Central Queensland Coal Project

Appendix 6 - Groundwater Technical Report

Supplementary Environmental Impact Statement

Central Queensland Coal Project

Appendix A6 – Groundwater Technical Report

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1 Introduction

This report provides technical details that support Chapter 10 – Groundwater of the Supplementary Environmental Impact Statement (SEIS) for the Central Queensland Coal Project, and includes:

1. Section 1- Introduction
2. Section 2 – 2018 Hydraulic conductivity test (slug and recovery test) analyses and results Details of aquifer testing methods, analysis methods, and resulting hydraulic conductivity estimates
3. Section 3 – Numerical Model
   Details of the numerical groundwater modelling undertaken to simulate the Project area groundwater system, mine water affecting activities and potential direct groundwater effects associated with the Project
4. Section4 – Styx River instream pools water balance
   Details the processes that sustains the persistence of water pools during the dry season along Deep creek and Tooloombah creek. Provide a preliminary quantification of the various sources of water to the pools and an assessment of the expected impact from the mining activities on those pools.
5. Section 5 – Targeted GDE investigations
   Details the targeted investigations were undertaken in August 2018 to better understand vegetation water use.
6. Section 6 – Connectivity assessment using isotope analysis
   Details isotope studies undertaken to better understand the relationship between the surface water and groundwater,

The information and data presented in this technical report provides baseline data of relevance to Chapter 10 of the SEIS, where additional detail concerning the physical setting of the Project that is of importance for hydrogeological characterisation and conceptualisation.

2 Aquifer testing

2.1 Overview

Slug tests and injection recovery tests have been performed on newly installed Styx WMP bores to derive estimates of hydraulic conductivity (K) of the strata directly adjacent the bores. The bores have been screened in the Alluvium and Styx Coal Measures, and at some locations the bores straddle the Alluvium and upper parts 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.

The following provides a description of methods and a summary of results. The bore logs are provided in Attachment 1 and graphical representation of the testing data and results for the tested bores is provided in Attachment 2.

2.2 Analysis methods

2.2.1 Solutions

2.2.1.1 Slug testing using the Hvorslev (1951) and Bouwer-Rice (1976) solutions

Hvorslev (1951) and Bouwer-Rice (1976) developed mathematical solutions for deriving estimates of hydraulic conductivity values for low to moderate permeability aquifers based on water level response to falling and rising head tests (i.e. slug tests).

The method developed by Hvorslev (1951) is applicable for slug tests of partially penetrating wells or piezometers. The method is intended for confined aquifers but can yield reasonable results for unconfined aquifers if the screened interval is sufficiently far from the water table and data are corrected for construction limitations.

The method developed by Bouwer-Rice (1976) is applicable for slug tests of fully or partially penetrating wells or piezometers installed in unconfined aquifers. However, reasonable results can also be obtained for tests conducted on wells or piezometers in confined aquifers.

2.2.1.2 Constant rate recovery testing: Theis (1935)

Theis (1935) developed a mathematical solution for determining aquifer transmissivities from the recovery response at the termination of pumping / injection tests. The solution is intended for analysing results from tests conducted on non-leaky confined aquifers and is suitable for tests where pumping / injection rates are variable, as long as the total volume of abstractions or injection, and the time of testing is known.

2.2.2 Method

All three solutions were implemented by fitting a straight line to water level response data. For slug test analyses, AQTESOLV (Duffield, 2007), an industry standard aquifer test analysis software was implemented. AQTESOLV was used to fit a straight line to a log-log plot of normalized head (i.e. relative to initial displacement) and elapsed time. Straight lines were fitted to early, mid and late time to obtain ranges for hydraulic conductivity estimates for the Bouwer-Rice solutions, and straight lines were fitted to the entire (0.1 to 1 displacement) data set for the Hvorslev solutions.

For constant rate recovery tests, manual methods were used to fit a straight line to mid- and late-time data on a semi-log plot of residual drawdown against t/t' (the ratio of total elapsed time since testing commenced and time since the end of testing).

2.2.3 Analysis summaries and results

Details of slug and constant rate recovery test analyses and the derived estimates of Ks for the bores tested are provided in Attachment 2, and a summary is presented in Table 2-1.

Table 2-1 Summary of derived hydraulic property estimates from aquifer tests

Bore ID	Analysis Method	Test type	Screened Stratigraphy [1]	Solution	Estimated K, m/d [2]	b, m [2]	Estimated T,m^2/d
WMP02	Recovery test	Rising head	Alluvium	Theis Recovery	5	8.5	43
WMP04	Slug test	Falling head	Alluvium	Bouwer-Rice	0.01	3.9	0.04
				Hvorslev	0.02		0.08
WMP04D	Slug test	Falling head	Alluvium / Styx Coal Measures - overburden	Bouwer-Rice	0.02	23.2	0.5
				Hvorslev	0.03		0.7
WMP05	Slug test	Falling head	Alluvium	Bouwer-Rice	0.03	4.9	0.1
				Hvorslev	0.07		0.3
WMP06	Slug test	Falling head	Alluvium / Styx Coal Measures - underburden	Bouwer-Rice	0.01	1.5	0.02
WMP08	Slug test	Falling head	Alluvium	Bouwer-Rice	0.0005	3.9	0.002
WMP08D	Slug test	Falling head	Styx Coal Measures - underburden	Bouwer-Rice	0.03	26.5	0.8
WMP09	Slug test	Falling head	Alluvium	Bouwer-Rice	0.1	4.2	0.5
				Hvorslev	0.2		0.9
WMP10	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice	0.004	10.7	0.04
WMP12	Recovery test	Falling head	Alluvium / Styx Coal Measures - overburden	Theis Recovery	2	8.5	17
WMP13	Slug test	Falling head	Alluvium / Styx Coal Measures - overburden	Bouwer-Rice	0.3	5.4	2
WMP16	Slug test	Falling head	Styx Coal Measures- overburden	Bouwer-Rice - Early	0.3	18.3	5
				Bouwer-Rice - Late	0.2		4
		Rising head		Bouwer-Rice - Early	0.2		4
				Bouwer-Rice – Mid	0.04		0.7
				Bouwer-Rice – Late	0.007		0.1
WMP16D	Slug test	Falling head	Styx Coal Measures - interburden	Bouwer-Rice - Early	0.02	28.6	0.6
				Bouwer-Rice – Mid	0.003		0.1
				Bouwer-Rice – Late	0.001		0.03

Bore ID	Analysis Method	Test type	Screened Stratigraphy [1]	Solution	Estimated K, m/d [2]	b, m [2]	Estimated T,m²/d
		Rising head		Bouwer-Rice - Early	0.01		0.3
				Bouwer-Rice – Mid	0.01		0.3
				Bouwer-Rice – Late	0.03		0.9
WMP17D	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice – Mid	0.08	11.4	0.9
				Bouwer-Rice– Late	0.01		0.1
		Rising head		Bouwer-Rice - Early	0.3		3
				Bouwer-Rice– Mid	0.06		0.7
WMP18D	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice - Early	0.7	9.4	7
				Bouwer-Rice - Mid/late	0.02		0.2
WMP19	Slug test	Falling head	Weathered basement	Bouwer-Rice	0.006	3.1	0.02
WMP19D	Slug test	Falling head	Weathered basement	Bouwer-Rice - Early	0.6	15	9
				Bouwer-Rice – Mid/late	0.3		5
WMP20	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice - Early	0.1	9.5	0.9
				Bouwer-Rice– Late	0.0004		0.004
		Rising head		Bouwer-Rice - Early	0.3		3
				Bouwer-Rice – Mid	0.2		2
				Bouwer-Rice – Late	0.04		0.4
WMP20D	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice – Mid	0.06	18.1	1
				Bouwer-Rice – Late	0.003		0.05
		Rising head		Bouwer-Rice - Early	0.09		2
				Bouwer-Rice – Mid	0.02		0.4
WMP21D	Slug test	Falling head	Alluvium / Styx Coal Measures - overburden	Bouwer-Rice	0.1	7	0.7
WMP22A	Slug test	Rising head	Styx Coal Measures - overburden	Bouwer-Rice	0.05	15.3	0.8
				Bouwer-Rice - Early	0.02		0.9

Bore ID	Analysis Method	Test type	Screened Stratigraphy [1]	Solution	Estimated K, m/d [2]	b, m [2]	Estimated T,m²/d
WMP22B	Slug test	Falling head	Styx Coal Measures - interburden	Bouwer-Rice– Late	0.01	43.8	0.4
WMP22B	Slug test	Rising head	Styx Coal Measures - interburden	Bouwer-Rice - Early	0.009	43.8	0.4
WMP22B	Slug test	Rising head	Styx Coal Measures - interburden	Bouwer-Rice – Mid	0.005	43.8	0.2
WMP22B	Slug test	Rising head	Styx Coal Measures - interburden	Bouwer-Rice – Late	0.01	43.8	0.4
WMP22B	Airlift recovery	Rising head	Styx Coal Measures - interburden	Cooper-Jacob	0.005	6	0.03
WMP22C	Slug test	Falling head	Styx Coal Measures - underburden	Bouwer-Rice	0.003	193.5	0.6
WMP22C	Slug test	Rising head	Styx Coal Measures - underburden	Bouwer-Rice - Early	0.003	193.5	0.6
WMP22C	Slug test	Rising head	Styx Coal Measures - underburden	Bouwer-Rice – Mid	0.002	193.5	0.4
WMP22C	Slug test	Rising head	Styx Coal Measures - underburden	Bouwer-Rice – Late	0.003	193.5	0.6
WMP22C	Airlift recovery	Rising head	Styx Coal Measures - underburden	Cooper-Jacob	0.008	6	0.05
WMP23A	Slug test	Falling head	Styx Coal Measures - interburden	Bouwer-Ric	0.0007	44.1	0.03
WMP24	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice	0.005	18.4	0.09
WMP24	Slug test	Falling head	Styx Coal Measures - overburden	Hvorslev	0.006	18.4	0.1
WMP25	Slug test	Falling head	Alluvium	Bouwer-Rice	0.006	17.8	0.1
WMP26	Slug test	Falling head	Alluvium	Bouwer-Rice– Early	0.03	5.6	0.2
WMP26	Slug test	Falling head	Alluvium	Bouwer-Rice– Mid/late	0.009	5.6	0.05
WMP27	Slug test	Falling head	Alluvium / Styx Coal Measures - overburden	Bouwer-Rice	0.006	1	0.006
WMP28	Slug test	Falling head	Styx Coal Measures - overburden	Bouwer-Rice	0.002	1	0.002
WMP29A	Slug test	Falling head	Alluvium	Bouwer-Rice - Early	6	0.7	4
WMP29A	Slug test	Falling head	Alluvium	Bouwer-Rice– Late	8	0.7	6
WMP29A	Slug test	Rising head	Alluvium	Bouwer-Rice - Early	7	0.7	5
WMP29B	Slug test	Falling head	Alluvium	Bouwer-Rice - Early	0.2	3	0.6
WMP29B	Slug test	Falling head	Alluvium	Bouwer-Rice– Mid	0.02	3	0.06
WMP29B	Slug test		Alluvium	Bouwer-Rice - Early	0.2	3	0.6

Bore ID	Analysis Method	Test type	Screened Stratigraphy [1]	Solution	Estimated K, m/d [2]	b, m [2]	Estimated T,m²/d
		Rising head		Bouwer-Rice – Mid	0.02		0.06
				Bouwer-Rice – Late	0.1		0.3
WMP29C	Qualitative[2]		Styx Coal Measures - overburden	Qualitative[2]	0.0001	6	0.0006
WMP29D	Qualitative[2]		Styx Coal Measures - interburden	Qualitative[2]	0.0001		0.0006
WMP29E	Qualitative[2]		Styx Coal Measures - underburden	Qualitative[2]	0.0001		0.0006

Notes:

1. Where a bore is screened across multiple stratigraphic units, the underlined unit is interpreted to be the dominant unit.
2. 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.
3. K = hydraulic conductivity, b = saturate aquifer thickness, T = transmissivity

3 Numerical groundwater flow model

3.1 Overview

Groundwater modelling is the only practical approach for assessing the potential effects of the Project on future groundwater conditions, dependent systems (surface water and ecological), and Styx Basin Environmental Values (EVs) in response to mine water affecting activities. This section provides a technical account of the numerical groundwater modelling that has been conducted for the Project. The conceptual modelling and the key results from predictive simulations are presented in Chapter 10 – Groundwater of the (SEIS).

This section provides details of the following:

- Model construction and calibration (Section 3.4 and 3.5) – describes how the numerical groundwater flow model is constructed, the hydrogeological processes that are represented within the model, and the ability of the model to simulate past groundwater conditions as an indication of its suitability for predictive simulation.
- Predictive simulations (Section 3.6) – describes how the model is built to simulate the potential effects of the Project on groundwater conditions including potential changes to water table elevation, groundwater pressures, and groundwater recharge and discharge processes, both during and after mining.
- Sensitivity and uncertainty analysis (Section 3.7) – describes how parameter sensitivity and predictive uncertainty has been conducted, and how the numerical model (and predicted potential effects on groundwater) responds to altered parameters and possible conceptualisations.

3.2 Modelling objectives

The primary objectives of the groundwater modelling are to:

- Predict the potential drawdown of the water table and depressurisation of the local (mine-scale) and regional groundwater system due to mine dewatering, and to provide the basis for
  a. Assessing potential impacts on existing groundwater users (environmental and economic) and EVs
  b. Informing groundwater monitoring and management requirements / commitments.
- Predict potential inflows of groundwater (dewatering requirements) to the proposed mine pits for input to the Water Management Plan, which will be implemented throughout the life of the Project.
- Predict recovery of groundwater pressures and potential long-term changes in groundwater conditions as
  a. the mine pits are progressively backfilled; and
  b. after mining has ceased.

3.3 Groundwater modelling guidelines

3.3.1 Background

The practice of groundwater modelling in Australia has been influenced by guidelines developed by the Murray-Darling Basin Commission (Middlemis et al. 2001), widely known as the "MDBC guidelines", and more recently by The Australian Groundwater Modelling Guidelines (Modelling Guidelines) released by the National Water Commission (Barnett et al. 2012). The guidelines were designed to reduce the level of uncertainty surrounding modelling by promoting transparency in methodologies and encouraging consistency and best practice. The Modelling Guidelines are similar to, and broadly consistent with, the earlier MDBC guidelines, providing information that is useful for all stakeholders regarding the outcomes of groundwater modelling and the reliance on results that can be achieved - from proponents of projects to regulators to professional groundwater modellers, and to members of the community.

The groundwater modelling detailed here has been undertaken in a manner consistent with the methods and recommendations of the Modelling Guidelines.

3.3.2 Model confidence level classification

The degree of confidence with which a model's predictions can be used is a critical consideration for any groundwater modelling exercise. Several factors are typically considered to determine model confidence level classification, and the Modelling Guidelines (Barnett et al. 2012) define a rigorous system to classify the confidence level of groundwater models based on the following factors:

- Available data;
- Calibration procedures;
- Calibration and prediction consistency; and
- Level of stress (i.e. hydraulic stress in the model).

Models are classified as Class 1, 2 or 3 in order of increasing confidence (and, often, complexity). In general, a model will not fit entirely into one class of confidence level because determining the most appropriate class depends upon multiple factors. Table 3-1 presents a review of Styx model compliance with modelling guidelines criteria (see Table 2-1 on pages 20 to 21 of the guidelines). The Styx groundwater model is consistent with criteria spanning over the 3 confidence levels. The model clearly complies or exceeds all criteria for a Class 1 model. It is mostly consistent with a Class 2 model and the data spatial distribution and availability are partially consistent with a Class 3 model. The confidence classification scheme in the modelling guidelines does not allow for a full compliance with a Class 2 or 3 confidence level for large regional-scale groundwater systems having long response and recovery times, and when the strata targeted for development and depressurisation hasn't been previously stressed at the magnitude expected of the project under consideration.

More generally, the Class 1 groundwater model developed for the Project is considered capable of providing appropriate physically-based predictions of relative responses to hydraulic stresses. On this basis, it is considered fit-for-purpose and an appropriate platform for assessing the potential impacts of the Project on existing and future groundwater conditions. As the mining project develops, monitoring of groundwater system response will further inform the certainty around model predictions and, so, the class of model will evolve to Class 2 and 3.

Table 3-1 Modelling guidelines characteristics and indicators for Styx model confidence level classification (Legend at the bottom of the table)

Confidence level classification	Data	Calibration	Prediction	Key indicator
Class 3	Spatial distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported, however temporal data distribution is lacking.	Adequate validation* is demonstrated	Length of predictive model is not excessive compared to length of calibration period	Key calibration statistics are acceptable and meet agreed targets
	Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry	Scaled RMS error (refer Chapter 5) or other calibration statistics are acceptable	Temporal discretisation used in the predictive model is consistent with the transient calibration	Model predictive time frame is less than 3 times the duration of transient calibration
	Reliable metered groundwater extraction and injection data is available	Long-term trends are adequately replicated where these are important	Level and type of stresses included in the predictive model are within the range of those used in the transient calibration	Stresses are not more than 2 times greater than those included in calibration
	Rainfall and evaporation data are available	Seasonal fluctuations are adequately replicated where these are important	Model validation* suggests calibration is appropriate for locations and/or times outside the calibration model	Temporal discretisation in predictive model is the same as that used in calibration
	Aquifer-testing data to define key parameters	Transient calibration is current, i.e. uses recent data	Steady-state predictions used when the model is calibrated in steady-state only	Mass balance closure error is less than 0.5% of total
	Streamflow and stage measurements are available with reliable baseflow estimates at a number of points	Model is calibrated to heads and fluxes		Model parameters consistent with conceptualisation

Legend:

- Not achievable for the current Styx model
- Consistent with the Styx model
- Partially achieved or not critical for Project objective(s)
- Styx model exceeds the guideline criteria
- Not applicable

Confidence level classification	Data	Calibration	Prediction	Key indicator
Class 3 (cont.)	Reliable land-use and soil-mapping data available	Observations of the key modelling outcomes dataset is used in calibration		Appropriate computational methods used with appropriate spatial discretisation to model the problem
	Reliable irrigation application data (where relevant) is available			The model has been reviewed and deemed fit for purpose by an experienced, independent hydrogeologist with modelling experience
	Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation			
Class 2	Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain	Validation* is either not undertaken or is not demonstrated for the full model domain	Transient calibration over a short time frame compared to that of prediction	Key calibration statistics suggest poor calibration in parts of the model domain
	Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive	Calibration statistics are generally reasonable but may suggest significant errors in parts of the model domain(s)	Temporal discretisation used in the predictive model is different from that used in transient calibration	Model predictive time frame is between 3 and 10 times the duration of transient calibration
	Streamflow data and baseflow estimates available at a few points	Long-term trends not replicated in all parts of the model domain	Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration	Stresses are between 2 and 5 times greater than those included in calibration
	Reliable irrigation-application data available in part of the area or for part of the model duration	Transient calibration to historic data but not extending to the present day	Validation* suggests relatively poor match to observations when calibration data is extended in time and/or space	Temporal discretisation in predictive model is not the same as that used in calibration

Legend:

- (Red) Not achievable for the current Styx model
- (Green) Consistent with the Styx model
- (Yellow) Partially achieved or not critical for Project objective(s)
- (Blue) Styx model exceeds the guideline criteria
- (Grey) Not applicable

Confidence level classification	Data	Calibration	Prediction	Key indicator
Class 2 (cont.)		Seasonal fluctuations not adequately replicated in all parts of the model domain		Mass balance closure error is less than 1% of total
		Observations of the key modelling outcome data set are not used in calibration.		Not all model parameters consistent with conceptualisation
				Spatial refinement too coarse in key parts of the model domain
				The model has been reviewed and deemed fit for purpose by an independent hydrogeologist
Class 1	Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information	No calibration is possible	Predictive model time frame far exceeds that of calibration	Model is uncalibrated or key calibration statistics do not meet agreed targets
	Observations and measurements unavailable or sparsely distributed in areas of greatest interest	Calibration illustrates unacceptable levels of error especially in key areas	Temporal discretisation is different to that of calibration	Model predictive time frame is more than 10 times longer than transient calibration period
	No available records of metered groundwater extraction or injection	Calibration is based on an inadequate distribution of data	Transient predictions are made when calibration is in steady state only	Stresses in predictions are more than 5 times higher than those in calibration
	Climate data only available from relatively remote locations	Calibration only to datasets other than that required for prediction	Model validation* suggests unacceptable errors when calibration dataset is extended in time and/or space	Stress period or calculation interval is different from that used in calibration

Legend:
- (red) Not achievable for the current Styx model
- (green) Consistent with the Styx model
- (yellow) Partially achieved or not critical for Project objective(s)
- (blue) Styx model exceeds the guideline criteria
- (grey) Not applicable

Confidence level classification	Data	Calibration	Prediction	Key indicator
Class 1 (cont.)	Land-use data available, but river flows and stage elevations			Transient predictions made but calibration in steady state only
				Cumulative mass-balance closure error exceeds 1% or exceeds 5% at any given calculation time
				Model parameters outside the range expected by the conceptualisation with no further justification
				Unsuitable spatial or temporal discretisation
				The model has not been reviewed

Legend:

- Not achievable for the current Styx model
- Consistent with the Styx model
- Partially achieved or not critical for Project objective(s)
- Styx model exceeds the guideline criteria
- Not applicable

3.4 Model construction

3.4.1 Overview

This section of the report describes how the numerical groundwater flow model has been constructed, particularly in regard to its representation of the conceptual hydrogeological model (presented in Chapter 10 of the SEIS, Section 10.5.6) and how the numerical model is calibrated to simulate existing groundwater conditions as an indication of its suitability for conducting predictive simulations. The geometry of the groundwater model is constructed from the regional-scale geological model developed for the Project, which utilised geological data and interpretations provided by CQC (for the Styx geological basin) and on published geological maps (1:250,000 St Lawrence geological map, sheet SF 55-12, 1970).

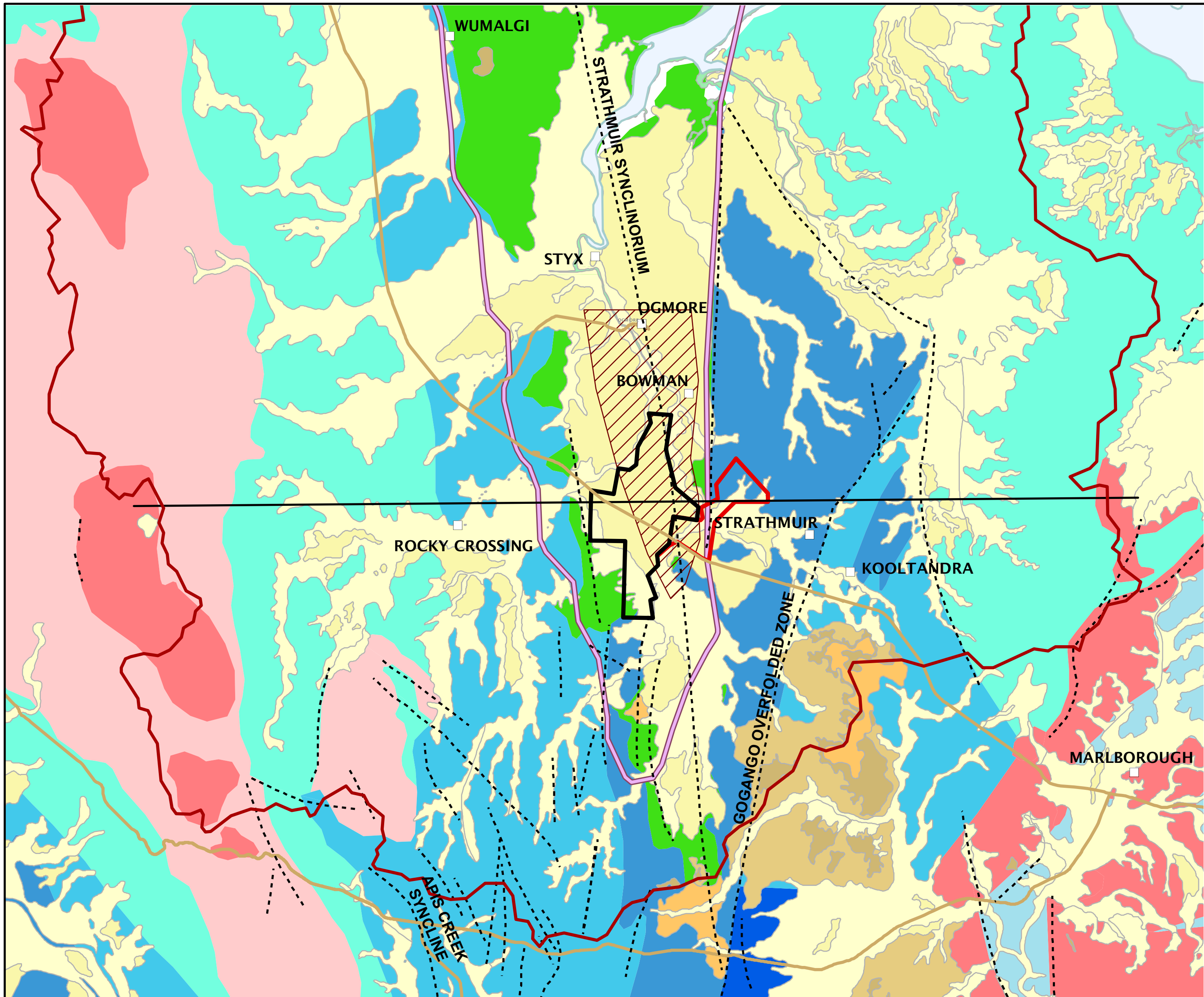
3.4.2 Regional-scale geological model

A regional-scale hydrostratigraphic model has been constructed using Leapfrog Hydro (v2.8) to support the construction of the groundwater model. The primary sources of information used for the geological model include the geological information discussed in Section 10.5.5 of the SEIS (including the surface and solid geological maps), lithological logs recorded in the GWDBQ and for recently drilled Project bores (WMP bores), as well as the upper and lower surfaces of coal seams from the Proponent's local-scale geological model. The regional surface geology, along with the geological model extent and Project Mining Lease (ML) is presented on Figure 3-1.

The regional-scale model consists of four main hydrostratigraphic units (HSUs) shown in Figure 3-2:

- HSU1 - Cenozoic surface deposits occurring mainly in association with alluvial infill deposits and colluvial slope deposits associated with the surface drainage network.
- HSU2 - Styx (geological) Basin – consisting of the Cretaceous Styx Coal Measures, which are sub-divided into
    a. 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
    b. Coal seams and 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
    c. 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.
- HSU3 - Outcropping and sub-cropping weathered basement (Back Creek Group, Lizzie Creek Volcanic Group and Connors Volcanic Group)
- HSU4 - Basement – consisting of Permian and older rocks that either underlie the Styx (geological) Basin, or sub-crop beneath Cenozoic sediments, or outcrop beyond the margin of Styx Basin, including undifferentiated Back Creek Group, Boomer Formation (Back Creek Group), Carmila Beds (Lizzie Creek Volcanic Group) and Connors Volcanic Group.

Each HSU represented in the Leapfrog Hydro model is a 3D volume that can be continuous or discontinuous within the geological model domain. The unit thicknesses and the contact surfaces between units are represented by the software based on interpolation and extrapolation of the input data, which include manually drawn lines and intersections, and specified stratigraphic relationships between the units.



BOWEN ROCK UNIT SOLID

CARBONIFEROUS-LATE PERMIAN

- Back Creek Group
- Boomer Formation
- Intrusives
- Carmila Beds
- Connors Volcanics
- Palaeozoic Metasediments
- Rannes Beds
- Styx Coal Measures

CENOZOIC SURFACE GEOLOGY

HOLOCENE

- Estuarine deposits

PLEISTOCENE

- Alluvium

QUATERNARY

- Alluvium

LATE TERTIARY-QUATERNARY

- Colluvium

TERTIARY

- Poorly consolidated sediments
- Ferricrete

N

0 5 10 km

Scale @ A4 1:300,000
Date: 28/11/18
Drawn: A. Aird

Legend

- Styx River Basin
- Geological structure
- Main road
- Conceptual geological and hydrostratigraphic cross-section line
- Waterbody
- Styx geological basin
- Styx Local Geological Model
- ML 80187
- ML 700022

Figure 3-1
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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Geology_R1.mxd 11/28/2018

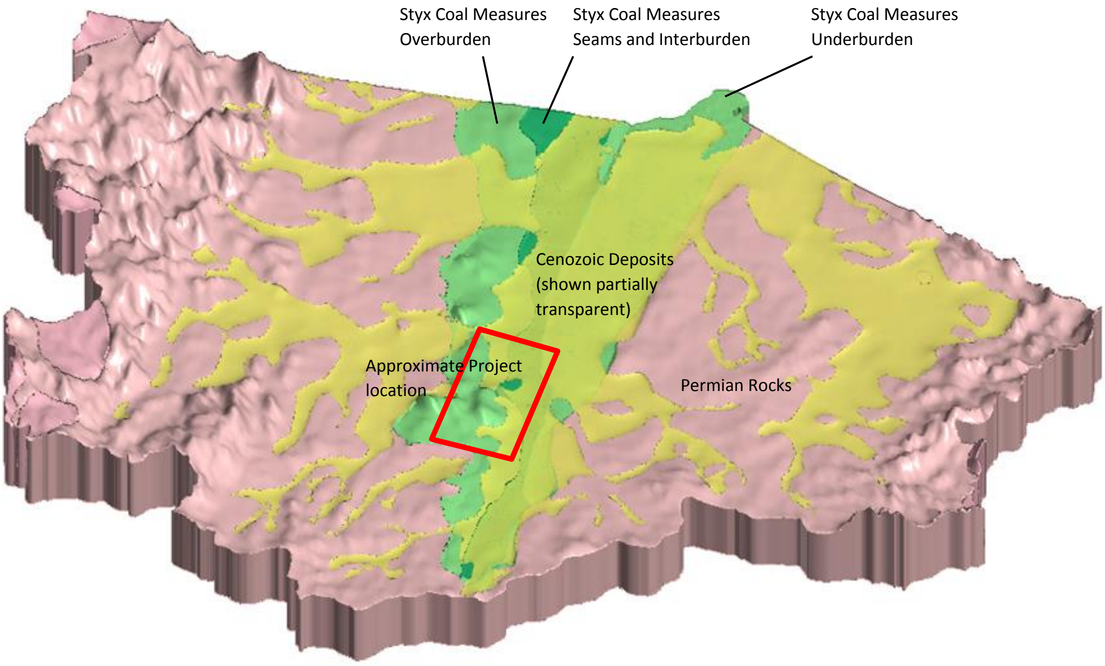


Figure 3-2 Regional-scale geological model (x5 vertical exaggeration)

3.4.3 Numerical groundwater flow model

3.4.3.1 Modelling platform

Several industry-standard model codes are available for simulation of regional-scale groundwater flow. They roughly fall into two categories - finite element (FE) and finite difference (FD). The MODFLOW FD model code was selected for this modelling project, the code was developed by the United States Geological Survey (USGS; McDonald and Harbaugh 1988). A recent version of MODFLOW called MODLFOW-USG (Unstructured Grid, first released in 2013) comprises older versions of MODFLOW but permits the development of a grid having cells of variable dimensions within the grid, much the same as can be achieved by use of a FE model code.

MODFLOW-USG has been chosen as the most appropriate numerical modelling package for this project. It was developed by the USGS (Panday et al., 2013) and has the following advantages:

- It handles issues associated with re-wetting of dry cells more effectively than previous MODFLOW versions.
- It allows for local refinement of the grid, which offers the possibility to progressively increase the refinement of the grid around the area of interest.

Groundwater Vistas version 6 (ESI 2011) was selected as the graphical user interface for building the model and some of the associated pre- and post-processing. Additional scripts were written in Excel VBA, Python and ArcGIS™ to perform customised pre- and post-processing tasks.

3.4.3.2 Model discretisation

Model Grid

The model domain extends about 43 km north to south and 54 km east to west. The model grid (Quadtree mesh, which allows grid cell refinement as a multiple of previous cells.) shown in Figure 3-3 and Figure 3-4 was generated in Groundwater Vistas. The columns are aligned due north and are approximately parallel to the regional orientation of the Styx Basin and the bounding Permian rocks, and the general regional strike of groundwater flow. The total number of active cells is 466,638, which is made up of six layers each comprising 77,773 cells.

Local refinement is introduced within and surrounding the Project area. The 5×5 km area representing ML 80187 has a uniform grid cell size of 40×40 m. The cells around Tooloombah and Deep Creeks that border the lease have a refinement of 20x20 m. The size of grid cells progressively increases to 40 m, 80 m, 160 m, 360 m and 640 m with increasing distance from the Project area.

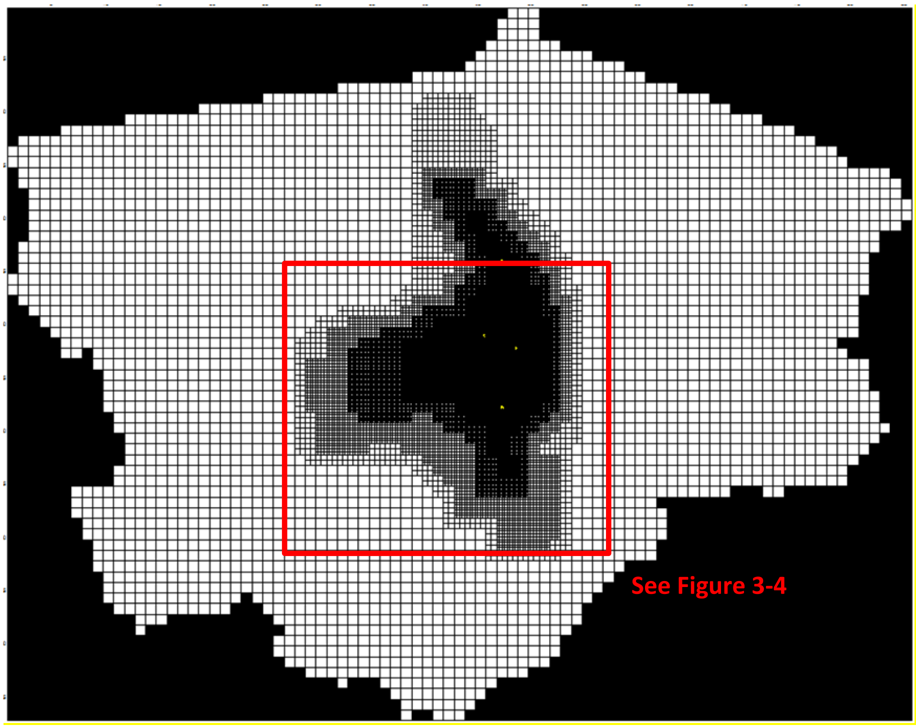


Figure 3-3 MODFLOW USG Quadtree Grid (model Domain)

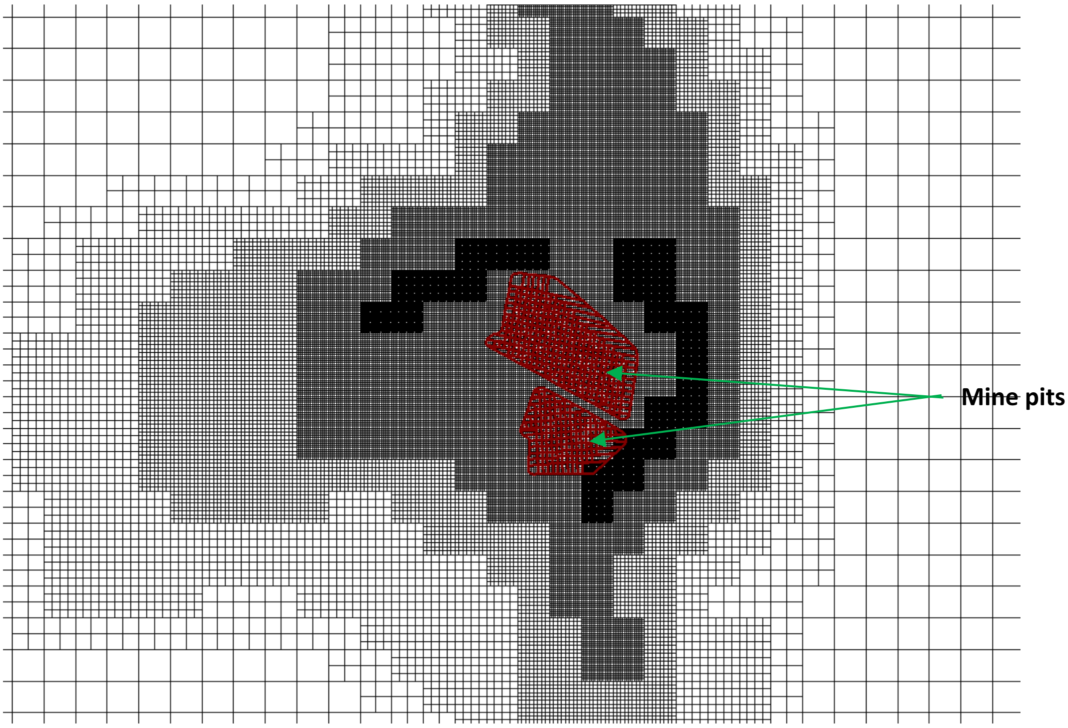


Figure 3-4 Close-up of the MODFLOW USG Quadtree grid centred on the refined area

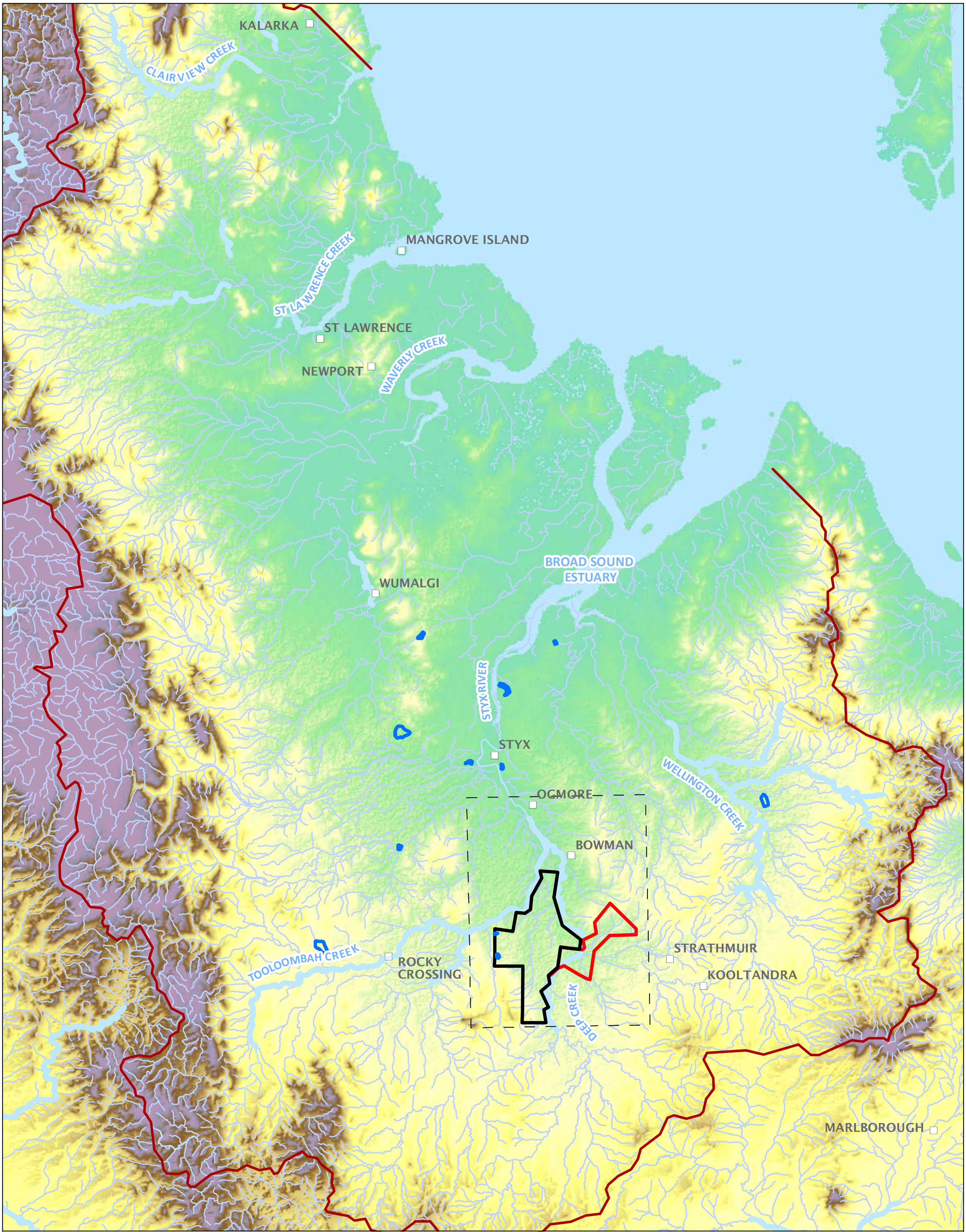
3.4.3.3 Model layering and hydrostratigraphic units

The model comprises six layers, as summarised in Table 3-2. The top surface of the model is set at topographic elevation and the bottom elevation of the model is set arbitrarily at -500 mAHD, within Permian rocks. The topographic elevation was constructed by merging information from three topographic datasets of varying definition (LIDAR: 1m resolution, DEM: 10m resolution and STRM: 90m resolution). The more precise resolution was used where available, typically within the Project area. The area covered by each dataset is illustrated on Figure 3-5. The HSUs described in Section 10.5 Hydrogeology of the SEIS Chapter 10 align with the model layering.

The expected range in hydraulic properties (horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv) and specific yield (Sy)) are presented in Table 3-2 and these parameters were assessed from the aquifer testing undertaken for the Project (see Section 2), regional aquifer testing results and as part of model calibration. The specific storage (Ss) value for all HSUs has been conservatively set at the value of water compressibility (5 x 10^{-6} m^{-1}).

3.4.3.4 Temporal discretisation

The model comprises an initial stress period to establish steady state pre-mine (baseline) conditions followed by monthly stress periods covering the period from 01/2017 to 03/2018. The steady state conditions are reached by applying average climatic stress for a 10,000 year period over a single transient stress period - refer to hydrographs in Figure 3-45 to Figure 3-47, which demonstrate steady state conditions (baseline) at the start of mining. This solution was favoured above a numerical steady state solution approach due to possible numerical instability and lack of reliability of the evapotranspiration (ET) package in steady state.



N

0 5 10 km

Scale @ A4 1:325,000
Date: 28/11/18
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 3-5

Topographic elevation and extent of DEM sets

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 11/28/2018

Table 3-2 Model layers and expected range of hydraulic properties

HSU	Layer	Layer Thickness (m)	Kh [m/d] [2]		Kv [m/d] [2]		Sy [m³/m³] [2]		Ss (m^{-1}) [2]
			Min	Max	Min	Max	Min	Max	
Alluvium	1 and 2	0 to 50	0.01	10	0.001	0.1	0.01	0.1	5×10^{-6}
Fractured and weathered basement zone [1]	1 and 2	0 to 10	0.01	1	0.01	0.1	0.005	0.1	
Styx Coal Measures - overburden	3	0 to 160	0.0005	0.5	0.0005	0.005	0.005	0.1	
Styx Coal Measures – coal seams and interburden	4	0 to 125	0.0005	0.5	0.0005	0.05	0.005	0.1	
Styx Coal Measures - underburden	5	0 to 273	0.0005	0.5	0.0005	0.05	0.005	0.1	
Unweathered Basement	6	Bottom elevation set at -500 mAHD	1×10^{-5}	0.001	1×10^{-6}	0.0001	0.005	0.1	

Notes: 1 The fractured and weathered basement zone is only present where basement (and a small portion of Styx Coal Measures) outcrops

2 Kh – horizontal hydraulic conductivity; Kv – vertical hydraulic conductivity; Sy – specific yield (dimensionless), Ss – specific storage

Min = minimum; Max = Maximum

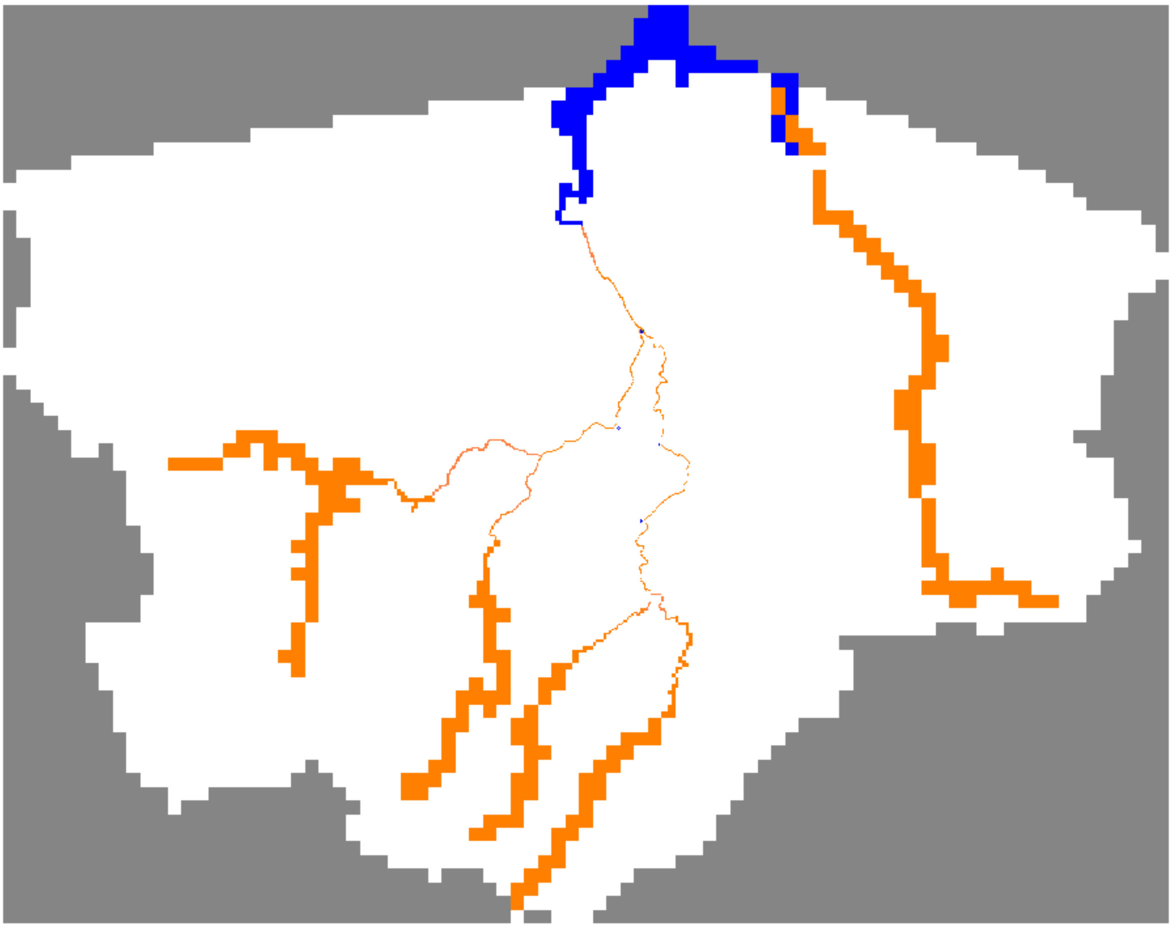
3.4.4 Model boundary conditions

The model boundary conditions (BCs) are specified as described in the conceptual hydrogeological model section of Chapter 10 - Groundwater (Section 10.5.6.8). The BCs are illustrated on Figure 3-6 and discussed further below.

3.4.4.1 Model external boundaries and Broad Sound

The western, eastern and southern parts of the model domain follow the ridgeline of the Styx River Basin (Figure 3-5), which includes the tributary catchments of Tooloombah and Deep Creeks within which the Project is located. These BCs have been defined as no-flow boundaries because the elevation of the water table is topographically controlled, and the ridge line of the Styx River catchment is also an approximate lateral flow divide for shallow groundwater. No water enters or exits the model through the no flow boundaries.

Broad Sound, located at the central part of the northern model boundary and extending into the model domain, is defined as a constant head BC at an average tidal elevation of 2 mAHD. At the constant head BCs, the model calculates the flux of water that is required to either enter or exit the model to maintain the head at the set elevation at those cells.



(Blue: Constant Head BC; Orange: Drain BC; Grey: No Flow BC)

Figure 3-6 Model boundary conditions

3.4.4.2 Ephemeral creeks

Tooloombah and Deep Creeks are represented in the model using DRAIN BCs (refer Figure 3-6). In a DRAIN cell, the model withdraws water when the calculated head in the cell exceeds the DRAIN elevation (or invert). For each model cell along the creeks, the DRAIN elevation has been derived from the elevation datasets used to define the ground elevation (refer Section 3.4.3). As the model grid resolution (20 m to 640 m) is coarser than the DEM datasets (1m for the LIDAR, 10 m for DEM and 90m for SRTM), the invert for each model DRAIN cell was set at the minimal elevation of the overlaying DEM subset. The rate of drainage into or out of the watercourses (representing groundwater and surface water interaction) is controlled by a conductance factor. The conductance factor was selected to be large enough to prevent water from building up at the drain cell. The flow to the creek from groundwater is then controlled by the aquifer hydraulic properties and hydraulic gradients established between the simulated aquifer(s) and adjoining DRAIN cells.

Streamflow was simulated using the MODFLOW Recharge package, which is discussed below.

3.4.4.3 Groundwater recharge

Recharge is applied to the upper-most active layer of the model domain, over three zones. The recharge rate for each zone has been represented as a percentage of monthly rainfall and have been based on recharge estimates derived using the chloride mass balance method (see Section 10.5.6.6 of SEIS Chapter 10 – Groundwater). The respective recharge factors were determined during calibration with the constraint that recharge of the Alluvium is greater than the recharge over

Basement and the Flood recharge is higher than the Alluvium recharge. During calibration, the recharge of the Alluvium and Basement were bounded by the estimated values from field data (see Chapter 10 – Groundwater, Section 10.5.6.6). The percentage rates were used as calibration parameters, which are discussed in Section 3.5.

Groundwater recharge was applied to the model in three zones (refer Figure 3-7):

- Flood recharge – located along Tooloombah and Deep Creeks to represent recharge following high streamflow events (15 mm/yr on average);
- Alluvium diffuse recharge – located where Cenozoic (alluvial) sediments are present in the model (4.5 mm/yr); and
- Basement diffuse recharge – located where Cenozoic (alluvial) sediments are absent (3 mm/yr).

3.4.4.4 Evapotranspiration

Excess groundwater recharge, which would otherwise result in the water table rising above ground surface, is removed during simulations by ET, which was modelled using the MODFLOW EVT package. ET occurs if the water table rises above a defined 'extinction depth', which in the Styx model is set equal to 3 m below ground surface. It does not include ET from the unsaturated zone, which is indirectly accounted for in the aquifer recharge rates (diffuse recharge).

The EVT package requires the definition of a maximum ET rate, which has been defined using the average monthly time series of potential evaporation.

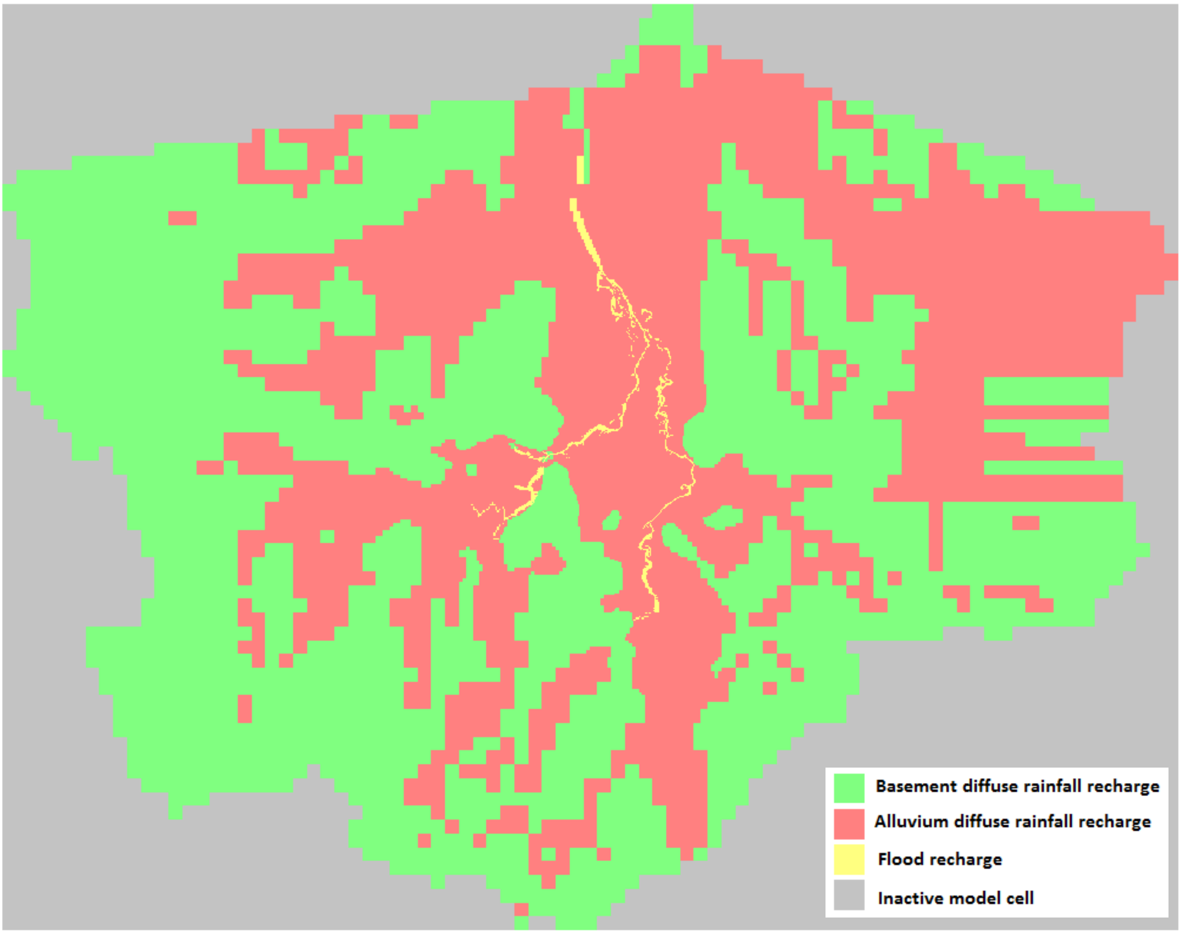


Figure 3-7 Recharge zones

3.5 Model calibration

3.5.1 Overview

Model calibration generally involves changing values of model parameters within reasonable bounds until model outputs (e.g. heads or fluxes) fit historical measurements, such that the model can be accepted as a reasonable representation of the physical system of interest (Barnett et al. 2012). The calibration procedure followed these iterative steps:

- Identify historical measurements of quantities that can be predicted by the model (calibration targets), which consists in this model of measurements of hydraulic head in groundwater bores;
- Identify the historical stresses on groundwater sources during the period when historical observations are available (rainfall recharge in this case);
- Run the groundwater model to simulate this historical period and compare the model predictions with the observations; and
- Adjust the model parameters within realistic/representative bounds and re-run the groundwater model until an acceptable statistical match is achieved between the simulated and observed values. These steps can be performed manually or automatically using parameter estimation software such as PEST. The model calibration reported here has been assisted by PEST followed by manual adjustment to select the parameter sets that provide the best fit with observed data as well as remaining consistent with the hydrogeological conceptualisation (further detail regarding the use of PEST is provided in sections 3.7.1 and 3.7.2.2) .

The model has been calibrated in steady state to determine initial heads for the transient model, and in transient mode for a period of 15 months.

3.5.2 Calibration targets

The model has been calibrated using hydraulic head data from 66 groundwater bores, described in Section 10.5.6.2 and Section 10.6.2.2 (SEIS Chapter 10 – Groundwater). Figure 3-9 presents a (pre-mining) water table elevation contour plan that has been inferred and hand-drawn from the available data, which indicates regional groundwater flow towards the estuary and coast, and local groundwater flow to watercourses.

For 49 of the bores, the calibration targets consist of single hydraulic head observations. Timeseries data are available for 17 bores (refer Figure 3-8), primarily interpreted to screen the Alluvium and Styx Coal Measures. The hydrographs show:

- Generally, minor variation in Basement and Styx Coal Measures groundwater elevations is observed in likely response to rainfall; and
- Some variation in Alluvium groundwater elevations is observed (e.g. bores WMP08, WMP05 BH16 and BH01X) with up to 3 m difference in heads between wet and dry seasons. However, the observed rise in hydraulic head at WMP08 and WMP05 is likely related to stabilisation of water level post construction of the bores (suggesting low permeability).

Table 3-3 lists the number of observation bores available for provision of head data for model calibration, separated by HSU. The hydraulic head targets range from 1.9 to 302 mAHD.

The location of the calibration target bores is shown in Figure 3-10.

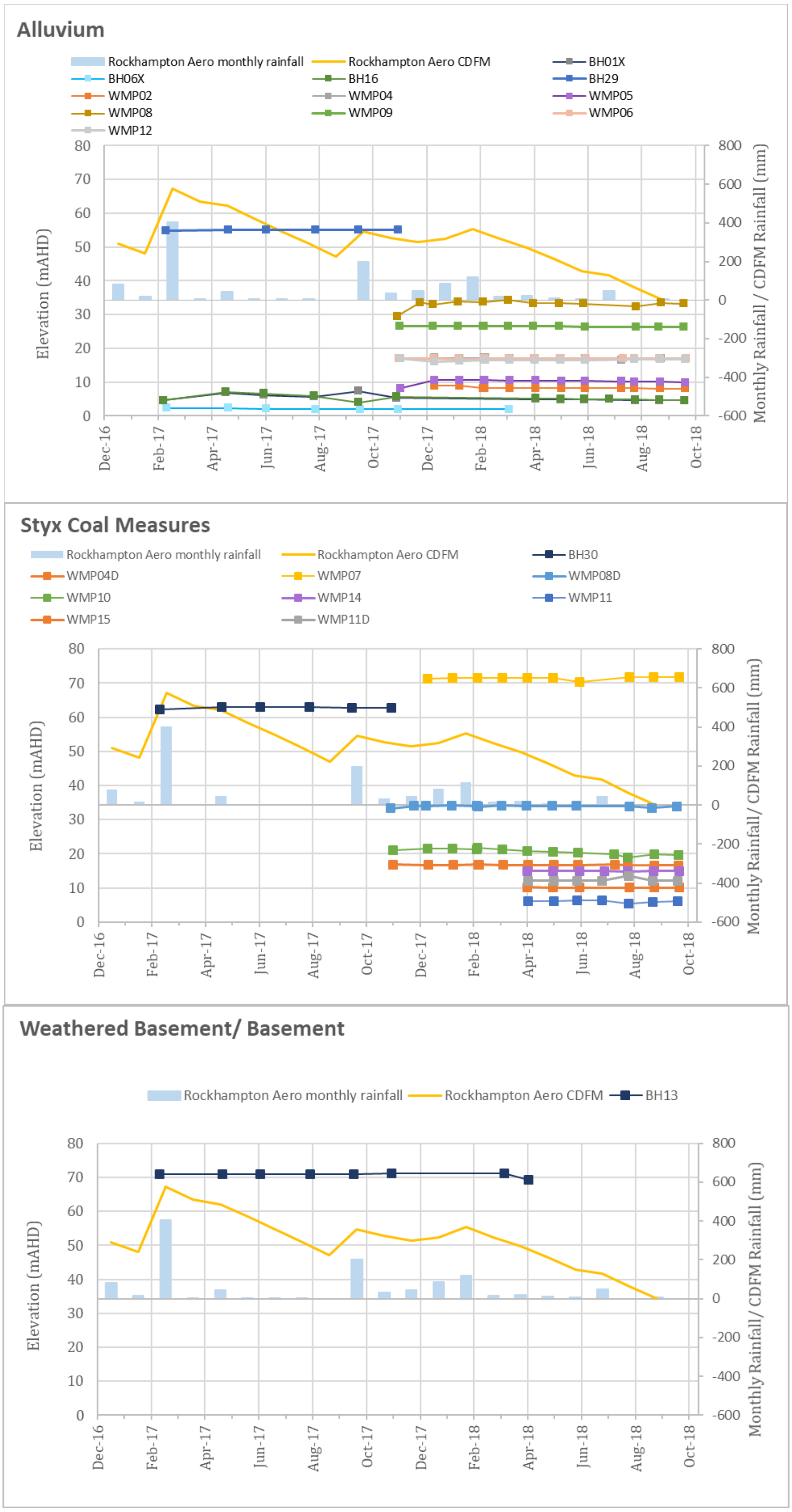
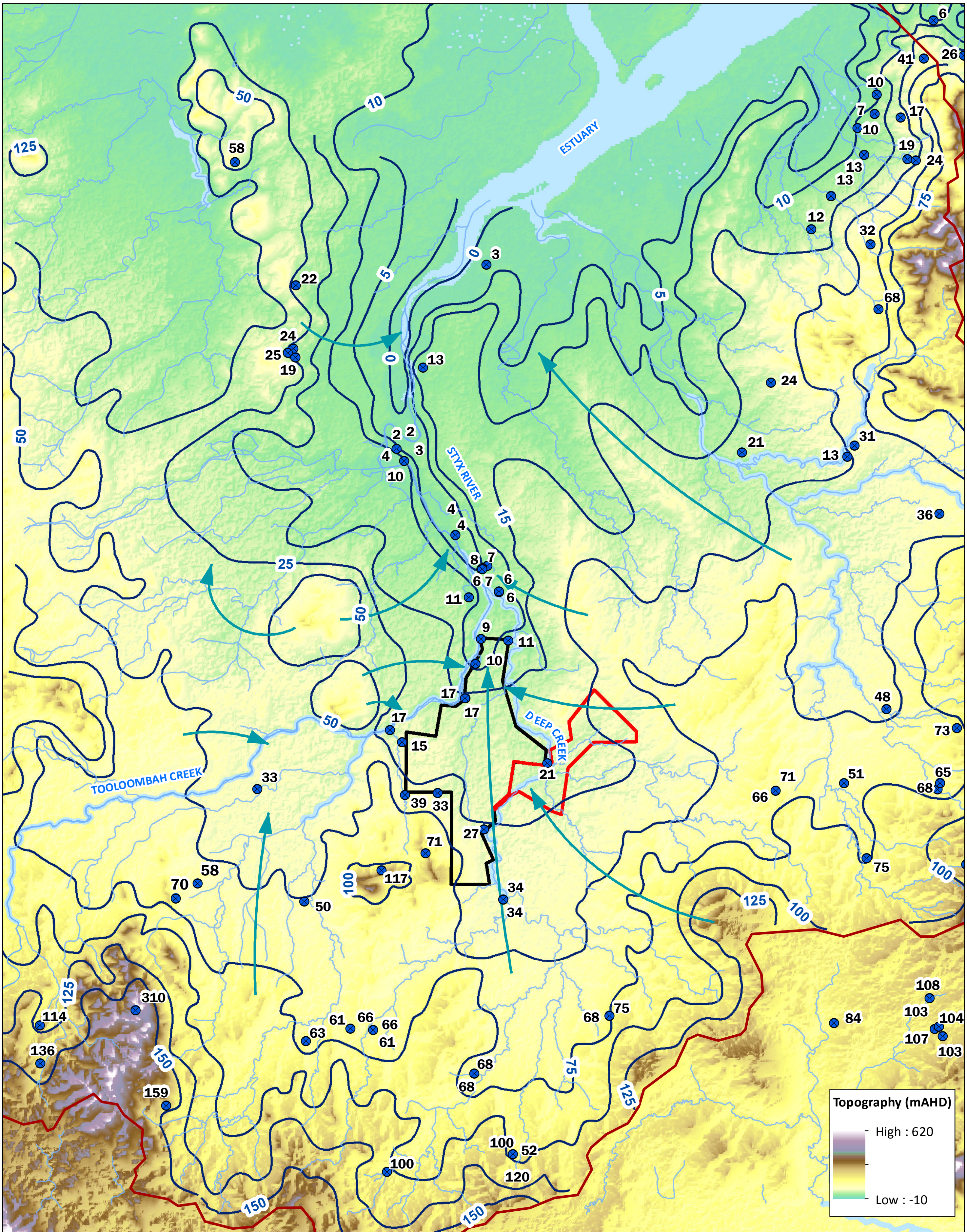


Figure 3-8 Observation bore hydrographs by HSU



N

0 2.5 5 km

Scale @ A4 1:200,000
Date: 04/12/18
Drawn: A. Aird

Legend

- Groundwater elevation (mAHD)
- Styx River Basin
- Watercourse
- Inferred water table contour (mAHD)
- Inferred groundwater flow
- ML 80187
- ML 700022

Figure 3-9
Inferred water table elevation and groundwater flow

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Inferred_WT_elevation.mxd 12/4/2018

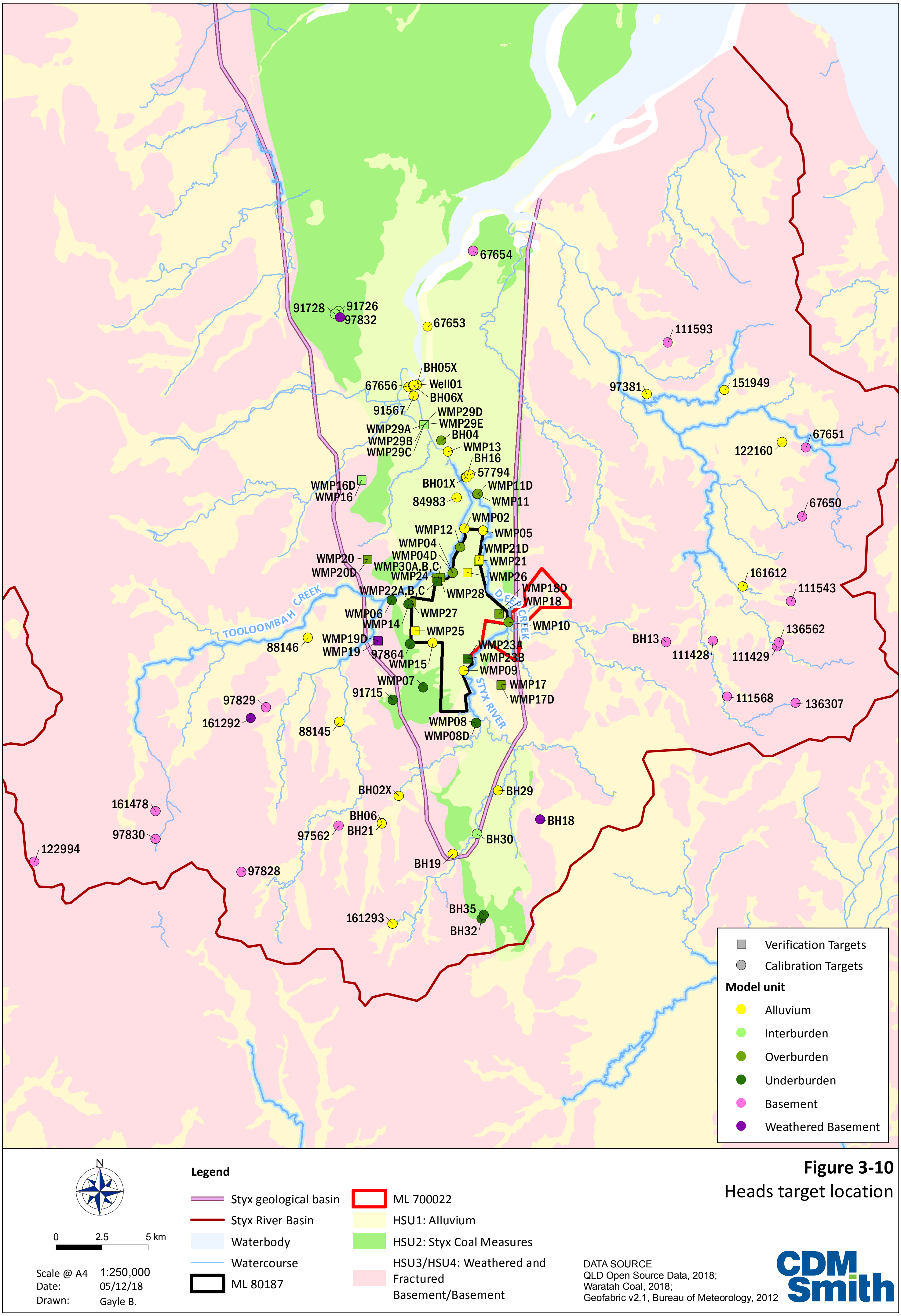


Figure 3-10
Heads target location

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 heads target location r2.mxd 12/5/2018

Table 3-3 Observation bores per unit

HSU	Model layer	No. of observation bores
Alluvium	1,2	28
Styx Coal Measures	3,4,5	18
Basement	6	20

3.5.3 Calibration results

Results of the model calibration are summarised in Table 3-4 and Table 3-5, representing the adopted values of hydraulic properties and recharge that are used later for the predictive simulations. Figure 3-11 shows a scattergram of observed verses simulated values of hydraulic head at the locations of the calibration targets, as well as the probability distribution for the calibration residuals (the differences between the observed and simulated values). The calibration residuals are presented on Figure 3-13. Much of the calibration fit reflects the relationship between water table elevation and topography. The calibration fit is achieved as a balance between the applied rate of groundwater recharge and hydraulic conductivity of all units, particularly the outcropping units (the Cenozoic deposits, and the fractured and weathered zone of the outcropping basement and Styx Coal Measures). The calibration accounted for anticipated ranges of hydraulic conductivities based on field pumping tests and slug tests results (Section 2), and results of testing completed elsewhere in the general area of the Project (see Section 10.5.6.3, SEIS Chapter 10 – Groundwater). For each HSU, a consistency with field geometrical mean results was favoured to marginal improvements of the calibration fit.

Table 3-4 Adopted hydraulic properties

HSU	Kh [1] (m/d)	Kv [1] (m/d)	Sy [1]
Alluvium	4.1	0.41	0.01
Fractured and weathered basement	1	0.1	0.005
Styx Coal Measures - overburden	0.02	0.02	0.005
Styx Coal Measures – coal seams and interburden	0.003	0.003	0.005
Styx Coal Measures - underburden	0.004	0.004	0.005
Unweathered basement	$4.0x10^{-4}$	$4.0x10^{-4}$	0.005

Notes: 1 Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity, Sy = Specific Yield

Table 3-5 Adopted Recharge

HSU	% of annual rainfall	Annual average recharge rate (mm/yr)
Flood zone recharge	2%	15
Alluvial diffuse recharge	0.6%	4.5
Basement recharge	0.4%	3

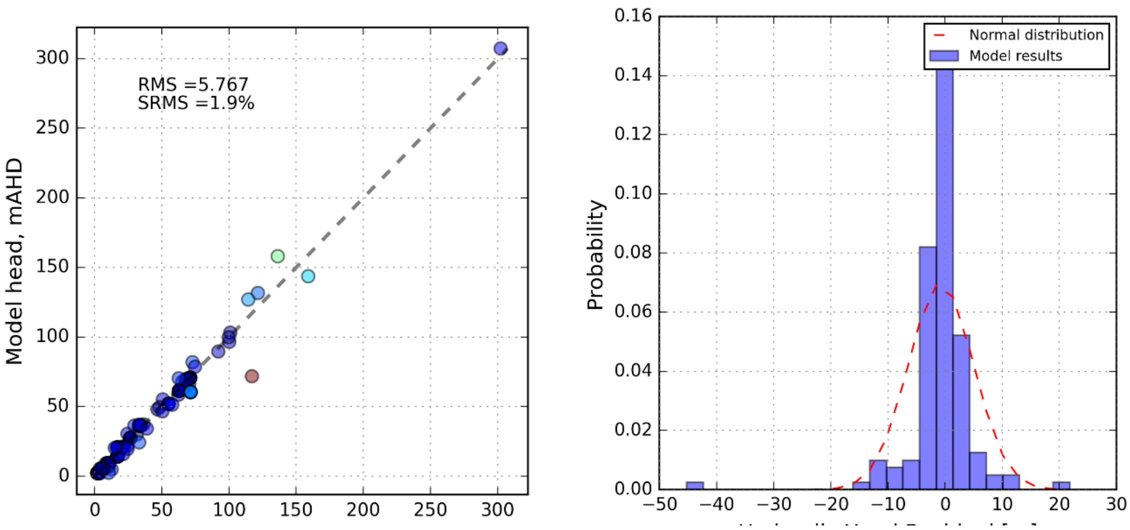


Figure 3-11 Calibration scattergram and residuals

The following presents a summary of calibration results and the adopted hydraulic properties:

- The adopted hydraulic conductivity value of the Styx Coal Measures is at the lower end of the expected range. This was required to obtain a suitable calibration to the observed hydraulic heads in the Styx Coal Measures, and to remain consistent with the overall conceptual understanding. The influence of this parameter on the model predictions is explored further in the uncertainty analysis (Section 3.7).
- The calibrated diffuse rainfall recharge rates for the alluvium and basement are within the anticipated ranges. Variations in recharge rates are also explored as part of the uncertainty analysis (Section 3.7).

The calibrated hydrographs are illustrated on Figure 3-14. The predicted water levels at the observation bores show limited amplitude (i.e. change in level over time) which is not consistent with observed variability at some bores (BH01X and BH16) in response to rainfall recharge. The model is structurally limited in its ability to represent this behaviour, principally as a result of the manner in which recharge is simulated (i.e. it is expected most recharge occurs following high rainfall events, rather than as a percentage of all rainfall). The regional hydraulic gradient is well calibrated, providing confidence that there is a good balance between regional recharge and corresponding hydraulic conductivity. There is also good agreement between inferred pre-mine water table elevation contours (Figure 3-9) and the model predicted pre-mine water table elevation contours (Figure 3-15).

3.5.4 Verification

An additional 25 project monitoring bores were installed following the model calibration. The breakdown of the newly implemented observation bores by HSU is illustrated on table Table 3-6. The newly acquired observations were imported into the calibrated model and a combined scatter plot was generated to assess how the new observations affect the overall calibration (Figure 3-12). The sRMS with the new observations remains identical to the statistic on the calibration set (sRMS= 1.9%). Therefore, the new observations are consistent with the calibrated parameters for the model.

Table 3-6 Observation bores per unit

HSU	Model layer	No. of observation bores for calibration	No. of observation bores in the verification set	Total
Alluvium	1,2	29	6	34
Styx Coal Measures	3,4,5	18	17	35
Basement	6	20	2	22

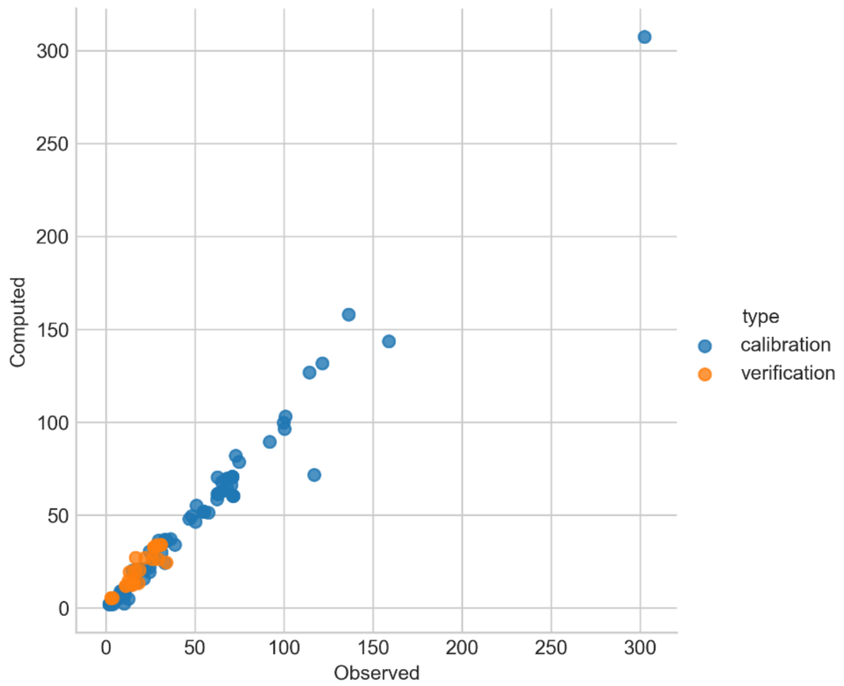
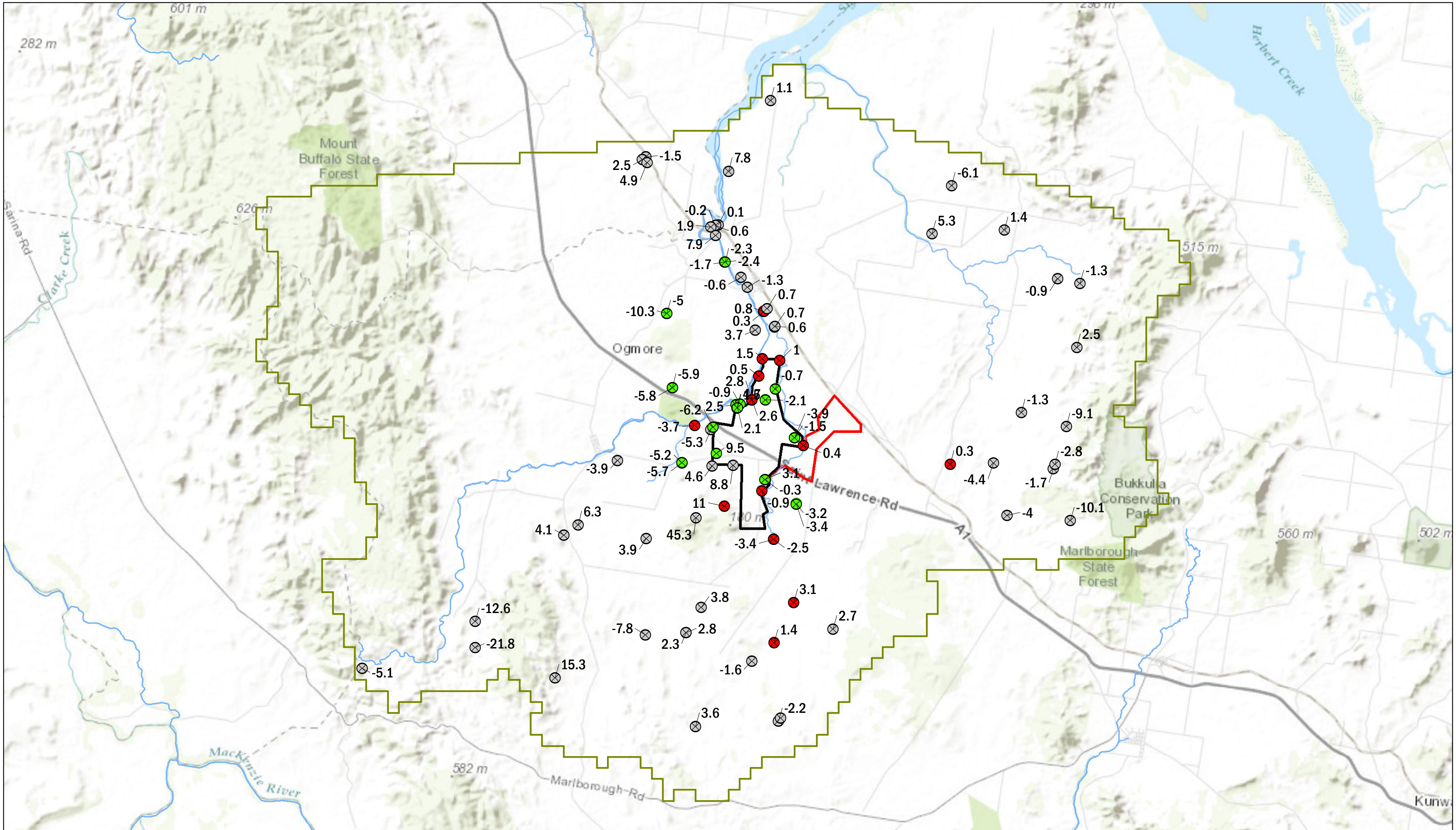


Figure 3-12 Calibration scattergram and residuals- verification

3.5.5 Model mass balance

The model water balance for the initial steady state period reported in Table 3-7 is used to check whether the steady-state model is solving accurately and does not contain a mass-balance discrepancy. The percent error in the model mass balance is smaller than 0.002% and demonstrates the results are numerically accurate (Table 3-7). The transient mass balance for the calibration period is illustrated on Figure 3-16 and Figure 3-17. It shows a large recharge spike following simulated rainfall events, which results in a rise in hydraulic heads. The increase in storage is balanced by removal of water from the model through ET and creek baseflow.



N

0 2.5 5 km

Scale @ A4 1:300,000
Date: 05/12/18
Drawn: A. Aird

Legend

Calibration targets

- Single data point
- Timeseries data
- Verification
- Model domain
- ML 80187
- ML 700022
- Major watercourse

Figure 3-13
Spatial distribution of calibration residuals

DATA SOURCE
QLD Open Source Data, 2018
Esri Basemaps, 2017

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6_Calibration residuals R7.mxd 12/5/2018

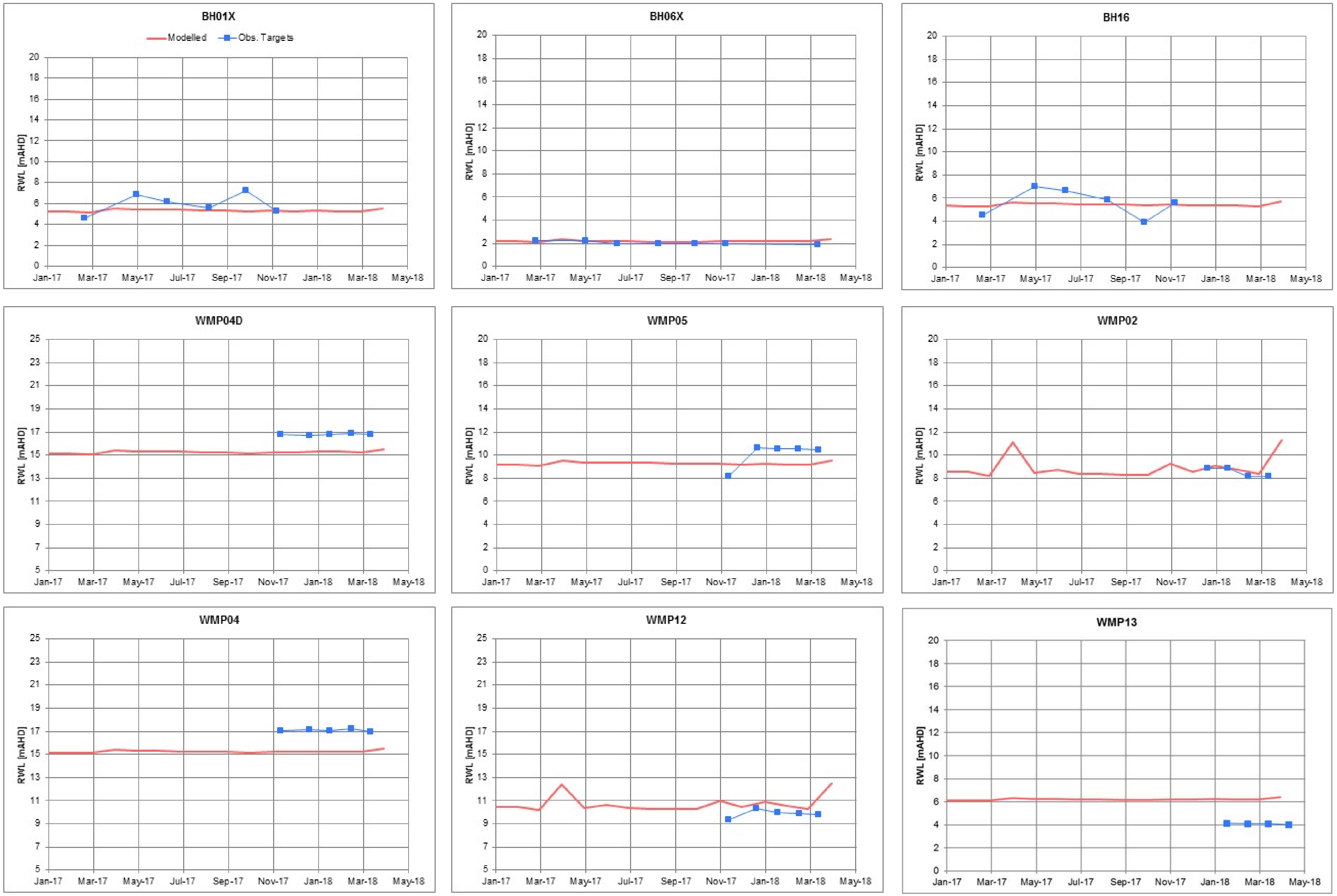


Figure 3-14

Calibration hydrographs - Model Layer 1 and 2

CDM Smith

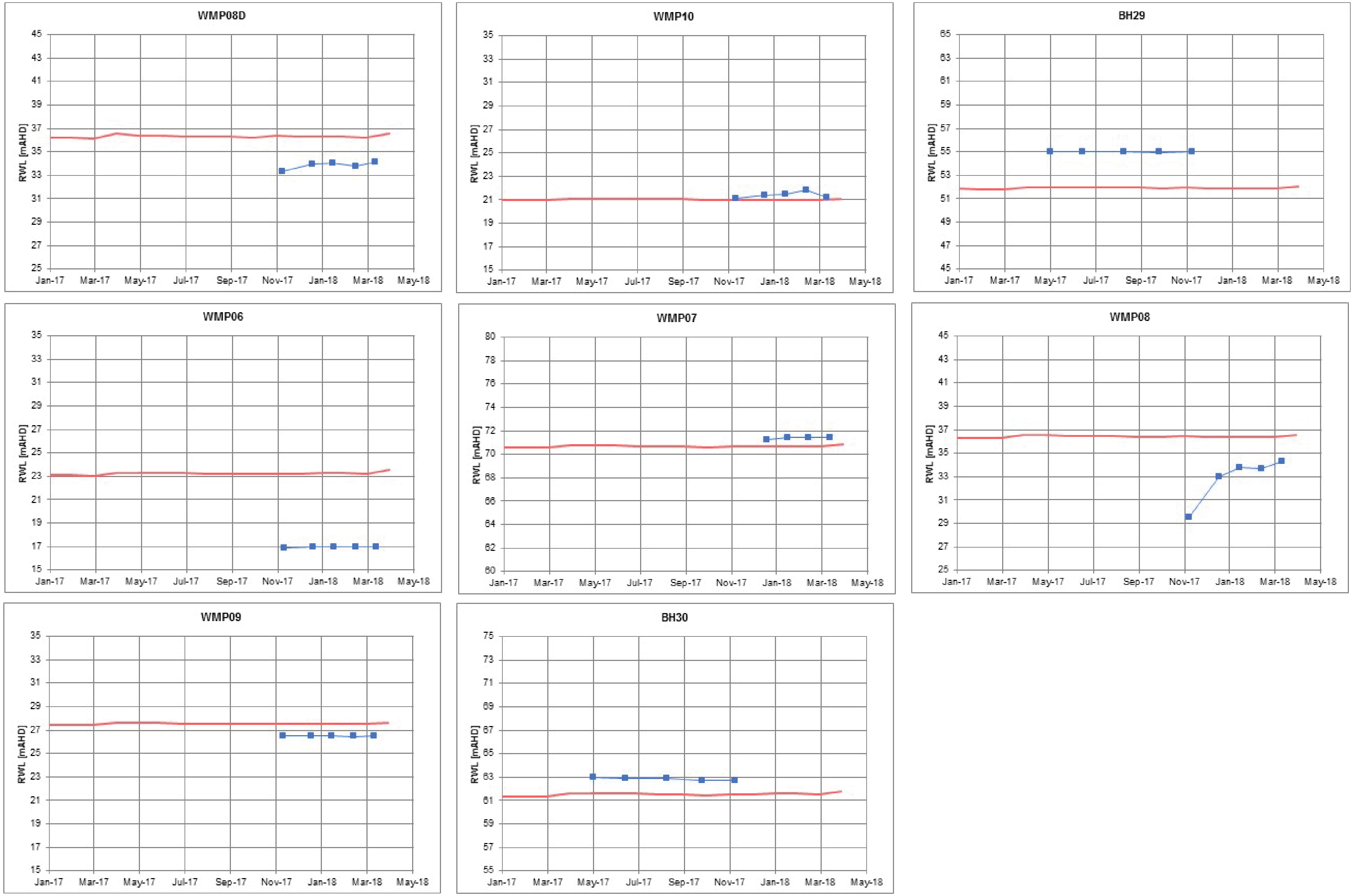


Figure 3-14

Calibration hydrographs - Model Layer 3 to 5

CDM Smith

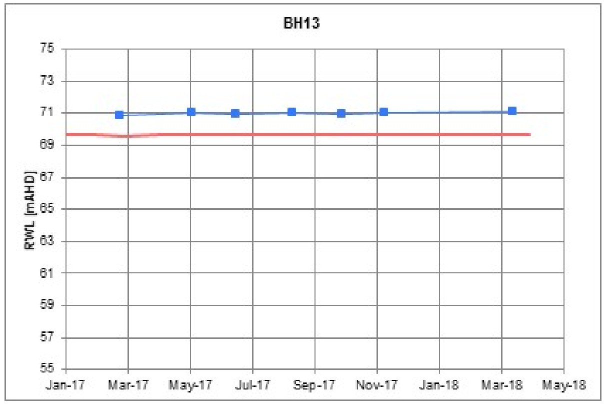


Figure 24c

Calibration hydrographs - Model Layer 6

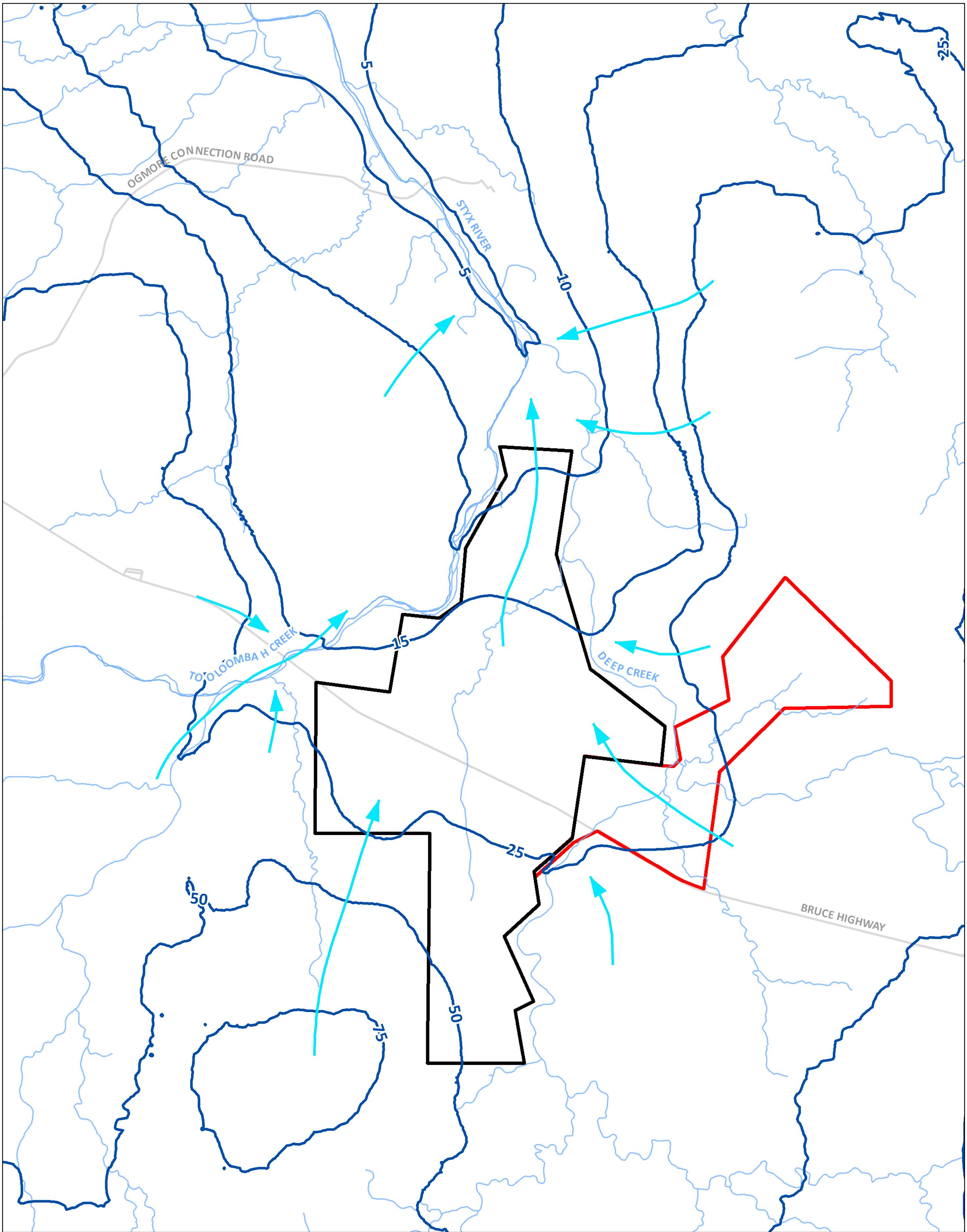


Figure 3-15
Predicted water table elevation contours – pre-mine

Legend

- Predicted water table contour (mAHD)
- Groundwater flow
- 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

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Table 3-7 Steady state calibrated model water balance

Component	Rate (ML/d) [1]
Groundwater recharge	14.7
Evapotranspiration (ET)	-10.8
Flow at DRAIN BCs (Creek baseflow)	-2.0
Flow at constant head BCs (Broad Sound)	-1.8
Imbalance	0.0

Notes: 1 Positive values represent inflows to the model. Negative values represent flows out of the model. Values are totals across the model domain

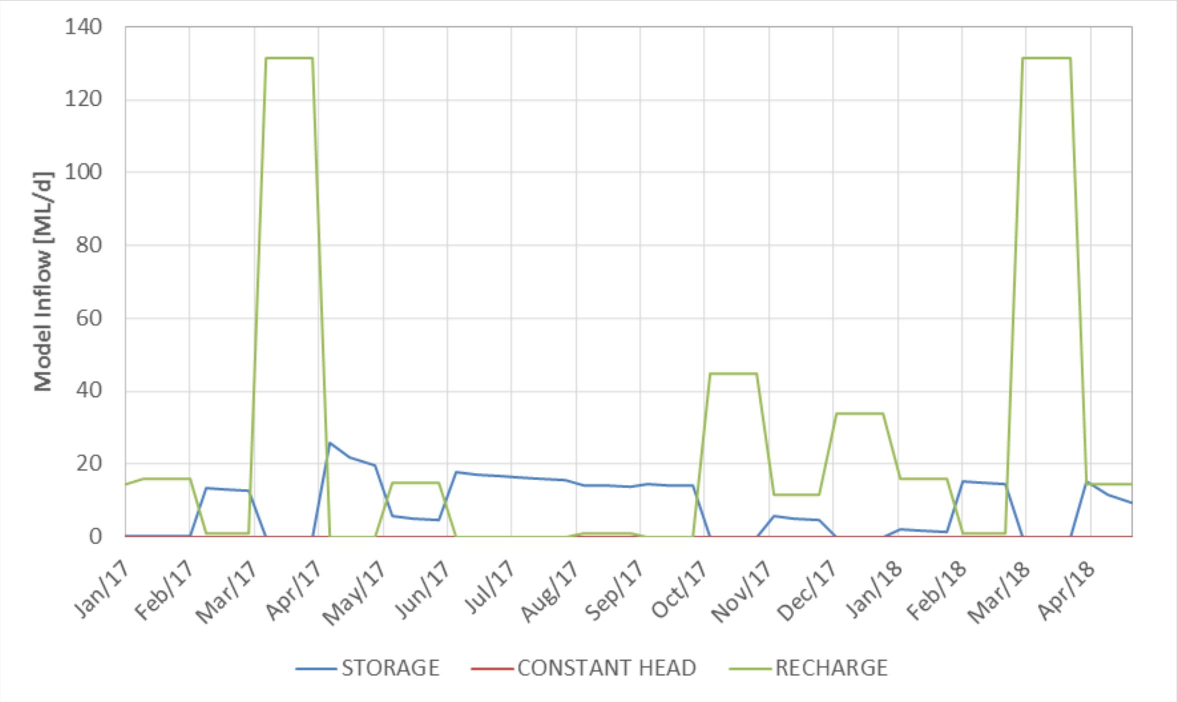


Figure 3-16 Transient calibrated model mass balance - inflows

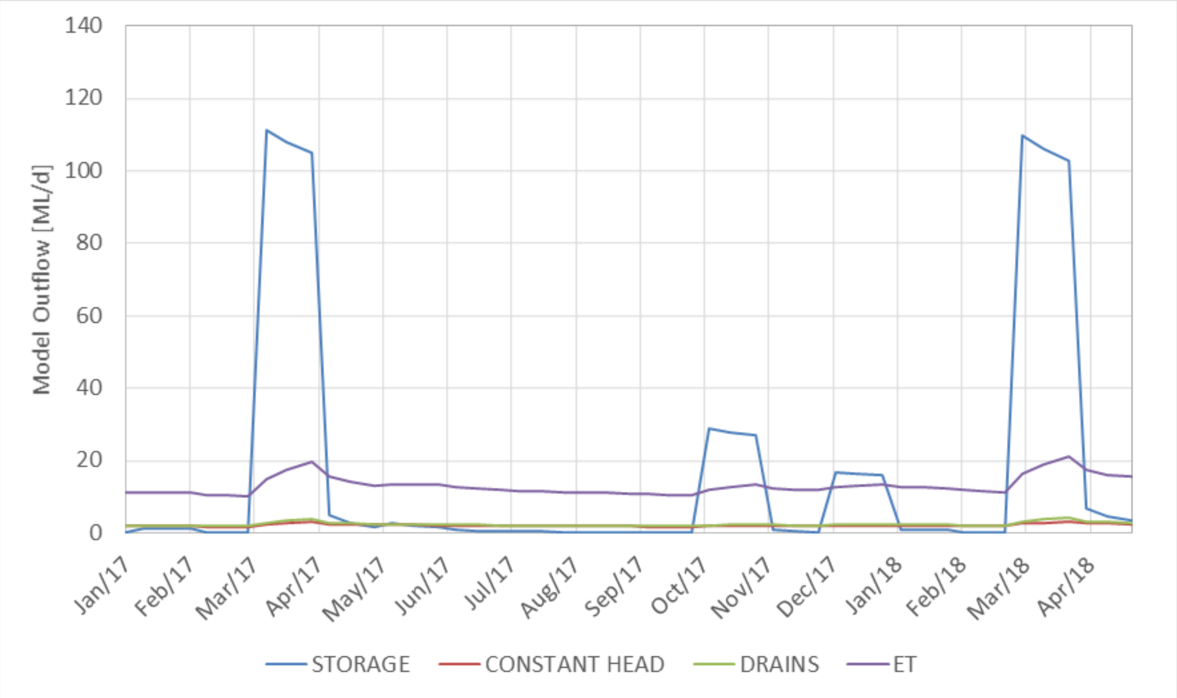


Figure 3-17 Transient calibrated model mass balance – outflows

3.6 Predictive simulations

3.6.1 Representation of mining

The mine development is represented in the groundwater modelling using the 18-year mine plan and schedule[1] provided by CQC, which is shown in Figure 3-18. The mine schedule has been used to develop a passive dewatering sequence that is simulated by collecting groundwater reporting to the active pit areas (adopting an approach representative of sump pumping).

The dewatering schedule implemented in the model is based on the following assumptions:

- All groundwater inflow reporting to active mining areas will be collected in sumps and pumped out; and
- The mine pits will be progressively backfilled during mining.

Dewatering of mine pits and depressurisation at the pit faces is represented in the groundwater modelling using DRAIN BCs at which the hydraulic head is constrained to the pit face elevation (and the DRAIN conductance is set high enough (640 m^2/d) so that flow to the cell is controlled by in-situ hydraulic properties rather than the ability of the drain to remove water). DRAIN BCs are activated sequentially according to the planned mine schedule as illustrated on Figure 3-18. When the DRAIN BCs are active, water discharges from the model to maintain the water table at the elevation of the pit floor. The water abstracted at the pit BCs over time is used to estimate the predicted mine dewatering rates.

3.6.1.1 Water storage dams

Five water storage dams are proposed during mining to manage and store water produced by the Project. The storage dams are not planned to be lined and therefore have the potential to leak water to the water table, thereby buffering the impact of dewatering on water table drawdown to some extent. The storage dams are not simulated in the model, which provides a conservative outcome in terms of potential water table drawdown during and following mining.

3.6.1.2 Pit backfill

The current mine plan includes progressive backfilling of the pits during the life of mine. The backfilling is represented in the model by removing the DRAIN BCs that represent mine dewatering after one year of simulated mining. The backfill material is assumed to have the same properties as the pre-mining material. This approximation has a limited influence on recovery of hydraulic heads in the backfilled pits, as the recovery is mainly controlled by regional aquifer properties.

3.6.1.3 Final mine-pit voids

All pits are backfilled to at least the pre-mine ground elevation and there will be no pit void following mine completion. Due to bulking of excavated materials, remnant waste rock stockpiles are likely to remain to some extent.

---

[1] The mining schedule has been modified during the course of this study. Both schedules (original and revised) were modelled in predictive mode and compared to each other. As the drawdown at end of mining was 2 % more conservative for the original schedule than for the revised schedule, the original schedule formed the basis for the modeling analysis. The revised schedule and associated predicted drawdowns are discussed in the uncertainty analysis section and illustrated on Figure 3-66 and Figure 3-67.

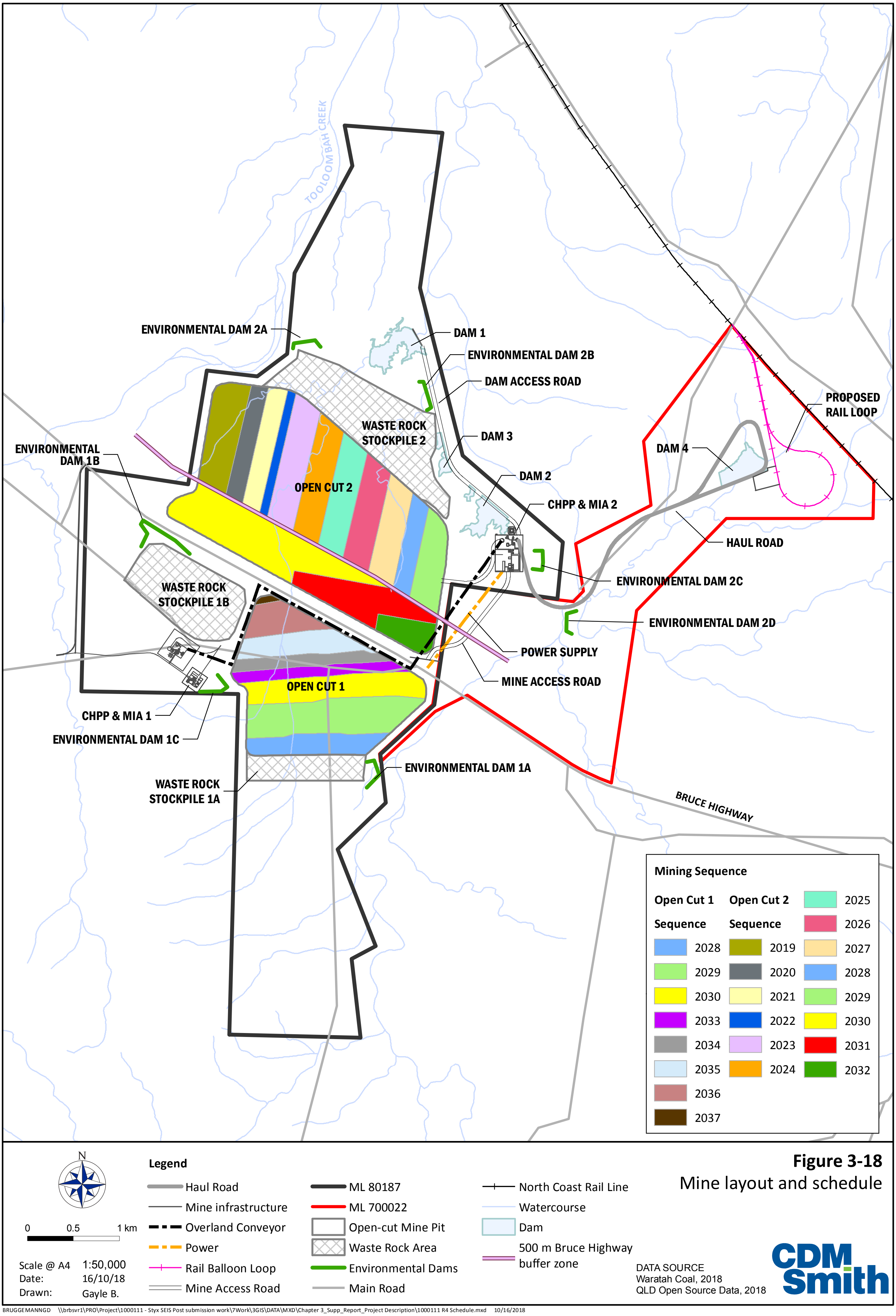


Figure 3-18
Mine layout and schedule

3.6.1.4 Stress periods

Predictive model simulations are run for the 18 years of mining followed by a 500 year post-mining period. The stress period length is one month and the timestep length is 7 to 12 days (adopting 3 timesteps per stress period and a timestep multiplier of 1.2).

3.6.2 Prediction results

3.6.2.1 Groundwater heads and drawdown

The following presents a summary of predictive results of the calibrated groundwater model. The model incorporates the original (most conservative) proposed mining schedule and mine plan (ref. Mine Schedule – 20180406.shp) that has been provided by CQC. The mine plan and schedule is presented in Figure 3-18. Model predicted pre-mine, during mining and post-mine groundwater heads and drawdown data are presented on the following figures:

- Water table (potentiometric) 'surface' and groundwater flow direction response (pre-mine, during mining and post-mine) – Figure 3-19 to Figure 3-25.
- Potentiometric surface 'drawdown' response (during mining and post-mine) – Figure 3-26 to Figure 3-32.
- Potentiometric surface drawdown at end of mining for each model layer showing the extent of desaturated HSUs for each layer– Figure 3-33 to Figure 3-37.
- Groundwater abstraction rates from mine pits (during mining) and cumulative life of mine groundwater production - Figure 3-38.
- Proportional changes to baseflow and evapotranspiration losses for selected reaches of Tooloombah and Deep Creeks - Figure 3-39 and Figure 3-40.
- Hydrographs at locations of potential sensitive groundwater dependent ecosystems (GDEs) occurring with the predicted mine water affecting activities zone of influence -Figure 3-42 and Figure 3-43.
- Hydrographs at locations of potential sensitive third party groundwater users - Figure 3-45 to Figure 3-47.
- Potentiometric surface 'drawdown' response at the end of mining for an abstraction mitigation scenario for offsetting predicted drawdown impacts (discussed in section 3.6.2.4) and a hydrograoh of the predicted available abstraction rate for a possible mitigation bore- Figure 3-48 and Figure 3-49.
- Maximum predicted drawdown extent in relation to potential ASS - Figure 3-50.
- Figure 3-51 to Figure 3-53 – predicted cross-sectional drawdown response for each model layer for pre-mine, year 12 (maximum pit depth) and at end of mining.

The following provides discussion around the changes predicted for the water table surface and shallow groundwater flow directions (Figure 3-19 to Figure 3-25) in response to mining water affecting activities:

- The predicted water table elevation contours are a reasonable representation of the inferred water table elevation contours presented in Figure 3-9 (manually drawn based on available standing water level data for the broader study area).
- By mining year 5 through to 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. However, away from the proposed mine

lease area, water table elevation contours are predicted to remain relatively consistent with 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.
- At all times during the simulated mining and recovery phases 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.

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 3-26 to Figure 3-37:

- Mining at the 'Open Cut 2' pit, by year 5
  - 1 m drawdown contour extends to Tooloombah and Deep Creeks on the western and eastern boundaries of ML80187; and
  - 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 through end of mining
  - 1 m drawdown contour extends to and beyond Tooloombah and Deep Creeks on the western and eastern boundaries of ML80187, as well as further to the south and north of the ML, to intersect stream reaches of the mid- to lower Deep Creek and mid-Tooloombah Creek
  - 0.1 m drawdown contour extends further beyond Tooloombah Creek to the northeast and within around 1,500 to 2,000 m of Styx River, but not to the confluence of the two creeks
  - alluvium (HSU1) is dewatered over much of the central portion of ML 80187, with small areas outside the ML also dewatered (Figure 3-33)
  - overburden coal measures (HSU3) is dewatered over the central portion of ML 80187 (Figure 3-34)
  - interburden coal measures (HSU3) is dewatered in the areas of 'Open Cut 1' and 'Open Cut 2' (Figure 3-35)
  - underburden coal measures (HSU3) remains saturated beneath ML 80187 (Figure 3-36)
- By year 10 through 25 into closure (with all voids backfilled) the predicted extent of the
  - 1 m drawdown contour remains similar to the contour predicted at the 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 the end of mining

- By year 50 into closure the predicted extent of the 0.1 and 1 m drawdown contours has begun to shrink back towards the decommissioned and back filled pits, and by year 100 into closure the groundwater system is predicted to have fully recovered.

3.6.2.2 Dewatering rates

Model predicted dewatering rates presented on Figure 3-38 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.

3.6.2.3 Direct effects at sensitive environmental receptors

A key direct effect of mining on groundwater is drawdown associated with dewatering and the associated indirect effects of reduced baseflow to support in-stream GDEs and riparian GDE access to the water table (Figure 3-41). Figure 3-39 and Figure 3-40 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); and
  - upwards of 40% reduction in flux between the 'no mine' and 'mining' scenario for the lower reach (below Bruce Highway), with flux slowly returning to background after closure (~50% recovery by around 65 years after closure, and the remaining ~50% occurring within another 20 years or so).
- Deep Creek
  - less than 15% reduction in flux between the 'no mine' and 'mining' scenario for the upper reach (above WMP10; Figure 3-10), 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 3-10), 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); and
  - 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), with flux slowly returning to background within around 75 years after closure

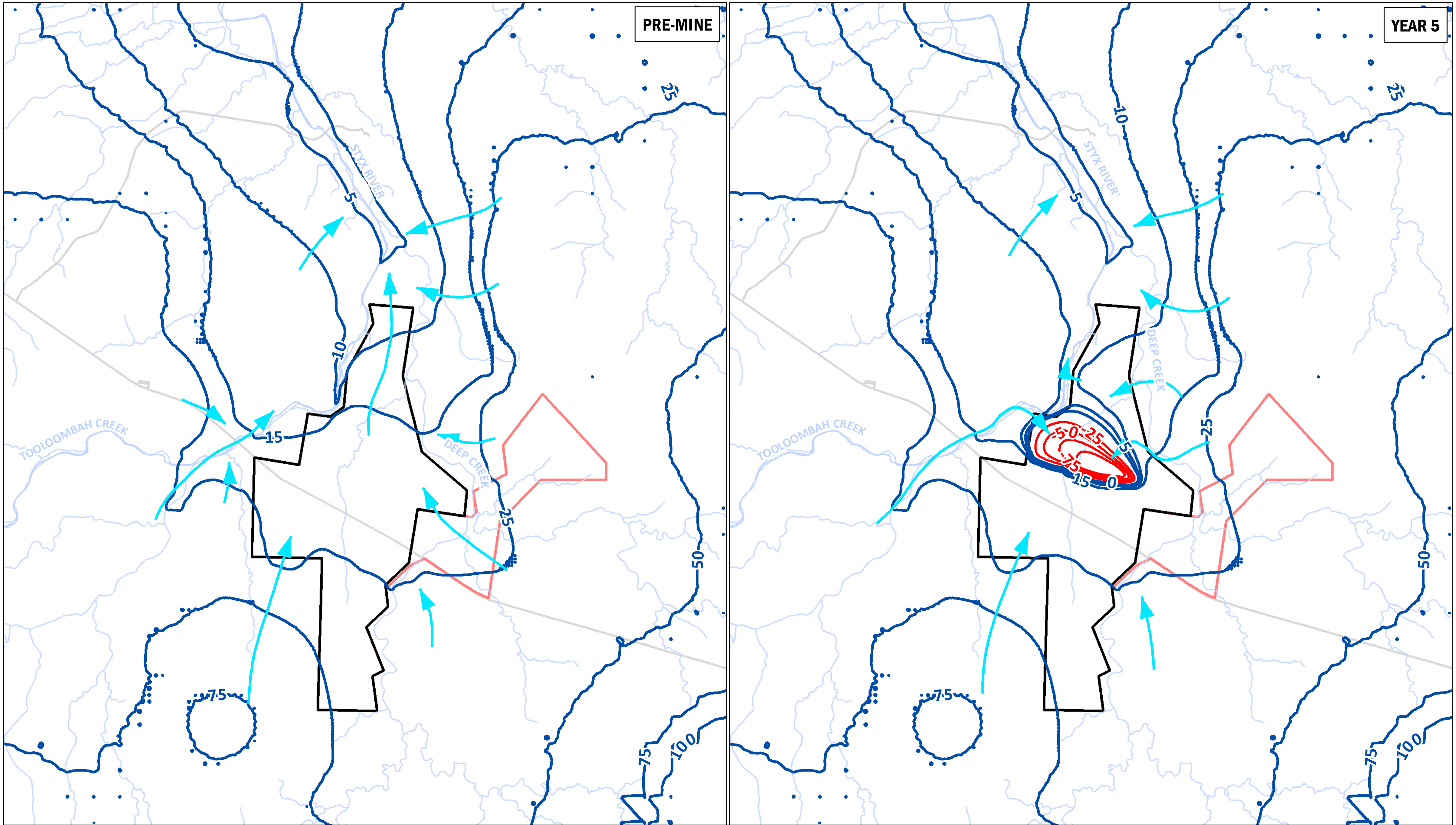
Model predicted hydrographs at selected locations where potential GDEs occur are presented in Figure 3-42 and Figure 3-43, and show:

- Drawdown at the location where stygofauna have been identified in Deep Creek catchment alluvium (bore STX093; Figure 3-26 and Figure 3-42) in response to mining activities is predicted to result in an almost 90% loss of vertical habitat over the life of mining after which full recovery occurs by around 50 years after closure (50% recovery occurring by around 15 years after closure).

- Drawdown at the location of a potential Type 3 GDEs (WMP25 and WMP27; Figure 3-10and Figure 3-43) 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.

Model predicted hydrographs at third-party bores (Figure 3-44) located in the Project area are presented in Figure 3-45 to Figure 3-47, 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.
- Drawdown in response to mining activities is unlikely to occur at other third-party bores in the area.



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.

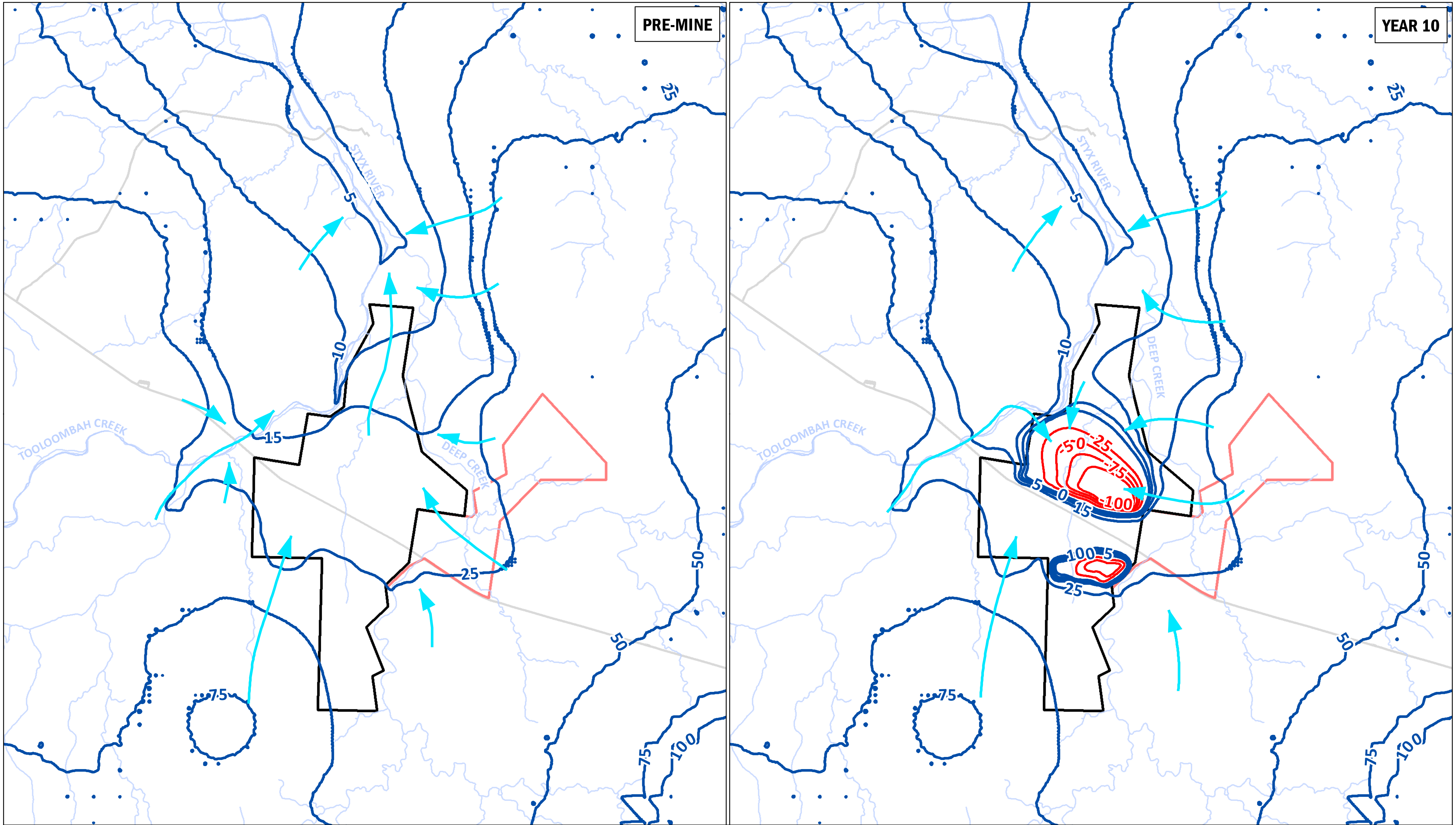
Figure 3-19

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

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT Pre-mining__LOM yr 5.mxd 12/20/2018



N

0 2 4 km

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

Legend

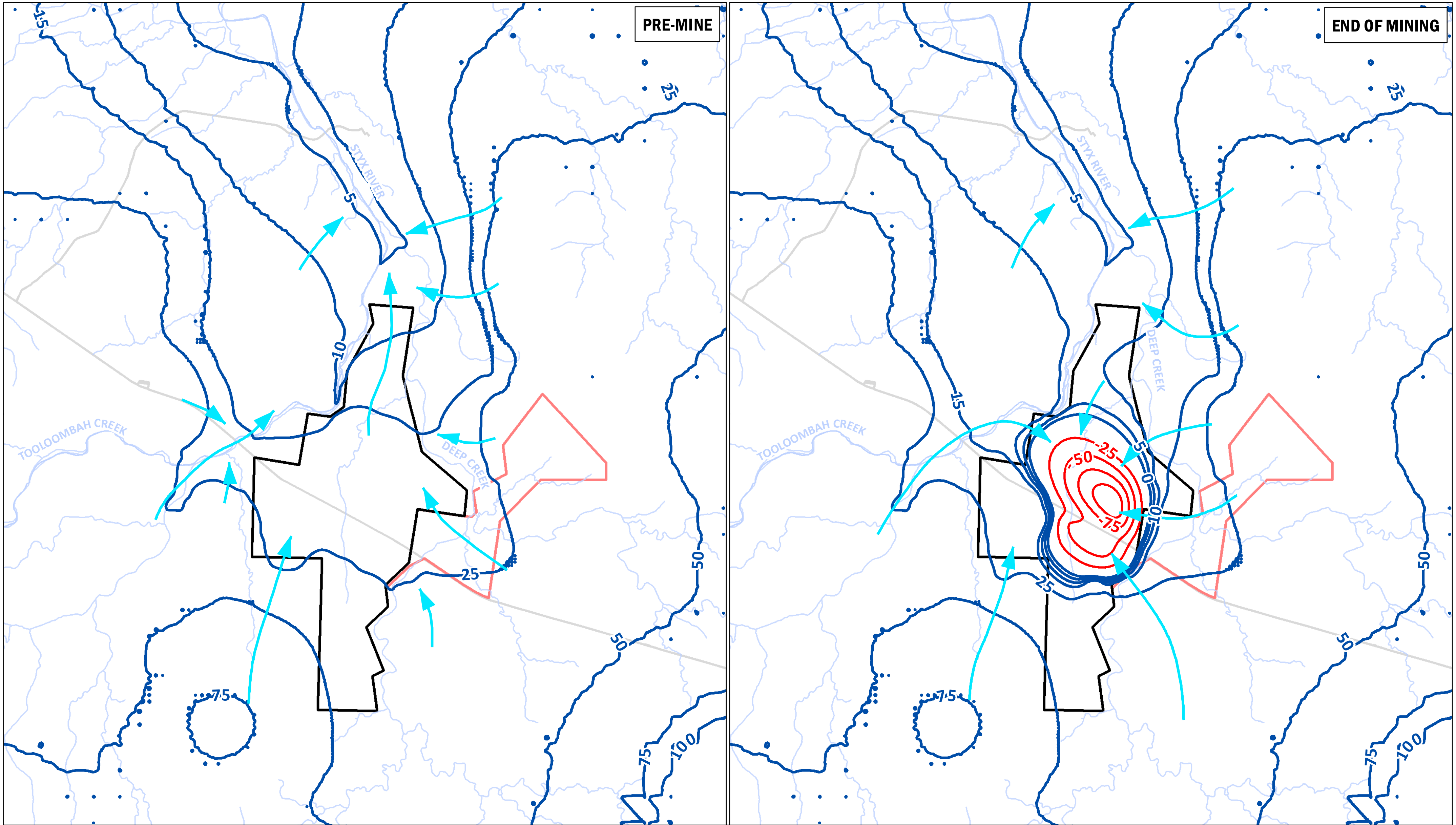
- Predicted water table contour (mAHD)
- Groundwater flow
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 3-20

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

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__LOM yr 10.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.

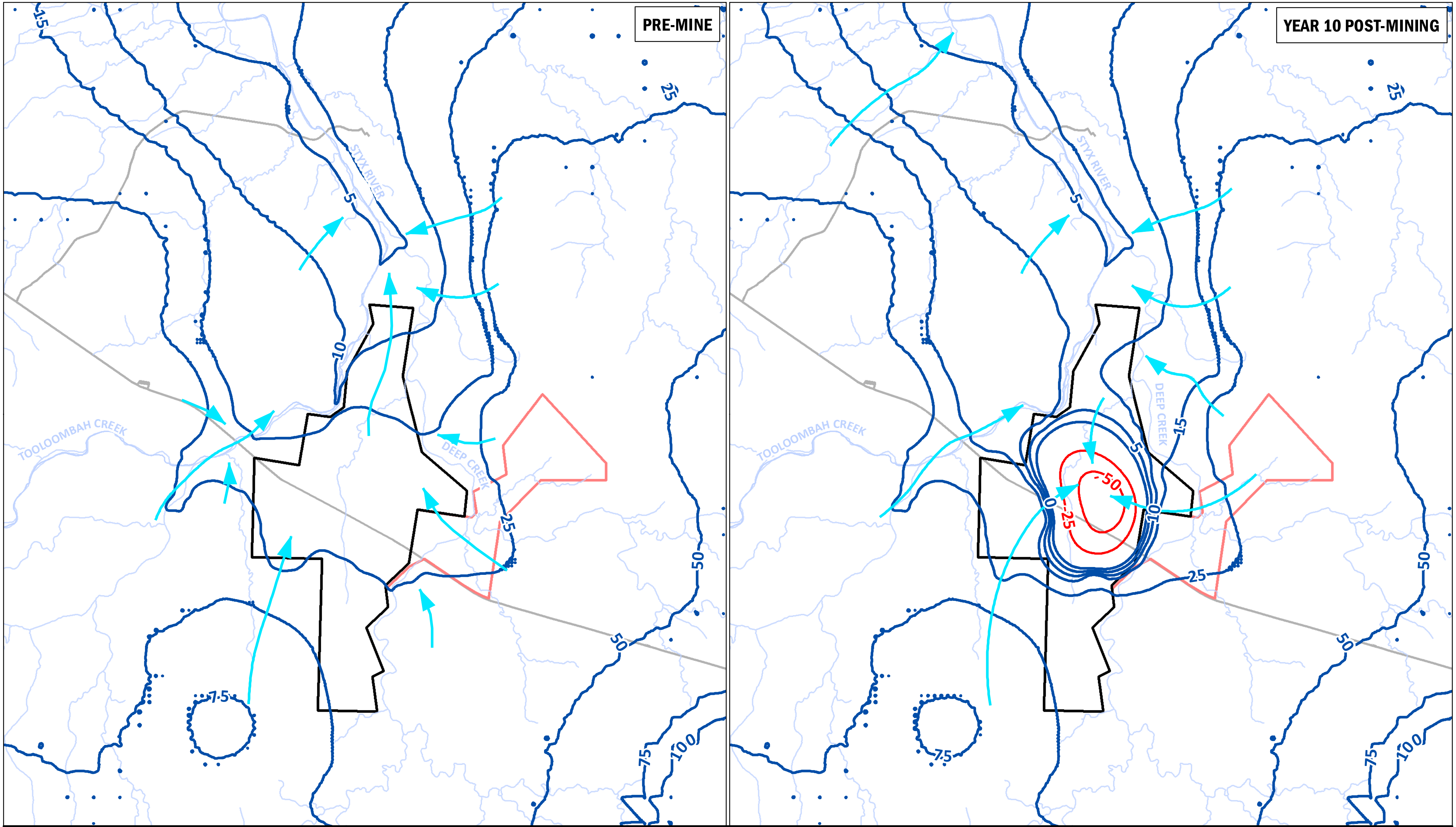
Figure 3-21

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



Legend

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

0 2 4 km

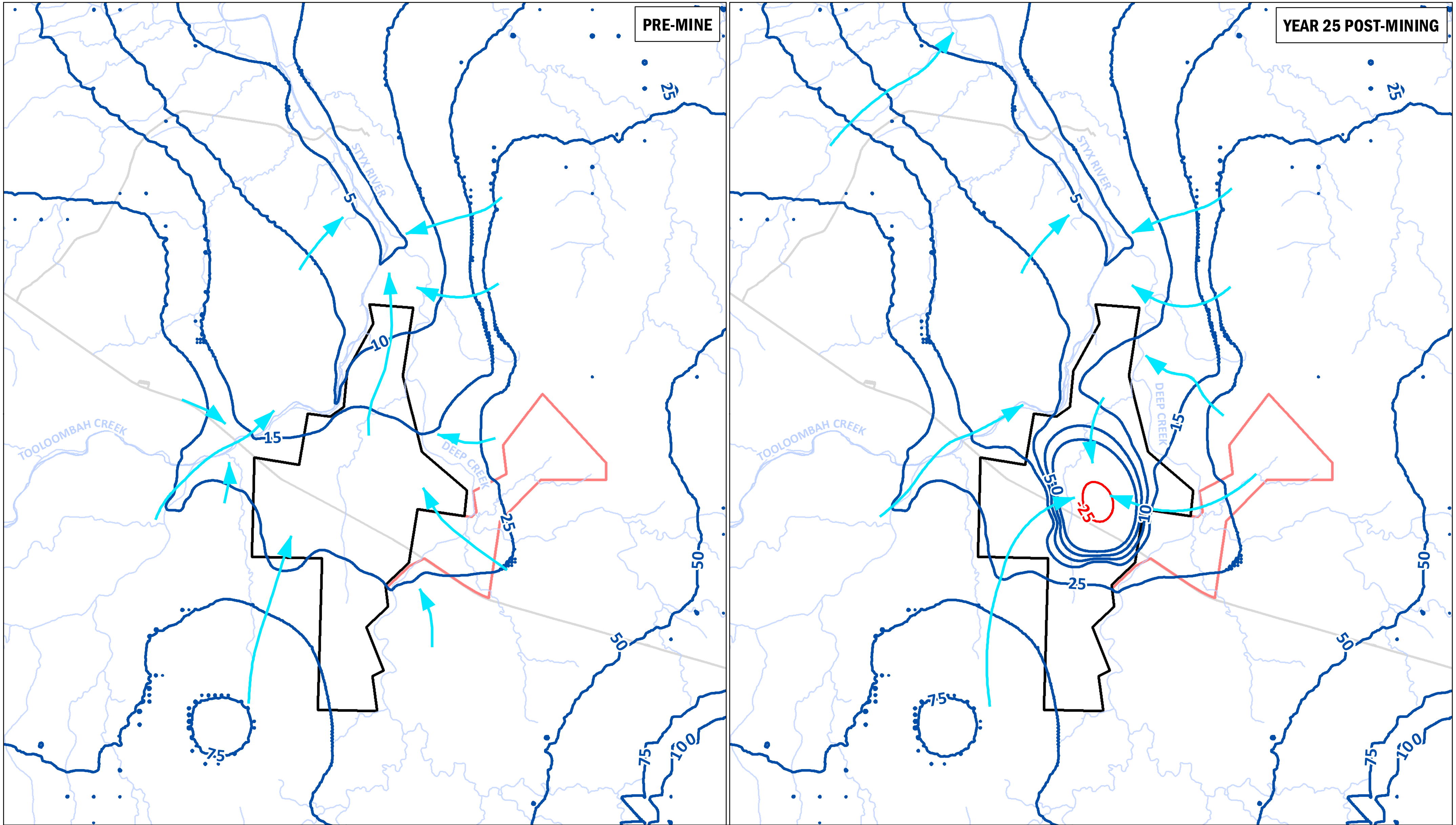
Scale @ A4 1:125,000
Date: 20/12/18
Drawn: Gayle B.

Figure 3-22
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.

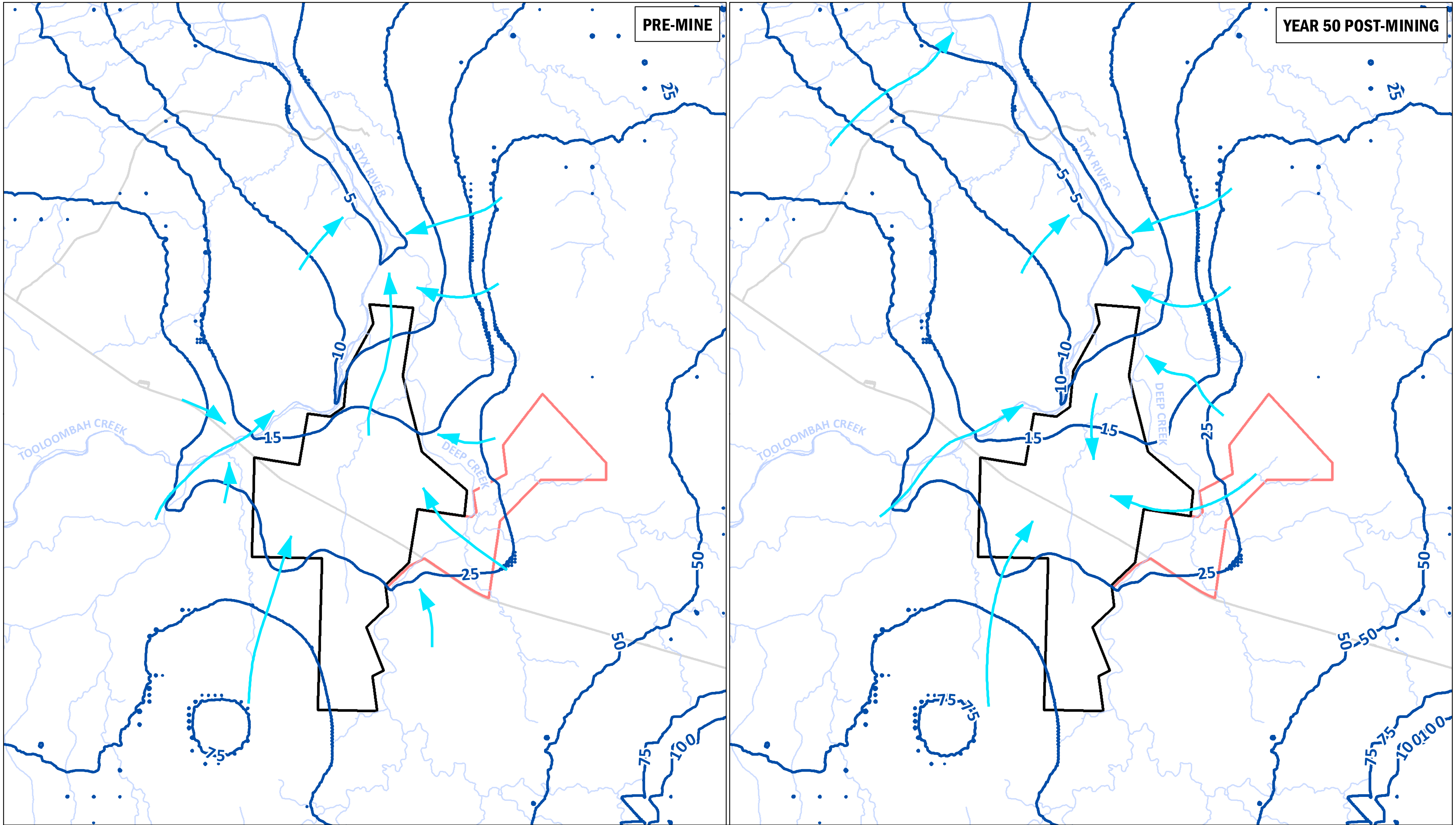
Legend

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

Figure 3-23
Predicted water table elevation contours – pre-mine and year 25 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__25yrs post-mining.mxd 12/20/2018



Legend

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

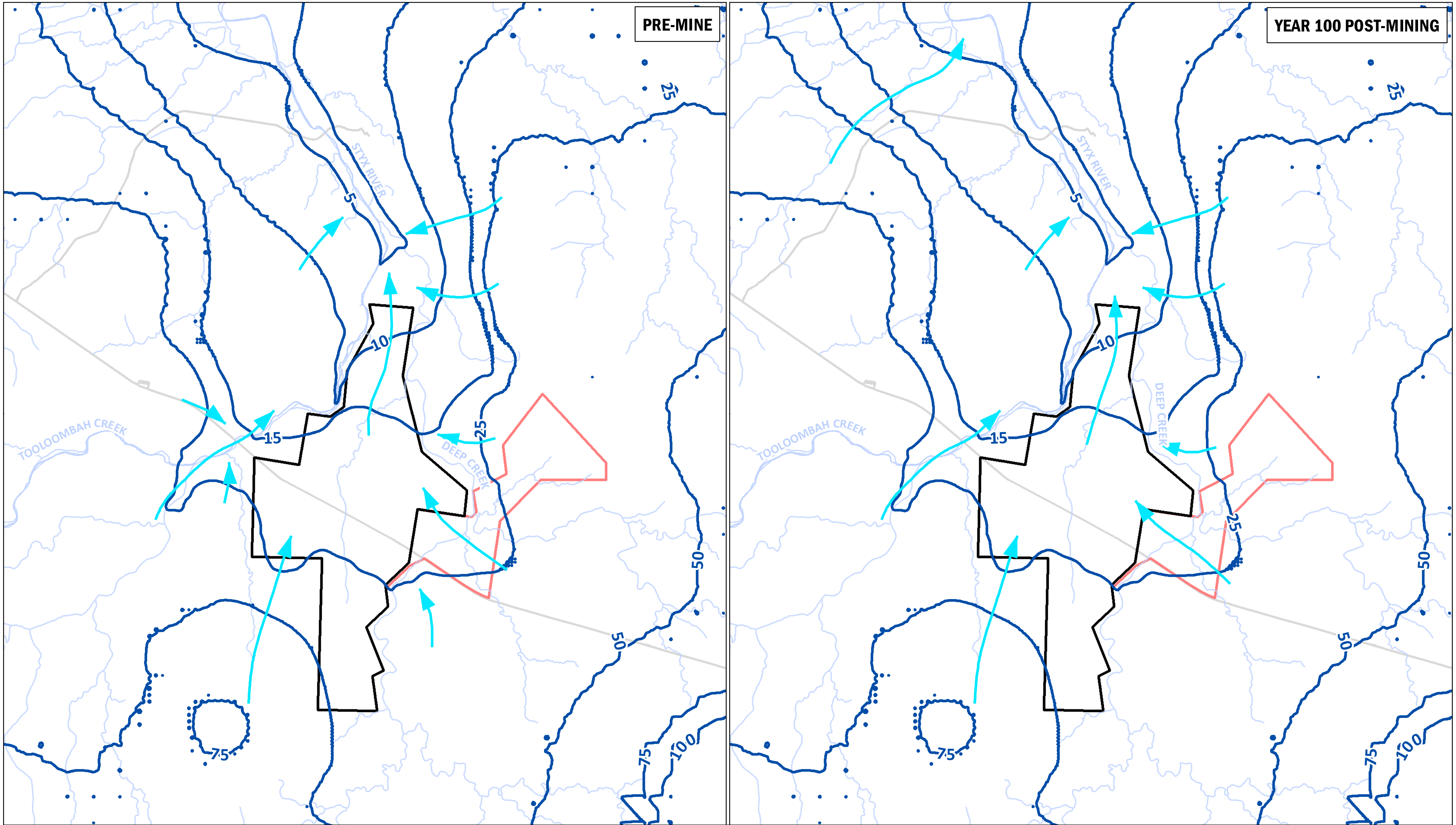
0 2 4 km

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

Figure 3-24
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 3-25
Predicted water table elevation contours – pre-mine and year 100 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__100yrs post-mining.mxd 12/20/2018

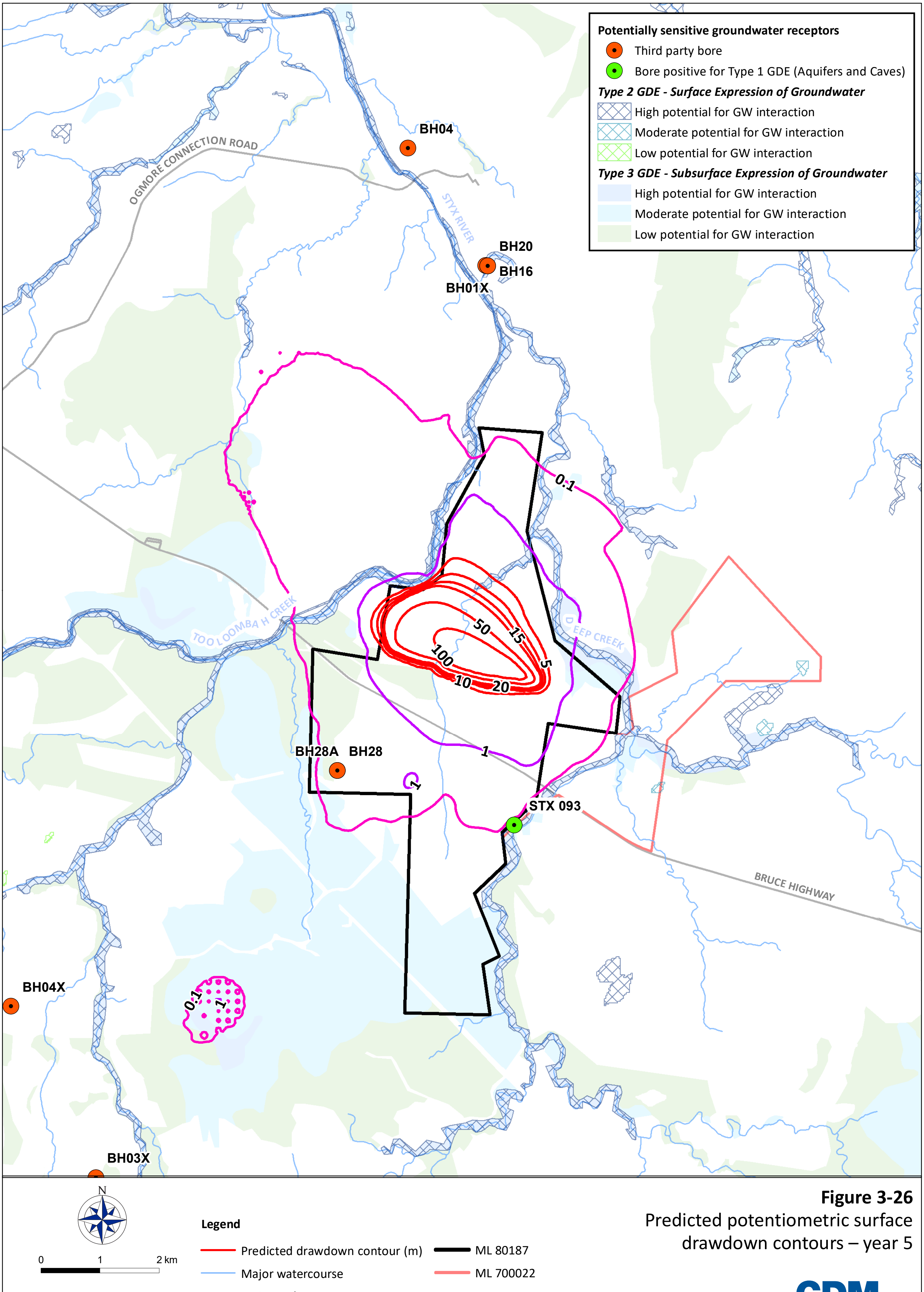


Figure 3-26
Predicted potentiometric surface drawdown contours – year 5

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

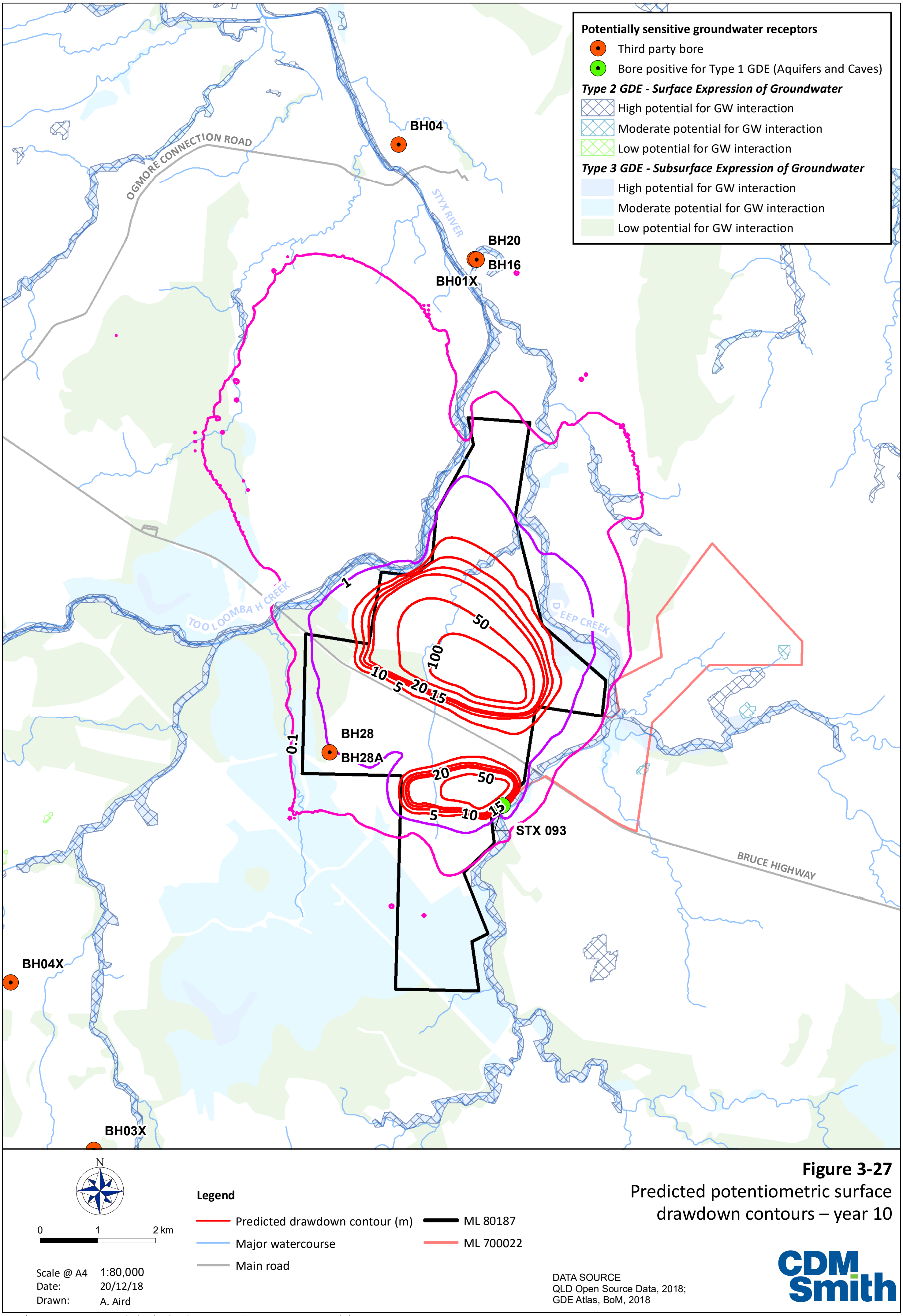


Figure 3-27
Predicted potentiometric surface drawdown contours – year 10

CDM Smith

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 Pot surface_all HSUs__LOM yr 10.mxd 20/12/2018

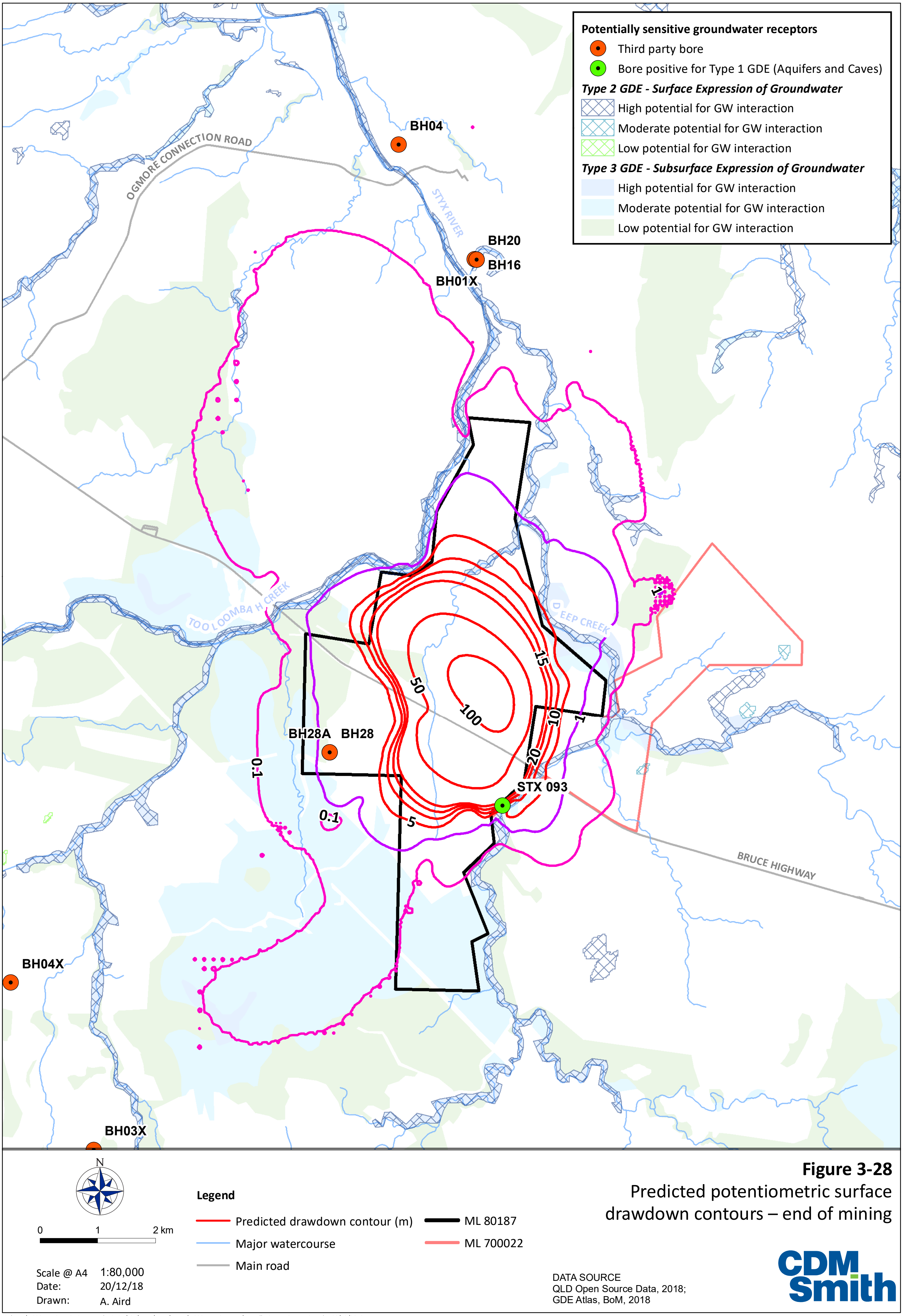


Figure 3-28
Predicted potentiometric surface drawdown contours – end of mining

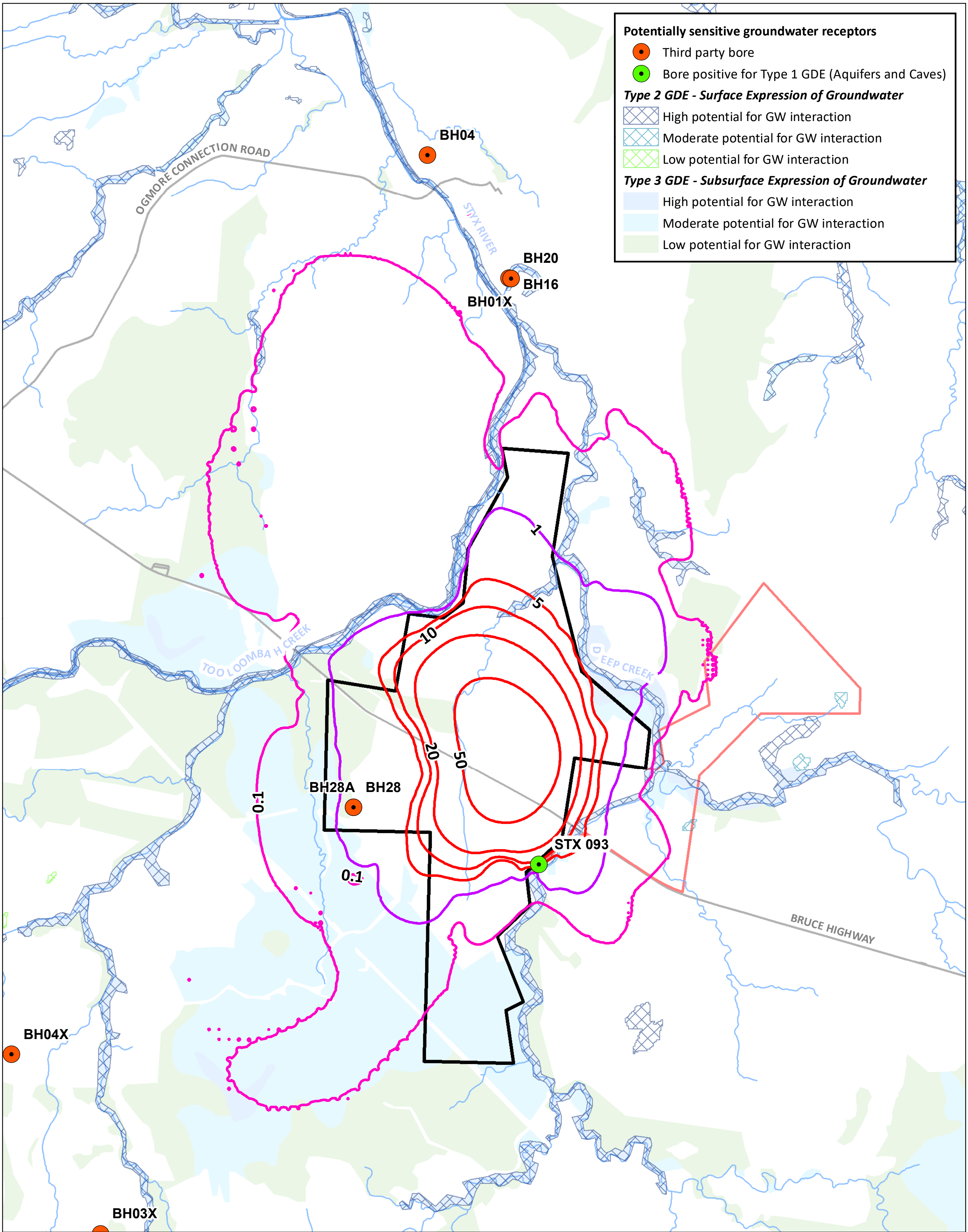


Figure 3-29
Predicted potentiometric surface drawdown contours – year 10 post-mining

Legend

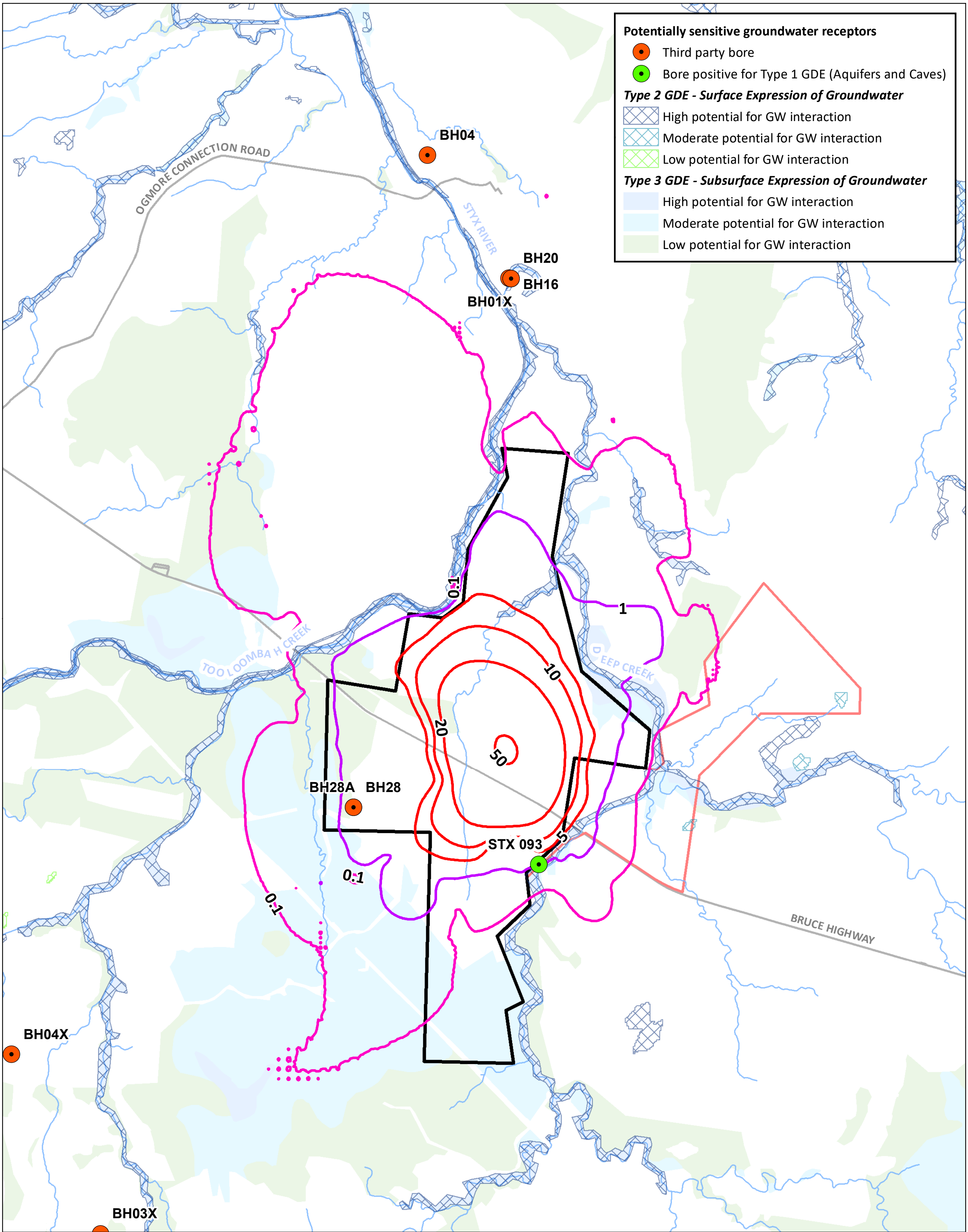
- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

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

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

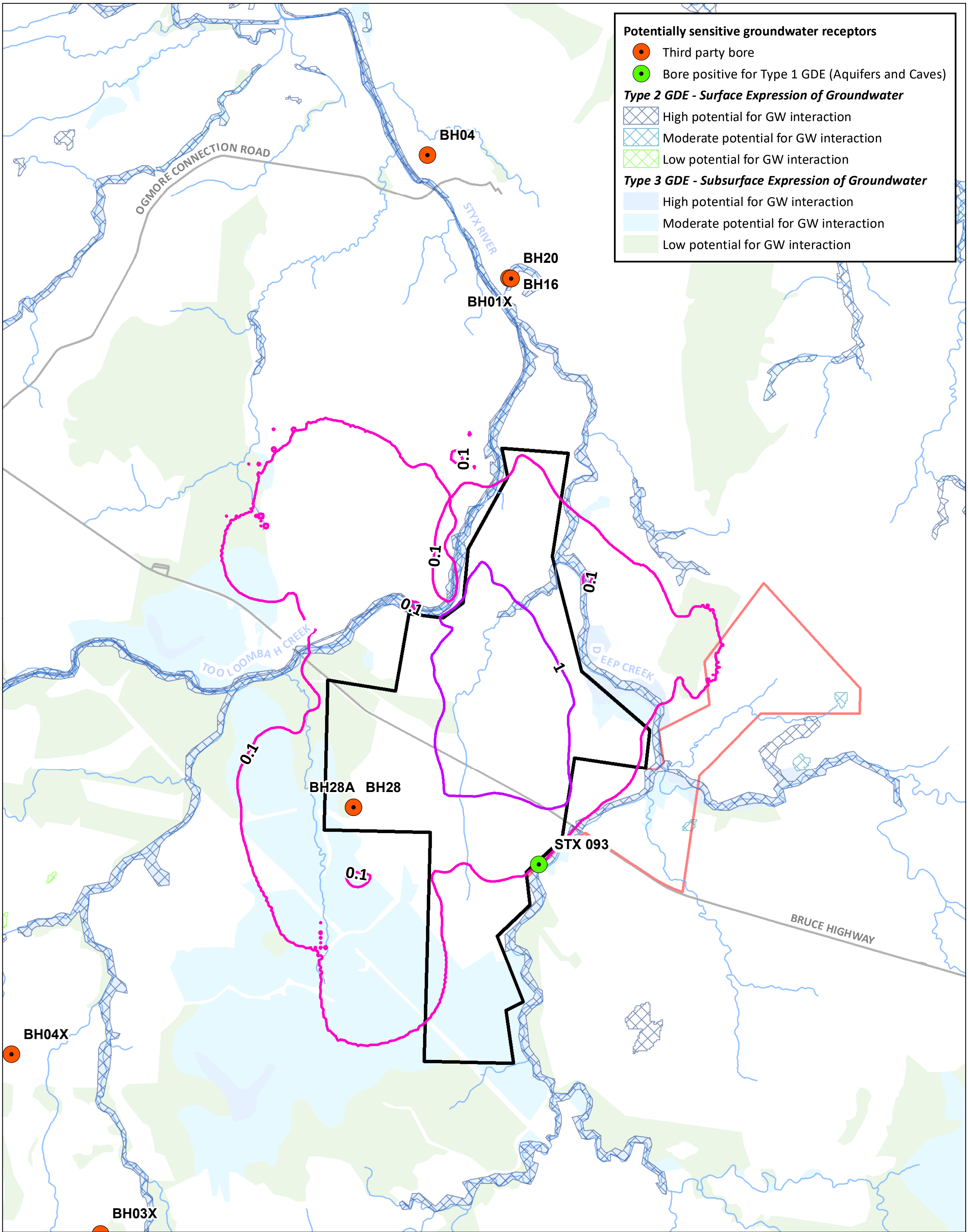
- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 3-30
Predicted potentiometric surface drawdown contours – 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

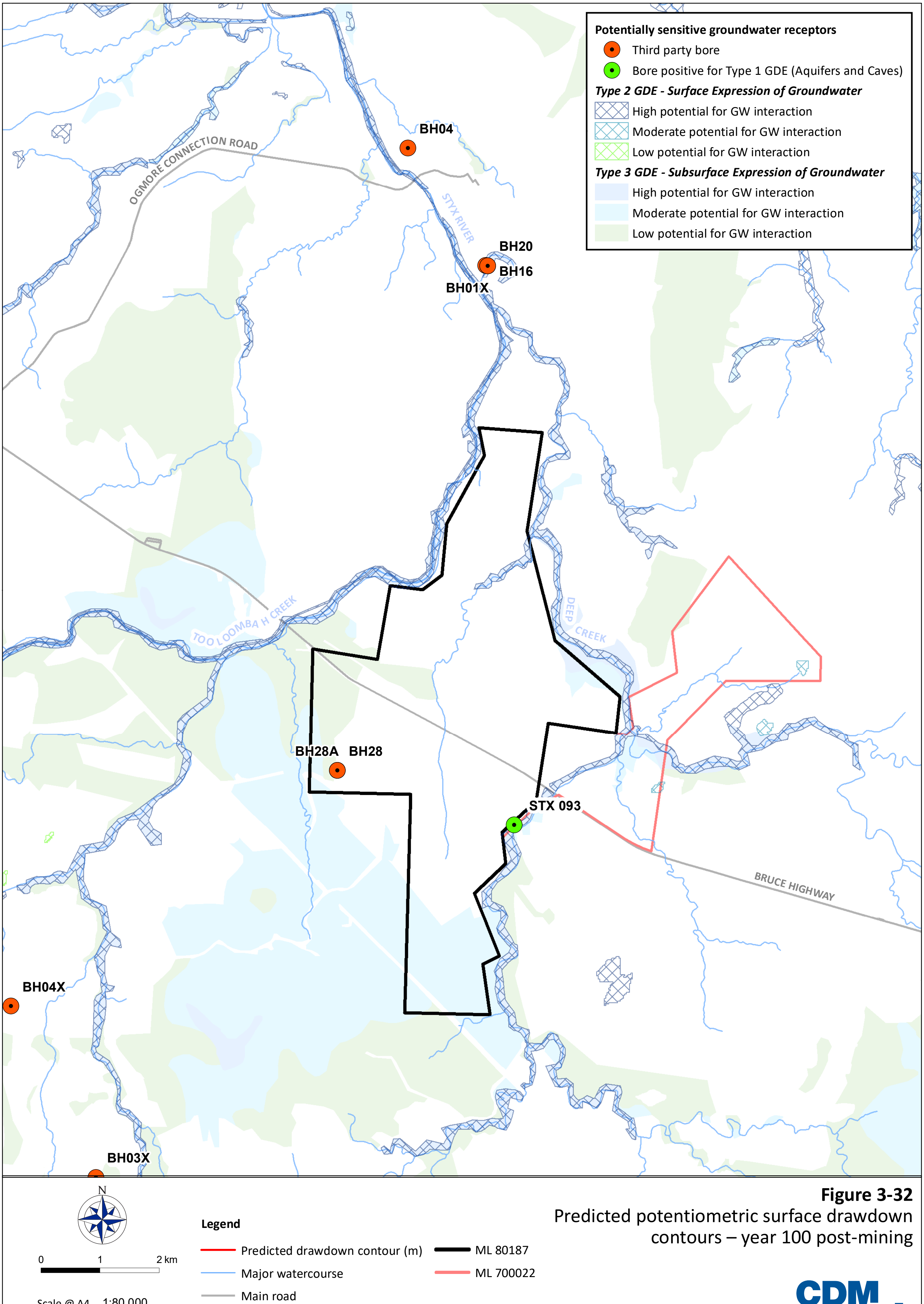
- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 3-31
Predicted potentiometric surface drawdown contours – 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



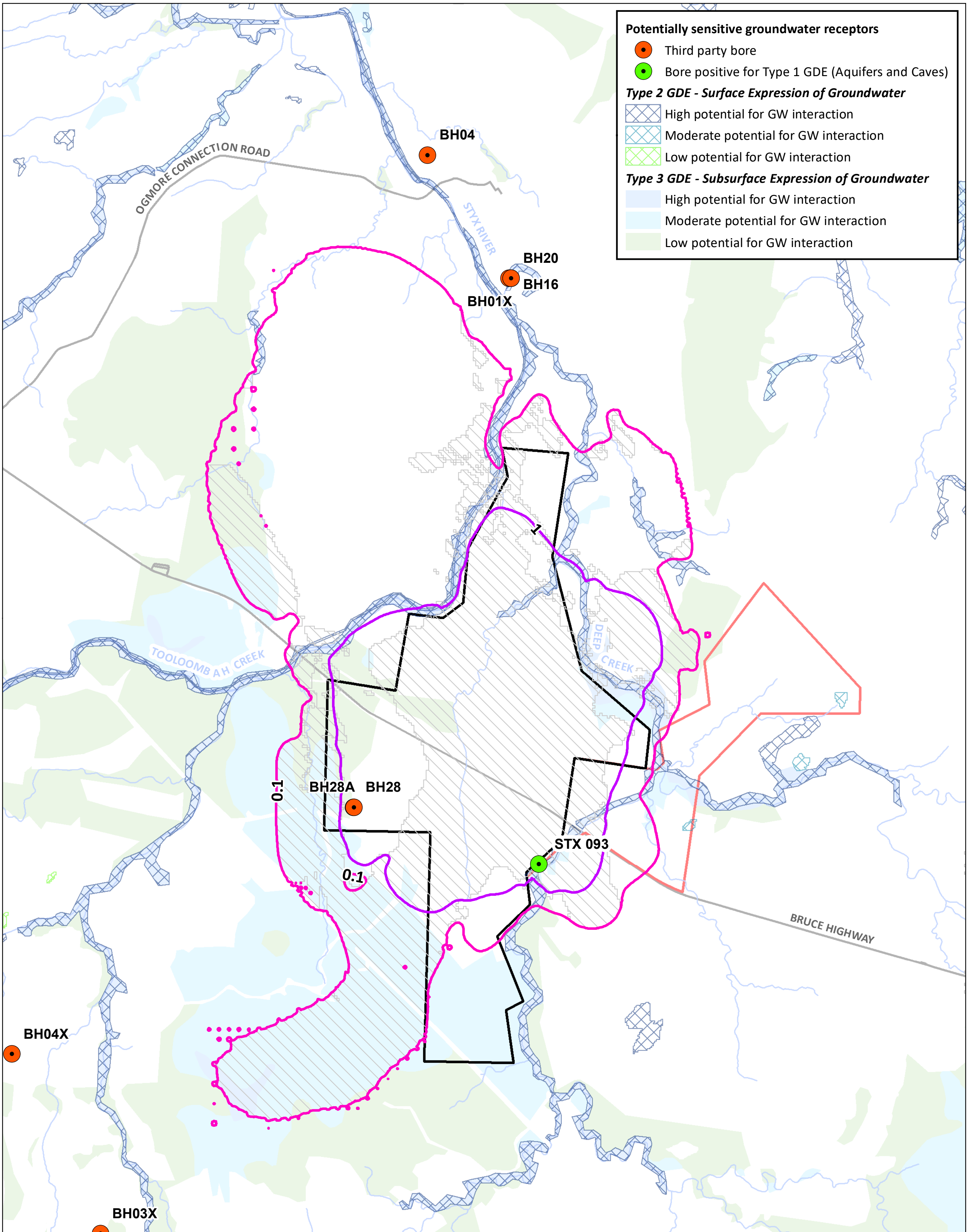
Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Figure 3-32
Predicted potentiometric surface drawdown contours – year 100 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__100yrs post-mining.mxd 20/12/2018



Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Legend

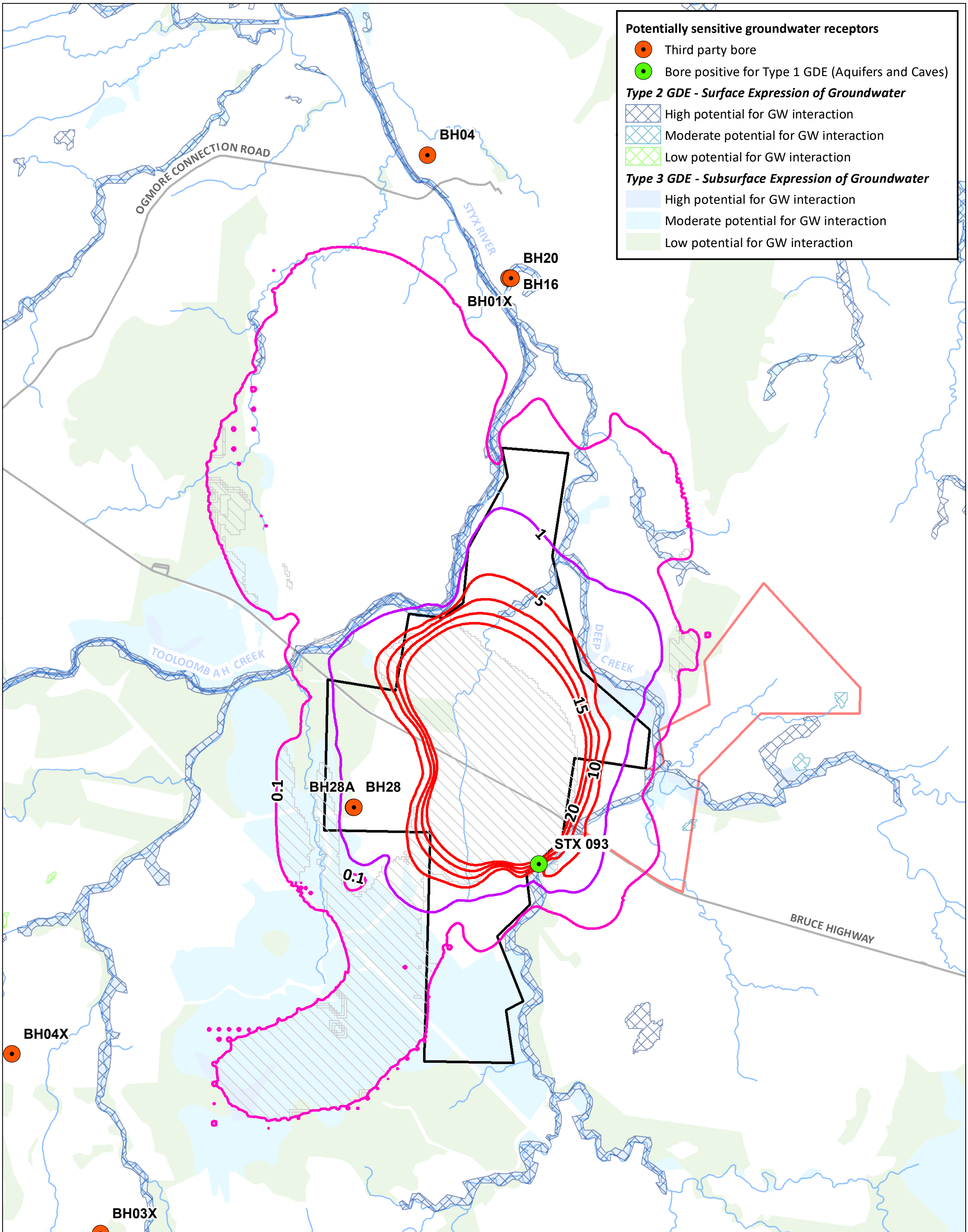
- Predicted drawdown contour (m)
- Major watercourse
- Main road
- Model dry cell
- ML 80187
- ML 700022

Figure 3-33
Predicted Layer 2 drawdown contours – 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 DDN_Lay2 EOM-yr18.mxd 20/12/2018



Legend

Predicted drawdown contour (m)
Major watercourse
Main road
Model dry cell
ML 80187
ML 700022

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

Figure 3-34
Predicted Layer 3 drawdown contours – 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 DDN_Lay3 EOM-yr18.mxd 20/12/2018

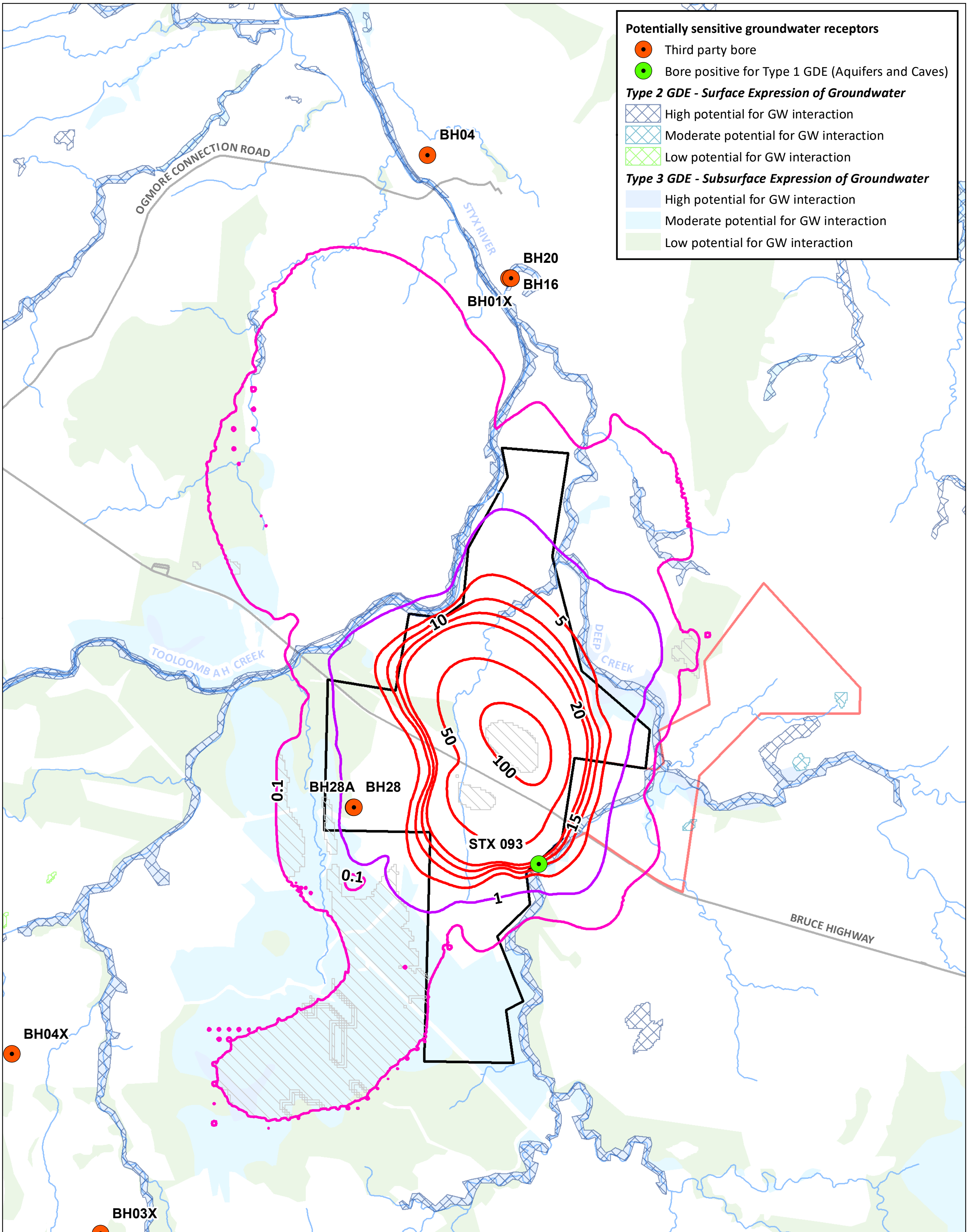


Figure 3-35
Predicted Layer 4 drawdown contours – at end of mining

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
- Model dry cell
- 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 DDN_Lay4 EOM-yr18.mxd 20/12/2018

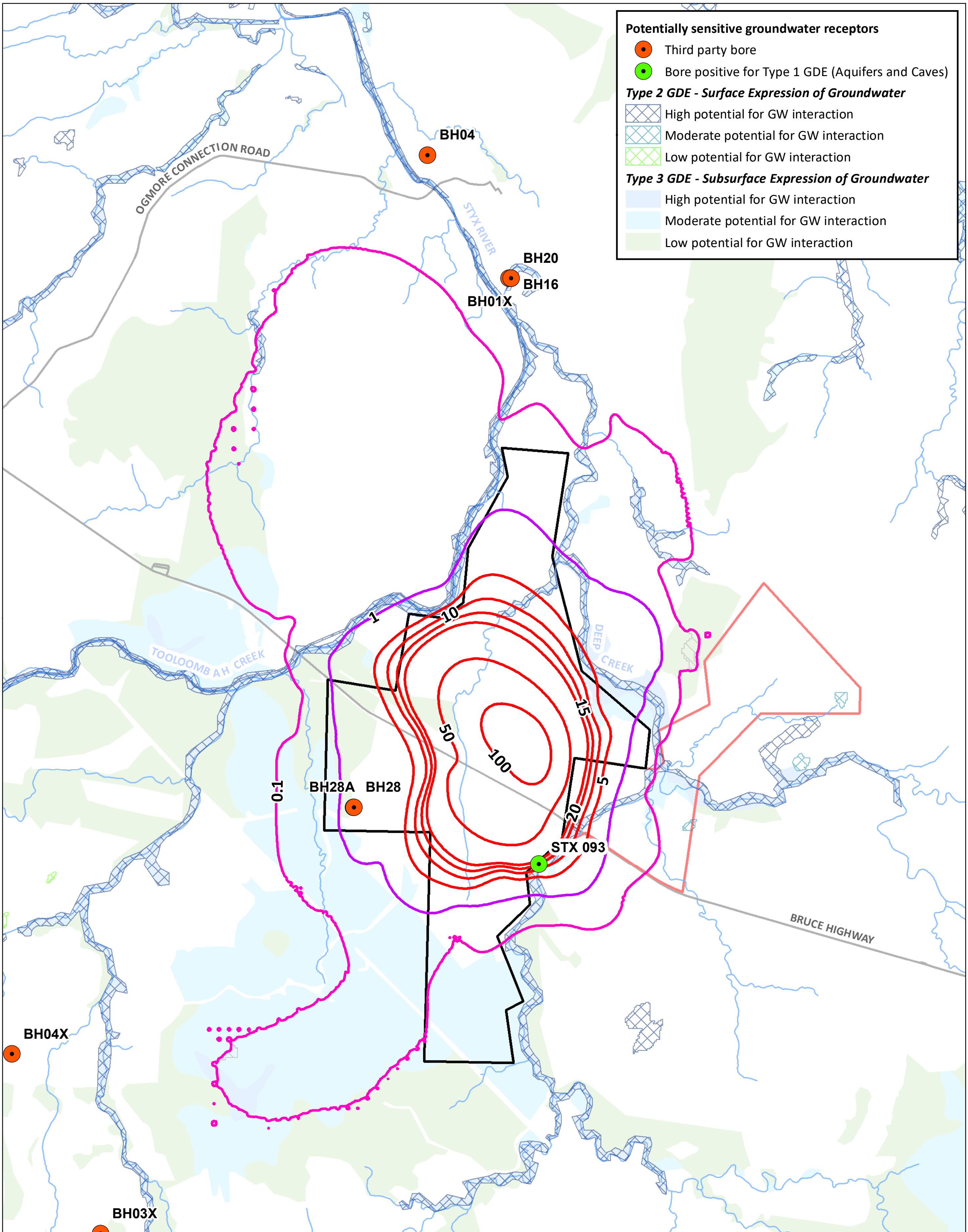


Figure 3-36
Predicted Layer 5 drawdown contours – at end of mining

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- Model dry cell
- 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

airda I:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DDN_Lay5 EOM-yr18.mxd 20/12/2018

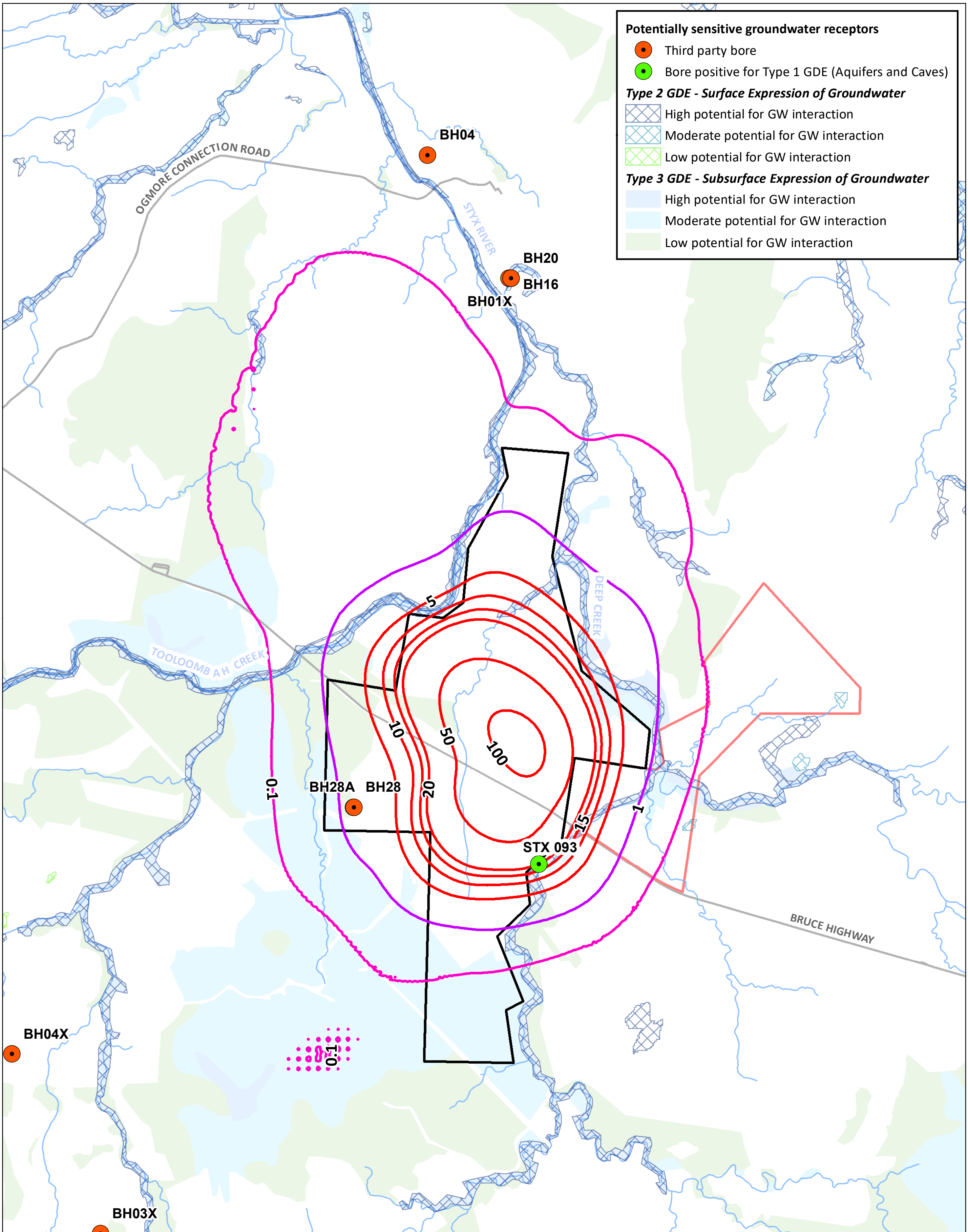


Figure 3-37

Predicted Layer 6 drawdown contours – at end of mining

N

0 1 2 km

Legend

Predicted drawdown contour (m)	ML 80187
Major watercourse	ML 700022
Main road	

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

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_Lay6 EOM-yr18.mxd 20/12/2018

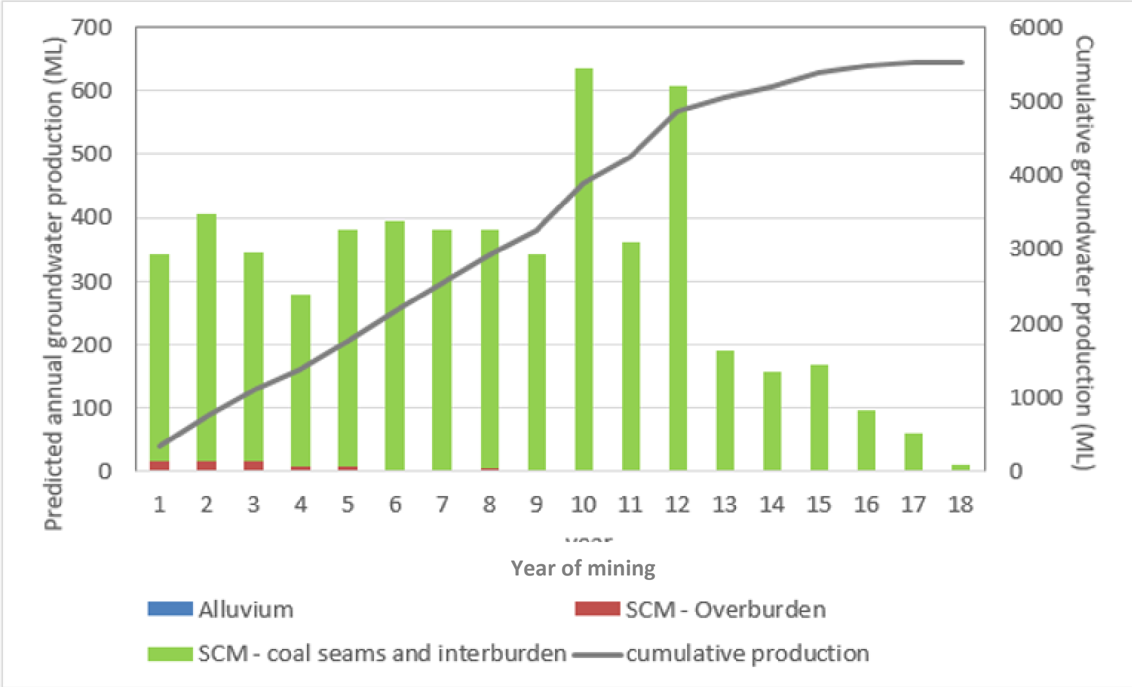


Figure 3-38 Predicted groundwater abstractions from mine (North and South Pits)

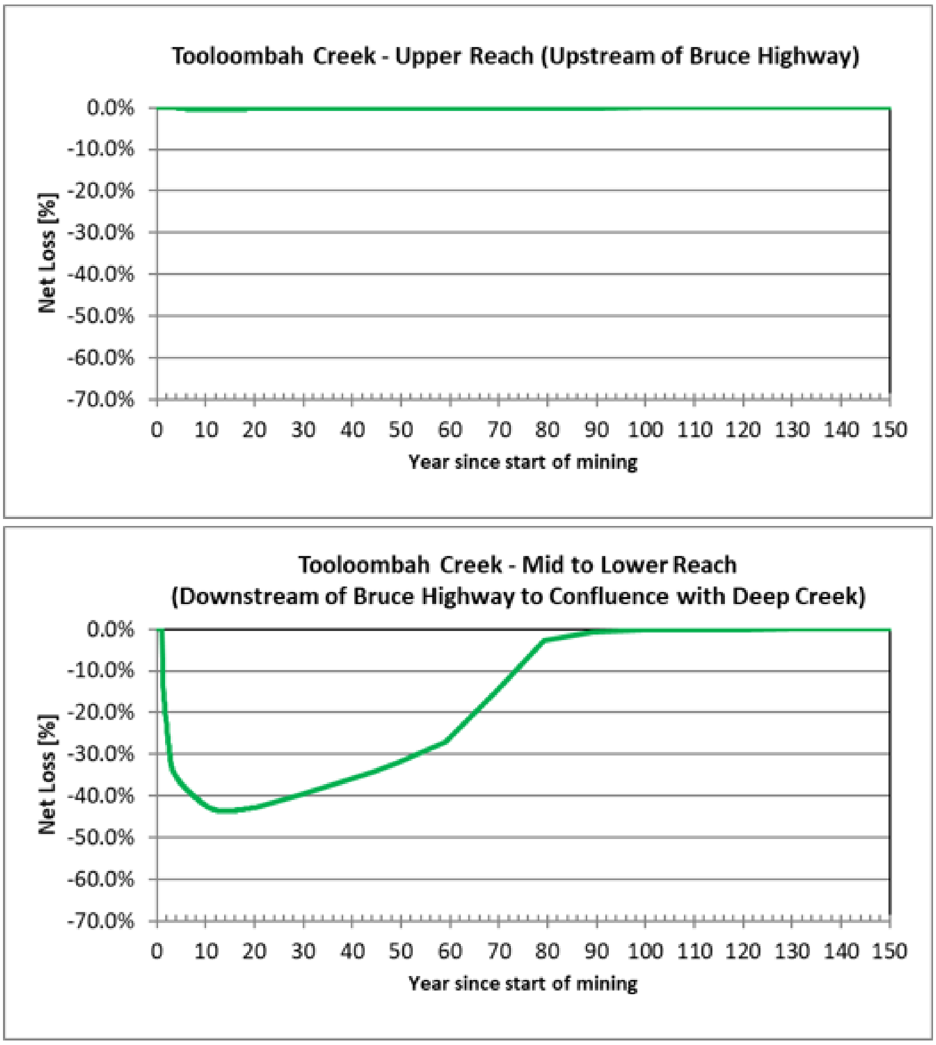


Figure 3-39 Predicted impact on baseflow and evapotranspiration (Tooloombah Creek)

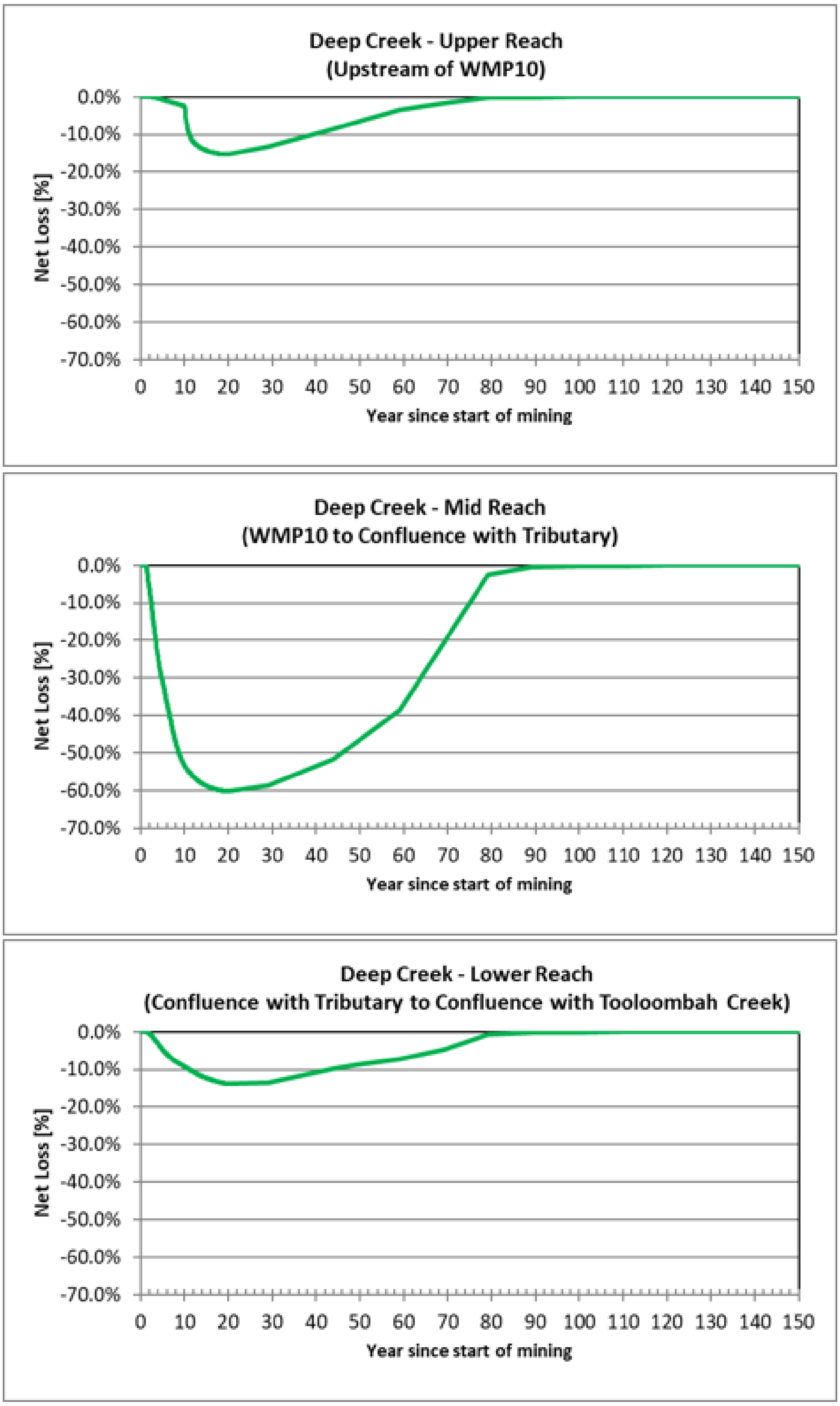
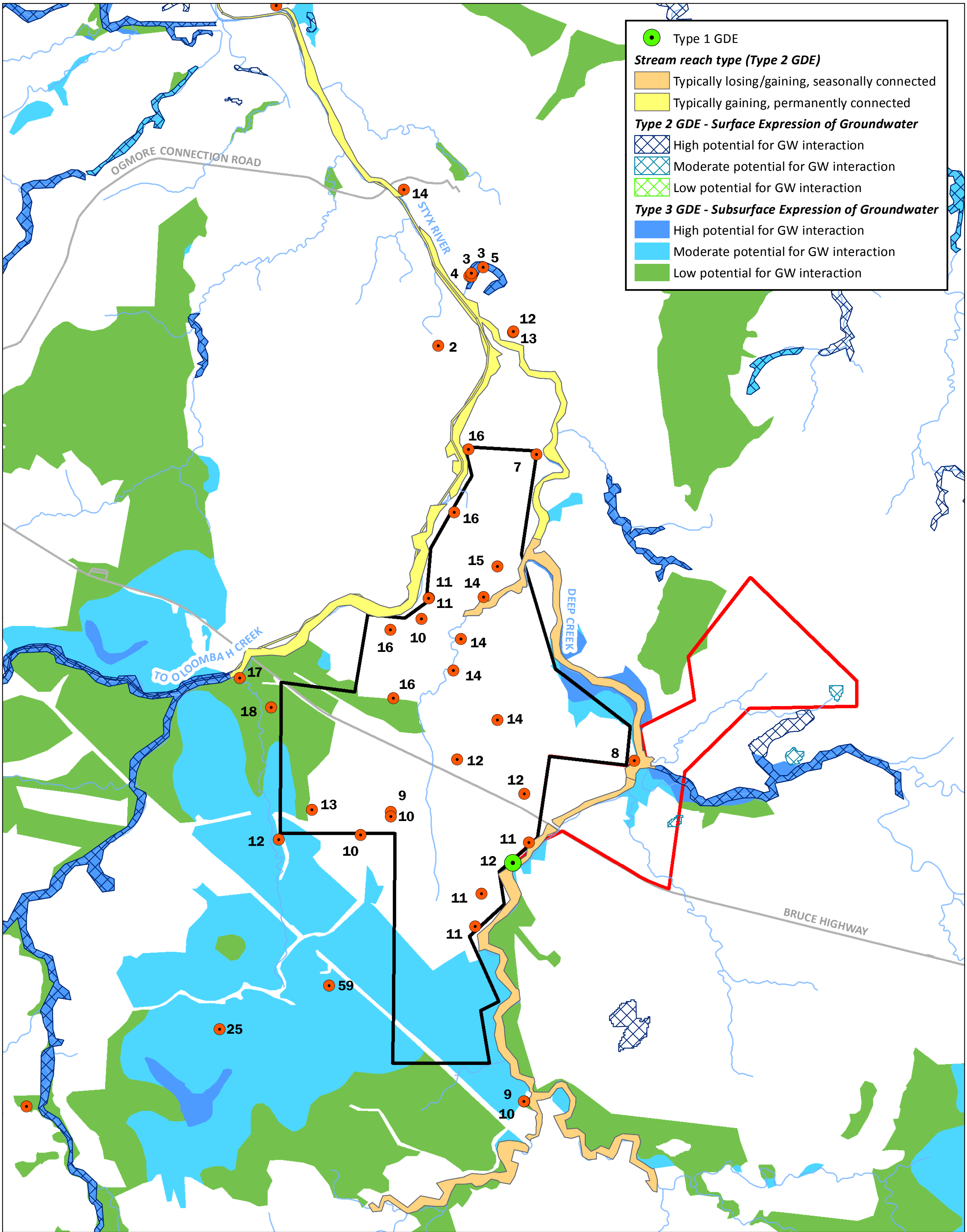


Figure 3-40 Predicted impact on baseflow and evapotranspiration (Deep Creek)



N

0 1 2 km

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

Legend

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

Figure 3-41
Ground-thruthed GDEs

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

Figure 3-42 Hydrograph showing predicted transient water table response to mine water affecting activities at STX 093 (stygofauna bore, Type 1 GDE)

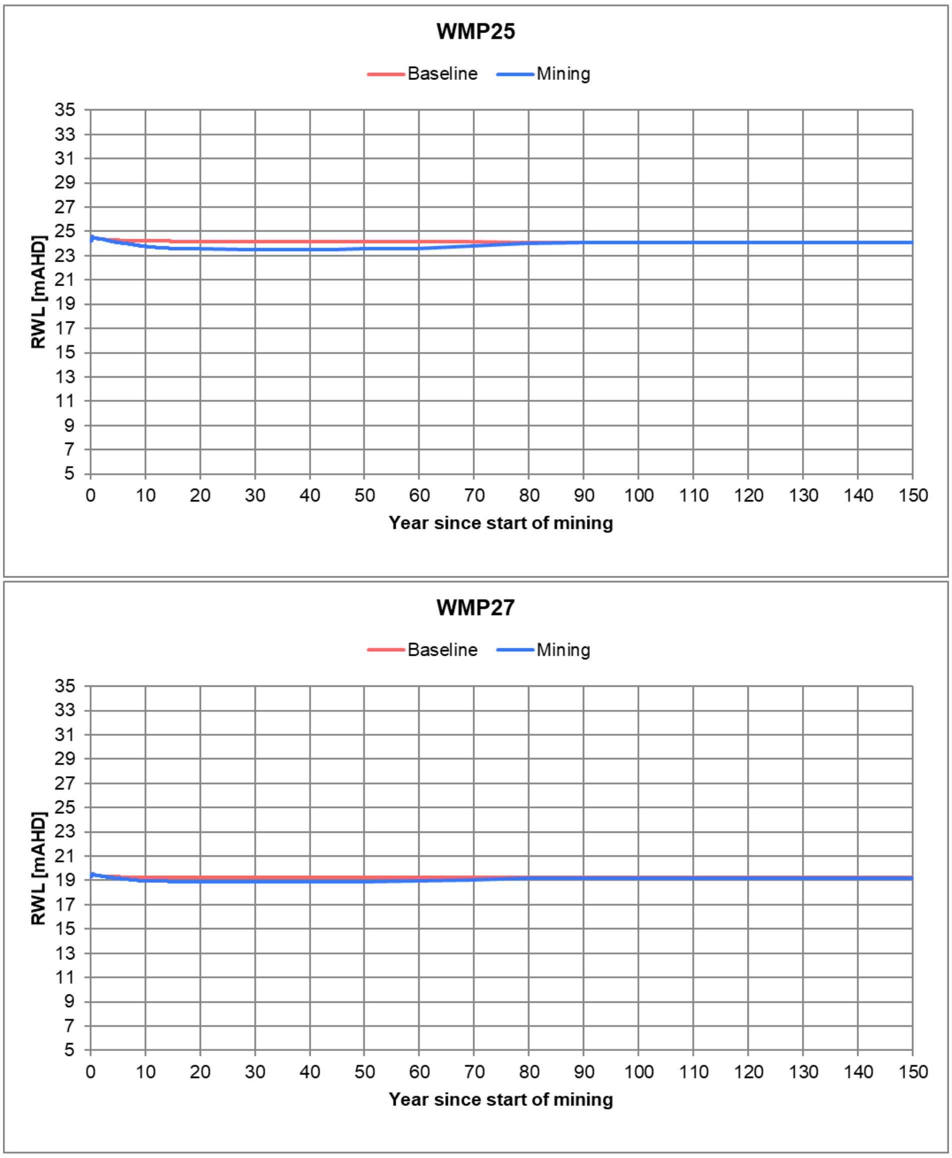
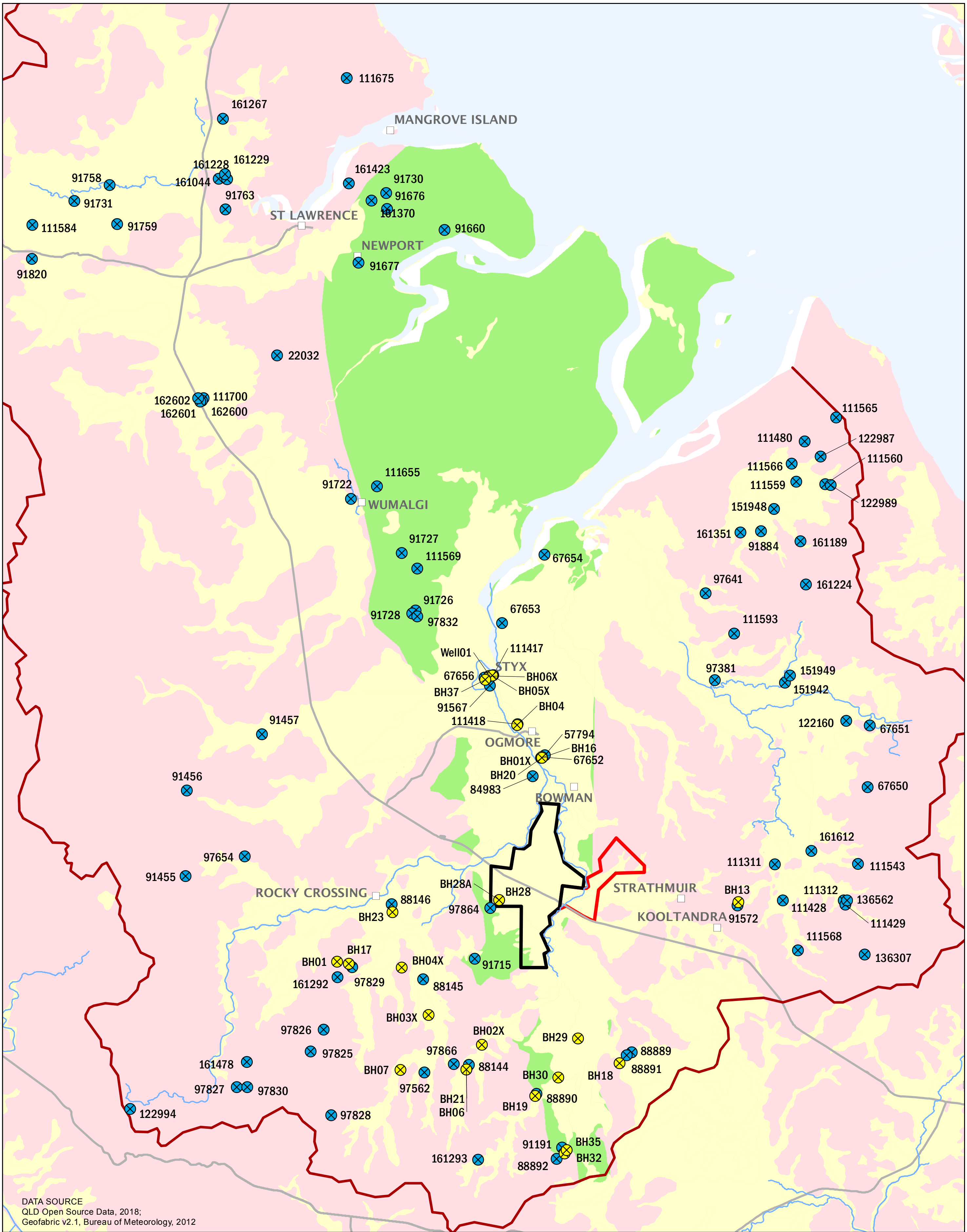


Figure 3-43 Hydrograph showing predicted transient water table response to mine water affecting activities at potential Type 3 GDEs on western ML 80187 boundary (WMP25 and WMP27)



N

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

0 4 8 km

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

Figure 3-44
Identified third party bores

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 Existing third party bores R1.mxd 12/13/2018

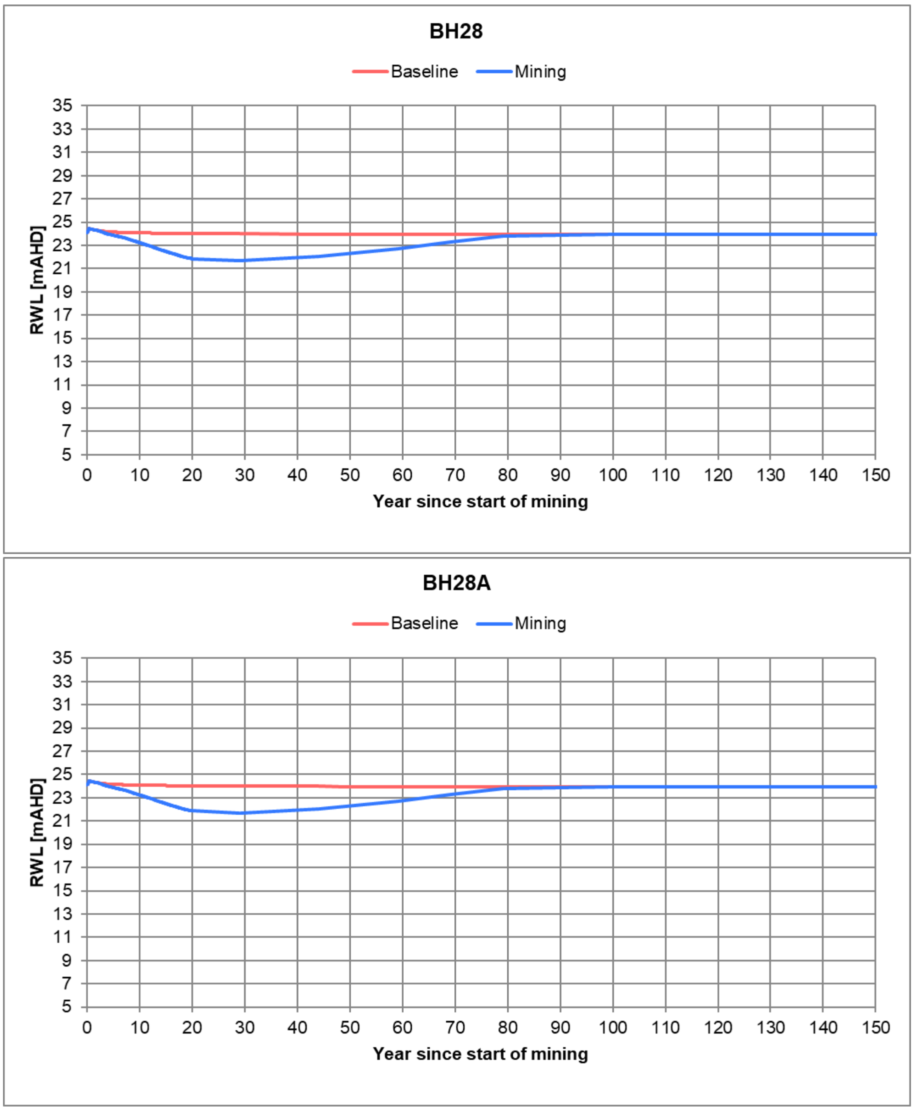
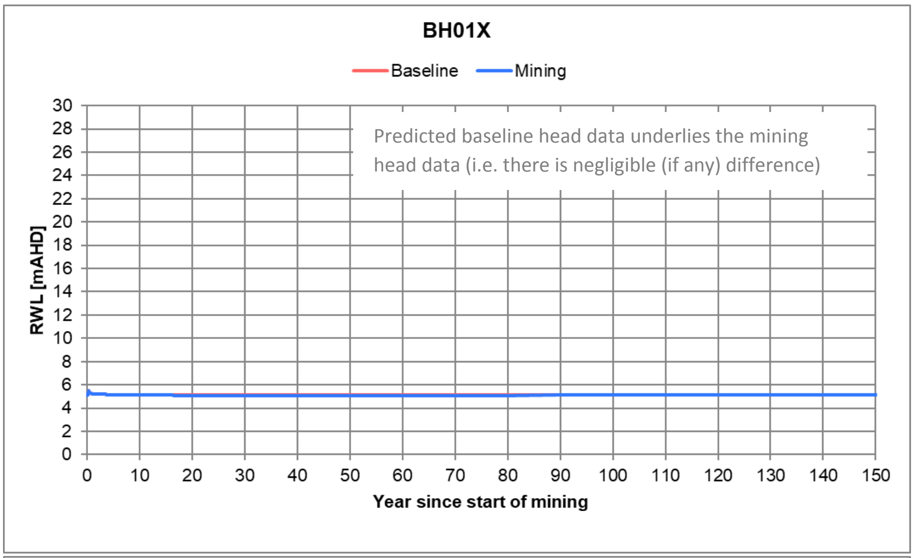
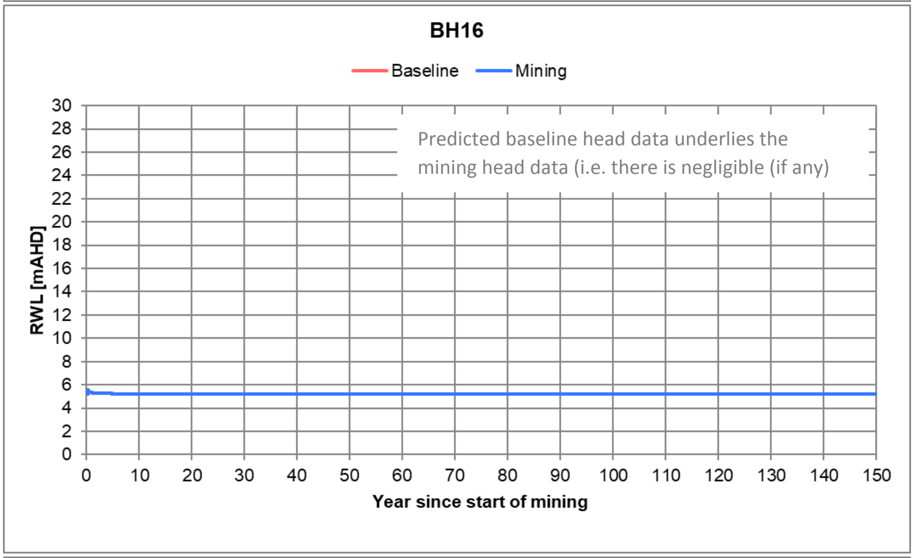


Figure 3-45 Hydrograph showing predicted transient water table response to mine water affecting activities at BH28A and BH28 (third party water user bores)





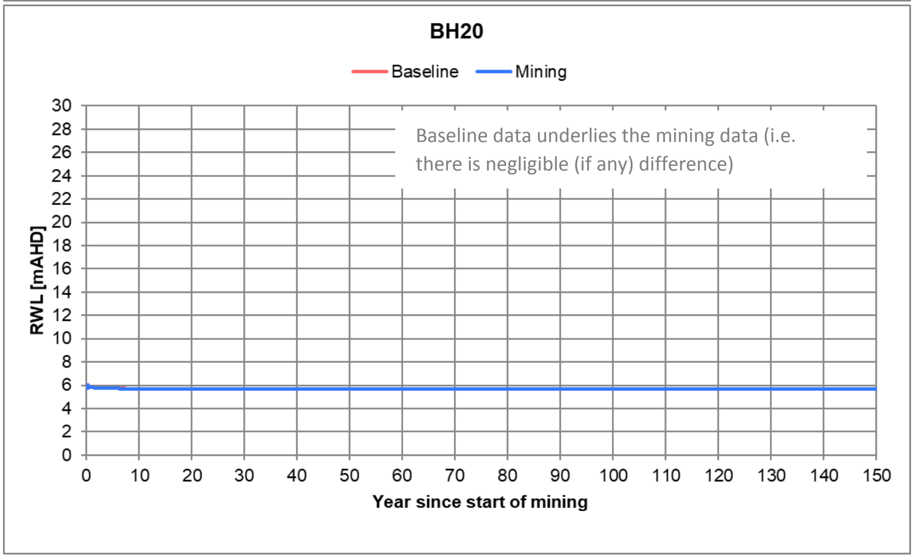


Figure 3-46 Hydrograph showing predicted transient water table response to mine water affecting activities at BH01X, BH16 and BH20 (third party water user bores)

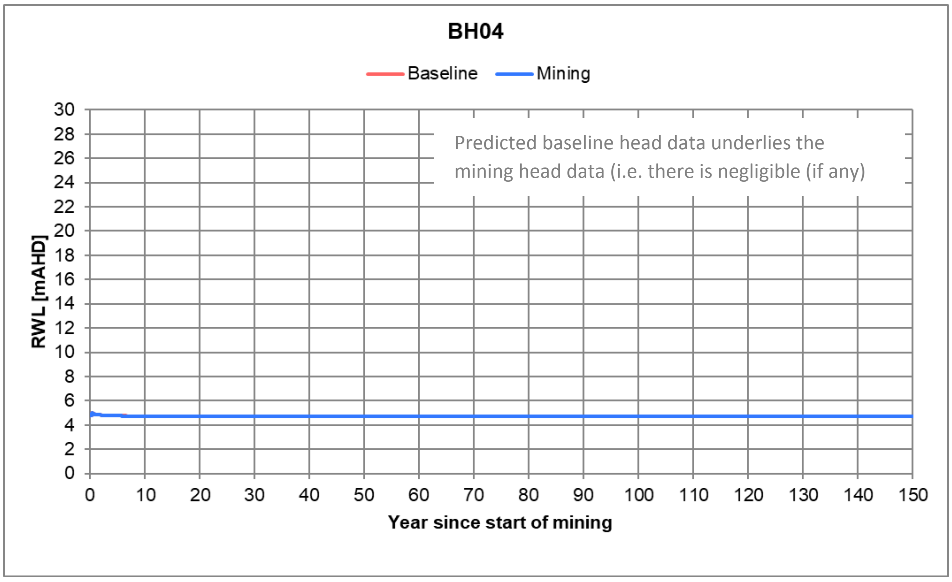


Figure 3-47 Hydrograph showing predicted transient water table response to mine water affecting activities at BH04 (third party water user bore)

3.6.2.4 Abstraction as mitigation measure to sustain permanent pools

The model was used to undertake a preliminary assessment of the feasibility of implementing abstraction bores to provide water to the permanent pools of Tooloombah and Deep Creeks during dry seasons, to mitigate the impact of drawdown associated with mining. The model tested six abstraction bores in the Styx Coal Measure interburden unit by setting a drain cells at the base of the interburden layer, active from the start of mining to 20 years post mining operation covering a period of 38 years. While the water demand for supplementing pools will likely only be required during the dry season, the scenario assumed continuous abstraction, providing an estimate of long-term sustainable yield. The average abstraction rate per bore for the 38 years of dewatering period was 0.7L/s with a minimum rate of 0.55L/s after 38 years (Figure 3-48). The drawdown resulting at the end of the mining period is illustrated on Figure 3-49 which shows only minor differences to the basecase predicted drawdown (Figure 3-28). This preliminary assessment suggests that the Styx Coal Measures may be a viable source of water for mitigating the impact to pools due to drawdown, although further detailed assessment would be required to account for the seasonal water demand at each pool and drawdown at the pumping bore, and further work required to reduce uncertainty associated with model predicted rates, integrate flux targets in the model calibration to better constrain the flux estimates and reduce uncertainty.

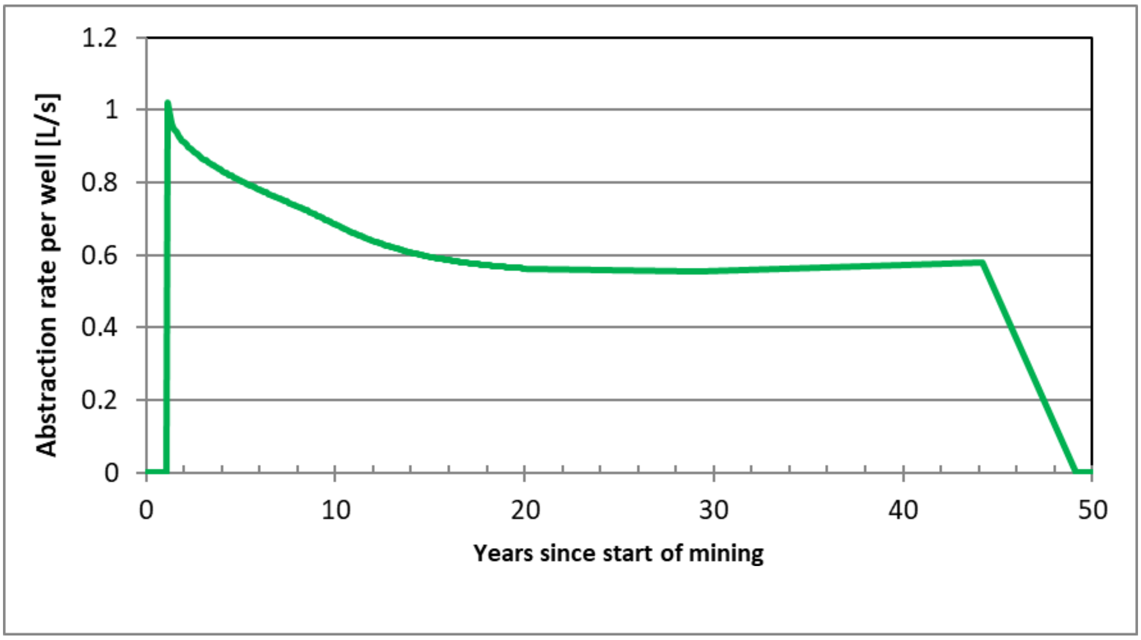


Figure 3-48 Predicted available abstraction rate for mitigation bore

3.6.2.5 Acid Sulfate Soil Interaction

Figure 3-50 presents a map showing the spatial distribution of ASS potential overlain with maximum model predicted drawdown contours. The figure shows there is low to extremely low probability of ASS in the Project area. Also plotted on Figure 3-50 are mineral exploration holes where predominantly Non-acid Forming (NAF) materials (less than 10% Potentially Acid Forming (PAF) materials) have been identified, which is consistent with the mapping undertaken by CSIRO (2011). Note that the predominantly NAF materials are logged as occurring more than 15 m below ground surface in the Styx Coal Measures.

The hydrographs presented on Figure 3-50 show:

- Outside the ML (one location), PAF materials occur more than 40 m below the water table at all times during and following mining.
- The full drawdown intersection at one location (STX145C, within Open Cut 2) might expose some material having a low probability of PAF material, but this material will be mined.
- Some exposure of low probability PAF material may occur very close to the northern limit of Open Cut 2 pit (STX136C) due to drawdown.

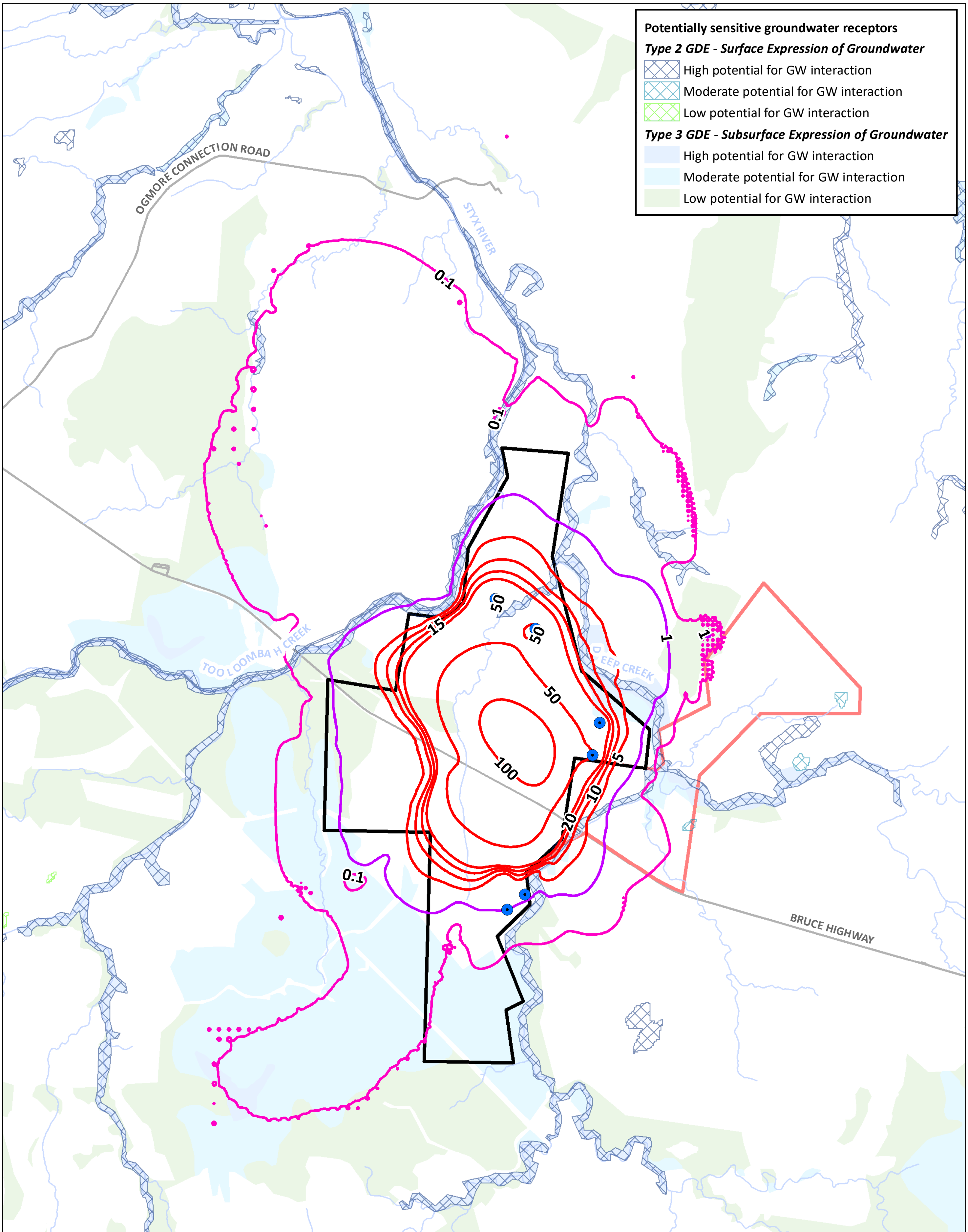
3.6.2.6 Groundwater system drawdown response in cross-section

Figure 3-51 through Figure 3-53 present a west-east aligned cross-section through ML 801887 showing the model predicted pre-mine, year 12 and at end of mining, potentiometric surfaces. Figure 3-54 to Figure 3-56 present the same information for a south-north aligned cross-section through ML 801887. The cross-sections and predicted potentiometric surfaces show:

- The pre-mine potentiometric surfaces for each HSU are essentially the same, with the potential for slightly higher heads in the Styx Coal Measures where they subcrop or outcrop on the western side of the geological basin.
- During mining, with the exception of the alluvium (HSU1) and the overburden coal measures (HSU2) that become unsaturated around the mine pits
  - the lateral extent of the drawn-down potentiometric surfaces are similar, with the basement (HSU3) zone of influence being slightly larger (likely the result of a lower storage coefficient); and
  - the vertical depths differ by many 10s of metres toward the end of mining possibly the result of targeted dewatering and recovery occurring from bottom up.
- The basement is not dewatered during mining but is depressurised.

3.6.2.7 Seawater-Freshwater Interface Interaction

Figure 3-55 and Figure 3-56 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 years 12 and 18. 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.



N

0 1 2 km

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: Gayle B.

Legend

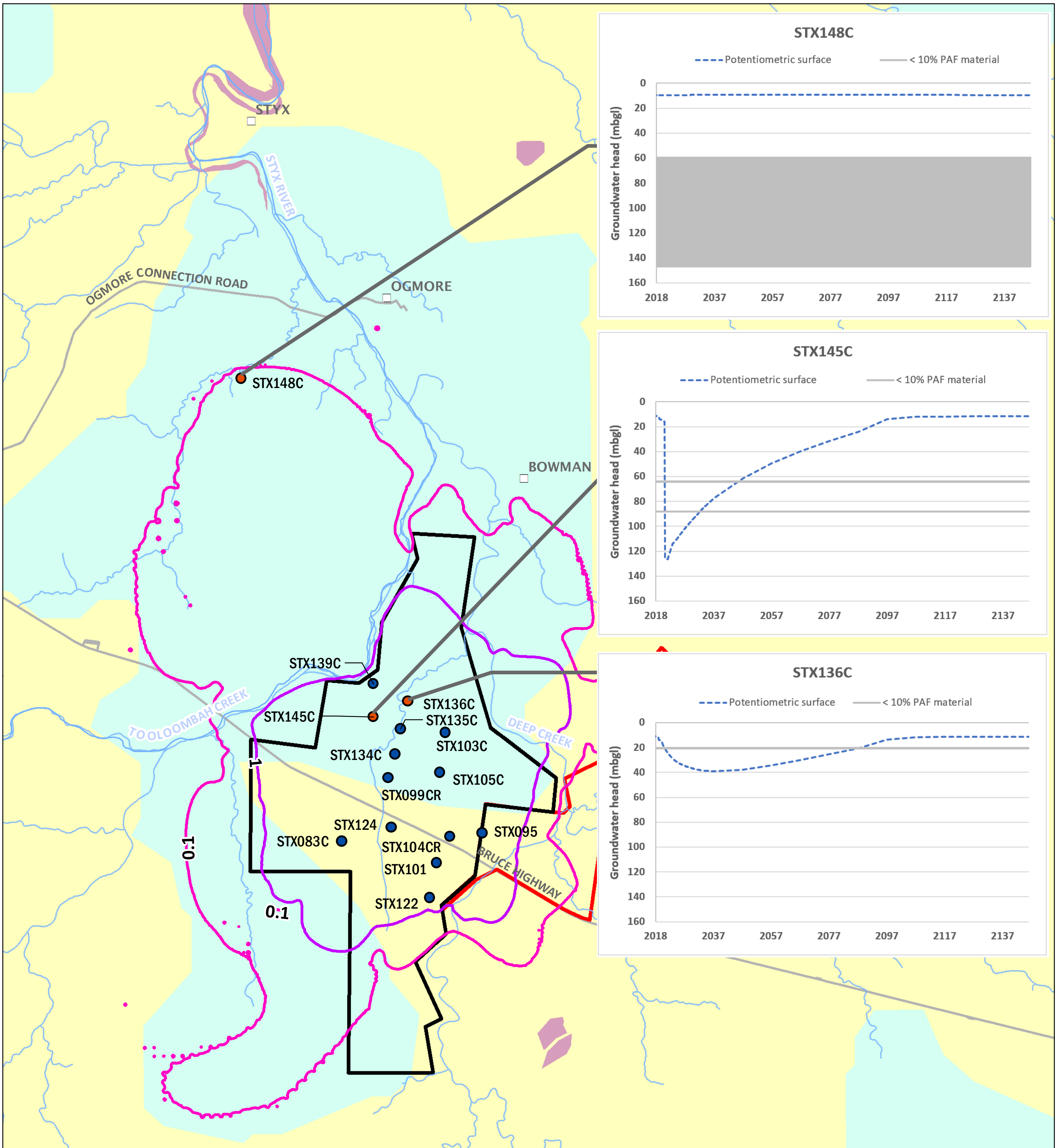
- Mitigation bore
- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

Figure 3-49
Drawdown at end of mining with 6 mitigation bores pumping at an average 0.17 L/s per bore

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 DDN_EOM_mitigation bores.mxd 20/12/2018



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

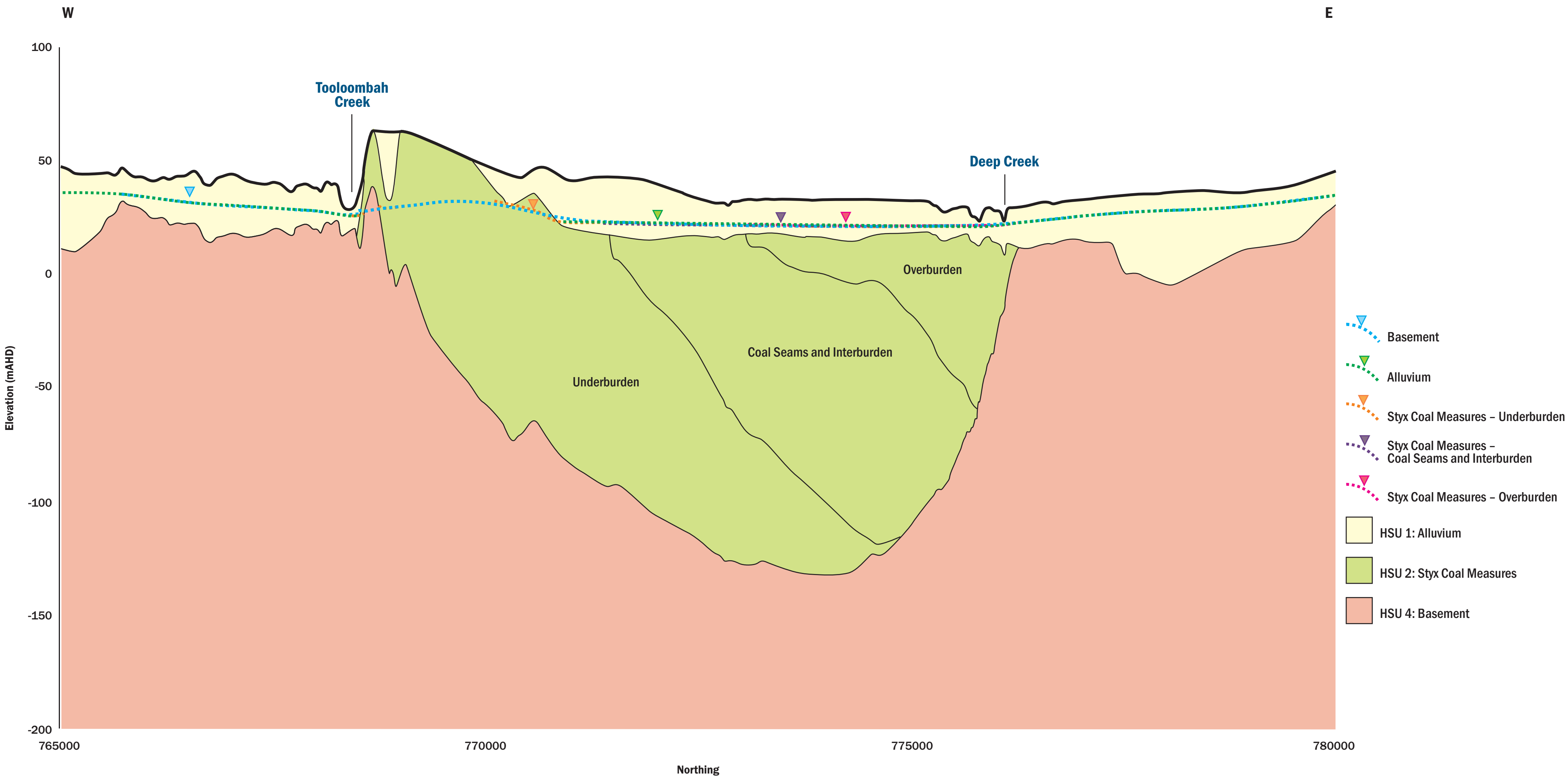
- 0.1m predicted drawdown
- 1m predicted drawdown
- Watercourse
- Main road
- ML 80187
- ML 700022

Figure 3-50
Maximum predicted water table drawdown extent and potential occurrence of ASS

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 max WT DD & potential ASS.mxd 11/28/2018



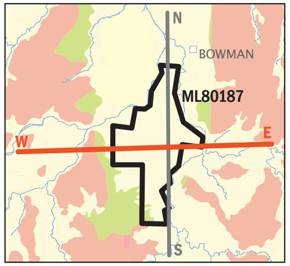
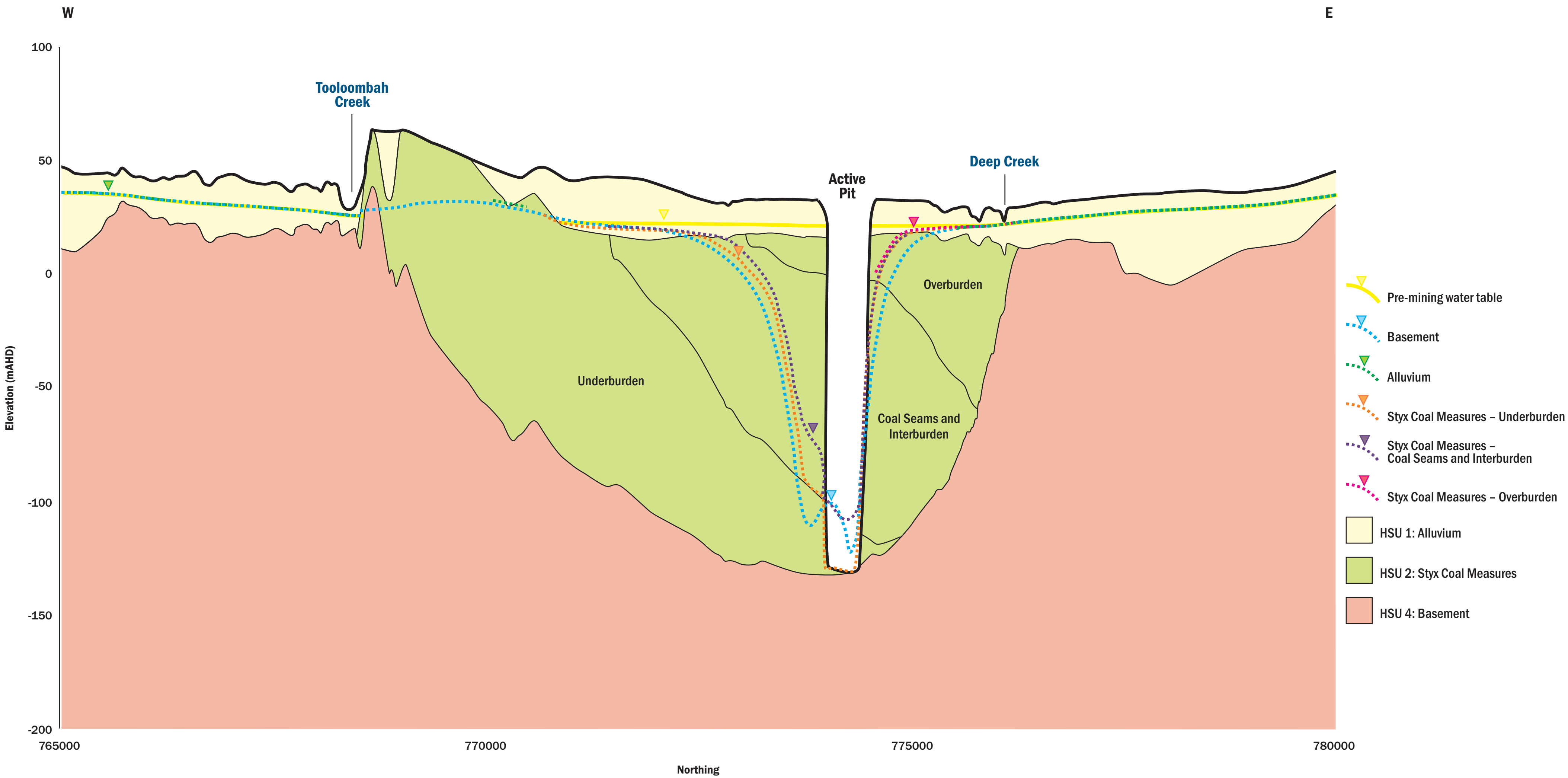


Figure 3-51
Cross-section showing model predicted pre-mine potentiometric surface (west to east through ML)



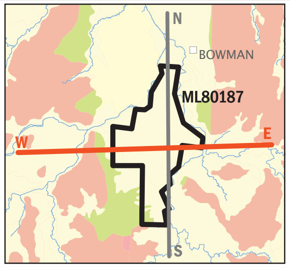
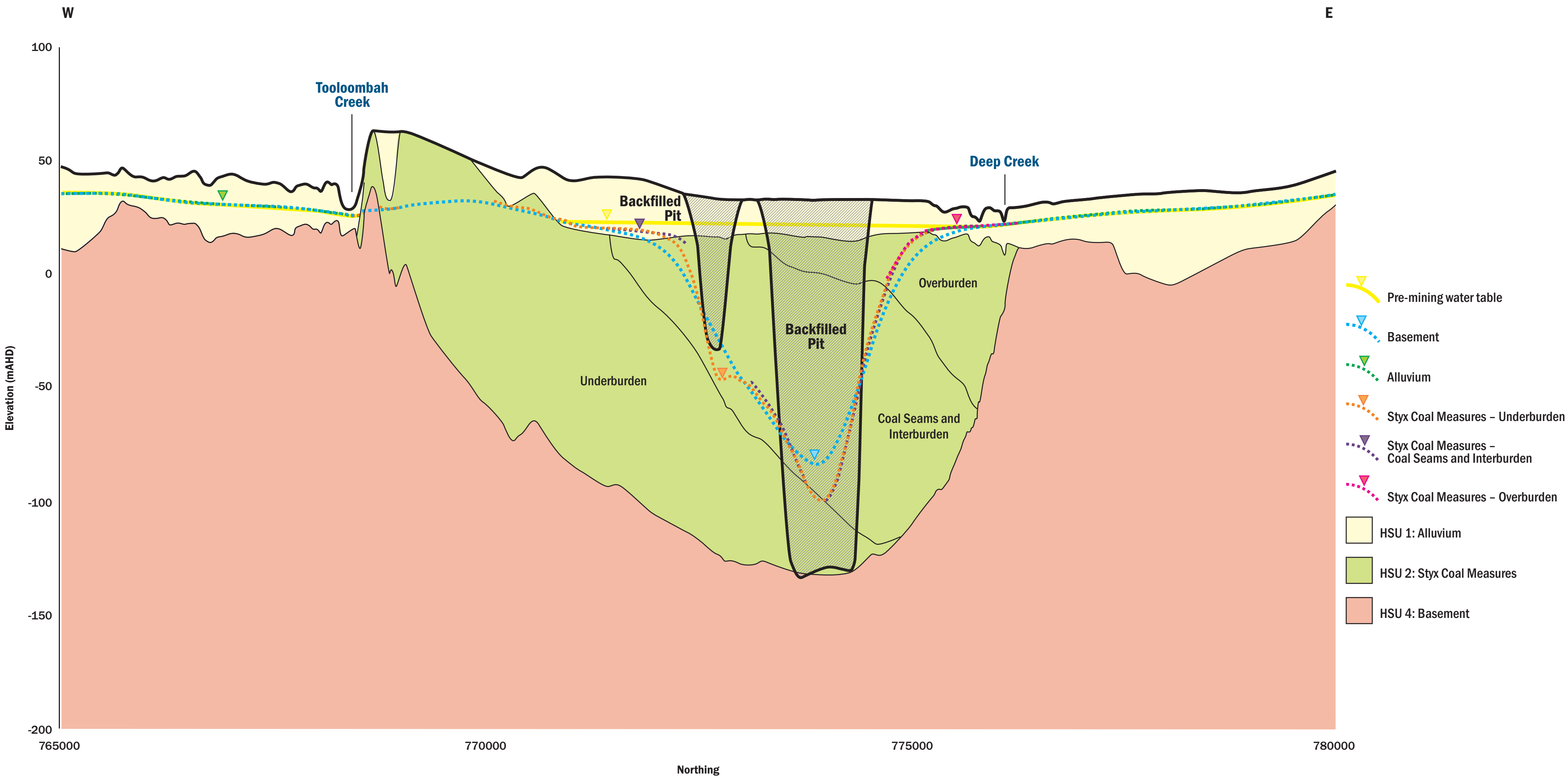


Figure 3-52

Cross-section showing model predicted drawdown (west to east through ML) – year 12 (maximum pit depth)



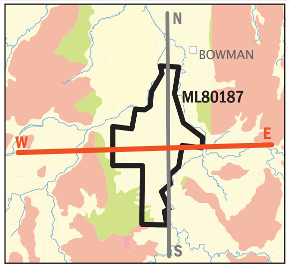
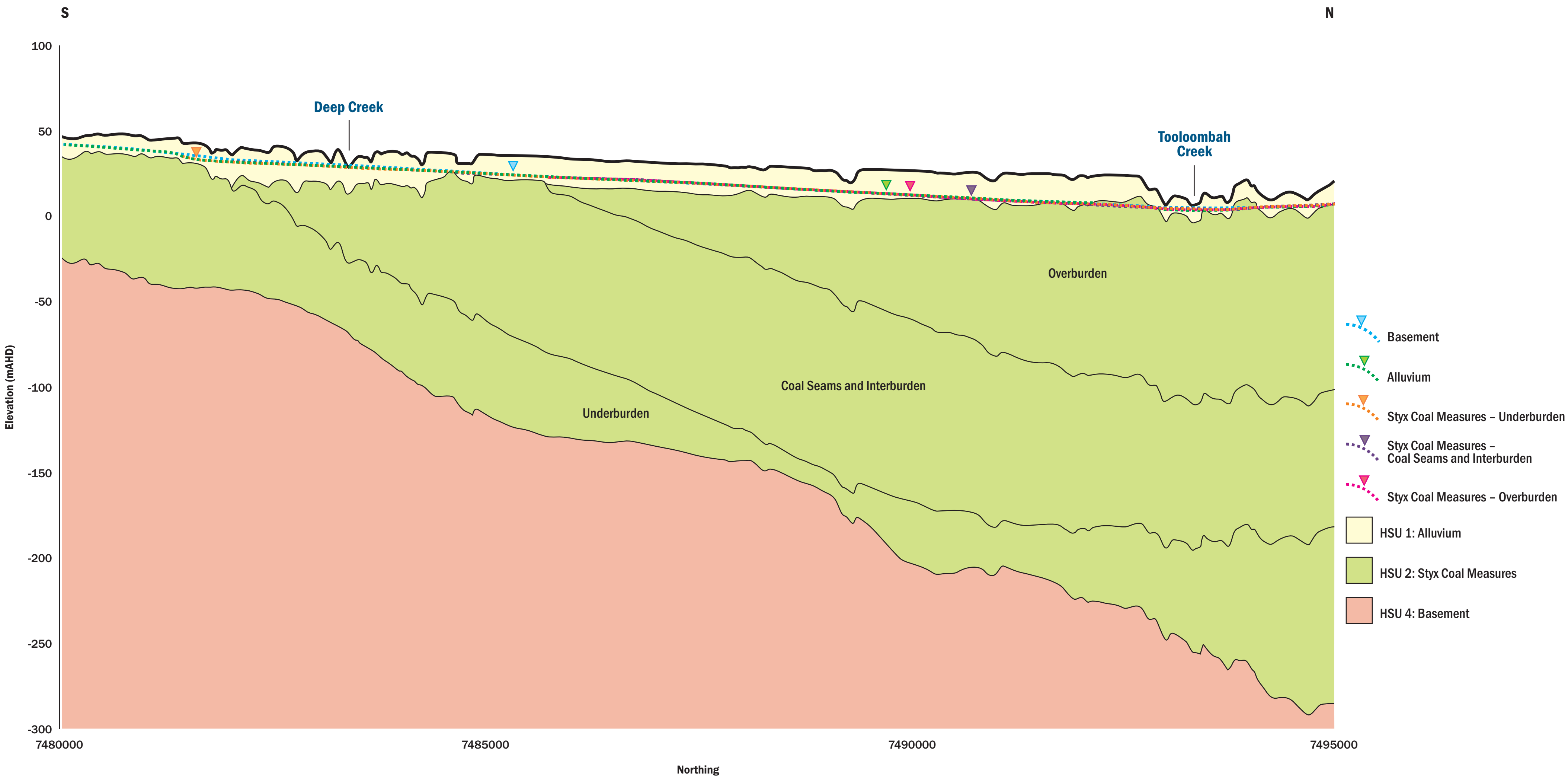


Figure 3-53

Cross-section showing model predicted drawdown (west to east through ML) – at end of mining

CDM Smith



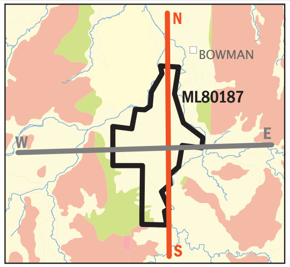
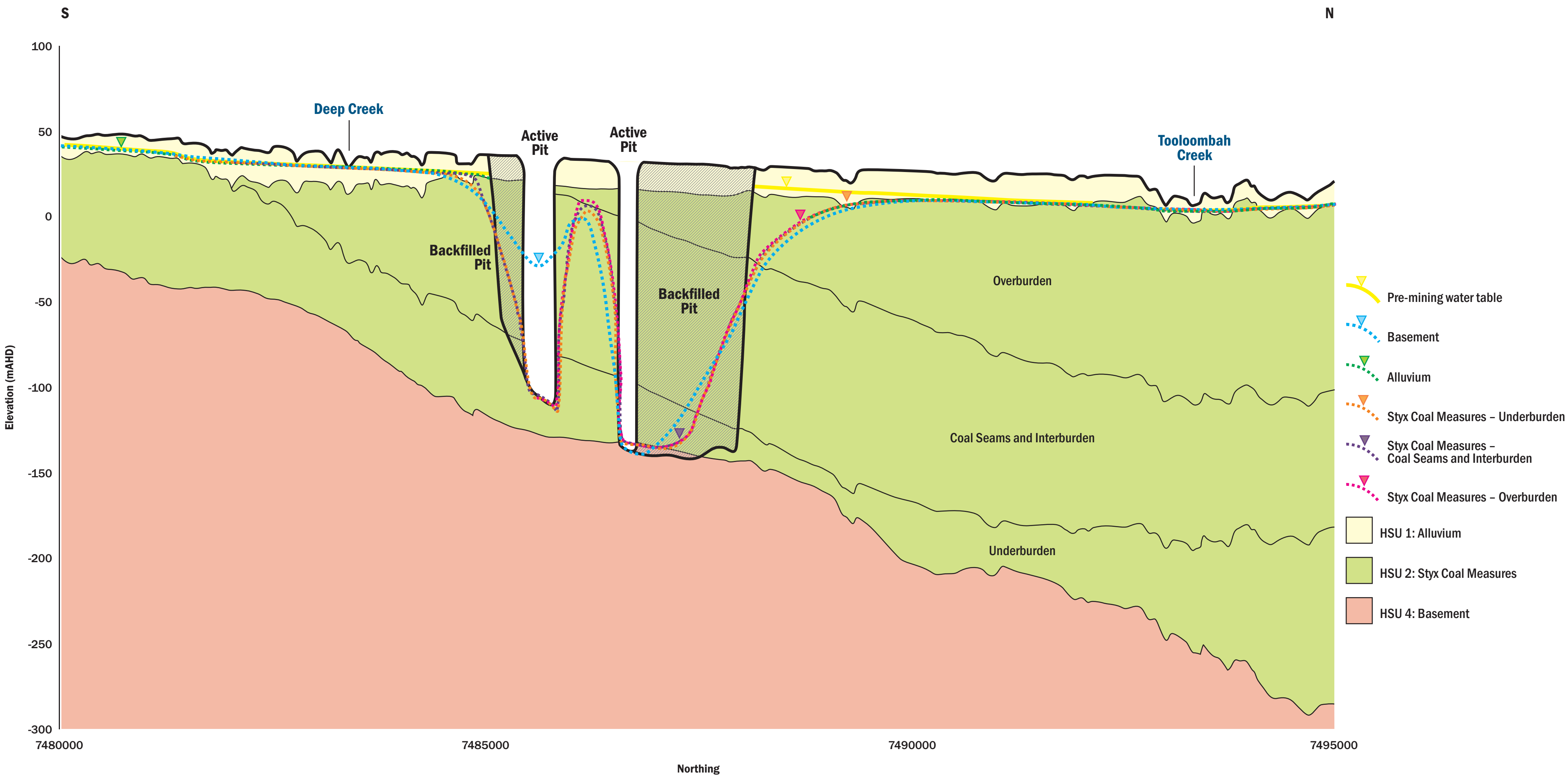


Figure 3-54

Cross-section showing model predicted pre-mine potentiometric surface (south to north through ML)

CDM Smith



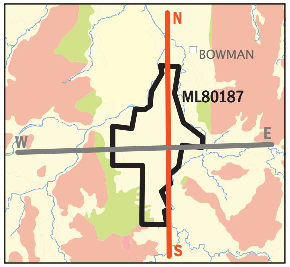
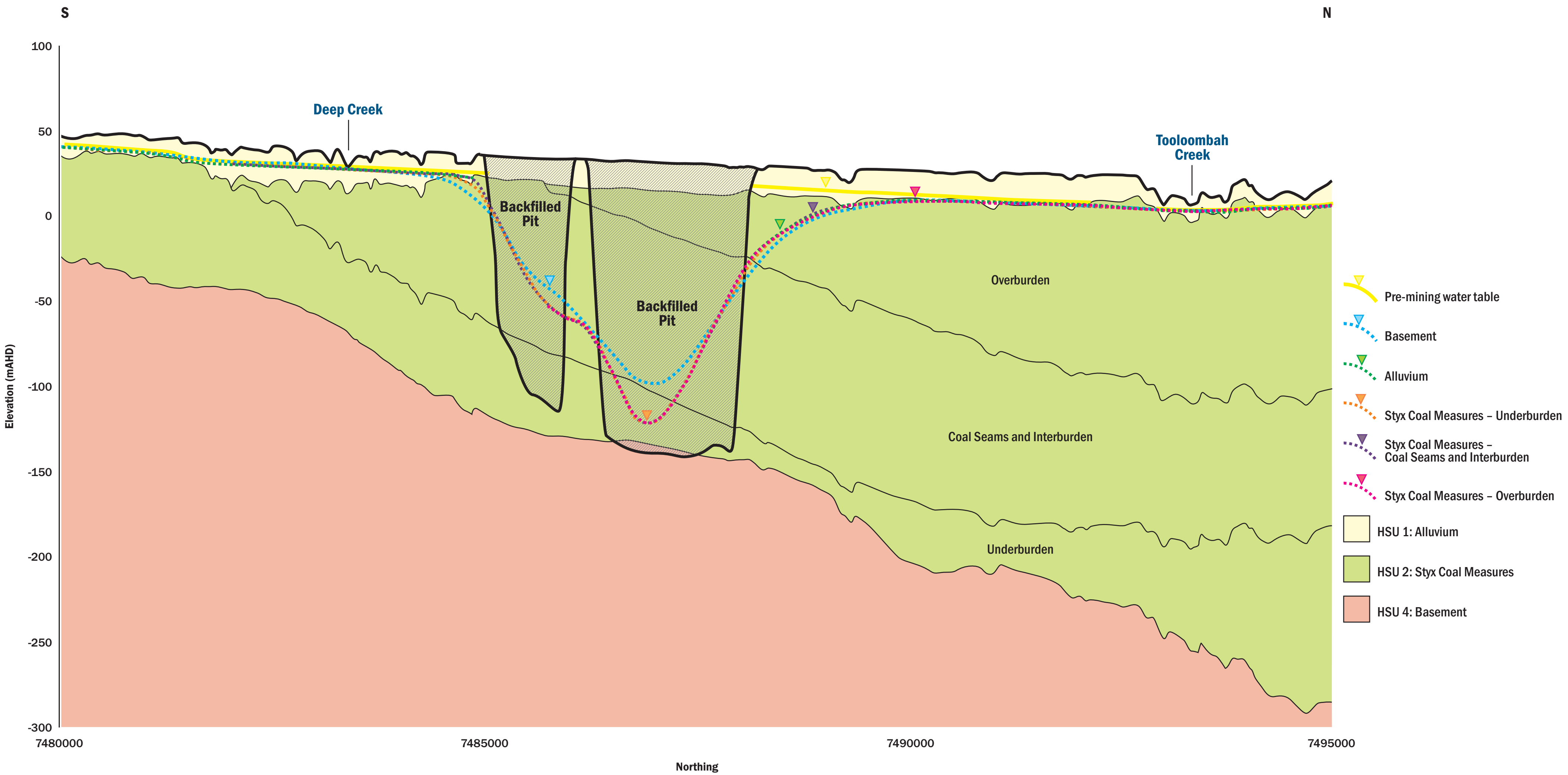


Figure 3-55

Cross-section showing model predicted drawdown (south to north through ML) – year 12 (maximum pit depth)



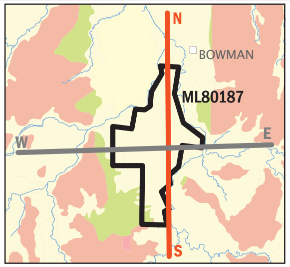


Figure 3-56

Cross-section showing model predicted drawdown (south to north through ML) – at end of mining

CDM Smith

3.6.3 Conservative approach to modelling

3.6.3.1 Details

Models are simplified representations of reality, consequently their predictions are always uncertain. A conservative approach to modelling involves adopting parameters that will provide an overestimation of predicted impacts. In the Styx mine environment, the key impacts to existing users (environmental, social and economic) will arise in response to water table drawdown, depressurisation of deeper (confined) hydrostratigraphic units (HSUs) and reduced baseflow to water courses (quantity and temporal) in response to mine water management. The impacts could include:

- Reduced access to groundwater by riparian and terrestrial GDEs;
- Exposure of acid sulphate soils to the atmosphere; and
- Inland mobilisation of the seawater-freshwater interface.

Conservatism in the case of the Styx model is a bias toward an overestimation of the expected 'cone' of drawdown in response to mining activities. The features of the modelling approach that provide conservatism to the results are summarised in Table 3-8.

Table 3-8 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 some moisture content, I.e. will not be entirely dry. 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, however will result in an underestimation of recovery.

Process	Model representation	Conservative aspect
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.
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).

3.6.3.2 Parsimony versus over-parameterization (or uniform hydraulic conductivity versus heterogeneous)

In the model, each HSU is represented by a single value of hydraulic conductivity uniformly distributed along the whole HSU. As the number of parameters is kept to a conceptually meaningful minimum and, as there are more observations (head targets) than parameters, this method fits the "parsimony approach".

An alternative to this approach is to allow different values of hydraulic conductivity to spatially characterise each HSU. This approach allows some heterogeneity to be represented within each HSU. As the number of parameters in this approach generally becomes greater than the number of observations this approach is called the "over-parameterised approach".

In a regional aquifer, heads are controlled by the distribution of hydraulic properties within the aquifer. The distribution is complex and often indeterminate with limited field observations. The parsimony approach considers the regional aquifer to be represented by a uniform regional value of each hydraulic parameter (Kh, Kv, Sy, Ss), and local variation from the regional value can be described as "noise from the main signal".

Overly simplistic models fail to capture the signal (i.e. they underfit the data and provide poor prediction). Overly complex models can hide the noise from the regional signal and, by overfitting, the data can provide for poor predictions. A decent parsimony model should derive a good fit with observation and achieve an unbiased normally distributed residual (i.e. the difference between observed and calculated values) of around zero, with a spatially randomly distributed residual. This is what is observed for the Styx model.

With an over-parameterized approach, a better calibration (at the cost of a more important computational effort) can be achieved as locally defined parameters can adjust to local observations. However, a better calibrated model doesn't make a better predictor as many parameters remain indeterminate. Those parameters are not constrained by observation and their value is only determined by pre-calibration consideration. Therefore, such an approach is only relevant with the implementation of a thorough uncertainty analysis (via a null space uncertainty analysis) that is demanding in terms of cost and computational effort. The null-space uncertainty analysis provides a sophisticated and refined uncertainty approach that maintains good compliance with observations. However, the uncertainty analysis for a parsimony approach can be designed to encompass the uncertainty that would be revealed in the over-parameterized approach. In other words, with conservative criteria such as those applied for the Styx model (i.e. "stretching" regional parameters to conservatively high values) the range of predictions (from minimum to maximum drawdown) are wider than the range of predictions that would arise from the null space uncertainty analysis. Over-parameterisation is more relevant when it becomes necessary to refine more precisely the range of predictions at any point.

3.7 Sensitivity and uncertainty analysis

3.7.1 Calibration sensitivity

During the automatic calibration, parameter estimation software (PEST; Doherty, 2016) calculates the sensitivity of calibration for each parameter. This allows the user to visualise the relative importance of each parameter in the calibration process. The most sensitive parameters have a stronger influence on calibration results and their value is more constrained by the calibration process. The least sensitive parameters have a lower influence on the calibration and their value is only loosely determined by the calibration. The parameter sensitivity results are illustrated in Table 3-9. To explore further the sensitivity of model parameters, a series of models have been run that changes a single parameter at a time from its calibrated value. For each of those runs, the sum of squared residual (Phi) has been calculated. Phi is an indication of the calibration fitness - the lower the value the better is the match between observed and calculated values. The range of parameters used for the sensitivity runs are summarised on Table 3-10 and the results are illustrated on Figure 3-57.

Table 3-9 Model calibration parameter sensitivity (sorted by most to least sensitive)

Parameter [1]	HSU	Sensitivity[2]
Kh, Kv	Underburden	0.370
Kh, Kv	Alluvium	0.309
Recharge	Recharge	0.226
Kh, Kv	Basement	0.188
Kh, Kv	Weathered	0.076
Kh, Kv	Overburden	0.026
Sy	Alluvium	0.010
Kh, Kv	Coal and interburden	0.006
Sy	Weathered basement	0.002

Note: 1. Kh – horizontal hydraulic conductivity; Kv – vertical hydraulic conductivity; Sy – Specific yield
2 This is a unitless qualitative measure of model sensitivity to changes in parameters (Doherty, 2016)

The three most sensitive parameters controlling model calibration are shown to be:

1. Hydraulic conductivity (Kh, Kv) of the Styx Coal Measures underburden;
2. Hydraulic conductivity (Kh, Kv) of the alluvium; and
3. Recharge rate(s).

The parameters that are least sensitive (in terms of model calibration) are specific yield of the alluvium and weathered basement aquifers, drain conductance, evaporation extinction depth and hydraulic conductivity of the coal seams and interburden layer (#3).

Table 3-10 Sensitivity runs

Parameter	HSU	Unit of measure	Sensitivity value list
Kh,Kv[1]	Alluvium	m/d	1. 00, 2.51, 4.15, 6.32, 15.91, 40.0
Kh,Kv[1]	Weathered	m/d	0.1, 0.32, 1.00 (max estimated range)
Kh,Kv[2]	Overburden	m/d	0.00017, 0.00053, 0.0017, 0.0053, 0.017
Kh,Kv[2]	Coal and interburden	m/d	7.0e-05, 2.2e-04, 7.0e-04, 2.2e-03, 0.007
Kh,Kv[2]	Underburden	m/d	0.0001, 0.0004, 0.001, 0.004, 0.01
Kh,Kv[2]	Basement	m/d	4.37e-05, 1.38e-04, 4.37e-04, 1.38e-03, 4.37e-03
Recharge	Recharge	[multiplier]	0.2, 0.5, 1.5, 3.8, 10.0
Sy	Alluvium & Weathered basement	m^3/m^3	0.001, 0.026, 0.05, 0.076, 0.1
Drain conductance[3]	Tooloombah, Deep creeks and Styx river	[multiplier]	0.2, 0.5, 2, 5
Evaporation Extinction depth[3]	All outcropping units	[m]	1, 5

Note: 1. Kv is an order of magnitude lower than Kh
2. Kv is equal to Kh.
3. Not part of calibration process, therefore included in sensitivity assessment

3.7.2 Predictive Uncertainty

3.7.2.1 Objective

Model calibration aims to optimise the match between field observations and their calculated equivalent. All the calibrated model parameter values emerge from the constraints the target observations apply to the model during calibration. For this reason, a single calibrated model offers the best estimate of predictive impacts based on those observations. However, due to the noise in the observation data and to some hydrogeological features that are not represented in the model, the calibrated model may not be the most accurate predictor of the real system. To explore alternatives to the calibrated model (and the hydrogeological conceptualisation), a predictive uncertainty analysis has been conducted. The aim of the uncertainty analysis is to explore the variability in the model prediction that is consistent with the target observations used to calibrate the model. The predictive uncertainty arises from parameters with low sensitivity and from correlation between parameters (meaning that recombining parameters according to their correlation doesn't affect the calibration). The different approaches detailed in this section explore both sources of uncertainty.

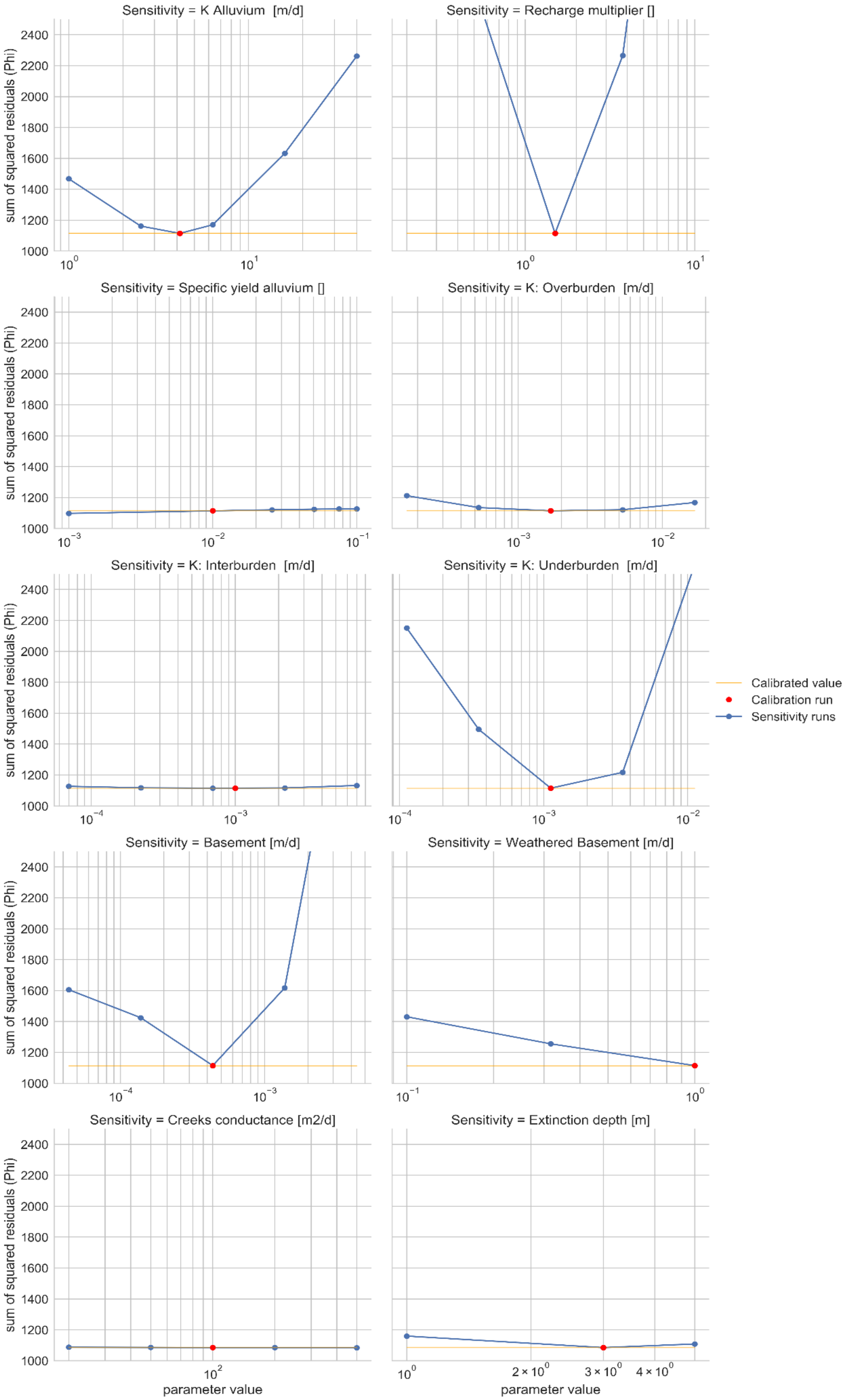


Figure 3-57 Sensitivity run results

3.7.2.2 Method

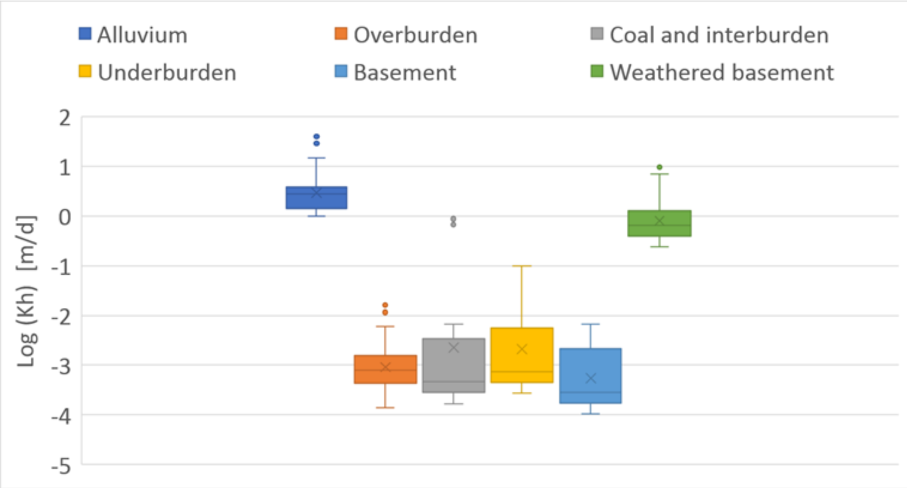
Non-uniqueness

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 different combinations of hydraulic properties that are varied within acceptable ranges based on observations of the simulated groundwater system, results of aquifer testing and the literature. The predictive uncertainty aims to explore possible range in predictive outcomes whilst maintaining acceptable calibration.

A total of 190 predictive models were generated and assessed. The following techniques were used to generate the uncertainty models:

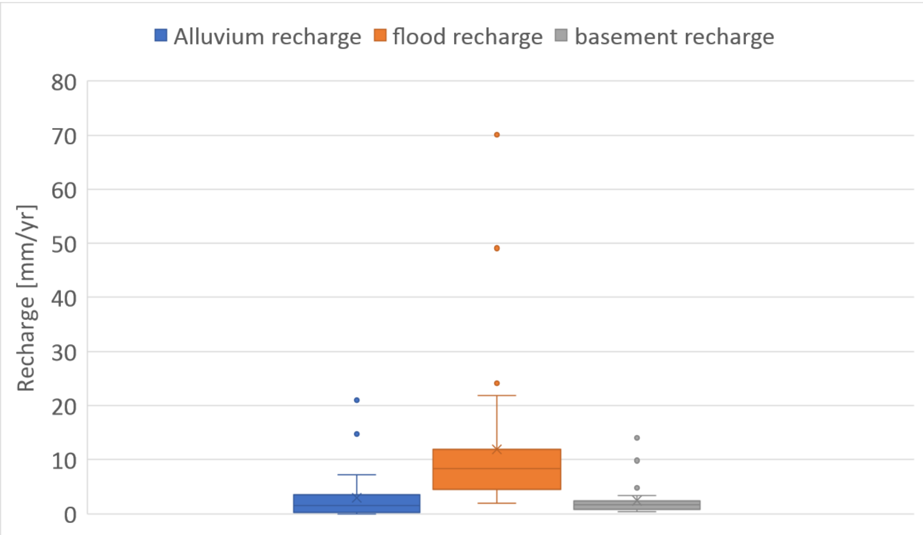
- From the calibration parameter sensitivity assessment, the PEST Null Space Monte Carlo technique (Doherty 2016) has been used to define the calibration null space, which identifies combination of parameters that have limited influence on the calibration (i.e. acceptable model calibration). Of the possible combinations identified, the models were reviewed to assess those models with parameters that remained consistent with the hydrogeological conceptualisation. Of the original 129 simulations, 106 models were selected and used for the predictive uncertainty analysis.
- Recharge / Kh correlation – The model calibration identified that estimated hydraulic heads have a strong correlation between recharge rate and hydraulic conductivity, as would be expected. It is possible to generate models that maintain acceptable calibration by varying recharge and hydraulic conductivity by a similar factor. Based on this, 100 models were generated and run to assess this observed correlation. Of the 100 models, 23 maintained acceptable calibration and were used to assess the effect on the predictive results. During calibration, the ratio between Kh and Kv was maintained constant for each HSU. The ratio was set to 10 for the quaternary alluvial deposits and weathered basement and to 1 for all other units (Styx Coal Measures and unweathered basement). The sensitivity of the Kh/Kv ratio on the predicted drawdown was assessed by running a scenario assuming a ratio of 10 and 100 for the Styx Coal Measures (see Section 3.7.2.3 and Figure 3-65.
- Based on model sensitivity results, model hydraulic conductivities within the Styx basin were ‘stretched’ to assess the breakpoint where drawdown becomes significative downstream at the confluence of the Tooloombah creek and Deep creek, and at the coast. Those scenarios allow an assessment of what conditions are required for significant impact to appear. Those conditions are then compared to the literature, field observations and calibration constraints to assess their eventuality. Those scenarios are reported in the following Section.

The distribution of the calibrated parameters assessed in the uncertainty analysis is illustrated in Figure 3-58 and Figure 3-59.



whiskers= minimum and maximum, box= 25th to 75th percentile,
line within box= median, cross= average, points= outliers

Figure 3-58 Box and Whisker plot showing range of horizontal hydraulic conductivity assessed as part of uncertainty analysis



whiskers= minimum and maximum, box= 25th to 75th percentile,
line within box= median, cross= average, points= outliers

Figure 3-59 Box and Whisker plot showing range of average annual recharge rates assessed as part of uncertainty analysis

Mine schedule

The uncertainty related to the mining schedule was assessed by running the predictive model with a revised mining schedule to compare with the original schedule predictions.

Climate variability

The uncertainty related to future climate conditions, including both a drier and a wetter climate over the period of mining. Four scenarios were simulated:

- During the driest period in the historical rainfall record (between 1990 to 2009) total rainfall was around 15% less than the average recorded at Rockhampton (station 039083) and Strathmuir (station 033189). It is likely that recharge rates do not have a linear relationship with rainfall rates, and a decline of 15% in rainfall will possibly give rise to greater rates of decline in recharge. To represent this situation, three 'drought' scenarios have been simulated for recharge - 15%, 30% and 60% reduction - during the life of mine, with climate conditions returning to average during the post mining period; and

- During the wettest period in the historical rainfall record (between 1949 to 1954), rainfall was around 15% higher than the average. To represent this situation, 15% more rainfall recharge has been simulated for a period of 5 years commencing from the start of mining activities.

Backfilling and hydraulic loading

The effect of stockpiling and above ground waste storage, backfilling the pits during mining operations, and the existence of residual waste landforms after closure has been assessed by conservatively assuming (in the absence of data):

- K and Sy of backfill material hydraulic are 0.02 m/d and 0.05, respectively (see Table 3-4 for comparison); and
- K and Sy of the alluvium beneath the landforms are reduced by 50% due to compression to 2 m/d and 0.005, respectively; see Table 3-4 for comparison).

3.7.2.3 Results

Non-uniqueness

The results of each predictive uncertainty model have been reviewed, and the following models have been selected for discussion:

- Predictive uncertainty models that result in the lowest and largest mine dewatering rates (Figure 3-60). The associated parameters for the uncertainty models that predicted the lowest and highest groundwater pit dewatering volumes (around 180 and 1,300 ML/yr, respectively) are presented, along with the base case parameters for comparison, in Table 3-11. The model with the maximum predicted inflows has higher hydraulic conductivity values in all modelled HSUs (greater than half an order of magnitude) and recharge is approximately five times greater than that of the base case model, which is considered unrealistic. As expected, the model with the minimum predicted inflows has lower hydraulic conductivity values in all modelled HSUs and recharge rates five times less than that of the base case model, which is again considered unrealistic.

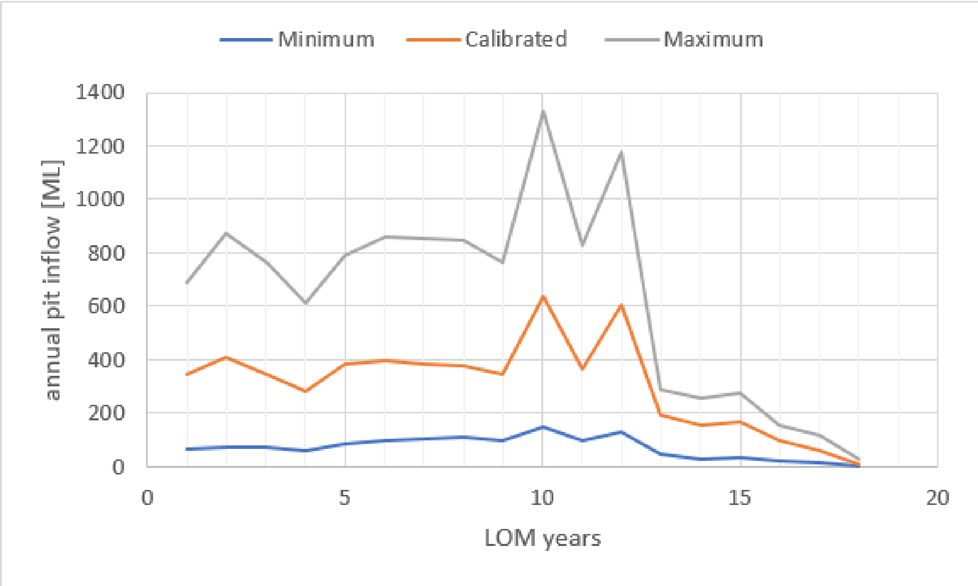


Figure 3-60 Groundwater abstraction from pits – predictive uncertainty results

Table 3-11 Model parameters used in the mine inflow uncertainty analyses

Parameter (units)	HSU	Hydraulic property / model parameter		
		Base case calibrated model	Maximum predicted inflow model	Minimum predicted inflow model
Kh (m/d)	Alluvium	4.1	28.6	1.0
Kh (m/d)	Styx Coal Measures - overburden	2.0×10^{-2}	1×10^{-2}	4×10^{-4}
Kh (m/d)	Styx Coal Measures - Coal seams and interburden	3.0×10^{-3}	5×10^{-3}	2×10^{-4}
Kh (m/d)	Styx Coal Measures - underburden	4.0×10^{-3}	1×10^{-2}	3×10^{-4}
Kh (m/d)	Weathered basement	1.0	6.9	0.2
Kh (m/d)	Basement	4×10^{-4}	3×10^{-3}	1×10^{-4}
Kv (m/d)	Alluvium	0.41	2.9	0.1
Kv (m/d)	Styx Coal Measures - overburden	2.0×10^{-2}	1×10^{-2}	4×10^{-4}
Kv (m/d)	Styx Coal Measures - Coal seams and interburden	3.0×10^{-3}	5×10^{-3}	2×10^{-4}
Kv (m/d)	Styx Coal Measures - underburden	4.0×10^{-3}	1×10^{-2}	3×10^{-4}
Kv (m/d)	Weathered basement	0.1	0.7	0.02
Kv (m/d)	Basement	4×10^{-4}	3×10^{-3}	1×10^{-4}
Alluvium diffuse recharge (mm/yr)	Alluvium	4.5	21.0	0.9
Flood recharge (mm/yr)	Creeks / alluvium	15	70.1	2.9
Weathered basement diffuse recharge (mm/yr)	Basement	3	14.0	0.6

Parameter (units)	HSU	Hydraulic property / model parameter		
		Base case calibrated model	Maximum predicted inflow model	Minimum predicted inflow model
Sy (-)	Alluvium	0.01	0.01	0.01
Sy (-)	Weathered basement	0.005	0.005	0.005

Predicted water table drawdowns from the uncertainty analysis having the greatest drawdown extent at the end of mining and 10-years post-mining are presented on Figure 3-61 and Figure 3-62. The following presents a summary of the outcomes, when compared to the basecase predictive model results (Figure 3-21 and Figure 3-22):

- The northern extent of the 0.1 m drawdown contour (the zone of impact extent) remains unchanged, but it extends closer to the Styx River (within 250 m at the end of mining and within 100 m at 10-years post-mining);
- The 1 m drawdown contour is still constrained largely to the east of Tooloombah Creek.; and
- The predicted drawdown remains unchanged at BH28A/BH28 (third party user) and the Type 3 GDE on western ML 80187 (shown as GDE6 on Figure 3-61 and Figure 3-62).

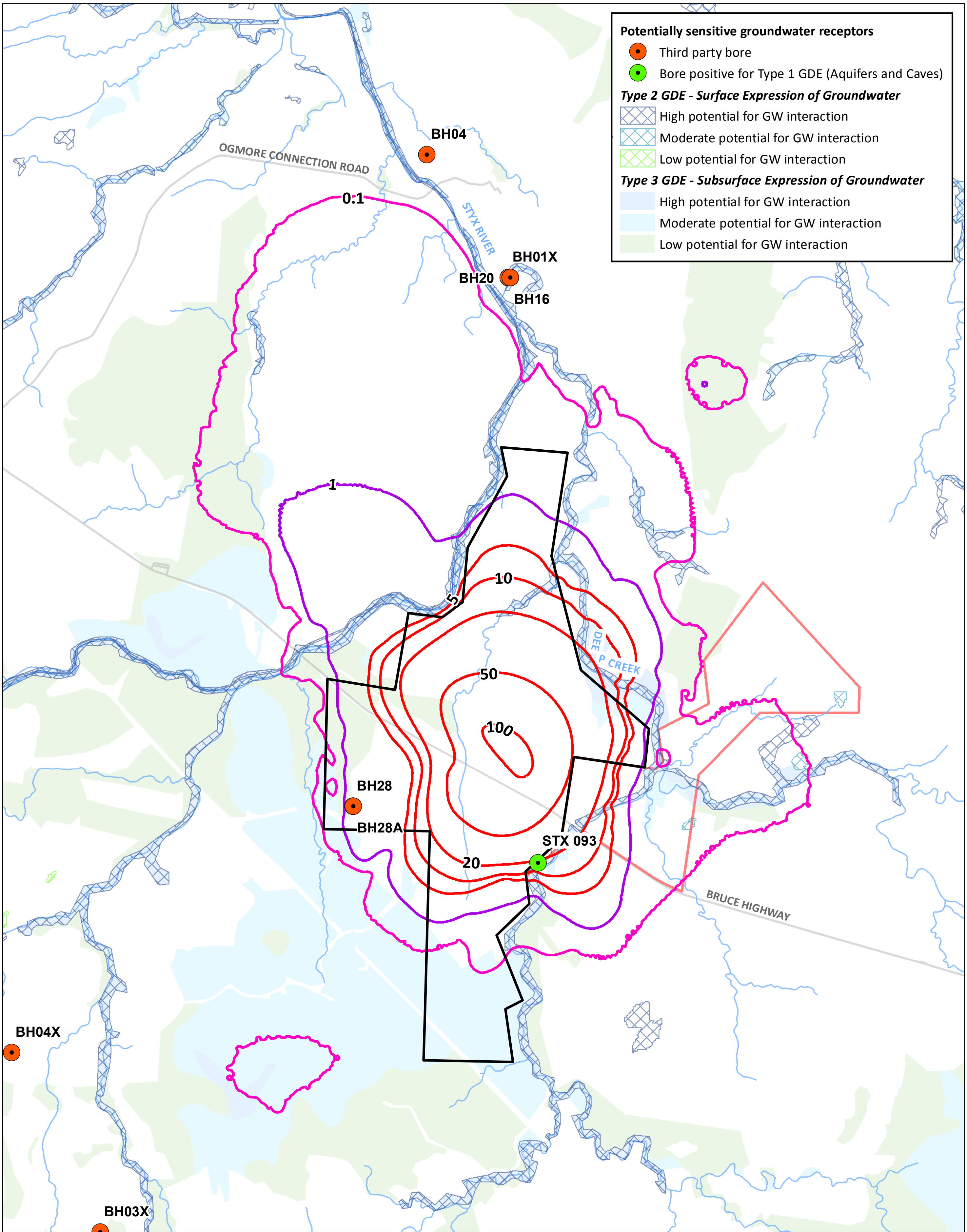


Figure 3-61
Predictive uncertainty "most severe possible" water table drawdown contours – at end of mining

Scale @ A4 1:80,000
Date: 20/12/18
Drawn: A. Aird

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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111_WT_DDN_EOM - UNCERTAINTY.mxd 12/20/2018

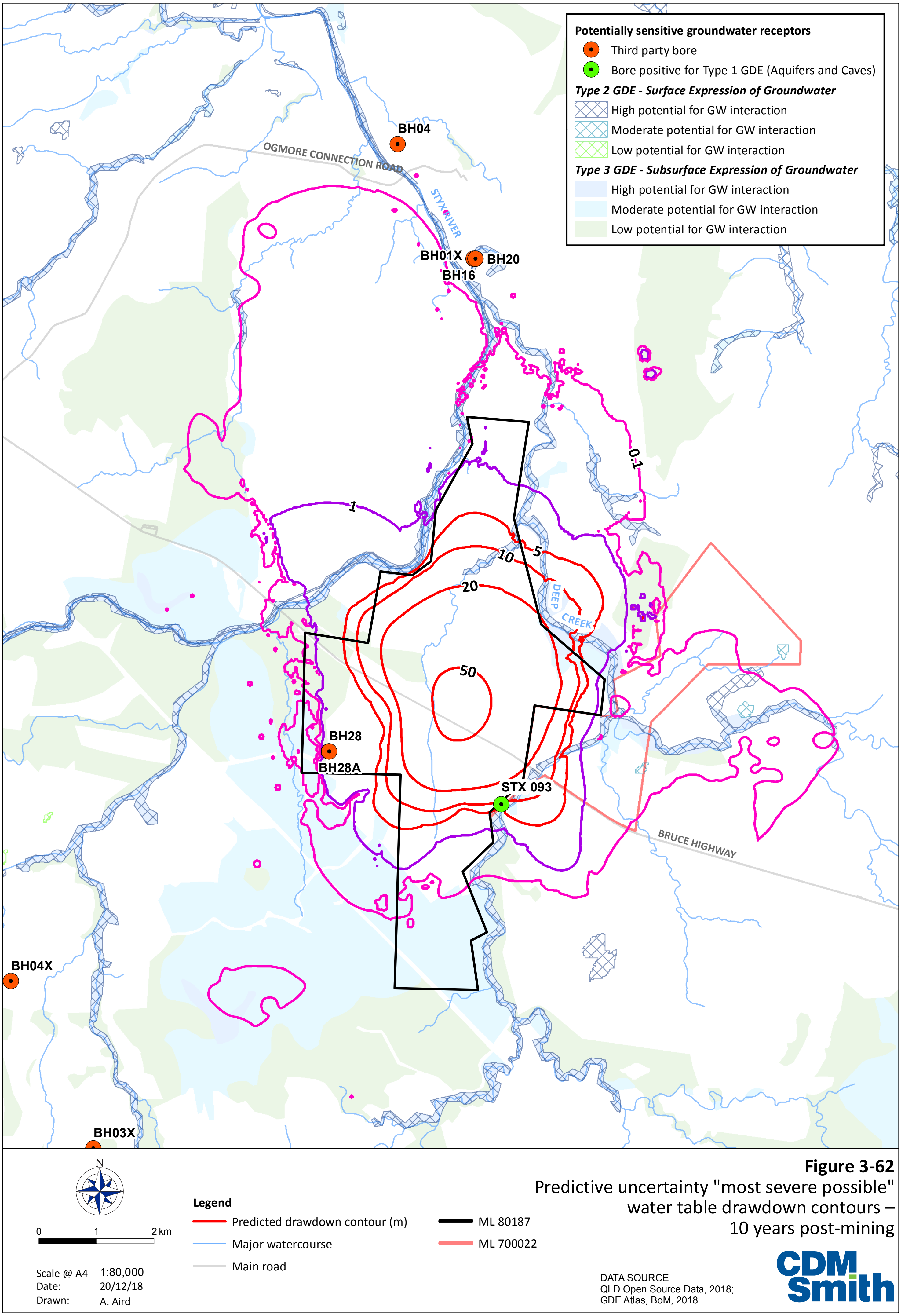


Figure 3-62
Predictive uncertainty "most severe possible" water table drawdown contours – 10 years post-mining

- The predicted water table drawdown at WMP28 (next to Tooloombah Creek, and close to the western boundary of ML 80187) is predicted to increase by a maximum of 4m during mining operations. By the end of mining operation the difference of drawdown at WMP28 has reduced to about 2m.
- The predicted water table drawdown at Deep Creek on the eastern boundary of ML 80187 is predicted to remain unchanged.
- Predictive uncertainty analysis indicates drawdown associated with mine water affecting activities will not extend to downstream areas identified with potential for acid sulphate soils or further north along the Styx River (indicating the conclusion from the adopted calibrated model that the potential for inland mobilisation of the seawater interface, if it were beneath Styx River remains valid, i.e. the potential for mobilisation is low / negligible).

Figure 3-63 and Figure 3-64, present predicted pre-mine and 10 years post-mine water table elevation contours for the 'most severe possible' scenario discussed above, and shows that downstream of the confluence of Tooloombah and Deep Creeks, the water table contours remain unchanged from the pre-mine condition.

The plausible parameter set that produces the 'most severe possible' model predictions in terms of groundwater head drawdown are presented on Table 3-12. The most significant change in parameters is in the modelled recharge, which is around two times less than that in the base case prediction model.

Table 3-12 Model parameters used in the 'worst-case' water table drawdown uncertainty analyses

Parameter	HSU	Base case calibrated value	Uncertainty value
Kh (m/d)	Alluvium	4.1	4.1
Kh (m/d)	Styx Coal Measures -overburden	2.0×10^{-2}	2×10^{-3}
Kh (m/d)	Styx Coal Measures - Coal seams and interburden	3.0×10^{-3}	1.8×10^{-2}
Kh (m/d)	Styx Coal Measures -underburden	4.0×10^{-3}	1.1×10^{-3}
Kh (m/d)	Weathered basement	1.0	1.0
Kh (m/d)	Basement	4×10^{-4}	4.4×10^{-4}
Kv (m/d)	Alluvium	0.41	0.41
Kv (m/d)	Styx Coal Measures -overburden	2.0×10^{-2}	2×10^{-3}
Kv (m/d)	Styx Coal Measures - coal seams and interburden	3.0×10^{-3}	1.8×10^{-2}
Kv (m/d)	Styx Coal Measures -underburden	4.0×10^{-3}	1.1×10^{-3}
Kv (m/d)	Weathered basement	0.1	0.1
Kv (m/d)	Basement	4×10^{-4}	4.4×10^{-4}
Alluvium diffuse recharge (mm/yr)	Alluvium	4.5	4.5
Flood recharge (mm/yr)	Creeks / alluvium	15	15
Weathered basement diffuse recharge (mm/yr)	Basement	3	3
Sy (-)	Alluvium	0.01	0.01
Sy (-)	Weathered basement	0.005	0.005

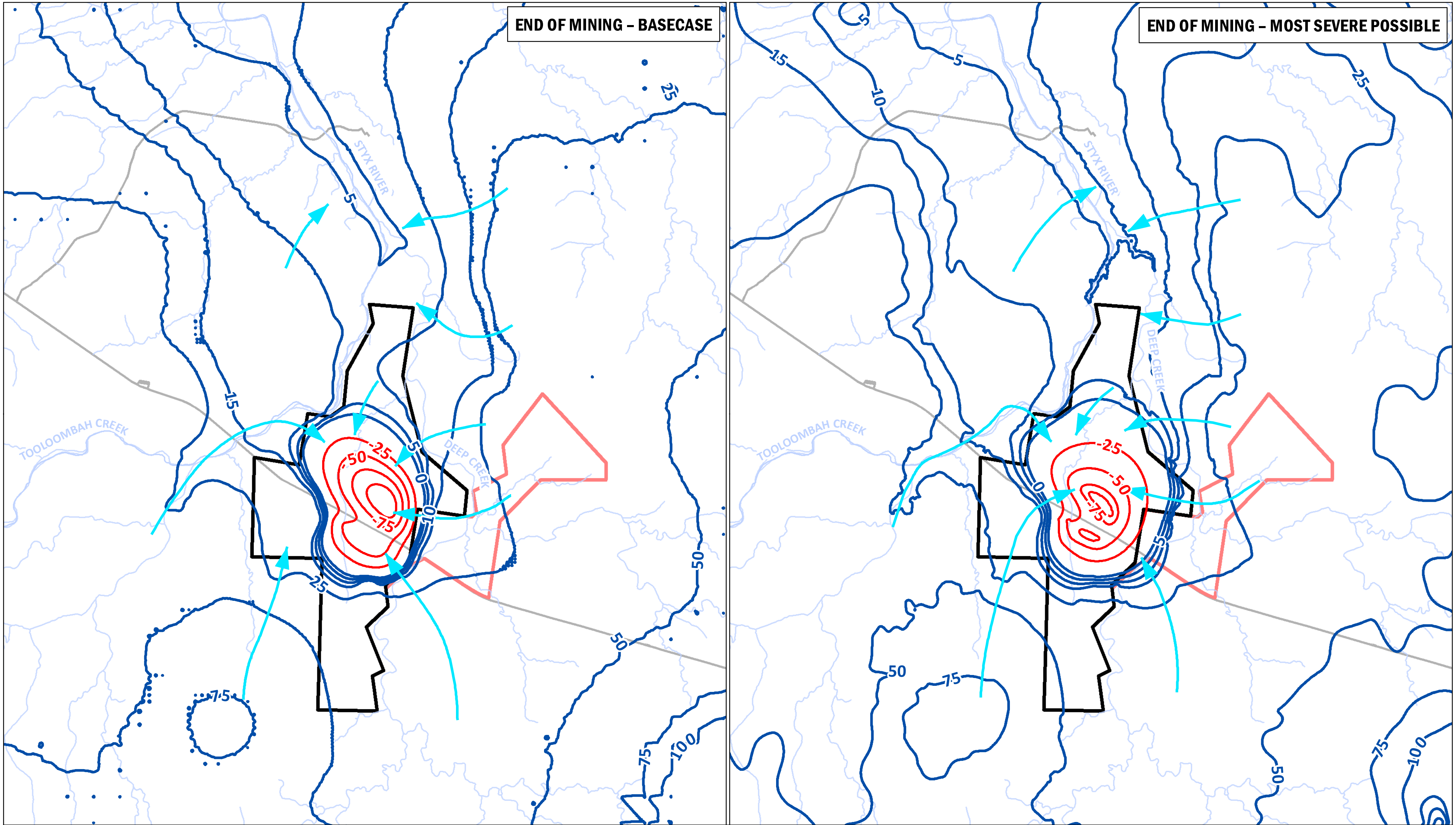
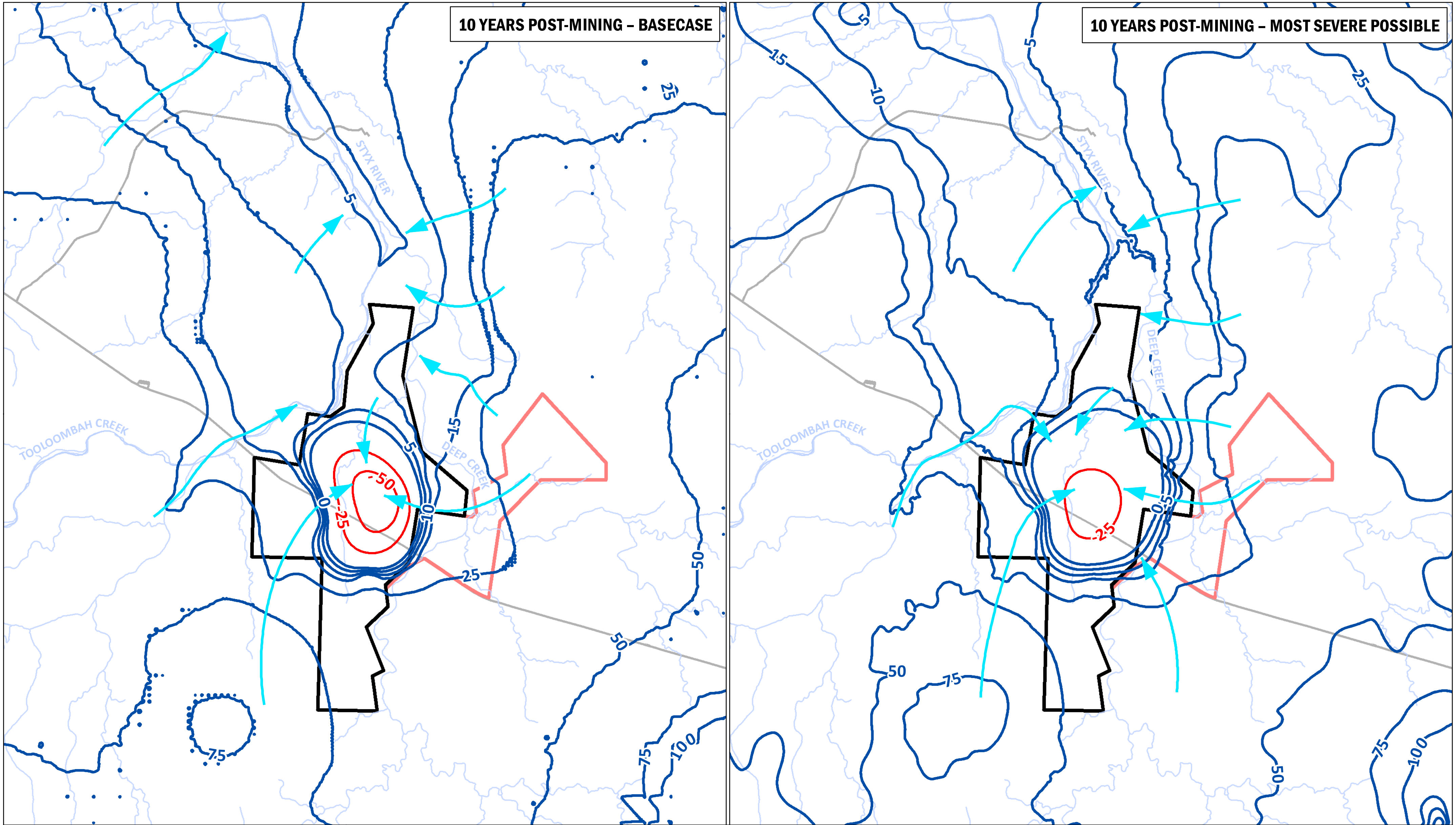


Figure 3-63

Predictive uncertainty "most severe possible" water table contours – at end of mining

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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 WT wcs_base case-worst case__end of mining R2.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 3-64

Predictive uncertainty "most severe possible" water table contours – 10 years 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 WT wcs_base case-worst case__10yrs post mining R2.mxd 12/20/2018

With a Kh/Kv ratio of 10 or 100 for the Styx Coal Measures (Figure 3-65), the variation in terms of predicted (spatial) drawdown is not significant and tends to show the isotropic condition (Kh/Kv =1, as adopted in the basecase) offers a more conservative approach, indicating the extent of drawdown is mainly controlled by values of Kh and storage coefficients in the Styx Coal Measures.

The 0.1m drawdown contour for the Kh/Kv ratio of 100 scenario shows a combination of effects due to mining and due to the numerical accuracy of the model solutions - noting drawdown is calculated as the difference between a reference simulation without mining and a predictive simulation with mining. Specifically, the areas of 'satellite' drawdown beyond the main area of mining-related drawdown are likely to reflect the limits of accuracy of the simulations. On this basis, the 0.1-m contours of drawdown should be interpreted as indicative results that include numerical error of similar order of magnitude to the drawdown.

Mine schedule

Figure 3-66 presents the revised mine layout and schedule for the Project (open cut 2 scenario; compare with the original mine layout and schedule in Figure 3-18). As shown the annual sequences of the revised schedule between 2019 and 2029 have a north-south direction while those sequences where in east-west direction in the original schedule. The life of the mine is very similar for both schedules and the differences are detailed in Table 3-13. The difference between the two schedules at the end of 2036 (after 18 years of mining) is very similar as illustrated on Figure 3-67. An integration of the volume of rock dewatered indicates the original schedule has 2% more drawdown than the revised schedule.

Table 3-13 Comparison of original and revised mining schedule

	Open cut 1	Open cut 2	Total
Original schedule	From 2028 to 2036 (8 years mining and 1 gap year)	From 2019 to 2033 (14 years mining and 1 gap year)	From 2019 to 2036 (span over 18 years)
Revised schedule	From 2028 to 2037 (8 years mining & 2 gap years)	From 2019 to 2032 (14 years)	From 2019 to 2037 (span over 19 years)

Climate variability

Under drier climate conditions (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 condition indicating the additional 'cumulative' effect of mine dewatering is negligible.

For above average recharge conditions (Figure 3-71), there is basically no change predicted from basecase mining average recharge scenario, except isolated areas where drawup is predicted.

Backfilling and hydraulic loading

The spatial distribution of, and altered (lower K and Sy) hydraulic properties of the alluvium beneath stockpiles, waste landforms combined with the altered (higher K and Sy) hydraulic properties of backfill materials results in a subtle NW-SE elongation of the predicted zone of influence, with the 1m drawdown contour passing through Tooloombah Creek (Figure 3-72). 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 scenario 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 have some moisture content. .

3.7.3 Impact breaking-point assessment

3.7.3.1 Methodology

The uncertainty analysis detailed in Section 3.7.2 explores various combinations of parameters that maintains model calibration. From those calibrated sets, an assessment of whether noticeable impact arises has been conducted. As reported, no parameter set triggered significant drawdown near the coast or at the confluence of Tooloombah and Deep Creeks (i.e. just upstream of the tidal zone) indicating the likelihood of impact to hydrology downstream of the confluence of Tooloombah and Deep Creek is relatively small.

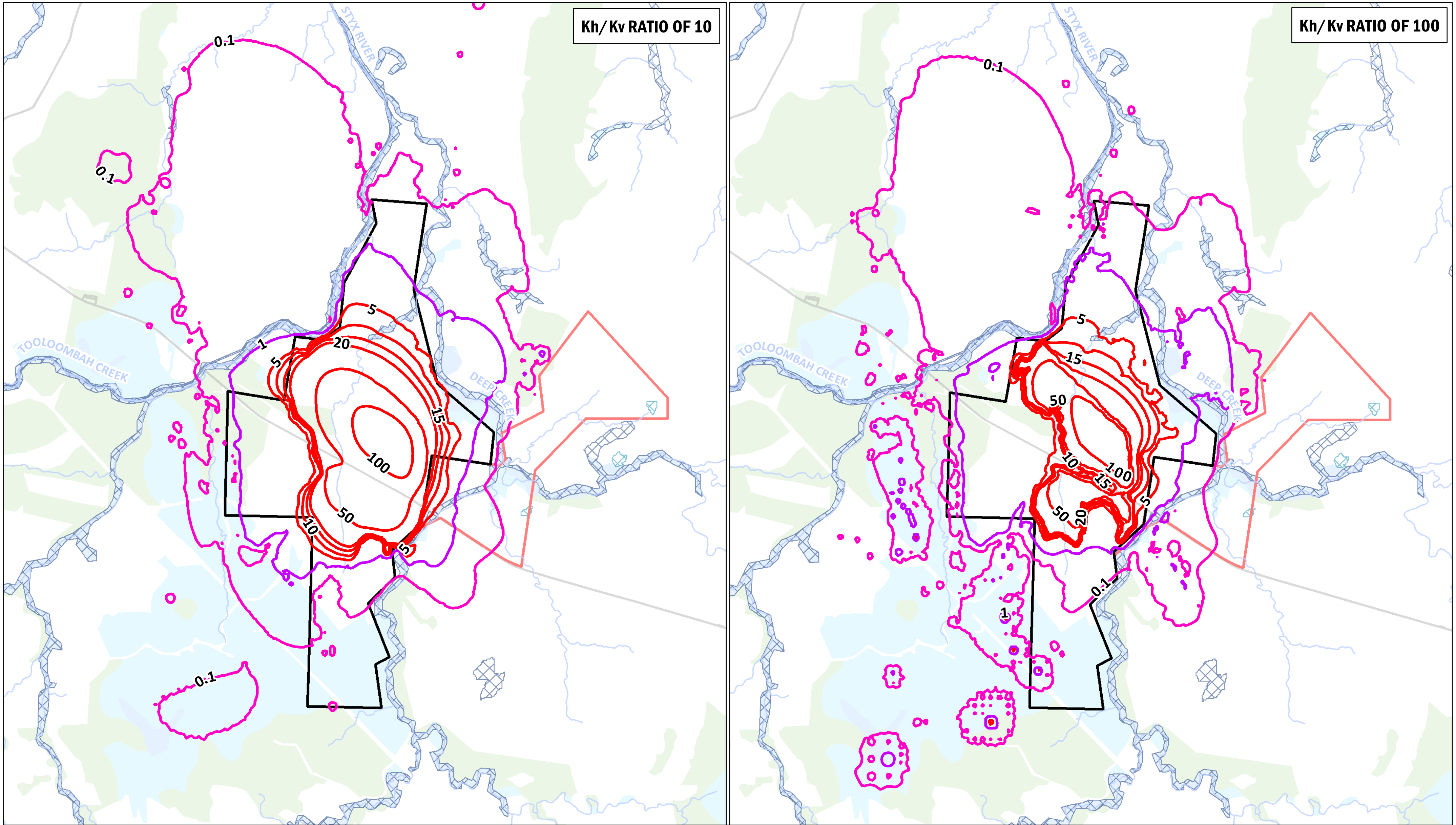
To complement the uncertainty analysis reported in the previous chapter, the approach reported in this chapter explores the condition necessary to trigger significant drawdown downstream of the confluence of Tooloombah and Deep Creeks. It is likely that such drawdown would pose a risk to environmental assets (e.g. by potentially triggering sea water intrusion and exposure of ASS). This 'breaking-point' assessment provides the opportunity to test the accepted hydrogeological conceptualisation.

Two observation points (as illustrated on Figure 3-73) are used as a proxy to demonstrating the possible evolution of the cone of water table drawdown (depression) for the 'breaking-point' assessment. It should be noted that the coast is represented in the model by a constant head BC. To prevent the constant head BC to fully control the head of the observation point, it was located 300m further south.

For this analysis, diffuse rainfall recharge was maintained at the calibrated value. It has already been demonstrated (see previous section) that higher hydraulic conductivities paired with higher recharge rates have only limited influence on the depression cone extent compared to the basecase. Consequently, to trigger larger drawdown, it is necessary to make the assessment with a recharge rate that does not change by the same ratio as hydraulic conductivity (in this case, recharge remains the same as the basecase)[2].

Conceptually, it is understood that, for a given recharge rate, a wider drawdown cone would be observed for hydraulic conductivities higher than the calibrated conductivities. For this analysis, only hydraulic conductivities higher than the calibrated value are considered.

[2] As recharge and hydraulic conductivity have a 1:1 correlation, it would be possible to extrapolate this analysis to a different value of recharge by applying the same multiplier on the value of hydraulic conductivities considered in this analysis



N

0 1 2 km

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

See Figure 3-61 for Type 2 and 3 GDE legend

Figure 3-65
Predictive uncertainty Kh/Kv ratio of 10 and 100 in the Styx Coal Measures – Water table drawdown contours – 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 Kx-Kz ratio comparisons LOM yr 18 EOM r2.mxd 12/20/2018

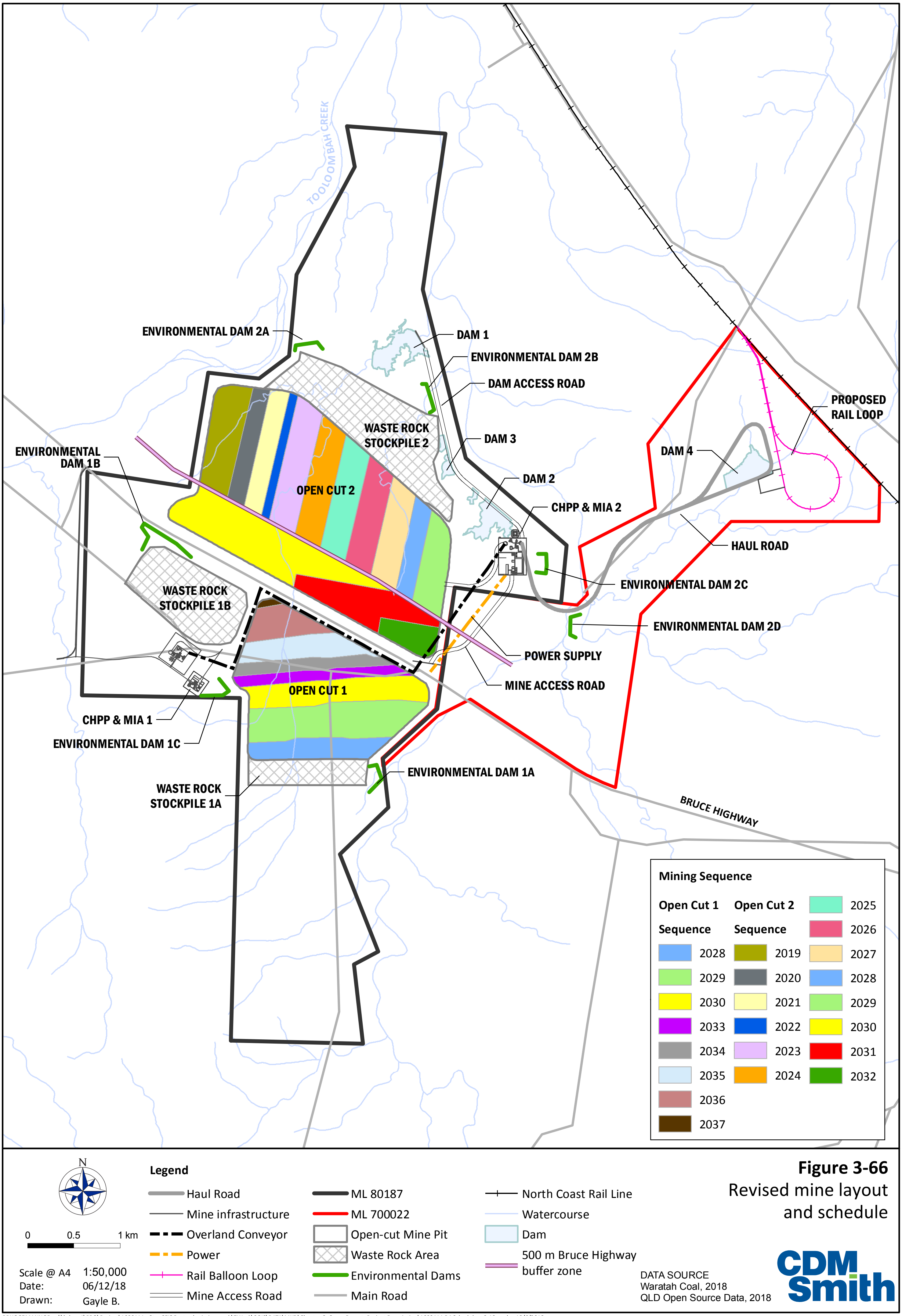
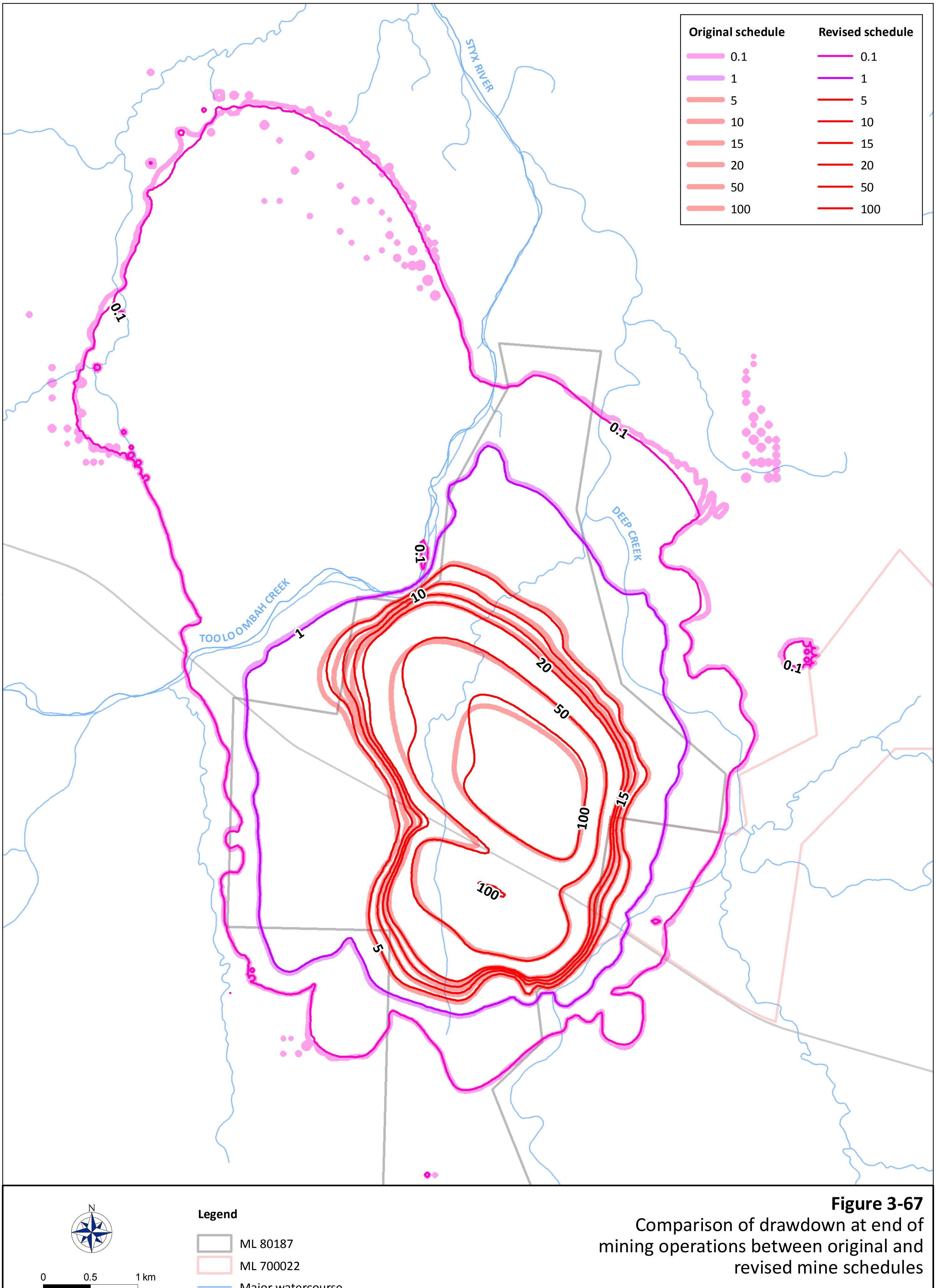


Figure 3-66
Revised mine layout and schedule

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 3_Supp_Report_Project Description\1000111 R4 Schedule__3-12.mxd 12/6/2018

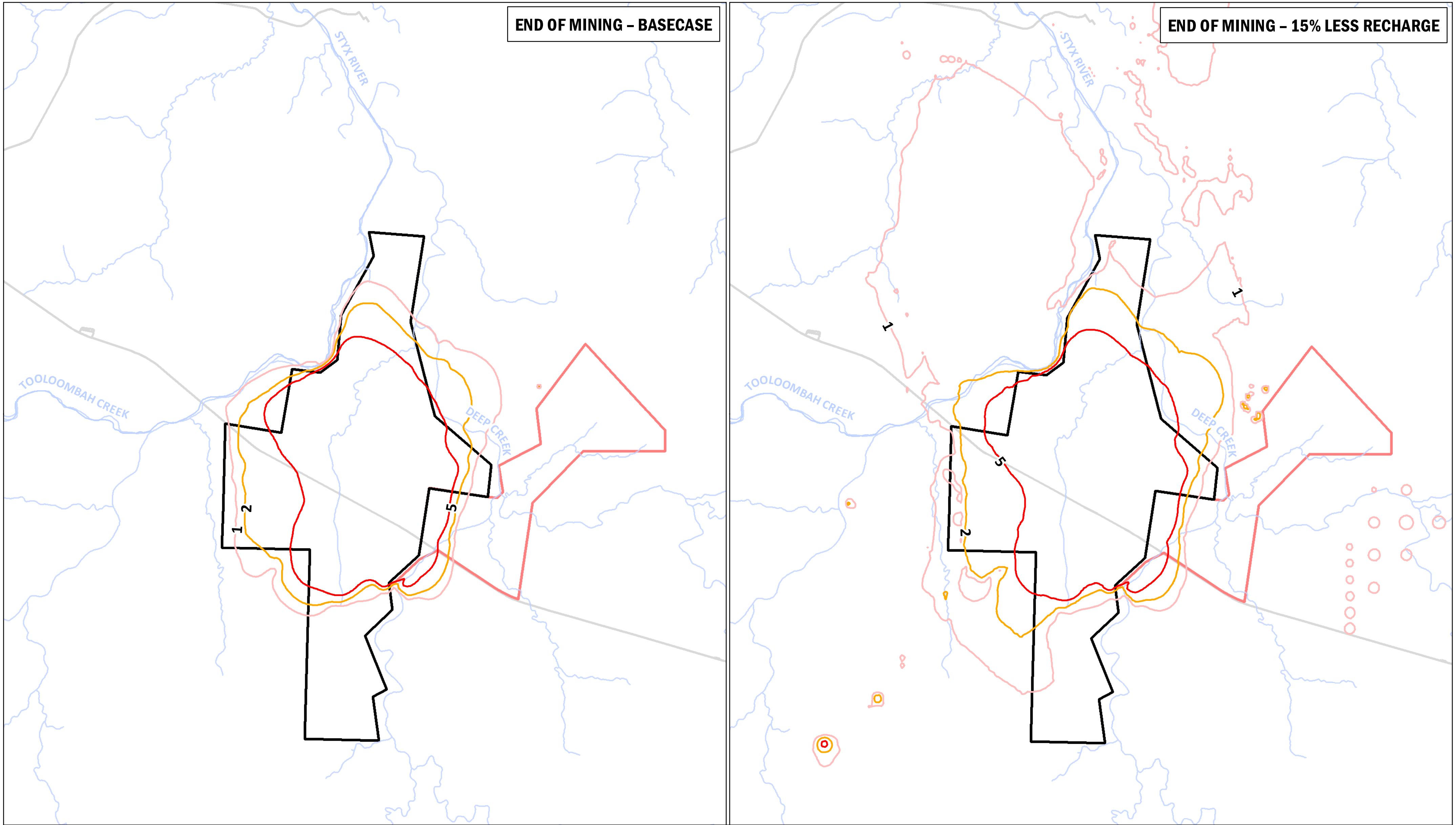


Scale @ A4 1:50,000
Date: 20/12/18
Drawn: Gayle B.

Figure 3-67
Comparison of drawdown at end of mining operations between original and revised mine schedules

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

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 DD comparison_original_new mine schedule.mxd 12/20/2018



N

0 1 2 km

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 3-68

Comparison of drawdown at end of mining operations between basecase and 15% less recharge during the life of mine

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 dry scenarios 15p less recharge during LOM r4.mxd 12/20/2018

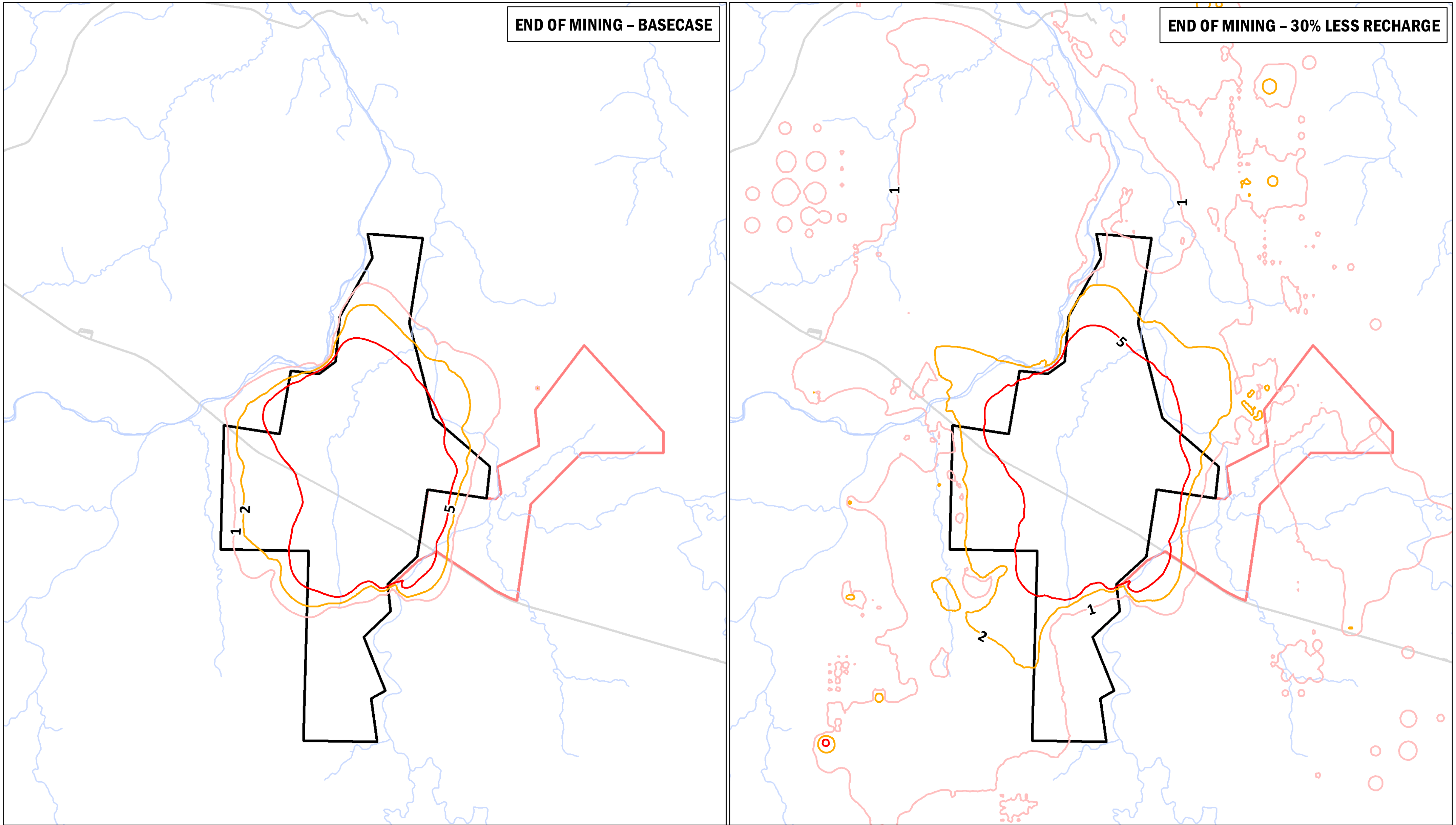


Figure 3-69

Comparison of drawdown at end of mining operations between basecase and 30% less recharge during the life of mine

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

N

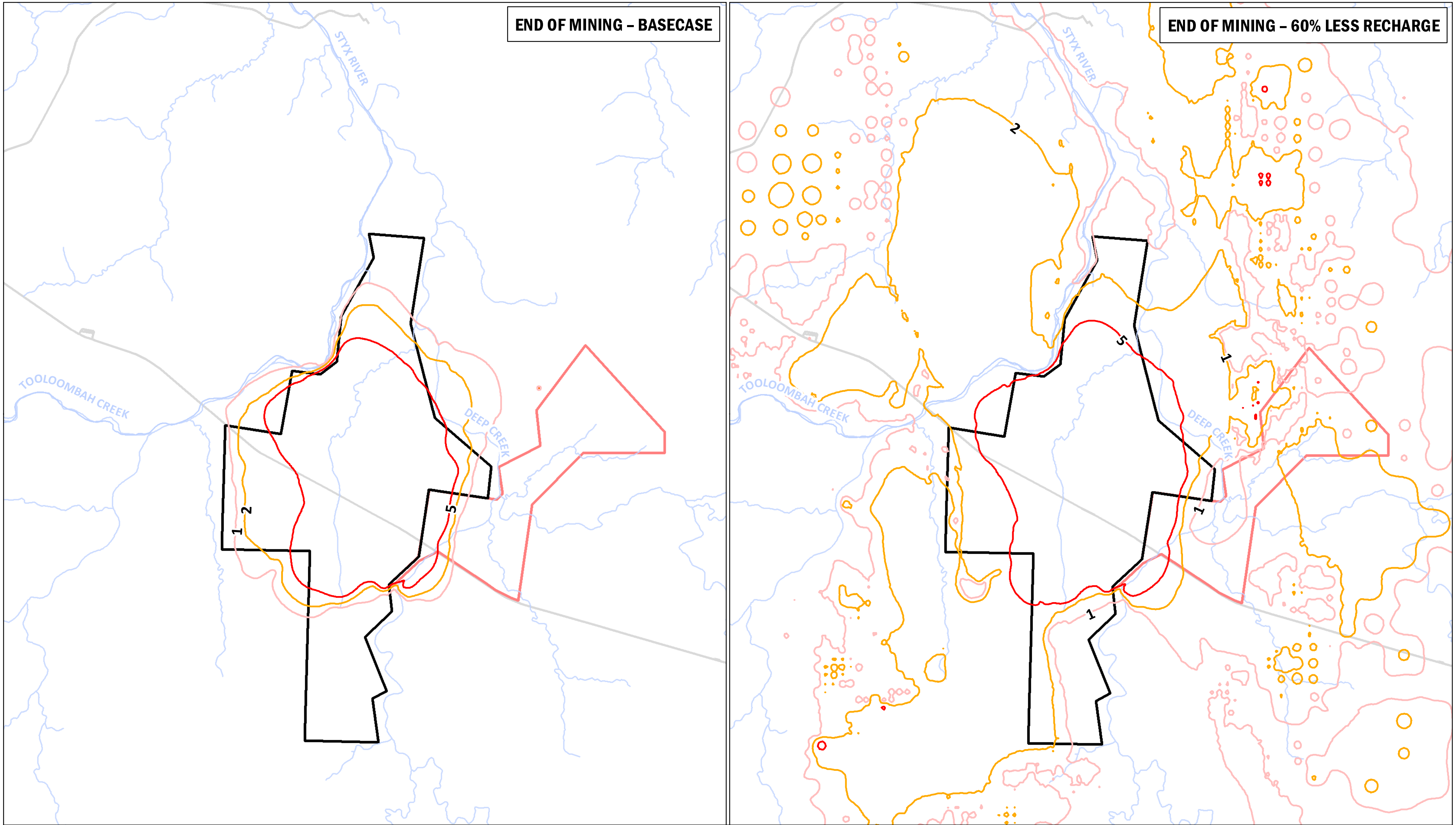
0 1 2 km

Scale @ A4 1:100,000
Date: 20/12/18
Drawn: Gayle B.

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

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\FINAL\1000111 A6 WT dry scenarios 30p less recharge during LOM r4.mxd 12/20/2018



N

0 1 2 km

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 3-70

Comparison of drawdown at end of mining operations between basecase and 60% less recharge during the life of mine

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 dry scenarios 60p less recharge during LOM r4.mxd 12/20/2018

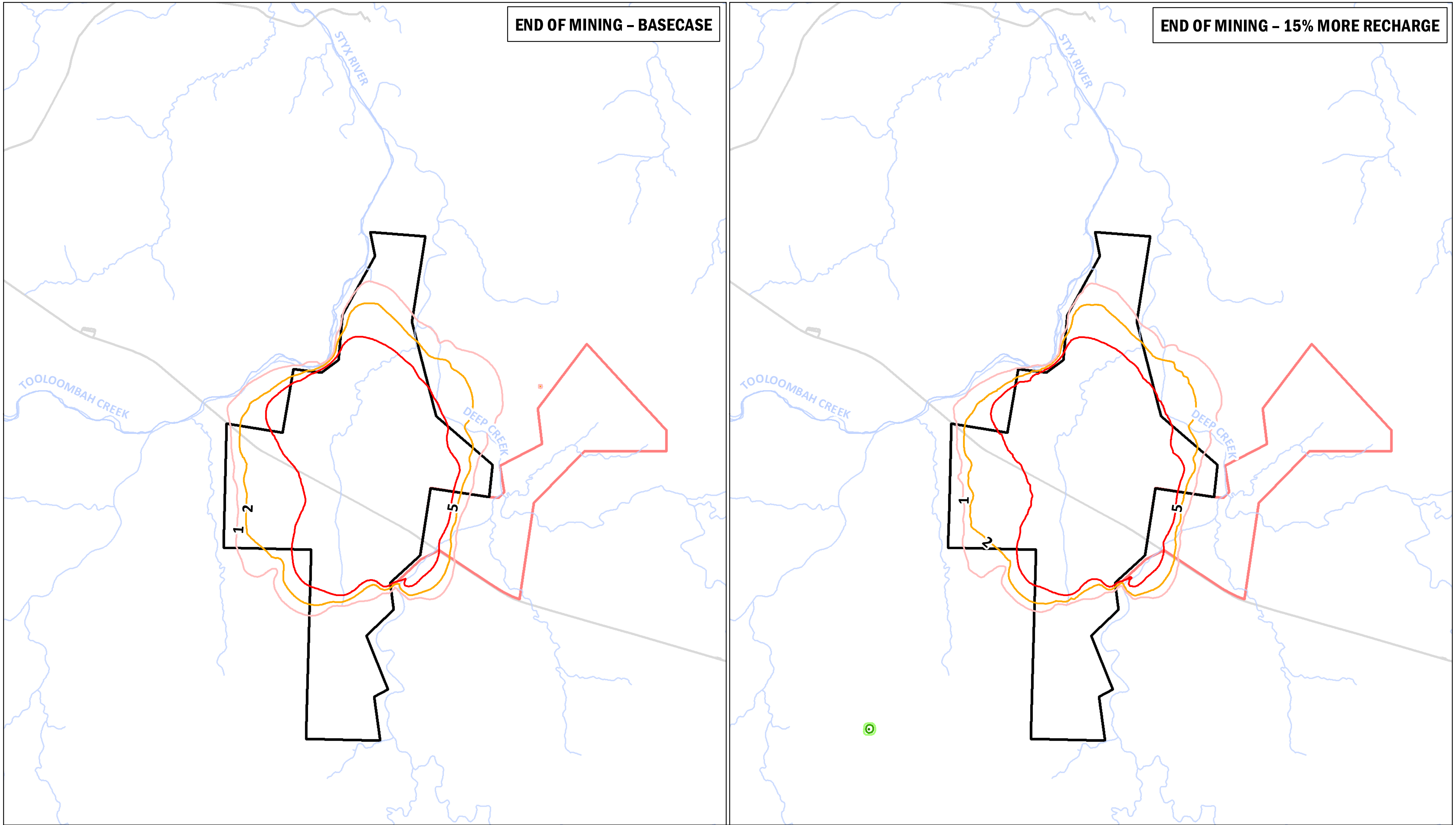


Figure 3-71

Comparison of drawdown at end of mining operations between basecase and 15% more recharge during 5 years of mining

N

0 1 2 km

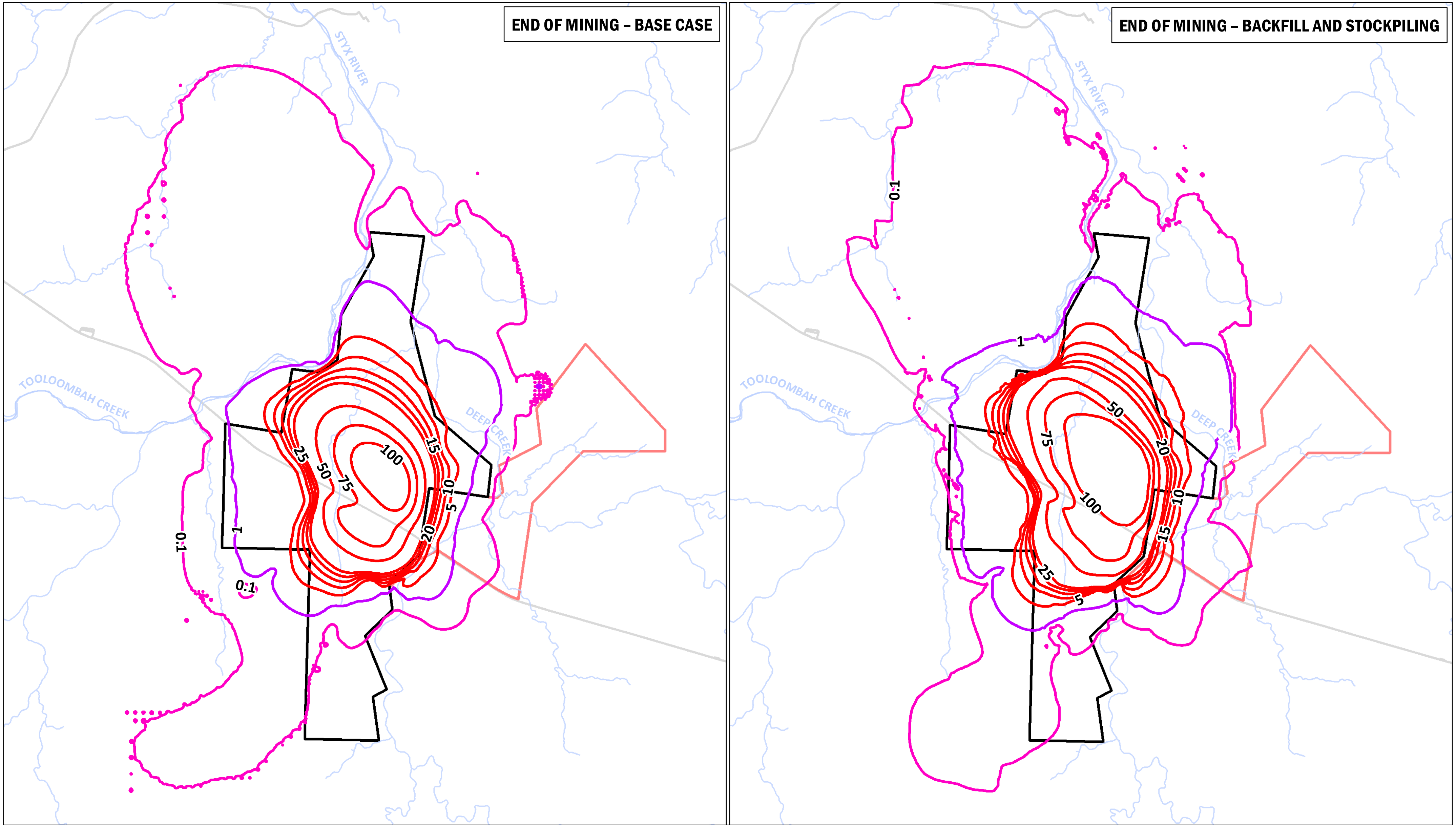
Scale @ A4 1:100,000
Date: 20/12/18
Drawn: Gayle B.

Legend

- Predicted drawdown contour (m)
- Major watercourse
- Main road
- ML 80187
- ML 700022

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

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



N

0 1 2 km

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 3-72
Comparison of drawdown at end of mining operations
between basecase and the representation of backfill and stockpiling

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

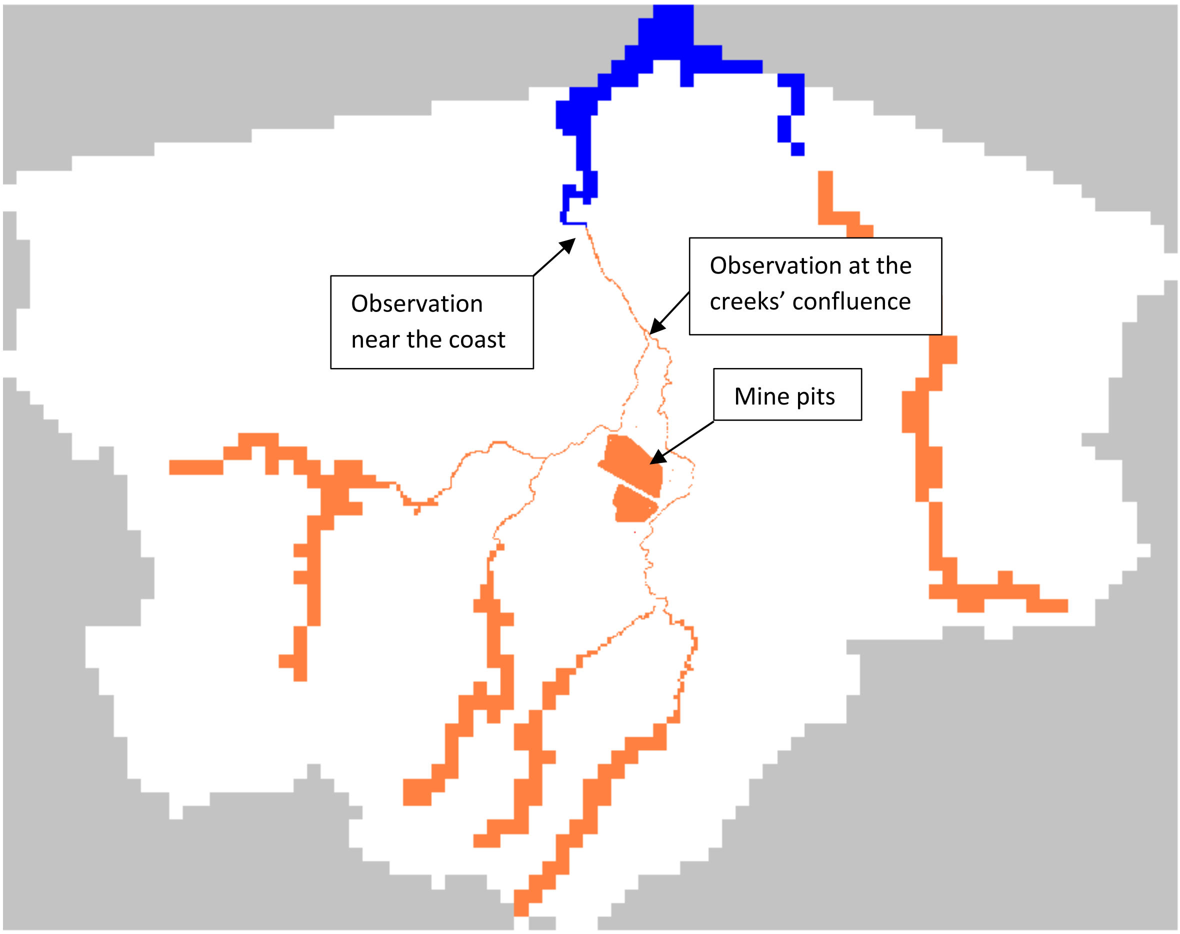


Figure 3-73 Location of observations for the analysis

Seven scenarios have been designed and run. The description of the scenarios and justification are as follow:

- Scenario 1

  For this scenario the hydraulic conductivity of the Styx overburden alone was progressively increased. The sensitivity analysis (Figure 3-57) showed this unit has limited influence on the calibration. The low sensitivity indicates the parameter value is not well constrained by the calibration and hence can potentially be higher. In particular, the calibrated value for this parameter (0.0017 m/d) is located at the lower end of the expected range based on slug test estimates (0.0005 to 0.05 m/d).

- Scenario 2

  For this scenario the hydraulic conductivity of the Styx interburden alone was increased. The interburden hydraulic conductivity is the least sensitive parameter of the calibration (Figure 3-57) and therefore its value is not well constrained by the calibration. However, as the interburden constitutes the targeted unit for mining operations, the predictive uncertainty related to this parameter is significant. The calibrated value for this parameter is also at the lower bound (0.001m/d) of expected range (0.001 to 0.5 m/d).

- Scenario 3

  For this scenario the hydraulic conductivity of the Styx interburden and overburden were increased concurrently. These units show the smallest sensitivities, and therefore they potentially have a high combined predictive uncertainty.

- Scenario 4
  For this scenario the hydraulic conductivity of all the Styx coal measures were increased. This scenario is more likely to rapidly break calibration as the underburden conductivity is highly sensitive. However, this analysis aims to identify which condition would be required within the whole coal measures sequence to trigger significant drawdown.
- Scenario 5
  For this scenario the hydraulic conductivity within the alluvium was increased. The alluvium hydraulic conductivity is the second most sensitive parameter. Increasing the alluvium hydraulic conductivity will likely rapidly impact the calibration and the confidence in its value.
- Scenario 6
  For this scenario the hydraulic conductivity of the basement was increased. The basement hydraulic conductivity is a sensitive parameter and therefore well constrained by the field observations during calibration. Moreover, the basement unit is not mined, and it is not expected to have a large associated predictive uncertainty. However, this scenario will evaluate whether an insufficient characterisation of the basement unit poses a risk to the model objectives;
- Scenario 7
  For this scenario all the model parameters described for Scenarios 1 to 6 were increased. This scenario assesses whether higher hydraulic conductivities than calibrated value for all units have the potential to trigger significant impact.

For each scenario, the range of hydraulic conductivities extends from the best calibrated value to at least two orders of magnitude higher. The assessed range covers and exceeds the anticipated range of values for each parameter. For each scenario, between 12 to 20 runs were processed with progressively rising values in order to identify where impact to predicted drawdowns becomes noticeable and to what extent predictions change.

Storativity uncertainty was not assessed in this analysis. Calibrated storativity is at the lowest bound of the pre-calibration range and lowest value of storativity are conservative in terms of drawdown. It makes little sense to decrease this parameter further to assess a potential breaking point. Moreover, storativity is not a particularly sensitive parameters concerning predictive heads as illustrated in the sensitivity analysis (see section 3.7.1).

Table 3-14 summarises the parameter ranges that were explored.

Table 3-14 Range of hydraulic conductivity values explored

Scenario	Alluvium	Overburden K [m/d]	Interburden K [m/d]	Underburden K [m/d]	Basement
1	4.1	1.7×10^{-3} to 1.7×10^{-1}	0.001	0.001	0.00044
2	4.1	1.7×10^{-3}	0.001 to 2	0.001	0.00044
3	4.1	1.7×10^{-3} to 1.7×10^{-1}	0.005 to 2	0.001	0.00044
4	4.1	1.7×10^{-3} to 1.7×10^{-1}	0.001 to 2	0.001 to 0.1	0.00044
5	4.1 to 150	1.7×10^{-3}	0.001	0.001	0.00044
6	4.1	1.7×10^{-3}	0.001	0.001	0.0004 to 0.044

Scenario	Alluvium	Overburden K [m/d]	Interburden K [m/d]	Underburden K [m/d]	Basement
7	4 to 50	1.7×10^{-3} to 2.5×10^{-3}	0.001 to 2.5	1×10^{-3} to 0.1	0.0004 to 0.044

3.7.3.2 Results

Drawdown at the simulated coast observation point for all scenarios is illustrated on Figure 3-74, and drawdown at the simulated creeks confluence observation point is illustrated on Figure 3-75.

Near the coast[3], the various scenarios indicate that:

- The drawdown is negligible (<0.05m) regardless of the value of hydraulic conductivity in the alluvium (scenario 5), overburden (scenario 1) and basement (scenario 6).
- A drawdown of more than 0.5m is triggered when the hydraulic conductivity of the interburden exceeds 0.5m/d. This is true whether only the interburden hydraulic conductivity is increased (scenario 2) or when it is in conjunction with other units (scenarios 3, 4 and 7).
- With a uniform hydraulic conductivity of 2m/d for the interburden, a drawdown maximum of 2 m would be observed near the coast. This is true regardless of the hydraulic conductivity of any of the other units.

At the confluence of Deep and Tooloombah Creek, the various scenarios indicate that:

- The drawdown is small (<0.2 m) regardless of the value of hydraulic conductivity in the Alluvium (scenario 5), overburden (scenario 1) and basement (scenario 6).
- A drawdown of more than 5 m is triggered when the hydraulic conductivity of the interburden exceeds 0.5 m/d. This is true whether only the interburden hydraulic conductivity is increased (scenario 2) or when it is in conjunction with other units (scenarios 3, 4 and 7).
- With a uniform hydraulic conductivity of 2 m/d in the interburden, a maximum drawdown of about 25 m would be observed. This is true regardless of the hydraulic conductivity in any of the other units.

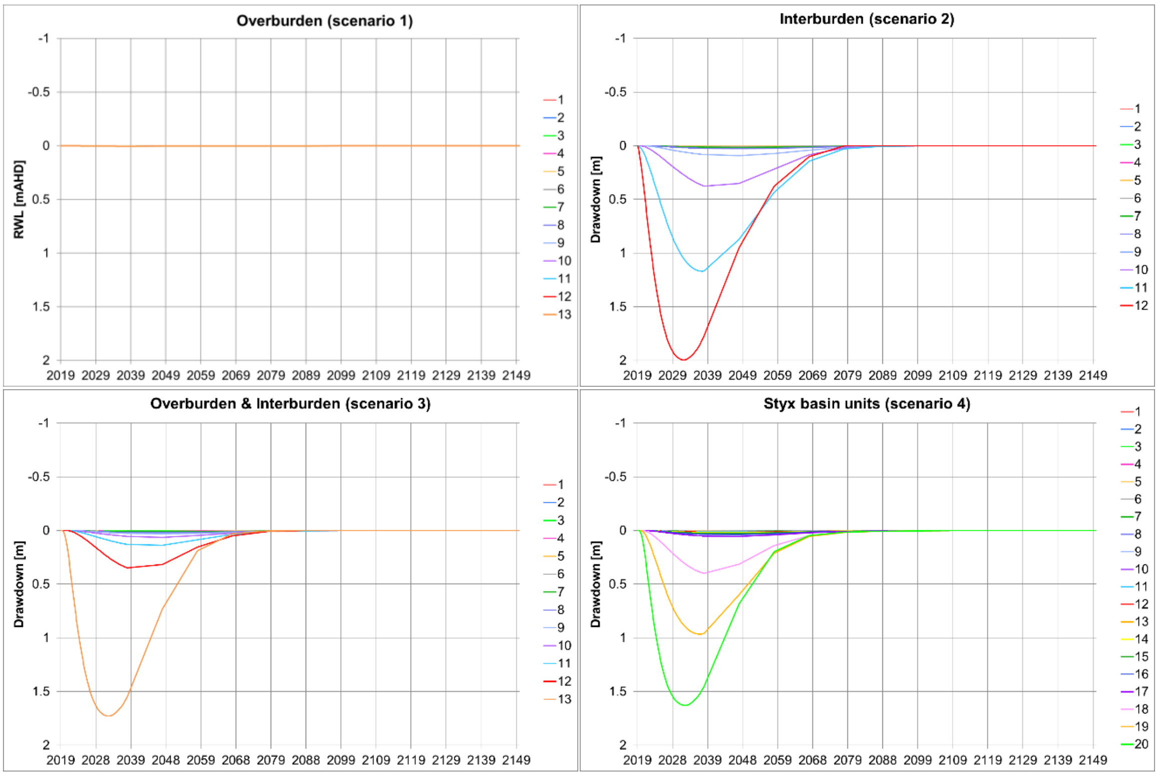
The following remarks can be derived from the 'breaking-point' assessment:

- Misestimation of the hydraulic conductivity within the alluvium, overburden, underburden and basement have only limited predictive consequence regarding the extent of the cone of depression in the modeled potentiometric surface.
- The extent of downstream drawdown within the Styx Basin is mainly controlled by the hydraulic conductivity of the Styx interburden unit. Most of the predictive uncertainty in terms of the extent of the cone of depression relies on the characterisation of the interburden.
- The pre-calibration range for the interburden hydraulic conductivity extends from 0.0005 to 0.5 m/d. At 0.5 m/d a drawdown of about 0.5 m is predicted near the coast and about 5 m at the creeks' confluence. To evaluate whether a uniform hydraulic conductivity of 0.5m/d or higher could reasonably define the regional interburden hydraulic property, for all the scenarios runs, calibration statistics have been calculated for observations located in the interburden unit (see target location on Figure 3-10). As illustrated on Figure 3-76, the best

[3] The coast is represented in the model by a constant head BC. To prevent the constant head BC to fully control the head of the observation point, it was located 300m further south

sRMS within the interburden is 5.3%. for the low value of hydraulic conductivity (<0.01 m/d for scenario 2).

- For values higher than 0.01 m/d the calibration deteriorates progressively and the sRMS is more 20 for any value of hydraulic conductivity above 0.2 m/d for all scenarios, indicating a regional hydraulic conductivity of more than 0.2 m/d is unlikely to be representative.
- A representative regional hydraulic conductivity value of 0.01 m/d or less is more likely to be representative[4]. For this range of interburden hydraulic conductivity, the cone of drawdown remains within the vicinity of the mine. At the confluence of the two creeks, the drawdown remains below 0.5 m and negligible near the coast (<0.05 m).



[4] Note. These estimations are relative to the calibrated regional recharge (see Table 3-5). For a different value of recharge the values would need to be adjusted accordingly. However, the uncertainty on those values mirroring recharge uncertainty is less than an order of magnitude.

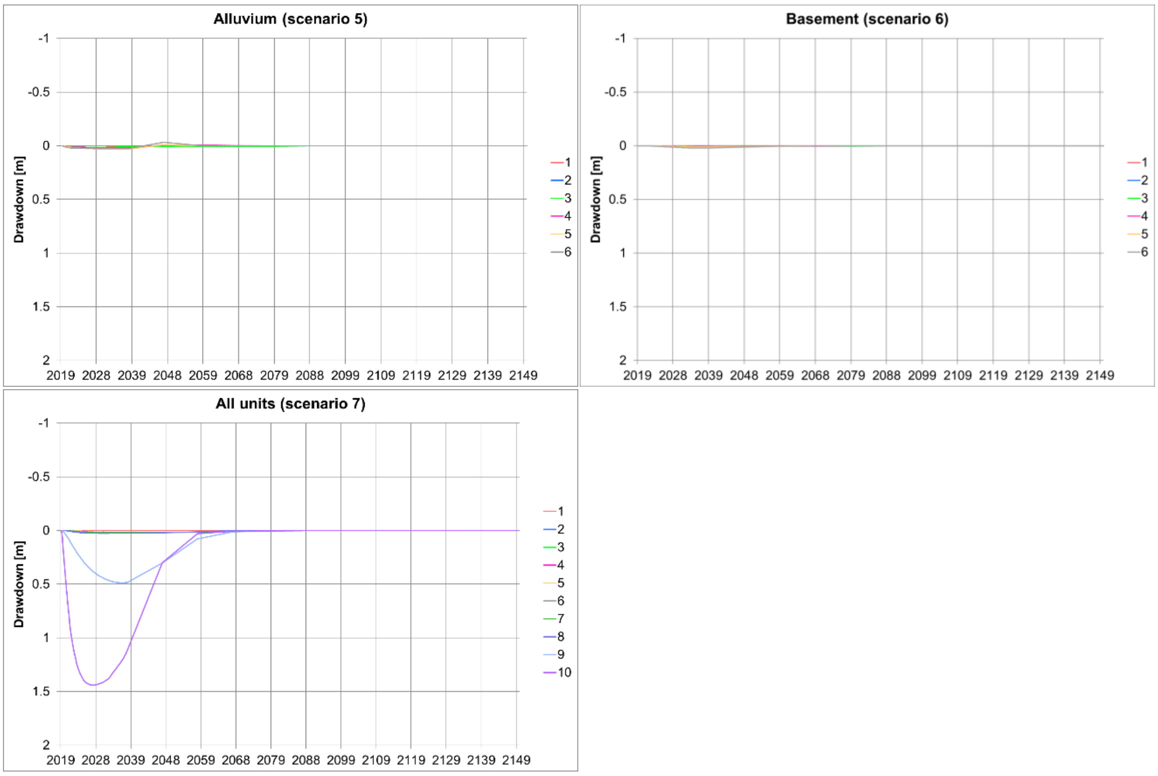
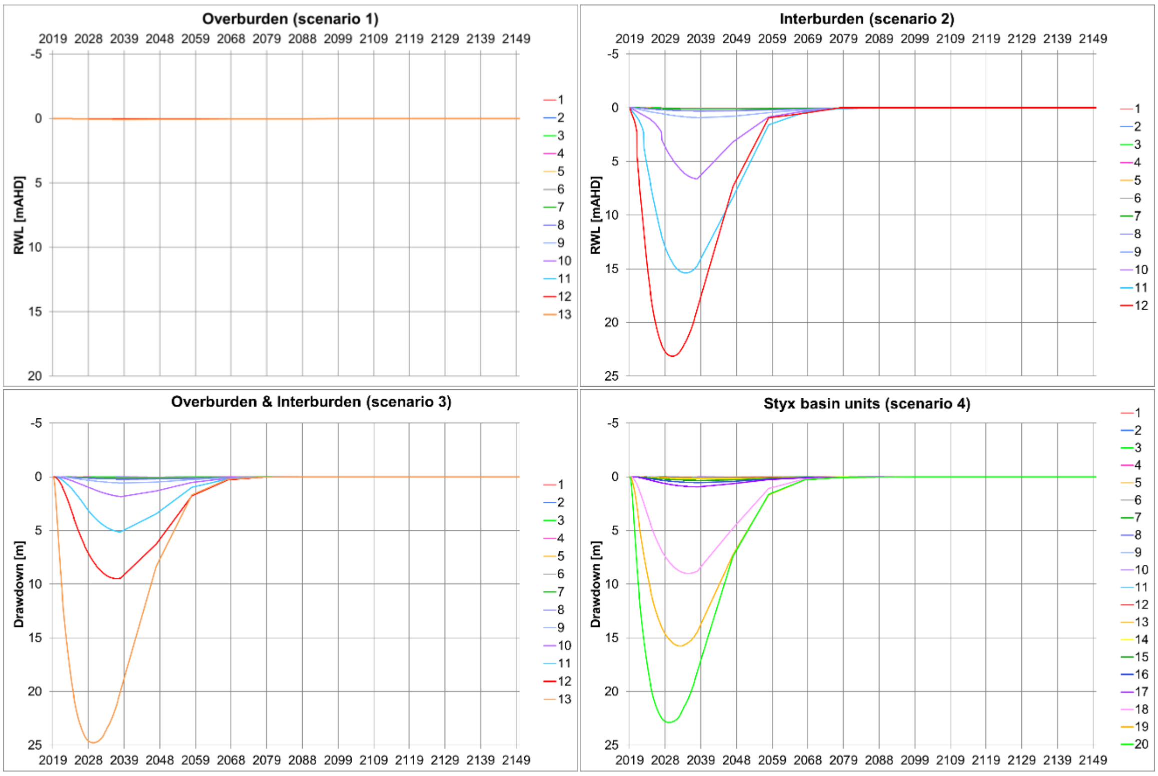


Figure 3-74 Predicted drawdown near the coast



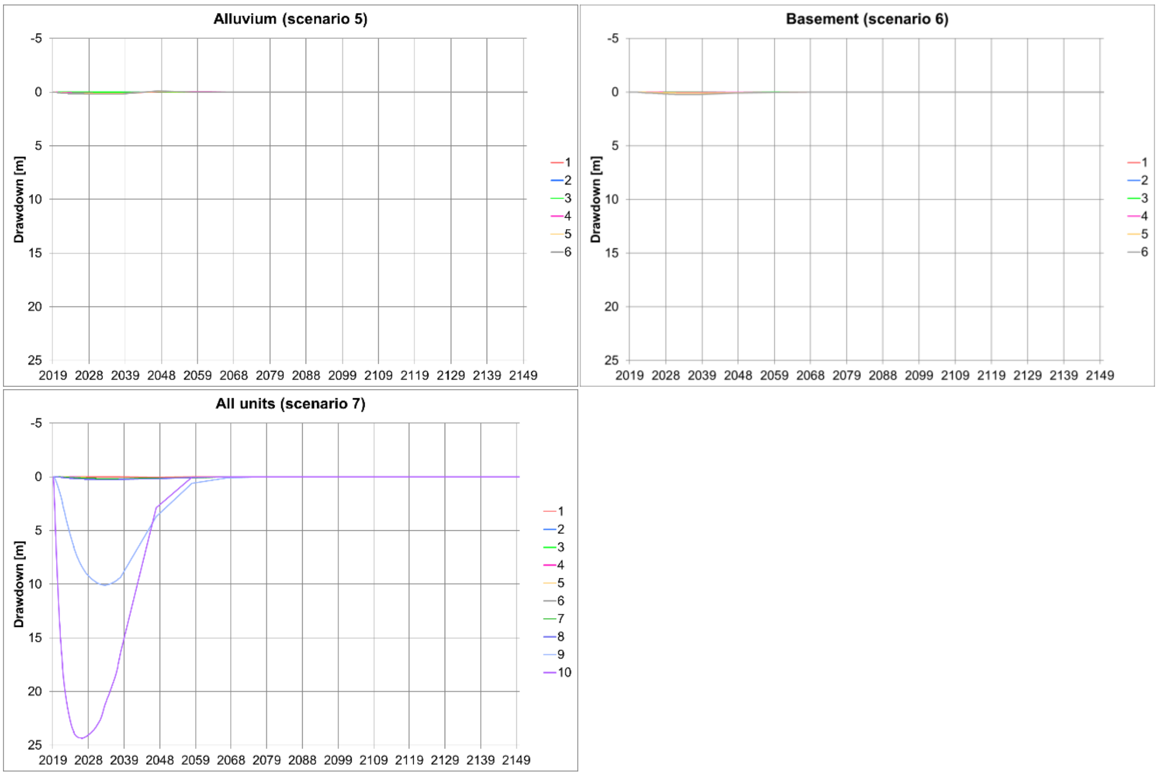


Figure 3-75 Predicted drawdown at the Tooloombah and Deep Creek confluence

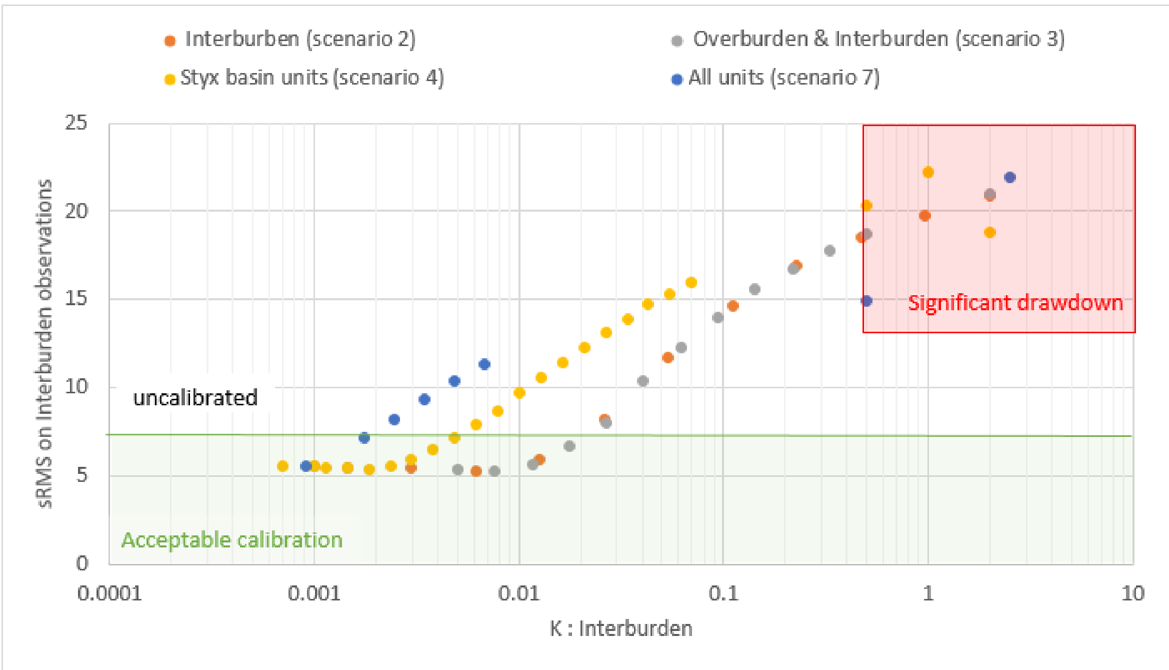


Figure 3-76 Interburden sRMS observations versus interburden hydraulic conductivity for all scenarios

The predictive consequence for a range of hydraulic conductivities spanning beyond the pre-calibration estimated range was explored. The range explored during the uncertainty analysis is illustrated on Figure 3-69.

The hydraulic conditions required for a significant impact are not supported by field water level observations. The conclusions for each HSU are as follow:

- Alluvium
  The calibrated hydraulic conductivity value is 4.1 m/d. This value is within the pre-calibration expected range. Moreover, it is demonstrated that higher values of hydraulic conductivity for the alluvial aquifer, while being less reliable as they impact calibration do not trigger a significantly wider depression cone, which is probably in relation to the limited depth of the alluvium aquifer.
- Overburden
  The calibrated hydraulic conductivity of the overburden (0.02 m/d) is in the lower end of the pre-calibration expected range (0.0005 to 0. 5 m/d). The e overburden is absent on the western side of the mine pits and therefore is only mined on the eastern side of the mine pits where it overlies the resource bearing interburden. As it is only marginally mined, it has only very limited control on the extension of the drawdown cone as illustrated at both observation points (Figure 3-74 and Figure 3-75). The influence of the overburden on the predictive uncertainty in terms of the extent of the cone of depression is small and even overly conservative values don't trigger significant impact.
- Interburden
  The interburden hydraulic conductivity value is the most critical for the assessment. The calibrated value (0.003) is at the lower end of the expected pre-calibration range (0.0005 to 0.5 m/d). At the upper end of the range, predicted drawdown related to mining would extend to the coast. However, such values, even though locally acceptable, are unlikely to be regionally representative of the unit as they are not compatible with the regional gradient within the unit as determined by observed head's calibration. A regional value of 0.01 m/d or less is compatible with the calibration to observed heads and hence more likely.
- Underburden and Basement
  The underburden and basement hydraulic conductivity are highly sensitive parameters and therefore well constrained by the calibration. There is good confidence in their estimation (respectively 0.004 and 0.0004 m/d for the calibrated recharge). Moreover, the predictive uncertainty related to these units is low mainly as they are located below the targeted mining units.
- Vertical anisotropy
  The modelling has assumed no vertical anisotropy for the basement and the three Styx coal measures units. This assumption is conservative as demonstrate in chapter 0 (see Figure 3-65).

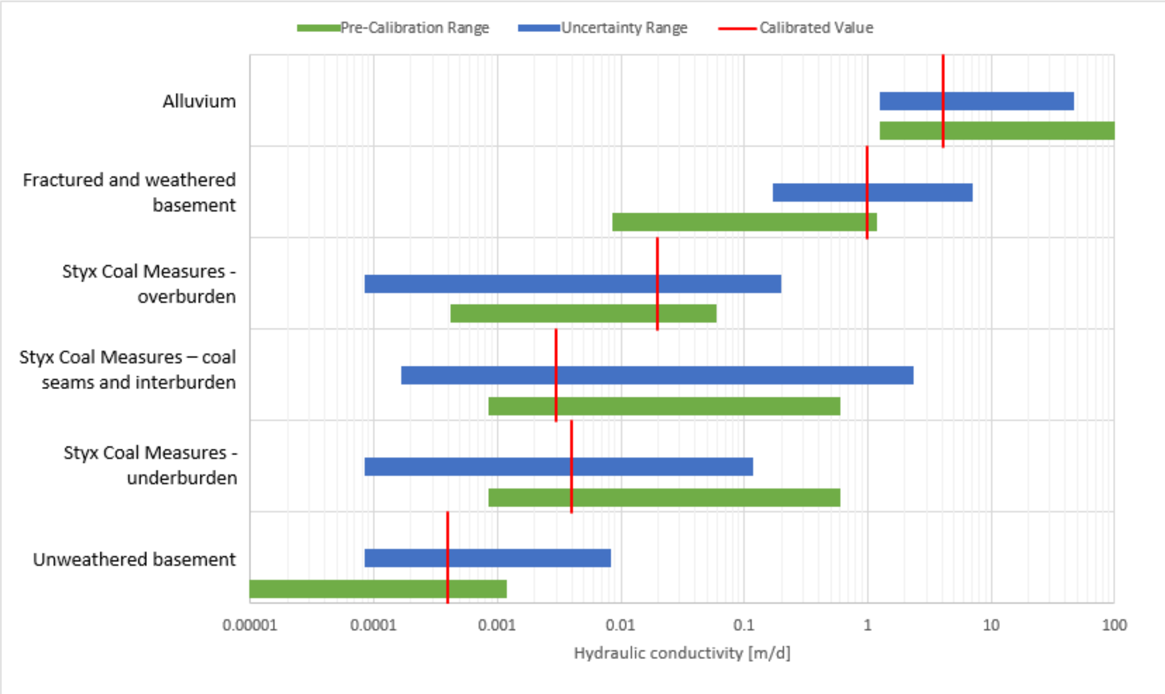


Figure 3-77 Hydraulic conductivity ranges (pre-model calibration, calibrated values and uncertainty analysis)

The uncertainty analysis has revealed the hydraulic conductivity of the interburden is the most critical modelled hydraulic property for the impact assessment. It carries most of the predictive uncertainty in terms of the extent of the predicted drawdown. To maintain the calibration of the interburden unit, a representative regional value ought to be lower than 0.01 m/d. With a hydraulic conductivity lower than 0.01m/d less than 0.5 m of drawdown is predicted to reach the confluence of Deep and Tooloombah Creeks. The calibrated regional value of hydraulic conductivity is within the range of the field program (see Chapter 10 of the SEIS, Section 10.5.6.3) which reports of hydraulic conductivities within the Styx Coal Measures spanning from 0.001m/d to 0.3m/d. These values have mainly been obtained by slug tests and therefore have only a local scope, while the numerical model reflects the regional behaviour. Field values indicate a large local variability of hydraulic conductivity within the Styx Basin.

Misestimation of hydraulic conductivity in the other units (alluvium, overburden, underburden and basement) have only very limited predictive consequences in terms of the extent of the depression cone.

3.8 Numerical model conclusions

The numerical model assessment consisted of a calibrated model and an additional 190 models build to assess the predictive uncertainty related to the mining operations;

The following provides summary conclusions for groundwater modelling undertaken for the Project:

1. During mining, the maximum predicted drawdown exceeds 100 m, but this is restricted to ML 80187 immediately surrounding the pits. 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 of the mine at around year 10 post-mine, and does not intercept Styx River.

2. 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 and associated riparian zones.

3. The model predictions and predictive uncertainty results also support the conceptualisation that the combined Tooloombah Creek and Deep Creek catchments, within which the Project is located, is essentially a closed groundwater catchment.

4. 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 in response to the Project is negligible.

5. 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 predicted to fully recover sometime after 50 years (but before 100 years).

6. The groundwater model calibration is most sensitive to the hydraulic conductivity of the Styx Coal Measures underburden, the hydraulic conductivity of the alluvium, and recharge rates.

7. The predictive uncertainty in term of drawdown extent is mainly controlled by the hydraulic conductivity within the interburden. For this reason, the characterisation of this unit is the most critical to further reduce predictive uncertainty. The uncertainty analysis showed that the calibration of interburden observations can be maintained with a representative regional value lower than 0.01 m/d.

8. Predictive uncertainty analysis indicates, in a most severe possible scenario, significant drawdown associated with mine water affecting activities will not extend to areas where there is a potential for exposure of ASS to occur, or along the tidal reach of Styx further. Consequently, any threat to marine and aquatic ecosystems associated with ASS is considered negligible.

9. The uncertainty analysis indicates the calibrated model, and the predictions presented in this report, are representative and consistent with the conceptual hydrogeological model, which is presented in SEIS Chapter 10 - Groundwater.

10. The zone of influence from mine dewatering activities is predicted to not reverse hydraulic gradients along Styx River, i.e. it remains a dominantly groundwater discharge zone during and following mining. North of ML 80187, continued groundwater discharge to Tooloombah and Deep Creeks is also predicted.

3.9 Model limitations

The geometry and properties of natural groundwater systems can never be fully characterised, and the past and potential future hydrogeological processes can only be inferred from a limited number of uncertain measurements. Therefore, simplifications are necessary and uncertainty is inherent in groundwater modelling.

The groundwater model for the Project has been constructed based on the available geological data (borehole logs, geological maps, CQC geological model) and calibrated to available groundwater heads using hydraulic property values that are consistent with those derived from on-site hydraulic testing and literature review.

Each HSU is represented by one or more layers that have a homogenous and isotropic distribution of hydraulic properties that aim to represent the behaviour of regional aquifers. Local variability of hydraulic properties is not represented in the model. However, the bulk representation of the hydraulic properties is appropriately simulated, given the purpose of the model is to assess regional effects of mine water affecting activities, particularly mine dewatering and depressurisation.

The uncertainty analysis has considered a wide range of possible hydraulic properties for the Project area groundwater system within the anticipated range of possible values. The analysis explored various combinations of properties that can maintain an adequate model calibration. Nevertheless, in the process of generating calibrated sets of parameters, some parameters extend beyond bounds that are considered reasonable based on observations made of the physical system. This represents a conservative approach that has the tendency to extend the range of possible predictive outcomes.

Mining operations are represented with a yearly time step, which is not an accurate representation of actual operations, i.e. mine pits and other facilities evolve over much shorter timeframes. Simulating mining as a yearly progression is conservative area as the progressive nature of pit development, backfilling and dewatering is not considered.

4 Styx River in-stream pools water balance

4.1 Background and objectives

Permanent pools have been observed along Tooloombah Creek and Deep Creek. The pool levels appear to remain relatively stable across the whole dry season (generally from April to July). Groundwater level observations in the alluvium aquifer indicate an upward hydraulic gradient (from aquifer to pools) across the wet and dry seasons, however the gradients are not strong gradients (i.e. there is less than a metre difference in heads).

The primary objective of the mass balance model is to understand the mechanisms that sustain the permanent and semi-permanent pools in the Tooloombah Creek and Deep Creek catchments.

The pool at To2 (see Figure 10-6 of SEIS Chapter 10 – Groundwater) pool was selected for this assessment as it is the main largest permanent pool in the closest vicinity of the mining operations with sufficient data available to apply a mass balance model.

4.2 Conceptualisation

Figure 4-1 illustrates the conceptual understanding of permanent pool hydrology. The water level in a pool is a balance between the pool inflows (incident rainfall, rainfall runoff, groundwater inflow, transfer along alluvial sediments) and outflows (evaporation, leakage to groundwater, transfer along alluvial sediments).

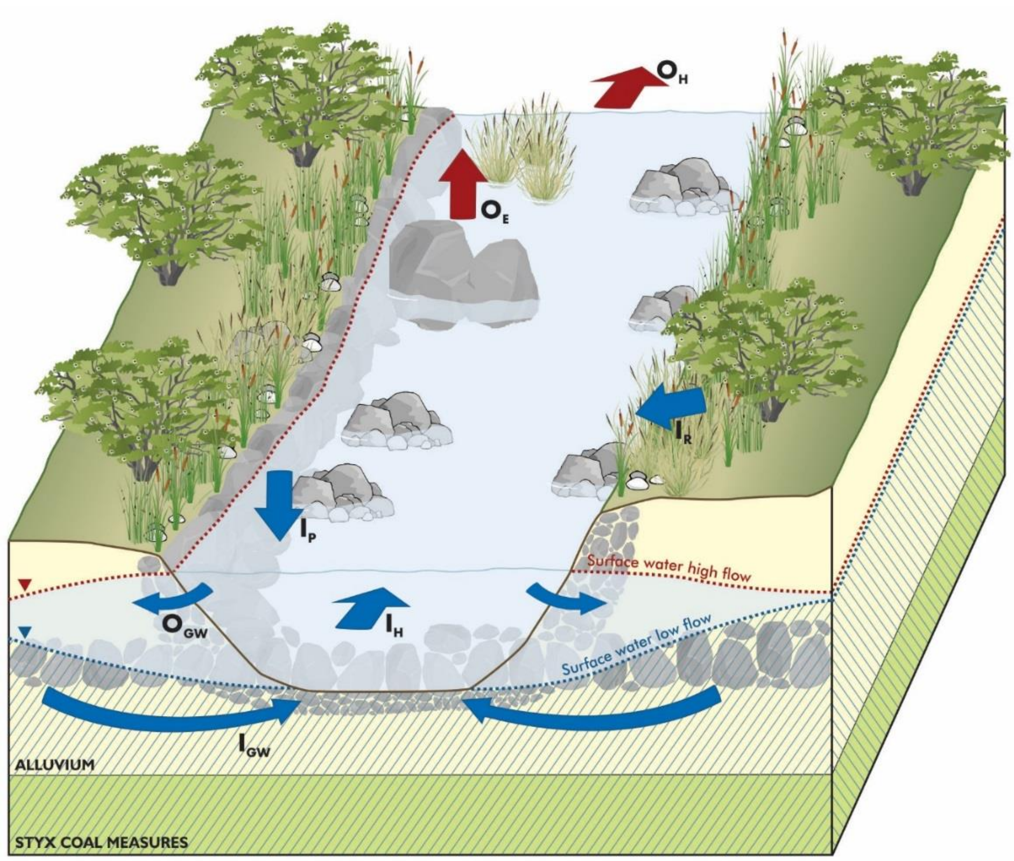


Figure 4-1 Pool conceptualisation

The mass balance can take the form of equation 1.

$$\Delta_{Storage} = I_{GW} + I_P + I_R + I_S - O_E - O_S - O_{GW} \quad (1)$$

where: $\Delta_{Storage}$ is change of storage within the pool (L^3/t)
I_{GW} is groundwater discharge to the pool[5]
I_P *is the* rainfall into the pool (L3/t)
I_R is the runoff to the pool (L3/t)
I_H is the upstream hyporheic zone inflow (L3/t)
O_E is the evaporation from pool (L3/t)
O_H is the downstream hyporheic zone outflow (L3/t)
O_{GW} is the water loss from pool to alluvial aquifer (L^3/t)

During a dry period (defined as the period with no stream flow) with a stable pool water levels, the terms I_R, I_H, O_H, O_{GW} and $\Delta_{Storage}$ become negligible, and the mass balance for a permanent or semi-permanent pool becomes:

$$\Delta_{Storage} = I_{GW} + I_P + O_E = 0 \quad (2)$$

or

$$I_{GW} = O_E - I_P \quad (3)$$

For a dry period, the groundwater contribution to the pool (I_{GW}) is equal to the amount removed by evaporation (O_E) less incident rainfall over the pool.

The groundwater contribution component is made up of water from a number of possible sources. Understanding and quantifying the various contributions is key to predicting the potential impact of mine water affecting activities on the pool water body as not all components will be equally affected.

The possible sources of water for the alluvial aquifer include:

- Rainfall diffuse recharge - Infiltration of rainfall water directly to the alluvial aquifer.
- Bank storage - The recharge of the near stream bank by streamflow during a flood event.
- Aquifer interactions - The exchange of water between adjacent and/or deeper aquifers and the alluvium. The contribution is positive if the head in the aquifer(s) is higher than in the alluvium aquifer, and negative otherwise.
- The creek hyporheic zone – The stream bed is recharged during a stream flow event. The upstream positive contribution to a pool might be matched by a similar negative contribution downstream of the pool if the structure and profile of the alluvium remains unchanged and evaporation is ignored.

Quantifying the respective contribution of all these parameters would be a complex task as the processes change both temporally and spatially (Table 4-1) and because only limited information can be made available to characterise them. The assessment could be made by exploring various lines of evidence including geochemical evidence (identify the chemical signature of each source

[5] I_{GW} is made of groundwater from various contribution including bank storage release (I_B), contribution from the creek hyporheic zone (Iss), from deeper aquifer and from the diffuse rainfall recharge over the alluvium and generating potentially localised perched conditions.

and modelling the potential mixing) and physical evidence (based on respective water level observation; see Table 4-2 for detail).

A detailed analysis of those contributions would allow to understand which portion of the groundwater inflow will be affected by the mining operation. A first approximation and conservative approach is to assume that all the groundwater contribution will be affected by the mining operation.

As illustrated in Table 4-1, the key water source for the alluvial aquifer that may be affected by the proposed mining operation is “aquifer interaction”.

Table 4-1 Characterisation of the alluvium aquifer

Component	Dynamic	Spatial distribution	Affected by mining operations
Bank storage return	The recharge of the alluvial aquifer - episodic and brief (possibly less than 1 month).	Localised in the vicinity of the pool. The extension is controlled by the area flooded and the water level in the creeks during flood events.	Limited as diversions of watercourses are not proposed. However, the bank return could be altered if the vertical gradient between the alluvium and underlaying unit is inverted during mining operations
Diffuse rainfall recharge	Seasonally variable. Controlled by soil and unsaturated zone water content, rainfall patterns and evapotranspiration.	Spread uniformly over the extent of alluvium.	Limited to the extent of the mine activities. Watercourses are unaffected.
Sub surface flow	The recharge of the alluvial aquifer is episodic and brief (possibly less than 1 month).	Localised upstream and downstream, including the pool (small transversal section).	Limited as watercourse diversions are not proposed. However, sub surface flow could be altered if the vertical gradient between the alluvium and underlaying unit is inverted during mining operations
Aquifer interactions	Relatively stable. Controlled by the head differences between heads in the adjacent and/or deeper aquifer(s) and the alluvial aquifer.	Spread variably/unevenly over the extent of the alluvium. The general gradient would support discharge of water from deeper aquifers (and the alluvium) near to watercourses and vice versa away from the watercourses.	The drawdown caused by mine dewatering will alter these dynamics during mining and for some time after the completion of mining.

Table 4-2 Approach to identify pool groundwater contribution

Component	Hydrochemistry	Physical constraint	Other assessments approaches
Bank storage return	Young water (weeks) with little mineralization. Hydrochemical signature likely to be similar to rainfall.	Limited extent restrained by the flood zone, with bank storage estimates based on physical dimensions.	- Bank storage volume assessment - Analytical model - 2D cross section numerical model
Diffuse rainfall recharge	Young water (years). Chloride and Carbonate likely to be dominant anions, and sodium the dominant cation.	Evapotranspiration demand, soil type(s), rainfall patterns and intensity.	- Bucket type model - Unsaturated / saturated model - Analytical model - 2D or 3D numerical models
Sub surface flow	Young water (weeks) with little mineralization. Hydrochemical signature likely to be similar to rainfall.	Pre-stream flow moisture content of sediments, homogeneity of hyporheic zone (connectivity, hydraulic conductivity, cross-sectional area).	- Analytical solution (Darcy) - Numerical solution
Aquifer interactions	Old water (>10 years). Hydrochemical signature likely to be similar to deeper aquifer(s). Chloride likely to be dominant anion, and sodium the dominant cation.	Hydraulic head gradients (direction and scale), vertical hydraulic conductivity in sediments and Styx Coal Measures	- Analytical solution (Darcy) - 3D numerical model (check from the existing model)

4.3 Pool water balance calculations

The pool at "To2" is on average approximately one meter deep and has a total surface area of around 4,060 m^2.

For the period from April to July 2018, minor rainfall occurred in the Project area (total of 60 mm for the 4 months, for an average of 0.5 mm/d) and the creeks didn't experience any stream flow. Over the same period the average rate of evapotranspiration is estimated at 4.1 mm/d. The pool water level has remained stable during the period. By applying equation (2) over this dry period, the groundwater contribution is estimated about 3.6mm/d. Assuming that all groundwater contribution will be affected by mining operations, 3.6mm/d would need to be supplied for each affected pool to sustain their level during the dry seasons.

Over the To2 pool area, rainfall is estimated to have contributed approximately 244 m^3 (0.5 mm/d over 4,060 m^2 for 4 months), and ET is estimated to remove around 2000 m^3 (4.1mm/d over 4,060m^2 for 4 months). Based on equation (2), groundwater is estimated to have contributed 1,756 m^3 (14.6 m^3/d, or around 3.6 mm/d). For a longer dry season (i.e. time between creek flow events) of six months long, at 3.6mm/d it is conservatively extrapolated that groundwater might contribute 2,635 m^3 to the permanent pool.
The numerical model (Section 3) estimated that a well in the Styx Coal Measures could sustain an average pumping of 0.7L/s (60m^3/d). At this rate, the well could support 17,000m^2 of pool during the dry season. Such a well could be enough to support To2 water level during the dry season.

The water balance model indicates the amount of water required to sustain in-stream pools during the dry season is around 3.6 mm/d.

5 Targeted GDE investigations

5.1 Introduction

Targeted investigations were undertaken in August 2018 to better understand vegetation water use at three sites where groundwater use by vegetation was considered likely (see Figure 5-1).

The Wetland 1 Assessment Area is listed under the Vegetation Management Act as having High Ecological Value and is also listed as a Wetland Protection Area. It is identified in the BoM GDE Atlas as an artificial/highly modified wetland reliant on surface expression of groundwater. It consists of a clay plan, inhabited predominantly by broad leaf tea tree (*Melaleuca viridiflora*). A single red gum (*Eucalyptus tereticornis*) is located in the centre of the wetland. Soils are heavy clays to a depth of 1.5 m.

The Wetland 2 Assessment Area is also listed under the Vegetation Management Act as having High Ecological Value and is identified in the BoM GDE Atlas as a coastal/sub-coastal floodplain swamp reliant on surface expression of groundwater. It comprises an internally draining swamp that inhabited by sedges and fringed by larger red gums (*E. tereticornis*).

The Alluvial Vine Thicket Assessment Area is located on the southern alluvial terraces of Tooloombah Creek and consists of a community of low canopy (7–10 m) trees comprising a variety of species with occasional emergent red gums (*E. tereticornis*). A varied understory with abundant vines is present. Soils are relatively sandy.

5.2 Methods

5.2.1 Theory

Several tests can be used to evaluate the dependence of vegetation on groundwater (Eamus 2009). Each test is subject to limitations, but a combination can be used to provide a robust assessment in which multiple lines of evidence are examined. The following tests have been selected for this investigation:

- Stable isotopes of water: Stable isotopes are those that do not radioactively decay over time. The stable isotopes of water are those derived from hydrogen (deuterium; ^{2}H) and oxygen ($^{18}0$). The ratio of ^{2}H to ^{1}H and the ratio of ^{18}O to ^{16}O varies for different bodies of water due to isotopic fractionation caused by transport processes and phase transitions through the atmosphere, lithosphere and biosphere (Barnes and Alison 1988). Since the fractionation processes are likely to be different for groundwater, surface water and soil water, different sources of plant water will often, but not always, have different isotopic compositions that will be reflected in the plant xylem water. Knowing the isotopic composition of these sources and plant water can assist in conceptualising plant water uptake.

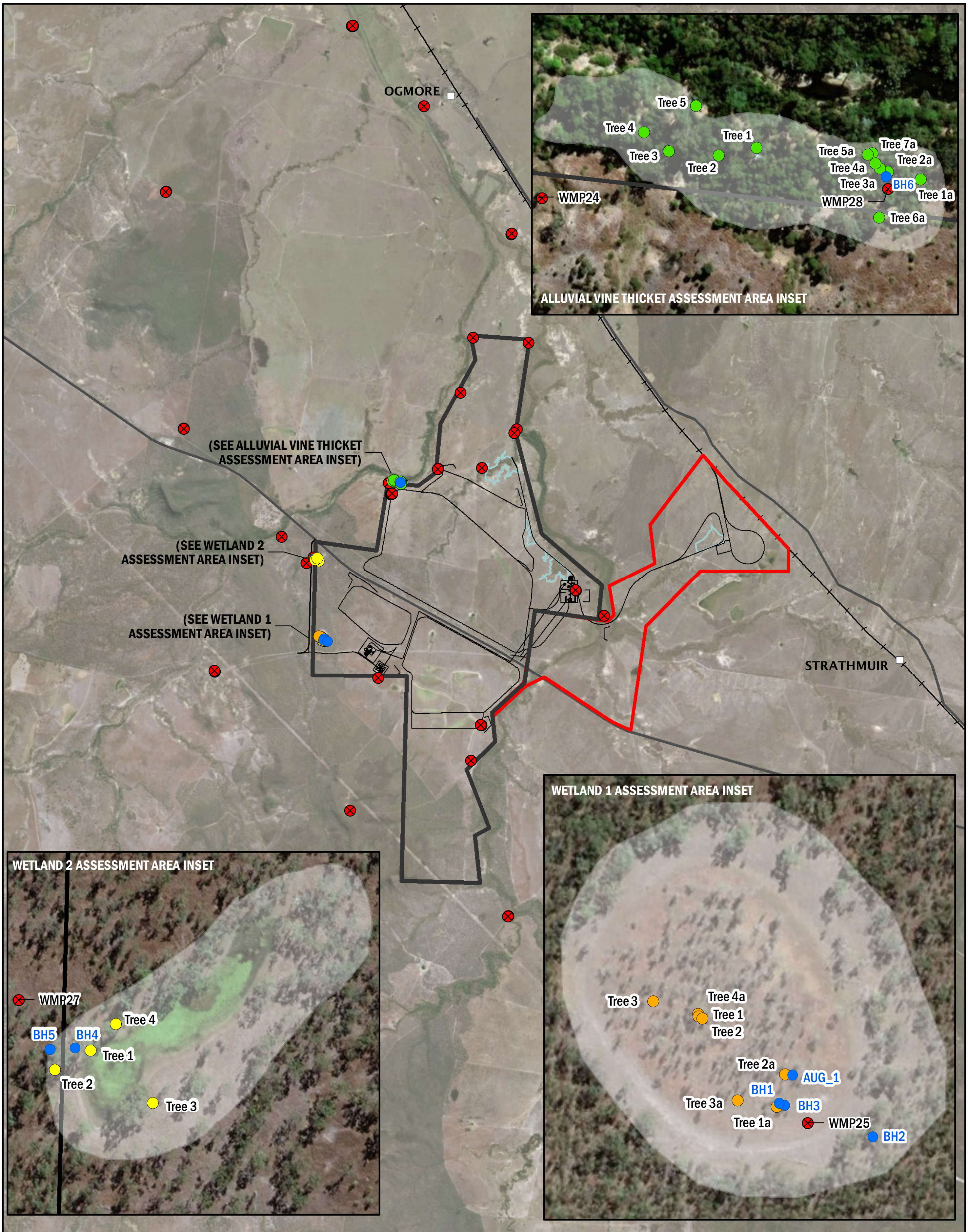


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Figure 5-1
Wetland assessment sites

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

CDM Smith

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- Soil-plant water relations: Plants require water for photosynthesis. Transpiration is the process of plant water use in which plants take up water through their roots, passively transport this water through the xylem, and regulate the diffusive evaporation of this water through the stomata in their leaves. The rate of transpiration is controlled by solar radiation, the evaporative demand of the atmosphere (which is influenced by temperature, humidity, wind speed and incident sunlight), soil water supply, and stomatal regulation. For plants to transpire they must maintain a leaf water potential (LWP) that is more negative than the soil water potential (SWP). A dry soil will have a highly negative SWP and a plant must be able to regulate their stomatal conductance and lower their LWP to be more negative than the SWP to extract water. By contrast, a moist soil or one that is maintained in moist state by shallow groundwater will not require plants to lower their LWP excessively to extract water. Thus, measuring LWP and SWP concurrently provides an indication of where in the soil profile plants are drawing their water from and it also provides an indication as to whether plants have access to groundwater (at the water table, SWP approaches zero). Measurements of LWP are usually made pre-dawn when the difference between LWP and SWP is likely to be smallest because nocturnal transpiration is minimal (Ritchie and Hinckley 1975).

5.2.2 Drilling, sampling and analysis

Six boreholes were drilled as shown in Figure 5-1. BH1, BH2 and BH3 were drilled at Wetland 1. BH4 and BH5 were drilled at Wetland 2. BH6 was drilled at the Alluvial Vine Thicket site. Each of the boreholes were drilled very near to the trees that were sampled and analysed.

Drilling was undertaken using a combination of direct push, and RC drilling methods. Direct push tubes were taken until refusal, with extended drilling undertaken using an RC rig. Care was taken to avoid the use of RC drilling and use of drilling fluids where possible—which compromise soil moisture and soil water isotope analysis—but in a few cases this could not be avoided, and drilling continued with the use of applied water to the base of the borehole. It is also noted that the use of air likely influenced the moisture content of the samples returned. Drilling logs are provided in Attachment 1 and a summary of the drilling undertaken is outlined in Table 5-1.

Table 5-1 Summary details of GDE investigation bore holes

GDE assessment area	Hole ID	Drilling method	Refusal (mbgl)	Total depth	Comments
Wetland 1	BH1	Direct push	1.4	5.0	Drilled in rotary mode from 1.4 to 5 m with applied water
	BH2	Direct push	0.35	5.0	Drilled in rotary mode from 0.35 to 5 m with applied water and not sampled
	BH3	RC		15	Water cut at 13.5 m
Wetland 2	BH4	Direct push	4.2	4.2	Push tube to 4.2 m
	BH5	Direct push/RC	4.2	14.5	RC from 4.2 to 14.5 mbgl, dry to total depth
Alluvial vine thicket	BH6	Direct push/RC		9.85	

Samples were taken in metre increments or at a finer scale. For isotope analysis, samples were immediately sealed in an air-tight sample bag, kept on ice and transported to a freezer before dispatch to the ANU Stable Isotope Laboratory where they were analysed. Soil moisture potential was measured in the field on sub-samples using a WP4C dew-point potentiometer from push tube or from RC cuttings.

5.2.3 Vegetation sampling and analysis

Pre-dawn LWP measurements were made using a pressure chamber device. Measurements were taken on leaves collected from several trees in close proximity to the boreholes at each site. Stem samples were also taken from the outer branches of trees for isotope analysis. As per sampling protocols, they were cut into 5 cm lengths, stripped of bark, stored in leak-proof containers, kept on ice and transported to a freezer for dispatch to the ANU Stable Isotope Laboratory where they were analysed.

5.2.4 Well installation and groundwater sampling

Groundwater wells were installed in September 2018 to monitor the water table at Wetland 1 (WMP25) and Wetland 2 (WMP27). These wells will form part of the monitoring network and can be sampled for isotope analysis if necessary.

5.3 Results

5.3.1 Wetland 1

Drilling logs for the boreholes completed at Wetland 1 (BH1, BH2 and BH3) are shown in Attachment 1. The lithology consists of heavy clay at the surface associated with the clay plan, which is underlain by calcrete bands and layers of sandstone and clay. A moist zone was encountered from 8 mBGL (alluvials and calcrete) and the water table at 10.2 mBGL.

Soil and leaf water potentials at Wetland 1 are presented on Figure 5-2. Much of the soil profile is very dry and well below the agronomic wilting point of -1.5 MPa, noting that native tree species can often tolerate soil moisture potentials well below this level. Root water uptake is indicated where the leaf water potentials are equivalent to or less than the soil water potential. For two of the trees measured, Tree 1 (*M. viridiflora*) and Tree 4a(*E. tereticornis*) root water uptake was indicated from depths of 0.5 to 1.0 m. For the remaining trees, several *M. viridiflora* trees and one *E. tereticornis* specimen, root water uptake was indicated at 8 m where the soil water reservoir appears to be more moist than higher up, possibly linked to the capillary fringe above the water table or to a 'perching' layer in the soil profile at around 8 m depth. The soil samples below the water table do not reflect saturated conditions and may have been influenced by the drilling method which required compressed air to retrieve the samples.

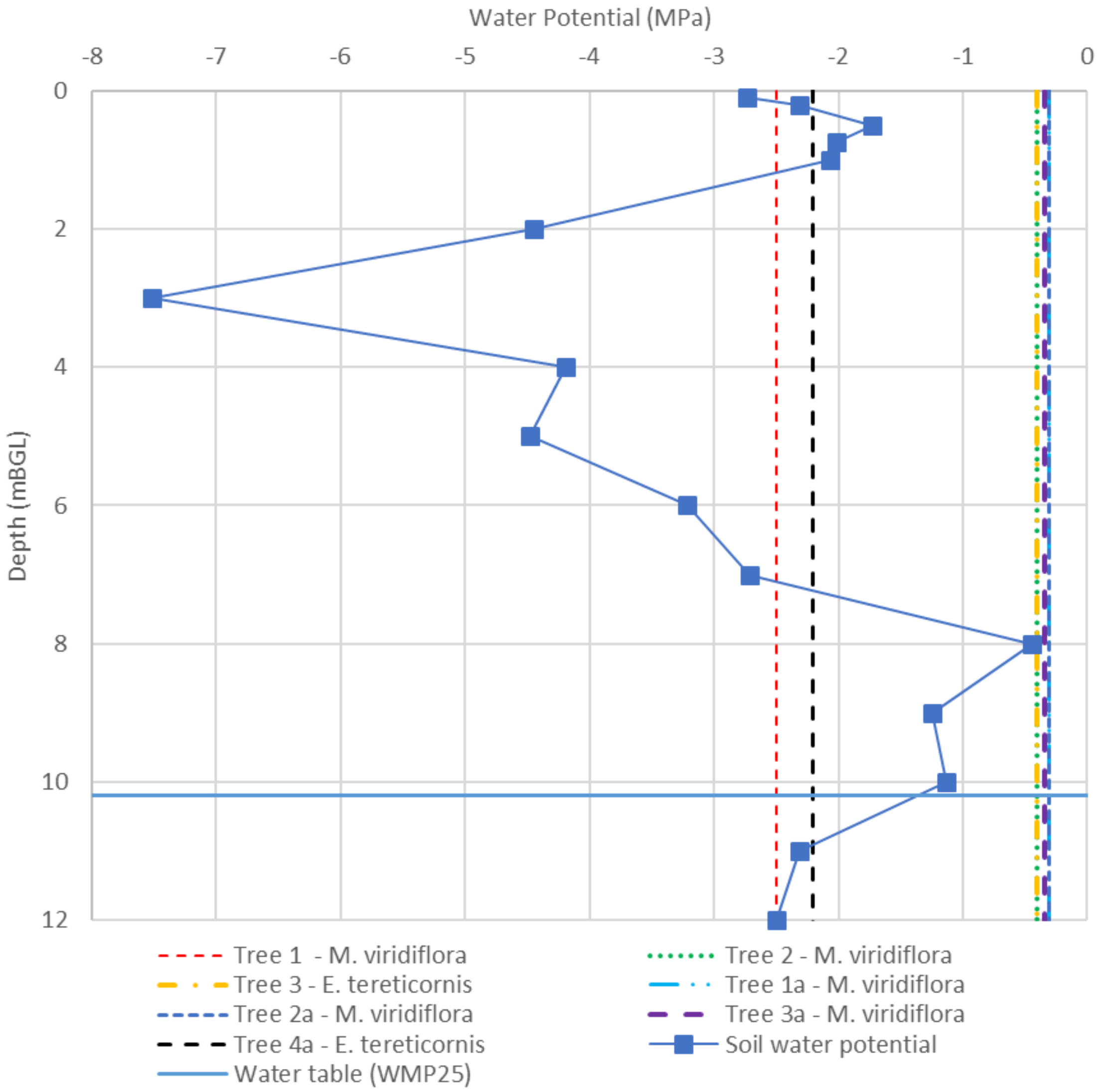


Figure 5-2 Soil and leaf water potentials with depth, Wetland 1

The stable isotopes of water in soil water and vegetation are plotted with respect to depth in Figure 5-3. The shallowest soil sample at 0.1 m is enriched in heavy isotopes due to the fractionation that occurs during evaporation whereby the lighter, standard water molecules (composed of ^{1}H and ^{16}O) are preferentially converted from the liquid to the vapour phase, compared to heavier water molecules composed on ^{2}H and ^{18}O. The isotopic enrichment is mostly confined to the upper few metres of the soil profile.

Groundwater is yet to be sampled directly for isotopic characterisation but the slight enrichment in the deeper samples, below 8m, may reflect the influence of a groundwater signature.

Figure 5-4 presents a scatter plot of $\delta^{18}O$ against $\delta^{2}H$. The Global Meteoric Water Line (GMWL) is presented as an approximate reference for rainfall, noting there may be local deviations from this relationship due to local meteorological processes. The relative enrichment of the ^{18}O molecule reflects an evaporation trend[6] which is interpreted on Figure 5-4 . The vegetation at Wetland 1 has xylem water that plots along this trendline, indicating the xylem water has been sourced primarily from the upper 2 m of the soil profile.

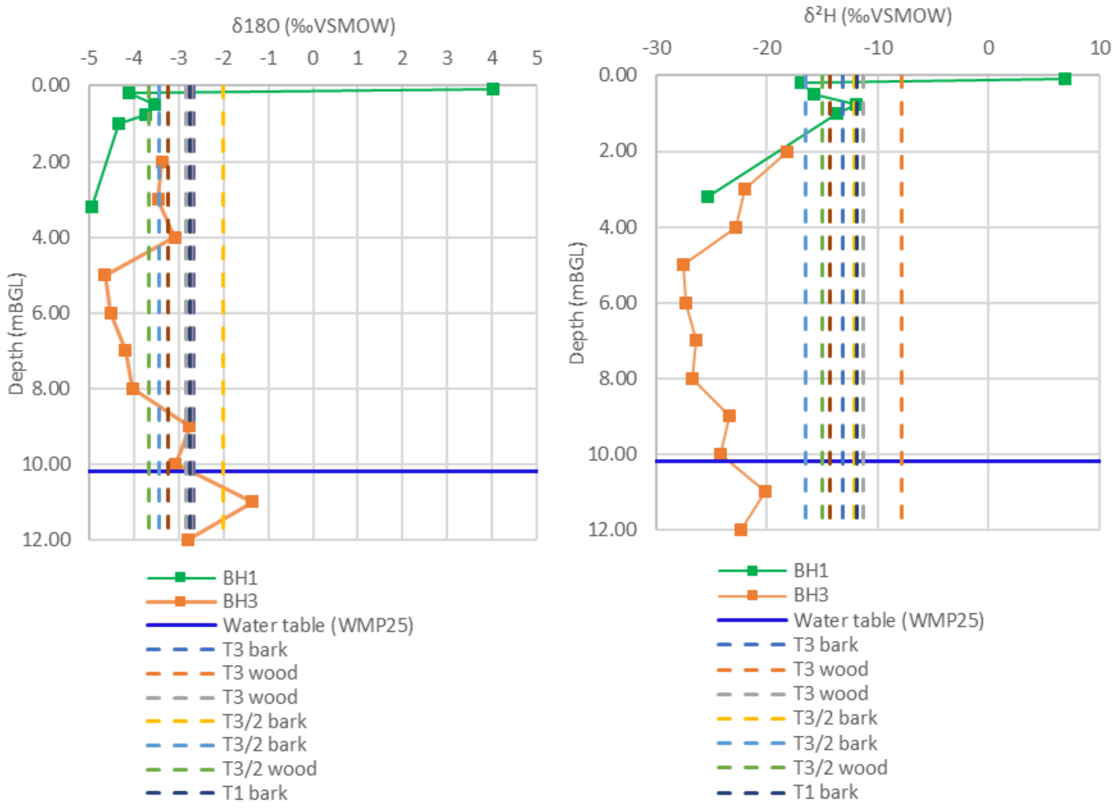


Figure 5-3 Stable isotopes of water in vegetation samples and in soil water with depth, Wetland 1

[6] Because oxygen has a higher atomic weight than hydrogen, the $^{1}H_2{}^{18}O$ molecule is less likely to change from the liquid to the vapour phase than the $^{1}H^{2}H^{16}O$ molecule. For this reason, the relationship between $\delta^{18}O$ and $\delta^{2}H$ will deviate from the GMWL during evaporation (Sprenger et al. 2016).

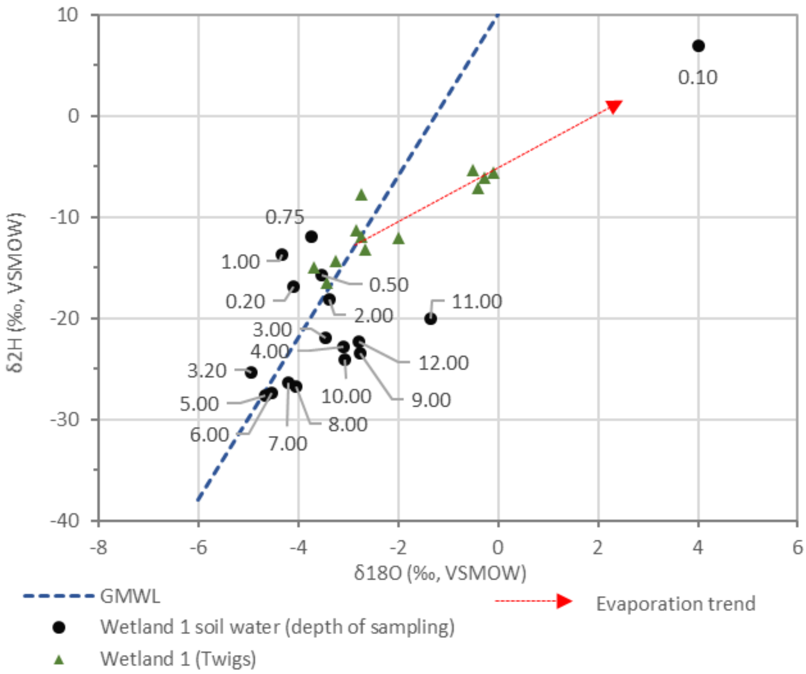


Figure 5-4 Stable isotopes of water in soil and vegetation samples, Wetland 1 (GMWL: Global Meteoric Water Line)

Together, the water potential measurements and the isotope data indicate vegetation at Wetland 1 is sourcing most of its water from the near surface, and maintenance of the surface hydrological regime (run-off and inundation) of the wetland is critically important for maintaining the wetland's environmental water requirements. However, the trees may access deep soil water that is maintained by groundwater to support transpiration requirements during sustained dry periods when the soil water reservoir is otherwise depleted.

5.3.2 Wetland 2

Drilling logs for the boreholes and well completed at Wetland 2 (BH4, BH5 and WMP27) are shown in Attachment 1. The lithology consists of clay at the surface underlain by layers of sand and clay, with sandstone from 15 mBGL. The water table is at about 20 mBGL.

Soil and leaf water potentials at Wetland 2 are presented in Figure 5-5 . Much of the soil profile is very dry and well below the agronomic wilting point of -1.5 MPa, noting that native tree species can often tolerate soil moisture potentials well below this level. Root water uptake is indicated where the leaf water potentials are equivalent to or less than the soil water potential and the results point to root uptake from depths of 2 to 4 m at the time of sampling. There is no indication of groundwater use at this site.

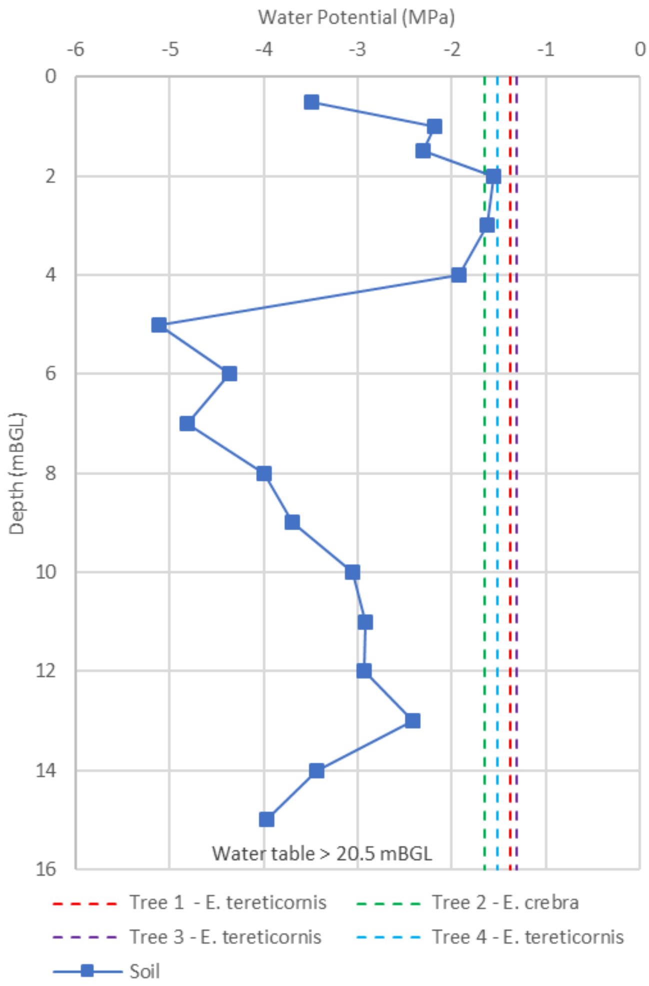


Figure 5-5 Soil and leaf water potentials with depth, Wetland 2

The stable isotopes of water in soil water and vegetation are plotted with respect to depth in Figure 5-6. Samples very near to the surface (e.g. at 0.1 m depth) were not analysed at Wetland 2 so an evaporative zone is not indicated. There is also a clear distinction between the samples taken at BH4 and BH5. This could be due to spatial variability, differences in sampling methods (push-tube vs RC drilling) or a combination of both.

Figure 5-7 presents a scatter plot of $\delta^{18}O$ against $\delta^{2}H$. The vegetation at Wetland 2 has Xylem water which is enriched in ^{18}O relative to the GMWL and is consistent with the majority of soil water samples at BH5. This is indicative of root water uptake throughout the soil profile. No groundwater use is indicated at Wetland 2 from either the water potential measurements or the isotope data.

No groundwater use is indicated at Wetland 2 from either the water potential measurements or the isotope data. The assessment presented indicates that maintenance of the surface hydrological regime (run-off and wetland inundation) as being critically important for maintenance of Wetland 2 environmental water requirements.

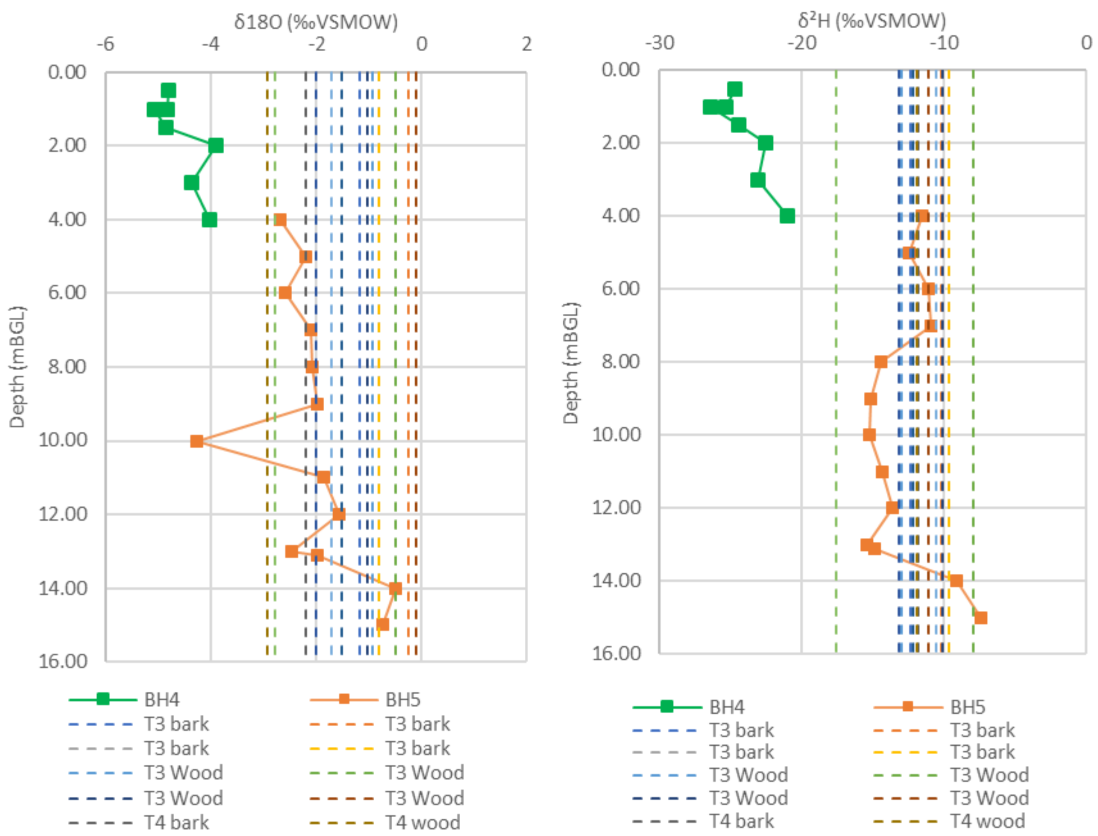


Figure 5-6 Stable isotopes of water in vegetation samples and in soil water with depth, Wetland 2

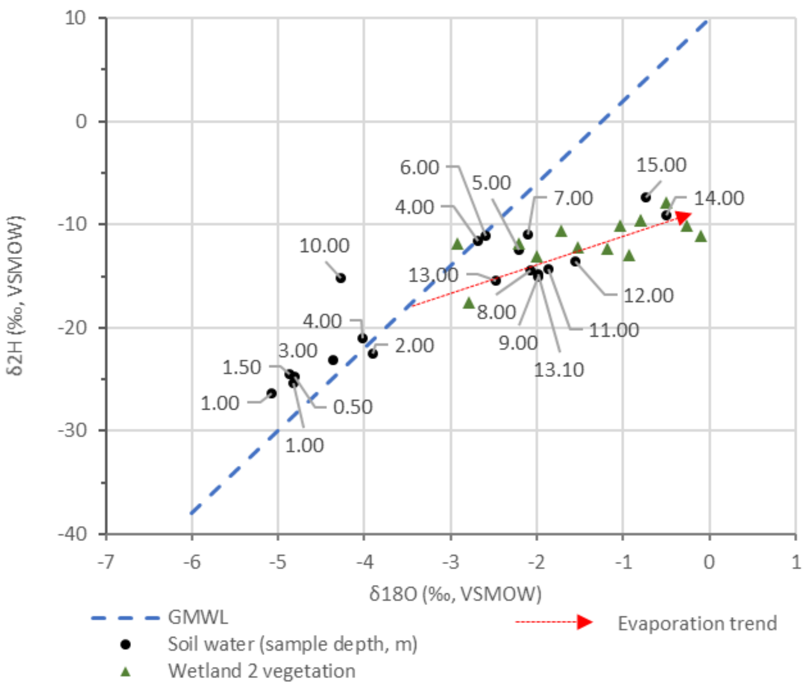


Figure 5-7 Stable isotopes of water in soil and vegetation samples, Wetland 2 (GMWL: Global Meteoric Water Line)

5.3.3 Vine thicket

The drilling log for the borehole completed at the Vine Thicket (BH6) is shown in Attachment 1. The lithology consists of mostly sandy sediments to a depth of 8.5 m, where weathered sandstone is encountered. The water table was not encountered during drilling, thus it is at least 10 mBGL.

Soil and leaf water potentials at the Vine Thicket are shown in Figure 5-8 . Much of the soil profile is very dry and well below the agronomic wilting point of -1.5 MPa, noting that native tree species can often tolerate soil moisture potentials well below this level. Root water uptake is indicated where the leaf water potentials are equivalent to or less than the soil water potential and the results point to root uptake from depths of 2 to 3 m at the time of sampling. There is no indication of groundwater use.

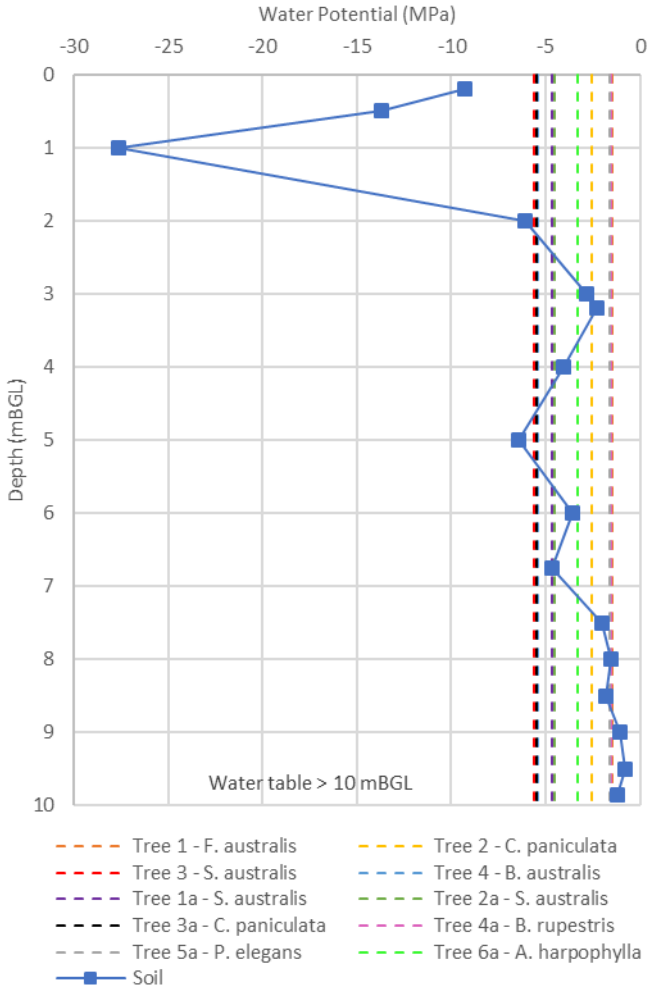
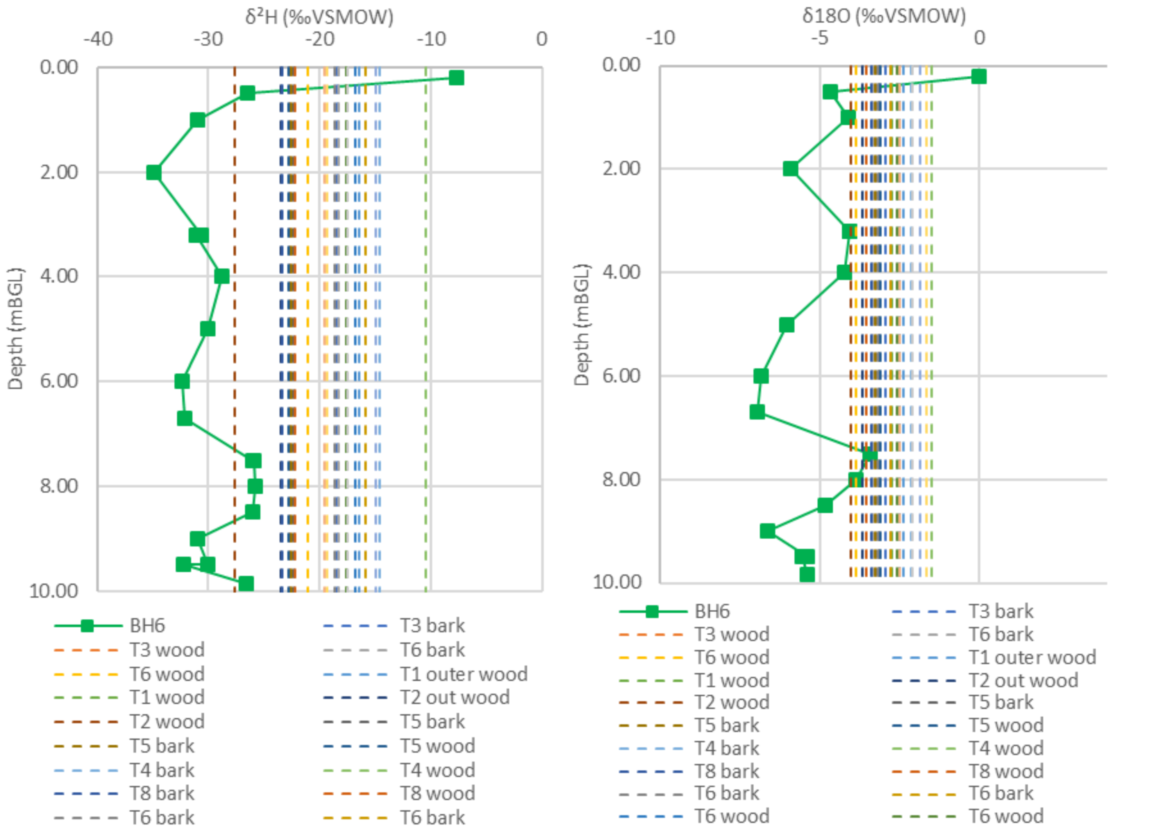


Figure 5-8 Soil and leaf water potentials with depth - Vine Thicket vegetation

The stable isotopes of water in soil water and vegetation are plotted with respect to depth in Figure 5-9. The shallowest soil sample at 0.2 m is enriched in heavy isotopes due to the fractionation that occurs during evaporation whereby the lighter, standard water molecules (composed of ^{1}H and ^{16}O) are preferentially converted from the liquid to the vapour phase, compared to heavier water molecules composed on ^{2}H and ^{18}O. The isotopic enrichment is mostly confined to this near-surface zone.



(see Figure 6-8 for vegetation sample legend)

Figure 5-9 Stable isotopes of water in vegetation samples and in soil water with depth at the Vine Thicket

Figure 5-10 presents a scatter plot of δ¹⁸O against δ²H. The relative enrichment of the ^{18}O molecule reflects an evaporation trend which is interpreted on Figure 5-10. The vegetation at vine thicket has xylem water which plots along this trendline, indicating the xylem water has been sourced primarily from the top 0.5 m of the soil profile.

There is no indication of groundwater use by the Vine Thicket vegetation. The assessment presented indicates that maintenance of the surface hydrological regime (stream flows and run-off) as being critically important for maintenance of Vine Thicket environmental water requirements.

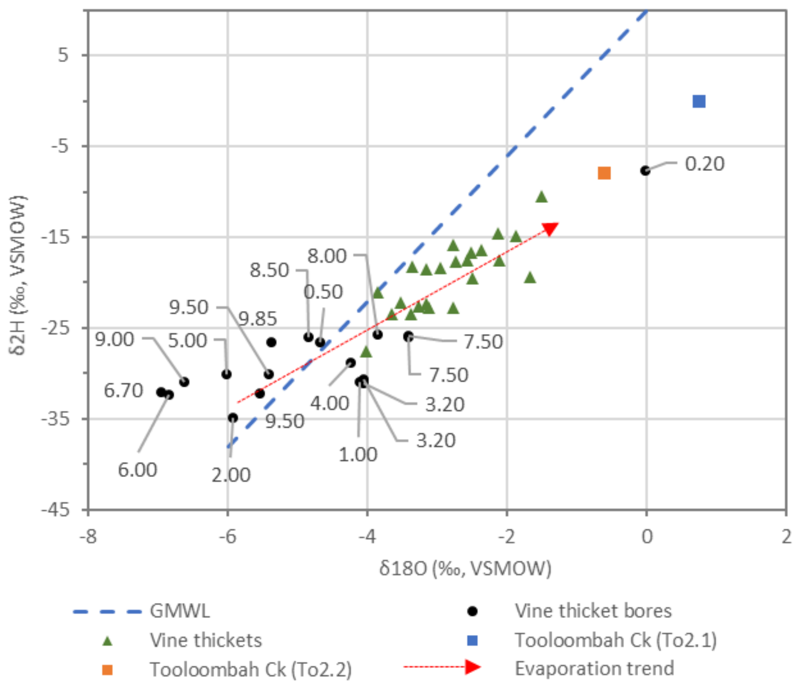


Figure 5-10 Stable isotopes of water in soil and vegetation samples, Vine Thicket (GMWL: Global Meteoric Water Line)

6 Connectivity assessment using isotope analysis

6.1 Overview

This preliminary isotope study has been undertaken to provide an initial indication of water sources supporting the watercourse pools, which are hypothesised to be supported to some extent by groundwater discharge (i.e. Type 2 GDEs, see SEIS Chapter 10 - Groundwater). This study forms part of the planned additional scope of works required to assist in improving the understanding of the water requirements of the GDEs and potential impacts arising from mining operations which will in turn enable appropriate management objectives and approaches to be developed to manage these GDEs during and post-mining.

To better understand the relationship between the surface water and groundwater, the stable isotopes of water (δ^2H and $\delta^{18}O$) and radon isotope (^{222}Rn) were analysed from water samples collected from the site.

6.2 Environmental (stable) isotopes

Craig (1961) observed that when stable isotopes of water (δ^2H and $\delta^{18}O$) have not undergone evaporation, they would have a linear relationship which can be represented by:

$$\delta^2H = 8\ \delta^{18}O + 10$$

This equation is referred to as the "Global Meteoric Water Line" (GMWL) and was developed based on precipitation data from across the globe. A "Local Meteoric Water Line" (LMWL) is usually developed from precipitation data collected from either a single location or a set of locations within a "localised" area of interest (USGS, 2018), noting that there are limited data available in the project area to construct this trend, thus there is some uncertainty in the LMWL derived.

The stable isotopes of water can be used to discriminate between different sources of water. The method relies on the distinct isotopic compositions which can arise as a result of isotopic fractionation caused mainly by transportation processes (i.e. mixing) and phase transitions (i.e. evaporation) through the atmosphere, lithosphere and biosphere (Barnes and Allison, 1988).

Six grab water samples were collected from Tooloombah Creek in-stream pools (two sampling points each from three pools within the creek) and another three from Deep Creek in-stream pools (a sampling point from three pools within the creek) between 16th and 18th July 2018. Groundwater samples were collected from six monitoring wells that are close to the surface water sampling points, using a low-flow groundwater sampling pump.

Water samples were analysed by Environmental Isotopes (contracted via Australian Laboratory Services, ALS). The hydrogen and oxygen isotope ratios were measured using a Wavelength Scanned-Cavity Ring-down Spectrometer (Picarro L2120) based on Munksgaard *et al*. (2011). Lake Eacham and Cairns Tap water were used as reference waters to develop localised water standards.

Laboratory results are presented in Table 6-1 while the results and water standards along with the relevant MWLs are plotted in Figure 6-1.

Table 6-1 Stable isotopes of water measured in groundwater and surface water samples

Location	Sample type	δ2H (‰, VSMOW)	δ18O (‰, VSMOW)
WMP02	Groundwater	-23.11	-3.94
WMP04		-27.23	-4.42
WMP04D		-25.12	-4.23
WMP05		-34.07	-5.44
WMP06		-11.77	-1.69
WMP10		-24.06	-4.04
De2	Surface water: Deep Creek	2.34	1.28
De3		-14.4	-1.71
De5		0.37	0.92
T01.1	Surface water: Tooloombah Creek	2.04	0.9
T01.2		0.49	0.65
T02.1		-0.07	0.76
T02.2		-7.98	-0.61
T03.1		-1.87	0.45
T03.2		1.51	1.07

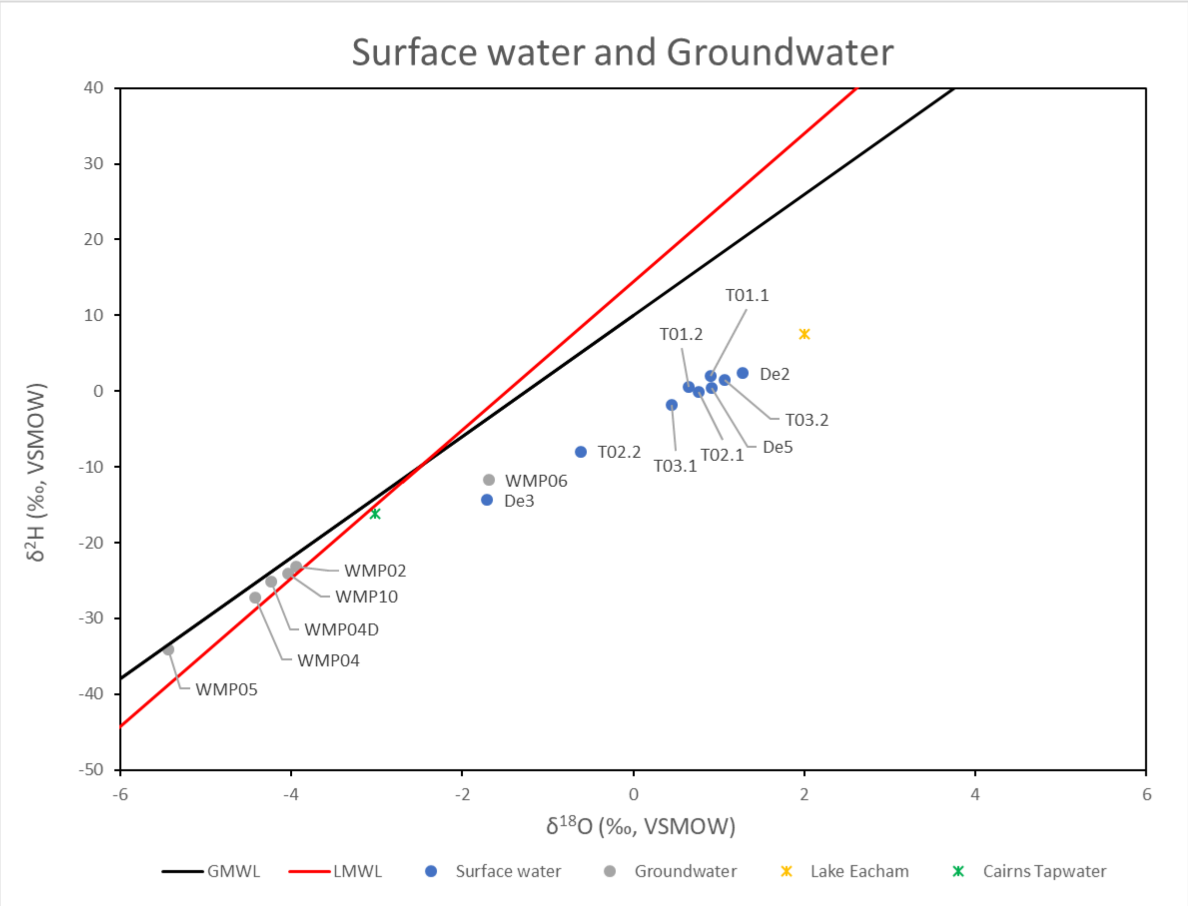


Figure 6-1 Environmental (stable) isotopes

The Global Meteoric Water Line is based on precipitation data from numerous locations across the globe while the Local Meteoric Water Line was developed from data collected by CSIRO between February and March 2010 in Rockhampton, Queensland (Crosbie et al., 2012).

The laboratory reported Lake Eacham and Cairns Tapwater are reference standards that the samples can be compared with. There is clear distinction between the isotopic values of samples from the surface water and groundwater, indicating different processes have affected the two sample groups. Gonfiantini, (1986) noted that when water undergoes evaporation, the residual isotopes become progressively enriched in heavier isotopes of δ^2H and δ^{18}O, and the ratio of δ^{18}O to δ^2H increases. However, when isotopic composition of a water sample plots close to the MWL, it is indicative of its meteoric origin.

The groundwater samples plot on or near the GMWL and LMWL, indicating that groundwater is derived mainly from rainfall recharge and that they underwent little to no evaporation prior to recharge. Surface water samples collected from in-stream pools plot well below the GMWL and LMWL, indicating that they have been affected by evaporation (heavier isotopes, relative to the groundwater samples), which is not unexpected. The data suggest that groundwater could be the source of water sampled from the pools.

6.3 Radioactive isotopes - Radon

Radon-222 (^{222}Rn) is a radioactive daughter isotope of Radium-226 and is the longest-lived and most-studied isotope of radon (it has a half-life of 3.82 days). Radon is a gas and will tend to seek a gaseous phase. This means that the natural waters that come into contact with the atmosphere will readily lose radon to the atmosphere, which has very low radon concentrations (USGS, 2018). For this reason, groundwater usually has a much higher concentration of ^{222}Rn than surface water.

^{222}Rn is often used in groundwater and surface water interaction studies because the surface water will have a very low natural ^{222}Rn due to degassing and any elevated concentrations can be used to indicate local discharges of groundwater.

Six grab water samples were collected from the Deep and Tooloombah Creeks (three each) between 16th and 18th July 2018. Groundwater samples were not collected for radon analysis during this preliminary assessment as the current monitoring bores are not in proximity to surface water bodies. Radon was extracted from the groundwater samples into a 20 mL mineral oil scintillant based on the method proposed by Leaney & Herczeg (2006).

Water samples were analysed on the 26th July 2018 at the Australian Nuclear Science and Technology Organisation (ANSTO) laboratory.

Table 6-2 provides a summary of the radon results. Notably, the holding period between the sampling and analysis was between 8 and 10 days, and given ^{222}Rn has a 3-day half-life, corrections have been required to account for this (using a correction equation described by Dawood *et al*., 2012).

Table 6-2 ^{222}Radon data

Date of sample collection	Date of sample analysis	Holding time (in days)	Sample ID	Lab result (Bq/L)	Corrected values (Bq/L)
16-07-18	26-07-18	10	DE3	0.19	1.17
17-07-18	26-07-18	9	De5	0.06	0.30
18-07-18	26-07-18	8	DE2	0.11	0.48
18-07-18	26-07-18	8	To1	0.65	2.75
18-07-18	26-07-18	8	To2	0.83	3.54
18-07-18	26-07-18	8	To3	0.45	1.93

The ranges of observed ^{222}Rn concentrations in the pools at Tooloombah Creek indicate that there is a likely connection between the creek and the groundwater while the concentrations from Deep Creek indicate low connectivity during the time of sampling (July 2018, which is dry season).

With the understanding that radon, bicarbonate and chloride are higher in groundwater than in surface water and that long residence time would facilitate the loss of radon from water to the atmosphere, O'Grady *et al*. (2007) plotted ^{222}Rn isotopes against chloride and ^{222}Rn against bicarbonate/chloride to determine the amount of groundwater inflow into wetlands. Comparing the ^{222}Rn and Cl^- present in different locations, the authors noted that sites with:

- low ^{222}Rn and low Cl^- concentrations are considered to have short residence times and low groundwater input;
- high ^{222}Rn and medium Cl^- concentrations are considered to have short residence times and a reasonable input of groundwater;
- high ^{222}Rn and very low Cl^- concentrations are considered to be unlikely as low chloride concentration indicates surface water is predominant, which would have negligible radon concentration; and
- high ^{222}Rn and high Cl^- concentrations are also considered to be unlikely as high concentrations of Cl^- would indicate long residence time resulting in high evaporation which would have led to the loss of ^{222}Rn to the atmosphere, exceptional cases include where groundwater is rich in chloride.

Comparing the ^{222}Rn and the ratio of bicarbonate and chloride values (HCO_3^-/Cl^-) present in different locations, the authors also noted that sites with:

- low ^{222}Rn concentration and low ratio of HCO_3^-/Cl^- are considered to have low groundwater input;
- low ^{222}Rn concentration and high ratio of HCO_3^-/Cl^- are considered to have higher groundwater input and long residence;
- high ^{222}Rn concentration and high ratio of HCO_3^-/Cl^- are considered to have higher groundwater input and short residence; and
- high ^{222}Rn concentration and low ratio of HCO_3^-/Cl^- are considered to be unlikely as a low ratio of bicarbonate to chloride indicates that groundwater input is negligible, meaning radon should not be present.

Figure 6-2 and Figure 6-3 show the plots of radon vs. chloride concentrations and radon vs. bicarbonate/chloride ratios, respectively. Figure 6-2indicates that groundwater contributes only a limited amount of water to Deep Creek (very low chloride and ^{222}Rn) while Tooloombah Creek receives relatively higher amount of groundwater inflow (higher amounts of chloride and ^{222}Rn). Deep Creek also has longer residence time relative to Tooloombah Creek due to lower ^{222}Rn values. This is further buttressed by Figure 6-3, which indicates that groundwater contributes to some extent in both creeks (medium values for the bicarbonate/chloride ratio, 0.4 – 1.8) at the time of sampling.

Overall, both creeks appear to connected to groundwater to some extent and undergo evaporation.

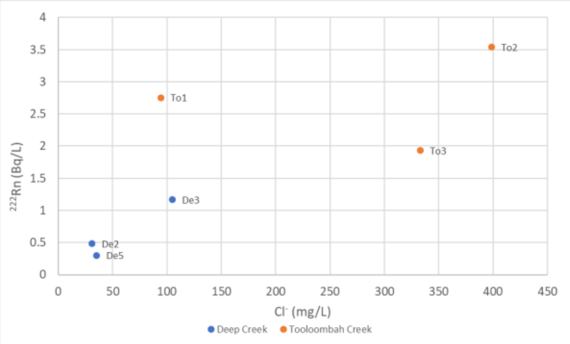


Figure 6-2 Radon vs. chloride

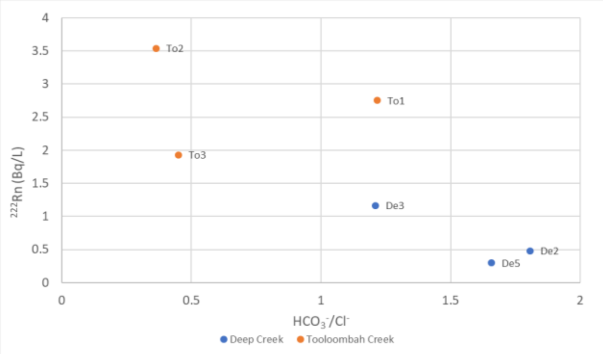


Figure 6-3 Radon vs. bicarbonate/chloride ratio

6.4 Further works

Further works could include collection of samples in the wet and dry season for both environmental and radon isotope analysis from both surface water and groundwater. Shallow in-stream piezometers should be used due to the radon's short half-life (3.82 days). Groundwater samples will also be collected from these piezometers and used for radon analysis to help quantify the groundwater flux. The flux can be calculated using the following equation (Atkinson *et al.*, 2015):

$$I = (Q^*(\delta\, C_r / \delta x) - w.E.\, C_r + k.d.w.\, C_r + \lambda.d.w.\, C_r) / (C_i - C_r)$$

Where,

I = groundwater inflow (m^3/m/day)

C_i = dissolved ^{222}Rn activity of groundwater (Bq/m^3)

C_r = dissolved ^{222}Rn activity of surface water (Bq/m^3)

Q = stream discharge, in m^3/day

w = stream width (m)

d = stream depth (m)

λ = radioactive decay rate (1/day)

E = evaporation rate (m/day)

K = reaeration coefficient, in 1/day (range is from 0.5 to 5 (Atkinson et al., 2015))

6.5 Conclusion

The environmental isotopes along with the radon isotopes indicate the creeks are, to some extent, connected to groundwater at the time of sampling. The clear distinction between the environmental isotopes of groundwater and the surface water samples indicate surface water has undergone more evaporation (longer residence time) relative to groundwater. The groundwater samples are less depleted and where they plot on the global and local MWL indicate rainfall is the main source of recharge and that the water underwent little to no evaporation prior to recharge.

$\delta^{2}H$ and $\delta^{18}O$ results from the Deep and Tooloombah Creeks pools shows the isotopes have been enriched as a result of evaporation. It also indicates they have higher retention time (relative to the recharge source of the groundwater).

The radon analysis on Deep and Tooloombah Creeks water samples indicate Deep Creek is less connected to groundwater and has longer residence time relative to the Tooloombah Creek (relatively higher chloride and ^{222}Rn). The presence of bicarbonate and chloride in both creeks (HCO_3^-/Cl^- ratio ranging between 0.4 and 1.9) indicate groundwater baseflow supports creek pools, albeit not in significant quantities.

7 References

Atkinson, A.P., Cartwright, I., Gilfedder, B.S., Hofmann, H., Unland, N.P., Cendón, D.I. and Chisari, R., 2015. A multi-tracer approach to quantifying groundwater inflows to an upland river; assessing the influence of variable groundwater chemistry. Hydrological processes, 29(1), pp.1-12.

Barnes, C.J. and Allison, G.B. (1988) Tracing of water movement in the unsaturated zone using stable isotopes of hydrogen and oxygen. Journal of Hydrology, 100:143–176)

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A. 2012. Australian groundwater modelling guidelines. Waterlines Report Series No. 82, National Water Commission, Canberra, 191 pp. June.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Craig, H., 1961. Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. Science, 133(3467), pp.1833-1834.

Crosbie R, Jolly I, Leaney F, Petheram C and Wohling D. 2010. Review of Australian Groundwater Recharge Studies. CSIRO: Water for a Healthy Country National Research Flagship.

Crosbie RS, Morrow D, Cresswell RG, Leaney FW, Lamontagne S and Lefournour M (2012) New insights into the chemical and isotopic composition of rainfall across Australia. CSIRO Water for a Healthy Country Flagship, Australia.

Dawood M, Jiang X, Schäfers K (2012) Correction Techniques in Emission Tomography. CRC Press. p. 69. ISBN 978-1-4398-1298-3.

Doherty J (2016) PEST, Model-Independent Parameter Estimation — User Manual Part I (sixth edition). Watermark Numerical Computing, Brisbane, Australia

Duffield, G.M., 2007. AQTESOLV for Windows Version 4.5, HydroSOLVE, Inc., Reston, VA.

Eamus, D., 2009. Identifying groundwater dependent ecosystems: a guide for land and water managers. Land & Water Australia.

ESI 2011. Guide to Using Groundwater Vistas Version 6. Environmental Systems Incorporated.

Gonfiantini, R. (1986). Environmental isotopes in lake studies. In P. Fritz and J.Ch. Fontes (Eds.), Handbook of Environmental Isotope Geochemistry (pp. 113 – 168). Amsterdam, Netherlands: Elsevier.

Hantush M., Harada M., Mariño M. 2001 Hydraulic Analysis of Baseflow and Bank Storage in Alluvial Streams. Wetlands Engineering and River Restoration Conference 2001

Healy, R. W. 2010. Estimating groundwater recharge, Cambridge University Press.

Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bulletin No. 36, Waterways Exper. Sta. Corps of Engineers, U.S. Army, Vicksburg, Mississippi, pp. 1-50.

HydroGeoLogic. 1998. MODFLOW-SURFACT v. 3.0: A comprehensive MODFLOW-based flow and transport simulator. Code Documentation Report. HydroGeoLogic, Reston, VA.

Leaney F, Crosbie R, O'Grady A, Jolly I, Gow L, Davies P, Wilford J and Kilgour P. 2011. Recharge and discharge estimation in data poor areas: Scientific reference guide. CSIRO: Water for a Healthy Country National Research Flagship.

Leaney, F. W. and Herczeg, A. L. (2006). A rapid field extraction method for determination of radon-222 in natural waters by liquid scintillation counting. Limnology and oceanography: methods, 4(7), 254-259.

Massarotto, P, Golding, S D and Rudolph, V. 2003, Anisotropic permeability characterisation of Permian coals. Proceedings of the International CBM Symposium. University of Alabama, USA.

McDonald M.G. and Harbaugh A.W. 1988. A modular three-dimensional finite-difference groundwater flow model: Techniques of Water-Resources Investigations of the United States Geological Survey.

Middlemis H, Merrick N, and Ross J. 2001. Groundwater flow modelling guideline, Murray- Darling Basin Commission, Project No. 125, Final Guideline – Issue I, January.

Munksgaard N. C., Wurster C. M. & Bird M. I. 2011. Continuous analysis of □18O and □D values of water by diffusion sampling cavity ringdown spectrometry: a novel sampling device for unattended field monitoring of precipitation, ground and surface waters. Rapid Communications in Mass Spectrometry 25, 3706–3712. doi:10.1002/rcm.5282

O'Grady, A.P., Cook, P.G. and Fas, T. (2007) A national framework for assessing the EWRs of GDEs – Report 2. CSIRO Land and Water Australia.

Panday S and Huyakorn PS. 2008. MODFLOW SURFACT: A State-of-the-Art Use of Vadose Zone Flow and Transport Equations and Numerical Techniques for Environmental Evaluations. Vadose Zone Journal 7:610–631.

Ritchie, G.A. and Hinckley, T.M., 1975. The pressure chamber as an instrument for ecological research. In Advances in ecological research (Vol. 9, pp. 165-254). Academic Press.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

USGS (2018) Radon < https://wwwrcamnl.wr.usgs.gov/isoig/period/rn_iig.html

Attachment A - Project water bore logs and soil core logs

COMPOSITE WELL LOG

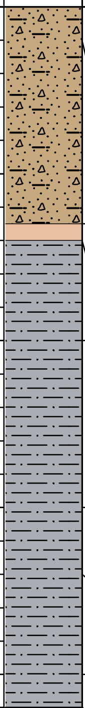
BOREHOLE / WELL NUMBER: BH1

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By:
Drilling Method: Push Tube/Hammer
Bore Diameter:
Date Drilled: 28-Aug-18

Total Depth (m bgl): 4.2
Well Stick Up (m):
Surface Elevation (m AHD):
Static Water Level
Date: **Depth (mbRP):**
Projection: GDA_94
Easting: 770792 **Northing:** 7486241

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

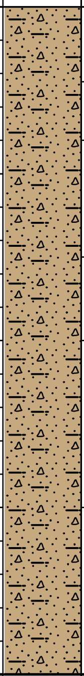
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	FIELD RECORDS
0		**Silty clay** Grey brown dry clay with 5% sand and ironstone gravel fragments. Minor yellow /orange mottling and ironstone staining. Minor organic content and root material, Very dry.	Cracking clay at surface. Recent alluvium. Fine matted root material in layers
		Plastic clay Grey / grey brown clay with yellow / orange mottling. Moist with minor fine root material.	Recent clay pan. Minor fine root material Push tube used from 0 to 1.4 mbgl. Core retrieved.
1			Basement interface. No root material identified
		Calcrete?? Hard, grey cemented layer.	
		Sandstone Grey / white fine grained quartz rich arenite.	
2		**Sandstone** Grey / white fine grained quartz rich arenite. Ironstone gravel with some orange and red iron staining on sandstone grains and fracture surfaces.	Rotary percursion rig with water used from 1.4 to 4.2 mbgl. Not sampled due to the drilling fluids contamination
3		**Sandstone** Fine to medium grained arkosic sandstone. Red iron staining (hematite) in matrix with orange (limonite) staining on fracture surfaces. Some ironstone gravel.	
		Sandstone Fine to medium grained arkosic sandstone. Red iron staining (hematite) in matrix with orange (limonite) staining on fracture surfaces. Some ironstone gravel.	
4		**Sandstone / gravelly sandstone** Fine to medium grained sandstone with strong orange ironstone staining. Rounded gravel and pebble sized clasts of iron stained sandstone and ironstone.	

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH2

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 4
Location: Styx Coal Basin	**Well Stick Up (m):**
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):**
Drilled By:	**Static Water Level**
Drilling Method: Push Tube/Hammer	**Date:** **Depth (mbRP):**
Bore Diameter:	**Projection:** GDA_94
Date Drilled: 28-Aug-18	**Easting:** 770858 **Northing:** 7486217



DEPTH (m)	GRAPHIC LOG	GEOLOGICAL DESCRIPTION – LITHOLOGY	CONSTRUCTION INFO. – FIELD RECORDS
0		**Silty sand** Grey brown fine grained silty sand. Angular to sub-angular fragments.	Finely dispersed root material in layers, core logging.
		Sandstone Fine grained arenite with yellow and red ironstone staining on grain surfaces.	No root material identified
1		**Sandstone** Weathered fine to medium grained arenite with yellow and red ironstone staining on grain surfaces. Some ironstone gravel	No root material identified
		Sandstone Weathered fine to medium grained arenite with yellow and red ironstone staining on grain surfaces. Some ironstone gravel	Drilled with rotary percussion from 0.45 to 4m. Chips only, not sampled due to contamination of samples by drilling fluids
2		**Sandstone** Grey / white fine to medium grained quartz rich arenite. Fresh with some minor red and yellow ironstaining on grain surfaces.	
3		**Sandstone** Grey / white fine to medium grained quartz rich arenite. Fresh with some minor red and yellow ironstaining on grain surfaces.	
4			

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH3

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 14
Location: Styx Coal Basin	**Well Stick Up (m):**
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):**
Drilled By:	**Static Water Level**
Drilling Method: Push Tube/Hammer	**Date:** **Depth (mbRP):**
Bore Diameter:	**Projection:** GDA_94
Date Drilled: 28-Aug-18	**Easting:** 770796 **Northing:** 7486240

DEPTH (m)	GEOLOGICAL DESCRIPTION – LITHOLOGY	CONSTRUCTION INFO. – FIELD RECORDS
0	**Silty clay** Grey brown dry clay with 5% sand and ironstone gravel fragments. Minor yellow /orange mottling and ironstone staining. Minor organic content and root material, Very dry.	Cracking clay at surface. Recent alluvium. Fine matted root material in layers
	Plastic clay Grey / grey brown clay with yellow / orange mottling. Moist with minor fine root material.	Recent clay pan. Minor fine root material Push tube used from 0 to 1.4 mbgl. Core retrieved.
1	**Calcrete??** Hard, grey cemented layer.	Basement interface. No root material identified
	Sandstone Grey / white fine grained quartz rich arenite.	
2	**Sandstone** Grey / white fine grained quartz rich arenite. Ironstone gravel with some orange and red iron staining on sandstone grains and fracture surfaces.	
3	**Sandstone** Fine to medium grained arkosic sandstone. Red iron staining (hematite) in matrix with orange (limonite) staining on fracture surfaces. Some ironstone gravel.	
	Sandstone Fine to medium grained arkosic sandstone. Red iron staining (hematite) in matrix with orange (limonite) staining on fracture surfaces. Some ironstone gravel.	
4	**Sandstone / gravelly sandstone** Fine to medium grained sandstone with strong orange ironstone staining. Rounded gravel and pebble sized clasts of iron stained sandstone and ironstone.	
5	**Sandstone / gravelly sandstone** Fine to medium grained sandstone with strong orange ironstone staining. Some larger rounded quartz clasts and inclusions and coal lithic fragments.	
6	**Sandstone / gravelly sandstone** Fine to medium grained sandstone with strong orange staining. Some larger ironstone and rounded quartz clasts and inclusions. Clay beads present	Rotary percursion rig with air used from 1.4 to 14.5 mbgl. Chips recovered
7	**Sandstone / gravelly sandstone** Fine to medium grained sandstone with strong orange and red staining. Arkosic sandstone lithics and ironstone gravel. Clay beads present	

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH3

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By:
Drilling Method: Push Tube/Hammer
Bore Diameter:
Date Drilled: 28-Aug-18

Total Depth (m bgl): 14
Well Stick Up (m):
Surface Elevation (m AHD):
Static Water Level
Date: **Depth (mbRP):**
Projection: GDA_94
Easting: 770796 **Northing:** 7486240

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	LITHOLOGY	FIELD RECORDS
	Sandstone / gravelly sandstone *(continued)*	
8	**Sandstone / gravelly sandstone / clay** Fine to medium grained sandstone. Strong orange limonite staining. Kaolin beads present within chips.	Moisture indicated at 8 mbgl
9	**Decomposed / clayey siltstone and minor sandstone** Yellow brown ironstone staining on gravel fragments. Abundant orange kaolin beads present.	
10	**Decomposed / clayey siltstone and minor sandstone** Yellow brown ironstone staining on decomposed siltstone fragments. Abundant orange and dark brown kaolin beads present.	
11	**Decomposed / clayey siltstone** Yellow brown to dark grey-brown siltstone. Abundant dark brown and orange clay beading ironstone staining on decomposed siltstone fragments. Abundant orange and dark brown kaolin beads present.	
12	**Sandstone** Fine to medium grained grey to white quartz arenite with minor limonite staining. Some white kaolin beading.	
13	**Sandstone** Fine to medium grained grey to white quartz arenite with minor limonite staining. Some white kaolin beading.	Aquifer strike at 13.5 mbgl
14	**Sandstone** Limited chip return	

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH4

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By:
Drilling Method: Push Tube/Hammer
Bore Diameter:
Date Drilled: 30-Aug-18

Total Depth (m bgl): 4.2
Well Stick Up (m):
Surface Elevation (m AHD):
Static Water Level
Date: **Depth (mbRP):**
Projection: GDA_94
Easting: 770643 **Northing:** 7487718

DEPTH (m)	GEOLOGICAL DESCRIPTION – LITHOLOGY	CONSTRUCTION INFO. – FIELD RECORDS
0	**Sandy silt / clay** Grey brown silt clay matrix with fine sand <20% total content. Orange brown mottling. Limited organic matter. Very dry.	Limited fine root material
	Clayey sand Grey / brown clayey sand. 50% fine grained sand with clay matrix. Abundant yellow orange mottling. Very dry.	No root material identified
1	**Clayey sand** Grey / brown clayey sand. 50% fine grained sand with clay matrix. Abundant yellow orange mottling.	No root material identified
2	**Clayey sand** Grey / brown clayey sand. 50% fine grained sand with clay matrix. Abundant yellow orange mottling.	No root material identified Push tube used from 0 to 4.2 mbgl. Core retrieved, except between 2 and 2.5m
3	**Clayey sand** Grey brown with orange limonite mottles. some coarser rounded to sub-angular grains. Fine grained angular to sub-angular quartz / feldspar sand with 20% silty clay matrix	No root material identified
	Clayey sand / sand Orange brown fine to medum grained quartz / feldspar sand. Weakly cemented with clay, <10% clay matrix. Brown with orange limonite mottling.	No root material identified
4	**Clayey Sand** Dark grey / grey brown angular to subangular sand with 40% clay matrix. Strong orange brown (limonite) mottles. Weakly cemented with some moisture.	No root material identified

COMPOSITE WELL LOG

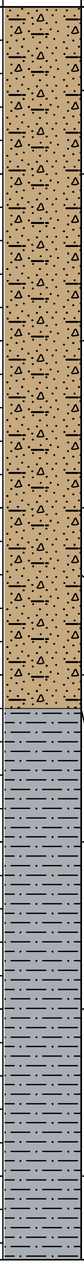
BOREHOLE / WELL NUMBER: BH5

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By:
Drilling Method: Push Tube/Hammer
Bore Diameter:
Date Drilled: 30-Aug-18

Total Depth (m bgl): 15
Well Stick Up (m):
Surface Elevation (m AHD):
Static Water Level
Date: **Depth (mbRP):**
Projection: GDA_94
Easting: 770627 **Northing:** 7487717

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**



DEPTH (m)	LITHOLOGY	FIELD RECORDS
0	**Sandy silt / clay** Grey brown silt clay matrix with fine sand <20% total content. Orange brown mottling. Limited organic matter. Very dry.	Limited fine root material
	Clayey sand Grey / brown clayey sand. 50% fine grained sand with clay matrix. Abundant yellow orange mottling. Very dry.	No root material identified
1	**Clayey sand** Grey / brown clayey sand. 50% fine grained sand with clay matrix. Abundant yellow orange mottling.	No root material identified
2	**Clayey sand** Grey / brown clayey sand. 50% fine grained sand with clay matrix. Abundant yellow orange mottling.	No root material identified Push tube used from 0 to 4.2 mbgl. Core retrieved, except between 2 and 2.5m
3	**Clayey sand** Grey brown with orange limonite mottles. some coarser rounded to sub-angular grains. Fine grained angular to sub-angular quartz / feldspar sand with 20% silty clay matrix	No root material identified
	Clayey sand / sand Orange brown fine to medum grained quartz / feldspar sand. Weakly cemented with clay, <10% clay matrix. Brown with orange limonite mottling.	No root material identified
4	**Clayey Sand** Dark grey / grey brown angular to subangular sand with 40% clay matrix. Strong orange brown (limonite) mottles. Weakly cemented with some moisture.	No root material identified
	Sand / Gravel Fine to medium grained sand and gravel with some lithic sandstone fragments. Possibly base of alluvium / top of Styx coal measures.	Rotary percursion rig with air used from 4.2 to 14.5 mbgl. Chips recovered
5	**Sand / Gravel** Fine to medium grained sand and gravel with lithic sandstone fragments. Likely to be top of the Styx Coal Measures??	
6	**Sandstone** Fine to medium grained quartz arenite with strong red and orange iron staining on grain and fracture surfaces. Some rounded quartz clasts and fragments.	
7	**Sandstone** Fine to medium grained quartz arenite with s orange iron staining on grain and fracture surfaces. Some ironstone gravel and clayey sandstone / silstone clasts mixed with coal fragments	

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH5

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 15
Location: Styx Coal Basin	**Well Stick Up (m):**
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):**
Drilled By:	**Static Water Level**
Drilling Method: Push Tube/Hammer	**Date:** **Depth (mbRP):**
Bore Diameter:	**Projection:** GDA_94
Date Drilled: 30-Aug-18	**Easting:** 770627 **Northing:** 7487717

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	FIELD RECORDS
		Sandstone *(continued)*	
8		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Angular to sub-angular quartz grains with some yellow -orange ironstone staining. Coal fragments.	
9		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Some orange ironstone staining on grain surfaces and rounded ironstone gravel fragments.	
10		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Some orange ironstone staining on grain surfaces. Carbonaceous siltstone and coal fragments.	
11		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Some orange ironstone staining on grain surfaces. Minor ironstone gravel and fragments with some coal fragments.	
12		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Some orange ironstone staining on grain surfaces. Carbonaceous siltstone and coal fragments.	
13		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Some orange ironstone staining on grain surfaces. Coal fragments.	
14		**Sandstone** Grey brown, fine to medium grained sandstone with weathered clay matrix. Some orange ironstone staining on grain surfaces. Coal fragments.	

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH6

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 9.85
Location: Styx Coal Basin	**Well Stick Up (m):**
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):**
Drilled By:	**Static Water Level**
Drilling Method: Push Tube/Hammer	**Date:** **Depth (mbRP):**
Bore Diameter:	**Projection:** GDA_94
Date Drilled: 29-Aug-18	**Easting:** 772191 **Northing:** 7489107

GEOLOGICAL DESCRIPTION

DEPTH (m)	LITHOLOGY
0	**Sandy Silt.** Grey / brown fine grained sand. <20% organic matter. Dry,
	Sandy Silt. Grey / brown. 30% fine grained sand with silt with <10% organic matter. Very dry.
	Sandy Silt. Grey / brown with some fine yellow / orange mottling. 50% fine grained sand with silt. Very dry.
1	**Sandy Silt.** Brown to orange brown with some finer orange specs and mottling. 30 fine grained sand with silt. Very dry.
2	**Silty Sand.** Orange -brown Fine to medium grained sand with some coarser rounded to sub-angular grains. 40% silty clay matrix
3	**Silty Sand.** Orange brown with some stronger bands with orange limonite mottling. 60% rounded to sub-angular quartz grains with 40% silty clay matrix, Very dry.
4	**Clayey Sand.** Orange brown with 40% silty clay matrix with fine grained rounded to sub-angular quartz rich sand . Some orange brown (limonite) mottles.
5	**Silty Sand.** Mottled grey to orange brown silty sand. Rounded to sub-angular quartz sand with 40% silty clay matrix, Very dry
6	**Silty / Clayey sand** Grey brown fine to medium sand with 50% silty clay matrix. Orange brown limonite mottles and staining throughout. Dry.
	Silty Sand. Orange / brown fine quarts and with 40% silty clay matrix. Abundant yellow brown limonite mottling and staining with orange coating on sand grains,
7	**Silty / Clayey sand** Orange grey mottled quartz / feldspar sand with fine angular to rounded grains. 40% silty clay matrix. Strong limonite mottling.

CONSTRUCTION INFO.

FIELD RECORDS

Abundant fibrous root material

Large yellow root 0.5cm diameter with some fibrous yellow root matter also evident.

Some matted fine root material and occasional larger yellow roots to 1mm.

Minor matted fine root material. Larger dead tree root at 2.0m with orange colour.

Large dead tree root at 2.5m. Strong yellow coloration. Core loss at 2 to 2.5m

Fine yellow tree roots recorded at 3.8m

Fine yellow tree roots recorded at 4.5m

Fine tree yellow tree roots recorded at 5.5m.

Fine yellow tree roots recorded at 6.1m

Large 0.5 cm tree root from river red gum (probably tree 7a) at 6.5m.

Large 0.5cm tree root from river red gum recorded at 7.5m

(Continued Next Page)

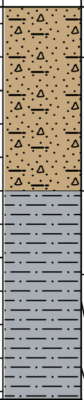
COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: BH6

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 9.85
Location: Styx Coal Basin	**Well Stick Up (m):**
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):**
Drilled By:	**Static Water Level**
Drilling Method: Push Tube/Hammer	**Date:** **Depth (mbRP):**
Bore Diameter:	**Projection:** GDA_94
Date Drilled: 29-Aug-18	**Easting:** 772191 **Northing:** 7489107

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	FIELD RECORDS
		**Silty / Sandy clay** Grey brown clay with stong orange mottling. 30% fine quartz sand with 70% silty clay matrix.	
8		**Sandy clay** Gey brown / orange clay. 40% sub-angular quartz / feldspar clay with 60% clay matrix. Cohesve texture with strong limonite mottling throughout.	
		Sandy clay (decomposed sandstone) Brown grey tight sandy clay with lithic sandstone and coal fragments. 80% clay matrix with 20% angular to sub-angular quartz and feldspar sand. Strong limonite mottling,	Top of Styx Coal at 8.6m
9		**Decomposed sandstone with coal lithics** Grey with orange / brown mottles. Medum angular quartz / feldspar sand fragments with tight clay matrix. Strong limonite coating on some fracture surfaces. Coal seams to 3cm thick in some intervals.	Matted fibrous tree roots in coal seam at 9.5m.
		Decomposed dirty / clayey coal seams in sandstone Mostly decomposed coal with interbeds of medium grained sandstone.	EOH due to drill rod refusal in Styx Coal Measures.
		Coal Vitreous coal seams interbedded with decomposed clayet sandstone. Fine to medium grained decomposed clayey sandstone interbeds.	

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP02

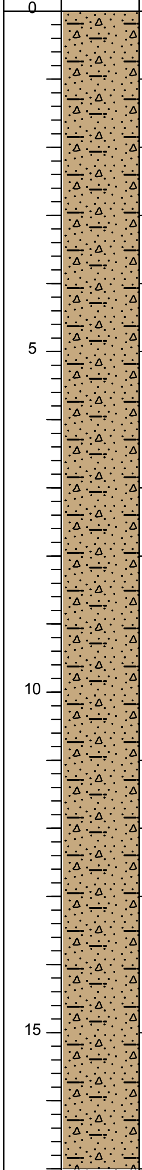
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 1/10/2017

Total Depth (m bgl): 18.4
Well Stick Up (m): 1.1
Surface Elevation (m AHD): 24.8
Static Water Level
Date: 20/12/2017 **Depth (mbRP):** 17.2
Projection: GDA_94
Easting: 773497 **Northing:** 7491734

GEOLOGICAL DESCRIPTION

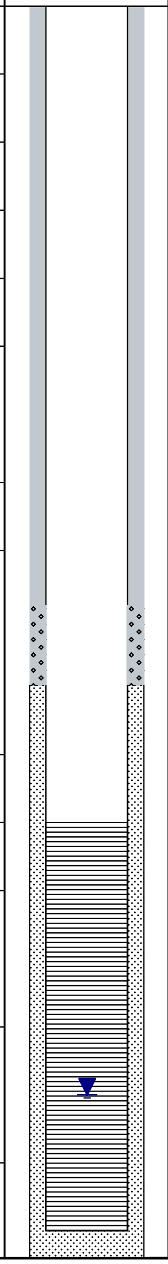
DEPTH (m) | GRAPHIC LOG | LITHOLOGY



Lithology
Alluvium Soil, medium-dark brown, clayey, C1
Alluvium Clay, medium buff brown, minor silt, C1
Alluvium Clay, medium reddish brown, sandy, carbonaceous, C1
Alluvium Sand, speckled reddish mottled, clayey, minor alluvial, C1
Alluvium Clay, light greenish buff, silfty, minor gravel, C1
Alluvium Clay, light-medium, creamish buff, minor silt, C1
Alluvium Clay, light-medium, reddish buff, C1
Alluvium Clay, light-brownish buff, minor silt, C1
Alluvium Sand, light-medium buff, clayey, S1
Alluvium Sand, medium greenish buff, minor clay, S1
Alluvium Sand, medium greenish-brown, clayey, minor gravel, alluvial, C1
Alluvium Gravel, medium mottled yellow, clayey, minor sand, abundant alluvium, C1

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 8.8m Cement/bentonite grout
0 - 12m 125mm CL12 PVC blank casing

8.8 - 9.98m Bentonite pellets

9.98 - 18.4m Gravel pack

12 - 18m 125mm CL12 PVC slotted casing, 1mm aperture

EOH @ 18.4m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP04

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

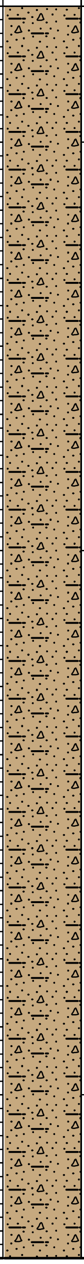
Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 11/10/2017

Total Depth (m bgl): 18.4
Well Stick Up (m): 1.2
Surface Elevation (m AHD): 28.2
Static Water Level
Date: 12/11/2017 **Depth (mbRP):** 12.4
Projection: GDA_94
Easting: 772865 **Northing:** 7489358

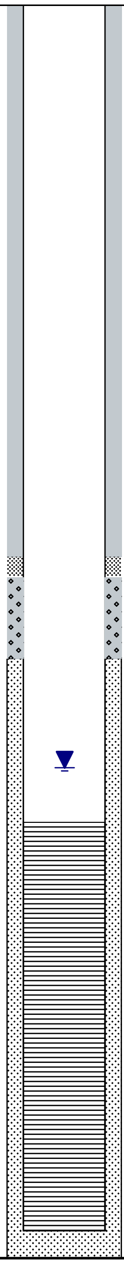
GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
0	**Alluvium** Soil, medium greyish yellow, clayey, oxidised, C1	0 - 8.1m Cement/bentonite grout 0 - 12m 125mm CL12 PVC blank casing
	Alluvium Clay, medium greyish yellow, sandy, clayey nodules, C1	
5		
	Alluvium Clay, medium brownish yellow, gravelly, sandy alluvial, S1	8.1 - 8.4m Sand 8.4 - 9.6m Bentonite pellets 9.6 - 18.4m Gravel pack
10		12 - 18m 125mm CL12 PVC slotted casing, 1mm aperture
15		
	Alluvium Conglomerate, medium yellowish brown, clayey, sandy, R2	EOH @ 18.4m

GRAPHIC LOG



WELL CONSTRUCTION



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP04D

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

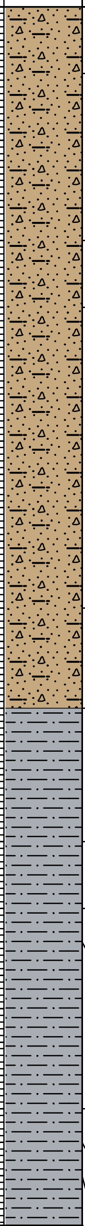
Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 29-Sep-17

Total Depth (m bgl): 36.5
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 28.3
Static Water Level
Date: 11/11/2017 **Depth (mbRP):** 12.3
Projection: GDA_94
Easting: 772859 **Northing:** 7489351

GEOLOGICAL DESCRIPTION

DEPTH (m): 0, 5, 10, 15, 20, 25, 30, 35

GRAPHIC LOG



LITHOLOGY

Alluvium
Soil, medium brown, clayey, C1

Alluvium
Clay, light-medium brown, sandy, C1

Alluvium
Sand, light-medium buff brown, clayey, alluvial, S1

Alluvium
Clay, light-medium buff brown, alluvial, gravelly, C1

Alluvium
Siltstone, medium yelowish grey, minor gravel, R2

Styx Coal Measures - Overburden
Claystone, medium-dark mottled brown, minor coal, R1

Styx Coal Measures - Overburden
Claystone, light-medium brownish grey, fresh, minor siltstone, R2

Styx Coal Measures - Overburden
Siltstone, light-medium brownish grey, minor sandstone, fresh, R2

Styx Coal Measures - Overburden
Sandstone, fine grained, dark brownish grey, carbonaceous mudstone and claystone, R3

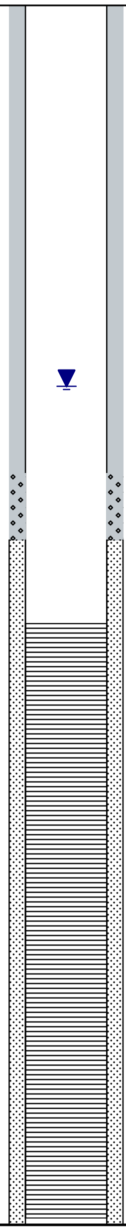
Styx Coal Measures - Overburden
Sandstone, medium-coarse grained, light greenish grey, R5

Styx Coal Measures - Overburden
Siltstone, light greenish grey, minor tuff and coaly wisps, R4

Styx Coal Measures - Overburden
Siltstone, light greenish grey, coaly wisps, R4

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 14m Cement/bentonite grout
0 - 18.5m 125mm CL12 PVC blank casing

14 - 16m Bentonite pellets

16 - 36.5m Gravel pack

18.5 - 36.3m 125mm CL12 PVC slotted casing, 1mm aperture

EOH @ 36.5m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP05

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

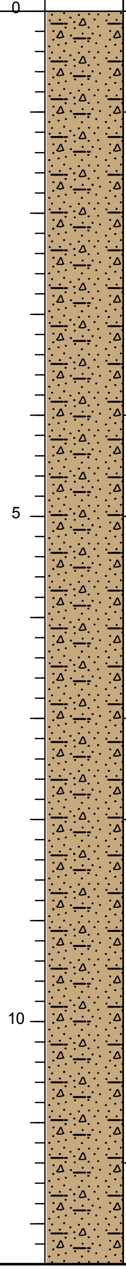
Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 30/09/2017

Total Depth (m bgl): 12.4
Well Stick Up (m): 1
Surface Elevation (m AHD): 17.2
Static Water Level
Date: 12/11/2017 **Depth (mbRP):** 9.9
Projection: GDA_94
Easting: 774507 **Northing:** 7491639

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m) | GRAPHIC LOG | LITHOLOGY | WELL CONSTRUCTION | WELL DESCRIPTION

Depth scale: 0, 5, 10



Alluvium
Soil, brown, C1

Alluvium
Clay, light buff brown, C1

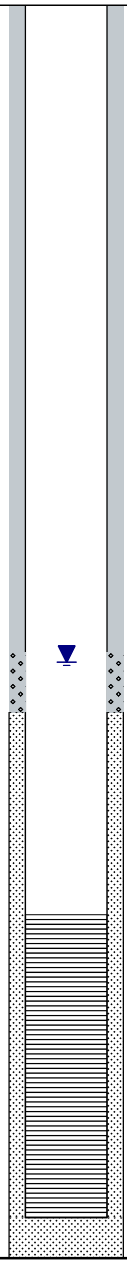
Alluvium
Clay, light brown, minor silt, C1

Alluvium
Sand, light-brownish buff, clayey, S1

Alluvium
Sand, medium multi-coloured yellow, gravel, alluvium, S1

Alluvium
Gravel, medium multi-coloured yellow, alluvial, S1

Alluvium
Gravel, medium multi-coloured yellow, clayey, sandy, alluvial, S1



0 - 6.4m Cement/bentonite grout
0 - 9m 125mm CL12 PVC blank casing

6.4 - 7m Bentonite pellets

7 - 12.4m Gravel pack

9 - 12m 125mm CL12 PVC slotted casing, 1mm aperture

EOH @ 12.4m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP06

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 18.4
Location: Styx Coal Basin	**Well Stick Up (m):** 0.7
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 33.9
Drilled By: Mitchell Services	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 10/11/2017 **Depth (mbRP):** 17.7
Bore Diameter: 200mm	**Projection:** GDA_94
Date Drilled: 3/11/2017	**Easting:** 770020 **Northing:** 7488120

GEOLOGICAL DESCRIPTION

DEPTH (m)	LITHOLOGY
0	**Alluvium** Soil, medium reddish-brown, clayey, C1
	Alluvium Clay (brown) C2
	Alluvium Clay, medium yellowish-brown, sandy, C2
5	
	Alluvium Sand, medium-yellow, alluvial, clayey (orange) S1
	Alluvium Clay, light-yellow, sandy, C2
10	
	Alluvium Sand, light-yellow, clayey, S1
	Alluvium Sand, light reddish yellow, alluvial, sandy, S1
15	
	Alluvium Gravel, light reddish yellow, alluvial, sandy, S1
	Styx Coal Measures - Underburden Sandstone, light-yellowish white, quartzose gravel, R3

CONSTRUCTION INFO.

WELL DESCRIPTION
0 - 6m Cement/bentonite grout
0 - 12m 125mm CL12 PVC blank casing
6 - 8.7m Bentonite pellets
8.7 - 18.4m Gravel pack
12 - 18m 125mm CL12 PVC slotted casing, 1mm aperture
EOH @ 18.4m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP07

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 16/10/2017

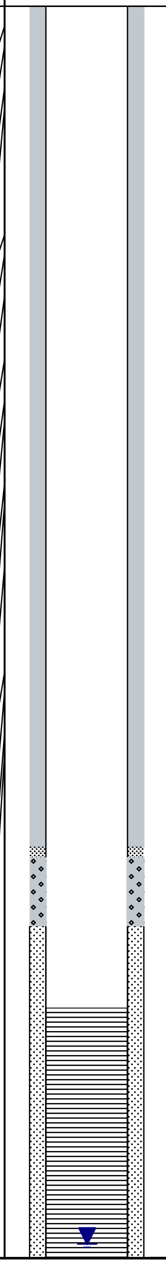
Total Depth (m bgl): 60
Well Stick Up (m): 1
Surface Elevation (m AHD): 130.9
Static Water Level
Date: 19/12/2017 **Depth (mbRP):** 60.56
Projection: GDA_94
Easting: 771264 **Northing:** 7483151

GEOLOGICAL DESCRIPTION

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
		Alluvium Gravel, medium yellowish red, oxidised
		Styx Coal Measures - Underburden Siltstone, light reddish cream, possibly chert, R6
		Styx Coal Measures - Underburden Siltstone, medium yellowish red, oxidised, possibly chert, R6
		Styx Coal Measures - Underburden Sandstone, fine-medium grained, medium-dark greyish red, oxidised, R5
		Styx Coal Measures - Underburden Sandstone, fine-medium grained, light grey, fresh rock, quartzose, R5
		Styx Coal Measures - Underburden Sandstone, fine-medium grained, medium greyish red, quartzose, oxidised, R5
		Styx Coal Measures - Underburden Sandstone, fine-medium grained, light grey, quartzose, R5
		Styx Coal Measures - Underburden Claystone, medium grey, high plasticity, R3
		Styx Coal Measures - Underburden Sandstone, fine-medium grained, grey, minor claystone, R4
		Styx Coal Measures - Underburden Sandstone, fine-coarse grained, medium reddish grey, quartzose, oxidised, R5
		Styx Coal Measures - Underburden Sandstone, fine-coarse grained, light whitish grey, quartzose, R5
		Styx Coal Measures - Underburden Sandstone, fine grained, medium grey, abundant claystone, R5
		Styx Coal Measures - Underburden Sanstone, fine-medium grained, medium grey, coaly wisps, R5
		Styx Coal Measures - Underburden Claystone, medium grey, minor siltone, R4
		Styx Coal Measures - Underburden Sandstone, fine-coarse grained medium brownish grey, minor conglomerate, tuff and siltstone, R4
		Styx Coal Measures - Underburden Sandstone, lithic, fine-coarse grained, light blackish grey, coaly wisps
		Styx Coal Measures - Underburden Siltstone, dark grey, R6
		Styx Coal Measures - Underburden Siltstone, dark grey, sandstone at base of unit, R6

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 40.3m Cement/bentonite grout
0 - 48m 125mm CL12 PVC blank casing

40.3 - 40.8m Sand
40.8 - 44.1m Bentonite pellets

44.1 - 60m Gravel pack

48 - 60m 125mm CL12 PVC slotted casing, 1mm aperture

EOH @ 60m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP08

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 2/11/2017

Total Depth (m bgl): 16
Well Stick Up (m): 1
Surface Elevation (m AHD): 46.9
Static Water Level
Date: 8/11/2017 **Depth (mbRP):** 11.14
Projection: GDA_94
Easting: 774134 **Northing:** 7481232

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Residual soil, medium pinkish brown, clayey and oxidised, C1		0 - 5.6m Cement/bentonite grout 0 - 10m 125mm CL12 PVC blank casing
		Alluvium Clays, medium brownish yellow, highly plastic with rare sand, C1		
5		**Alluvium** Sand, medium reddish yellow, alluvial, with gravel and clay, S1		5.6 - 7.1m Sand
		Alluvium Clays, light yellowish grey, highly plastic, weathered, C1		7.1 - 8.2m Bentonite pellets 8.2 - 16m Gravel pack
10				10 - 16m 125mm CL12 PVC slotted casing, 1mm aperture
15				EOH @ 16m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP09

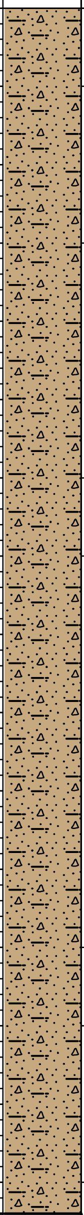
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 14/10/2017

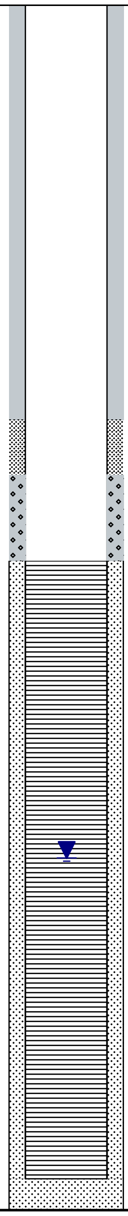
Total Depth (m bgl): 15.4
Well Stick Up (m): 1.0
Surface Elevation (m AHD): 37.6
Static Water Level
Date: 11/11/2017 **Depth (mbRP):** 12
Projection: GDA_94
Easting: 773459 **Northing:** 7484062

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m) | GRAPHIC LOG | LITHOLOGY | WELL CONSTRUCTION | WELL DESCRIPTION



Depth (m)	Lithology
0	**Alluvium** Soil, medium-dark greenish brown, sandy, carbonaceous, gravelly, C1
	Alluvium Clay, medium-dark buff brown, rare gravel, C1
	Alluvium Gravel, mottled yellow, alluvial, clayey, rare oxidisation, R1
5	**Alluvium** Gravel, mottled buff, alluvial, claystone, carbonaceous, alluvial, R1
	Alluvium Claystone, light yellowish grey, C1
10	**Alluvium** Claystone, light yellowish brown, gravelly, carbonaceous, alluvial, C1
	Alluvium Clay, light yellowish brown, gravelly carbonaceous, alluvial, oxidised, C1
15	**Alluvium** Claystone, light-yellowish brown, C1



Well Description

- 0 - 5.3m Cement/bentonite grout
- 0 - 7.1m 125mm CL12 PVC blank casing
- 5.3 - 6m Sand
- 6 - 7.1m Bentonite pellets
- 7.1 - 15.4m Gravel pack
- 7.1 - 15m 125mm CL12 PVC slotted casing, 1mm aperture
- EOH @ 16m

COMPOSITE WELL LOG

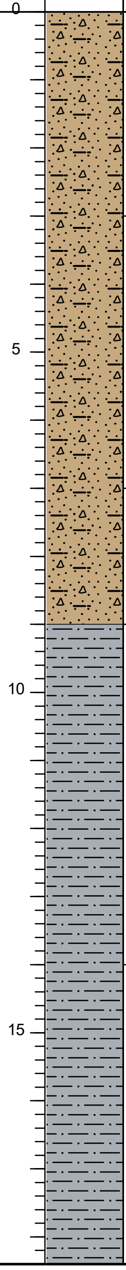
BOREHOLE / WELL NUMBER: WMP10

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 18.4
Location: Styx Coal Basin	**Well Stick Up (m):** 0.8
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 29.3
Drilled By: Mitchell Services	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 11/11/2017 **Depth (mbRP):** 8.95
Bore Diameter: 200mm	**Projection:** GDA_94
Date Drilled: 13-Oct-17	**Easting:** 775878 **Northing:** 7486688

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY



Alluvium
Soil, medium brownish yellow, sandy, oxidised, C1

Alluvium
Sand, medium-coarse grained, medium brownish yellow, alluvial, S1

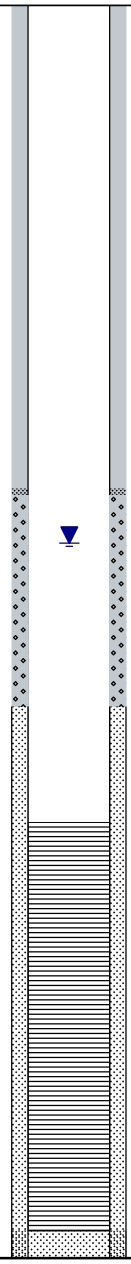
Alluvium
Gravel, medium yellowish brown, sandy clayey in parts, S1

Styx Coal Measures - Overburden
Claystone, medium greyish yellow, gravelly, oxidised, R2

Styx Coal Measures - Overburden
Claystone, medium yellowish grey, R2

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 7.2m Cement/bentonite grout
0 - 12m 125mm CL12 PVC blank casing

7.1 - 7.2m Sand
7.2 - 10.3m Bentonite pellets

10.3 - 18.4m Gravel pack

12 - 18m 125mm CL12 PVC slotted casing, 1mm aperture

18 - 18.4m sump
EOH @ 18.4m

COMPOSITE WELL LOG

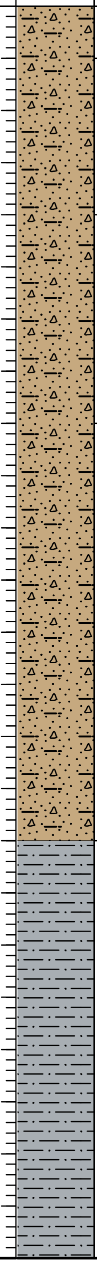
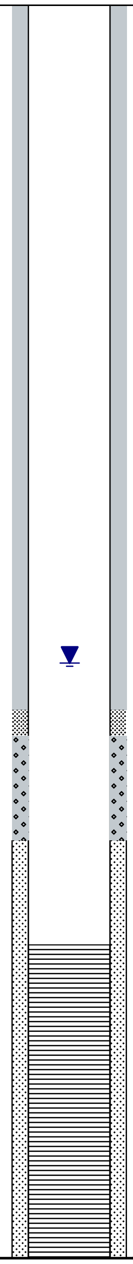
BOREHOLE / WELL NUMBER: WMP11

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 18/03/2018

Total Depth (m bgl): 24
Well Stick Up (m): 1.1
Surface Elevation (m AHD): 18.7
Static Water Level
Date: 11/04/2018 **Depth (mbRP):** 13.66
Projection: GDA_94
Easting: 774194 **Northing:** 7493610

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Clay, residual soil, mottled brownish-green, low plasticity, sandy (fine-medium grained)		0 - 13.5m Cement/bentonite grout 0 - 18m 125mm CL12 PVC blank casing
		Alluvium Clay, light-medium creamy-brown, sand abundant, medium-coarse grained, extremely weathered, C1		
5		**Alluvium** Clay, light-medium buff brown, abundant fine-medium grained sand, extremely weaterhed, C1		
10		**Alluvium** Clay, light-medium brown, minor sand (fine-medium grained) and gravel, extremely weathered, C1		13.5 - 14m Sand 14 - 16m Bentonite pellets
15		**Styx Coal Measures - Overburden** Siltstone, medium-dark bluish-green with fine-grained sand, fresh rock, R1		16 - 24m Gravel pack 18- 24m 125mm CL12 PVC slotted casing, 1mm aperture
20				EOH @ 24m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP12

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 18
Location: Styx Coal Basin	**Well Stick Up (m):** 1.1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 26.4
Drilled By: Mitchell Services	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 12/11/2017 **Depth (mbRP):** 18
Bore Diameter: 200mm	**Projection:** GDA_94
Date Drilled: 06-Nov-17	**Easting:** 773266 **Northing:** 7490731

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m) | GRAPHIC LOG | LITHOLOGY | WELL CONSTRUCTION | WELL DESCRIPTION

Depth scale: 0, 5, 10, 15

Alluvium
Gravel, medium brownish mottled, alluvial, clayey, low plasticity, C1

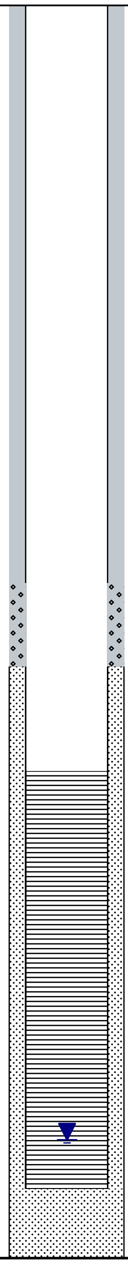
Alluvium
Clay, light brownish buff, gravelly, alluvial, high plasticitiy C1

Alluvium
Clay, light-medium brownish buff, high plasticity, C1

Alluvium
Clay, medium reddish brown, high plasticity, sandy, C1

Alluvium
Clay, light reddish brown, high plasticity, C1

Styx Coal Measures - Overburden
Claystone, light-medium creamish brown, clayey, sandy, R1



Well description:

0 - 8.3m Cement/bentonite grout
0 - 11m 125mm CL12 PVC blank casing

8.3 - 9.5m Bentonite pellets

9.5 - 18m Gravel pack

11 - 17m 125mm CL12 PVC slotted casing, 1mm aperture

17 - 18m sump

EOH @ 18m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP13

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 12-Jan-18

Total Depth (m bgl): 19.7
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 18.8
Static Water Level
Date: 17/01/2018 **Depth (mbRP):** 14.9
Projection: GDA_94
Easting: 772604 **Northing:** 7495931

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Soil, medium reddish brown, C1		0 - 9.6m Cement/bentonite grout 0 - 12.7m 125mm CL12 PVC blank casing
		Alluvium Clay, medium greyish brown, high plasticity, C1		
5		**Alluvium** Clay, medium, greyish brown, staining, high plasticity, C1		
		Alluvium Clay, medium brownish cream, staining, high plasticity, C2		
		Alluvium Sand, very fine grained medium brownish yellow, S1		9.6 - 11.4m Bentonite pellets
10		**Alluvium** Sand, very fine grained light yellowish cream, quartzose, S1		
		Alluvium Clay, light yellowish cream, staining, moderate plasticity, C2		11.4 - 19.7m Gravel pack
		Alluvium Sand, fine-coarse grained, medium brownish yellow, clayey, low plasticity, S1		12.7 - 19.7m 125mm CL12 PVC slotted casing, 1mm aperture
		Styx Coal Measures - Overburden Siltstone, medium brownish, yellow, sandy, R2		
15				
		Styx Coal Measures - Overburden Siltstone, medium yellow grey, R3		
		Styx Coal Measures - Overburden Sandstone, fine-medium grained, medium greenish grey, fresh rock, R4		EOH @ 19.7m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP14

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 19/03/2018

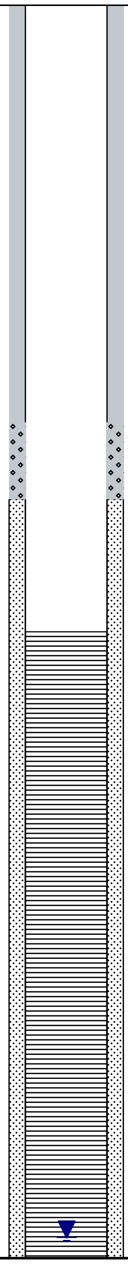
Total Depth (m bgl): 18
Well Stick Up (m): 1.1
Surface Elevation (m AHD): 32.9
Static Water Level
Date: 10/04/2018 **Depth (mbRP):** 18.83
Projection: GDA_94
Easting: 770477 **Northing:** 7487637

GEOLOGICAL DESCRIPTION

DEPTH (m)	LITHOLOGY
0	**Alluvium** Clay, residual soil, medium brownish-grey, low plasticity, C1
	Alluvium Clay, light-medium greyish buff, low plasticity, minor fine-medium grained sand, weathered, C1
5	**Alluvium** Sand, light-medium buff orange, minor gravel, weathered, S1
	Alluvium Sand, fine-medium, grained, medium-dark brown, rare gravel, weathered, S1
	Alluvium Sand, fine-medium, grained, medium-dark orangey brown, gravelly with rare coarse sand, weathered, S1
10	**Alluvium** Sand, fine-medium, grained, speckled orangey buff, alluvial with minor coarse grains, weathered, S1
	Alluvium Sand, speckled greyish multi-coloured, minor gravel, weathered, S1
15	**Styx Coal Measures - Overburden** Siltstone, medium to dark bluish-grey, weathered, R1
	Styx Coal Measures - Overburden Sand, granular to pebbly grained, speckled greyish red, minor gravel, weathered, R1.

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 6m Cement/bentonite grout
0 - 9m 125mm CL12 PVC blank casing
6 - 7.1m Bentonite pellets
7.1 - 18m Gravel pack
9 - 18m 125mm CL12 PVC slotted casing, 1mm aperture
EOH @ 18m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP15

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Mitchell Services
Drilling Method: Air Hammer
Bore Diameter: 200mm
Date Drilled: 20-Mar-18

Total Depth (m bgl): 21
Well Stick Up (m): 1.2
Surface Elevation (m AHD): 43.2
Static Water Level
Date: 10/04/2018 **Depth (mbRP):** 11.44
Projection: GDA_94
Easting: 771774 **Northing:** 7485564

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m) | GRAPHIC LOG | LITHOLOGY | WELL CONSTRUCTION | WELL DESCRIPTION

Depth scale: 0, 5, 10, 15, 20

Alluvium
Clay, medium brownish red, residual soil, commonly pebbly, C1

Alluvium
Clay, light brown, weathered, C1

Alluvium
Clay, light greyish brown, weathered, C1

Alluvium
Clay, light yellowish brown, weatehred, C1

Alluvium
Clay, light whitish brown, weathered, C1

Alluvium
Clay, light-dark reddish brown, weathered, C1

Alluvium
Clay, light brownish white, weathered, C1

Alluvium
Sand, medium grained, light-medium reddish brown, wethered, S1

Alluvium
Clay, light brown, weathered, C1

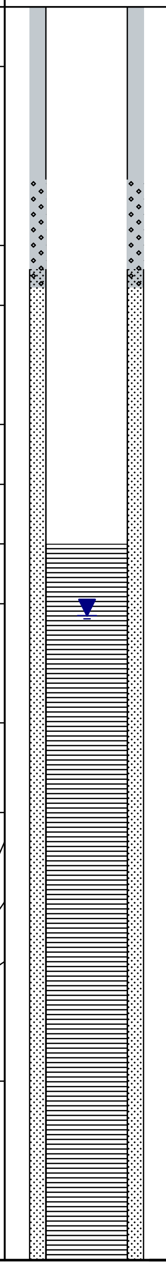
Alluvium
Clay, light grey, weathered, C1

Alluvium
Clay, light brown, weathered, C1

Alluvium
Sand, medium, grained, light brown, weathered, S1

Styx Coal Measures - Underburden
Sandstone, medium grained, fresh rock, R5

Styx Coal Measures - Underburden
Siltstone, dark grey, fresh rock, R3



Well description:

0 - 2.9m Cement/bentonite grout
0 - 9m 125mm CL12 PVC blank casing

2.9 - 4.7m Bentonite pellets

4.4 - 21m Gravel pack

9 - 21m 125mm CL12 PVC slotted casing, 1mm aperture

EOH @ 21m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP16

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 31.5
Location: Styx Coal Basin	**Well Stick Up (m):** 0.65
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 43
Drilled By: Waratah Coal	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 21/10/2018 **Depth (mbRP):** 22.15
Bore Diameter: 5"	**Projection:** GDA_94
Date Drilled: 20-Oct-18	**Easting:** 767930 **Northing:** 7494387

GEOLOGICAL DESCRIPTION / CONSTRUCTION INFO.

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
0	**Alluvium** Sandy clay. Low plasticity, reddish-brown, dry, hard. Very sandy, with gravel and cobble lenses. Gravels: rounded to subangular sandstone, diameter is up to 10cm	0 - 22.5m Cement/bentonite grout 0 - 25.5m 50mm CL18 uPVC blank casing, thread jointed
	Alluvium Clayey sand. Reddish-brown, dry. Some gravels present	
5	**Alluvium** Clayey silt with some hard cemented lenses, red/white, dry.	
	Styx Coal Measures - Overburden Silt. (Extremely weathered sandstone). Light brown	
10	**Styx Coal Measures - Overburden** Sandstone. (Highly weathered) Brown/grey, dry. Siltstone lenses	
15		
	Styx Coal Measures - Overburden Siltstone. (Highly weathered) Grey with brown stains, dry.	
20		
	Styx Coal Measures - Overburden Siltstone. Hard competent rock, grey with brown stains. Evidence of weathering in fractures	22.5 - 24.5m Bentonite pellets
	Styx Coal Measures - Overburden Sandstone. Fresh, grey, very hard.	24.5 - 31.5m Gravel pack, (3mm rounded gravels) 25.5 - 31.5m 50mm CL18 uPVC slotted casing, 1mm aperture, thread jointed
25		
	Styx Coal Measures - Overburden Siltstone. Fresh, dark grey.	
30		EOH @ 31.5m
	Styx Coal Measures - Overburden Siltstone. Fresh, dark grey, with traces of coal.	

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP16D

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project		**Total Depth (m bgl):** 42	
Location: Styx Coal Basin		**Well Stick Up (m):** 0.75	
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd		**Surface Elevation (m AHD):** 43	
Drilled By: Waratah Coal		**Static Water Level**	
Drilling Method: Air Hammer		**Date:** 01/11/2018	**Depth (mbRP):** 27.64
Bore Diameter: 5"		**Projection:** GDA_94	
Date Drilled: 21-Oct-18		**Easting:** 767923	**Northing:** 7494380

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION

Alluvium
Sandy clay. Low plasticity, reddish-brown, dry, hard. Very sandy, with gravel and cobble lenses.
Gravels: rounded to subangular sandstone, diameter is up to 10cm

Alluvium
Clayey sand. Reddish-brown, dry. Some gravels present

Alluvium
Clayey silt with some hard cemented lenses, red/white, dry.

Styx Coal Measures - Overburden
Silt. (Extremely weathered sandstone). Light brown

Styx Coal Measures - Overburden
Sandstone. (Highly weathered) Brown/grey, dry. Siltstone lenses

Styx Coal Measures - Overburden
Siltstone. (Highly weathered) Grey with brown stains, dry.

Styx Coal Measures - Overburden
Siltstone. Hard competent rock, grey with brown stains. Evidence of weathering in fractures

Styx Coal Measures - Overburden
Sandstone. Fresh, grey, very hard.

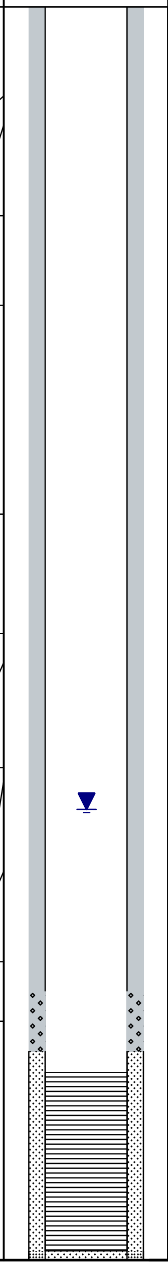
Styx Coal Measures - Overburden
Gravel. Rounded to sub-angular, well graded, diameter up to 5cm. Various origins, red/brown/grey/white

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey.

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey/black, with traces of coal.

Styx Coal Measures - Overburden
Coal/carbonaceous siltstone, black

Styx Coal Measures - Interburden
Altered sandstone. Glauconite? Igneous rock? Grey, stained green, with quartz-filled veins, some pyrite.



Well description:

0 - 33m Cement/bentonite grout
0 - 35.7m 50mm CL9 uPVC blank casing, bell jointed with glue

33 - 35m Bentonite pellets

35 - 42m Gravel pack, (3mm)
35.7 - 41.7m 50mm CL9 uPVC slotted casing, 1mm aperture, bell jointed with glue

EOH @ 42m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP17

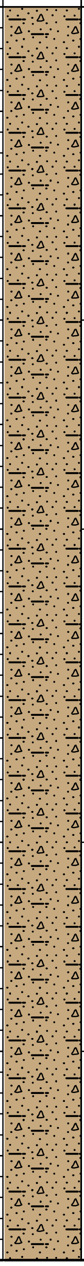
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 12
Location: Styx Coal Basin	**Well Stick Up (m):** 0.77
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 39
Drilled By: Waratah Coal	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 03/11/2018 **Depth (mbRP):** 12.59
Bore Diameter: 6.75"	**Projection:** GDA_94
Date Drilled: 03-Oct-18	**Easting:** 775465 **Northing:** 7483308

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY

0



Alluvium
Silty clay. Low plasticity, very stiff, brown, dry

Alluvium
Clayey silt. Loose cuttings, light brown / gold, dry

5

Alluvium
Sandy silt. Loose cuttings, light brown / gold, very fine grained sands

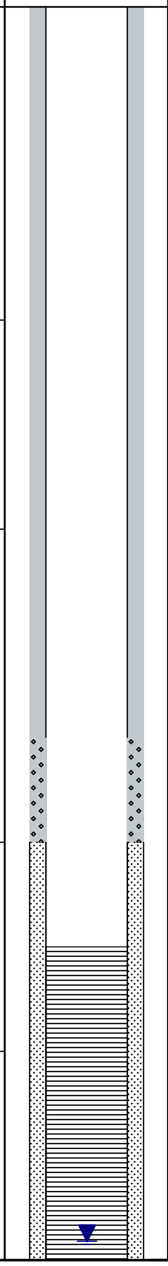
Alluvium
Sandy silt. Slightly moist

10

Alluvium
Clayey silt. Very low plasticity, light brown, slightly moist

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 7m Cement/bentonite grout
0 - 9m 50mm CL18 uPVC blank casing, thread jointed

7 - 8m Bentonite pellets

8 - 12m Gravel pack, (2 - 5mm)

9 - 12m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 12m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP17D

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 03-Oct-18

Total Depth (m bgl): 24
Well Stick Up (m): 0.53
Surface Elevation (m AHD): 39
Static Water Level
Date: 31/10/2018 **Depth (mbRP):** 12.25
Projection: GDA_94
Easting: 775470 **Northing:** 7483286

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY

0 5 10 15 20

Alluvium
Silty clay. Low plasticity, very stiff, brown, dry

Alluvium
Silty clay. Very silty, light brown

Alluvium
Clayey silt. Loose cuttings, light brown / gold

Alluvium
Sandy silt. Loose cuttings, very fine grained sands, light brown / gold, very slight moisture

Alluvium
Sandy silt. Slightly moist

Alluvium
Clayey silt. Very low plasticity, light brown, increasing moisture

Alluvium
Clayey silt. With some fine grained sands

Alluvium
Silt. (Extremely weathered Siltstone) Grey, slightly moist

Styx Coal Measures - Overburden
Siltstone. Weathered, grey with trace coal

Styx Coal Measures - Overburden
Sand. (Extremely weathered sandstone) Light grey, slightly moist

Styx Coal Measures - Overburden
Clayey sand. Very dense, fine grained, grey, low clay content, slightly moist

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey, competent rock

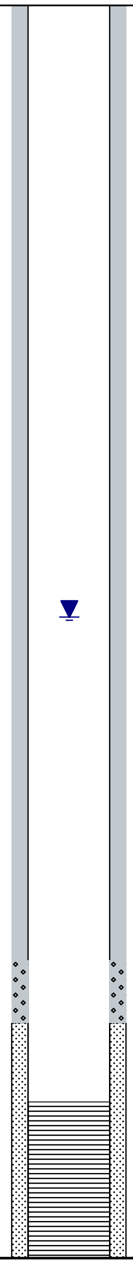
Styx Coal Measures - Overburden
Siltstone. Carbonaceous, black, moist

Styx Coal Measures - Overburden
Siltstone. Very moist

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 18.3m Cement/bentonite grout
0 - 21m 50mm CL18 uPVC blank casing, thread jointed

18.3 - 19.5m Bentonite pellets

19.5 - 24m Gravel pack, (2 - 5mm)
21 - 24m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 24m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP18

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 13-Sep-18

Total Depth (m bgl): 12.2
Well Stick Up (m): 0.56
Surface Elevation (m AHD): 34
Static Water Level
Date: 18/09/2018 **Depth (mbRP):** 12.15
Projection: GDA_94
Easting: 775366 **Northing:** 7487144

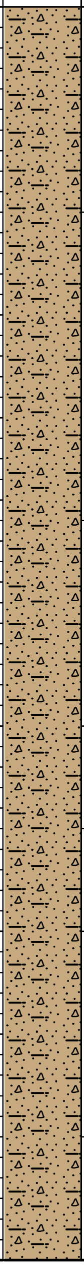
GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY

0

5

10



Alluvium
Clay. Medium plasticity, dark brown, dry

Alluvium
Clay. Medium plasticity, brown, dry

Alluvium
Sand. Fine to medium grained, with trace of fine gravel, pale yellow

Alluvium
Sand. Fine grained, with trace of clay, pale yellow

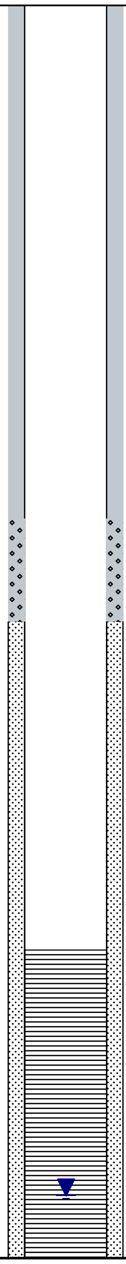
Alluvium
Clayey sand. Fine to medium grained, light brown-yellow, moist

Alluvium
Clay. Medium plasticity, grey, moist

Alluvium
Clay. Medium plasticity, grey mottled brown, moist

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 5m Cement/bentonite grout
0 - 9.2m 50mm CL18 uPVC blank casing, thread jointed

5 - 6m Bentonite pellets

6 - 12.2m Gravel pack, (2 - 5mm)

9.2 - 12.2m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 12.2m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP18D

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 23.5
Location: Styx Coal Basin	**Well Stick Up (m):** 0.44
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 33
Drilled By: Waratah Coal	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 18/09/2018 **Depth (mbRP):** 14.56
Bore Diameter: 6.75"	**Projection:** GDA_94
Date Drilled: 12-Sep-18	**Easting:** 775358 **Northing:** 7487152

GEOLOGICAL DESCRIPTION

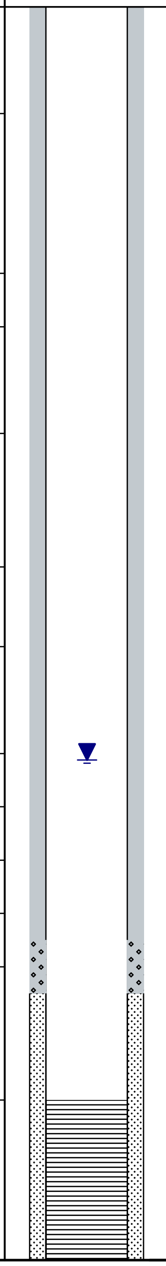
DEPTH (m): 0, 5, 10, 15, 20

GRAPHIC LOG

LITHOLOGY
Alluvium Clay. Medium plasticity, grey-brown, dry
Alluvium Clay. Low plasticity, brown, dry
Alluvium Clay. Medium plasticity, grey-brown, dry
Alluvium Sand. Fine grained, with trace fine gravel (conglomerate), pale yellow, dry
Alluvium Gravel / Conglomerate. Fine to coarse sized with some fine sand, dry to moist
Alluvium Clay. Medium plasticity, orange-brown, moist
Styx Coal Measures- Overburden Mudstone. (Siltstone) Weathered, grey-brown, moist
Styx Coal Measures- Overburden Siltstone. Weathered, grey, moist
Styx Coal Measures- Overburden Siltstone. Slightly weathered, grey-brown, moist
Styx Coal Measures- Overburden Sandstone. Slightly weathered, grey
Styx Coal Measures- Overburden Sandstone. Slightly weathered, very dark grey
Styx Coal Measures- Overburden Siltstone. Fresh, with some coal, black
Styx Coal Measures- Overburden Siltstone. Fresh, grey

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 17.5m Cement/bentonite grout

0 - 20.5m 50mm CL18 uPVC blank casing, thread jointed

17.5 - 18.5m Bentonite pellets

18.5 - 23.5m Gravel pack, (2 - 5mm)

18.5 - 23.5m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 23.5m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP19

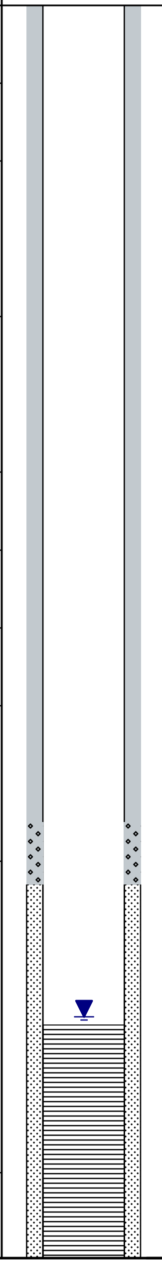
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 16.1
Location: Styx Coal Basin	**Well Stick Up (m):** 0.64
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 46
Drilled By: Waratah Coal	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 17/09/2018 **Depth (mbRP):** 13.64
Bore Diameter: 6.75"	**Projection:** GDA_94
Date Drilled: 06-Sep-18	**Easting:** 768808 **Northing:** 7485676

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
0		**Weathered Basement** Clay. With trace fine gravel, medium plasticity, grey
		Weathered Basement Clay. With trace fine to medium gravel, medium plasticity, grey
		Weathered Basement Clay. With some fine sand and fine gravel, medium plasticity, light brown
		Weathered Basement Sandstone. Weathered, light grey
5		
		Weathered Basement Sandstone. Weathered, grey
		Weathered Basement Siltstone / Sandstone. Weathered, grey
		Weathered Basement Siltstone. With sandstone, laminated, grey
		Weathered Basement Siltstone / Claystone. Weathered, dark grey
10		
		Weathered Basement Siltstone. Fresh, dark grey / black
15		
		Weathered Basement Siltstone. Fresh, carbonated, black

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 10.5m Cement/bentonite grout
0 - 13.1m 50mm CL9 uPVC blank casing, thread jointed

10.5 - 11.3m Bentonite pellets

11.3 - 16.1m Gravel pack, (2 - 5mm)

13.1- 16.1m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 16.1m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP19D

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 07-Sep-18

Total Depth (m bgl): 28
Well Stick Up (m): 0.58
Surface Elevation (m AHD): 47
Static Water Level
Date: 17/09/2018 **Depth (mbRP):** 13.58
Projection: GDA_94
Easting: 768801 **Northing:** 7485692

GEOLOGICAL DESCRIPTION

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
0		**Weathered Basement** Clay. With trace fine gravel, medium plasticity, grey
		Weathered Basement Clay. With trace fine gravel, medium plasticity, light brown
		Weathered Basement Clay. Medium plasticity, light brown
		Weathered Basement Sandstone. Extremely weathered, with some laminated clay, light grey
5		**Weathered Basement** Sandstone. Weathered, with laminated siltstone, light grey
		Weathered Basement Siltstone. Weathered, grey
10		**Weathered Basement** Siltstone. Fresh, grey to dark grey
		Weathered Basement Siltstone. Fresh, very dark grey
		Weathered Basement Siltstone. With lenses of coal and carbonaceous siltstone, carbonated black
15		
20		
25		

CONSTRUCTION INFO.

WELL CONSTRUCTION	WELL DESCRIPTION
	0 - 17.8m Cement/bentonite grout 0 - 24.9m 50mm CL9 uPVC blank casing, thread jointed
	17.8 - 18.8m Bentonite pellets
	18.8 - 28m Gravel pack, (2 - 5mm)
	24.9 - 27.9m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed
	EOH @ 28m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP20

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 20.5
Location: Styx Coal Basin	**Well Stick Up (m):** 0.53
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 40
Drilled By: Waratah Coal	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 01/11/2018 **Depth (mbRP):** 19.68
Bore Diameter: 5"	**Projection:** GDA_94
Date Drilled: 20-Oct-18	**Easting:** 768251 **Northing:** 7490084

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY

0

Styx Coal Measures - Overburden
Silty clay. Low plasticity, very silty, brown, dry, very hard

Styx Coal Measures - Overburden
Sandstone. Highly weathered, brown and grey lenses

5

Styx Coal Measures - Overburden
Siltstone. Highly weathered, brown and grey lenses

Styx Coal Measures - Overburden
Sandstone. Highly weathered, brown and grey lenses

Styx Coal Measures - Overburden
Fresh, dark grey

10

Styx Coal Measures - Overburden
Siltstone. Highly weathered with sandstone lenses, brown and grey

15

Styx Coal Measures - Overburden
Sandstone. Highly weathered, brown and grey lenses

Styx Coal Measures - Overburden
Sandstone. Highly weathered, brown with some white infilled veins, oxide stained fractures, potential water cut.

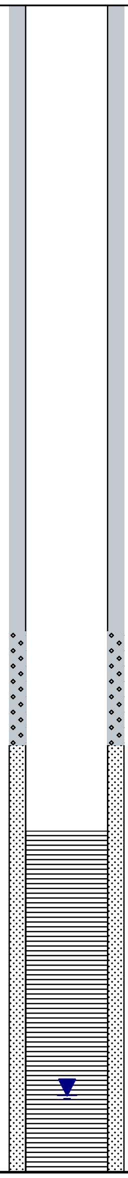
Styx Coal Measures - Overburden
Sandstone. Fresh, grey, hard

20

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 11m Cement/bentonite grout
0 - 14.5m 50mm CL18 uPVC blank casing, thread jointed

11 - 13m Bentonite pellets

13 - 20.5m Gravel pack, (3mm rounded gravels)
14.5 - 20.5m 50mm CL18 uPVC slotted casing, 1mm aperture, thread jointed

EOH @ 20.5m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP20D

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Rotary Air
Bore Diameter: 5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 30
Well Stick Up (m): 0.5
Surface Elevation (m AHD): 40
Static Water Level
Date: 02/11/2018 **Depth (mbRP):** 19.53
Projection: GDA_94
Easting: 768246 **Northing:** 7490082

GEOLOGICAL DESCRIPTION / CONSTRUCTION INFO.

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
0	**Styx Coal Measures - Overburden** Silty clay. Low plasticity, very silty, brown, dry, very hard	0 - 21m Cement/bentonite grout 0 - 24m 50mm CL18 uPVC blank casing, thread jointed
	Styx Coal Measures - Overburden Sandstone. Highly weathered, brown and grey lenses	
5	**Styx Coal Measures - Overburden** Siltstone. Highly weathered, brown and grey lenses	
	Styx Coal Measures - Overburden Sandstone. Highly weathered, brown and grey lenses	
10	**Styx Coal Measures - Overburden** Fresh, dark grey	
	Styx Coal Measures - Overburden Siltstone. Highly weathered with sandstone lenses, brown and grey	
15	**Styx Coal Measures - Overburden** Sandstone. Highly weathered, brown and grey lenses	
	Styx Coal Measures - Overburden Sandstone. Highly weathered, brown with some white infilled veins, oxide stained fractures, potential water cut.	
20	**Styx Coal Measures - Overburden** Sandstone. Fresh, grey, hard	21 - 23m Bentonite pellets
	Styx Coal Measures - Overburden Siltstone. Fresh, dark grey	23 - 30m Gravel pack, (3mm rounded gravels) 24 - 30m 50mm CL18 uPVC slotted casing, 1mm aperture, thread jointed
	Styx Coal Measures - Overburden Sandstone. Fresh, grey	
25	**Styx Coal Measures - Overburden** Siltstone. Fresh, dark grey	
	Styx Coal Measures - Overburden Sandstone. Grey with brown weathered lenses. Water cut	
30	**Styx Coal Measures - Overburden** Siltstone. Fresh, dark grey	EOH @ 30m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP21

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 10-Sep-18

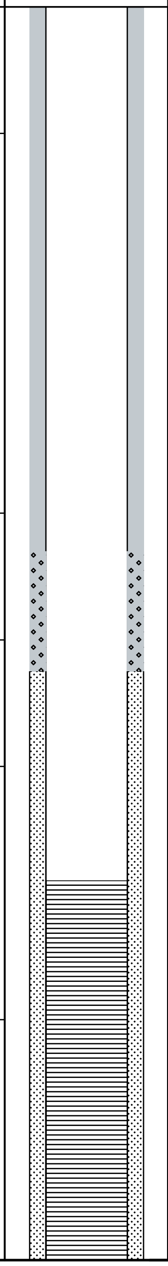
Total Depth (m bgl): 9.9
Well Stick Up (m): 0.66
Surface Elevation (m AHD): 12
Static Water Level
Date: 17/09/2018 **Depth (mbRP):** Dry
Projection: GDA_94
Easting: 774294 **Northing:** 7490072

GEOLOGICAL DESCRIPTION

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
0		**Alluvium** Clay. Medium plasticity, brown
		Alluvium Clay. With trace fine gravel, medium plasticity, brown
		Alluvium Clay. With some sand, medium plasticity, light brown
5		**Alluvium** Sand. Fine grained with trace pebbles, brown
		Alluvium Sand. Fine to medium grained with some pebbles, light brown
		Alluvium Sand. Medium to coarse grained with some pebbles (conglomerate of nature and colour), light brown, moist

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 4.3m Cement/bentonite grout
0 - 6.9m 50mm CL18 uPVC blank casing, thread jointed

4.3 - 5.25m Bentonite pellets

5.25 - 9.9m Gravel pack, (2 - 5mm)

6.9 - 9.9m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

Dry well (17 Sept 2018)
EOH @ 9.9m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP21D

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 10-Sep-18

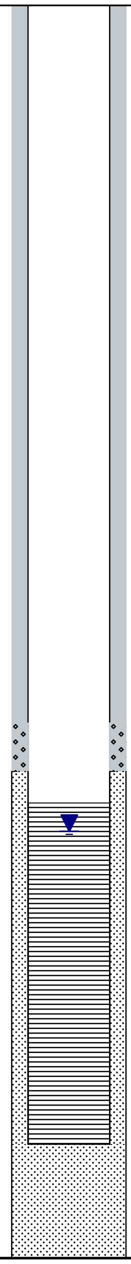
Total Depth (m bgl): 22
Well Stick Up (m): 0.54
Surface Elevation (m AHD): 26
Static Water Level
Date: 17/09/2018 **Depth (mbRP):** 15.04
Projection: GDA_94
Easting: 774243 **Northing:** 7490004

GEOLOGICAL DESCRIPTION

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
0		**Alluvium** Clay. Medium plasticity, brown
		Alluvium Clay. With fine sand, medium plasticity, brown
5		**Alluvium** Sand. Fine grained with minor layer of pebbles, light brown
		Alluvium Sand. Fine grained with pebbles, light brown
		Alluvium Sand. Medium grained with pebbles, light brown
10		**Alluvium** Sand. Medium to coarse grained with pebbles, light brown
		Alluvium Clay. Medium plasticity, brown
		Alluvium Sand. Coarse grained, yellow-brown
15		**Alluvium** Gravel / Conglomerate. Fine to coarse sized, subangular to subrounded
		Styx Coal Measures- Overburden Mudstone. Weathered, grey-brown
20		**Styx Coal Measures- Overburden** Mudstone. Slightly weathered, grey

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 12.6m Cement/bentonite grout
0 - 14m 50mm CL18 uPVC blank casing, thread jointed
12.6 - 13.45m Bentonite pellets
13.45 - 22m Gravel pack, (2 - 5mm)
14 - 20m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed
20 - 22m Backfilled with gravels (2 - 5mm)
EOH @ 22m

COMPOSITE WELL LOG

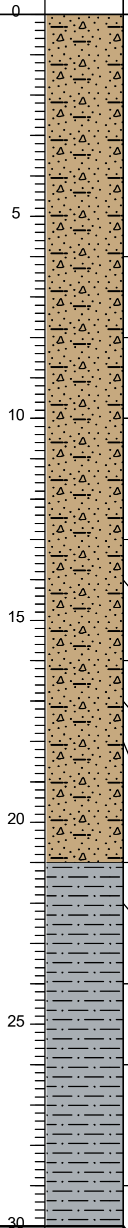
BOREHOLE / WELL NUMBER: WMP22A

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

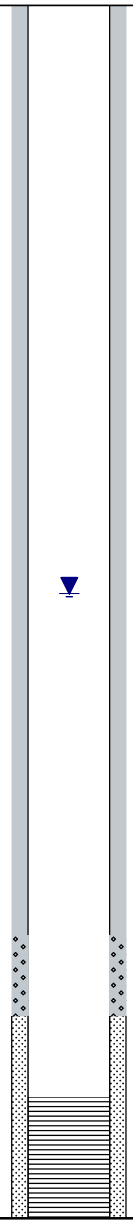
Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 30
Well Stick Up (m): 0.35
Surface Elevation (m AHD): 33
Static Water Level
Date: 01/11/2018 **Depth (mbRP):** 14.90
Projection: GDA_94
Easting: 772008 **Northing:** 7488891

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION



LITHOLOGY
Alluvium Silty clay. Moderate plasticity, very stiff, brown/grey, dry
Alluvium Sandy silt. Loose, very fine grained sands, light brown/orange, dry
Alluvium Silty clay. Low to moderate plasticity, very stiff, brown/grey, dry
Alluvium Clayey silt. Minimal cohesion, light brown, slightly moist
Alluvium Silty clay. Low plasticity, stiff, grey, slightly moist
Alluvium Clayey silt. Minimal cohesion, brown, slightly moist
Alluvium Sandy silt. Minimal cohesion, Fine grained sands, grey, slightly moist
Alluvium Sandy silt. Very sandy, fine to medium grains
Alluvium Clayey sand. (Extremely weathered SANDSTONE) Very dense, fine to medium grains, distinct colour change to grey, moist
Styx Coal Measures - Overburden Siltstone. Fresh, laminar, black
Styx Coal Measures - Overburden Siltstone. Dark grey, with trace of coal
Styx Coal Measures - Overburden Coal
Styx Coal Measures - Overburden Siltstone. Fresh, dark grey
Styx Coal Measures - Overburden Siltstone with trace coal



WELL DESCRIPTION:

0 - 23m Cement/bentonite grout
0 - 27m 100mm CL12 uPVC blank casing, jointed with screws and glue

23 - 25m Bentonite pellets

25 - 30m Gravel pack
27 - 30m 100mm CL12 uPVC slotted casing, jointed with screws and glue

EOH @ 30m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22B

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 56
Well Stick Up (m): 0.3
Surface Elevation (m AHD): 33
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 14.66
Projection: GDA_94
Easting: 772011 **Northing:** 7488896

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty clay. Moderate plasticity, very stiff, brown/grey, dry		0 - 46m Cement/bentonite grout 0 - 50m 100mm CL12 uPVC blank casing, jointed with screws and glue
5		**Alluvium** Sandy silt. Loose, very fine grained sands, light brown/orange, dry		
		Alluvium Silty clay. Low to moderate plasticity, very stiff, brown/grey, dry		
10		**Alluvium** Clayey silt. Minimal cohesion, light brown, slightly moist		
		Alluvium Silty clay. Low plasticity, stiff, grey, slightly moist		
15		**Alluvium** Clayey silt. Minimal cohesion, brown, slightly moist		
		Alluvium Sandy silt. Minimal cohesion, Fine grained sands, grey, slightly moist		
		Alluvium Sandy silt. Very sandy, fine to medium grains		
20		**Alluvium** Clayey sand. (Extremely weathered SANDSTONE) Very dense, fine to medium grains, distinct colour change to grey, moist		
		Styx Coal Measures - Overburden Siltstone. Fresh, laminar, black		
25		**Styx Coal Measures - Overburden** Siltstone. Dark grey, with trace of coal		
		Styx Coal Measures - Overburden Coal		
		Styx Coal Measures - Overburden Siltstone. Fresh, dark grey		
30		**Styx Coal Measures - Overburden** Siltstone with trace coal		
35		**Styx Coal Measures - Interburden** Siltstone with interbedded sandstone lenses		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22B

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 56
Location: Styx Coal Basin	**Well Stick Up (m):** 0.3
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 33
Drilled By: Depco	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 05/11/2018 **Depth (mbRP):** 14.66
Bore Diameter: 6.5"	**Projection:** GDA_94
Date Drilled: 19-Oct-18	**Easting:** 772011 **Northing:** 7488896

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
40		**Styx Coal Measures - Interburden** *(continued)*		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey		
		Styx Coal Measures - Interburden Sandstone with trace coal		
45		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		46 - 48m Bentonite pellets
		Styx Coal Measures - Interburden Siltstone with trace coal		48 - 56m Gravel pack 50 - 56m 100mm CL12 uPVC slotted casing, jointed with screws and glue
		Styx Coal Measures - Interburden Coal		
50		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
55		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		EOH @ 56m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22C

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 206
Location: Styx Coal Basin	**Well Stick Up (m):** 0.5
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 34
Drilled By: Depco	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 05/11/2018 **Depth (mbRP):** 10.34
Bore Diameter: 10", 6.5"	**Projection:** GDA_94
Date Drilled: 19-Oct-18	**Easting:** 772012 **Northing:** 7488900

GEOLOGICAL DESCRIPTION / **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty clay. Moderate plasticity, very stiff, brown/grey, dry		0 - 196m Cement/bentonite grout 0 - 200m 100mm CL12 uPVC blank casing, jointed with screws and glue
5		**Alluvium** Sandy silt. Loose, very fine grained sands, light brown/orange, dry		
		Alluvium Silty clay. Low to moderate plasticity, very stiff, brown/grey, dry		
10		**Alluvium** Clayey silt. Minimal cohesion, light brown, slightly moist		10" hole from 0 to 22m
		Alluvium Silty clay. Low plasticity, stiff, grey, slightly moist		
15		**Alluvium** Clayey silt. Minimal cohesion, brown, slightly moist		
		Alluvium Sandy silt. Minimal cohesion, Fine grained sands, grey, slightly moist		
		Alluvium Sandy silt. Very sandy, fine to medium grains		
20		**Alluvium** Clayey sand. (Extremely weathered SANDSTONE) Very dense, fine to medium grains, distinct colour change to grey, moist		
		Styx Coal Measures - Overburden Siltstone. Fresh, laminar, black		
25		**Styx Coal Measures - Overburden** Siltstone. Dark grey, with trace of coal		
		Styx Coal Measures - Overburden Coal		
		Styx Coal Measures - Overburden Siltstone. Fresh, dark grey		6.5" hole from 22 to 206m (EOH)
30		**Styx Coal Measures - Overburden** Siltstone with trace coal		
35		**Styx Coal Measures - Interburden** Siltstone with interbedded sandstone lenses		
40		**Styx Coal Measures - Interburden**		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.5
Surface Elevation (m AHD): 34
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 10.34
Projection: GDA_94
Easting: 772012 **Northing:** 7488900

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
		Sandstone. Fresh, grey **Styx Coal Measures - Interburden** *(continued)*		
45		**Styx Coal Measures - Interburden** Sandstone with trace coal		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Siltstone with trace coal		
50		**Styx Coal Measures - Interburden** Coal		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
55		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
60		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey, with trace coal		
		Styx Coal Measures - Interburden Coal		
65		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
70		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with interbedded sandstone lenses at 72m		
75		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with coal lenses between 80 and 82m. Trace coal present at 85m		
80				

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 206
Location: Styx Coal Basin	**Well Stick Up (m):** 0.5
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 34
Drilled By: Depco	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 05/11/2018 **Depth (mbRP):** 10.34
Bore Diameter: 10", 6.5"	**Projection:** GDA_94
Date Drilled: 19-Oct-18	**Easting:** 772012 **Northing:** 7488900

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
85		**Styx Coal Measures - Interburden** *(continued)*		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey with trace coal (Violet Seam) at 90m		
90				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey with interbedded siltstone lenses at 95m		
95				
		Styx Coal Measures - Underburden Siltstone. Fresh, dark grey		
100				
105				
		Styx Coal Measures - Underburden Sandstone. Very coarse grained, fresh, light grey mottled dark grey diorite appearance. Interbedded siltstone lenses present at 109m		
110		**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		
115				
		Styx Coal Measures - Underburden Sandstone. Very coarse grained, fresh, light grey / grey / dark grey. Some cuttings as rounded gravels, not chips.		
120				
		Styx Coal Measures - Underburden Sandstone. With interbedded siltstone lenses, fresh, light grey / dark grey		
125		**Styx Coal Measures - Underburden** Sandstone. Fresh, grey with interbedded siltstone at 130m		

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Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22C

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.5
Surface Elevation (m AHD): 34
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 10.34
Projection: GDA_94
Easting: 772012 **Northing:** 7488900

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
		Styx Coal Measures - Underburden *(continued)*		
130				
		Styx Coal Measures - Underburden Sandstone. Distinct colour change to brown, suspected weathering, potential water cut		
135		**Styx Coal Measures - Underburden** Sandstone. Fresh, grey, with interbedded siltstone with some brown lenses, weathered materials? at 141m		
140				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		
145				
150				
		Styx Coal Measures - Underburden Siltstone. Dark grey with some brown, drilled quicker, suspected weathered zone, likely water cut.		
155		**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey with traces of brown at 156m		
160				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		
		Styx Coal Measures - Underburden Siltstone. Fresh, grey		
165				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP22C

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

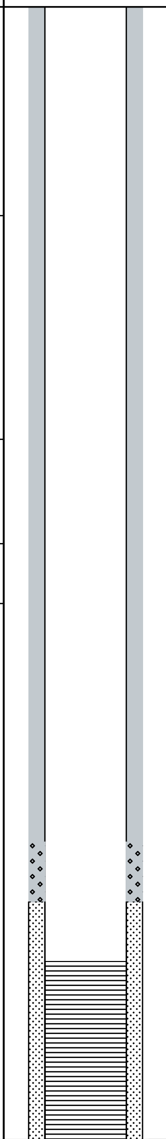
Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.5
Surface Elevation (m AHD): 34
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 10.34
Projection: GDA_94
Easting: 772012 **Northing:** 7488900

GEOLOGICAL DESCRIPTION | CONSTRUCTION INFO.

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
170		**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey
175		**Styx Coal Measures - Underburden** Igneous rock. Distinct colour change to light grey with green tinge, intrusive igneous rock with interbedded metasiltstone
180		
		Styx Coal Measures - Underburden Siltstone. Fresh, dark grey, with sandstone lenses throughout
185		**Styx Coal Measures - Underburden** Sandstone. Fresh, grey
		Styx Coal Measures - Underburden Siltstone. Fresh, dark grey with purple tinge, very hard.
190		
195		
200		
205		

WELL CONSTRUCTION



WELL DESCRIPTION

196 - 198m Bentonite pellets

198 - 206m Gravel pack, (2 - 5mm)

200 - 206m 100mm CL12 uPVC slotted casing, jointed with screws and glue

EOH @ 206m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP23A

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 6.5"
Date Drilled: 06-Oct-18

Total Depth (m bgl): 56.5
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 36
Static Water Level
Date: 02/11/2018 **Depth (mbRP):** 11.13
Projection: GDA_94
Easting: 773651 **Northing:** 7484701

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty clay. Low plasticity, brown, dry		0 - 43m Cement/bentonite grout 0 - 48.5m 100mm CL12 uPVC blank casing, jointed with screws and glue
5		**Alluvium** Clayey silt. No plasticity, loose cuttings, brown, dry		
		Alluvium Sandy silt. Loose cuttings, fine grained sands, light brown		
		Alluvium Clayey gravel. Fine to coarse, various origin and colour, grey/brown clay		
10		**Alluvium** Gravelly clay, medium plasticity		
15		**Alluvium** Siltstone. Slightly weathered, brown / grey		
20		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
25		**Styx Coal Measures - Interburden** Siltstone. Fresh, carbonaceous, black with traces of coal		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey, with traces of coal		
		Styx Coal Measures - Interburden Coal lense		
		Styx Coal Measures - Interburden		

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COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP23A

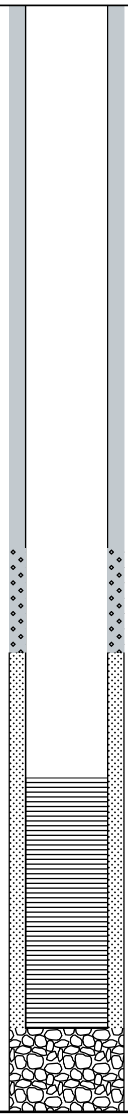
Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 56.5
Location: Styx Coal Basin	**Well Stick Up (m):** 0.9
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 36
Drilled By: Depco	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 02/11/2018 **Depth (mbRP):** 11.13
Bore Diameter: 6.5"	**Projection:** GDA_94
Date Drilled: 06-Oct-18	**Easting:** 773651 **Northing:** 7484701

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
30	Siltstone. Fresh, dark grey, with traces of coal **Styx Coal Measures - Interburden** *(continued)*	
35		
	Styx Coal Measures - Interburden Siltstone. Fresh, dark grey	
40		
	Styx Coal Measures - Interburden Sandstone. Fresh, coarse grained, with interbedded siltstone, grey	43 - 45.5m Bentonite pellets
45	**Styx Coal Measures - Interburden** Sandstone. Fresh, coarse grained, grey	45.5 - 54.5m Gravel pack, (5mm rounded river gravel) 48.5 - 54.5m 100mm CL12 uPVC slotted casing, jointed with screws and glue
50		
	Styx Coal Measures - Interburden Sandstone. Fresh, with interbedded siltstone lenses, grey	
	Styx Coal Measures - Interburden Sandstone. Fresh, grey	EOH @ 54.5m 2m collapse at bottom of well
55		
	Styx Coal Measures - Interburden Siltstone. Fresh, carbonaceous, black	

WELL CONSTRUCTION



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP23B

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 06-Oct-18

Total Depth (m bgl): 194
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 32
Static Water Level
Date: 02/11/2018 **Depth (mbRP):** 7.8
Projection: GDA_94
Easting: 773638 **Northing:** 7484709

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

Alluvium
Clay. Medium plasticity, grey

Alluvium
Clay. Low-medium plasticity, brown

Alluvium
Gravel. Fine to coarse grained, mostly subrounded, various origin, various colour

Alluvium
Clayey gravel. As above, with some grey clay

Alluvium
Gravel. As above

Alluvium
Clay. With some fine to medium gravel, medium plasticity, grey

Alluvium
Clayey gravel. Fine to coarse grained, subangular to subrounded, various origin and colour. With grey-brown clay.

Alluvium

Alluvium
Siltstone. Slightly weathered, brown to very dark grey

Alluvium
Siltstone. Fresh, very dark grey

Styx Coal Measures - Overburden
Sandstone. Slightly weathered, grey to very dark grey

Styx Coal Measures - Overburden
Siltstone. Slightly weathered, very dark grey

Styx Coal Measures - Overburden
Siltstone. Fresh, carbonated, with some coal, black

Styx Coal Measures - Overburden
Siltstone. Fresh, grey to very dark grey

Styx Coal Measures - Overburden
Sandstone. Fresh, grey

Styx Coal Measures - Overburden
Siltstone. Fresh, carbonated with trace coal, very dark grey

Styx Coal Measures - Interburden
Sandstone. Fresh, grey

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION

0 - 182m Cement/bentonite grout
0 - 187m 100mm CL12 uPVC blank casing, jointed with screws and glue

10" hole from 0 to 18m

6.5" hole from 18 to 194m (EOH)

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP23B

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 194
Location: Styx Coal Basin	**Well Stick Up (m):** 0.9
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 32
Drilled By: Depco	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 02/11/2018 **Depth (mbRP):** 7.8
Bore Diameter: 10", 6.5"	**Projection:** GDA_94
Date Drilled: 06-Oct-18	**Easting:** 773638 **Northing:** 7484709

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m) | GRAPHIC LOG | LITHOLOGY | WELL CONSTRUCTION | WELL DESCRIPTION

40

Styx Coal Measures - Interburden
Sandstone. Fresh, very dark grey

Styx Coal Measures - Interburden
Sandstone. Fresh, grey

45

50

Styx Coal Measures - Interburden
Siltstone. Fresh, carbonated, with some coal, black

55

Styx Coal Measures - Interburden
Siltstone. Fresh, with sandy lenses, very dark grey

Styx Coal Measures - Interburden
Sandstone. Fresh, with interbedded siltstone, grey

60

Styx Coal Measures - Interburden
Siltstone. Fresh, carbonated, black

Styx Coal Measures - Interburden
Siltstone. Fresh, very dark grey

Styx Coal Measures - Interburden
Siltstone. Fresh, with interbedded sandstone, very dark grey

65

Styx Coal Measures - Interburden
Sandstone. Fresh, with interbedded siltstone, grey

Styx Coal Measures - Interburden
Sandstone. Fresh, dark grey-black

Styx Coal Measures - Interburden
Sandstone. Slightly weathered, grey. Coal (violet seam)

70

Styx Coal Measures - Interburden
Siltstone. Fresh, carbonaceous with trace coal, black (violet seam)

Styx Coal Measures - Underburden
Sandstone. Fresh, grey

75

(Continued Next Page)

	COMPOSITE WELL LOG	BOREHOLE / WELL NUMBER: WMP23B

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 06-Oct-18

Total Depth (m bgl): 194
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 32
Static Water Level
Date: 02/11/2018 **Depth (mbRP):** 7.8
Projection: GDA_94
Easting: 773638 **Northing:** 7484709

DEPTH (m)	LITHOLOGY (GEOLOGICAL DESCRIPTION)	WELL CONSTRUCTION	WELL DESCRIPTION
80	**Styx Coal Measures - Underburden** *(continued)*		
90	**Styx Coal Measures - Underburden** Siltstone. Fresh, with sandstone lenses, very dark grey		
100	**Styx Coal Measures - Underburden** Sandstone. Fresh, very dark grey		
	Styx Coal Measures - Underburden Siltstone. Fresh, very dark grey		
115	**Styx Coal Measures - Underburden** With trace coal		

Depth scale: 80, 85, 90, 95, 100, 105, 110, 115

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP23B

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 06-Oct-18

Total Depth (m bgl): 194
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 32
Static Water Level
Date: 02/11/2018 **Depth (mbRP):** 7.8
Projection: GDA_94
Easting: 773638 **Northing:** 7484709

DEPTH (m)	LITHOLOGY
120	**Styx Coal Measures - Underburden** *(continued)*
130	**Styx Coal Measures - Underburden** Sandstone. Fresh, light grey
	Styx Coal Measures - Underburden Siltstone. Fresh, dark grey
135	**Styx Coal Measures - Underburden** Sandstone. Fresh, coarse grained, with trace coal. Light grey mottled dark grey (Diorite appearance) and some brown chips
	Styx Coal Measures - Underburden Siltstone. Fresh, with trace coal, dark grey
	Styx Coal Measures - Underburden Sandstone. Fresh, grey
	Styx Coal Measures - Underburden Siltstone. Fresh, dark grey, laminar

Depth scale: 120, 125, 130, 135, 140, 145, 150, 155

GEOLOGICAL DESCRIPTION — CONSTRUCTION INFO. (WELL CONSTRUCTION, WELL DESCRIPTION)

(Continued Next Page)

COMPOSITE WELL LOG

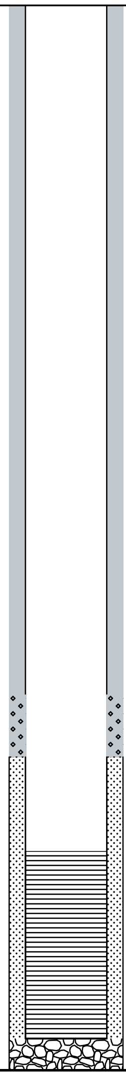
BOREHOLE / WELL NUMBER: WMP23B

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Air Hammer
Bore Diameter: 10", 6.5"
Date Drilled: 06-Oct-18

Total Depth (m bgl): 194
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 32
Static Water Level
Date: 02/11/2018 **Depth (mbRP):** 7.8
Projection: GDA_94
Easting: 773638 **Northing:** 7484709

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
160		**Styx Coal Measures - Underburden** *(continued)*		
165				
170				
175				
180				182 - 184m Bentonite pellets 184 - 193m Gravel pack, (5mm rounded river gravel)
185				187 - 193m 100mm CL12 uPVC slotted casing, jointed with screws and glue
190		**Styx Coal Measures - Underburden** Siltstone/mudstone. Distinct colour change to lighter grey. Softer rock. No calcareous reaction with acid		EOH @ 193m 1m collapse at bottom of well



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP24

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 26.4
Location: Styx Coal Basin	**Well Stick Up (m):** 0.48
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 20
Drilled By: Waratah Coal	**Static Water Level**
Drilling Method: Air Hammer	**Date:** 18/09/2018 **Depth (mbRP):** 4.94
Bore Diameter: 6.75"	**Projection:** GDA_94
Date Drilled: 11-Sep-18	**Easting:** 771965 **Northing:** 7489093

GEOLOGICAL DESCRIPTION / CONSTRUCTION INFO.

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
0	**Alluvium** Clay. Medium plasticity, brown, dry	0 - 20.3m Cement/bentonite grout; 0 - 23.4m 50mm CL18 uPVC blank casing, thread jointed
	Alluvium Clay. Medium plasticity, brown-grey, dry	
	Alluvium Clay. With trace conglomerate, low plasticity, grey to orange-brown, dry	
	Alluvium Conglomerate. Fine to medium size, various colours and origin, dry	
5	**Alluvium** Clay. Medium plasticity, grey dry	
	Alluvium Calcrete. Brown to red-brown, dry	
	Alluvium Clay. Medium plasticity, brown, dry	
	Alluvium Siltstone / Sandstone. Laminated, slightly weathered, brown-grey, dry	
10	**Alluvium** Gravel / Conglomerate. Fine to coarse grained, mostly red-brown.	
	Styx Coal Measures- Overburden Sandstone. With some carbonaceous siltstone, fresh, grey to dark grey	
	Styx Coal Measures- Overburden Sandstone. With coal and carbonaceous siltstone, fresh, dark grey	
15	**Styx Coal Measures- Overburden** Siltstone. Laminated, fresh, very dark grey	
	Styx Coal Measures- Overburden Siltstone. As above, with igneous material	
	Styx Coal Measures- Overburden Siltstone. As above with coal, black	
	Styx Coal Measures- Overburden Siltstone. Fresh, very dark grey	
20		20.3 - 21.5m Bentonite pellets
	Styx Coal Measures- Overburden Siltstone. With some coal and carbonaceous siltstone, fresh, black	21.5 - 26.4m Gravel pack, (2 - 5mm); 23.4 - 26.4m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed
25	**Styx Coal Measures- Overburden** Siltstone. Fresh, dark grey	EOH @ 26.4m

COMPOSITE WELL LOG

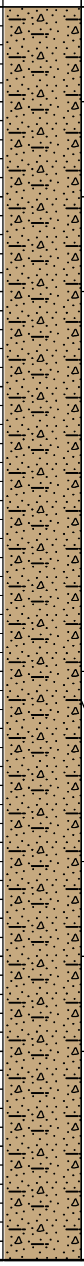
BOREHOLE / WELL NUMBER: WMP25

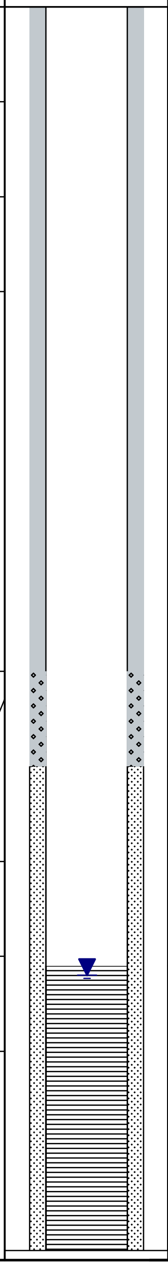
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 08-Sep-18

Total Depth (m bgl): 13.2
Well Stick Up (m): 0.58
Surface Elevation (m AHD): 50
Static Water Level
Date: 17/09/2018 **Depth (mbRP):** 10.78
Projection: GDA_94
Easting: 770812 **Northing:** 7486227

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Clay. With trace fine rootlets, medium plasticity, grey, dry		0 - 7m Cement/bentonite grout 0 - 10.1m 50mm CL18 uPVC blank casing, thread jointed
		Alluvium Sandstone. Highly weathered, brown to red-brown, with lenses of grey clay		
		Alluvium Clay. With some fine sand, medium plasticity, red and pale grey		
5		**Alluvium** Clay. With lenses of sandstone (approximately equal proportion), low-medium plasticity, white.		
		Alluvium Calcrete. 20 - 30cm lens. White		7 - 8m Bentonite pellets
		Alluvium Clay. With calcrete lenses, medium plasticity, light brown		8 - 13.1m Gravel pack, (2 - 5mm)
10		**Alluvium** Clay. Medium plasticity, light brown		10.1 - 13.1m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed
		Alluvium Sandy Clay. Low-medium plasticity, dark brown		
		Alluvium Sand. Fine to medium grained, well sorted, grey		EOH @ 13.2m





COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP26

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 09-Sep-18

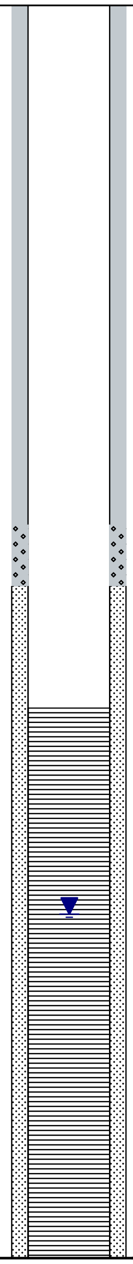
Total Depth (m bgl): 20.5
Well Stick Up (m): 0.52
Surface Elevation (m AHD): 31
Static Water Level
Date: 17/09/2018 **Depth (mbRP):** 15.39
Projection: GDA_94
Easting: 773655 **Northing:** 7489372

GEOLOGICAL DESCRIPTION

DEPTH (m)	GRAPHIC LOG	LITHOLOGY
0		**Alluvium** Clay. High plasticity, dark brown
		Alluvium Sandy Clay. Medium plasticity, fine to medium grained sands, light brown
		Alluvium Sandy Clay. Medium plasticity, fine to medium grained sands, grey mottled brown
5		**Alluvium** Sandy Clay. Medium plasticity, fine grained sands, orange-brown mottled grey
		Alluvium Silt. With some clay, brown, dry
10		**Alluvium** Silt. With some clay, brown, moist
		Alluvium Silt. With some clay lenses, brown
		Alluvium Clay & Gravel. Subangular to subrounded, various????? And colour, with trace cobbles
15		**Alluvium** Silt. Brown
20		**Alluvium** Mudstone. (Siltstone / Claystone), highly weathered, grey

CONSTRUCTION INFO.

WELL CONSTRUCTION



WELL DESCRIPTION

0 - 8.5m Cement/bentonite grout
0 - 11.5m 50mm CL18 uPVC blank casing, thread jointed

8.5 - 9.5m Bentonite pellets

9.5 - 20.5m Gravel pack, (2 - 5mm)

11.5 - 20.5m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 20.5m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP27

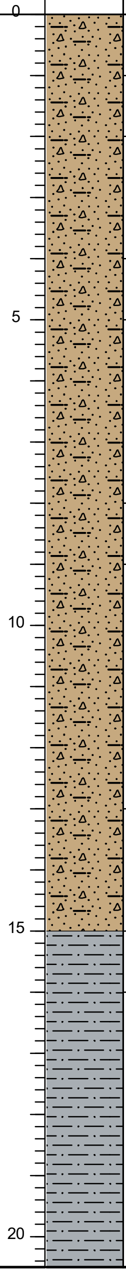
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 08-Sep-18

Total Depth (m bgl): 20.5
Well Stick Up (m): 0.85
Surface Elevation (m AHD): 49
Static Water Level
Date: 17/09/2018 **Depth (mbRP):** 20.59
Projection: GDA_94
Easting: 770606 **Northing:** 7487750

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY



Alluvium
Clay. High plasticity, firm, grey, dry

Alluvium
Clay. Medium plasticity, grey-brown, dry

Alluvium
Clay. Medium plasticity, light grey

Alluvium
Clay. With trace of fine sand, low-medium plasticity, grey-brown

Alluvium
Sand. With some clay, fine grained, pale yellow

Alluvium
Clay. With trace of fine sand, low-medium plasticity, yellow-brown

Alluvium
Clay. With trace of fine sand, medium plasticity, brown

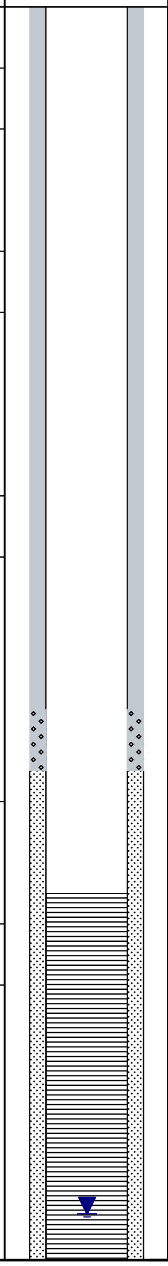
Alluvium
Sand. With some clay, fine grained, uniformly graded

Styx Coal Measures - Overburden
Sandstone. Weathered, grey-brown

Styx Coal Measures - Overburden
Sandstone. Fresh, grey

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 11.5m Cement/bentonite grout
0 - 14.5m 50mm CL18 uPVC blank casing, thread jointed

11.5 - 12.5m Bentonite pellets

12.5 - 20.5m Gravel pack (2 - 5mm)

14.5 - 20.5m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed

EOH @ 20.5m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP28

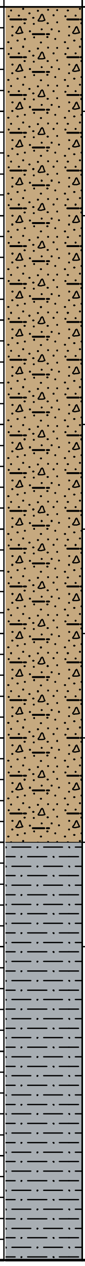
Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Waratah Coal
Drilling Method: Air Hammer
Bore Diameter: 6.75"
Date Drilled: 11-Sep-18

Total Depth (m bgl): 12
Well Stick Up (m): 0.58
Surface Elevation (m AHD): 32
Static Water Level
Date: 18/09/2018 **Depth (mbRP):** 11.47
Projection: GDA_94
Easting: 772192 **Northing:** 7489099

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY

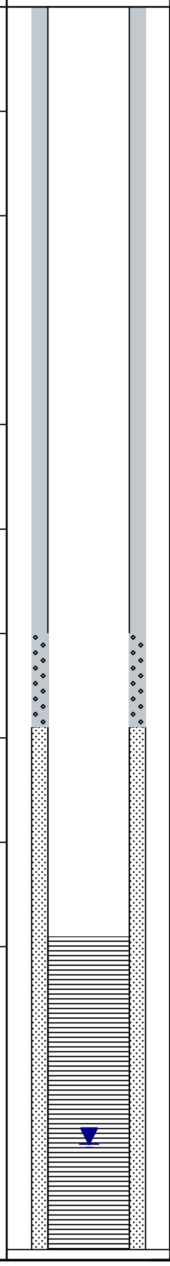


Lithology
Alluvium Clay. Medium plasticity, brown
Alluvium Clay. With trace fine sand, medium plasticity, brown
Alluvium Clay. With some fine to medium grained sand, low plasticity, grey-brown
Alluvium Sand. Fine grained with some conglomerate, grey-brown
Alluvium Conglomerate. Fine to coarse, brown-yellow
Alluvium Clay. With some sand, low plasticity, brown-yellow
Alluvium Clay. Highly weathered mudstone, medium plasticity, grey, dry
Styx Coal Measures - Overburden Mudstone. Carbonated, black, moist
Styx Coal Measures - Overburden Sandstone. Highly weathered, grey, dry to moist

Depth scale: 0, 5, 10

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



- 0 - 6m Cement/bentonite grout
- 0 - 8.9m 50mm CL18 uPVC blank casing, thread jointed
- 6 - 6.9m Bentonite pellets
- 6.9 - 11.9m Gravel pack, (2 - 5mm)
- 8.9 - 11.9m 50mm CL18 PVC slotted casing, 2mm aperture, thread jointed
- EOH @ 12m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29A

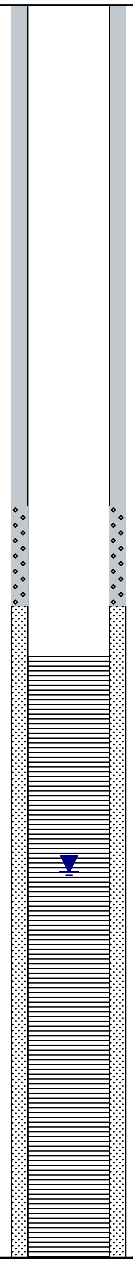
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project		**Total Depth (m bgl):** 12.5	
Location: Styx Coal Basin		**Well Stick Up (m):** 1	
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd		**Surface Elevation (m AHD):** 13	
Drilled By: Depco		**Static Water Level**	
Drilling Method: Rotary Air		**Date:** 03/11/2018	**Depth (mbRP):** 9.65
Bore Diameter: 6.5"		**Projection:** GDA_94	
Date Drilled: 28-Oct-18		**Easting:** 771298	**Northing:** 7497385

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
0	**Alluvium** Silty sand. Fine to medium grained, loose cuttings, brown, dry	0 - 5m Cement/bentonite grout 0 - 6.5m 100mm CL12 uPVC blank casing, bell jointed with glue and screws
5		5 - 6m Bentonite pellets
	Alluvium Gravel. Loose, well graded, sandstone/quartz gravels, angular to sub-angular, various colours (brown/white/red/grey)	6 - 12.5m Gravel pack, (5 - 7mm rounded river gravels) 6.5 - 12.5m 100mm CL12 uPVC slotted casing, 2mm vertical slots bell jointed with glue and screws
10	**Alluvium** Sandy gravels. As above, more rounded gravels, coarse grained sands	
		EOH @ 12.5m

WELL CONSTRUCTION



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29B

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 28-Oct-18

Total Depth (m bgl): 20
Well Stick Up (m): 1
Surface Elevation (m AHD): 13
Static Water Level
Date: 03/11/2018 **Depth (mbRP):** 10.35
Projection: GDA_94
Easting: 771301 **Northing:** 7497385

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty sand. Fine to medium grained, loose cuttings, brown, dry		0 - 14.5m Cement/bentonite grout 0 - 16m 100mm CL12 uPVC blank casing, bell jointed with glue and screws
5		**Alluvium** Gravel. Loose, well graded, sandstone/quartz gravels, angular to sub-angular, various colours (brown/white/red/grey)		
10		**Alluvium** Sandy gravels. As above, more rounded gravels, coarse grained sands		
		Alluvium Clay. High plasticity, grey, very soft		14.5 - 15.5m Bentonite pellets 15.5 - 20m Gravel pack, (5 - 7mm rounded river gravels) 16 - 20m 100mm CL12 uPVC slotted casing, 2mm vertical slots bell jointed with glue and screws
15		**Alluvium** Gravel. Well graded, rounded to angular, various origins (angular, up to 3cm diameter, various colours (brown/white/red/grey/clear)		
		Alluvium Clayey gravel. As above, with clay		EOH @ 20m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 58
Location: Styx Coal Basin	**Well Stick Up (m):** 1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 14
Drilled By: Depco	**Static Water Level**
Drilling Method: Mud Rotary, Air Hammer	**Date:** 27/10/2018 **Depth (mbRP):** 51
Bore Diameter: 10", 7"	**Projection:** GDA_94
Date Drilled: 27-Oct-18	**Easting:** 771318 **Northing:** 7497394

GEOLOGICAL DESCRIPTION / CONSTRUCTION INFO.

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty sand. Fine to medium grained, loose cuttings, brown, dry		0 - 49m Cement/bentonite grout 0 - 52m 100mm CL12 uPVC blank casing, bell jointed with glue and screws
5		**Alluvium** Gravel. Loose, well graded, sandstone/quartz gravels, angular to sub-angular, various colours (brown/white/red/grey)		
10		**Alluvium** Sandy gravels. As above, more rounded gravels, coarse grained sands		10" hole from 0 to 22m
15		**Alluvium** Clay. High plasticity, grey, very soft		
		Alluvium Gravel. Well graded, rounded to angular, various origins (angular, up to 3cm diameter, various colours (brown/white/red/grey/clear)		
20		**Alluvium** Clayey gravel. As above, with clay		
		Styx Coal Measures - Overburden Sandstone. Grey with some brown lenses, slightly weathered		
25		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey, dry		7" hole from 22 to 58m (EOH)
30				
		Styx Coal Measures - Overburden Siltstone. Fresh, dark grey, dry		
35		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey, dry		
		Styx Coal Measures - Overburden		

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COMPOSITE WELL LOG

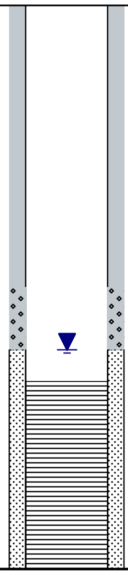
BOREHOLE / WELL NUMBER: WMP29C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Mud Rotary, Air Hammer
Bore Diameter: 10", 7"
Date Drilled: 27-Oct-18

Total Depth (m bgl): 58
Well Stick Up (m): 1
Surface Elevation (m AHD): 14
Static Water Level
Date: 27/10/2018 **Depth (mbRP):** 51
Projection: GDA_94
Easting: 771318 **Northing:** 7497394

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
40		Siltstone with sandstone lenses. Fresh, dark grey **Styx Coal Measures - Overburden** *(continued)*		
45		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey		49 - 51m Bentonite pellets 51 - 58m Gravel pack, (5 - 7mm rounded river gravels) 52 - 58m 100mm CL12 uPVC slotted casing, 2mm vertical slots bell jointed with glue and screws
50		**Styx Coal Measures - Overburden** Siltstone. Carbonaceous, very dark grey/black with traces of coal		
55		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey, dry		EOH @ 58m



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29D

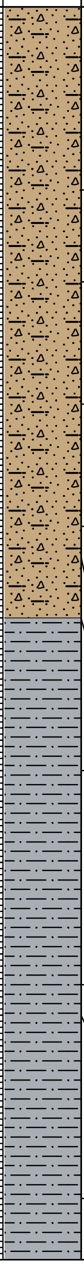
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 121
Location: Styx Coal Basin	**Well Stick Up (m):** 1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 14
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 05/11/2018 **Depth (mbRP):** >100
Bore Diameter: 6.5"	**Projection:** GDA_94
Date Drilled: 01-Nov-18	**Easting:** 771317 **Northing:** 7497387

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m) | GRAPHIC LOG | LITHOLOGY | WELL CONSTRUCTION | WELL DESCRIPTION

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40



Alluvium
Silty sand. Fine to medium grained, loose cuttings, brown, dry

Alluvium
Gravel. Loose, well graded, sandstone/quartz gravels, angular to sub-angular, various colours (brown/white/red/grey)

Alluvium
Sandy gravels. As above, more rounded gravels, coarse grained sands

Alluvium
Clay. High plasticity, grey, very soft

Alluvium
Gravel. Well graded, rounded to angular, various origins (angular, up to 3cm diameter, various colours (brown/white/red/grey/clear)

Alluvium
Clayey gravel. As above, with clay

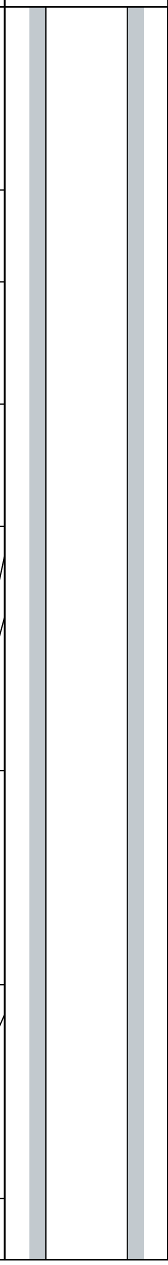
Styx Coal Measures - Overburden
Sandstone. Grey with some brown lenses, slightly weathered

Styx Coal Measures - Overburden
Sandstone. Fresh, grey, dry

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey, dry

Styx Coal Measures - Overburden
Sandstone. Fresh, grey, dry

Styx Coal Measures - Overburden
Siltstone with sandstone lenses. Fresh, dark grey



Well description:
0 - 112m Cement/bentonite grout
0 - 115m 100mm CL12 uPVC blank casing, bell jointed with glue and screws

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COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29D

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 121
Location: Styx Coal Basin	**Well Stick Up (m):** 1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 14
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 05/11/2018 **Depth (mbRP):** >100
Bore Diameter: 6.5"	**Projection:** GDA_94
Date Drilled: 01-Nov-18	**Easting:** 771317 **Northing:** 7497387

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
		Styx Coal Measures - Overburden *(continued)*		
45		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey		
50		**Styx Coal Measures - Overburden** Siltstone. Carbonaceous, very dark grey/black with traces of coal		
		Styx Coal Measures - Overburden Sandstone. Fresh, grey, dry		
55				
60		**Styx Coal Measures - Overburden** Siltstone. Fresh, dark grey		
65		**Styx Coal Measures - Overburden** Coal. Black		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey		
70		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with sandstone lenses and coal traces		
75				
80		**Styx Coal Measures - Interburden** Sandstone. Fresh, grey		

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COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29D

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

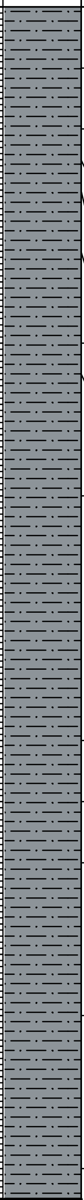
Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 01-Nov-18

Total Depth (m bgl): 121
Well Stick Up (m): 1
Surface Elevation (m AHD): 14
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** >100
Projection: GDA_94
Easting: 771317 **Northing:** 7497387

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION

85, 90, 95, 100, 105, 110, 115, 120



Styx Coal Measures - Interburden
Coal. Black

Styx Coal Measures - Interburden
Siltstone. Carbonaceous, very dark grey/black

Styx Coal Measures - Interburden
Sandstone. Fresh, grey

Styx Coal Measures - Interburden
Siltstone. Carbonaceous, very dark grey/black

Styx Coal Measures - Interburden
Siltstone. Fresh, dark grey

Styx Coal Measures - Interburden
Sandstone. Fresh, grey

Styx Coal Measures - Interburden
Sandstone. Fresh, grey, slight moisture

Styx Coal Measures - Interburden
Siltstone. Carbonaceous, very dark grey/dark brown

Styx Coal Measures - Interburden
Siltstone. Fresh, dark grey

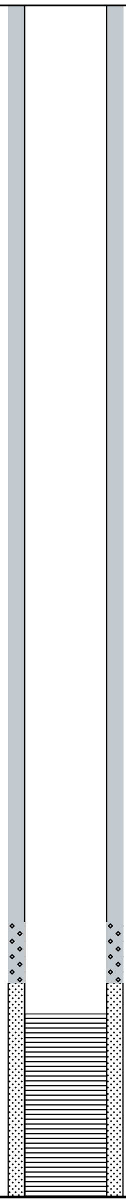
Styx Coal Measures - Interburden
Sandstone. Fresh, grey

Styx Coal Measures - Interburden
Coal. Black

Styx Coal Measures - Interburden
Siltstone. Carbonaceous, very dark grey/dark brown

Styx Coal Measures - Interburden
Siltstone. Fresh, dark grey with sandstone lenses

Styx Coal Measures - Interburden
Siltstone. Fresh, dark grey



112 - 114m Bentonite pellets
114 - 121m Gravel pack, (5 - 7mm rounded river gravels)
115 - 121m 100mm CL12 uPVC slotted casing, 2mm vertical slots bell jointed with glue and screws

EOH @ 121m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29E

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 228.5
Location: Styx Coal Basin	**Well Stick Up (m):** 1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 14
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 27/10/2018 **Depth (mbRP):** 10.5
Bore Diameter: 7"	**Projection:** GDA_94
Date Drilled: 31-Oct-18	**Easting:** 771312 **Northing:** 7497397

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty sand. Fine to medium grained, loose cuttings, brown, dry		0 - 220m Cement/bentonite grout 0 - 222.5m 100mm CL12 uPVC blank casing, bell jointed with glue and screws
5		**Alluvium** Gravel. Loose, well graded, sandstone/quartz gravels, angular to sub-angular, various colours (brown/white/red/grey)		
10		**Alluvium** Sandy gravels. As above, more rounded gravels, coarse grained sands		
		Alluvium Clay. High plasticity, grey, very soft		
15		**Alluvium** Gravel. Well graded, rounded to angular, various origins (angular, up to 3cm diameter, various colours (brown/white/red/grey/clear)		
20		**Alluvium** Clayey gravel. As above, with clay		
		Styx Coal Measures - Overburden Sandstone. Grey with some brown lenses, slightly weathered		
25		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey, dry		
30		**Styx Coal Measures - Overburden** Siltstone. Fresh, dark grey, dry		
35		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey, dry		
		Styx Coal Measures - Overburden		

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COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29E

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 7"
Date Drilled: 31-Oct-18

Total Depth (m bgl): 228.5
Well Stick Up (m): 1
Surface Elevation (m AHD): 14
Static Water Level
Date: 27/10/2018 **Depth (mbRP):** 10.5
Projection: GDA_94
Easting: 771312 **Northing:** 7497397

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
40		Siltstone with sandstone lenses. Fresh, dark grey **Styx Coal Measures - Overburden** *(continued)*		
45		**Styx Coal Measures - Overburden** Sandstone. Fresh, grey		
50		**Styx Coal Measures - Overburden** Siltstone. Carbonaceous, very dark grey/black with traces of coal		
		Styx Coal Measures - Overburden Sandstone. Fresh, grey, dry		
55				
60		**Styx Coal Measures - Overburden** Siltstone. Fresh, dark grey		
65		**Styx Coal Measures - Overburden** Coal. Black		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey		
70		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with sandstone lenses and coal traces		
75				
		Styx Coal Measures - Interburden		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29E

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 228.5
Location: Styx Coal Basin	**Well Stick Up (m):** 1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 14
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 27/10/2018 **Depth (mbRP):** 10.5
Bore Diameter: 7"	**Projection:** GDA_94
Date Drilled: 31-Oct-18	**Easting:** 771312 **Northing:** 7497397

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
80		Sandstone. Fresh, grey **Styx Coal Measures - Interburden** *(continued)*		
		Styx Coal Measures - Interburden Coal. Black		
85		**Styx Coal Measures - Interburden** Siltstone. Carbonaceous, very dark grey/black		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey		
		Styx Coal Measures - Interburden Siltstone. Carbonaceous, very dark grey/black		
90		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey, slight moisture		
95		**Styx Coal Measures - Interburden** Siltstone. Carbonaceous, very dark grey/dark brown		
100		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
105		**Styx Coal Measures - Interburden** Sandstone. Fresh, grey		
		Styx Coal Measures - Interburden Coal. Black		
110		**Styx Coal Measures - Interburden** Siltstone. Carbonaceous, very dark grey/dark brown		
115		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with sandstone lenses		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29E

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 228.5
Location: Styx Coal Basin	**Well Stick Up (m):** 1
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 14
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 27/10/2018 **Depth (mbRP):** 10.5
Bore Diameter: 7"	**Projection:** GDA_94
Date Drilled: 31-Oct-18	**Easting:** 771312 **Northing:** 7497397

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
120		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey with coal traces		
125		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal. Black		
130		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey, carbonaceous lens at 134m		
135				
140		**Styx Coal Measures - Interburden** Siltstone. Carbonaceous, very dark grey/dark brown		
145		**Styx Coal Measures - Interburden** Coal. Black		
		Styx Coal Measures - Interburden Sandstone. Fresh, grey		
150				
155				

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP29E

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 7"
Date Drilled: 31-Oct-18

Total Depth (m bgl): 228.5
Well Stick Up (m): 1
Surface Elevation (m AHD): 14
Static Water Level
Date: 27/10/2018 **Depth (mbRP):** 10.5
Projection: GDA_94
Easting: 771312 **Northing:** 7497397

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
160		**Styx Coal Measures - Interburden** Siltstone. Carbonaceous, very dark grey/dark brown		
		Styx Coal Measures - Interburden Coal. Black		
165		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
170		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with coal traces		
		Styx Coal Measures - Interburden Coal. Black		
175, 180, 185		**Styx Coal Measures - Underburden** Sandstone. Fresh, grey		
190, 195		**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		

(Continued Next Page)

COMPOSITE WELL LOG

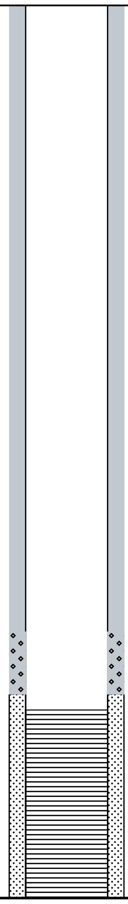
BOREHOLE / WELL NUMBER: WMP29E

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name:	Central Queensland Coal Project	**Total Depth (m bgl):**	228.5
Location:	Styx Coal Basin	**Well Stick Up (m):**	1
Client:	Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):**	14
Drilled By:	Depco	**Static Water Level**	
Drilling Method:	Rotary Air	**Date:** 27/10/2018	**Depth (mbRP):** 10.5
Bore Diameter:	7"	**Projection:**	GDA_94
Date Drilled:	31-Oct-18	**Easting:** 771312	**Northing:** 7497397

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
200	**Styx Coal Measures - Underburden** *(continued)*	
	Styx Coal Measures - Underburden Siltstone. Fresh, dark grey	
205	**Styx Coal Measures - Underburden** Sandstone. Fresh, grey, slightly moist	
	Styx Coal Measures - Underburden Siltstone. Fresh, dark grey	
210	**Styx Coal Measures - Underburden** Sandstone. Fresh, grey, slightly moist	
215		
220	**Styx Coal Measures - Underburden** Sandstone. Fresh, grey, slightly moist, clay present throughout	220 - 222m Bentonite pellets 222 - 228.5m Gravel pack, (5 - 7mm rounded river gravels) 222.5 - 228.5m 100mm CL12 uPVC slotted casing, 2mm vertical slots bell jointed with glue and screws
225	**Styx Coal Measures - Underburden** Sandstone. Fresh, grey, slightly moist. Colour change to lighter grey/light brown. Loose silty sand cuttings with minimal rock chips	EOH @ 228.5m



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30A

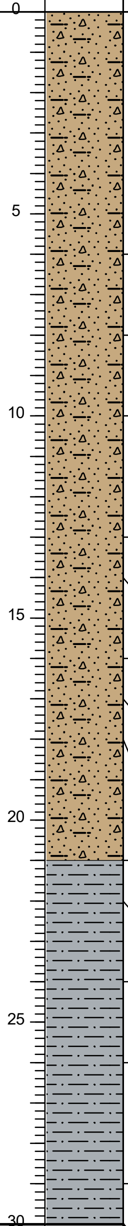
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 30
Well Stick Up (m): 0.9
Surface Elevation (m AHD): 34
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 15.09
Projection: GDA_94
Easting: 772028 **Northing:** 7488896

GEOLOGICAL DESCRIPTION

DEPTH (m) | GRAPHIC LOG | LITHOLOGY



Alluvium
Silty clay. Moderate plasticity, very stiff, brown/grey, dry

Alluvium
Sandy silt. Loose, very fine grained sands, light brown/orange, dry

Alluvium
Silty clay. Low to moderate plasticity, very stiff, brown/grey, dry

Alluvium
Clayey silt. Minimal cohesion, light brown, slightly moist

Alluvium
Silty clay. Low plasticity, stiff, grey, slightly moist

Alluvium
Clayey silt. Minimal cohesion, brown, slightly moist

Alluvium
Sandy silt. Minimal cohesion, Fine grained sands, grey, slightly moist

Alluvium
Sandy silt. Very sandy, fine to medium grains

Alluvium
Clayey sand. (Extremely weathered SANDSTONE) Very dense, fine to medium grains, distinct colour change to grey, moist

Styx Coal Measures - Overburden
Siltstone. Fresh, laminar, black

Styx Coal Measures - Overburden
Siltstone. Dark grey, with trace of coal

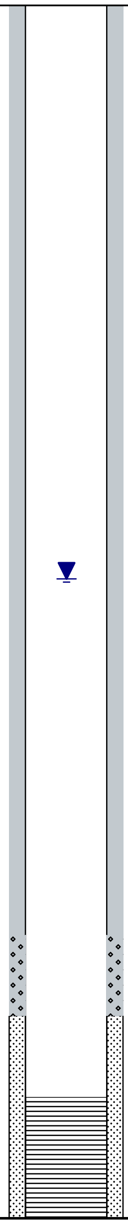
Styx Coal Measures - Overburden
Coal

Styx Coal Measures - Overburden
Siltstone. Fresh, dark grey

Styx Coal Measures - Overburden
Siltstone with trace coal

CONSTRUCTION INFO.

WELL CONSTRUCTION | WELL DESCRIPTION



0 - 23m Cement/bentonite grout
0 - 27m 50mm CL18 uPVC blank casing, bell jointed with glue and screws

23 - 25m Bentonite pellets

25 - 30m Gravel pack
27 - 30m 50mm CL18 uPVC slotted casing, 2mm apperture, bell jointed with glue and screws

EOH @ 30m

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30B

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 56
Location: Styx Coal Basin	**Well Stick Up (m):** 0.9
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 34
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 05/11/2018 **Depth (mbRP):** 15.05
Bore Diameter: 6.5"	**Projection:** GDA_94
Date Drilled: 19-Oct-18	**Easting:** 772028 **Northing:** 7488900

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty clay. Moderate plasticity, very stiff, brown/grey, dry		0 - 46m Cement/bentonite grout 0 - 50m 50mm CL18 uPVC blank casing, bell jointed with glue and screws
5		**Alluvium** Sandy silt. Loose, very fine grained sands, light brown/orange, dry		
		Alluvium Silty clay. Low to moderate plasticity, very stiff, brown/grey, dry		
10		**Alluvium** Clayey silt. Minimal cohesion, light brown, slightly moist		
		Alluvium Silty clay. Low plasticity, stiff, grey, slightly moist		
15		**Alluvium** Clayey silt. Minimal cohesion, brown, slightly moist		
		Alluvium Sandy silt. Minimal cohesion, Fine grained sands, grey, slightly moist		
		Alluvium Sandy silt. Very sandy, fine to medium grains		
20		**Alluvium** Clayey sand. (Extremely weathered SANDSTONE) Very dense, fine to medium grains, distinct colour change to grey, moist		
		Styx Coal Measures - Overburden Siltstone. Fresh, laminar, black		
25		**Styx Coal Measures - Overburden** Siltstone. Dark grey, with trace of coal		
		Styx Coal Measures - Overburden Coal		
		Styx Coal Measures - Overburden Siltstone. Fresh, dark grey		
30		**Styx Coal Measures - Overburden** Siltstone with trace coal		
35		**Styx Coal Measures - Interburden** Siltstone with interbedded sandstone lenses		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30B

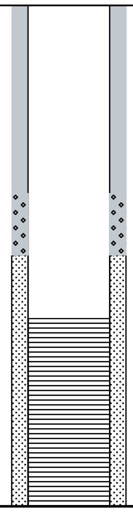
Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project	**Total Depth (m bgl):** 56
Location: Styx Coal Basin	**Well Stick Up (m):** 0.9
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd	**Surface Elevation (m AHD):** 34
Drilled By: Depco	**Static Water Level**
Drilling Method: Rotary Air	**Date:** 05/11/2018 **Depth (mbRP):** 15.05
Bore Diameter: 6.5"	**Projection:** GDA_94
Date Drilled: 19-Oct-18	**Easting:** 772028 **Northing:** 7488900

GEOLOGICAL DESCRIPTION / CONSTRUCTION INFO.

DEPTH (m)	LITHOLOGY	WELL DESCRIPTION
40	**Styx Coal Measures - Interburden** *(continued)*	
	Styx Coal Measures - Interburden Sandstone. Fresh, grey	
	Styx Coal Measures - Interburden Sandstone with trace coal	
45	**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey	46 - 48m Bentonite pellets
	Styx Coal Measures - Interburden Siltstone with trace coal	48 - 56m Gravel pack
	Styx Coal Measures - Interburden Coal	50 - 56m 50mm CL18 uPVC slotted casing, 2mm apperture, bell jointed with glue and screws
50	**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey	
	Styx Coal Measures - Interburden Coal	
55	**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey	EOH @ 56m

WELL CONSTRUCTION



COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.8
Surface Elevation (m AHD): 33
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 12.27
Projection: GDA_94
Easting: 772029 **Northing:** 7488905

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
0		**Alluvium** Silty clay. Moderate plasticity, very stiff, brown/grey, dry		0 - 196m Cement/bentonite grout 0 - 200m 50mm CL18 uPVC blank casing, bell jointed with glue and screws
		Alluvium Sandy silt. Loose, very fine grained sands, light brown/orange, dry		
		Alluvium Silty clay. Low to moderate plasticity, very stiff, brown/grey, dry		
10		**Alluvium** Clayey silt. Minimal cohesion, light brown, slightly moist		
		Alluvium Silty clay. Low plasticity, stiff, grey, slightly moist		
15		**Alluvium** Clayey silt. Minimal cohesion, brown, slightly moist		
		Alluvium Sandy silt. Minimal cohesion, Fine grained sands, grey, slightly moist		
		Alluvium Sandy silt. Very sandy, fine to medium grains		
20		**Alluvium** Clayey sand. (Extremely weathered SANDSTONE) Very dense, fine to medium grains, distinct colour change to grey, moist		
		Styx Coal Measures - Overburden Siltstone. Fresh, laminar, black		
25		**Styx Coal Measures - Overburden** Siltstone. Dark grey, with trace of coal		
		Styx Coal Measures - Overburden Coal		
		Styx Coal Measures - Overburden Siltstone. Fresh, dark grey		
30		**Styx Coal Measures - Overburden** Siltstone with trace coal		
35		**Styx Coal Measures - Interburden** Siltstone with interbedded sandstone lenses		
40		**Styx Coal Measures - Interburden**		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.8
Surface Elevation (m AHD): 33
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 12.27
Projection: GDA_94
Easting: 772029 **Northing:** 7488905

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
		Sandstone. Fresh, grey **Styx Coal Measures - Interburden** *(continued)*		
45		**Styx Coal Measures - Interburden** Sandstone with trace coal		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Siltstone with trace coal		
50		**Styx Coal Measures - Interburden** Coal		
		Styx Coal Measures - Interburden Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
55		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
60		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey, with trace coal		
		Styx Coal Measures - Interburden Coal		
65		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey		
		Styx Coal Measures - Interburden Coal		
70 75		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with interbedded sandstone lenses at 72m		
80		**Styx Coal Measures - Interburden** Siltstone. Fresh, dark grey with coal lenses between 80 and 82m. Trace coal present at 85m		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.8
Surface Elevation (m AHD): 33
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 12.27
Projection: GDA_94
Easting: 772029 **Northing:** 7488905

GEOLOGICAL DESCRIPTION			CONSTRUCTION INFO.	
DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION

Styx Coal Measures - Interburden *(continued)*

Styx Coal Measures - Interburden
Siltstone. Fresh, dark grey with trace coal (Violet Seam) at 90m

Styx Coal Measures - Underburden
Sandstone. Fresh, grey with interbedded siltstone lenses at 95m

Styx Coal Measures - Underburden
Siltstone. Fresh, dark grey

Styx Coal Measures - Underburden
Sandstone. Very coarse grained, fresh, light grey mottled dark grey diorite appearance. Interbedded siltstone lenses present at 109m

Styx Coal Measures - Underburden
Siltstone. Fresh, dark grey

Styx Coal Measures - Underburden
Sandstone. Fresh, grey

Styx Coal Measures - Underburden
Sandstone. Very coarse grained, fresh, light grey / grey / dark grey. Some cuttings as rounded gravels, not chips.

Styx Coal Measures - Underburden
Sandstone. With interbedded siltstone lenses, fresh, light grey / dark grey

Styx Coal Measures - Underburden
Sandstone. Fresh, grey with interbedded siltstone at 130m

(Continued Next Page)

	COMPOSITE WELL LOG	BOREHOLE / WELL NUMBER: WMP30C

Central Coal Queensland Pty Ltd & Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.8
Surface Elevation (m AHD): 33
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 12.27
Projection: GDA_94
Easting: 772029 **Northing:** 7488905

GEOLOGICAL DESCRIPTION | **CONSTRUCTION INFO.**

DEPTH (m)	GRAPHIC LOG	LITHOLOGY	WELL CONSTRUCTION	WELL DESCRIPTION
		Styx Coal Measures - Underburden *(continued)*		
130				
		Styx Coal Measures - Underburden Sandstone. Distinct colour change to brown, suspected weathering, potential water cut		
135		**Styx Coal Measures - Underburden** Sandstone. Fresh, grey, with interbedded siltstone with some brown lenses, weathered materials? at 141m		
140				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		
145				
150				
		Styx Coal Measures - Underburden Siltstone. Dark grey with some brown, drilled quicker, suspected weathered zone, likely water cut.		
155		**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey with traces of brown at 156m		
160				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		
		Styx Coal Measures - Underburden Siltstone. Fresh, grey		
165				
		Styx Coal Measures - Underburden Sandstone. Fresh, grey		

(Continued Next Page)

COMPOSITE WELL LOG

BOREHOLE / WELL NUMBER: WMP30C

Central Coal Queensland Pty Ltd
&
Fairway Coal Pty Ltd

Project Name: Central Queensland Coal Project
Location: Styx Coal Basin
Client: Central Queensland Coal Pty Ltd and Fairway Coal Pty/Ltd
Drilled By: Depco
Drilling Method: Rotary Air
Bore Diameter: 6.5"
Date Drilled: 19-Oct-18

Total Depth (m bgl): 206
Well Stick Up (m): 0.8
Surface Elevation (m AHD): 33
Static Water Level
Date: 05/11/2018 **Depth (mbRP):** 12.27
Projection: GDA_94
Easting: 772029 **Northing:** 7488905

DEPTH (m)	LITHOLOGY (GEOLOGICAL DESCRIPTION)	WELL DESCRIPTION (CONSTRUCTION INFO.)
169–175	**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey	
175–182.5	**Styx Coal Measures - Underburden** Igneous rock. Distinct colour change to light grey with green tinge, intrusive igneous rock with interbedded metasiltstone	
182.5–186	**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey, with sandstone lenses throughout	
186–188	**Styx Coal Measures - Underburden** Sandstone. Fresh, grey	
188–206	**Styx Coal Measures - Underburden** Siltstone. Fresh, dark grey with purple tinge, very hard.	196 - 198m Bentonite pellets 198 - 206m Gravel pack 200 - 206m 50mm CL18 uPVC slotted casing, 2mm apperture, bell jointed with glue and screws EOH @ 206m

Depth scale: 170, 175, 180, 185, 190, 195, 200, 205

Attachment B - Aquifer test results

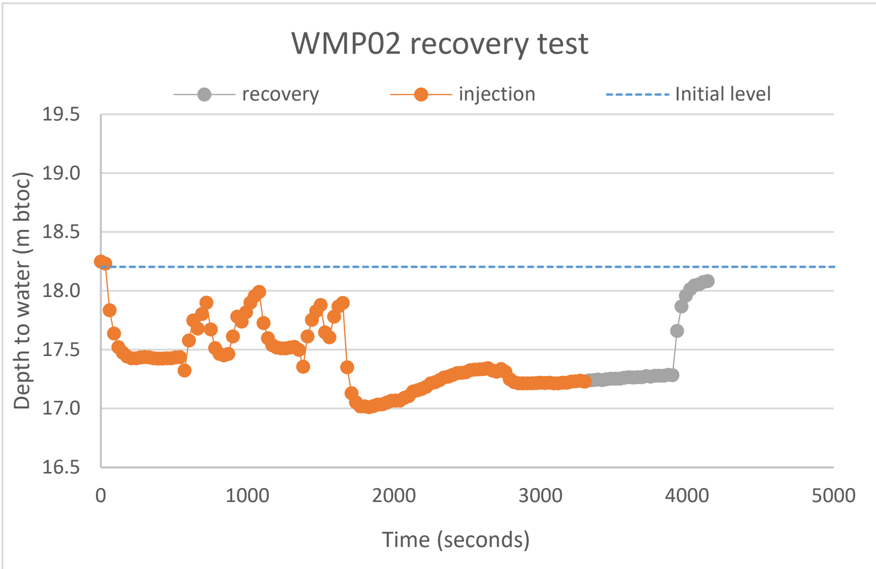
Well details

Well ID	WMP02
Initial water level	18.204 m btoc
Well depth	18.4 m bgl
Screen interval	12.0 - 18.0 m bgl
Inferred HSU	Alluvium

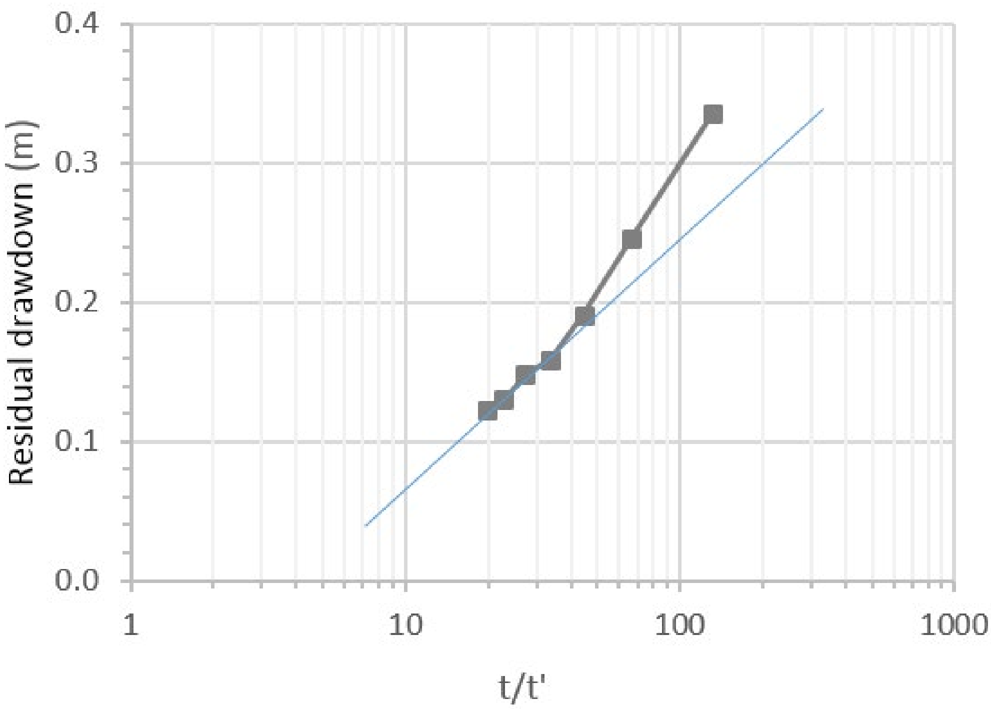
Analysis details

Aquifer type	Unconfined
Test type	Constant rate recovery test
Analysis solution	Theis recovery (1935)
Analysis method	Graphical
Pumping rate (Q)	45.4 m^3/day
Curve slope (Δs')	0.18
Saturated thickness (b)	8.45 m
Transmissivity (T)	46.2 m^2/day

Test data



Test analysis



Well details

Well ID	WMP04
Initial water level	12.216 m btoc
Well depth	18.4 m bgl
Screen interval	12.0 - 18.0 m bgl
Inferred HSUs	Alluvium

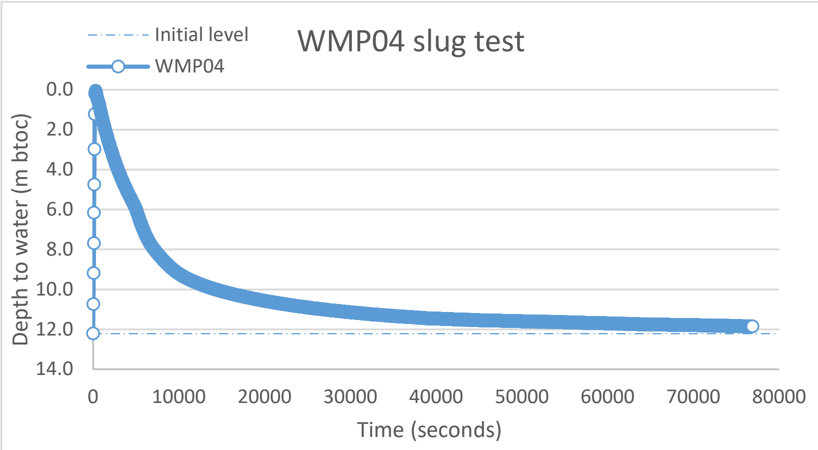
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
	Hvorslev (1951)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

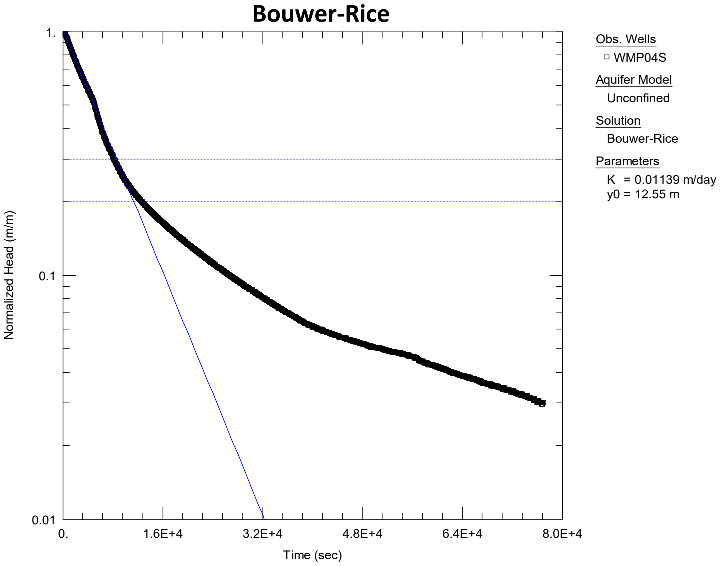
Bouwer-Rice	0.01 m/day
Hvorslev	0.02 m/day

Test data

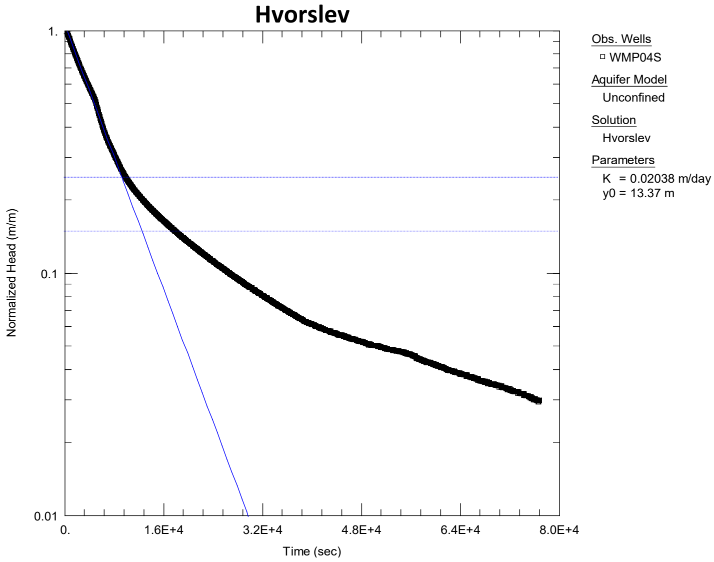


Test analyses

Bouwer-Rice



Hvorslev



Well details

Well ID	WMP04D
Initial water level	14.0 m btoc
Well depth	36.5 m bgl
Screen interval	18.5 - 36.3 m bgl
Inferred HSUs	Alluvium / Styx Coal Measures - overburden

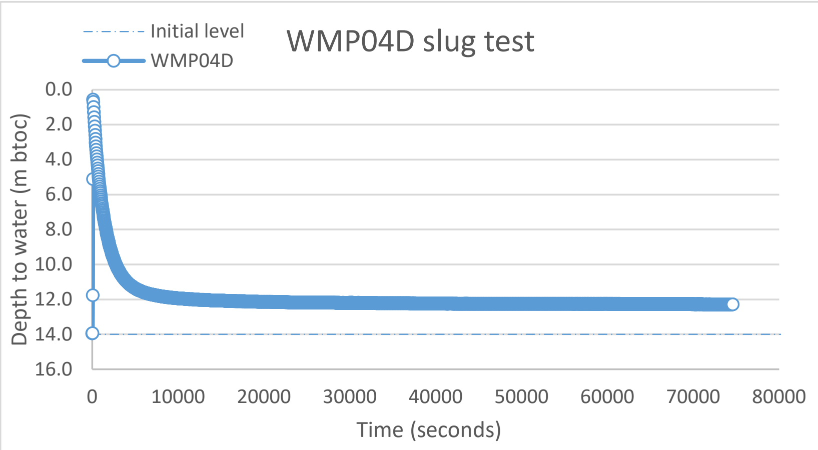
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
	Hvorslev (1951)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

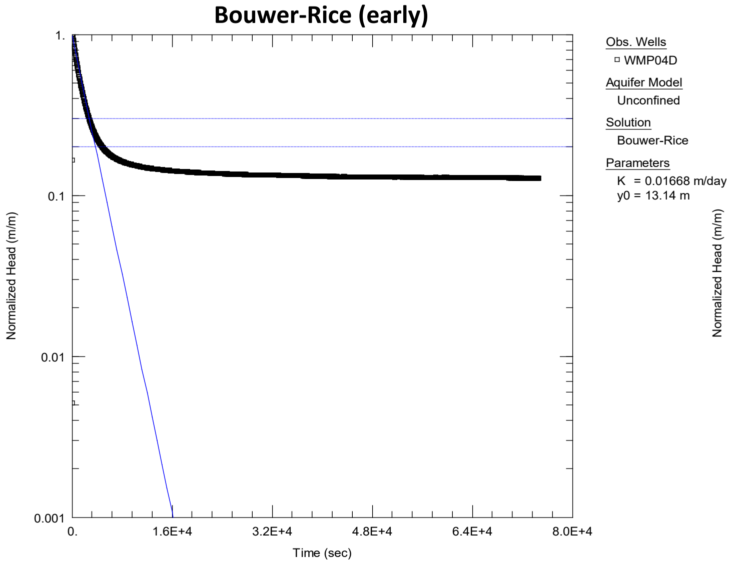
Bouwer-Rice	0.02 m/day
Hvorslev	0.03 m/day

Test data

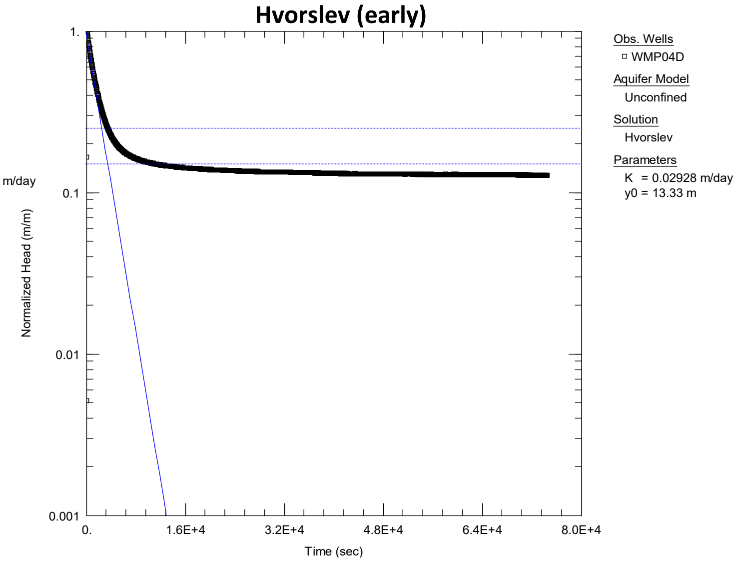


Test analyses

Bouwer-Rice (early)



Hvorslev (early)



Well details

Well ID	WMP05
Initial water level	7.546 m btoc
Well depth	12.4 m bgl
Screen interval	9.0 - 12.0 m bgl
Inferred HSUs	Alluvium

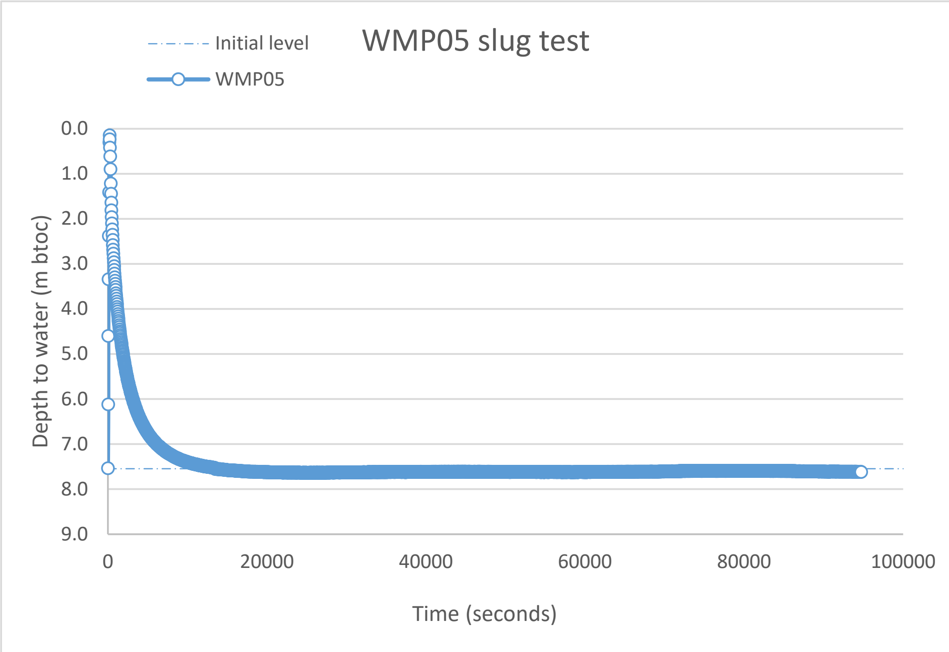
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
	Hvorslev (1951)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

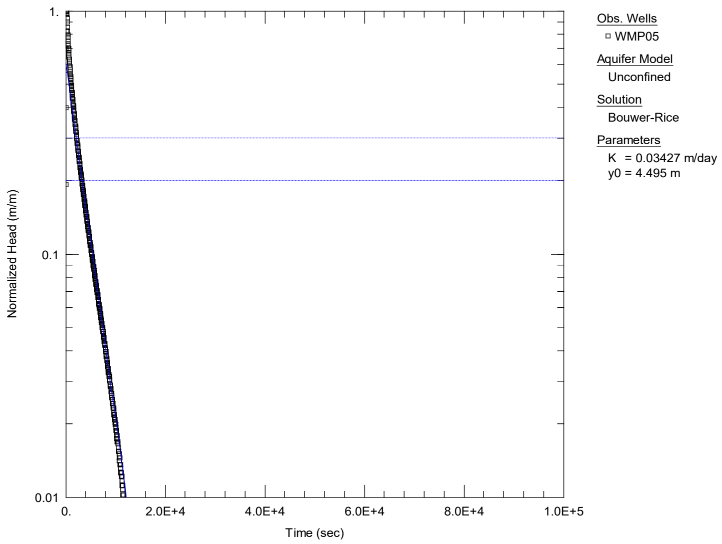
Bouwer-Rice	0.03 m/day
Hvorslev	0.07 m/day

Test data

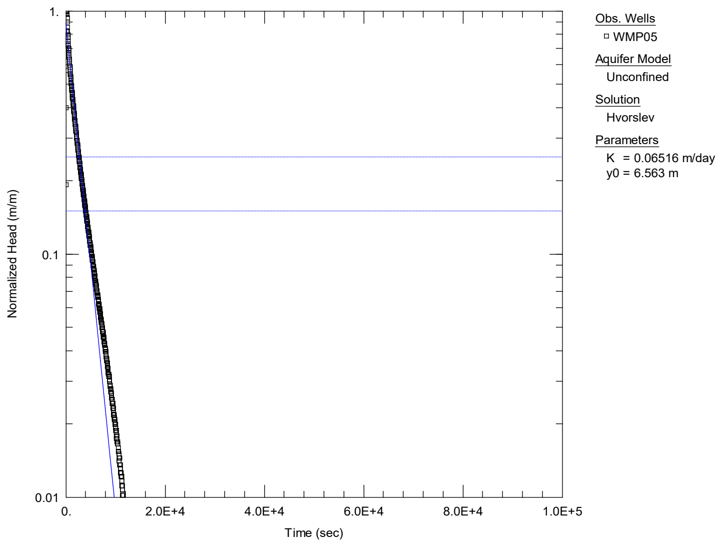


Test analyses

Bouwer-Rice



Hvorslev



Well details

Well ID	WMP06
Initial water level	17.767 m btoc
Well depth	18.4 m bgl
Screen interval	12.0 - 18.0 m bgl
Inferred HSUs	Alluvium / Styx Coal Measures - underburden

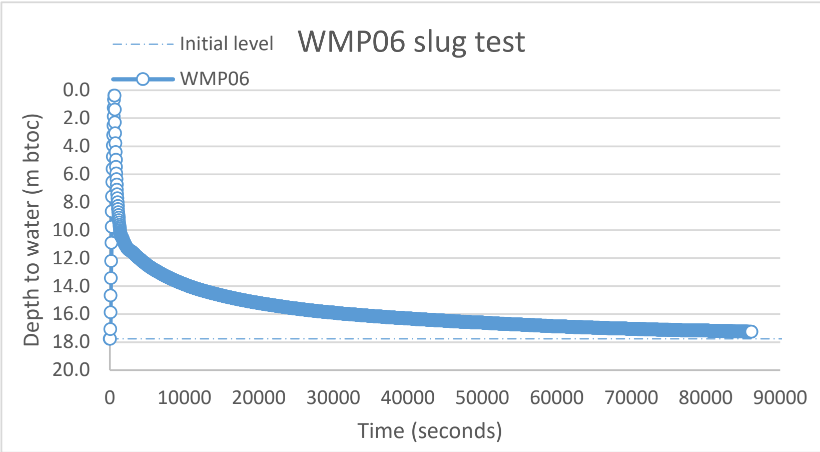
Analysis details

Test type	Slug test (Falling Head Test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

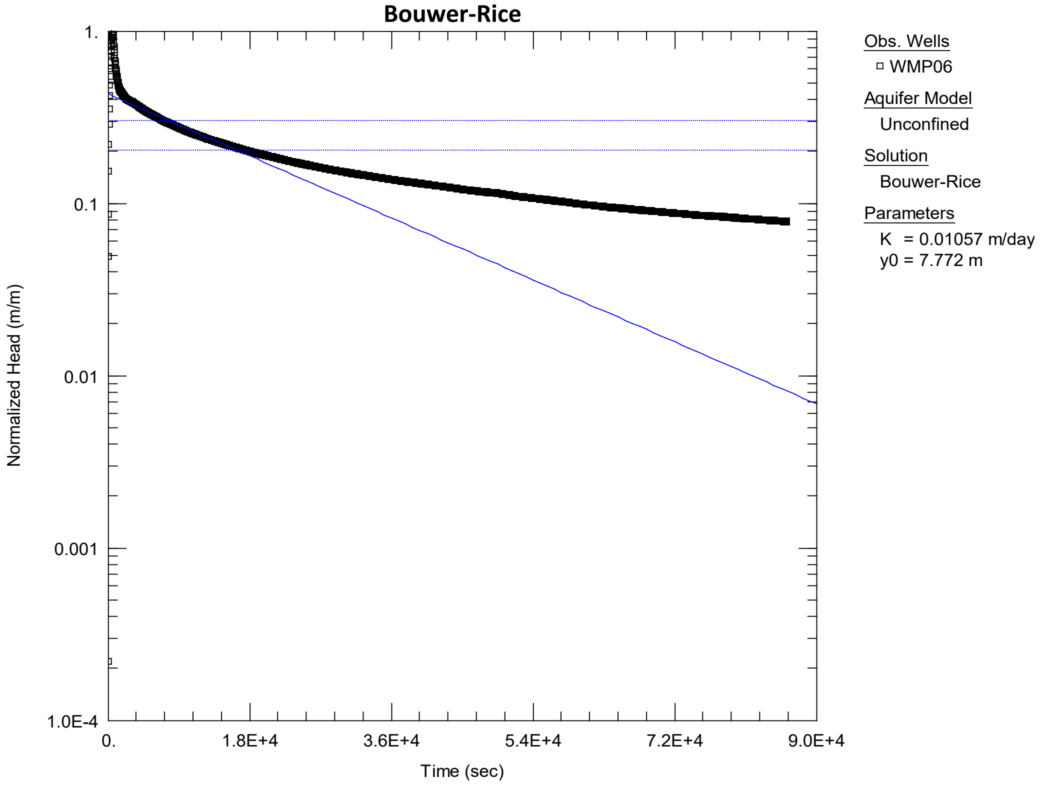
Bouwer-Rice	0.01 m/day

Test data



Test analyses

Bouwer-Rice



Aquifer test analysis details

Well details

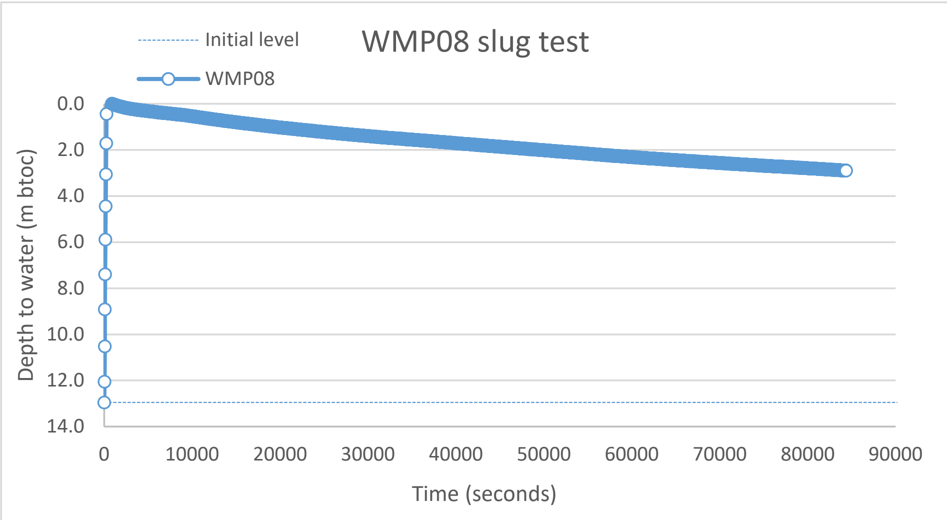
Well ID WMP08
Initial water level 12.953 m btoc
Well depth 16.0 m bgl
Screen interval 10.0 - 16.0 m bgl
Inferred HSUs Alluvium

Analysis details

Test type Slug test (Falling Head Test)
Analysis solutions Bouwer-Rice (1976)

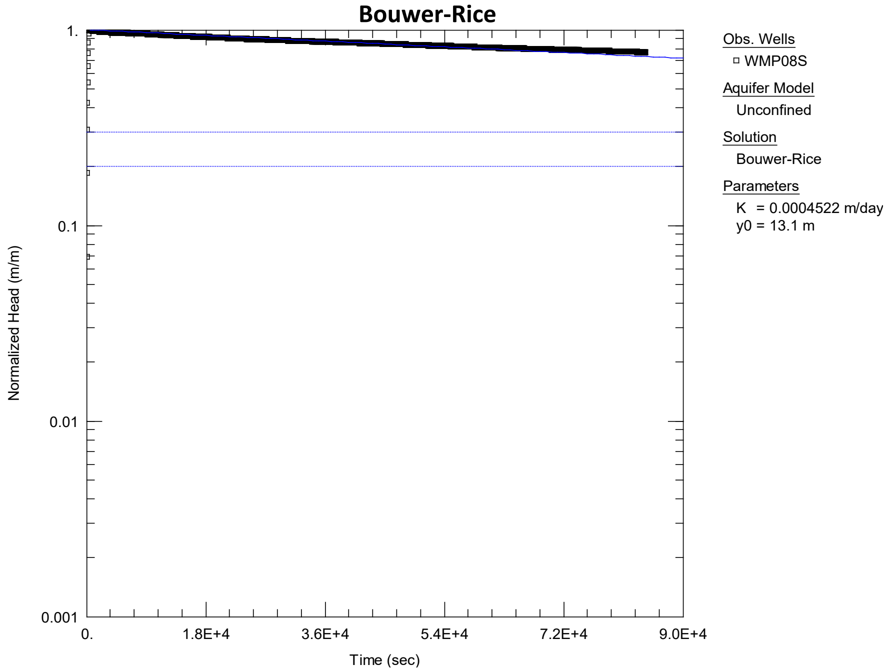
Analysis method AQTESOLV
Hydraulic conductivity (K)
Bouwer-Rice 0.0005 m/day

Test data



Test analyses

Bouwer-Rice



Well details

Well ID	WMP09
Initial water level	12.085 m btoc
Well depth	15.4 m bgl
Screen interval	7.1 - 15.0 m bgl
Inferred HSUs	Alluvium

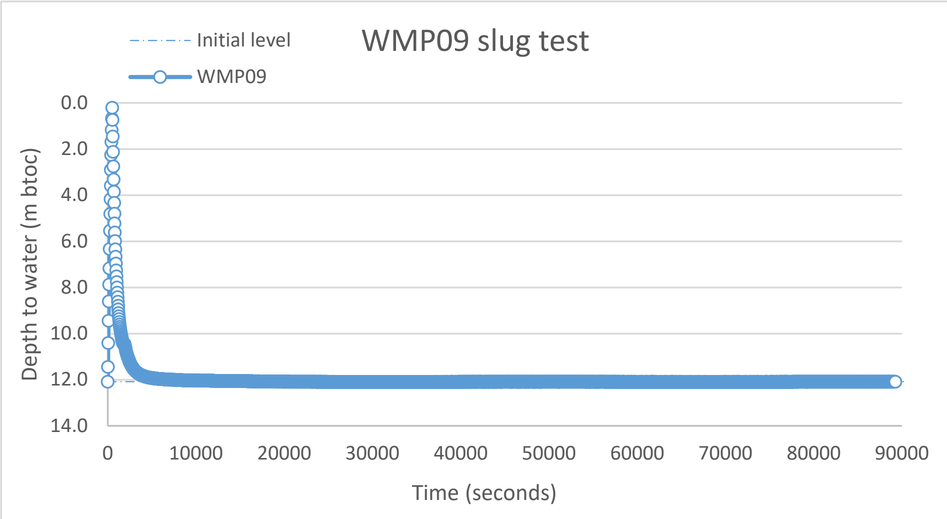
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
	Hvorslev (1951)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

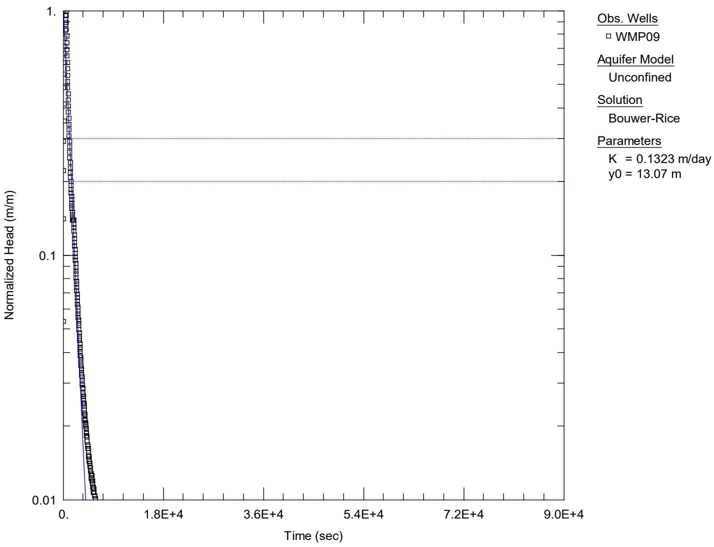
Bouwer-Rice	0.1 m/day
Hvorslev	0.2 m/day

Test data

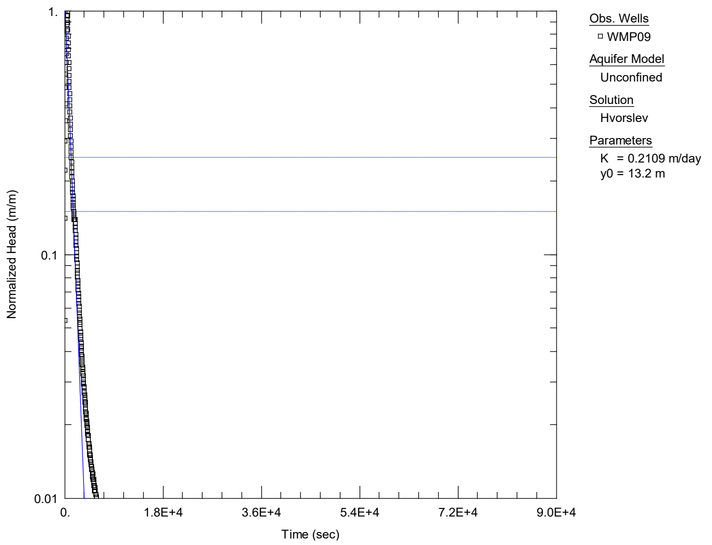


Test analyses

Bouwer-Rice



Hvorslev



Well details

Well ID	WMP10
Initial water level	8.558 m btoc
Well depth	18.4 m bgl
Screen interval	12.0 - 18.0 m bgl
Inferred HSUs	Styx Coal Measures - overburden

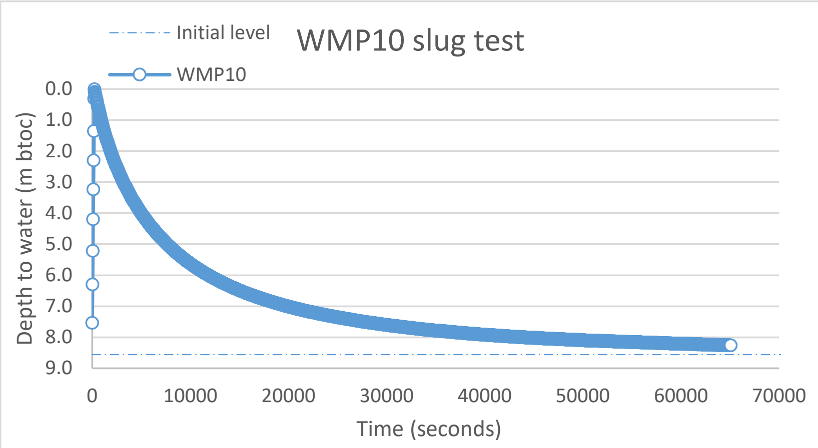
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

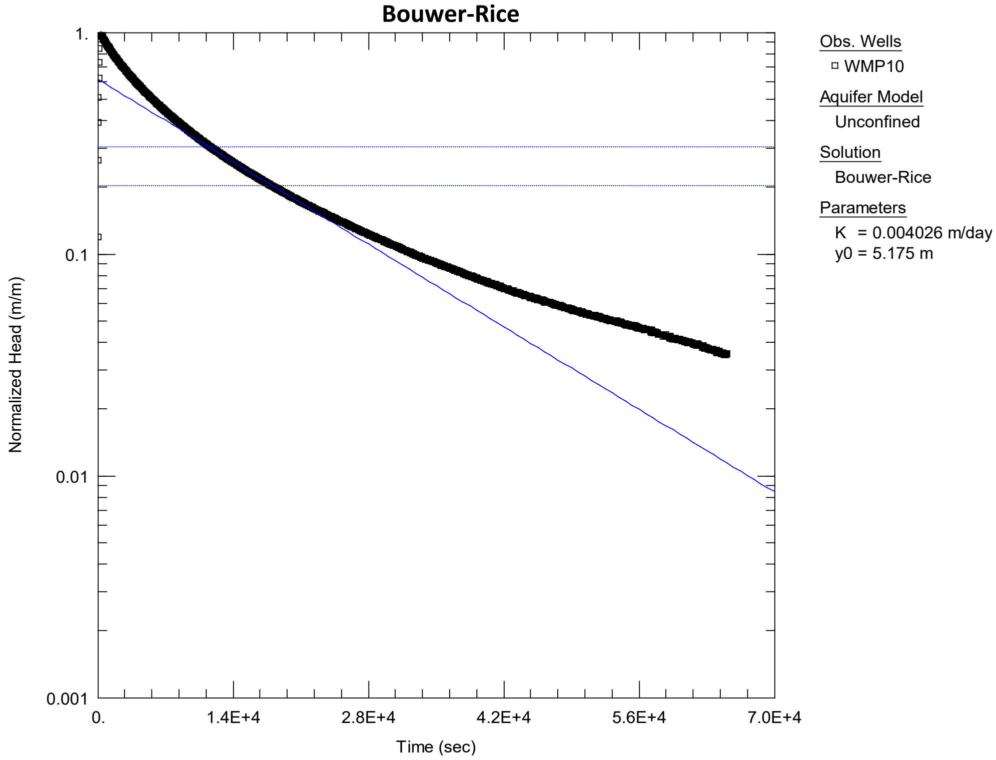
Bouwer-Rice 0.004 m/day

Test data



Test analyses

Bouwer-Rice



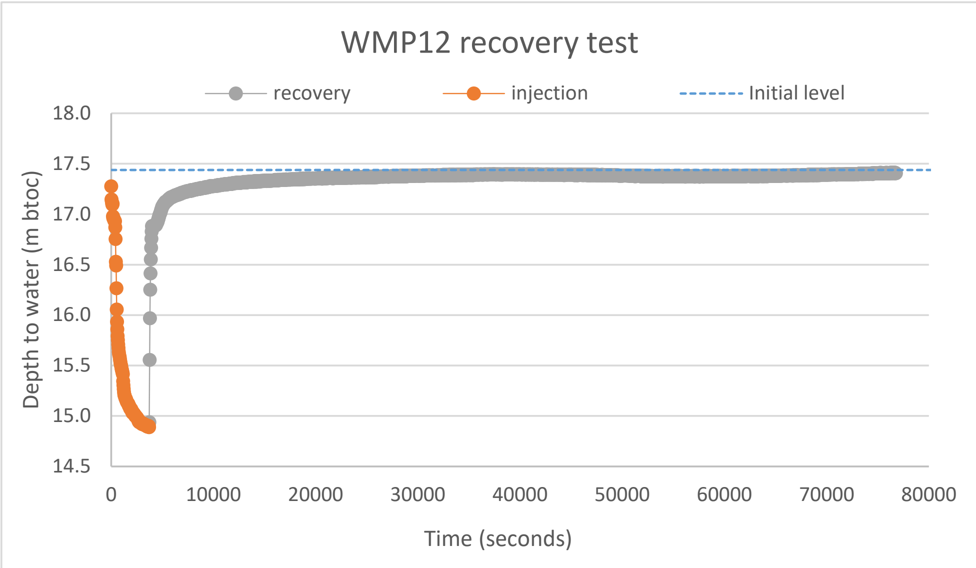
Well details

Well ID WMP12
Initial water level 17.438 m btoc
Well depth 18.4 m bgl
Screen interval 12.0 - 18.0 m bgl
Inferred HSU Alluvium / Styx Coal Measures - overburden

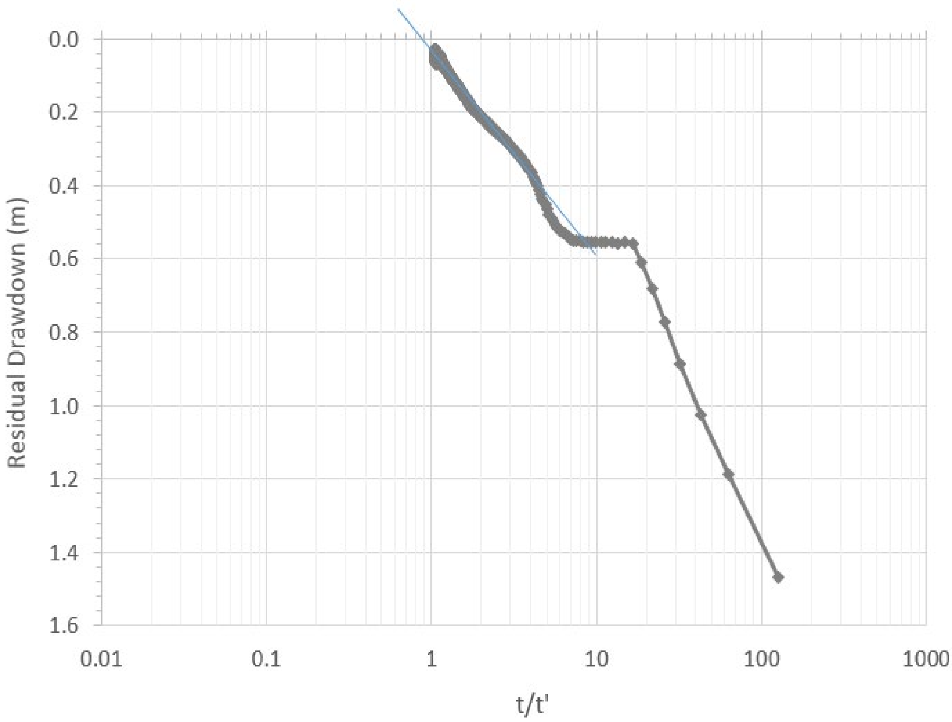
Analysis details

Aquifer type Unconfined
Test type Constant rate recovery test
Analysis solution Theis recovery (1935)
Analysis method Graphical
Pumping rate (Q) 58.3 m^3/day
Curve slope (Δs') 0.55
Saturated thickness (b) 8.5 m
Transmissivity (T) 19.4 m^2/day

Test data



Test analysis



Well details

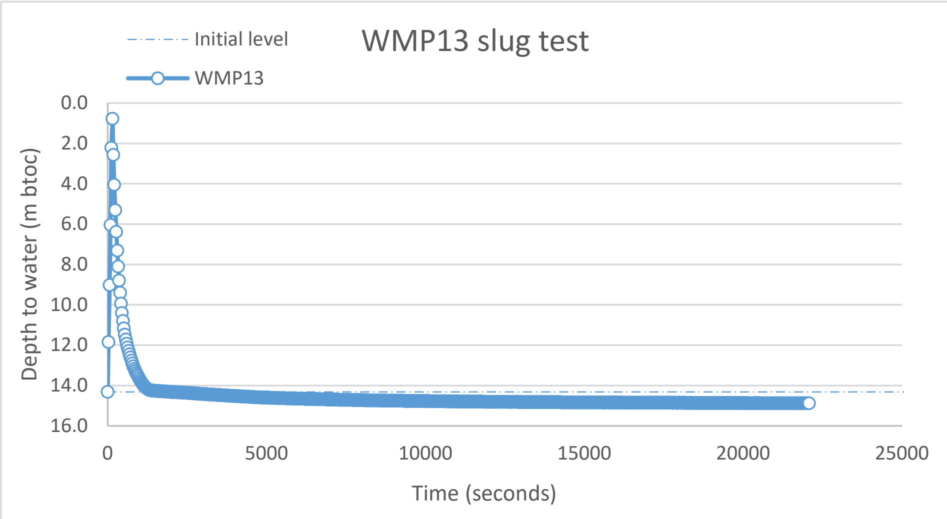
Well ID WMP13
Initial water level 14.319 m btoc
Well depth 19.7 m bgl
Screen interval 12.7 - 19.7 m bgl
Inferred HSUs Alluvium / Styx Coal Measures - overburden

Analysis details

Test type Slug test (Falling head test)
Analysis solutions Bouwer-Rice (1976)

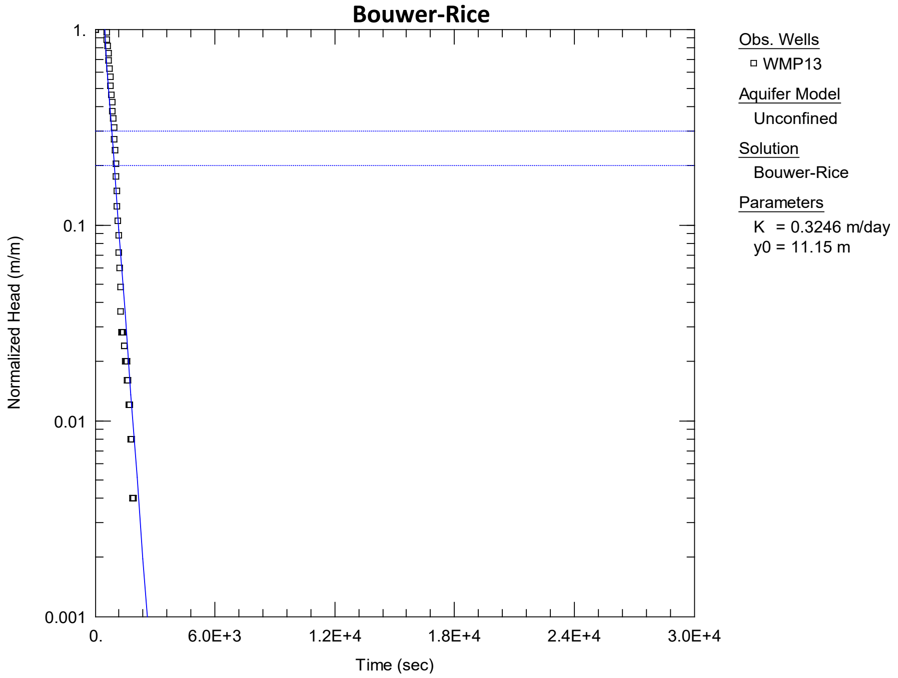
Analysis method AQTESOLV
Hydraulic conductivity (K)
Bouwer-Rice 0.3 m/day

Test data



Test analyses

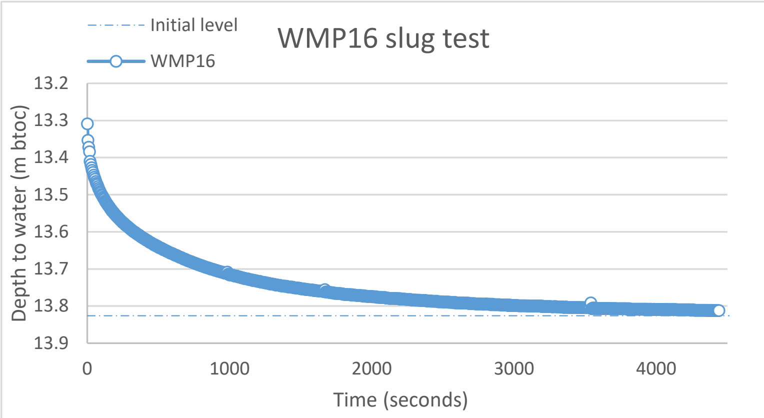
Bouwer-Rice



Well details		
Well ID	WMP16	
Initial water level	13.83	m btoc
Well depth	31.5	m bgl
Screen interval	25.5 - 31.5	m bgl
Inferred HSUs	Styx Coal Measures - Overburden	

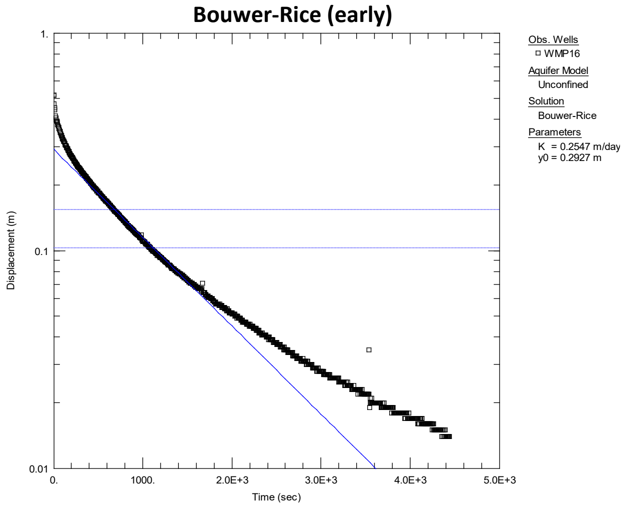
Analysis details		
Test type	Slug test (Falling head test)	
Analysis solutions	Bouwer-Rice (1976)	
Analysis method	AQTESOLV	
Hydraulic conductivity (K)		
Bouwer-Rice	Early	0.3 m/day
	Late	0.2 m/day

Test data

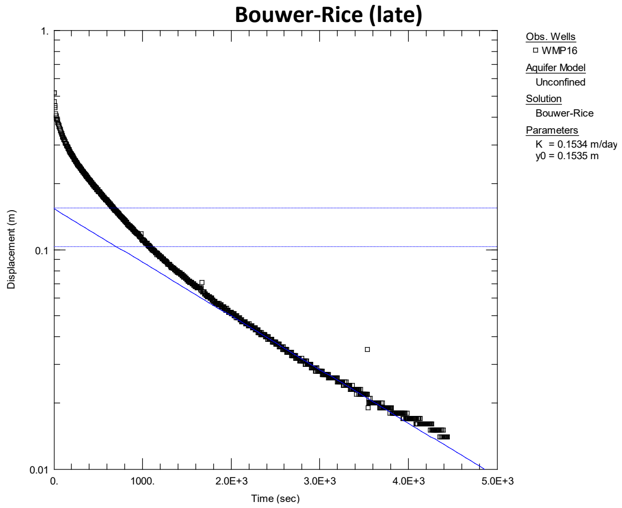


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (late)



Well details

Well ID	WMP16D
Initial water level	14.13 m btoc
Well depth	42 m bgl
Screen interval	35.7 - 41.7 m bgl
Inferred HSUs	Styx Coal Measures - Interburden

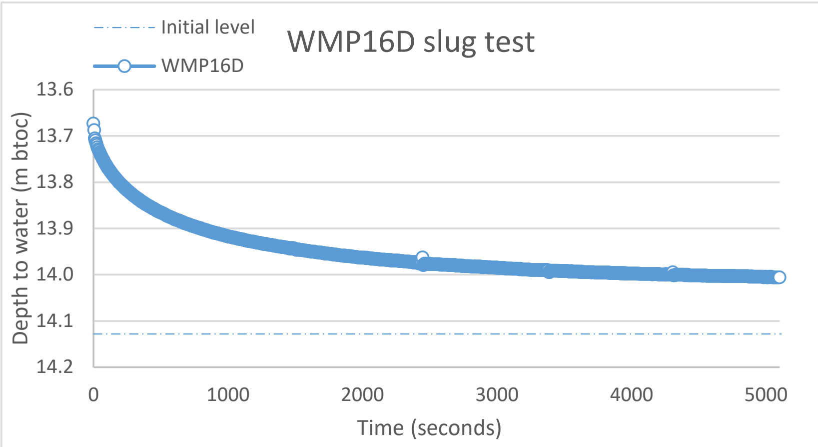
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

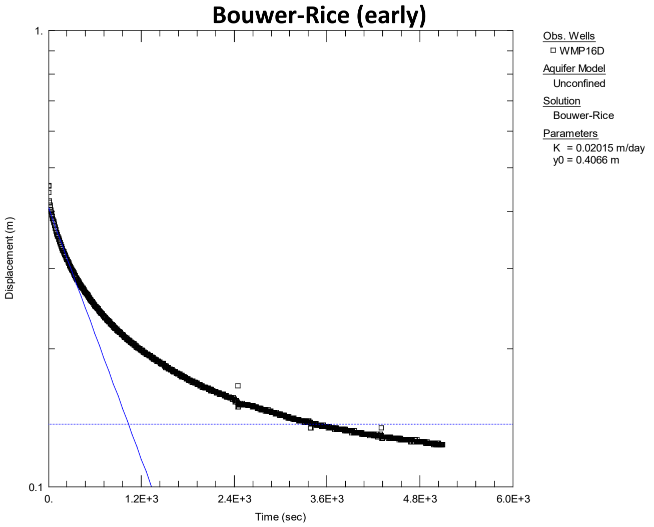
Bouwer-Rice	Early	0.02	m/day
	Mid	0.003	m/day
	Late	0.001	m/day

Test data

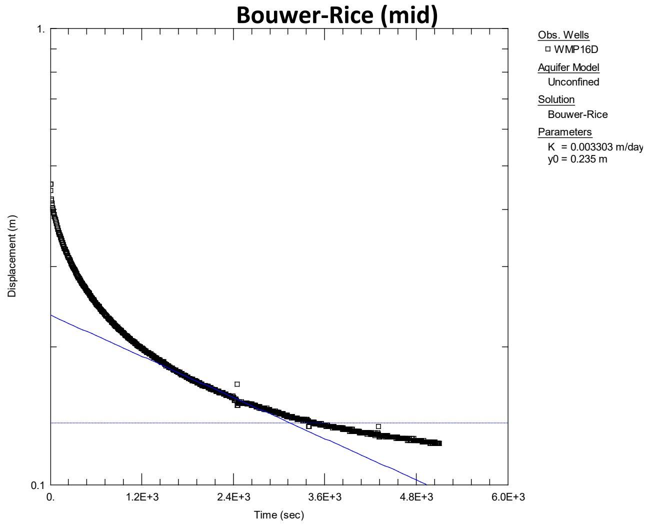


Test analyses

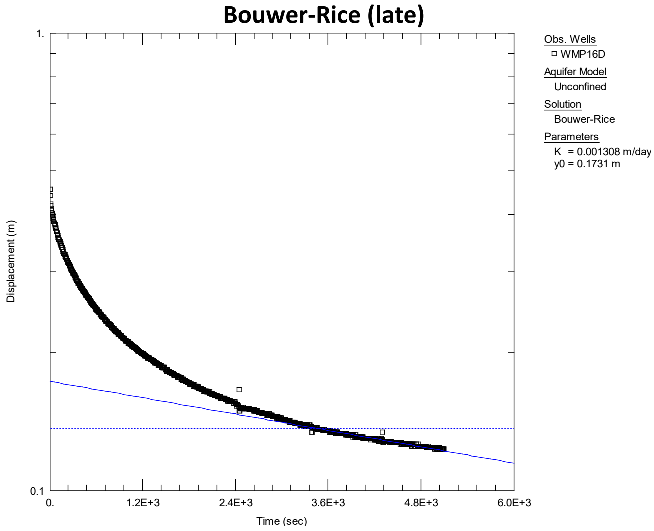
Bouwer-Rice (early)



Bouwer-Rice (mid)



Bouwer-Rice (late)



Well details

Well ID	WMP16D
Initial water level	14.13 m btoc
Well depth	42 m bgl
Screen interval	35.7 - 41.7 m bgl
Inferred HSUs	Styx Coal Measures - Interburden

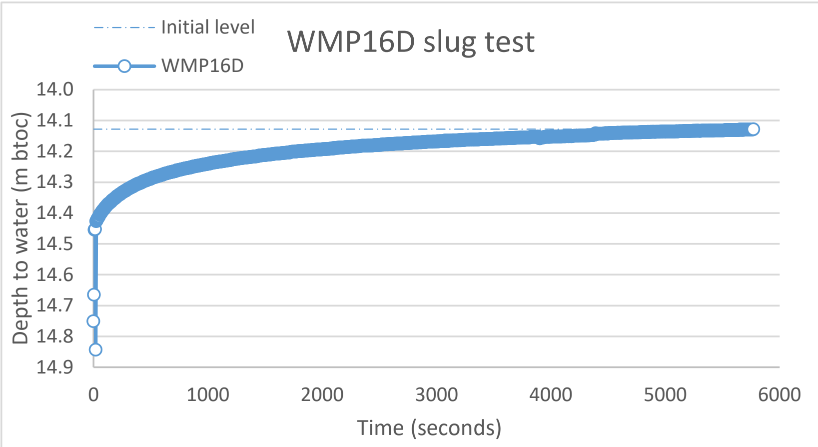
Analysis details

Test type	Slug test (Rising head test)	
Analysis solutions	Bouwer-Rice (1976)	
Analysis method	AQTESOLV	

Hydraulic conductivity (K)

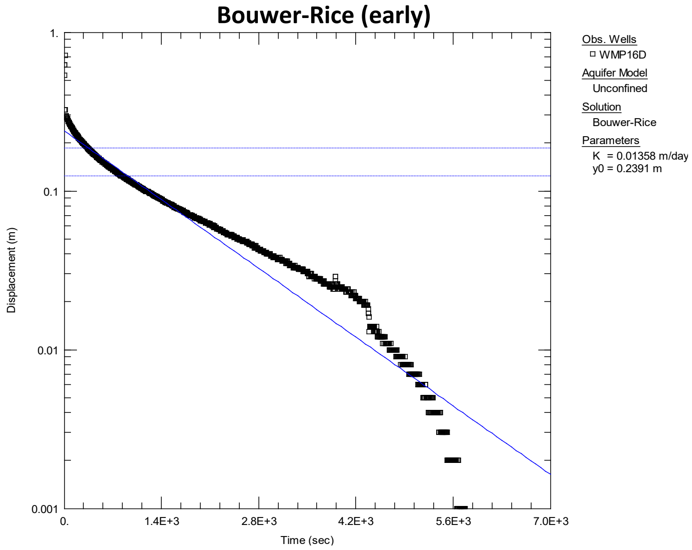
Bouwer-Rice	Early	0.01 m/day
	Mid	0.01 m/day
	Late	0.03 m/day

Test data

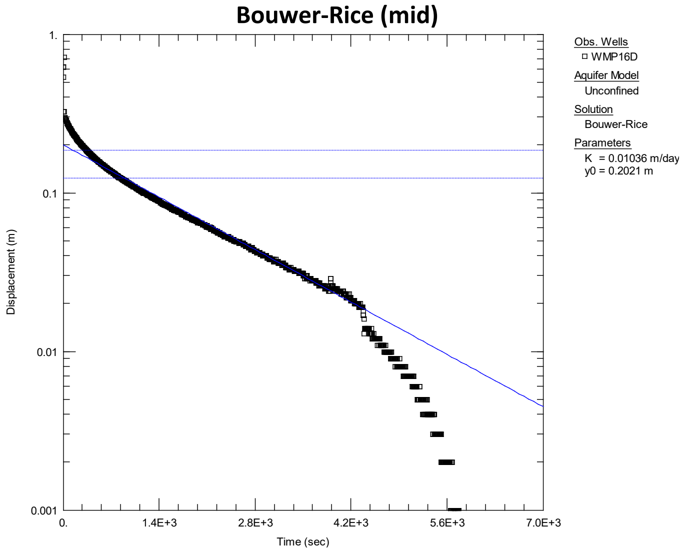


Test analyses

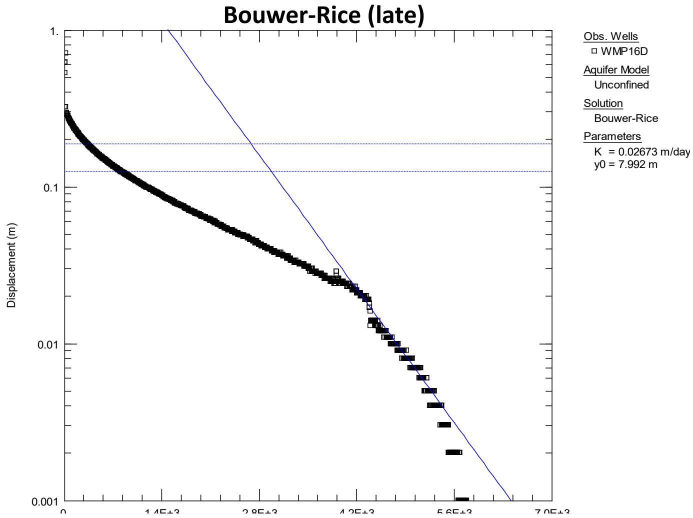
Bouwer-Rice (early)



Bouwer-Rice (mid)



Bouwer-Rice (late)



Well details

Well ID	WMP17D
Initial water level	13.13 m btoc
Well depth	24 m bgl
Screen interval	21 - 24 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

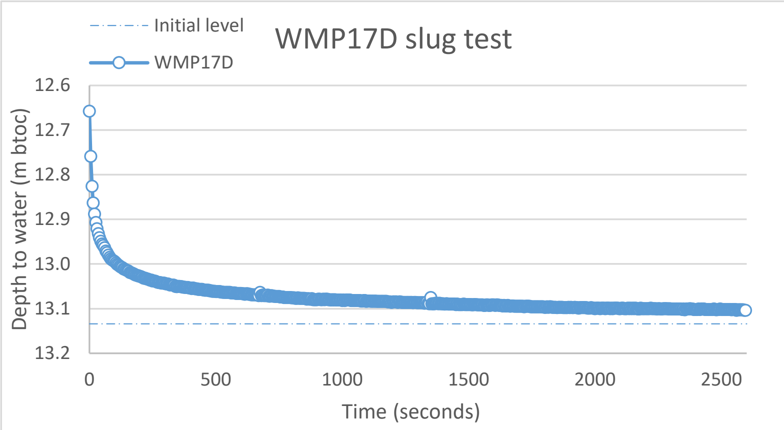
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

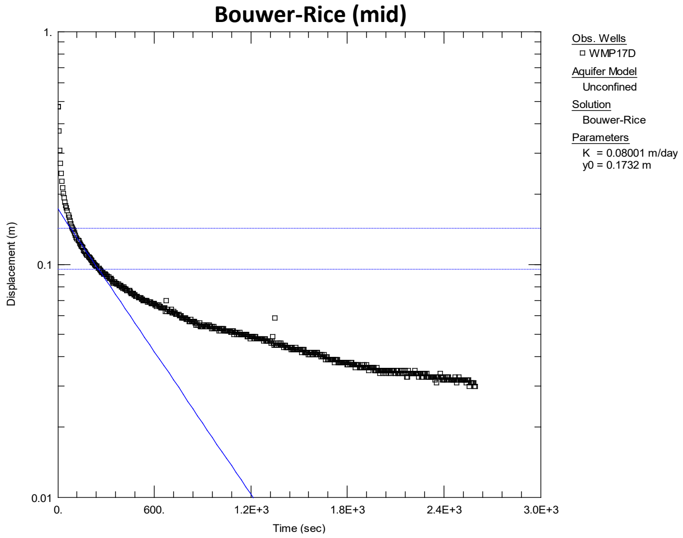
Bouwer-Rice	Mid	0.08 m/day
	Late	0.01 m/day

Test data

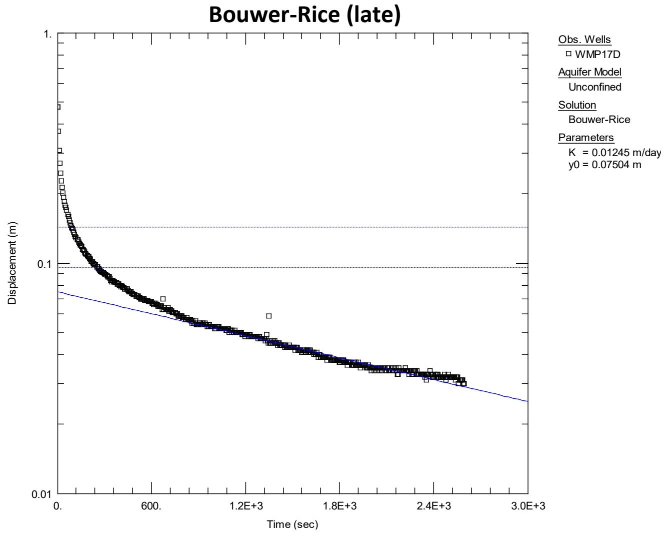


Test analyses

Bouwer-Rice (mid)



Bouwer-Rice (late)



Well details

Well ID	WMP17D
Initial water level	13.13 m btoc
Well depth	24 m bgl
Screen interval	21 - 24 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

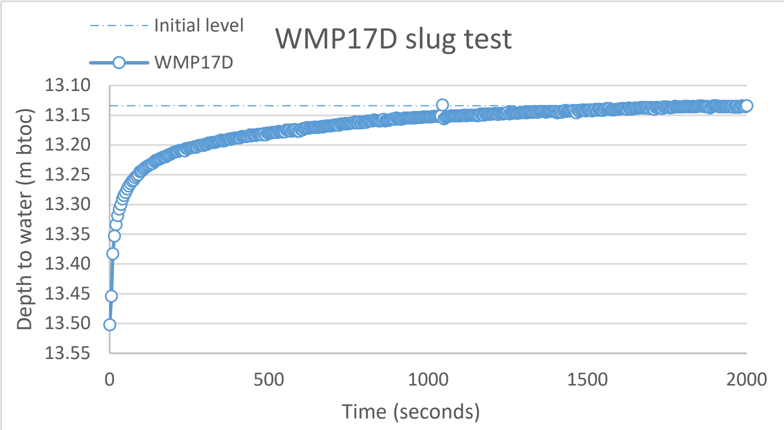
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

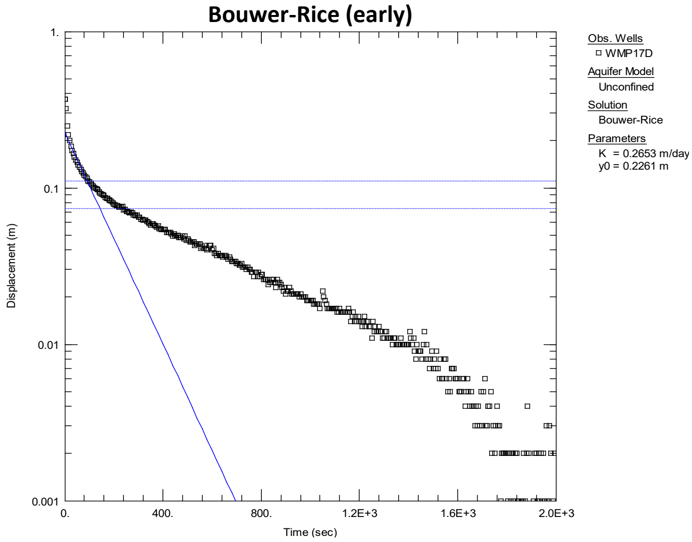
Bouwer-Rice	Early	0.3 m/day
	Mid	0.06 m/day

Test data

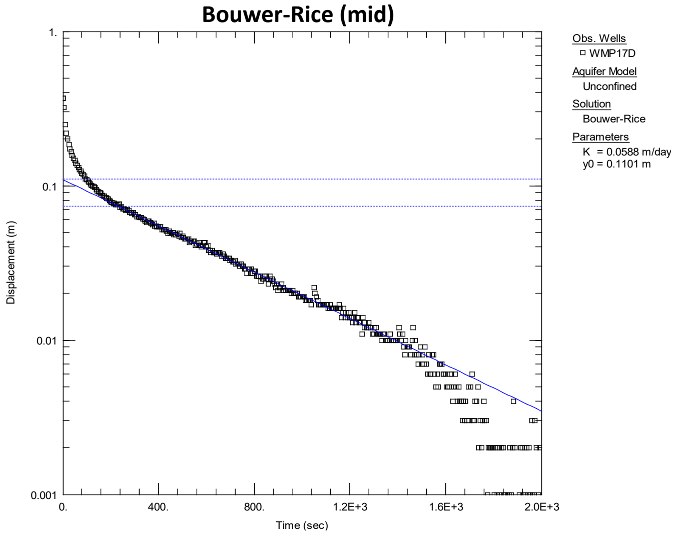


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid)



Well details

Well ID	WMP18D
Initial water level	14.54 m btoc
Well depth	23.5 m bgl
Screen interval	20.5 - 23.5 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

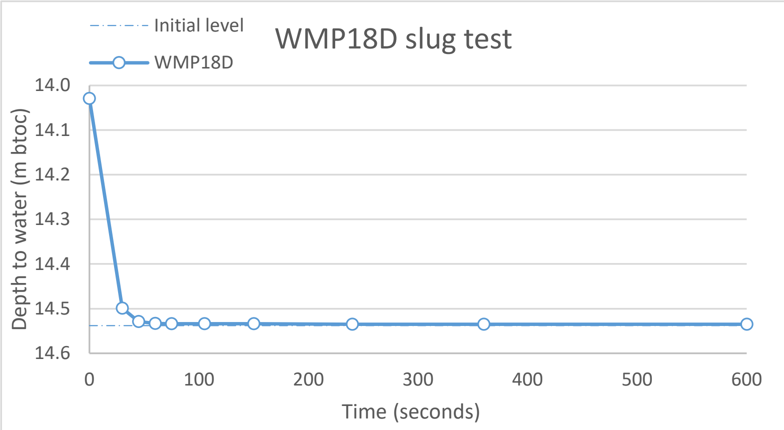
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

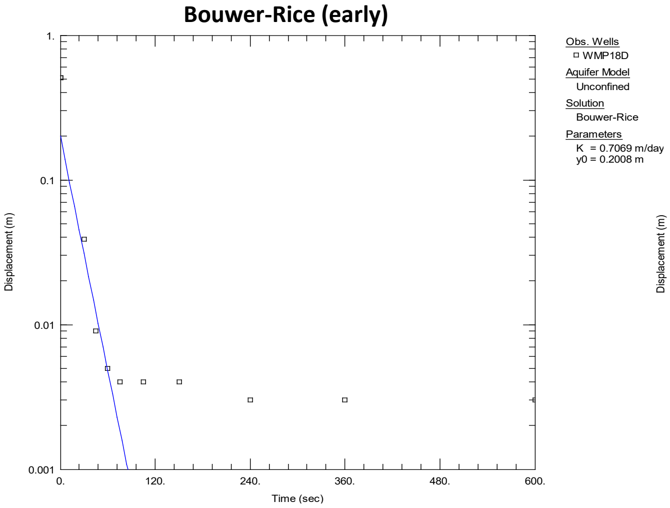
Bouwer-Rice	Early	0.7 m/day
	Mid-late	0.02 m/day

Test data

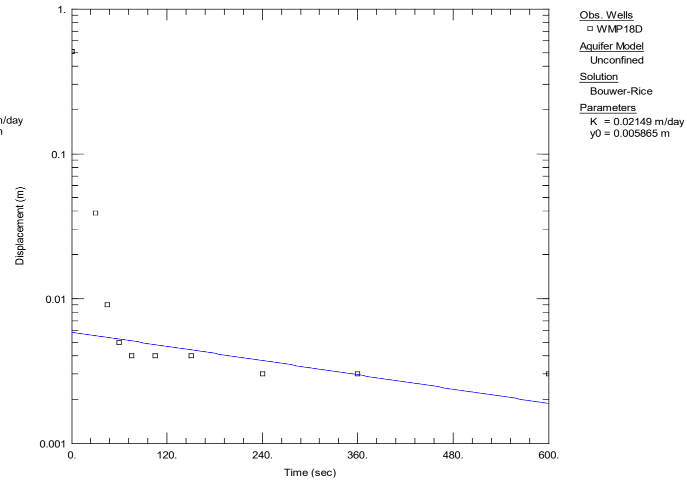


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid-late)



Well details

Well ID	WMP19
Initial water level	13.68 m btoc
Well depth	16.1 m bgl
Screen interval	13.1 - 16.1 m bgl
Inferred HSUs	Weathered Basement

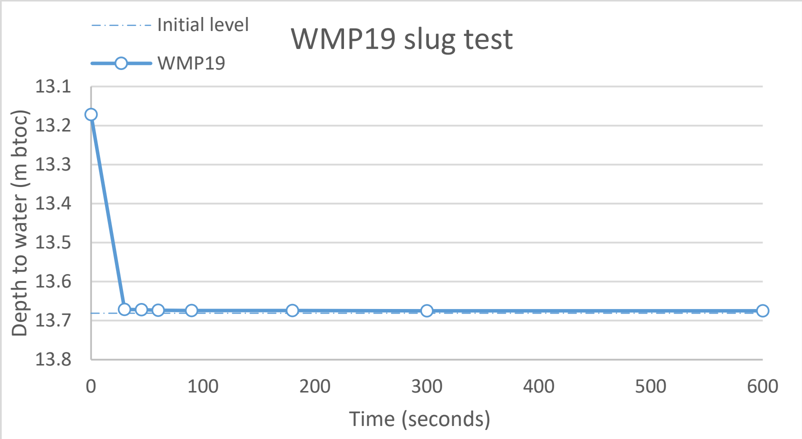
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

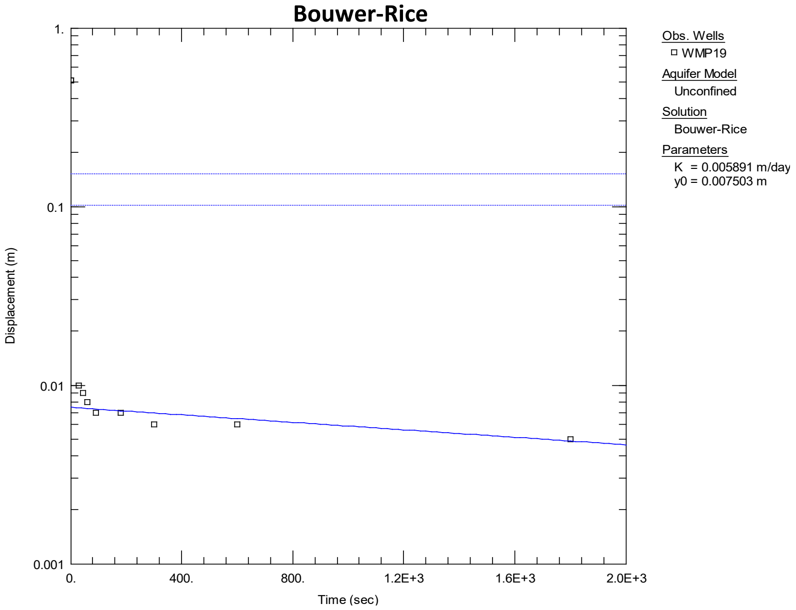
Bouwer-Rice	0.006 m/day

Test data



Test analyses

Bouwer-Rice



Well details

Well ID	WMP19D
Initial water level	13.63 m btoc
Well depth	28 m bgl
Screen interval	24.9 - 27.9 m bgl
Inferred HSUs	Weathered Basement

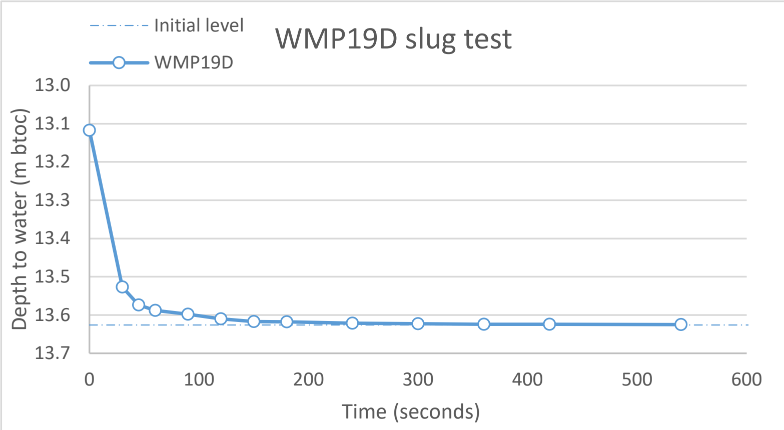
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

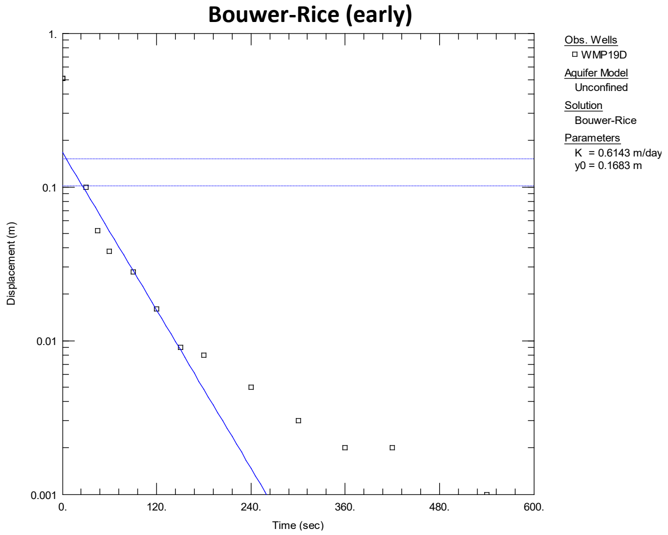
Bouwer-Rice	Early	0.6 m/day
	Mid-late	0.3 m/day

Test data

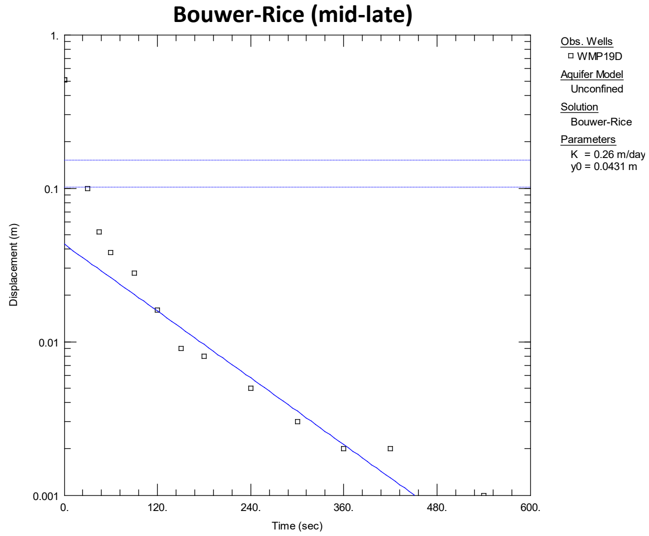


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid-late)



Well details

Well ID	WMP20
Initial water level	11.58 m btoc
Well depth	20.5 m bgl
Screen interval	14.5 - 20.5 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

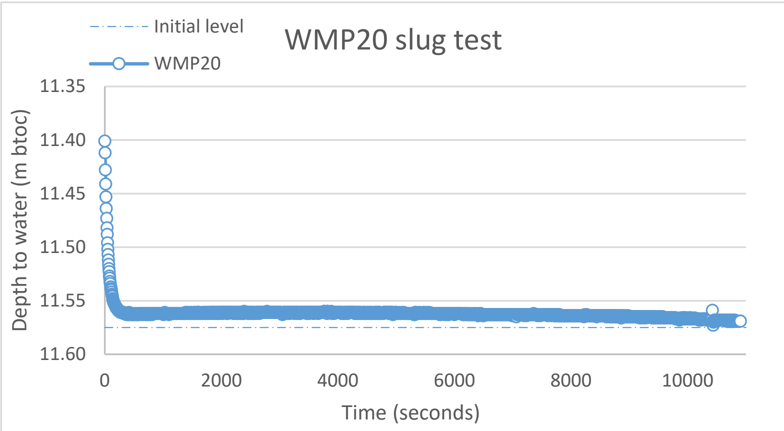
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

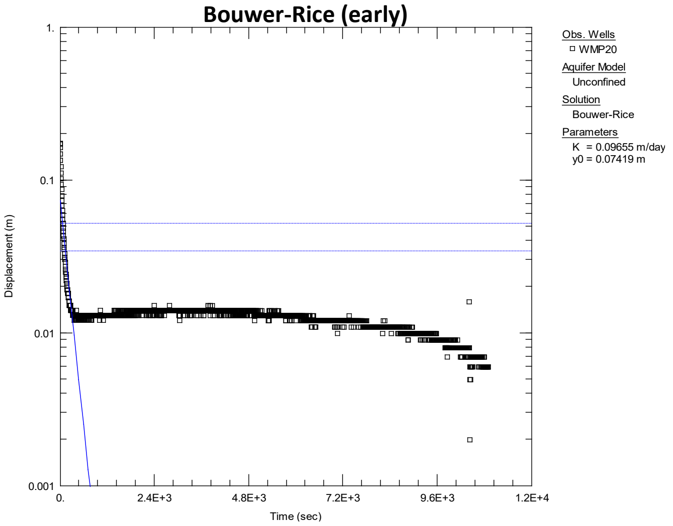
Bouwer-Rice	Early	0.1 m/day
	Late	0.0004 m/day

Test data

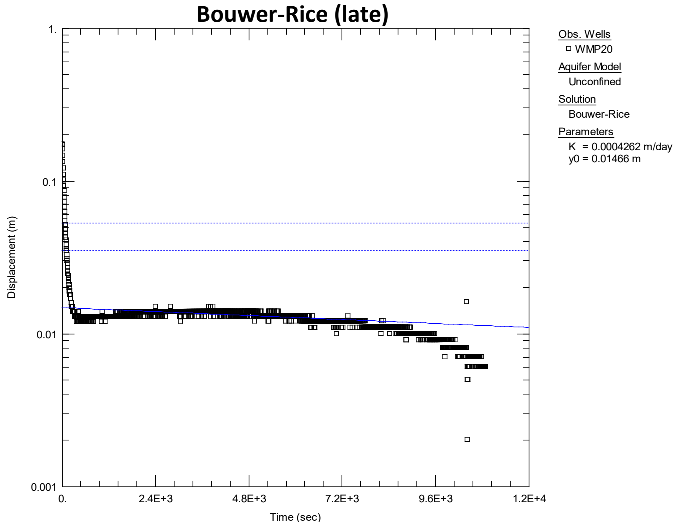


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (late)



Well details

Well ID	WMP20
Initial water level	11.58 m btoc
Well depth	20.5 m bgl
Screen interval	14.5 - 20.5 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

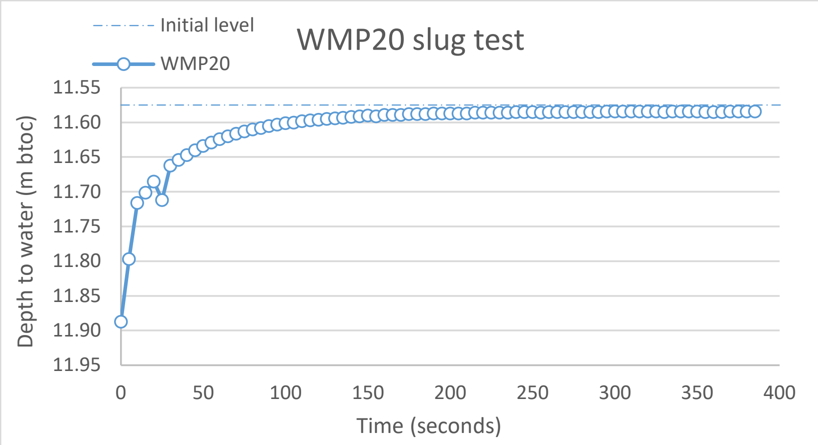
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

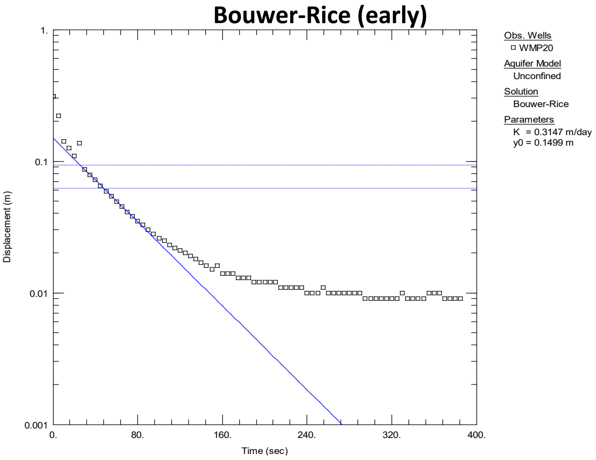
Bouwer-Rice	Early	0.3	m/day
	Mid	0.2	m/day
	Late	0.04	m/day

Test data

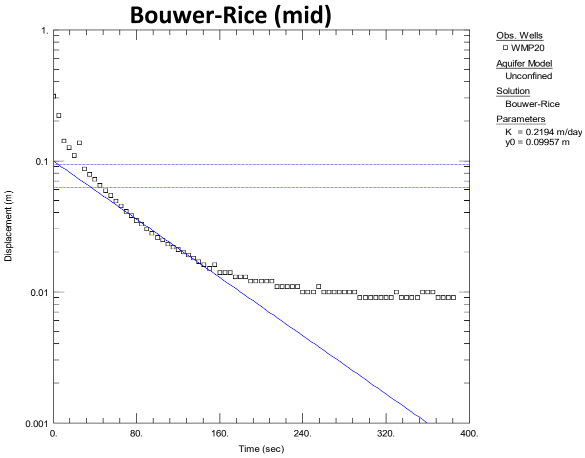


Test analyses

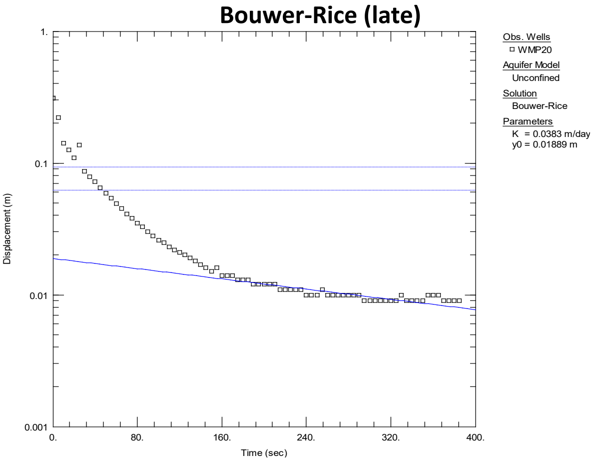
Bouwer-Rice (early)



Bouwer-Rice (mid)



Bouwer-Rice (late)



Well details

Well ID	WMP20D
Initial water level	12.41 m btoc
Well depth	30 m bgl
Screen interval	24 - 30 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

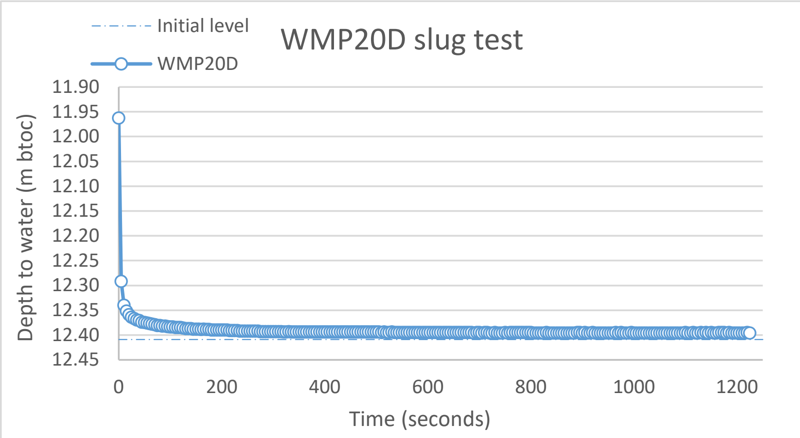
Analysis details

Test type	Slug test (Falling head test)	
Analysis solutions	Bouwer-Rice (1976)	
Analysis method	AQTESOLV	

Hydraulic conductivity (K)

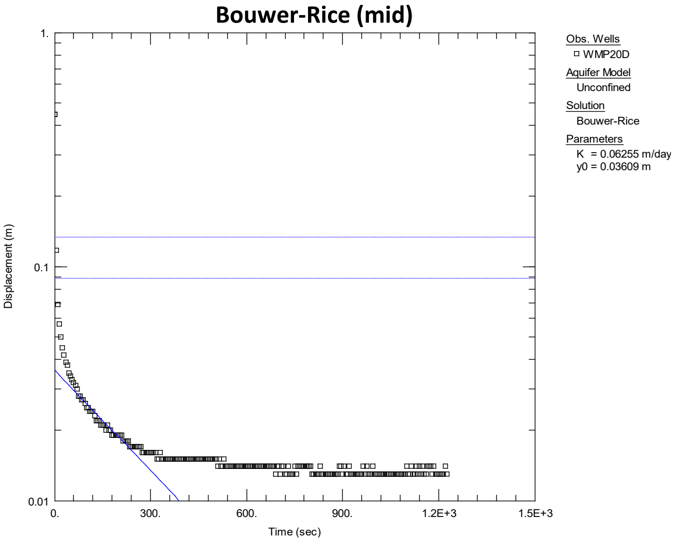
Bouwer-Rice	Mid	0.06 m/day
	Late	0.003 m/day

Test data

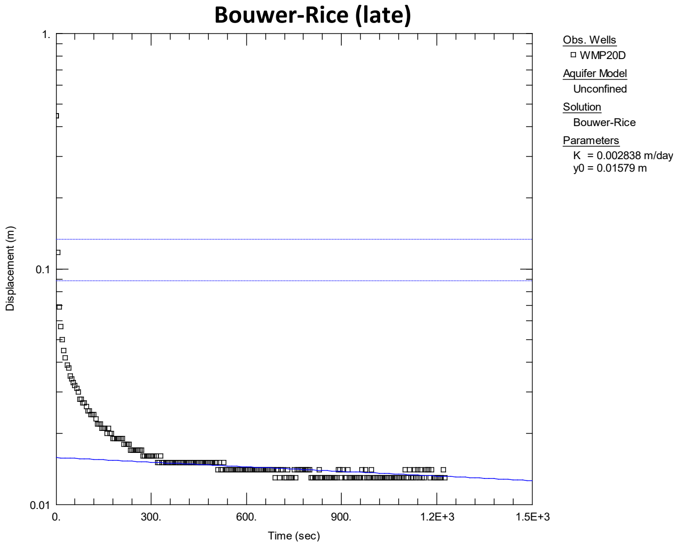


Test analyses

Bouwer-Rice (mid)



Bouwer-Rice (late)



Well details

Well ID	WMP20D
Initial water level	12.41 m btoc
Well depth	30 m bgl
Screen interval	24 - 30 m bgl
Inferred HSUs	Styx Coal Measures - Overburden

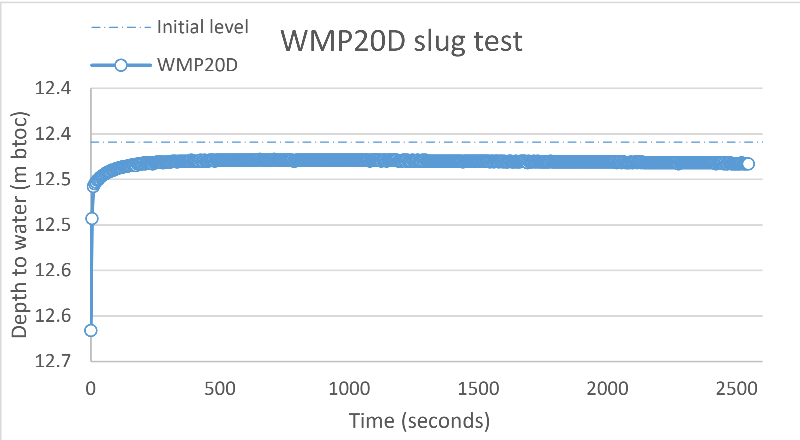
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

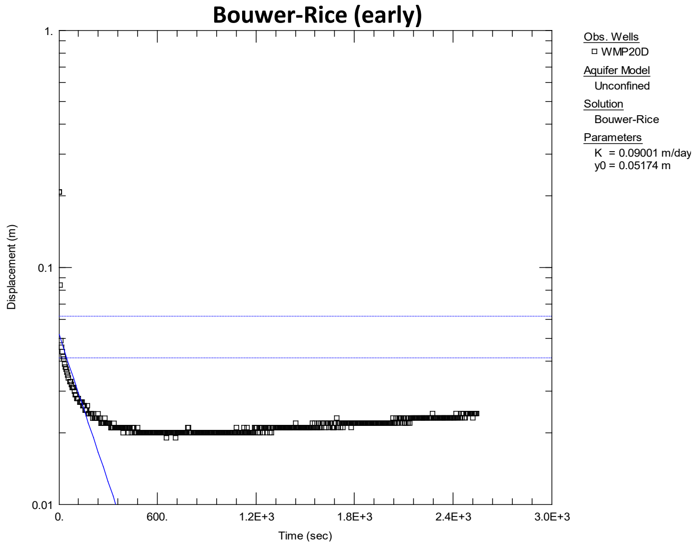
Bouwer-Rice	Early	0.09	m/day
	Mid	0.02	m/day

Test data

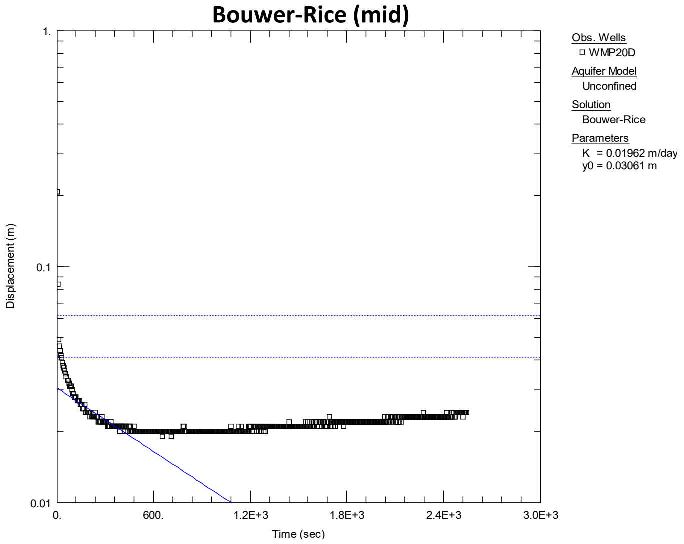


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid)



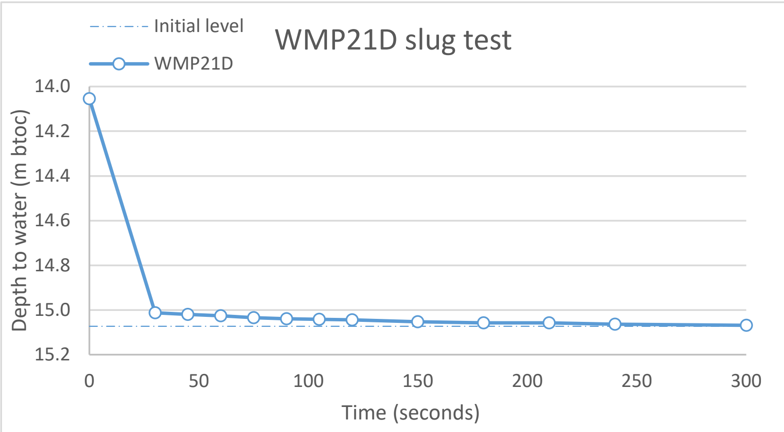
Well details

Well ID	WMP21D
Initial water level	15.07 m btoc
Well depth	22 m bgl
Screen interval	14 - 20 m bgl
Inferred HSUs	Alluvium / Styx Coal Measures - overburden

Analysis details

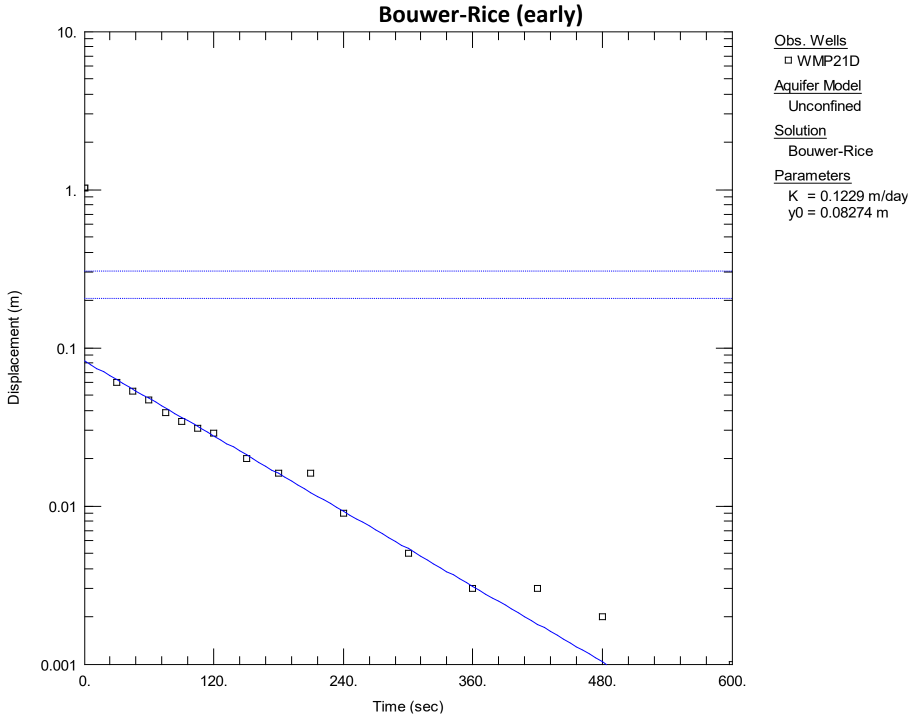
Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV
Hydraulic conductivity (K)	
Bouwer-Rice	0.1 m/day

Test data



Test analyses

Bouwer-Rice (early)



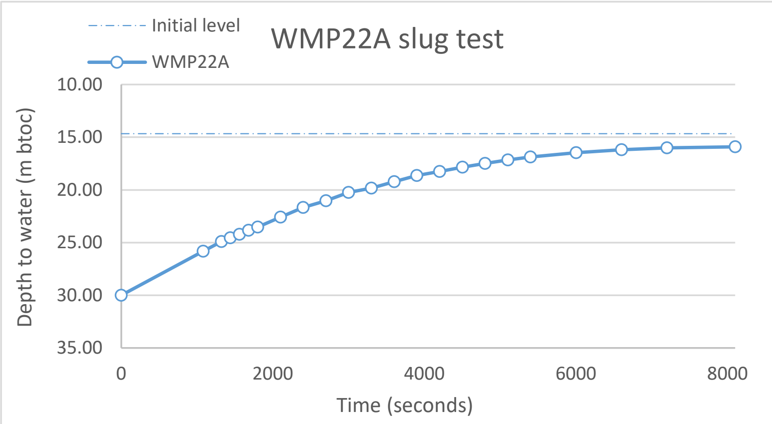
Well details

Well ID	WMP22A
Initial water level	14.67 m btoc
Well depth	30 m bgl
Screen interval	27 - 30 m bgl
Inferred HSUs	Styx Coal Measures - overburden

Analysis details

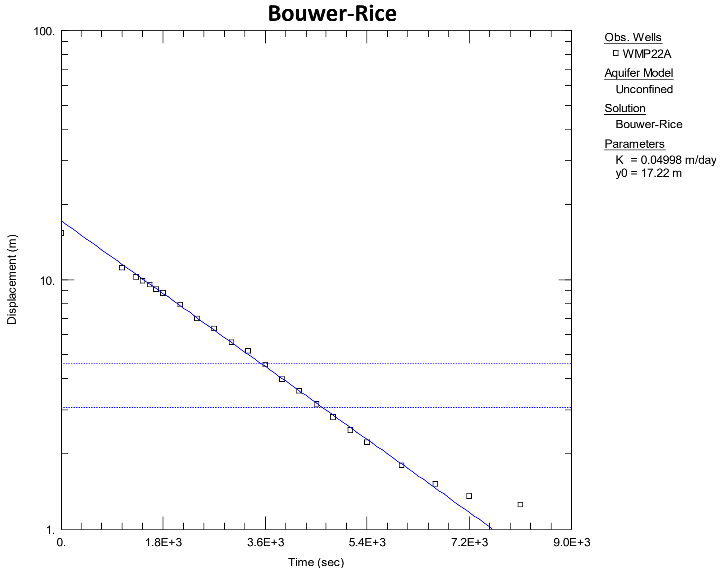
Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV
Hydraulic conductivity (K)	
Bouwer-Rice	0.05 m/day

Test data



Test analyses

Bouwer-Rice



Well details

Well ID	WMP22B
Initial water level	12.48 m btoc
Well depth	56 m bgl
Screen interval	50 - 56 m bgl
Inferred HSUs	Styx Coal Measures - Interburden

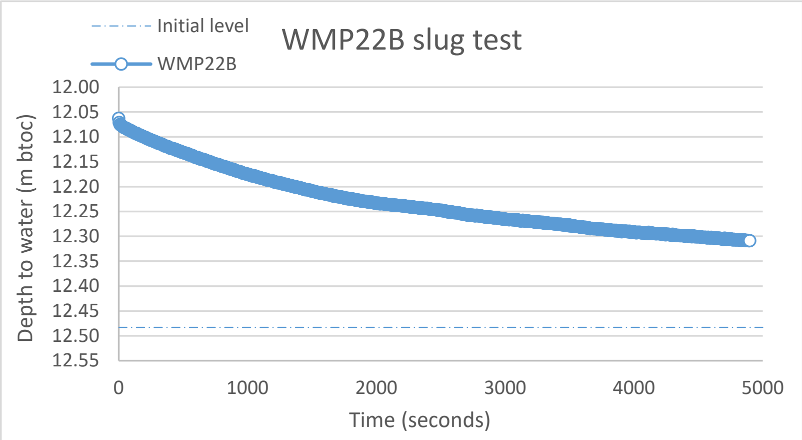
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

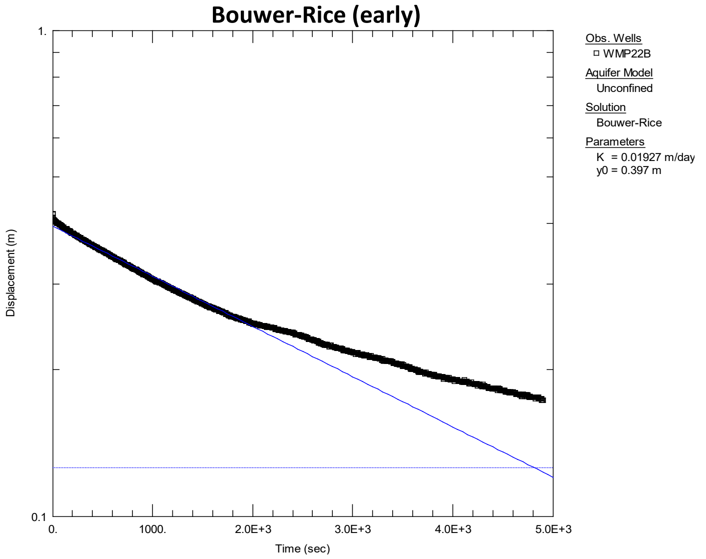
Bouwer-Rice	Early	0.02 m/day
	Late	0.01 m/day

Test data

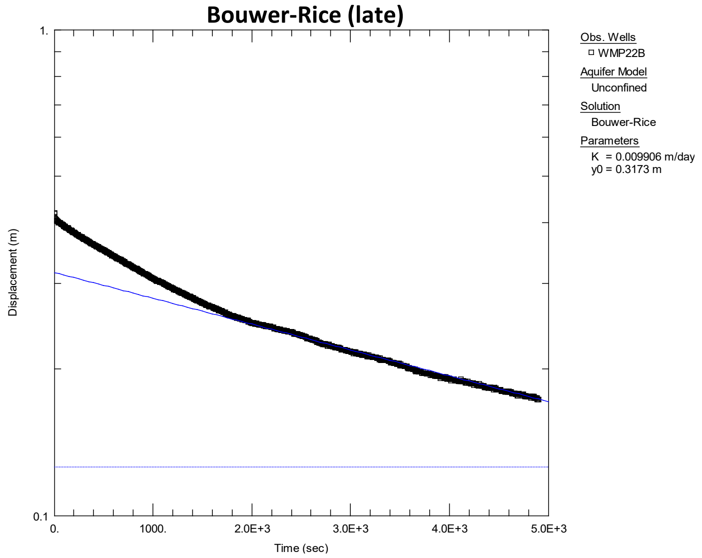


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (late)



Well details

Well ID	WMP22B
Initial water level	12.48 m btoc
Well depth	56 m bgl
Screen interval	50 - 56 m bgl
Inferred HSUs	Styx Coal Measures - Interburden

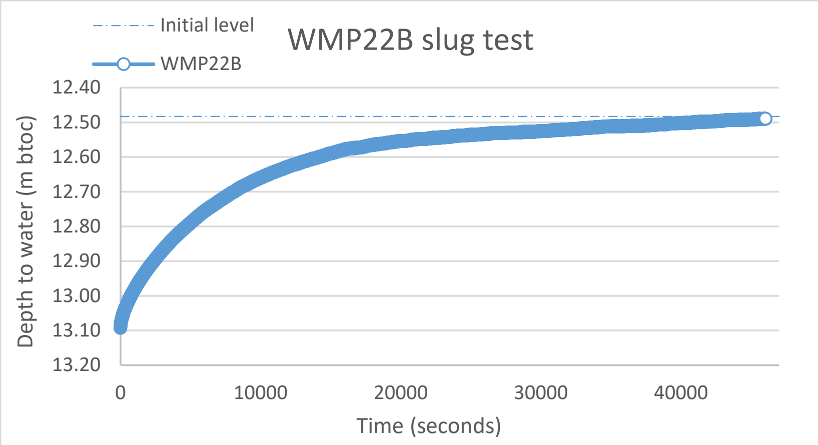
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

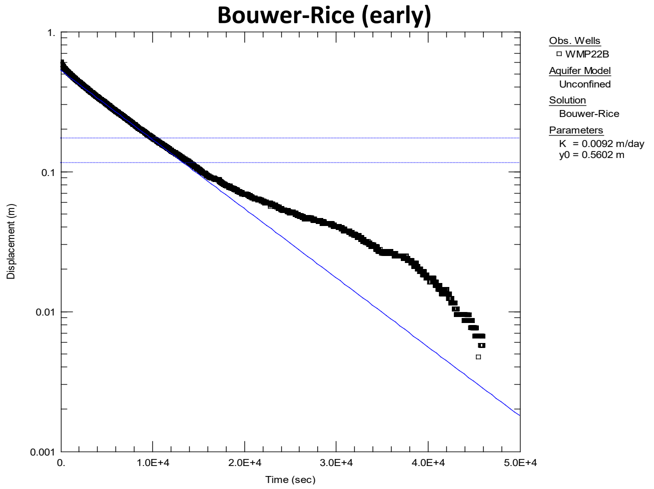
Bouwer-Rice	Early	0.009 m/day
	Mid	0.005 m/day
	Late	0.01 m/day

Test data

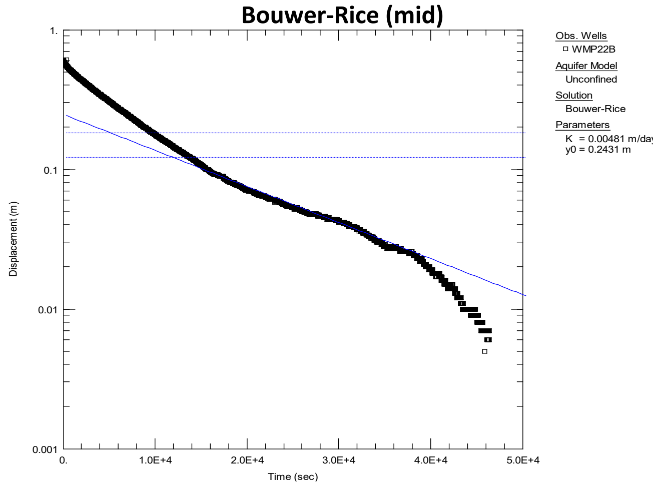


Test analyses

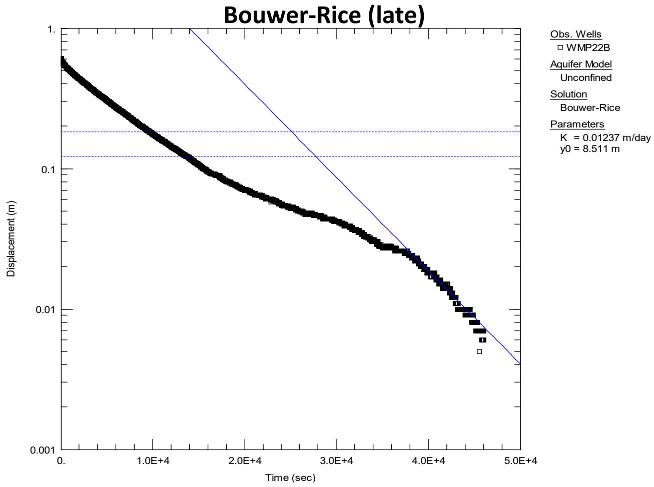
Bouwer-Rice (early)



Bouwer-Rice (mid)



Bouwer-Rice (late)



Well details

Well ID	WMP22C
Initial water level	12.98 m btoc
Well depth	206 m bgl
Screen interval	200 - 206 m bgl
Inferred HSUs	Styx Coal Measures - underburden

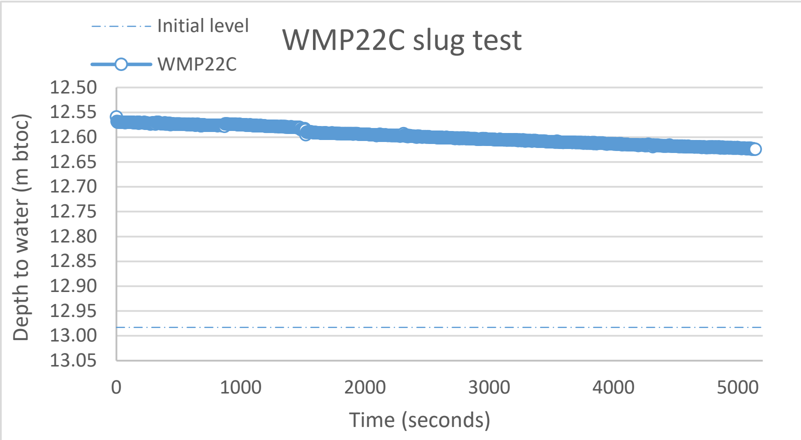
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

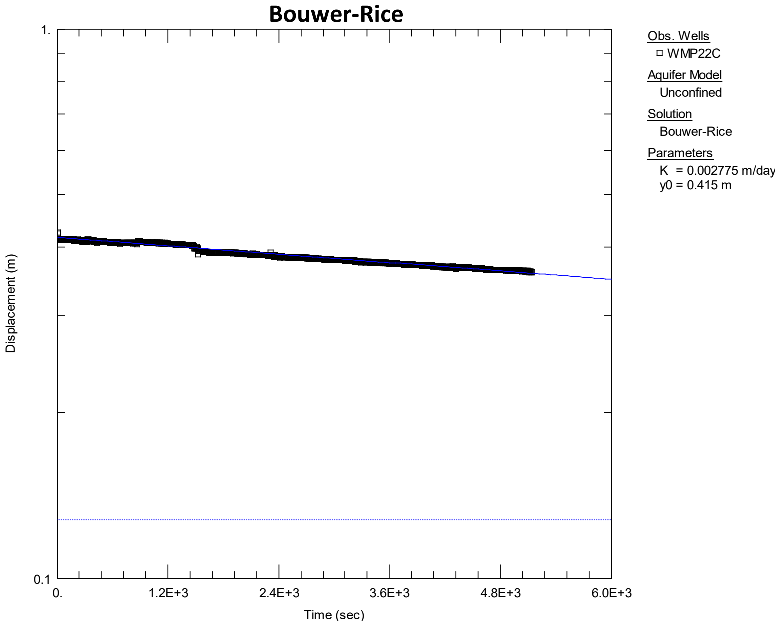
Bouwer-Rice	0.003 m/day

Test data



Test analyses

Bouwer-Rice



Well details

Well ID	WMP22C
Initial water level	12.98 m btoc
Well depth	206 m bgl
Screen interval	200 - 206 m bgl
Inferred HSUs	Styx Coal Measures - underburden

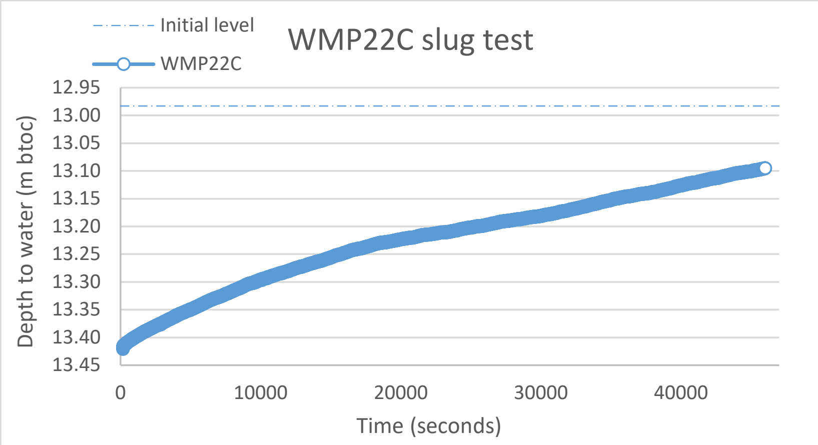
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

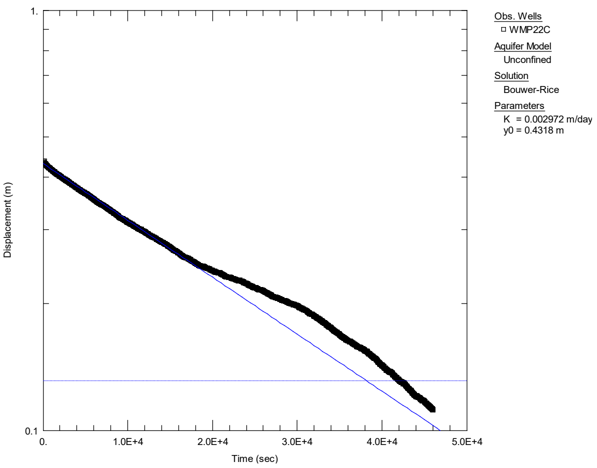
Bouwer-Rice	Early	0.003 m/day
	Mid	0.002 m/day
	Late	0.003 m/day

Test data

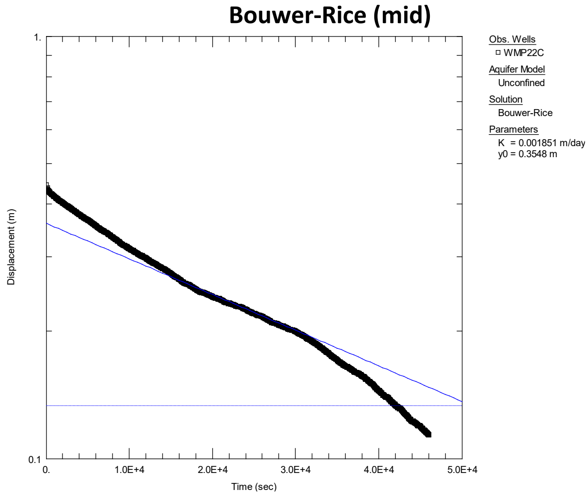


Test analyses

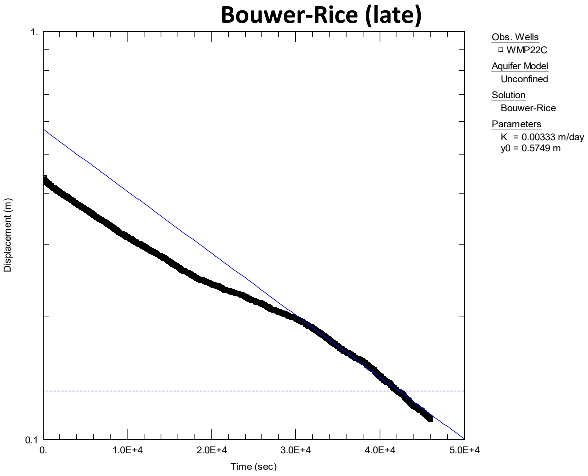
Bouwer-Rice (early)



Bouwer-Rice (mid)



Bouwer-Rice (late)



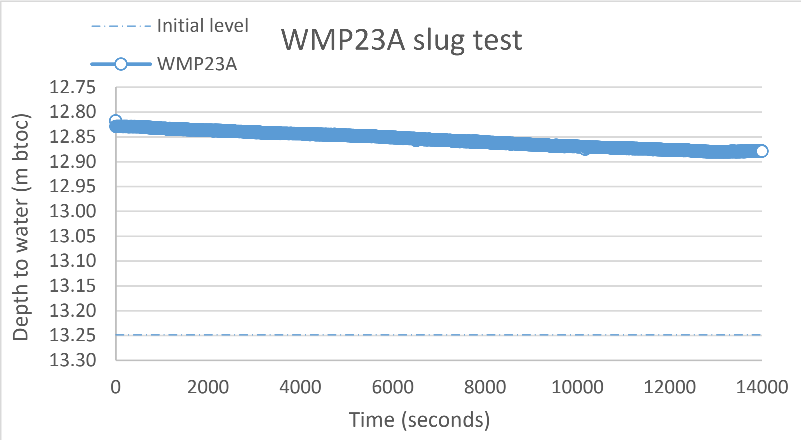
Well details

Well ID	WMP23A
Initial water level	13.25 m btoc
Well depth	56.5 m bgl
Screen interval	48.5 - 54.5 m bgl
Inferred HSUs	Styx Coal Measures - interburden

Analysis details

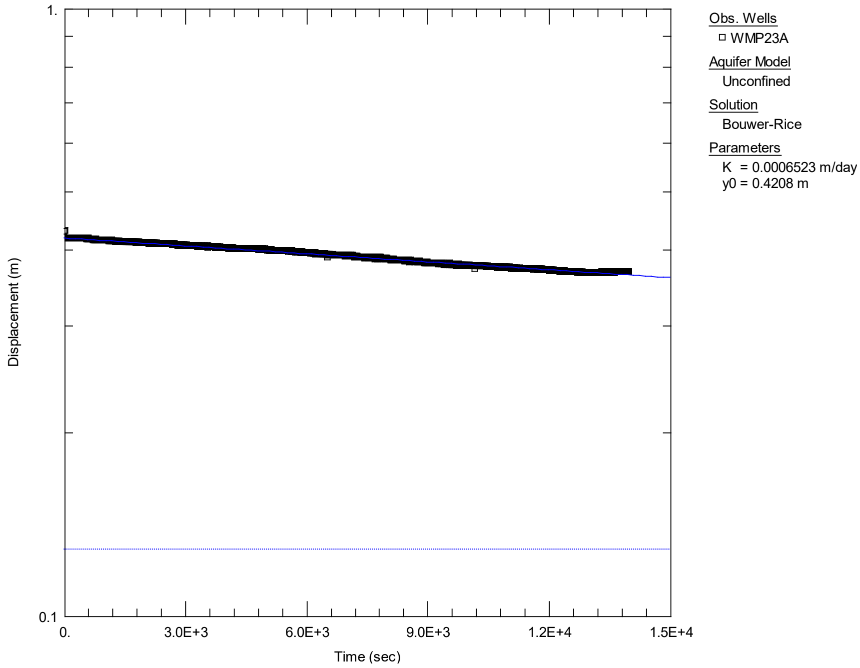
Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV
Hydraulic conductivity (K)	
Bouwer-Rice	0.0007 m/day

Test data



Test analyses

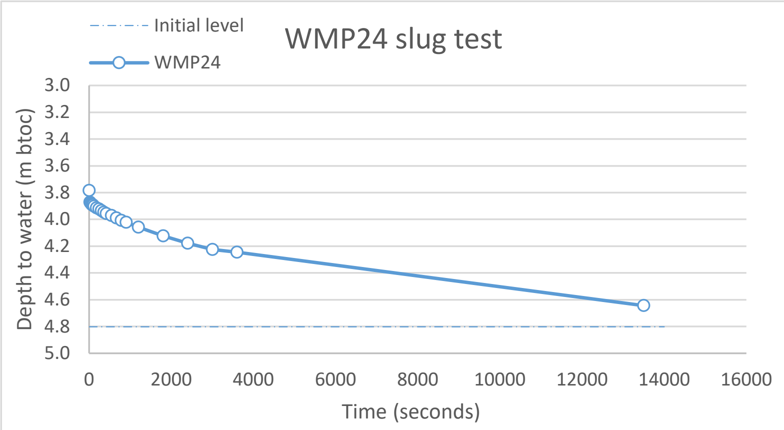
Bouwer-Rice



Well details	
Well ID	WMP24
Initial water level	4.80 m btoc
Well depth	26.4 m bgl
Screen interval	23.4 - 26.4 m bgl
Inferred HSUs	Styx Coal Measures - overburden

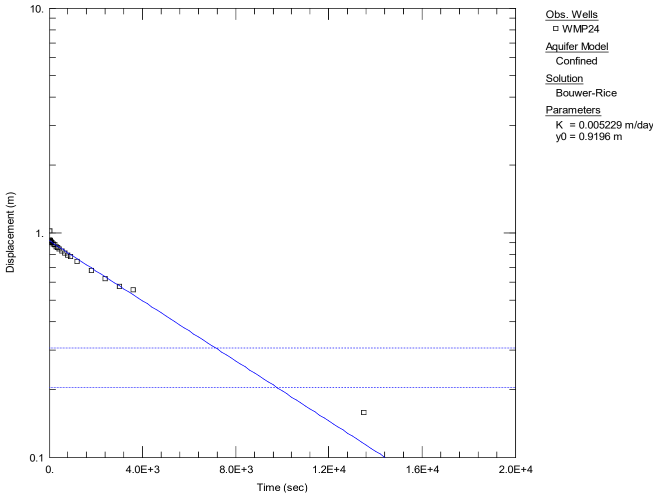
Analysis details	
Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
	Hvorslev (1951)
Analysis method	AQTESOLV
Hydraulic conductivity (K)	
Bouwer-Rice	0.005 m/day
Hvorslev	0.006 m/day

Test data

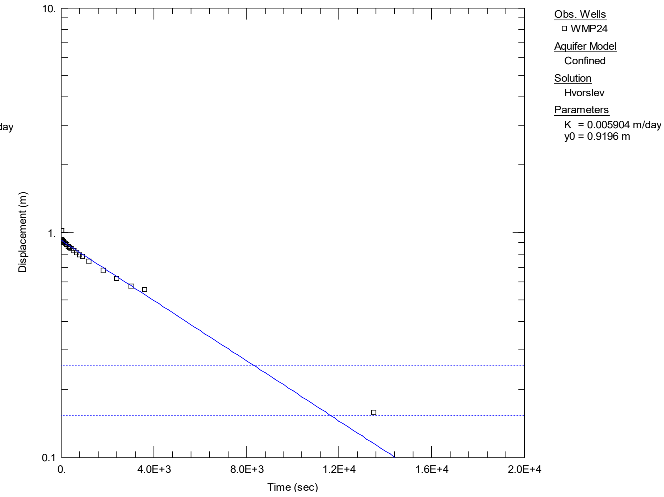


Test analyses

Bouwer-Rice



Hvorslev



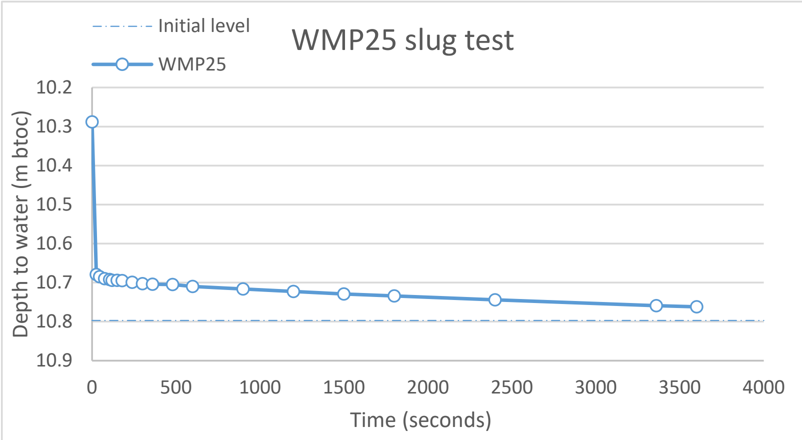
Well details

Well ID WMP25
Initial water level 10.80 m btoc
Well depth 28 m bgl
Screen interval 10.1 - 13.1 m bgl
Inferred HSUs Alluvium

Analysis details

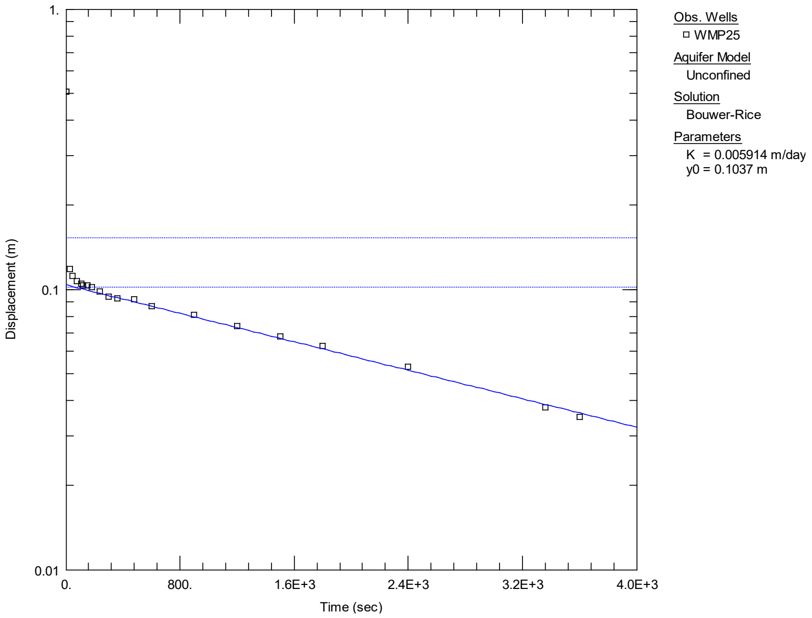
Test type Slug test (Falling head test)
Analysis solutions Bouwer-Rice (1976)
Analysis method AQTESOLV
Hydraulic conductivity (K)
Bouwer-Rice 0.006 m/day

Test data



Test analyses

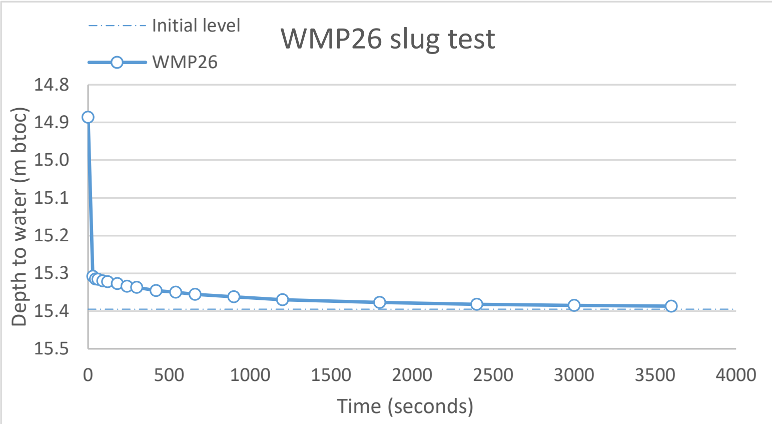
Bouwer-Rice



Well details	
Well ID	WMP26
Initial water level	15.40 m btoc
Well depth	20.5 m bgl
Screen interval	11.5 - 20.5 m bgl
Inferred HSUs	Alluvium

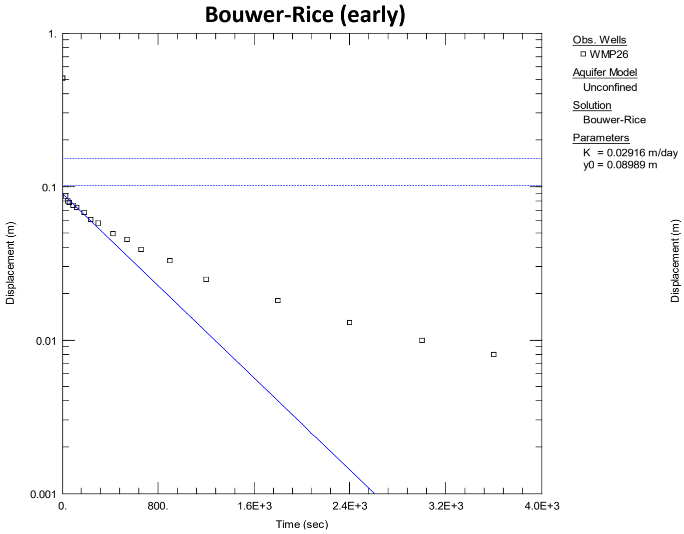
Analysis details		
Test type	Slug test (Falling head test)	
Analysis solutions	Bouwer-Rice (1976)	
Analysis method	AQTESOLV	
Hydraulic conductivity (K)		
Bouwer-Rice	Early	0.03 m/day
	Mid-late	0.009 m/day

Test data

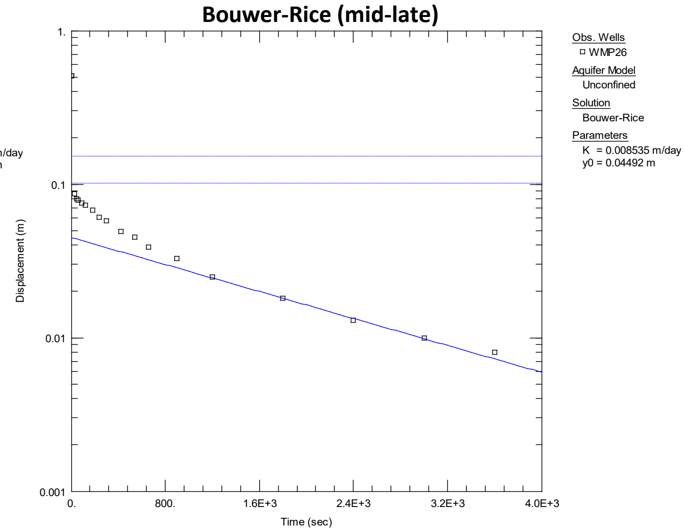


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid-late)



Well details

Well ID	WMP27
Initial water level	20.99 m btoc
Well depth	21.7 m bgl
Screen interval	14.5 - 20.5 m bgl
Inferred HSUs	Alluvium / Styx Coal Measures - overburden

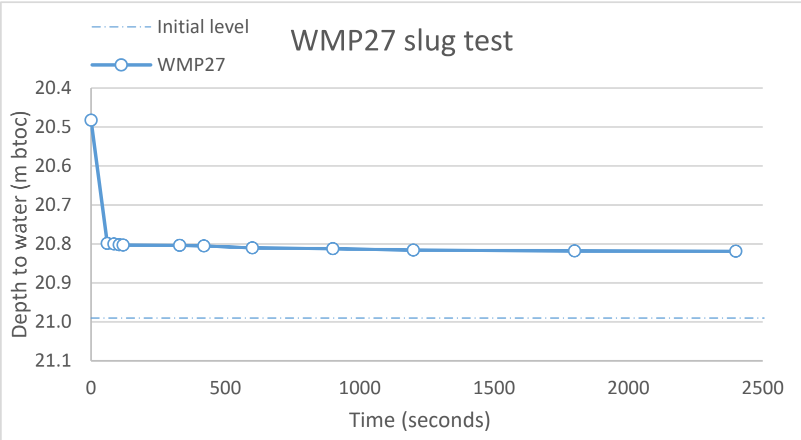
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

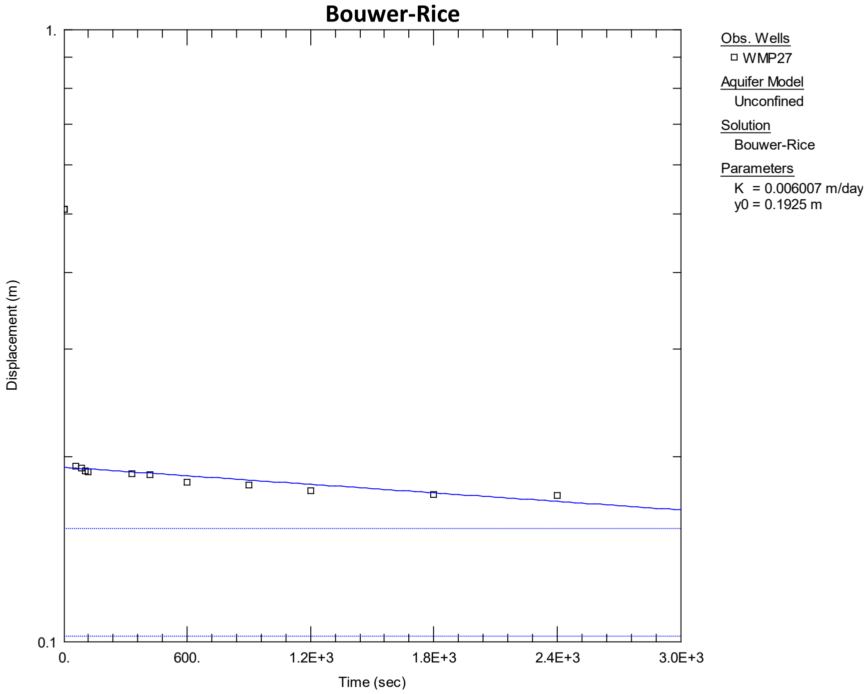
Bouwer-Rice	0.006 m/day

Test data



Test analyses

Bouwer-Rice



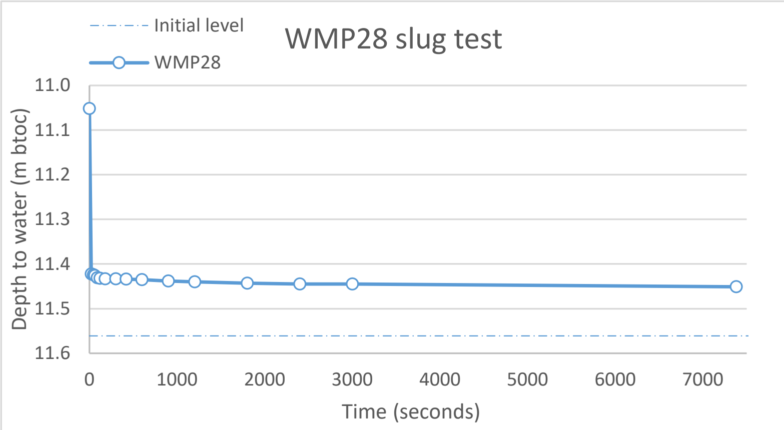
Well details

Well ID	WMP28
Initial water level	11.56 m btoc
Well depth	12 m bgl
Screen interval	8.9 - 11.9 m bgl
Inferred HSUs	Styx Coal Measures - overburden

Analysis details

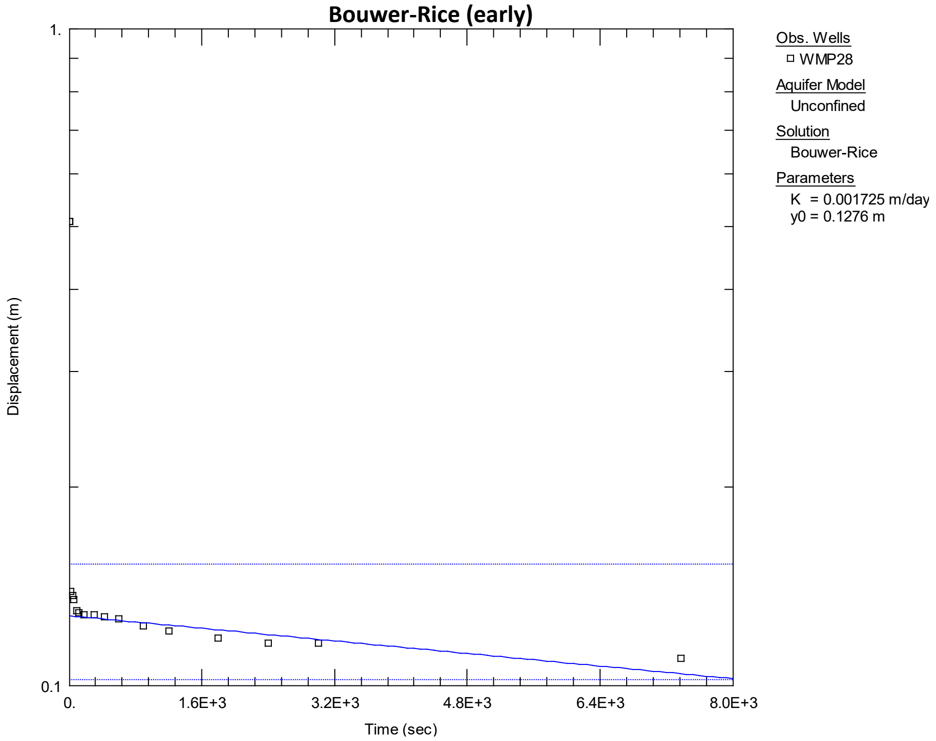
Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV
Hydraulic conductivity (K)	
Bouwer-Rice	0.002 m/day

Test data



Test analyses

Bouwer-Rice (early)



Well details

Well ID	WMP29A
Initial water level	12.78 m btoc
Well depth	12.5 m bgl
Screen interval	6.5 - 12.5 m bgl
Inferred HSUs	Alluvium

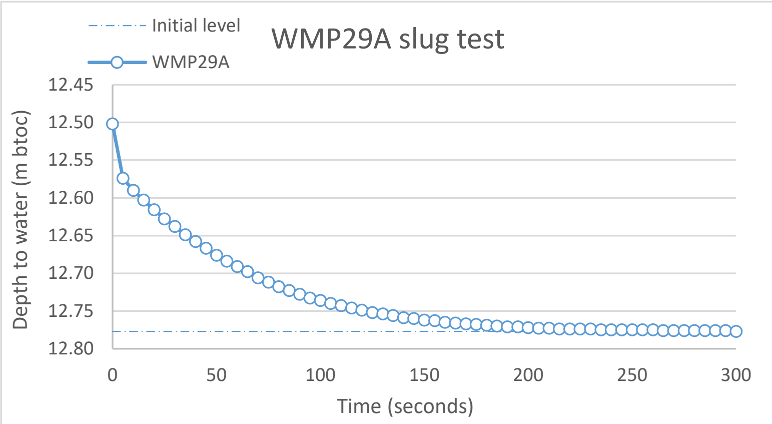
Analysis details

Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

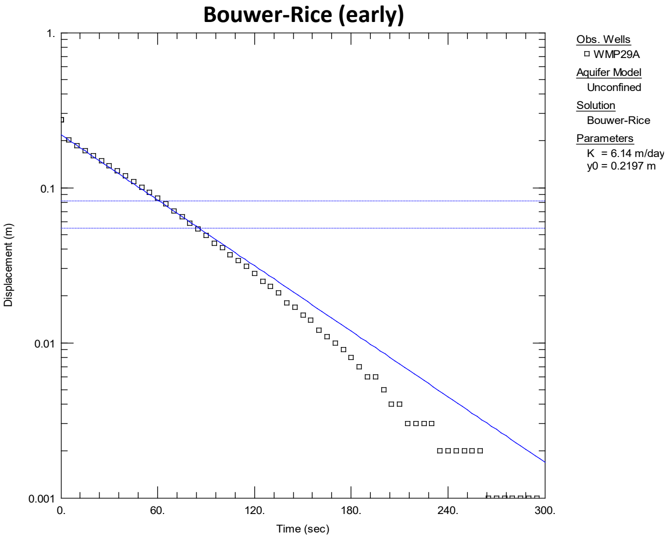
Bouwer-Rice	Early	6 m/day
	Late	8 m/day

Test data

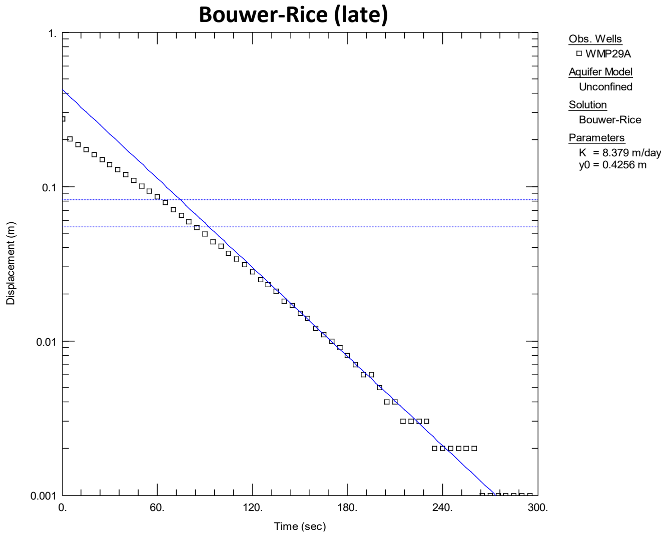


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (late)



Well details

Well ID	WMP29A
Initial water level	12.78 m btoc
Well depth	12.5 m bgl
Screen interval	6.5 - 12.5 m bgl
Inferred HSUs	Alluvium

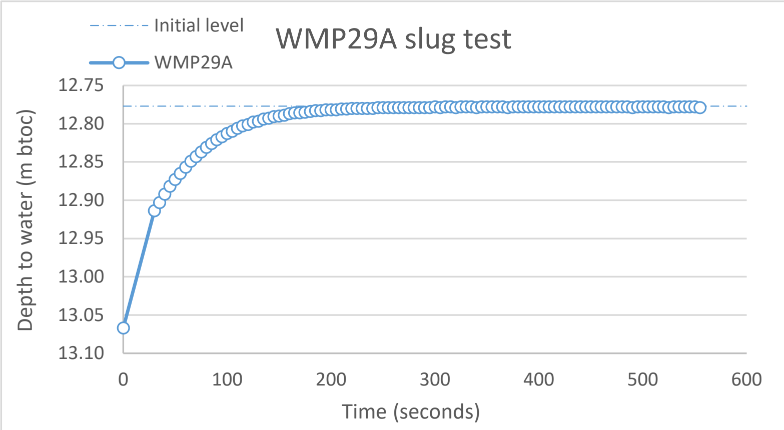
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

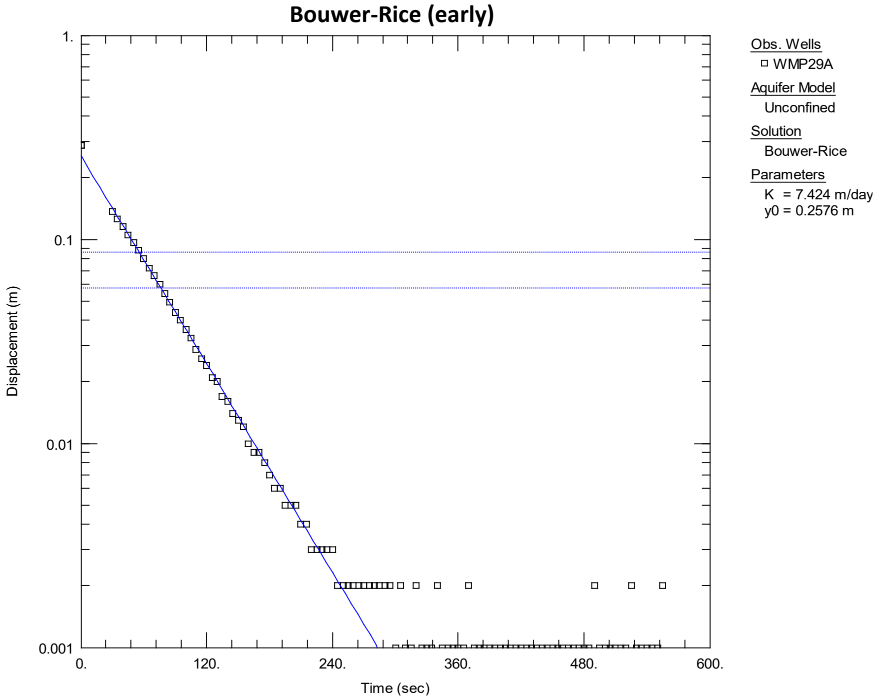
Bouwer-Rice	Early	7 m/day

Test data



Test analyses

Bouwer-Rice (early)



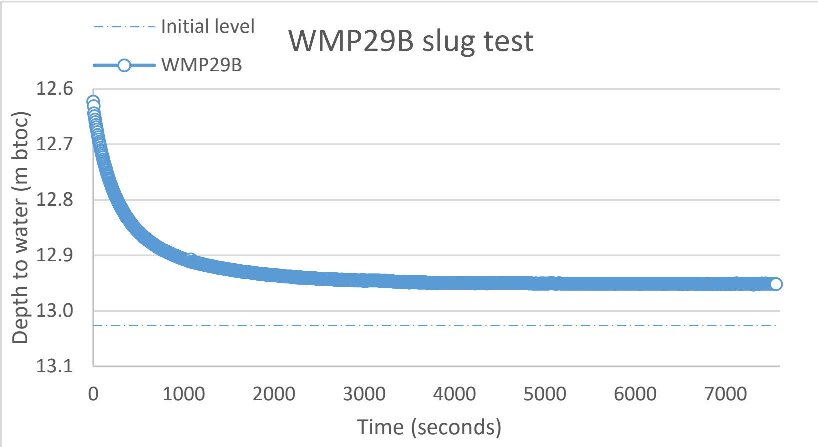
Well details	
Well ID	WMP29B
Initial water level	13.03 m btoc
Well depth	20 m bgl
Screen interval	16 - 20 m bgl
Inferred HSUs	Alluvium

Analysis details	
Test type	Slug test (Falling head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

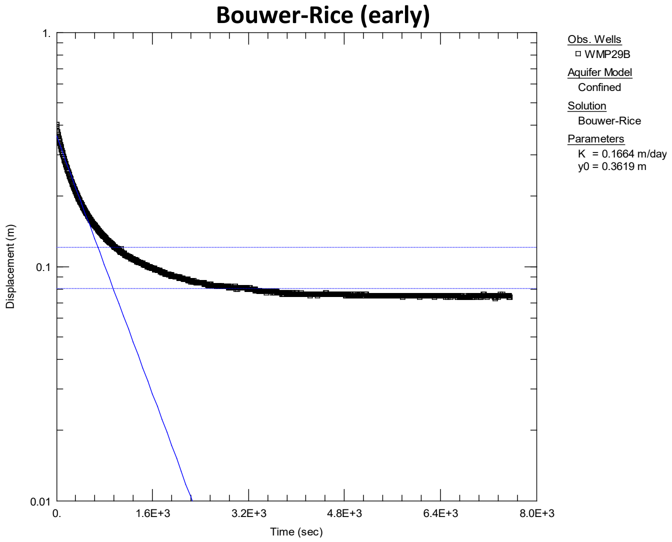
Bouwer-Rice	Early	0.2	m/day
	Mid	0.02	m/day

Test data

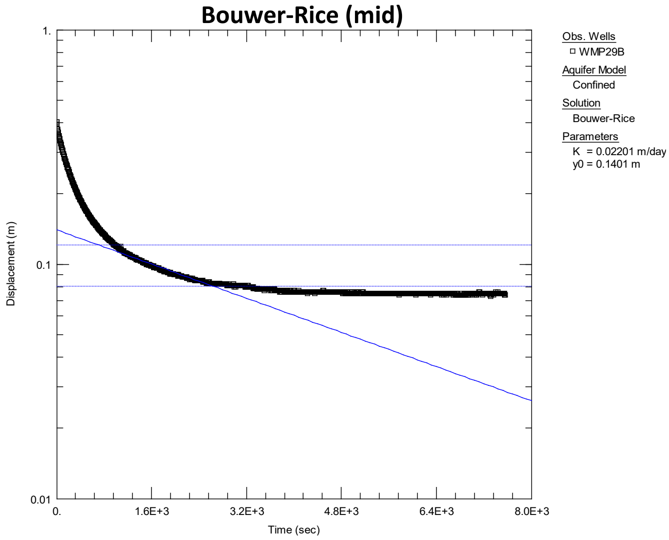


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid)



Well details

Well ID	WMP29B
Initial water level	13.10 m btoc
Well depth	20 m bgl
Screen interval	16 - 20 m bgl
Inferred HSUs	Alluvium

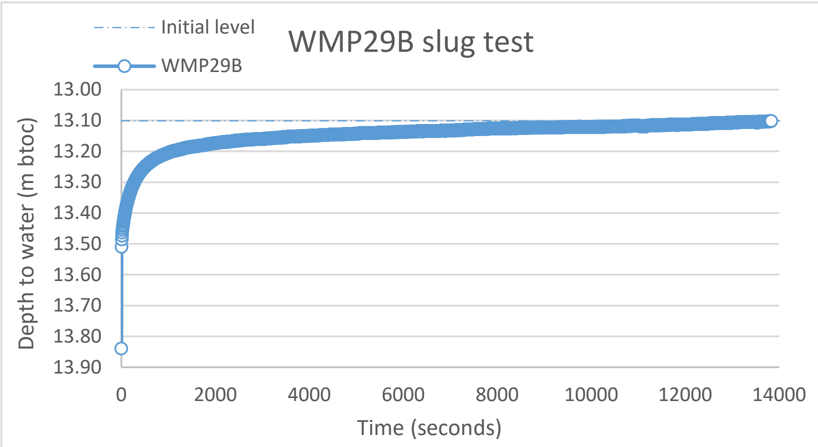
Analysis details

Test type	Slug test (Rising head test)
Analysis solutions	Bouwer-Rice (1976)
Analysis method	AQTESOLV

Hydraulic conductivity (K)

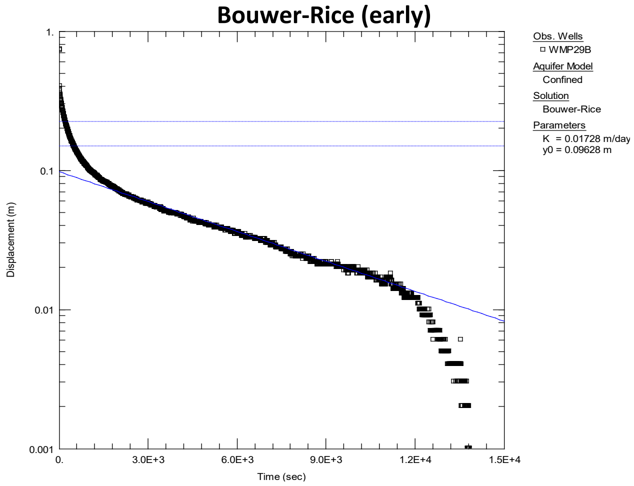
Bouwer-Rice	Early	0.2 m/day
	Mid	0.02 m/day
	Late	0.1 m/day

Test data

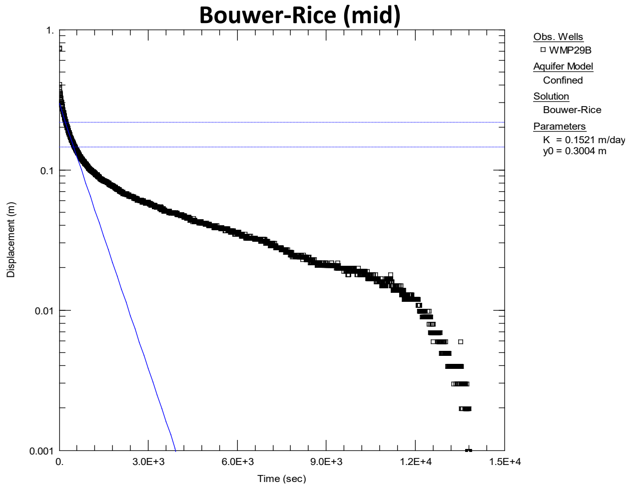


Test analyses

Bouwer-Rice (early)



Bouwer-Rice (mid)



Bouwer-Rice (late)