,300	17,424	16,862	16,624	16,321	16,335	19,104	19,508	18,200	18,416	16,599
pH (field)		8.1	7.0	7.2	7.0	7.0	6.8	7.4	7.3	6.5	7	7	7
TDS	1		10,500	11,000	9,410	9,730	9,840	10,900	11,100	11,400	11,200	10,900	10,600
TSS	5		749	1,770	823	1,190	2,770	4,260	1,200	2,420	1,890	3,900	2,080
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	506	1,250	1,160	1,160	1,150	1,160	1,280	1,160	1,270	1,240	1,270	1,290
Total Alkalinity as CaCO3	1	417.6	1,250	1,160	1,160	1,150	1,160	1,280	1,160	1,270	1,240	1,270	1,290
Sulphate (SO4)	1	44	682	705	751	688	729	754	772	734	735	799	715
Chloride (Cl)	1	97	5,340	5,020	5,390	4,860	5,260	5,400	5,420	5,490	5,600	5,540	5,360
Calcium (Ca)	1	84	97	99	86	89	91	72	83	69	65	59	58
Magnesium (Mg)	1	39	245	273	252	244	234	230	249	246	235	212	244
Sodium (Na)	1	100	3,420	3,700	3,630	3,280	3,510	3,490	3,710	3,610	3,770	3,320	3,720
Potassium (K)	1	-	8	9	8	8	8	8	11,100	9	8	8	8

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-33 Laboratory reported major ion and physico-chemical data – WMP11

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	11-Apr-18	10-May-18	6-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
EC (field)		3,675	25,206	30,546	27,935	27,787	31,200	33,333	29,618
pH (field)		8	7.0	6.9	6.9	6.3	7	7	7
TDS	1		17,700	21,700	22,300	20,900	20,400	18,800	18,500
TSS	5		224	210	91	252	173	237	661
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	605	412	528	561	475	478	457	522
Total Alkalinity as CaCO3	1	500	412	528	561	475	478	457	522
Sulphate (SO4)	1	153	63	146	135	74	78	40	82
Chloride (Cl)	1	995	8,790	11,300	11,800	11,700	11,400	11,100	11,200
Calcium (Ca)	1	402	429	455	549	487	513	545	647
Magnesium (Mg)	1	106	479	631	664	667	744	716	786
Sodium (Na)	1	289	4,550	5,280	5,870	5,260	6,170	6,550	6,200
Potassium (K)	1	-	11	10	10	10	13	10	10

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-34 Laboratory reported major ion and physico-chemical data – WMP11D

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
EC (field)		7,500	30,714	30,547	26,996	27,535	31,100	32,458	29,122
pH (field)		7.5	6.75	7.1	7.0	6.3	7	6	7
TDS	1		21,900	21,300	21,800	21,400	20,600	20,500	20,800
TSS	5		61	45	31	45	50	18	696
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	263	526	547	568	498	512	540	541
Total Alkalinity as CaCO3	1	217	526	547	568	498	512	540	541
Sulphate (SO4)	1	215	197	176	180	177	175	187	172
Chloride (Cl)	1	3,474	10,700	11,200	11,600	10,100	11,100	11,400	10,900
Calcium (Ca)	1	623	599	482	546	444	525	426	625
Magnesium (Mg)	1	361	587	599	597	592	670	679	704
Sodium (Na)	1	396	5,750	5,500	5,870	6,270	5,940	5,360	6,060
Potassium (K)	1	-	13	12	12	12	14	11	13

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderate groundwater

Table 10-35 Laboratory reported major ion and physico-chemical data – WMP12

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date						
			20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18	6-Jun-18	4-Jul-18
EC (field)		970	4,550	8,315	5,464	7,661	9,705	NS	NS
pH (field)		8.1	8.6	7.0	7.0	6.8	7.0	NS	NS
TDS	1		3,380	4,290	2,920	5,960	5,680	NS	NS
TSS	5		19,100	34,900	22,600	20,900	11,300	NS	NS
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	NS	NS
Carbonate Alkalinity as CaCO3	1		89	<1	<1	<1	<1	NS	NS
Bicarbonate Alkalinity as CaCO3	1	506	439	596	310	312	340	NS	NS
Total Alkalinity as CaCO3	1	417.6	528	596	310	312	340	NS	NS
Sulphate (SO4)	1	44	107	148	101	142	169	NS	NS
Chloride (Cl)	1	97	1,170	2,500	1,570	2,650	3,420	NS	NS
Calcium (Ca)	1	84	91	183	120	172	192	NS	NS
Magnesium (Mg)	1	39	40	181	120	207	213	NS	NS
Sodium (Na)	1	100	715	1,190	814	1,260	1,420	NS	NS
Potassium (K)	1	-	2	4	1	1	2	NS	NS

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for either Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids, NS: Not Sampled

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-36 Laboratory reported major ion and physico-chemical data – WMP13

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date									
			17-Jan-18	15-Feb-18	14-Mar-18	11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
EC (field)		9,887	31,921	270.6 [3]	45,569	44,632	44,903	39,613	42,511	60,390	47,580	44,688
pH (field)		8	6.7	7.6	6.2	6.3	6.5	6.8	5.6	6	6	6
TDS	1		22,300	28,300	36,900	37,400	36,700	35,600	34,300	35,330	32,800	33,700
TSS	5		343	425	529	573	697	346	243	402	66	911
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	628	390	481	511	509	513	515	510	506	527	535
Total Alkalinity as CaCO3	1	524.5	390	481	511	509	513	515	510	506	527	535
Sulphate (SO4)	1	653	**1,290**	**1,580**	**1,650**	**1,680**	**1,750**	**1,800**	**1,760**	**1,640**	**1,700**	**1,640**
Chloride (Cl)	1	3,607	12,100	15,500	16,600	17,200	17,500	19,300	15,300	18,100	17,400	17,000
Calcium (Ca)	1	315	841	**1,130**	**1,300**	**1,240**	**1,410**	**1,490**	**1,110**	**1,350**	**1,410**	**1,500**
Magnesium (Mg)	1	310	1,150	1,590	1,800	1,790	1,900	2,120	1,850	2,000	2,100	2,050
Sodium (Na)	1	1,564	5,470	6,680	7,350	7,600	8,020	8,770	7,700	8,070	8,990	8,060
Potassium (K)	1	-	8	8	6	8	7	6	6	10	6	6

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater
3. EC parameter thought to be erroneous (e.g. instrument error)

Table 10-37 Laboratory reported major ion and physico-chemical data – WMP15

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date						
			10-Apr-18	9-May-18	7-Jun-18	5-Jul-18	2-Aug-18	30-Aug-18	27-Sep-18
EC (field)		9,887	8,490	4,589	3,656	3,568	4,030	4,099	3,680
pH (field)		8	7.9	7.2	7.9	6.7	8	7	7
TDS	1		4,600	2,780	2,250	2,220	2,410	2,330	2,220
TSS	5		4,874	118	40	51	181	109	84
Hydroxide Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	1		<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	1	628	340	511	448	484	492	484	489
Total Alkalinity as CaCO3	1	524.5	340	511	448	484	492	484	489
Sulphate (SO4)	1	653	156	78	61	58	59	59	52
Chloride (Cl)	1	3,607	2,660	1,270	1,030	992	941	1,010	970
Calcium (Ca)	1	315	75	40	32	29	33	35	34
Magnesium (Mg)	1	310	114	77	53	54	57	49	57
Sodium (Na)	1	1,564	1,440	1,070	779	721	752	664	737
Potassium (K)	1	-	13	8	6	6	6	6	6

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-38 Laboratory reported major ion and physico-chemical data – WMP18

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date
			18-Sep-18
EC (field)		970	9,000
pH (field)		8.1	7.89
TDS	1		-
TSS	5		-
Hydroxide Alkalinity as CaCO3	1		<1
Carbonate Alkalinity as CaCO3	1		<1
Bicarbonate Alkalinity as CaCO3	1	506	350
Total Alkalinity as CaCO3	1	417.6	350
Sulphate (SO4)	1	44	206
Chloride (Cl)	1	97	3,830
Calcium (Ca)	1	84	70
Magnesium (Mg)	1	39	114
Sodium (Na)	1	100	2,190
Potassium (K)	1	-	8

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-39 Laboratory reported major ion and physico-chemical data – WMP18D

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date
			18-Sep-18
EC (field)		970	33,590
pH (field)		8.1	7.82
TDS	1		-
TSS	5		-
Hydroxide Alkalinity as CaCO3	1		<1
Carbonate Alkalinity as CaCO3	1		<1
Bicarbonate Alkalinity as CaCO3	1	590	919
Total Alkalinity as CaCO3	1	486.2	919
Sulphate (SO4)	1	38	683
Chloride (Cl)	1	111	11,000
Calcium (Ca)	1	98	84
Magnesium (Mg)	1	64	652
Sodium (Na)	1	108	6,390
Potassium (K)	1	-	13

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderately deep groundwater

Table 10-40 Laboratory reported major ion and physico-chemical data – WMP19

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date
			17-Sep-18
EC (field)		-	1,660
pH (field)		-	7.72
TDS	1	-	-
TSS	5	-	-
Hydroxide Alkalinity as CaCO3	1	-	<1
Carbonate Alkalinity as CaCO3	1	-	<1
Bicarbonate Alkalinity as CaCO3	1	628	449
Total Alkalinity as CaCO3	1	524.5	449
Sulphate (SO4)	1	653	228
Chloride (Cl)	1	3,607	171
Calcium (Ca)	1	315	122
Magnesium (Mg)	1	310	43
Sodium (Na)	1	1,564	151
Potassium (K)	1	-	2

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-41 Laboratory reported major ion and physico-chemical data – WMP19D

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date
			17-Sep-18
EC (field)		-	1,770
pH (field)		-	8
TDS	1	-	-
TSS	5	-	-
Hydroxide Alkalinity as CaCO3	1	-	<1
Carbonate Alkalinity as CaCO3	1	-	<1
Bicarbonate Alkalinity as CaCO3	1	793	458
Total Alkalinity as CaCO3	1	654	458
Sulphate (SO4)	1	278	220
Chloride (Cl)	1	3,045	230
Calcium (Ca)	1	235	133
Magnesium (Mg)	1	211	49
Sodium (Na)	1	1,650	165
Potassium (K)	1	-	2

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderately deep groundwater

Table 10-42 Laboratory reported major ion and physico-chemical data – WMP21D

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date
			17-Sep-18
EC (field)		-	>20000
pH (field)		-	7.6
TDS	1	-	-
TSS	5	-	-
Hydroxide Alkalinity as CaCO3	1	-	<1
Carbonate Alkalinity as CaCO3	1	-	<1
Bicarbonate Alkalinity as CaCO3	1	590	732
Total Alkalinity as CaCO3	1	486.2	732
Sulphate (SO4)	1	38	**1,470**
Chloride (Cl)	1	111	15,200
Calcium (Ca)	1	98	279
Magnesium (Mg)	1	64	1,110
Sodium (Na)	1	108	8,730
Potassium (K)	1	-	12

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderately deep groundwater

Table 10-43 Laboratory reported major ion and physico-chemical data – WMP24

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date
			18-Sep-18
EC (field)		-	18,900
pH (field)		-	7.9
TDS	1	-	-
TSS	5	-	-
Hydroxide Alkalinity as CaCO3	1	-	<1
Carbonate Alkalinity as CaCO3	1	-	<1
Bicarbonate Alkalinity as CaCO3	1	590	926
Total Alkalinity as CaCO3	1	486.2	926
Sulphate (SO4)	1	38	445
Chloride (Cl)	1	111	8,200
Calcium (Ca)	1	98	39
Magnesium (Mg)	1	64	286
Sodium (Na)	1	108	4,790
Potassium (K)	1	-	15

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderately deep groundwater

Table 10-44 Laboratory reported major ion and physico-chemical data – WMP25

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date
			18-Sep-18
EC (field)		-	900
pH (field)		-	7.84
TDS	1	-	-
TSS	5	-	-
Hydroxide Alkalinity as CaCO3	1	-	<1
Carbonate Alkalinity as CaCO3	1	-	<1
Bicarbonate Alkalinity as CaCO3	1	628	71
Total Alkalinity as CaCO3	1	524.5	71
Sulphate (SO4)	1	653	14
Chloride (Cl)	1	3,607	276
Calcium (Ca)	1	315	7
Magnesium (Mg)	1	310	8
Sodium (Na)	1	1,564	178
Potassium (K)	1	-	3

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for shallow groundwater

Table 10-45 Laboratory reported major ion and physico-chemical data – WMP26

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date
			17-Sep-18
EC (field)		-	>20000
pH (field)		-	7.6
TDS	1	-	-
TSS	5	-	-
Hydroxide Alkalinity as CaCO3	1	-	<1
Carbonate Alkalinity as CaCO3	1	-	<1
Bicarbonate Alkalinity as CaCO3	1	590	906
Total Alkalinity as CaCO3	1	486.2	906
Sulphate (SO4)	1	38	**1,870**
Chloride (Cl)	1	111	18,700
Calcium (Ca)	1	98	432
Magnesium (Mg)	1	64	1,370
Sodium (Na)	1	108	10,700
Potassium (K)	1	-	10

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

LOR: laboratory level of reporting, EC: electrical conductivity, TDS: total dissolved solids, TSS: total suspended solids

1. All units are mg/L, except for EC units which are µS/cm and pH which is pH units
2. Water Quality Objectives for moderately deep groundwater

Table 10-46 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH01X

Analyte	LOR	Bison GCZ WQO 80th percentile	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-June-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Arsenic	0.001		***0.052***	***0.032***	***0.024***	0.002	-	0.015	0.016	0.01	0.009	0.012	0.013	0.01
Barium	0.001		0.077	0.162	0.139	0.081	-	0.093	0.123	0.104	0.121	0.124	0.146	0.074
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.001	-	<0.001	0.001	0.001	0.002	-	0.001	<0.001	0.003	0.001	<0.001	0.001	<0.001
Cobalt	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Nickel	0.001		0.002	<0.001	<0.001	<0.001	-	0.003	<0.001	0.002	<0.001	0.002	<0.001	<0.001
Lead	0.001		<0.001	***0.803***	***0.603***	***0.586***	-	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	***0.443***
Zinc	0.005	-	<0.005	<0.001	0.001	<0.001	-	<0.005	<0.005	*0.01*	*0.438*	<0.005	*0.033*	<0.001
Manganese	0.001	-	1.28	0.002	0.003	0.002	-	0.329	0.461	0.367	<0.001	0.465	0.773	0.002
Molybdenum	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001
Silver	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		<0.001	<0.01	<0.01	<0.01	-	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.01
Vanadium	0.01		<0.01	<0.005	<0.005	<0.005	-	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.005
Iron	0.05	0.02	*10*	*8.91*	*4.49*	0.15	-	0.35	1.07	1.08	1.24	1.92	1.27	0.6
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Analyte	LOR	Bison GCZ WQO 80th percentile	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-June-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Ammonia as N	0.01		0.92	0.47	0.5	0.06	-	35.5	29.5	26.3	45.6	65.7	25	23.7
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	-	0.01	0.01	0.01	0.03	-	0.12	0.04	0.03	0.02	0.01	0.01	0.01
Nitrite + Nitrate as N	0.01		0.01	0.01	0.01	0.03	-	0.13	0.04	0.03	0.02	0.01	0.01	0.01
Total Kjeldahl Nitrogen as N	0.1		2	1.1	0.8	0.2	-	40.6	28.8	22.4	51	68.4	21.3	22.8
Total Nitrogen as N	0.1		2	1.1	0.8	0.2	-	40.7	28.8	22.4	51	68.4	21.3	22.8
Total Phosphorus as P	0.01		0.93	0.55	0.39	0.13	-	2.43	2.26	1.85	3.75	5.35	2.32	2.76
Reactive Phosphorus as P	0.01		0.02	0.04	<0.01	0.03	-	1.43	1.55	1.24	3.18	2.74	0.8	0.8
Total Petroleum Hydrocarbons														
C6 - C9 Fraction	20		<20	<20	<20	<20	-	<20	<20	<20	180	840	<20	20
C10 - C14 Fraction	50		<50	<50	<50	<50	-	<50	<50	<50	300	<50	<50	<50
C15 - C28 Fraction	100		<100	<100	<100	<100	-	120	<100	130	130	110	<100	<100
C29 - C36 Fraction	50		60	<50	<50	<50	-	340	90	160	390	710	430	160
C10 - C36 Fraction (sum)	50		60	<50	<50	<50	-	460	90	290	820	820	430	160
Total Recoverable Hydrocarbons														
C6 - C10 Fraction	20		<20	<20	<20	<20	-	<20	<20	<20	180	840	<20	20
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-	<20	<20	<20	50	180	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	-	<100	<100	<100	290	<100	<100	<100
>C16 - C34 Fraction	100		120	<100	<100	<100	-	410	120	260	330	700	450	180
>C34 - C40 Fraction	100		<100	<100	<100	<100	-	<100	<100	<100	270	160	<100	<100
>C10 - C40 Fraction (sum)	100		120	<100	<100	<100	-	410	120	260	890	860	450	180
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	-	<100	<100	<100	290	<100	<100	<100

Analyte	LOR	Bison GCZ WQO 80th percentile	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-June-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
BTEXN														
Benzene	1		<1	<1	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	-	<2	<2	<2	132	664	<2	22
Ethylbenzene	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	-	<1	<1	<1	132	664	<1	22
Naphthalene	5		<5	<5	<5	<5	-	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-47 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH05X

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	24-Feb-17
Aluminium	0.01		<0.01
Arsenic	0.001		0.007
Barium	0.001		0.065
Cadmium	0.0001		<0.0001
Chromium	0.001		<0.001
Copper	0.001	0.041	0.001
Cobalt	0.001		<0.001
Nickel	0.001		<0.001
Lead	0.001		***1.27***
Zinc	0.005	12.67	<0.001
Manganese	0.001	0.478	<0.001
Molybdenum	0.001		<0.01
Selenium	0.01		<0.001
Silver	0.001		0.002
Uranium	0.001		<0.01
Vanadium	0.01		0.101
Iron	0.05	0.09	*3.96*
Mercury	0.0001		<0.0001
Fluoride	0.1	1.07	0.6
Ammonia as N	0.01		0.21
Nitrite as N	0.01		<0.01
Nitrate as N	0.01	3.26	0.05
Nitrite + Nitrate as N	0.01		0.05
Total Kjeldahl Nitrogen as N	0.1		<0.5
Total Nitrogen as N	0.1		<0.5
Total Phosphorus as P	0.01		0.26
Reactive Phosphorus as P	0.01		<0.01
Total Petroleum Hydrocarbons			
C6 - C9 Fraction	20		<20
C10 - C14 Fraction	50		<50
C15 - C28 Fraction	100		130
C29 - C36 Fraction	50		100
C10 - C36 Fraction (sum)	50		230
Total Recoverable Hydrocarbons			
C6 - C10 Fraction	20		<20
C6 - C10 Fraction minus BTEX (F1)	20		<20
>C10 - C16 Fraction	100		<100
>C16 - C34 Fraction	100		200
>C34 - C40 Fraction	100		<100

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	24-Feb-17
>C10 - C40 Fraction (sum)	100		200
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100
BTEXN			
Benzene	1		<1
Toluene	2		<2
Ethylbenzene	2		<2
meta- & para-Xylene	2		<2
ortho-Xylene	2		<2
Total Xylenes	2		<2
Sum of BTEX	1		<1
Naphthalene	5		<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-48 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH06X

Analyte	LOR	Styx GCZ WQO 80th percentile [2]	Sample Date					
			3-May-17	15-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	13-Mar-18
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	-	<0.01
Arsenic	0.001		0.004	0.004	0.004	0.004	-	0.003
Barium	0.001		0.08	0.067	0.077	0.07	-	0.044
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001
Cobalt	0.001		<0.001	<0.001	<0.001	0.001	-	<0.001
Copper	0.001	0.041	<0.001	<0.001	<0.001	<0.001	-	<0.001
Iron	0.05	0.09	*0.54*	*0.43*	*0.32*	*0.41*	-	0.08
Lead	0.001		<0.001	***0.129***	***0.126***	***0.116***	-	<0.001
Manganese	0.001	0.478	0.12	<0.001	<0.001	<0.001	-	0.15
Molybdenum	0.001		<0.001	<0.01	<0.01	<0.01	-	<0.001
Nickel	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-	<0.01
Silver	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001
Uranium	0.001		<0.001	<0.01	<0.01	<0.01	-	<0.001
Vanadium	0.01		<0.01	*0.058*	*0.012*	<0.005	-	<0.01
Zinc	0.005	12.67	<0.005	<0.001	<0.001	<0.001	-	<0.005
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
Fluoride	0.1	1.07	0.6	0.7	0.5	0.5	0.4	0.6
Ammonia as N	0.01		125	26.1	24.3	40.5	-	31
Nitrite as N	0.01		0.02	<0.01	<0.01	0.07	-	0.02
Nitrate as N	0.01	3.26	<0.01	<0.01	0.01	<0.01	-	0.01
Nitrite + Nitrate as N	0.01		<0.01	<0.01	0.01	0.04	-	0.03

Analyte	LOR	Styx GCZ WQO 80th percentile [2]	Sample Date					
			3-May-17	15-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	13-Mar-18
Total Kjeldahl Nitrogen as N	0.1		110	35.4	25	50.2	-	36.5
Total Nitrogen as N	0.1		110	35.4	25	50.2	-	36.5
Total Phosphorus as P	0.01		3.71	4.29	2.28	3.22	-	3.68
Reactive Phosphorus as P	0.01		1.55	0.46	0.64	1.28	-	0.06
Total Petroleum Hydrocarbons								
C6 - C9 Fraction	20		<20	<20	<20	<20	-	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	-	<50
C15 - C28 Fraction	100		190	110	<100	120	-	<100
C29 - C36 Fraction	50		280	580	140	170	-	220
C10 - C36 Fraction (sum)	50		470	690	140	290	-	220
Total Recoverable Hydrocarbons								
C6 - C10 Fraction	20		<20	<20	<20	<20	-	<20
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100		<100
>C16 - C34 Fraction	100		450	640	200	240		270
>C34 - C40 Fraction	100		<100	<100	<100	<100		<100
>C10 - C40 Fraction (sum)	100		450	640	200	240		270
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100		<100
BTEXN								
Benzene	1		<1	<1	<1	<1		<1
Toluene	2		<2	<2	<2	<2		<2
Ethylbenzene	2		<2	<2	<2	<2		<2
meta- & para-Xylene	2		<2	<2	<2	<2		<2
ortho-Xylene	2		<2	<2	<2	<2		<2

Analyte	LOR	Styx GCZ WQO 80th percentile [2]	Sample Date					
			3-May-17	15-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	13-Mar-18
Total Xylenes	2		<2	<2	<2	<2		<2
Sum of BTEX	1		<1	<1	<1	<1		<1
Naphthalene	5		<5	<5	<5	<5		<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-49 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH13

Analyte	LOR	Styx GCZ WQO 80th percentile [2]	Sample Date					
			4-May-17	16-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	15-Mar-18
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	-	<0.01
Arsenic	0.001		0.001	0.002	0.002	0.002	-	<0.001
Barium	0.001		0.045	0.119	0.132	0.112	-	0.056
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001
Copper	0.001	0.476	*0.002*	0.001	*0.002*	*0.002*	-	*0.004*
Cobalt	0.001		0.003	<0.001	<0.001	<0.001	-	0.001
Nickel	0.001		0.003	<0.001	<0.001	<0.001	-	<0.001
Lead	0.001		<0.001	***1.98***	***2.08***	***1.77***	**-**	***1.13***
Zinc	0.005	1.035	*0.008*	0.002	0.002	0.002	-	0.001
Manganese	0.001	1.878	1.13	0.001	<0.001	0.002	-	0.002
Molybdenum	0.001		0.001	<0.01	<0.01	<0.01	-	<0.01
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-	<0.001
Silver	0.001		<0.001	*0.002*	*0.002*	*0.002*	-	*0.001*
Uranium	0.001		<0.001	<0.01	<0.01	<0.01	-	<0.01

Analyte	LOR	Styx GCZ WQO 80th percentile [2]	Sample Date					
			4-May-17	16-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	15-Mar-18
Vanadium	0.01		<0.01	<0.005	<0.005	<0.005	-	*0.006*
Iron	0.05	0.34	0.15	*1.31*	*0.86*	*0.98*	-	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
Fluoride	0.1	1.08	0.4	0.3	0.2	0.4	0.4	0.4
Ammonia as N	0.01		0.18	0.67	0.68	0.47	-	0.12
Nitrite as N	0.01		<0.01	<0.01	<0.01	0.01	-	0.03
Nitrate as N	0.01	5.5	<0.01	<0.01	0.04	0.1	-	0.24
Nitrite + Nitrate as N	0.01		<0.01	<0.01	0.04	0.11	-	0.27
Total Kjeldahl Nitrogen as N	0.1		1.2	0.9	0.7	0.7	-	0.4
Total Nitrogen as N	0.1		1.2	0.9	0.7	0.8	-	0.7
Total Phosphorus as P	0.01		0.24	0.06	0.08	0.65	-	0.08
Reactive Phosphorus as P	0.01		0.02	<0.01	<0.01	<0.01	-	<0.01
Total Petroleum Hydrocarbons								
C6 - C9 Fraction	20		<20	<20	<20	<20	-	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	-	<50
C15 - C28 Fraction	100		<100	<100	<100	<100	-	<100
C29 - C36 Fraction	50		<50	<50	<50	<50	-	<50
C10 - C36 Fraction (sum)	50		<50	<50	<50	<50	-	<50
Total Recoverable Hydrocarbons								
C6 - C10 Fraction	20		<20	<20	<20	<20	-	<20
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	-	<100
>C16 - C34 Fraction	100		110	<100	<100	<100	-	<100
>C34 - C40 Fraction	100		<100	<100	<100	<100	-	<100
>C10 - C40 Fraction (sum)	100		110	<100	<100	<100	-	<100

Analyte	LOR	Styx GCZ WQO 80th percentile [2]	Sample Date					
			4-May-17	16-Jun-17	9-Aug-17	28-Sep-17	10-Nov-17	15-Mar-18
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	-	<100
BTEXN								
Benzene	1		<1	<1	<1	<1	-	<1
Toluene	2		<2	<2	<2	<2	-	<2
Ethylbenzene	2		<2	<2	<2	<2	-	<2
meta- & para-Xylene	2		<2	<2	<2	<2	-	<2
ortho-Xylene	2		<2	<2	<2	<2	-	<2
Total Xylenes	2		<2	<2	<2	<2	-	<2
Sum of BTEX	1		<1	<1	<1	<1	-	<1
Naphthalene	5		<5	<5	<5	<5	-	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for moderate groundwater

Table 10-50 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH16

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Aluminium	0.01		0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01
Arsenic	0.001		<0.001	<0.001	<0.001	0.018	-	0.002	0.002	<0.001	<0.001	0.001	0.001	0.001
Barium	0.001		0.052	0.058	0.071	0.139	-	0.062	0.052	0.048	0.078	0.093	0.097	0.074
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.003	<0.001	0.002	0.002	-	0.002	0.001	0.001	0.002	0.002	0.003	0.002

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Copper	0.001	-	0.001	*0.002*	<0.001	<0.001	-	*0.008*	*0.004*	*0.002*	0.001	*0.002*	*0.008*	*0.002*
Iron	0.05	0.02	*0.55*	0.25	0.15	*5.61*	-	0.12	0.06	0.08	0.21	0.13	0.08	<0.001
Lead	0.001		<0.001	***0.468***	***0.639***	***0.573***	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	***0.732***
Manganese	0.001	-	0.895	0.002	0.001	0.001	-	0.519	0.419	0.553	0.751	0.931	0.971	<0.001
Molybdenum	0.001		<0.001	<0.01	<0.01	<0.01	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Nickel	0.001		0.002	<0.001	<0.001	<0.001	-	0.002	<0.001	0.002	0.001	0.001	<0.001	<0.01
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001
Silver	0.001		<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		<0.001	<0.01	<0.01	<0.01	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01
Vanadium	0.01		<0.01	<0.005	<0.005	<0.005	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005
Zinc	0.005	-	<0.005	<0.001	0.003	<0.001	-	*0.01*	<0.005	<0.005	0.005	0.007	*0.011*	*0.09*
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ammonia as N	0.01		0.05	0.06	0.3	4.2	-	0.14	0.18	0.11	0.16	0.15	0.15	0.13
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	-	0.03	0.01	0.01	<0.01	-	0.05	0.02	0.04	0.05	0.03	0.04	0.03
Nitrite + Nitrate as N	0.01		0.03	0.01	0.01	<0.01	-	0.05	0.02	0.04	0.05	0.03	0.04	0.03
Total Kjeldahl Nitrogen as N	0.1		0.6	0.3	0.2	4.8	-	0.5	0.4	0.4	0.3	0.3	0.3	0.2
Total Nitrogen as N	0.1		0.6	0.3	0.2	4.8	-	0.6	0.4	0.4	0.4	0.3	0.3	0.2
Total Phosphorus as P	0.01		0.12	0.07	0.09	0.64	-	0.16	0.09	0.08	0.07	0.1	0.1	0.08
Reactive Phosphorus as P	0.01		0.04	0.04	0.04	<0.01	-	0.03	0.04	0.04	0.02	0.01	0.02	0.02
Total Petroleum Hydrocarbons														

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
C6 - C9 Fraction	20		<20	<20	<20	30	-	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	-	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		<100	<100	<100	<100	-	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction	50		<50	<50	<50	<50	-	50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	50		<50	<50	<50	<50	-	50	<50	<50	<50	<50	<50	<50
Total Recoverable Hydrocarbons														
C6 - C10 Fraction	20		<20	<20	<20	30	-	<20	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-	<20	<20	<20	<20	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	-	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		<100	<100	<100	<100	-	100	<100	<100	<100	<100	<100	<100
>C34 - C40 Fraction	100		<100	<100	<100	<100	-	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		<100	<100	<100	<100	-	100	<100	<100	<100	<100	<100	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	-	<100	<100	<100	<100	<100	<100	<100
BTEXN														
Benzene	1		<1	<1	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	17	-	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	<2

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date											
			1-May-17	12-Jun-17	7-Aug-17	27-Sep-17	7-Nov-17	12-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Sum of BTEX	1		<1	<1	<1	17	-	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	-	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-51 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH29

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	-
Arsenic	0.001		<0.001	<0.001	<0.001	<0.001	-
Barium	0.001		0.01	0.006	0.008	0.008	-
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-
Copper	0.001	0.015	0.001	<0.001	<0.001	<0.001	-
Cobalt	0.001		<0.001	<0.001	<0.001	<0.001	-
Nickel	0.001	0.01	<0.001	<0.001	<0.001	<0.001	-
Lead	0.001		<0.001	*0.006*	*0.007*	*0.006*	-
Zinc	0.005		<0.005	<0.001	<0.001	<0.001	-
Manganese	0.001		0.006	<0.001	<0.001	<0.001	-
Molybdenum	0.001		<0.001	<0.01	<0.01	<0.01	-
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-
Silver	0.001		<0.001	<0.001	<0.001	<0.001	-

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
Uranium	0.001	0.045	<0.001	<0.01	<0.01	<0.01	-
Vanadium	0.01	0.03	<0.01	<0.005	<0.005	<0.005	-
Iron	0.05		<0.05	<0.05	<0.05	<0.05	-
Mercury	0.0001	0.5	<0.0001	<0.0001	<0.0001	<0.0001	-
Fluoride	0.1		0.1	0.1	<0.1	<0.1	0.1
Ammonia as N	0.01		0.1	0.04	<0.01	0.02	-
Nitrite as N	0.01	7	<0.01	<0.01	<0.01	<0.01	-
Nitrate as N	0.01		3.94	0.41	0.25	0.13	-
Nitrite + Nitrate as N	0.01		3.94	0.41	0.25	0.13	-
Total Kjeldahl Nitrogen as N	0.1		0.6	0.4	<0.1	0.2	-
Total Nitrogen as N	0.1		4.5	0.4	0.2	0.3	-
Total Phosphorus as P	0.01		0.09	0.14	0.13	0.07	-
Reactive Phosphorus as P	0.01		0.04	0.04	0.04	0.04	-
Total Petroleum Hydrocarbons							
C6 - C9 Fraction	20		<20	<20	<20	<20	-
C10 - C14 Fraction	50		<50	<50	<50	<50	-
C15 - C28 Fraction	100		<100	<100	<100	<100	-
C29 - C36 Fraction	50		<50	<50	<50	<50	-
C10 - C36 Fraction (sum)	50		<50	<50	<50	<50	-
Total Recoverable Hydrocarbons							
C6 - C10 Fraction	20		<20	<20	<20	<20	-
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-
>C10 - C16 Fraction	100		<100	<100	<100	<100	-
>C16 - C34 Fraction	100		<100	<100	<100	<100	-

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
>C34 - C40 Fraction	100		<100	<100	<100	<100	-
>C10 - C40 Fraction (sum)	100		<100	<100	<100	<100	-
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	-
BTEXN							
Benzene	1		<1	<1	<1	<1	-
Toluene	2		<2	<2	<2	<2	-
Ethylbenzene	2		<2	<2	<2	<2	-
meta- & para-Xylene	2		<2	<2	<2	<2	-
ortho-Xylene	2		<2	<2	<2	<2	-
Total Xylenes	2		<2	<2	<2	<2	-
Sum of BTEX	1		<1	<1	<1	<1	-
Naphthalene	5		<5	<5	<5	<5	-

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-52 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH30

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	-
Arsenic	0.001		0.003	0.002	0.003	0.003	-
Barium	0.001		0.166	0.132	0.164	0.164	-
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
Copper	0.001	0.041	<0.001	0.001	<0.001	0.001	-
Cobalt	0.001		0.002	<0.001	<0.001	0.002	-
Nickel	0.001		0.002	<0.001	<0.001	<0.001	-
Lead	0.001		<0.001	***3.41***	***3.25***	***3.32***	-
Zinc	0.005	12.67	<0.005	<0.001	<0.001	<0.001	-
Manganese	0.001	0.478	*2.98*	0.002	0.001	0.002	-
Molybdenum	0.001		<0.001	<0.01	<0.01	<0.01	-
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-
Silver	0.001		<0.001	*0.001*	*0.002*	*0.002*	-
Uranium	0.001		0.001	<0.01	<0.01	<0.01	-
Vanadium	0.01		<0.01	<0.005	<0.005	<0.005	-
Iron	0.05	0.09	***3.95***	***4.4***	***3.63***	***3.75***	-
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-
Fluoride	0.1	1.07	0.2	0.2	0.1	0.2	0.2
Ammonia as N	0.01		0.94	0.85	0.73	0.85	-
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	-
Nitrate as N	0.01	3.26	<0.01	<0.01	0.01	0.02	-
Nitrite + Nitrate as N	0.01		<0.01	<0.01	0.01	0.02	-
Total Kjeldahl Nitrogen as N	0.1		1.1	0.9	0.7	0.8	-
Total Nitrogen as N	0.1		1.1	0.9	0.7	0.8	-
Total Phosphorus as P	0.01		0.13	0.14	0.18	0.14	-
Reactive Phosphorus as P	0.01		<0.01	<0.01	<0.01	<0.01	-
Total Petroleum Hydrocarbons							
C6 - C9 Fraction	20		<20	<20	<20	<20	-
C10 - C14 Fraction	50		<50	<50	<50	<50	-

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
C15 - C28 Fraction	100		<100	<100	<100	<100	-
C29 - C36 Fraction	50		<50	<50	<50	<50	-
C10 - C36 Fraction (sum)	50		<50	<50	<50	<50	-
Total Recoverable Hydrocarbons							
C6 - C10 Fraction	20		<20	<20	<20	<20	-
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-
>C10 - C16 Fraction	100		<100	<100	<100	<100	-
>C16 - C34 Fraction	100		<100	<100	<100	<100	-
>C34 - C40 Fraction	100		<100	<100	<100	<100	-
>C10 - C40 Fraction (sum)	100		<100	<100	<100	<100	-
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	-
BTEXN							
Benzene	1		<1	<1	<1	<1	-
Toluene	2		<2	<2	<2	<2	-
Ethylbenzene	2		<2	<2	<2	<2	-
meta- & para-Xylene	2		<2	<2	<2	<2	-
ortho-Xylene	2		<2	<2	<2	<2	-
Total Xylenes	2		<2	<2	<2	<2	-
Sum of BTEX	1		<1	<1	<1	<1	-
Naphthalene	5		<5	<5	<5	<5	-

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-53 Laboratory reported dissolved metals, nutrients and hydrocarbons data – BH32

Analyte [1]	LOR	Styx 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	-
Arsenic	0.001		<0.001	<0.001	<0.001	<0.001	-
Barium	0.001		0.04	0.03	0.034	0.037	-
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	-
Copper	0.001	0.041	<0.001	<0.001	<0.001	<0.001	-
Cobalt	0.001		<0.001	<0.001	<0.001	<0.001	-
Nickel	0.001		<0.001	<0.001	<0.001	<0.001	-
Lead	0.001		<0.001	***0.345***	***0.326***	***0.348***	-
Zinc	0.005	12.67	<0.005	<0.001	<0.001	<0.001	-
Manganese	0.001	0.478	***0.386***	<0.001	<0.001	<0.001	-
Molybdenum	0.001		<0.001	<0.01	<0.01	<0.01	-
Selenium	0.01		<0.01	<0.001	<0.001	<0.001	-
Silver	0.001		<0.001	*0.001*	*0.001*	*0.001*	-
Uranium	0.001		<0.001	<0.01	<0.01	<0.01	-
Vanadium	0.01		<0.01	<0.005	<0.005	<0.005	-
Iron	0.05	0.09	<0.05	<0.05	<0.05	<0.05	-
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	-
Fluoride	0.1	1.07	0.7	0.7	0.5	0.7	0.8
Ammonia as N	0.01		10.7	1.77	0.55	0.54	-
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	-
Nitrate as N	0.01	3.26	<0.01	<0.01	<0.01	0.01	-

Analyte [1]	LOR	Styx 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
Nitrite + Nitrate as N	0.01		<0.01	<0.01	<0.01	0.01	-
Total Kjeldahl Nitrogen as N	0.1		9.9	2	0.6	0.6	-
Total Nitrogen as N	0.1		9.9	2	0.6	0.6	-
Total Phosphorus as P	0.01		0.66	0.13	0.06	0.05	-
Reactive Phosphorus as P	0.01		0.55	0.1	0.05	0.04	-
Total Petroleum Hydrocarbons							
C6 - C9 Fraction	20		<20	<20	<20	<20	-
C10 - C14 Fraction	50		<50	<50	<50	<50	-
C15 - C28 Fraction	100		<100	<100	<100	<100	-
C29 - C36 Fraction	50		<50	<50	<50	<50	-
C10 - C36 Fraction (sum)	50		<50	<50	<50	<50	-
Total Recoverable Hydrocarbons							
C6 - C10 Fraction	20		<20	<20	<20	<20	-
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	-
>C10 - C16 Fraction	100		<100	<100	<100	<100	-
>C16 - C34 Fraction	100		<100	<100	<100	<100	-
>C34 - C40 Fraction	100		<100	<100	<100	<100	-
>C10 - C40 Fraction (sum)	100		<100	<100	<100	<100	-
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	-
BTEXN							
Benzene	1		<1	<1	<1	<1	-
Toluene	2		<2	<2	<2	<2	-
Ethylbenzene	2		<2	<2	<2	<2	-

Analyte [1]	LOR	Styx 80th percentile WQO [2]	Sample Date				
			3-May-17	15-Jun-17	9-Aug-17	27-Sep-17	10-Nov-17
meta- & para-Xylene	2		<2	<2	<2	<2	-
ortho-Xylene	2		<2	<2	<2	<2	-
Total Xylenes	2		<2	<2	<2	<2	-
Sum of BTEX	1		<1	<1	<1	<1	-
Naphthalene	5		<5	<5	<5	<5	-

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-54 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP02

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date									
			20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
Aluminium	0.01		<0.01	0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Arsenic	0.001		0.003	0.002	0.001	0.002	0.002	0.002	0.002	0.003	0.002	0.003
Barium	0.001		0.454	0.441	0.36	0.335	0.326	0.309	0.279	0.295	0.289	0.306
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.021	0.002	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Copper	0.001	-	<0.001	*0.002*	0.001	*0.002*	*0.002*	<0.001	*0.002*	0.001	<0.001	<0.001
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001		*2.99*	*0.381*	*0.399*	0.085	0.053	0.029	0.007	0.01	0.03	0.014
Molybdenum	0.005	-	0.002	0.002	0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.001	-	0.006	0.002	0.003	0.001	0.008	<0.001	0.001	<0.001	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	*0.008*	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	*0.002*	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.007	0.005	0.003	0.004	<0.001	0.007	0.006	0.006	0.006	0.006
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	*0.008*	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01		*0.009*	<0.005	*0.039*	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005
Iron	0.05	0.02	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.8	0.6	0.6	0.7	0.6	0.6	0.7	0.7	0.6	0.8
Ammonia as N	0.01		0.07	0.03	0.03	0.07	0.04	0.01	0.03	0.11	0.05	0.05
Nitrite as N	0.01		0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	-	1.88	2.19	2.53	2.48	2.63	2.64	2.75	2.84	3.07	2.97
Nitrite + Nitrate as N	0.01		1.89	2.22	2.53	2.48	2.63	2.64	2.75	2.84	3.07	2.97

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date									
			20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
Total Kjeldahl Nitrogen as N	0.1		11.2	1.8	1.4	1.7	1.2	1.2	<0.5	2.4	1.5	1.3
Total Nitrogen as N	0.1		13.1	4	3.9	4.2	3.8	3.8	2.8	5.2	4.6	4.3
Total Phosphorus as P	0.01		7.27	2.3	1.48	1.21	0.78	0.64	0.27	1.09	1.1	0.98
Reactive Phosphorus as P	0.01		0.03	0.04	0.08	0.12	0.11	0.11	0.11	0.12	0.13	0.12
Total Petroleum Hydrocarbons												
C6 - C9 Fraction	20		40	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		350	220	<100	150	<100	100	<100	<100	<100	<100
C29 - C36 Fraction	50		140	110	<50	60	<50	<50	<50	50	<50	<50
C10 - C36 Fraction (sum)	50		490	330	<50	210	<50	100	<50	50	<50	<50
Total Recoverable Hydrocarbons												
C6 - C10 Fraction	20		40	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		40	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		450	290	<100	200	<100	130	<100	100	<100	<100
>C34 - C40 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		450	290	<100	200	<100	130	<100	100	<100	<100

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date									
			20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN												
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-55 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP04

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
Aluminium	0.01		*0.61*	0.02	0.02	<0.01	0.01	0.01	<0.01	<0.01	0.01	0.04	0.02
Arsenic	0.001		<0.001	0.003	0.004	0.002	0.005	0.004	0.003	0.004	0.004	0.003	0.002
Barium	0.001		0.238	0.121	0.254	0.24	0.268	0.346	0.267	0.265	0.33	0.299	0.182
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
Chromium	0.001		0.166	0.055	0.008	0.014	0.011	0.005	0.001	0.002	0.006	0.005	0.004
Cobalt	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.001	0.015	*0.009*	*0.002*	<0.001	*0.002*	*0.002*	*0.002*	*0.002*	*0.002*	0.001	*0.004*	<0.001
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	<0.001	0.002	0.046	<0.001	0.029	0.074	0.102	0.066	0.04	0.066	0.025
Molybdenum	0.005		***0.202***	*0.102*	*0.047*	*0.033*	*0.045*	0.026	0.02	0.021	0.023	0.019	0.016
Nickel	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	*0.002*	*0.002*	<0.001	<0.001	<0.01	<0.001	<0.001	0.001	<0.001	<0.001
Uranium	0.001		<0.001	<0.001	0.001	<0.001	0.002	<0.001	0.002	0.002	0.002	0.003	0.002
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	0.002	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	0.045	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	0.019
Iron	0.05	0.04	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.7	0.5	0.5	<1.0	0.4	0.4	0.6	0.4	0.5	0.4	0.8
Ammonia as N	0.01		0.19	0.02	<0.01	0.22	0.15	0.12	0.38	0.08	0.04	0.03	0.07
Nitrite as N	0.01		0.02	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Nitrate as N	0.01	7	0.07	0.1	0.25	0.47	0.23	0.4	0.08	0.29	0.43	0.52	0.19
Nitrite + Nitrate as N	0.01		0.09	0.11	0.25	0.48	0.24	0.4	0.08	0.29	0.44	0.52	0.19

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
Total Kjeldahl Nitrogen as N	0.1		<0.5	9.6	<0.5	12.2	2.4	0.5	1.2	0.7	<0.5	<0.5	0.8
Total Nitrogen as N	0.1		<0.5	9.7	<0.5	12.7	2.6	0.9	1.3	1	<0.5	0.5	1.0
Total Phosphorus as P	0.01		0.59	5.95	0.18	9.66	1.82	0.1	0.33	0.87	<0.05	<0.05	0.11
Reactive Phosphorus as P	0.01		<0.01	<0.01	0.01	<0.01	<0.01	0.02	0.03	0.01	0.02	0.01	0.02
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	20		130	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		160	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		160	140	480	920	370	<100	150	230	<100	<100	<100
C29 - C36 Fraction	50		<50	<50	700	380	150	<50	60	110	<50	<50	<50
C10 - C36 Fraction (sum)	50		320	140	1,180	1,300	520	<50	210	340	<50	<50	<50
Total Recoverable Hydrocarbons													
C6 - C10 Fraction	20		130	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		130	20	<20	<20	<20	<20	<20	<20	<20	<20	<20

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
>C10 - C16 Fraction	100		150	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		170	160	2,320	1,200	490	<100	190	320	<100	<100	<100
>C34 - C40 Fraction	100		<100	<100	280	170	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		320	160	2,600	1,370	490	<100	190	320	<100	<100	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		150	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN													
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-56 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP04D

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
Aluminium	0.01		<0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.01	<0.01
Arsenic	0.001		0.001	0.001	0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium	0.001		0.103	0.085	0.09	0.126	0.098	0.107	0.17	0.12	0.131	0.132	0.132
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.001	0.03	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	*0.004*	<0.001	<0.001	<0.001
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	0.095	0.087	0.093	0.179	0.079	0.067	0.066	0.038	0.039	0.034	0.039
Molybdenum	0.005		0.003	0.003	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.007	0.005	0.004	0.005	0.005	<0.001	0.005	0.005	0.005	0.005	0.004
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	0.004	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	0.068	*0.06*	*0.058*	*0.098*	*0.085*	*0.068*	<0.01	*0.028*	*0.02*	*0.022*	*0.01*	*0.022*
Iron	0.05	0.03	<0.05	0.06	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.6	0.4	<0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
Ammonia as N	0.01		0.02	0.04	0.04	0.1	0.08	0.03	0.06	0.02	0.03	0.03	0.05
Nitrite as N	0.01		0.03	0.06	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate as N	0.01	11.27	0.32	0.36	0.34	0.44	0.39	0.46	0.46	0.43	0.4	0.42	0.45
Nitrite + Nitrate as N	0.01		0.35	0.42	0.38	0.46	0.40	0.47	0.47	0.44	0.41	0.43	0.46

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
Total Kjeldahl Nitrogen as N	0.1		<0.5	0.6	<0.5	0.9	1.2	0.5	0.6	<0.5	0.6	<0.5	0.8
Total Nitrogen as N	0.1		<0.5	1	<0.5	1.4	1.6	1	1.1	<0.5	1	<0.5	1.3
Total Phosphorus as P	0.01		0.1	<0.05	0.09	0.08	0.16	0.07	0.06	<0.05	<0.05	0.08	0.06
Reactive Phosphorus as P	0.01		<0.01	<0.01	<0.01	0.02	0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		310	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction	50		160	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	50		470	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Recoverable Hydrocarbons													
C6 - C10 Fraction	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		440	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C34 - C40 Fraction	100		110	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		550	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN													
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for moderate groundwater

Table 10-57 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP05

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	0.01	*0.13*	<0.01	<0.01	*0.29*	*1.09*	*0.57*
Arsenic	0.001		0.001	0.002	0.002	<0.001	0.002	0.004	0.004	0.004	0.004	0.006	0.008
Barium	0.001		0.218	0.262	0.225	0.54	0.105	0.183	0.191	0.172	0.222	0.267	0.194
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002
Cobalt	0.001		0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.002
Copper	0.001	-	<0.001	0.001	<0.001	<0.001	*0.002*	0.001	0.001	*0.002*	<0.001	0.001	*0.004*
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002
Manganese	0.001	-	0.8	0.669	0.323	<0.001	0.140	0.301	0.066	0.014	0.911	0.25	0.112
Molybdenum	0.005		0.003	0.002	0.002	0.005	0.002	0.003	0.005	0.003	0.003	0.003	0.002
Nickel	0.001		0.002	<0.001	<0.001	0.001	<0.001	0.003	<0.001	<0.001	0.002	<0.001	0.002
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	0.003	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.005	0.006	0.005	0.005	0.003	<0.001	0.004	0.004	0.002	0.003	0.002
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	0.003	*0.02*	*0.01*	<0.01	0.01	0.03
Zinc	0.01	-	*0.034*	*0.01*	*0.013*	<0.005	<0.005	<0.01	<0.005	<0.005	*0.013*	*0.03*	*0.038*
Iron	0.05	0.02	<0.05	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	<0.05	0.24	0.66	0.95
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.7	0.6	0.5	1.1	1.0	1	1	1.1	1.1	1	1.2
Ammonia as N	0.01		0.03	0.06	0.06	0.07	0.12	0.08	0.12	0.09	0.17	0.14	0.11
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	-	<0.01	<0.01	0.04	0.04	0.04	0.02	0.04	0.02	0.05	0.11	0.01
Nitrite + Nitrate as N	0.01		<0.01	<0.01	0.04	0.04	0.04	0.02	0.04	0.02	0.05	0.11	0.01

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
Total Kjeldahl Nitrogen as N	0.1		0.8	0.5	<0.5	19.2	3.4	1.6	1.4	0.4	2.6	4.5	1.9
Total Nitrogen as N	0.1		0.8	0.5	<0.5	19.2	3.4	1.6	1.4	0.4	2.6	4.6	1.9
Total Phosphorus as P	0.01		0.8	0.26	0.2	16.2	2.66	0.98	0.74	0.39	1.37	3.22	1.28
Reactive Phosphorus as P	0.01		0.06	0.03		0.07	0.07	0.05	0.06	0.06	0.04	0.04	0.05
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	20		<20	<20	<20	30	<20	20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		90	<50	<50	60	<50	<50	120	<50	<50	<50	<50
C15 - C28 Fraction	100		220	<100	<100	1,290	360	350	210	<100	240	210	<100
C29 - C36 Fraction	50		120	<50	60	890	240	250	90	<50	150	120	<50
C10 - C36 Fraction (sum)	50		430	<50	60	2,240	600	600	420	<50	390	330	<50
Total Recoverable Hydrocarbons													
C6 - C10 Fraction	20		<20	<20	<20	30	<20	20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		<20	<20	<20	30	<20	20	<20	<20	<20	<20	<20

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	11-May-18	6-Jun-18	4-Jul-18	31-Jul-18	29-Aug-18	26-Sep-18
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		290	<100	140	1,920	530	550	270	<100	350	300	<100
>C34 - C40 Fraction	100		<100	<100	<100	560	140	150	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		290	<100	140	2,480	670	700	270	<100	350	300	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN													
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-58 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP06

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	9-May-2018	6-Jun-18	5-Jul-18	31-Jul-18	28-Aug-18	27-Sep-18
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	<0.01	<0.01
Arsenic	0.001		*0.024*	0.021	0.021	0.004	0.012	0.006	0.012	0.011	0.02	0.019	0.016
Barium	0.001		0.323	0.419	0.427	0.168	0.180	0.125	0.191	0.259	0.606	0.328	0.233
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.021	0.006	0.006	0.007	0.001	<0.001	<0.001	<0.001	0.003	0.004	0.003
Copper	0.001	0.041	<0.001	*0.003*	*0.003*	<0.001	*0.004*	*0.004*	*0.002*	*0.003*	<0.001	<0.001	*0.002*
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.478	*9.05*	*3.92*	*2.62*	*3.43*	0.423	0.164	0.31	0.093	*1.94*	*2.21*	1.13
Molybdenum	0.005		0.004	0.009	0.006	0.002	0.006	0.006	0.002	0.006	0.002	0.001	0.002
Nickel	0.001		0.007	0.002	0.002	0.003	<0.001	0.001	<0.001	<0.001	0.002	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.004	0.008	0.008	0.001	0.002	0.005	0.003	0.004	0.002	0.002	0.004
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	12.67	0.007	*0.011*	*0.01*	<0.005	<0.005	<0.005	<0.005	<0.005	*0.026*	<0.005	*0.014*
Iron	0.05	0.09	*6.41*	*2.9*	*1.75*	0.12	0.33	0.16	0.32	<0.05	6.73	5.79	2.18
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	1.07	0.3	0.5	0.5	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6
Ammonia as N	0.01		0.16	0.01	0.07	0.26	0.15	0.12	0.38	0.12	0.14	0.12	0.15
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	3.26	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.03	0.02	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	0.01		<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.03	0.02	<0.01	<0.01	<0.01

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	9-May-2018	6-Jun-18	5-Jul-18	31-Jul-18	28-Aug-18	27-Sep-18
Total Kjeldahl Nitrogen as N	0.1		7.7	0.5	3.3	4.3	5.1	3	4.9	1.1	4.7	3.2	1.4
Total Nitrogen as N	0.1		7.7	0.5	3.3	4.3	5.1	3	4.9	1.1	4.7	3.2	1.4
Total Phosphorus as P	0.01		3.65	0.2	1.76	1.29	2.00	1.05	2.71	0.45	2.21	1.44	0.49
Reactive Phosphorus as P	0.01		<0.01	0.2	<0.01	<0.01	0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	20		960	300	390	60	50	40	40	50	40	50	20
C10 - C14 Fraction	50		340	120	<280	120	150	100	310	90	<280	180	60
C15 - C28 Fraction	100		15,400	1,990	14,500	8,850	11,700	10,400	13,600	4,350	13,300	10,800	3,540
C29 - C36 Fraction	50		26,200	3,250	25,700	15,400	14,800	18,300	20,600	7,600	24,800	19,700	6,300
C10 - C36 Fraction (sum)	50		41,900	5,360	40,200	24,400	26,600	28,800	34,500	12,000	38,100	30,700	9,900
Total Recoverable Hydrocarbons													
C6 - C10 Fraction	20		950	320	400	50	50	40	40	50	30	50	30
C6 - C10 Fraction minus BTEX (F1)	20		950	320	400	50	50	40	40	50	30	50	30

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			12-Nov-17	20-Dec-17	17-Jan-18	14-Mar-18	12-Apr-18	9-May-2018	6-Jun-18	5-Jul-18	31-Jul-18	28-Aug-18	27-Sep-18
>C10 - C16 Fraction	100		550	170	<280	180	220	150	310	110	<280	210	100
>C16 - C34 Fraction	100		33,600	4,220	33,400	19,900	23,700	24,000	29,200	10,000	31,400	25,500	7,900
>C34 - C40 Fraction	100		20,000	2,820	20,800	12,000	7,370	12,100	12,000	6,410	21,500	12,500	5,450
>C10 - C40 Fraction (sum)	100		54,200	7,210	54,200	32,100	31,300	36,200	41,500	16,500	52,900	38,200	13,400
>C10 - C16 Fraction minus Naphthalene (F2)	100		550	170	<280	180	220	150	310	110	<280	210	100
BTEXN													
Benzene	1-5		<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2-5		<5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2-5		<5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2-10		<10	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2-5		<5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2-5		<5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1-5		<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-59 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP08

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date											
			6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	30-Aug-18	24-Sep-18
Aluminium	0.01		<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	0.001		0.002	0.003	0.003	0.003	0.003	0.004	0.003	0.002	0.002	0.002	0.002	0.002
Barium	0.001		0.269	0.197	0.218	0.21	0.212	0.217	0.179	0.16	0.136	0.223	0.16	0.123
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.008	0.004	0.005	0.005	0.004	0.004	0.003	0.001	0.001	0.002	<0.001	<0.001
Copper	0.001	0.015	<0.001	*0.002*	*0.002*	0.001	*0.002*	*0.002*	<0.001	*0.003*	*0.002*	*0.002*	*0.002*	*0.002*
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	*2.2*	1.23	1.31	1.32	1.38	1.28	0.978	0.616	0.395	0.639	0.27	0.15
Molybdenum	0.005		0.005	0.004	0.003	0.002	0.004	0.002	0.002	0.001	<0.001	0.002	0.002	<0.001
Nickel	0.001		0.004	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.011	0.01	0.01	0.01	0.004	0.008	0.007	0.008	0.008	0.009	0.009	0.009
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	0.045	*0.027*	*0.015*	*0.025*	*0.026*	*0.013*	*0.017*	0.007	*0.027*	*0.019*	*0.009*	*0.014*	*0.017*
Iron	0.05	0.04	<0.05	<0.05	0.06	<0.05	<0.05	0.17	0.18	<0.05	<0.05	0.08	<0.05	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.5	0.4	0.5	0.4	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5
Ammonia as N	0.01		0.09	0.11	0.08	0.08	0.2	0.29	0.21	0.1	0.08	0.15	0.08	0.04
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	7	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.04	<0.01	<0.01	<0.01	<0.01

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date											
			6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	30-Aug-18	24-Sep-18
Total Kjeldahl Nitrogen as N	0.1		0.6	<0.5	0.2	<0.5	2.8	0.8	2.3	1.5	<0.5	0.8	<0.5	1
Total Nitrogen as N	0.1		0.6	<0.5	0.2	<0.5	2.8	0.8	2.3	1.5	<0.5	0.8	<0.5	1
Total Phosphorus as P	0.01		0.42	0.46	0.12	0.28	1.58	0.33	1.58	0.48	0.25	0.68	1.06	0.38
Reactive Phosphorus as P	0.01		<0.01	0.01	0.12	0.04	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01
Total Petroleum Hydrocarbons														
C6 - C9 Fraction			90	80	60	70	60	80	40	<20	<20	<20	<20	<20
C10 - C14 Fraction			80	<50	<50	<50	70	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction			3,070	1,300	1,000	640	5,770	1,570	4,960	1,760	250	1,230	760	190
C29 - C36 Fraction			6,070	2,460	1,840	1,210	10,800	2,750	9,350	3,460	350	2,330	1,450	290
C10 - C36 Fraction (sum)			9,220	3,760	2,840	1,850	16,600	4,320	14,300	5,220	600	3,560	2,210	480
Total Recoverable Hydrocarbons														
C6 - C10 Fraction			100	80	60	70	60	80	40	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)			100	80	60	70	60	80	40	<20	<20	<20	<20	<20
>C10 - C16 Fraction			<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction			7,400	2,990	2,270	1,520	13,500	3,440	11,800	4,050	500	2,840	1,750	370

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date											
			6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	30-Aug-18	24-Sep-18
>C34 - C40 Fraction			5,390	2,160	1,700	1,050	8,910	2,480	7,190	3,280	310	2,060	1,350	260
>C10 - C40 Fraction (sum)			12,800	5,150	3,970	2,570	22,400	5,920	19,000	7,330	810	4,900	3,100	630
>C10 - C16 Fraction minus Naphthalene (F2)			<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN														
Benzene			<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene			<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene			<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene			<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene			<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes			<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX			<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene			<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-60 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP08D

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			8-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
Aluminium	0.01		<0.01	0.03	<0.01	0.02	0.02	<0.01	0.02	0.03	<0.01	0.01	0.01	0.05	0.03
Arsenic	0.001		<0.001	0.001	0.004	0.004	0.005	0.003	0.004	0.004	0.004	0.004	0.002	0.003	0.003
Barium	0.001		0.092	0.101	0.126	0.141	0.143	0.168	0.132	0.115	0.128	0.115	0.118	0.119	0.112
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001
Copper	0.001	0.03	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	*0.003*	<0.001	*0.002*	<0.001	<0.001	<0.001	<0.001
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	0.07	0.18	0.422	0.341	0.32	0.577	0.204	0.27	0.285	0.217	0.157	0.174	0.175
Molybdenum	0.005		<0.001	0.002	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		<0.001	0.002	0.002	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	0.068	*0.01*	<0.005	<0.005	<0.005	<0.005	*0.027*	<0.005	*0.081*	0.007	*0.026*	*0.019*	*0.013*	*0.012*
Iron	0.05	0.03	<0.05	0.08	0.4	0.35	0.35	<0.05	0.24	0.28	0.3	0.27	0.47	0.5	0.29
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.6	0.7	0.7	0.6	0.7	0.6	0.6	0.8	0.7	0.7	0.9	0.8	0.7	0.7
Ammonia as N	0.01		0.83	0.79	0.81	0.81	0.79	0.91	0.77	0.88	0.87	0.81	0.86	0.86	0.88

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			8-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	11.27	0.01	0.01	0.04	<0.01	<0.01	<0.01	0.01	<0.01	0.03	<0.01	<0.01	0.02	<0.01
Nitrite + Nitrate as N	0.01		0.01	0.01	0.04	<0.01	<0.01	<0.01	0.01	<0.01	0.03	<0.01	<0.01	0.02	<0.01
Total Kjeldahl Nitrogen as N	0.1		0.9	0.8	0.7	0.8	0.8	1.1	1.0	1	1.1	1	1	1.2	0.8
Total Nitrogen as N	0.1		0.9	0.8	0.7	0.8	0.8	1.1	1.0	1	1.1	1	1	1.2	0.8
Total Phosphorus as P	0.01		0.02	0.07	<0.05	0.03	0.11	0.07	<0.05	0.01	0.09	0.06	0.05	0.07	0.09
Reactive Phosphorus as P	0.01		<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Petroleum Hydrocarbons															
C6 - C9 Fraction	20		70	40	<20	30	30	<20	70	20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction	50		60	<50	<50	<50	<50	<50	60	<50	<50	<50	50	120	<50
C10 - C36 Fraction (sum)	50		60	<50	<50	<50	<50	<50	60	<50	<50	<50	50	120	<50
Total Recoverable Hydrocarbons															
C6 - C10 Fraction	20		70	40	<20	50	20	<20	70	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		60	40	<20	50	20	<20	60	<20	<20	<20	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		100	<100	<100	<100	<100	<100	100	<100	<100	<100	100	160	<100

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			8-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	4-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
>C34 - C40 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		100	<100	<100	<100	<100	<100	100	<100	<100	<100	100	160	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN															
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for moderate groundwater

Table 10-61 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP09

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			11-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	6-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
Aluminium	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
Arsenic	0.001		0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.002
Barium	0.001		0.133	0.153	0.13	0.125	0.103	0.11	0.109	0.078	0.087	0.083	0.081	0.088	0.069
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.002	0.007	0.007	0.006	0.004	0.003	0.004	0.003	0.003	0.003	0.002	0.004	0.002
Copper	0.001	0.015	0.001	<0.001	*0.002*	0.001	<0.001	*0.002*	*0.002*	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	0.495	0.917	0.899	0.719	0.483	0.619	0.435	0.337	0.365	0.323	0.276	0.361	0.22
Molybdenum	0.005		0.001	0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Nickel	0.001		0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.002	0.001	0.002	0.002	<0.001	0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.012	0.01	0.01	0.01	0.008	0.003	0.008	0.009	0.01	0.009	0.009	0.01	0.009
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	0.045	*0.026*	*0.022*	*0.032*	*0.03*	*0.027*	*0.015*	*0.015*	*0.016*	*0.024*	*0.03*	*0.029*	*0.021*	*0.026*
Iron	0.05	0.04	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	0.05	<0.05	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5
Ammonia as N	0.01		0.01	0.05	0.06	0.02	0.01	0.06	0.06	0.03	0.07	0.05	0.05	0.06	0.02
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	7	0.02	<0.01	<0.01	0.03	<0.01	0.02	0.03	0.02	0.02	0.03	0.02	0.03	0.03
Nitrite + Nitrate as N	0.01		0.02	<0.01	<0.01	0.03	<0.01	0.02	0.03	0.02	0.02	0.03	0.02	0.03	0.03

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			11-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	6-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
Total Kjeldahl Nitrogen as N	0.1		<0.5	<0.5	<0.5	0.2	<0.5	0.9	<0.5	0.6	<0.5	<0.5	0.7	0.7	<0.5
Total Nitrogen as N	0.1		<0.5	<0.5	<0.5	0.2	<0.5	0.9	<0.5	0.6	<0.5	<0.5	0.7	0.7	<0.5
Total Phosphorus as P	0.01		0.42	0.23	0.09	0.11	0.10	0.34	0.32	0.22	0.11	0.15	0.47	0.14	0.13
Reactive Phosphorus as P	0.01		0.07	0.04	0.04	0.11	0.06	0.03	0.06	0.02	0.04	0.04	0.04	0.05	0.04
Total Petroleum Hydrocarbons															
C6 - C9 Fraction	20		<20	30	30	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		70	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		310	240	100	<100	<100	130	260	<100	<100	120	340	<100	<100
C29 - C36 Fraction	50		120	130	<50	<50	<50	70	140	<50	<50	80	200	<50	<50
C10 - C36 Fraction (sum)	50		500	370	100	<50	<50	200	400	<50	<50	200	540	<50	<50
Total Recoverable Hydrocarbons															
C6 - C10 Fraction	20		<20	30	30	<20	20	<20	<20	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		<20	30	30	<20	20	<20	<20	<20	<20	<20	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		370	320	120	100	<100	180	370	130	100	180	480	<100	<100

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date												
			11-Nov-17	6-Dec-17	20-Dec-17	16-Jan-18	12-Feb-18	12-Mar-18	9-Apr-18	8-May-18	6-Jun-18	2-Jul-18	2-Aug-18	27-Aug-18	24-Sep-18
>C34 - C40 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		370	320	120	100	<100	180	370	130	100	180	480	<100	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN															
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-62 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP10

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	16-Jan-18	13-Mar-18	10-Apr-18	9-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
Aluminium	0.01		<0.01	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
Arsenic	0.001		0.001	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001
Barium	0.001		0.3	0.228	0.209	0.146	0.153	0.116	0.142	0.142	0.101	0.089	0.081
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.002	<0.001	0.004	0.001	0.002	0.002	0.002	0.002	<0.001	<0.001	<0.001
Copper	0.001	0.015	0.001	*0.002*	<0.001	*0.002*	*0.002*	<0.001	<0.001	*0.003*	0.001	<0.001	0.001
Lead	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	0.573	0.16	0.992	0.367	0.502	0.424	0.562	0.408	0.168	0.312	0.188
Molybdenum	0.005		0.003	0.004	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Nickel	0.001		0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	*0.002*	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		0.007	0.006	0.007	0.005	0.007	0.007	0.008	0.008	0.007	0.006	0.007
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	0.045	*0.029*	*0.011*	*0.04*	<0.005	0.008	<0.005	*0.033*	*0.01*	0.006	0.005	0.01
Iron	0.05	0.04	<0.05	<0.05	0.24	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.3	0.3	0.3	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.5
Ammonia as N	0.01		0.03	0.05	0.03	0.1	0.05	0.07	0.11	0.08	0.16	0.11	0.08
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	7	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.01
Nitrite + Nitrate as N	0.01		<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.01

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	16-Jan-18	13-Mar-18	10-Apr-18	9-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
Total Kjeldahl Nitrogen as N	0.1		<0.5	1.6	8.5	1.3	2.0	2.9	1.6	0.9	1.6	<1.0	1.8
Total Nitrogen as N	0.1		<0.5	1.6	8.5	1.3	2.0	2.9	1.6	0.9	1.6	<1.0	1.8
Total Phosphorus as P	0.01		0.61	1.47	0.48	0.8	1.46	1.68	0.61	1.13	1.18	2.69	1.08
Reactive Phosphorus as P	0.01		0.02	<0.01	0.48	<0.01	0.02	0.02	0.01	0.01	0.01	<0.01	0.01
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	20		50	110	60	40	30	30	20	<20	<20	<20	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		<100	<100	<100	<100	280	200	110	130	120	<100	200
C29 - C36 Fraction	50		<50	<50	<50	<50	80	90	<50	80	70	<50	<50
C10 - C36 Fraction (sum)	50		<50	<50	<50	<50	360	290	110	210	190	<50	200
Total Recoverable Hydrocarbons													
C6 - C10 Fraction	20		50	110	60	40	30	20	20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		50	110	60	40	30	20	20	<20	<20	<20	<20

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date										
			11-Nov-17	20-Dec-17	16-Jan-18	13-Mar-18	10-Apr-18	9-May-18	6-Jun-18	4-Jul-18	31-Jul-18	30-Aug-18	26-Sep-18
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		100	110	<100	<100	330	270	140	180	160	<100	170
>C34 - C40 Fraction	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		100	110	<100	<100	330	270	140	180	160	<100	170
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN													
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-63 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP11

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date						
			10-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Aluminium	0.01		0.01	<0.01	<0.01	<0.01	<0.05	<0.05	<0.01
Arsenic	0.001		0.005	0.004	0.004	0.003	<0.005	<0.005	0.002
Barium	0.001		5.42	4.21	4.26	4.97	5.53	8.15	4.24
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0005	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Cobalt	0.001		0.012	0.006	0.005	0.003	<0.005	<0.005	0.004
Copper	0.001	-	*0.018*	*0.003*	*0.002*	<0.001	<0.005	<0.005	<0.001
Lead	0.001		0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Manganese	0.001	-	*3.51*	*1.98*	1.87	0.8	0.768	0.68	0.565
Molybdenum	0.005		0.009	0.004	0.001	<0.001	<0.005	<0.005	<0.001
Nickel	0.001		*0.013*	0.002	0.003	0.001	<0.005	<0.005	0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Uranium	0.001		0.003	0.003	0.002	<0.001	<0.005	<0.005	<0.001
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	<0.01
Zinc	0.01	-	*0.047*	*0.008*	*0.018*	*0.037*	*0.05*	*0.05*	*0.089*
Iron	0.05	0.02	0.10	1.89	2.56	2.26	2.33	1.91	3.16
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	0.5	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonia as N	0.01		1.08	1.22	1.38	1.49	1.19	2.15	1.35
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	-	0.04	<0.01	0.03	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	0.01		0.04	<0.01	0.03	<0.01	<0.01	<0.01	<0.01

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date						
			10-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Total Kjeldahl Nitrogen as N	0.1		1.7	1.3	1.3	1.3	1.5	1.8	1.8
Total Nitrogen as N	0.1		1.7	1.3	1.3	1.3	1.5	1.8	1.8
Total Phosphorus as P	0.01		0.11	0.09	<0.05	0.1	<0.05	0.14	0.46
Reactive Phosphorus as P	0.01		<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	20		250	140	20	20	<20	<20	<20
C10 - C14 Fraction	50		70	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		710	600	180	260	<100	260	100
C29 - C36 Fraction	50		1,140	1,010	200	470	90	470	180
C10 - C36 Fraction (sum)	50		1,920	1,610	380	730	90	730	280
Total Recoverable Hydrocarbons									
C6 - C10 Fraction	20		250	120	20	20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		250	120	20	20	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		1,460	1,370	300	560	130	590	220
>C34 - C40 Fraction	100		1,150	1,000	210	460	<100	470	180
>C10 - C40 Fraction (sum)	100		2,610	2,370	510	1,020	130	1060	400
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100
BTEXN									
Benzene	1		<1	<1	<1	<1	<1	<1	<1

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date						
			10-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Toluene	2		<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-64 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP11D

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date						
			11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Aluminium	0.01		0.02	0.01	0.01	<0.01	<0.05	0.01	<0.01
Arsenic	0.001		0.011	0.017	0.009	0.017	0.018	0.006	0.006
Barium	0.001		3.58	2.82	2.22	2.94	2.53	1.07	1.38
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0001	<0.0001
Chromium	0.001		<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Cobalt	0.001		0.007	0.007	0.004	0.005	<0.005	0.002	0.002
Copper	0.001	-	*0.018*	*0.002*	*0.002*	*0.003*	<0.005	<0.001	0.002
Lead	0.001		0.002	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Manganese	0.001	-	0.373	0.554	0.338	0.413	0.379	0.166	0.193
Molybdenum	0.005		0.007	0.006	0.003	0.003	<0.005	0.001	<0.001
Nickel	0.001		*0.014*	0.008	0.005	0.004	<0.005	<0.001	0.002
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Uranium	0.001		0.006	0.006	0.004	0.003	<0.005	0.002	0.002
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01
Zinc	0.01	-	*1.16*	*0.038*	*0.013*	*0.024*	*0.029*	*0.019*	*0.041*
Iron	0.05	-	0.35	2.01	2.44	2.82	3.65	3.23	0.82
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	33	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
Ammonia as N	0.01		2.52	2.49	2.31	2.74	2.02	2.64	2.5
Nitrite as N	0.01		<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	34.2	0.05	<0.01	<0.01	0.02	0.01	<0.01	0.08
Nitrite + Nitrate as N	0.01		0.05	<0.01	0.01	0.02	0.01	<0.01	0.08

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date						
			11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Total Kjeldahl Nitrogen as N	0.1		3.4	2.6	2.3	2.7	2.4	2.5	2.2
Total Nitrogen as N	0.1		3.4	2.6	2.3	2.7	2.4	2.5	2.3
Total Phosphorus as P	0.01		<0.05	<0.05	<0.05	0.07	<0.05	0.08	0.12
Reactive Phosphorus as P	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	20		100	130	<20	40	<20	<20	<20
C10 - C14 Fraction	50		50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		440	180	<100	<100	<100	<100	<100
C29 - C36 Fraction	50		380	140	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	50		870	320	<50	<50	<50	<50	<50
Total Recoverable Hydrocarbons									
C6 - C10 Fraction	20		110	110	<20	40	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		110	110	<20	40	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		660	260	<100	<100	<100	<100	<100
>C34 - C40 Fraction	100		320	120	<100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		980	380	<100	<100	<100	<100	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100
BTEXN									

Analyte [1]	LOR	Bison GCZ 80th percentile WQO [2]	Sample Date						
			11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Benzene	1		<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Bison GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for moderate groundwater

Table 10-65 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP12

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18
Aluminium	0.01		*1.69*	0.02	<0.01	*0.12*	0.05
Arsenic	0.001		0.006	0.004	0.002	0.004	0.003
Barium	0.001		0.123	0.355	0.278	0.338	0.485
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		0.001	0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.001	<0.001	*0.003*	<0.001	<0.001
Copper	0.001	0.015	*0.002*	*0.003*	<0.001	*0.004*	*0.003*
Lead	0.001		0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.01	0.167	0.122	1.26	0.157	0.05
Molybdenum	0.005		0.012	0.008	0.002	0.005	0.002
Nickel	0.001		0.002	<0.001	0.001	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.001
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.01
Uranium	0.001		0.004	0.004	0.002	0.001	<0.001
Vanadium	0.001		*0.02*	<0.01	<0.01	<0.01	0.002
Zinc	0.01	0.045	*0.01*	0.01	<0.005	<0.005	*0.01*
Iron	0.05	0.04	*1.02*	<0.05	<0.05	0.09	0.05
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1-1	0.5	1	<1.0	<1.0	0.4	0.4
Ammonia as N	0.01		0.49	0.27	0.21	0.25	0.08
Nitrite as N	0.01		0.12	0.2	0.08	0.06	0.04
Nitrate as N	0.01	7	0.14	0.62	0.42	1.32	1.75
Nitrite + Nitrate as N	0.01		0.26	0.82	0.5	1.38	1.79

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18
Total Kjeldahl Nitrogen as N	0.1		31.8	2.5	18.5	21.1	8.6
Total Nitrogen as N	0.1		32.1	3.3	19	22.5	10.4
Total Phosphorus as P	0.01		15.1	3.74	8.68	8.95	4.16
Reactive Phosphorus as P	0.01		0.14	0.06	0.04	0.02	0.03
Total Petroleum Hydrocarbons							
C6 - C9 Fraction	20		240	80	40	20	30
C10 - C14 Fraction	50		80	480	60	<50	60
C15 - C28 Fraction	100		5,980	7,680	4,220	4,710	1,970
C29 - C36 Fraction	50		10,200	51,300	7,360	8,320	3,590
C10 - C36 Fraction (sum)	50		16,300	59,500	11,600	13,000	5,620
Total Recoverable Hydrocarbons							
C6 - C10 Fraction	20		240	80	40	20	20
C6 - C10 Fraction minus BTEX (F1)	20		240	80	40	20	20
>C10 - C16 Fraction	100		140	600	<100	<100	<100
>C16 - C34 Fraction	100		13,000	70,400	9,420	10,400	4,780
>C34 - C40 Fraction	100		8,480	35,800	6,330	7,130	3,060
>C10 - C40 Fraction (sum)	100		21,600	107,000	15,800	17,500	7,840
>C10 - C16 Fraction minus Naphthalene (F2)	100		140	600	<100	<100	<100
BTEXN							
Benzene	1		<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2

Analyte [1]	LOR	Uplands GCZ 80th percentile WQO [2]	Sample Date				
			20-Dec-17	17-Jan-18	14-Mar-18	11-Apr-18	10-May-18
Total Xylenes	2		<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Uplands GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-66 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP13

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date									
			17-Jan-18	15-Feb-18	14-Mar-18	11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Aluminium	0.01-0.05		<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1
Arsenic	0.001-0.005		0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01
Barium	0.001		0.185	0.256	0.171	0.184	0.144	0.125	0.116	0.137	0.112	0.187
Cadmium	0.0005		*0.0003*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001
Chromium	0.005		<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01
Cobalt	0.001		0.008	0.016	0.01	0.007	0.006	0.006	<0.005	<0.005	0.005	<0.01
Copper	0.005	0.041	*0.002*	<0.005	<0.005	<0.005	<0.005	<0.005	*0.007*	<0.005	<0.005	<0.01
Lead	0.001-0.005		<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01
Manganese	0.001	0.478	*1.93*	*3.55*	*2.62*	1.84	1.71	1.59	1.28	1.48	1.72	1.22
Molybdenum	0.005		0.004	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01
Nickel	0.001		0.007	0.008	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01
Selenium	0.001		<0.01	<0.05	<0.05	<0.05	<0.005	<0.05	<0.05	<0.05	<0.05	<0.10

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date									
			17-Jan-18	15-Feb-18	14-Mar-18	11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Silver	0.01		<0.001	*0.009*	<0.005	<0.005	<0.05	<0.005	<0.005	<0.005	<0.005	<0.01
Uranium	0.001		0.04	0.035	0.015	0.029	<0.005	0.02	0.02	0.02	0.023	0.018
Vanadium	0.001		<0.01	<0.05	<0.05	<0.05	*0.023*	<0.05	<0.05	<0.05	<0.05	<0.10
Zinc	0.01	12.67	*0.128*	<0.025	*0.038*	<0.025	<0.05	<0.025	<0.025	0.035	0.07	<0.05
Iron	0.05	0.09	<0.05	0.52	0.2	0.88	0.98	0.55	0.76	0.73	1.02	0.83
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	1.07	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	<0.5	0.1
Ammonia as N	0.01		0.22	0.17	0.45	0.21	0.22	0.23	0.23	0.07	0.18	0.19
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	3.26	0.04	<0.01	<0.01	0.24	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	0.01		0.04	<0.01	<0.01	0.24	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen as N	0.1		0.7	0.8	0.9	0.9	0.5	0.5	<0.5	0.6	0.7	<0.5
Total Nitrogen as N	0.1		0.7	0.8	0.9	1.1	0.5	0.5	<0.5	0.6	0.7	<0.5
Total Phosphorus as P	0.01		0.11	0.16	0.21	0.12	0.11	0.09	0.13	<0.05	0.8	0.17
Reactive Phosphorus as P	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Petroleum Hydrocarbons												
C6 - C9 Fraction	20		80	50	30	20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		80	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		640	170	<100	130	<100	<100	<100	<100	170	270

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date									
			17-Jan-18	15-Feb-18	14-Mar-18	11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
C29 - C36 Fraction	50		130	80	<50	<50	<50	<50	<50	<50	150	60
C10 - C36 Fraction (sum)	50		850	250	<50	130	<50	<50	<50	<50	320	330
Total Recoverable Hydrocarbons												
C6 - C10 Fraction	20		70	50	30	30	<20	-	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		70	50	30	30	<20	-	<20	<20	<20	<20
>C10 - C16 Fraction	100		110	<100	<100	<100	<100	-	<100	<100	<100	190
>C16 - C34 Fraction	100		580	210	<100	160	<100	-	<100	<100	270	120
>C34 - C40 Fraction	100		<100	<100	<100	<100	<100	-	<100	<100	<100	<100
>C10 - C40 Fraction (sum)	100		690	210	<100	160	<100	-	<100	<100	270	310
>C10 - C16 Fraction minus Naphthalene (F2)	100		110	<100	<100	<100	<100	-	<100	<100	<100	190
BTEXN												
Benzene	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Analyte [1]	LOR	Styx GCZ 80^{th} percentile WQO [2]	Sample Date									
			17-Jan-18	15-Feb-18	14-Mar-18	11-Apr-18	10-May-18	5-Jun-18	3-Jul-18	1-Aug-18	28-Aug-18	25-Sep-18
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80^{th} percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

Table 10-67 Laboratory reported dissolved metals, nutrients and hydrocarbons data – WMP15

Analyte [1]	LOR	Styx GCZ 80^{th} percentile WQO [2]	Sample Date						
			10-Apr-18	9-May-18	6-Jun-18	5-Jul-18	2-Aug-18	30-Aug-18	27-Sep-18
Aluminium	0.01		0.03	0.01	0.01	0.01	0.05	<0.01	0.01
Arsenic	0.001		0.002	0.002	0.002	0.001	0.001	0.001	0.001
Barium	0.001		0.117	0.099	0.11	0.108	0.122	0.139	0.137
Cadmium	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.001		0.03	0.008	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	0.001		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.001	0.041	*0.019*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	0.001		0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.001	0.478	0.186	0.116	0.122	0.11	0.119	0.129	0.111
Molybdenum	0.005		0.054	0.02	0.002	0.002	0.001	0.001	<0.001
Nickel	0.001		0.007	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date						
			10-Apr-18	9-May-18	6-Jun-18	5-Jul-18	2-Aug-18	30-Aug-18	27-Sep-18
Silver	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.001		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.01	12.67	*0.059*	*0.01*	*0.017*	*0.033*	*0.086*	*0.029*	*0.029*
Iron	0.05	0.09	<0.05	0.1	0.17	0.19	0.16	0.16	0.22
Mercury	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	0.1	1.07	0.9	0.8	0.7	0.7	0.6	0.6	0.6
Ammonia as N	0.01		0.08	0.07	0.09	0.08	0.08	0.06	0.1
Nitrite as N	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	0.01	3.26	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	0.01		0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen as N	0.1		0.4	0.5	0.1	0.1	0.2	<0.1	0.3
Total Nitrogen as N	0.1		0.4	0.5	0.1	0.1	0.2	<0.1	0.3
Total Phosphorus as P	0.01		0.23	0.16	0.08	0.09	0.13	0.09	0.08
Reactive Phosphorus as P	0.01		0.13	0.09	0.04	0.04	0.03	0.02	0.01
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	20		50	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	50		<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	100		290	<100	<100	<100	110	<100	<100
C29 - C36 Fraction	50		320	60	50	<50	120	<50	<50
C10 - C36 Fraction (sum)	50		610	60	50	<50	230	<50	<50

Analyte [1]	LOR	Styx GCZ 80th percentile WQO [2]	Sample Date						
			10-Apr-18	9-May-18	6-Jun-18	5-Jul-18	2-Aug-18	30-Aug-18	27-Sep-18
Total Recoverable Hydrocarbons									
C6 - C10 Fraction	20		50	<20	<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX (F1)	20		50	<20	<20	<20	<20	<20	<20
>C10 - C16 Fraction	100		<100	<100	<100	<100	<100	<100	<100
>C16 - C34 Fraction	100		550	100	120	<100	190	<100	<100
>C34 - C40 Fraction	100		200	<100	<100	<100	110	<100	<100
>C10 - C40 Fraction (sum)	100		750	100	120	<100	300	<100	<100
>C10 - C16 Fraction minus Naphthalene (F2)	100		<100	<100	<100	<100	<100	<100	<100
BTEXN									
Benzene	1		<1	<1	<1	<1	<1	<1	<1
Toluene	2		<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2		<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	2		<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	2		<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2		<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1		<1	<1	<1	<1	<1	<1	<1
Naphthalene	5		<5	<5	<5	<5	<5	<5	<5

Notes: Grey cells identify where groundwater quality concentrations exceed the 80th percentile WQO for Styx GCZ; cells with a red border identify where groundwater quality concentrations exceed ADWG guidelines; red, bold, italic font identifies where groundwater quality concentrations exceed protection of aquatic ecosystems, underlined font identifies exceedances of long term trigger values for irrigation water and bold font identifies exceedances of protection of livestock drinking water as defined by the ANZECC (2000) guidelines.

1. All units are mg/L except for hydrocarbons which are µg/L
2. Water Quality Objectives for shallow groundwater

The laboratory reported dissolved metals, nutrients and hydrocarbon results show (Table 10-46 to Table 10-67):

- Concentrations of aluminium (Al), arsenic (As), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), molybdenum (Mo), iron (Fe), fluoride (F), zinc (Zn), chromium (Cr), barium (Ba), nickel (Ni), (Se), silver (Ag), uranium (U) and vanadium (V) reported are generally above the WQOs and guidelines values across multiple sites and monitoring events;
- BTEXN hydrocarbon baseline concentrations are below detection limits, with the exception of detectable toluene concentrations at three locations (BH01X, BH16 and WMP08D). The toluene concentrations reported at BH01X exceeded the NHMRC (2011) drinking water guidelines but the remaining detectable concentrations are below the guideline values;
- Total Petroleum Hydrocarbons (TPH) and Total Recoverable Hydrocarbons (TRH) concentrations are above detection limits at a large number of sample locations (BH01X, BH05X, BH06X, BH13, BH16, WMP02, WMP04, WMP04D, WMP05, WMP06, WMP08, WMP08D, WMP09, WMP10, WMP11, WMP11D, WMP12, WMP13 and WMP15), and are likely representative of groundwater that is in contact with coal bearing strata; and
- Ammonia as N concentrations consistently exceeded the NHMRC (2011) drinking water guidelines at a number of locations (BH01X, BH06X, BH13, BH32, WMP08D, WMP11 and WMP11D) throughout the monitoring events. It should be noted, one Ammonia as N concentration reported at BH16 from the September 2017 monitoring event exceeded the NHMRC (2011) drinking water guidelines and was an order of magnitude higher than concentrations reported from other monitoring events at BH16. The remaining concentrations reported at BH16 were less than the guideline values.

Aluminium, arsenic, cobalt copper, lead, manganese, molybdenum, iron, fluoride, zinc, chromium, barium, nickel, silver, uranium and vanadium occur above the WQOs defined for each of the GCZs within which the Project area. Hydrocarbons are reported in laboratory analyses, particularly for groundwaters sampled from the Styx Coal Measures.

10.5.6.6 Groundwater Recharge and Discharge Mechanisms

Recharge

There are a number of recharge mechanisms that are active within the Styx River catchment, including diffuse rainfall recharge over much of the catchment and episodic local-scale recharge along the major watercourses (at least) associated with stream losses during and following streamflow events.

A review of the literature has not identified any references that can assist in providing estimates of recharge rates specific to the Styx River catchment. Crosbie et al. (2010) found there have been comparatively few published recharge studies in the region. The national map of groundwater recharge produced by Leaney et al. (2011) utilises the Method of Last Resort (MOLR) approach for estimating recharge rates in data poor areas and suggests recharge rates within the Styx River catchment are in the range of 1 to 5 mm/yr (0.1% to 0.7% of mean annual rainfall; 759 mm/yr, see Section 10.5.2). However, it can be expected that higher rates of recharge might occur along watercourses during flow events due to stream losses, and that recharge over those parts of the catchment characterised by alluvial soils will be higher than elsewhere in the catchment where basement rocks and Styx Coal Measures outcrop or sub-crop, or in steep sloping locations.

The Chloride Mass Balance method has been used to estimate recharge rates over different parts of the Styx River catchment. The method assumes Cl concentrations in groundwater arise from dry fall and precipitation, and that there are negligible contributions from rock weathering and anthropogenic sources. The (steady state) chloride mass balance is described by Equation 1 (Cook 2003).

$$C_P P = C_R R + C_Q Q \qquad \textit{Eq. 1}$$

Where C_P= Chloride concentration in precipitation
P= Precipitation rate
C_R= Chloride concentration in recharge
R= Recharge rate
C_Q= Chloride concentration in surface water runoff
Q= Surface water runoff rate

In simple terms, for estimates of groundwater recharge the surface runoff component can be ignored and Equation 1 becomes Equation 2.

$$R = \frac{C_P P}{C_R} \qquad \textit{Eq. 2}$$

Using this method, Table 10-68 presents recharge estimates for the Styx River catchment based on the following criteria:

- Average precipitation rate 759 mm/yr
- Rainfall Cl concentration 2.59 mg/L (Crosbie et al, 2012)
- Groundwater Cl concentrations (adopting the lowest concentration reported)
  - Alluvium 64 to 8,560 mg/L
  - Styx Coal Measures 110 to 5,063 mg/L
  - Basement rocks 290 to 4,608 mg/L

Table 10-68 Estimated rainfall recharge rates

HSU	% of rainfall	mm/yr
Alluvium (HSU1)	<0.1 to 4	<0.5 to 31
Styx Coal Measures (HSU2)	<0.1 to 2.5	<0.5 to 18
Basement (HSU3 / HSU4)	<0.1 to 0.9	<0.5 to 7

In a groundwater modelling sense, climate, vegetative cover, soil type and degree of weathering of out-cropping and sub-cropping rocks are probably the greatest constraints on recharge rates. However, a number of other factors will also affect the potential for recharge to occur, when it occurs and at what rate. For example:

- Topographic relief – recharge potential will be greatest in ‘flat’ areas where rainfall runoff potential is lower than areas where steep topography occurs;
- Depth to water table – recharge potential may be lower in areas where the water table is close to the surface, e.g. in groundwater discharge areas, but this will also depend on the K of the sub-surface and hydraulic gradients; and
- The degree to which the soil water reservoir is depleted.

Discharge

Groundwater discharge occurs from the catchment via evapotranspirative losses from shallow water tables (direct evaporation) and riparian vegetation (transpiration), and discharge to surface water bodies (including permanent pools and baseflow fed streams).

10.5.6.7 Groundwater – Surface Water Interactions

Observations

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 (Figure 10-18 and Section 10.5.6.2);
- Mapping of groundwater dependent ecosystems (GDEs), see Section 10.6;
- Field observations of watercourse pools (Table 10-69), streambed morphology and geology (Section 10.5.5), vegetation (Section 10.6, EIS Chapter 14 – Terrestrial Ecology and EIS Chapter 15 – Aquatic Ecology);
- Water quality monitoring results (Sections 10.5.4 and 10.5.6.5);
- Interpreted extents of HSUs (Figure 10-32 and Section 10.5.6.3); and
- Analysis of radon isotopes (^{222}Rn) and stable isotopes of water (^{2}H and ^{18}O), see Section 10.6.

Figure 10-47 presents the alignments of the hydrogeological cross-sections presented in Figure 10-48 to Figure 10-52 that are used to provide conceptualisations of groundwater and surface water interactions in the area of the proposed mine, i.e.:

- Figure 10-48 and Figure 10-49 along the streambed thalwegs of Tooloombah and Deep Creeks;
- Figure 10-50 (cross-section 1, west-east) and Figure 10-51 (cross-section 2, north-south) through the Project area; and
- Figure 10-52 (cross-section 3, west-east) around 2 km above the confluence of Tooloombah and Deep Creeks.

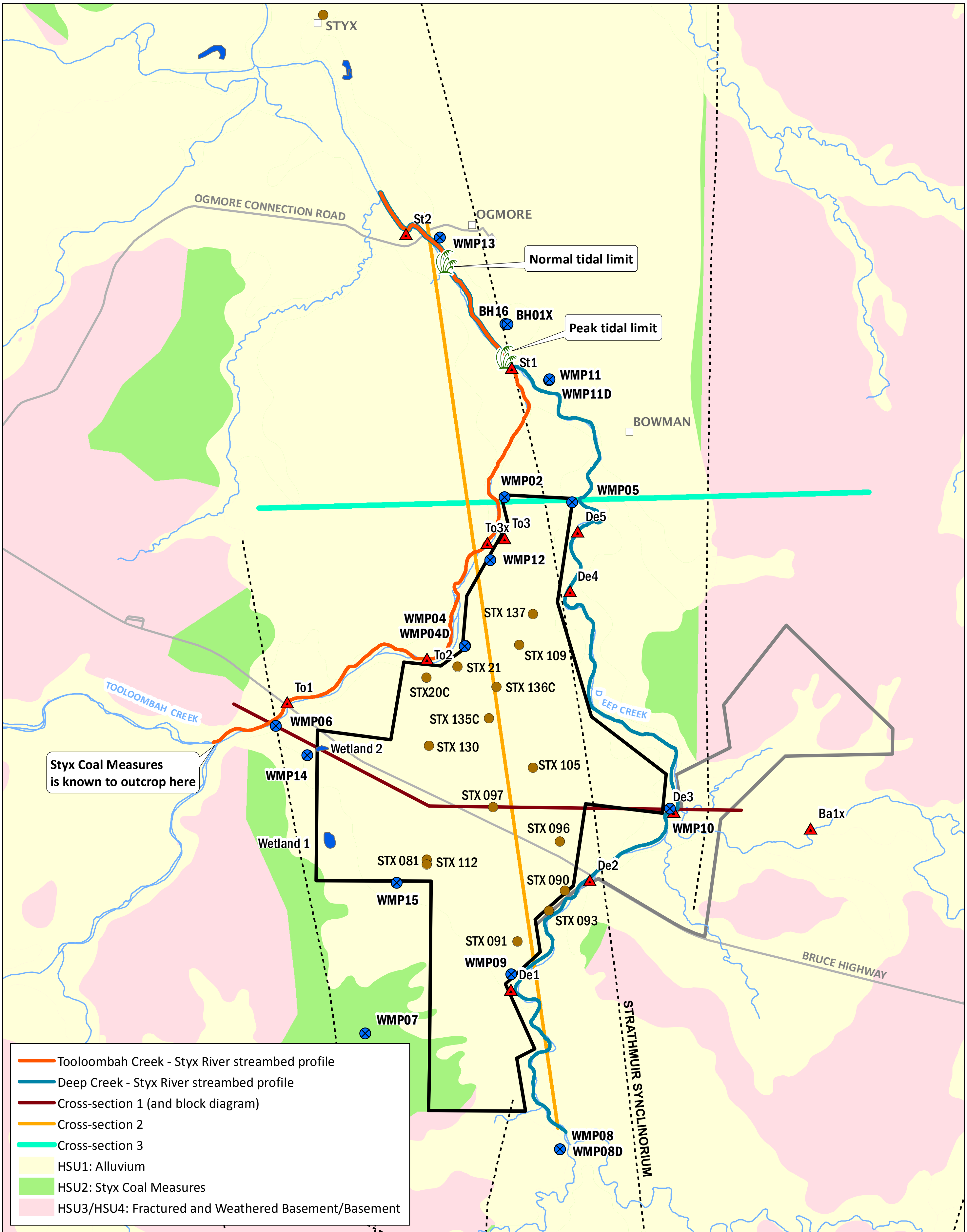
Table 10-69 Field observations of watercourse pools

Days since last rainfall- Strathmuir Station (033189)	Days since last rainfall- Rockhampton on Aero Station (039083)[1]	Monitoring event	Deep Creek					Tooloombah Creek			Styx River	
			De1	De2	De3	De4	De5	T01	T02	T03	St1	St2
9	1	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	8	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	0	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	0	Aug-17	Wet	Wet	Wet	Wet	Not visited	Wet	Wet	Wet	Wet	Not visited
53	50	Sep-17	Wet	Wet	Wet	Wet	Not visited	Wet	Wet	Wet	Wet	Not visited
3	7	Nov-17	Wet	Wet	Wet	Wet	Not visited	Wet	Wet	Wet	Wet	Not visited
0	8	Jan-18	Wet, brown turbid	Wet, very turbid	Wet, very turbid	Wet, very turbid	Wet, very turbid	Wet, turbid	Wet, turbid	Wet	Wet, green, low turbidity, significant algae	Not visited
6	7	Feb-18	Partly wet, brown, turbid	Wet, very turbid	Wet, very turbid	Wet	Wet	Wet	Wet	Wet	Wet	Not visited

N/A	3	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	4	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	0[2]	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	0[2]	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	0[2]	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)
N/A	2	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
N/A	33	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

N/A	6	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

Wet =		Large/continuous pool that extends beyond view
Partly wet =		Small/isolated ponded pool
Dry =		No water present
Notes:	N/A= No rainfall record available	
	1. Anecdotal evidence from site personnel suggests that the Project area did not experience rainfall between March and September 2018, so Rockhampton Aero station data may not be a good indicator of rainfall occurrence at site.	



Scale @ A4 1:80,000
Date: 06/12/18
Drawn: Gayle B.

Legend

- Bore
- Styx drillhole
- Surface water monitoring site
- Inferred tidal limit
- Geological structure
- Wetland (VM Act)
- ML 80187
- ML 700022
- Main road
- Major watercourse
- Waterbody

DATA SOURCE
QLD Open Source Data, 2018;
Waratah Coal, 2018;
St. Lawrence 1:250k geological map, BoMN, 1970

CDM Smith

Figure 10-47
Locations of hydrogeological cross-sections

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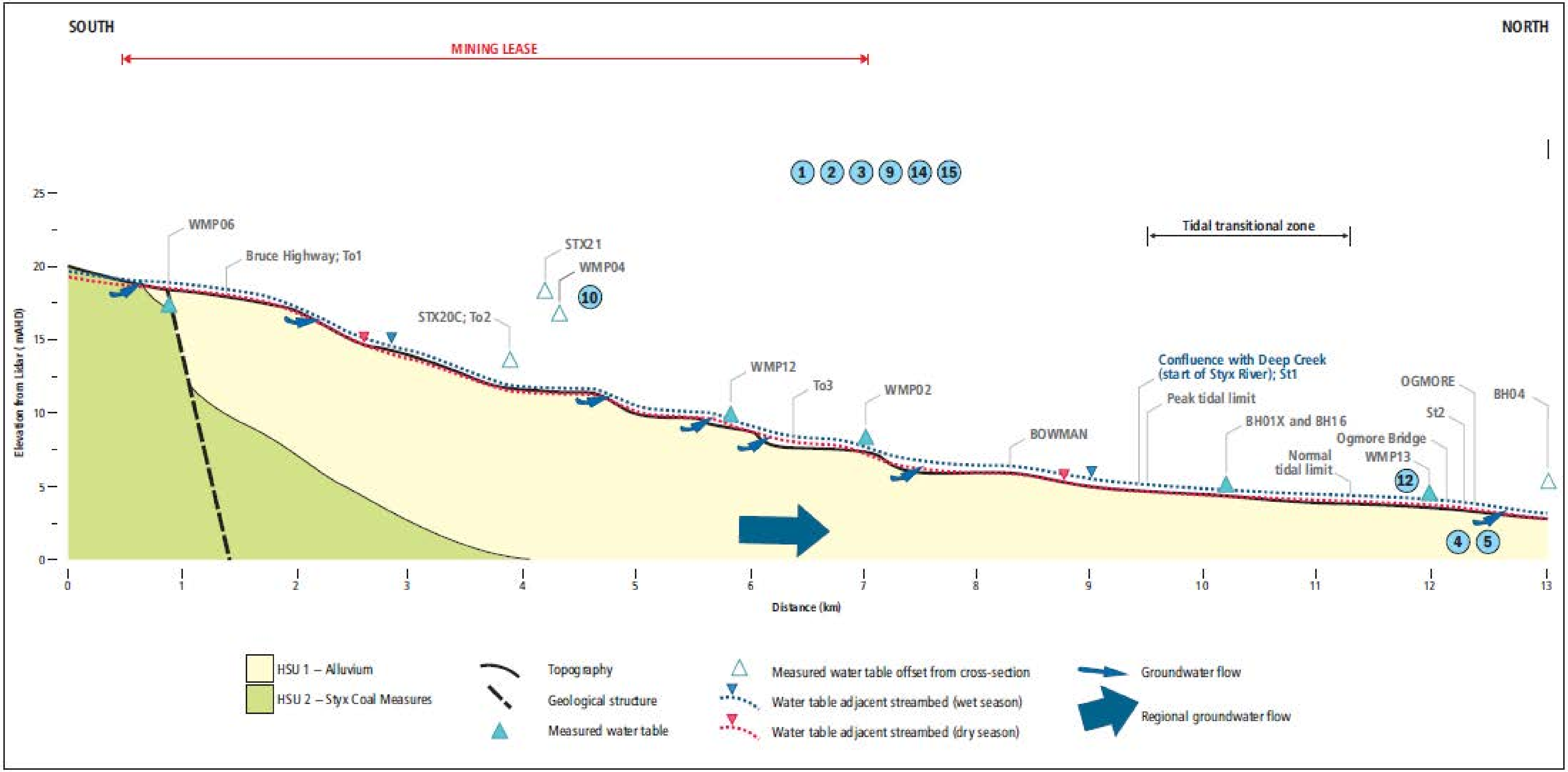


Figure 10-48

Cross-section along Tooloombah Creek streambed

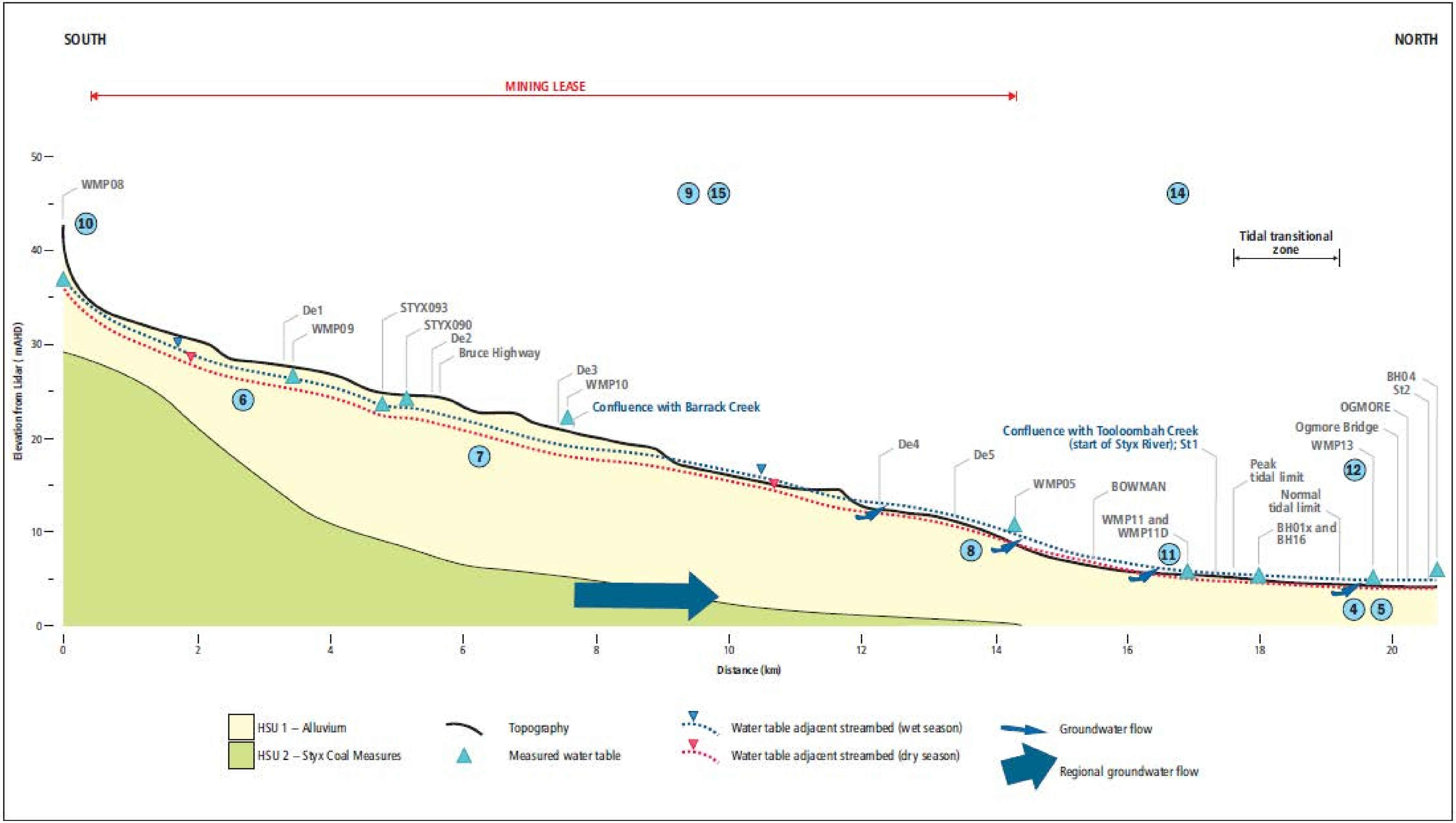


Figure 10-49

Cross-section along Deep Creek streambed

CDM Smith

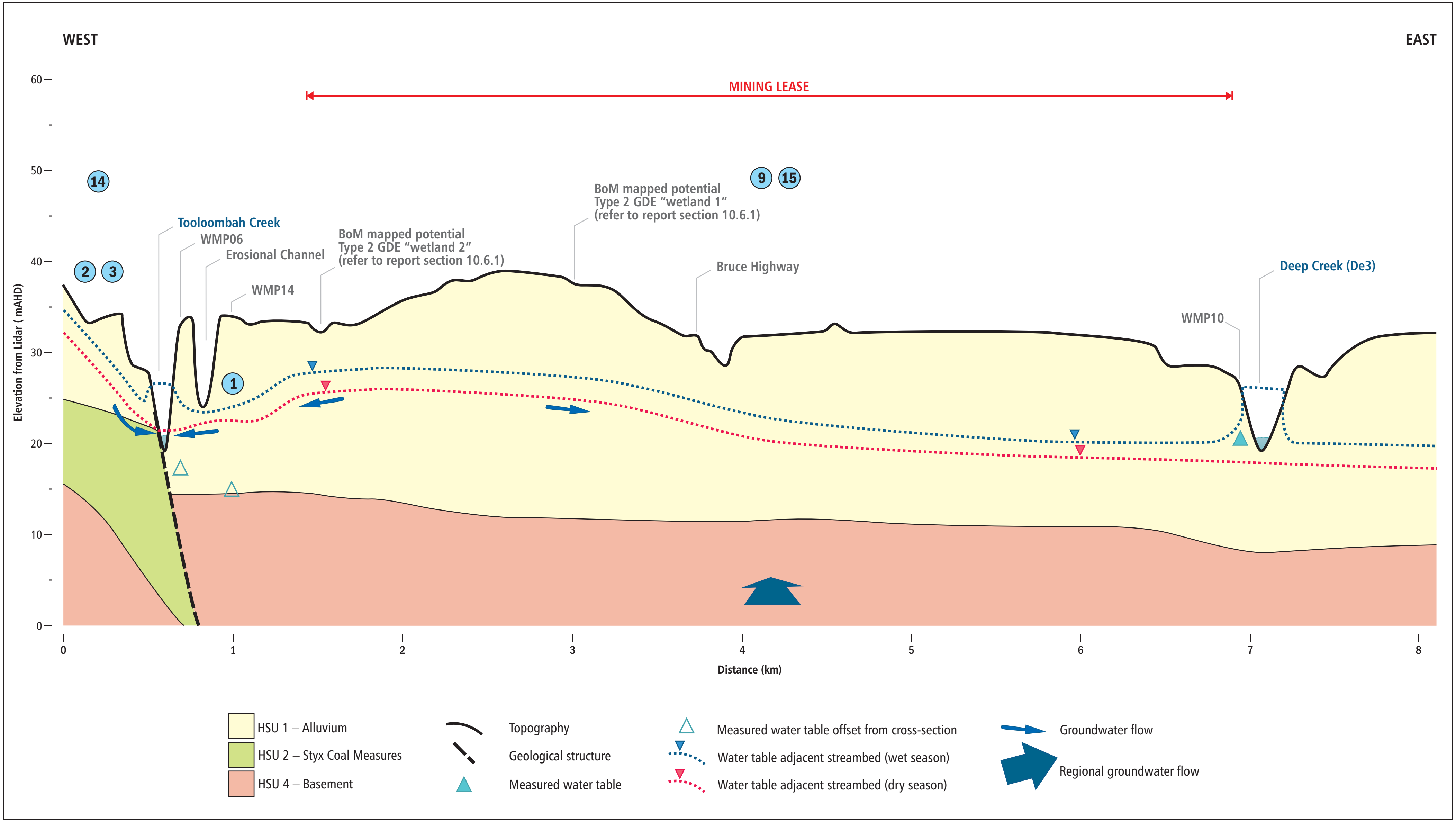


Figure 10-50

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

CDM Smith

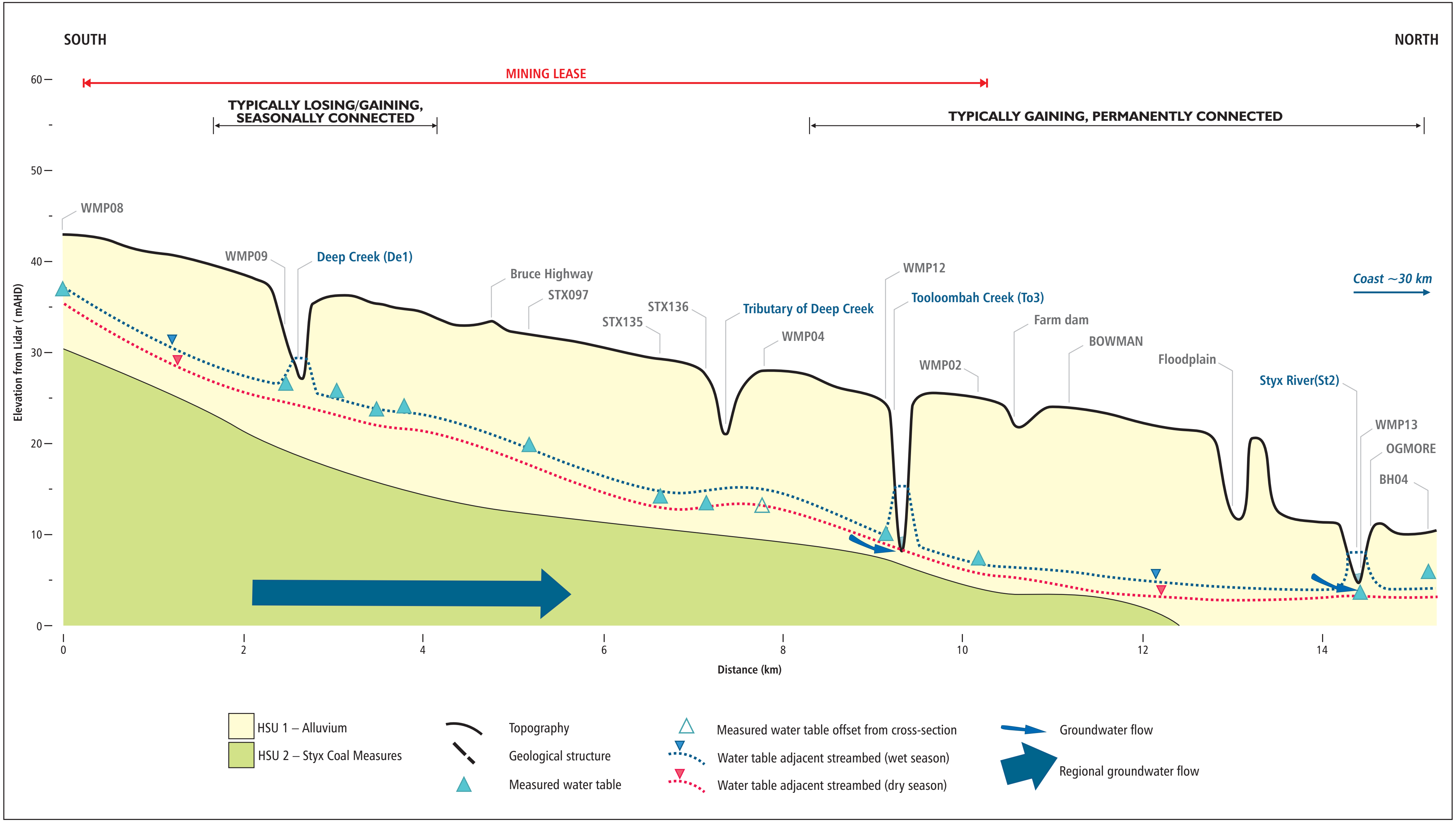


Figure 10-51
Cross-section 2 (Project area north to south)

CDM Smith

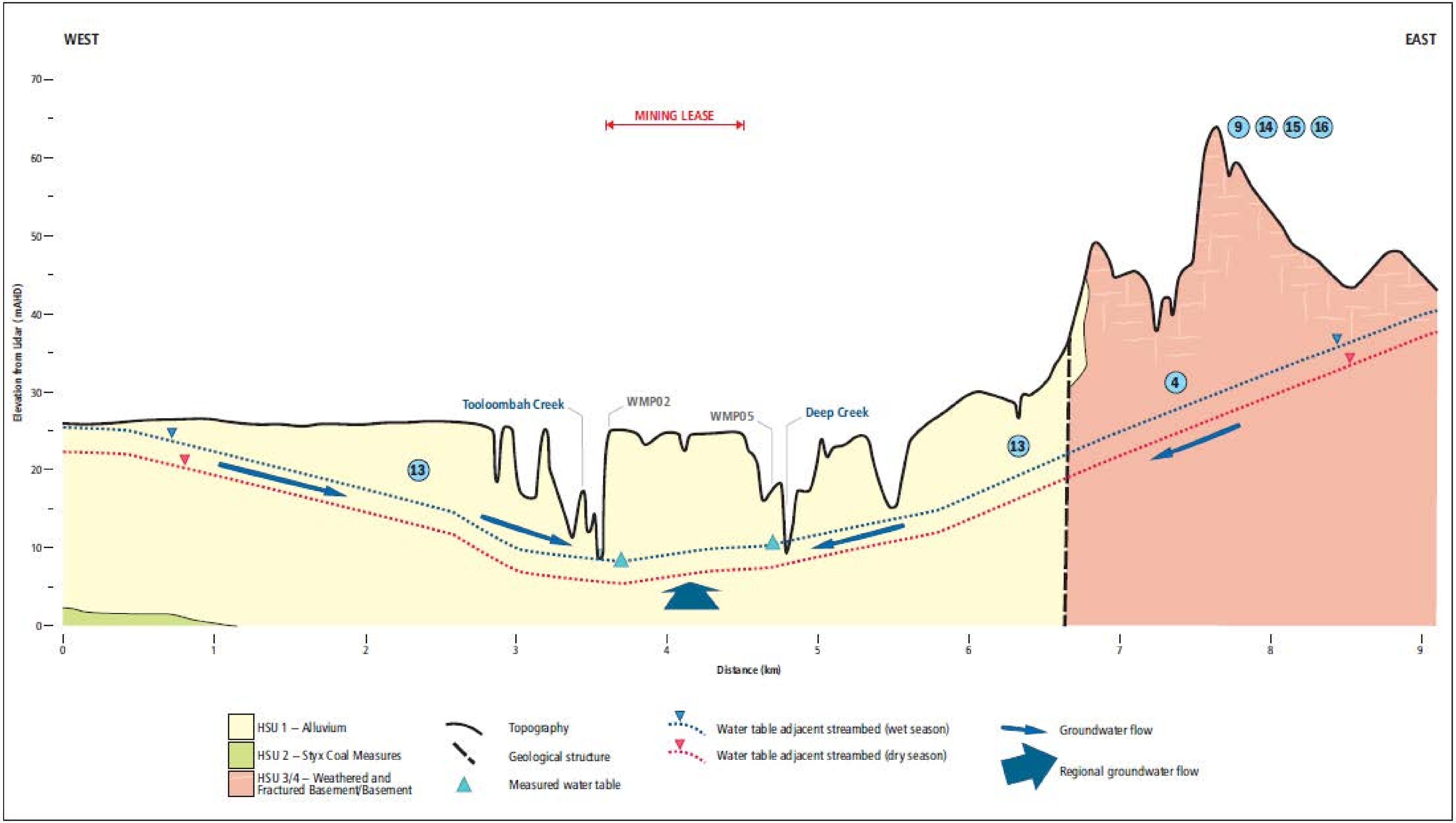


Figure 10-52

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

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:

1. Figure 10-48 and Figure 10-50

   The hydraulic gradient is relatively steeply dipping (laterally) towards Tooloombah Creek along most of its length (see Sections 10.5.4.2 and 10.5.6.2 for more detail). This gradient drives local groundwater flow toward and discharge to Tooloombah Creek and possibly Styx River.

2. Figure 10-48 and Figure 10-50

   Field observations (Table 10-69) 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.

3. Figure 10-48 and Figure 10-50

   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 10-53 and Stiff patterns presented in Sections 0 and 0).

4. Figure 10-48, Figure 10-49 and Figure 10-52

   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.

5. Figure 10-48 and Figure 10-49

   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 Sections 10.5.6.5). The water chemistry data strongly indicate the dominant source of water in the Styx River is from the estuary (tidal) or from runoff, and a strong groundwater signature is not evident although groundwater contours (Figure 10-20) suggest groundwater discharges to the river.

6. Figure 10-49

   The hydraulic gradient is relatively flat in the mid to upper reaches of Deep Creek. Table 10-69 shows the pools in the upper reaches of Deep Creek (e.g. De1, De2, De3) persisted through the 2017 dry season but dried out in the 2018 dry season, indicating an intermittent supply of water (including groundwater; see Sections 10.5.4.2 and 10.5.6.2 for more detail).

7. Figure 10-49

   In the mid and upper reaches of Deep Creek (De1, De2, De3, De4), surface water shows a similar signature to rainfall, more so than groundwater sourced from the Styx Coal Measures (see Sections 10.5.4.2 and 10.5.6.5 for more detail).

8. Figure 10-49 and Figure 10-52

   In the downstream reach of Deep Creek (De5), the hydraulic gradient toward the stream is steeper and dry season surface water samples show a similarity to nearby groundwater (WMP05), refer Figure 10-54 and Stiff patterns presented in Sections 0 and 0. In addition, this pool persisted through the 2018 dry season, indicating that groundwater may be a source of water to sustain the pool.

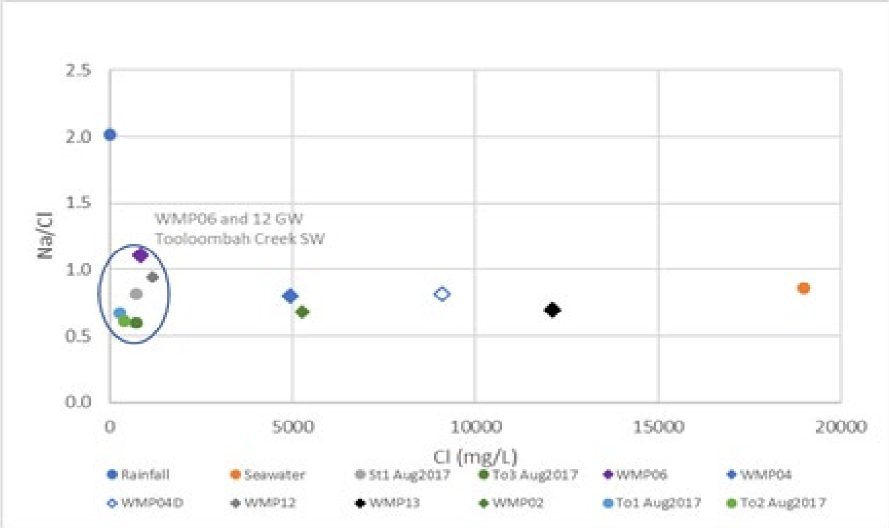


Figure 10-53 Tooloombah Creek Na/Cl vs Cl ratio plot – August 2017 surface water sampling event

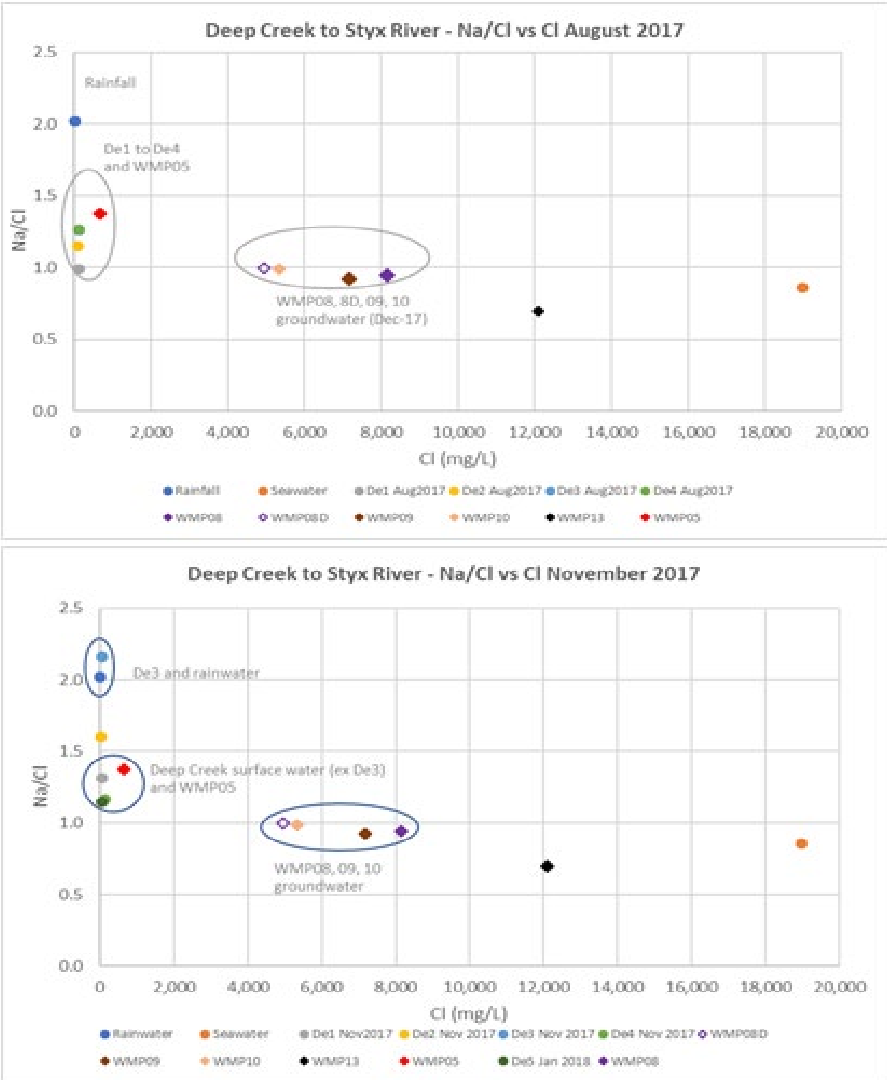


Figure 10-54 Deep Creek Na/Cl vs Cl ratio plot – August and November 2017 surface water sampling event

9. Figure 10-48, Figure 10-49, Figure 10-50, Figure 10-51 and Figure 10-52

   Following the wet season and either during or following stream flow events, all surface water samples show a reduced groundwater influence and a stronger rainfall signature (refer Stiff patterns presented in Sections 10.5.4 and 10.5.6.5).

10. Figure 10-48, Figure 10-49 and Figure 10-51

    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.

11. Figure 10-49

    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, 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.

12. Figure 10-48, Figure 10-49 and Figure 10-51

    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 10.5.4.3 and Figure 10-5).

13. Figure 10-52

    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.

14. Figure 10-48, Figure 10-49, Figure 10-50, Figure 10-51 and Figure 10-52

    Tooloombah Creek and the lower reaches of Deep Creek have thick stands of riparian vegetation (see Section 10.6), as well as algae and aquatic vegetation in Tooloombah Creek pools and in Styx River (see Table 10-69), indicating permanence of water availability (soil water, surface water or groundwater, or a combination of two or more of these sources).

15. Figure 10-48, Figure 10-49, Figure 10-50, Figure 10-51 and Figure 10-52

    In both creeks, field observations (see Table 10-69) indicate that pools tend to be turbid in the wet season (due to sediment load and erosion) and less turbid in the dry season (potentially due to sediment load settling, groundwater discharges, which is filtered, or both). Additionally, the less turbid pools could be a result of the high salinity (from groundwater inflow and concentration) causing suspended clays to flocculate and settle. Generally, the pools of Tooloombah Creek are less turbid than Deep Creek, which might be the result of less access by stock or relatively more interaction with groundwater (see Section 10.5.4.2).

16. Figure 10-50

    The water table is elevated the central parts of the Project area and a hydraulic gradient between these areas and the creeks drives groundwater discharge toward the creeks.

Analysis of available hydraulic head, topographical and hydrochemical data shows the main sources of water present in Styx River are derived from tidal (estuarine) waters or surface water runoff.

Groundwater baseflow to Styx River, whilst likely occurring, is not significant compared to these other sources.

Groundwater interaction with Tooloombah Creek is likely more sustained over the dry season than is the case along Deep Creek. Ecological reliance on groundwater (either as baseflow or as a shallow water table) is possible toward the northern extents of the Tooloombah and Deep Creek catchments.

10.5.6.8 Conceptual Hydrogeological Model

Figure 10-55 presents the conceptual processes driving interactions between surface water and groundwater in the Styx River catchment. The following provides a general description:

- General

  The Project area is characterised by local to intermediate groundwater flow systems (i.e. the distance between recharge and discharge zones ranges between less than a few kilometres up to 20 km). Groundwater flow lines presented in Figure 10-20 show groundwater discharges locally to the major tributaries of Styx River (Tooloombah and Deep Creeks), as well as Styx River itself and the Broad Sound estuary. Groundwater discharge is also expected to low lying areas closer to the coast (beyond the confluence of Styx River with the Broad Sound estuary) via evaporation. Significant amounts of groundwater are expected to be lost via evapotranspiration (ET), either directly from the water table or from plant transpiration, across the broader study area;

- Losing stream conditions

  When stream water levels are above the adjacent water table, a hydraulic gradient is generated away from the watercourse, resulting in stream losses to groundwater (i.e. the stream is losing). As well as recharging the water table aquifer, these stream losses potentially replenish storage in the stream banks (bank storage). In disconnected stream reaches, bank storage will drain away to the water table or back to the stream as flood heights decline.

- All watercourses in the tributary Tooloombah and Deep Creek catchments of Styx River are likely to experience losing conditions during and following high streamflow events. Given there is no streamflow gauging in the Styx River catchment, the frequency and magnitude of flows are not known but it is inferred that losing conditions will sometimes occur during and following high intensity rainfall and runoff events from tributary catchments.

  Downstream of the confluence of Tooloombah and Deep Creeks, Styx River will likely be a losing stream during hide tide periods when the river pool level is higher than the adjacent water table; and

- 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; Figure 10-7) are likely to be permanently connected to groundwater and receive inputs from a combination of bank storage return following stream flow events and local groundwater flow systems in drier periods. Watercourse pools that persist for long periods after stream flow events are likely maintained by groundwater discharge.

Below the confluence of Tooloombah and Deep Creeks, Styx River is, on average, a nett gaining stream, i.e. even though stream losses to groundwater may occur during high tide periods the overall water balance is dominated by groundwater discharge to the river.

Figure 10-55 Mechanisms of surface water – groundwater interactions

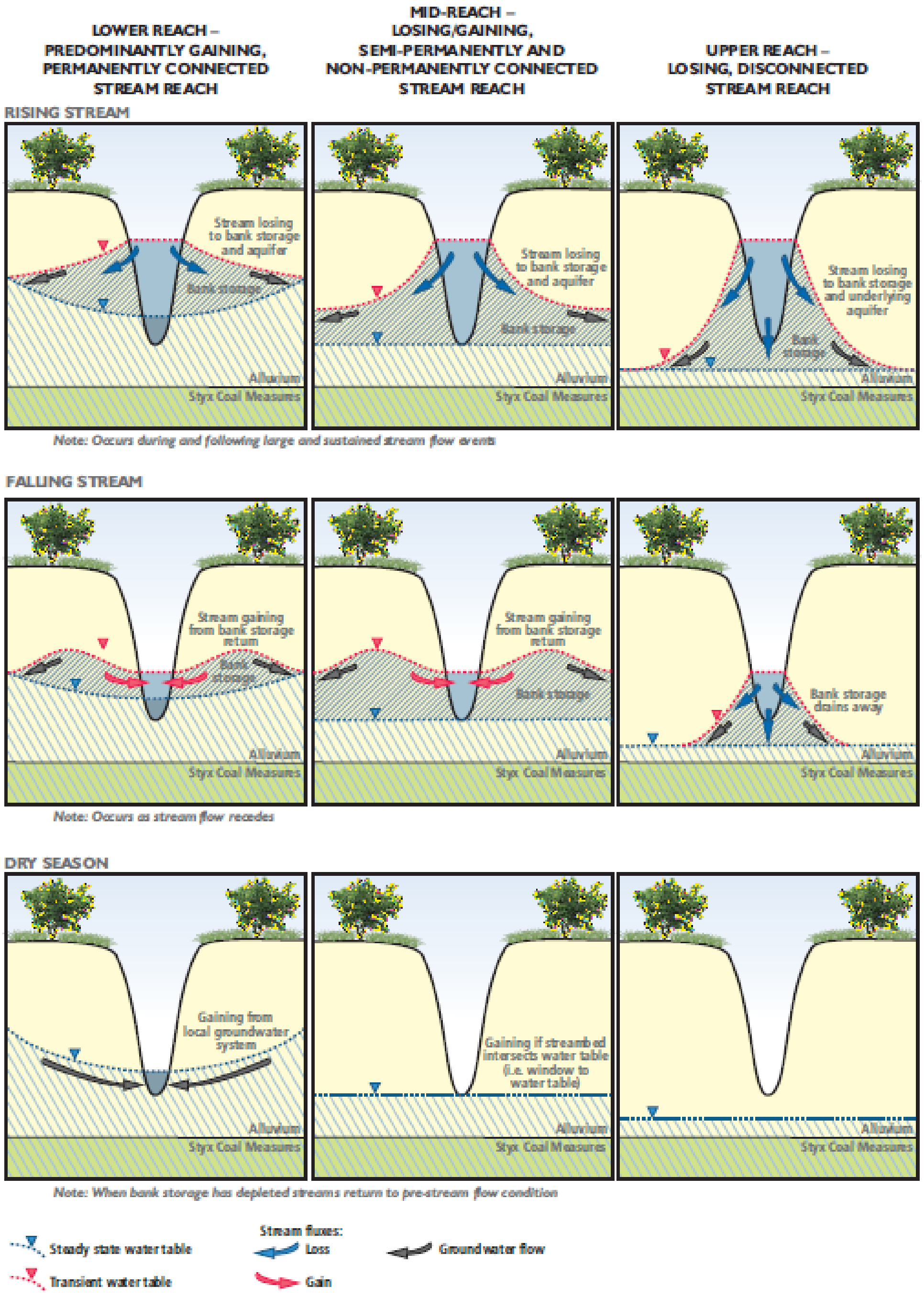


Figure 10-55

Mechanisms of surface water – groundwater interactions

All of the information and conceptualisations presented in Section 10.5 provide the basis for developing a conceptual hydrogeological model for the Project area and more broadly. Figure 10-56 presents a schematic of the conceptual model. The following describes the key elements of the model that are important in consideration of the potential effects of mining on the Styx River catchment groundwater resources and connected systems, with the following aligning with the numbering in each schematic:

1. The water table is typically hosted in unconsolidated alluvial deposits (HSU1) and also within fractured and weathered (residual) zones of outcropping and sub-cropping basement rocks (HSU3), and is generally a subdued reflection of topography, with depth to water table typically less than 15 metres below the surface. The water table varies by up to around 3 m seasonally in unconsolidated alluvial deposits (see Section 10.5.6.2 and Figure 10-20 to Figure 10-22).

2. Regional groundwater flow is generally to the north, towards Styx River and the coast. The head and salinity data for the nested WMP29 monitoring bores (Figure 10-27 and Table 10-15) 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 10-20).

3. Diffuse rainfall recharge occurs across the Styx River Basin, with higher rates of recharge expected over those parts of the catchments covered by cleared alluvial sediments (as detailed in Section 10.5.6.6).

4. Episodic local groundwater recharge (to bank storage and the underlying / adjacent aquifer) occurs from stream losses during large and sustained streamflow events (generally associated with the wet season, see Figure 10-55), as evidenced by the trend in groundwater chemistry towards a rainfall/streamflow signature (see Figure 10-46).

5. Groundwater discharge via evapotranspiration occurs from -
    a. 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);
    b. watercourse pools where the streambed intersects the water table;
    c. bank storage return, following streamflow events (see Figure 10-55); and
    d. in lower lying areas below the confluence of Tooloombah and Deep Creeks, particularly below Styx township.

6. Watercourse pools are likely to be supported at least partly by bank storage return following high streamflow periods, combined with shallow water tables along mid- to lower-reaches of Tooloombah Creek, and lower reaches of Deep Creek. The pools may be seasonally (mid-reaches) or permanently (mid- to lower-reaches) connected to the water table (see Table 10-69).

7. The occurrence of Marine Couch is an indicator of the tidally influenced zone of Styx River. Marine Couch has been observed along the river banks to an in-stream elevation of approximately 6.5 m AHD, below the confluence of Tooloombah and Deep creeks (see Figure 10-5). Groundwater discharge occurs to Styx River and the Broad Sound estuary, although at times during high tides this discharge may be interrupted by leakage for these surface water features (see Figure 10-20 and Stiff patterns presented in Sections 10.5.6.5).

8. In the central parts of the Tooloombah and Deep Creek catchments, the Styx Coal Measures (HSU2) discharge upwards to the alluvium (HSU1) except for those periods when local groundwater recharge (from streamflows or seasonal diffuse recharge) might reverse the hydraulic gradient (see Figure 10-27).

9. A mixing zone occurs along Styx River and Broad Sound estuary, where groundwater and surface water interact seasonally (rising and falling water tables, stream flow events) and diurnally (due to tidal effects).

10. Little is known about the dynamics of deeper groundwater systems associated with HSU3 and HSU4. However, residual bedrock (HSU3) will likely be important in moving groundwater from the basement rocks to overlying aquifers or to watercourses.

11. The proposed mine will be progressively mined and backfilled, with voids remaining open for up to around three years (this is discussed further in Section 10.7.1). No voids will remain open at the end of the mining and processing operation. The mine pits will be dewatered by dedicated ex-pit dewatering bores or in-pit sumps, or a combination of both.

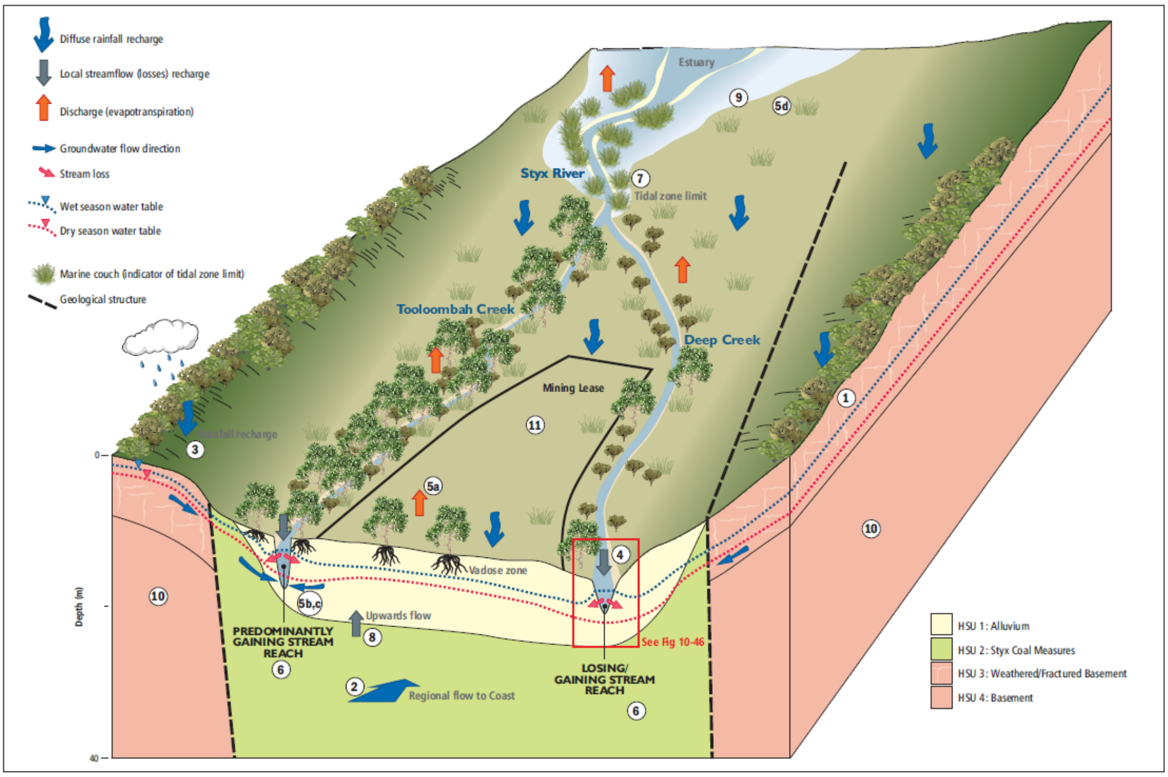


Figure 10-56 Project conceptual hydrogeological model

10.6 Potentially Sensitive Groundwater Receptors

10.6.1 Groundwater Dependent Ecosystems

10.6.1.1 Overview

Figure 10-3 presents rainfall data in a manner that shows the temporal scale over which below average (dry) and above average (wet) rainfall periods. 'Dry' periods are shown to typically occur over decades, whereas 'wet' periods typically occur over just a few years. Vegetation that is found in the study area has physical attributes that allows resilience and resistance to climate variability, such as being able to cope with low soil moisture levels, reduce water loss during dry periods or being able to access groundwater when the soil water reservoir is depleted.

Whilst regional groundwater systems provide water sources for pastoral and other anthropogenic uses, groundwater also supports surface (above ground) and subsurface (below ground) ecosystems that are assessed as beneficial users of groundwater. The Australian GDE toolbox (Richardson et al. 2011) provides a framework to assist with the identification of GDEs and the management of their water requirements. The toolbox adopts the approach of Eamus et al. (2006) by classifying GDEs based on the role groundwater plays in maintaining biodiversity and ecological condition.

Three types of GDEs are defined by the GDE toolbox:

- Subterranean ecosystems dependent on water held in aquifers (e.g. stygofauna) or inundated caves (Type 1 GDEs). These ecosystems typically include karst aquifer systems, sedimentary aquifers and fractured rock groundwater environments;
- Ecosystems dependent on the surface expression of groundwater (Type 2 GDEs), including wetlands, lakes, seeps, springs, and river baseflow systems. In these cases, surface expression of groundwater exists to provide water that can support aquatic biodiversity through access to habitat (especially when surface run-off is low or non-existent), as well as regulation of water quality and temperature; and
- Ecosystems dependent on subsurface presence of groundwater (Type 3 GDEs), including terrestrial and riparian vegetation that depend on groundwater either seasonally, episodically or permanently to prevent water stress and avoid adverse impacts to their condition. Groundwater that Type 3 GDEs depend on is not visible from the surface. Type 3 GDEs can exist wherever the water table and capillary fringe is within the root zone of the plants, either permanently or episodically. The capillary fringe is the semi-saturated zone of soil above the water table.

There are two sources of information pertaining to the presence of GDEs in the Project area:

- Queensland Wetland GDE Layer:
  - provides information regarding Type 2 and 3 GDEs
  - the Queensland Wetland GDE Layer presents the current knowledge of ecosystems likely to have some degree of reliance on groundwater across Queensland; and
- The National Atlas of GDEs (GDE Atlas):
  - presents the current knowledge of ecosystems that may have some degree of reliance on groundwater across Australia (noting the Atlas provides a preliminary basis for

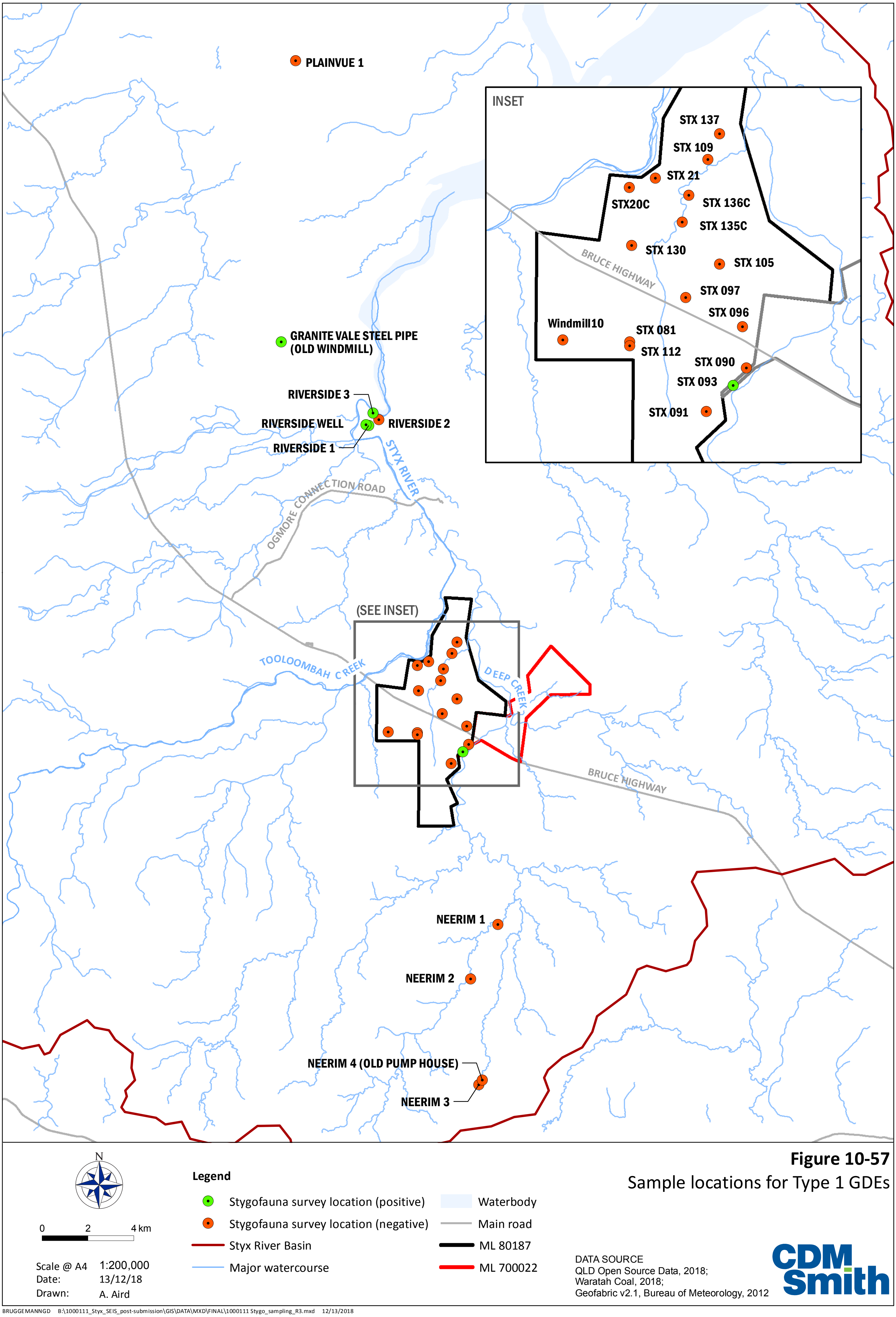
assessing locations of GDEs, it is not always definitive and use of the Atlas should be followed up by field studies)

– at the beginning of 2017, the GDE Atlas was updated with the latest information pertaining to GDEs from the Queensland Wetland GDE Layer, and therefore the GDE Atlas can be considered as the primary data source for commencing the assessment presented in this document (Sections 10.6.1.2, 10.6.1.3 and 10.6.1.4).

Information pertaining to Type 1 GDEs is sourced from field surveys undertaken for the Project. Locations sampled for Type 1 GDEs are shown on Figure 10-57, whilst Figure 10-58 presents the spatial distribution of potential Type 2 and 3 GDEs.

Several ecological field surveys, including recent studies specifically targeting GDEs, have been undertaken for the Project to ground-truth desktop information and identify any additional terrestrial and aquatic values associated with potential GDEs (refer Chapter 14 – Terrestrial Ecology and Chapter 15 – Aquatic Ecology). These include earlier studies carried out for the Project, which encompassed a much larger area (EPC 1029). Field surveys have comprised:

- Detailed summer (wet season) fauna survey of EPC 1029 (five days), 21 to 25 March 2011 by Ed Meyer (ecological consultant);
- Summer (wet season) flora survey of EPC 1029 (five days), 21 to 25 March 2011 by Oberonia Botanical Services;
- Detailed winter (dry season) aquatic ecology survey of EPC 1029 (six days), 1 to 6 June 2011 by ALS Water Sciences;
- Detailed spring (dry season) fauna survey of EPC 1029 (five days), 25 to 29 September 2011 by Ed Meyer (ecological consultant);
- Targeted threatened fauna survey of EPC 1029 (four days), 7 to 10 February 2012 by Ed Meyer (ecological consultant);
- Stygofauna pilot survey (four days) 21 to 24 November 2011, by ALS Water Sciences;
- Stygofauna follow-up survey (three days), 15 to 18 March 2012, by ALS Water Sciences;
- Summer (wet season) flora survey of ML 80187 and immediate surrounds (three days), 8 to 10 February 2017 by Terrestria (led by Dr Andrew Daniel – Terrestria); and
- Summer (wet season) aquatic ecology survey of ML 80187 and immediate surrounds (three days) 10 to 13 February 2017 by CDM Smith (led by Brett Taylor);
- Summer wetland flora survey of mapped wetlands, 17 to 18 January 2018 by CDM Smith;
- On-site inspection of potential GDEs associated with the Project area by CDM Smith (Dr Jon Fawcett);
- Analysis of samples collected in Deep Creek and Tooloombah Creek in July 2018 for radon isotopes and the stable isotopes of water to better understand the relationship between surface water and groundwater, by CDM Smith; and
- Targeted investigations in August–September 2018 (by David Stanton, 3D Environmental) of tree water use comparing: a) soil and leaf water potentials; and b) stable isotopic compositions of soil and xylem water.



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Drawn: A. Aird

Figure 10-57
Sample locations for Type 1 GDEs

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

CDM Smith

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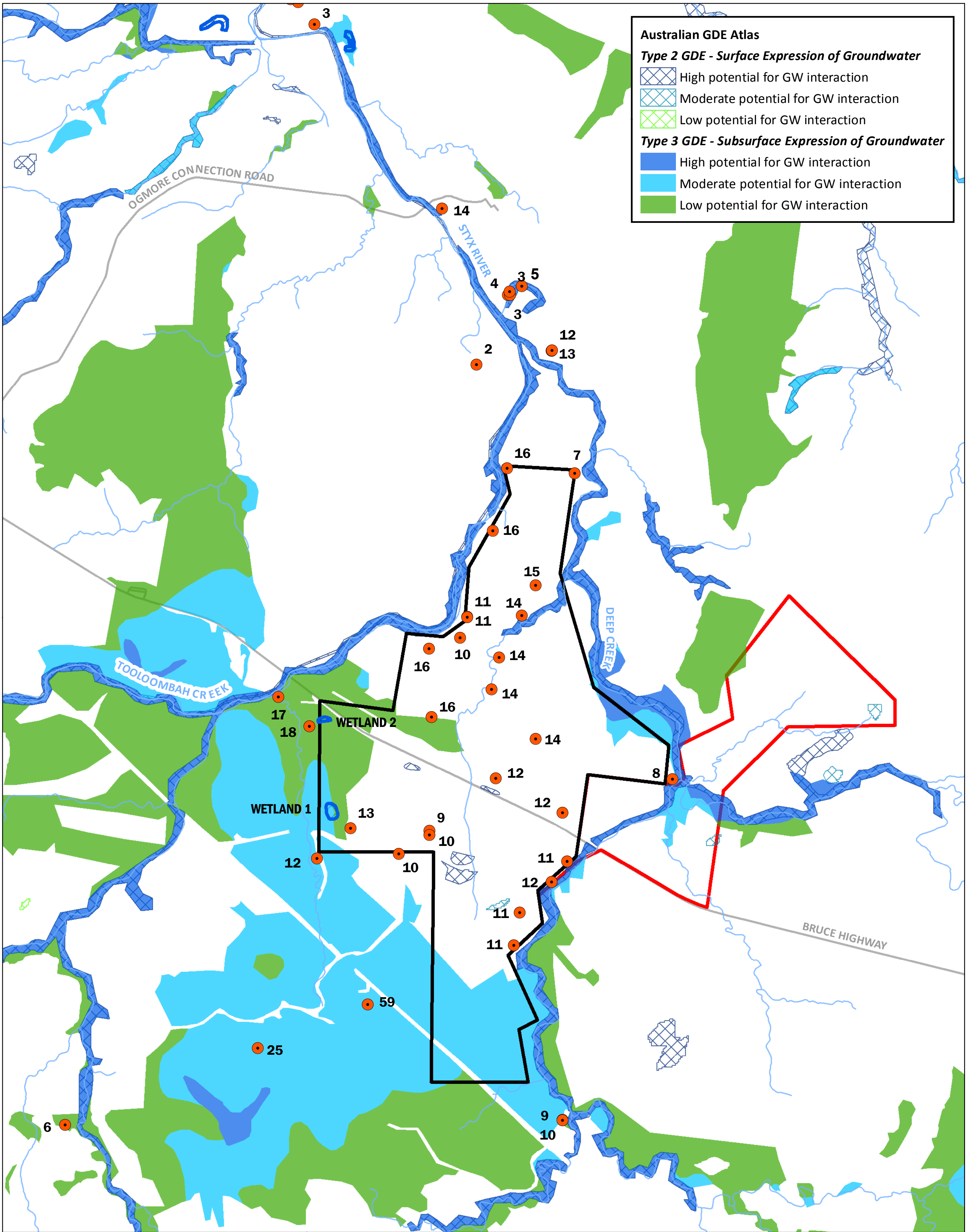

Figure 10-58

Mapped potential Type 2 and Type 3 GDEs

Legend

- Bore (DTW mbgl)
- Major watercourse
- Main road
- Wetland (VM Act)
- ML 80187
- ML 700022

0 1 2 km

Scale @ A4 1:80,000

Date: 13/12/18

Drawn: A. Aird

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018.

CDM Smith

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Surveys were designed to encapsulate seasonal variation in species detectability, and survey sites were selected at locations representing key threatened vegetation communities and dominant habitat types present within the Project area and surrounds, as well as to explore sources of water meeting ecosystem water requirements. All surveyed areas within the Project area have been visited at least once during the site studies.

The surface water and groundwater monitoring network has been expanded by the construction of 16 new bores (locations shown in Figure 10-18). As the understanding of GDEs develops, it may be necessary to expand or consolidate the network in the future.

Eco-hydrological studies have been carried out to build on the baseline understanding of GDE interactions with groundwater, including stable isotopes of water analyses, water potential measurements and groundwater heads.

10.6.1.2 GDEs Reliant on Subterranean Water (Type 1)

Information relating to Type 1 GDEs has been sourced from field surveys conducted by Yeats (2012) and ALS Water Sciences, who undertook two seasonal surveys in November 2011 and March 2012. The ALS Water Sciences surveys comprised collection of 21 (2011) and 19 (2012) borewater samples for examination of the presence of stygofauna. Overall, 30 bores within the Project area and surrounds have been assessed for stygofauna presence (see Figure 10-57), including 20 bores established specifically for the Project and 10 landholder bores.

During the field surveys, five sites (STX 093, 'Granite vale steel pipe (Old Windmill)', 'Riverside Well', 'Riverside 1' and 'Riverside 3', as shown in Figure 10-57) recorded the presence of subterranean fauna with four sites recording subsurface species that can be classified as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments. In total, six taxa classified as stygofauna were collected from the five sites - one species belonging to the Order Bathynellacea (Syncarid crustacean), three Families of Oligochaeta (segmented worms), and one species each from the Subclasses Copepoda and Acari.

The results of the two surveys show most of the identified stygofauna communities were recorded in the alluvial aquifer associated with the Styx River more than 8 km downstream of the boundary of the Project area. A single taxon (five individuals) was identified in samples collected adjacent to the Project boundary (STX093; Figure 10-57). However, it is very unlikely the taxa will be restricted to the sample points where presence has been recorded.

The shallow groundwater levels (i.e. generally less than 20 mbgl; see Figure 10-21) gauged within bores constructed in alluvial sediments within or close to the riparian zone and the presence of species of Bathynellacea (Syncarida), as well as three Families of the Subclasses Oligochaeta and Copepoda, suggest direct association / connectivity with the river system and an interconnected hyporheic zone (Hancock and Boulton 2008), and fresh to brackish water quality.

The absence of stygofauna from the remaining sampled locations does not indicate stygofauna are not present in the aquifers sampled. However, absence of stygofauna can be attributed to a number of factors, e.g. unsuitable geological conditions (low porosity, low hydraulic conductivity), poor water quality (e.g. high EC or presence of other toxicants) or sampling from a recently drilled bore that has yet to stabilise and attract stygofauna (reduced likelihood of collection).

10.6.1.3 GDEs Reliant on Surface Expression of Groundwater (Type 2)

The GDE Atlas identifies potential GDEs that are reliant on the surface expression of groundwater (Type 2 GDEs) along extensive reaches of watercourses, both within and marginal to the Project area (i.e. Styx River, Tooloombah Creek and Deep Creek) as well as several small isolated areas away from riparian zones, including:

- Two wetlands specified under the Vegetation Management Act as having High Ecological Value (Figure 10-7), namely:
  - 'Wetland 1' (UFI 3797128) identified as an artificial/highly modified wetland reliant on surface expression of groundwater (this wetland is also mapped as a Wetland Protection Area under the Queensland government 'map of referrable wetlands')
  - 'Wetland 2' (UFI 3797178) identified as a coastal/sub-coastal floodplain swamp reliant on surface expression of groundwater
- Other artificially created water reservoirs (Figure 10-7):
  - Most of these potential Type 2 GDEs are classified as having high potential for interaction with groundwater (see Figure 10-58). However, the water table at these locations is inferred to be around 10 mbgl, so it is unlikely that these features are supported by groundwater entirely.

Field investigations have identified the presence of surface pools (Plate 10-1 through Plate 10-8) along the ephemeral watercourses (Tooloombah and Deep Creeks) that have persisted throughout dry periods (refer Table 10-69 for details). The observations indicate a potential seasonal reliance of surface expression of groundwater, which is supported by available data (e.g. as presented in Section 10.5.6.7), including:

- Groundwater elevation contours and flow lines that show relatively steep horizontal hydraulic gradients and local groundwater flow along the length of Tooloombah Creek, the down-catchment reach of Deep Creek near the confluence with Tooloombah Creek, and along Styx River (Figure 10-20);
- Water table mapping, which shows depth to water table along riparian zones is typically between 10 and 15 mbgl (Figure 10-21; note that the monitoring bores used to develop the water table mapping are typically installed on ground adjacent to steeply incised creeks meaning the water table beneath the creek beds is shallower than these data suggest). The incised streambeds (to depths of up to around 10 m) likely intersect the water table in places and at different times, e.g. in response to water table fluctuations due to recharge (Figure 10-22 to Figure 10-26);
- Measured water levels at nested monitoring bores show upward vertical hydraulic gradients (Figure 10-27), which possibly supports groundwater discharge to the surface and prevents drainage of pools;
- Water chemistry data, which show similarities between surface waters and nearby groundwaters (e.g. Figure 10-38, Figure 10-39, Figure 10-40, Figure 10-43, Figure 10-53 and Figure 10-54), indicating watercourse pools are likely to be sustained at least partly by groundwater;
- Analysis of surface water samples for radon isotopes reported concentrations of ^{222}Rn in Tooloombah Creek pools that are indicative of groundwater discharge. However, reported concentrations of ^{222}Rn at Deep Creek pools indicates low connectivity during the time of sampling (July 2018, which is dry season). Figure 10-59a plots ^{222}Rn against chloride concentrations and Figure 10-59b plots ^{222}Rn against bicarbonate / chloride ratios:
  - Figure 10-59a indicates groundwater contributes only a limited amount of water to Deep Creek (very low chloride and ^{222}Rn) while Tooloombah Creek possibly receives a comparatively higher amount of groundwater inflow (higher amounts of chloride

and ^{222}Rn). The lower ^{222}Rn values encountered at Deep Creek suggest that the pools along Deep Creek have a longer residence time relative to Tooloombah Creek

- Figure 10-59b indicates that groundwater baseflow to some extent contributes to water sampled from pools in both creeks (medium values for the bicarbonate/chloride ratio, see Appendix A6 – Groundwater Technical Report for details) at the time of sampling. The isotope analysis indicates that, overall, both creeks are connected to groundwater to some extent and undergo evaporation

- Observations of thick stands of potentially groundwater dependent vegetation along riparian zones, as well as algae and aquatic vegetation in areas where pools are permanent, indicating permanence of water that is likely supported by a shallow water table; and
- Observed locations of watercourse pools are broadly consistent with the mapped Type 2 GDEs along riparian zones.

Plate 10-1 Sample point De1 watercourse pool (February 2017)

Plate 10-2 Sample point De2 watercourse pool (February 2017)

Plate 10-3 Sample point De3 watercourse pool (February 2017)

Plate 10-4 Sample point De4 watercourse pool (February 2017)

Plate 10-5 Sample point De5 watercourse pool (February 2018)

Plate 10-6 Sample point To1 watercourse pool (February 2017)

Plate 10-7 Sample point To2 watercourse pool (February 2017)

Plate 10-8 Sample point To3 watercourse pool (February 2017)

The nature of surface water – groundwater interactions supporting Type 2 (baseflow) GDEs in the area have been classified based on the two typical stream reach types that can be inferred from the available data. These stream reach types are described by the temporal nature of connection and flow dynamics, as outlined in Table 10-70 (see Figure 10-55 for reference). Both stream reach types are interpreted to have a period of losing conditions during high flows but differ according to the degree of sustained connection with groundwater during low / no flow periods.

Based on depth to water table data (see bores WMP25 and WMP27; Figure 10-18 and Figure 10-21), mapped potential Type 2 GDEs located away from riparian zones (i.e. Wetland 1 and Wetland 2; Figure 10-7) are unlikely to be supported by surface expression of groundwater. Depth to water table at these locations is more than 10 mbgl and observed seasonal variation of the water table is around 3 m (Figure 10-22 and Figure 10-23). These wetlands are unlikely to interact with groundwater, except as a recharge source.

Wetland 1 and Wetland 2 are formed in shallow depressions of less than around 1 m depth (see Figure 10-50) that become inundated after large rainfall runoff events, as evidenced during two field surveys in early-2017 (see Plate 10-9 and Plate 10-10), which likely serve to maintain the soil water reservoir at these locations.

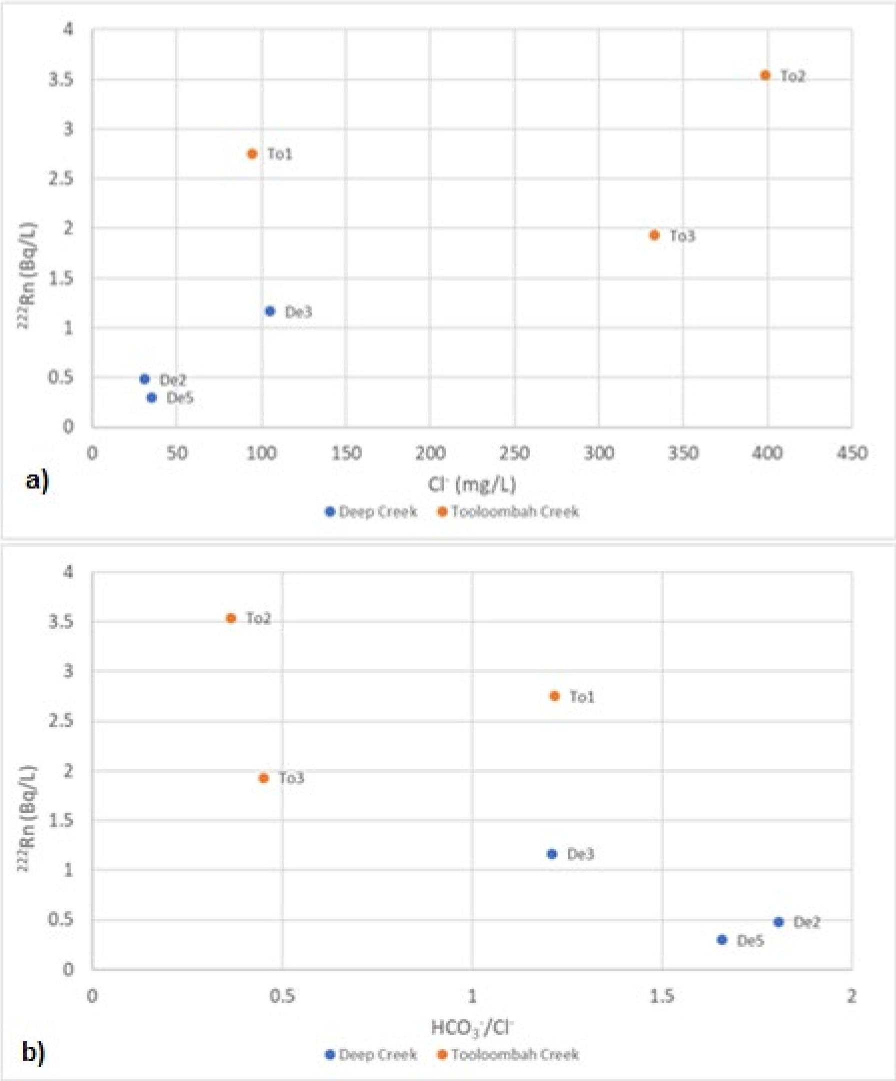

Figure 10-59 Radon vs chloride (a) and radon vs bicarbonate/chloride ratios (b)

Table 10-70 Classification of Type 2 GDEs by stream reach type (refer Figure 10-55)

Stream reach type	Temporal nature of GDE reliance on groundwater	Streamflow period	Flow dynamics
Typically losing / gaining, seasonally connected to groundwater	Stream flow critically important for meeting environmental water requirements of ecosystem	High flow	Streamflow recharges bank storage and adjacent water table aquifer (i.e. losing conditions)
		Low / no flow	Groundwater baseflow (discharge) to stream from shallow water table and / or bank storage return (i.e. gaining conditions), baseflow may or may not persist between rainfall runoff generated stream flow events
Typically gaining, permanently connected to groundwater	Groundwater baseflow likely to be critically important for meeting environmental water requirements	High flow	Streamflow recharges bank storage (i.e. losing conditions)
		Low / no flow (non-tidal)	Groundwater baseflow (discharge) to stream from shallow water table and / or bank storage return (i.e. gaining conditions), baseflow persists between rainfall runoff generated stream flow events
		Low / no-flow (tidally influenced)	Groundwater discharge can occur during ebb from and flow to high tide, when the hydraulic gradient is towards the stream (i.e. gaining conditions)

Plate 10-9 Wetland 1 prior to Cyclone Debbie (February 2017)

Plate 10-10 Wetland 1 after Cyclone Debbie (May 2017)

Figure 10-60 presents those areas mapped as potential GDEs based on available Project-specific data (i.e. they have been ground-truthed). The presence of Type 2 GDEs is confined to the riparian environments, but not to the identified wetlands (1 and 2; refer Figure 10-7). Type 2 GDEs are likely to have year-round access to groundwater in the lower catchment (i.e. Styx River and lower reach of Deep Creek, near the confluence) and along the mid- to lower-reach of Tooloombah Creek (at least from the confluence up to Bruce Highway). Elsewhere (e.g. middle and upper reaches of Deep Creek), Type 2 GDEs, if present, are likely to only be seasonally connected to groundwater. The dominant source of groundwater supporting Type 2 GDEs in the area is likely to be discharge from the shallow alluvial aquifer, whilst bank storage return after streamflow events will contribute some water back to the watercourses.

10.6.1.4 GDEs Reliant Subsurface Expression of Groundwater (Type 3)

The GDE Atlas identifies high potential GDEs that may be reliant on the subsurface expression of groundwater (Type 3 GDEs) along the drainage lines (i.e. riparian zones) associated with Styx River, Deep Creek and Tooloombah Creek, and areas of low to moderate potential Type 3 GDEs on the southwestern and southeastern margins of the Project area. (Figure 10-58).

A number of the Regional Ecosystems (REs) mapped in these areas during field surveys (refer to Chapter 14 - Terrestrial Ecology) have the potential for incorporating groundwater as a component of their water use, including:

- Forest Red Gum woodland fringing drainage lines (RE 11.3.25):
  - Occur along riparian areas of drainage lines, with vegetation dominated by Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea Tree (*Melaleuca leucadendra*)
- Forest Red Gum woodland on alluvial plains (RE 11.3.4):
  - Occur in patches across the eastern side of the Project area where it is associated with the alluvial plains adjacent Deep Creek, vegetation is dominated by Forest Red Gum (*E. tereticornis*), Poplar Gum (*E. platyphylla*) with Carbeen (*Corymbia tessellaris*)
- *Melaleuca viridiflora* on alluvial plains (RE 11.3.12):
  - This is an isolated community occurring on a natural depression on the western side of the Project area (i.e. Wetland 1). The wetland is characterised by a centralised patch of Broad-leaved Paperbark (*M. viridiflora*) with a ground layer of low sedges and forbs underneath and around the wetland margin. Hydrophytes are present where there is surface water
- Areas of Semi-evergreen Vine Thicket (RE 11.13.11) along Tooloombah Creek and the downstream portion of Deep Creek.

In riparian areas, the depth to water varies from around 10 m along floodplain terraces (Figure 10-21), to being very shallow in areas adjacent to the watercourses themselves. Vegetation communities in areas of shallow water table are likely to use groundwater during dry periods when the soil water reservoir becomes depleted (i.e. seasonally), but groundwater use is expected to be less where the water table is deeper.

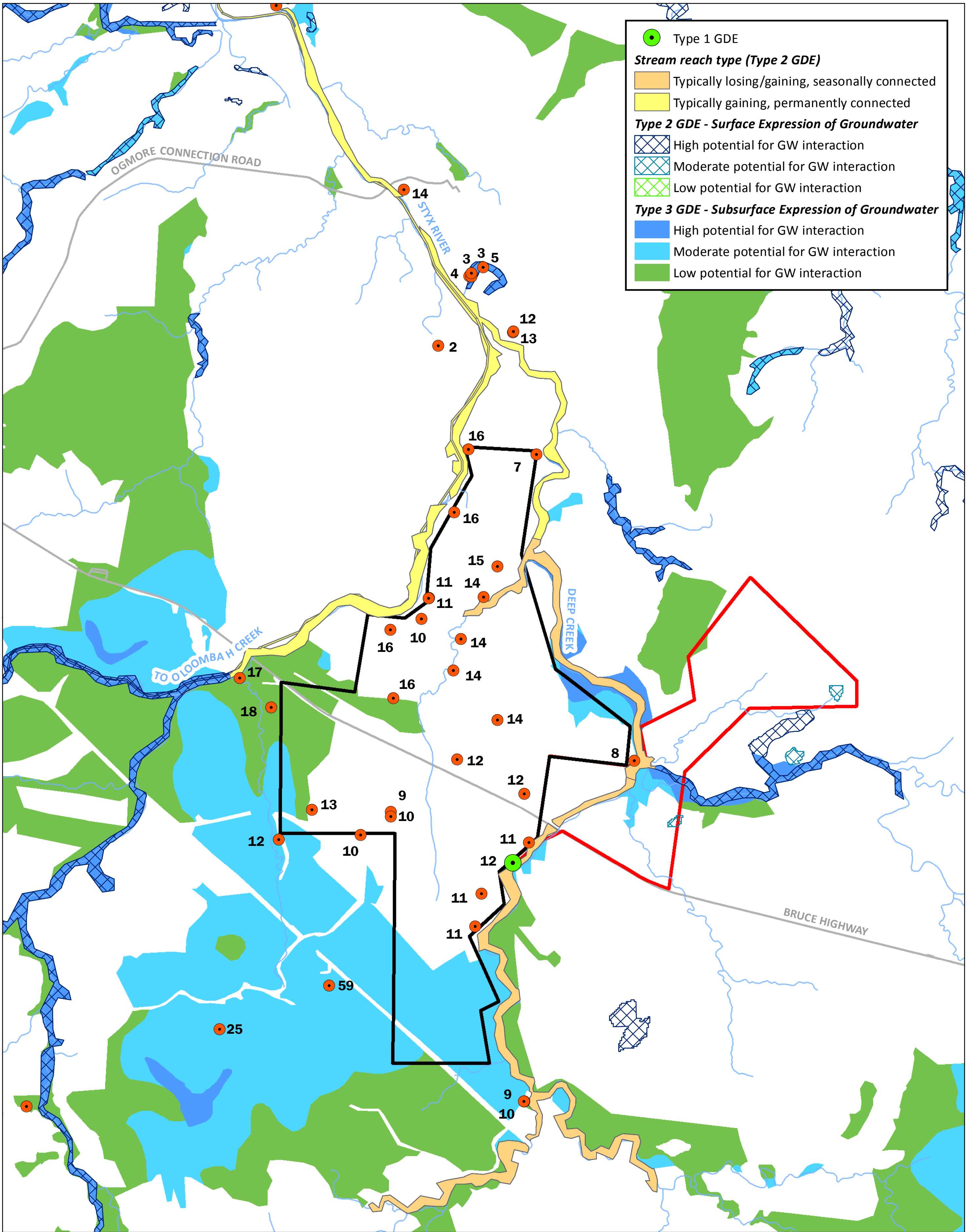

Figure 10-60
Ground-thruthed GDEs

N

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Scale @ A4 1:80,000
Date: 13/12/18
Drawn: A. Aird

Legend
- Bore (DTW mbgl)
- Major watercourse
- Main road
- ML 80187
- ML 700022

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Ground-truthed_GDEs_R4.mxd 12/13/2018

A targeted GDE investigation was carried out in September 2018 in the area of Semi-Evergreen Vine Thicket along Tooloombah Creek, and in the areas of Wetland 1 and 2 to better understand plant water use in these ecological community. The following presents a summary of the findings of the investigations, and Appendix A6 - Groundwater Technical Report presents the details:

- Semi-Evergreen Vine Thicket;
  - Soil and plant material were sampled and analysed to provide stable isotopes of water data, and at the same time measurements were made of soil water and leaf water potentials
  - Groundwater was not encountered during sampling as the water table was beyond the limit of sampling (drilling refusal), which was 10 m
  - The soil and leaf water potentials together with the isotope measurements, strongly indicate a shallow vadose zone (soil water) source of water for the plants sampled, which is well above the water table
- Wetland 1 (see Plate 10-11);
  - Soil and plant material were sampled and analysed to provide stable isotopes of water data, and at the same time measurements were made of soil water and leaf water potentials
  - The water table was 10.2 m deep at the time of sampling (bore WMP25)
  - Stable isotopes of water data indicate vegetation is sourcing almost all of its water from the near surface (well above the water table)
  - Leaf water potentials were equilibrated to a zone of moist soil immediately above the water table (between 8 and 10.2 m deep); and
- Wetland 2:
  - Soil and plant material were sampled and analysed to provide stable isotopes of water data, and at the same time measurements were made of soil water and leaf water potentials
  - The water table was 20.5 m deep at the time of sampling (bore WMP27)
  - Both stable isotopes of water data and the water potential measurements indicate no interaction with groundwater, meaning the vegetation is solely supported by the soil water reservoir.

Plate 10-11 Wetland 1 (February 2017)

Figure 10-60 presents those areas mapped as potential GDEs based on available Project-specific data (i.e. they have been ground-truthed). The following presents key outcomes arising from the GDE investigations undertaken.

There is no indication of groundwater use by the riparian Semi-Evergreen Vine Thicket vegetation (RE 11.13.11), with sampled vegetation accessing the soil water reservoir at depths well above the water table measured in this area.

During dry periods, although the results of the study are inconclusive, there is some potential for groundwater to support Poplar Box on palustrine wetland (RE 11.5.3b / UFI 379 7128; Wetland 1), Forest Red Gum woodland fringing drainage lines (RE 11.3.25), and Forest Red Gum woodland on alluvial plains (RE 11.3.4), where water tables are less than 10 mbgl.

There is no indication the coastal/sub-coastal floodplain swamp (UFI 379 7178; Wetland 2) and other terrestrial areas are reliant on groundwater, particularly where depths to water table are more than 10 mbgl.

In all instances, the results of the GDE assessment indicates that maintenance of the surface hydrological regime (stream flows and run-off to wetlands) will be critically important for maintenance of environmental water requirements for all identified GDEs.

10.6.2 Third Party Groundwater Users

10.6.2.1 Overview

Third party bores have been identified through a search of the GWDBQ as well as a bore census, undertaken by CDM Smith in 2017. Details of third party bores identified are discussed in the following sub-sections.

A search of the GWDBQ (February 2018) identified 447 bores within a 50 km radius of the Project, of which, 118 are within the Styx River Basin (Figure 10-61 and Table 10-71). Of the bores located within the portion of Styx River catchment, 94 (80%) are listed as existing and the remaining 24 (20%) are listed as abandoned and destroyed. DNRME is listed as the owner of 24 bores (20%), and the remainder have unspecified ownership but are likely to be privately owned. Table 10-71 presents statistics sourced from the GWDBQ concerning the purpose of these bores.

Table 10-71 Styx River Basin bore purposes

Registered purpose	Count	%age
Stock water supply	105	89
Mineral exploration (incl. coal)	7	6
Water resources investigation	2	2
Sub-artesian monitoring	3	3
Not specified	1	1
	118	**100**

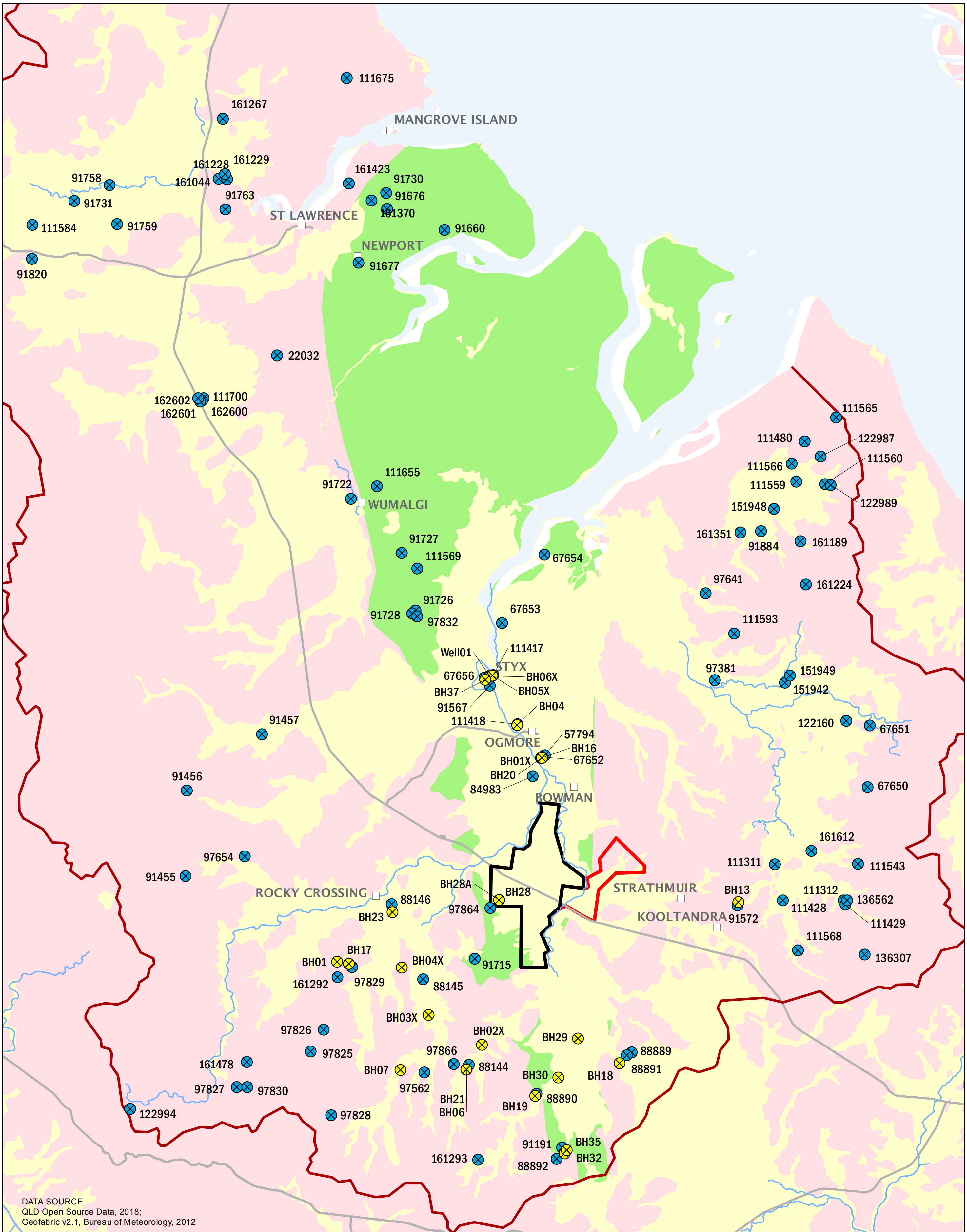
Most bores are located within or at the fringes of the mapped Cenozoic deposits (Figure 10-61), which suggests the alluvium and, possibly, geological structure that controls the occurrence and alignment of water courses have been targeted for local groundwater supplies by third-party users.

10.6.2.2 Bore Census

A census of third party groundwater bores within approximately a 10 km radius of the Project was conducted by CDM Smith in February 2017. The census plan included 27 bores, identified from the GWDBQ or previous studies. Of these locations, 20 could be visited and verified, four could not be accessed and three could not be found (expected to be abandoned/destroyed). An additional six bores were identified during the census, which are expected to be unregistered or location details in the GWDBQ inaccurate. The census found that of the bores that could be visited, only 10 are currently in use or possibly in use. Table 10-72 and Table 10-73 summarise the census results.

Depth to standing water levels were able to be measured at 17 bores and the collection of water samples was possible from eight. The following general observations are made:

- several bores identified from the GWDBQ were either found in different locations or could not be found;
- bores that were not in use are generally in poor condition;
- pumping equipment present within some bores prevented access for measurement of water levels and collection of water samples;
- bores that were operational are used for stock watering, domestic or industrial / farm use; and
- bores are constructed to between 6 and 31 m deep, and measured standing water levels are inferred to be representative of the water table elevation.



Legend

- Landholder bore (census 2017)
- Existing registered bore (GWDBQ)
- Major watercourse
- Main road
- Styx River Basin
- ML 80187
- ML 700022
- Waterbody
- HSU1: Alluvium
- HSU2: Styx Coal Measures
- HSU3/HSU4: Weathered Basement/Basement

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0 4 8 km

Scale @ A4 1:300,000
Date: 13/12/18
Drawn: A. Aird

Figure 10-61
Identified third party bores

CDM Smith

Table 10-72 Third party bores identified during the February 2017 bore census – location, ownership and bore status

Planned ID	Actual ID	Registered number (RN)	Registered original name	Other name	Comment	Registered Easting (GDA94 Z55)	Registered Northing (GDA94 Z55)	Field Easting (GDA94 Z55)	Field Northing (GDA94 Z55)	Elevation (m AHD)	Bore description	Bore infrastructure	Use status	Bore use
-	BH01X	Unknown/ not registered				N/A	N/A	773561	7494524	11	PVC casing, no cap	Nil	Not in use	
-	BH02X	Unknown/ not registered				N/A	N/A	769932	7477272	64	PVC casing, no cap	Disconnected pump in well, adjacent tank	Not in use	
-	BH03X	Unknown/ not registered				N/A	N/A	766972	7479111	59	PVC casing, sealed by pump headworks	Solar pump infrastructure installed and functional, pumps to adjacent tank	In use / possibly in use	Unknown
-	BH04X	Unknown/ not registered				N/A	N/A	765542	7482007	56	PVC casing, partially covered	Pump infrastructure installed and functional	In use / possibly in use	Domestic
-	BH06X	Unknown/ not registered				N/A	N/A	770732	7499500	8	PVC casing, with steel monument and concrete block, no cap	Historically had windmill installed but not currently equipped	Not in use	Industrial
-	Well01	Unknown/ not registered				N/A	N/A	770773	7499515	9	Concrete well, open	Nil	In use / possibly in use	Unknown
BH01	BH01	161292?	HILL PADDOCK BORE?			761934	7481483	761920	7482423	69	Cement casing, collapsed / mangled headworks	Windmill	Not in use	
BH03/ BH35	BH05X	111417?	SOPPA?	Riversi de 2	Damaged during Cyclone Debbie and now destroyed	770957	7499555	770918	7499541	9	Bailer does not fit but dipping possible	Pump infrastructure installed and functional	In use / possibly in use	Unknown

Planned ID	Actual ID	Registered number (RN)	Registered original name	Other name	Comment	Registered Easting (GDA94 Z55)	Registered Northing (GDA94 Z55)	Field Easting (GDA94 Z55)	Field Northing (GDA94 Z55)	Elevation (m AHD)	Bore description	Bore infrastructure	Use status	Bore use
BH04	BH04	111418?	SOPPA?			772271	7496576	772246	7496509	10	PVC casing, no cap, possible surface ingress (bailer does not fit)	Windmill equipped, pumps to tank	Not in use	Stock Watering
BH05	BH28	97864 or unknown/ not registered	MCCARTN EY?			770551	7485508	771053	7485988	44	PVC casing, no cap but covered by shed, obstruction at 1.716m	Pump infrastructure installed, rusted/broken	Not in use	
BH06	BH06	97866 or 88144	SHANNON or OFFICE LICENCE ONLY?			768350 or 769191	7476146 or 7476071	769036	7475802	74	PVC casing, no cap	Pump infrastructure installed and functional, pumps to tank	In use/poss ibly in use	Unknown
BH07	BH07	97562	F G SHANNON ?		Large discrepancy in registered and field coordinates	766679	7475663	765346	7475831	77	PVC casing, sealed by pump headworks	Solar pump infrastructure installed and functional, pumps to adjacent tank	In use/poss ibly in use	Unknown
BH08	BH08	91715	MCCARTN EY		Access not possible	769614	7482476							
BH13	BH13	91572	RACKERM ANN OLO	Lorna Vale		784369	7485422	784427	7485608	83	PVC casing, well cap	Disconnected pump in well	In use/poss ibly in use	Unknown
BH14	BH14	91567	SOPPA OLO		Abandoned / destroyed	770754	7498930							

Planned ID	Actual ID	Registered number (RN)	Registered original name	Other name	Comment	Registered Easting (GDA94 Z55)	Registered Northing (GDA94 Z55)	Field Easting (GDA94 Z55)	Field Northing (GDA94 Z55)	Elevation (m AHD)	Bore description	Bore infrastructure	Use status	Bore use
BH15/ BH33	BH37	67656?	SOPPA OLO?	Riversi de 1		770476	7499420	770505	7499287	12	PVC casing, steel and cement surface casing, broken stickup, no cap but semi-covered by shelter	Nil	Not in use	
BH16	BH16	67652?	OFFICE LICENCE ONLY			773589	7494573	773592	7494520	10	PVC casing, no cap	Nil	Not in use	
BH17	BH17	97829	WHITE (HOUSE BORE)			762757	7482077	762574	7482280	64	Cement surface casing, sealed	Pump infrastructure installed and functional, pumps to tank?	In use/poss ibly in use	Unknown
BH18	BH18	88891	REPLACES NO.1 BORE			778009	7476490	777605	7476010	73	Cement headworks, sealed	Pump infrastructure installed	Not in use	
BH19	BH19	88890	NEW BORE 2 OLO			772928	7474249	772863	7474143	74	PVC casing, cement surface casing, open	Pump infrastructure installed, headworks rusted/broken	Not in use	
BH20	BH20	57794?	OFFICE LICENCE ONLY			773770	7494662	773592	7494520	10	PVC casing, sealed by pump headworks	Pump infrastructure installed and functional	In use	Stock Watering
BH21	BH21	97866 or 88144	SHANNON or OFFICE LICENCE ONLY?			768350 or 769191	7476146 or 7476071	769040	7475799	74	Steel casing, open	Windmill equipped, pumps to tank	In use/poss ibly in use	Unknown

Planned ID	Actual ID	Registered number (RN)	Registered original name	Other name	Comment	Registered Easting (GDA94 Z55)	Registered Northing (GDA94 Z55)	Field Easting (GDA94 Z55)	Field Northing (GDA94 Z55)	Elevation (m AHD)	Bore description	Bore infrastructure	Use status	Bore use
BH22	BH22	88145	OFFICE LICENCE ONLY		Abandoned/ destroyed	766718	7481287							
BH23	BH23	88146	OFFICE LICENCE ONLY			765035	7485839	765068	7485360	47	Steel casing, open, totally overgrown	Windmill equipped, adjacent tank	Not in use	
BH24	BH24	84983	WELL NO 1		Access not possible	773072	7493413							
BH25	BH25	67654	OLIVE AM OLO		Access not possible	773963	7506776							
BH26	BH26	67653	OFFICE LICENCE ONLY		Access not possible	771516	7502680							
BH27	BH28A	97864 or unknown/ not registered	MCCARTN EY?	Wind mill10		770551	7485508	771056	7485987	44	Cement casing, open	Windmill equipped, rusted, adjacent tank	Not in use	
BH29	BH29	Unknown/ not registered		Neeri m 1		N/A	N/A	775322	7477562	57	PVC casing, no cap	Nil	Not in use	
BH30	BH30	Unknown/ not registered		Neeri m 2		N/A	N/A	774175	7475211	67	PVC casing, no cap	Nil	Not in use	
BH31	BH32	Unknown/ not registered		Neeri m 3		N/A	N/A	774433	7470634	106	PVC casing, cement plinth/surface casing, no cap, strong sulphurous odour	Nil	Not in use	

Planned ID	Actual ID	Registered number (RN)	Registered original name	Other name	Comment	Registered Easting (GDA94 Z55)	Registered Northing (GDA94 Z55)	Field Easting (GDA94 Z55)	Field Northing (GDA94 Z55)	Elevation (m AHD)	Bore description	Bore infrastructure	Use status	Bore use
BH32	BH35	91191	RICHARDSON	Neerim 4 (old pump house)		N/A	N/A	774560	7470829	102	PVC casing, steel and cement surface casing, no cap but covered by shed, strong sulphurous odour	Pump infrastructure installed, rusted/broken	Not in use	
BH36	BH36	Unknown/ not registered ?		Riverside 3	Abandoned/ destroyed									

Notes: Entries that are shaded grey represent locations that could not be accessed or have been destroyed

Table 10-73 Details of third party bores identified during the February 2017 bore census – HSU screened, depth to water and condition assessment

Actual ID	Casing Diameter (m)	Total depth (m bgl)	Inferred HSU	Depth to water (mbgl)	Date	Water Sampled	Condition
BH01X	0.124	10.5	Alluvium	3.80	26-Sep-17	Yes	Poor
BH02X	0.125	13.3	Alluvium	1.90	21-Feb-17	No	Poor
BH03X	0.150	N/A	Alluvium	N/A	21-Feb-17	No	Good
BH04X	0.155	N/A	Basement (Back Creek Group)	N/A	21-Feb-17	No	Good
BH06X	0.140	8.9	Alluvium	6.42	9-Nov-17	Yes	Poor
Well01	0.130	7.6	Alluvium	6.16	23-Feb-17	No	Fair
BH01	N/A	N/A	Basement (Carmila Beds)	N/A	21-Feb-17	No	Poor
BH05X	0.140	10.6	Alluvium	6.41	24-Feb-17	Yes	Fair
BH04	0.125	10.2	Alluvium	6.03	20-Feb-17	No	Poor
BH28	0.125	N/A	Basement (Boomer Form'n)	N/A	21-Jan-17	No	Poor
BH06	0.125	20.5	Basement (Back Creek Group)	8.89	21-Feb-17	No	Fair
BH07	0.160	N/A	Basement (Back Creek Group)	N/A	21-Feb-17	Yes	Good
BH13	0.140	30.8	Basement (Boomer Form'n)	12.61	23-Feb-17	Yes	Poor
BH37	0.140	6.8	Alluvium	Dry	24-Feb-17	No	
BH16	0.147	9.1	Alluvium	3.03	12-Jun-17	Yes	Poor
BH17	N/A	N/A	Basement (Carmila Beds)	N/A	21-Jan-17	No	Fair
BH18	0.140	14.1	Alluvium	5.82	23-Feb-17	No	Poor
BH19	0.140	17.3	Styx Coal Measures	5.26	23-Feb-17	No	Poor
BH20	N/A	N/A	Alluvium	N/A	20-Feb-17	No	Fair
BH21	0.135	14.4	Basement (Back Creek Group)	8.40	21-Feb-17	No	Fair
BH23	N/A	N/A	Basement (Back Creek Group)	N/A	21-Feb-17	No	Poor
BH28A	N/A	N/A	Basement (Boomer Form'n)	N/A	21-Jan-17	No	Fair
BH29	0.140	9.0	Alluvium	2.11	23-Feb-17	Yes	Poor
BH30	0.140	30.0	Styx Coal Measures	4.82	23-Feb-17	No	Poor
BH32	0.130	16.8	Basement (Boomer Form'n)	5.07	23-Feb-17	Yes	Poor
BH35	0.140	11.8	Styx Coal Measures	2.27	23-Feb-17	No	Poor

Notes: Bores that could not be accessed or have been destroyed were not assessed

Water chemistry data for those bores able to be sampled are presented in Section 10.5.6.5.

Only one landholder bore is located on the MLs (BH28A). The well is not currently in use and likely screens the basement aquifer.

10.7 Impact Assessment

10.7.1 Background

The National Water Commission (NWC) mining risk framework (Howe, 2011) has been adopted for the groundwater impacts assessment. Figure 10-62 presents the framework, which incorporates seven steps:

- Impact assessment starts with Step 1, which involves setting the context for assessing potential water-related impacts arising from a proposed mining operation (see Section 10.5 for details), and Step 2, which involves the setting of management objectives (see Section 10.3 and 10.4);
- Steps 3 to 4 cover the effects assessment, essentially following a *source-receptor-pathway* analysis that describe how water affecting activities (see Section 10.7.2) might impact on sensitive groundwater receptors (see Sections 10.6, 10.7.3 and 10.7.4). For an effect to occur to a sensitive groundwater receptor an exposure pathway must exist between a mine water affecting activity and a receptor;
- Step 5 brings together the outcomes of Steps 3 and 4 (see Section 10.7.4.8, and Table 10-80 to Table 10-83) to identify threats posed to receptors identified as being at risk from mine water affecting activities (where an exposure pathway exists between the water affecting activity and sensitive receptors). Threat assessment is central to the typical environmental approvals process (Moran et al, 2010), serving to assess the actual consequences arising from mine water affecting activities - not just in terms of direct effects (altered water resource condition) but more importantly in terms of possible receptor response (such as loss of biodiversity or reduced water access for other users and engagement with stakeholders);
- Step 6 (risk characterisation) involves making an informed decision as to the potential for adverse effects to arise to sensitive groundwater receptors as a result of mine development, and is where the task of communicating risk management strategies to stakeholders commences. The nature of water resources, in particular groundwater, does not always lend complete certainty to risk characterisation in regard to understanding the way the system works and how it will respond to mine water affecting activities; and
- Monitoring activities that are supported by data evaluation and analysis (Step 7) is a fundamental component of any impact assessment process, i.e. the assessment of risk posed to sensitive groundwater receptors is ongoing during mining and for some time after closure. If necessary, based on the monitoring and evaluation program, it may be that management objectives need to change or the effects assessment needs to be revisited during the life of the mine (see Section 10.8).

10.7.2 Direct Effects of Mining on Groundwater

10.7.2.1 Overview

The NWC framework defines the following four direct groundwater effects arising from mining:

- altered groundwater quantity;
- altered groundwater quality;
- altered surface water – groundwater interaction; and
- physical disruption of aquifers.

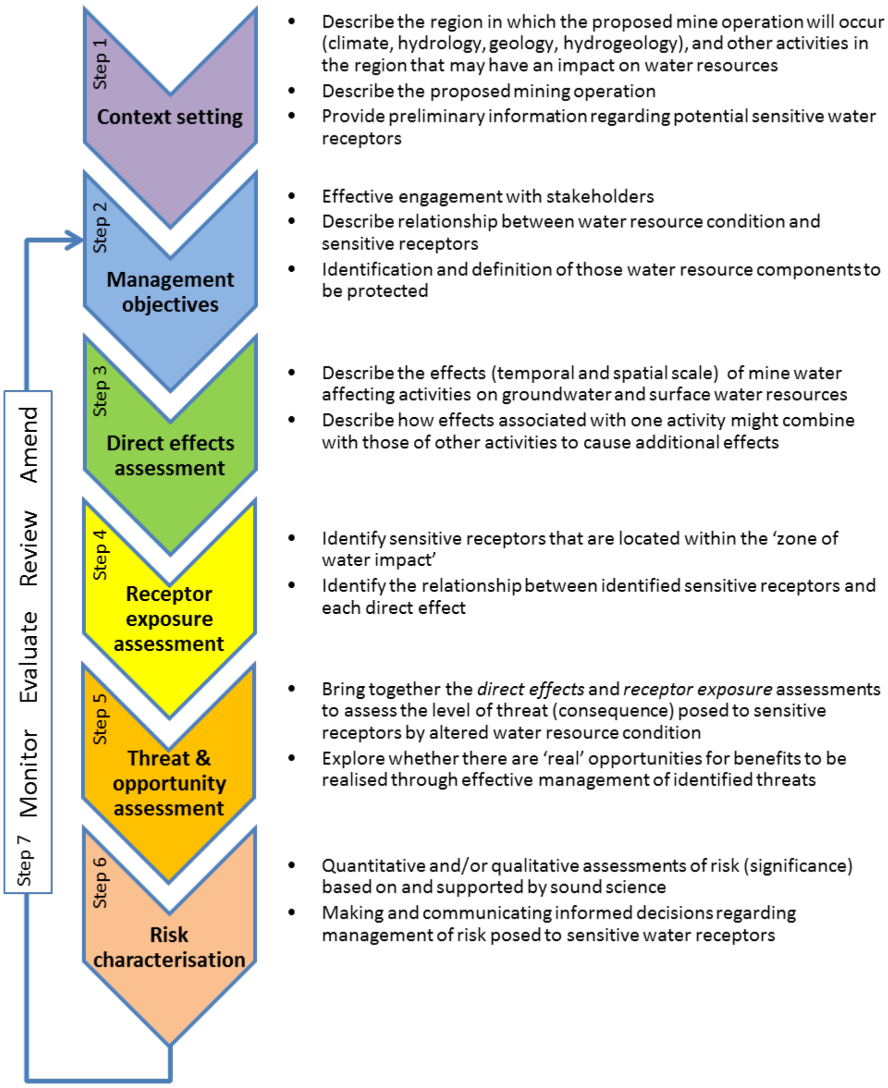


Figure 10-62 Flowchart for assessing the effects of mining on water resources
(adapted from Moran et al. 2010)

Direct effects encompass the changes to physical and/or quality aspects of groundwater as a consequence of mining activities, or the changes to the physical characteristics of aquifers affected by mining activities. Examples include changes in water levels, changes in groundwater chemistry or changes in hydraulic properties of aquifers (Moran et al., 2010).

Table 10-74 presents a brief description of water affecting activities (hazards) typically associated with a mining project and how they might arise - the entries rely on descriptions provided by deliverables for the NWC *Framework for assessing local and cumulative effects of mining on groundwater and connected systems* (Howe, 2011) and the Dept. of Energy / CSIRO / Geoscience Australia *Bioregional assessments* (Ford et al. 2016). Further description of the hazards, specifically in relation to the Project, is provided in Sections 10.7.2.2 to 10.7.2.5.

For reference against Table 10-74, Table 10-75 presents summary details of the key mine water affecting activities (hazards) associated with the Project.

Table 10-74 Possible direct effects and key mine water affecting activities (hazards) [1]

Direct effect	Water affecting activity / hazard	Direct effect	Present for Styx Project
Quantity	Mine dewatering	Depletion of groundwater storage, depressurisation of HSUs (resulting in inter-HSU water transfer, mobilisation of seawater-freshwater interface)	Yes, full recovery after mining due to backfilling
	Groundwater supply development	Depletion of groundwater storage, interconnection between aquifers	No
	Open pit post-closure	Evaporative losses from open voids, depletion of groundwater storage	No, backfilling takes place as mining advances
	Stockpiling & waste storages	Perched water tables, seepage, altered hydraulic properties	Yes, but limited due to backfilling
	Water storages	Seepage, water table drawup	Yes, low potential as close to mine pits
	Backfilling	Altered hydraulic properties (backfill materials)	Yes, likely to have similar hydraulic properties to in-situ materials
	Containment and pipeline failure	Short-term recharge enhancement	Potential, will rely on good engineering design and management practices
Quality	Mine dewatering	Mobilisation of salts from poorer water quality stores (aquifers, aquitards, surface water), ASS exposure	Yes, limited potential for ASS, all HSUs (except alluvials) typically saline
	Mine dewatering, HSU depressurisation	Mobilisation of 'seawater-freshwater' interface	Yes, interface likely occurs east of Styx River and Broad Sound confluence
	Mine waste management	Leaching of solutes and potential AMD	Yes, restricted potential for AMD
	Equipment & containment failure	Short-term source of potential contaminants	Potential, will rely on good engineering design and management practices
	Open pits during mining and post-closure	Evaporative concentration of salts within mine voids	Limited, during mining limited due to dewatering and after due to backfilling as mining advances
	Interconnection of aquifers by poor well completion	Mobilisation of salts from poorer water quality stores (aquifers, aquitards, surface water)	Yes, limited potential as bore completions undertaken in accordance with National Guidelines
Groundwater – surface water interaction	Mine dewatering	Depletion of storage, reduction of baseflow	Yes, full recovery after mining due to backfilling
	Groundwater supply development	Depletion of storage, reduction of baseflow	No
	Water storages	Recharge and water table rise, higher baseflow	Yes, low potential as close to mine pits
	Mine waste management	Hydraulic loading, water table rise, higher baseflow	Yes, but limited due to backfilling
	Disruption / diversion of surface drainages	Altered recharge mechanisms, water table rise/fall (depending)	No, no diversions proposed

Direct effect	Water affecting activity / hazard	Direct effect	Present for Styx Project
Aquifer [2] disruption	▪ Excavation / mining ▪ Backfilling ▪ Stockpiling & waste storages	▪ Removal of part or whole of aquifer ▪ Altered hydraulic properties (backfill materials) ▪ Hydraulic loading of aquifers	▪ Yes, backfilling will address this issue ▪ Yes, likely to have similar hydraulic properties ▪ Yes, but limited due to backfilling

Notes: 1. Adapted from Howe, 2011, and Ford et al, 2016
2. Only the alluvial and weathered basement HSUs are considered aquifers (for context)

Table 10-75 Summary details – mine water affecting activities

Water affecting activity	Description [1]
Mine pits and dewatering	▪ All groundwater inflow reporting to active areas of pits will be collected in sumps and pumped from the pits for use in mine water circuit or released to the environment if water in excess of mine requirements exists ▪ No voids present at mine closure and no ongoing dewatering due to evaporative losses, allowing groundwater heads to recover back toward the pre-mine condition
Pit backfill	▪ Simulated backfill hydraulic properties may or may not be consistent with compacted materials ▪ Groundwater recovery in backfilled materials occurs as mining progresses, limited by ongoing dewatering of pits as they open
Water storages	▪ Storages operated for life of mine only ▪ The storages are not planned to be lined and so will leak at a rate determined by permeability of storage bed materials and hydraulic gradient between storage and underlying aquifer
Waste Rock Stockpile	▪ Waste Rock Stockpile could be a source of water recharge to the underlying groundwater system during and following mining ▪ Recharge rates determined by permeability of waste materials ▪ Hydraulic loading of underlying aquifer could reduce transmissivity of alluvium, a post-mine issue following recovery of groundwater system

Notes: 1. For details see Appendix A6 – Groundwater Technical Report

10.7.2.2 Groundwater Quantity

Potential for inter-HSU transfers of water

Water affecting activities – mine dewatering and depressurisation

Open cut mining will extend below the water table within the proposed mine lease. As overburden sediments and coal seams below the water table are removed, groundwater will seep into the mine void from the intersected saturated strata. Collection of this water to facilitate dry and safe mining conditions, either via ex-pit dewatering bores or in-pit sumps, will depress groundwater heads immediately surrounding the pit to the approximate elevation of the pit floor and a cone of depression (groundwater drawdown / depressurisation) will extend outwards from the pit void within the surrounding HSUs, decreasing in magnitude with increasing distance from the pit void. The zone of depressurisation represents depletion of groundwater storage (unconfined and confined). The degree to which inter-HSU (aquifer and aquitard) transfers of groundwater will depend substantially on K and hydraulic gradients.

Once backfilling commences and active dewatering ceases, groundwater storage (and groundwater heads) will commence recovery back toward the pre-mine condition.

Potential for raised water tables

Water affecting activities – mine waste management, water storages

Water storages (dams) have the potential to seep water to the underlying water table aquifer. In addition, rainfall infiltration to waste landforms has the potential to give rise to perched water tables within the landforms (depending on K of the different materials) and subsequent seepage to the underlying water table aquifer. This seepage may result in raised water table surfaces beneath the facilities. However, development of drawdown local to the mine pits will reduce the potential for significant water table rise.

The waste storages also have the potential to hydraulically load the water table aquifer (predominantly the alluvials, HSU1), which may reduce the K and Sy of this aquifer. In the event this occurs, the water table may ‘bank up’ upstream of the facilities and water table aquifer groundwater flowpaths may diverge from the baseline.

Backfilling of the mine fits has the potential for differing hydraulic properties between the backfill and in-situ (pre-mine) materials. This has the potential to contribute to water table rise, but the offset of possible higher K by higher Sy will likely mitigate this.

Potential for mobilisation of the seawater – fresh water interface

Water affecting activities – mine dewatering and depressurisation

Groundwater flowlines within the deeper Styx Basin sediments and basement rocks are also expected beneath the shallower groundwater system, with discharge occurring near to the coast or via ET from low lying coastal areas. Vertical hydraulic gradients near to Broad Sound (Figure 10-27) show the deep coal seams and interburden as well as the underburden have a higher head than the shallow Styx River alluvials, indicating the potential for upward leakage and deeper throughflow toward the coast. The head in the deeper units of the Coal Measures HSU would need to decline by around 1.5 m in response to mine dewatering to induce downward seepage of more saline shallower alluvial groundwaters to the Coal Measures.

Potential for accidental release / containment failure

Water affecting activities –water storages / pipelines

Water storages (dams) and water transfer pipelines have the potential to fail and provide temporary potential for local recharge enhancement. However, development of drawdown local to the mine pits will reduce the potential for significant water table rise in response to accidental release and containment failure.

Appropriate engineering design and management practices (including audits, stock takes and training) will be important in removing or mitigating these risks.

10.7.2.3 Groundwater Quality

Potential for groundwater quality degradation

Water affecting activities – mine dewatering and depressurisation, evaporative losses from open mine pits, installation of monitoring wells

Mine dewatering will result in altered vertical and lateral hydraulic gradients within and between HSUs, which may have the effect of inducing flow of water of different quality (groundwater and surface water) towards depressurised parts of the groundwater system.

Dewatering of the alluvial aquifer (HSU1) and the Coal Measures' (HSU2) overburden and coal seams / interburden is required for mining to proceed. As such, evaporative loss of water from the pits will have limited potential to result in the evaporative concentration of salts in groundwater. Backfilling of the pits as mining progresses will also give rise to limited potential for salinisation of groundwater due to evaporative concentration of salts.

The installation of monitoring bores requires the isolation of screened intervals from other parts of the groundwater system using the placement of cement grout within the well annulus immediately above the screened lithology. Construction of monitoring bores in accordance with best industry practice (NUDLC, 2012) will mitigate the potential for inter-aquifer/aquitard transfer of waters of different quality due to poor bore construction methodologies.

Potential for ASS

Water affecting activities – mine dewatering

The Styx River catchment, including Tooloombah and Deep Creeks, is classified as largely having low to extremely low probability of ASS generation potential (see Section 10.5.6.5), with only a small pocket of high probability of ASS occurrence around 7 km downstream of the Project, near Broad Sound.

Potential for inland mobilisation of the seawater-freshwater interface

Water affecting activities – mine dewatering and depressurisation of HSUs

Hydraulic head and groundwater salinity data for the WMP29 nested monitoring site (Figure 10-27 and Table 10-15) indicate the 'seawater-freshwater' interface is not located near the confluence of Styx River and the Broad Sound estuary, and must be located further toward the coast (i.e. further from the proposed mine). The potential for mobilisation of the 'seawater-freshwater' interface at the coast, or along tidal reaches of Styx River and Broad Sound estuary, will depend on extent of depressurisation (vertical and lateral) of groundwater system in response to mine dewatering.

Potential for acidic metalliferous drainage (AMD)

Water affecting activities – mine waste management

As discussed in Section 10.5.5.3, waste rock characterisation has been undertaken by RGS Environmental and is detailed in Chapter 8 – Waste Rock and Rejects.

Waste rock and fine rejects have been classified as:

- Acid consuming:
  - Will likely remain pH neutral to alkaline following excavation (composite waste rock and potential coal reject samples are alkaline, with pH ranging from 8.6 to 10)
  - Dissolution of heavy metals in an acidic environment is unlikely
- Having low potential to be potentially acid forming;
- Having moderate saline drainage potential (salinity of the samples ranged from 440 to 660 µS/cm, falling within baseline range; see Section 10.5.6.5); and
- Potential to be highly sodic.

Based on works to date, the waste rock and coarse/ fine rejects generated during the extraction and processing of the resource have limited potential to impact upon the EVs.

Without appropriate management, there is the potential for leachate from extracted waste rock and fine rejects to enter local waterways and degrade water quality. Although the waste rock is expected to have a low capacity to generate acidity, it does have moderate saline drainage potential (although salinity concentrations are expected at the low end of the baseline range) and the kinetic leach column results indicate that leachate may contain elevated concentrations of dissolved As, Mo, Se and V when compared to WQO and aquatic ecosystem criteria. The leachate derived from the kinetic leach study generally shows an initial flush of soluble metals / metalloids and salts which decreased after the first two to three flushes. This initial flush is likely related to the particle size; the fine materials with smaller particle size have a larger surface area for chemical reactions to occur and thus tend to yield higher leached metals / metalloids and sals concentrations. The kinetic leach study, although a short-term study, indicates a reduction in leached concentrations of most species with time. The study indicates the release of As, Mo, Se and V are not controlled by pyrite oxidation, which is indicated by the steady decline in leached concentrations.

Leach testing demonstrates there is low potential for generation of acid from waste materials (including coal rejects), and that leachate generated from waste materials is expected to be less saline than baseline surface water and groundwater. However, there is the potential for some metals / metalloids (such as As, Mo, Se and V) to be elevated above aquatic ecosystem criteria (e.g. ANZECC 2000), although many metals / metalloids do naturally occur above these criteria (see Section 10.5.6.5).

Accidental release / equipment failure / containment failure

Water affecting activities – mine waste management

As with any industrial activity, the risk of accidental release of chemicals or mine impacted waters and materials (such as unintended fuel spill, leakage of sewage effluent, infiltration of stormwater from mine 'contact' areas, failure of water storage dams) will be present on the ML 80187 and ML

700022. Appropriate engineering design and management practices (including audits, stock takes and training) will be important in removing or mitigating these risks.

10.7.2.4 Surface Water and Groundwater Interaction

Potential for reduced water tables

Water affecting activities – mine dewatering and depressurisation

The Project area is characterised by local to intermediate groundwater flow systems (see Section 10.5.6.8 for prior discussion). Groundwater flow lines presented in Figure 10-20 show that groundwater likely discharges locally (as baseflow) to the mid-lower reaches of the major tributaries of Styx River (Tooloombah and Deep Creeks), as well as Styx River itself and the Broad Sound estuary.

Mine dewatering and depressurisation will give rise to local depletion of groundwater storage, resulting in lower water tables especially near to the proposed mine. As a consequence it is expected in some areas close to watercourses water table decline will result in reduced baseflow to the watercourses during mining and for some time after mining is completed.

Groundwater often discharges as baseflow to surface water features (streams and wetlands), and via evapotranspiration when the water table surface lies close to the ground surface, often in low parts of the landscape such as wetlands and along riparian zones. Discharge to surface water features and connected systems forms the basis of the assessment of impacts associated with groundwater and surface water interactions. Impacts associated with receptors reliant on shallow water tables are addressed as part of groundwater quantity (see Section 10.7.2.2).

The capture of groundwater during mining (to meet Project water demands, where this is necessary, and provide dry and safe mining conditions) can alter the degree and form of interaction between groundwater and surface water, and connected systems. For example:

- if baseflow fed water courses are located within the zone of drawdown influence of mine pits or borefields, it is probable the rate and timing of baseflow will diminish or cease until post-mine recovery occurs;
- if wetlands relying on shallow water tables or surface expression of groundwater are located within the zone of drawdown influence of mine pits or borefields, the wetlands may become disconnected from groundwater until post-mine recovery occurs;
- water storages and sediment ponds may leak and cause water table mounding beneath the facilities, which may raise water tables near wetlands and terrestrial vegetation to cause water logging, or increase rates of baseflow to nearby water courses; and
- placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers or mounding of the water table beneath the facilities, which can give rise to displacement of water away from Waste Rock Stockpiles, potentially increasing baseflow discharge to watercourses and wetlands.

Potential for seepage between above ground infrastructure and groundwater

Water affecting activities – mine waste management, water storages

Water storages (dams) have the potential to seep water to the underlying water table aquifer. In addition, rainfall infiltration to waste landforms has the potential to give rise to perched water tables within the landforms (depending on K of the different materials) and subsequent seepage to the underlying water table aquifer. This seepage may result in raised water table surfaces beneath the facilities. However, development of drawdown local to the mine pits will reduce the potential for significant water table rise.

These effects do not impact on existing surface water features. In terms of long-term effects, the waste management facilities (e.g. waste landforms) can provide an ongoing source of enhanced recharge but at a very local scale, and depending on landform closure works.

Potential for altered recharge regimes

Water affecting activities – Disruption and diversion of surface drainages

The only disruptions planned for sub-catchments occur within the mine pit footprint, via excavation of the pits and construction of water storage dams. There are no other plans to alter other sub-catchments. As a result, any effect on spatial recharge regimes will only be very local.

10.7.2.5 Physical disruption of Aquifers

Potential for long-term disruption of groundwater system

Water affecting activities – mining (excavation), backfilling

Open cut mining involves removal and translocation of coal, overburden and interburden strata to create mine-pit voids. Disruption of the groundwater system by mining will only be temporary for this Project as all voids will be progressively backfilled and rehabilitated. The hydraulic properties of the backfilled materials may not be consistent with those occurring prior to mine depending on the degree of compaction, but this change is unlikely to be significant as the effect is restricted to the mine voids themselves.

Potential for long-term disruption of groundwater system

Water affecting activities – hydraulic loading

Placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers, in particular, which can give rise to compaction and reduction in transmissivity and storage capacity of these aquifers (where they occur) possibly resulting in displacement of groundwater away from Waste Rock Stockpiles and potentially increasing baseflow discharge to watercourses and wetlands. This effect, if it occurs, will only become apparent once the groundwater system recovers post-mining.

10.7.3 Indirect Effects of Mining on Groundwater

Indirect effects of mine-water affecting activities are those that arise in response to direct effects (Moran et al., 2010) and typically relate to the potential for impact on sensitive receptors. The assessment of potential receptor exposure to adverse changes in the groundwater regime (quantity, quality, groundwater and surface water interactions and physical disruption of aquifers) requires the following:

- knowledge of the position of sensitive receptors within the landscape, particularly in relation to the location and area of influence of mine water affecting activities;
- an understanding of response pathways (connections) between groundwater and potential receptors, in other words the form of receptor reliance on groundwater (e.g. depth to water table, groundwater flux to baseflow fed streams, groundwater quality to meet beneficial purposes);

- an understanding of the capacity for receptors to adapt to altered groundwater regimes (resilience and resistance); and
- an understanding of the spatial and temporal scale of direct groundwater effects at the location of sensitive receptors.

EVs that have been identified for the Project area provide a basis for assessing receptors that may be sensitive to altered groundwater resource condition (i.e. direct effects). Table 10-76 presents a summary of direct effects against relevant EVs, existence of an exposure pathway, and possible scale of effect. Table 10-77 presents a list of specifically identified potentially sensitive groundwater receptors for each of the EVs identified by EHP (2014).

Table 10-76 Linkage between direct effects and EVs

Direct effect	EVs that can be impacted	Potential effect
Quantity	▪ Aquatic ecosystems	▪ Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream (potentially extending as far as estuary)
	▪ Irrigation ▪ Farm supply ▪ Stock supply	▪ Potential reduction in pumping rates due to deeper pumping water levels as a result of drawdown ▪ Potential failure of bores if drawdowns exceed aquifer thickness or screen sections
	▪ Cultural / spiritual	▪ Largely associated with 'aquatic ecosystems EV'
Quality	▪ Aquatic ecosystems ▪ Irrigation ▪ Farm supply ▪ Stock supply ▪ Cultural / spiritual	▪ Limited in association with evaporative salinisation as mine voids will be open for short periods (around three years) prior to backfilling ▪ Limited in association with AMD due to coal measures being typically NAF ▪ Potential impact to estuarine ecosystems if ASS is allowed to become exposed due to altered groundwater flow conditions and drawdown
Groundwater – surface water interaction	▪ Aquatic ecosystems	▪ Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream ▪ Possible significant effect to estuarine and marine (aquatic) ecosystems if surface water discharges from Styx River catchment due to substantial baseflow reduction (combined with reduced stormwater discharge) is sustained in the mid- to long-term
	▪ Irrigation	▪ None
	▪ Farm supply	▪ None
	▪ Stock supply	▪ None
	▪ Cultural / spiritual	▪ Largely associated with 'aquatic ecosystems EV'
Aquifer disruption	▪ Aquatic ecosystems	▪ Limited to the mine pits
	▪ Irrigation ▪ Farm supply ▪ Stock supply	▪ Limited as there are no bores within the mine pit area
	▪ Cultural / spiritual	▪ Limited

Table 10-77 EVs and specific receptors

EVs that can be impacted	Specific potentially sensitive groundwater receptors
Aquatic ecosystems	▪ Baseflow-fed stream reaches of Tooloombah and Deep Creeks, incl. permanent and semi-permanent pools ▪ Baseflow-fed stream reaches of Styx River and Broad Sound estuary ▪ Coastal marine ecosystems
Irrigation	▪ None identified
Farm supply	▪ None identified
Stock supply	▪ Possibly 105 bores within Styx River Basin
Cultural / spiritual	▪ None identified
Other [1]	▪ Tooloombah and Deep Creek riparian vegetation ▪ Terrestrial vegetation outside riparian zones ▪ Stygofauna

Notes: 1. Not defined in EHP, 2014

10.7.4 Assessment of Effects

10.7.4.1 Overview

Numerical model for effects assessment

Mine water affecting activities give rise to direct groundwater effects (see Section 10.7.1), which in turn have the potential to give rise to indirect groundwater (receptor) effects (see Section 10.7.3). Groundwater modelling is the only practical way to simulate and predict groundwater system response to mine water affecting activities associated with the Project. In this assessment, the primary objectives of groundwater modelling are to predict potential rates of mine dewatering, to facilitate planning for operational mine water management, and to predict associated effects on groundwater quantity (drawdown and flux) at the Project and surrounding areas during and after mining.

The industry standard model code MODFLOW USG (Panday et al, 2013) has been used to simulate the groundwater system and groundwater affecting activities associated with the Project. Pre- and post-processing of model files has been undertaken using Groundwater Vistas (ESI 2011). Details of the numerical groundwater modelling are provided as Appendix A6 – Groundwater Technical Report, including guidelines, calibration, prediction, sensitivity and uncertainty analysis, model confidence and model limitations.

The hydrogeological conceptualisation presented in Section 10.5.6.8 is represented by the numerical model.

The water affecting activities simulated by the groundwater model include pit excavation / dewatering and pit backfill (Figure 10-63 presents a mine layout plan for the Project). The groundwater model has also been used to simulate possible management strategies to offset unacceptable effects of water affecting activities, and this is discussed further in Section 10.7.5. Table 10-75 presents summary details of the water affecting activities that have the potential to give rise to the direct effects presented in Table 10-74.

The numerical groundwater flow modelling does not directly address the issue of potential groundwater quality change in response to mining. However, model predictions of groundwater quantity change (drawdown / depressurisation) provide a basis from which to assess the potential for changes to water quality associated with the primary water affecting activities (see Table 10-74) to impact on catchment scale groundwater and surface water resources, including the potential for inland mobilisation of the 'seawater-freshwater' interface.

Calibrated hydraulic properties

The calibrated hydraulic parameters for each of the simulated HSUs are summarised in Table 10-78, along with the geometric mean value of field measured Ks. Appendix A6 – Groundwater Technical Report presents details of the model calibration process.

Table 10-78 Field measured and adopted (calibrated) hydraulic properties for the Styx groundwater model

HSU	K (m/d)		Sy	S	Recharge (mm/yr)		
	Measured [1]	Modelled	Modelled		Alluvium	Flood zone	Basement
Alluvium	6.3×10^{-1}	4.1×10^{0}	1×10^{-2}	5×10^{-6}			
Styx Coal Measures			5×10^{-3}	5×10^{-6}	4.5	15	3
Overburden	2.0×10^{-2}	2.0×10^{-2}					
Coal seams/interburden	2.3×10^{-3}	3.0×10^{-3}					
Underburden	5.4×10^{-3}	4.0×10^{-3}					
Weathered Basement	4.2×10^{-2}	1.0×10^{0}	5×10^{-3}	5×10^{-6}			
Basement	n/a	4.0×10^{-4}					

Notes: 1. Geometric mean or average, depending on number of available data points (see Table 10-11). Basement not tested.

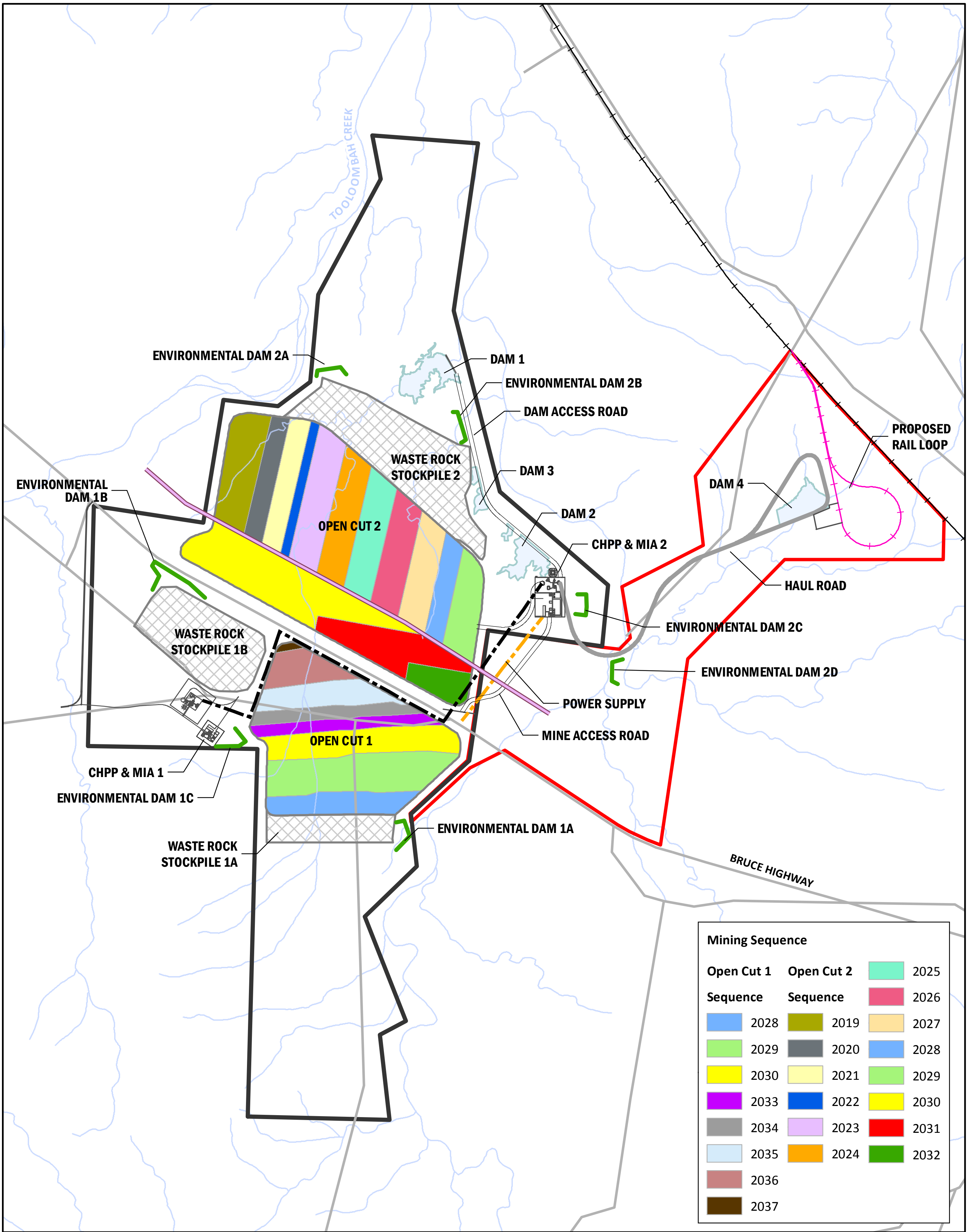
The model mass balance is smaller than 0.002%, which demonstrates the model is numerically stable and accurate.

10.7.4.2 Groundwater Heads

The following presents a summary of predictive results of the calibrated groundwater model. The model incorporates the proposed mining schedule and mine plan (ref. Mine Schedule – 20180406.shp) that has been provided by Central Queensland Coal (Figure 10-63). Model predicted pre-mine, during mining and post-mine groundwater level and drawdown data are presented on Figure 10-64 to Figure 10-81.

The following provides discussion around the changes predicted for the water table surface and shallow groundwater flow directions (Figure 10-64 to Figure 10-70) in response to mining activities:

- The predicted pre-mine water table elevation contours are a reasonable representation of the inferred water table elevation contours presented in Figure 10-20;
- Between mining year 5 and end of mining pit dewatering is predicted to capture groundwater from within the proposed lease area and to some extent from the mid- to lower catchment areas of Tooloombah and Deep Creeks. Away from the proposed mine lease area, water table elevation contours are predicted to remain consistent the pre-mine condition;
- During the early recovery phase, the year 10 post-mining water table elevation contours are predicted to remain much the same as the end of mining contours, but by year 25 post-mining the effects of recovery can begin to be seen. During the post-mining recovery phase, water table elevation contours outside the proposed mine lease area are predicted to remain relatively consistent with the pre-mine condition; and
- At all times during the simulated mining and recovery phases the water table contours downstream of the Tooloombah and Deep Creek confluence remain very consistent with the pre-mine condition, indicating the water affecting activities of the proposed mine will not impact on groundwater quantity or groundwater-surface water interactions below the confluence (groundwater quality downstream of the confluence is predicted to remain consistent with pre-mine conditions, by default).



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Legend

- Haul Road
- Mine infrastructure
- Overland Conveyor
- Power
- 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
- Watercourse
- Dam
- 500 m Bruce Highway buffer zone

Figure 10-63
Mine layout and schedule

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

CDM Smith

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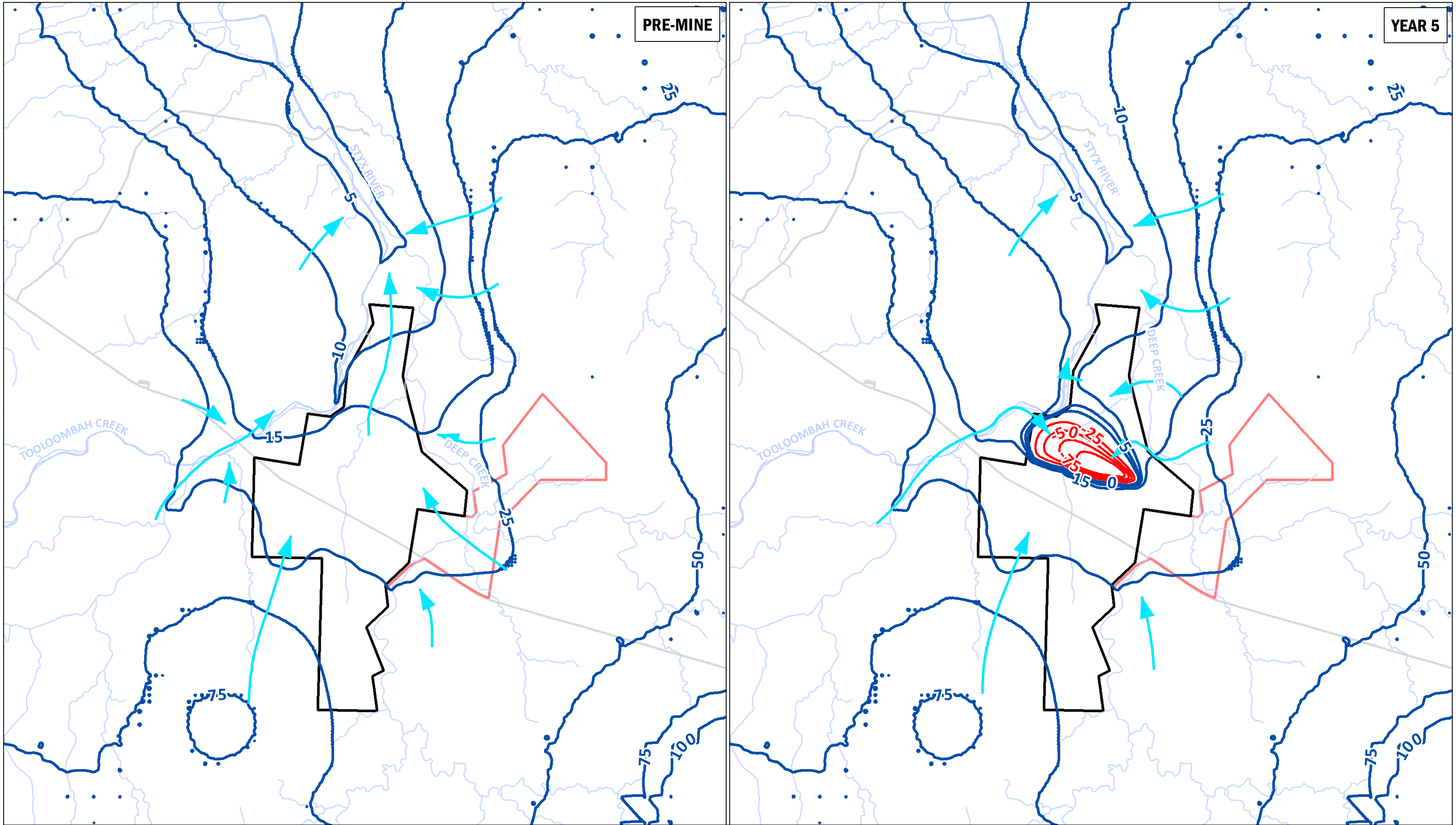

Figure 10-64

Predicted water table elevation contours – pre-mine and year 5

Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

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Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

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

CDM Smith

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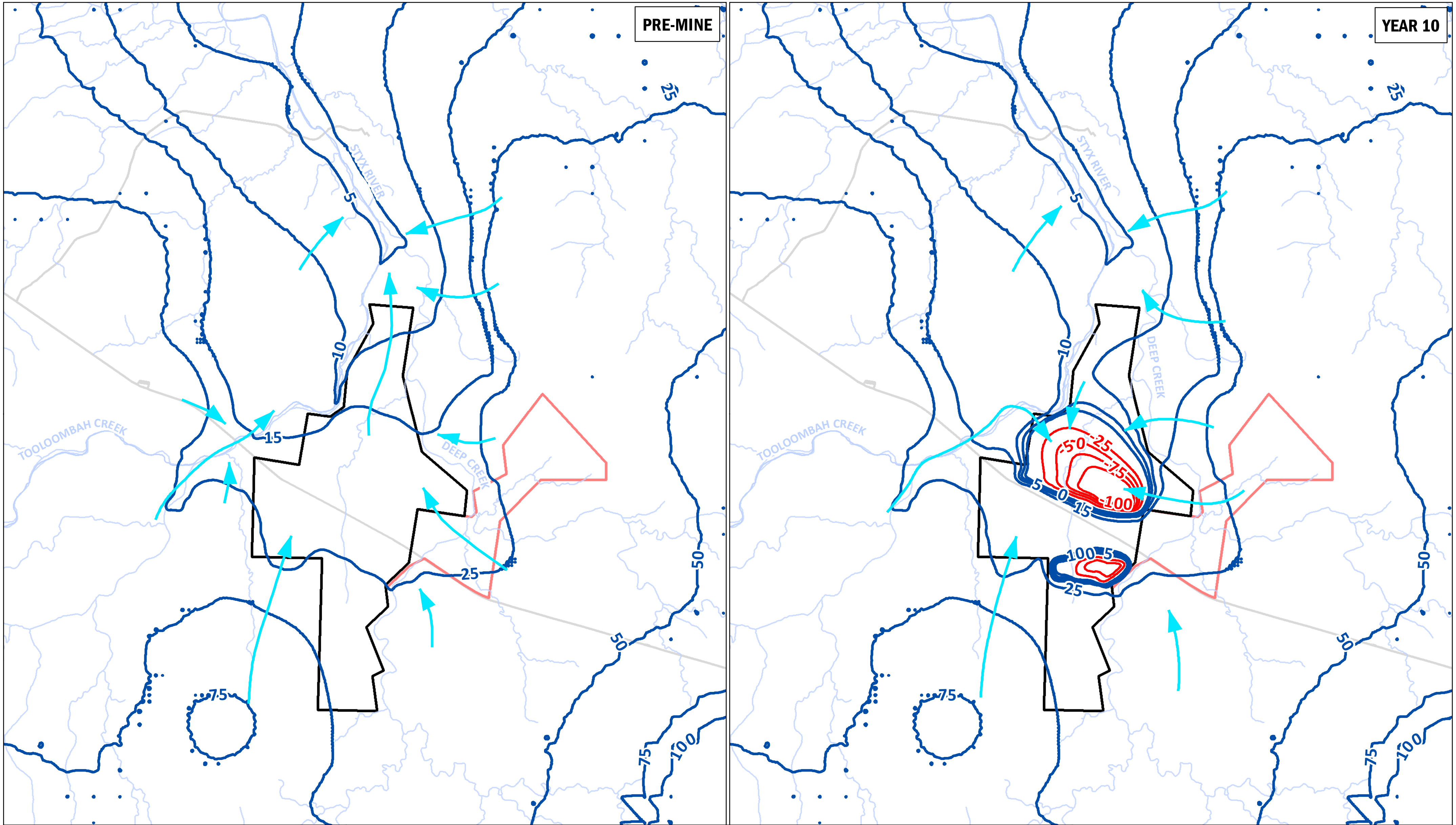

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Date: 20/12/18
Drawn: Gayle B.

Legend

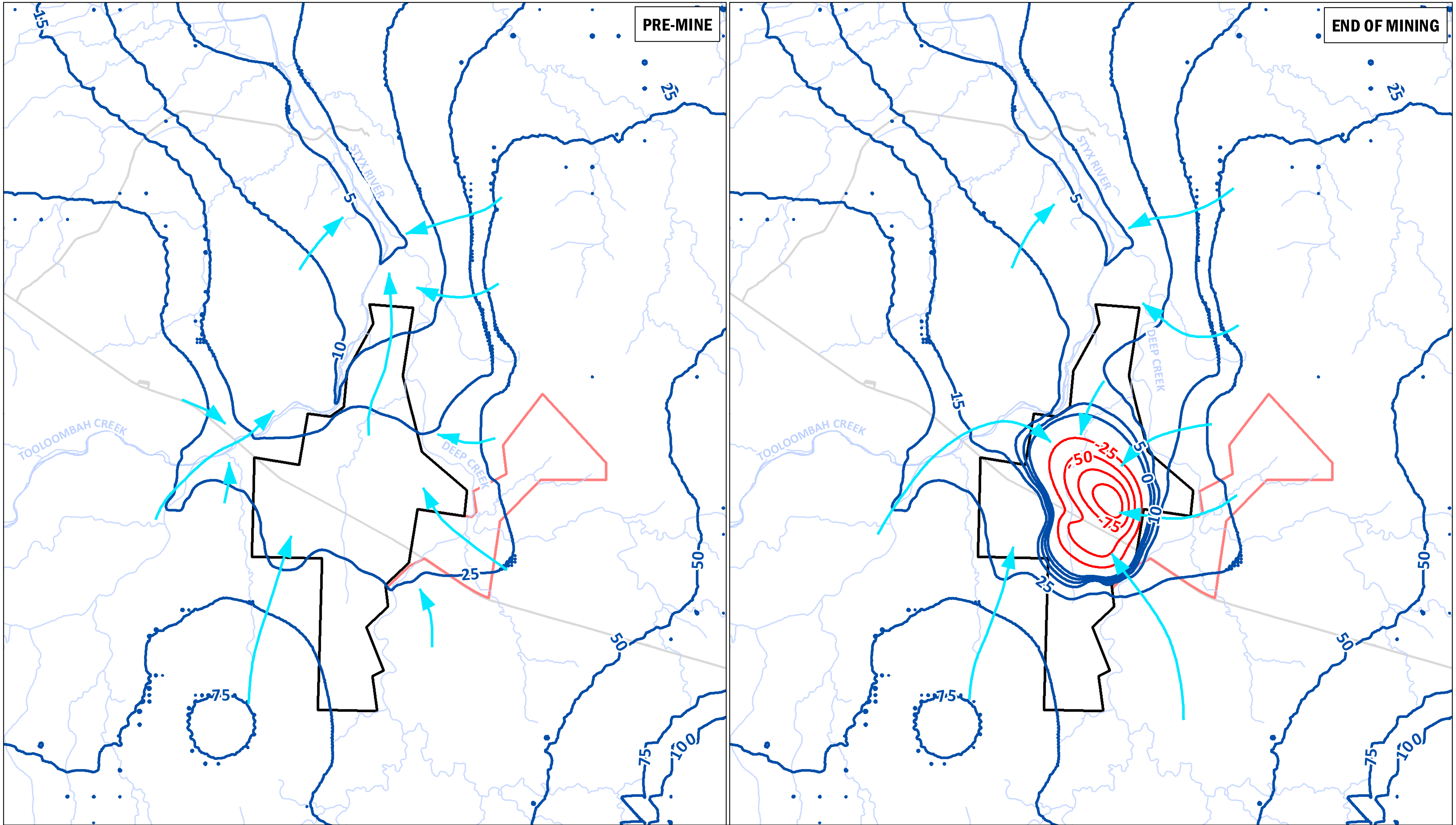
- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-65

Predicted water table elevation contours – pre-mine and year 10

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

CDM Smith



Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

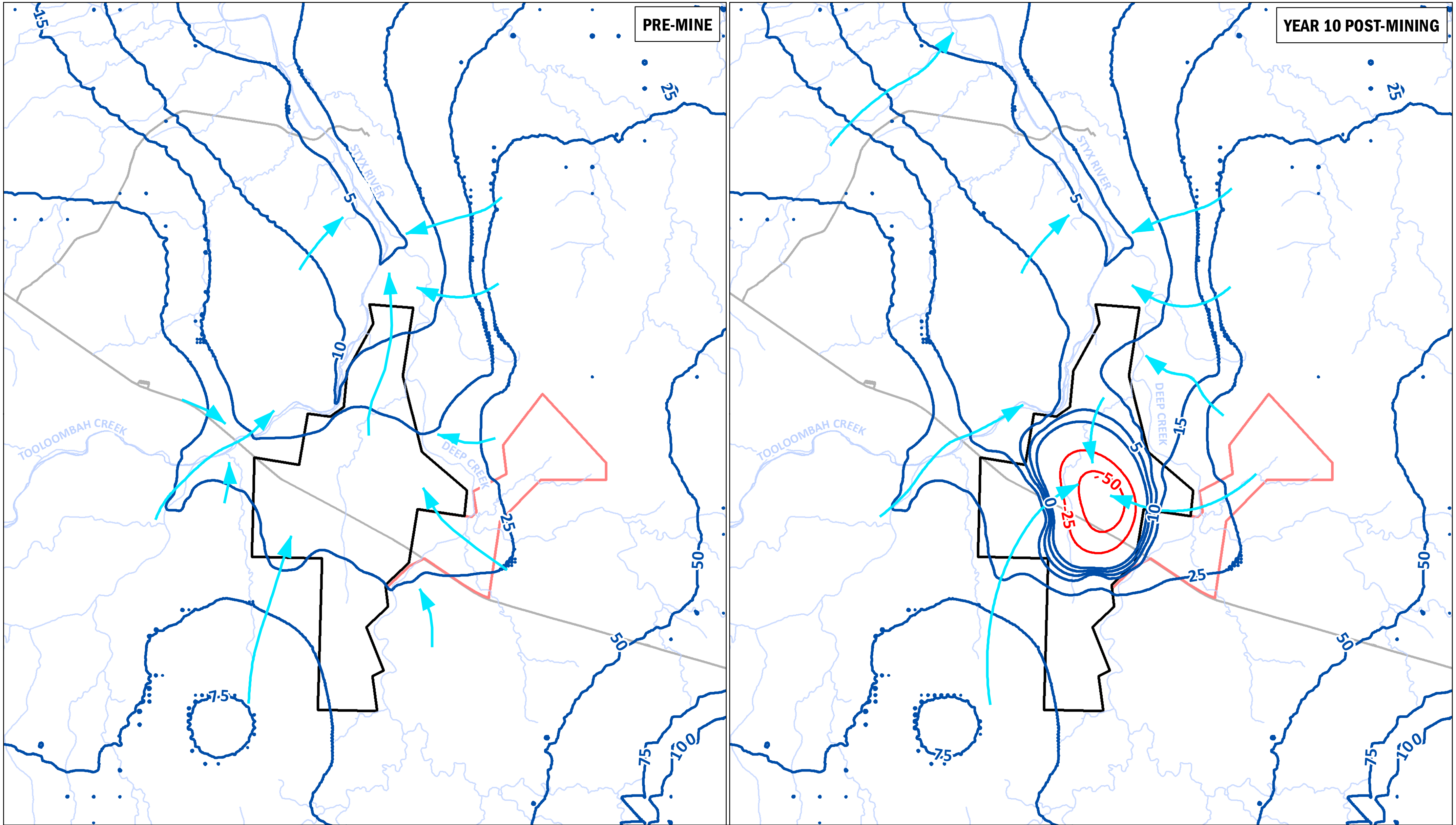
Figure 10-66

Predicted water table elevation contours – pre-mine and at end of mining

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__LOM yr 18.mxd 12/20/2018



N

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Legend

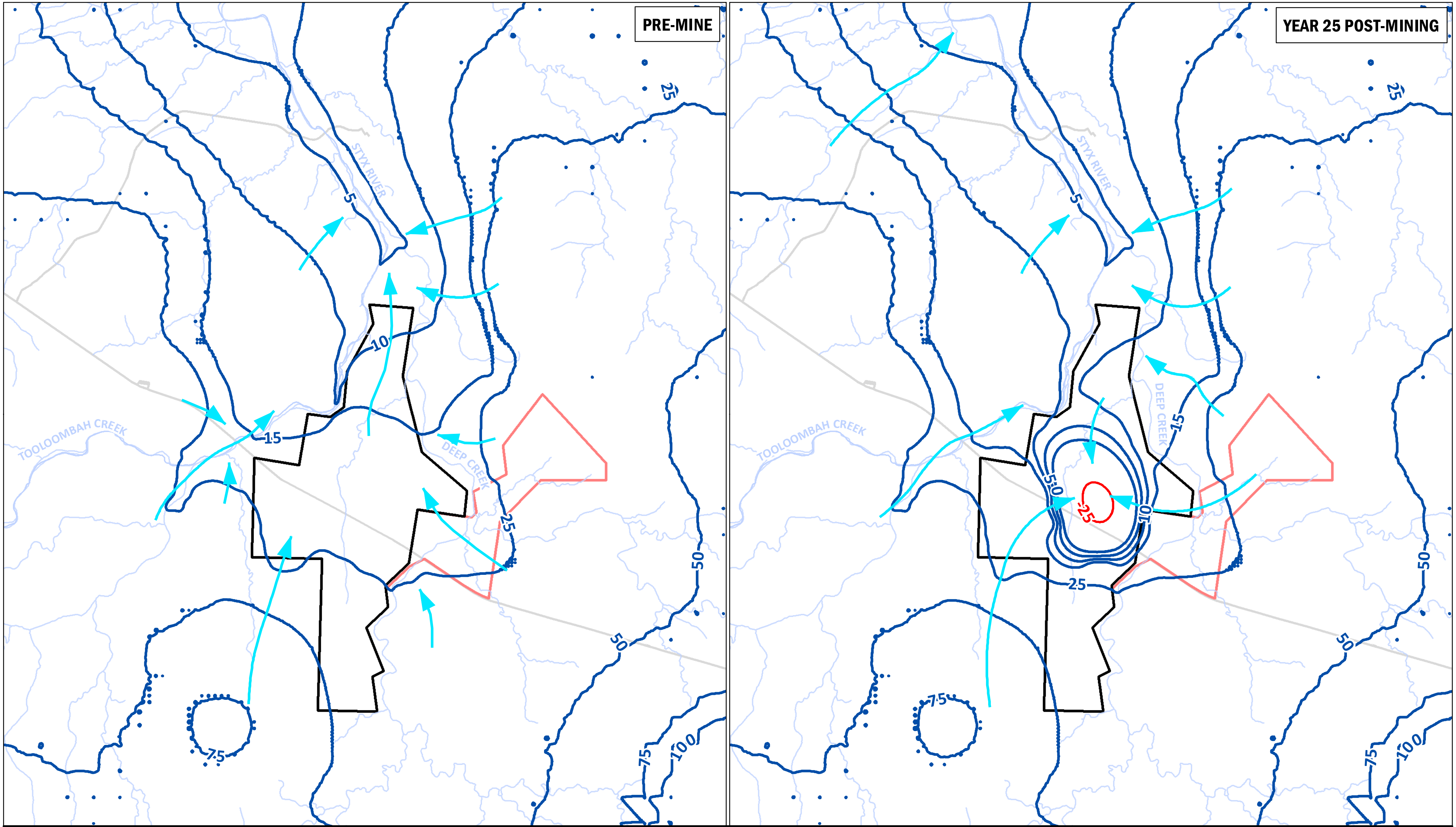
- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-67
Predicted water table elevation contours – pre-mine and year 10 post-mining

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__10yrs post-mining.mxd 12/20/2018



N

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-68
Predicted water table elevation contours – pre-mine and year 25 post-mining

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

CDM Smith

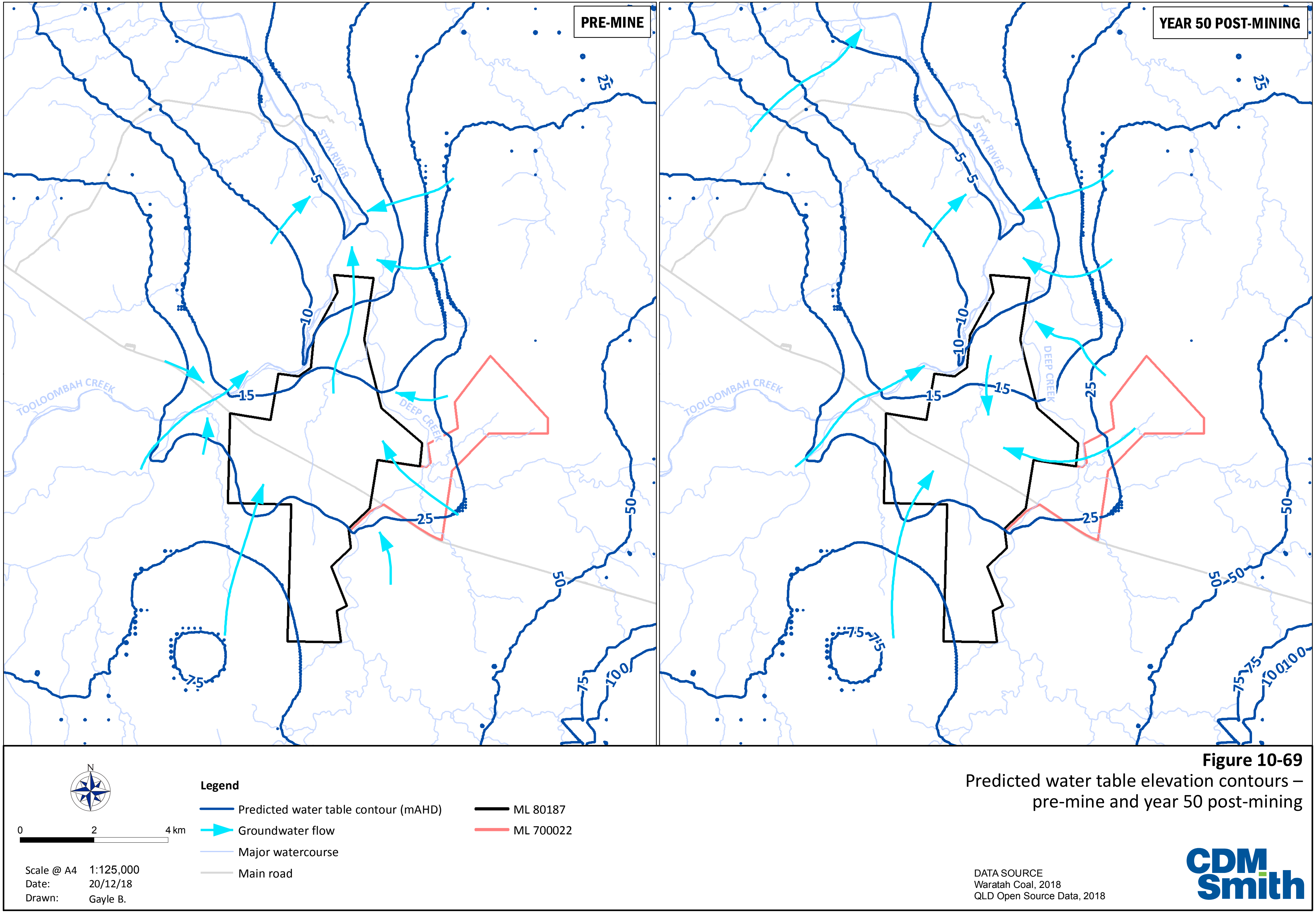
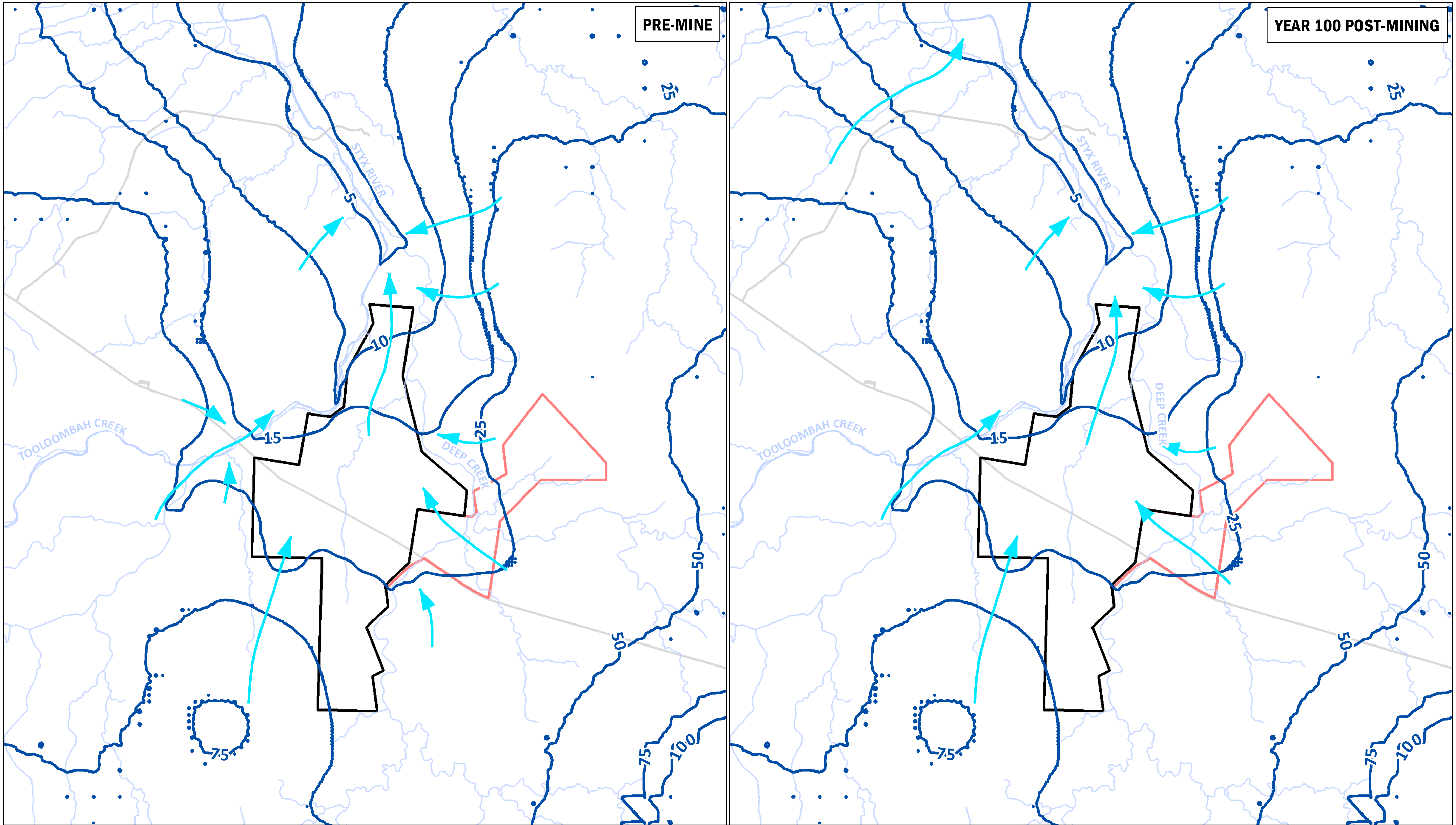


Figure 10-69
Predicted water table elevation contours – pre-mine and year 50 post-mining

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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__50yrs post-mining.mxd 12/20/2018



Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Figure 10-70
Predicted water table elevation contours – pre-mine and year 100 post-mining

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__100yrs post-mining.mxd 12/20/2018

The following provides a discussion of the changes predicted for the potentiometric surface and the saturated extent of HSU1 (alluvium) and HSU2 (the over-, inter- and under-burden units of the Styx Coal Measures) in response to mining activities, which are presented in Figure 10-71 to Figure 10-81, in response to mining and closure:

- Mining at the 'Open Cut 2' pit, by year 5 (Figure 10-71):
  - 1 m drawdown contour extends to Tooloombah and Deep Creeks on the western and eastern boundaries of ML80187
  - 0.1 m drawdown contour (adopted as the zone of influence) extends beyond Tooloombah Creek to the northeast, but not to the confluence of the two creeks
- Mining at both the 'Open Cut 1' and 'Open Cut 2' pits, by year 10 (Figure 10-72) through to end of mining (Figure 10-73 and Figure 10-78 to Figure 10-81):
  - 1 m drawdown contour extends to and beyond Tooloombah and Deep Creeks on the western and eastern boundaries of ML80187, as well as further to the south and north of the ML, to intersect stream reaches of the mid- to lower Deep Creek and mid-Tooloombah Creek
  - 0.1 m drawdown contour extends further beyond Tooloombah Creek to the northeast and within around 1,500 to 2,000 m of Styx River, but not to the confluence of the two creeks
  - alluvium (HSU1) is dewatered over much of the central portion of ML 80187, with small areas outside the ML also dewatered (Figure 10-78)
  - overburden coal measures (HSU2) is dewatered over the central portion of ML 80187 (Figure 10-79)
  - coal seams/interburden coal measures (HSU2) is dewatered in the areas of 'Open Cut 1' and 'Open Cut 2' (Figure 10-80)
  - underburden coal measures (HSU2) remains saturated beneath ML 80187 (Figure 10-81)
- By year 10 through 25 into closure (with all voids backfilled; Figure 10-74 and Figure 10-75, respectively) the predicted extent of the:
  - 1 m drawdown contour remains similar to the contour predicted at end of mining, but extends further east into the Deep Creek catchment and south into both the Deep and Tooloombah Creek catchments
  - 0.1 m drawdown contour extent remains similar to the contour predicted at end of mining
- by year 50 into closure (Figure 10-76) the predicted extent of the 0.1 and 1 m drawdown contours have begun to shrink back towards the decommissioned and back filled pits, and by year 100 into closure (Figure 10-77) the groundwater system is predicted to have fully recovered.

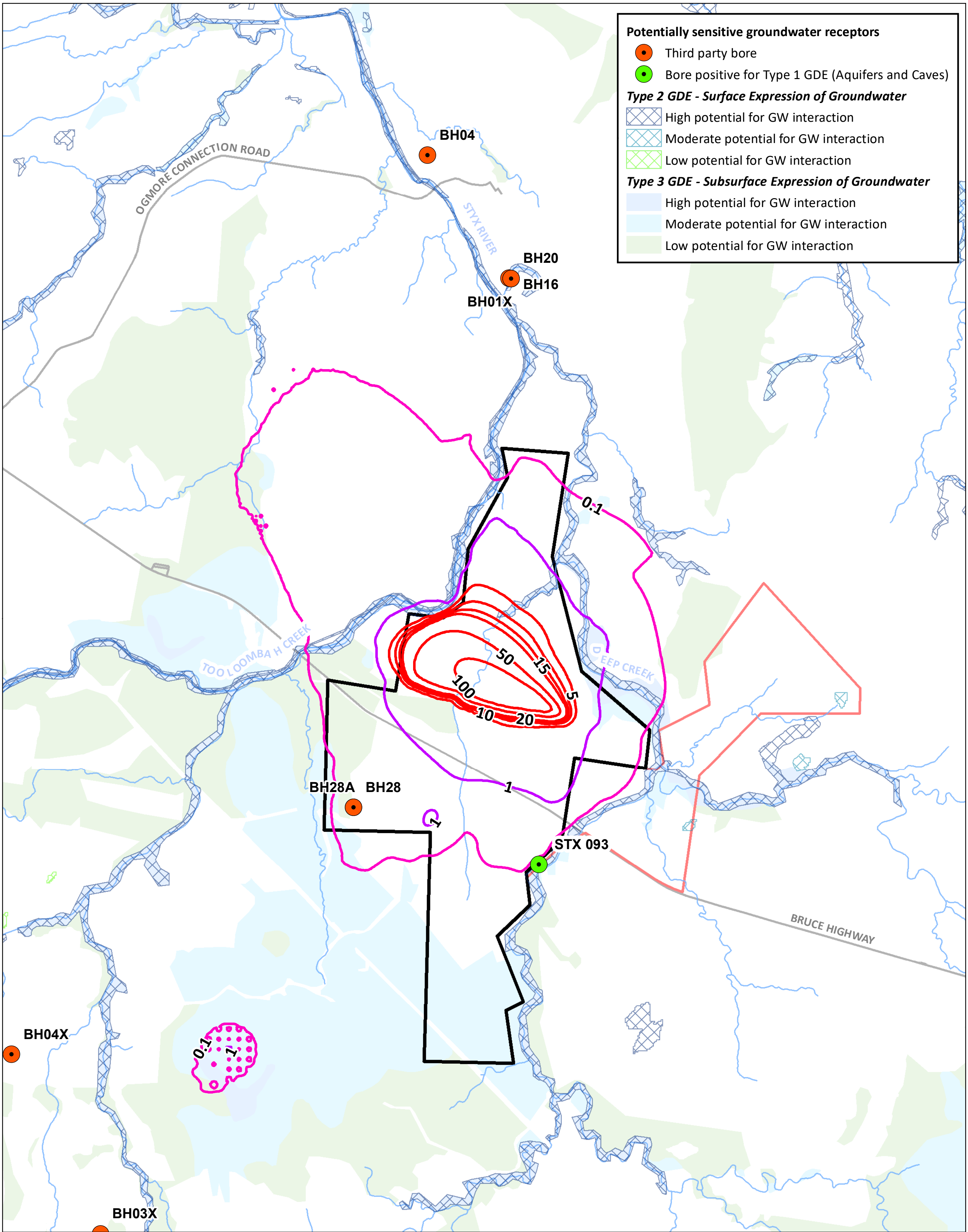


Figure 10-71
Predicted potentiometric surface drawdown contours for all HSUs – year 5

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__LOM yr 5.mxd 20/12/2018

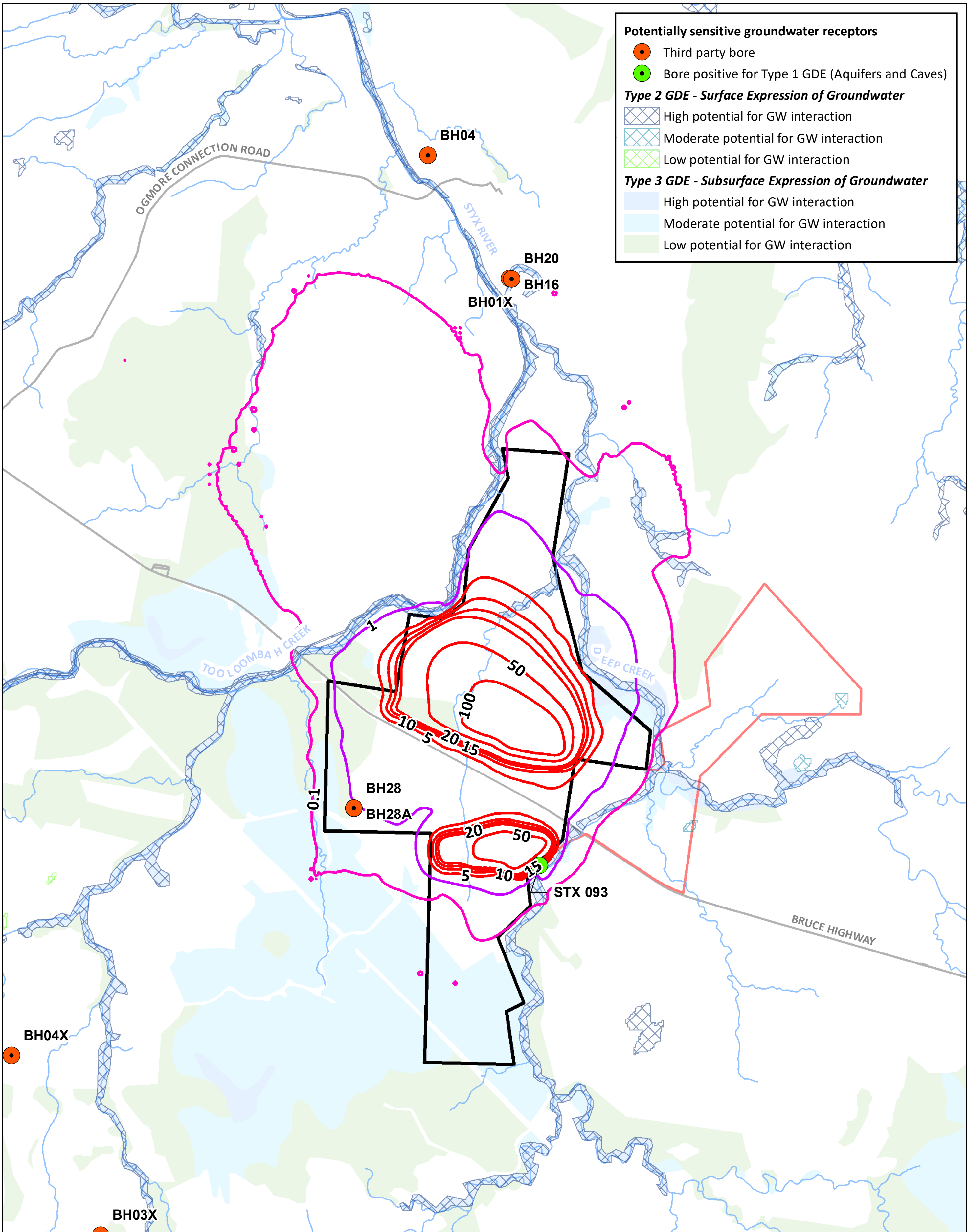


Figure 10-72

Predicted potentiometric surface drawdown contours for all HSUs – year 10

N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

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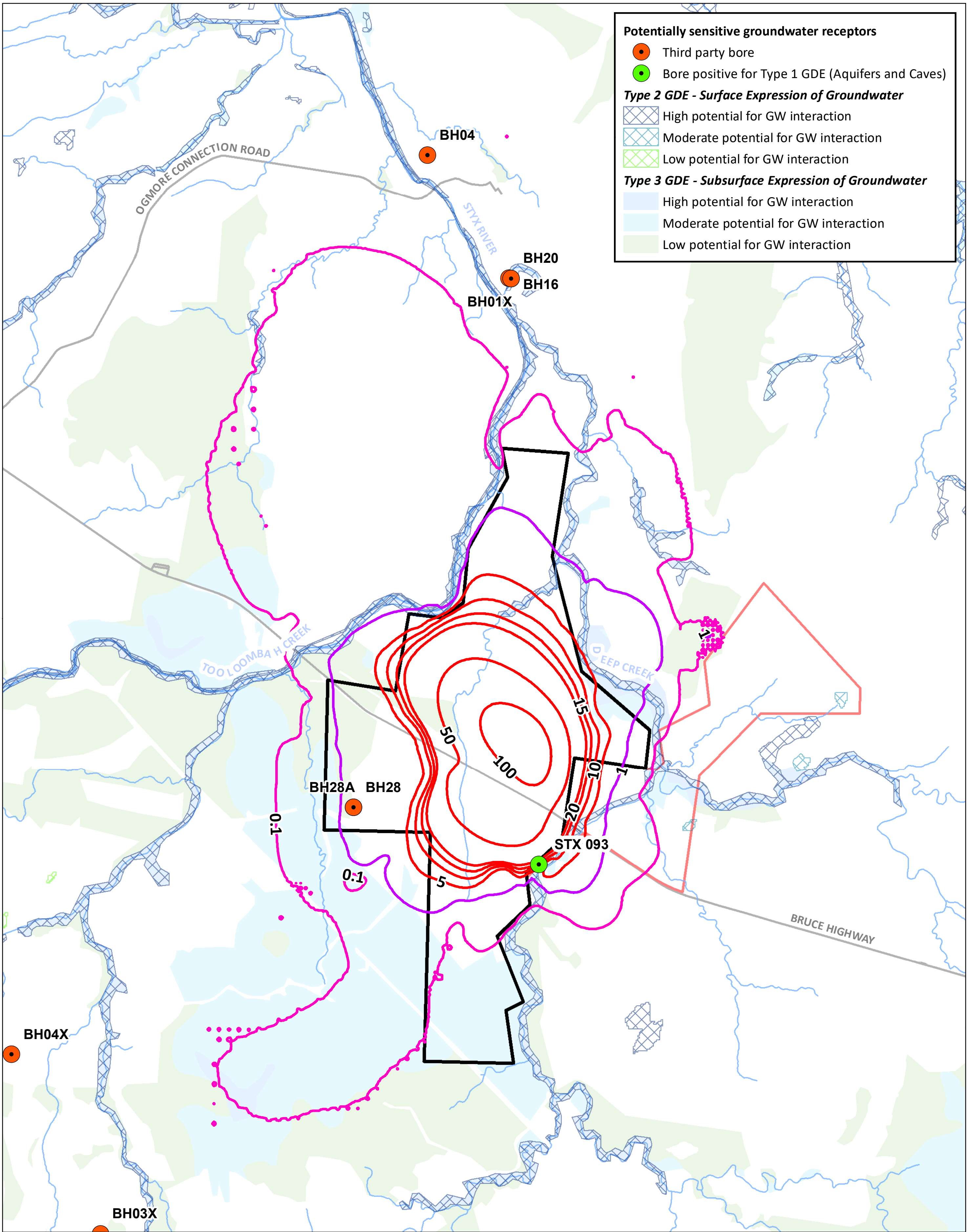


Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Figure 10-73
Predicted potentiometric surface drawdown contours for all HSUs – at end of mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__LOM yr 18.mxd 20/12/2018

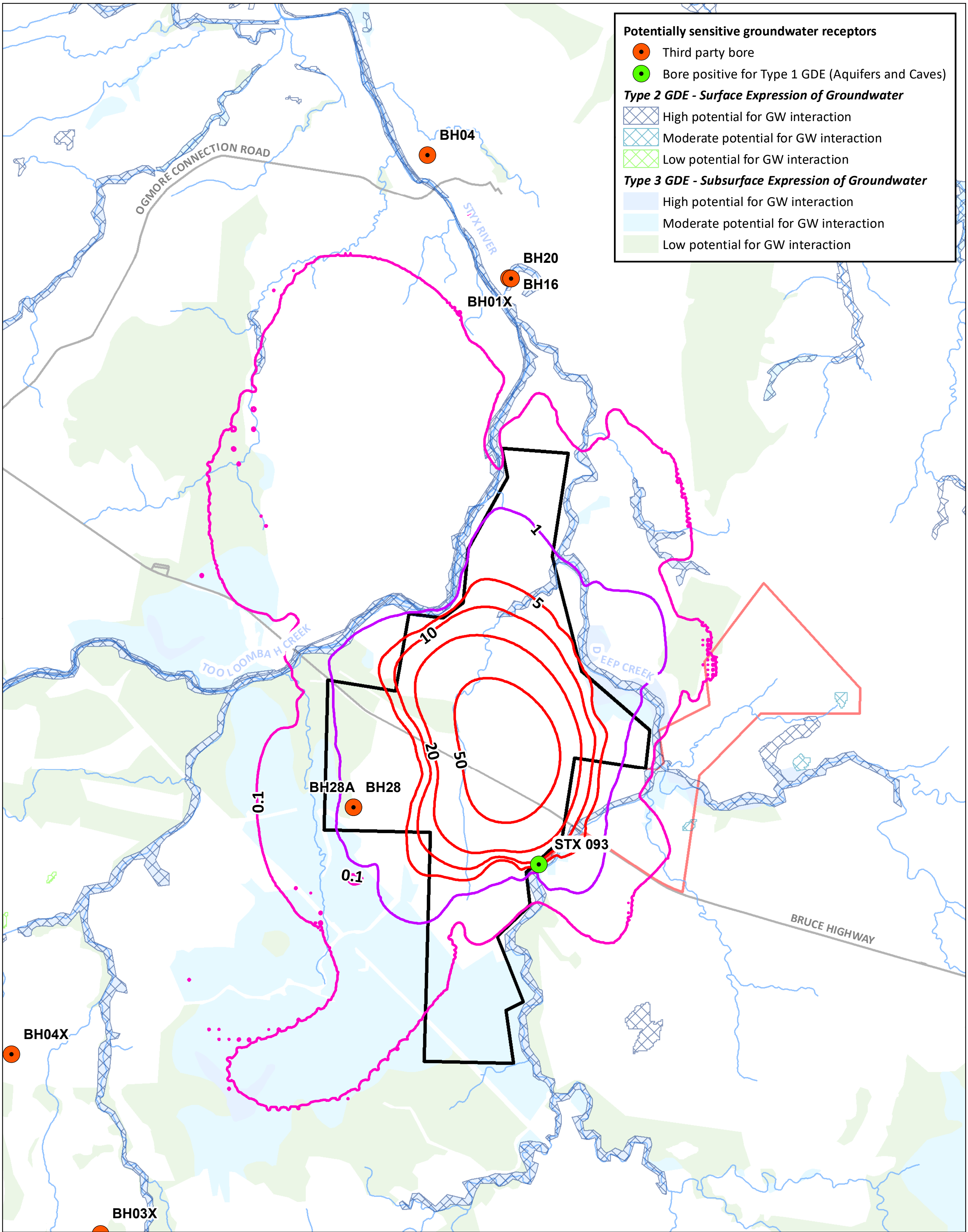


Figure 10-74

Predicted potentiometric surface drawdown contours for all HSUs – year 10 post-mining

N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

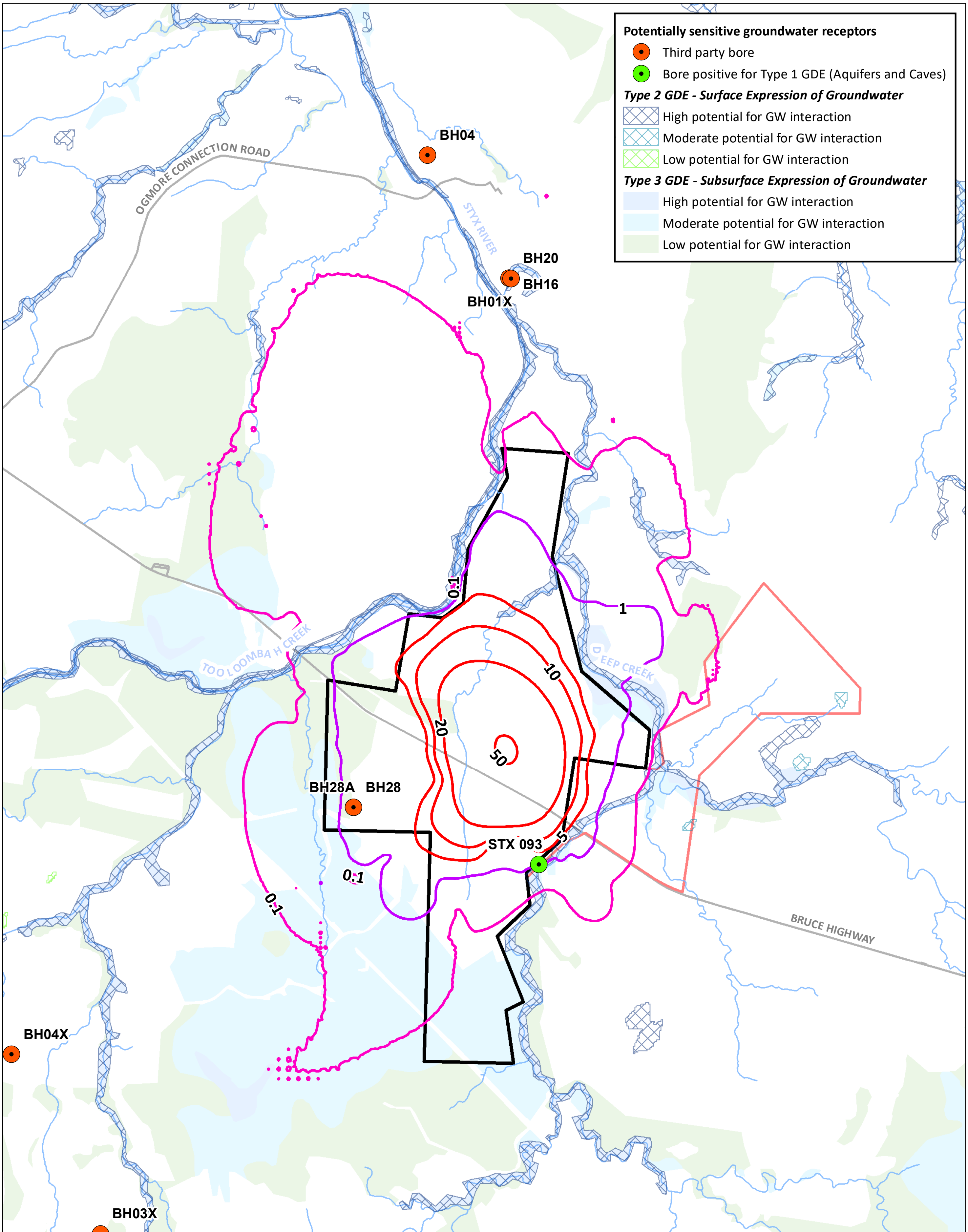
Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__10yrs post-mining.mxd 20/12/2018



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

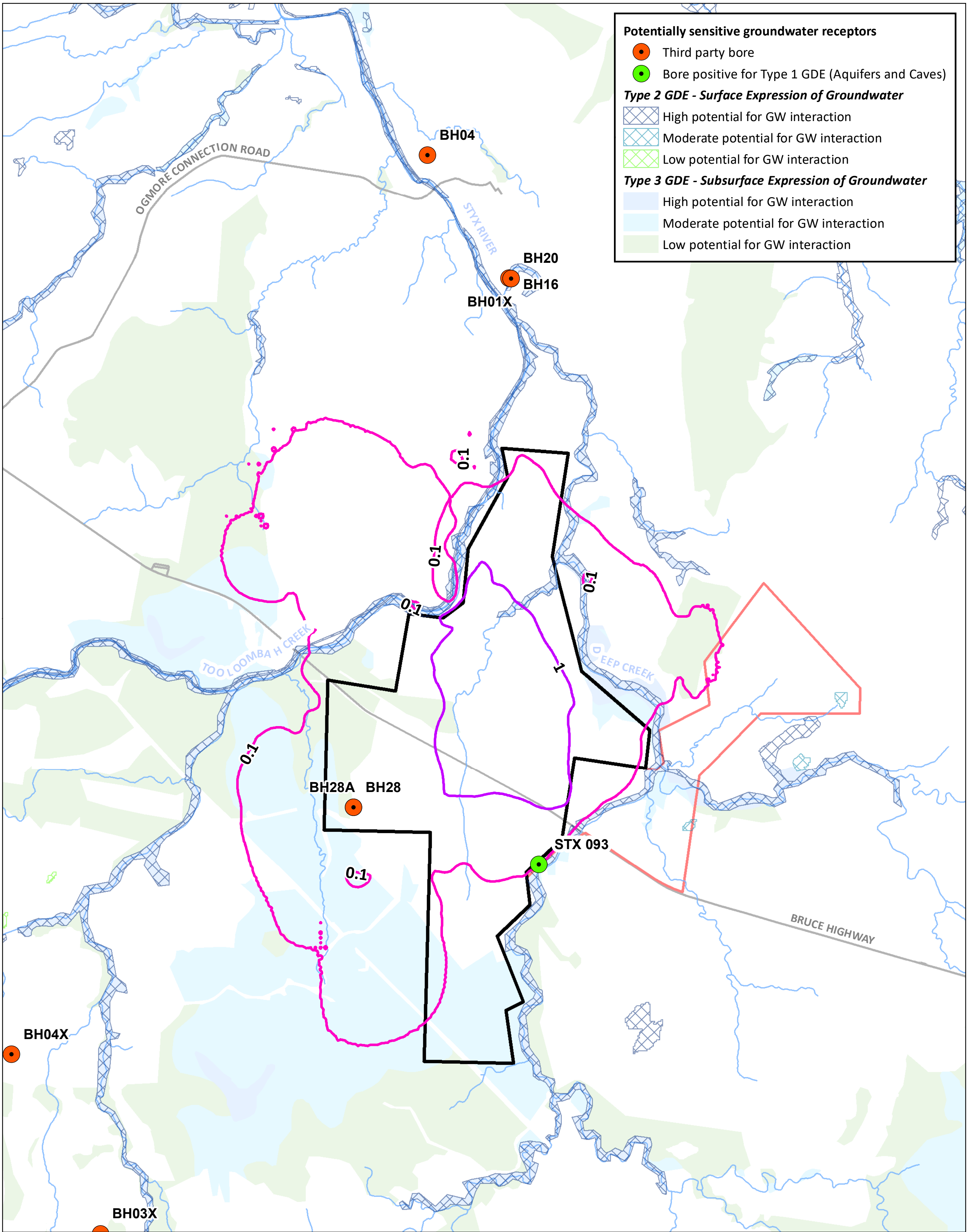
Figure 10-75

Predicted potentiometric surface drawdown contours for all HSUs – year 25 post-mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__25yrs post-mining.mxd 20/12/2018



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-76

Predicted potentiometric surface drawdown contours for all HSUs – year 50 post-mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__50yrs post-mining.mxd 20/12/2018

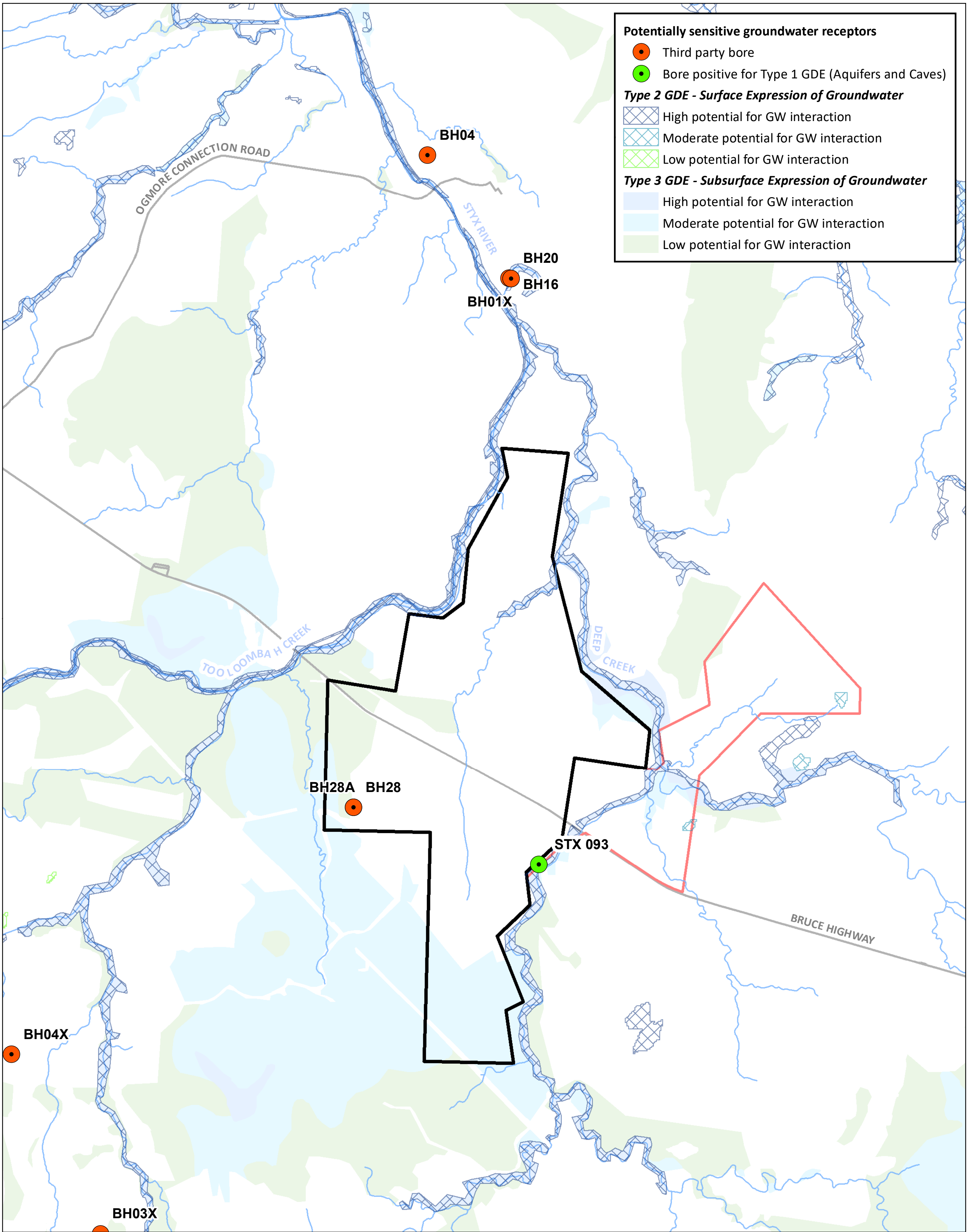


Figure 10-77

Predicted potentiometric surface drawdown contours for all HSUs – year 100 post-mining

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__100yrs post-mining.mxd 20/12/2018

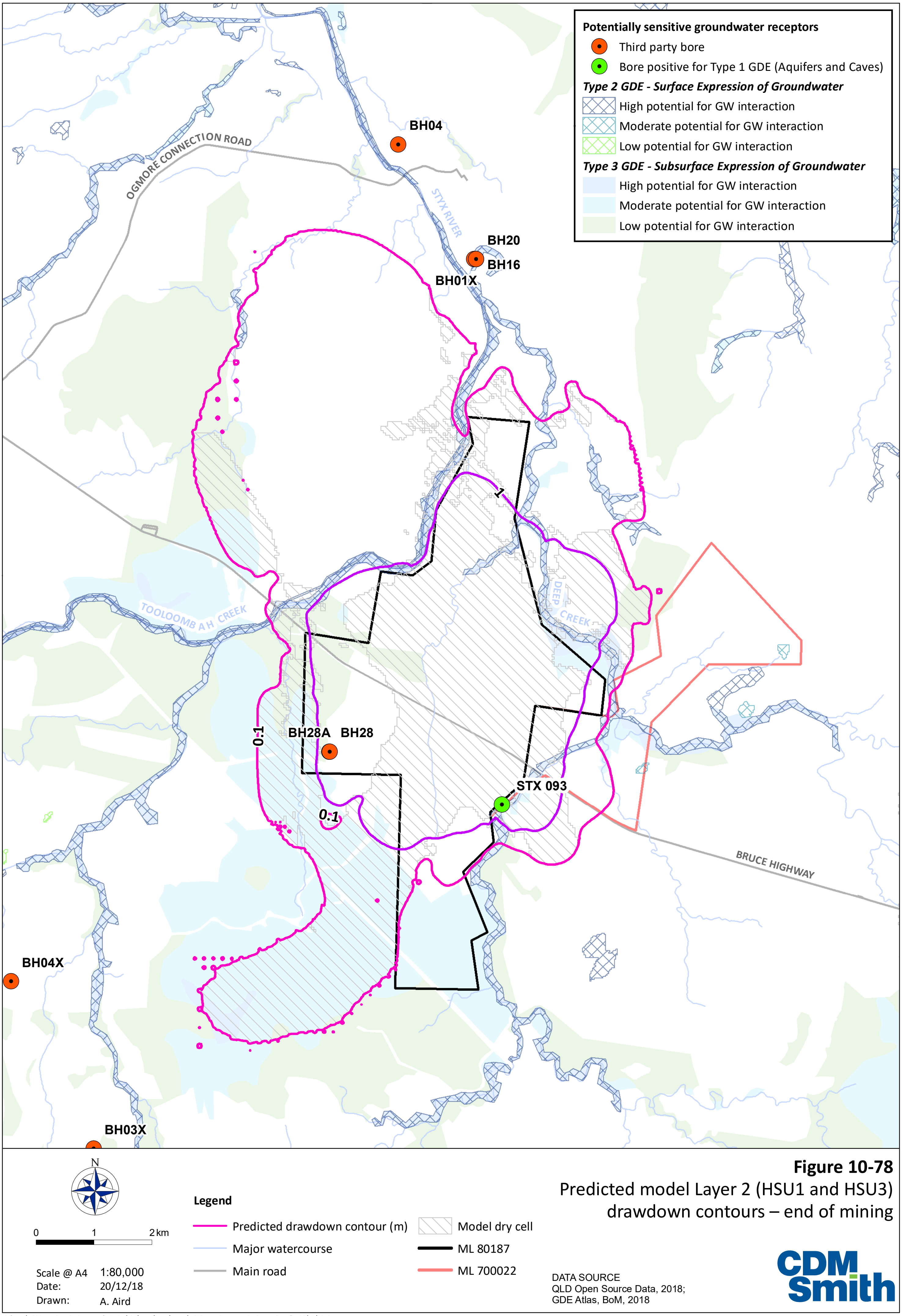
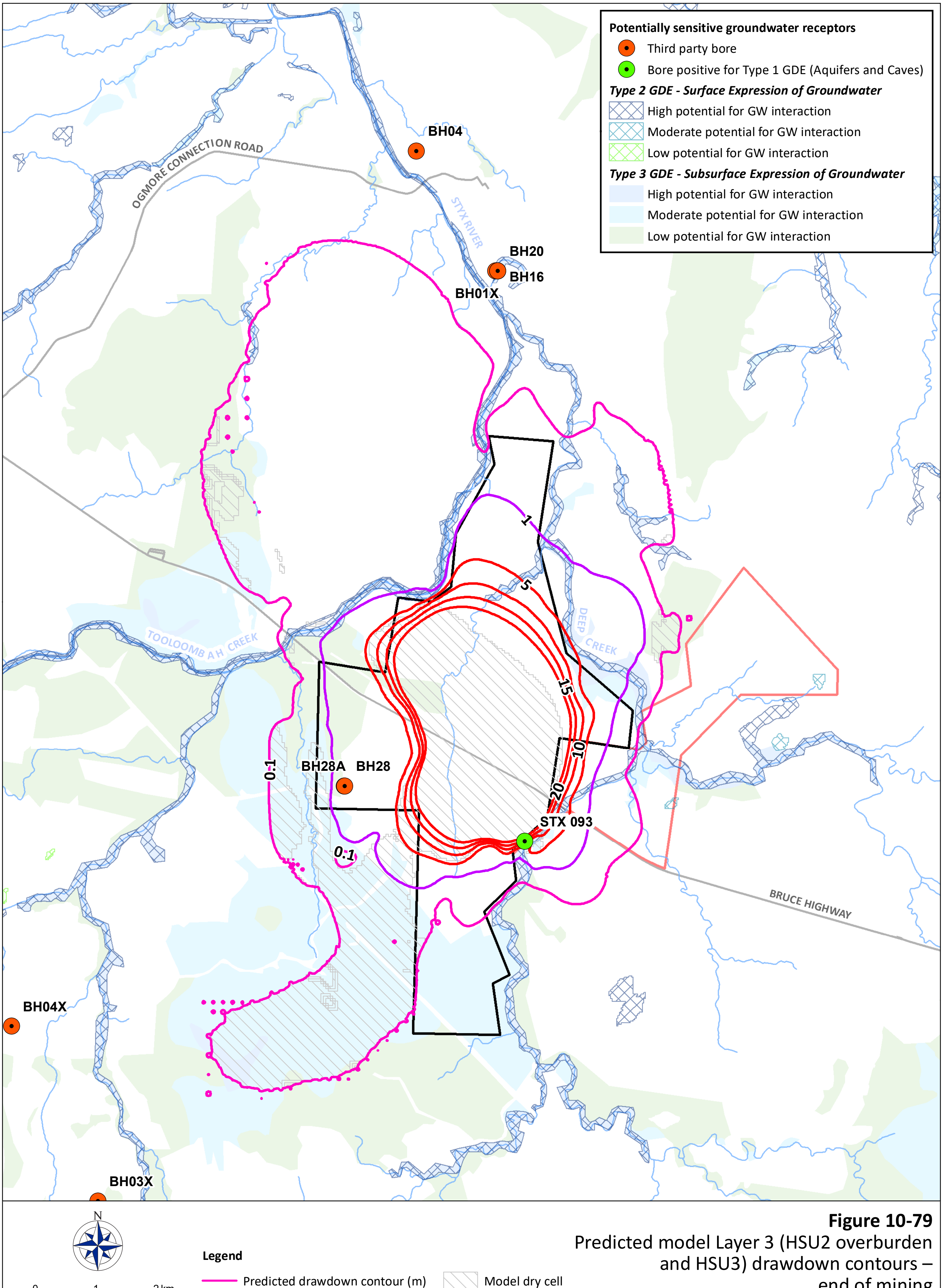


Figure 10-78
Predicted model Layer 2 (HSU1 and HSU3) drawdown contours – end of mining

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DDN_Lay2 EOM-yr18.mxd 20/12/2018



Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Figure 10-79
Predicted model Layer 3 (HSU2 overburden and HSU3) drawdown contours – end of mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DDN_Lay3 EOM-yr18.mxd 20/12/2018

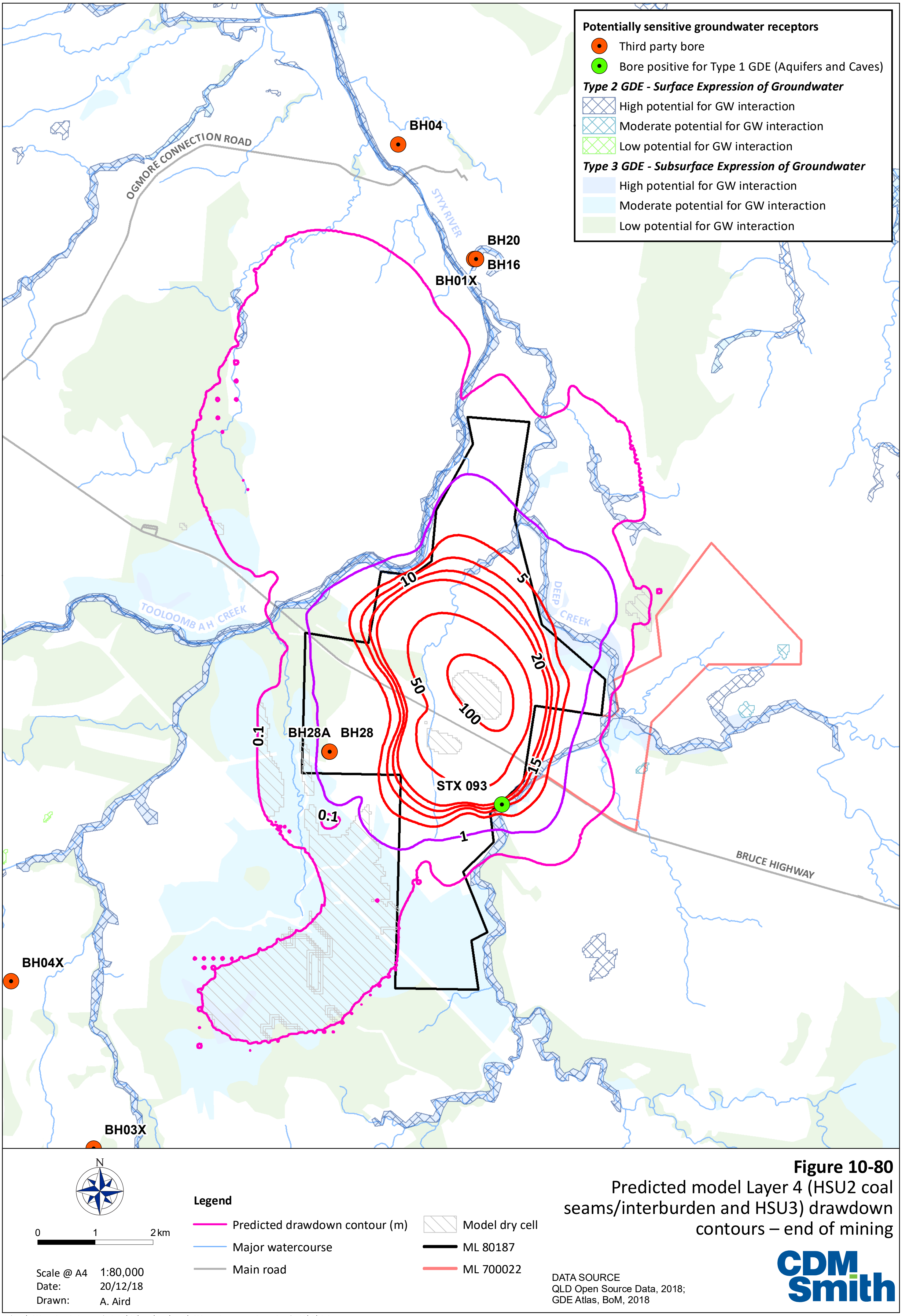


Figure 10-80
Predicted model Layer 4 (HSU2 coal seams/interburden and HSU3) drawdown contours – end of mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DDN_Lay4 EOM-yr18.mxd 20/12/2018

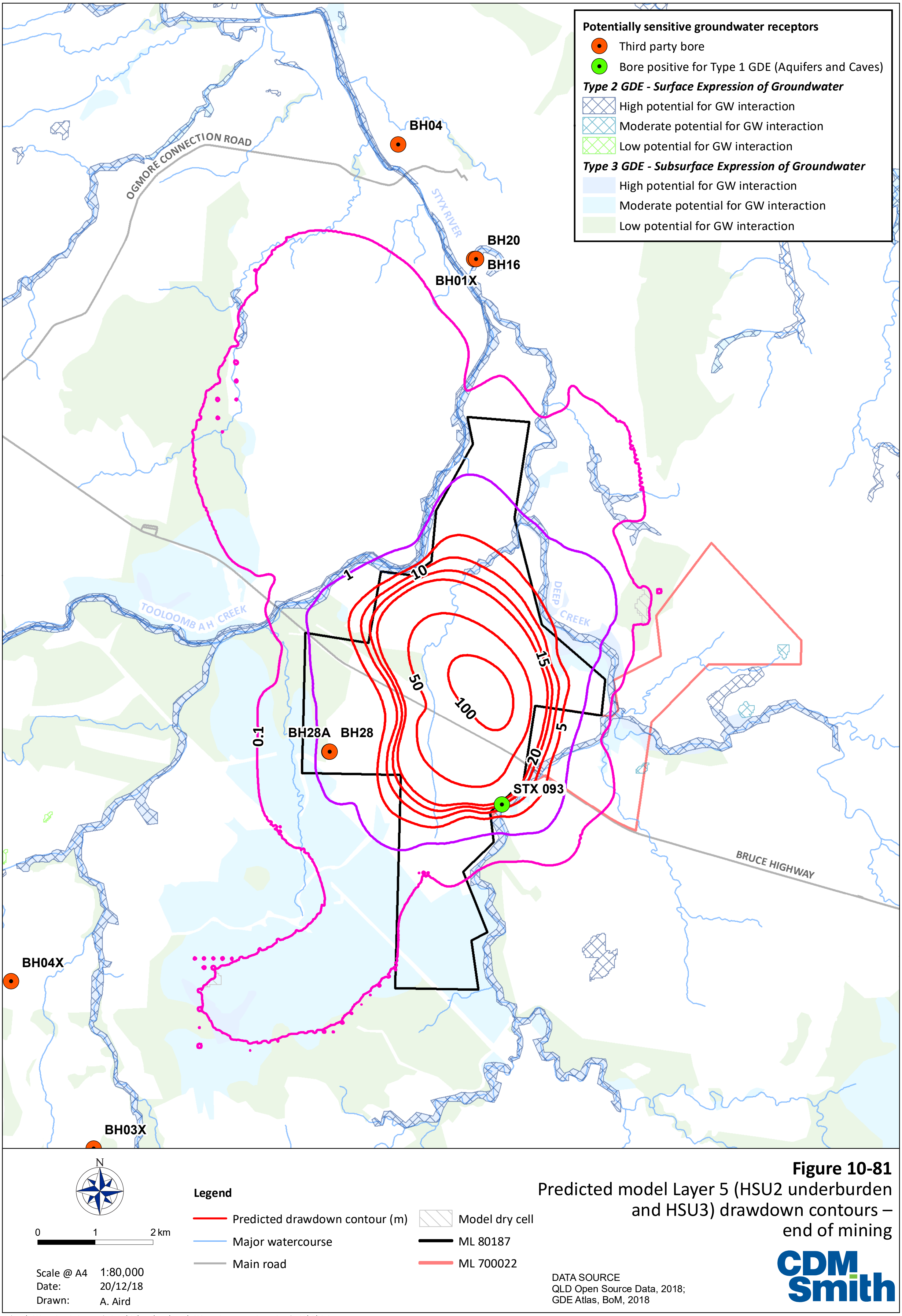


Figure 10-81
Predicted model Layer 5 (HSU2 underburden and HSU3) drawdown contours – end of mining

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DDN_Lay5 EOM-yr18.mxd 20/12/2018

A key direct effect of mining on groundwater is drawdown associated with dewatering and the associated indirect effects of water table drawdown to support groundwater access by potential riparian GDEs and reduced baseflow to support in-stream GDEs. The quantification of interactions between groundwater and surface water is often constrained by the available topographic data used to represent the ground surface and stream beds in a numerical model, as well as adopted values of stream bed conductance. In this assessment, changes to baseflow (and evapotranspiration) in response to mining have been semi-quantified, i.e. they are presented as relative changes from the predicted pre-mine (baseline) condition.

Figure 10-82 and Figure 10-83 present model predicted changes in flux (baseflow and ET) to the riparian zones of Tooloombah and Deep Creeks in response to mining activities as a proportion of the predicted (no mine) basecase, showing:

- Tooloombah Creek:
  - little to no change in flux between the 'no mine' and 'mining' scenario for the upper reach (above Bruce Highway)
  - upwards of 40% reduction in flux between the 'no mine' and 'mining' scenario for the lower reach (below Bruce Highway), with flux slowly returning to background after closure (~50% recovery by around 65 years after closure, and the remaining ~50% occurring within another 20 years or so); and
- Deep Creek:
  - less than 15% reduction in flux between the 'no mine' and 'mining' scenario for the upper reach (above WMP10; Figure 10-18), with flux slowly returning to background within around 75 years after closure
  - 60% reduction in flux between the 'no mine' and 'mining' scenario for the middle reach (between WMP10 and the confluence with the tributary creek that runs through ML 80187; Figure 10-18), with flux slowly returning to background after closure (~25% recovery by around 60 years after closure, and the remaining ~75% occurring within another 20 years or so)
  - less than 15% reduction in flux between the 'no mine' and 'mining' scenario for the lower reach (from the confluence with the tributary creek that runs through ML 80187and the confluence of Deep and Tooloombah Creeks; Figure 10-18), with flux slowly returning to background within around 75 years after closure.

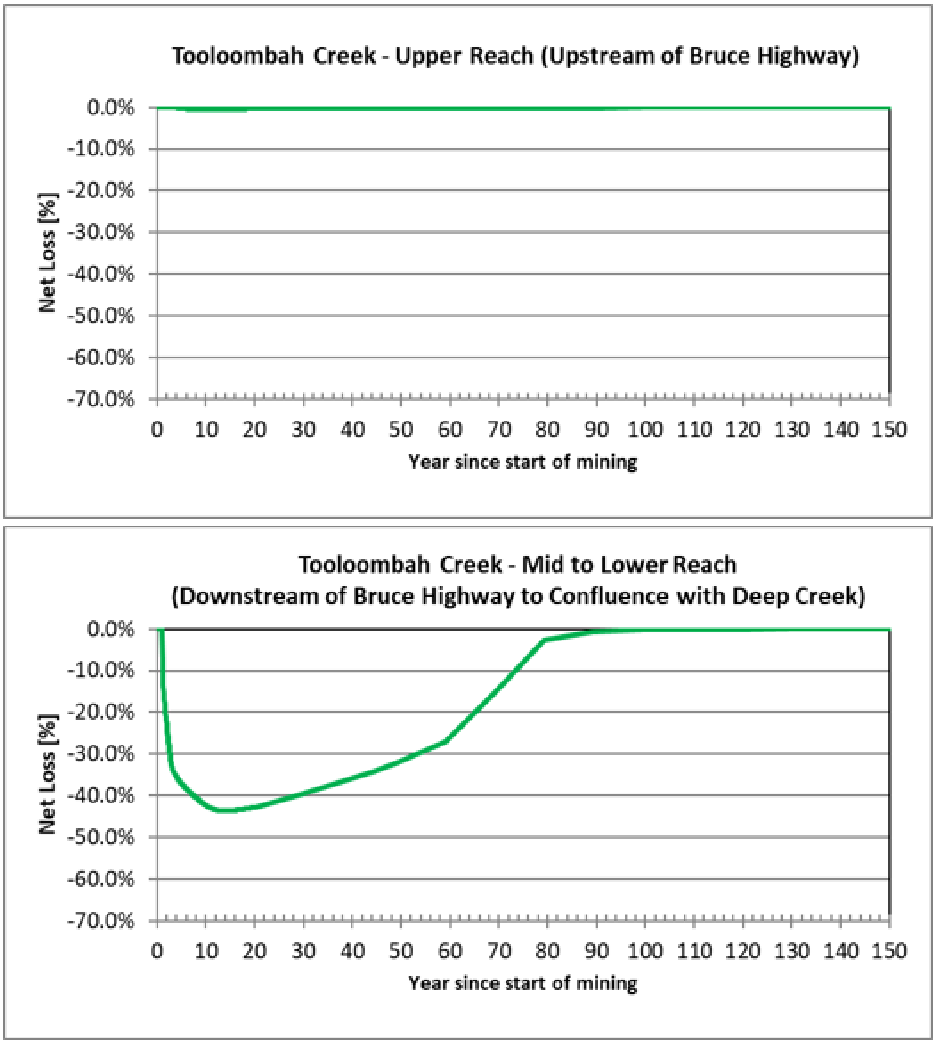


Figure 10-82 Predicted impact on baseflow and evapotranspiration (Tooloombah Creek)

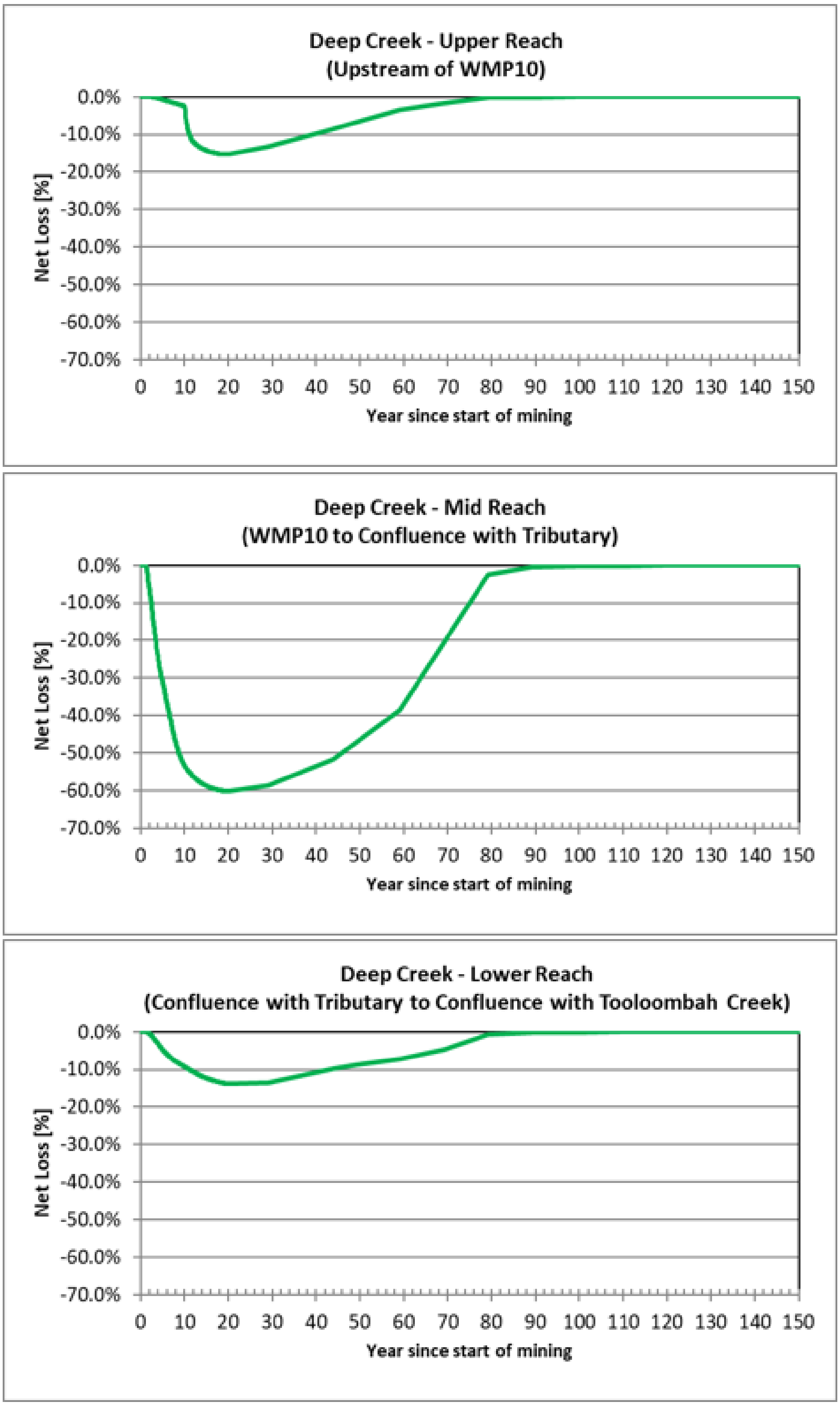


Figure 10-83 Predicted impact on baseflow and evapotranspiration (Deep Creek)

Model predicted hydrographs at selected locations where potential GDEs occur are presented in Figure 10-84 and Figure 10-85, and show:

- Drawdown at the location where stygofauna have been identified in Deep Creek catchment alluvium (bore STX093; Figure 10-18 and Figure 10-84) in response to mining activities is predicted to result in an almost 90% loss of vertical habitat over the life of mine after which full recovery is predicted to occur by around 50 years after closure (50% recovery occurring by around 15 years after closure); and
- Drawdown at the location of a potential Type 3 GDE (WMP25 and WMP27; Figure 10-18 and Figure 10-85) in response to mining activities is predicted to be less than 2 m in an area where the water table has been gauged at around 10 m or more.

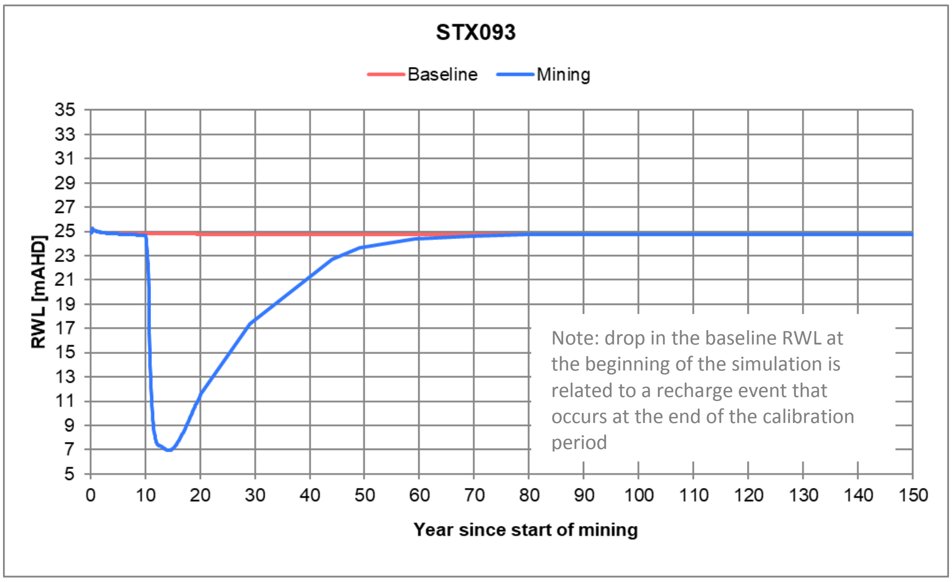
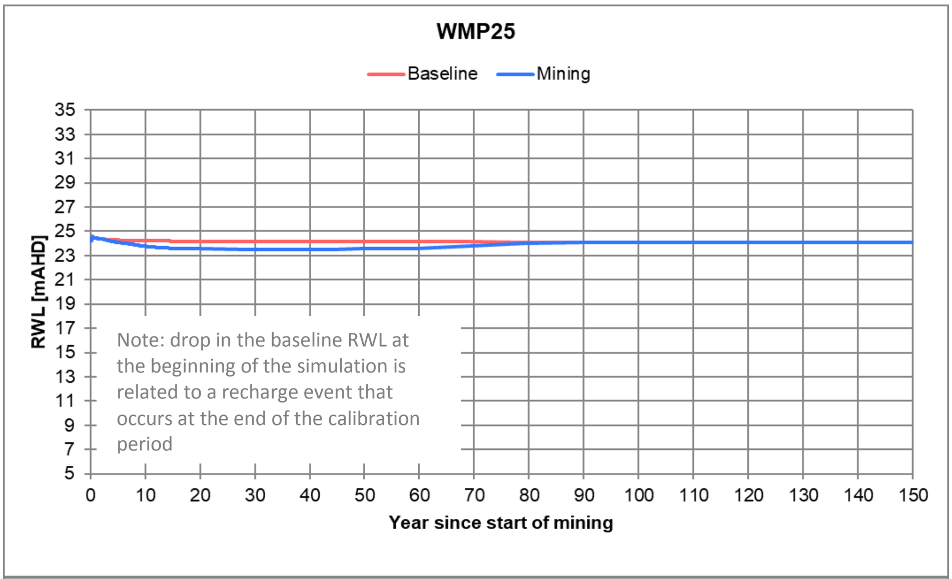


Figure 10-84 Hydrograph showing predicted transient water table response to mine water affecting activities at STX 093 (stygofauna bore, Type 1 GDE)



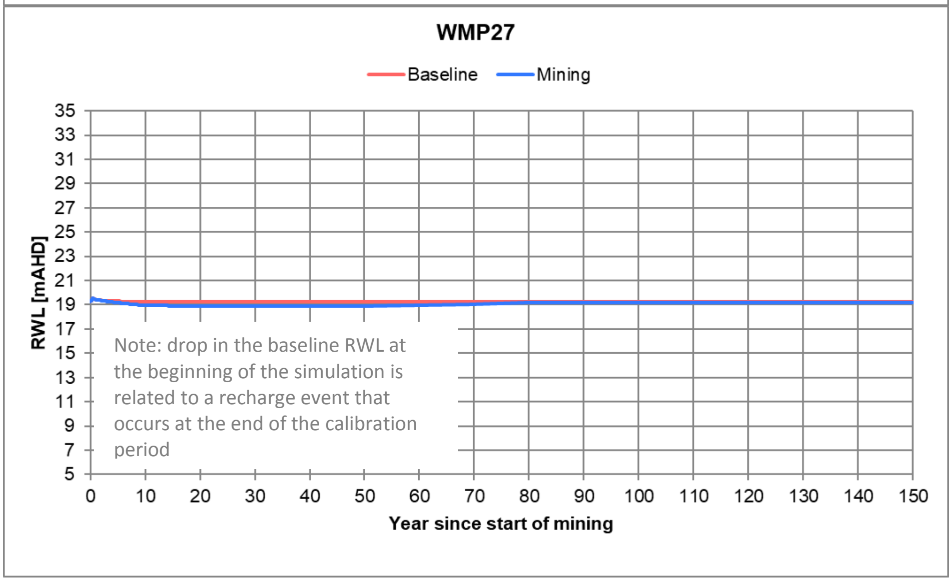


Figure 10-85 Hydrograph showing predicted transient water table response to mine water affecting activities at potential Type 3 GDEs on western ML 80187 boundary (WMP25 and WMP27)

Model predicted hydrographs at third-party bores (Figure 10-61) located in the Project area are presented in Figure 10-86 to Figure 10-88, and show:

- Drawdown in response to mining activities at the location of BH28 and BH28a of up to around 2 m is predicted over the life of mine and out to 70 years after closure; and
- Drawdown in response to mining activities is unlikely to occur at other third-party bores in the area.

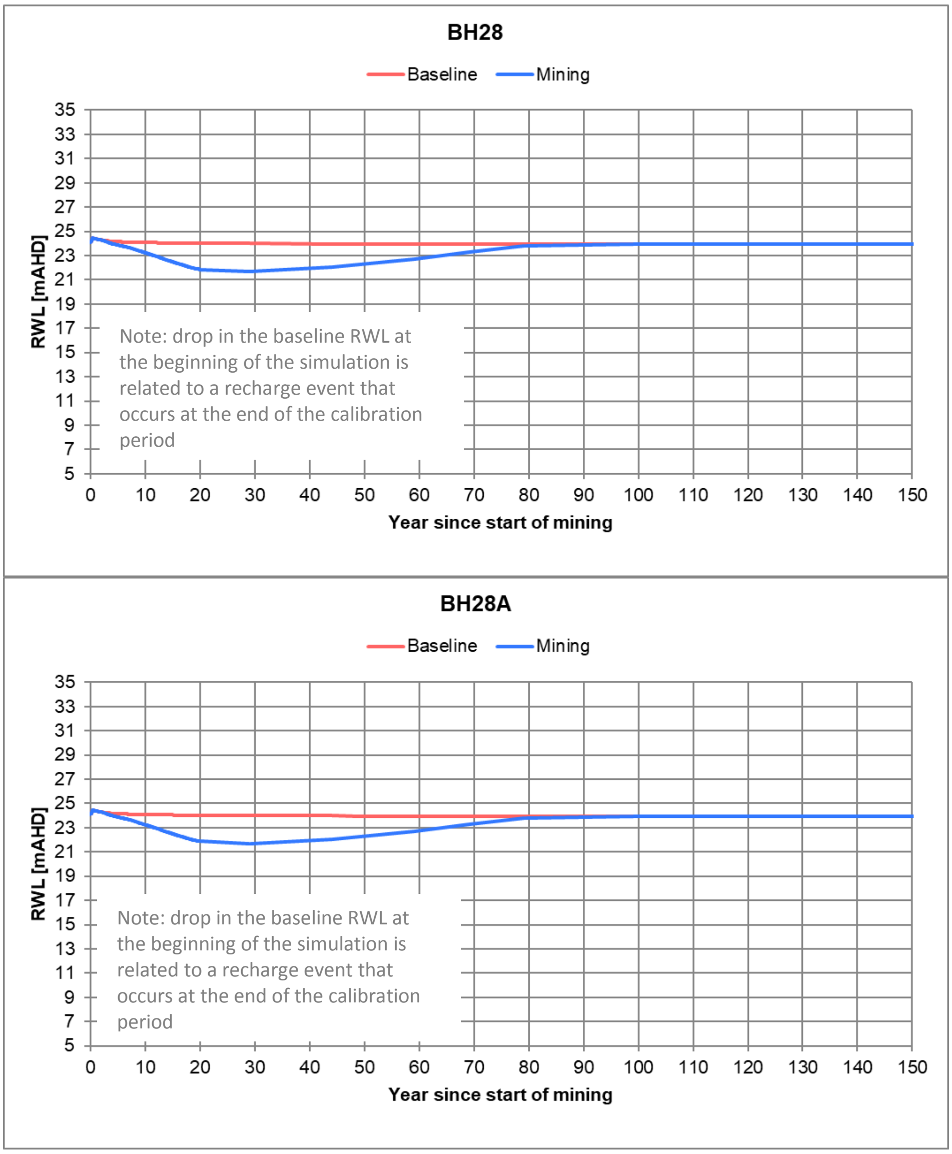


Figure 10-86 Hydrograph showing predicted transient water table response to mine water affecting activities at BH28A and BH28 (third party water user bores, inferred to target the Basement)

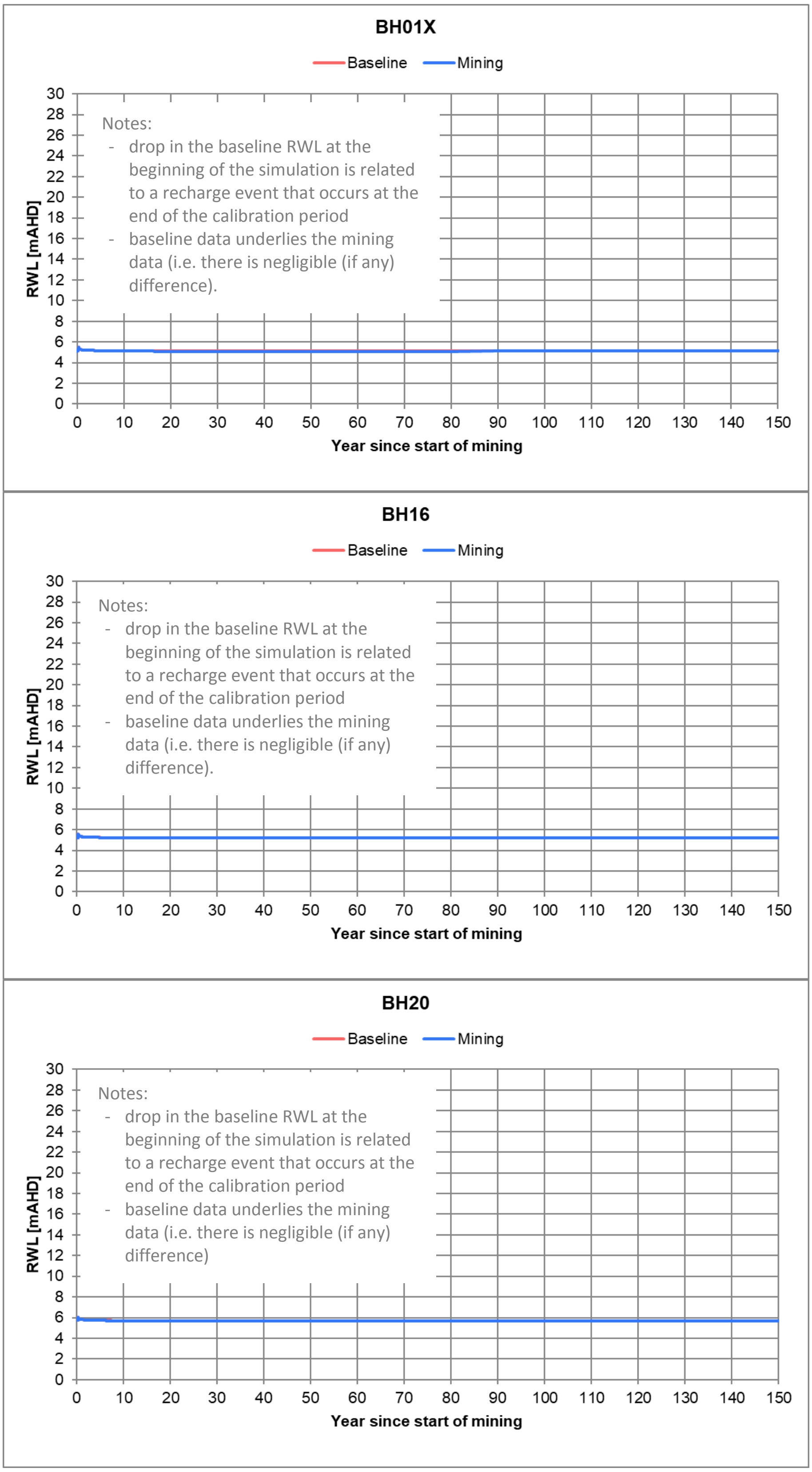


Figure 10-87 Hydrograph showing predicted transient water table response to mine water affecting activities at BH01X, BH16 and BH20 (third party water user bores)

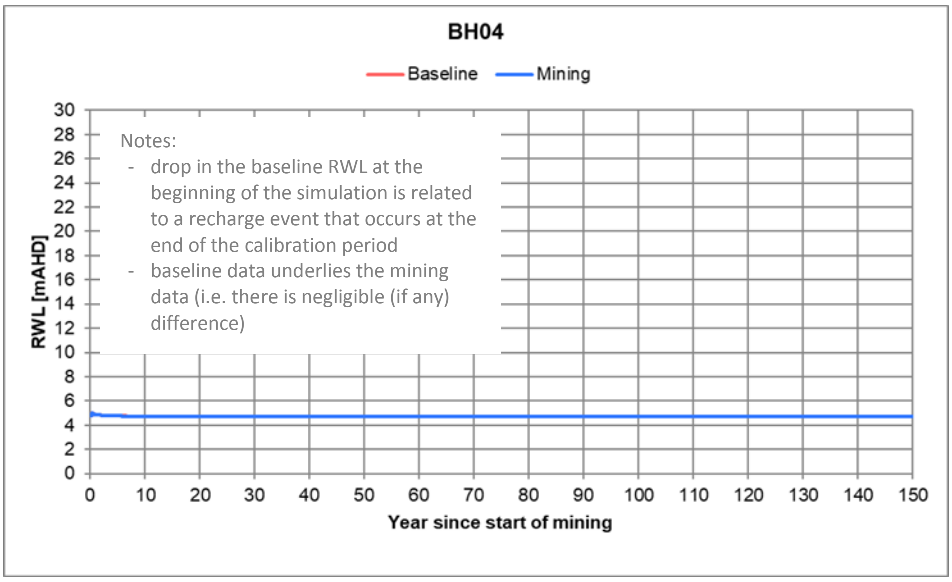
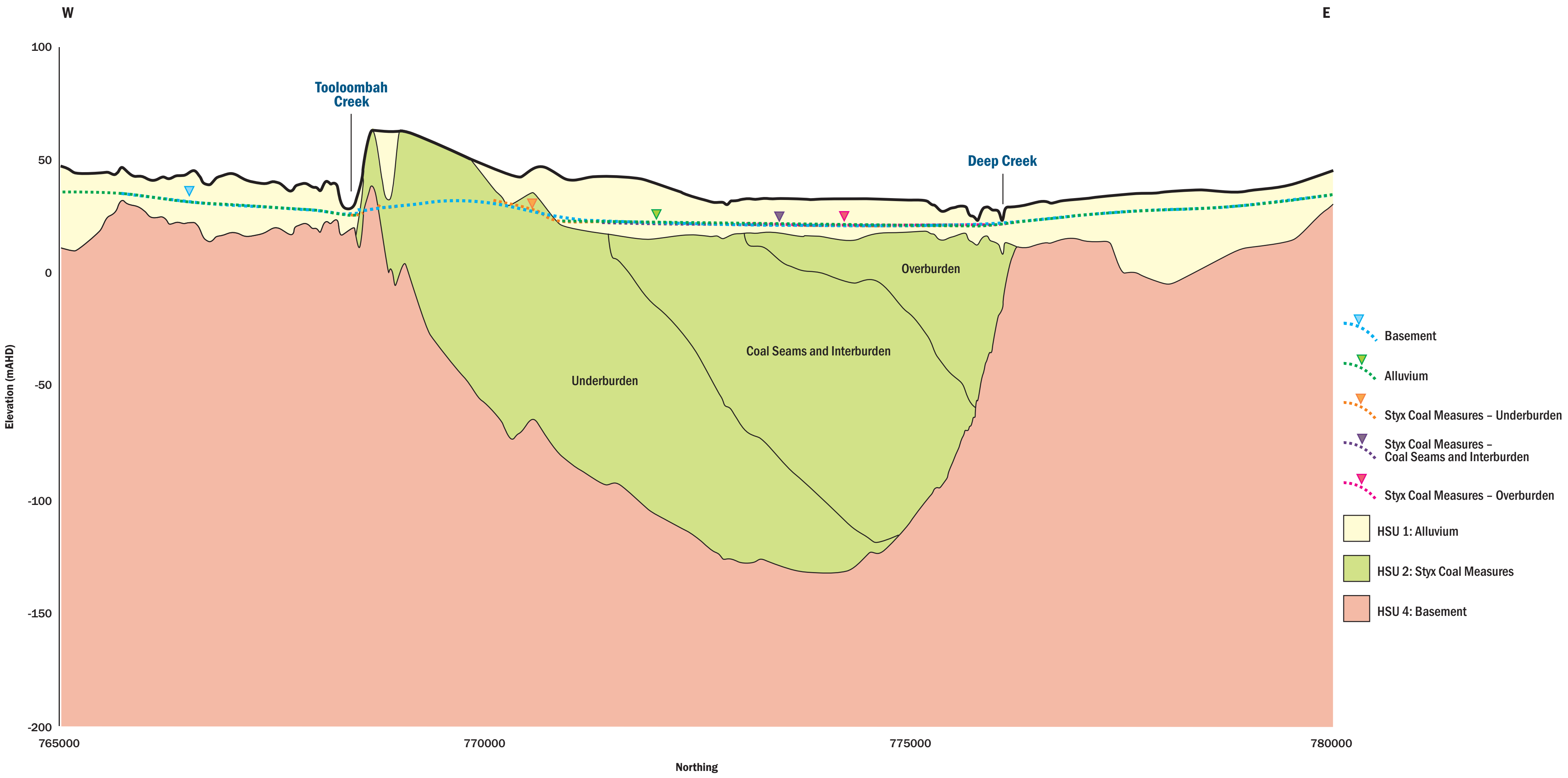


Figure 10-88 Hydrograph showing predicted transient water table response to mine water affecting activities at BH04 (third party water user bores)

Figure 10-89 through Figure 10-91 present a west-east aligned cross-section through ML 801887 showing the model predicted pre-mine, year 12 and at the end of mining, potentiometric surfaces. Figure 10-92 and Figure 10-94 present the same information for a south-north aligned cross-section through ML 801887. The cross-sections and predicted potentiometric surfaces show:

- The pre-mine potentiometric surfaces for each HSU are essentially the same, with the potential for slightly higher heads in the Styx Coal Measures where they subcrop or outcrop on the western side of the geological basin;
- During mining, with the exception of the alluvium (HSU1) and the overburden coal measures (HSU2) that become unsaturated around the mine pits:
  - the lateral extent of the drawn-down potentiometric surfaces are similar, with the basement (HSU3) zone of influence being slightly larger (likely the result of a lower storage coefficient)
  - the vertical depths differ by many 10s of metres toward the end of mining, as would be expected because of targeted dewatering depths and recovery occurring from bottom up; and
- The basement is not dewatered during mining but is depressurised.



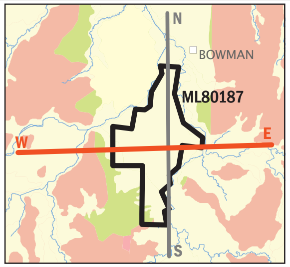
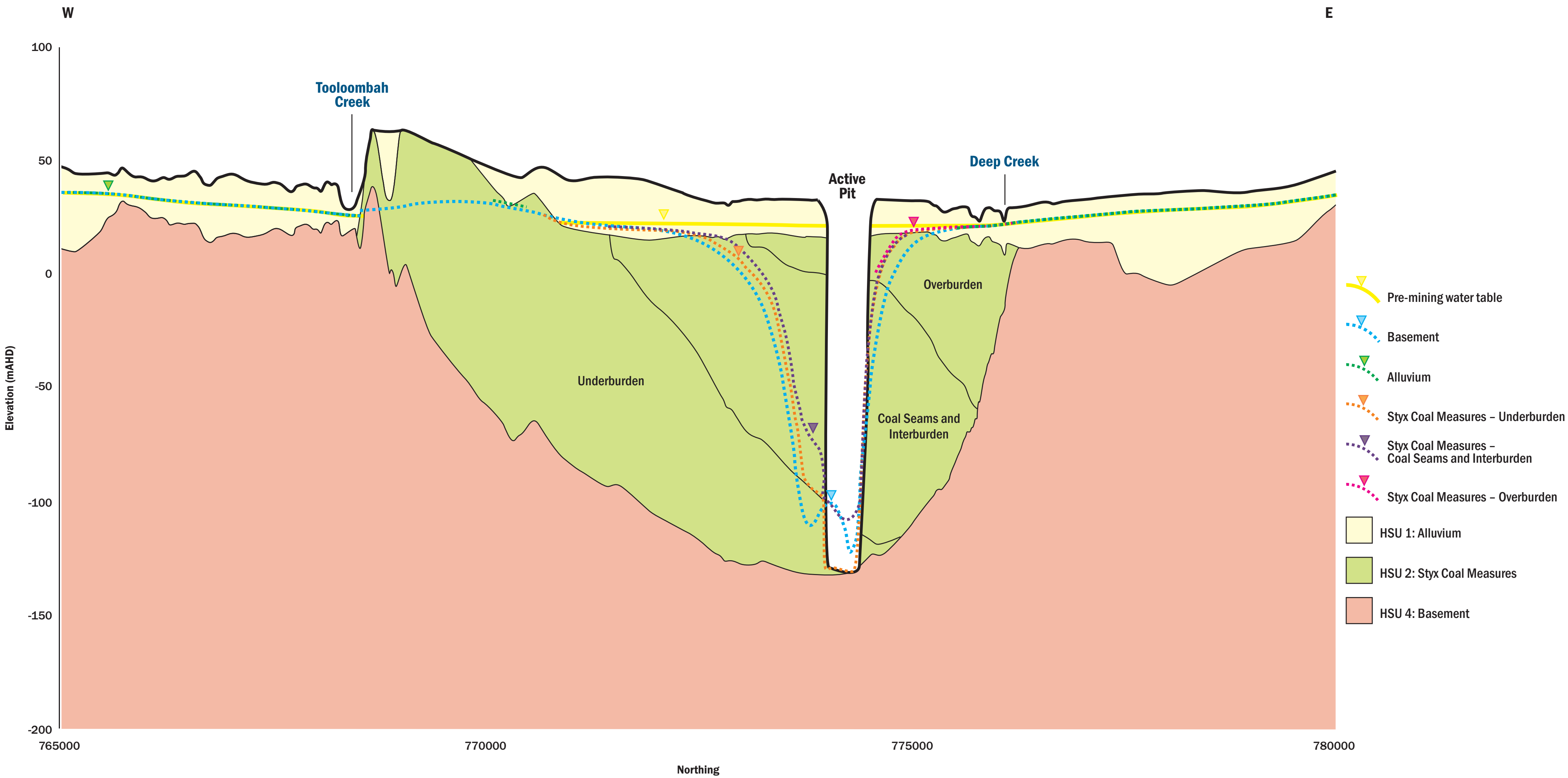


Figure 10-89

Cross-section showing model predicted pre-mine potentiometric surface (west to east through ML)



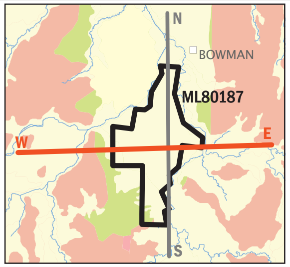
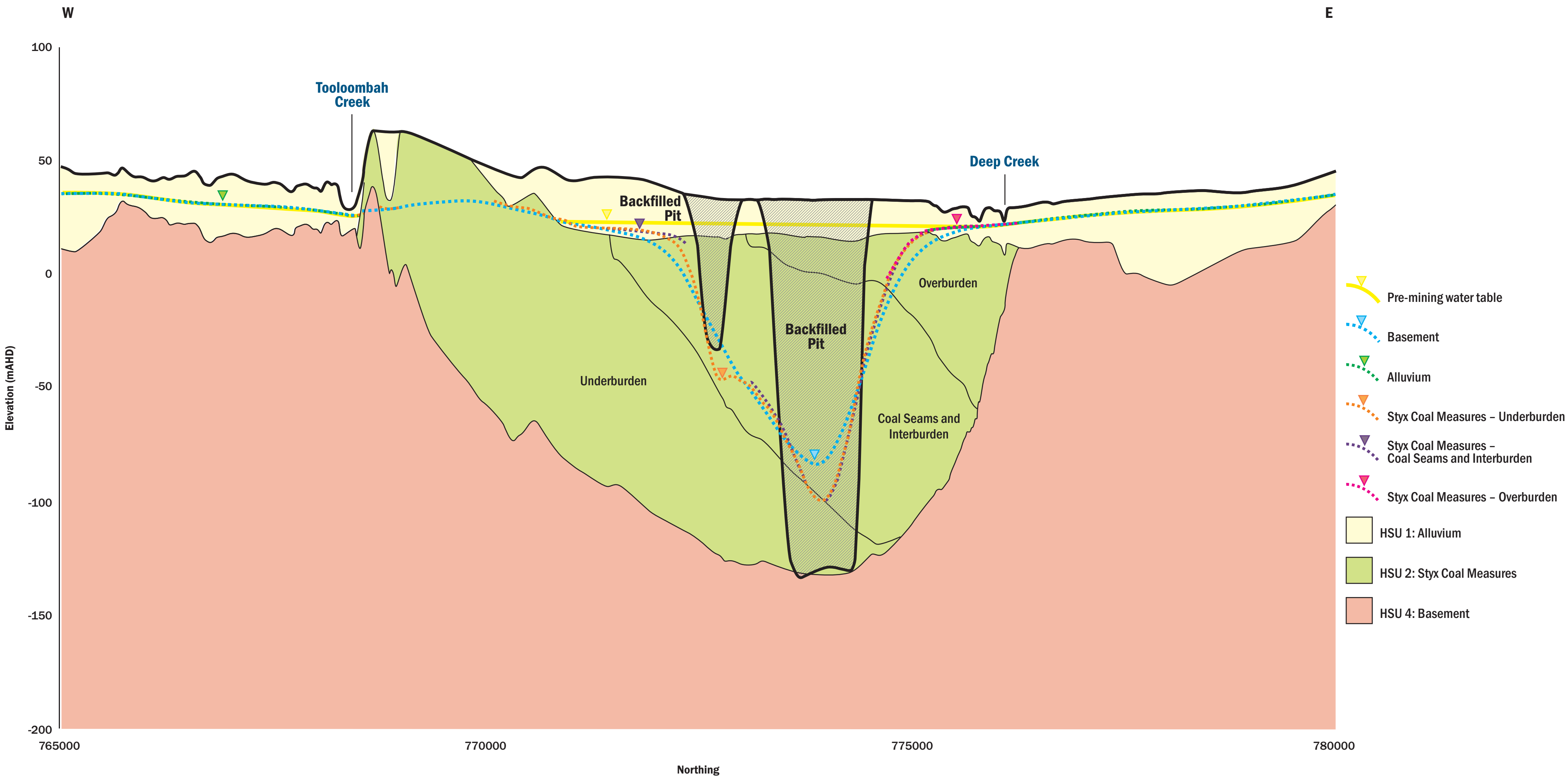


Figure 10-90

Cross-section showing model predicted drawdown (west to east through ML) – year 12 (maximum pit depth)

CDM Smith



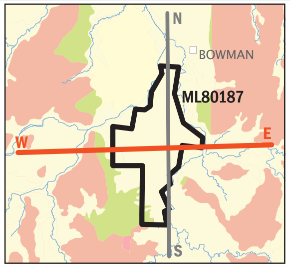
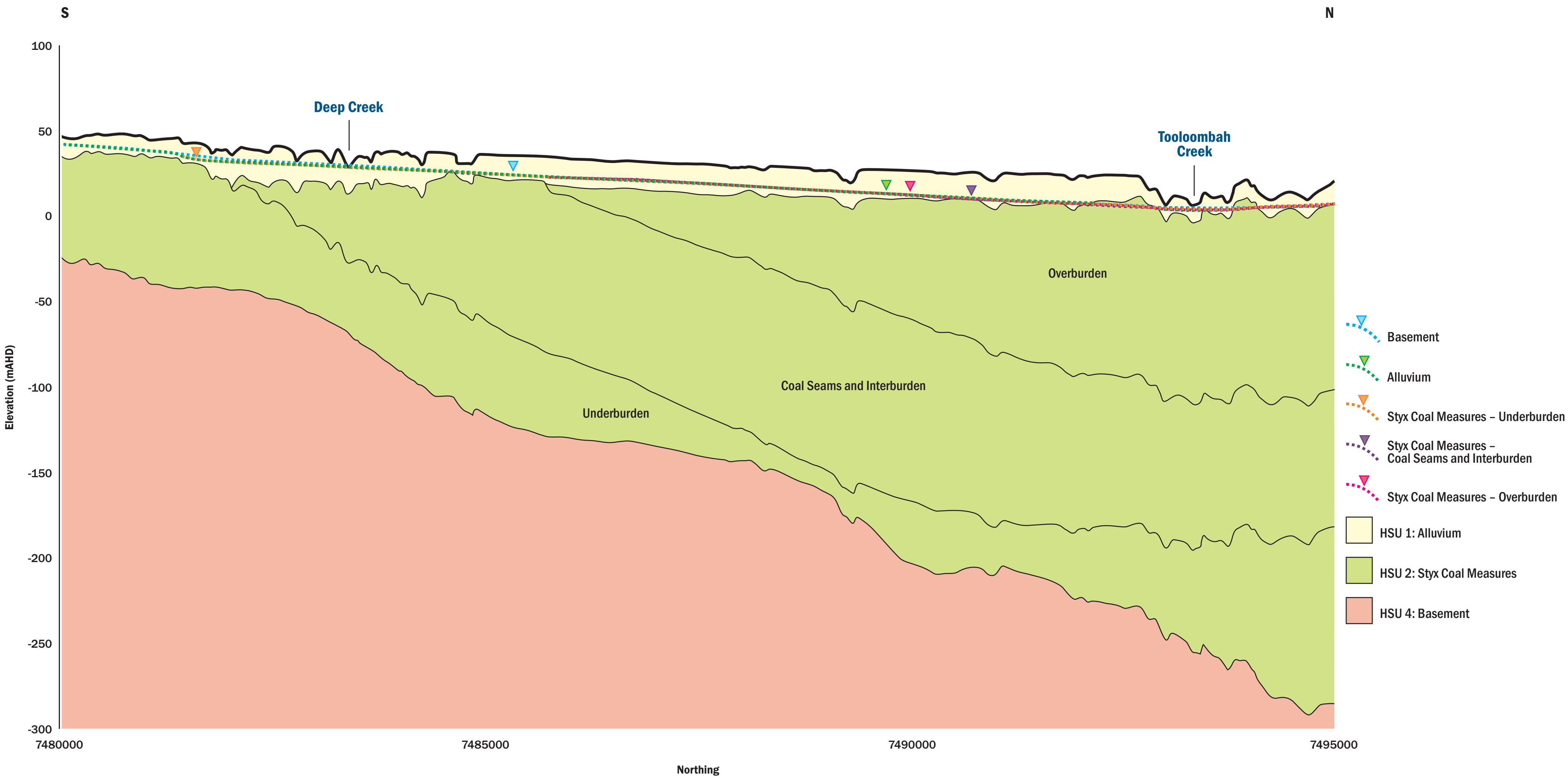


Figure 10-91
Cross-section showing model predicted drawdown (west to east through ML) – at end of mining

CDM Smith



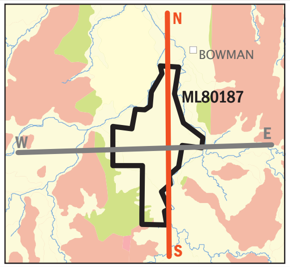
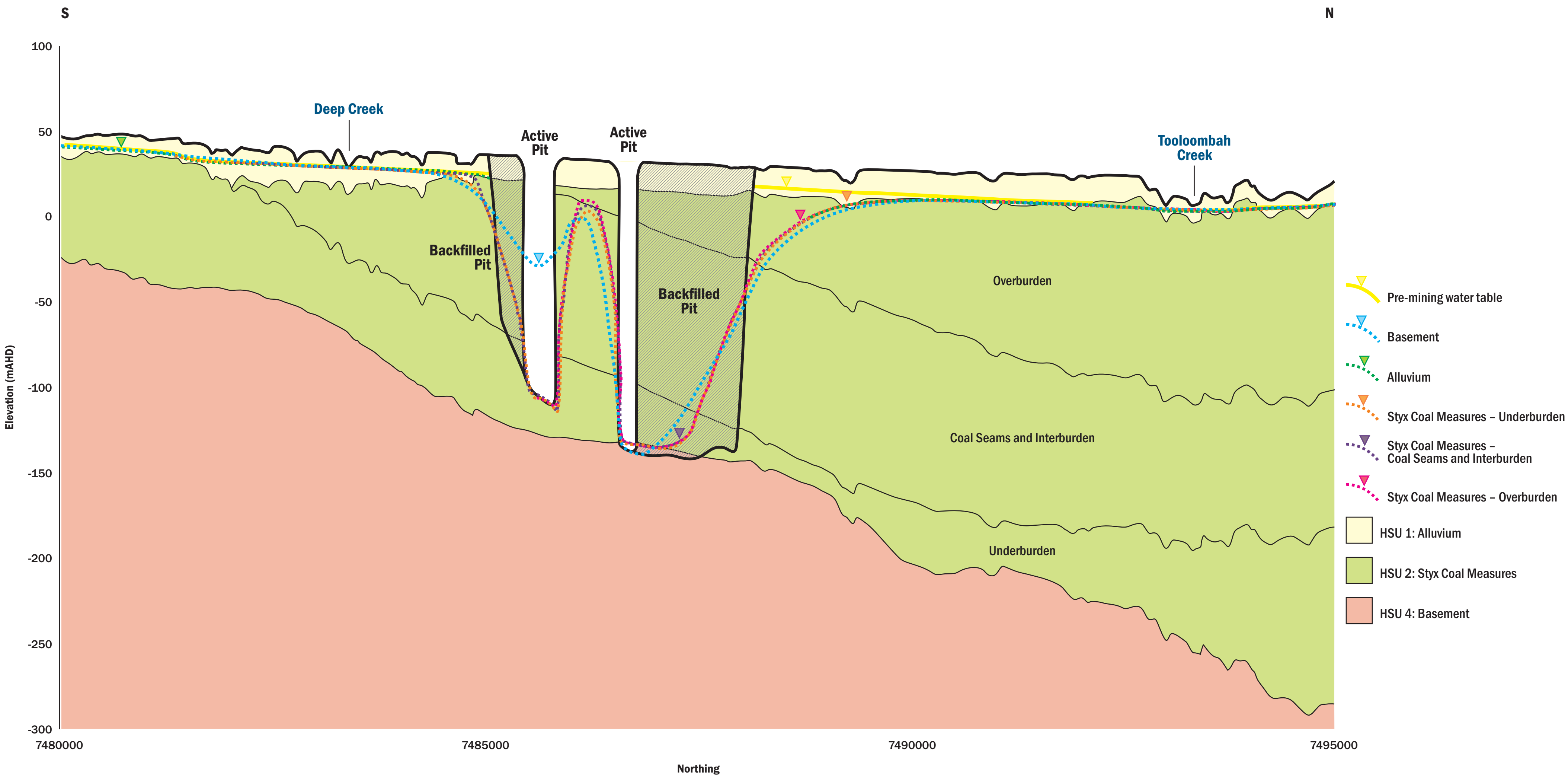


Figure 10-92
Cross-section showing model predicted pre-mine potentiometric surface (south to north through ML)

CDM Smith



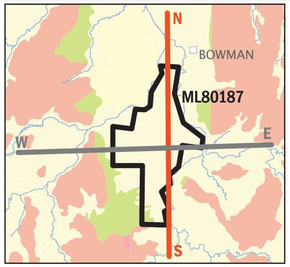
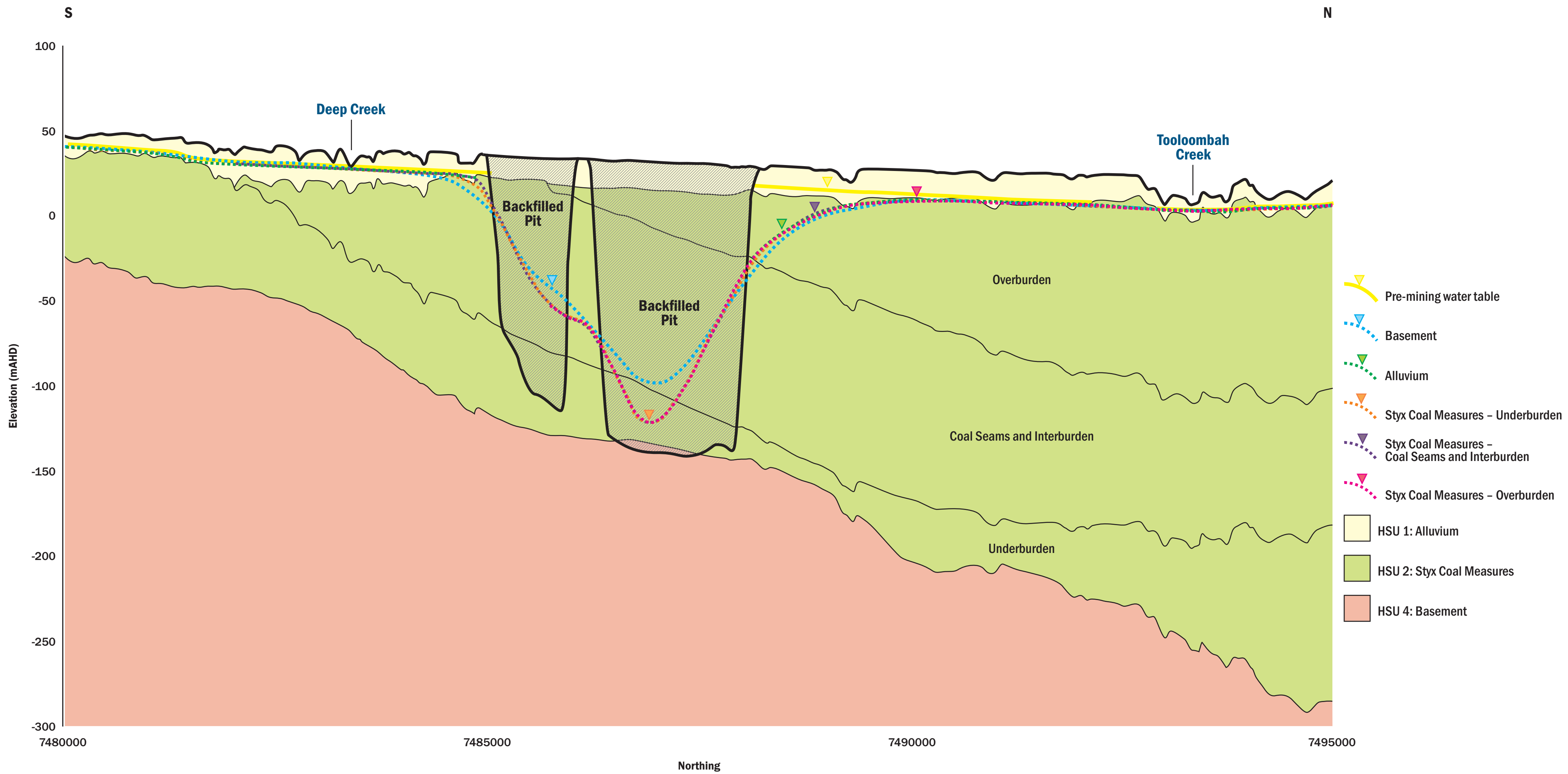


Figure 10-93

Cross-section showing model predicted drawdown (south to north through ML) – year 12 (maximum pit depth)

CDM Smith



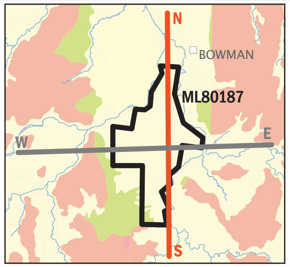


Figure 10-94

Cross-section showing model predicted drawdown (south to north through ML) – at end of mining

CDM Smith

10.7.4.3 Dewatering and Depressurisation

Model predicted dewatering rates presented on Figure 10-95 indicate the peak dewatering rate of around 640 ML/yr will be reached in year 10, rising from around 340 ML/yr at commencement of mining and declining to less than 50 ML/yr at completion of mining. The cumulative abstraction over the life of mine is predicted to be around 5,500 ML (Figure 10-95).

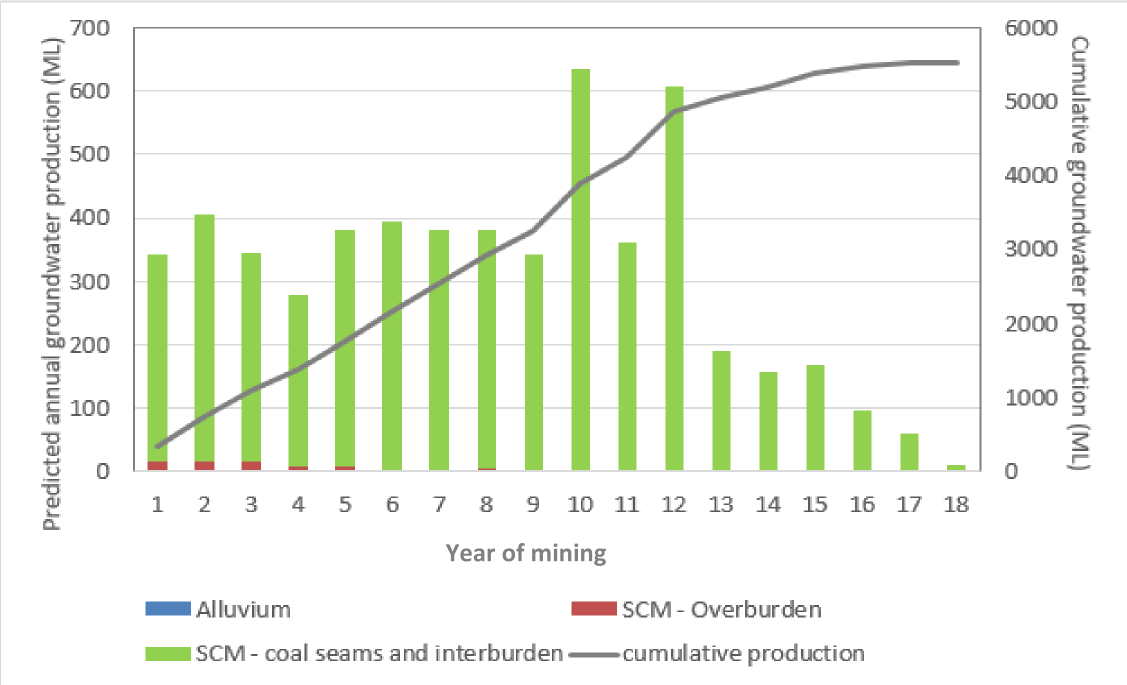


Figure 10-95 Predicted groundwater abstractions (North and South Pits)

Active dewatering of the mine pits is designed to ensure the pits are 'dry' to assist in efficient recovery of coal. However, dewatering results in depressurisation of the local to sub-regional groundwater system - Figure 10-73 presents the predicted zone of a depressurisation / drawdown arising from dewatering (the 0.1 drawdown contour). This zone of depressurisation and dewatering effectively represents the predicted 3,800 ML of water abstracted from the groundwater system over the life of mine.

Figure 10-93 presents a schematic of the potentiometric surface profile for each HSU at the time when both pits 1 and 2 are at their maximum mined depth and dewatered, and the backfilled pits are beginning to recover but remained dewatered to some extent. Adjacent to the mine pits the basement, and all but the overburden sequence of the Styx Coal Measures are depressurised, i.e. they remain almost to fully saturated but pressures are lower than the pre-mine condition (Figure 10-92).

10.7.4.4 GDEs

Type 1 (subterranean)

Stygofauna have only been identified at one location within the predicted 1 m drawdown contour resulting from active dewatering of the mine (bore STX 093; Figure 10-57), but it is expected there are other locations along Tooloombah and Deep Creeks where stygofauna may be present. At this location, and others where more than 10 m of drawdown is predicted for watercourse alluvial aquifers (see Figure 10-66), it is predicted that up to 90% or more of potential stygofaunal habitat will be lost during mining and for some time after closure. However, streamflow recharge can be expected to mitigate this loss of habitat to some extent.

Mine dewatering has the potential to adversely impact on stygofauna habitat in those areas where watercourse alluvial aquifers experience drawdowns of 10 m or more. However, after mining is completed stygofaunal habitat will recover as the groundwater system recovers.

Type 2 (surface expression of groundwater)

Where drawdown occurs near to watercourses and wetlands that rely on surface expression of groundwater there is the potential for impact on the capacity of potential Type 2 GDEs to meet environmental water requirements. In the Project area, the only Type 2 GDEs that have been identified are aquatic baseflow fed Tooloombah and Deep Creek pools and the upper reach of Styx River, and to a lesser extent the estuarine lower reach of Styx River and Broad Sound.

The numerical model predicts groundwater interactions with Styx River and Broad Sound are unlikely to be adversely impacted by mine dewatering. However, it is predicted the mid- to lower-reaches of Tooloombah and Deep Creeks will experience lower rates of baseflow (seasonally and annually), as described in Section 10.7.4.2.

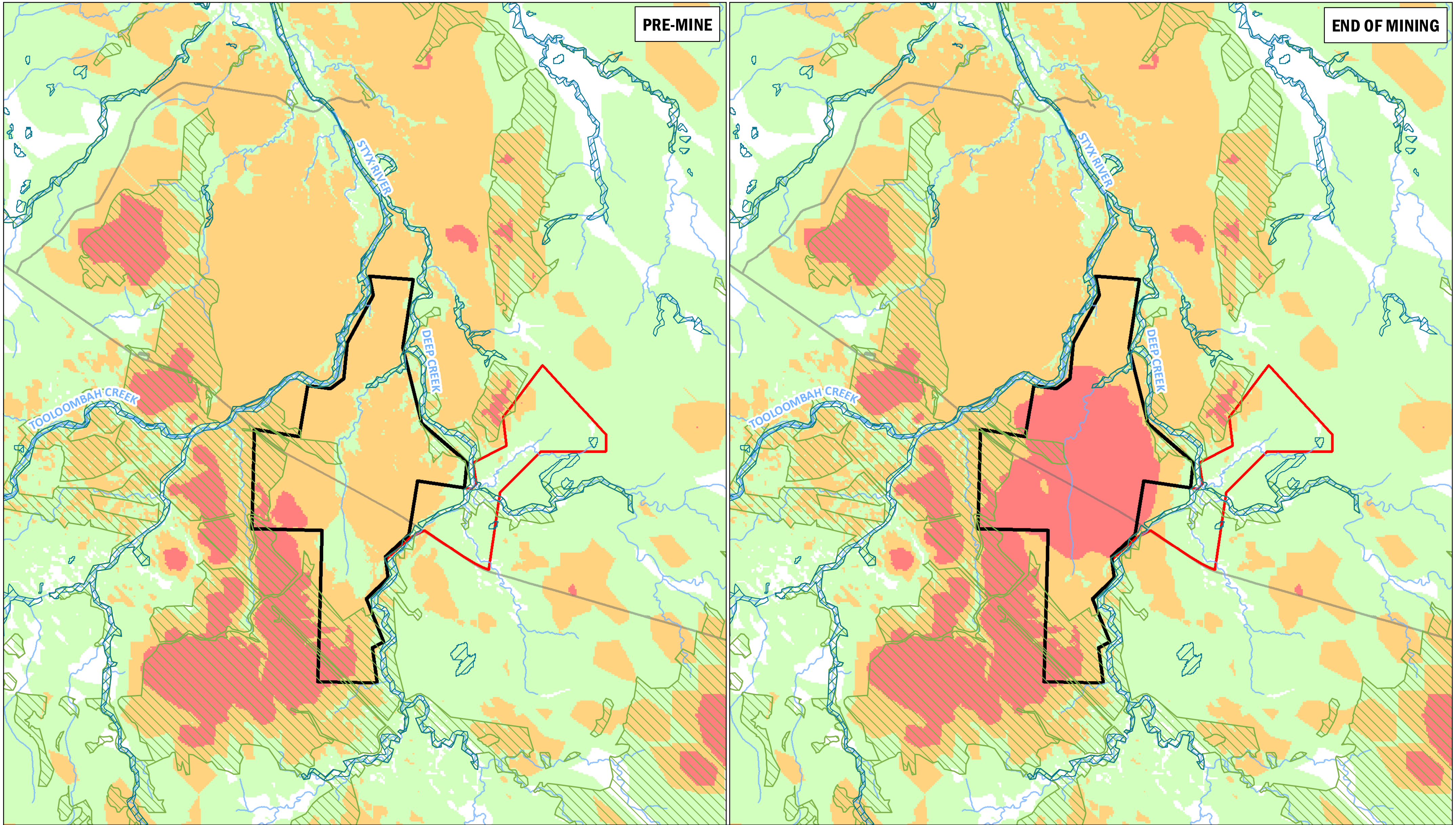
Hydrogeological conceptualisations, GDE-related studies for the Project area and model predictions (Sections 10.5.6.8, 10.6.1 and 10.7.4.2) indicate stream pools, where they occur, may be supported between wet seasons by baseflow. A water balance model has been developed for these pools to estimate the average rate of water consumption by a pool located near the northwestern boundary of ML 80187 (sample point To2; Figure 10-7). Details are presented in Appendix A6 – Groundwater Technical Report.

The water balance model indicates the amount of water required to sustain in-stream pools during the dry season is around 4 mm/d.

Type 3 (subsurface expression of groundwater)

Type 3 GDEs have been identified in the Project area, including riparian and wetland ecosystems. Studies undertaken (see Appendix A6 – Groundwater Technical Report and Section 10.6.1) indicate these GDEs rely on the soil water reservoir (vadose zone) to meet what might be regarded as their typical water requirements. However in areas where the water table is less than 10 m from the ground surface there is an indication of potential groundwater dependence, possibly during extended dry periods when the soil water reservoir becomes depleted. Figure 10-96 presents a map showing ranges of pre-mine and life of mine water table depth overlain on potential GDE type occurrences, which can be used to identify likelihood of impact arising from mine-related drawdowns.

Apart from existing pre-mine areas where the depth to water table is greater than 20mbgl (Figure 10-96), the predicted additional area where the depth to water is greater than 20mbgl due to mine water affecting activities is largely constrained to ML 80187 and ML 700022. This is also the case for areas where the depth to water is greater than 10mbgl



N

0 2 4 km

Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Legend

Depth to water table

- <5 m
- 5–10 m
- 10–20 m
- >20 m

- Type 2 GDE – Surface Expression of Groundwater
- Type 3 GDE – Subsurface Expression of Groundwater

- ML 80187
- ML 700022
- Major watercourse
- Main road

Figure 10-96
Comparison between depth to water table pre-mine and at end of mining

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111_DTW comparison__premine-EOM-2036 r2.mxd 12/20/2018

10.7.4.5 Acid Sulphate Soil Interactions

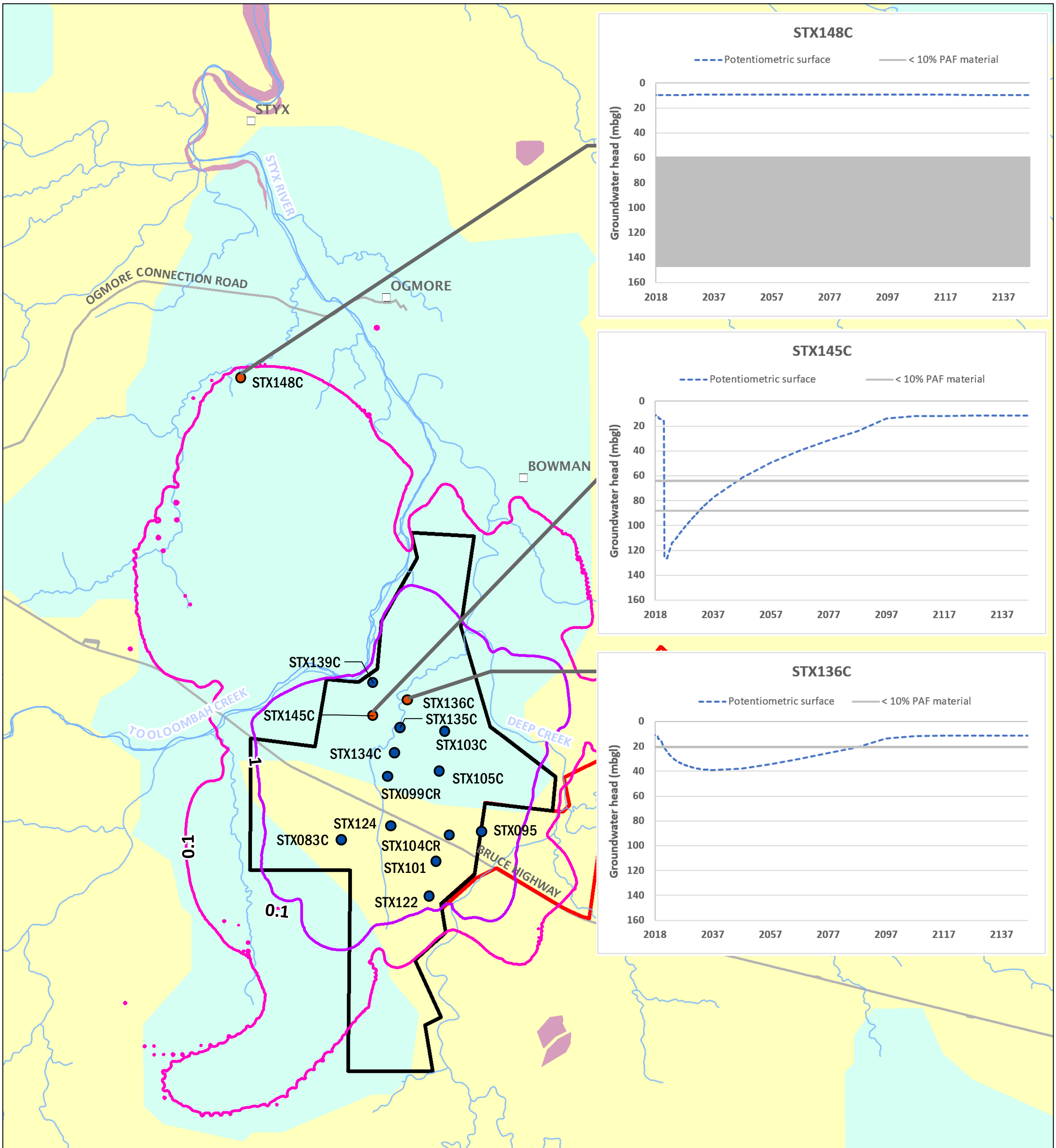
Figure 10-97 presents a map identifying the spatial distribution of ASS potential and shows the probability of ASS in the Project area is low to extremely low. Also presented is the predicted maximum drawdown contours (0.1 and 1 m), and mineral exploration holes where the potential for acid generation from encountered geological materials has been tested (sample depth range and depth where Potentially Acid Forming (PAF) materials have been identified.

Geochemical testing indicates predominantly Non-acid Forming (NAF) materials (less than 10% PAF materials) have been identified, which is consistent with the mapping undertaken by CSIRO (Fitzpatrick et al. 2011). Note that the predominantly NAF materials are logged as occurring more than 15 m below ground surface within the Styx Coal Measures. The testing also indicates the waste rock has some neutralising capacity (see Section 10.5.5.3).

The hydrographs presented on Figure 10-97 show the depth intersection of largely NAF materials as well as :

- Outside the ML (one location), PAF materials occur more than 40 m below the water table at all times during and following mining, which is more than 40 m below predicted drawdown depth;
- The full drawdown intersection at one location (STX145C, within Open Cut 2) might expose some material having a low probability of PAF material. However this will be mined; and
- Some exposure of low probability of PAF material may occur very close to the northern limit of Open Cut 2 pit (STX136C) due to drawdown. However, this will also be mined.

The analysis indicates the potential for ASS exposure in response to mine dewatering is low. The areas most at risk of exposure of ASS occurs within the ML where drawdowns of more than 10 m are predicted, and any development of acid drainage in this area will drain toward the mine pits during mining and post-mining recovery. Back filling of mine pits with materials having neutralising capacity will provide adequate management of this risk.



Styx drillhole geochemical characterisation

- 0% PAF (NAF)
- <10% PAF

CSIRO Probable ASS Class

- High probability of ASS occurrence
- Low probability of ASS occurrence
- Extremely low probability of ASS occurrence

Borehole	No. of samples	Sample depth range (m)	Lithology of PAF samples	Sample classification
STX136C	11	14 - 74.6	Sandstone (Pyritic) (20.35 - 20.6 m)	91% NAF and 9% PAF
STX145C	17	14 - 128.6	Mudstone/Siltstone (64 - 64.5 m) and Siltstone (87.8 - 88.2 m)	94% NAF and 6% PAF
STX148C	11	59.6 - 147	Sandstone (Pyritic)	79% NAF, 14% uncertain and 7% PAF (low capacity)

N

0 1 2 km

Scale @ A4 1:100,000
Date: 28/11/18
Drawn: A. Aird

Legend

- 0.1m predicted drawdown
- 1m predicted drawdown
- Watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-97
Maximum predicted water table drawdown extent and potential occurrence of ASS

DATA SOURCE
QLD Open Source Data, 2018;
CSIRO, 2011;
Geofabric v2.1, Bureau of Meteorology, 2012

CDM Smith

10.7.4.6 Seawater-Freshwater Interface Interaction

Hydraulic head and salinity data for the nested WMP29 monitoring bores (Figure 10-27 and Table 10-15), located near Ogmore on Styx River close to Broad Sound indicates underflow toward the coast, and no presence of the seawater-freshwater interface at this location (which must be located closer to the coast).

Regardless, in terms of potential mobilisation of the seawater-freshwater interface due to mine dewatering and associated drawdown, the predicted drawdown data do not indicate this is a likely outcome. Figure 10-93 and Figure 10-94 present south-north aligned cross-sections through ML 80187 that show the HSUs and the model predicted potentiometric surfaces for each of the HSUs at year 12 and at the end of mining. Also, overlain on these cross-sections is the model predicted pre-mine water table surface. The cross-sections show that at the most northerly extent (around the upper reach of Styx River) there is unlikely to be any measurable drawdown in response to mine dewatering that can induce inland mobilisation of the seawater-'freshwater' interface, whether it be located near the point of discharge of Styx River into the Broad Sound estuary or closer to the coast at Broad Sound.

The predicted zone of drawdown is restricted to the southern and western side of Styx River. Vertical hydraulic gradient data for the WMP29 nested monitoring bore site show no indication of a seawater-freshwater interface in this location. As such, the potential for seawater intrusion in response to mine dewatering is considered low to negligible.

10.7.4.7 Numerical Model Sensitivity and Uncertainty Testing

Model parameter sensitivity

Model parameterisation

Model calibration sensitivity to hydraulic properties has been tested using parameter estimation software. Details of the analysis are provided in Appendix A6 – Groundwater Technical Report and show the numerical groundwater model is most sensitive to the hydraulic conductivity (K) of the Styx Coal Measures underburden and the alluvium, and recharge rate. The model is least sensitive to specific yield (Sy) of the basement and alluvium and the K of the Styx Coal Measures coal seams/interburden.

In terms of the hydraulic properties the calibration is least sensitive to HSU properties having the least number of observation points. The original model was shown to be least sensitive to the adopted values of Sy of the Basement and Alluvium, and to the K of the Coal Measures coal seams/interburden. Subsequently, additional bores (including nested completions) were installed within the Coal Measures coal seams/interburden and other Coal Measures units to address this issue. Sy has been conservatively represented as 0.01 (alluvium) and 0.005 (Coal Measures and basement), and S has been conservatively represented as $5x10^{-6}$. Sy and S have not been not adjusted for any model runs.

Climate variability

The calibrated model assumes average recharge conditions over the 20 years of mining and 100 year post closure recovery period, including pre-mine initial conditions. It is recognised that climate variability is 'normal' for the Project area, as it is for many parts of Australia, e.g. the number and intensity of cyclones that develop off northeastern Australia is widely variable between years and decades.

Figure 10-3 presents monthly CDFM rainfall data for Strathmuir (BoM Station 033189) and Rockhampton Aero (BoM Station 039083) for the period January 1941 to February 2018 (77 years).

The plot shows intra-decadal trends of above average rainfall are typical and, significantly, inter-decadal trends of below average rainfall are not uncommon. Modelling of an extended drought period during the course of mining (20 years) has been undertaken to conservatively test model sensitivity to lower rates of recharge that would be expected under drought conditions (flood recharge as well as diffuse recharge to the alluvium and outcropping basement, where it occurs). Also, a limited above average rainfall period (over 5-years from start of mining) has been simulated to assess groundwater system response to a temporarily wetter climate.

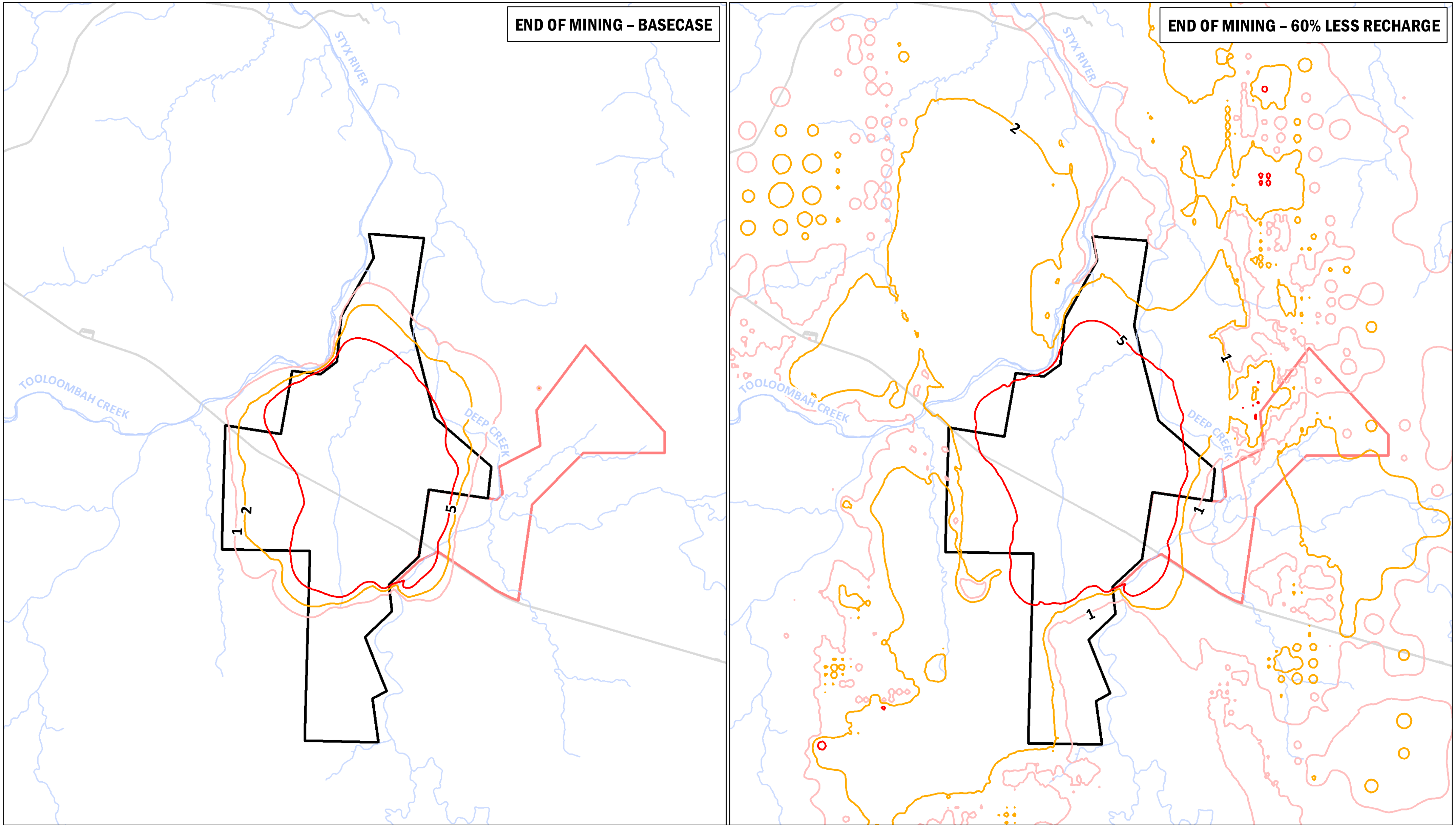
The results show:

- Under drier climate conditions (see Appendix A6 – Groundwater Technical Report, Figure 3-68 to Figure 3-70), there is a predicted ‘general’ drawdown across the entire model domain of between 0.1 to more than 2 m that is attributable to lower rates of recharge with progressively more drawdown predicted for progressively drier conditions (i.e. moving from 15% less recharge through to 30% and 60% less recharge), as would be expected. However, the model predicted 5 m drawdown remains relatively unchanged between the different drought scenarios when compared against the base case mining / average rainfall scenario, indicating the additional ‘cumulative’ effect of mine dewatering is negligible; and
- For above average recharge conditions (see Appendix A6 – Groundwater Technical Report, Figure 3-71), there is basically no change predicted from basecase mining average recharge scenario, except isolated areas where drawup is predicted.

Backfill material hydraulic properties and Hydraulic loading of shallow sediments

Backfilling of mine pits with coal rejects and waste rock may mean the backfilled materials has hydraulic properties that differ from in-situ materials. If this is the case, it is likely that K and S values will be higher than in-situ values but not significantly different due to compaction occurring as the backfill materials are placed back into the pits as well as mixing of materials during mining and backfilling. To assess the possible effects of this outcome, a simulation has been undertaken where the K of backfilled materials is twice that of the overburden ($4x10^{-2}$ cf. $2x10^{-2}$ m/d) and Sy is an order of magnitude higher ($5x10^{-2}$ cf. $5x10^{-3}$).

Along with the assessment of the effects of backfilled materials having different hydraulic properties compared to in-situ materials, an assessment of the potential for stockpiling and waste storage hydraulic loading of shallow sediments has also been undertaken. If hydraulic loading occurs, there will likely be a reduction in hydraulic properties and, to assess the possible effects, the K and Sy of alluvium beneath these storages have been simulated as half that of the basecase ($2x10^{0}$ cf. $4.1x10^{0}$ m/d, and $5x10^{-3}$ cf. $1x10^{-2}$, respectively).



N

0 1 2 km

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

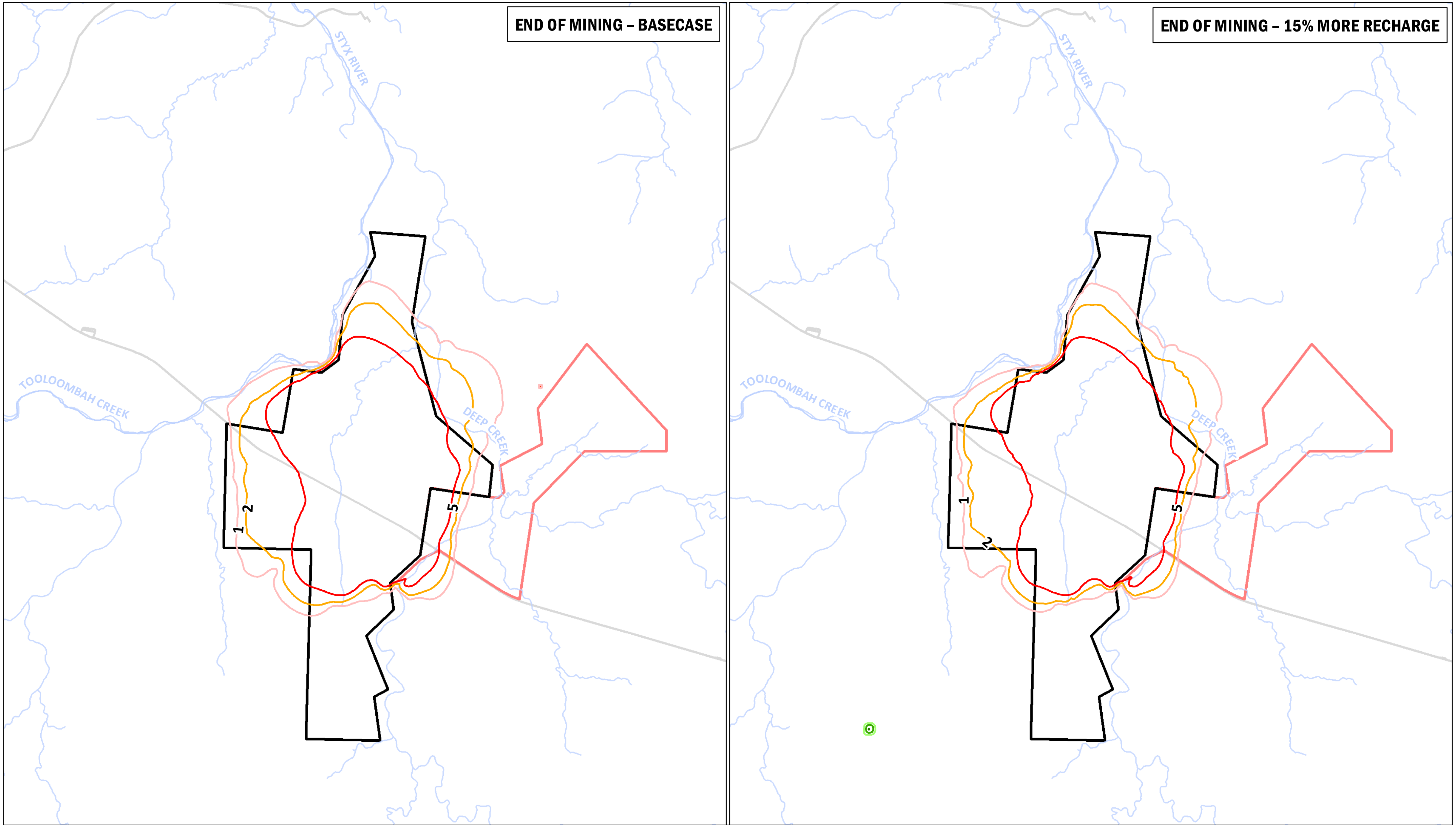
Scale @ A4 1:100,000
Date: 20/12/18
Drawn: Gayle B.

Figure 10-98

Predicted potentiometric surface drawdown contours, drought period scenario at end of mining compared to basecase end of mining

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

CDM Smith



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Scale @ A4 1:100,000
Date: 20/12/18
Drawn: Gayle B.

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-99

Predicted potentiometric surface drawdown contours, above average recharge scenario at end of mining compared to basecase end of mining

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT wet scenarios 15p more recharge during LOM r4.mxd 12/20/2018

The combined spatial distributions of and changes to hydraulic properties of stockpiles, waste landforms and backfill materials result in a subtle NW-SE elongation of the predicted zone of drawdown, with the 1m drawdown contour passing through Tooloombah Creek (which would have additional effect on Type 2 and Type 3 CDES located in this area; Figure 10-100). However the extent of drawdown (as indicated by the 0.1m contour) remains similar to the base case (which simulates no backfill or hydraulic loading) and emphasises the extent of the drawdown cone is mainly controlled by the properties of the coal seams and interburden.

This assessment can be considered conservative, as it assumes the backfill material is dry when it returns to the pit, although in reality the backfill material will be wet.

Model uncertainty

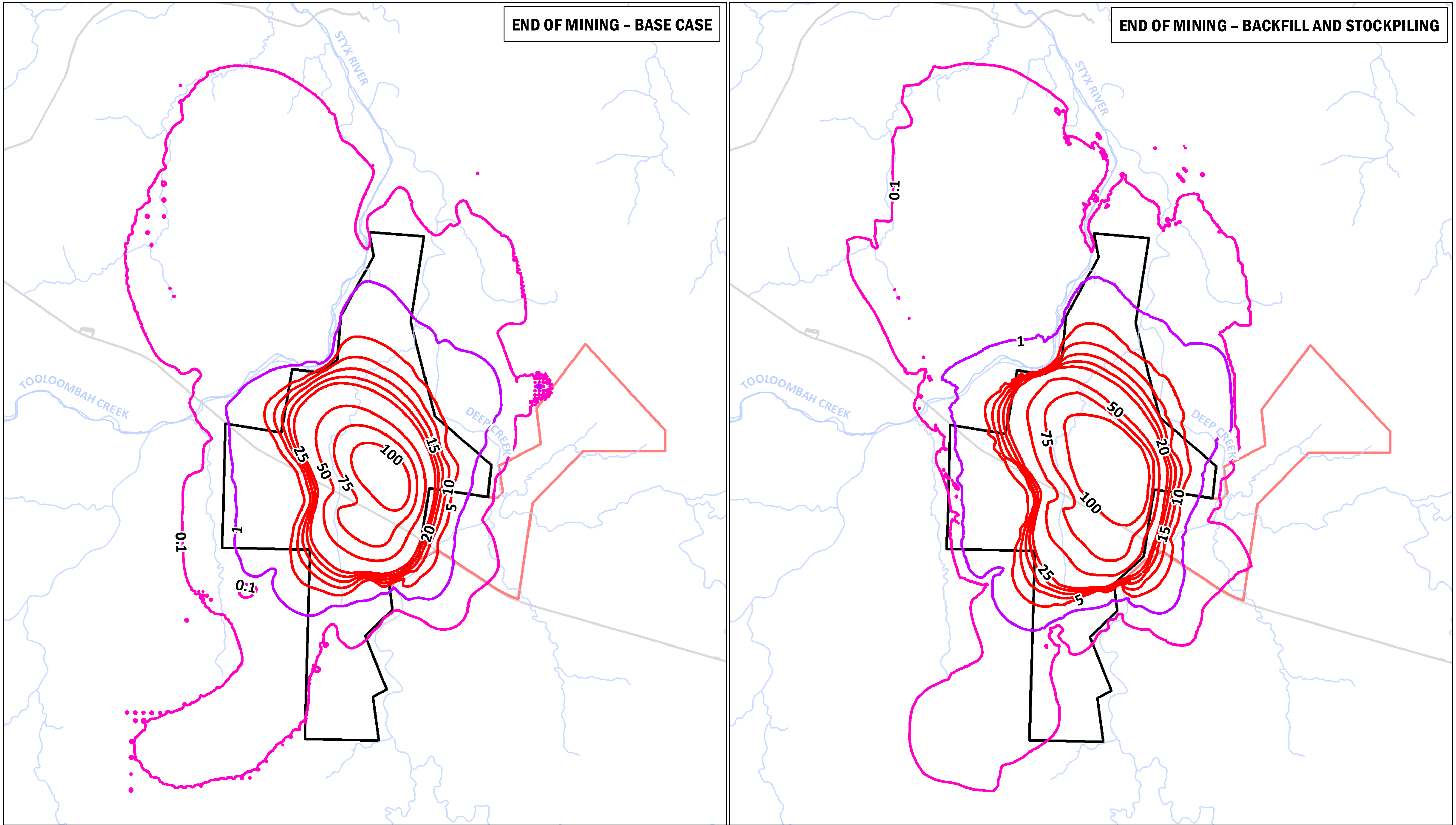
As there is often non-uniqueness in relation to combinations of simulated hydraulic properties that achieve an acceptable calibration, the model has been tested for predictive uncertainty relating to this issue, where different combinations of hydraulic properties have been varied within acceptable ranges based on observations of the groundwater system, results of aquifer testing and the literature. A total of 190 predictive uncertainty scenarios have been simulated including models that assess an extended range of hydraulic properties (essentially representing alternative hydrogeological conceptualisations) whilst maintaining an acceptable calibration. In addition, an alternative mining schedule (that generally advances south to north rather than east to west (see Appendix A6 – Groundwater Technical Report, Table 3-9 and Figure 3-63 for the modelled alternative mining schedule) was tested to ascertain if different mine plans & schedules having the same tonnages might impact model predictions.

Details of the assessment of predictive uncertainty are detailed in Appendix A6 - Groundwater Technical Report. The following presents a summary of the outcomes:

- 190 alternative predictive simulations have been simulated to identify possible parameter combinations that maintain an acceptable calibration, and a strong correlation between hydraulic heads and recharge rates was observed, as would be expected;
- Analysis of the effect of varying the K of different HSUs across a broad and conservative range of values has on model calibration and the related extent of drawdown has been undertaken. 106 simulations have been undertaken to test this effect;
- Compared to the basecase calibrated model, peak mine dewatering rates might range between 180 and 1,300 ML/yr:
  - the highest predicted dewatering rate requires K values of all HSUs and recharge rates to be more than half an order of magnitude higher than the adopted values (Table 10-78), which is considered unrealistic
  - the lowest predicted dewatering rate requires K values of all HSUs and recharge rates to be more than half an order of magnitude lower than the adopted values (Table 10-78), which is also considered unrealistic
- Compared to the basecase calibrated model, the spatial extent of drawdown is shown to not be particularly sensitive to the ratio of Kh/Kv, where a ratio of 10 and 100 for the Styx Coal Measures was assessed, and tends to show the isotropic condition (Kh/Kv =1) offers a more conservative outcome;

- Compared to the basecase calibrated model, all predictive uncertainty analyses indicate drawdown associated with mine water affecting activities will not extend to areas where potential ASS might be exposed;
- Compared to the basecase calibrated model, the simulated mining schedule and plan predicts a slightly more conservative outcome than the alternative plan and schedule described above; and
- In terms of the hydrogeological conceptualisation adopted for the model:
  - the predictive uncertainty analysis supports the conceptualisation that the combined Tooloombah Creek and Deep Creek catchment is essentially a closed groundwater catchment
  - the calibrated model is representative of the simulated groundwater system.

The uncertainty analysis detailed in Appendix A6 – Groundwater Technical Report explores various combinations of parameters that maintain model calibration. Uncertainty testing in relation to combinations of modelled hydraulic properties has shown there are no parameter sets that trigger sgnificant drawdown near the coast or at the confluence of Tooloombah and Deep Creeks.



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Date: 20/12/18
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0 1 2 km

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 10-100

Predicted potentiometric surface drawdown contours, backfill and hydraulic loading scenario at end of mining compared to basecase end of mining

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DD stockpile scenarios comparison LOM yr 18 EOM r2.mxd 12/20/2018

Alternative conceptualisations (further uncertainty testing)

To complement the uncertainty analysis, an assessment of alternative conceptualisations that might result in significant impact on the study area groundwater system(s) has been undertaken (essentially a "breaking point" assessment). This assessment explores the conditions necessary to trigger significant drawdown to impact on the receiving environment downstream of the confluence of Tooloombah and Deep Creeks (to Styx River, Broad Sound and the coast, potentially triggering sea water intrusion and exposure of ASS). The assessment is based on model predictions at two locations – the confluence of Tooloombah and Deep Creeks, and where Styx River discharges to Broad Sound. The alternative conceptualisation assessment also assumes recharge rates over the model domain remain unchanged from the basecase calibrated model (providing a very conservative basis for predicting impact where K for the various HSUs increases), and that storativity (S; and important constraint on the extent of drawdown at any point in time) remains the same (i.e. the lowest conceivably possible value of $5x10^{-6}$).

Seven scenarios have been tested:

1. Gradually increasing the K of the Coal Measures overburden from $1.7x10^{-3}$ to $1.7x10^{-1}$ m/d – the sensitivity assessment shows this parameter is not well constrained by the calibration and could be higher or lower.

2. Gradually increasing the K of the Coal Measures coal seams/interburden from $1.0x10^{-3}$ to $2.0x10^{0}$ m/d – the sensitivity assessment shows this parameter is also not well constrained by the calibration and could be higher or lower.

3. Concurrently increasing the K of both the overburden and coal seams/interburden across the ranges presented for scenarios 1 and 2, to test a combined predictive uncertainty.

4. Concurrently increasing the K of the combined Coal Measures (over-, inter- and underburden materials) across the ranges presented for scenarios 1 and 2, and $1.0x10^{-3}$ to $1.0x10^{-1}$ m/d for the underburden - the sensitivity assessment shows the K of the underburden is also not well constrained by the calibration.

5. Gradually increasing the K of the Alluvium from $4.1x10^{0}$ to $1.5x10^{2}$ m/d – the sensitivity assessment shows this parameter is not well constrained by the calibration, and the inferred water table contours along the watercourses might be explained by a higher K value.

6. Gradually increasing the K of the Basement from $4.0x10^{-4}$ to $4.4x10^{-2}$ m/d – the sensitivity assessment shows this parameter is well constrained by the calibration.

7. Concurrently increasing the K of all HSUs across the ranges presented for scenarios 1 through 6, to test a combined predictive uncertainty.

The following presents a summary of the outcomes, and details are presented in Appendix A6 – Groundwater Technical Report:

- The K of the Alluvium, Coal Measures over- and underburden, and Basement provides negligible predictive uncertainty for the model;
- The K of the Coal Measures coal seams/interburden provides the greatest predictive uncertainty for the model;
- Near the coast (where Styx River discharges to Broad Sound) a predicted drawdown of more than 0.5 and 2 m is triggered when the coal seams/interburden K exceeds 0.5 and 2 m/d, respectively -

this is true whether coal seams/interburden hydraulic conductivity is increased alone or in conjunction with other units; and

- At the confluence of Deep and Tooloombah Creeks a drawdown of more than 5 m and 25 m is triggered when coal seams/interburden K exceeds 0.5 and 2 m/d, respectively - this is true whether only the coal seams/interburden hydraulic conductivity is increased or when it is in conjunction with other units.

The following summary conclusions remarks can be derived from the alternative conceptualisation assessment:

- Under- or over-estimation, by association, of alluvium, overburden, underburden and basement K has only limited predictive consequence regarding the predicted extent of drawdown arising from mine dewatering;
- The predicted extent of drawdown within the Styx Basin is mainly controlled by Coal Measures coal seams / interburden K;
- Where the Coal Measures coal seams/interburden K values are simulated above $1x10^{-2}$ m/d, model calibration deteriorates progressively to a point where K values above $2x10^{-1}$ m/d would be considered unrepresentative (see Appendix A6 – Groundwater Technical Report, Figure 3-71); and
- A regional Coal Measures coal seams/interburden K value of $1x10^{-2}$ m/d or less would be considered representative[1]. For this range of coal seams/interburden hydraulic conductivity, the cone of drawdown remains within the vicinity of the mine as predicted by the basecase calibrated model, with drawdown at the confluence of the two creeks only likely to ever be less than 0.5 m and much less than 0.01 m where Styx River discharges Broad Sound.

Sensitivity testing and uncertainty testing of the model has revealed Coal Measures coal seams/interburden K is the most critical of the modelled hydraulic properties for impact assessment. It carries most of the predictive uncertainty in terms of the extent of the predicted drawdown. To maintain reasonable calibration though, a representative regional value of Coal Measures coal seams/interburden K ought to be lower than 0.01 m/d, which is predicted to result in the spatial and vertical extent of drawdown remaining consistent with that predicted by the basecase model.

The alternative conceptualisation assessment shows the values of Coal Measures coal seams/interburden K required for a significant impact to occur downstream of the Project are not supported by field observations or the general understanding of coal bed hydrogeological characterisation (see Section 10.5.6.3 for further discussion).

10.7.4.8 Receptor Exposure and Threat Assessment

The assessment of receptor exposure to altered groundwater conditions and the threat posed to those receptors is based on the analysis and findings described in Section 10.7.4.2 through Section 10.7.4.4. An overview of the linkages between the potential direct groundwater effects of mining and EVs is summarised in Table 10-76. More detail is presented in the following sub-sections.

[1] But any change to the range presented for the basecase calibrated model would require an adjustment of recharge rates (by approximately the same range)

The EVs listed in Table 10-1, Table 10-76 and Table 10-77 identify the potentially sensitive receptors that may be adversely impacted by mine water affecting activities. The EVs carried through to the assessment presented in this Section are stock groundwater supplies, aquatic ecosystems (Type 2 GDEs), and 'other' (stygofauna, wetlands, and terrestrial and riparian vegetation; Type 1, 2 and 3 GDEs). The protection of any Cultural and spiritual EVs that may be present in the Project area will be undertaken through the Cultural Heritage Management Plans that are being developed for the Project with the relevant Indigenous parties.

Altered groundwater quantity (drawdown, head, flux) and altered interactions between groundwater and surface water (and connected systems) are considered the primary threatening processes for all receptors, whereas altered groundwater quality and aquifer disruption are considered secondary threatening processes. For all indirect effects, however, a threat assessment needs to consider the following:

- Scale of direct effect:
  - Spatially, e.g. the extent an 'at risk' ecosystem is exposed to an adverse impact
  - Temporally, e.g. will any adverse impact be realised for only a limited period, or will it be permanent; and
- Capacity for adaptation to altered conditions:
  - Resistance describes the ability of ecosystem components to resist impact by, for example by switching to an alternate water source (vegetation), translocating (stygofauna moving deeper into an aquifer) or via a physiological adaptation (stomatal control in plants)
  - Resilience describes the degree to which groundwater is relied upon to maintain ecosystem function. Stygofauna and most baseflow maintained aquatic ecosystems, for example, will have an obligate reliance whereby removal of access to groundwater will be detrimental. Terrestrial vegetation, though, typically have a facultative reliance, relying on the soil reservoir and only use groundwater when the soil reservoir is depleted.

Table 10-79 presents a summary of direct effects (hazards) carried through to the receptor exposure and threat assessment. The selection is based on whether or not there are engineered controls or management approaches that can be employed to mitigate / remove exposure of receptors to threatening processes, if there are then the applicable direct effects are not addressed further.

Table 10-79 Direct effects carried through to the receptor exposure and threat assessment

Direct effect	Included / excluded from assessment
▪ Open pit mining / excavation	☑ Dictated by the extent of the mineable resource
▪ Backfilling	☑ Has potential issues associated with geochemistry
▪ Mine dewatering / depressurisation	☑ Dewatering required to allow access for mining
▪ Groundwater supply development	☐ No groundwater supply, other dewatering, proposed
▪ Open pit (post-closure)	☐ Pits progressively backfilled during mining
▪ Stockpiling & waste storages	☑ Facilities required for materials management
▪ Water storages	☑ Facilities required for water management
▪ Equipment, containment and pipeline failure	☐ Controlled management through engineering design and management plans
▪ Interconnection of aquifers (bores)	☐ Controlled management through application of National guidance
▪ Disruption / diversion of surface drainages	☐ No major diversions or disruptions to major drainages proposed

Notes: ☑ Included ☐ Excluded

The following tables provide summary details of predicted direct effects and the associated receptor exposure (pathways) and threat assessments for the Project - Table 10-80 (groundwater quantity), Table 10-81 (groundwater quantity), Table 10-82 (groundwater and surface water interactions) and Table 10-83 (physical disruption of aquifers).

Table 10-80 Summary details effects, receptor exposure assessment and threat assessment - groundwater quantity

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
WATER TABLE SURFACE AND GROUNDWATER FLOW DIRECTION ▪ Pre-mine: - Predicted pre-mine steady state water table contours are consistent with inferred water table contours (Figure 10-20), with regional groundwater flow to the north (toward coast), and a large component of local groundwater flow occurring toward watercourses (baseflow and ET) ▪ During mining: - Mid-catchment of Tooloombah and Deep Creeks - Predicted water table contours during mining show groundwater flow is diverted to the mine pit (due to dewatering / depressurisation) (Figure 10-64 to Figure 10-66) - Lower catchment of Tooloombah and Deep Creeks, Styx River and Broad Sound estuary - Predicted water table contours downstream of ML 80187 remain similar to the pre-mine condition (Figure 10-64 to Figure 10-66) - The limited predicted extent of drawdown effect, if any, on groundwater flow fields in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks indicates the potential for seawater intrusion is negligible (see 10.7.4.6) ▪ Post-mine: - Mid-catchment of Tooloombah and Deep Creeks - Predicted water table contours show continued recovery of groundwater storage in Project area up to 50 years post-mining, full recovery occurs between 50 and 100 years post-mining (Figure 10-67 and Figure 10-70). - Lower catchment of Tooloombah and Deep Creeks, Styx River and Broad Sound estuary - Predicted water table contours downstream of ML 80187 remain similar to the pre-mine condition (Figure 10-67 to Figure 10-70) - Placement of backfill materials assumes dry materials, a very conservative assumption as full recovery will be aided by fact that materials returned to pits will be partially saturated (above zero) **DRAWDOWN AND DEPRESSURISATION** ▪ During mining: - The maximum predicted potentiometric surface drawdown exceeds 100m, but is restricted to ML 80187 immediately surrounding the pits - The 10m potentiometric surface drawdown contour largely remains within ML 80187 and does not extend to Tooloombah Creek or Deep Creek - The 1m potentiometric surface drawdown contour intercepts the mid portion of Tooloombah Creek and Deep Creek - The 0.1m potentiometric surface drawdown contour extends to a maximum of approximately 4.5 km northwest and 1 km southeast of ML 80187 (or a total 'elliptical' diameter of around 10 km) occurring at some time between 10 years of mining and the end of mining, as shown in Figure 10-72 and Figure 10-73) but does not intercept Styx River - The lack of drawdown in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks indicates the potential for seawater intrusion and ASS beyond the ML 80187 boundary is negligible ▪ Post-mine: - The maximum extent of the zone of influence occurs around 10 years post-mining (Figure 10-74) - The maximum predicted potentiometric surface drawdown ranges up to 100m until some time after 25 years post-mining immediately surround the backfilled mine pits, but by 50 years post-mining predicted drawdown is less than 50m and by 100 years post-mining full recovery is predicted - The predicted 10m potentiometric surface drawdown contour largely remains within ML 80187 and does not extend to Tooloombah Creek but intercepts a relatively small portion of the mid to upper reach of Deep Creek, adjacent to Open Cut Pit 1, until 50 years post mining - The predicted 1m potentiometric surface drawdown contour intercepts the mid reach of Tooloombah Creek and Deep Creek until 50 years post mining - The 0.1m potentiometric surface drawdown contour extends to a maximum of approximately 4.5 km northwest of the of the ML 80187 boundary, but does not extend to within 1 km of Styx River, at some time between the end of mining and 10 years post-mining (Figure 10-73 and Figure 10-74)	GDEs *Type 1* *Type 2* *Type 3*	 NI Aquatic ecosystems NI	▪ Type 1 GDEs: - Drawdown has potential to impact on vertical extent of stygofauna habitat - A maximum drawdown of around 13 m is predicted at the location of the bore where stygofauna have been identified (STX 093, Figure 10-57) between the end of mining and 10 years post-mine - Predicted rate of drawdown at this location is around 1.5 m/yr (Figure 10-84). Water is not suddenly removed, possibly allowing stygofauna to move deeper into the alluvium water column - At this location the alluvial aquifer is estimated to have a saturated thickness of around 15 m, corresponding to an approximate maximum 90% loss of vertical habitat over a relatively short reach of Deep Creek - No other locations where stygofauna have been detected are likely to be impacted (locations over 5 km away from nearest predicted drawdown contour) ▪ Type 2 GDEs: - Drawdown has potential to impact on baseflow rates (flux) to streams and, consequently, aquatic ecosystem function - 1 to 5 m drawdown predicted along reaches of Tooloombah Creek (mid-reach) until around 50 years post-mine (maximum predicted drawdown occurs around 10 years post-mine) - 1 to 15 m drawdown predicted along reaches of Deep Creek (mid-reach) until around 50 years post-mine (maximum predicted drawdown occurs around 10 years post-mine) - Negligible drawdown predicted along lower reaches of Tooloombah and Deep Creeks (immediately upstream of their confluence), Styx River and Broad Sound estuary ▪ Type 3 GDEs: - Drawdown has potential to impact on transpiration rates (and photosynthesis) and, consequently, riparian and terrestrial ecosystem function - Depending on location, between 0.1 and more than 10 m (limited occurrence) drawdown predicted beneath riparian GDEs, typically near to Project e.g. Forest Red Gum woodlands on drainage lines and alluvial plains (RE 11.3.4), Semi-evergreen Vine Thicket on drainage lines (RE 11.13.11, determined as not being a GDE) – the rate of drawdown along mid-reaches of both creeks is predicted to be up to around 1 m/yr (Figure 10-85), possibly allowing vegetation to adapt to the lowering water table if surface flow (and stream loss) regime is maintained - Depending on location, between 0.1 and more than 50 m drawdown predicted beneath terrestrial GDEs, typically near to Project e.g. Forest Red Gum woodlands on alluvial plains (11.3.4) – rate of drawdown at western boundary of ML is predicted to be around 0.2 m/yr, possibly allowing vegetation to adapt to the lowering water table - No drawdown predicted along lower reaches of Tooloombah and Deep Creeks (immediately upstream of their confluence), Styx River and Broad Sound estuary - Either side of Tooloombah and Deep Creeks (west and east, respectively) less than 1 m drawdown is typically predicted	▪ Type 1 GDEs: - **High** threat of adverse effects expected at location of bore STX 093, until around 25 years post-mine - **Negligible** threat of adverse impact at other locations where stygofauna have been reported ▪ Type 2 GDEs: - **Low** threat of adverse effects expected along stream reaches supporting permanent pools, within the predicted 0.1 to 0.5 m drawdown contours (Figure 10-74) - along a reach length of 3.4 km (Tooloombah Creek) and 3.3 km (Deep Creek) - **Moderate** to **high** threat of adverse effects expected along stream reaches supporting permanent pools, where predicted drawdown of more than 0.5 m occurs (Figure 10-74) – along a reach of 2.4 km (Tooloombah Creek) and 3.9 km (Deep Creek) - **Note: watercourse pools have only been observed along isolated sections of the creeks/BoM mapped potential Type 2 GDE areas, therefore the actual predicted impacted stream length will likely be less** ▪ Type 3 GDEs - Riparian - **Low** threat of adverse effects expected for riparian zones where predicted drawdown of between 0.1 and 1 m occurs (Figure 10-74) – an area of 70 Ha (Tooloombah Creek) and 65 Ha (Deep Creek) - **Moderate** to **high** threat of adverse effects expected for riparian zones where predicted drawdown of more than 1 m occurs (Figure 10-74) - an area of 3 Ha (Tooloombah Creek) and 35 Ha (Deep Creek) - **Note: Ground-truthed vegetation mapping (Chapter 15-Aquatic Ecology) of aquatic vegetation listed under the MNES (RE 11.3.25) indicates a predicted low threat to 40.3 Ha (Tooloombah Creek) and 62.4 Ha (Deep Creek) and a moderate to high threat to 8.3 Ha (Tooloombah Creek) and 34.2 Ha (Deep Creek)** - Terrestrial, where predicted pre-mine water table <10m - **Low** threat of adverse effects for terrestrial GDEs within the predicted 0.1 to 5 m drawdown contour (Figure 10-74), covering an area of 97 Ha - **Moderate** to **high** threat of adverse effects expected for terrestrial GDEs where predicted drawdown of more than 5 m occurs (Figure 10-74), covering an area of 3 Ha. - **Note: Ground-truthed vegetation mapping (Chapter 14 – Terrestrial Ecology) of terrestrial ecosystems listed under the MNES (RE 11.3.4) indicates a predicted low threat to 14.25 Ha an and no areas of predicted moderate to high threat.**

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
- The lack of drawdown in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks indicates the potential for seawater intrusion and ASS beyond the ML 80187 boundary is negligible. **PERCHED WATER TABLES / RAISED WATER TABLES** ▪ Seepage from waste management facilities: - Potential for perched water tables to form unlikely due to permeability difference between waste materials and alluvials. ▪ Hydraulic loading from waste management facilities / stockpiles: - Hydraulic loading is predicted to have negligible effect on water table elevation. **SEEPAGE RELATED DRAWUP** ▪ During mining: - Around the mine pits, the maximum predicted potentiometric surface drawdown beneath water storages exceeds 10m, which reduces the potential for water table drawup.				- Terrestrial, where predicted pre-mine water table >10m - **Low** threat of adverse effects for terrestrial GDEs within the predicted 5 to 10 m drawdown contour (Figure 10-74), covering an area of 8 Ha - **Moderate** to **high** threat of adverse effects expected for terrestrial GDEs where predicted drawdown of more than 10 m occurs (Figure 10-74), covering an area of 18 Ha - **Note: Ground-truthed vegetation mapping (Chapter 14 – Terrestrial Ecology) of terrestrial ecosystems listed under the MNES (RE 11.3.4) indicates no areas of predicted threat.**
	Third party users	▪ Stockwater; ▪ Irrigation; and ▪ Farm supply use.	▪ Drawdown at (census) identified third party user bores used to assess threat, with six bores identified within the potential zone of effect; ▪ At BH28 / BH28A predicted drawdown is around 1.5 m (Figure 10-86) at 10 years post-mine; ▪ At BH28 / BH28A the pre-mine available drawdown is around 12 to 15 m, based on WMP15 data (refer Table 10-6, Figure 10-21), indicating around 10% loss of available drawdown; and ▪ At remaining bores (BH04, BH01X, BH16, BH20; along Styx River reach) drawdown is predicted to be negligible.	▪ BH28/28A: - **Low** threat of adverse effect expected in regard to continued operation (currently not in use), and the owner of the bores is Central Queensland Coal. ▪ Other bores: - **Negligible** threat of adverse effect expected in regard to continued operation.
	Other	▪ Cultural and Spiritual.	▪ Receptor exposure assessment likely corresponds to GDE exposure assessment.	▪ Threat likely corresponds to GDE threat assessment.

Notes: NI – not (specifically) identified as an EV for the Styx River Basin

Table 10-81 Summary details effects, receptor exposure assessment and threat assessment - groundwater quality

<table>
<tr><th>Effects assessment</th><th>Receptor</th><th>Styx River Basin EV</th><th>Receptor exposure assessment</th><th>Threat assessment</th></tr>
<tr><td rowspan="3">GROUNDWATER SALINISATION
▪ Mining:
- Pit voids will not remain after mining, as progressive backfilling will occur during mining
- During mining, when mine pits are open, some evaporation of groundwater seepage to the pits will occur, which will result in concentration of salts in the pits but to a limited degree, some of which will be removed with the coal and some of which will remain in the pit prior to backfilling
- Because baseline groundwater salinity of the Styx Coal Measures in the vicinity of the mine pits is shown to be brackish to saline (e.g. WMP04,
- Figure 10-34), it is not expected salts remaining in the pit prior to backfilling will cause a significant increase in the salinity of recovering groundwater in the backfill materials
- Movement of groundwater toward pits during mining and after closure (until recovery is complete) is unlikely to result in adverse water quality change as salinity and other analyte concentrations for Coal Measures, except alluvium, is consistent although widely varying
▪ Water storages:
- Possible leakage from water storages can be expected to be of similar quality as the water source used to fill the storages, which arises from dewatering
- Residence time of water in the storages will not be significant and so the potential for evaporation to cause significant salinisation of stored water is considered low
ACID MINE DRAINAGE (AMD)
▪ Mining:
- The available geochemistry data indicate there is little potential for generation of AMD from pit wall materials (refer Section 10.5.5.3)
- Leaching of metals / metalloids from pit walls will likely have minimal impact on surface and groundwater quality, if any
▪ Waste materials:
- The available geochemistry data indicate there is little potential for generation of AMD from waste materials (refer Section 10.5.5.3)
- Leaching of metals / metalloids from waste rock (e.g. aluminium (Al), arsenic (As), selenium (Se) and vanadium (V)), where it occurs, will likely have minimal impact on surface water and groundwater quality, if any
ACID SULPHATE SOILS (ASS)
▪ Mapping:
- ASS mapping for the Styx River catchment (Figure 10-5) shows the catchment is classified as largely having low to extremely low probability of ASS potential
- Only small pockets of high probability ASS occur (i.e., below Ogmore near to Styx River and the Broad Sound estuary, more than 7 km downstream of the Project)
- Predicted contours of water table elevation (Figure 10-64 to Figure 10-70) and drawdown (Figure 10-71 to Figure 10-77) show there will be little, if any, change to average water table elevations below Ogmore and beyond the boundaries of ML 80187, and so there is little to no risk of the Project causing onset of ASS conditions
SEAWATER – FRESH WATER INTERFACE
▪ Predicted contours of water table elevation (Figure 10-64 to Figure 10-70) and drawdown (Figure 10-71 to Figure 10-77) show there will be little, if any, change to average water table elevations along Styx River or below Ogmore, indicating the potential for mobilisation of the seawater-fresh water interface (which has not been observed at confluence of Styx River and Broad Sound estuary) is negligible.</td>
<td>GDEs
Type 1
Type 2
Type 3</td>
<td>
NI
Aquatic ecosystems
NI</td>
<td rowspan="3">▪ GDEs:
- Little potential exists for salinisation of groundwater resources supporting GDEs, including possible mobilisation of the seawater-freshwater interface
- Little potential exists for GDEs to be impacted by AMD or ASS
▪ Third party groundwater users:
- Little potential exists for salinisation of groundwater resources supporting third party users, including possible mobilisation of the seawater-freshwater interface
- Little potential exists for third party users to be impacted by AMD or ASS
▪ Cultural and spiritual:
- Little potential for groundwater quality change exists to impact on cultural or spiritual values.</td>
<td>▪ Low to moderate threat of adverse impact associated with water quality change.</td></tr>
<tr><td>Third party users</td><td>▪ Stockwater;
▪ Irrigation; and
▪ Farm supply use.</td><td>▪ Low to moderate threat of adverse impact associated with water quality change.</td></tr>
<tr><td>Other</td><td>▪ Cultural and Spiritual.</td><td>▪ Low to moderate threat of adverse impact associated with water quality change.</td></tr>
</table>

Notes: NI – not (specifically) identified as an EV for the Styx River Basin

Table 10-82 Summary details effects, receptor exposure assessment and threat assessment - groundwater and surface water interaction

Effects assessment	Receptor	Styx River Basin EV	Receptor exposure assessment	Threat assessment
BASEFLOW: ▪ Pre-mine - Predicted pre-mine steady state water table contours are consistent with inferred water table contours (Figure 10-20), with regional groundwater flow to the north (toward coast), and a component of local groundwater flow occurring toward watercourses (baseflow and ET) ▪ Mine: - Model-generated hydrographs (see Figure 10-82) show baseflow / ET along the upper reach of Tooloombah Creek and tributaries is predicted to remain unchanged from the pre-mine condition, but there is a predicted reduction along the mid to lower reach of up to around 37% - Model-generated hydrographs (see Figure 10-83) show baseflow / ET along the upper (and tributaries) and lower reaches of Deep Creek is predicted to decline by less than 10% from the pre-mine condition, with a predicted reduction along the mid (and tributaries) of Deep Creek of more than 40% - Predicted water table elevation and drawdown contours indicate there is negligible, if any, baseflow decline to Styx River and Broad Sound estuary ▪ Post-mine: - Model-generated hydrographs (see Figure 10-82) show baseflow / ET recovery commences along the mid to lower reach of Tooloombah Creek prior to completion of mining (from around year 12) - Model-generated hydrographs (see Figure 10-83) show baseflow / ET recovery along the affected reaches of Deep Creek commences after mining (and dewatering / depressurisation) is completed. **PERCHED WATER TABLES / RAISED WATER TABLES** ▪ Seepage from waste management facilities: - Potential for perched water tables to form unlikely due to permeability difference between waste materials and alluvials, so little opportunity for perched water tables to interact with drainages ▪ Hydraulic loading from waste management facilities / stockpiles: - Hydraulic loading is predicted to have negligible effect on long-term water table elevation and baseflow conditions. **SEEPAGE RELATED DRAWUP** ▪ During mining: - Around the mine pits, the maximum predicted potentiometric surface drawdown beneath water storages exceeds 10m, which reduces the potential for water table drawup	GDEs *Type 1* *Type 2* *Type 3*	 NI Aquatic ecosystems NI	▪ Baseflow reduction will likely occur along the mid-lower reaches of Tooloombah Creek and tributaries during mining, and this will persist for up to 80 years post-mining, with recovery to around 90% of the baseline not occurring until around 50 years post-mine; ▪ Baseflow reduction will likely occur along the entire modelled reach of Deep Creek and tributaries during mining. This effect will persist for up to 80 years post-mining, with recovery to 90% of baseline flow in the mid-reach not occurring until around 60 years post-mine; and ▪ The reaches adjacent to the mine (i.e. the mid-reach of both creeks) are predicted to experience a substantially larger baseflow reduction than the upper or lower reaches.	▪ Type 1 GDEs: - Unaffected by potential baseflow reduction / groundwater - surface water interactions ▪ Type 2 GDEs: - Tooloombah Creek - **High** threat of adverse impact along the mid-lower reach - **Low** threat of adverse impact along the upper reach - Deep Creek - **High** threat of adverse impact along the mid reach - **Moderate** threat of adverse impact along the upper and lower reaches.
	Third party users	▪ Stockwater; ▪ Irrigation; and ▪ Farm supply use.	▪ Reduction in base flow is unlikely to directly impact on third party users.	▪ Negligible threat posed to third party users as a result of baseflow impacts.
	Other	▪ Cultural and Spiritual.	▪ Receptor exposure assessment likely corresponds to GDE exposure assessment.	▪ Threat likely corresponds to GDE threat assessment.

Notes: NI – not (specifically) identified as an EV for the Styx River Basin

Table 10-83 Summary details effects, receptor exposure assessment and threat assessment – physical disruption of aquifers

<table>
<tr><th>Effects assessment</th><th>Receptor</th><th>Styx River Basin EV</th><th>Receptor exposure assessment</th><th>Threat assessment</th></tr>
<tr><td rowspan="3">MINE PITS
▪ Mine:
- Mining involves excavating / removal of ore and waste (barren) materials
- Mine pit development does not require removal of Type 1, Type 2 or Type 3 habitat (refer Figure 10-60)
- From a hydrogeological perspective, mining intersects and removes HSUs (aquifer and aquitards), thereby disrupting the baseline hydrogeological setting
- As mining progresses, the pits will be backfilled, with backfilled materials compacted using trucks, potential exists for materials to have higher K and S values cf. in-situ materials
- Coal measures coal seams/interburden and overburden materials will be backfilled first, followed by alluvium to reimpose to the extent possible baseline hydrostratigraphy
▪ Post-mining:
- Backfilling of mine pits will allow the groundwater system (quantity and quality) to recover toward pre-mine (baseline) conditions.
WASTE ROCK STOCKPILES
▪ Mine:
- Waste stockpiling does not require removal of Type 1, Type 2 or Type 3 habitat (refer Figure 10-44 and 10-56)
- Waste materials (coal measures coal seams/interburden and overburden) and alluvium materials will be kept separate and stockpiled (see Figure 10-63 for general arrangement of stockpiles)
- The stockpiles have the potential to load the unconsolidated sediments on which they are placed, and possibly cause subtle changes (reduction) to alluvium HSU hydraulic properties (e.g. hydraulic conductivity, porosity and storativity)
- The effects of loading of the sediments could result in backing up of hydraulic gradients upstream of the stockpiles (possibly reducing impacts to Type 2 and 3 GDEs), and reducing groundwater discharge to the dewatered pits, although modelling suggests this effect is unlikely to be significant
- If water tables were to rise due to hydraulic loading, it is considered unlikely they will rise close to ground surface (see Figure 10-21 for baseline depth to water table upstream of the mine)
- As pits will be progressively backfilled during mining, the effect of loading effect will be less than would be the case if backfilling did not occur or was delayed until after mining is completed
▪ Post-mine:
- Due to bulking, it is expected that small waste storages will need to remain in place after closure
- Any effect of loading will persist through to the post-mine period, although this is likely to be negligible</td><td>GDEs
Type 1
Type 2
Type 3</td><td>
NI
Aquatic ecosystems
NI</td><td>▪ Mine pits:
- During mining, the development of mine pits will temporarily interfere with the local-scale alluvium and coal measures HSUs, resulting in dewatering and depressurisation of adjacent stratigraphy, which will alter access to groundwater by GDEs
- Backfilling of the mine pits will allow GDEs to regain access to groundwater at some time after mining and, if impacted, re-establish, i.e. the interference is not permanent, with recovery commencing from year 10 post-mine
▪ Waste storages and stockpiles:
- Due to progressive backfilling of mine pits, the impact of loading of hydraulic HSUs by waste storages and stockpiles is expected to be limited, and may assist in reducing effects on nearby GDEs
- Effect is predicted to be limited / negligible.</td><td>▪ GDEs:
- Low threat of adverse impact in response to mine pit development and backfilling
- Low threat of adverse impact in response to waste storages and stockpiling.</td></tr>
<tr><td>Third party users</td><td>▪ Stockwater;
▪ Irrigation; and
▪ Farm supply use.</td><td>▪ Mine pits:
- The development of mine pits is unlikely to significantly impact on third party groundwater users, as the pits will occur some distance (~1 km) from the nearest identified bore (BH28/28A), where available drawdown is predicted to not be critically impacted
▪ Waste storages and stockpiles:
- The development of waste storages and stockpiles is also unlikely to significantly impact on third party groundwater users for reasons outlined above</td><td>▪ Third party users:
- Low threat of adverse impact in response to mine pit development and backfilling
- Low threat of adverse impact in response to waste storages and stockpiling.</td></tr>
<tr><td>Other</td><td>▪ Cultural and Spiritual.</td><td>▪ Aesthetic impact is likely, but only in relation to the infrastructure and not due to groundwater effects.</td><td>▪ Threat likely corresponds to GDE threat assessment.</td></tr>
</table>

Notes: NI – not (specifically) identified as an EV for the Styx River Basin

10.7.4.9 Impact Assessment Summary

The following provides a summary of the key findings of the impact assessment:

(i) During mining, maximum predicted drawdowns of more than 100 m are restricted to ML 80187, in the immediate vicinity of the mine pits. The predicted 10 m drawdown contour is almost wholly constrained between Tooloombah and Deep Creeks, and within ML 80187. The 1 m drawdown contour intercepts the mid-portion of Tooloombah Creek and Deep Creek and the 0.1 m drawdown contour (assumed to represent the zone of drawdown influence) extends to a maximum of approximately 5.5 km northwest and less than 2 km southeast of the mine at around year 10 after mine closure.

(ii) The predicted zone of mine-related drawdown influence is aligned northwest to southeast, and does not interfere with the tidal reach of Styx River.

(iii) The mine pits will be progressively backfilled as mining advances, which removes the possibility of the pits acting as long-term evaporative sinks for the groundwater systems. As a result the groundwater system is conservatively predicted to fully recover sometime after 50 years (but before 100 years) after closure.

(iv) Drawdown of the water table within the Tooloombah and Deep Creek catchments results in dewatering, to some extent, of the alluvial aquifers that likely support the mid- to lower reaches of the two creeks (baseflow reduction) and associated riparian zones (water table depth).

(v) Model predictions and the results of predictive uncertainty support the hydrogeological conceptualisation that the Tooloombah and Deep Creek catchments, within which the Project is located, are essentially closed groundwater catchments.

(vi) The groundwater model is most sensitive to the K of the Styx Coal Measures coal seams and interburden, underburden, alluvium; and recharge rates. Uncertainty analysis has determined the K of the coal seams and interburden, however, is the most critical in terms of predicting catastrophic failure of the groundwater system in response to mine dewatering. K of the coal seams and interburden is shown to unlikely be greater than 0.01 m/d, which is consistent with aquifer testing results.

(vii) Predicted drawdown associated with mine water affecting activities is very unlikely to extend to areas where there is a potential for exposure of ASS, including along the tidal reach of Styx River. Consequently, any threat to marine and aquatic ecosystems associated with ASS is considered negligible.

(viii) a) The lack of drawdown predicted for the lower reaches of Tooloombah and Deep Creeks, as well as downstream of the confluence of these creeks along Styx River, and
b) The lack of evidence of a seawater-freshwater interface near the confluence of Styx River with Broad Sound
c) Indicates the risk of seawater intrusion in response to mine dewatering is low to negligible.

(ix) Predictive uncertainty analysis indicates the calibrated model, and the predictions presented in this report, are representative and consistent with the conceptual hydrogeological model (Section 10.5.6.8).

(x) The predicted zone of influence from mine dewatering activities is predicted to not change the nature of groundwater – surface water interactions along Styx River, i.e. the river remains a predominantly groundwater discharge zone during and following mining. North of ML 80187, continued groundwater discharge to Tooloombah and Deep Creeks is also predicted.

10.8 Monitoring, Management and Mitigation Measures

10.8.1 Approach

Central Queensland Coal commits to responsible resource recovery, including mitigation of potentially unacceptable mining related impacts on groundwater resources and connected surface systems in order to protect groundwater EVs and ensure groundwater continues to meet the requirements of identified sensitive groundwater receptors (e.g. GDEs and third party users). To this end, Central Queensland Coal will prepare and implement the following documents:

- A Receiving Environment Monitoring (Management and Mitigation) Plan (REMP) to describe how groundwater resources and dependent receptors will be monitored and managed to achieve the Company's commitment to responsible resource recovery, as well as management measures that may be required to mitigate any adverse impacts that might arise as a result of mine-water affecting activities. The REMP will include a Trigger Action Response Plan (TARP) process which will outline the responses required in the event that operations result, or are likely to result, in unacceptable effects to groundwater and connected surface water environments; and

- A Water Management Plan (WMP) has an on-site focus, and will prescribe the management of mine-water affecting activities to minimise the risk of adverse impacts on groundwater (and surface water) systems. The WMP will refer to the REMP for all monitoring and mitigation efforts associated with the mine-site water balance. It is assumed the WMP will be a requirement of the Project's EA and will be provided to DES for review prior to the commencement of construction and mining activities.

The WMP and REMP together form the approach to management of onsite water usage and storage, and monitoring of EVs in relation to water management (including groundwater drawdown) and water release. The overall monitoring, management and mitigation approach is summarised in Figure 10-101.

Ongoing monitoring will comply with relevant state and national guidelines including Queensland Government's *Monitoring and Sampling Manual: Environmental Protection (Water) Policy* (DES, 2018).

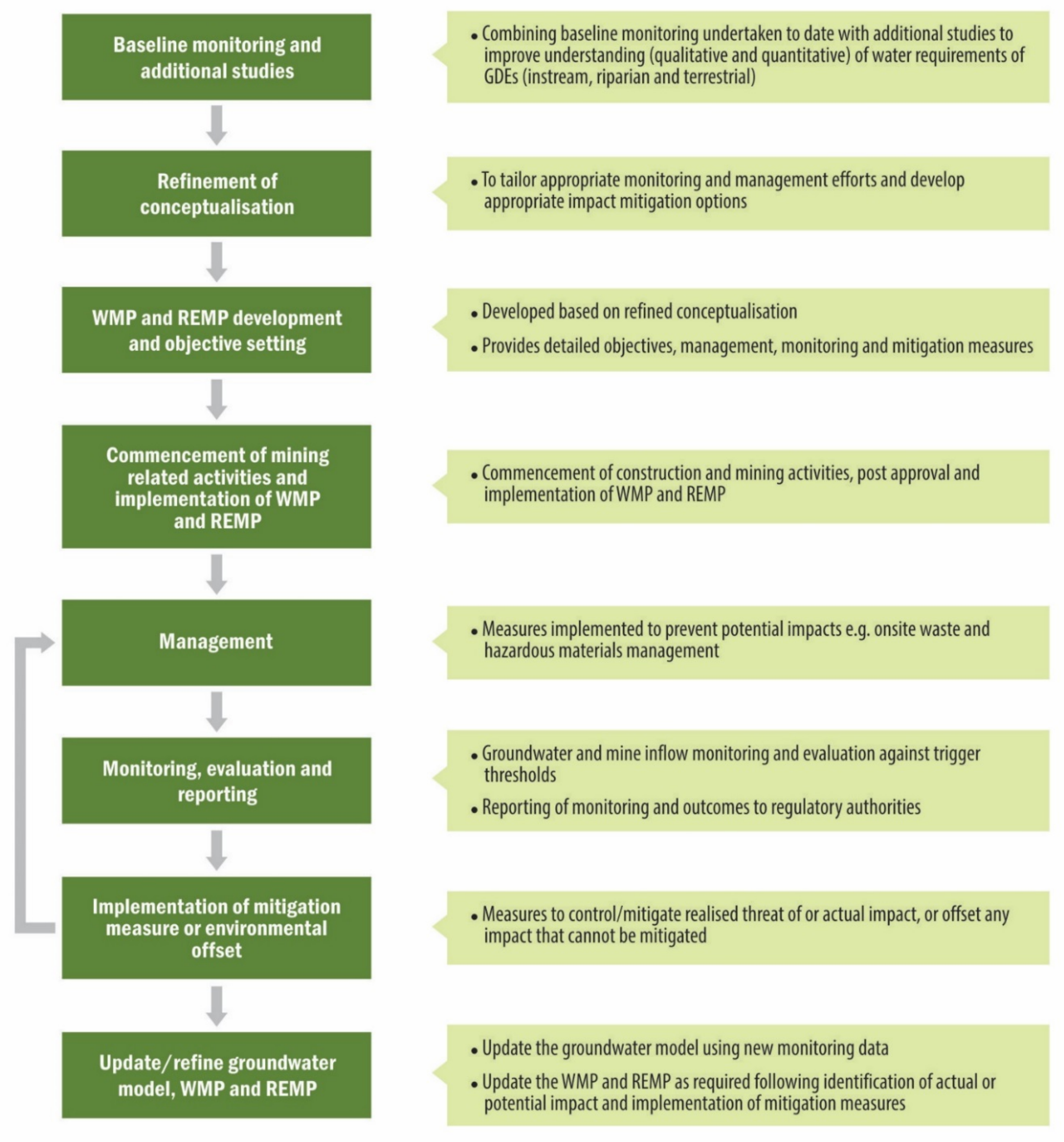


Figure 10-101 Groundwater monitoring, management and mitigation approach

10.8.2 Baseline Studies

10.8.2.1 Overview

This Section of the SEIS presents a conceptualisation that has been developed from baseline monitoring data, which suggests some ecosystems within the Project area are likely to be supported (at least to some extent) by groundwater (i.e. those identified as GDEs, see Section 10.6.1). The hypothesis presented is that GDEs are supported to some extent by Alluvial or shallow Styx Coal Measures groundwater resources, either within an aquifer (Type 1 GDEs), expressed at the surface (Type 2 GDEs) or available in the sub-surface (Type 3 GDEs).

The existing baseline investigations are presented in Section 10.5 and 10.6. The following sets out details of further works planned to provide additional understanding of:

- The degree or frequency of reliance by ecosystems on groundwater to meet environmental water requirements;
- The pre-mine condition (i.e. function) of GDEs, and to establish the possible extent to which they may already be impacted by anthropogenic effects such as clearing, grazing, fire, pests and weeds; and
- The level of resilience and resistance GDEs might have groundwater conditions altered from the baseline.

The outcomes of these investigations will assist in the development of the REMP including:

- Setting management objectives;
- Refinement of the monitoring program; and
- Detailed and effective management and mitigation strategies, should they be required.

10.8.2.2 Additional and Ongoing Groundwater Monitoring and Assessment of Ecosystem Interactions with Groundwater

Ongoing monitoring and assessment will include:

- Extended baseline hydrological and hydrogeological monitoring (e.g. depth to water table, hydraulic gradients, water quality);
- Isotope analysis of surface waters and groundwaters for assessment of interactions supporting in-stream pools (Type 2 GDEs); and
- Analysis of soil and plant xylem stable isotopes of water, and leaf and soil water potentials at locations of identified potential groundwater dependent vegetation (Type 3 GDEs), to improve the understanding of plant water use and reliance on soil water and groundwater.

In addition to the above, the following investigations will be undertaken:

- Development of a detailed water and solute balance for in-stream pools (Type 2 GDEs; building on from the work documented in Appendix A6 – Groundwater Technical Report) to determine and quantify water source(s) sustaining all permanent pools identified along Tooloombah and Deep Creeks. The work will rely on the following data:
  - outcomes of further ^{222}Rn and major ion sampling
  - in-stream flow measurements to quantify streamflow rates and stage heights
  - pool surveys to map the extent and depth of pools and longevity between stream flow events
  - site specific climate data (rainfall, evaporation)
  - extended record of near-stream groundwater levels through time
- Analytic modelling of leaf water potential data to understand the implications of a declining water table for plant water requirements;

- Development of a soil water reservoir balance to assess the quantity of soil water available to meet plant water requirements between wet seasons; and
- Pre-mining GDE condition monitoring including vegetation and aquatic surveys discussed further in Section 10.8.5.

10.8.3 Water Management Plan

The WMP will describe the mine water balance, key water infrastructure (e.g. water storages, water distribution network, drainage system) and flood protection infrastructure. The WMP will address both the construction and operational phases of the Project. From a groundwater management perspective, the WMP will also:

- specify the water source for each water storage; and
- identify the likely water quality for each water storage and possible worst case water quality that could occur under extreme climate conditions.

10.8.4 Receiving Environment Monitoring (Management and Mitigation) Plan

10.8.4.1 Overview

This component of the Project effectively addresses Step 7 (*Monitor, evaluate, review, amend*) of the NWC framework (see Figure 10-62). The REMP will document proposed groundwater monitoring and evaluation commitments, and outline appropriate mitigation measures that can be employed if water management activities are shown to not achieve environmental objectives. The REMP will include:

- Roles and responsibilities;
- Management objectives, with consideration of the Environmental Authority conditions;
- The TARP process, including trigger thresholds and detailed management and mitigation responses;
- Detailed monitoring program:
  - GDE condition monitoring, including vegetation and aquatic surveys
  - groundwater monitoring, including level gauging, water sampling and laboratory testing program, consistent with baseline monitoring analytes
  - monitoring of mine water dewatering rates/volumes and produced water laboratory testing program
  - a monitoring schedule, detailing the required monitoring locations, monitoring frequency, methods and protocols, analytes to be sampled for, etc
  - data evaluation criteria and requirements
  - requirements for revision of the REMP
  - reporting requirements.

Each of these REMP components are described below.

10.8.4.2 Roles and Responsibilities

The various roles associated with water management for the Project will be documented, along with responsibility statements e and the required training that responsible personnel will need to have to fulfil roles.

10.8.4.3 Management Objectives

The management objectives of the REMP will be prescribed following completion of the baseline studies and will focus on maintaining the EVs of groundwater and connected surface waters surrounding the Project. The water quantity (levels, pressures, fluxes) and quality triggers developed for the REMP form the basis for assessing the success of water management strategies.

10.8.4.4 Trigger Action Response Plan

TARPs will form part of the REMP and will outline the actions and responses required in the event that operations have or are likely to result in management objectives and approvals conditions not being achieved. TARPs will identify:

- Further investigations to identify EVs and sensitive receptors that may be impacted and to assess level of impact / threat posed to the sensitive receptors, and if pre-determined trigger thresholds are reached;
- Of those mitigation measures identified in the REMP, which are appropriate to manage or remove the specific cause or pathway of the impact / threat and what other mitigation measures may be available to improve outcomes (e.g. new technology);
- Implementation of the mitigation plan(s) deemed most appropriate, including providing notification (where necessary) to relevant authorities and stakeholders;
- Reporting (internal and external) to summarise monitoring results, investigation findings and mitigation approaches, with follow up information provided to relevant authorities and stakeholders; and
- Review and update of the REMP to ensure adequate monitoring of detected impacts and mitigation efforts is incorporated, and to re-assess appropriateness of mitigation measures outlined in the plan (i.e. to ensure the mitigation measures will appropriately address the level of impact identified into the future).

Groundwater quality performance triggers will be based on statistical analysis of the reported ranges in baseline concentrations of identified analytes of concern (e.g. pH, salinity concentrations, and concentrations of dissolved metals such as As, Al, Mo, Se and V). Groundwater 'quantity' (head) performance triggers will be based on a combination of baseline head data for selected monitoring bores as well as comparison of observed and model predicted heads for different stages of mine development (operational and closure).

Two types of triggers will be defined for groundwater quality and quantity, the first will be a performance trigger and the second an early warning trigger (assigned, say, as 75% of the performance trigger). Response (review, further investigations and evaluation) will be required when the early warning trigger is exceeded and, depending on the results, action may be required on implementing mitigation measures to ensure the performance trigger is not exceeded. In terms of groundwater heads, review will also be required if there is divergence of observed from predicted heads.

10.8.4.5 Preliminary Management and Mitigation Measures

Overview

Mitigation measures will be defined to address any unacceptable impact arising to sensitive receptors (see Table 10-77) from reduced groundwater quantity or diminished groundwater quality, when and where these outcomes arise. The TARPS (see Section 10.8.4.4) will form the basis for determining when management and mitigation measures will need to be confirmed and implemented.

It is recognised that GDEs within this landscape will have evolved some resilience, whereby they are able to cope with some degree of change to baseline water regimes (quantity, quality and timing). For example, Type 3 terrestrial GDEs may be able to extend the depth of rooting to access deeper soil water or the capillary fringe, and macro-invertebrates may persist in surface water pools that are reduced in surface area and depth compared to what may have existed pre-mining. Resilience levels need to be further assessed by ongoing monitoring but, for the purpose of identifying suitable mitigation measures, at this stage it is conservatively assumed that sensitive ecosystems have no resilience to changed water regimes (i.e. the temporal nature of environmental water requirements is static / unchanging). So, in the first instance, mitigation measures are defined on this 'static' basis, but once environmental water requirements are better understood an adaptive mitigation plan will be able to be implemented.

The following sets out examples of groundwater management and impact mitigation measures for the Project. These and other mitigation measures will be further detailed in the REMP, building on from the baseline understanding of receptor water requirements with understandings developed from ongoing studies (see Section 10.8.2.2). It is anticipated that, where an adverse impact is indicated as part of the approved monitoring, evaluation and reporting program, a wide range of management and mitigation approaches will be considered, not only those that may be detailed in the REMP as additional approaches may evolve with time and technology, and new knowledge gained may lead to the development of new approaches that are not identified here. Any new mitigation measures identified as part of this process will require an update of the REMP.

Physical Disruption to Aquifers

The proposed open cut mining method will physically disrupt and drain the saturated profile below the water table, resulting in groundwater depressurisation of deeper lithologies and decline of the potentiometric surface in the immediate area of the open cut pits during mining – all of which is controlled by HSU hydrogeological properties and final depth of mining. The mine plan has evolved to include the progressive backfilling of mine voids as mining proceeds, which is a primary management and mitigation measure in relation to long-term potential groundwater drawdown.

Placement of waste materials, which is restricted by the area of the ML, has the potential to mechanically load the water table aquifer resulting in reduced porosity and higher pore water pressures in the saturated zone. This effect has the potential to reduce aquifer transmissivity and higher water tables up-hydraulic gradient of the landforms. Backfilling of the mine voids is an important management measure to mitigate this effect, as the remnant waste landforms will be much smaller than would have been otherwise.

Apart from these two strategies there are no other effective mitigation measures that can be implemented to manage the effects of aquifer disruption caused by mining.

Water Quantity

An approach that will be considered to manage impacts where Type 2 and Type 3 GDE access to groundwater might be compromised due to drawdown arising from mine dewatering involves supplementing environmental flows to waterways and soil water stores so that baseline flow/water availability regimes can be maintained or supported. Table 10-84 presents summary details, which are expanded upon below.

Table 10-84 Available management and mitigation measures

Direct effect	In-stream habitat	Riparian habitat	Terrestrial habitat	Third party bores
Change in groundwater quantity, and surface water – groundwater interactions	Supplementary environmental flows provided directly to pools from mine produced water or other groundwater sources (e.g. pumping bores)	Supplementary environmental flows provided via irrigation from mine produced water or other groundwater sources (e.g. pumping bores) Land contouring, which will retard surface water run-off and encourage additional recharge to the soil profile		Lowering of pump/ deepening bore Provision of surplus water from mine dewatering if suitable Provision of an alternative water supply
Change in groundwater quality	Onsite water and hazardous materials management Containment or capture of contaminant/pollutant e.g. cut off walls, pumping bores. Treatment of contaminated/polluted water Geochemical controls, e.g. mixing PAF materials with materials having neutralising capacity			

Note: Existing examples of the provision of environmental flows made directly into pools in response to groundwater dewatering include 1) Upper Collie Water Allocation Plan (2009), 2) Solomon Iron Ore Project Bore Field FMG (2016), 3) Hope Downs Iron Ore Mine (WA EPA, 2001).

For Type 2 GDEs, supplementary water can be provided directly to permanent or ephemeral pools in a manner that provides the minimum required volume and frequency to maintain GDE function, the understanding of which will be improved with ongoing monitoring. If surface water is the dominant source of water in at risk pools, the groundwater supplementing pool levels may need to be treated prior to application. However, if groundwater provides a major component of Type 2 GDE water requirements it is probable that water treatment will not be required for this purpose, but this will be further explored as part of REMP development.

Supplementary water can be sourced from excess mine water during the life of mine, but there remains a risk of impact to GDEs after mine closure when mine produced water will not be available. In this circumstance it may be necessary to continue with the mitigation measure at least until sufficient recovery of groundwater heads occurs.

The practice of supplementing surface water flow to maintain aquatic ecosystems and riparian vegetation health is widely used as a management tool in providing environmental flow requirements to waterways and wetlands across Australia. Examples of where the provision of environmental flows is made directly to pools in response to groundwater dewatering include the Collie Basin in southwest Western Australia, and Fortescue Metals Solomon Iron Ore Project Bore Field and Rio Tinto's Hope Downs Iron Ore Project in the Pilbara region of Western Australia (see Table 10-84 for references).

For Type 3 GDEs, supplementary water can be applied to soil water reservoirs (i.e. the root zone) either directly through irrigation or indirectly through leakage from water provided to waterways/wetlands/bunded areas. Contouring of the surface could be considered to encourage ponding of any surface runoff or direct rainfall to encourage additional recharge to the underlying soils. However, the efficacy of this approach also needs to consider impact to creek flow regimes.

The source of supplementary water would ideally be mine produced water, as there would be no associated additional drawdown impacts. Mine water balance modelling, as presented in Chapter 9 – Surface Water, predicts the mine water supply exceeds the mine water demand for the duration of mining almost all of the time, with a predicted minimum available excess in the order of 40 ML in the worst case dry year, when in-stream pools would be expected to be naturally under stress. This suggests that mine produced water is likely to be a viable source of water to offset any reduction in groundwater baseflow to the dependent pools, with adequate treatment if necessary. However, a supply deficit will exist post-closure when mine produced water is no longer available. Alternatively, sourcing the supplementary flows from a groundwater resource is a strategy that may be considered – whilst the Alluvium aquifer would likely not present as a viable long term option (due to drawdown effects), the Styx Coal Measures, which has similar water quality to the Alluvium (see Section 10.5.6.5) may provide a suitable source.

To provide a preliminary analysis of the amount of water potentially 'consumed' by a pool located near the northwestern boundary of ML 80187 (sample point To2; Figure 10-7) a water balance model has been prepared, the details of which are presented in Appendix A6 – Groundwater Technical Report, Section 4. The water balance model indicates the amount of water required to sustain in-stream pools during the dry season is around 4 mm/d, on average. The numerical groundwater model has been used to assess whether pool-groundwater requirements can be met via abstraction from pumping wells accessing the Styx Coal Measures (discussed in Appendix A6 – Groundwater Technical Report, Section 3.6.2.4). The modelling has shown the Styx Coal Measures is capable of supplying between 0.55 to 0.7 L/s in the long-term, which could sustain around 13,000 to 17,000 m^2 of pools over a dry season, with little additional effect to the predicted drawdown. Solar energy could be used to power these types of bores after closure.

Water Quality

The proposed groundwater monitoring network (see Section 10.8.2.2, Table 10-85 and Figure 10-102) will provide the capacity to identify where there may be situations that water quality is impacted and requires mitigation. However, the circumstances contributing to water quality decline will need to be investigated to identify (natural variability or activity or facility) and rectify the cause of observed trends prior to identifying an appropriate mitigation strategy.

Any evidence of PAF or AMD impacted seepage waters from waste storages, for example, will be addressed immediately by investigating potential scale of impact, and followed up as required by implementing management / mitigation strategies such as mixing or compartmentalising with materials having neutralising capacity, or backfilling to base of pits.

Adverse groundwater quality impacts arising from uncontrolled discharge of possible contaminants can be mitigated through engineered or non-engineered measures that have the objective of containing, intercepting and/or treating impacted groundwater / pollutant source (e.g. cut-off walls, interception trenches or recovery bores), but mitigation strategies outlined in the REMP would need to be adapted for site specific conditions.

To prevent potential contamination of groundwater from uncontrolled release of contaminants , the REMP will detail onsite water and hazardous materials management protocols. These will include:

- personnel training and awareness in regards to the potential for groundwater quality to be impacted and the requirement to report any spills;

- provision of appropriate spill control materials including containment booms and absorbent materials at refuelling facilities to contain spills;
- personnel training in the use of spill control materials, and appropriate reporting protocols;
- ensure all refuelling facilities, and the storage and handling of hazardous goods and chemical complies with relevant Australian Standards (management and mitigation measures for wastewater are discussed in Chapter 7 - Waste Management); and
- establish procedures to ensure safe and effective fuel, oil and chemical storage and handling, including storing materials within roofed and bunded areas to contain spills, and prevent uncontrolled discharge to the environment.

All uncontrolled discharges will be reported to the DES under legislative requirements of the EP Act. Control of surface water discharges and dirty water management systems, including storage of mine dewatering water, are discussed in Chapter 9 – Surface Water. Reducing the potential for salinisation of pit waters through evapo-concentration of salts will be mitigated by efficiently removing water from sumps.

A summary of available indicative management and mitigation measures that may be employed are summarised in Table 10-84.

Third Party Users

If access to groundwater for third party users is compromised by effects from the Project, the following mitigation measures may be implemented:

- where sufficient available drawdown exists, lowering pumps deeper within the bore column can be undertaken;
- where sufficient unscreened aquifer interval exists, deepening of a bore can be undertaken or a new bore can be established outside of the area of impact;
- provision of surplus water from mine dewatering, if the quality is deemed suitable for the existing use; and
- provision of an alternative water supply of comparable quantity and quality to the meet the existing demand.

Where the Project impacts on third party water use, Central Queensland Coal will liaise with landholders to agree arrangements that will ensure provision of water of adequate yield and quality during and after mining until the aquifers are replenished or access to groundwater for stock water is no longer deemed compromised.

Table 10-85 Indicative location of groundwater monitoring bores

Monitoring bore	Baseline monitoring ID	Status	Location: Latitude (DD)	Location: Longitude (DD)	Location: Easting MGA55	Location: Northing MGA55	Screened depth (mbgl)	GCZ	Aquifer/Aquitard	Receptor monitoring	Purpose	Monitoring frequency
Reference bores												
RMB01	WMP13	Existing	-22.621682	149.652024	772604	7495931	14.1-21.1	Styx	Alluvium and Styx Coal Measures (overburden)	Type 2 and 3 GDEs, and Styx River	Monitor the extent of drawdown and groundwater quality	Bi-annual
RMB02	WMP11	Existing	-22.642371	149.667884	774194	7493610	18-24	Bison	Styx Coal Measures (overburden)	Type 2 and 3 GDEs - Deep Creek/Styx River		
RMB03	WMP11D	Existing	-22.642252	149.667950	774201	7493623	30-36	Bison	Styx Coal Measures (overburden)			
RMB04	WMP17	Existing	-22.735128	149.682050	775465	7483308	9-12	Uplands	Alluvium	Background		
RMB05	WMP17D	Existing	-22.735326	149.682103	775470	7483286	21-24	Uplands	Styx Coal Measures (overburden)			
RMB06	WMP08	Existing	-22.754042	149.669504	774138	7481236	10.4-16.4	Uplands	Alluvium	Type 2 and 3GDEs- Deep Creek		
RMB07	WMP08D	Existing	-22.754079	149.669466	774134	7481232	24-36	Uplands	Styx Coal Measures (underburden)			
RMB08	WMP19	Existing	-22.714833	149.616881	768808	7485676	13.1-16.1	Styx	Weathered Basement	Type 2 and 3 GDEs- Tooloombah Creek		
RMB09	WMP19D	Existing	-22.714690	149.616810	768801	7485692	24.9-27.9	Styx	Weathered Basement			
RMB10	WMP16	Existing	-22.636361	149.606853	767930	7494387	25.5-31.5	Styx	Styx Coal Measures (overburden)	Type 3 GDEs		
RMB11	WMP16D	Existing	-22.636426	149.606786	767923	7494380	35.7-41.7	Styx	Styx Coal Measures (coal seams and interburden)			
RMB12	WMP20	Existing	-22.675143	149.610708	768251	7490084	14.5-20.5	Styx	Styx Coal Measures (overburden)			
RMB13	WMP20D	Existing	-22.675161	149.610660	768246	7490082	24-30	Styx	Styx Coal Measures (overburden)			
RMB14	WMP29A	Existing	-22.608771	149.639079	771298	7497385	6.5-12.5	Styx	Alluvium	Type 2 and 3GDEs - Styx River/estuary	Sentinel for monitoring seawater-fresh water interface Monitor the extent of drawdown and groundwater quality	
RMB15	WMP29B	Existing	-22.608770	149.639108	771301	7497385	16-20	Styx	Alluvium			
RMB16	WMP29C	Existing	-22.608686	149.639271	771318	7497394	52-58	Styx	Styx Coal Measures (overburden)			
RMB17	WMP29D	Existing	-22.608750	149.639263	771317	7497387	115-121	Styx	Styx Coal Measures (coal seams and interburden)			
RMB18	WMP29E	Existing	-22.608660	149.639213	771312	7497397	222.5-228.5	Styx	Styx Coal Measures (underburden)			
Compliance bores												
CMB01	WMP05	Existing	-22.660106	149.671271	774507	7491639	9-12	Bison	Alluvium	Type 2 and 3 GDEs- Deep Creek	Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	Quarterly for field parameters Bi-annual for complete suite of analytes
CMB02	WMP21	Existing	-22.674281	149.669474	774294	7490072	6.9-9.9	Uplands	Alluvium	Type 2 and 3 GDEs- Deep Creek	Groundwater quality and quantity changes associated with dam, and mine dewatering	
CMB03	WMP21D	Existing	-22.674903	149.668990	774243	7490004	14-20	Uplands	Alluvium and Styx Coal Measures (overburden)			
CMB04	WMP18	Existing	-22.700529	149.680412	775366	7487144	9.2-12.2	Uplands	Alluvium		Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	
CMB05	WMP18D	Existing	-22.700458	149.680333	775358	7487152	18.5-23.5	Uplands	Styx Coal Measures (overburden)			
CMB06	WMP10	Existing	-22.704560	149.685472	775878	7486688	13.9-19.9	Uplands	Alluvium and Styx Coal Measures (overburden)		Extent of drawdown and groundwater quality	
CMB07	WMP09	Existing	-22.728651	149.662403	773459	7484062	7.1-15.1	Uplands	Alluvium		Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	
CMB08	WMP07	Existing	-22.737226	149.641208	771264	7483151	53-65	Styx	Styx Coal Measures (underburden)	Type 3 GDEs	Extent of drawdown and groundwater quality	
CMB09	WMP15	Existing	-22.715369	149.645751	771774	7485564	9.3-21.3	Styx	Alluvium and Styx Coal Measures (underburden)		Extent of drawdown and groundwater quality	
CMB10	WMP25	Existing	-22.709541	149.636279	770812	7486227	10.1-13.1	Styx	Alluvium	Type 3 GDEs (Wetland 1)	Extent of drawdown and groundwater quality	
CMB11	WMP14	Existing	-22.696779	149.632833	770483	7487647	10-19	Styx	Alluvium and Styx Coal Measures (overburden)		Groundwater quality and quantity changes associated with dam	
CMB12	WMP06	Existing	-22.692585	149.628249	770020	7488120	12-18	Styx	Alluvium and Styx Coal Measures (underburden)	Type 2 and 3 GDEs- Tooloombah Creek	Extent of drawdown and groundwater quality	
CMB13	WMP04	Existing	-22.680956	149.655703	772865	7489358	12.6-18.6	Uplands	Alluvium		Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	

Monitoring bore	Baseline monitoring ID	Status	Location				Screened depth (mbgl)	GCZ	Aquifer/Aquitard	Receptor monitoring	Purpose	Monitoring frequency
			Latitude (DD)	Longitude (DD)	Easting MGA55	Northing MGA55						
CMB14	WMP04D	Existing	-22.681020	149.655645	772859	7489351	21.9-39.9	Uplands	Alluvium and Styx Coal Measures (overburden)		Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	
CMB15	WMP12	Existing	-22.668501	149.659363	773266	7490731	11.9-17.9	Uplands	Alluvium and Styx Coal Measures (overburden)	Type 2 and 3 GDEs-Tooloombah Creek	Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	
CMB16	WMP02	Existing	-22.659413	149.661435	773497	7491734	13.4-19.4	Bison	Alluvium		Extent of drawdown and groundwater quality	
CMB17	WMP22A	Existing	-22.685308	149.647450	772008	7488891	27-30	Uplands	Styx Coal Measures (overburden)	Type 3 GDEs	Extent of drawdown and groundwater quality	
CMB18	WMP22B	Existing	-22.685263	149.647478	772011	7488896	50-56	Uplands	Styx Coal Measures (coal seams and interburden)			
CMB19	WMP22C	Existing	-22.685226	149.647487	772012	7488900	200-206	Uplands	Styx Coal Measures (underburden)			
CMB20	WMP23A	Existing	-22.722853	149.664159	773651	7484701	48.5-54.5	Uplands	Styx Coal Measures (coal seams and interburden)	Type 1 and Type 3 GDEs		
CMB21	WMP23B	Existing	-22.722783	149.664032	773638	7484709	187-193	Uplands	Styx Coal Measures (underburden)			
CMB22	WMP24	Existing	-22.683492	149.646996	771965	7489093	23.4-26.4	Uplands	Styx Coal Measures (overburden)	Type 2 and Type 3 GDEs – Tooloombah Creek		
CMB23	WMP26	Existing	-22.680702	149.663383	773655	7489372	11.5-20.5	Uplands	Alluvium	Type 2 GDEs – Deep Creek tributary	Groundwater quality and quantity changes associated with Waste Rock Stockpile, and mine dewatering	
CMB24	WMP27	Existing	-22.695830	149.634012	770606	7487750	14.5-20.5	Styx	Styx Coal Measures (overburden) and minor Alluvium	Type 3 GDE (Wetland 2)	Extent of drawdown and groundwater quality	
CMB25	WMP28	Existing	-22.683402	149.649203	772192	7489099	8.9-11.9	Uplands	Styx Coal Measures (overburden)	Type 2 and 3 GDE	Extent of drawdown and groundwater quality	

10.8.5 Groundwater and GDE Monitoring

Groundwater monitoring (water quantity and quality) will occur on the MLs and off-lease during the construction, operational and post-operational phase of the Project to:

1) Determine whether an impact has or will likely be realised, triggering (based on pre-determined trigger thresholds) implementation of appropriate mitigation measures, including initial review and evaluation; and

2) Assess the environmental performance of any adopted management and mitigation measures once implemented, which may require expansion of the monitoring network and analytical program.

The groundwater monitoring program will be designed to monitor the condition of the target 'end point' of the system - in this case, the EVs identified for the Styx River catchment and associated sensitive receptors (Type 1, 2 and 3 GDEs, third party water users), which are identified in Table 10-77.

The location and configuration of monitoring bores is designed to provide sufficient coverage of identified HSUs and GCZs, as well as sensitive receptors within the Project and surrounding area to detect and monitor groundwater effects from the Project, and provide a baseline from which management objectives are set, updated or maintained. Groundwater monitoring bore locations are shown in Figure 10-102 and described in Table 10-85. Based on the information collected during the first few years of mining, a need for expansion or rationalisation of the monitoring network may be identified.

The monitoring program will be designed to take into consideration the Environmental Authority conditions, as well as State and National groundwater monitoring guidelines.

The initial monitoring program will include at least:

- Monitoring of groundwater drawdown and depressurisation, which will involve:
  - gauging of hydraulic head in selected groundwater monitoring bores and landholder bores located within the predicted zone of mine influence (compliance bores, see Table 10-85), as a minimum
  - automated pressure transducers will be installed at selected monitoring bores to provide daily observations that can be used to distinguish short-term changes, such as seasonal recharge, from potential long-term effects of the Project (dewatering and backfilling)
  - gauging hydraulic heads at selected locations outside of the predicted area of impact to confirm the extent of impact and to assess baseline conditions away from potential mining effects (reference bores, see Table 10-85)
- Monitoring of groundwater quality, which will involve:
  - quarterly field measurements of EC and pH of groundwater sampled from compliance monitoring bores located on the mine lease (Table 10-85) and monthly field measurements of the same parameters for water pumped from the mine
  - quarterly field measurements of EC and pH of groundwater sampled from compliance monitoring bores located off the mine lease (Table 10-85)
  - six monthly sampling (quarterly or more frequently for the first 2 years of mining, or if trigger is reached) of groundwater sampled from compliance monitoring bores (Table

10-85) for laboratory analyses of major ions, TDS, EC, dissolved metals (including aluminium, arsenic, selenium and vanadium) and hydrocarbons (TPH, TRH and BTEXN) using laboratories that are NATA-registered for the analyses undertaken, and methodologies that are suitable for comparison with the baseline monitoring

- six monthly sampling (quarterly or more frequently if trigger is reached) of groundwater from reference monitoring bores (located outside the predicted zone of drawdown influence, Table 10-85) for laboratory analyses of major ions, TDS, EC and dissolved metals using laboratories that are NATA-registered for the analyses undertaken, and methodologies that are suitable for comparison with the baseline monitoring
- groundwater chemistry data will be analysed graphically for trends (e.g. using concentration vs. time graphs, Piper plots and Stiff patterns) and any correlation with observed groundwater levels, mine inflow and rainfall
- data collected from the recently installed monitoring bores will be assessed and evaluated to allow adjustment of the nominated trigger values for groundwater quality (following 24 months of data collection)
- if a monitoring trigger is realised, after review and where required the appropriate mitigation measure or offset will be implemented and the monitoring program appropriately adjusted, e.g. if a water quality trigger is realised, sampling frequency for analysis of water quality may be increased from six monthly to quarterly or more frequently, and additional monitoring locations may be incorporated (i.e. between bores where the trigger is reached and the threatened receptor)

- Ongoing GDE condition monitoring, which will involve:
  - Type 1 GDEs
    - sampling event at nominated bores every in accordance with the Department of Science, Information Technology and Innovation's *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna*
  - Type 2 GDEs
    - in-stream pool longevity and water sources supporting these water features to identify intra- and inter-annual trends (both natural and potentially Project affected)
    - macroinvertebrate surveys to establish the existing distribution, abundance and richness of macroinvertebrate communities, in association with ongoing water quality monitoring
    - macroinvertebrates sampling will be conducted in accordance with standards and protocols outlined by Conrick and Cockayne (2001)
  - Type 3 GDEs:
    - Identification of pre-mine condition (as affected by existing anthropological activities, climate variability)

    - establishment of permanent vegetation monitoring transects to measure structural characteristics and baseline condition of GDE habitats subject to impact (also including the consideration of the need for control sites)
    - monitoring transects will provide dedicated sites for structured and repeatable temporal measurements of Foliage Index / Leaf Area Index using canopy photography / hemispherical lenses
    - temporal measurement of Leaf Water Potential at reference trees when GDE vegetation monitoring sites are established and at subsequent monitoring events, this will provide a direct measure of water stress
    - capture of high resolution Normalised Differential Vegetation Index (NDVI) imagery over possible impact areas and any control sites, timed to coincide with monitoring events and undertaken biannually for an initial three years to establish a seasonal baseline for ongoing comparison (the data sets provide a measure of all vegetation, rather than selected sites within the transects)
  - Comparison of results against observed changes in GDE water budgets to link the cause, if possible, of monitored stress to changes in the water budget attributable to the Project, and other factors such as existing land-use, climate variability, fire, pests and weeds; and
- Evaluation of data arising to ensure management (and mitigation measures) are achieving the Project's environmental management objectives. It is anticipated that annual compliance reporting will be required.

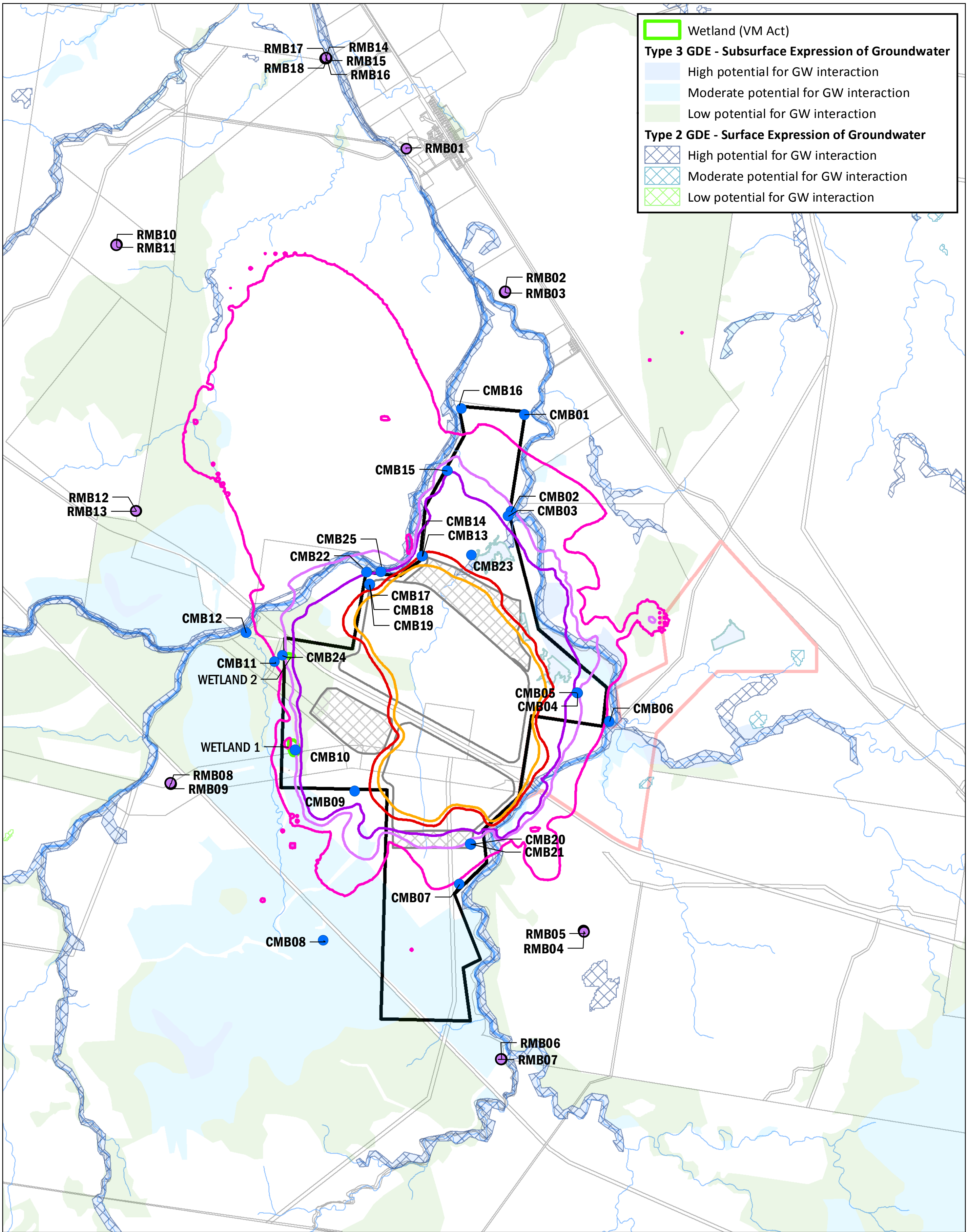
10.8.6 Mine Water Production Monitoring

Mine water inflow monitoring will consist of daily measurements of rates and/or volumes of all water pumped from the mine pit using a suitable method (note: aquifer testing strongly indicates ex-pit dewatering bores will not provide an effective means of mine water control). Mine produced waters will be subject to quarterly:

- Measurements of field water quality parameters (e.g. TDS, EC, pH); and
- Laboratory analyses of major ions, TDS, EC, dissolved metals (including aluminium, arsenic, selenium and vanadium) and hydrocarbons (TPH, TRH and BTEXN) using laboratories that are NATA-registered for the analyses undertaken, using methodologies that are suitable for comparison with the baseline monitoring.

10.8.7 Evaluation

A critically important aspect of any monitoring program involves the routine evaluation of the data against pre-defined triggers to identify whether there is any divergence from the expected, and whether any divergence is likely to give rise to an adverse effect. In addition, data evaluation will provide the opportunity to revise / update the REMP, if necessary, and to revisit management objectives to ensure they are appropriate for the Project.



N

0 1 2 km

Scale @ A4 1:80,000
Date: 13/12/18
Drawn: KMH

Legend

Monitoring bore

- Compliance
- Reference
- Dam
- Open-cut Mine Pit
- Waste Rock Area
- Major watercourse
- 0.1m predicted drawdown
- 0.5m predicted drawdown
- 1m predicted drawdown
- 5m predicted drawdown
- 10m predicted drawdown
- ML 80187
- ML 700022
- Cadastral boundary

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

Figure 10-102
Groundwater monitoring bore location plan

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Groundwater MB_locations_R5.mxd 12/13/2018

10.8.8 Frequency and Reporting

Groundwater compliance reports will be prepared to facilitate the transfer of monitoring data and the evolving knowledge gained to relevant regulatory authorities. The frequency of reporting will be decided in the relevant Project environmental authority. Issues relating to groundwater samples that are reported by the landholder or mine staff will be recorded and documented in the monitoring report, including any corrective actions that have been implemented.

10.8.9 Validation and Updating of the Conceptualisation and Groundwater Model

Future improvements to the numerical groundwater flow model will be undertaken as and when new data become available, particularly where there is a divergence of observed groundwater system response from the predicted. New data may require a revision and update of the conceptual (eco-) hydrogeological model prior to updating and recalibrating the numerical model and re-running of predictive scenarios. Where this is deemed necessary, the REMP and WMP may also need to be updated depending on any reconceptualization and model predictions.

As mining progresses, a need for further model updates will be assessed every two years based on quarterly reviews and evaluation of groundwater monitoring data and findings of impact verification. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater from the monitoring program.

Where additional management strategies are required in response to environmental performance, the existing numerical model, or new models depending on the type of impact observed (e.g. density coupled models to simulate seawater intrusion, which has been shown to be unlikely), will be used to test the effectiveness of mitigation measures prior to implementation to improve the outcomes of the proposed measures.

10.8.10 Environmental Offsets

A key management and mitigation measure that is available to deal with unacceptable outcomes that cannot be adequately managed involves committing to Project environmental offsets (see Chapter 14 – Terrestrial Ecology).

Central Queensland Coal will commit to an offset for the direct loss of habitat within the mine footprint (e.g. Type 3 GDEs), and will commit to appropriate monitoring and management efforts to monitor for potential indirect loss of habitat outside the mine footprint (i.e. Type 2 and Type 3 GDEs), as appropriate.

10.8.11 Qualitative Risk Assessment

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

For the purposes of risk associated with groundwater 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.

The qualitative risk assessment for the Project draws upon the impact assessment presented in Section 10.7. Table 10-86 presents an outline of how the level of risk derived based on longevity of effect and the assessed level of threat posed.

Table 10-86 Potential impacts to groundwater – groundwater quantity

EV / sensitive receptor	Potential impacts	Potential risk	Mitigation measures	Residual risk
Type 1 GDEs	▪ Dewatering of stygofauna habitat – location STX 093 (Figure 10-57), potential loss of 90% of habitat until around 25 years post-mine ▪ Stygofauna bore STX 093 is located on Deep Creek where greatest drawdown is predicted	Medium	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ Further investigations relating to understanding potential Type 1 GDE occurrences will be implemented to assist in assessing long-term impacts on Type 1 GDEs, and on development of appropriate management strategies where required - a stygofauna survey is to be conducted in accordance with the Department of Science, Information Technology and Innovation's *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna*, every five years during operation of the mine ▪ Maintenance of natural stream flow (and stream loss) regime will buffer drawdown effects	Medium
	▪ Dewatering of stygofauna habitat – all locations where stygofauna identified (other than STX 093; Figure 10-57) are predicted to register negligible drawdown (i.e. much less than 1 m) life of mine and post-mine	Low		Low
Type 2 GDEs	▪ Reduced water table elevation due to dewatering / depressurisation has the potential to reduce longevity of permanent pools that are connected to groundwater – where more than 0.5 m drawdown is predicted, impact expected for between 10 and 25 years post-mine, after which recovery is predicted	High	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ Maintenance of natural seasonal streamflow regimes during and post mining ▪ Maintain refuge pools that can be used to re-colonise any pools that might be impacted by the Project, this will	Medium
	▪ Reduced water table elevation due to dewatering / depressurisation has the potential to reduce longevity of permanent pools that are connected to groundwater – where between 0.1 and 0.5 m drawdown is predicted,	Medium		Medium

<table>
<tr><th>EV / sensitive receptor</th><th>Potential impacts</th><th>Potential risk</th><th>Mitigation measures</th><th>Residual risk</th></tr>
<tr><td></td><td>impact expected for between 10 and 25 years post-mine, after which recovery is predicted</td><td></td><td>involve management of pest and weeds and removal of stock access, for example
- Investigate potential for artificial maintenance of pools having significant biodiversity, and sources of water that can be used to do this
- Further investigations, such as stable isotope and radon studies to assist in identifying and understanding potential GDE interactions with groundwater (timing, form of interaction) and their pre-mining condition, will be implemented to assist in assessing long-term impacts on potential GDEs, and on development of appropriate management strategies where required</td><td></td></tr>
<tr><td rowspan="3">Type 3 GDEs</td><td>- Riparian - reduced water table elevation due to dewatering / depressurisation has a moderate/high potential to reduce access to groundwater by riparian vegetation in areas where more than 1 m of drawdown is predicted to around 25 years post-mine</td><td>High</td><td rowspan="3">- Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required
- Maintenance of natural seasonal streamflow regimes during and post mining to support near stream soil moisture reservoir
- Rate of drawdown is not sudden, vegetation has the capacity to follow a declining water table – but riparian vegetation will be at risk in areas where drawdown of more than 1 m occurs
- Investigate potential for artificial maintenance of soil moisture levels in areas of riparian vegetation having significant biodiversity, and sources of water that can be used to do this</td><td>Medium</td></tr>
<tr><td>- Riparian - reduced water table elevation due to dewatering / depressurisation has a low potential to reduce access to groundwater by riparian vegetation in areas where drawdown of less than 1 m is predicted until between 10 and 25 years post-mine, after which recovery is predicted</td><td>Low</td><td>Low</td></tr>
<tr><td>- Terrestrial, where the pre-mine water table is <10m - reduced water table elevation due to dewatering / depressurisation has a high potential to reduce access to groundwater by terrestrial vegetation in areas where more than 5 m of drawdown is predicted until between 10 and 25 years post-mine, after which recovery is predicted</td><td>High</td><td>Medium</td></tr>
</table>

EV / sensitive receptor	Potential impacts	Potential risk	Mitigation measures	Residual risk
	▪ Terrestrial, where the pre-mine water table is <10m - reduced water table elevation due to dewatering / depressurisation has a low/moderate potential to reduce access to groundwater by terrestrial vegetation in areas where between 0.1 and 5 m drawdown is predicted until between 10 and 25 years post-mine, after which recovery is predicted	Medium	▪ Maintain refuge riparian zones that can be used to re-colonise any areas that might be impacted by the Project, this will involve management of pest and weeds and removal of stock access, for example ▪ Investigate potential land management practices, e.g. contouring, to retain runoff waters and encourage recharge of soil reservoir in areas of significant terrestrial GDEs that may be impacted by groundwater drawdown associated with the Project ▪ Further investigations, such as stable isotope and water potential studies to assist in identifying and understanding potential GDE interactions with groundwater (timing, form of interaction) and their pre-mining condition, will be implemented to assist in assessing long-term impacts on potential GDEs, and on development of appropriate management strategies where required	Low
	▪ Terrestrial, where the pre-mine water t able is >10m- reduced water table elevation due to dewatering / depressurisation has a high potential to reduce access to groundwater by terrestrial vegetation in areas where more than 10 m of drawdown is predicted until between 10 and 25 years post-mine, after which recovery is predicted	High		Medium
	▪ Terrestrial, where the pre-mine water t able is >10m- reduced water table elevation due to dewatering / depressurisation has a high potential to reduce access to groundwater by terrestrial vegetation in areas where between 5 and 10 m drawdown is predicted until between 10 and 25 years post-mine, after which recovery is predicted	Medium		Low

Third party groundwater users	▪ Bore BH28/28A is currently not in use, however if it is to be recommissioned in the future around 1.5 m of drawdown is predicted through to 10 years post-mine, less than 10% loss of available drawdown, after which recovery is predicted	Low	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ If required, to provide ongoing access to groundwater, the following management options are available: - If sufficient available drawdown remains in the bore - lowering of the existing pump or fitting with a new pump - If insufficient available drawdown remains in the bore - deepening or relocation of the bore to an area outside of the area of impact - Provision of an alternative water supply of comparable quantity and quality to meet end-use requirements	Low
	▪ Other identified bores in the catchment are predicted to register negligible drawdown life of mine and post-mine, i.e. much less than 1 m.	Low		

Table 10-87 Potential impacts to groundwater – groundwater quality

EV / sensitive receptor	Potential impacts	Potential risk	Mitigation measures	Residual risk
GDEs	▪ The potential for groundwater quality decline to impact on Type 1, Type 2 and Type 3 GDEs is low to moderate	Medium	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ Manage water storages and mine pits to reduce the potential for salinisation of water, e.g. separation of contact and non-contact water	Low
	▪ The potential for GDEs to be impacted by AMD is considered low ▪ The potential for GDEs to be impacted by ASS is considered negligible ▪ The potential for seawater intrusion to impact on groundwater quality supporting GDEs is considered low	Low	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ The zone of drawdown influence of pits (during mining and for up to 50 years post-mine) will limit the potential for any contaminants to move significant distance from Project, thereby allowing remedial works if required	

Third party groundwater users	▪ The potential for groundwater quality decline to impact on third party groundwater user bore BH28/28A is considered low to moderate	Medium	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ Manage water storages and mine pits to reduce the potential for salinisation of water storages, e.g. consider use of natural (clay) liners, separation of contact and non-contact water	Low
	▪ The potential for groundwater quality decline to impact on other third party groundwater users is considered low ▪ The potential for third party groundwater users to be impacted by AMD is considered low ▪ The potential for GDEs to be impacted by ASS is considered negligible ▪ The potential for seawater intrusion to impact on groundwater quality supporting third party groundwater users GDEs is considered low	Low	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ The zone of drawdown influence of pits (during mining and for up to 50 years post-mine) will limit the potential for any contaminants to move significant distance from Project, thereby allowing remedial works if required	

Table 10-88 Potential impacts to groundwater – groundwater and surface water interactions

EV / sensitive receptor	Potential impacts	Potential risk	Mitigation measures	Residual risk
GDEs	▪ Tooloombah Creek - Baseflow reduction to sustain dry season streamflow and permanent pools is expected during mining and post-mine along the mid-lower reach	High	▪ Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring bores will take place during the life of mine – resulting data will be evaluated routinely to identify departures from predicted groundwater system response to mine water affecting activities and development of appropriate management strategies if required ▪ Maintenance of natural seasonal streamflow regimes during and post mining to support near stream soil moisture reservoir ▪ Investigate potential for artificial maintenance of soil moisture levels in areas of riparian vegetation having significant biodiversity, and sources of water that can be used to do this Maintain refuge riparian zones that can be used to re-colonise any areas that might be impacted by the Project, this will involve management of pest and weeds and removal of stock access, for example ▪ Investigate potential land management practices, e.g. contouring, to retain runoff waters and encourage recharge of soil reservoir in areas of significant terrestrial GDEs that may be impacted by groundwater drawdown associated with the Project	Medium
	▪ Tooloombah Creek – Low potential for baseflow reduction along the upper reach is expected	Low		Low
	▪ Deep Creek - Baseflow reduction to sustain dry season streamflow and permanent pools is expected during mining and post-mine along the mid-reach	High		Medium
	▪ Deep Creek – Moderate potential for baseflow reduction along the upper and lower reaches is expected	Moderate		Low
Third party groundwater users	▪ Baseflow reduction is not likely to impact on third party water use (negligible potential)	Low	▪ No management required, as bores are not maintained by baseflow	Low

Table 10-89 Potential impacts to groundwater – aquifer disruption

EV / sensitive receptor	Potential impacts	Potential risk	Mitigation measures	Residual risk
GDEs	▪ Mining will temporarily interrupt the local groundwater system ▪ Hydraulic loading has potential to change HSU1 (alluvium) hydraulic properties beneath waste storages and stockpiles, potentially causing higher groundwater levels / pressures upstream of stockpiles ▪ Remnant waste storages will remain after closure	Medium	▪ Progressive backfilling of mine pits will occur during mining, limiting the timeframe over which aquifer interruption by mining occurs ▪ Size of waste storages will be managed by progressive backfilling of mine pits during mining ▪ Depth to water table beneath stockpiles is typically greater than 10 m, mitigating potential for hydraulic loading to cause water tables to rise to ground surface	Low
Third party groundwater users	▪ Aquifer disruption is not likely to impact on third party water use (negligible potential)	Low		

Table 10-90 Potential impacts to groundwater in relation to other activities not associated with direct groundwater effects

EV / sensitive receptor	Potential impacts	Potential risk	Mitigation measures	Residual risk
All EVs and receptors	▪ The potential exists for groundwater quality to be impacted by accidental release of contaminants to shallow groundwater, this may be caused in the event of ▪ Uncontrolled releases of hydrocarbon from haul trucks, fuel tankers and storages ▪ Uncontrolled release from chemical and hazardous goods stores	Medium	▪ Engineered design of chemicals and hazardous goods storage areas ▪ Management plans, assignment of roles and responsibilities for management plans and strategies ▪ Machinery will be well maintained ▪ Fuel and chemical stores will be designed, constructed and operated in accordance with industry standards ▪ The zone of drawdown influence of pits (during mining and for up to 50 years post-mine) will limit the potential for any contaminants to move significant distance from Project, thereby allowing remedial works if required ▪ Spill kits with appropriate spill control materials will be available to all personnel in the event of a spill or leak	Low
Dust suppression				
All EVs and receptors	▪ Watering activities to suppress dust may be required, particularly during the dry season ▪ Watering and wetting of the soil will be managed to reduce potential for seepage to shallow groundwater	Low	▪ Manage dewatering activities such that water is not applied in excess of requirements ▪ The zone of drawdown influence of pits (during mining and for up to 50 years post-mine) will limit the potential for any contaminants to move significant distance from Project, thereby allowing remedial works if required	Low

10.9 Conclusions

10.9.1 Baseline Environment

10.9.1.1 EVs and WQOs

EVs considered applicable for the Project include aquatic ecosystems, irrigation, farm supply / uses, stock water, and cultural and spiritual values. WQOs for the Project are those defined for the Styx, Uplands and Bison GCZs of the Styx River Basin.

10.9.1.2 Physical setting

The physical setting for the Project is described in Section 10.5. The following presents summary details:

- Climate (Section 10.5.2):
  - Sub-tropical, with cool winters and hot summers
  - Wet and dry seasons but distinct climate variability exists, with decadal trends in below and above average rainfall, and short intra-decadal trends of around average rainfall
  - Average evaporation rates exceed average rainfall rates in every month of the year
  - Recharge rates could range between 1 and 4% of average annual rainfall (7 to 30 mm/yr)
- Topography (Section 10.5.3) of Styx River catchment ranges from around 540 m to near sea level at Broad Sound;
- Hydrology (Section 10.5.4):
  - Project is wholly contained within Styx River catchment, and is bounded by the major tributaries of Tooloombah and Deep Creeks
  - Catchment has been cleared for grazing and limited dryland cropping
  - Styx River is tidally influenced downstream of the confluence of Tooloombah and Deep Creeks
  - Tooloombah and Deep Creeks are typically deeply incised into the landscape, but overbank flow of the mid- to lower-reaches is common during high intensity rainfall events
  - In-stream pools occur along the mid- to lower-reaches of both creeks (predominantly Tooloombah Creek) and some persist during the dry season, which suggests some level of interaction with groundwater (baseflow)
  - Water quality data for Tooloombah and Deep Creeks indicate Deep Creek possibly interacts less with groundwater than Tooloombah Creek, where in-stream pools show a divergence away from a rainfall signature at the end of the dry season toward a groundwater signature

- Geology (Section 10.5.5):
  - Unconsolidated Cenozoic sediments (alluvium) cover most of the Project area to depths of up to 18 m or more
  - The Cretaceous Styx Coal Measures underlie the alluvium, and occur to depths of more than 300 m in the Project area, with
    - overburden materials typically comprising of variably weathered interbedded quartzose sandstone (dominant) and siltstone/mudstone, and traces of coal
    - the coal seams and interburden materials typically comprising of coal seams, and variably weathered interbedded siltstone/mudstone (dominant) and sandstone
    - underburden materials typically comprising of interbedded sandstone (dominant) and siltstone/mudstone
  - Beneath the Coal Measures and outcropping in some areas, basement comprises of sandstones, mudstones and volcanics, with a residual (weathered) basement observed in outcrops.
- Geochemistry (Section 10.5.5.3)
  - Waste materials are characterised as having low to negligible potential for generation of acidic leachate
  - Significant deterioration of groundwater quality in response to waste materials management is considered very unlikely to occur
- Hydrogeology (Section 10.5.6)
  - The available data shows there is little evidence of a distinct seasonal response to rainfall and stream flow events in any of the stratigraphic units, particularly the Styx Coal Measures and Basement
  - Groundwater head data show
    - the lower reaches of Tooloombah and Deep Creeks, and both Styx River and Broad Sound are zones of nett groundwater discharge
    - the tributary Tooloombah and Deep Creek catchments appear to be predominantly closed groundwater catchments
    - potential for upward flow beneath Tooloombah and Deep Creeks, and beneath Styx River near Broad Sound
    - the seawater-fresh water interface is not present as far inland as the confluence of Styx River and Broad Sound estuary
  - Aquifer testing results indicate
    - only the alluvium (HSU1) and weathered basement (HSU3) can be considered to form aquifers in the Project area

  - the Coal Measures can be considered as aquitards (low permeability and low storage co-efficient)
- Groundwater quality data
  - the Queensland Government has identified EVs for groundwater in the Styx River Basin – aquatic ecosystems, irrigation, farm supplies, stock water, and cultural and spiritual. The groundwater studies undertaken and described in this chapter suggest that each of these EVs have varying degrees of reliance on groundwater
  - groundwater samples have been collected during 2017 and 2018 from privately owned bores, as well as Project WMP bores. Groundwater salinity (as TDS) is variable across the Styx River Basin, ranging from drinking water quality (TDS less than 600 mg/L) to water quality unacceptable for drinking or livestock (TDS greater than 1,200 and 5,000 mg/L, respectively). Of the available data, approximately 60% of samples report TDS concentrations within the acceptable salinity tolerance range of most livestock. Groundwater salinity of the Styx Coal Measures is generally slightly higher than groundwater in the alluvium HSUs
  - the Styx Coal Measures do not show a distinctly seawater signature, but do show evidence of direct recharge from rainfall or interaction with surface water, with seasonal variability in water quality evident
  - seasonal variability in water quality is not evident in the Styx Coal Measures groundwaters
  - the alluvium show evidence of direct recharge from rainfall or interaction with surface water, and also interaction with Styx Coal Measures groundwater, with seasonal variability in water quality also evident
  - the available groundwater chemistry data shows alluvial groundwaters typically demonstrate a shift toward a rainwater signature toward the end of the wet season
  - concentrations of major ions in Basement groundwater typically do not display a dominant water type but is generally Ca-Cl dominant, which likely indicates reverse ion exchange processes where Na in groundwater is exchanged with Ca in the lithology, resulting in the Ca-Cl dominance
  - the seawater-fresh water interface is not present as far inland as the confluence of Styx River and Broad Sound estuary
  - aluminium, arsenic, cobalt copper, lead, manganese, molybdenum, iron, fluoride, zinc, chromium, barium, nickel, silver, uranium and vanadium typically occur above the WQOs defined for each of the GCZs within which the Project area
  - hydrocarbons are reported in some laboratory analyses, particularly for groundwaters sampled from the Styx Coal Measures
- Groundwater and surface water interactions
  - analysis of available hydraulic head, topographical and hydro-chemical data shows the main sources of water present in Styx River are derived from tidal

(estuarine) waters or surface water runoff, and groundwater baseflow to Styx River is unlikely to be 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.

10.9.1.3 Potentially sensitive groundwater receptors

The location of potentially sensitive groundwater users is described in Section 10.6. The following presents summary details:

- GDEs (Section 10.6.1 and Section 10.7.4.4):
  - Type 1 GDEs (stygofauna) have been identified in the Project area within the alluvial aquifer, but do not appear to be widely occurring
  - Type 2 GDEs (ecosystems reliant on the surface expression of groundwater)
    - are present within Tooloombah and Deep Creeks (in-stream pools) as well as Styx River and Broad Sound estuary (estuarine)
    - both Wetland 1 and Wetland 2 have been found to not be Type 2 GDEs (Wetlands 1 and 2 appear to be reliant on surface water inundation following rainfall events, and Wetland 1 may be reliant to some extent on groundwater)
  - Type 3 GDEs (ecosystems reliant on subsurface expression of groundwater) occur within the Project area
    - Although the Semi-evergreen Vine Thicket has been found not to be a Type 3 GDE, demonstrating vadophytic tendencies
    - Wetland 1 appears to have some reliance on groundwater, as do Forest Gum woodlands where the water table occurs at depths of less than 10 m
- Third party groundwater users (Section 10.6.2) may exist in the Project area, but only one bore (BH28A) is located on the mine lease.

10.9.2 Impact assessment

10.9.2.1 Approach

The NWC *Framework for assessing local and cumulative effects of mining on groundwater and connected systems* (Howe, 2011) has provided the template for undertaking the groundwater impact assessment for the Project, the framework essentially requires a 'source-receptor-pathway' analysis. The framework involves a seven step methodology, and the following provides brief details (Section 10.7.1 provides more detail, and Figure 10-62 presents the framework flowchart):

- Step 1 – Context
  Provides context for the impact assessment, including physical setting (see Section 10.5), description of mining operation (see Chapter 1, Introduction, Section 1.3), and introduces potential sensitive receptors (see Section 10.6);

- Step 2 – Management objectives
  Sets the scene for effective engagement with external stakeholders, describes the relationship between water resource condition and sensitive receptors (see Section 10.4 and 10.7.4.4);

- Step 3 – Direct effects assessment
  Could be called 'hazard assessment', describes the effects of mine water affecting activities on groundwater resources and connected systems (see Section 10.7.2), has been informed by outcomes of bioregional assessments (Ford, 2016);

- Step 4 – Receptor exposure assessment
  Presents an assessment of sensitive receptors located within the Project's 'zone of influence', including whether some form of groundwater reliance exists for particular receptors or receptor groups (see Section 10.7.4.4), and identification of the relationship (pathways) between the receptors and each hazard (see Section 10.7.4.8);

- Step 5 – Threat and opportunity assessment
  This brings together the hazard and exposure assessments to assess the level of threat posed to sensitive receptors due to development of hazards (see Section 10.7.4.8), and whether there are opportunities to mitigate threats (such as backfilling of mine pits);

- Step 6 – Risk characterisation
  A semi-qualitative assessment of risk posed to sensitive receptors due to Project hazards, provides a basis for communicating risk to stakeholders and identifying management strategies should they be necessary (see Section 10.8.11); and

- Step 7 – Monitor, evaluate, review and amend
  This step involves implementation of REMP and WMP (see Section 10.8) to provide data and knowledge that will inform whether or not Project environmental performance is meeting Management Objectives (Step 2), and whether it is necessary to undertake any additional management or mitigation activities to ensure the Management Objectives are being met.

10.9.2.2 Numerical groundwater flow modelling

Groundwater modelling has been used as a practical manner by which to simulate and predict groundwater system response to mine water affecting activities associated with the Project by predicting potential rates of mine dewatering and groundwater system response to dewatering, management of mine wastes and water storages, as well as climate variability (see Section 10.7.4 for details). In addition, the model has been used in combination with knowledge developed as part of describing the groundwater baseline (see Sections 10.5 and 10.6) to assess the potential for mine water affecting activities to give rise to ASS, AMD and inland mobilisation of the seawater-freshwater interface.

The numerical groundwater flow model is defined as a Class 1 model (in accordance with the Australian Groundwater Modelling Guidelines; Barnett et al. 2012), but has elements of Class 2 and Class 3 models. The model has been prepared to represent and test the conceptual hydrogeological model developed for the Project area (see Section 10.5.6.8 and Section 10.7.4.7, respectively).

Model calibration and verification has involved representing hydraulic property values (K and S) based on available aquifer testing results and estimated rainfall recharge rates (see Section 10.7.4.1, and Appendix A6, Groundwater Technical Report, Section 3).

A conservative approach to model development, i.e. in regards to assignment of boundary conditions and hydraulic properties. Table 10-91 presents a summary of key conservative aspects of model development.

Sensitivity and uncertainty testing of the model has revealed Coal Measures coal seams/interburden K is the most critical of the modelled hydraulic properties for impact assessment, and it carries most of the predictive uncertainty in terms of the extent of the predicted drawdown. To maintain reasonable calibration though, a representative regional value of Coal Measures coal seams/interburden K ought to be lower than 0.01 m/d, which is consistent with the adopted value for the basecase model. The alternative conceptualisation assessment (see Section 10.7.4.7) shows the values of Coal Measures coal seams/interburden K required for a significant impact to occur downstream of the Project are not supported by field observations or the general understanding of coal bed hydrogeological characterisation (see Section 10.5.6.3 for further discussion).

Table 10-91 Summary details of conservative aspects of the Project numerical groundwater flow model

Process	Model representation	Conservative aspect
HSU hydraulic parameters	During the uncertainty analysis, conservative (high) values of regional hydraulic conductivities in all HSUs have been simulated. It was shown that the predictive uncertainty is primarily carried by the coal seams and interburden HSU. By adopting conservative hydraulic conductivities, it is predicted that drawdown remains less than 0.1 m above the confluence of Tooloombah and Deep Creeks (i.e. the 0.1 m drawdown contour does not extend to Styx River, Broad Sound estuary or the coast).	Assumed range in hydraulic conductivity values for the uncertainty analysis: ▪ spanned at least 1 order of magnitude beyond best calibrated values; ▪ extended at least up to the maximum value of field estimate for each HSU (from slug and pumping tests).
Mining operation	Two mining schedules have been modelled to test groundwater system sensitivity to pit development and backfilling schedules.	The most conservative of the two schedules has been represented for the predictive analysis.
Backfill moisture content	Backfill materials are assumed to be completely dry.	Backfill materials will have moisture contents above zero. Not simulating this ‘starting point’ means that predicted timeframes for groundwater recovery will be over-estimated.
Storage coefficient	Storage parameters (S and Sy) have been represented at very low values.	Low storage values will result in an over-estimate of drawdown extent when compared to higher values.
River and Creek flows	Creeks have been represented by the MODFLOW model Drain package. Flood recharge is represented through the Recharge package.	In comparison to the River package, the Drain package doesn’t generate discharge to groundwater that would be expected to constrain the propagation of drawdown. Assigning flood recharge through the Recharge package controls recharge (stream losses) related to stream flow. Uncertainty analysis has incorporated an analysis of how reductions and increases in flood recharge (representing drought and above average rainfall conditions, respectively) impact on the groundwater baseline.

Process	Model representation	Conservative aspect
Water storage dams	Not represented	Water storages are expected to induce recharge that will counter-balance drawdown (i.e. least conservative). Not representing the water storages will result in over-estimated drawdown extent (vertically and laterally).

10.9.2.3 Direct effects (hazard) assessment

Direct effects taken through to the impact assessment (see Section 10.7.4.8 and Table 10-79 for details) include:

- Mining (excavation);
- Backfilling of mine pits;
- Mine dewatering / depressurisation;
- Stockpiling and waste storages; and
- Water storages.

Those hazards that can be controlled though management plans and engineering design have largely been excluded from the assessment so that the focus is on those effects that cannot be directly controlled.

10.9.2.4 Groundwater effects assessment

The following presents a summary of the groundwater effects assessment undertaken for the Project:

- **Groundwater quantity**

  During mining, it is predicted there will be very little change to water table elevations upstream and downstream of the proposed mine, but there will likely be significant reduction in water table/potentiometric surface elevation in the vicinity of the mine (due to dewatering that is required to provide efficient and safe conditions for mining). The limited drawdown predicted to occur downstream of the mine is consistent with the observation that the Tooloombah and Deep Creek catchments behave as closed groundwater catchments, and that mining intercepts groundwater discharge above the confluence of the creeks and has little measurable, if any, impact to Styx River and Broad Sound downstream of the confluence.

  The zone of mine-related drawdown influence is predicted to align northwest to southeast, and does not interfere with the tidal reach of Styx River. This drawdown persists for up to 50 years post-mining but, because the mine pits are progressively backfilled, the groundwater system is conservatively predicted to fully recover sometime after 50 years (but before 100 years).

  The mid- to lower reaches of both Tooloombah and Deep Creeks are predicted to receive lower rates of baseflow due to drawdown, which may impact on the longevity of in-stream pools that occur along these reaches. Recovery of groundwater levels such that baseflow returns to average pre-mine conditions is conservatively predicted to occur sometime after 50 years following mine closure.

The rate of water table decline in areas of terrestrial and riparian GDEs is not expected to be sudden and may allow vegetation to adapt to a declining water table through extension of root systems. Of course, due to physiological limitations, there will be a depth where different types of phreatophytic vegetation cannot extend their roots to. The rate of decline, however, will allow observations to be made concerning vegetation health and development of management approaches to address any circumstances where adverse impacts are likely.

- **Groundwater quality**
  As the backfilled mine pits will recover from bottom up, i.e. the Styx Coal Measures (HSU2) and then later the alluvium (HSU1), groundwater salinity (and other water quality parameters) will likely represent the source of recovering waters after mining is completed.

  Geochemical studies undertaken for the Project indicate the coal measures and other materials that will be excavated and stockpiled as top soil, overburden or waste are unlikely to be acid forming, meaning AMD is unlikely to impact on any leachate that may be generated from these materials.

  The potential for ASS in the Styx River catchment is largely restricted to the coastal zone below Ogmore on Styx River. Groundwater model predictions indicate drawdown associated with mine water affecting activities will not extend downstream to Styx River and, so, any threat to marine and aquatic ecosystems associated with ASS is considered negligible.

  The seawater-fresh water interface does not extend as far inland as the confluence of Styx River and Broad Sound estuary (below Ogmore). Based on drawdown predictions and the hydrogeological conceptualisation, it is considered highly unlikely that the interface will be mobilised.

  With regard to the handling and storage of hazardous goods and chemicals on site, engineering design of storage and handling infrastructure along with strict handling, use and storage controls will reduce the potential for uncontrolled release of pollutants to the environment and contamination of groundwater.

- **Groundwater and surface water interaction**
  Water table drawdowns associated with mine dewatering and during recovery of groundwater after completion of mining will result in temporarily (around 50 years post mining) reduced interactions between groundwater and surface water, particularly during dry periods. The zone of influence is predicted to not extend as far as the confluence between Tooloombah and Deep Creeks or Styx River, and be largely restricted to the mid-and lower reaches of the creeks.

- **Aquifer disruption**
  Pit voids will not remain after closure as the pits will be progressively backfilled during mining. However relatively small (remnant) waste rock stockpiles will remain after mining (most of the waste storages will be used to backfill the mine pits). These storages are unlikely to result in hydraulic loading that is significant enough to result in water table rise to the surface or disrupt groundwater flow paths.

10.9.2.5 Risk Assessment

The direct groundwater effects described above are expected to impact on the environmental water requirements of Type 1 (stygofauna), Type 2 (aquatic ecosystems) and, to a more limited extent, on Type 3 (riparian and terrestrial vegetation communities) GDEs that occur within the predicted zone of drawdown influence.

The following presents a summary of the EV / receptor impact and (residual[2]) risk assessment that comprises an assessment of receptor exposure to direct groundwater effects (adopting Groundwater Quantity as the key measure) and threat posed to receptors that have an exposure pathway to direct effects:

- Type 1 GDEs (stygofauna):
  - Of the locations where stygofauna has been identified, the nearest location (STX 093) is predicted to experience the greatest drawdown, with the predicted loss of habitat (saturated thickness) to be around 90%
  - The assessed level of threat posed to Type 1 GDEs is assessed as ranging low to high
  - The longevity of threat posed is temporary
  - The residual risk posed to Type 1 GDEs from mine water affecting activities is considered **LOW** to **MEDIUM**
- Type 2 GDEs (aquatic ecosystems):
  - Predicted drawdown of between 0.1 and 0.5 m along reaches of Tooloombah and Deep Creeks total around 7 km, and reaches where more than 0.5 m drawdown is predicted total around 6 km
  - The assessed level of threat posed to Type 2 GDEs is assessed as low/moderate to high
  - The longevity of threat posed is temporary
  - The residual risk posed to Type 2 GDEs from mine water affecting activities is considered **MEDIUM** to **HIGH** (due to limited management options)
- Type 3 GDEs (riparian):
  - Predicted drawdown of between 0.1 and 1 m within the riparian zone along reaches of Tooloombah and Deep Creeks total around 135 Ha, and reaches where more than 1 m drawdown is predicted total around 38 Ha
  - The assessed level of threat posed to Type 3 riparian GDEs is assessed as low to high
  - The longevity of threat posed is temporary
  - The residual risk posed to Type 3 GDEs from mine water affecting activities is considered **LOW** to **MEDIUM**
- Type 3 GDEs (terrestrial), in areas where the water table lies within 10 m of the ground surface:
  - Predicted drawdown of between 0.1 and 5 m along reaches of Tooloombah and Deep Creeks total around 97 Ha, and reaches where more than 5 m drawdown is predicted to total around 3 Ha
  - The assessed level of threat posed to Type 3 terrestrial GDEs is assessed as low to high, depending on drawdown threshold (0 to 5 m, and more than 5 m)

[2] After mitigation measures are implemented

  - The longevity of threat posed is temporary
  - The residual risk posed to Type 3 GDEs from mine water affecting activities is considered **LOW** to **MEDIUM**
- Type 3 GDEs (terrestrial), in areas where the water table lies more than 10 m from the ground surface:
  - Predicted drawdown of between 5 and 10 m along reaches of Tooloombah and Deep Creeks total around 8 Ha, and reaches where more than 10 m drawdown is predicted total around 18 Ha
  - The assessed level of threat posed to Type 3 terrestrial GDEs is assessed as low to high, depending on drawdown threshold (5 to 10 m, and more than 10 m)
  - The longevity of threat posed is temporary
  - The residual risk posed to Type 3 GDEs from mine water affecting activities is considered **LOW** to **MEDIUM**
- Third party groundwater users (Irrigation, Farm and Stock Supply):
  - The assessed level of threat posed to existing third party users of groundwater is assessed as negligible to low
  - The longevity of threat posed is temporary
  - The residual risk posed to third party water users from mine water affecting activities is considered **LOW**.

In relation to groundwater response to mine water affecting activities and the potential for generation of ASS and AMD, and mobilisation of the seawater-freshwater interface, Table 10-92 presents key details arising from the groundwater study presented in this report.

Table 10-92 Summary of key groundwater risk issues

Key risk issue	Discussion
Seawater intrusion	The groundwater study presented in this report, supported by gauging groundwater pressures and analysis of groundwater salinity, mapping of water table elevation contours and numerical groundwater modelling, strongly indicates the combined Tooloombah Creek and Deep Creek catchments, within which the Project is located, is essentially a closed groundwater catchment. Shallow groundwater and possibly deeper groundwater discharges to the mid- and lower reaches of the creeks above the confluence of the creeks where they merge to form the Styx River. Upstream of the confluence, dewatering of the mine is predicted to result in groundwater drawdowns (and depressurisation) of between 0.1 and more than 100 m. Downstream of the confluence, within the tidally influenced Styx River, water table elevations and groundwater pressures are predicted to remain much the same as the pre-mine baseline conditions. It is concluded the mine poses little threat to inland mobilisation of the seawater interface (which is identified as not extending as far inland as the confluence of Styx River and Broad Sound estuary).

Key risk issue	Discussion
AMD	Geochemical studies undertaken on samples of the alluvium and coal measures has found the materials are essentially non-acid forming. It is concluded that mining (pit walls) and top soil / waste stockpiling poses little threat to generation of AMD and adverse impact to groundwater quality, with significant neutralising capacity existing within the materials.
ASS	Soils mapping in the Styx River catchment, including the Tooloombah and Deep Creek tributary catchments, shows that soils and sediments of the catchment below the confluence of the creeks have the potential to generate acid if exposed to the atmosphere (an issue if drawdown were to expose these ASS). Modelling has shown there is little potential for exposure of ASS, with drawdowns of less than 1 m predicted for areas northwest of the ML 80187, and no drawdown predicted at Styx River or Broad Sound estuary.

10.10 Commitments

In relation to managing groundwater, Central Queensland Coal's commitments are provided in Table 10-93.

Table 10-93 Commitments – groundwater

Commitment
During the life of the mine, monitor and evaluate groundwater levels/pressures at on-lease and off-lease monitoring bores and evaluate data to identify departures from predicted groundwater system response to mine water affecting activities and develop management strategies if required.
Maintain natural seasonal streamflow regimes during and post mining to support near stream soil moisture reservoir.
Investigate potential for artificial maintenance of soil moisture levels in areas of riparian vegetation having significant biodiversity. This will involve management of pest and weeds and removal of stock access.
Investigate potential land management practices, e.g. contouring, to retain runoff waters and encourage recharge of soil reservoir in areas of significant terrestrial GDEs that may be impacted by groundwater drawdown associated with the Project.
Responsible resource recovery, including mitigation of unacceptable potential impacts on groundwater and connected systems.
Prepare an Underground Water Impact Report (UWIR) prior to commencing mining. The UWIR will address the obligations under chapter three, division four, section 376 of the Water Act.
Prepare and implement a Water Management Plan that outlines the monitoring and management measures for surface water and groundwater. This will include sampling surface waters and groundwater for analysis of stable isotopes of water to further inform groundwater and surface water interactions and the potential mixing with seawater.
Prepare and implement a water management network to manage impact to water resources.
Conduct additional studies to further assess the degree to which ecosystems in the area may rely on groundwater to inform how the Project will meet environmental water requirements.
Carefully manage and put in place control measures for potential pollutants and contaminant sources to prevent uncontrolled release to the environment.
Ensure all staff are aware of the potential for groundwater quality to be impacted and the requirement to report any spills.
Liaise with the landholder (at BH28/BH28A) with the aim of reaching arrangements that will ensure provision of water of adequate yield and quality during and after mining until the aquifers are replenished or access to groundwater for stock water is no longer deemed compromised.
As mining progresses and new data associated with the groundwater system response to mining become available, the groundwater model will be reviewed and, if necessary, recalibrated every two years, and predictions reassessed in terms of potential groundwater and receptor effects.
The health of riparian vegetation adjacent to the mine will be monitored at least annually throughout construction, operation and decommissioning to identify impacts to environmental values.
Develop and implement a REMP in accordance with DES Guidelines and periodically update as required throughout the life of the Project.
Develop and implement a Waste Management Plan including management of hazardous materials and a spill management plan.

10.11 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 proposed 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 9 – Surface Water, Chapter 14 – Terrestrial Ecology, Chapter 15 Aquatic Ecology and Chapter 16 – Matters of National Environmental Significance. Baseline data are included where relevant in each of the technical chapters as are details concerning 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 groundwater are discussed in Table 10-94 and Table 10-95. A completed full version of the IESC checklist is provided in Appendix 23 – Checklist for IESC Information Guidelines.

Table 10-94 Groundwater – IESC Compliance Checklist

Checklist item	Addressed	Not addressed/ Justifications
Context and conceptualisation		
▪ Describe and map geology at an appropriate level of horizontal and vertical resolution including: - definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data. - geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.	▪ Section 10.5.5 describes the geological sequence ▪ Figure 10-16 shows the regional surface geology ▪ Figure 10-17 shows a schematic geological cross section interpreted from the surface geology regional geological studies	▪ Significant structure not identified in geological units of interest, although there may be structural control to Styx Basin
▪ Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	▪ Bore logs from the project area are provided in Appendix A6- Groundwater Technical Report which show interpretation of hydrogeological units and a record of standing water levels ▪ Figure 10-20 shows the water table elevation across the study area and groundwater flow direction, inferred from field data ▪ Figure 10-21 shows the measured depth to groundwater across the study area ▪ Figure 10-22 to 10-26 present groundwater elevation hydrographs for all available timeseries data in the study area ▪ Figure 10-27 presents groundwater elevations from nested monitoring sites for interpretation of vertical gradients	▪ Groundwater elevations have been interpreted from from Lidar and SRTM datasets and TOC height for all bores, rather than from surveyed bore elevations.
▪ Define and describe or characterise significant geological structures (e.g. faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. ▪ Site-specific studies (e.g. geophysical, coring / wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g. damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays). ▪ Discussion on how this fits into the fault's potential influence on regional-scale groundwater conditions should also be included.	▪ Geological structures presented in Figure 10-16	▪ Fracturing and faulting unlikely to be significant in control of groundwater flow, and recharge/discharge given the (hydro)geological setting – generally low permeability units ▪ Modelling assesses regional scale impacts, and therefore it is considered justified to give less priority to potential basin scale structural features that already control hydrostratigraphic response to mine water affecting activities.

Checklist item	Addressed	Not addressed/ Justifications
▪ Provide hydrochemical (e.g. acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g. stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	▪ Section 10.5.4.2 presents water quality data for the surface water features in the study area including the two adjacent creeks (Tooloombah and Deep) and Styx River, in the form of EC timeseries, piper plots and seasonal stiff patterns. ▪ Section 10.5.6.5 presents water quality data for all identified hydro stratigraphic units in the form of EC timeseries, piper plots and seasonal stiff patterns. ▪ Section 10.5.6.6 presents a chloride mass balance approach for estimating recharge rates. ▪ Section 10.5.6.7 presents sodium vs. chloride ratio plots used to inform connectivity between groundwater and surface water ▪ Section 10.6.1.3 presents a targeted stable isotope and radon studies used to inform connectivity between groundwater and surface water, and identify sources of water used by potential GDEs.	
▪ Provide site-specific values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	▪ Section 10.5.6.3 provides a summary of site specific hydraulic property estimates (including horizontal conductivity and storativity) obtained from aquifer tests performed in all identified hydrostratigraphic units as well as a literature review of hydraulic property information for the regional area and other relevant units. ▪ Appendix A6- Groundwater Technical Report provides the data and summary of the analyses for tests undertaken on Project bores.	▪ Low permeability sediments are not conducive to pumping tests that could provide data for analysis of K' and leakance. ▪ Low permeability sediments were generally only suitable for slug testing (deriving estimates of K, only).
▪ Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	▪ Figures 10-46 to 10-51 present conceptual cross-sections which show the likely recharge, discharge and flow pathways, also discussed in Section 10.5.6.6, 10.5.6.7 and 10.5.6.8. ▪ Figure 10-20 shows the water table elevation across the study area and groundwater flow direction, inferred from field data.	

Checklist item	Addressed	Not addressed/ Justifications
▪ Provide time series groundwater level and quality data representative of seasonal and climatic cycles.	▪ Timeseries groundwater levels from February 2017 to November 2018 (21 months) are provided in Figures 10-22 to 10-26 The groundwater level data timeseries spans two wet seasons and two dry seasons with minor variations in water levels observed across the timeseries (max. up to 3m). ▪ Timeseries groundwater water quality data from May 2017 to September 2018 are presented in Tables 10-16 to 10-67. The water quality data spans two dry seasons and one wet season. The quality of Alluvium groundwater shows some variation between the wet and dry seasons but the Styx Coal Measures does not show significant seasonal variability. ▪ Climate data (presented in Section 10.5.2) indicates that the site has experienced average long term rainfall during the baseline period. ▪ The available baseline data timeseries is considered representative of long term average seasonal cycles.	
▪ Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	▪ Section 10.5.6.2 and 10.5.6.7 discuss hydraulic gradients (vertical and horizontal) and seasonal interactions between identified hydrostratigraphic units and surface waters, including estuarine and tidally influenced stream reaches (Styx River). ▪ Figures 10-46 to 10-51 present conceptual cross-sections which show the hypothesised interactions spatially. ▪ Table 10-69 presents field observations of watercourse pools which indicates the location, frequency and duration of potential connections ▪ Section 10.7.3.4 provides a summary of water balance modelling undertaken (details provided in Appendix A6- Groundwater Technical Report) to estimate the volume of groundwater discharge to connected surface waters.	
Analytical and numerical modelling		
▪ Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	▪ A detailed description of all modelling undertaken is provided in Appendix A6- Groundwater Technical Report, including numerical groundwater effects modelling and an analytical water balance model. ▪ Summary details of model are presented in Section 10.7.4.1.	

Checklist item	Addressed	Not addressed/ Justifications
▪ Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.	▪ The conceptualisation underpinning the numerical modelling is described in Section 10.5.6.8. ▪ Alternative conceptualisations are presented in Section 10.7.4.7. ▪ The model limitations are described in Section 3.9 of Appendix A6- Groundwater Technical Report, and a description of the conservative aspects of model development is presented in Section 10.9.2.2. ▪ Model sensitivity and uncertainty testing supports the conceptualisation and model parameters adopted.	
▪ Undertaken groundwater modelling in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), including independent peer review.	▪ Groundwater modelling has been undertaken in accordance with the Australian Modelling Guidelines, as demonstrated in Section 3.3 of Appendix A6- Groundwater Technical Report. ▪ Technical peer review by external experts is underway, with delivery planned for December 2018 / January 2019.	
▪ Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	▪ The model has been constructed with drain cells, constant head and no-flow cells, as described in Section 3.4.4 of Appendix A6- Groundwater Technical Report. ▪ Recharge has been used to represent diffuse rainfall recharge and watercourse flood recharge. Sensitivity of predictions to climate variability has been tested (see Section (10.7.4.7).	▪ The boundary conditions adopted are considered appropriate. ▪ The full groundwater catchment was modelled, therefore no flow boundaries at the catchment boundaries are appropriate. ▪ At the coast, constant head boundary was used rather than general head boundaries, which is more appropriate given the location of the coast (and mean sea level, the governing head control) is known. ▪ With regard to the creeks represented in the model, drain cells are considered more conservative than river cells for an ephemeral stream. For these cells, the heads have been defined by elevation and bed conductance is set high enough to enable drainage the be controlled solely by the hydraulic properties of the aquifers.

Checklist item	Addressed	Not addressed/ Justifications
▪ Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	▪ Model calibration is discussed in Section 3.5 of Appendix A6-Groundwater Technical Report. ▪ Model calibration is considered satisfactory, with calibration statistics consistent with what would be expected for a well calibrated (steady state) model. However, most observation points only have a single observation, with a smaller number having time series data of almost 2-years – showing response of groundwater heads across more than two seasons. This could be regarded as a weakness in the calibration, but this is compensated by a comprehensive sensitivity and uncertainty analysis (see Appendix A6 - Groundwater Technical Report, Section 3.7).	▪ Given the lack of stream gauging data, baseflow has not been calibrated and therefore, uncertainty exists in the estimation of baseflow. ▪ Baseflow and evaporation are the main two outflows for the model (the third one being outflow at the constant head boundary representing the coast). ▪ The model may not accurately represent the ratio between baseflow and evaporation, but what may be an overestimation of one is an underestimation of the other (and vice versa) as they act as surrogates. Establishing the correct ratio would have also limited consequence in the propagation of drawdown which is mainly controlled by hydraulic conductivity and aquifer geometry (natural surface elevation and geometry of hydrostratigraphic units) which is well characterised.
▪ Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]).	▪ Detailed sensitivity and uncertainty analyses have been undertaken, as presented in Appendix A6 - Groundwater Technical Report, Section 3.7. ▪ The sensitivity analysis included testing of a range of values for hydraulic conductivities and storage parameters, recharge rates, evaporation extinction depth and drain cell conductance. ▪ The adopted parameters for the model have shown to be more representative than any alternative conceptualisation tested.	▪ The model conditions not included in the sensitivity analysis are those which cannot be adjusted during calibration, including: - The Drain boundary conditions – these are used to represent the creeks and are defined by the elevation of the creek and a conductance term. The creek bed elevation is not adjustable and not suitable for sensitivity analysis. As there are no in situ observations supporting a tighter river bed conductance vs. underlying units, the conductance was set with a sufficiently high value to enable the aquifer to control the baseflow. It was therefore designed to be insensitive, which has been confirmed during the sensitivity analysis. - The Constant head boundary conditions – these are applied at the coast, set at mean sea level. Given it is a known/measured value, it is not a calibration parameter and is therefore inappropriate to include as part of sensitivity analysis. - The no-flow boundary condition – these are used to represent the edge of the mapped groundwater catchment, and therefore were not a calibration parameter and do not require sensitivity analysis.

Checklist item	Addressed	Not addressed/ Justifications
▪ Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]). CONTINUED		- Evaporation is controlled by potential-evaporation and the extension depth, which is representative of the depth to which evaporation can access the water table. Potential evaporation is a measured/ known value and is therefore not included in the calibration process or sensitivity analysis however a range of extension depths of 1-5m was tested, showing limited sensitivity. - Storage parameters were not included in the uncertainty analysis, as conservative values were assumed
▪ Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	▪ A description of the model construction in terms of model layering and hydraulic properties to represent each hydrostratigraphic unit is presented in Section 3.4.3.3 of Appendix A6 – Groundwater Technical Report.	
▪ Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	▪ In terms of modelling, the uncertainty analysis discussed in Section 3.7 of Appendix A6 - Groundwater Technical Report explores the consequence of a not representing hydraulic conductivity within modelled hydrostratigraphic units accurately by exploring a wide range of conservative values which also provides an insight of the conditions that would be required to trigger a significant expansion of the drawdown cone and related environmental risks (see section 3.7.3 of Appendix A6 - Groundwater Technical Report). ▪ Outcomes of the uncertainty analysis indicates that for most units (except the Styx Coal Measures- coal seams and interburden), even a non-accurate estimation of the hydraulic conductivity of those units has only very limited consequence in terms of drawdown propagation and risk to the environment.	
▪ Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	▪ Predicted changes to discharge (baseflow) during and post mining are provided in Section 10.7.3.4 and Figures 10-81 and 10-82. ▪ Model predictive sensitivity to climate variability has been undertaken and is described in Appendix A6 – Groundwater, Section 3.7 and in Section .10.7.4.7.	
▪ Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters [in press]).	▪ Detailed sensitivity and uncertainty analyses have been undertaken, as presented in Appendix A6 - Groundwater Technical Report, Section 3.7 and in Section .10.7.4.7.	

Checklist item	Addressed	Not addressed/ Justifications
▪ Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	▪ The representation of mining in the model is discussed in Appendix A6 - Groundwater Technical Report, Section 3.6.1, and in Section 10.7.4. ▪ Predictions of potentiometric surface drawdown is discussed and spatially presented in in Appendix A6 - Groundwater Technical Report, Section 3.6.2 and Figures 3-26 to 3-37, respectively, and in Figure 10-71to Figure 10-77.	
▪ Provide a program for review and update of models as more data and information become available, including reporting requirements.	▪ Described in Section 10.8.9.	
▪ Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	▪ Figure 10-95 presents the predicted groundwater abstractions over time from each hydrogeological unit.	
▪ Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	▪ The magnitude and time for maximum drawdown is shown in Figures 10-62 to 10-79 and discussed in Table 10-80.	
▪ Undertake model verification with past and/or existing site monitoring data.	▪ Model verification is provided in Appendix A6 - Groundwater Technical Report, Section 3.5.4.	

Checklist item	Addressed	Not addressed/ Justifications
Impacts to water resources and water-dependent assets		
▪ Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: - any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. - the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. - the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.	▪ The identified potential effects of mining are described in Section 10.7.2 and 10.7.3 ▪ The assessment of effects, including effects that result in changes to groundwater quantity, quality, interactions between surface water and groundwater and physical disruption to aquifers, and the associated threats to sensitive receptors is discussed in Section 10.7.4 and summarised in Tables 10-79 to 10-82. ▪ Connectivity with (and therefore, impacts to) seawater has been shown to be unlikely (see Section 10.5.6.2, 10.5.6.8 10.7.4.2 and 10.7.4.3)	
▪ Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	▪ The sensitive receptors (third party users, Type 1, 2 and 3 GDEs) that are predicted to be affected by mining are discussed in Section 10.7.4 and summarised in Table 10-79. ▪ Section 10.7.4describes the mining schedule, which involves backfilling of pits as mining progresses.	
▪ For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	▪ The assessment of mining induced effects on the groundwater system (in terms of quantity, quality, interactions between surface water and groundwater and physical disruption to aquifers), and the associated threats to sensitive receptors is discussed in Section 10.7.4 and summarised in Tables 10-79 to 10-82. ▪ A threat assessment is provided in Section 10.7.4.8, and a risk assessment of identified threats is provided in Section 10.8.11.	

Checklist item	Addressed	Not addressed/ Justifications
▪ Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	▪ A description of the environmental objectives and applicable Environmental Values and Water Quality Objectives are outlined in Sections 10.3 and 10.4, respectively. ▪ Section 10.2 presents details concerning relevant legislation, plans and guidelines.	
▪ Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.		▪ As there are no other known coal resources or CSG projects existing or foreseeably proposed for the Styx Basin, cumulative impacts have been considered in the context of the proposed Project and the existing land uses. ▪ Field data and modelling (Section 10.5.6.3 and 10.8.4.5, respectively) indicate the groundwater system provides very low sustainable yields under a pumping scenario (less than 1L/s) and Water quality data (Section 10.5.6.5) indicate existing groundwater is generally only suitable for stock water/agricultural uses. Therefore, any future water supply development outside the ML is likely to be limited to stock/agriculture uses with low demands and are therefore unlikely to cause any additional (measurable) impact.
▪ Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	▪ Mitigation approaches are provided for each direct effect of mining linked to a potentially threatened sensitive receptor, as discussed in Section 10.8.4.	
▪ Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	▪ Mitigation measures are described and discussed in Section 10.8.4 including examples of where identified measures have been applied elsewhere.	
Data and monitoring		
▪ Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	▪ Estimates of aquifer properties are presented in Section 10.5.6.3. It is considered that sufficient aquifer testing results (local and more regional) are available to assist with characterisation of the hydrogeology of the four HSUs present in the Project area. ▪ Timeseries groundwater levels from February 2017 to November 2018 are provided in Figures 10-22 to 10-26 The	

Checklist item	Addressed	Not addressed/ Justifications
	groundwater level data timeseries spans two wet seasons and two dry seasons with minor variations in water levels observed across the timeseries (max. up to 3 m in shallowest HSU (alluvium). ▪ Timeseries groundwater water quality data from May 2017 to September 2018 are presented in Tables 10-16 to 10-67. The water quality data spans two dry seasons and one wet season. The quality of Alluvium groundwater shows some variation between the wet and dry seasons but the Styx Coal Measures does not show significant seasonal variability. ▪ Climate data (presented in Section 10.5.2) indicates that the site has experienced around the average long term rainfall during the baseline period. ▪ The available baseline data timeseries is considered representative of long term average seasonal cycles.	
▪ Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	▪ Timeseries groundwater water quality data from May 2017 to September 2018 are presented in Tables 10-16 to 10-67. These data have been compared against relevant guidelines and criteria and exceedances have been highlighted. ▪ Box and whisker plots for each hydrostratigraphic unit are presented in Figures 10-34 to 10-36, which show the range of baseline monitoring data for selected analytes.	
▪ Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	▪ Table 10-84 presents a summary of the existing monitoring network that will be subject to ongoing monitoring. The network comprises dedicated monitoring bores including nested bores that target the various hydrostratigraphic units both within and outside the predicted zone of impact in order to monitor the changes to the groundwater regime due to mining and non-mining related (i.e. background) effects over time.	
▪ 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).	▪ The baseline monitoring program is consistent with National and Queensland guidelines and protocols ((ANZECC/ARMCANZ 2000 and QLD Government 2013). The ongoing monitoring program will be fully consistent with afore mentioned guidelines, namely: - Sampling frequency- monthly sampling, sufficient for identifying background trends - Spatial coverage- sampling locations within anticipated potential impact area situated for early detection of impacts (and targeted locations near sensitive receptors)	▪ Baseline monitoring has not included any field spikes or field blanks. This will be incorporated into the ongoing program.

Checklist item	Addressed	Not addressed/ Justifications
	as well as comparable background (anticipated unimpacted) areas - Quality control/assurance protocols- appropriate decontamination and calibration of sampling equipment, samples collected using appropriate sampling procedures, water quality analysis performed in accredited NATA laboratories, all laboratory holding times, sample storage, transport and preservation requirements adhered to, Chain of Custody records kept, duplicate samples collected, all data reviewed, and evaluated against relevant guidelines/criteria. ▪ Future monitoring will occur as per the Environmental Authority conditions.	
▪ Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	▪ Section 10.8.2.2 outlines additional and ongoing monitoring and ecosystem investigations that will be undertaken to provide additional understanding of ecosystem dependence on groundwater and the pre-mine condition on dependent ecosystems. Studies include: - Extended baseline monitoring - Isotope analysis of surface water, groundwaters to assess connectivity over time - Isotope analysis of soil water and plant xylem water, and leaf and soil water potentials to improve understanding of potentially dependent vegetation water use - Development of a detailed water and solute balance for in-stream pools to improve estimates of groundwater discharge volumes over time. - Analytic modelling of leaf water potentials to understand implications of declining water table over time. - A soil water reservoir balance to assess quantity of soil water available to meet plant water requirements. - Pre-mining condition monitoring of identified potential dependent ecosystems including macroinvertebrate surveys, vegetation transects, foliage index/leaf area index and canopy cover monitoring.	

Table 10-95 Groundwater Dependent Ecosystem – IESC Compliance Checklist

Checklist item	Addressed	Not addressed/ Justifications
Context and conceptualisation		
▪ Identify water-dependent assets, including: - water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna) (see Doody et al. [in press]). - public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	▪ Potential Groundwater Dependent Ecosystems are identified in Section 10.6.1. ▪ Other third party users are identified in Section 10.6.2.	
▪ Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody et al. [in press]).	▪ The environmental water requirements for Type 2 GDEs are estimated through the water balance presented in Section 4 of Appendix A6 – Groundwater Technical Report and summarised in Section 10.7.4.4 of this Chapter. ▪ The environmental water requirements for Type 3 GDEs have been investigated via targeted isotope and water potential studies, as presented in Section 5 of Appendix A6 – Groundwater Technical Report Section 10.7.4.4 of this Chapter. Determination of water table depths in terms of potential threat have been identified (see Table 10-79).	
▪ Identify the hydrogeological units on which any identified GDEs are dependent (see Doody et al. [in press]).	▪ Identified GDE assets have been identified to interact with alluvial aquifers/aquitards, and have limited interaction with Coal Measures aquitard and weathered basement aquifers/aquitards.	
▪ Identify GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox (Richardson et al. 2011) and GDE Atlas (CoA 2017a) may assist in identification of GDEs (see Doody et al. [in press]).	▪ GDEs are identified in accordance with Eamus et al. (2006) and (Richardson et al. 2011) and the GDE Atlas, as discussed in Section 10.6.1.1	

Checklist item	Addressed	Not addressed/ Justifications
▪ Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	▪ The model objectives are outlined in Section 3.2 of Appendix A6 – Groundwater Technical Report, which are in-line with the Project objectives, outlined in Section 10.3.2 of this Chapter. ▪ Section 3.2 of Appendix A6 – Groundwater Technical Report, and Section 10.7.4 and Section 10.8.11.	
▪ Describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015).	▪ The conceptualisation is presented in Section 10.5 and rationale for the likely water dependence of GDEs is discussed in Section 10.6.1. ▪ Impact pathways are described in Tables 10-80 to 10-83.	
▪ Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	▪ Water quantity threat thresholds are defined in Table 10-80, developed on the basis of conceptual understanding of GDE environmental water requirements presented in Section 10.6.1. ▪ Project objectives are to maintain water quality as close to baseline conditions as possible (see Section 10.3).	▪ Water quality (TDS) varies widely within each HSU and between HSUs. ▪ There is no distinct difference in TDS between each HSU and the potential for any one HSU to impact on another HSU is unlikely, as is salinisation of groundwater due to water affecting activities, therefore water quality triggers have not yet been determined .
Impacts, risk assessment and management of risks		
▪ Provide an assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs (see Doody et al. [in press]).	▪ Section 10.7 presents the impact assessment and predicted threats to GDEs.	
▪ Provide estimates of the volume, beneficial uses and impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.		▪ No planned discharges during normal operations. ▪ Discharge during extreme rainfall events may be necessary.
▪ Describe the potential range of drawdown at each affected bore, and clearly articulate of the scale of impacts to other water users.	▪ The predicted drawdown at identified third party bores is presented in Section 10.7.4.2. ▪ The scale of drawdown at other identified users (GDEs) is presented in Table 10-80.	
▪ Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	▪ A qualitative risk assessment is provided in Section 10.8.11.	

Checklist item	Addressed	Not addressed/ Justifications
▪ Indicate the vulnerability to contamination (e.g. from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	▪ The potential water quality impacts are discussed in Table 10-81.	
▪ Identify the proposed acceptable level of impact for each water-dependent asset based on leading-practice science and site-specific data, and ideally developed in conjunction with stakeholders.	▪ Threat assessment is presented in Section 10.7.4.8.	
▪ Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	▪ Addressed in Chapter 9 - Surface Water	
▪ Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	▪ Mitigation measures will be defined in the Receiving Environment Monitoring (Management and Mitigation) Plan (as outlined in Section 10.8 and specifically, 10.8.4.4) ▪ Ongoing development of mitigation and management options will occur as mining proceeds, based on observation. ▪ Examples of possible mitigation measures are provided in Section 10.8.4.5 ▪ As part of the REMP, a Trigger Action Response Plan will be developed that will be used to monitor and assess the performance of mitigation measures.	
▪ Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions, and test potential responses to impacts of the proposal (see Doody et al. [in press]).	▪ Section 10.8.2.2 outlines additional GDE baseline monitoring that will occur to establish the pre-development condition of GDEs. ▪ Section 10.8.5 outlines the GDE monitoring plan designed for early detection of possible impacts and to assess the performance of any adopted management and mitigation measures.	
▪ Develop and describe a monitoring program that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change (see Doody et al. [in press]).	▪ Section 10.8.5 outlines the GDE monitoring plan designed for early detection of possible impacts and to assess the performance of any adopted management and mitigation measures.	

Checklist item	Addressed	Not addressed/ Justifications
▪ Consider concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design, see Doody et al. [in press]).	▪ Section 10.8.5, Figure 10-102 and Table 10-86 present the monitoring network and program that is designed to concurrently monitor within the predicted zone of impact (compliance bores) as well as outside the predicted zone of impact (reference bores) to detect any changes to GDEs not resulting from mining (i.e. the background trends).	
▪ Describe the proposed process for regular reporting, review and revisions to the monitoring program.	▪ The monitoring program approach is outlined in Section 10.8.1 and Figure 10-101 and described in more detail in the subsequent sections.	
▪ Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna (QLD Government 2015)).	▪ The ecological monitoring plan is outlined in Section 10.8.5 ▪ More detail will be provided in the REMP and LUMP.	

10.12 ToR Cross-reference Table

Table 10-96 ToR cross-reference

Terms of Reference	Section of SEIS
Describe present and potential users and uses of water in areas potentially affected by the project, including municipal, agricultural[3], industrial, recreational and environmental uses of water.	Section 10.6 and 10.7
Provide details of any proposed changes to, or use of, surface water or groundwater.	Section 10.7
Identify any approval or allocation that would be needed under the *Water Act 2000*.	Section 10.2.1 and Chapter 1 – Introduction
Describe all aquifers that would be impacted by the project, including the following information: ▪ nature of the aquifer/s	Section 10.5
▪ geology/stratigraphy - such as alluvium, volcanic, metamorphic	Section 10.5
▪ aquifer type - such as confined, unconfined	Section 10.5
▪ depth to and thickness of the aquifers	Section 10.5
▪ groundwater quality and volume	Section 10.5
▪ current use of groundwater in the area	Section 10.6
▪ survey of existing groundwater supply facilities (e.g. bores, wells, or excavations)	Sections 10.5 and 10.6
▪ information to be gathered for analysis to include: – location – pumping parameters – drawdown and recharge at normal pumping rates, and – seasonal variations (if records exist) of groundwater levels	Sections 10.1, 10.5, 10.5.6, 10.5.6.3 and 10.5.6.2
▪ proposal to develop network of groundwater monitoring bores before and after the commencement of the project.	Section 10.8.5
Describe how 'make good' provisions would apply to any water users that may be adversely affected by the project.	Section 10.8
Describe the practices and procedures that would be used to avoid or minimise impacts on water resources.	Sections 10.8 and 10.9
Quantify the volume of all takes from the groundwater system (including pit dewatering, degassing, etc.) and assess the impacts on groundwater levels, quality and ecosystem interactions for each aquifer and any implications for surface-groundwater interactions.	Sections 10.7, 10.8 and 10.8

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