Vulcan South

Surface water assessment

Vitrinite Pty Ltd

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Executive Summary

Overview

The proposed Vulcan South (the Project) is a proposed open pit mining operation located to the southeast of Moranbah, in Central Queensland. The Project will operate for approximately nine years, including primary rehabilitation works, following a 2 year construction period and will extract approximately 13.5 million-tonnes (Mt) of ROM coal, consisting predominately of hard coking coal with an incidental thermal secondary product at a rate of up to 1.95 Mt per annum.

The Project will include three open pits, construction of a Coal Handling and Preparation Plant (CHPP) and train loadout facilities within the Mining Lease Application (MLA) area. The Project also includes a small-scale highwall mining trial program in the north of the MLA. No tailings dams are proposed as part of the Project.

The Project is located within the Isaac River catchment. The majority of the Project is located within the Harrow, Boomerang, East, Hughes, and Barrett creek catchments, which all drain to the Isaac River. These creeks have been altered due to existing mining operations downstream of the Project.

The Project surface water management system would be designed to accommodate the proposed production schedule and to mitigate potential natural surface water and flooding impacts. With appropriate mitigation measures in place, the potential impact of the proposed mining operations on surface flows and water quality in the receiving waters downstream of the Project will be insignificant.

Surface Water Management Strategy

The proposed Project surface water management strategy consists of a number of surface water management measures that will be implemented during construction and operational periods.

For surface water management purposes, the surface water that is generated and/or managed at the Project is divided into the following types based on water quality:

- **Mine affected water**: Mine affected water means the following water types:
    - pit water, tailings dam water, processing plant water;
    - rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;
    - groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;
    - groundwater from the mine dewatering activities; and
    - a mix of mine affected water (under any of paragraphs i to v) and other water
- **Surface water**: Surface water runoff from areas that are disturbed by mining operations (including out-of-pit waste rock emplacements). This runoff does not come into contact with coal or other carbonaceous material and may contain high sediment loads but does not contain elevated levels of other water quality parameters (e.g. electrical conductivity, pH, metals, metalloids, non-metals). This runoff must be managed to ensure adequate sediment removal prior to release to receiving waters.

- **Diverted water**: Surface runoff from areas unaffected by mining operations. Diverted catchment water includes runoff from undisturbed areas and fully rehabilitated areas.
- **Raw water**: Untreated water that has not been contaminated by mining activities.
- **Potable water**: Treated water suitable for human consumption.
- **External water**: Water supplied from a source that is external to the Project area to make up water shortfalls for onsite water demands when site water sources cannot meet demand.

The water management system for the Project aims to protect the identified downstream Environmental Values and comprises the following key objectives:

- separate diverted water from mine affected water to ensure that up-catchment water and mine affected water do not mix wherever practicable;
- capture of mine affected runoff (e.g. mine industrial area, haul road/ROM pad runoff), storage and priority reuse as mine water supply;
- divert up-catchment water runoff from upstream catchments around the active mining area;
- limit external catchment runoff draining into pits;
- manage sediment from disturbed catchment areas (e.g. out-of-pit waste rock emplacements, cleared/pre-strip areas) by using erosion and sediment control (ESC) measures prior to release offsite;
- reuse onsite water (e.g. mine affected water) where possible to support mine operational water demands (and therefore limit mine affected water inventories under normal operating conditions); and
- manage any mine affected water releases to the receiving waters to meet environmental release conditions (not currently proposed).

The above objectives will be achieved by implementing the following water-related infrastructure:

- diverted water drains, bunds and drainage diversions to divert runoff from undisturbed catchments around areas disturbed by mining;
- flood protection levees along the southern side of the Vulcan North pit extent, along the western and southeastern sides of the Vulcan Main pit, and around the Vulcan South pit;
- sediment dams and drains to collect and treat runoff from waste rock emplacement areas; and
- mine-affected water drains and dams to store water pumped out of the open cut mining areas and to collect runoff from the infrastructure areas.

The above water management objectives, when implemented through appropriate management plans, will mitigate the effects of the Project operations on natural surface water quantity and quality and flooding downstream of the mine site during operations.

Water Balance

The Project will be a net importer of water due to the predicted water demands exceeding rainfall runoff and groundwater inflows into the mine site water management system.

The OPSIM model was used to assess varying rainfall and climatic conditions using a daily timestep to simulate all major components of the water management system. The water balance model results show that:

- there are no predicted mine water spills to the receiving environment during the life of mine from the mine water dams or open cut pits;
- under 'average' climatic conditions, the proposed water management system is in deficit, meaning external water will be required to meet site demands such as dust suppression, CHPP makeup demands, and TLO demands. During 50%ile climate conditions, the predicted external water required is up to 1,260 ML/yr and up to 1520 ML/yr during 1%ile (very dry) climate conditions; and
- the site water management system has been designed such that the risk of offsite release of mine affected water is very low (with no mine affected dam uncontrolled releases predicted under any modelled climatic conditions).

Flood assessment

A hydraulic (TUFLOW) model was developed for the Project to design the proposed flood protection infrastructure required to protect key mining infrastructure and to assess the potential flood impacts caused by the proposed infrastructure on downstream property. The TUFLOW model results show that:

- flood level impacts as a result of the Project are generally within the Project MLA area. Any impacts that extend into the Norwich Park Branch Railway corridor and downstream of the Project boundary may require mitigation measures. Where impacts cannot be fully mitigated, consent may be required from impacted neighbouring landowners/stakeholders (e.g., Aurizon, council, BMA); and
- there are only minor impacts under the final landform configuration. These impacts are generally confined within the Project MLA area. Existing conditions natural topography will be reinstated within the Hughes Creek floodplain as well as Drainage line 6 and Drainage line 8 Post-closure to replicate the existing drainage line channels to minimise the impacts associated with the Post-closure Conditions landform.

Final landform

A conceptual water management plan for proposed final landform of the Project was developed. As part of the final landform, no final voids are proposed and all open cut pits will be backfilled with overburden material and drainage structures will be implemented on and around the final landform to ensure that the landform is free draining. When sediment dam catchments are completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned.

Summary

Overall, the impact of the Project on the hydraulic characteristics of Boomerang Creek, Hughes Creek and their tributaries do not affect the existing conditions significantly. It is expected that the channel and floodplain will undergo little, if any, adjustment to the hydraulic conditions upstream or downstream of the Project as a result of the Project.

Mine affected water from the proposed Project will be managed through a mine water management system which is designed to operate in accordance with proposed EA conditions that are based on Model Mining Conditions, and incorporated into the release criteria used in modelling the mine water management system in this report.

In consideration of the already heavily disturbed nature of the surrounding catchment, it is unlikely that Project releases will have a measurable impact on receiving water quality or environmental values.

In summary, the conceptual final landform is not considered likely to have a long-term significant impact on the receiving waters.

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1 Introduction

1.1 BACKGROUND

The Vulcan South (the Project), which is managed by Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite), is a proposed open pit and highwall mining operation located to the southeast of Moranbah, in Central Queensland. The Project is located immediately south and west of Vitrinite's initial mining project, the Vulcan Coal Mine (VCM), located on ML700060. The Project mining lease application area abuts ML700060; however, proposed activities will be implemented separately. The VCM has been considered in a previous surface water assessment titled '*Vulcan Coal Mine EA Amendment Surface Water Assessment*' (WRM, 2021) and has not been considered further in this report.

The location of the EPCs and the proposed Project mining lease (ML) Application area are shown in Figure 1.1. Figure 1.2 shows an overview of the Project area including the Highwall mining area in the northwest, the Vulcan North mining area in the north, the Vulcan Main mining area in the Project centre and the Vulcan South mining area in the south.

The proposed mine stage layouts for the Project, including all major surface water infrastructure elements required during operations and post-mining, are shown in Figure 1.3 to Figure 1.13.

WRM Water & Environment Pty Ltd (WRM) was engaged by Mining and Energy Technical Services Pty Ltd (METServe), on behalf of Vitrinite, to undertake a surface water impact assessment for the Project. The surface water impact assessment will form part of an Environmental Authority application for the Project.

This report presents the following:

- An overview of the regulatory framework which applies to the Project (including aspects which do not directly relate to the surface water assessment) (Section 2);
- A description of the environmental values (EVs) of the receiving waters surrounding the Project (Section 3);
- A description of the existing surface water environment at the Project (Section 4);
- A description of the proposed water management strategy and details regarding water management infrastructure (Section 5);
- A detailed description of the configuration of the Project water balance model (Section 6);
- An assessment of the Project water management system performance (Section 7);
- An assessment of the potential flooding impacts of the Project (Section 8);
- A description of the surface water monitoring strategy proposed for the Project (Section 9);
- An assessment of the cumulative impacts of the Project (Section 10); and
- A summary of the Project findings (Section 11).

1.2 PROJECT DESCRIPTION

The Vulcan hard coking coal target has been defined and selected for open cut development via 3 separate open cut pits (known as Vulcan North, Vulcan Main and Vulcan South) that form the primary mining focus of the Project. The Project will operate for approximately nine years, including primary rehabilitation works, following a 2 year construction period and will extract approximately 13.5 million-tonnes (Mt) of ROM coal, consisting predominately of hard coking coal with an incidental thermal secondary product at a rate of up to 1.95 Mt per annum. The Project will target the Alex and multiple Dysart Lower coal seams.

Truck and shovel mining operations will be employed to develop the pits. A mine infrastructure area (MIA) will be established along with a modular coal handling and preparation plant (CHPP), rail loop and train load-out facility (TLO) at a location between the northern and central pits. The CHPP will include dry tailings technology to maximise water recycling and to produce a dry tailings waste product for permanent storage within active waste rock dumps. No wet tailings wastes are proposed and therefore no tailings dams are required.

Ex-pit waste rock dumps will be established prior to commencing in-pit dumping activities that will continue for the life of the operation. Ancillary infrastructure, including a Run of Mine (ROM) pad, offices, roads and surface water management infrastructure will be established to support the operation.

A realignment of the existing Saraji Road and services infrastructure to the eastern boundary of the proposed Mining Lease Application (MLA) area, adjacent to the existing rail easement, is also proposed in a number of locations. The re-alignment will occur within the MLA area.

In-pit dumping will fill the majority of the pit volumes during operations with the remaining final voids to be backfilled upon cessation of mining, resulting in the establishment of low waste rock dump landforms over the former pit areas. Following backfill of the final voids, the remaining material stored in the initial out-of-pit waste rock dumps will be rehabilitated in-situ.

The Project includes a small-scale highwall mining trial program in the north of the MLA. The trial will involve the establishment of 4 highwall mining benches across a number of hillsides to facilitate extraction of coal utilising a CAT HW300 highwall miner, or similar. The highwall mining trial will target up to 750 kilotonnes of coal, which will be transported by truck to the Project CHPP via a dedicated haul road within the MLA area. The trial is scheduled to be completed within the first year of mining operations.

The conceptual drainage plans for the open cut mining areas are shown in Figure 1.3 to Figure 1.8. The conceptual drainage plans of the Highwall mining area are shown in Figure 1.9 and Figure 1.10. The final landform plans are shown in Figure 1.11 to Figure 1.13.

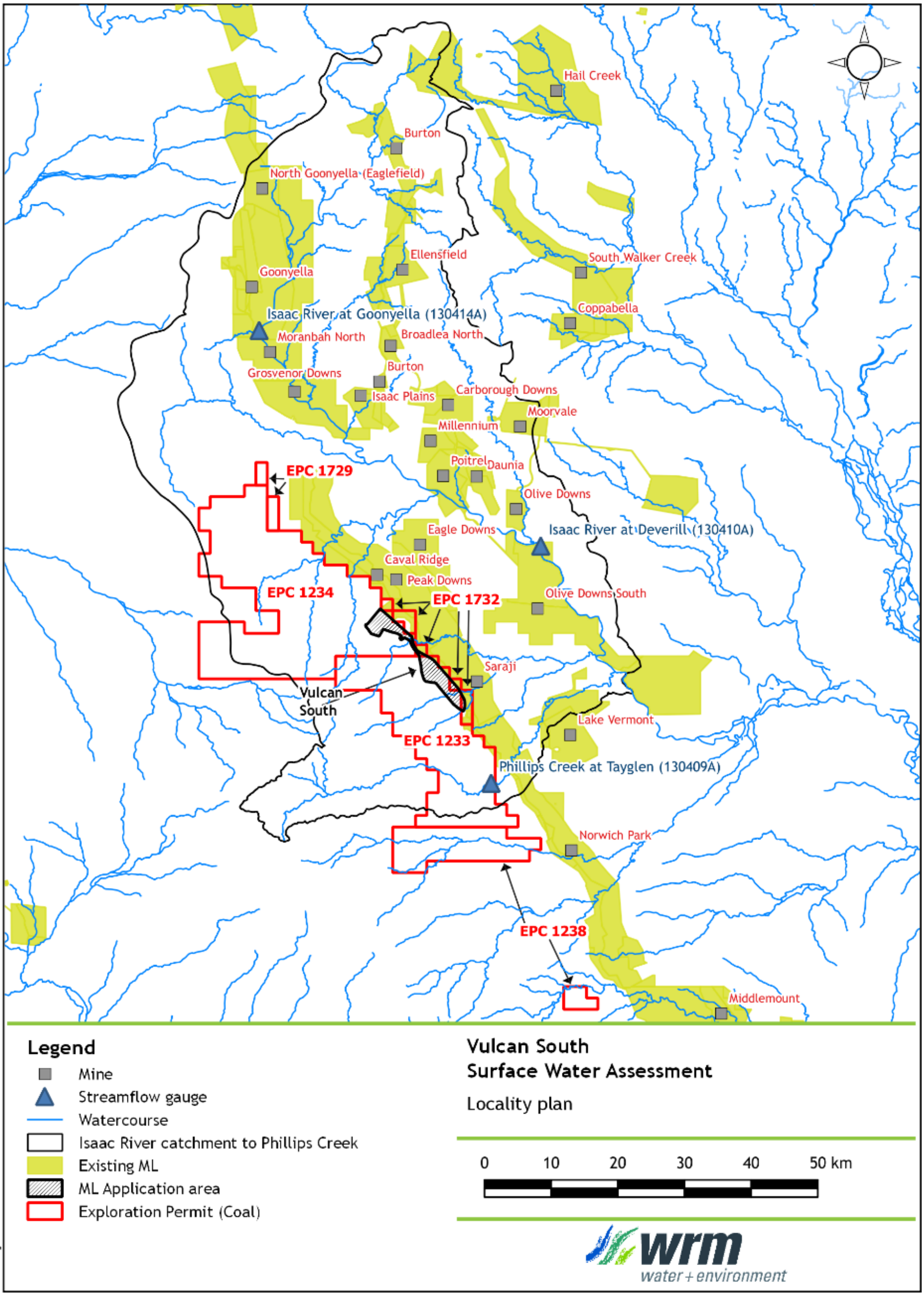


Figure 1.1 – Locality plan

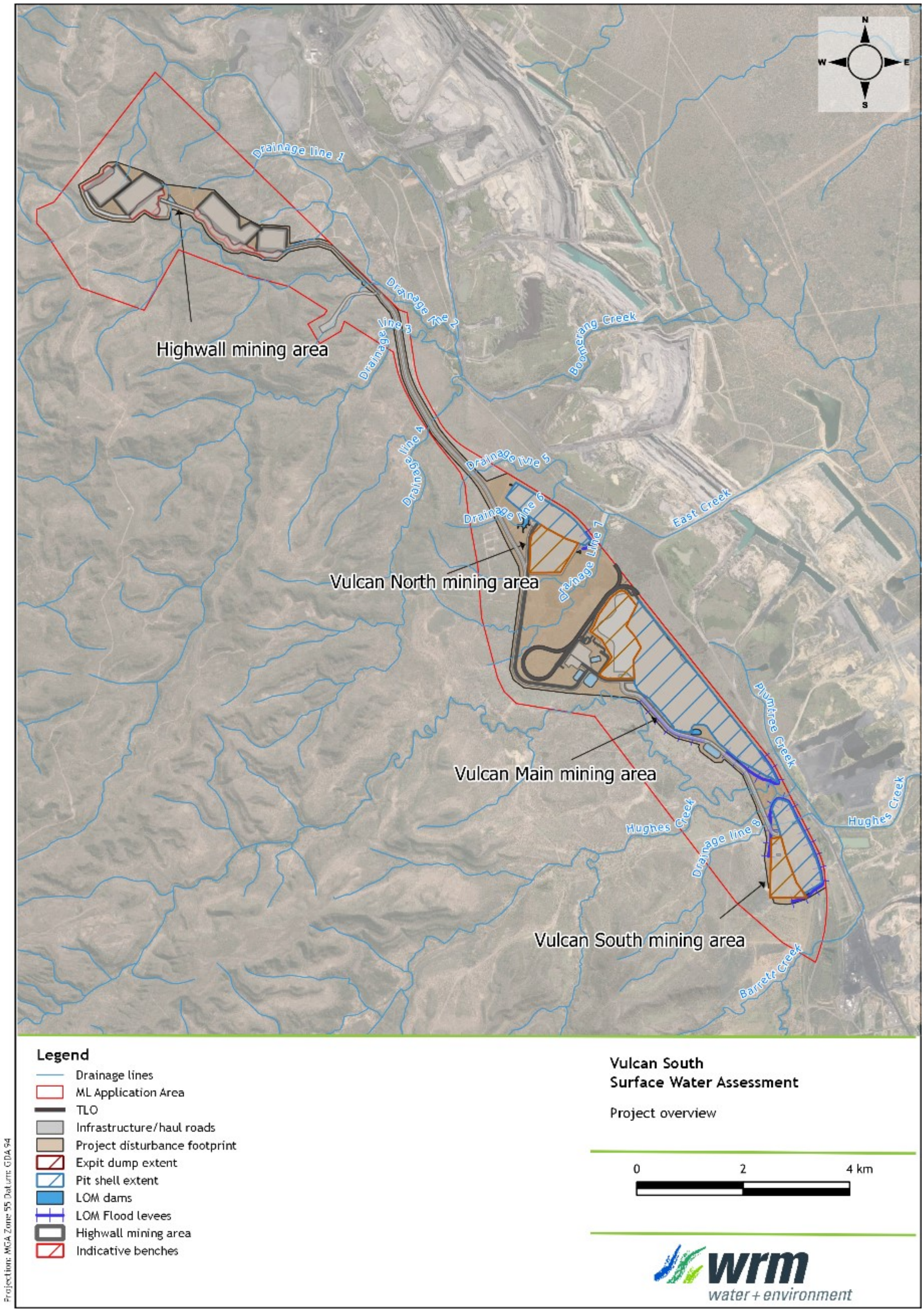
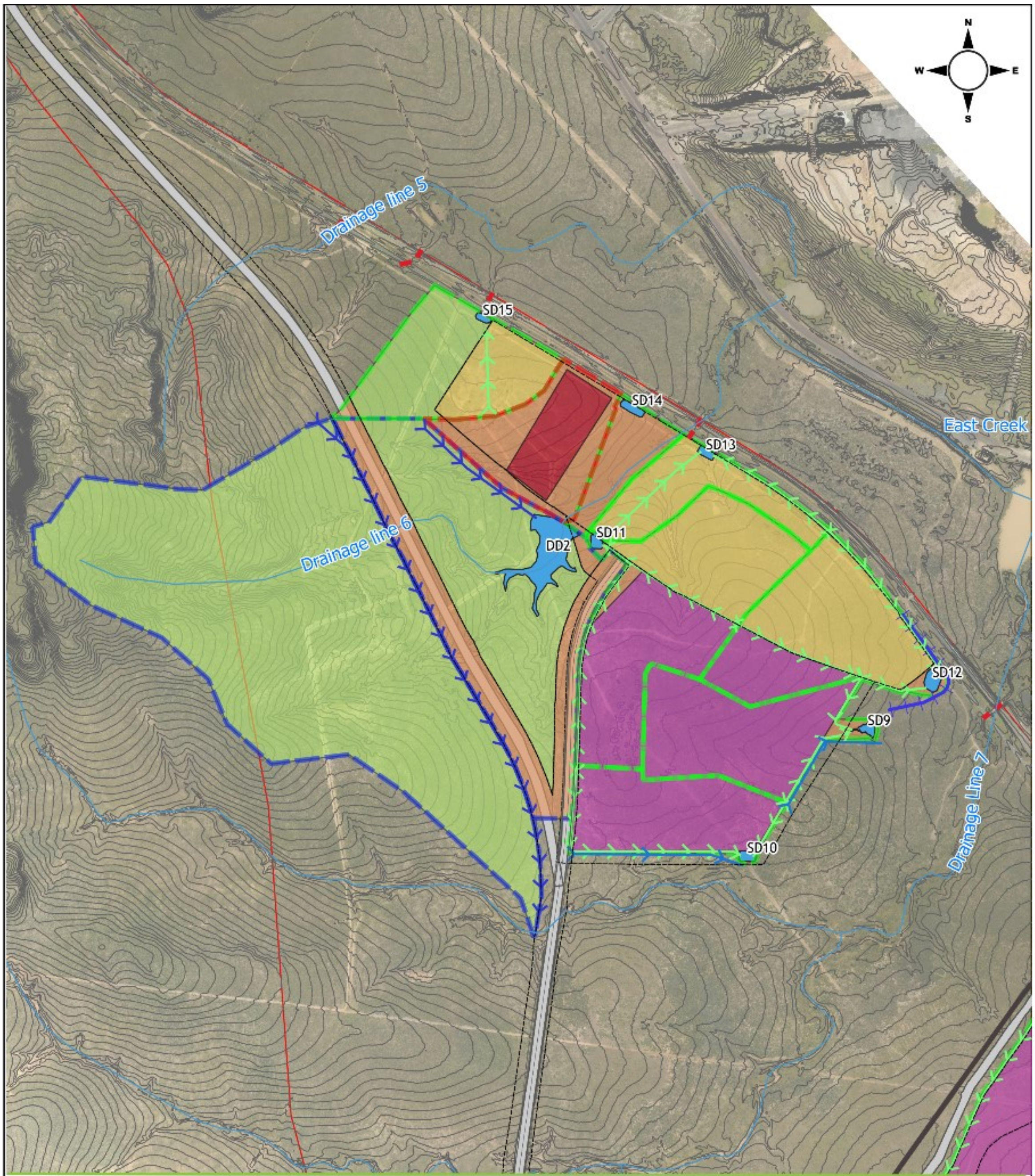


Figure 1.2 – Project overview



Legend

- Contours (1m)
- Drainage lines
- ML Application Area
- Existing culverts
- Dams
- Infrastructure/haul roads

WMS infrastructure

- Flood levee
- Diverted water bund
- Diverted water drain
- Mine water drain
- Surface water drain
- Possible ESC Controls

Catchments

- Surface water
- Mine water
- Diverted water

Landuses

- Pit
- Out of pit spoil
- Natural
- In pit spoil
- Disturbed

Projection: MGA Zone 55 Datum: GDA 94

Vulcan South
Surface Water Assessment

Stage 1 (2024) Vulcan North Conceptual drainage plan

0 0.25 0.5 km

wrm water+environment

Figure 1.3 - Stage 1 (Year 2024) Vulcan North mining area conceptual drainage plan

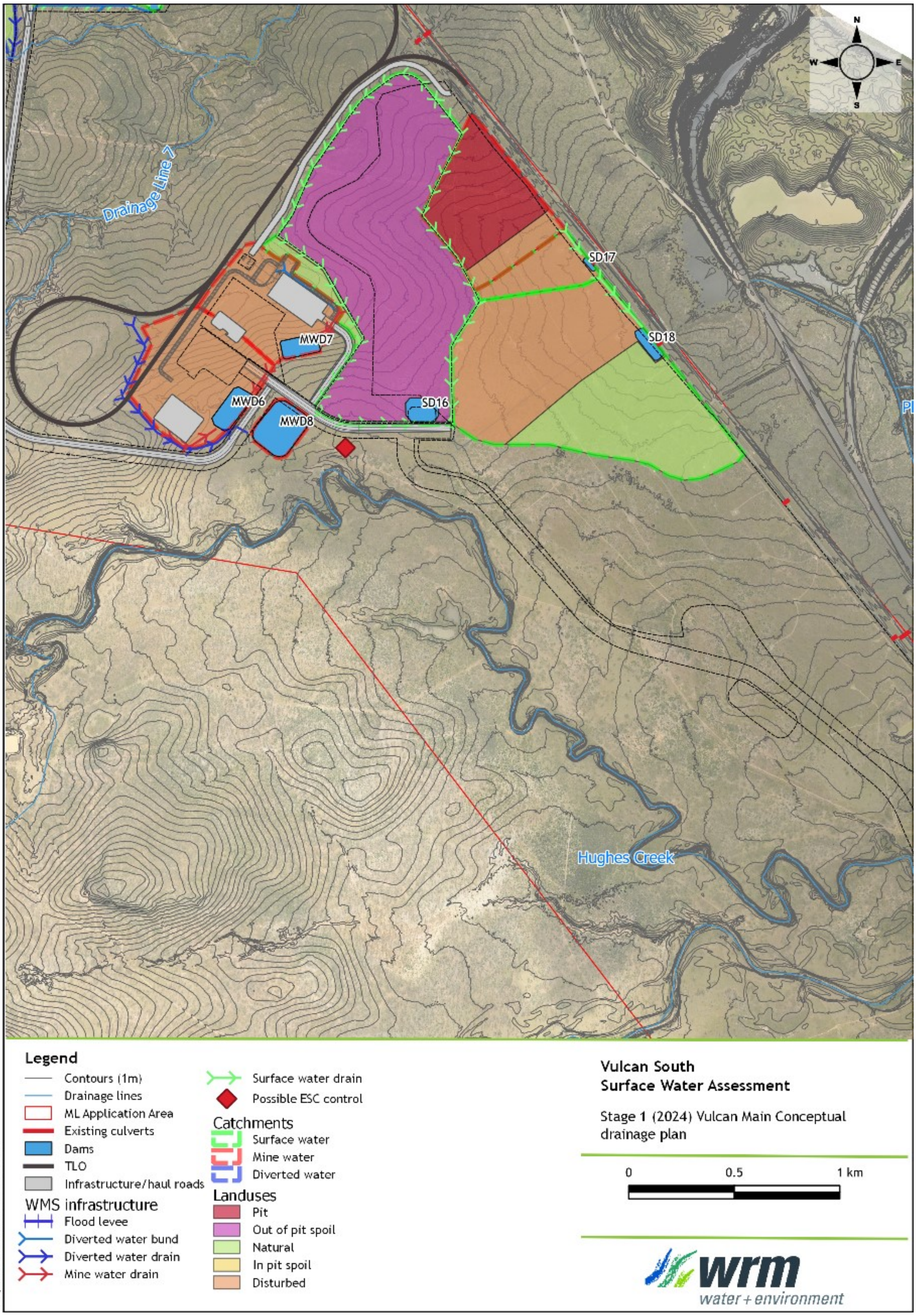


Figure 1.4 - Stage 1 (Year 2024) Vulcan Main mining area conceptual drainage plan

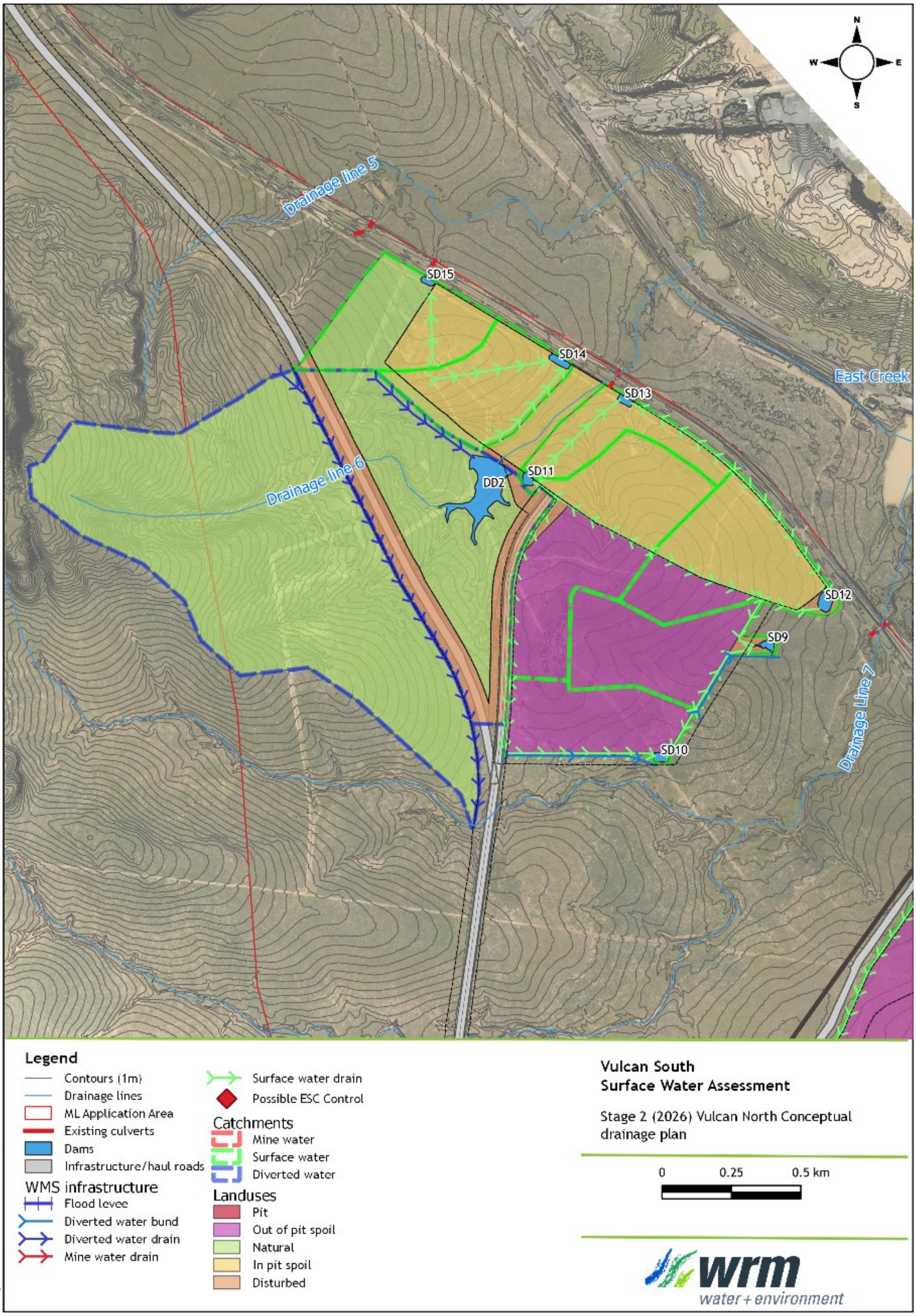


Figure 1.5 - Stage 2 (Year 2026) Vulcan North mining area conceptual drainage plan

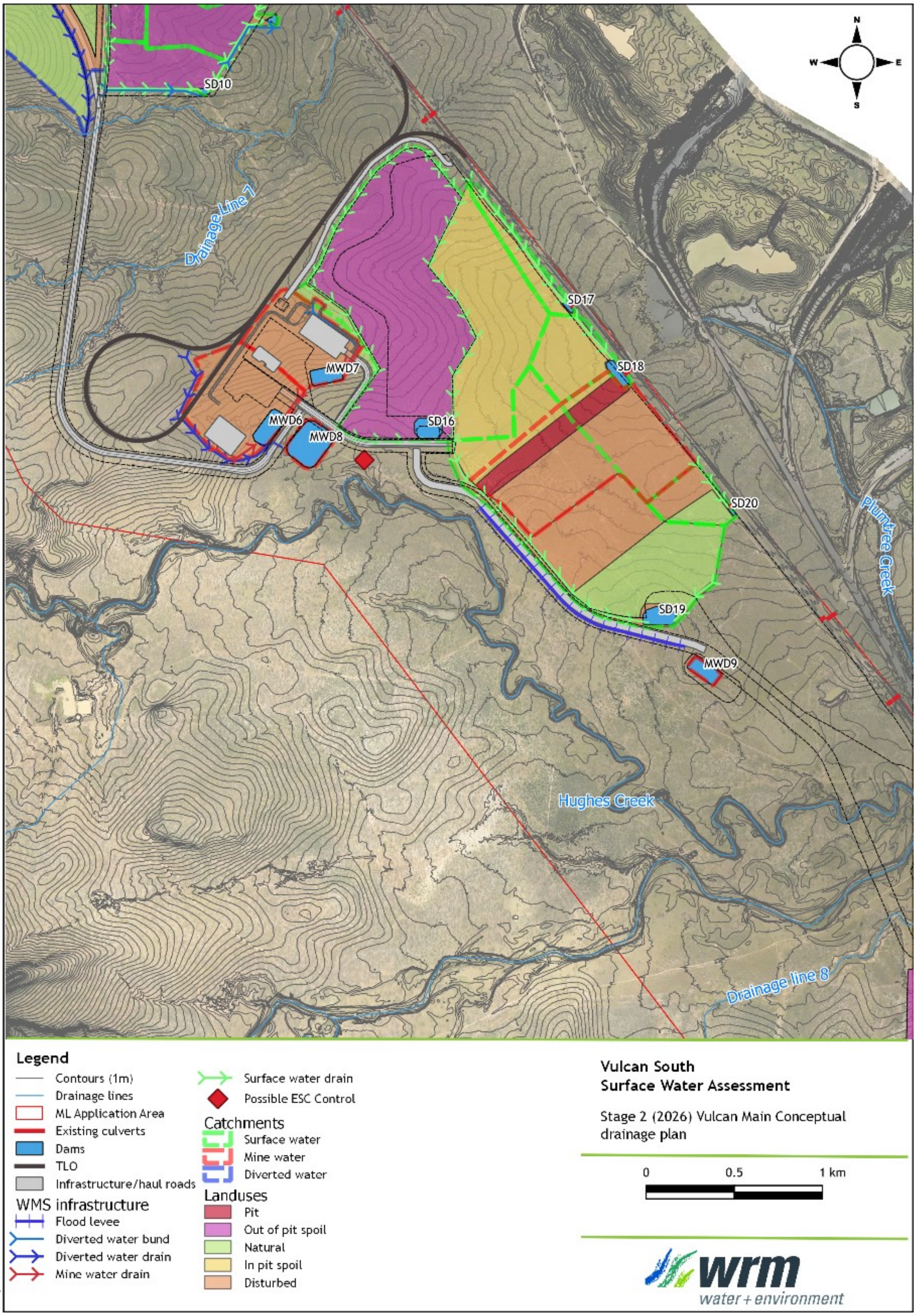


Figure 1.6 - Stage 2 (Year 2026) Vulcan Main mining area conceptual drainage plan

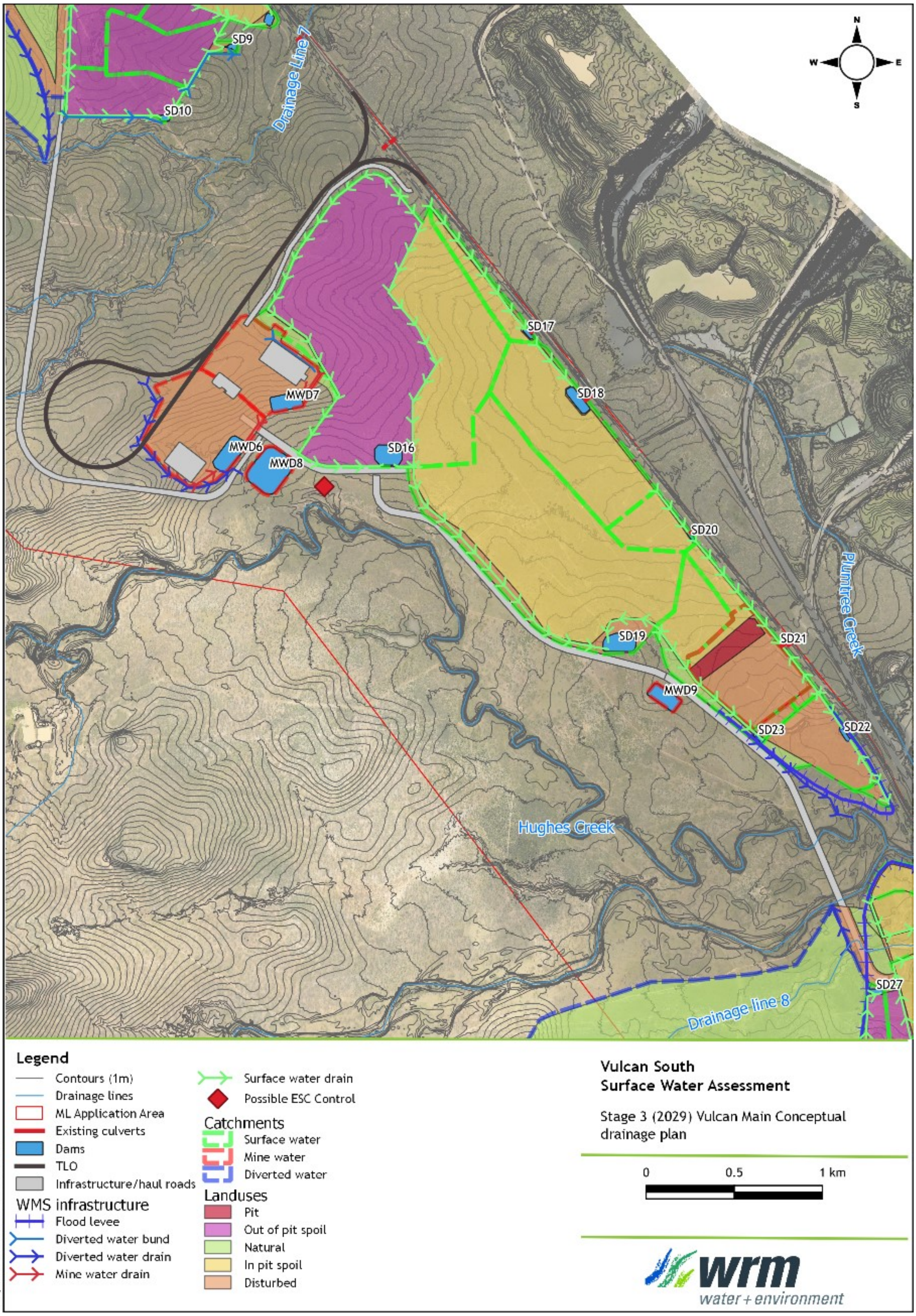


Figure 1.7 - Stage 3 (Year 2029) Vulcan Main mining area conceptual drainage plan

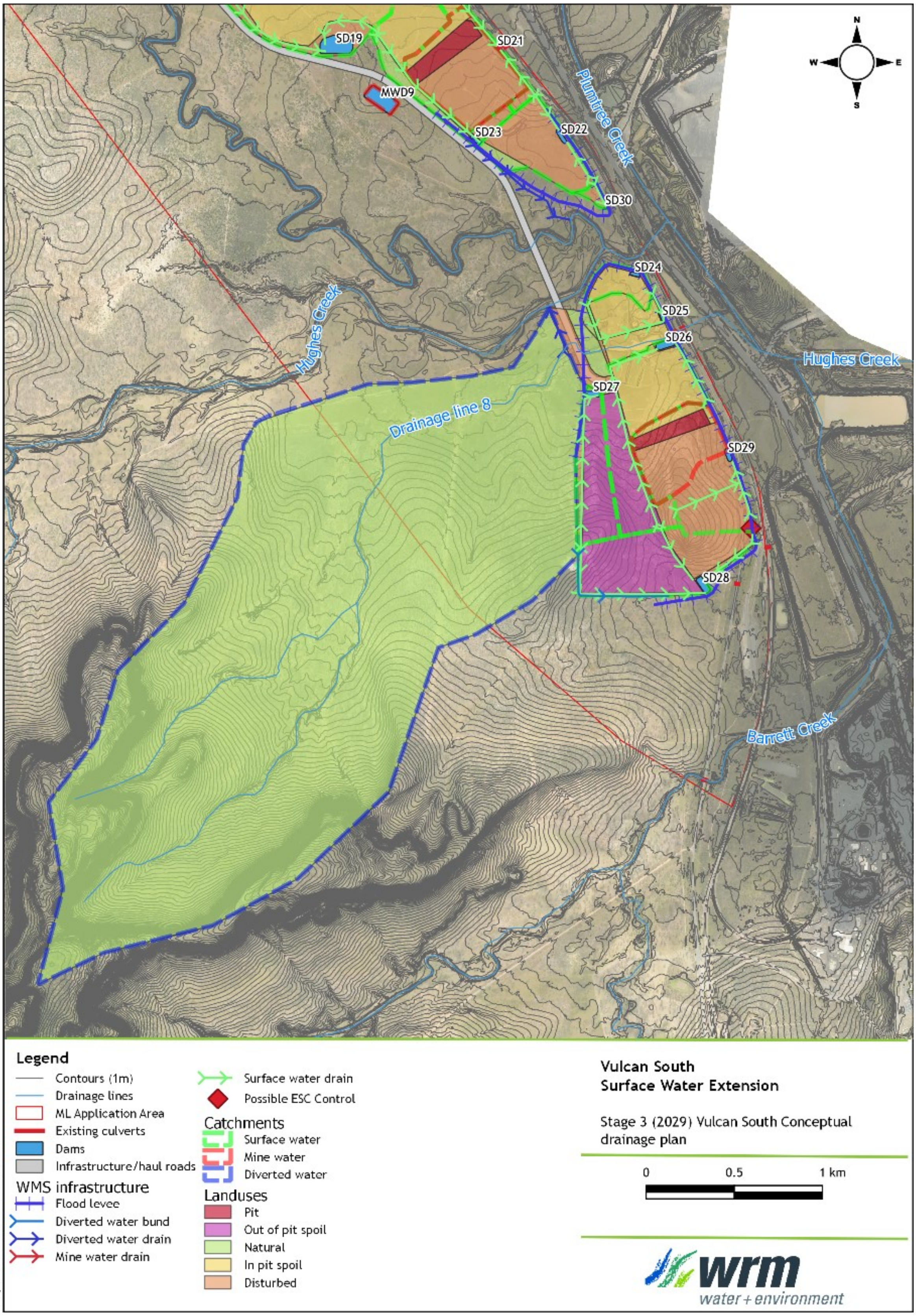


Figure 1.8 - Stage 3 (Year 2029) Vulcan South mining area conceptual drainage plan

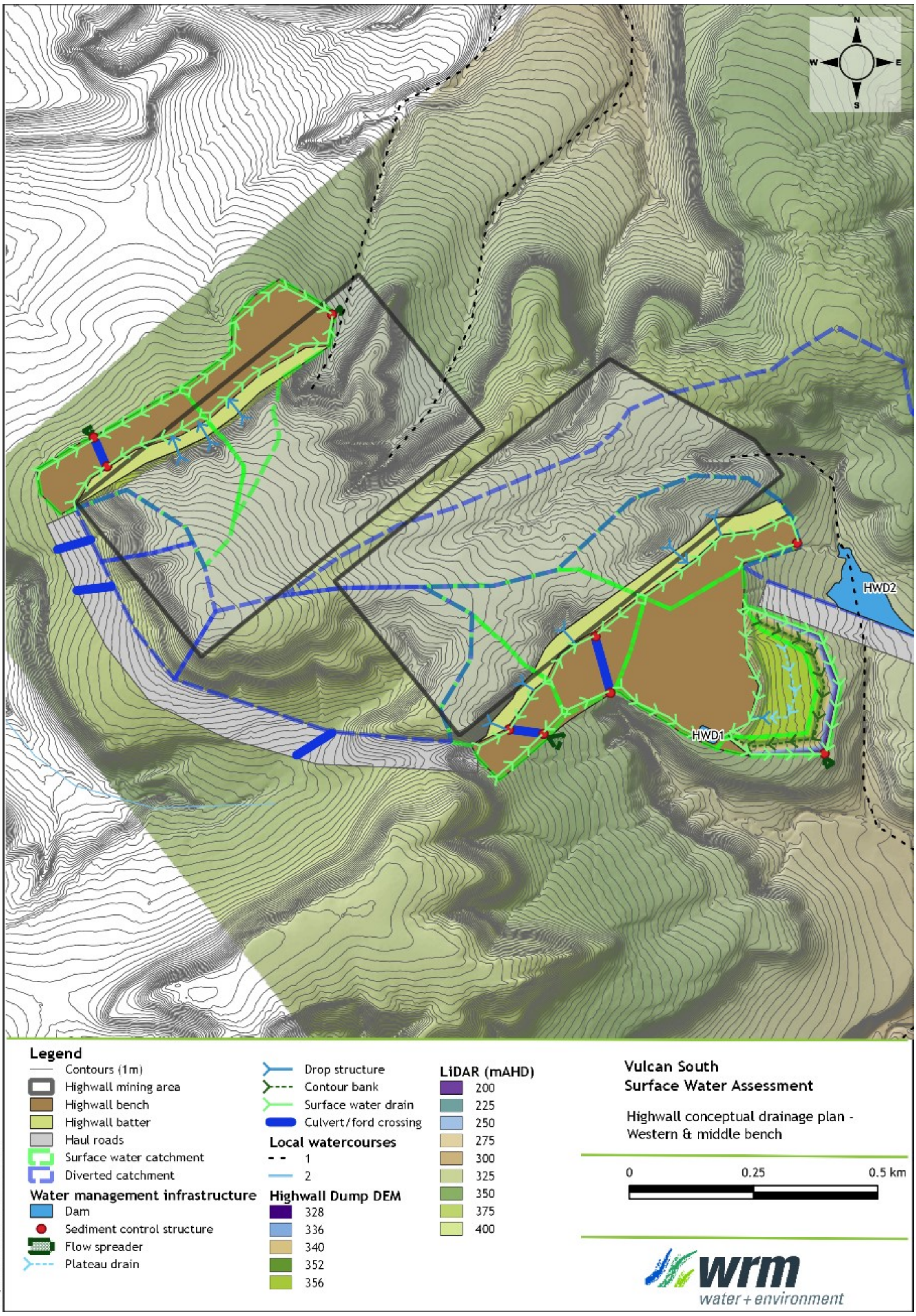


Figure 1.9 – Highwall western and middle bench mining area conceptual drainage plan (Year 2024)

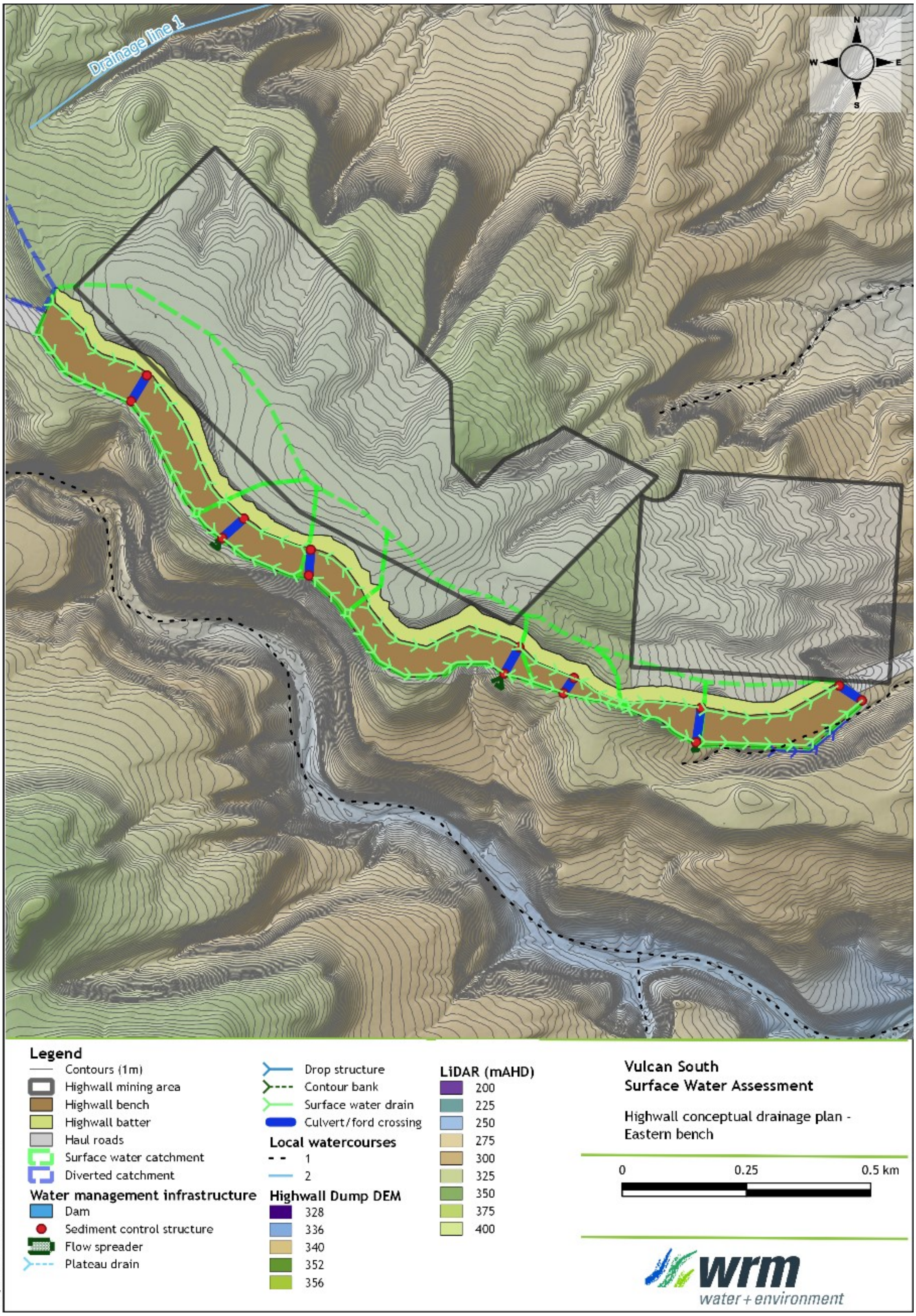


Figure 1.10 – Highwall eastern bench mining area conceptual drainage plan (Year 2024)

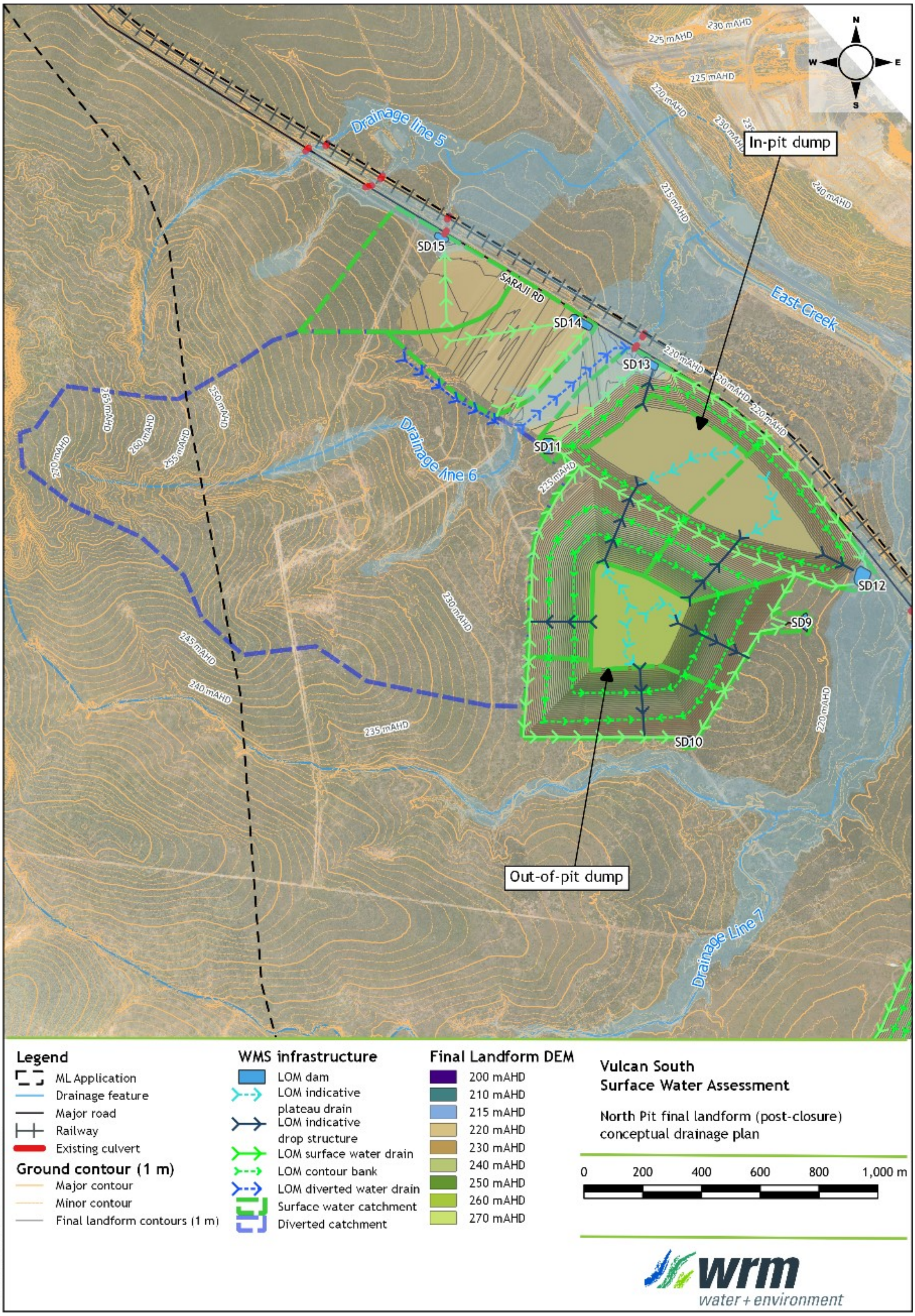


Figure 1.11 – Vulcan North final landform (post-closure) conceptual drainage plan

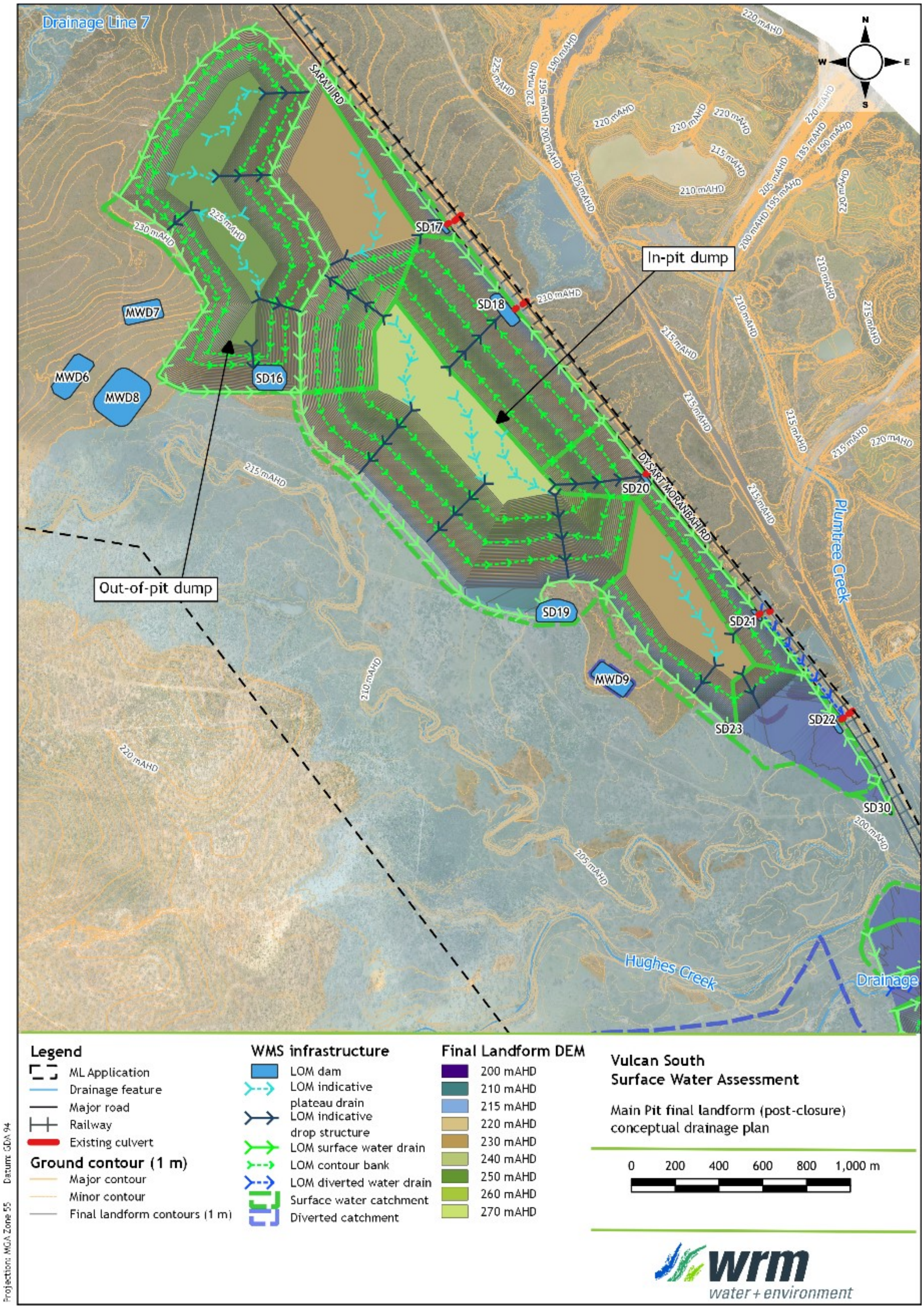


Figure 1.12 – Vulcan Main final landform (post-closure) conceptual drainage plan

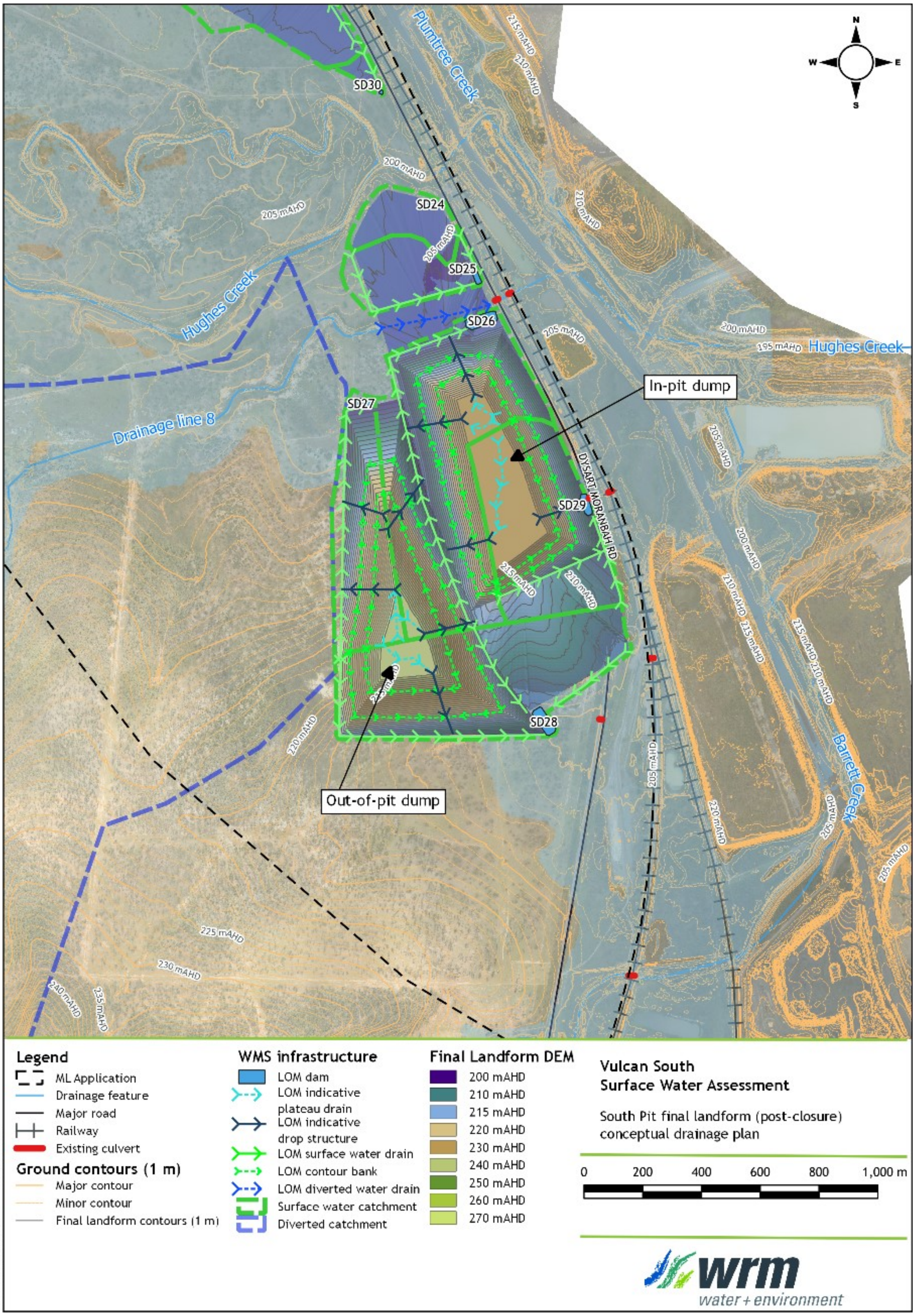


Figure 1.13 – Vulcan South final landform (post-closure) conceptual drainage plan

2 Regulatory framework

This section describes the regulatory framework (legislation, policies and standards) at Commonwealth and State level that would apply to surface water management for the Project.

2.1 COMMONWEALTH

The Project will be referred to the Department of the Environment and Energy for consideration under the *Environment Protection and Biodiversity Conservation Act 1999*.

The Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development has published information guidelines (IESC, 2018) for advice on coal seam gas and large coal mining development proposals. The report sections where the IESC information requirements have been addressed are outlined in Table 2.1.

Table 2.1 - IESC information requirements - surface water

Project information	Report section
Description of the proposal	
Provide a regional overview of the proposed project area including a description of the geological basin; coal resource; surface water catchments; groundwater systems; water-dependent assets; and past, current and reasonably foreseeable coal mining and CSG developments.	Section 1 and Main EA Report
Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Section 1 and Main EA Report
Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies.	Section 2 and Main EIS Report
Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Surface water - context and conceptualisation	
Describe the hydrological regime of all watercourses, standing waters and springs across the site including:	
• geomorphology, including drainage patterns, sediment regime, and floodplain features;	Section 4
• spatial, temporal and seasonal trends in streamflow and/or standing water levels;	Section 4.4
• spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides); and	Section 4.5
• current stressors on watercourses, including impacts from any currently approved projects.	Section 4 & 10
Describe the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	Section 8

Project information	Report section
Provide an assessment of the frequency, volume, seasonal variability and direction of interactions between water resources, including surface water/groundwater connectivity and connectivity with sea water.	Refer to Groundwater report
<u>Surface water - analytical and numerical modelling</u>	
Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Section 5, 6 & 7
Use methods in accordance with the most recent publication of *Australian Rainfall and Runoff* (Ball *et al*. 2016).	Section 8.3
Develop and describe a program for review and update of the models as more data and information becomes available.	Section 7.5 & 8.5
Describe and justify model assumptions and limitations and calibrate with appropriate surface water monitoring data.	Section 6 & 8
Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	Section 7.4
Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	N/A
<u>Surface water - impacts to water resources and water-dependent assets</u>	
Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider:	
• Impacts on streamflow under the full range of flow conditions.	Section 8.7 & 8.8
• Impacts associated with surface water diversions.	Section 8.7
• Impacts to water quality, including consideration of mixing zones.	Section 7.3.9
• The quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets.	Section 7.3.9
• Landscape modifications such as subsidence, voids, post rehabilitation landform collapses, onsite earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Sections 5, 7.3.9, 8.5 & 8.8
Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Section 2 & 3
Identify processes to determine surface water guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets.	Section 9
Propose mitigation actions for each identified significant impact.	Section 6 & 8
Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	Section 6 & 8
Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 10

Project information	Report section
Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	Section 8
Surface water – data and monitoring	
Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	Section 4.5 & 9
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Section 4.5 & 9
Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and a describe of data methods, including whether missing data has been patched.	Sections 4.3 & 4.4
Develop and describe a surface water monitoring programme that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions and assess the effectiveness of mitigation and management measures. The program will:	
• include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals).	Section 4.5 & Appendix A
• comparison of physico-chemical data to national/regional guidelines or to site- specific guidelines derived from reference condition monitoring if available.	Section 4.5 & Appendix A
• identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.	Section 4.5 & Appendix A
Describe the rationale for selected monitoring parameters, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	Section 9
Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	Section 9
Water-dependent assets – context and conceptualisation	
Identify water-dependent assets, including:	
• water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna) (see Doody *et al.* [in press]).	Refer to Main EA Report
• public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	
Identify GDEs in accordance with the method outlined by Eamus *et al.* (2006). Information from the GDE Toolbox15 (Richardson *et al.* 2011) and GDE Atlas (CoA 2017a) may assist in identification of GDEs (see Doody *et al.* [in press]).	Refer to Groundwater Report
Describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015).	Refer to Groundwater Report
Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody *et al.* [in press]).	Refer to Groundwater Report

Project information	Report section
Identify the hydrogeological units on which any identified GDEs are dependent (see Doody *et al*. [in press]).	Refer to Groundwater Report
Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	Section 3 & 4
Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	Section 9
Water dependent assets – impacts, risk assessment and management of risk	
Provide an assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs (see Doody *et al*. [in press]).	Refer to Groundwater Report
Describe the potential range of drawdown at each affected bore, and clearly articulate the scale of impacts to other water users.	Refer to Groundwater Report
Indicate the vulnerability to contamination (e.g. from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	Section 7.3.9
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	Section 5
Provide estimates of the volume, beneficial uses and impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.	Section 7.3.9 & 7.3.10
Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	Section 7 & 8
Identify the proposed acceptable level of impact for each water-dependent asset based on leading-practice science and site-specific data, and ideally developed in conjunction with stakeholders.	Section 7 & 8
Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	Section 5, 8 & 9
Water-dependent assets – data and monitoring	
Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions, and test potential responses to impacts of the proposal (see Doody *et al*. [in press]).	Section 9
Consider concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design, see Doody *et al*. [in press]).	
Develop and describe a monitoring program that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change (see Doody *et al*. [in press]).	
Describe the process for regular reporting, review and revisions to the monitoring program.	

Project information	Report section
Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna (QLD Government 2015)).	
Water and salt balance, and water management quality	
Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Section 7
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	Section 7
Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	Section 7.3.7 & 7.3.10
Provide salt balance modelling that includes stores and the movement of salt between stores and takes into account seasonal and long-term variation.	Section 7.3.8
Cumulative impacts - context and conceptualisation	
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 10
Consider all past, present, and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	Section 10
Cumulative impacts - impacts	
Provide an assessment of the condition of affected water resources which includes: • identification of all water resources likely to be cumulatively impacted by the proposed development; • a description of the current condition and quality of water resources and information on condition trends; • identification of ecological characteristics, processes, conditions, trends and values of water resources; • adequate water and salt balances; and • identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	Section 4, 7 & 10
Assess the cumulative impacts to water resources considering: • the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally; • all stages of the development, including exploration, operations and post closure/decommissioning; • appropriately robust, repeatable and transparent methods;	Section 10

Project information	Report section
• the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and • opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.	
Cumulative impacts - mitigation, monitoring and management	
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	Section 7.4, 7.5, 8, 9 & 10
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	
Identify cumulative impact environmental objectives.	
Describe appropriate reporting mechanisms.	
Propose adaptive management measures and management responses.	
Final landforms and voids - coal mines	
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Section 5 and Main EA report
Assess the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	
Provide an assessment of the long-term impacts to water resources and water-dependent assets posed by various options for the final landform design, including complete or partial backfilling of mining voids. Assessment of the final landform for which approval is being sought should considers: • groundwater behaviour - sink or lateral flow from void. • water level recovery - rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation). • seepage - geochemistry and potential impacts. • long-term water quality, including salinity, pH, metals and toxicity. • measures to prevent migration of void water off-site. For other final landform options considered sufficient detail of potential impacts should be provided to clearly justify the proposed option.	
Assess the probability of overtopping of final voids with variable climate extremes, and management mitigations.	N/A
Acid-forming materials and other contaminants of concern	
Identify the presence and potential exposure of acid-sulfate soils (including oxidation from groundwater drawdown).	Refer to Main EA Report, Geochemical Assessment Report and Section 6.8
Identify the presence and volume of potentially acid-forming waste rock, fine-grained amorphous sulphide minerals and coal reject/tailings material and exposure pathways.	
Identify other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths.	

Project information	Report section
Describe handling and storage plans for acid-forming material (co-disposal, tailings dam, encapsulation).	
Assess the potential impact to water-dependent assets, taking into account dilution factors, and including solute transport modelling where relevant, representative and statistically valid sampling, and appropriate analytical techniques.	
Describe proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.	

2.2 STATE

2.2.1 EP Act 1994

Resource activities are defined as environmentally relevant activities (ERAs) under the Queensland *Environmental Protection Act 1994* (EP Act) and as such, the development and operation of the Project are governed by the EP Act. The aim of the EP Act is to:

> *Protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).*

2.2.1.1 Environmental Authority

An EA is granted in accordance with the EP Act and details the prescribed conditions that govern the ERA. In the context of surface water management, the EA sets out conditions that will be relevant to the Project, including:

- Management of contained water including release;
- Water management plan requirements;
- Regulation of water structures including dams and levees;
- Saline drainage management;
- Acid rock drainage management; and
- Storm water and sediment laden runoff management.

2.2.1.2 Model Mining Conditions

New mining project applications should apply the model mining conditions as outlined in *Model mining conditions* (DES, 2017). The purpose of the model mining conditions is to provide a set of model conditions to form the general environmental protection commitments given for EA's for mining activities administered under the EP Act. The model conditions may be used as a basis for proposing environmental protection commitments in application documents.

Model conditions can be modified to suit the specific circumstances of a mining project, subject to the assessment criteria outlined in the EP Act. It is unlikely that the administering authority will accept less rigorous environmental protection commitments or EA conditions without clear evidence that the risk of the environmental harm is addressed by environmental management practices, technologies or the nature of the EVs impacted by the project.

Schedule F – Water (Fitzroy model conditions) form the basis of the requirements for the Project water management system design.

2.2.1.3 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water) is the primary instrument for surface water management under the EP Act. The EPP Water governs discharge to land, surface water and groundwater, aims to protect EVs and sets water quality guidelines and objectives.

The processes to identify EVs and to determine Water Quality Guidelines (WQGs) and Water Quality Objectives (WQOs) in Queensland waters is based on the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ guidelines).

The EVs for the Project location are outlined in Section 3.

2.2.1.4 Isaac River sub-basin Environmental Values and Water Quality Objectives 2011

The relevant document, pursuant to the EPP Water, for the Project is the *Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part)*, including all waters of the Isaac River Sub-basin (including Connors River, September 2011 [DEHP, 2011]). The document is made pursuant to the provisions of the EPP Water. It contains EVs and WQOs for waters in the Isaac River Sub-basin, and they are listed under Schedule 1 of EPP Water. Refer to Section 3 for further details.

2.2.1.5 Manual for Assessing Consequence Categories and Hydraulic Performance of Structures

The *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (the Manual) defines the methodology and assessment criteria to determine if a structure associated with an ERA should be regulated under the EP Act. The manual details the hydraulic design requirements for regulated structures and this document has been used as a reference in the preliminary design of the water management system and preliminary sizing of dams associated with the Project.

2.2.1.6 Guideline - Application Requirements for Activities with Impacts to Water

This guideline focuses on the types of impacts that environmentally relevant activities (ERAs) can have on water and outlines the information to be provided to the department as part of the ERA application process.

Section 4 of the guideline requires the applicant to provide details on a number of surface water-related issues, including:

- Discharges and releases;
- Unplanned and uncontrolled releases;
- Water infrastructure;
- Wetlands;
- Hydrology of receiving waters; and
- Mixing zones.

Table 2.2 lists the elements of the guideline relevant to this assessment and the sections of this report where those elements are addressed.

The guideline also refers to the department's technical guideline "Wastewater releases to Queensland waters", which is discussed in Section 2.2.1.7.

Table 2.2 – Application requirements for activities with impact to Water – Guideline

Item	Report section
Discharges and releases	
Identify activities that could lead to indirect impacts and unplanned/uncontrolled release of contaminants to water, such as, spills and leaks or stream bed and/or bank disturbance and describe the magnitude of the disturbance	Section 7.3.7 & 7.3.10
Identify the location, depth and configuration (if relevant) of the areas where the unplanned/uncontrolled release could be discharged to waters	Section 5, 6, 7.3.7 & 7.3.10
Identify infrastructure (including containment devices) with the potential to release unplanned/uncontrolled contaminants to waters	Section 6.4
Identify the potential contaminant type and quantities that could be released from infrastructure	Section 6.8 & 7.3.7
Water infrastructure	
Provide detail on the location and storage capacity of water infrastructure on the site which may include regulated structures, tailings dams, waste rock dams, water storage dams, levees, heap leach pads and any other water management infrastructure	Section 6.4 & 8.5
Wetlands	
Applicants must describe how the existing environmental values of any wetlands on, or adjacent to, the site will be maintained, or enhanced	Section 3 & 9
Ecology and hydrology of receiving waters	
Describe, preferably through the use of water quality monitoring or modelling, how the proposed ERA will impact on hydrology of receiving waters, preferably through modelling	Section 7.3

2.2.1.7 Technical Guideline – Wastewater release to Queensland Waters

This guideline is provided to support a risk-based assessment approach to licensing releases of wastewater to surface water and applies the philosophy of the ANZECC & ARMCANZ (2000) Water Quality Guidelines and the intent of the EPP Water.

The information requirements identified in this guideline are as follows:

- Describe the proposed activity.
- Describe the receiving environment.
- Predict outcomes or impacts of the proposed wastewater release.
- Set circumstances, limits and monitoring conditions.

Table 2.3 lists the elements of the guideline relevant to this assessment and the sections of this report where those elements are addressed.

2.2.1.8 Reef discharge standards for industrial activities

New or expanded prescribed ERAs and resource activities are assessed against Section 41AA of the EP Regulation in relation to water quality. Since 1 June 2021, the administering authority must consider section 41AA of the EP Regulation when making an environmental management decision (EMD) for an ERA discharging dissolved inorganic nitrogen (DIN)/fine sediment in the Great Barrier Reef (GBR) catchment waters.

Table 2.3 – Wastewater release to Queensland waters – technical guideline

Item	Report section
Step 1 – Describe the proposed activity	
Define industry type and size (estimated production, current and ultimate)	Section 1.2
Identify the potential contaminants of concern in the proposed release	Section 6.8
Location and configuration of the proposed release	Section 6.4, 7.3.7 & 7.3.10
Step 2 – Describe the receiving environment	
Identify water bodies potentially affected by the proposed release	
Provide all relevant information on the receiving environment based on desktop and field studies (e.g. current, background water quality condition)	Section 4
Include special consideration for ephemeral streams	
Identify all relevant EV and WQOs	Section 3
Ensure all government planning requirements applying to the water bodies have been considered	Section 2
Step 3 - Predict outcomes or impacts of the proposed wastewater release	
Assess whether contaminants are potentially toxic	Section 6.8 and 7.3
Predict the assimilative capacity and sustainable load	Section 7.3
Consider other potential impacts	Section 7.3
Step 4 - Set circumstances, limits and monitoring conditions	
Specify any circumstances related to the approved wastewater release	Section 6.4
Include a receiving environment monitoring program (REMP) requirement	Section 9.6
Include reporting requirements for the approved activity	Section 9

2.2.2 Water Act 2000

In Queensland, the Water Act 2000 (Water Act) is the primary statutory document that establishes a framework for the planning, allocation and use of non-tidal water. The Water Act is primarily administered by the Department of Natural Resources, Mines and Energy (DNRME).

The main purpose of the Water Act is to provide a framework for the following:

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

A watercourse is defined by the Water Act as a river, creek or stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently. The DNRME have published a watercourse identification map of the state that shows: watercourses (other than their lateral limits); the downstream limit of watercourses; drainage features; lakes; and springs.

A watercourse determination for drainage features in the Project area has been undertaken by the DNRME. The watercourses and drainage features which intersect the Project are described in Section 4.

2.2.2.1 Water Plan (Fitzroy Basin) 2011

The Water Plan (Fitzroy Basin) 2011 is subordinate legislation to the Water Act. The plan is developed and administered by DNRME. The purpose of the plan is:

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

2.2.2.2 Water Regulation 2016

The Water Regulation 2016 is subordinate legislation to the Water Act and provides details, protocol and instruction for the following:

- Water rights and planning;
- Statutory authorisations to take or interfere with water;
- Matters relating to water licenses;
- Water allocations;
- Water supply and demand management;
- Declarations about watercourses.

2.2.3 Water Supply (Safety & Reliability) Act 2008

The Water Supply (Safety and Reliability) Act 2008 provides for the safety and reliability of water supply in Queensland. The purpose is achieved primarily by:

- Providing a regulatory framework for providing water and sewerage services in the State;
- Providing a regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health;
- The regulation of referable dams; and
- Stating flood mitigation responsibilities.

3 Environmental Values

The Queensland Water Quality Guidelines and EPP Water guidelines establish EVs and WQOs for natural waters in Queensland. The Project is located within the 'Isaac western upland tributaries' area of the Isaac River sub-basin, shown in Figure 3.1. Under the EPP Water, the following EVs have been nominated for this area:

- Aquatic ecosystems
- Irrigation
- Farm supply/use
- Stock Water
- Aquaculture
- Human consumption
- Primary recreation
- Secondary recreation
- Visual recreation
- Drinking water
- Industrial use
- Cultural and spiritual values

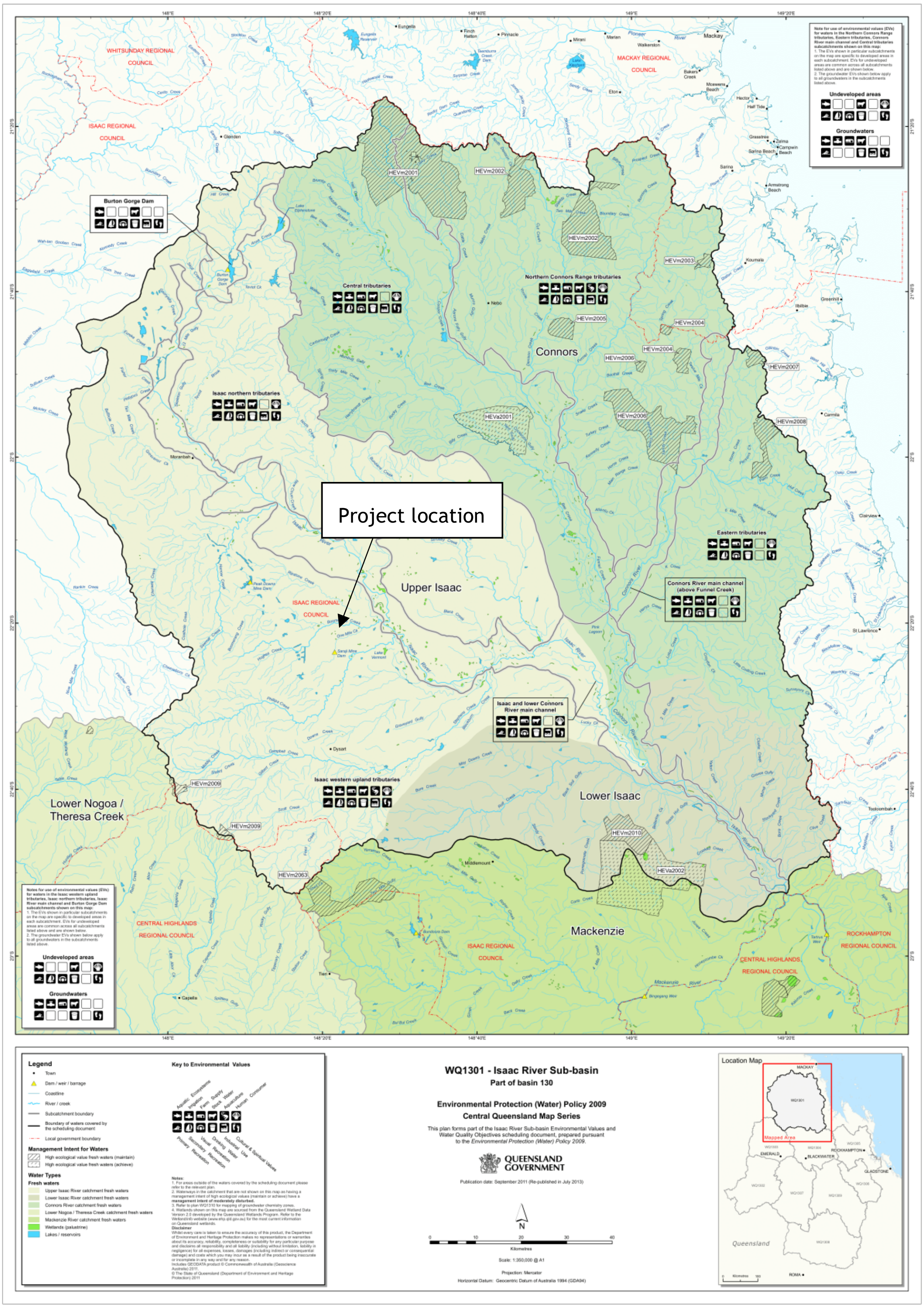


Figure 3.1 - Isaac River Sub-Basin EVs (source: DES, 2013)

The WQO default trigger values for the above EVs are provided in Table 3.1. The indicators and water quality guidelines relevant to the above surface water EVs are listed in the EPP Water (2011) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018).

Where different EVs have different WQOs, the Project has adopted the lowest concentration value for mine water and receiving waters trigger levels. WQO default trigger values are displayed for physio-chemical parameters only.

Table 3.1 - Water Quality Objectives default trigger values for the Project (from EPP Water [2009] for Isaac Western Upland Tributaries)

Parameter	WQO	Relevant EV
Ammonia N	< 20 µg/L	Aquatic ecosystem[a]
Oxidised N	< 60 µg/L	Aquatic ecosystem[a]
Organic N	< 420 µg/L	Aquatic ecosystem[a]
Total nitrogen	< 500 µg/L	Aquatic ecosystem[a]
Filterable Reactive Phosphorus (FRP)	< 20 µg/L	Aquatic ecosystem[a]
Total Phosphorus	< 50 µg/L	Aquatic ecosystem[a]
Chlorophyll a	< 5 µg/L	Aquatic ecosystem[a]
Dissolved oxygen	85-110% saturation > 4 mg/L at surface	Aquatic ecosystem[a] Drinking water[b]
Turbidity	< 50 NTU	Aquatic ecosystem[a]
Suspended solids	< 55 mg/L	Aquatic ecosystem[a]
pH	pH 6.5-8.5	Aquatic ecosystem[a]
Conductivity (EC) baseflow	720 µS/cm	Aquatic ecosystem[a]
Conductivity (EC) high flow	250 µS/cm	Aquatic ecosystem[a]
Sulfate	25 mg/L	Aquatic ecosystem[a]
Total Dissolved Solids	< 2000 mg/L	Stock watering[c]
Colour	50 Hazen Units	Drinking water[b]
Total Hardness	150 mg/L as CaCO3	Drinking water[b]
Sodium	< 30 mg/L	Drinking water[b]
Aluminium	< 5 mg/L < 0.055 mg/L	Stock watering[c] Aquatic ecosystem[d]
Arsenic	2.0 mg/L 0.5 mg/L up to 5 mg/L < 0.024 mg/L	Irrigation[b, e] Stock watering[f] Aquatic ecosystem[d]
Beryllium	< 0.5 mg/L	Irrigation[g]
Boron	< 5 mg/L < 0.37 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Cadmium	< 0.01 mg/L < 0.0002 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Chromium	< 1 mg/L < 0.001 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Cobalt	< 0.1 mg/L	Irrigation[g]
Copper	< 1 mg/L < 0.0014 mg/L	Stock watering (cattle)[f,e] Aquatic ecosystem[d]

Parameter	WQO	Relevant EV
Fluoride	< 2 mg/L	Irrigation[g]
Iron	< 10 mg/L	Irrigation[g]
Lead	< 0.1 mg/L < 0.0034 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Lithium	< 2.5 mg/L	Irrigation[g]
Manganese	< 10 mg/L < 1.9 mg/L	Irrigation[g] Aquatic ecosystem[d]
Mercury	< 0.002 mg/L < 0.00006 mg/L	Irrigation[g] Aquatic ecosystem[d]
Molybdenum	< 0.05 mg/L	Irrigation[g]
Nickel	< 1 mg/L < 0.011 mg/L	Stock watering[f, e] Aquatic ecosystem[d]
Selenium	< 0.02 mg/L < 0.005 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Uranium	< 0.1 mg/L	Irrigation[g]
Vanadium	< 0.5 mg/L	Irrigation[g]
Zinc	< 5 mg/L < 0.008 mg/L	Irrigation[g] Aquatic ecosystem[d]

[a] Table 2 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem - moderately disturbed
[b] Table 4 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Drinking water EV
[c] Table 10 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Stock watering EV: salinity
[d] Table 3.4.1 of Australian and New Zealand Guidelines for Fresh and Marine Water Quality: trigger values for slightly-moderately disturbed systems (95% level of protection)
[e] short-term trigger value
[f] Table 11 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Stock watering EV: heavy metals and metalloids
[g] Table 9 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Irrigation EV: heavy metals and metalloids

The Queensland Globe service (Queensland Government, 2019) was used to identify any wetlands in the vicinity of the Project. There were no matters of state environmental significance (MSES) wetlands, wetland values or wetland protection areas identified in or adjacent the Project area.

4 Existing surface water environment

4.1 REGIONAL DRAINAGE CHARACTERISTICS

The Project is located within the Isaac River sub-basin of the greater Fitzroy Basin. Figure 4.1 shows the Upper Isaac River catchment to its confluence with Phillips Creek. The Isaac River commences approximately 100 km to the north of the Project site within the Denham Range. It drains in a south westerly direction through the Carborough and Kerlong Ranges before turning in a south easterly direction near the Goonyella Riverside Mine. It drains approximately 30 km to the east of the Project, and eventually flows to the Mackenzie River some 150 km to the southeast.

Three open water bodies are located in the Isaac upper catchment including Lake Elphinstone, Teviot Creek Dam and Burton Gorge Dam (Figure 4.1). Lake Elphinstone is a natural lake formed behind the Carborough Range whereas Teviot Creek Dam and Burton Gorge Dam are man-made structures that supply water to Burton and North Goonyella mines in the upper catchment.

Other than along the ranges, the majority of the Isaac River catchment has been cleared for agricultural use or for mining. There are several existing coal mines in the catchment, including Burton, North Goonyella, Goonyella Riverside, Broadmeadow, Broadlea North, Isaac Plains, Moranbah North, Millennium, Daunia, Poitrel, Grosvenor, Peak Downs, Saraji, Norwich Park and Lake Vermont mines.

Figure 4.2 shows the surrounding catchments of the Project area. The Project is located in the headwaters of the Boomerang, Hughes, Barret and Harrow creek catchments:

- Headwater drainage features of Boomerang Creek, which is a watercourse and tributary of the Isaac River, drains the northern portion of the Project area. Within the Project MLA boundary, Boomerang Creek and its tributaries are identified as drainage lines. Boomerang Creek is identified as a watercourse approximately 1 km downstream (east) of the Project MLA where Drainage lines 1, 2, 3 and 4 join. Boomerang Creek and its tributaries drain from Project MLA boundary via a series of culverts under the Norwich Park Branch Railway.
- Hughes Creek is a watercourse and tributary of Boomerang Creek and drains the majority of the southern Project area. Hughes Creek is identified as a watercourse within the Project MLA boundary. Hughes Creek drains from the Project MLA boundary via a rail bridge under the Norwich Park Branch Railway.
- Barrett Creek, which is identified as a watercourse within the Project MLA and is and tributary of Hughes Creek, drains a small portion of the southern Project area. Barrett Creek drains from the Project MLA boundary via a culvert under the Norwich Park Branch Railway.
- Headwater drainage features of Harrow Creek, which is a tributary of Cherwell Creek and the Isaac River, drains a small portion of the northern Project MLA area. Harrow Creek is identified as a watercourse approximately 2.2 km downstream (northwest) of the Project MLA.

The confluence of Boomerang and Hughes Creek occurs approximately 10 km to the east of the Project. Boomerang Creek drains into the Isaac River a further 10 km to the east of the Project. The catchment area of the Isaac River to Boomerang Creek is approximately 5,226 square kilometres (km^2). The catchment area of Boomerang Creek is 788 km^2, of which 177 km^2 makes up the Hughes Creek catchment.

The catchments of Boomerang Creek, Hughes Creek and Barrett Creek commence to the west of the Project area and drain in an easterly direction towards Saraji Road and the Norwich Park Branch Railway. The Ripstone Creek catchment lies to the north of the Project area and drains into Boomerang Creek approximately 30 km southeast of the Project. The headwater tributaries of Boomerang and Hughes Creek are ephemeral streams which experience flow only after sustained or intense rainfall.

The predominant catchment land uses of Boomerang Creek include undeveloped areas with some stock grazing to the west of Saraji Road and stock grazing and coal mining to the east. Boomerang Creek, Hughes Creek and Barrett Creek flow into the existing BHP Billiton Mitsubishi Alliance (BMA) operations (Peak Downs and Saraji). The existing BMA operations have diverted the original alignment of Boomerang Creek and its tributaries, as well as Harrow Creek to the north. Additional diversions of Boomerang Creek and its floodplain are also planned for approved operations further to the east.

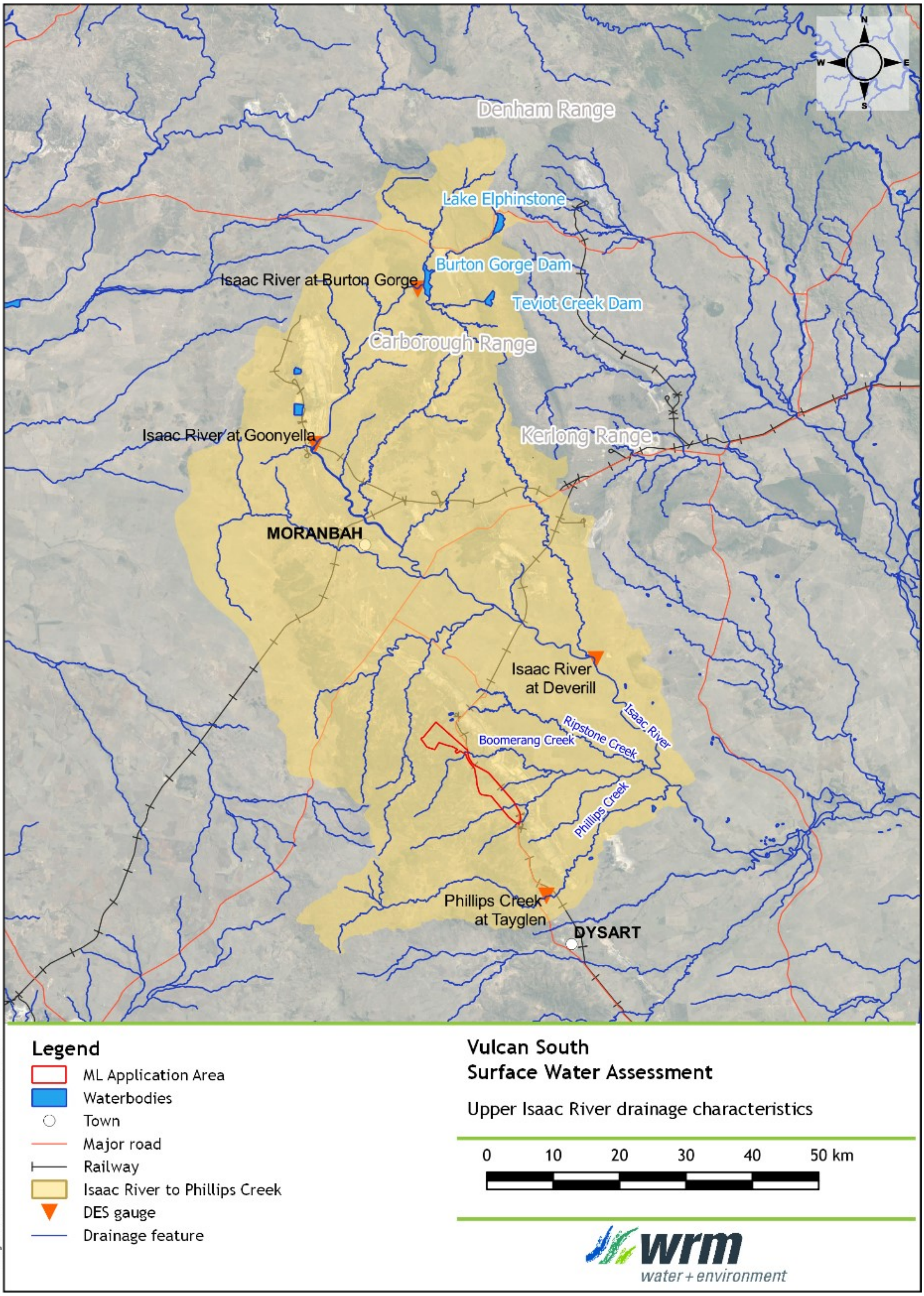


Figure 4.1 – Upper Isaac River drainage characteristics

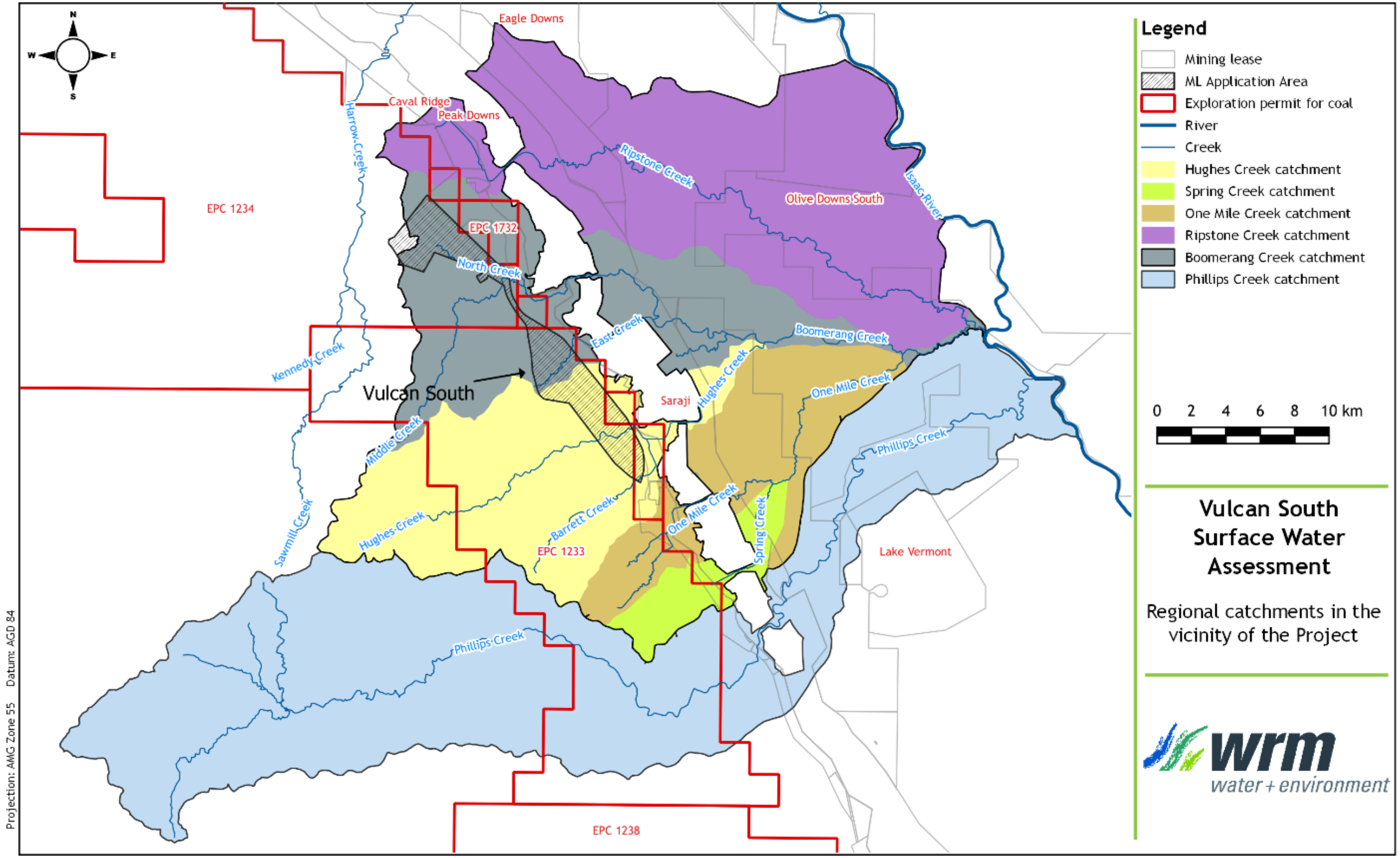


Figure 4.2 – Regional catchments in the vicinity of the Project

The northwest Project MLA area interacts with a small portion of the Harrow Creek catchment (Figure 4.2). Harrow Creek is a watercourse to the west of the Project that flows, which flows in a northerly direction. Sawmill Creek and Kennedy Creek are named tributaries of Harrow Creek. Harrow Creek flows into Cherwell Creek, which in turn discharges into the Isaac River to the north of the Project.

4.2 LOCAL DRAINAGE NETWORK

Figure 4.4 to Figure 4.5 shows the local drainage features within the northern, central and southern Project areas respectively. Drainage features in the north of the Project area (in the vicinity of the highwall mining test area) primarily drain to Boomerang Creek. Drainage features in the centre of the Project area (near the Vulcan North pit) primarily drain to Boomerang Creek. Drainage features in the central and southern areas of the Project area (near the Vulcan Main and Vulcan South pits) primarily drain to Hughes Creek and Barrett Creek. All drainage lines within the Project area eventually drain to the Isaac River.

The main drainage features which intersect the mining areas are (Figure 4.3 to Figure 4.5):

- Drainage line 1 (a tributary of Boomerang Creek);
- Drainage line 2 (a tributary of Boomerang Creek);
- Drainage line 6 (a tributary of Boomerang Creek);
- Drainage line 7 (a tributary of Boomerang Creek);
- Hughes Creek; and
- Drainage line 8 (a tributary of Hughes Creek).

Figure 4.6 shows typical cross sections along the three local drainage features through the Project area with corresponding 1% AEP flood levels at the locations shown in Figure 4.4 and Figure 4.5.

4.2.1 Drainage line 1 and 2

Drainage lines 1 and 2 are tributaries of Boomerang Creek which drain the northern extent of the Project area (Figure 4.3). Drainage lines 1 and 2 drain a significant portion of the VCM and have previously been described in detail (WRM, 2021).

Drainage line 1 drains the northeastern extent of the Project area, in particular the northern extent of the Highwall mining area. Drainage Line 1 crosses the Saraji Road and the Norwich Park branch railway to the northeast of the Project area before discharging into the Peak Downs Mine Lease (ML) downstream of the railway. Drainage Line 1 flows into an existing on-line water storage within the Peak Downs operations before eventually discharging into Drainage Line 2 to the east of the Project boundary. Drainage Line 1 has been diverted and significantly modified within the Peak Downs ML.

The typical dimensions of the Drainage Line 1 channel are (WRM, 2021):

- channel bed widths of 2 m to 5 m;
- channel top widths of 10 m to 25 m;
- channel depths 0.5 to 1 m; and
- overbank floodplain widths of 20 m to 50 m.

Drainage line 1 is proposed to be diverted and subsequently reinstated as part of the VCM (WRM,2021). No further works are proposed for Drainage line 1 as part of this Project.

A minor drainage feature which is a tributary of Drainage line 2 drains the southern extent of the Highwall mining area before discharging into Drainage line 2 at the eastern Project extent (Figure 4.3). Drainage line 2 has a catchment area of approximately 30 km^2. Drainage Line 2 crosses the Saraji Road and the Norwich Park branch railway to the east of the Project area before discharging into the Peak Downs ML downstream of the railway.

The typical dimensions of the Drainage Line 2 channel are (WRM, 2021):

- channel bed widths of 3 m to 5 m;
- channel top widths of 10 m to 30 m;
- channel depths 1 to 2 m; and
- overbank floodplain widths of 50 m to 150 m.

Drainage Line 2 will not be modified as part of the Project.

4.2.2 Drainage line 6

Drainage line 6 drains the majority of the Vulcan North mining area. The drainage line passes through a culvert under Saraji Road and the Norwich Park branch railway within the Project area (Figure 4.7). Drainage line 6 discharges into an existing drainage diversion within the Saraji Mine known as East Creek which in turn, passes through the Saraji Mine operation before draining into Boomerang Creek approximately 5 km to the east of the Project.

The typical dimensions of the Drainage Line 6 channel through the Project area are (Figure 4.6):

- channel bed widths of 1 m to 5 m;
- channel top widths of 5 m to 20 m;
- channel depths 0.5 to 1 m; and
- overbank floodplain widths of 15 m to 80 m.

Drainage line 6 will be diverted as part of the Project to avoid the Vulcan North mining area (Figure 1.3). The 1.8 km long drainage diversion will divert Drainage line 6 into Drainage line 7 during operations. Drainage Line 6 will be reinstated post-mining by constructing a drainage corridor through backfilled spoil. DD2 will collect runoff from the remaining Drainage line 6 catchment.

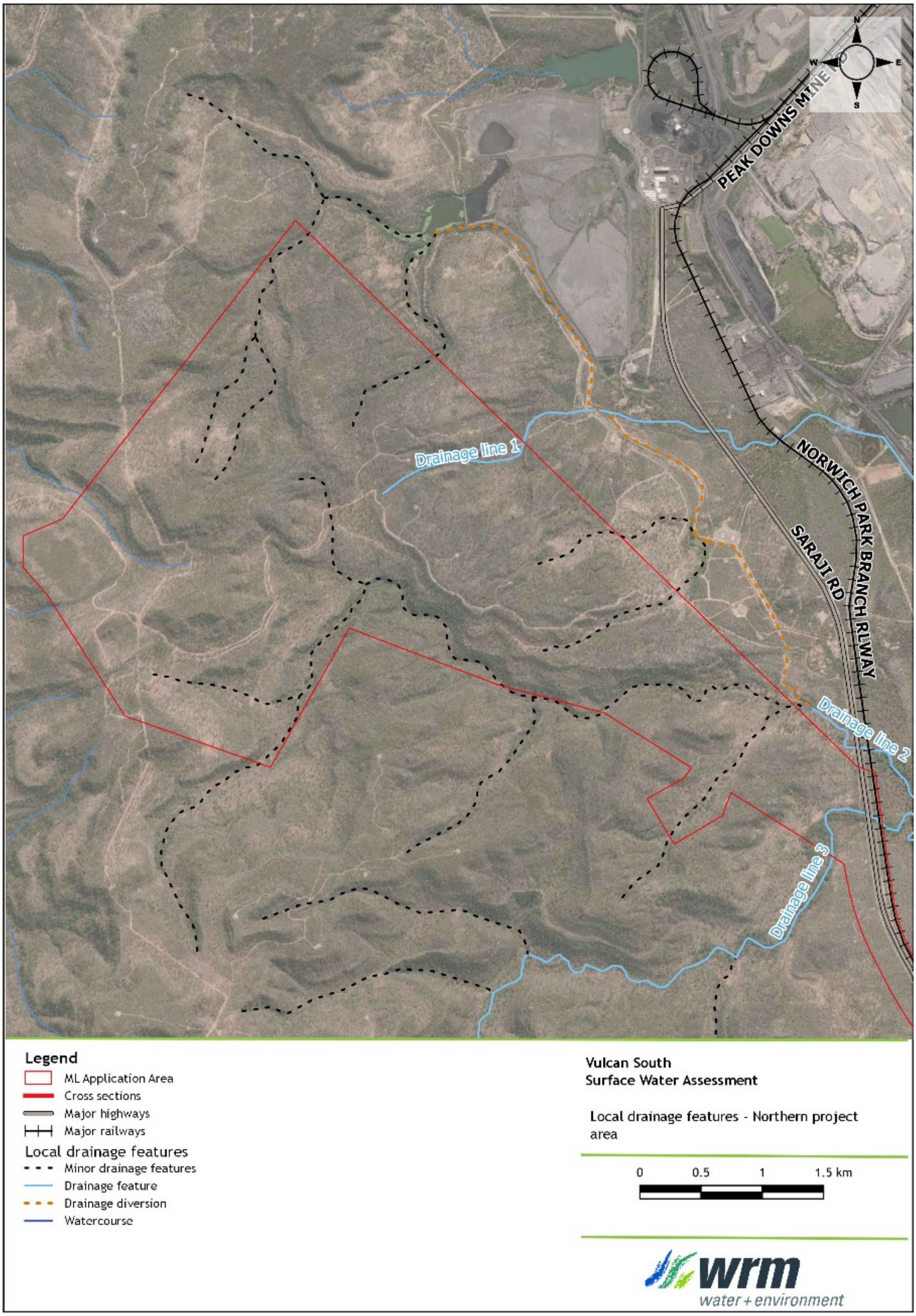


Figure 4.3 – Local drainage features – northern Project area

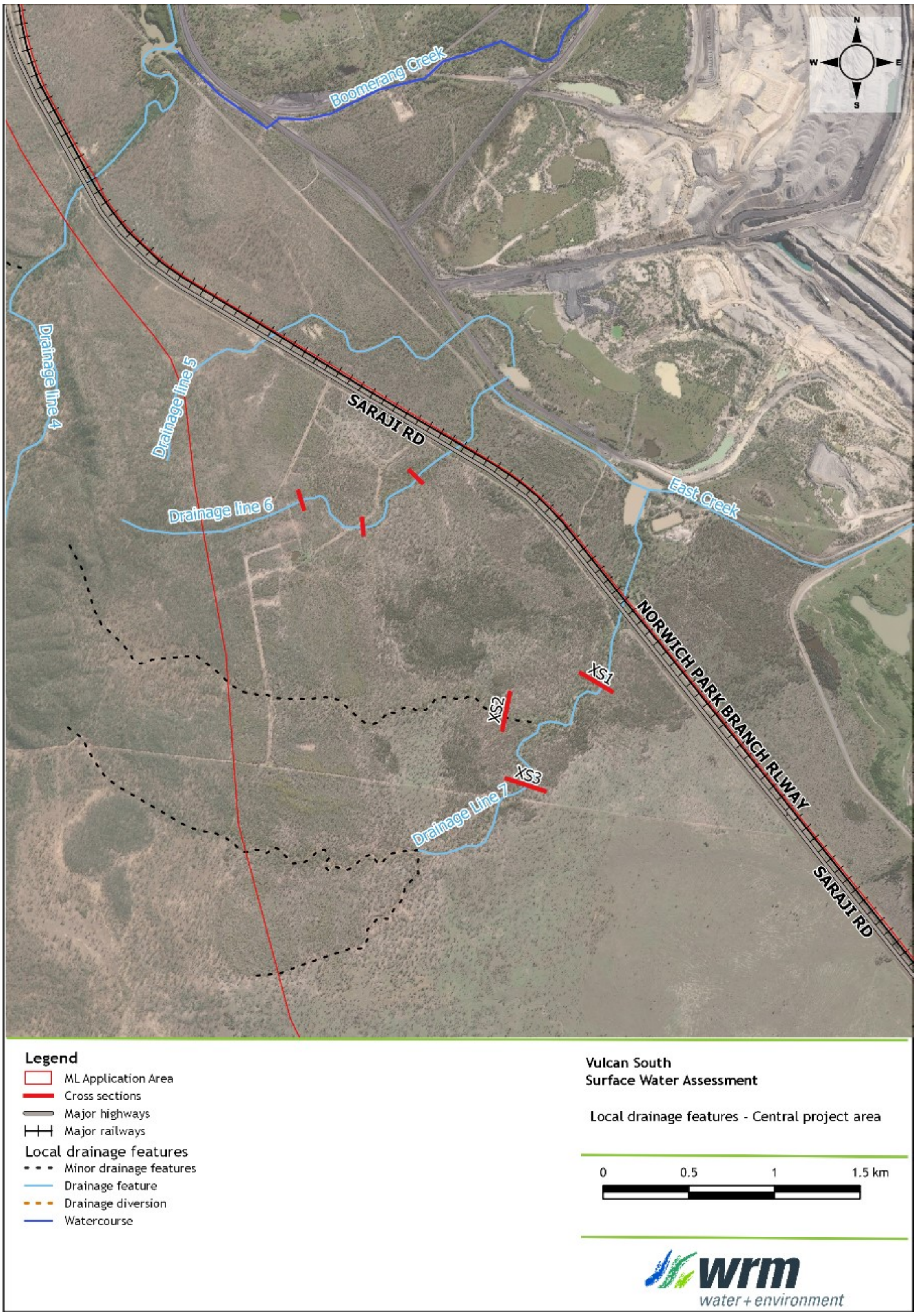


Figure 4.4 – Local drainage features – central Project area

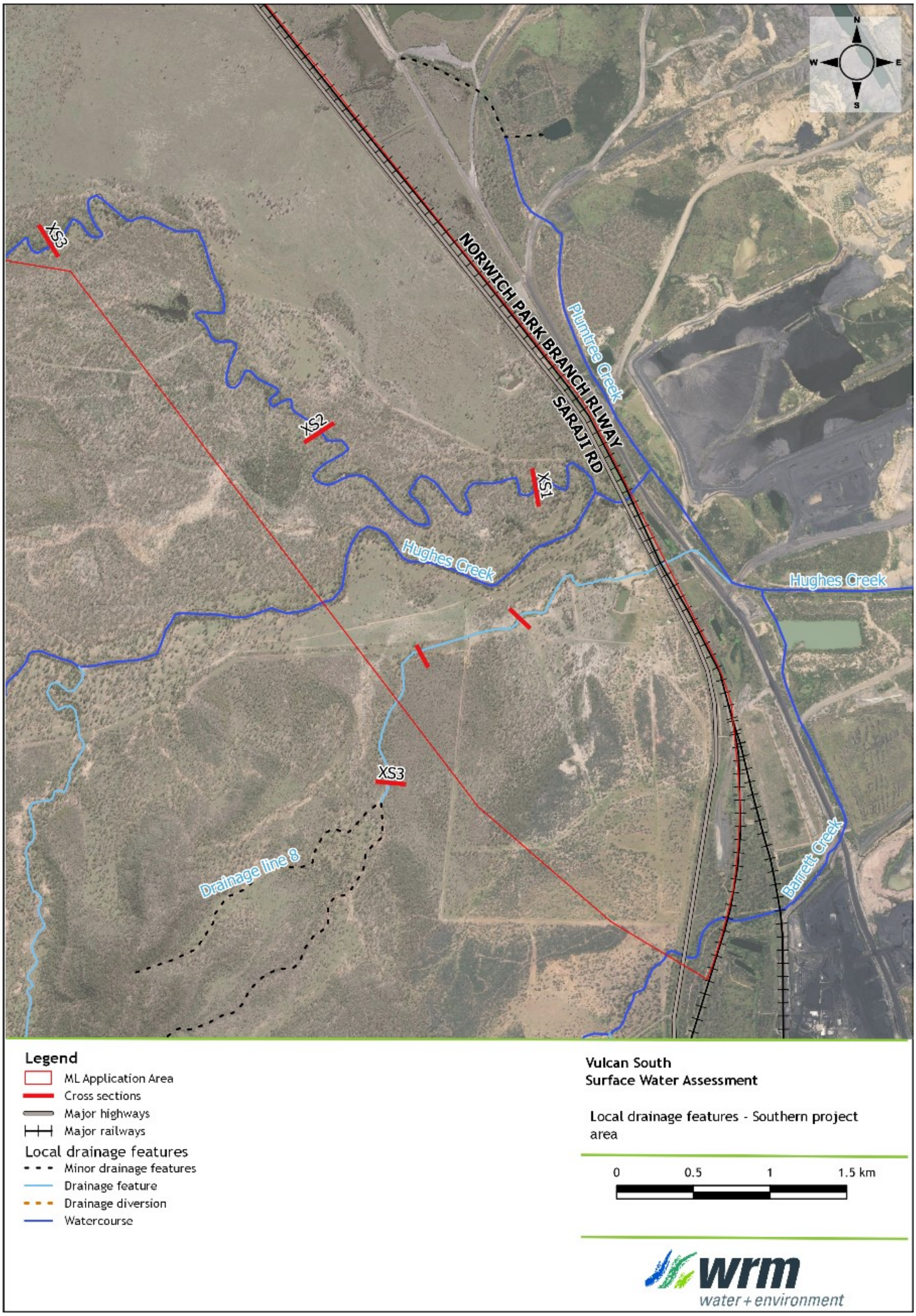


Figure 4.5 – Local drainage features – southern Project area

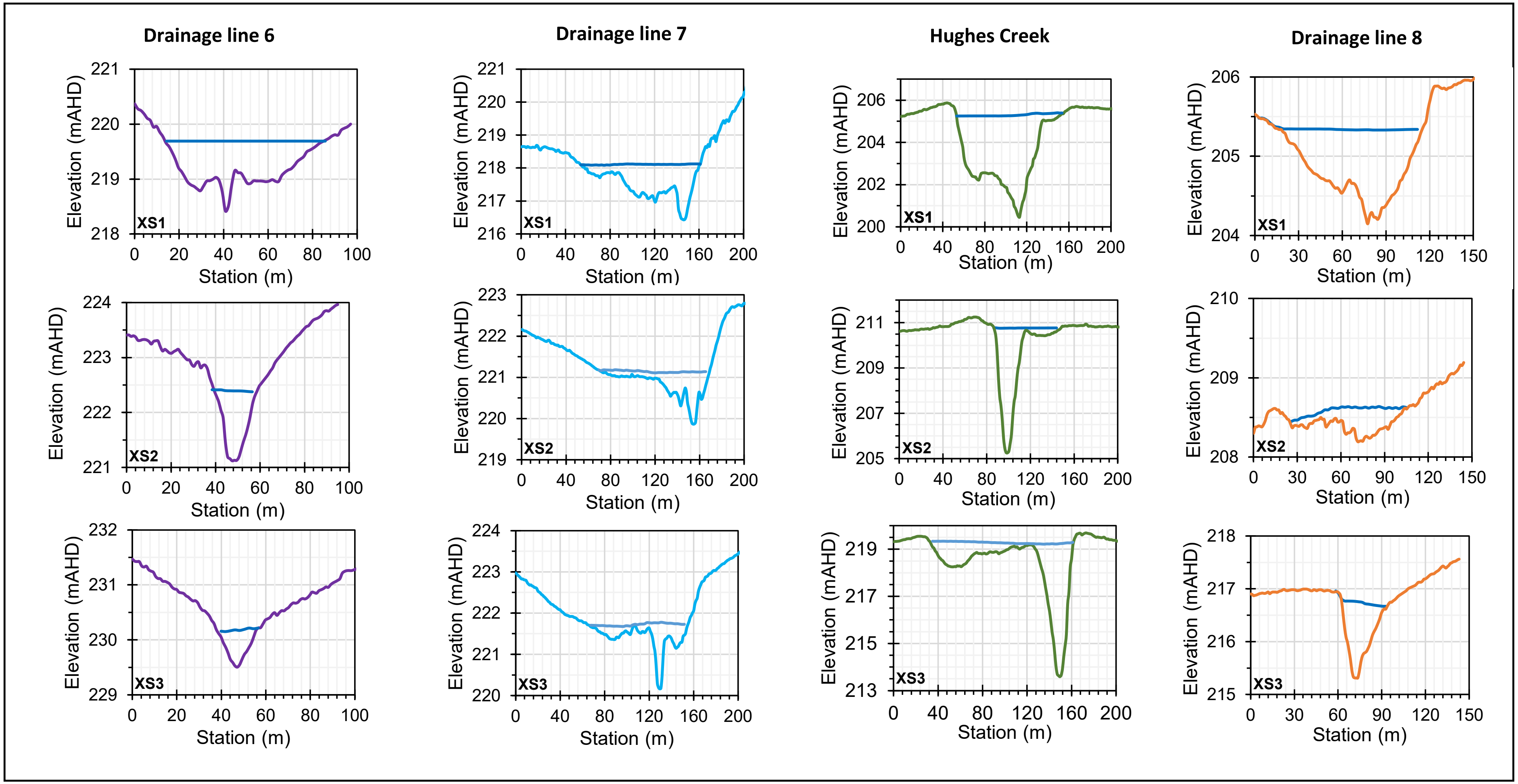


Figure 4.6 – Drainage line cross sections with 1% AEP flood levels

Figure 4.7 – Photograph of Drainage line 6 passing under the Norwich Park Branch railway

4.2.3 Drainage line 7

Drainage line 7 (Figure 4.8) lies between the proposed Vulcan North and Vulcan Main mining areas, and north of the TLO and CHPP area. Drainage line 7 will receive releases from sediment dams around the Vulcan North out of pit emplacement area and the diverted water catchment from Drainage line 6 during operations (Section 4.2.2).

Drainage line 7 collects a natural catchment to the west of the Project area and discharges through existing box culverts under Saraji Road and the Norwich Park Branch railway (Figure 4.9). The Drainage line 7 flows into a dam 400 m east of the Project area, which forms part of the drainage diversion known herein as East Creek within the Saraji Mine.

The typical dimensions of the Drainage Line 7 channel through the Project area are (Figure 4.6):

- channel bed widths of 3 m to 5 m;
- channel top widths of 10 m to 15 m;
- channel depths 1.0 to 2.0 m; and
- overbank floodplain widths of 50 m to 100 m.

Figure 4.8 – Photograph of Drainage line 7 south of the Vulcan North mining area

Figure 4.9 – Photograph of Drainage line 7 passing through box culverts under Saraji Road

4.2.4 Hughes Creek

Hughes Creek is a watercourse which collects a significant natural catchment to the west of the Project area. The creek flows west-east between the Vulcan Main and Vulcan South areas, passing under two bridges crossings of Saraji Road and the Norwich Park branch railway (Figure 4.10). A number of drainage features discharge into Hughes Creek to the east of the Project Area, including Barrett Creek and Drainage line 8. Hughes Creek passes through the Saraji Mine operation before discharging to Boomerang Creek, approximately 10 km to the east of the Project area. Hughes Creek has been diverted and significantly modified within the Saraji ML.

A tributary of Hughes Creek flows on the southern edge of the Vulcan Main mining area and will receive releases from sediment dams around the southern side of the Vulcan Main in pit and out of pit emplacement areas and the northern side of the Vulcan South in pit emplacement areas. Hughes Creek will also receive the diverted water catchment from Drainage line 8 during operations (Section 4.2.5).

The typical dimensions of the Hughes Creek channel within the Project area are (Figure 4.6):

- channel bed widths of 3 m to 10 m;
- channel top widths of 30 m to 50 m;
- channel depths 2 to 5 m; and
- overbank floodplain widths of 50 m to 150 m.

Figure 4.10 – Photograph of Hughes Creek passing under Saraji Road

4.2.5 Drainage line 8

Drainage line 8 is a tributary of Hughes Creek which flows through the proposed Vulcan South mining area. Drainage line 8 currently passes through box culverts under Saraji Road and the Norwich Park branch Railway before discharging into Hughes Creek to the east of the Project area. Drainage line 8 is proposed to be diverted during operations around the Vulcan South mining area into Hughes Creek (Figure 1.8) to the north. Drainage Line 8 will be reinstated postmining by constructing a drainage corridor through backfilled spoil.

The typical dimensions of the Drainage Line 8 channel through/upstream of the Project area are (Figure 4.6):

- channel bed widths of 1 m to 3 m;
- channel top widths of 10 m to 20 m;
- channel depths 0.5 to 1.0 m; and
- overbank floodplain widths of 50 m to 150 m.

Drainage line 8 is not well defined in its lower reaches (i.e. closer to the proposed Vulcan South mining area) and an existing farm is located on the section of Drainage Line 8 that is to be diverted.

4.3 RAINFALL AND EVAPORATION

Long term rainfall and evaporation data at the Project was not available. As such, long term daily evaporation and rainfall data was sourced from the DES SILO climate data service at the approximate Project coordinates (Latitude: -22.35, Longitude: 148.2) from January 1889 to January 2020 (i.e. 131 years of data).

Table 4.1 shows statistics for Morton's lake evaporation and Table 4.2 shows statistics for rainfall (as mm/month and mm/year) over the historical dataset.

Figure 4.11 shows a comparison between the evaporation and rainfall. Evaporation rates are generally higher than rainfall throughout the year.

Table 4.1 - Evaporation (Morton's lake) statistics over the historical period (mm)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	240	204	201	152	118	94	103	142	171	215	222	239	1,967
90th %ile	224	190	186	144	109	88	97	125	160	199	214	229	1,891
Median	201	168	167	132	102	80	91	118	152	189	201	213	1,804
10th %ile	171	143	150	121	93	75	83	110	141	174	182	188	1,726
Min	120	122	127	94	76	59	77	97	121	160	121	145	1,506

Table 4.2 - Rainfall statistics over the historical period (mm)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	502	471	324	267	208	168	132	273	134	143	191	351	1,254
90th %ile	208	221	162	70	66	74	61	61	47	88	100	149	881
Median	98	85	45	19	15	21	7	6	6	20	39	71	567
10th %ile	20	14	2	0	0	0	0	0	0	0	7	23	362
Min	0	0	0	0	0	0	0	0	0	0	0	2	221

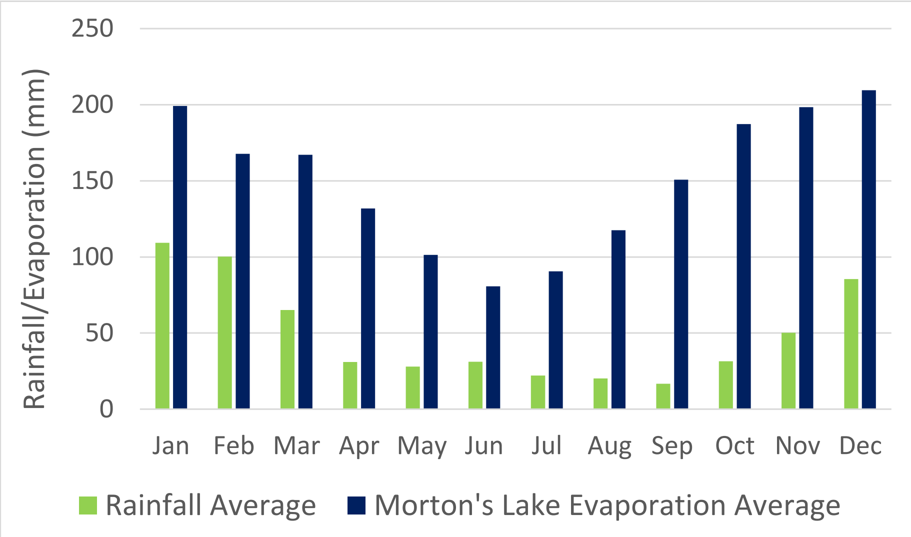


Figure 4.11 - Long term SILO mean monthly rainfall and evaporation at the Project

4.4 STREAMFLOW

There are no stream flow data available for East Creek or Hughes Creek at the time of preparing this report. There are two streamflow gauges operated by the Department of Natural Resources, Mines and Energy (DNRME) in the vicinity of the Project including (see Figure 1.1):

- Isaac River at Deverill (approximately 25 km northeast of the Project); and
- Phillips Creek at Tayglen (approximately 15 km southeast of the Project).

The stream gauge on the Isaac River at Deverill (Station ID: 130410A) is located approximately 20 km upstream of where Boomerang Creek meets the Isaac River.

Historical flow and river height monitoring data (1968 to 2018) for the Isaac River at Deverill, provides an indication of the flow regime (refer Figure 4.12). Surveyed cross section data for this gauging station collected in September 2014 (DNRME, 2017) indicates that sediment covers the bottom one metre of the gauge range. The mean river height data shown in Figure 4.12 suggests that surface flow above the sand is more likely to occur only in the wetter months from November to April, reducing to shallow subsurface flows from about May to October in an average year.

The Phillips Creek at Tayglen Creek streamflow gauge (Station ID: 130409A) is located on Phillips Creek. Phillips Creek is an easterly draining tributary of the Isaac River, south of Hughes Creek. DNRME maintains data for the gauge between 1968 and 1988. The catchment area to the gauge location is 344 km^2.

A typical sequence of recorded flows from this station is shown in Figure 4.13. The creek is characterised by brief periods of flow interspersed by long periods of no flow. This ephemeral behaviour is typical for streams in this part of the Fitzroy Basin.

The median annual flow over the period of record was approximately 12,730 ML/a (52 mm of runoff), most of which occurred in the summer months (as shown in Figure 4.14). Figure 4.15 compares flow frequency curves for a number of gauged catchments in the Isaac River catchment which are located in the vicinity of the Project. Figure 4.15 shows that for Phillips Creek at Tayglen, flow only occurred approximately 22% of the time, which would be similar to other creeks in the vicinity of the Project.

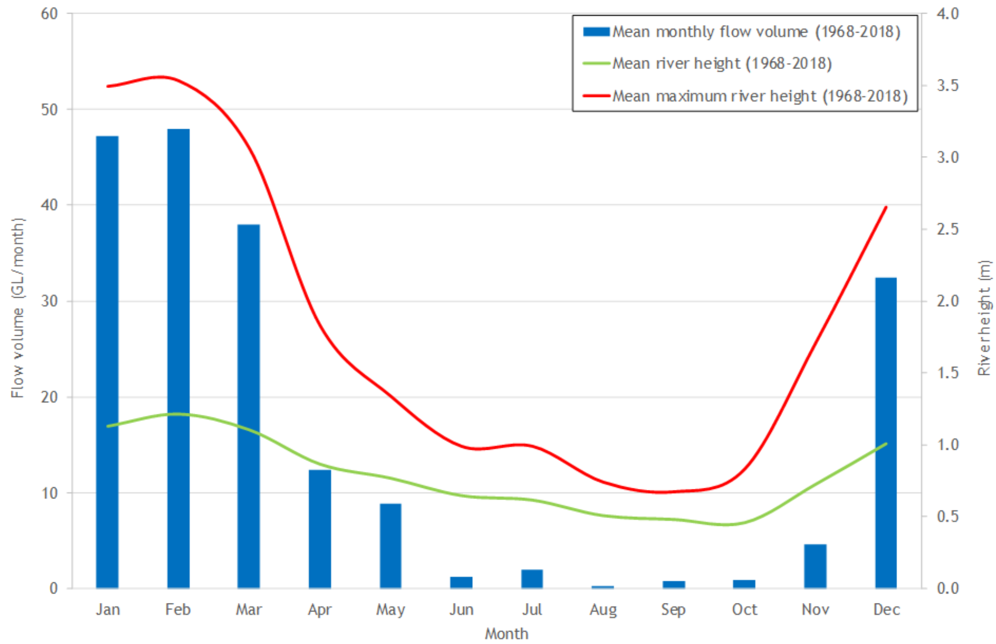


Figure 4.12 - Flow volume and river height in the Isaac River at Deverill

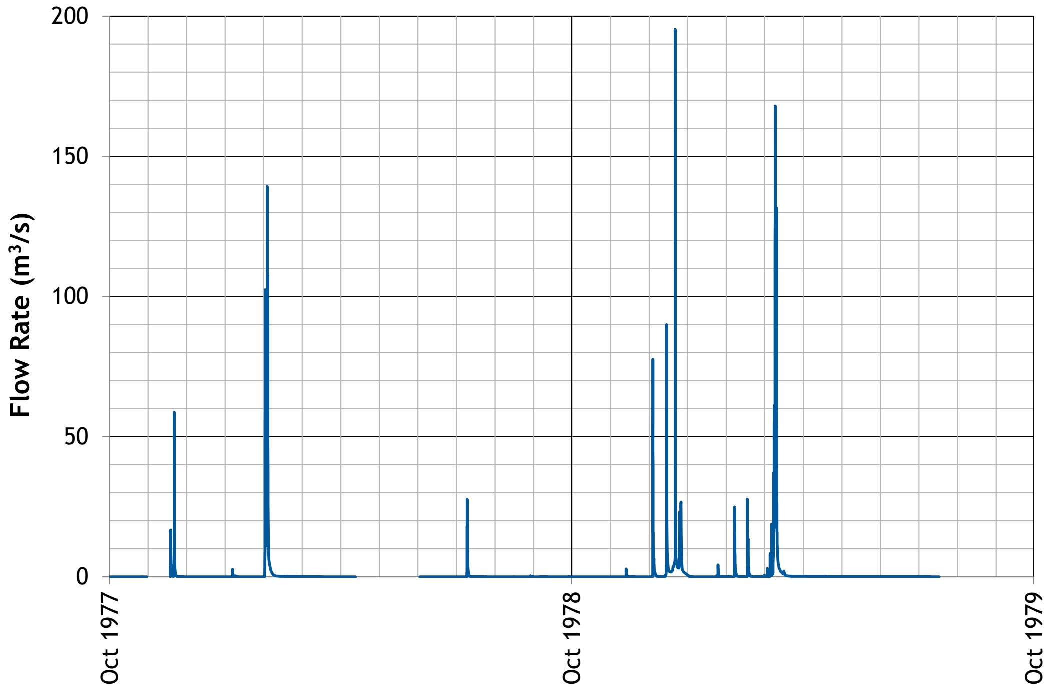


Figure 4.13 - Sample flow sequence - Phillips Creek at Tayglen 1977 - 1979

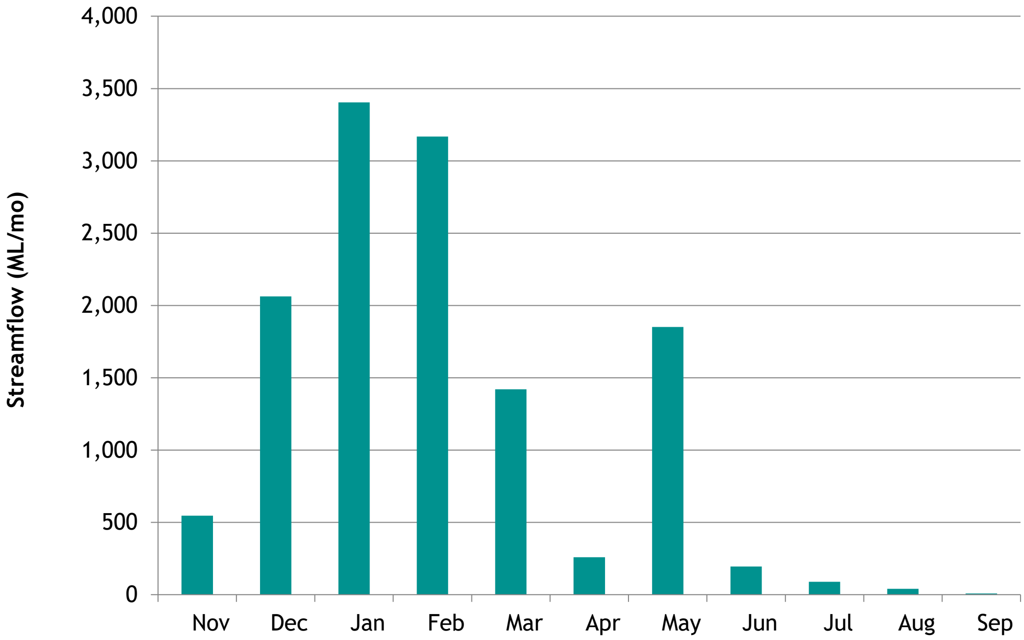


Figure 4.14 - Measured mean monthly streamflow - Phillips Creek at Tayglen 1968-1988

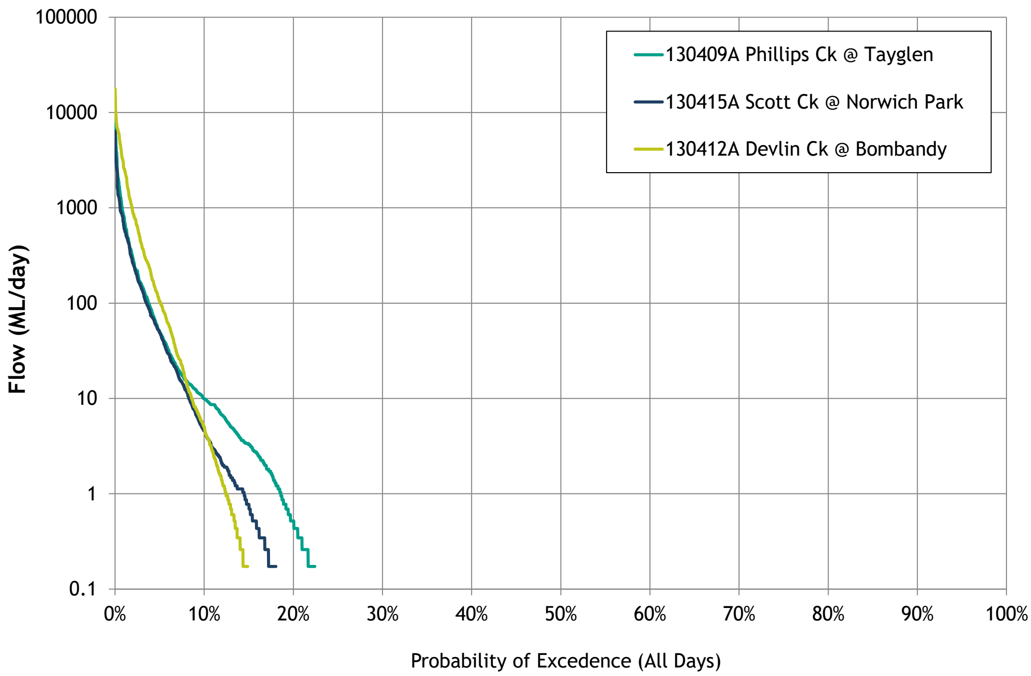


Figure 4.15 - Recorded frequency curves at nearby DNRME gauges (no flow days included)

4.5 WATER QUALITY

4.5.1 Regional Isaac River water quality

Publicly available regional water quality data for the Isaac River at the Deverill Gauging Station has been analysed for median results and are displayed in Table 4.3. This site was selected as complete datasets (i.e. individual sample analysis results) are publicly available, as opposed to summary data only.

DNRME has collected daily electrical conductivity (EC) data at the Isaac River at Deverill gauge. The Deverill gauge is located upstream of the point where Boomerang Creek drains into the Isaac River. The gauge would therefore be representative of water quality in the receiving waters of the Isaac River from the Project.

Figure 4.16 presents a time history of recorded instantaneous EC and stream flow for the Isaac River at Deverill gauging station. Figure 4.17 details the relationship between instantaneous flow and EC at the Isaac River at Deverill gauging station. The data collected by DNRME at the Deverill gauging station spans the period from 2011 to 2018 and indicates:

- The EC values for high flows greater than 200 m^3/s are generally below the high flow WQO EC of 250 µs/cm.
- The EC of instantaneous flows below 100 m^3/s vary significantly from 50 µS/cm to 1,870 µS/cm with many recorded values exceeding the low flow WQO EC of 720 µS/cm but are below the Peak Downs EA receiving waters trigger value of 2,000 µS/cm.
- The mean daily EC has exceeded the low flow WQO on a total of 23 days over this period and all of these days experienced some flow (not stagnant flow).
- The stream flows are highly ephemeral with baseflows ceasing within a few days or weeks of a runoff event, or at least flowing below the top of the sandy bed.

Table 4.3 – Water quality median data in the Isaac River at Deverill

Parameter	Unit	Isaac River at Deverill	WQO default guideline value (refer Table 3.1)
Aluminium - Total	mg/L	-	< 5 (stock)
Aluminium - Dissolved	mg/L	0.05	< 0.055 (aquatic)
Boron - Total	mg/L	0.06	< 5 (stock)
Calcium - Dissolved	mg/L	16	-
Chloride - Total	mg/L	32	-
Copper - Dissolved	mg/L	0.03	< 0.0014 (aquatic)
EC	µS/cm	261	< 720 (baseflow) < 250 (high flow)
Filterable Reactive Phosphorus	µg/L	0.35	< 20 (aquatic)
Fluoride - Total	mg/L	0.14	< 2 (irrigation)
Iron - Dissolved	mg/L	0.06	-
Manganese - Dissolved	mg/L	0.01	< 1.9 (aquatic)
Nitrate - Total	mg/L	1.4	-
Nitrogen – Total	µg/L	0.76	< 500 (aquatic)
pH	-	7.6	6.5-8.5 (aquatic)
Phosphorus - Total	µg/L	0.35	< 50 (aquatic)
Potassium - Total	mg/L	4.55	-
Sodium - Total	mg/L	22	< 30 (drinking water)

Parameter	Unit	Isaac River at Deverill	WQO default guideline value (refer Table 3.1)
Sulfate - Total	mg/L	10.9	< 25 (aquatic)
Total Alkalinity	mg/L	78	-
Total Dissolved Solids	mg/L	155	< 2,000 (stock)
Total Suspended Solids	mg/L	135	< 55 (aquatic)
Turbidity	NTU	247	< 50 (aquatic)
Zinc - Dissolved	mg/L	0.01	< 0.008 (aquatic)

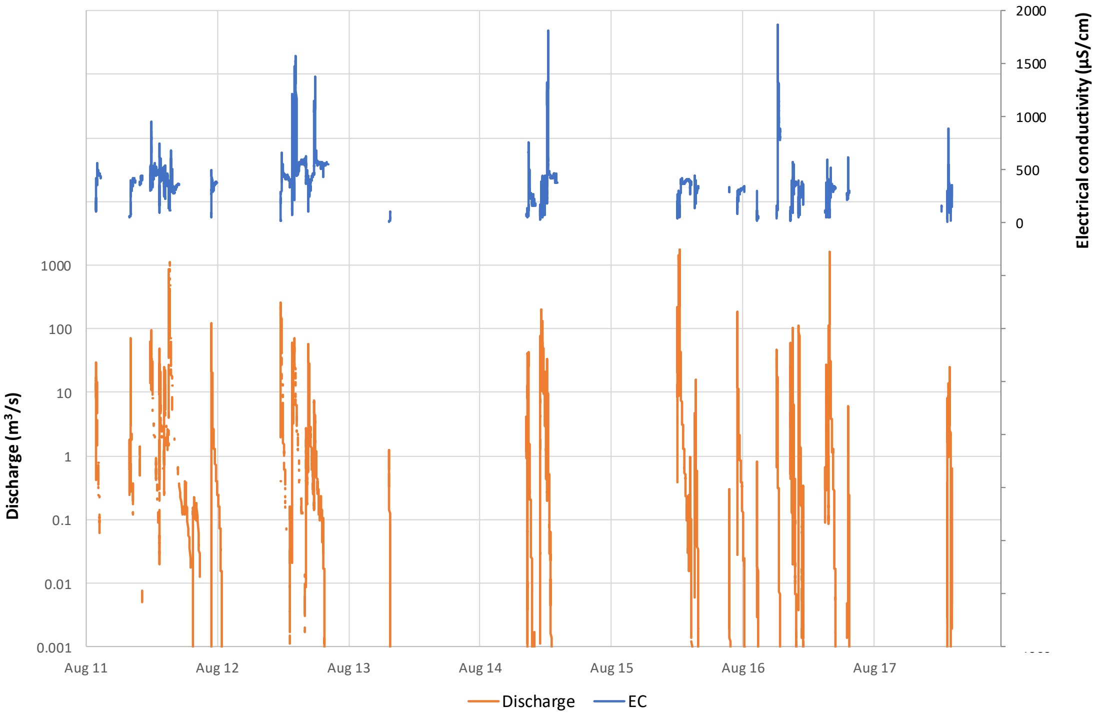


Figure 4.16 - Electrical Conductivity and Flow (Isaac River at Deverill Gauge)

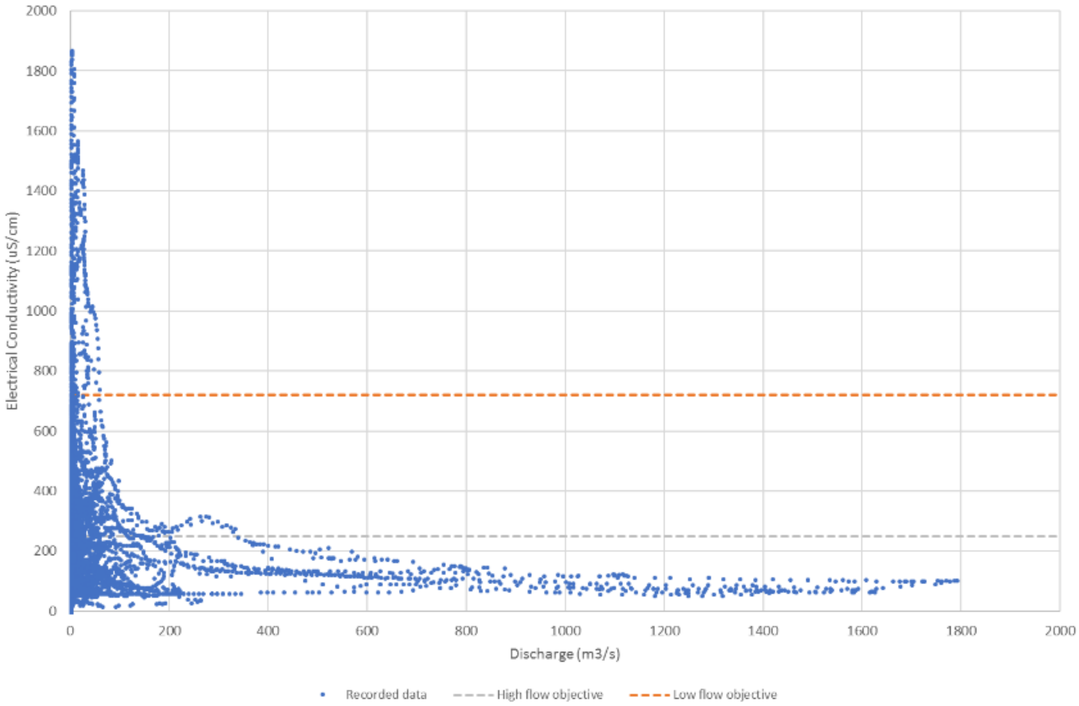


Figure 4.17 - Flow vs Electrical Conductivity (Isaac River at Deverill Gauge)

4.5.2 Local water quality

Water quality sampling has been undertaken as a component of the baseline surface water quality sampling in early 2020. Analyses for a comprehensive range of physio-chemical parameters were completed at the monitoring sites.

The baseline monitoring locations are shown in Figure 4.18 and the full suite of baseline monitoring undertaken for the broader Project area is presented in Appendix A. Monitoring results from the sites most relevant to the Project are outlined in Table 4.4.

Review of Table 4.4 shows that certain baseline water quality values surrounding the Project do not meet the WQO for the region, these include:

- Suspended solids;
- Turbidity;
- Sulfate as SO_4;
- Aluminium (filtered);
- Copper (filtered);
- Aluminium (total);
- Iron (total);
- Ammonia as N;
- Total Nitrogen as N;
- Total Phosphorous as P;
- Reactive Phosphorous as P; and
- Dissolved Oxygen.

To establish local water quality objectives, the Queensland Water Quality Guidelines require that with 3 or more reference sites, 12 samples are collected over at least 12, but preferably 24 months. Vitrinite has established more than 3 reference sites, which will continue to be either upstream reference sites or reference sites until mining commences. However, data collection is limited to periods of flow in an ephemeral system. Therefore, reliance is placed on regional water quality data to establish WQOs until there is sufficient data to develop local water quality objectives.

Table 4.4 - Baseline water quality monitoring

Parameter	Unit	VSW-4 4/03/2020	VSW-6 4/03/2020	VSW-7 4/03/2020	VSW-5 18/03/2020	VSW-4 19/03/2020	VSW-6 19/03/2020	VSW-7 19/03/2020	VESW-4 19/03/2020	WQO (see Table 3.1)
pH Value	-	7.16	7.12	7.57	6.78	7.11	6.89	7.57	7.13	6.5 - 8.5
Sodium Adsorption Ratio	-	0.61	0.26	0.34	0.68	0.37	0.77	0.42	0.51	-
Electrical Conductivity	µS/cm	81	46	106	44	74	80	124	129	> 720 (baseflow) > 250 (high flow)
Total Dissolved Solids (Calc.)	mg/L	53	30	69	29	48	52	81	84	> 2,000
Suspended Solids (SS)	mg/L	296	379	1200	77	2050	386	51	168	> 55
Turbidity	NTU	1590	503	1240	339	850	701	346	419	> 50
Total Hardness as CaCO3	mg/L	18	12	40	7	22	16	51	18	> 150
Hydroxide Alkalinity as CaCO3	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	-
Carbonate Alkalinity as CaCO3	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	-
Bicarbonate Alkalinity as CaCO3	mg/L	33	6	49	11	26	21	65	45	-
Total Alkalinity as CaCO3	mg/L	33	6	49	11	26	21	65	45	-
Sulfate as SO4 - Turbidimetric	mg/L	4	2	<1	2	6	4	1	2	> 25
Chloride	mg/L	6	3	6	5	5	9	6	7	-
Calcium	mg/L	4	3	8	1	4	3	9	4	-
Magnesium	mg/L	2	1	5	1	3	2	7	2	-
Sodium	mg/L	6	2	5	4	4	7	7	5	> 30
Potassium	mg/L	3	3	2	3	4	4	2	5	-
Dissolved Metals										
Aluminium	mg/L	0.26	0.2	0.07	1.11	0.35	0.22	0.02	0.09	> 0.055
Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.004	> 0.024
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.0002
Chromium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.001

Cobalt	mg/L	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.006	-
Copper	mg/L	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	> 0.0014
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.0034
Manganese	mg/L	0.125	0.04	0.066	0.011	0.192	0.026	0.002	0.295	> 1.9
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Nickel	mg/L	0.001	<0.001	0.001	<0.001	0.002	0.001	0.001	0.003	> 0.011
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.005
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Uranium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.1
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.5
Zinc	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	> 0.008
Boron	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	> 0.37
Iron	mg/L	0.18	0.13	0.15	0.63	0.33	0.21	0.11	3.02	-
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.00006
					Total Metals					
Aluminium	mg/L	22.8	6.62	21.8	7.97	16.5	10.3	9.22	6.36	> 5
Arsenic	mg/L	0.005	0.003	0.003	0.002	0.005	0.005	0.002	0.005	> 0.5
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.01
Chromium	mg/L	0.02	0.006	0.026	0.005	0.017	0.008	0.011	0.004	> 1
Cobalt	mg/L	0.014	0.003	0.013	0.003	0.018	0.005	0.004	0.01	> 0.1
Copper	mg/L	0.023	0.008	0.016	0.006	0.02	0.009	0.005	0.012	> 1
Lead	mg/L	0.032	0.009	0.022	0.007	0.028	0.011	0.006	0.01	> 0.1
Manganese	mg/L	0.477	0.112	0.334	0.077	0.804	0.13	0.108	0.383	> 10
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.05
Nickel	mg/L	0.028	0.006	0.022	0.006	0.025	0.012	0.008	0.009	> 1
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.02
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Uranium	mg/L	0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	-
Vanadium	mg/L	0.03	<0.01	0.03	<0.01	0.02	0.01	0.01	<0.01	-

Zinc	mg/L	0.058	0.022	0.037	0.024	0.059	0.031	0.022	0.031	> 5
Boron	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	> 5
Iron	mg/L	27.7	8.42	25.7	7.88	21.8	12.9	7.86	12.5	> 10
Mercury	mg/L	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.002
Fluoride	mg/L	0.2	<0.1	0.2	<0.1	0.1	0.1	0.2	0.1	< 2
Ammonia as N	mg/L	0.11	0.07	0.11	0.1	0.09	0.21	0.12	6.95	> 0.02
Nitrite as N	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.21	-
Nitrate as N	mg/L	0.02	0.02	0.04	0.14	<0.01	0.08	0.03	0.1	-
Nitrite + Nitrate as N	mg/L	0.02	0.02	0.04	0.14	<0.01	0.09	0.07	0.31	-
Total Kjeldahl Nitrogen as N	mg/L	1.8	0.8	0.6	1.3	2.6	2	1.1	9.9	-
Total Nitrogen as N	mg/L	1.8	0.8	0.6	1.4	2.6	2.1	1.2	10.2	> 0.5
Total Phosphorus as P	mg/L	0.43	0.19	0.18	0.12	0.58	0.37	0.1	0.41	> 0.05
Reactive Phosphorus as P	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.02
Total Anions	meq/L	0.91	0.25	1.15	0.4	0.78	0.76	1.49	1.14	-
Total Cations	meq/L	0.7	0.4	1.08	0.38	0.72	0.72	1.38	1.33	-
Chlorophyll a	mg/m^3	<12	<4	<10	-	-	<8	<3	-	-
Dissolved Oxygen	mg/L	6.4	6.8	7.6	7.5	7.1	5.9	6.7	4.9	< 4

Note: Recorded exceedances of the WQOs have been shaded in grey.

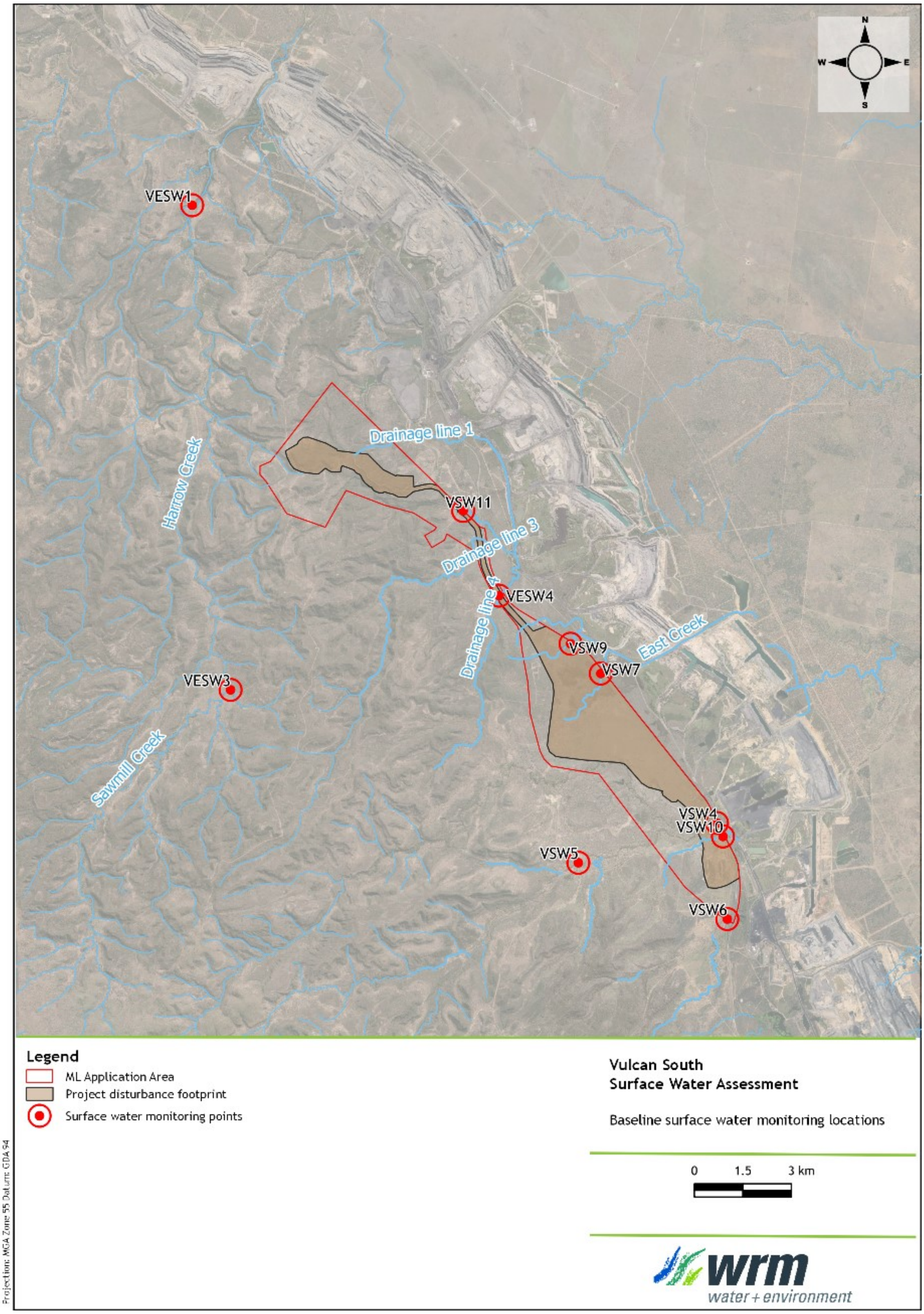


Figure 4.18 – Baseline surface water monitoring locations

4.6 SOIL CHARACTERISTICS

AARC Environmental Solutions Pty Ltd (2022) completed a *Soil and Land Suitability Assessment* (SLSA) for the Project and surrounds. To characterise the soils at the site, AARC collected 42 detailed soil profiles and analysed 12 laboratory samples from the site vicinity.

The area surrounding the Project is dominated by clastic sedimentary rocks of marine and lacustrine origin, including sandstones, mudstones, siltstones and coal. Surface geology at the site includes Quaternary clay, silt, sand, gravel and soil with colluvial and residual deposits, as well as late Tertiary to Quaternary poorly consolidated sand, silt, clay, minor gravel and high-level alluvial deposits (AARC, 2022).

4.6.1 Soil management units

AARC mapped the Soil Management Units (SMUs) across the site using the methodologies specified in the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al*, 2008) based on soil morphology, parent material and land attributes.

A description of each SMU found within the Project area is outlined in Table 4.5. The majority of the site consists of the Limpopo SMU, the Orange SMU and the Zambezi SMU.

Table 4.5 – Soil Management Units surveyed on site (AARC, 2022)

Soil Management Unit	Description
Crocodile	A shallow rocky soil unit associated with hill slopes and plateaus. Soil textures grade from loam at the surface, to loamy sands with depth; often containing rock material with little to no pedologic development throughout the solum.
Limpopo	The Limpopo unit is a brown texture-contrast soil. Soil textures predominantly grade from sands to clay sands in the surface soils to light clays in deeper horizons.
Zambezi	A predominantly grey coloured texture contrast soil with surface soils consisting of sands, increasing in clay content in deeper horizons. Lower horizons display diffuse orange to yellow mottles.
Orange	A dark cracking clay associated with the flat grassy plains in the middle of the Project area. The predominant textures of soils within this unit range from light clays in surface soils to light medium clays in deeper horizons.
Sabie	A dark-coloured texture contrast soil with surface soils consisting of sands, increasing in clay content in deeper horizons. Lower horizons display red to orange mottles.
Komati	A dark brown coloured soil unit displaying vertic properties. Soil textures predominantly grade from light to medium clays with calcareous segregations occurring within the deeper horizons.
Fish	A predominantly sandy soil unit occurring on the flats of the southeastern end of the Project area. Soil textures grade from loamy sand at the surface, to clay and silty sands with depth.
Kei	A brown coloured soil unit occurring on the flats of the southeastern end of the Project area. Soil textures grade from clayey to loamy sands at the surface, to medium clay with depth and orange to yellow mottles present in the deeper horizons.

4.6.2 Sodic and dispersive soils

Sodic soils contain large concentrations of Sodium relative to other cations. These soils have a degree of dispersivity and can accelerate erosion.

AARC (2022) identified areas of high sodicity on site through the measurement of the Exchangeable sodium percentage and Emerson Class of surveyed soils. The Crocodile and Kei SMU were identified as having a low risk of dispersion and were not identified as being sodic.

For the remaining SMUs, AARC (2019) identified the depth horizons with sodic properties as follows:

- Fish SMU: Sodic below a depth of 0.2 m;
- Komati SMU: Sodic below a depth of 0.2 m;
- Limpopo SMU: Sodic below a depth of 0.5 m;
- Orange SMU: Sodic below a depth of 0.2 m;
- Sabie SMU: Sodic below a depth of 0.2 m; and
- Zambezi SMU: Sodic below a depth of 0.5 m.

To control erosion from sodic dispersive soils, soils will be selectively handled and managed where required, as per the ameliorative measures outlined by AARC (2019), and further detailed in the *Vulcan South Progressive Rehabilitation and Closure Plan* (METServe, 2022).

5 Proposed surface water management strategy and infrastructure

5.1 TYPES OF WATER GENERATED ONSITE

Land disturbance associated with mining has the potential to adversely affect the quality of surface runoff in downstream receiving waters through increased sediment loads. In addition, runoff from active mining areas (including coal stockpiles, etc.) may have increased concentrations of salts and other pollutants when compared to natural runoff. The proposed strategy for the management of surface water at the Project is based on the separation of water from different sources based on anticipated water quality.

Definitions of the types of water generated within the Project are shown in Table 5.1.

5.2 PROPOSED WATER MANAGEMENT INFRASTRUCTURE

The operational period of mining is expected to run for eight years from 2023 to 2031.

Figure 1.3 to Figure 1.10 show indicative locations of the key features of the mine, including infrastructure related to the management of water on the Project site for three different stages of mining (Stages 1, 2 and 3). The main components of water-related infrastructure include:

- diverted water drains, bunds and drainage diversions to divert runoff from undisturbed catchments around areas disturbed by mining;
- flood protection levees along the southern side of the Vulcan North pit extent, along the western and southeastern sides of the Vulcan Main pit, and around the Vulcan South pit;
- sediment dams and drains to collect and treat runoff from waste rock emplacement areas; and
- mine-affected water drains and dams to store water pumped out of the open cut mining areas and to collect runoff from the infrastructure areas.

The catchment areas of each of the mine water storages, as well as the assumed landuse contributing to each catchment are also shown in Figure 1.3 to Figure 1.10.

Details of proposed water storages, including indicative storage sizes and pumping rules are provided in Section 6.4.

5.3 WATER MANAGEMENT STRATEGY OVERVIEW

The water management system for the Project aims to protect the identified downstream EVs and comprises the following key objectives:

- separate diverted water from mine affected water to ensure that up-catchment water and mine affected water do not mix wherever practicable;
- capture of mine affected runoff (e.g. mine industrial area, haul road/ROM pad runoff), storage and priority reuse as mine water supply;
- divert up-catchment water runoff from upstream catchments around the active mining area;
- limit external catchment runoff draining into pits;

- manage sediment from disturbed catchment areas (e.g. out-of-pit waste rock emplacements, cleared/pre-strip areas) by using erosion and sediment control (ESC) measures prior to release offsite;
- reuse onsite water (e.g. mine affected water) where possible to support mine operational water demands (and therefore limit mine affected water inventories under normal operating conditions); and
- manage any mine affected water releases to the receiving waters to meet environmental release conditions (not currently proposed).

The Project water management system will include mine water drainage, mine water storages, sediment dams, pit water storages and flood protection works (i.e. levees). Further details of the mine water management system are provided in Section 6.4.

Table 5.1 – Types of water managed within the Project

Water type	Definition
Mine affected water	In accordance with the DES *Guideline Model Mining Conditions* (2017), mine affected water means the following types of water: i) pit water, tailings dam water, processing plant water ii) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity iii) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water iv) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated v) groundwater from the mine dewatering activities vi) a mix of mine affected water (under any of paragraphs i to v) and other water
Surface water	Surface water runoff from areas that are disturbed by mining operations (including out-of-pit waste rock emplacements). This runoff does not come into contact with coal or other carbonaceous material and may contain high sediment loads but does not contain elevated levels of other water quality parameters (e.g. electrical conductivity, pH, metals, metalloids, non-metals). This runoff must be managed to ensure adequate sediment removal prior to release to receiving waters.
Diverted water	Surface runoff from areas unaffected by mining operations. Diverted catchment water includes runoff from undisturbed areas and fully rehabilitated areas.
Raw water	Untreated water that has not been contaminated by mining activities.
Potable water	Treated water suitable for human consumption.
External water	Water supplied from a source that is external to Project area to make up water shortfalls for onsite water demands when site water sources cannot meet demand.

5.4 DIVERTED RUNOFF WATER MANAGEMENT

5.4.1 Flood levees

A number of flood levees are proposed for the Project, as shown on Figure 1.3 to Figure 1.10 including:

- Vulcan North levee on the southern edge of the Vulcan North pit to be constructed in Stage 1;
- Vulcan Main levee 2 on the western edge of the Vulcan Main pit to be constructed in Stage 2 and Vulcan Main levee 1 on the southern edge of the Vulcan Main pit to be constructed in Stage 3; and
- Vulcan South levee around the full extent of the Vulcan South pit to be constructed in Stage 3.

The flood levees will be regulated structures under the EP Act and will therefore be required to have a crest above the 0.1% AEP event. An assessment of the levees against the requirements of the EP Act is given in Section 8.5.4.

5.4.2 Diverted water drains, bunds and dams

The water management system has been designed to divert undisturbed catchments around mining operations wherever practicable.

Three diverted water drains are proposed as part of the Project (Figure 1.3 to Figure 1.10):

- Drainage diversion 2 will be constructed in Stage 1 and will divert a catchment of approximately 105 ha away from the Vulcan North pit and dam DD2. This drainage diversion will collect an undisturbed catchment to the west of the Vulcan North pit and associated haul road. This drainage diversion will divert a portion of Drainage line 6 and discharge under a haul road to Drainage line 7 (which is a tributary of East Creek).
- Drainage diversion 3 will be constructed in Stage 3 and will divert a portion of Drainage line 8 around the Vulcan South pit. This drainage diversion will collect an undisturbed catchment of approximately 570 ha and discharge to Hughes Creek.
- A minor drainage diversion diverts water southward around the Vulcan Main levee 1, to discharge into Hughes Creek.

A number of diverted water bunds are proposed in the vicinity of the three open cut pits, as shown on Figure 1.3 to Figure 1.10. These bunds will collect runoff from minor catchments (i.e. smaller than 15 ha) where a drain is not deemed necessary and divert these catchments around mining operations.

Dam DD2 will be constructed in Stage 1 to collect water from an undisturbed catchment (catchment area of approx. 46.5 ha) to the west of the Vulcan North pit, between the pit and the haul road. In addition, DD2 may potentially provide some level of flood protection for the Vulcan North pit.

Dam HWD2 will be constructed during highwall operations north of the highwall central haul road (Figure 1.9) to collect an undisturbed catchment north of the highwall central bench. The dam will collect an undisturbed catchment of approximately 34 ha.

Additional temporary drainage management measures including bunds, drains and re-contouring adjacent pit progression may be constructed as required to prevent runoff and flood waters from flowing into the open pits. These drainage management measures will be mined through as the pits progress. It is expected that temporary drainage measures will be designed to convey at least a 5% AEP (1 in 20-year ARI) flow event.

5.5 SURFACE WATER MANAGEMENT

Sediment water containment (runoff from spoil and incomplete rehabilitated areas) will be managed in accordance with the site Erosion and Sediment Control Plan (ESCP). The ESCP will adopt the three cornerstones of ESC:

- Drainage control - prevention or reduction of soil erosion caused by concentrated flows and appropriate management and separation of the movement of diverted and surface water through the area of concern.
- Erosion control – prevention or minimisation of soil erosion (from dispersive, nondispersive or competent material) caused by rain drop impact and exacerbated overland flow on disturbed surfaces.
- Sediment control – trapping or retention of sediment either moving along the land surface, contained within runoff (i.e. from up-slope erosion) or from windborne particles.

The Project will require a combination of the three control measures to effectively manage sediment and erosion at the site.

5.5.1 Sediment dam locations and sizing

Catchment runoff from both active and newly rehabilitated overburden dumps at the Project will be managed in accordance with an ESCP. The sediment dams have been sized in accordance with the IECA method (IECA, 2008), and have been based on the following design standards and methodology:

- 'Type D' sediment basins with a depth of 3m;
- total sediment basin volume = settling zone + sediment storage volume. The sediment storage volume is the portion of the basin storage volume that progressively fills with sediment until the basin is de-silted. The settling zone is the minimum required free storage capacity that must be restored within 5 days after a runoff event;
- sediment basin settling volume based on 85th percentile 5-day duration rainfall with an adopted volumetric event runoff coefficient for disturbed catchments of 0.45 (Group C soils – loamy clay); and
- solids storage volume = 50% of settling zone volume.

The adopted design standard does not provide 100% containment for runoff from disturbed areas. Hence, it is possible that overflows will occur from sediment dams several times during a wet season if rainfall exceeds the design standard.

A summary of the conceptual sediment dam capacities and surface areas (based on a depth of 3 m) is provided in Table 5.2.

Table 5.2 - Proposed sediment dams

Storage name	Indicative commissioning year	Max. catchment area (ha)	Total volume required (ML)	Dam surface area (ha)	5-day dewatering rate (ML/d)	Overflows to
East Creek Out of pit spoil						
SD9	2023	19.0	4.2	0.19	0.56	Drainage line 7
SD10	2023	15.8	3.5	0.15	0.46	
SD15	2023	18.1	4.0	0.18	0.53	Drainage line 5
East Creek In pit spoil						
SD11	2023	32.6	7.1	0.32	0.95	Drainage line 6
SD12	2023	23.3	5.1	0.23	0.68	Drainage line 7
SD13	2023	10.5	2.3	0.10	0.31	Drainage line 6
SD14	2023	15.9	3.5	0.16	0.47	
Hughes Creek In pit spoil						
SD17	2023	9.4	2.1	0.09	0.27	Hughes Creek
SD18	2023	43.7	9.6	0.43	1.28	
SD19	2025	105.0	23.0	1.02	3.07	Hughes Creek
SD20	2028	10.3	2.3	0.10	0.30	Hughes Creek
SD21	2028	12.7	2.8	0.12	0.37	
SD22	2028	22.6	5.0	0.22	0.66	
SD23	2028	34.5	7.6	0.34	1.01	Hughes Creek
SD24	2028	5.8	1.3	0.06	0.17	
SD25	2028	8.5	1.9	0.08	0.25	
SD26	2028	39.5	8.7	0.38	1.15	
SD29	2028	15.5	3.4	0.15	0.45	
SD30	2028	1.1	0.2	0.01	0.03	
Hughes Creek Out of pit spoil						
SD16	2023	148.8	32.6	1.45	4.35	Hughes Creek
SD27*	2028	15.5	3.4	0.15	0.45	
SD28	2028	32.4	7.1	0.32	0.95	Barrett Creek
Highwall dams						
HWD1	2023	10.0	2.2	0.1	0.29	Drainage line 2

For modelling purposes, the sediment dams have been grouped into four discrete nodes based upon the type of sediment they primarily collect and the waterway which they overflow to, as follows:

1. East Creek In pit spoil
2. East Creek Out of pit spoil
3. Hughes Creek In pit spoil

4. Hughes Creek Out of pit spoil

The sediment dams have been grouped into the above nodes in Table 5.2 and Figure 6.1.

Runoff from haul roads and access roads will be managed through the sites ESCP, which will be developed prior to the commencement of construction activities.

Management of runoff from these roads will be a combination of drainage control, erosion control and sediment control measures. The design of the measures will be undertaken during detailed design, but will likely include some of the following measures:

- Catch drains;
- Check dams;
- Grass swales;
- Rock lining/protection;
- Road surface gravelling;
- Sediment traps; and
- Sediment basins.

The sizing of haul/access road sediment basins will be undertaken in accordance with the Best Practice Erosion and Sediment Control Guidelines (IECA, 2008). Any runoff captured within the sediment basins will be released to the downstream environment in accordance with the site ESCP or pumped back into the mine water system.

5.6 MINE AFFECTED WATER MANAGEMENT

5.6.1 Mine affected water dams

Table 5.3 shows the capacities of the proposed mine affected water dams at the Project. The dam sizes have been determined based on the water balance model (see Section 7) to ensure that the open cut pits can be adequately dewatered and limit the spill risk to the receiving waters.

The adopted full storage volumes (FSVs), surface areas, operating volumes (OVs) and max operating volumes (MOVs) were refined using the water balance model and available space from site mapping. MWD8 and MWD9 have been designed to keep the pit dewatered for as long as practical. The CHPP mine water dams (MWD6 & MWD7) have been sized to limit the risk of spills to the receiving waters.

Vitrinite are not currently planning any controlled mine affected water releases to the environment from the mine water dams. Therefore, under normal operating conditions any releases from mine affected water dams to the receiving waters would be uncontrolled releases. As outlined above, the water management system has been optimised to reduce the risk of this occurrence and this risk has been assessed in Section 7.3.7.

Notwithstanding the above, during future operations and depending upon future climate conditions, controlled mine affected water releases may be required to manage mine water inventories stored within the mine water system. If required, these discharges would be performed in accordance with the mine affected water release conditions within a future Project EA.

To limit the risk of uncontrolled discharges from the mine water storages, OVs have been set for these water storages (as shown in Table 5.3) as follows:

- MWD8 and MWD9 have a maximum operating volume (MOV) of 131.6 ML and 25.0 ML respectively. When the water inventory in these dams exceeds its MOV, all transfers to these dams (i.e. pit dewatering and mine water transfers) cease.
- MWD6 and MWD7 have OVs. When the water inventory in these dams exceeds their respective OVs, these storages commence dewatering to MWD9.

Table 5.3 - Proposed mine affected water dams

Storage	FSV (ML)	OV (ML)	MOV (ML)	FSV surface area (ha)	FSV water depth (m)	Adopted dewatering rate (ML/d)
MWD6	73.9	64.3	-	1.97	5	2.15
MWD7	56.1	48.8	-	1.50	5	2.15
MWD8	159.8	-	131.6	2.92	7	-
MWD9	30.0	-	25.0	1.33	3	4.32

5.6.2 Preliminary consequence assessment

A preliminary consequence assessment of the mine affected water dams using the *Manual for assessing consequence categories and hydraulic performance of structures* (DES, 2016) suggests that the consequence category of mine water dams will be low. This is based on the following:

- The expected harm to humans consequence category is low. MWD6, MWD7 and MWD9 are small dams and do not have a significant constructed wall (less than 3 m) that could fail. Although MWD8 has a significant volume it is not located adjacent to or upstream of any planned buildings, other places of occupation or public infrastructure (e.g., roads or rail) that would lie within the failure impact zone. MWD8 and MWD9 would fail away from populated areas towards Hughes Creek. The CHPP Dams (MWD6 and MWD7), although located adjacent the CHPP area, are located at a lower elevation than the workshop area and would not impact the CHPP area in the event of a dam break. The downstream drainage structures (Figure 4.10) under Saraji Road and the Norwich Park branch railway are designed to service a significant undisturbed catchment associated with Hughes Creek (i.e. greater than 10,000 ha) and would therefore be suited to withstand any failure from the Project mine water dams. The downstream receiving waters are unlikely to be used for water supply.
- The expected harm to general environment consequence category is low. The downstream receiving waters are heavily modified and have been diverted through the Peak Downs and Saraji operations. Controlled releases of mine water are not proposed. Further, groundwater assessments predict there will negligible groundwater to manage in the mine water management system and dump runoff quality is expected to be of a suitable quality to release to the receiving waters (following sediment removal). Hence any potential releases of contaminants to the receiving waters from mine water dams are unlikely to have an adverse effect.
- The expected general economic loss or property damage consequence category is low. This is for similar reasons given for the expected harm to humans consequence category and remedial costs would likely be less than $1 million.

5.6.3 Pit dewatering rates

The timeframes required to dewater the pits will be governed by the available pumping capacity. For this assessment, the pit dewatering rates within the model have been nominated as follows:

- Vulcan North pit dewaters to MWD8 at 100 L/s during Stage 1;
- Vulcan Main pit dewaters to MWD8 at 100 L/s during Stage 1, to MWD8 and MWD9 at 100 L/s during Stage 2 - 3; and

- Vulcan South pit dewaters to MWD8 and MWD9 at 100 L/s during Stage 3.

Alternative pumping capacities based upon the required duration to dewater the pits following a 1% AEP 24 hour storm event (assuming a volumetric rainfall/runoff coefficient of 1.0) are outlined in Table 5.4.

Table 5.4: 1% AEP 24 hour pit dewatering rates

Stage	Dewatering duration (days)	Pit dewatering rate (L/s)		
		Vulcan North	Vulcan Main	Vulcan South
1	5	81	150	-
	10	41	75	-
	30	14	25	-
2	5	-	306	-
	10	-	153	-
	30	-	51	-
3	5	-	140	97
	10	-	70	48
	30	-	23	16

The alternative dewatering pump rates shown above may be adopted by site depending upon available pumping infrastructure.

5.7 RELEASE OF WATERS TO THE RECEIVING WATERS

There are four key mechanisms through which water from the Project can enter the receiving waters:

- dewatering overflows from sediment dams;
- overflows from mine affected water dams and the open cut pits;
- runoff from diverted water catchments; and
- runoff from rehabilitated catchments.

Sediment dam/mine affected overflows are a point source. Model predictions of volumes from sediment dam and mine affected dam overflows are provided in Section 7.3.7. Runoff from rehabilitated catchments is likely to be both a point and diffuse source of water to the receiving environment. When a sediment dam catchment is completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving environment.

5.8 SEWAGE AND EFFLUENT DISPOSAL

Sewage will be trucked offsite by registered waste transport contractors.

5.9 POST-CLOSURE CONDITIONS WATER MANAGEMENT

Figure 1.11, Figure 1.12 and Figure 1.13 show the conceptual final landform drainage plan for the Vulcan North, Vulcan Main and Vulcan South mining areas respectively under post-closure conditions. The final landform plan has been developed with an aim to use water infrastructure constructed during operations. The post-closure layout shown are conceptual only and may be updated should the mine plan and final landform plans change over the mine life.

The key features of the final landform include the following:

- No final voids are proposed as part of the final landform. The open cut pits will be backfilled with overburden material;
- Final landform batter slopes will be 1(V):6(H);
- Contour banks will be constructed on batters to limit topsoil erosion until vegetation has been suitably established;
- Drainage structures will be constructed to direct runoff from disturbed areas to sediment dams;
- The plateaus include proposed drains and drop structures to drain the top of the landform to natural ground level;
- Mine water dams will be decommissioned following rehabilitation of infrastructure areas;
- Drainage line 6 and Drainage line 8 will be reinstated through the Vulcan North and Vulcan South final landforms respectively; and
- The Hughes Creek floodplain will be reinstated through the Vulcan Main and Vulcan South landforms.

When a sediment dam catchment is completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with EA release conditions, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving waters.

When Drainage line 6 is rehabilitated, DD2 will be decommissioned. DD2 will remain until this time to allow in-stream vegetation to establish before receiving upstream catchment flows.

6 Water balance model configuration

6.1 OVERVIEW

A computer-based operational simulation model (OPSIM) was used to assess the dynamics of the mine water balance under conditions of varying rainfall and catchment conditions throughout the development of the Project. The OPSIM model dynamically simulates the operation of the water management system and keeps complete account of all site water volumes and representative water quality on a daily time step.

The model has been configured to simulate the operations of all major components of the water management system. The simulated inflows and outflows included in the model are given in Table 6.1.

Table 6.1 - Simulated inflows and outflows to the water management system

Inflows	Outflows
Direct rainfall on water surface of storages	Evaporation from water surface of storages
Catchment runoff	Haul road dust suppression demand
Moisture stored within the ROM coal	Potable water demand
Groundwater inflows to the open cut pit	Moisture stored within product coal and rejects
External water pipeline	TLO demand
Trucked potable water	Dam overflows

6.2 SIMULATION METHODOLOGY

The Project water management system will change over the eight year mine life, including changes in catchment areas, production profile and site water demands. To represent the evolution of the mine layout over time, the Project was modelled in three discrete stages. Three representative years of the mine plan have been selected to reflect the average conditions over the mine stage.

The modelled mining stages are summarised in Table 6.2.

Table 6.2 - Representative mine stages adopted for assessment and modelling purposes

Mine stage	Representative year	Applied range of mine life	Stage duration
Stage 1	2024	1/1/2023 – 1/1/2025	2 years
Stage 2	2027	1/1/2025 – 1/1/2028	3 years
Stage 3	2031	1/1/2028 – 1/1/2031	3 years

Over the mine stages, the three mine pits progress their active status within the water balance model as follows:

- Inactive: Mining in the pit has either not yet commenced in the mine plan or has been completed and backfilled. For modelling purposes, the pit does not receive rainfall runoff, is not dewatered and does not spill.
- Active: The pit is actively being mined. For modelling purposes, the pit has a storage curve which varies per Stage, receives runoff and is actively dewatered.

The mining status for each pit during each mine stage is outlined in Table 6.3.

Table 6.3 - Pit status progression over mine stages

Stage	Mine pit		
	Vulcan North	Vulcan Main	Vulcan South
1	Active	Active	Inactive
2	Inactive	Active	Inactive
3	Inactive	Active	Active

6.3 CATCHMENT YIELD PARAMETERS

The OPSIM model uses the Australian Water Balance Model (AWBM) (Boughton, 2003) to estimate runoff from rainfall. The AWBM is a saturated overland flow model which allows for variable source areas of surface runoff. The AWBM uses a group of connected conceptual storages (three surface water storages and one ground water storage) to represent a catchment. Water in the conceptual storages is replenished by rainfall and is reduced by evaporation (surface stores only). Simulated surface runoff occurs when the conceptual storages fill and overflow.

The model uses daily rainfalls and estimates of catchment evapotranspiration to calculate values of runoff using a daily water balance of soil moisture. The model has a baseflow component which simulates the recharge and discharge of a shallow subsurface store. Runoff depth calculated by the AWBM is converted into a runoff volume by multiplying the contributing catchment area.

The model parameters define the storage depths (C1, C2 and C3), the proportion of the catchment draining to each of the storages (A1, A2 and A3), and the rate of flux between them (K_{base}, K_{surf} and BFI). Catchments across the site have been characterised into the following land use types:

- Natural, representing areas in their undisturbed state;
- Open cut mining pit;
- In pit spoil, representing uncompacted dumped overburden material within the pit shell;
- Out of pit spoil, representing dumped overburden material outside of the pit shell; and
- Disturbed/industrial, representing roads, hardstands and stripped areas.

The adopted AWBM parameters are shown in Table 6.4. These parameters have been based on parameters typical for coal mines in this part of the Bowen Basin. The landuse configurations for the mining areas over the three modelled stages are shown in Figure 1.3 to Figure 1.8 and are outlined in Table 6.6, Table 6.7, and Table 6.8.

Table 6.4 – Adopted AWBM parameters

Parameter	Natural	Disturbed/Industrial	Pit	In pit spoil/Out of pit spoil
A1	0.134	0.1	0.134	0.07
A2	0.433	0.9	0.433	0.10
A3	0.433	-	0.433	0.83
C1	5.7	4	2.6	5
C2	57.8	16	26.7	10
C3	115.7	-	53.3	200
C_{avg}	75.9	14.8	35.0	167.4
BFI	0	0	0	0.5
k_{base}	0	0	0	0.9
k_{surf}	0.1	0	0	0.1
C_{v^*}	18.7%	37.6%	28.3%	12.0%

* Long term volumetric runoff coefficient.

6.4 CONCEPTUAL WATER MANAGEMENT SYSTEM CONFIGURATION AND SCHEMATIC

Figure 1.3 – Figure 1.8 show the conceptual Project water management system layout as well as catchment areas and land uses for the three mine stages. Figure 6.1 shows the schematised plan of the proposed water management system configuration. The modelled water management system configuration is outlined in Table 6.5.

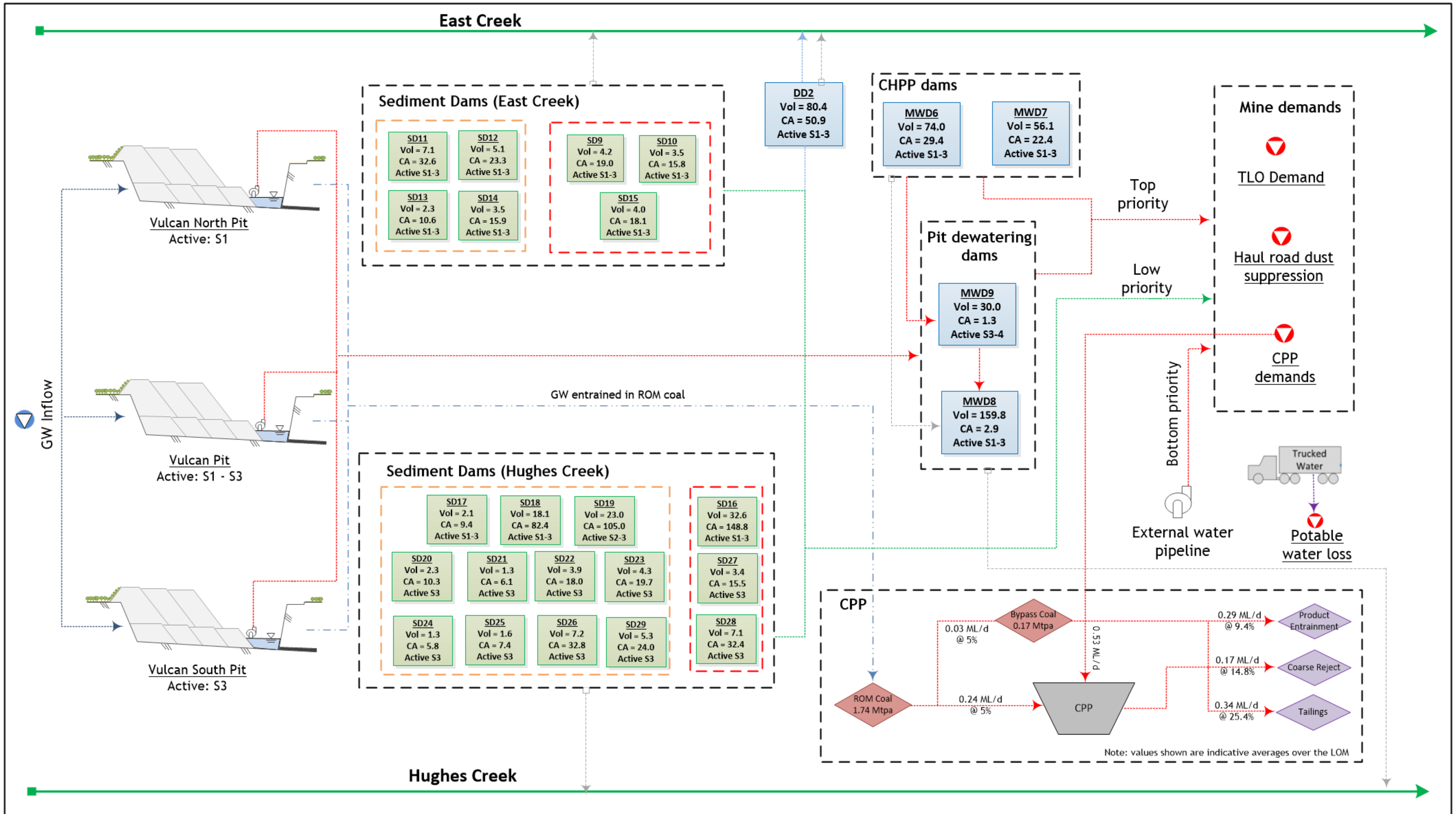
Table 5.2 and Table 5.3 shows the sediment dam and mine water dam sizes respectively that were adopted for the water balance assessment.

Table 6.5 – Water management system operating rules for the Project

Item	Node Name	Operating Rules
1	***External water supply***	
1.1	External water pipeline	• Mine affected water can be imported to supplement mine water demands • Supplies mine demands (3rd priority)
1.2	Trucked water	• Supplies the potable water demand
2	***Supply to demands***	
2.1	Haul road dust suppression/TLO Demand	• Supplied from the following sources: ○ 1st priority: Mine affected water dams; ○ 2nd priority: Sediment/diverted water dams; and ○ 3rd priority: External water pipeline. • 100% loss assumed • Haul road dust suppression values vary depending on haul road length, as outlined in Section 6.5.1

		• TLO demand assumed as constant 0.2 ML/d as outlined in Section 6.5.3
2.2	CHPP demand	• Supplied by the following sources: ○ 1st priority: Mine affected dams; ○ 2nd priority: Sediment/clean water dams; and ○ 3rd priority: External water pipeline. • Varies depending upon production schedule, as outlined in Section 6.5.2
2.3	Potable water demand	• Sourced from trucked water delivered to site • 100% loss assumed • Assumed constant rate of 50 ML/yr (as outlined in Section 6.5.4)
3	***Pit water***	
3.1	All pits	• Pit status progression outlined in Table 6.3 • Active pits dewater to the pit dewatering dams (MWD8 and MWD9) at 100 L/s (8.64 ML/d) • Receive groundwater inflows as outlined in Section 6.6
4	***Operation of mine affected water dams***	
4.1	MWD6 & MWD7 (CHPP dams)	• Mine affected water storages that capture runoff from the CHPP/ROM pad • Supply water to the mine demands as outlined in Item 2 above • In Stages 2 and 3 when above their OV, transfer water to MWD9 at 4.32 ML/d • Overflows to MWD8
4.2	MWD8	• Turkeys nest dams, receiving no external catchment • Main pit dewatering dam, pits dewater to this storage at 100 L/s (8.64 ML/d) • Supplies water to the mine demands as outlined in Item 2 above
4.3	MWD9	• Turkeys nest dams, receiving no external catchment • Secondary pit dewatering dam, dewatering the pits at 100 L/s (8.64 ML/d) and transferring the water to MWD8 when MWD8 is below its MOV • When MWD8 is above its MOV, MWD9 stores water • Receives transfers from the CHPP dams when they are above their OV
5	***Operation of sediment dams***	
5.1	Sediment dams (SD9 - SD29)	• Up to 20 sediment dams active over the mine life • Assumed to be dewatered to 33% of capacity every 5 days following sediment removal (not modelled) • Supplies water to the mine demands as outlined in Item 2 above

		• Overflows to the receiving waters (i.e. to East Creek or Hughes Creek)
6	***Clean water storages***	
6.1	DD2	• Diverted water dam that receives inflows from the rural catchment to the southwest of Vulcan North pit • Transfers water from empty to the diversion drain to the southwest of Vulcan North pit at 100 L/s (8.64 ML/d), which flows to East Creek, from empty



Vulcan South	
Figure	Proposed integrated water management system schematic
Job	1571-20
Date	18/03/2022

Legend

- Surface water
- Mine affected water
- Raw water
- Groundwater
- External/diverted water
- Pumped flow
- Coal moisture
- Spillway/overflow
- Receiving waterway
- In pit runoff
- Out of pit runoff

Notes

Spill Flow Directions:
Good engineering practice is to include a stabilised spillway as a contingency for dam safety. This arrow does not indicate that these discharges (spills/overflows) are a part of the water management system or that spills will occur. The arrow is to show the direction of water flow (by gravity) should the dam water level exceed the dam spillway level.

Volumes (Vol.) recorded in ML, catchment areas (CA) in hectares, coal amounts in dry tonnage.

Figure 6.1 - Water management system schematic for the Project

Table 6.6 - Storage catchment areas (Stage 1)

Storage	Landuse area (ha)					
	Natural	Disturbed	In pit spoil	Out of pit spoil	Pit	Total Area
Sediment dams						
	0.0	1.2	0.0	17.8	0.0	19.0
SD10	0.0	0.8	0.0	15.0	0.0	15.8
SD11	0.0	1.4	14.2	16.9	0.0	32.6
SD12	0.0	1.4	15.4	6.4	0.0	23.2
SD13	0.0	0.4	10.1	0.0	0.0	10.5
SD14	0.0	6.0	0.0	0.0	0.0	6.0
SD15	10.4	0.5	7.1	0.0	0.0	18.1
SD16	3.0	2.1	0.0	92.9	0.0	98.0
SD17	0.0	9.4	0.0	0.0	0.0	9.4
SD18	36.9	45.5	0.0	0.0	0.0	82.4
Other dams						
DD2	32.5	18.4	0.0	0.0	0.0	50.9
Mine affected water dams						
MWD6	0.0	29.5	0.0	0.0	0.0	29.5
MWD7	0.0	22.4	0.0	0.0	0.0	22.4
MWD8	0.0	4.8	0.0	0.0	0.0	4.8
Mine pits						
Vulcan North	3.8	2.5	2.6	0.0	6.2	15.1
Vulcan Main	0.0	5.7	0.0	0.0	22.1	27.8

Table 6.7 - Storage catchment areas (Stage 2)

Storage	Landuse area (ha)					
	Natural	Disturbed	In pit spoil	Out of pit spoil	Pit	Total Area
Sediment dams						
SD9	0.0	1.2	0.0	17.8	0.0	19.0
SD10	0.0	0.8	0.0	15.0	0.0	15.8
SD11	0.0	1.4	14.2	16.9	0.0	32.6
SD12	0.0	1.4	15.4	6.4	0.0	23.2
SD13	0.0	0.4	10.1	0.0	0.0	10.5
SD14	0.0	2.2	13.7	0.0	0.0	15.9
SD15	10.4	0.5	7.1	0.0	0.0	18.1
SD16	2.3	4.5	51.2	92.9	0.0	150.9
SD17	0.0	2.0	6.7	0.0	0.0	8.7
SD18	0.0	1.2	14.4	0.0	0.0	15.6
SD19	28.5	34.5	11.2	0.0	0.0	74.1
SD20	4.1	6.2	0.0	0.0	0.0	10.3
Other dams						
DD2	32.5	18.4	0.0	0.0	0.0	50.9
Mine affected water dams						
MWD6	0.0	29.5	0.0	0.0	0.0	29.5
MWD7	0.0	22.4	0.0	0.0	0.0	22.4
MWD8	0.0	4.8	0.0	0.0	0.0	4.8
Mine pits						
Vulcan Main	0.0	40.9	4.7	0.0	11.4	57.0

Table 6.8 - Storage catchment areas (Stage 3)

Storage	Landuse area (ha)					
	Natural	Disturbed	In pit spoil	Out of pit spoil	Pit	Total Area
Sediment dams						
SD9	0.0	1.2	0.0	17.8	0.0	19.0
SD10	0.0	0.8	0.0	15.0	0.0	15.8
SD11	0.0	1.4	14.2	16.9	0.0	32.6
SD12	0.0	1.4	15.4	6.4	0.0	23.2
SD13	0.0	0.4	10.1	0.0	0.0	10.5
SD14	0.0	2.2	13.7	0.0	0.0	15.9
SD15	10.4	0.5	7.1	0.0	0.0	18.1
SD16	2.3	4.5	51.2	92.8	0.0	150.8
SD17	0.0	4.0	6.7	0.0	0.0	10.7
SD18	0.0	4.0	40.9	0.0	0.0	44.9
SD19	0.0	12.6	92.4	0.0	0.0	105.0
SD20	0.0	0.6	9.6	0.0	0.0	10.3
SD21	0.0	2.2	3.9	0.0	0.0	6.1
SD22	1.8	16.2	0.0	0.0	0.0	18.0
SD23	3.9	3.1	12.7	0.0	0.0	19.7
SD24	0.0	1.1	4.7	0.0	0.0	5.8
SD25	0.0	0.3	7.0	0.0	0.0	7.4
SD26	0.0	3.0	16.4	13.4	0.0	32.8
SD27	0.0	3.1	0.0	12.5	0.0	15.5
SD28	0.0	13.6	0.0	18.8	0.0	32.3
SD29	0.0	12.0	0.0	0.0	0.0	12.0
SD30	0.0	1.1	0.0	0.0	0.0	1.1
Other dams						
DD2	32.5	18.4	0.0	0.0	0.0	50.9
Mine affected water dams						
MWD6	0.0	29.5	0.0	0.0	0.0	29.5
MWD7	0.0	22.4	0.0	0.0	0.0	22.4
MWD8	0.0	4.8	0.0	0.0	0.0	4.8
MWD9	0.0	5.0	0.0	0.0	0.0	5.0
Mine pits						
Vulcan Main	0.0	18.4	2.6	0.0	5.1	26.1
Vulcan South	0.0	12.2	2.1	0.0	3.7	17.9

6.5 SITE WATER DEMANDS

6.5.1 Haul road dust suppression

Water for haul road dust suppression is primarily sourced from the mine dams (with the priorities outlined in Table 6.5). Haul road designs were provided by Vitrinite.

Haul road dust suppression demands are estimated using supplied haul road design plans and historical climate data as follows:

- Daily pan evaporation and rainfall rates are sourced from the SILO database;
- For a dry day (zero rainfall), the haul road watering rate is equal to the daily evaporation rate;
- For a rainy day when rainfall is less than the daily evaporation rate, the watering rate is reduced and is only required to make up the remaining depth to the daily evaporation rate; and
- For a rainy day when rainfall exceeds the daily evaporation rate, no haul road watering is required.

Assuming a haul road width of 30 m, an in-pit haul road length of 3 km for Vulcan North/South pits and 5 km for Vulcan Main pit, the estimated demand rates averaged over each month are summarised in Table 6.9.

Table 6.9 - Forecast Haul Road Dust Suppression usage

Month	Haul road demand (kL/d)		
	Stage 1	Stage 2	Stage 3
January	4073	1412	2310
February	3583	1242	2033
March	3752	1300	2128
April	3234	1121	1835
May	2463	854	1397
June	2006	695	1138
July	2216	768	1257
August	2867	994	1626
September	3934	1364	2232
October	4569	1584	2592
November	4652	1613	2639
December	4486	1555	2545
Annual	3486	1208	1977

6.5.2 CHPP demand

The projected annual coal production schedule for the Project (provided by Vitrinite), is summarised in Table 6.10. The amount of washed coal for each stage was derived from the average value over the stage period. In addition, Vitrinite indicated that all coking coal would be processed and an initial estimate of 20% of thermal coal would bypass the CHPP. The assumed volumes of washed coal and bypass coal per stage are also provided in Table 6.10.

Table 6.10: Forecast annual production data

Stage	Year	Coking Coal	Thermal Coal	Bypass Coal	Washed coal	Bypass coal
		Dry coal tonnes/annum				
	2023*	-	-	-	1,738,694	188,956
1	**2024**	956,733	944,780	188,956		
	2025	802,743	1,006,624	201,325	1,630,963	162,177
	2026	954,886	886,235	177,247		
2	**2027**	1,189,133	539,799	107,960		
	2028	1,080,609	729,842	145,968	1,576,083	170,768
	2029	926,571	1,025,096	205,019		
3	**2030**	671,848	806,589	161,318		

* Note that coking and thermal coal breakdowns of ROM coal were not provided for 2023.

Key parameters regarding the CHPP process (provided by DRA Global and also derived from coal physicals) are outlined in Table 6.11.

Table 6.11: Key CHPP parameters

Parameter	Value
ROM coal moisture	5%
Product coal moisture	9.4%
Coarse reject moisture	14.8%
Tailings moisture	25.4%
Plant efficiency (ROM:Product)	56.5%
Feed rejects (ROM:Coarse reject)	21.5%
Plant tailings (ROM:Tailings)	22.0%

The key CHPP parameters (Table 6.11) and stage washed coal values (Table 6.10) were input to the model to produce water makeup requirements over the mine life. The makeup requirements are supplied by the dams as outlined in Table 6.5.

The average CHPP water makeup requirement over each stage are provided in Table 6.12.

Table 6.12: Estimated CHPP makeup requirements

Stage	CHPP makeup requirement (ML/d)
1	0.56
2	0.53
3	0.51

6.5.3 TLO demand

Water for the TLO demand is sourced from the mine dams (with the priorities outlined in Table 6.5). A nominal TLO demand of 0.2 ML/d (200 kL/d) was assumed.

6.5.4 Potable water demand

Potable water demand is supplied by trucked water delivered onsite. Potable water demand was assumed at 50 ML/annum (137 kL/d).

6.6 WATER SOURCES

6.6.1 Groundwater inflows to the open cut pits

Groundwater inflow estimates to the open cut pits were provided by Hydrogeologist.com.au (2020) and have been provided as daily rates for six-monthly periods over the mine life. A summary of the predicted groundwater inflows (grouped by pit area) are provided in Table 6.13.

Table 6.13: Estimated groundwater inflows

Period	Groundwater inflow (m^3/day)		
	Vulcan North	Vulcan Main	Vulcan South
1/01/2023	0	0	0
1/07/2023	0.88	0	0
1/01/2024	1.86	0.21	0
1/07/2024	1.45	2.6	0
1/01/2025	4.71	6.41	0
1/07/2025	3.09	35.93	0
1/01/2026	1.15	37.14	0
1/07/2026	0	33.72	0
1/01/2027	0	35.09	0
1/07/2027	0	42.42	0
1/01/2028	0	32.2	0
1/07/2028	0	29	0
1/01/2029	0	21.9	0.15
1/07/2029	0	9.05	0.77
1/01/2030	0	2.62	2.34
1/07/2030	0	10.72	2.05
1/01/2031	0	6.28	0.89

The low magnitude of the predicted groundwater inflows means that the inflows will likely have a negligible impact on the Project water balance. Notwithstanding, groundwater inflows for each stage have been averaged and were input into the model as per Table 6.14.

Table 6.14: Modelled groundwater inflows

	Groundwater inflow (kL/d)		
	Vulcan North	Vulcan Main	Vulcan South
Stage 1	1.05	0.7	0
Stage 2	0	31.79	0
Stage 3	0	13.97	0.91

6.6.2 External water

A key objective of the mine site water management system is to reuse surface water runoff captured within the mine affected water system. Recycling mine water will reduce the volume of water from external sources that is required to satisfy site demands. However, the volume of water captured onsite is highly variable and dependent upon climatic conditions. Hence, there is a requirement to source water from reliable external sources.

For the purposes of the assessment, it has been assumed that Vitrinite will source external mine water from neighbouring operations to provide water as required via a pipeline for the life of the Project. The pipeline will transfer mine affected water to be stored in MWD8 when mine affected water inventories are low.

6.7 WATERCOURSE FLOW MODELLING

As outlined in Section 4.4 and 4.5, Hughes Creek and East Creek streamflow and water quality data was not available for this assessment.

Flows in the surrounding natural watercourses have therefore been simulated using the calibrated AWBM parameter set previously derived for Phillips Creek (WRM, 2012) (as shown in Table 6.15). Phillips Creek is a tributary of the Isaac River and is located approximately 12 km south of the Project area. Phillips Creek drains primarily undisturbed land to the west of the Norwich Park Branch Railway through Saraji Mine to the Isaac River. Phillips Creek drains into the Isaac River approximately 4 km downstream of Hughes Creek. The undisturbed catchment which drains to Phillips Creek is similar in nature to the undisturbed catchment to the west of the Project which drains to East and Hughes Creek.

The catchment area of East Creek directly downstream of the Project (i.e. approximately where Drainage Line 7 meets East Creek) is approximately 1,550 ha. The catchment area of Hughes Creek directly downstream of the Project (i.e. approximately where Hughes Creek meets Barrett Creek) is 16,600 ha. These catchment areas have been adopted for assessing the potential mixing within the downstream receiving waters.

Table 6.15 - Phillips Creek AWBM parameters

Parameter	Phillips Creek Value
A1	0.013
A2	0.444
A3	0.543
BFI	0.21
C1	15.0
C2	100.0
C3	651.0
C_{av}	398.1
Kbase	0.914
Ksurf	0.502
Average annual runoff co-efficient (C_v)	4.5%

6.8 WATER QUALITY MODELLING

RGS Environmental (2022) have undertaken an assessment of the overburden and potential coal reject materials at Vulcan South. RGS (2022) presented initial results from the Jupiter Pit area. A series of geochemical tests were completed on samples from the Jupiter pit to assess the risk of potential oxidation of sulphides, acid and metalliferous drainage, potential presence and potential leaching of soluble metals/metalloids and other salinity/erosion issues. RGS (2022) made the following findings regarding the geochemical characterisation of the potential spoil:

- all samples tested had a high factor of safety and negligible risk of generating acid mine drainage;
- assay of the multi-element concentration present in selected representative samples indicates that there are no elements (metals/metalloids) enriched in the sample materials compared to median crustal abundance in unmineralised soils;
- the initial static and kinetic test results indicate that surface runoff and seepage from the sample materials are likely to be pH neutral with moderate excess alkalinity, and low levels of salinity;
- the initial geochemistry results are consistent with the larger data set of results obtained from geochemical characterisation of 139 samples from 21 drill holes across the broader Jupiter and Vulcan areas in the VCM and Vulcan South; and
- the results represent an 'assumed worst case' scenario as the samples are pulverised (to minus 75 micrometres) prior to testing. Therefore, samples have a very high surface area compared to materials in the field. This process provides a greater potential for dissolution and reaction and represents an assumed initial 'worst case' scenario for geochemical testing of these materials.

In consideration of the RGS (2022) findings from the preliminary geochemical characterisation, salinity is considered the key contaminant for assessment purposes. Assessment of other contaminants has not been undertaken as part of this surface water assessment. If subsequent monitoring data indicates that there are other contaminants of concern, the assessment can be updated to include additional water quality parameters.

6.8.1 Adopted salinity parameters

The water balance model is configured to use salinity as an indicator of water quality using electrical conductivity (EC) values runoff for each landuse type and other sources of water.

The proposed EC values are shown in Table 6.16. EC values have been sourced from previous water balance models for mines in similar areas of the Bowen Basin.

Table 6.16 - Adopted salinity concentrations

Water source/land use	EC (µS/cm)	Comment
Natural/ undisturbed	300	Value adopted for Olive Downs SWA and Lake Vermont Northern Extension SWA
Disturbed	500	Runoff value typical for cleared/stripped areas
Mining pit	4,500	Value adopted for Lake Vermont Northern Extension SWA
In pit spoil/out of pit spoil	350	Value adopted for Olive Downs SWA
External water (pipelines from BMA Peak Downs)	10,000	Salinity of mine water unknown, conservatively high value adopted
Industrial area	900	Salinity of ROM coal unknown, conservatively high value adopted
Groundwater	9,520	Average groundwater salinity reading from historical groundwater monitoring undertaken at site (Hydrogeologist.com.au, 2020)

7 Water management system assessment

7.1 OVERVIEW

The Project OPSIM model was used to assess the performance of the water management system, using the following key performance indicators:

- overall water balance – the average inflows and outflows of the water management system based on all model realisations (Section 7.3.1);
- mine water inventory – the risk of accumulation (or reduction) of the overall mine water inventory (Section 7.3.2);
- in-pit storage – the risk of accumulation of water in the mining pits, and the associated water volumes (Section 7.3.3, 7.3.4 and 7.3.5);
- external water demand – the volumes of imported external water (via the external pipeline) required to supplement site mine water supplies (Section 7.3.6);
- uncontrolled spillway discharges – the risk and associated volumes of uncontrolled discharge from the mine affected water storages and sediment dams to the receiving waters (Section 7.3.7);
- overall salt balance – the average salt loads in and out of the water management system based on all model realisations (Section 7.3.8);
- potential receiving water impacts - predicted water quality in the receiving waters during predicted 'worst case' release scenarios (Section 7.3.9 and 7.3.10); and
- sensitivity analysis - varying the assumed haul road dust suppression over the mine life and the potential impacts of climate change (Section 7.4).

The use of a large number of climate sequences reflecting the full range of historical climatic conditions provides an indication of the system performance under very wet, very dry and average climatic conditions. It is important to note that the results of the water balance modelling are dependent on the accuracy of input assumptions. There is inherent uncertainty with respect to some key site characteristics (e.g. catchment yield/runoff, groundwater inflows etc.).

7.2 INTERPRETATION OF MODEL RESULTS

In interpreting the results of the water balance assessment, it should be noted that the results provide a statistical analysis of the water management system's performance over the 8 years of mine life, based on 122 stochastically generated climatic rainfall sequences and historical average monthly evaporation. The model results are presented as a probability of exceedance. For example, the 10%ile represents 10% probability of exceedance and the 90%ile represents 90% probability of exceedance. There is an 80% chance that the result will lie between the 10%ile and 90%ile traces.

Whether a percentile trace corresponds to wet or dry conditions depends upon the parameter being considered. For site water storage, where the risk is that available storage capacity will be exceeded, the lower percentiles correspond to wet conditions. For example, there is only a small chance that the 1%ile storage volume will be exceeded, which would correspond to very wet climatic conditions. For off-site site water supply volumes (for example), where the risk is that insufficient water will be available, there is only a small chance that more than the 1%ile water supply volume would be required. This would correspond to very dry climatic conditions.

It is important to note that a percentile trace shows the likelihood of a particular value on each day and does not represent continuous results from a single model realisation. For example, the 50%ile trace does not represent the model time series for median climatic conditions.

7.3 WATER BALANCE MODEL RESULTS

7.3.1 Overall water balance

Average water balance results based on all of the 122 model realisations are presented in Table 7.1. The results presented in Table 7.1 are the average of all realisations and will include wet and dry periods distributed throughout the mine life. Rainfall yield and evaporation for each stage is affected by the variation in climatic conditions within the adopted climate sequence.

Table 7.1 provides an indication of the long-term average annual inflows and outflows. Key outcomes from the overall water balance are as follows:

- Average annual inflows from rainfall runoff for surface water dams increases from Stage 1 to Stage 3, as the pit progresses, and more catchment runoff is collected in these dams.
- Average inflow volumes to mine storages are greatest in Stage 2, when the Vulcan Main pit catchment area is greatest.
- The proposed water management system is in negative balance under 'average' climate conditions. This indicates that the Project will require significant volumes of external water to meet mine water demands every year.
- External water requirements are greatest in Stage 1 due to the significantly larger haul road length during this Stage to the Highwall mining area.

It should be recognised that the following items are subject to climatic variability:

- Rainfall runoff;
- Evaporation;
- External water requirement;
- Dust suppression demand; and
- Dam overflows.

Whilst it provides an indication of the long-term average annual inflows and outflows, application of the nominated values for other purposes should only be undertaken with due consideration of the suitability of the nominated value and any potential implications.

In particular, the "average" sediment dam overflows do not necessarily mean that discharges occur under median climatic conditions. It means that there was a discharge in at least one of the 122 model realisations. A more detailed analysis of the performance of the various components of the water management system is provided in the following sections.

Table 7.1 - Average annual water balance - all realisations

Description	Stage 1	Stage 2	Stage 3
Inflows (ML/year)			
Rainfall Runoff			
Mine affected water	188	240	214
Surface water	297	347	524
Diverted water	70	71	71
Groundwater inflow	1	12	5
ROM Coal Moisture	91	86	83
External Pipeline	1,222	332	526
Trucked potable water	50	50	50
Total Inflows	1,920	1,138	1,474
Outflows (ML/year)			
Evaporation	23	56	57
Dam overflows			
Mine affected water	0	0	0
Surface water	125	160	231
Diverted water	70	70	71
CHPP			
Product moisture	102	96	92
Coarse rejects moisture	65	61	59
Fine rejects moisture	130	122	118
Haul road dust suppression	1,273	441	722
TLO demand	73	73	73
Potable water demand	50	50	50
Total Outflows	1,911	1,129	1,474
Change in volume (ML/year)			
Change in stored volume	9	8	-1

7.3.2 Mine affected water inventory

7.3.2.1 MWD8 inventory

Figure 7.1 shows the forecast inventory for MWD8 which is the key out-of-pit mine affected water storage, controlling the dewatering of the pit. Figure 7.2 shows the annual maximum forecast inventory for MWD8 over the mine life.

These results show the 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile traces.

As outlined in Section 5.6.1, to prevent uncontrolled discharges from MWD8 a MOV is required. If the MOV is exceeded, all transfers to the storage cease (i.e. pit dewatering and mine water dam dewatering). The MWD8 MOV, in addition to the FSV are shown in Figure 7.1 and Figure 7.2.

The model results show the following:

- The MWD8 inventory is maintained below the FSV for all climatic conditions assessed and therefore is not predicted to spill under any modelled climate sequence.
- The MWD8 inventory is maintained below its MOV for 5%ile and drier conditions in Stage 1 and 25%ile & drier conditions in Stages 2 & 3. This means pit and mine dam dewatering is restricted under 1%ile in Stage 1 and 10%ile and wetter conditions in Stages 2 and 3.
- Under the 50%ile trace, the MWD8 inventory is maintained below 55 ML for the entire mine life.
- Under very wet (1%ile) conditions, MWD8 has an inventory of up to 153 ML during Stage 2.
- Under wet (10%ile conditions), MWD8 has a maximum inventory of approximately:
    - up to 90 ML during Stage 1; and
    - up to 135 ML during Stage 2 and 3.

7.3.2.2 MWD9 inventory

Figure 7.3 shows the annual maximum forecast inventory for MWD9. MWD9 acts as a transfer dam for Vulcan Main pit and Vulcan South pit. MWD9 is not active in Stage 1. The results show the 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile traces.

The model results show the following:

- The MWD9 inventory is maintained below the FSV for all climatic conditions assessed and therefore is not predicted to spill under any modelled climate sequence.
- Under wet (10%ile conditions), MWD9 has a maximum inventory of approximately up to 25 ML during both Stage 1 & 2.

7.3.2.3 MWD6 and MWD7 inventories

Mine water dams MWD6 and MWD7 collect mine water draining from the CHPP area and the TLO area. They have been grouped together for the purpose of this assessment as they are operated in a similar way. Figure 7.4 shows the annual maximum forecast combined inventory for MWD6 and MWD7.

The model results show that:

- The combined water inventories in MWD6 and MWD7 remain below the combined FSV under the 1%ile and drier climate sequence. Model results indicate that the mine dams spill into MWD8 very infrequently (i.e. less than 1% of the time).
- Under the 50%ile trace, the maximum mine water inventory is maintained well below the MOV for all years.
- The maximum water inventory only rises above the MOV under conditions wetter than the 5%ile during all stages.

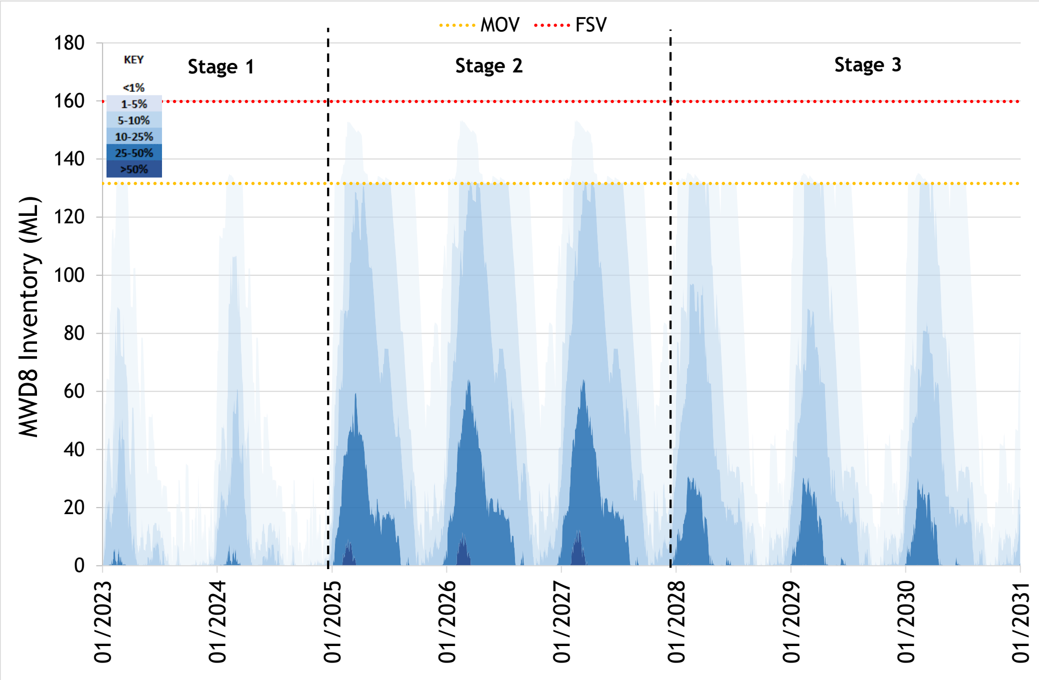


Figure 7.1 - Forecast MWD8 inventory

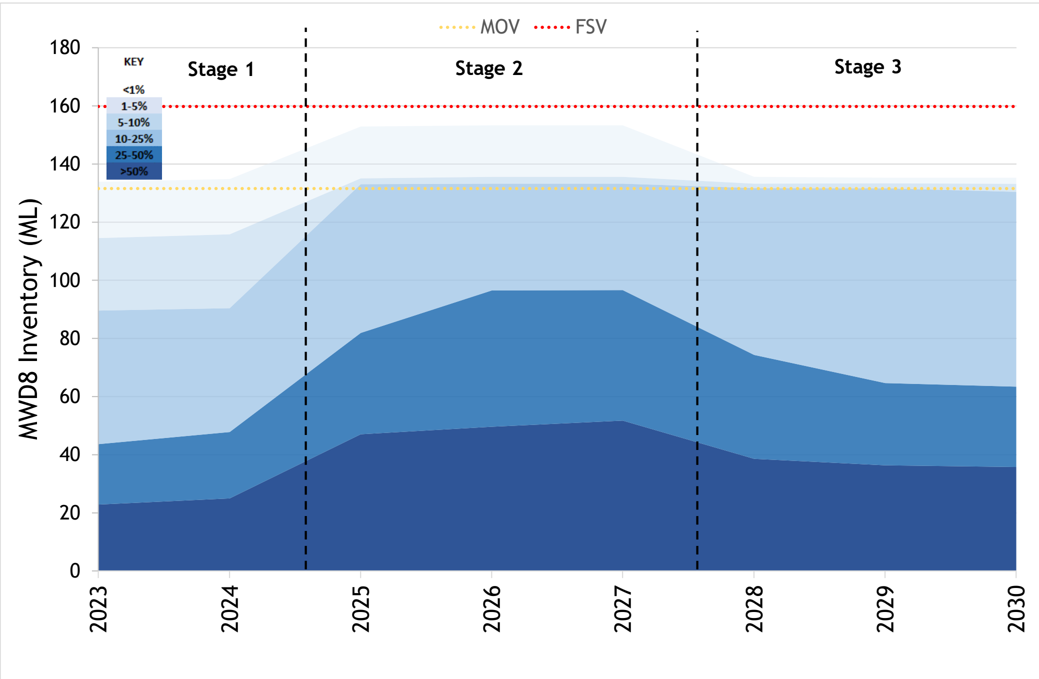


Figure 7.2 - Forecast annual maximum MWD8 inventory

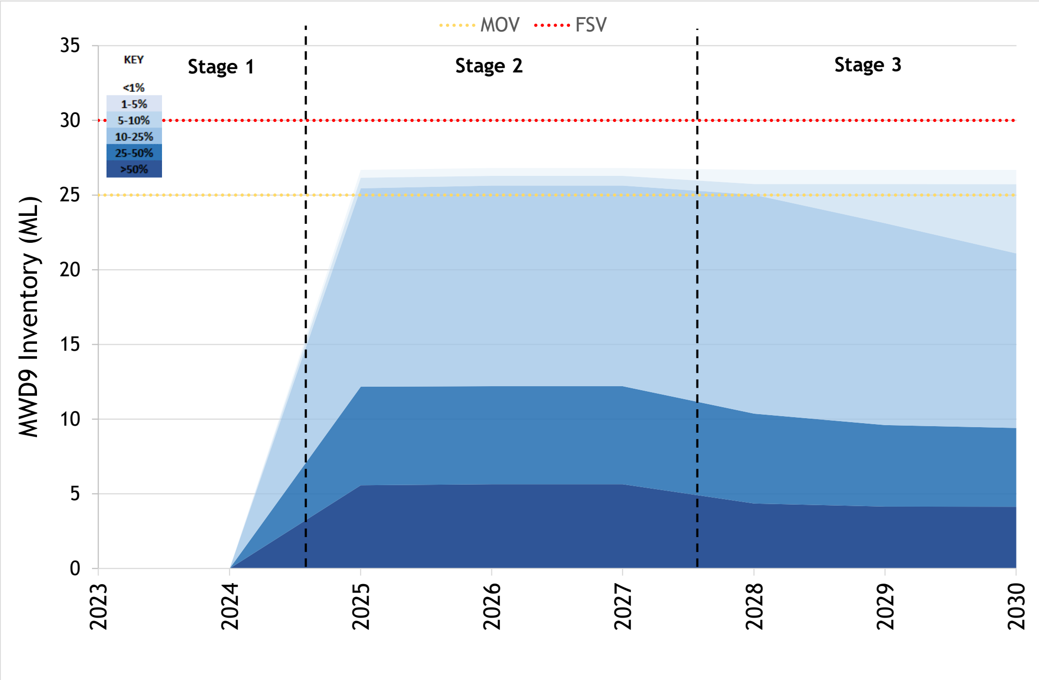


Figure 7.3 – Forecast annual maximum MWD9 inventory

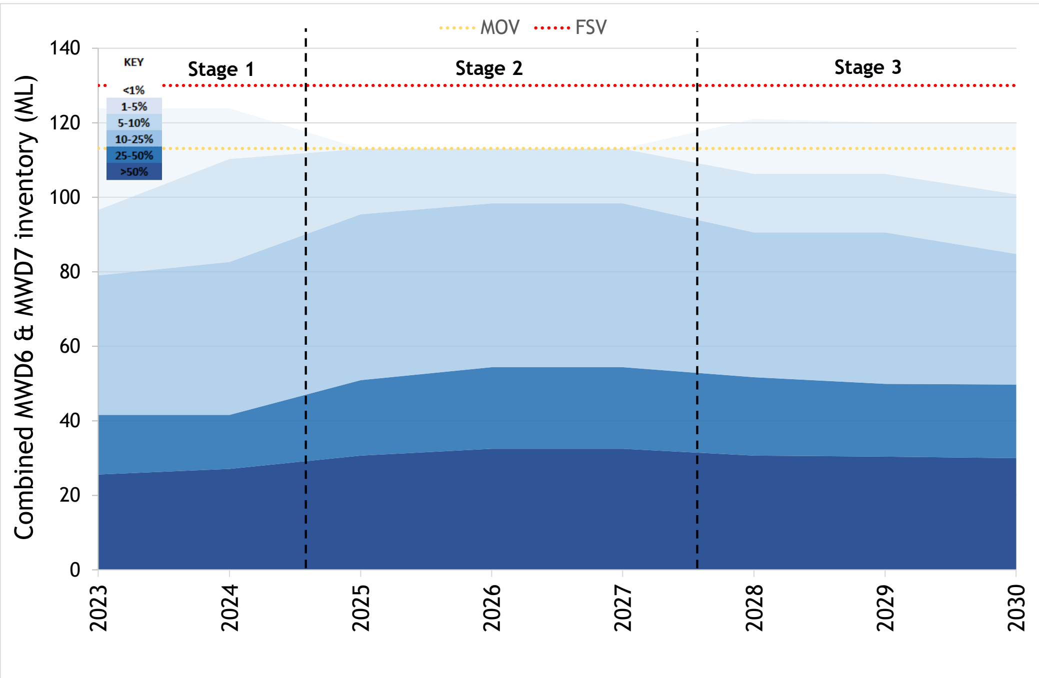


Figure 7.4 – Forecast annual combined maximum water inventory in MWD6 and MWD7

7.3.3 Vulcan North pit water inventory

Figure 7.5 shows the forecast annual maximum Vulcan North pit inventory during Stage 1. The pit is inactive and therefore empty during Stages 2 and 3.

The 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown. As outlined in Section 5.6.1, the pit is continuously dewatered into MWD8 as long as MWD8 is maintained below its MOV.

The model results show the following:

- The pit is empty for the majority of the mine life.
- The Vulcan North pit will have a forecast inventory of approximately:
  - up to 20 ML under very wet (1%ile conditions); and
  - up to 2 ML under wet (10%ile conditions).

The results suggest that MWD8 has sufficient capacity to dewater the Vulcan North pit for the entirety of its active mine life.

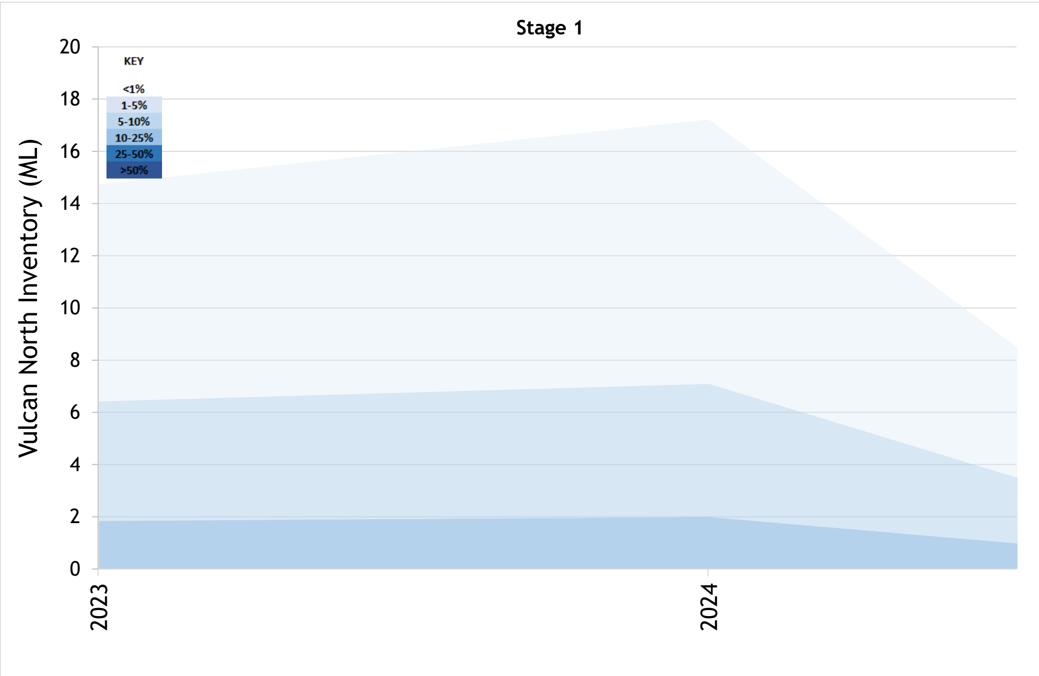


Figure 7.5 – Vulcan North forecast annual maximum pit inventory

7.3.4 Vulcan Main pit water inventory

Figure 7.6 shows the forecast pit inventory for Vulcan Main pit. Figure 7.7 shows the forecast annual maximum inventory in Vulcan Main pit.

The 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown. As outlined in Section 5.6.1, the pit is continuously dewatered into MWD8 and MWD9.

The model results show the following:

- Under very wet (1%ile) conditions, the Vulcan Main pit will have a forecast inventory of approximately:
  - up to 50 ML during Stage 1;
  - up to 130 ML during Stage 2; and
  - up to 65 ML during Stage 3.
- Under wet (10%ile conditions), the Vulcan pit will have an inventory of approximately:
  - up to 20 ML during Stage 1;
  - up to 60 ML during Stage 2; and
  - up to 10 ML during Stage 3.
- Under 50%ile conditions, the maximum pit inventory is less than 1 ML for Stages 1 and 3, and less than 5 ML during Stage 2.

The results suggest that the Vulcan Main pit may begin to accumulate water during Stage 2 during very wet climate conditions due to capacity being reached in MWD8 and MWD9. If there is a 5%ile or wetter climatic condition then the on-site water storages would be filled to capacity and the Vulcan Main pit would be required to store excess water potentially disrupting mining activities.

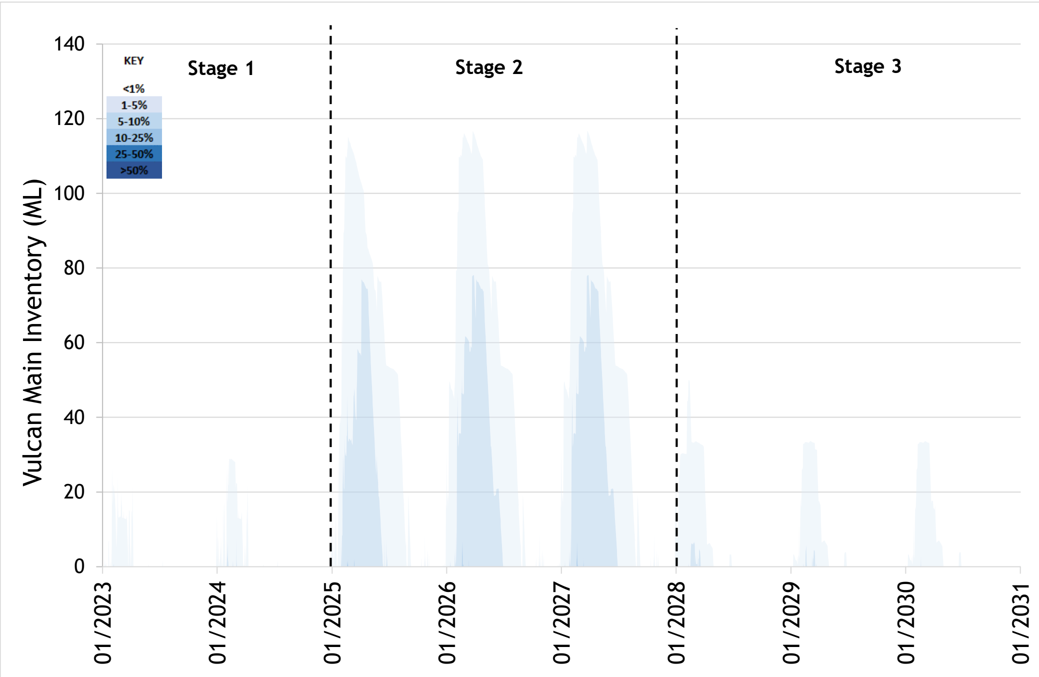


Figure 7.6 - Vulcan Main pit forecast mine pit inventory

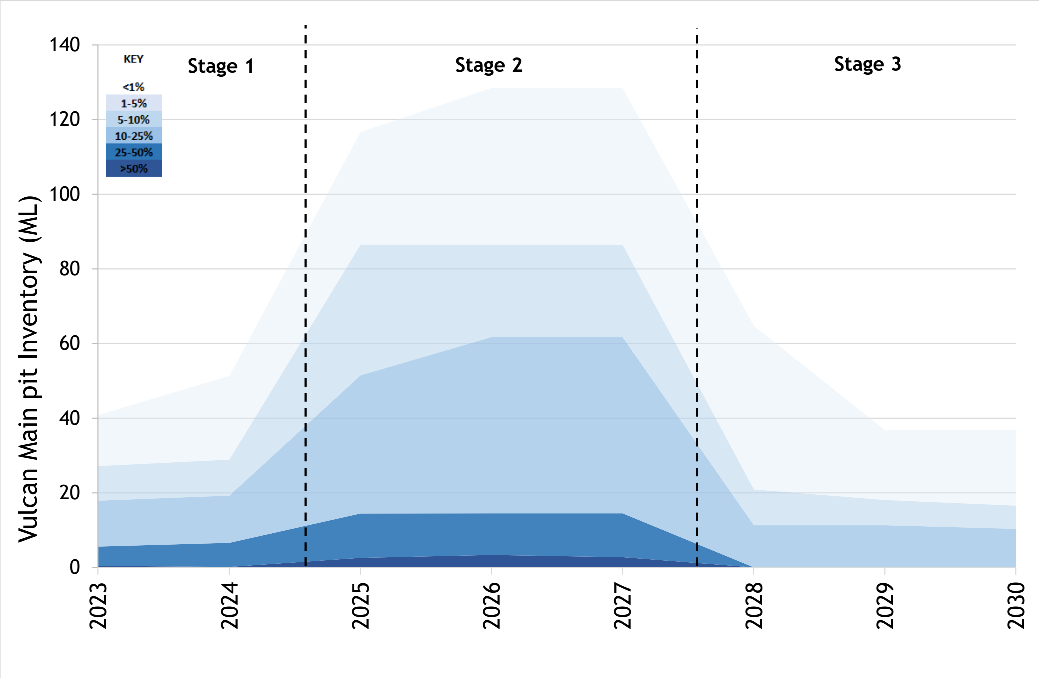


Figure 7.7 – Vulcan Main pit forecast annual maximum pit inventory

7.3.5 Vulcan South pit water inventory

Figure 7.8 shows the forecast annual maximum inventory in Vulcan South pit. The Vulcan South pit is only active in Stage 3.

The 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown. As outlined in Section 5.6.1, the pit is continuously dewatered into MWD8 and MWD9.

The model results show the following:

- The Vulcan South pit will have a forecast inventory of approximately:
  - up to 25 ML during very wet (1%ile) climate conditions; and
  - up to 5 ML during wet (10%ile) climate conditions.
- Under 25%ile and drier conditions the pit is kept dewatered for the entirety of its mine life.

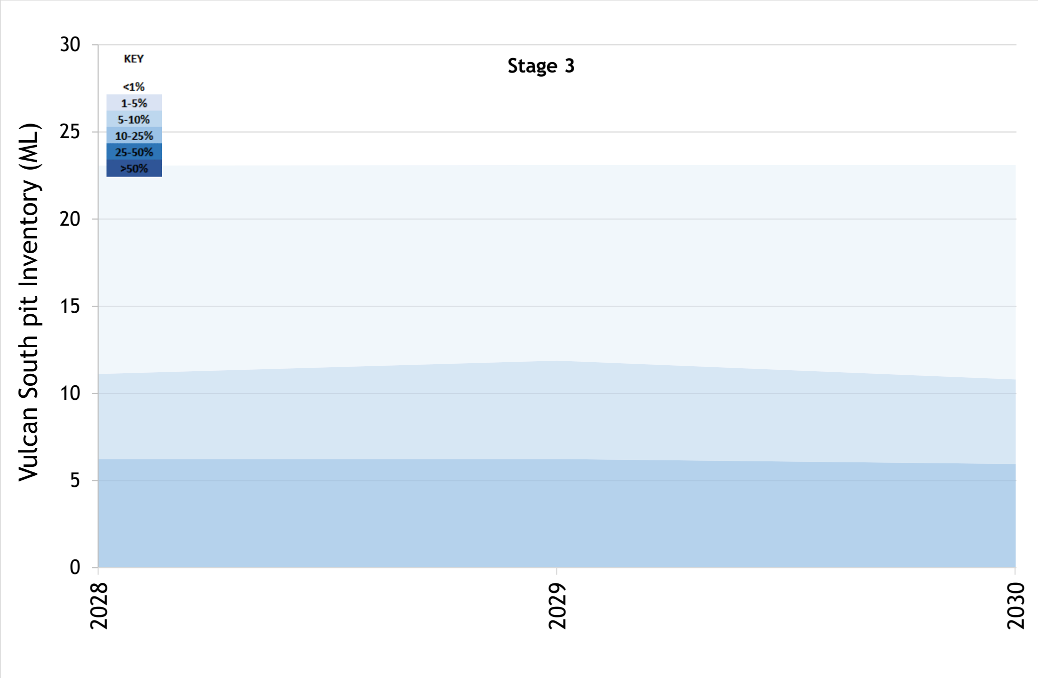


Figure 7.8 – Vulcan South pit forecast annual maximum pit inventory

7.3.6 External makeup requirements

Figure 7.9 shows the total annual modelled external water required to meet predicted mine demands. The 1%ile (driest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown. As outlined in Section 6.4, the external pipeline is used to satisfy mine demands as lowest priority when all other sources are empty.

The modelling results show the following:

- Stage 1 requires significantly more external water than Stages 2 and 3 because Stage 1 has the largest haul road dust suppression requirements and therefore the highest mine water demands.
- During the driest (1%ile) climatic conditions, the external water requirement is:
  - up to approximately 1,520 ML/annum during Stage 1;
  - up to 655 ML/annum during Stage 2; and
  - up to 930 ML/annum during Stage 3.
- During 50%ile conditions, the predicted external water requirements is:
  - up to approximately 1,260 ML/annum during Stage 1;
  - up to approximately 355 ML/annum during Stage 2; and
  - up to approximately 540 ML/annum during Stage 3.

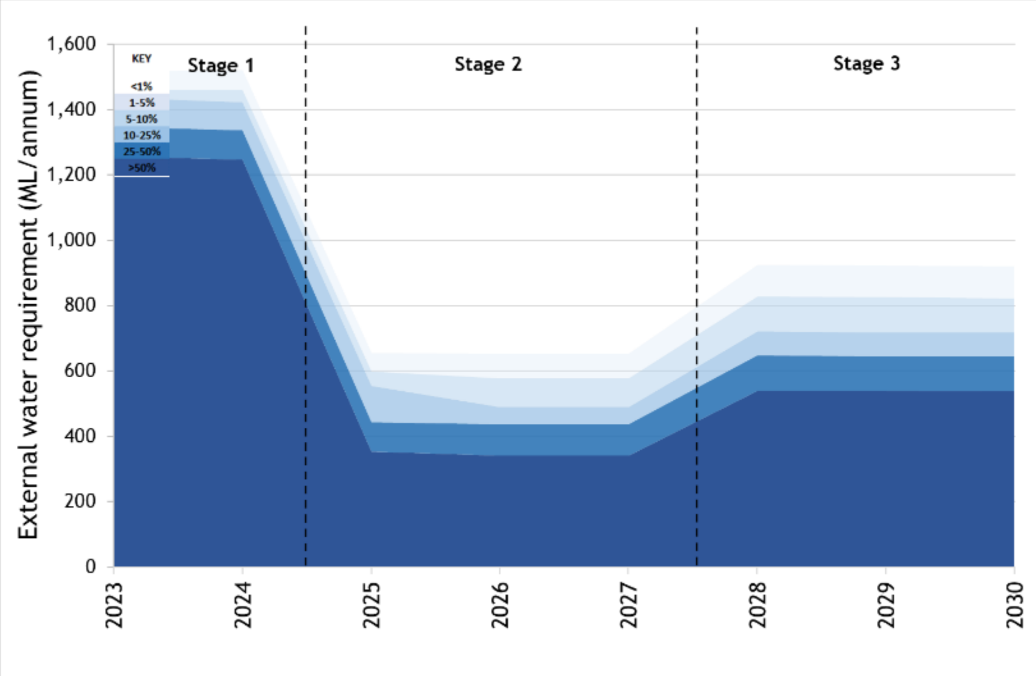


Figure 7.9 – Forecast external water requirement for dust suppression

7.3.7 Releases/overflows to the receiving waters

7.3.7.1 Mine Affected Water Dams

As outlined in Section 7.3.2, no spills are predicted from any of the mine affected water dams (i.e. MWD6, MWD7, MWD8 and MWD9) to the extenral environment under any of the climate sequences modelled.

Under very rare circumstances (i.e. <1%ile) MWD6 and MWD7 are predicted to spill to MWD8. This does not cause MWD8 to spill to Hughes Creek.

7.3.7.2 Sediment Dams

Consistent with the IECA guidelines (2008), sediment dams do not provide 100% containment for captured runoff. Hence overflows will occur from sediment dams when rainfall exceeds the design standard.

The potential for releases from the proposed sediment dam has been modelled using a passive overflow rather than active release (to regain storage capacity within 5 days).

Figure 7.10 shows the forecast annual sediment dam releases to Hughes Creek. Figure 7.11 shows the forecast annual sediment dam releases to East Creek.

The model results indicate that:

- The predicted sediment dam releases to Hughes Creek progressively increases over the mine life. This is due to sediment dams which release to Hughes Creek progressively being constructed over the mine life as the dump areas associated with the Vulcan Main and Vulcan South pits increases.
- The predicted sediment dam releases to East Creek increase in Stage 2 compared to Stage 1 before decreasing again in Stage 3. This is due to no new sediment dams draining to this creek being constructed at the commencement of Stage 3. The surface water catchment areas do not change between Stages 2 and 3, however mine demands for the sediment dam water increase in Stage 3.

- Under wet (10%ile) conditions, the annual volume of sediment dam releases to Hughes Creek is approximately:
  - up to 308 ML/yr during Stage 1;
  - up to 376 ML/yr during Stage 2; and
  - up to 574 ML/yr during Stage 3.
- Under wet (10%ile) conditions, the annual volume of sediment dam releases to East Creek is approximately:
  - up to 105 ML/yr during Stage 1;
  - up to 157 ML/yr during Stage 2; and
  - up to 159 ML/yr during Stage 3.
- Under 50%ile conditions, the annual volume of sediment dam releases to Hughes Creek is approximately:
  - up to 43 ML/yr during Stage 1;
  - up to 31 ML/yr during Stage 2; and
  - up to 66 ML/yr during Stage 3.
- Under 50%ile conditions, the annual volume of sediment dam releases to East Creek is approximately:
  - 0 ML/yr during Stage 1;
  - up to 10 ML/yr during Stage 2; and
  - up to 11 ML/yr during Stage 3.
- Overall, the results indicate that under average or drier conditions low spill volumes are expected to the receiving waters, while wet conditions result in more significant spill volumes.

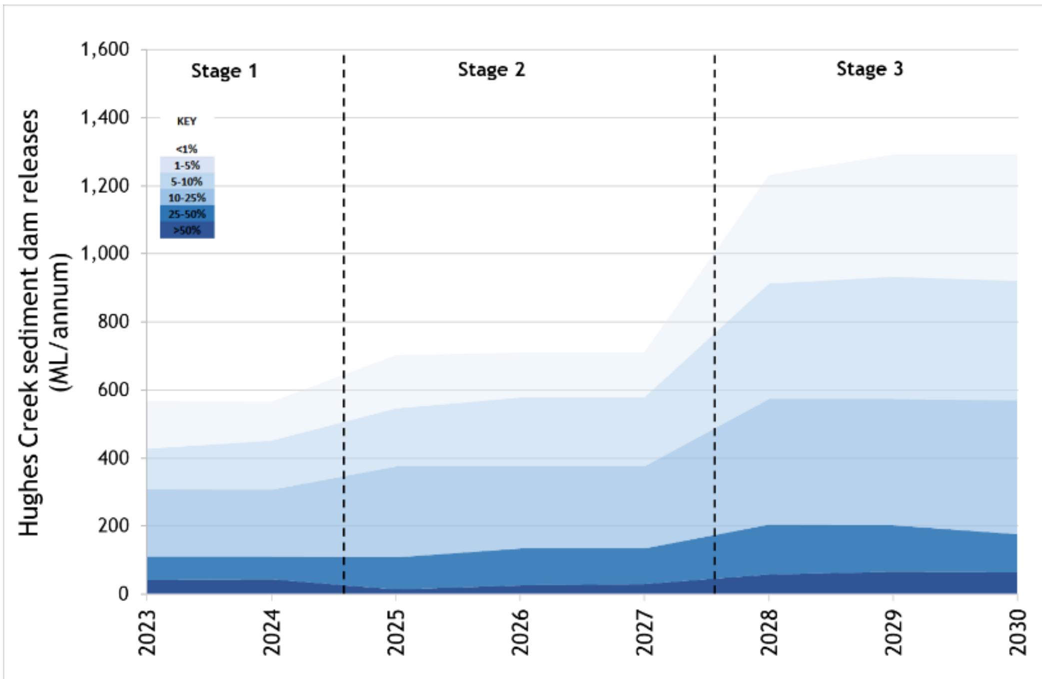


Figure 7.10 – Forecast annual sediment dam releases to Hughes Creek

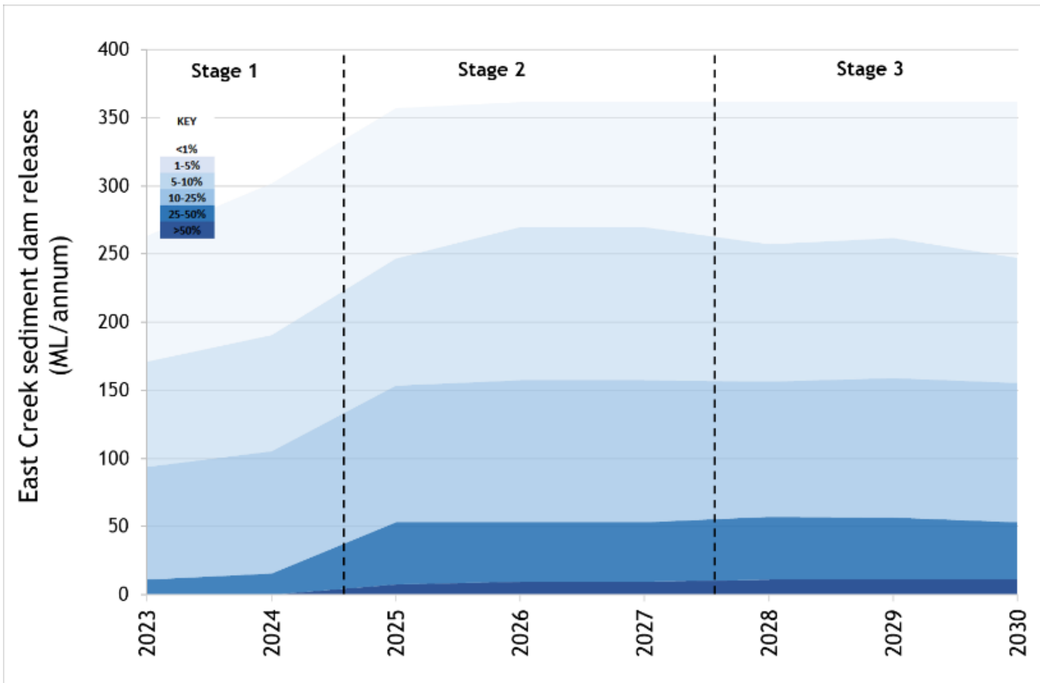


Figure 7.11 – Forecast annual sediment dam releases to East Creek

7.3.7.3 DD2

DD2 collects water from a primarily undisturbed catchment to the southwest of the Vulcan North pit, with a small area of haul road. Water stored in DD2 is dewatered to the existing drainage diversion at 100 L/s. If the capacity of DD2 is exceeded, water would spill to the Vulcan North pit in Stage 1 and East Creek in Stages 2 and 3.

Figure 7.12 shows the combined annual total pumped flows from DD2 to the existing drainage diversion, as well as any overflows. The 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown.

The model results predict the following:

- DD2 does not spill either to the pit or to the receiving waters under any climate sequence. Therefore, the results in Figure 7.12 represent only pumps to the drainage diversion from DD2.
- Under wet (10%ile) conditions DD2 dewaters up to approximately 120 ML/year to the receiving waters in all stages.
- Under very wet (1%ile climatic conditions) DD2 dewaters up to approximately 170 ML/year to the receiving waters in all stages.

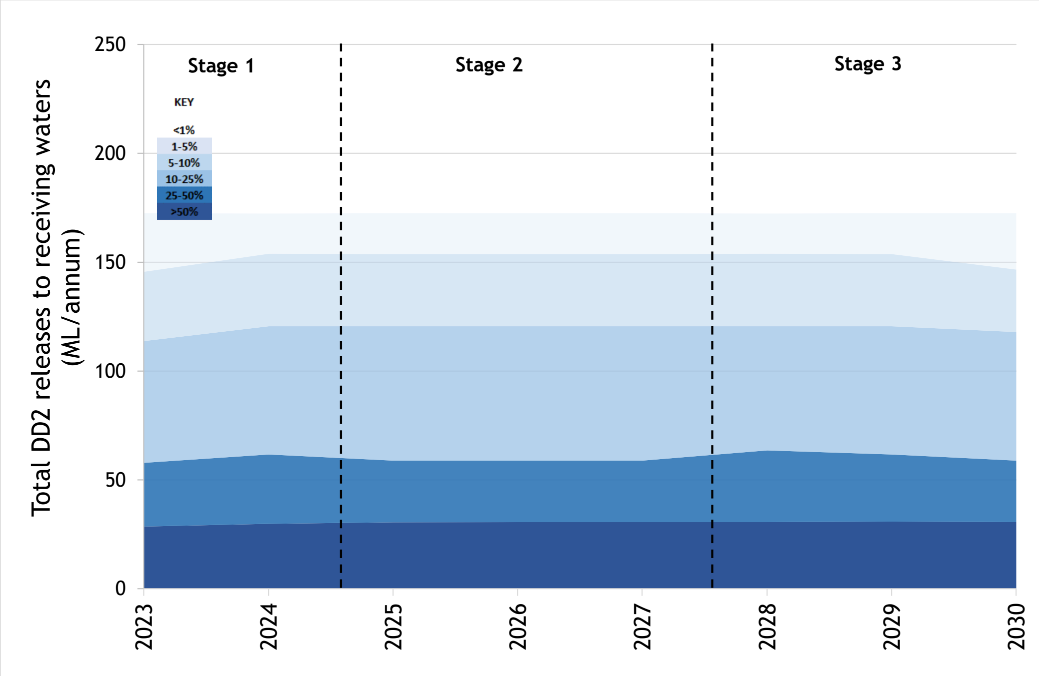


Figure 7.12 - Forecast total annual releases from DD2 to the existing waters

7.3.8 Overall salt balance

Table 7.2 shows the average annual salt balance for the Project for each stage.

Salt inputs to the Project include salts in the groundwater inflow, catchment runoff, salt store din ROM coal and external water. Salt inputs from direct rainfall was assumed to be zero.

Salt outputs from the Project include site demands and offsite (spillway) discharges from the water management system.

The results indicate the following:

- The largest contributor to the Project salt load is due to external water assuming it is sourced from BMA. This is due to the high assumed salinity of the BMA water (Section 6.8.1).
- The largest outflow in the salt balance from the Project is haul road dust suppression demands.
- The change in stored salt load is generally low in comparison to the total inputs and outputs, which suggests that salt will not accumulate within the site water management system.

Note that the salt balance is reported in annual tonnes of total dissolved solids (TDS) based on an EC to TDS conversion factor of 0.7.

Table 7.2 - Average annual salt balance (based on TDS)

Description	Stage 1	Stage 2	Stage 3
	Inflows (t/year)		
Rainfall Runoff			
Mine affected water	214	156	139
Surface water	83	92	143
Diverted water	20	31	20
Groundwater inflow	4	77	36
ROM Coal Moisture	640	602	581
External Pipeline	8,552	2,326	3,681
Trucked potable water	0	0	0
Total Input	9,515	3,285	4,601
	Outflows (t/year)		
Evaporation	0	0	0
Dam overflows			
Mine affected water	0	0	0
Surface water	36	43	64
Diverted water	20	31	20
CHPP			
Product moisture	576	380	390
Coarse rejects moisture	455	427	412
Fine rejects moisture	736	486	498
Haul road dust suppression	7,266	1,651	2,929
TLO demand	419	264	289
Potable water demand	0	0	0
Total Output	9,508	3,283	4,602
	Change in salt (t/year)		
Change in stored volume	7	2	-1

7.3.9 Receiving waters water quality

The three potential sources of receiving waters contamination from the water management system are releases from the sediment dams, releases from the mine affected dams and pumped releases from DD2. As outlined in Section 7.3.7, the mine affected dams are not predicted to spill under any of the modelled climate sequences. Releases from DD2 are expected to be of a water quality that is similar to the receiving waters as it primarily collects water from an undisturbed rural catchment.

Potential impacts to EC in the receiving waters were assessed at points directly downstream of the Project. The reporting location for East Creek is downstream of the Project, where Drainage line 7 joins East Creek. The reporting location for Hughes Creek is downstream of the Project, where Barrett Creek joins Hughes Creek. The default WQO trigger levels for EC outlined in Section 3 have been used for this assessment.

Figure 7.13 shows the predicted annual maximum EC in East Creek over the mine life. Figure 7.14 shows the predicted annual maximum EC in Hughes Creek over the mine life. The 1%ile, 5%ile, 10%ile, 25%ile and 50%ile (median climatic conditions) traces are shown. The results predict that:

- For East Creek:
  - Under 1%ile conditions the maximum EC is approximately 460 µS/cm in Stage 1, 470 µS/cm in Stage 2 and 440 µS/cm in Stage 3; and
  - Under 50%ile conditions the maximum EC is approximately 420 µS/cm in Stage 1, 430 µS/cm in Stage 2 and 420 µS/cm in Stage 3.
- For Hughes Creek:
  - Under 1%ile conditions the maximum EC is approximately 370 µS/cm in Stage 1, 400 µS/cm in Stage 2 and 410 µS/cm in Stage 3; and
  - Under 50%ile conditions the maximum EC is approximately 350 µS/cm in Stage 1, 330 µS/cm in Stage 2 and 350 µS/cm in Stage 3.

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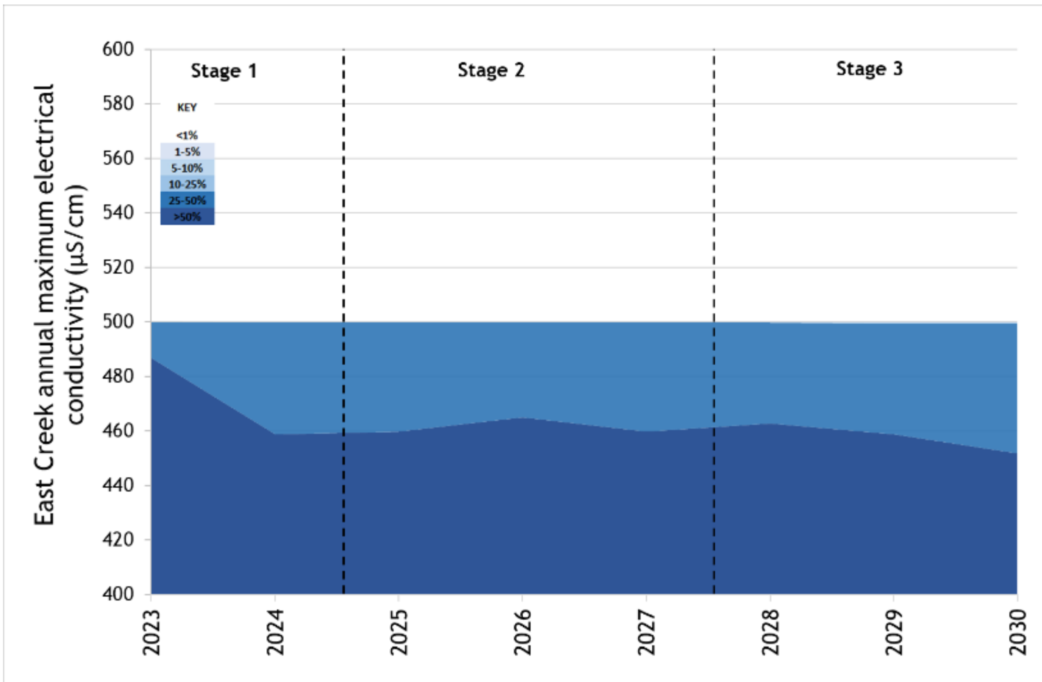

Figure 7.13 – Predicted East Creek annual maximum EC variation downstream of the Project

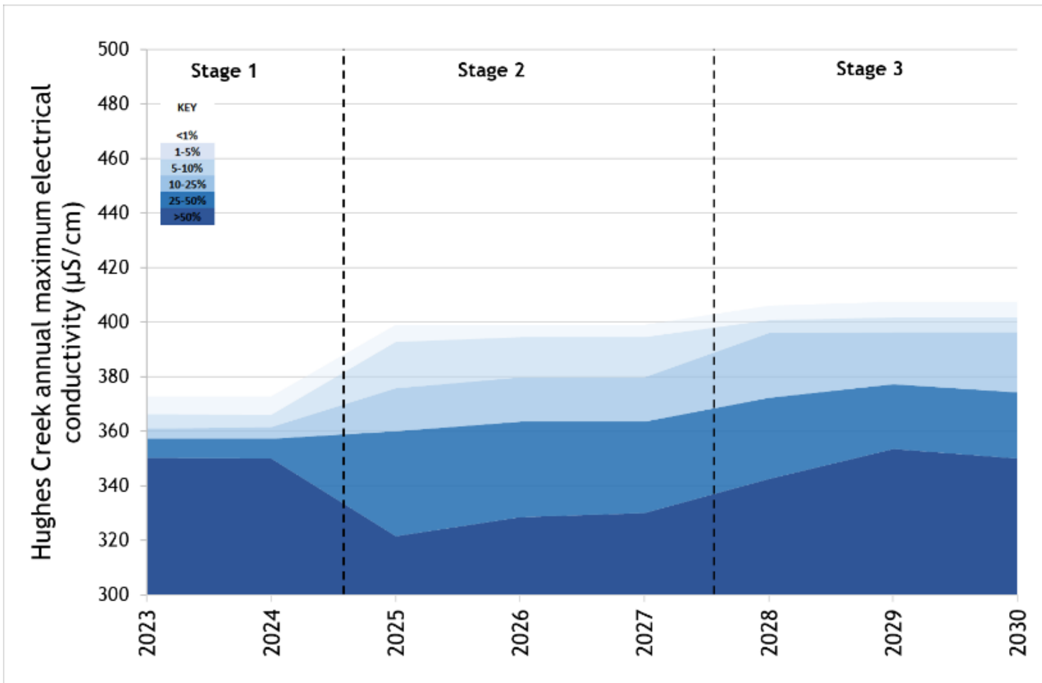

Figure 7.14 - Predicted Hughes Creek annual maximum EC variation downstream of the Project

7.3.10 Release scenarios

The OPSIM model was used to assess the release (spill or transfer) from sediment dams and DD2. No other dams or storages are predicted to release to the receiving waters. The release scenarios that were investigated include:

- Scenario 1 – The highest EC release from the sediment dams; and
- Scenario 2 – The highest flow rate release from the sediment dams.

The release events were compared to the WQO levels outlined in Section 3.

7.3.10.1 Scenario 1 - Sediment dams highest EC release

The cumulative release with the highest EC from the Project occurs during Stage 2 to East Creek at approximately 480 µS/cm with a flow rate of approximately 0.7 ML/d. Figure 7.15 and Figure 7.16 shows the release rate and EC compared to the rates in the receiving waters. The WQO levels outlined in Section 3 are also shown.

The OPSIM model predicts that during the Scenario 1 release, the release causes a minor increase to EC levels in the receiving waters. This is due to the low flow rate of the release in comparison to the high flows already present within the receiving waters. The model predicts that during the event both the EC levels of the release, and within the receiving waters remain above the high flow WQO but below the baseflow WQO. It is noted that for this assessment, the assumed receiving waters EC level (300 µS/cm) is greater than the high flow WQO of 250 µS/cm.

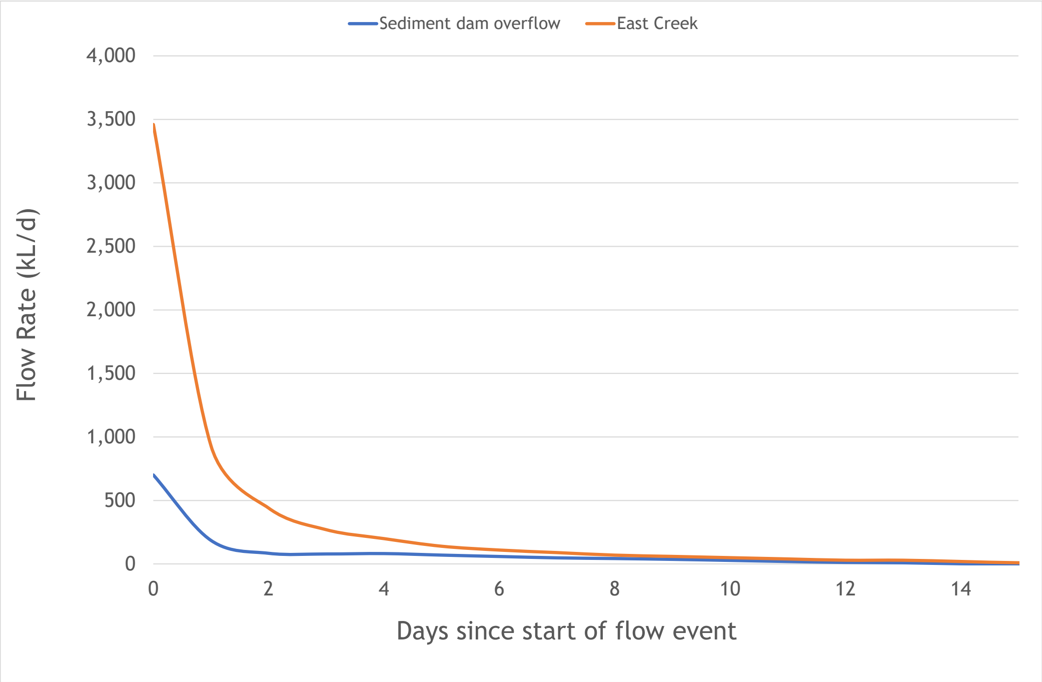

Figure 7.15 - Project release rate compared to flow rate in the receiving waters - Scenario 1

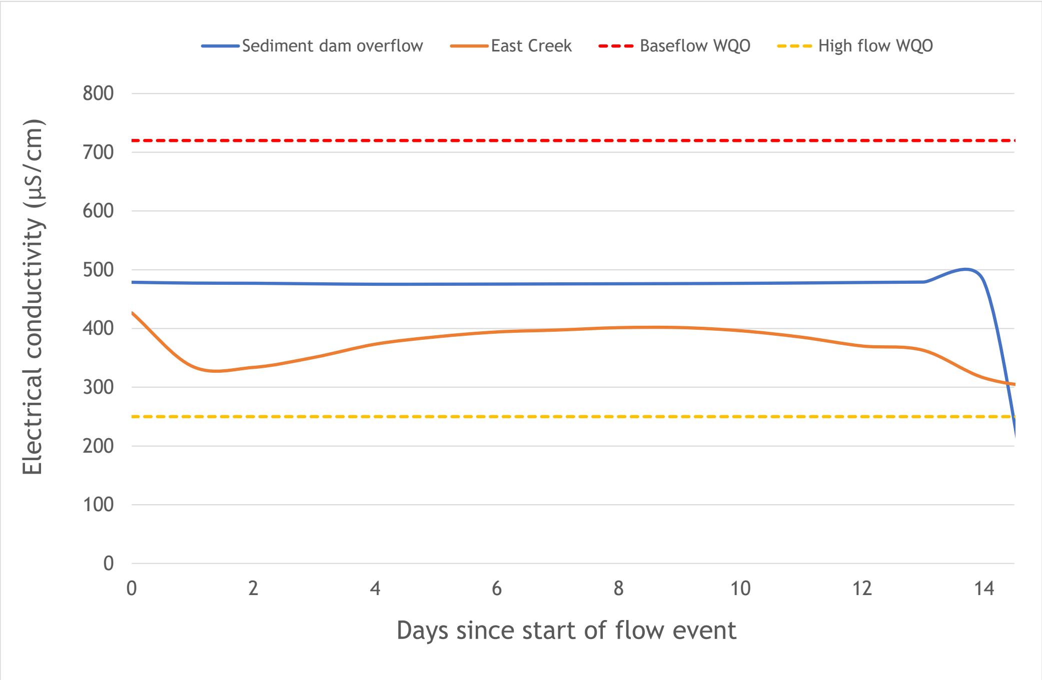

Figure 7.16 - Project release EC levels compared to EC levels in the receiving waters and corresponding water quality criteria - Scenario 1

7.3.10.2 Scenario 2 – Sediment dam highest flow rate

The Scenario 2 highest release rate occurs during Stage 3 with a cumulative release of approximately 306 ML/d to Hughes Creek. Figure 7.17 and Figure 7.18 shows the Scenario 2 release rate and EC from the cumulative release compared to the flow rate and EC in Hughes Creek during and following the release event.

The OPSIM model predicts that during the Scenario 2 release, Hughes Creek will already have a very large flow. The cumulative release has a negligible effect on the Hughes Creek EC levels due to the already high flows present. The model predicts that during the event both the EC levels of the release, and within Hughes Creek remain above the high flow WQO but below the baseflow WQO. It is noted that for this assessment, the assumed Hughes Creek EC is greater than the high flow WQO of 250 µS/cm.

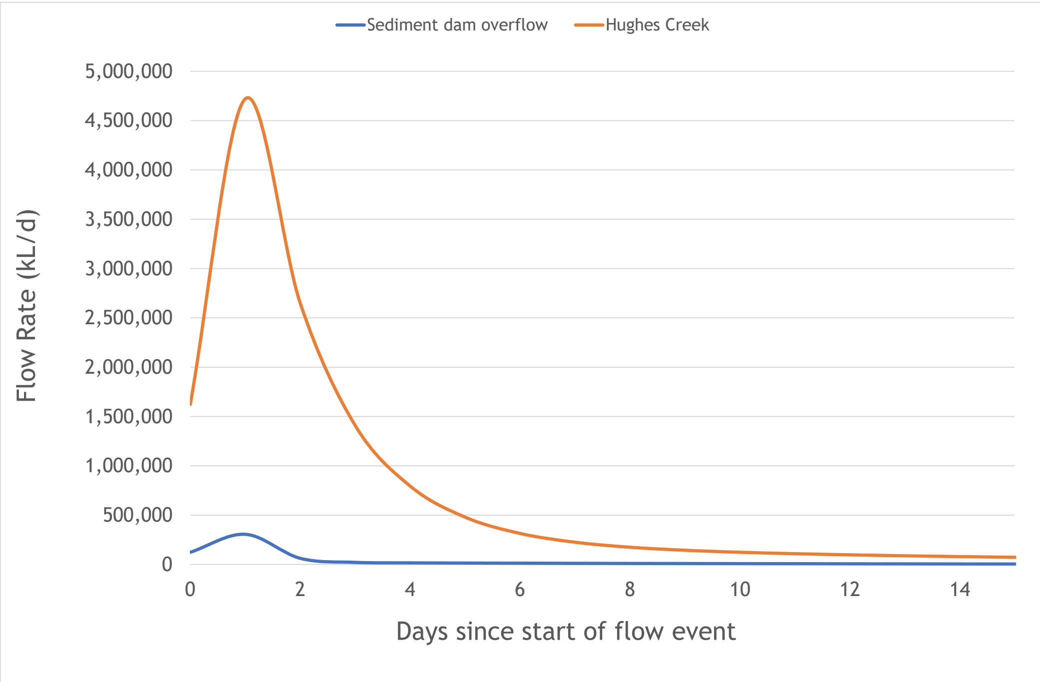

Figure 7.17 – Project release rates compared to flow rates in the receiving waters- Scenario 2

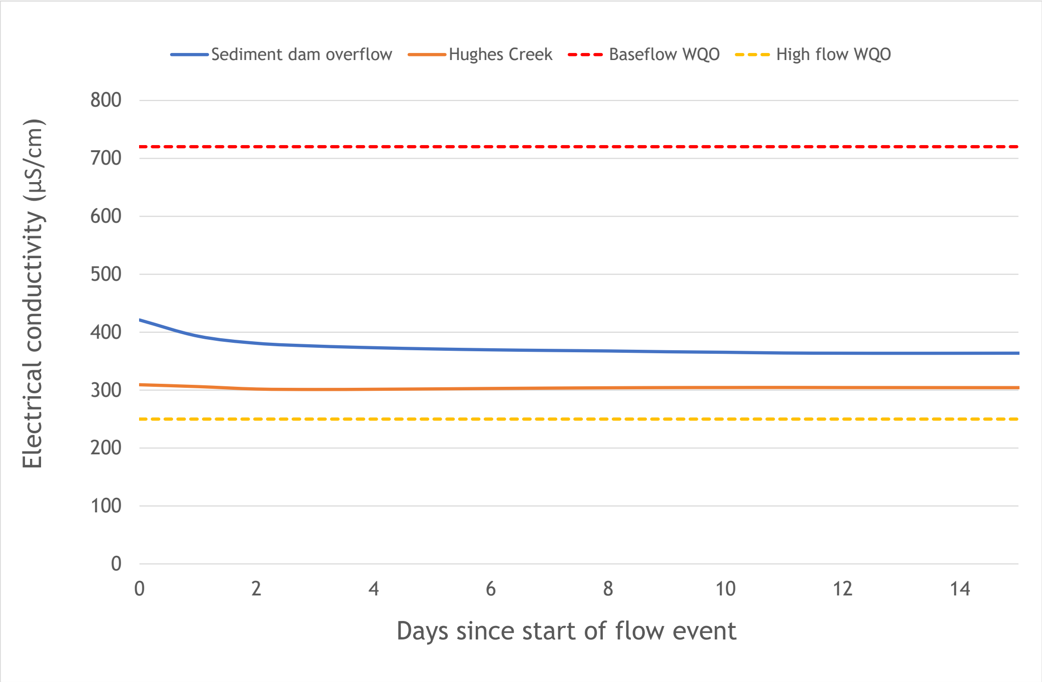

Figure 7.18 - Project release EC levels compared to EC levels in the receiving waters as well as the corresponding water quality criteria - Scenario 2

7.4 SENSITIVITY ANALYSIS

7.4.1 Haul road dust suppression

A sensitivity analysis was undertaken by varying the haul road dust suppression demand to assess the potential impacts on the overall water balance and MWD spill risk.

As outlined in Section 7.3, haul road dust suppression has the biggest influence on the Project water and salt balance. The haul road dust suppression demand has been estimated using the methodology outlined in Section 6.5.1. It is likely that the dust suppression demand will vary over the mine life as operations progress, as well as climatic and seasonal conditions. The haul road dust suppression is therefore likely the largest uncertainty for the water balance model and will have the greatest effect on the overall water balance.

7.4.1.1 Higher haul road dust suppression

It is noted that the highest haul road demand occurs in Stage 1, when the haul road to the Highwall mining area is active. To assess the impact of retaining a high haul road dust suppression across the entire mine life, this scenario has been run retaining the haul road dust suppression from Stage 1 across Stages 2 and 3.

Figure 7.19 shows the annual maximum MWD8 inventory, Figure 7.20 shows the annual maximum Vulcan Main pit inventory and Figure 7.21 shows the forecast annual total external water requirement.

The results of the sensitivity analysis indicate that:

- Slightly less water would accumulate in onsite water storages and the Vulcan Main pit when compared to the base case:
    - Under 10%ile conditions, MWD8 would store up to 131 ML in Stage 2 and 99 ML in Stage 3 when compared with 133 and 131 ML respectively in the base case.
    - During Stage 2, MWD8 would not significantly rise above its MOV under wettest (1%ile) conditions, unlike under the base case.
    - During Stage 2, under 1%ile conditions the Vulcan Main pit would store up to approximately 100 ML compared to 130 ML in the base case.
- Significantly more external water would be required to meet site water demands in Stages 2 and 3. During the driest climatic conditions (1%ile), external water demand would be up to 1480 ML/annum in Stage 2 and 3. This is in comparison to the base case external pipeline demand which is up to 650 ML/annum and 920 ML/annum respectively under 1%ile conditions.
- No mine affected water dam spills to the environment occur for this sensitivity assessment or the base case.

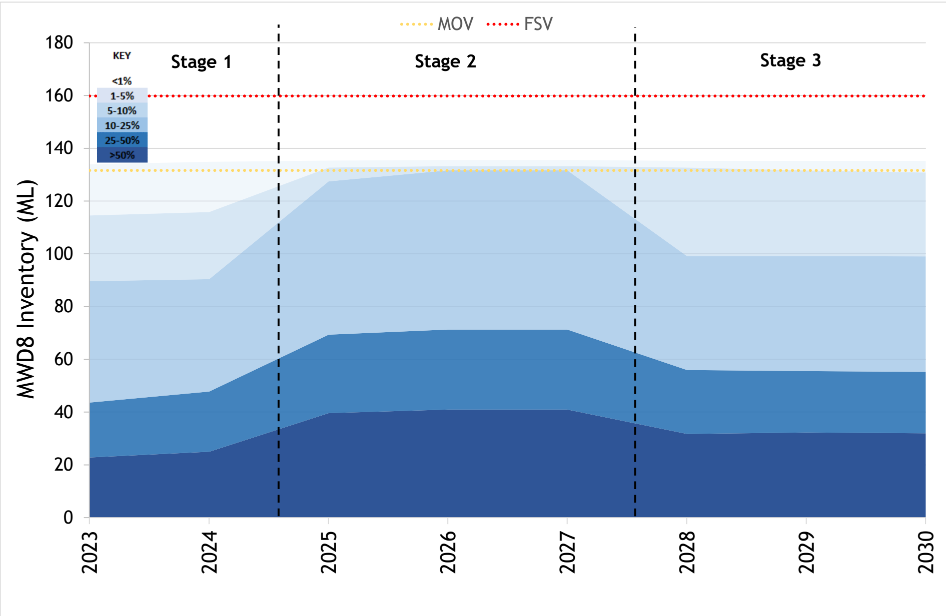

Figure 7.19 - Forecast annual maximum MWD8 inventory - high dust suppression sensitivity analysis

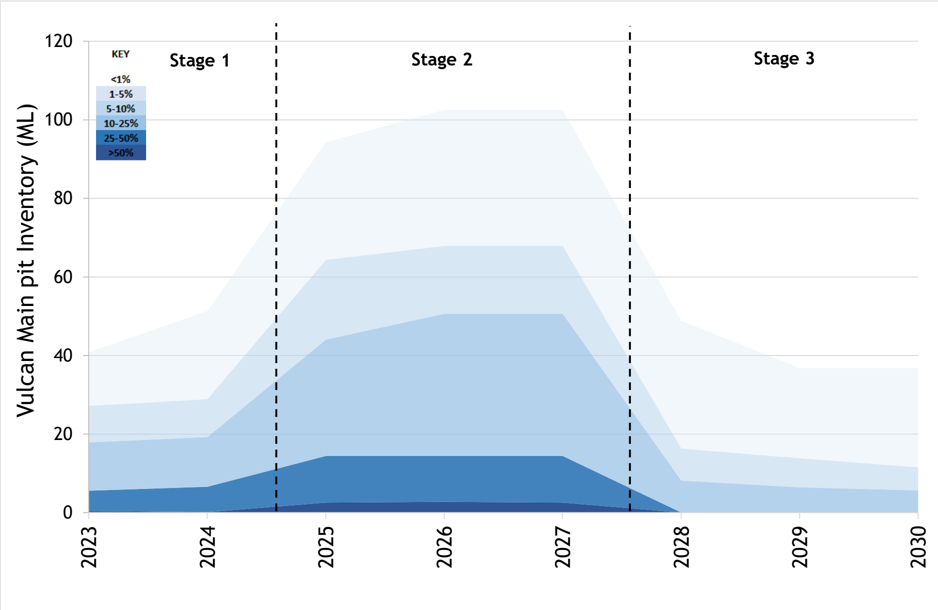

Figure 7.20 – Vulcan Main pit forecast annual maximum mine pit inventory – high dust suppression sensitivity analysis

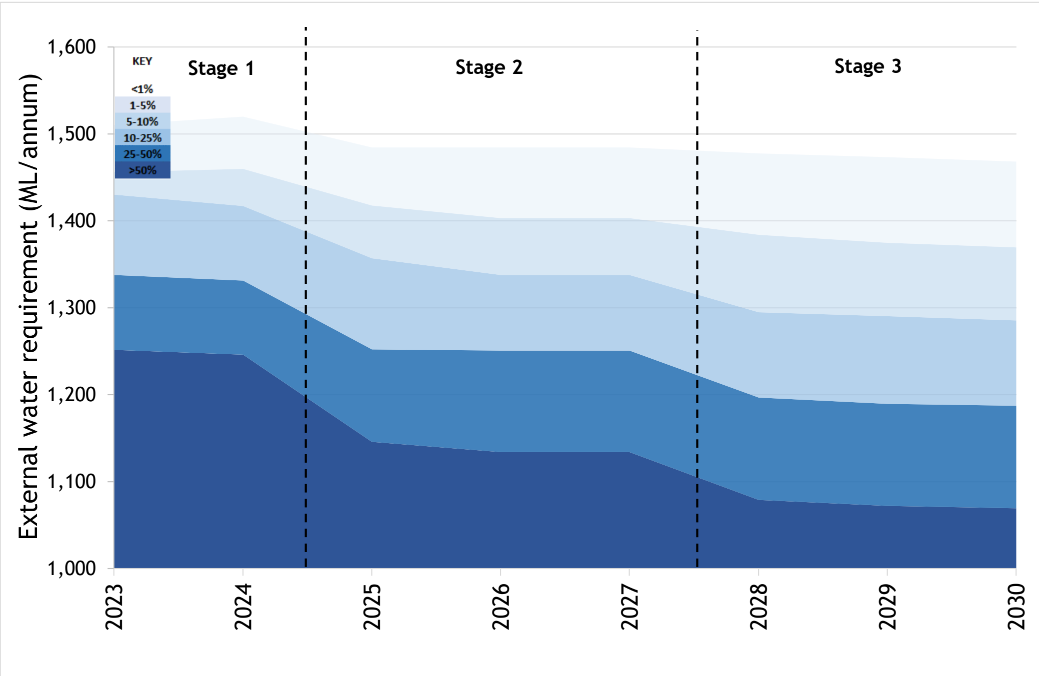

Figure 7.21 - Forecast annual total external water requirement - high dust suppression sensitivity analysis

7.4.1.2 Lower haul road dust suppression

To assess the impact of retaining a low haul road dust suppression across the entire mine life, this scenario has been run retaining the haul road dust suppression from Stage 2 across Stages 1 and 3. It is noted that the lowest haul road demand occurs in Stage 2.

Figure 7.22 shows the annual maximum MWD8 inventory, Figure 7.23 shows the annual maximum Vulcan Main pit inventory and Figure 7.24 shows the forecast annual total external water requirement.

The results of the sensitivity analysis indicate that:

- Slightly more water would accumulate in onsite water storages and the Vulcan Main pit when compared to the base case:
    - Under 10%ile conditions, MWD8 would store up to 120 ML in Stage 1 and 132 ML in Stage 3 when compared with 90 and 131 ML respectively in the base case.
    - During Stage 1, MWD8 would rise above its MOV under wettest (1%ile) conditions, unlike under the base case.
    - During Stage 1 & 3, under 1%ile conditions the Vulcan Main pit would store up to approximately 50 ML and 55 ML, compared to 51 and 64 ML in the base case respectively.
- Far less external water would be required to meet site water demands in Stages 1 and 3. During the driest climatic conditions (1%ile), external water demand would be up to 680 ML/annum and 640 ML/annum in Stage 1 and 3 respectively. This is in comparison to the base case external pipeline demand which is up to 1,520 ML/annum and 925 ML/annum respectively under 1%ile conditions.
- Under this scenario, MWD6, MWD7, MWD8 and the pits would not spill. However MWD9, would spill in Stage 3 under 2% of modelled simulations, with an annual spill volume of up to 12 ML.

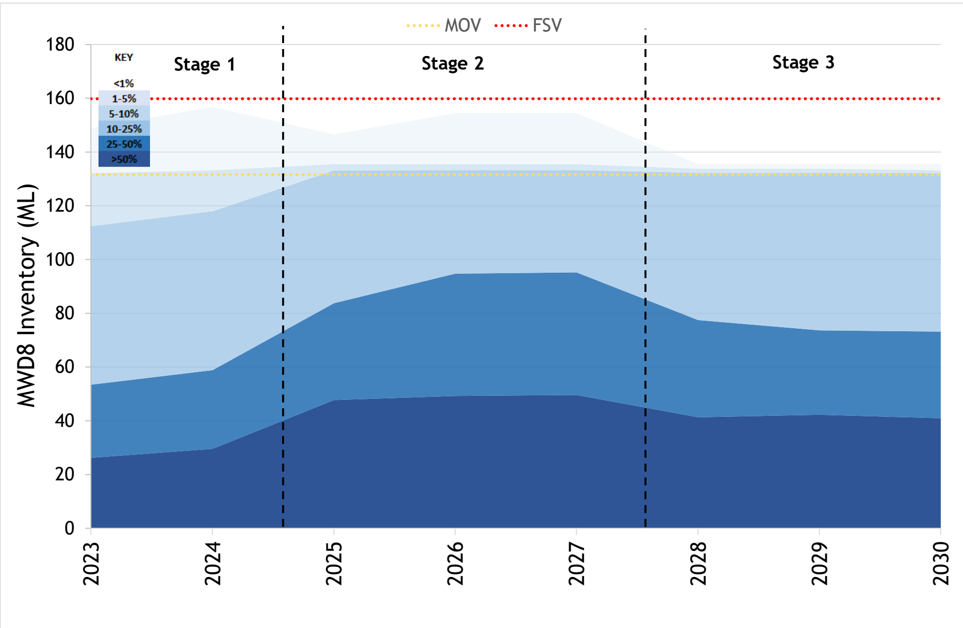

Figure 7.22 - Forecast annual maximum MWD8 inventory - low dust suppression sensitivity analysis

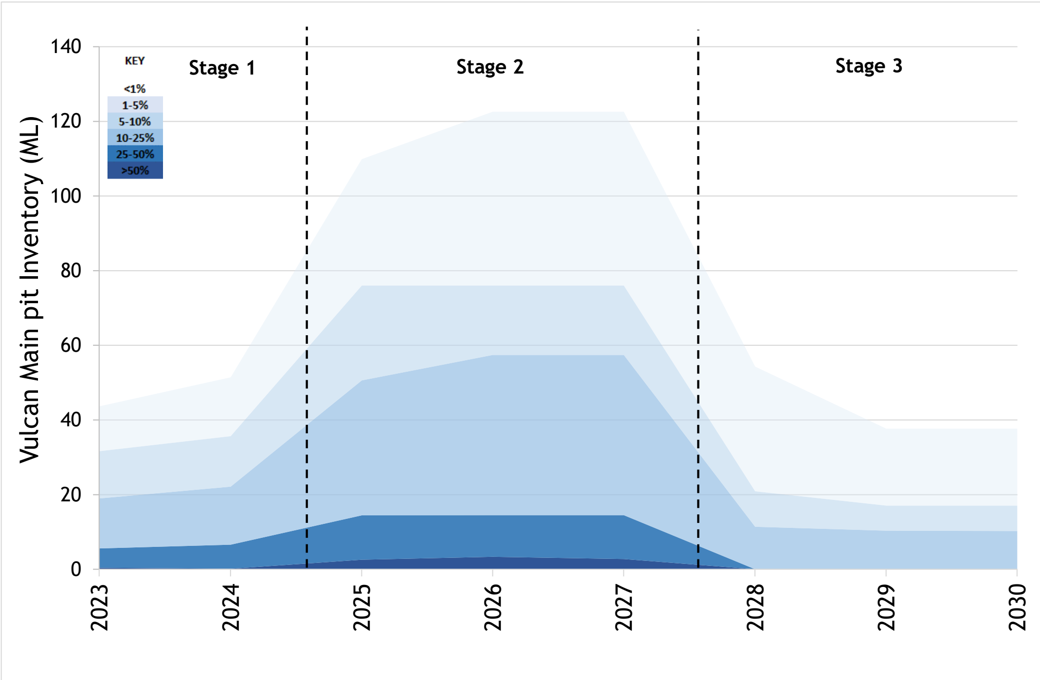

Figure 7.23 - Vulcan Main pit forecast annual maximum mine pit inventory - low dust suppression sensitivity analysis

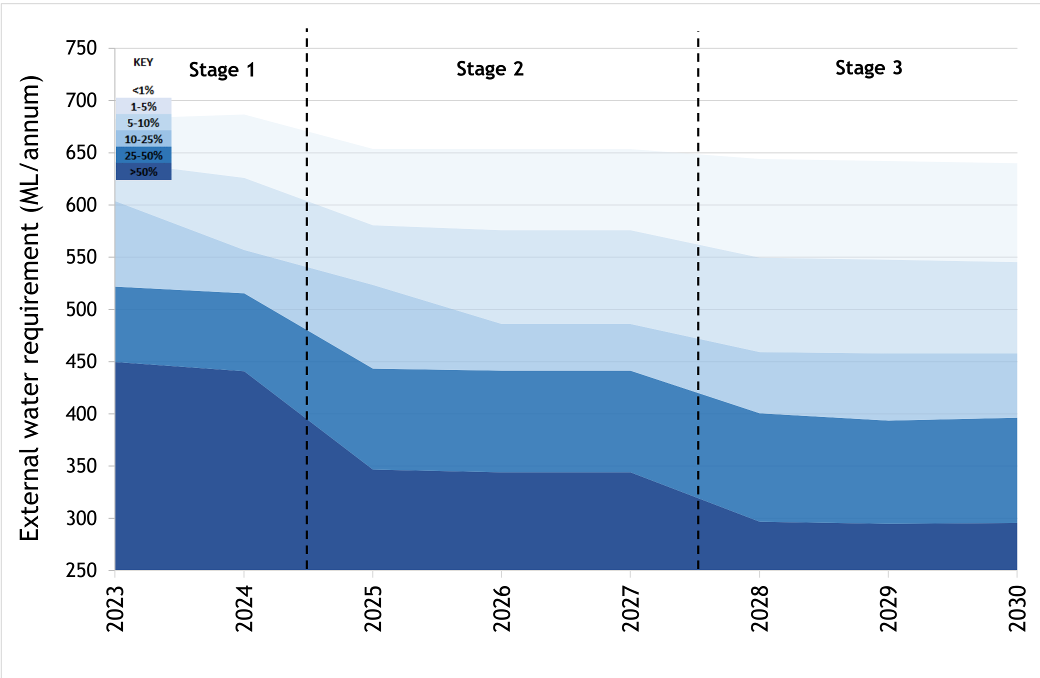

Figure 7.24 - Forecast annual total external water requirement - low dust suppression sensitivity analysis

7.4.2 Climate change

The potential changes to climate within the operational life of the Project were assessed using the projections and methodologies given in the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Commonwealth Bureau of Meteorology (BoM) report entitled "Climate Change in Australia Technical Report" (CSIRO, 2015). This report provides guidance on the possible projections of future climate for the Australian East Coast based on a current understanding of the climate system, historical trends and model simulations of the climate response to changing greenhouse gas and decreasing aerosol emissions.

Projections are given for a number of climatic variables including (but not limited to) temperature, rainfall, wind speed and potential evapotranspiration. CSIRO (2015) presents a number of possible approaches to quantify risks associated with climate change impacts.

For this assessment, the Representative Concentration Pathway 4.5 (RCP4.5) emissions scenario has been adopted. Potential changes in climate have been obtained using the projection builder tool provided in the Climate Change Australia website. Climate variable inputs for the 'best case', 'maximum consensus' case 'and 'worst case' RCP4.5 climate change scenarios are provided in Table 7.3.

Temperatures are expected to increase by approximately 1°C, rainfall is expected to decline by between 3% and 10% and evapotranspiration is expected to increase by between 3% and 4%.

The climate variable inputs (rainfall and evaporation) to the Project water balance model were adjusted to undertake the climate change impact assessment. Table 7.3 shows the adopted climate projections for the 'best case' and 'worst case' RCP4.5 climate change scenarios. The 'maximum consensus' scenario has not been run as it falls between 'best case' and 'worst case' scenarios.

Table 7.3 - Projections of changes to climate

Scenario	Climate model	Mean surface temperature	Rainfall	Evapotranspiration
		Annual change	Annual change	Annual change
Best case	MIROC5	1.02°C	-3.1%	3.2%
Maximum consensus	MIROC5	1.02°C	-3.1%	3.2%
Worst case	GFDL-ESM2M	1.07°C	-10.4%	3.9%

Figure 7.25 and Figure 7.26 show the forecast annual modelled demand for water from external sources for the 'best' and 'worst' case climate scenarios respectively.

The model results are summarised as follows:

- 'Best' case climate scenario (Figure 7.25):
  - For the 1%ile results (very dry climatic conditions), the 'best' case modelled annual external water demands are up to approximately 15 ML/a higher than the base case results.
  - For the 50%ile results the 'best' case modelled annual external water requirement be up to 10 ML/a higher than the base case results.
- 'Worst' case climate scenario (Figure 7.26):
  - For the 1%ile results (very dry climatic conditions), the 'worst' case modelled annual external water demands are up to approximately 30 ML/a higher than the base case results.

- For the 50%ile conditions, the 'worst' case modelled annual external water requirements are up to 80 ML/a higher than the base case.

There is an increase in external water demand requirements under both the 'best' and 'worst' climate scenarios, when compared with the base case results. This is due to the increase in evaporation and decrease in rainfall under both scenarios.

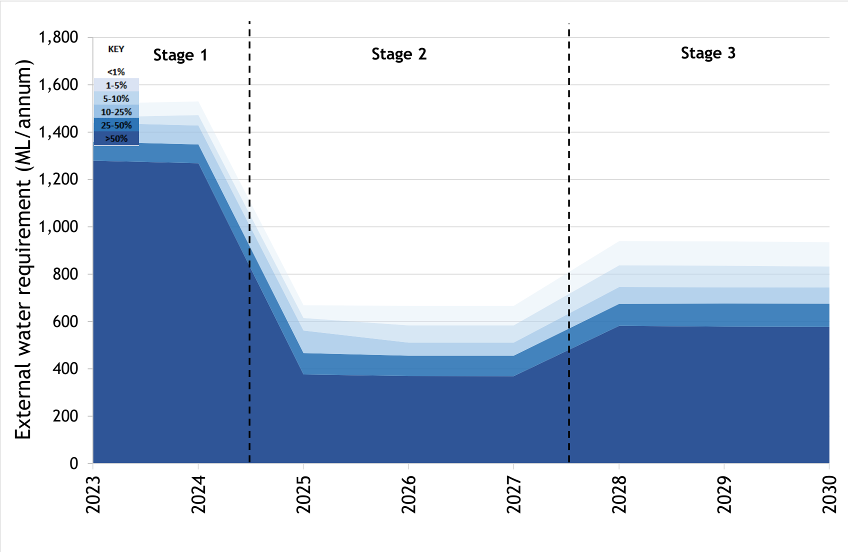

Figure 7.25 - Forecast annual total external water requirement - climate change 'best case' sensitivity analysis

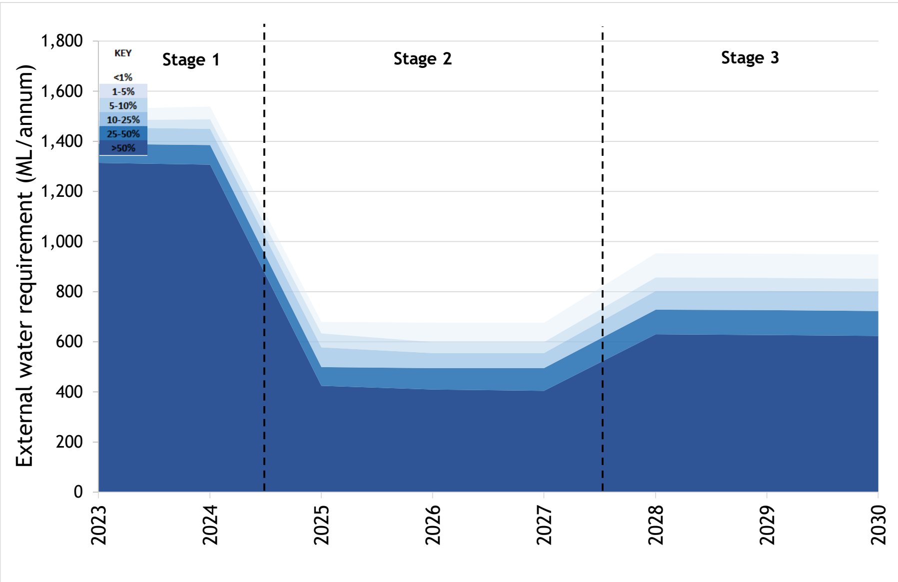

Figure 7.26 - Forecast annual total external water requirement - climate change 'worst case' sensitivity analysis

7.5 ADAPTIVE MANAGEMENT OF THE WATER MANAGEMENT SYSTEM

The model results presented above represent the application of the proposed water management system rules over the mine life, regardless of climatic conditions. There are numerous options for adaptive management of the mine water system to respond to climatic conditions and the current site water inventory in a way that will reduce the risks of impacts to surface water resources.

A site water balance model will be developed once the mine is operational and will be updated regularly (annually or biennially) using site monitoring data.

8 Flood modelling and impact assessment

8.1 OVERVIEW

The drainage features that cross the Project have been assessed to determine the potential impact of the Project on flood behaviour including:

- The potential to impact on flood levels;
- The potential to increase the extent of flooding;
- The potential to increase erosion and/or sedimentation of the impacted waterways;
- The potential to impact on the morphology of the adjacent floodplains; and
- The potential loss of flow from the catchment.

8.2 ADOPTED METHODOLOGY

8.2.1 Hydrological model

A hydrological model was developed for the Boomerang Creek and Hughes Creek catchments, including the features that cross the Project area, using the XP-RAFTS runoff-routing software (Innovyze, 2019). Section 8.3 describes the development, configuration and calibration of the hydrological model.

There was no publicly available recorded streamflow data in the drainage lines that cross the proposed Project area to calibrate the model. As a result, the XP-RAFTS design discharges estimated for Boomerang Creek and Hughes Creek catchments were validated against the Rational Method for the 10% and 1% AEP design flood event.

The Phillips Creek catchment was also included in the hydrologic model because of the availability of recorded water levels and flows. The peak 10% and 1% AEP design discharges estimated for Phillips Creek by the XP-RAFTS model were validated against a Flood Frequency Analysis (FFA) of the annual series peak discharges recorded at the (now closed) Phillips Creek at Tayglen streamflow gauge.

Design flood hydrographs estimated using the calibrated XP-RAFTS model were adopted as inflows in the hydraulic model.

8.2.2 Hydraulic model

The TUFLOW model was used to estimate design flood levels, velocities and extents in Boomerang Creek, Hughes Creek and their tributaries across the Project area for the 10% (1 in 10) AEP, 1% (1 in 100) AEP and 0.1% (1 in 1000) AEP design flood events for the Existing Conditions, Life of Mine (Operational) Conditions and the proposed Final Landform Conditions. The model results were used to assess the potential impacts on flood levels, velocities and extents along Boomerang Creek, Hughes Creek and their tributaries for the Operational and Post-closure conditions. Section 8.4 and Section 8.5 describes the development and configuration of the hydraulic model and Section 8.6 to Section 8.9 provide the flood modelling results and impact assessment.

The potential flood impacts of the Project were assessed for the following three conditions:

- Existing Conditions;
- Life of Mine (Operational) Conditions; and
- Post-closure Conditions.

8.3 EXISTING CONDITIONS HYDROLOGIC MODEL CONFIGURATION

8.3.1 General

Figure 8.1 shows the configuration of the XP-RAFTS model of the Boomerang, Hughes and Phillips Creek catchments. The model consists of a total of 93 sub-catchments, ranging in size from 0.1 km^2 to 59.8 km^2. This includes 49 sub-catchments for Boomerang Creek, 30 sub-catchments for Hughes Creek, 3 sub-catchments for Barrett Creek and 11 sub-catchments for Phillips Creek.

The XP-RAFTS model uses a single sub-catchment approach to determine runoff hydrographs, based on the overall sub-catchment parameters (fraction impervious, slope and roughness). All sub-catchments were assigned a fraction impervious of 0%, catchment slope based on the available topographic data and a Manning's n (roughness) of 0.04. Channel routing was modelled using the Muskingum-Cunge method, based on the channel length and average channel slope for each "link" between catchment nodes.

8.3.2 Design rainfall depths, intensities and temporal patterns

Design rainfall depths and intensities for the design events were derived using intensity-frequency duration (IFD) data obtained from the Bureau of Meteorology's (BOM's) 2019 Rainfall IFD Data System.

The East Coast North temporal patterns were adopted for events up to the 1% AEP as per recommendations in Australian Rainfall and Runoff (AR&R) Data Hub (Geoscience Australia, 2019). For the 0.1% AEP event, one temporal pattern was applied to each storm duration. The 0.1% AEP temporal patterns were adopted from the Generalised Short Duration Method (GSDM) (BOM, 2003) for storm durations of 6 hours and less.

8.3.3 Design rainfall losses

The initial (IL) and continuing loss (CL) method of accounting for rainfall losses was adopted for this assessment. The recommended regional IL and CL values for the Boomerang Creek and Hughes Creek catchments from the AR&R Data Hub (Geoscience Australia, 2019), were 45 mm (prior to adjustment for preburst rainfall) and 1.9 mm/hr respectively. The IL and CL adopted for the 0.1% AEP was 0.0 mm and 1.9 mm/h respectively.

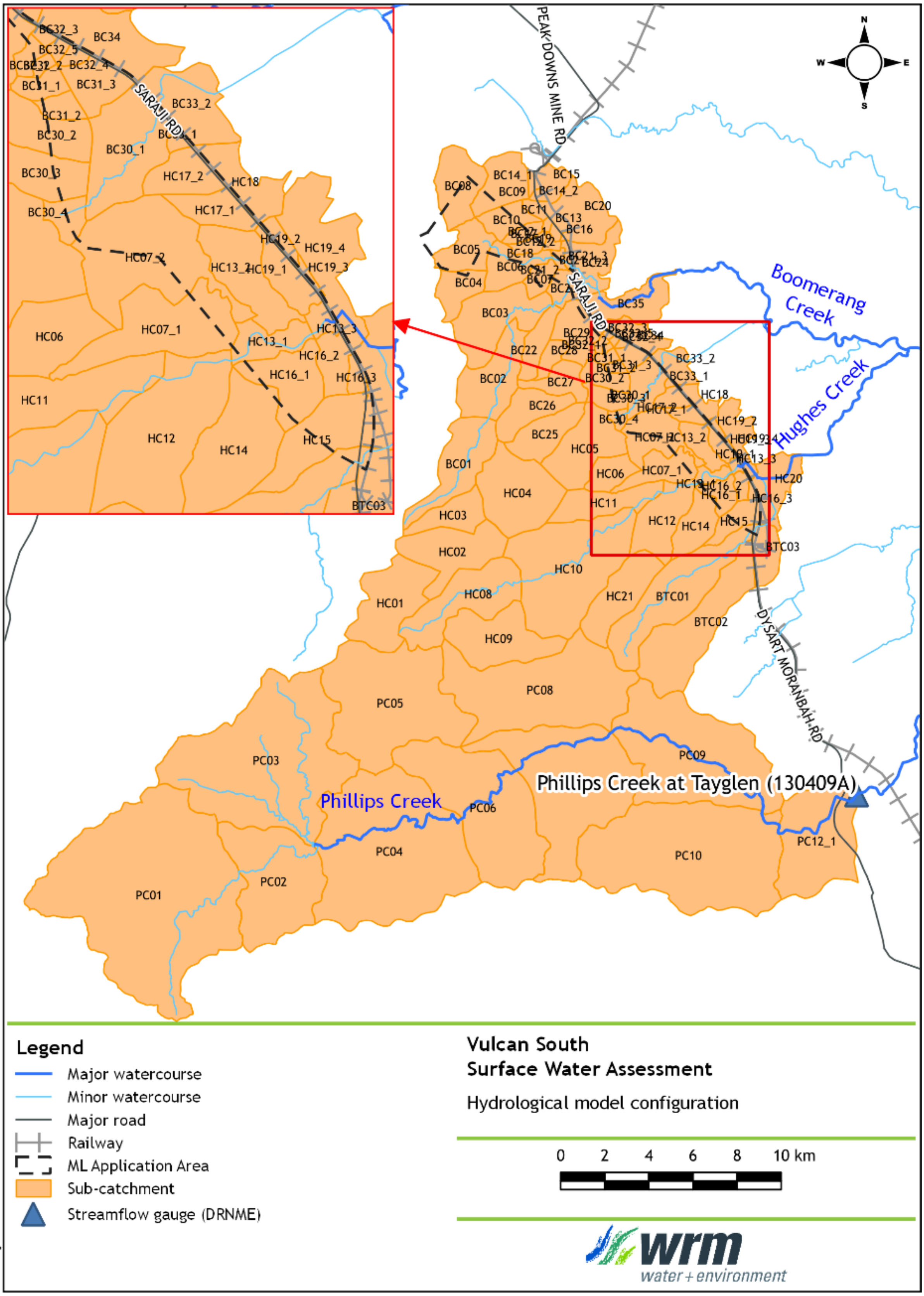

Figure 8.1 – XP-RAFTS model configuration

8.3.4 Peak flow validation

8.3.4.1 Boomerang Creek and Hughes Creek catchments

The Rational Method was used to validate the 10% and 1% AEP design flood discharges in Boomerang Creek and Hughes Creek estimated by XP-RAFTS. Table 8.1 compares the XP-RAFTS design discharge estimates for Boomerang Creek at BC11 and BC17 and for Hughes Creek at HC14 against the Rational Method estimates. The table shows that the design discharges derived by the XP-RAFTS model are generally within 15% of the Rational Method estimates.

Table 8.1 – Peak design discharge comparison between XP-RAFTS and Rational Method

Sub-catchment ID (see Figure 8.1)	Sub-catchment area (ha)	AEP event (%)	Design Discharge (m^3/s)		
			Rational Method	XP-RAFTS	Difference
BC11	61	10%	3.8	3.3	-0.5
		1%	6.7	7.2	0.5
BC17	107	10%	8.1	7.2	-0.9
		1%	14.0	15.5	1.5
HC15	225	10%	11.7	9.9	-1.8
		1%	21.0	21.5	0.5

8.3.4.2 Phillips Creek catchment

The results of the XP-RAFTS model for Phillips Creek were validated by comparing the peak design discharges from XP-RAFTS to the results of a FFA undertaken to the annual flood peak series from DNRME's Tayglen gauge (gauge no. 130409A), which operated between 1968 and 1988. The catchment to the gauge is approximately 344 km^2.

The results compared in Table 8.2 show that the XP-RAFTS 1% AEP peak discharge compares reasonably well with the FFA expected result. The 10% AEP XP-RAFTS peak discharge overestimates the FFA peak discharge, however it is within the 90th percentile confidence limits.

Table 8.2 - FFA at Tayglen gauge compared to XP-RAFTS peak discharge

Design event	XP-RAFTS design peak discharge (m^3/s)	FFA design peak discharges (m^3/s)			% Difference
		Expected result	Lower confidence limit	Upper confidence limit	
10%	490	376	227	622	23%
1%	1,109	1,083	402	2,922	2%

8.3.4.3 Summary

Overall, the XP-RAFTS hydrological model is considered satisfactorily validated and acceptable for estimating design hydrographs for input into the hydraulic model.

8.3.5 Adopted design discharges

The hydrologic model was run for the 1 hr to 24 hr storm durations. Table 8.3 shows the adopted peak design discharges estimated by the XP-RAFTS model at key locations in the vicinity of the Project area for the 10%, 1% and 0.1% AEP design flood events. Table 8.3 also shows the critical storm durations and representative temporal patterns producing the peak discharge at each location.

Table 8.3 - Adopted design discharges, critical storm durations and temporal pattern

Key location	AEP event (%)	XP-RAFTS Ensemble mean peak discharge (m^3/s)	XP-RAFTS adopted design peak discharge (m^3/s)[1]	Critical storm duration (hours)	Temporal pattern number
Drainage Line 2 upstream of Saraji Road (BC06)	10%	50.9	51.5	3	4*
	1%	102.4	102.8	2	8*
	0.1%	NA	233.4	2	NA
Drainage Line 3 at Saraji Road (BC23)	10%	69.4	71.0	6	7
	1%	164.7	166.8	6	2*
	0.1%	NA	323.9	3	NA
Drainage Line 4 at Saraji Road (BC29)	10%	68.5	70.2	6	4
	1%	143.1	145.2	4.5	2
	0.1%	NA	342.4	2	NA
Drainage Line 6 at Saraji Road (BC31_3)	10%	10.9	11.0	3	4
	1%	22.3	23.1	2	1
	0.1%	NA	51.6	1	NA
Drainage Line 7 at Saraji Road (BC30_1)	10%	23.5	23.9	6	4
	1%	52.3	53.5	6	8
	0.1%	NA	115.4	2	NA
Hughes Creek at Norwich Park Branch Railway (HC13_3)	10%	237.3	240.5	6	7*
	1%	554.1	558.7	6	10
	0.1%	NA	1095.4	6	NA
Drainage Line 8 at Norwich Park Branch Railway (HC16_2)	10%	23.5	23.9	6	4
	1%	50.6	50.9	4.5	3
	0.1%	NA	117.8	2	NA
Barrett Creek at Saraji Road (BTC01)	10%	74.8	76.0	6	8
	1%	177.7	182.0	6	3
	0.1%	NA	383.9	3	NA

NA – not applicable; Note that the 1 hour to 6 hour storm durations were all run in the hydraulic model for the 0.1% AEP event.
[1]Adopted design peak discharge calculated from the temporal pattern which generated a peak discharge closest to, but higher than, the ensemble mean.
*Indicates the selected temporal pattern run in the hydraulic model.

8.4 HYDRAULIC MODEL DEVELOPMENT

The two-dimensional TUFLOW hydraulic model (BMT, 2018a) was used to simulate the flow behaviour of Boomerang Creek, Hughes Creek and their tributaries in the vicinity of (and through) the proposed Project area. Separate TUFLOW hydraulic models were developed for Boomerang Creek and Hughes Creek. Figure 8.2 shows the extent of the Existing Conditions TUFLOW model

TUFLOW represents hydraulic behaviour on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow (BMT, 2018b). The model automatically calculates breakout points and flow directions within the study area. A 2 m grid cell size was adopted for both TUFLOW models to obtain the best representation of flow distributions between the drainage channels, drainage diversions, hydraulic structures (e.g. culverts) and floodplains.

8.4.1 Topographic data

The TUFLOW model used topographic aerial survey data (LiDAR) supplied by Aerometrex Pty Ltd via Vitrinite. The ground surface data was obtained by LiDAR capture on 7, 8 and 27 May 2019. Aerometrex Pty Ltd quote that the LiDAR data has a vertical root mean squared error of 0.0755 m.

8.4.2 Inflow and outflow boundaries

Figure 8.2 to Figure 8.4 shows the locations of the 2D inflow and outflow boundaries used in the TUFLOW model. The discharge hydrographs estimated using the XP-RAFTS runoff-routing model were adopted as inflows to the TUFLOW model.

Normal depth outflow boundaries were adopted at Peak Downs's Boomerang Creek diversion and East Creek diversion as well as Saraji's Hughes Creek diversion, all located at least 1.6 km downstream of the Project area to ensure that the boundary assumptions have no material impact on peak flood levels in the study area. The adopted tailwater slopes are as follows:

- Boomerang Creek diversion: 0.0025 m/m;
- East Creek diversion: 0.0045 m/m; and
- Hughes Creek diversion: 0.0020 m/m.

8.4.3 Manning's 'n' values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance. Manning's 'n' values were adopted based on typical published values (e.g. Chow (1959)) and consistent with Manning's 'n' value adopted in nearby flood studies. Manning's 'n' values were mapped within the study area based on aerial photography taken on 27 May 2019. The following Manning's 'n' values were adopted:

- Vegetated channels: 'n' = 0.060;
- Rocky channels: 'n' = 0.045;
- Light vegetation: 'n' = 0.050;
- Dense vegetation: 'n' = 0.080;
- Exposed soil / unsealed roads: 'n' = 0.025;
- Water bodies / dams: 'n' = 0.015;
- Sealed roads: 'n' = 0.020; and
- Buildings: 'n' = 0.300.

8.4.4 Hydraulic structures

There are 43 culvert structures modelled as 1d structures in the 2d domain (22 in the Boomerang Creek model and 21 in the Hughes Creek model). The culvert locations are shown in Figure 8.2 to Figure 8.4 and include the culverts beneath Saraji Road and the Norwich Park Branch Railway.

The culvert structures within the Peak Downs and Saraji mining leases were modelled as gaps or openings to represent the culverts as information on these structures were not available for this study.

The Hughes Creek bridge was modelled as a layered flow constriction.

8.5 CHANGES TO EXISTING CONDITIONS

8.5.1 Operational Conditions model changes

The Existing Conditions TUFLOW models developed for Boomerang Creek and Hughes Creek were updated to include mine water infrastructure required during operations. The model updates representing the Operational Conditions configuration is shown in Figure 8.3 and include:

- Proposed life-of-mine landforms and open cut pits;
- Modified inflow boundary locations to represent Operational Conditions catchment areas;
- Proposed culverts along the proposed haul roads, levees, and diversions;
- Proposed levees and diversions; and
- Proposed haul roads.

8.5.2 Post-closure Conditions model changes

The Existing Conditions TUFLOW models developed for the Project was updated to reflect the Post-closure Conditions configuration. The model updates shown in Figure 8.4 include:

- Proposed final landforms drainage corridors;
- Modified inflow boundary locations to represent Post-closure Conditions catchment areas; and
- Proposed culverts.

8.5.3 Proposed culverts

The proposed culvert configurations shown in Figure 8.3 and Figure 8.4 are summarised in Table 8.4 below. The proposed culvert configurations were sized based on the following:

- Proposed culverts along the proposed haul road in the Operational Conditions model were provided by Vitrinite; and
- Proposed culverts along Saraji Road in the Operational and Post-closure conditions models were based on existing culverts.

Table 8.4 - Proposed culvert configurations, Operational and Post-closure conditions

Culvert ID	Type	Diameter / width (m)	Height (m)	No. of barrels	US Invert level (mAHD)	DS Invert level (mAHD)
CulvHR1.3[1]	CSP	1.2	-	4	224.98	224.02
CulvHR1.4[1]	CSP	1.2	-	4	226.19	225.9
CulvHR1.5[1]	CSP	1.05	-	2	231.0	230.12
CulvHR2.3[1]	CSP	1.2	-	6	204.93	204.75
CulvHR2.2[1]	CSP	1.2	-	10	200.9	200.45
CulvHR2.1[1]	CSP	1.2	-	10	200.16	200.09
C0023393*	RCP	0.75	-	4	209.39	208.51
C0023391*	RCP	0.9	-	1	202.85	202.7
C0023390*	RCBC	2.0	1.5	2	201.20	201.20
C0023389*	RCP	0.75	-	2	203.6	203.5

CSP = Corrugated steel pipe
RCP = Reinforced concrete pipe
RCBC = Reinforced concrete box culvert
[1] = Provided by Vitrinite
* = Based on existing culverts

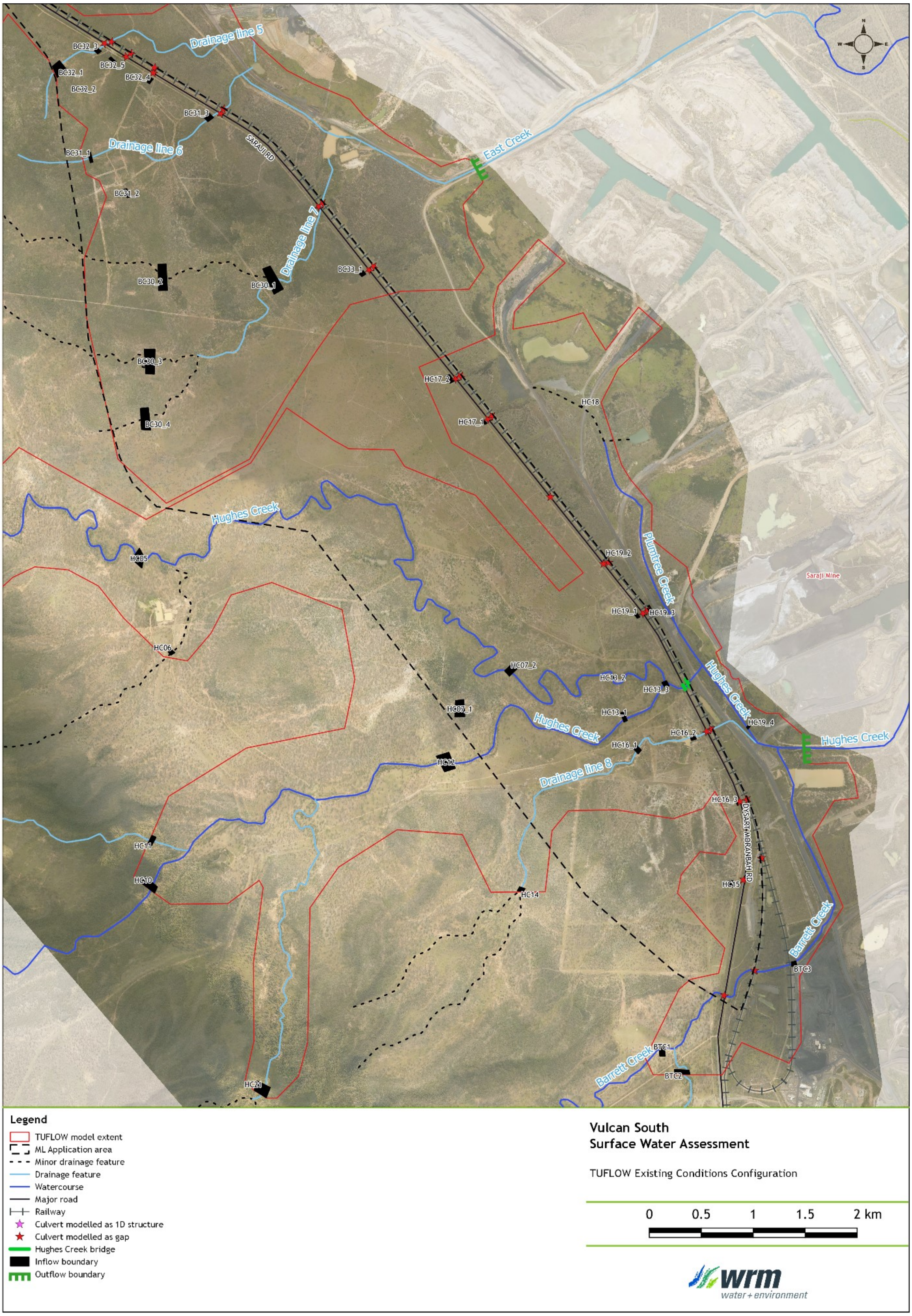

Figure 8.2 – Existing Conditions hydraulic model configuration

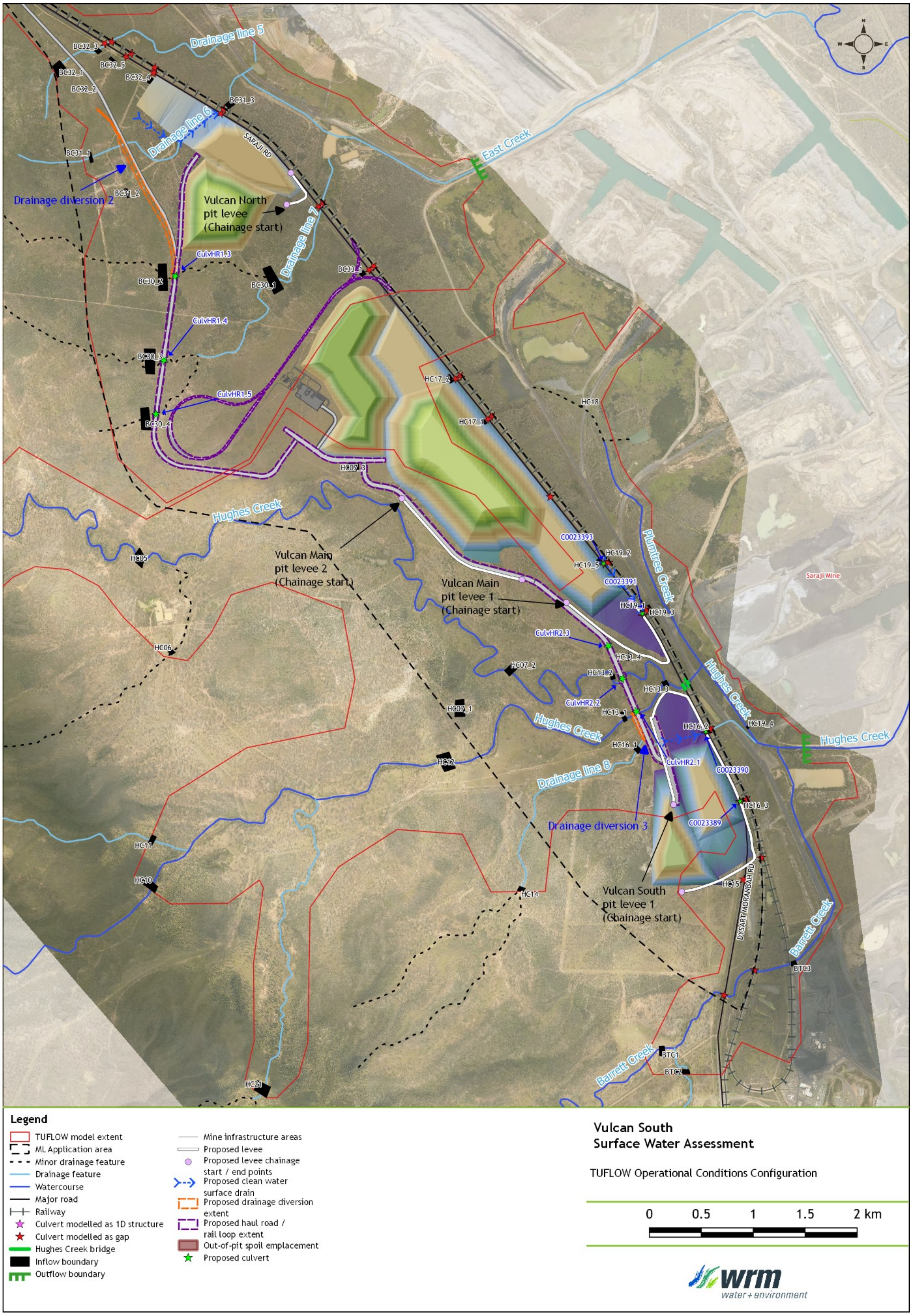

Figure 8.3 - Life of mine (Operational) Conditions hydraulic model configuration

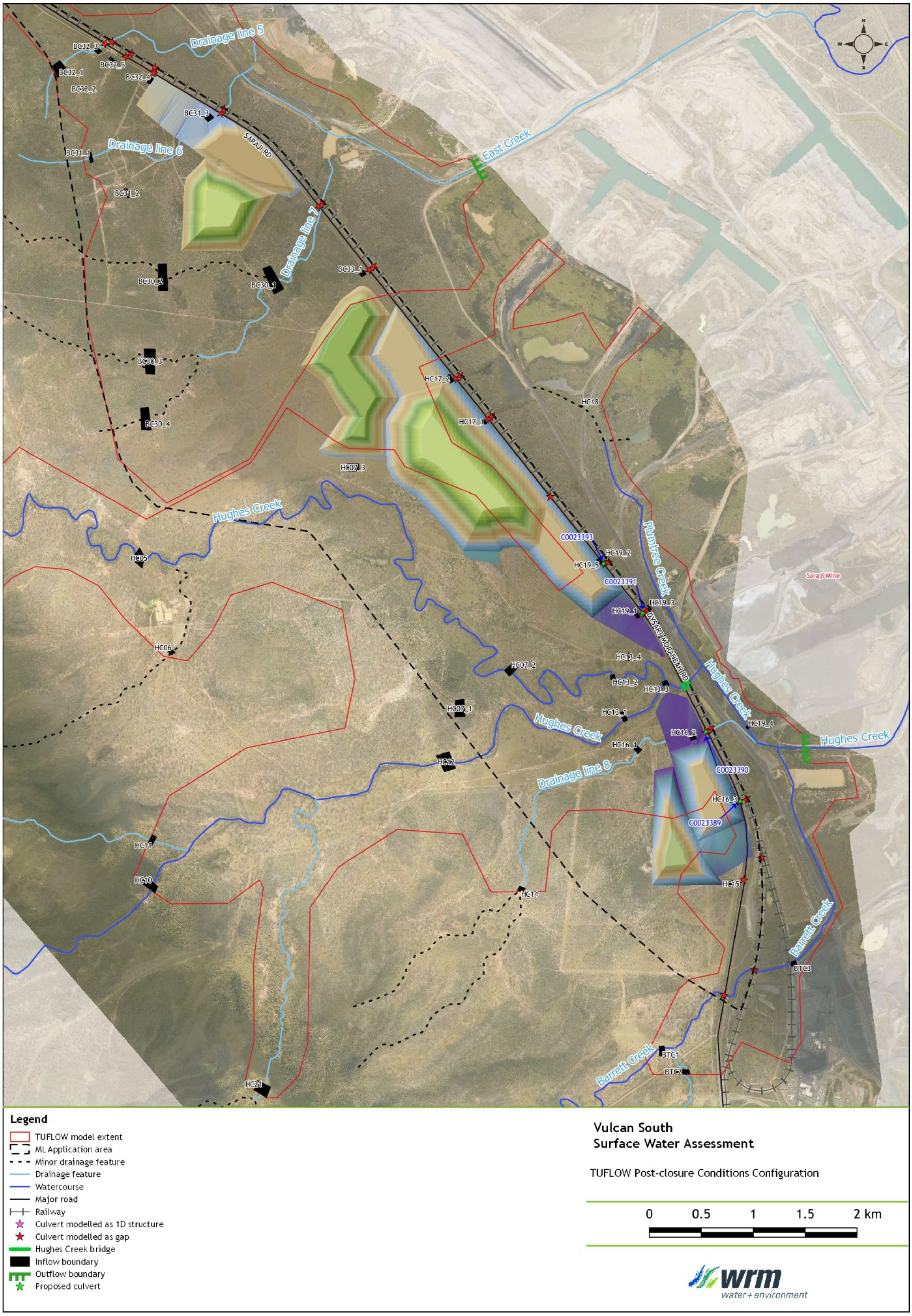

Figure 8.4 - Post-closure Conditions hydraulic model configuration

8.5.4 Proposed flood protection levees

Table 8.5 shows the required minimum crest levee levels during Operational Conditions along the proposed pit flood protection levees (see Figure 8.3). The proposed flood protection levees will be required during operations to protect the mining pit from ingress of clean water. Figure 8.3 shows the reported chainage start (0 m) locations along the proposed flood protection levees.

It is recommended that peak 0.1% AEP peak flood levels are adopted for the basis of the flood levee requirements during operations and the freeboard for determining the required levee crest level is 1 m above the flood level. The results show that the proposed flood protection levees will range between 1 m and 5 m high.

The proposed flood protection levee configurations are preliminary only. The final horizontal and vertical alignment will be confirmed in conjunction with the proposed haul road and final landform requirements during the design phase.

Table 8.5 - 0.1% AEP flood levels plus 1 m freboard height adjacent to the proposed flood protection levees required for operations

Chainage (m)	Required minimum crest levee level with 1 m freeboard requirement included (mAHD)			
	Vulcan North pit levee	Vulcan Main pit levee 1	Vulcan Main pit levee 2	Vulcan South pit levee
0	-	-	-	-
200	221.1	208.6	217.3	208.0
400	221.1	208.3	216.0	208.0
600	-	207.4	215.0	208.0
800	-	207.4	214.5	207.8
1000	-	207.4	212.6	207.5
1200	-	207.1	211.3	207.1
1400	-	206.9	211.0	206.7
1600	-	206.9	211.0	206.4
1800	-	206.9	211.0	206.4
2000	-	-	-	206.4
2200	-	-	-	206.2
2400	-	-	-	206.2
2600	-	-	-	206.1
2800	-	-	-	206.9
3000	-	-	-	208.2
3200	-	-	-	208.6
3400	-	-	-	208.7
3600	-	-	-	208.7

8.5.5 Proposed drainage diversions

The proposed drainage diversions were designed to divert runoff from undisturbed catchments around the proposed Vulcan North, Vulcan Main and Vulcan South pits to adjacent existing drainage lines. Figure 8.3 shows the location of the proposed drainage diversion.

The preliminary sizing of the proposed drainage diversions was based on attaining sufficient capacity to ensure that the proposed pits are protected against floodwater during the 0.1% AEP event.

Drainage diversion 2 was designed with the following characteristics:

- a 10 m base width
- a 1(V):3(H) batter slope to existing ground levels; and
- a 2 m high bund along the western side of the drain.

The preliminary Drainage diversion 3 configuration was designed for local 10% AEP flows as the results of the modelled events show that the Hughes Creek floodplain is inundated during larger events. Drainage diversion 3 was designed with a 10 m base width and with 1(V):3(H) batter slopes that grade up to existing ground levels.

The results show that the drainage diversions have sufficient capacity to convey flood events up to the 0.1% AEP. Refinements to the design will be required to be undertaken in conjunction with confirmation of the proposed haul road and final landform configurations. Also, careful consideration of scour protection will be required at the upstream and downstream ends of the drainage diversions as well as at tributary inflow locations.

8.6 EXISTING CONDITIONS DESIGN FLOOD LEVELS AND EXTENTS

8.6.1 General

The TUFLOW model was used to determine the Existing Conditions 10%, 1% and 0.1% AEP design flood levels, depth, extents and velocities in the vicinity of the Project. Figure B.1 to Figure B.6 in Appendix B show the predicted flood depth and flood velocity profiles under Existing Conditions for the 10%, 1% and 0.1% AEP events.

8.6.2 East Creek

Key findings on flooding within the East Creek catchment and its tributaries are summarised below:

- For the 10% AEP event (see Figure B.1 and Figure B.4):
  - floodwaters through the Project area are generally conveyed within the channel banks of natural drainage lines. Saraji Road is overtopped at some crossing locations. The Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 10% AEP event;
  - peak flood velocities along natural drainage channels in the vicinity of the Project area are up to 2.0 m/s in localised areas; and
  - overbank flood depths adjacent to natural drainage lines are generally shallow (less than 0.5 m).
- For the 1% AEP event (see Figure B.2 and Figure B.5):
  - floodwaters through the Project area are generally conveyed within the channel banks of natural drainage lines with limited overbank flooding. Saraji Road is overtopped at most crossing locations. The Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 1% AEP event;
  - peak flood velocities in natural drainage channels are typically elevated (greater than 2.0 m/s in localised areas). Overbank velocities are generally up to 1 m/s; and
  - flood widths and depths adjacent to natural drainage lines are greatest upstream of Saraji Road and Norwich Park Branch Railway where floodwaters are impounded behind the constructed embankments.

- For the 0.1% AEP event (see Figure B.3 and Figure B.6):
  - floodwaters through the Project area are generally conveyed within the channel banks of natural drainage lines with confined overbank flooding;
  - flood velocities along natural drainage channels are typically elevated (greater than 2.5 m/s in localised areas). Overbank velocities are generally up to 1 m/s; and
  - peak flood widths and depths along the eastern side of the Project area increase as natural drainage lines drain towards Saraji Road and Norwich Park Branch Railway where floodwaters are impounded behind the constructed embankments. Flood depths impounded behind the railway embankment at the eastern boundary of the Project are up to 5 m.

8.6.3 Hughes Creek

Key findings on flooding within the Hughes Creek catchment and its tributaries are summarised below:

- For the 10% AEP event (see Figure B.1 and Figure B.4):
  - floodwaters through the Project area are generally conveyed within the Hughes Creek channel. Minor breakouts occur along the Drainage line 8 and Barrett Creek channels upstream of Saraji Road. The Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 10% AEP event;
  - peak flood velocities along natural drainage channels are typically elevated in the vicinity of the Project area (greater than 2.0 m/s in localised areas). Overbank velocities are generally up to 1 m/s; and
  - overbank flood depths adjacent to natural drainage lines are generally shallow (less than 0.5 m). Notwithstanding this, Hughes Creek flood depths are up to 3 m upstream of the railway.
- For the 1% AEP event (see Figure B.2 and Figure B.5):
  - overbank flooding occurs at several locations within the Project area along Hughes Creek, with flood widths of up to 1.6 km just upstream of the railway;
  - overbank flood depths are up to 4.5 m adjacent to Hughes Creek upstream of the railway. The railway embankment is overtopped during this event; and
  - peak flood velocities along natural drainage channels are typically elevated (up to 3.2 m/s in localised areas). Overbank velocities are generally up to 1.5 m/s.
- For the 0.1% AEP event (see Figure B.3 and Figure B.6):
  - significant overbank flooding occurs along Hughes Creek within the Project area along Hughes Creek and Barrett Creek, with flood widths of up to 2 km;
  - overbank flood depths are up to 5 m adjacent to Hughes Creek, with some localised areas that exceed 5 m; and
  - peak flood velocities along natural drainage channels are typically elevated (up to 4 m/s in localised areas). Overbank velocities are generally up to 2.0 m/s.

8.7 OPERATIONAL CONDITIONS POTENTIAL FLOOD IMPACTS

8.7.1 General

Figure 8.3 shows the proposed Life of Mine (Operational) Conditions configuration used in the TUFLOW model. The TUFLOW model results show that the proposed Operational Conditions configuration may cause potential flow constraints and flood impacts as a result of the life of mine infrastructure. These include:

- Changed flow conditions between the Norwich Park Branch Railway and proposed Saraji Road realignment and operational flood protection levees;

- Changed catchment areas due to the Operational Conditions configuration;
- Constriction of the overbank flooding areas at locations where the permanent out-of-pit spoil emplacement are proposed;
- Constriction of the overbank flooding at proposed levee locations to protect pits from inundation; and
- Diversion of floodwaters around proposed pit locations into adjacent drainage lines.

Figure C.1 to Figure C.6 in Appendix C show the change in peak water levels and the change in peak velocities for Operational Conditions compared to Existing Conditions across the Project.

Table 8.6 summarises the changes in peak water levels and peak velocities for the 10%, 1% and 0.1% AEP events at the reporting location points shown in Figure C.1 to Figure C.6. Figure 8.5 and Figure 8.6 provide a comparison of peak water levels along East Creek and along Hughes Creek, respectively.

A range of measures would be required to mitigate the potential impacts. These mitigation measures may include erosion protection in locations of increased flood velocities, staged flood protection levee construction (acknowledging this may impact on mine plan scheduling), limit the timeframe that the proposed infrastructure is in place, additional road/rail culverts, etc. Where impacts cannot be fully mitigated, consent may be required from impacted neighbouring landowners/stakeholders (e.g., Aurizon, council, BMA).

Table 8.6 – Changes in peak water levels (m) and peak velocities (m/s) under Operational Conditions at reporting locations in the vicinity of the Project

Location ID	Modelled change in peak water level (m)			Modelled change in peak velocities (m/s)		
	10%	1%	0.1%	10%	1%	0.1%
RP1	-0.04	-0.02	-0.04	-0.11	-0.06	-0.18
RP2	0.01	0.02	-0.06	0.01	0.01	-0.03
RP3	0.29	0.21	0.28	-0.06	-0.09	-0.02
RP4	0.18	0.28	0.45	0.06	0.06	0.04
RP5	0.04	0.04	-0.05	0.02	0.01	0.02
RP6	0.73	0.67	0.83	-0.57	-0.60	-0.61
RP7	-0.01	0.20	0.32	0.04	-0.03	0.16
RP8	-0.13	0.05	0.04	-0.01	-0.03	-0.03
RP9	0.53	0.77	1.07	-0.07	-0.03	-0.09
RP10	-0.01	0.17	0.24	-0.01	-0.01	0.04
RP11	-0.01	0.15	0.24	0.01	0.02	0.09

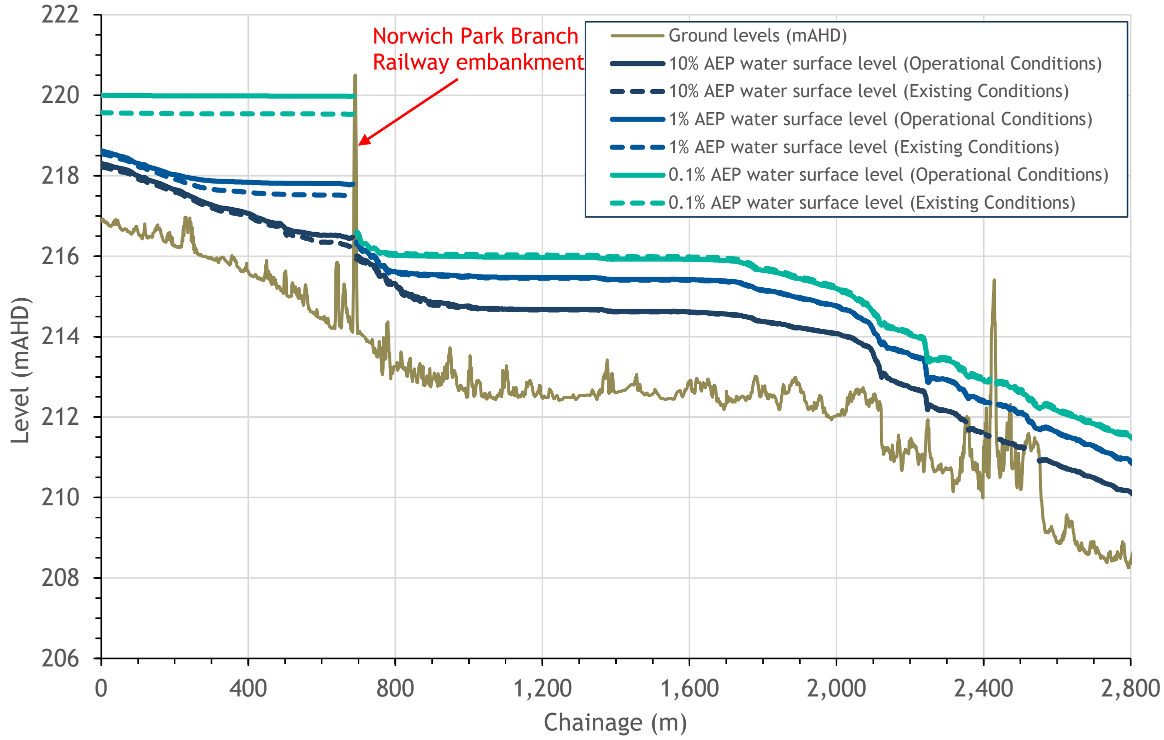

Figure 8.5 - Comparison of Operational and Existing conditions water surface levels along East Creek for the 10%, 1% and 0.1% AEP events

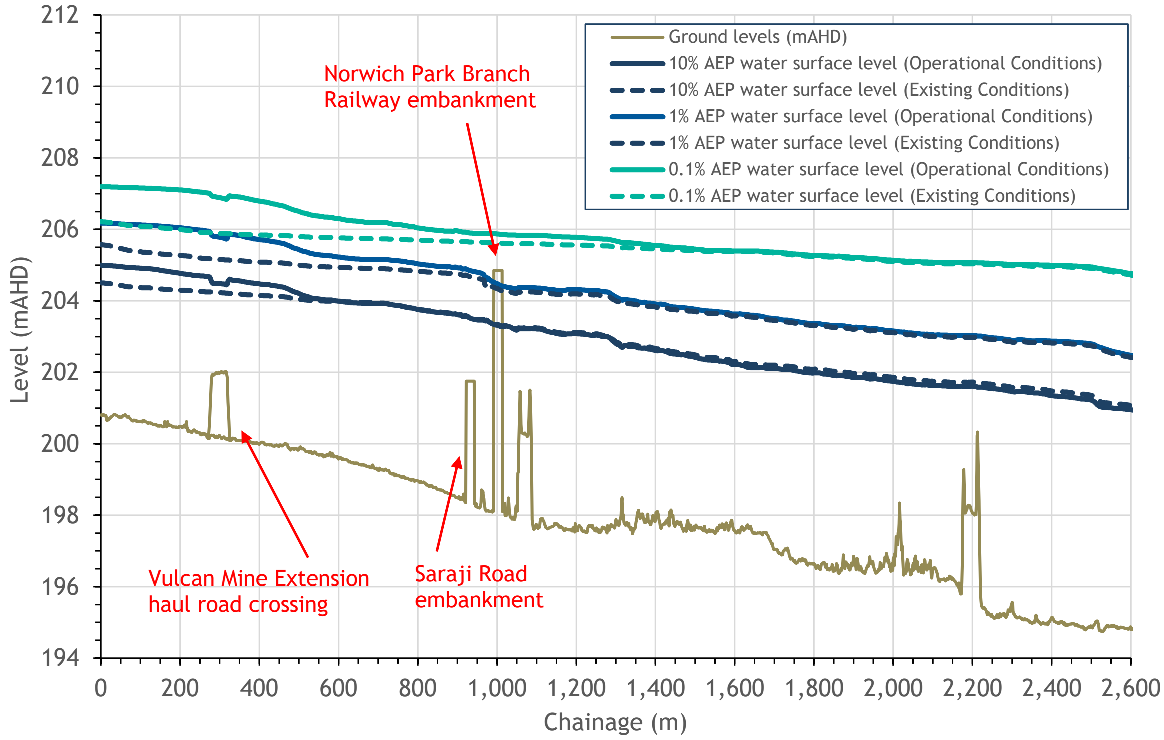

Figure 8.6 - Comparison of Operational and Existing conditions water surface levels along Hughes Creek for the 10%, 1% and 0.1% AEP events

8.7.2 East Creek

Key findings on potential Operational Conditions flooding impacts along East Creek in the vicinity of the project include:

- For the 10% AEP event (see Figure C.1 and Figure C.4):
  - within the Project MLA area, there are increases in peak water levels and peak velocities along Drainage line 7 due to Drainage Diversion 2 diverting flows from Drainage line 6 around the proposed Vulcan Main pit;
  - within the railway corridor, there are increases in peak water levels of up to 0.2 m and increases in peak velocities of up to 0.23 m/s; and
  - at the TUFLOW model downstream boundary (Location ID RP2) there are negligible impacts.
- For the 1% AEP event (see Figure C.2 and Figure C.5):
  - impacts are generally confined within the Project MLA area, upstream of the Norwich Park Branch Railway corridor; and
  - at the railway culvert upstream invert along Drainage line 7, there are increases in peak water levels and peak velocities of up to 0.3 m and 0.12 m/s, respectively;
  - the Norwich Park Branch Railway culverts along Drainage line 7 have sufficient flow capacity to drain the additional catchment flows without overtopping the railway finished formation level; and
  - at the TUFLOW model downstream boundary (Location ID RP2) there are negligible impacts.
- For the 0.1% AEP event (see Figure C.3 and Figure C.6):
  - floodwaters are impounded behind the constructed embankment of the Norwich Park Branch Railway;
  - impacts are generally confined within the Project MLA area, upstream of the Norwich Park Branch Railway corridor;
  - at the railway culvert upstream invert along Drainage line 7, there are increases in peak water levels and peak velocities of up to 0.45 m and 0.2 m/s, respectively;
  - the Norwich Park Branch Railway culverts along Drainage line 7 have sufficient flow capacity to drain the additional catchment flows without overtopping the top of ballast level; and
  - at the TUFLOW model downstream boundary (Location ID RP2) there are negligible impacts.

8.7.3 Hughes Creek

Key findings on potential Operational Conditions flooding impacts along Hughes Creek in the vicinity of the project include:

- For the 10% AEP event (see Figure C.1 and Figure C.4):
  - within the Project MLA area, there are increases in peak water levels and peak velocities along Hughes Creek upstream of the proposed haul road; and
  - within the railway corridor and downstream of the railway, there are no increases in peak water levels and localised area of increases in peak velocities of up to 0.5 m/s.
- For the 1% AEP event (see Figure C.2 and Figure C.5):
  - within the Project MLA area, there are impacts due to the overbank constriction created between the proposed Vulcan South and Vulcan Main pit levees;

- downstream of the railway, at the model boundary (Location ID RP8), there are negligible increases in peak velocities and increases in peak water levels of 0.05 m; and
- The railway embankment is not overtopped due to increases in peak water levels during Operational Conditions and therefore has a 1% AEP flood immunity.

- For the 0.1% AEP event (see Figure C.3 and Figure C.6):
  - floodwaters overtop the Norwich Park Branch Railway under both Existing and Operational conditions;
  - within the Project MLA area, there are impacts due to the overbank constriction created between the proposed Vulcan South and Vulcan Main pit levees. Peak water levels increase by up to 1.4 m and peak velocities increase by up to 3.4 m/s along the haul road. Erosion and scour protection measures will be required to mitigate these impacts;
  - at the Hughes Creek bridge, there are increases in peak water levels and peak velocities of up to 0.32 m and 1.1 m/s, respectively; and
  - at the TUFLOW model downstream boundary (Location ID RP8) there are negligible impacts.

8.8 POST-CLOSURE CONDITIONS POTENTIAL FLOOD IMPACTS

8.8.1 General

Figure 8.4 shows the proposed Post-closure Conditions configuration used in the TUFLOW model. The TUFLOW model results show that the proposed Post-closure Conditions configuration may cause potential flow constraints and flood impacts within the Project area. These include:

- Changed flow conditions between the Norwich Park Branch Railway and proposed final landform locations;
- Changed catchment areas due to the final landform configuration; and
- Constriction of the overbank flooding areas at locations where the permanent out-of-pit spoil emplacement is proposed.

Figure D.1 to Figure D.6 in Appendix D show the change in peak water levels and the change in peak velocities for the 10%, 1% and 0.1% AEP events for Post-closure Conditions compared to Existing Conditions across the Project.

Table 8.7 summarises the changes in peak water levels and peak velocities for the 10%, 1% and 0.1% AEP events at the reporting location points shown in Figure D.1 to Figure D.6.

In general, the Post-closure Conditions configuration will not impact on peak water levels or velocities along Drainage line 5, Drainage line 6, Drainage line 7 and East Creek for events up to and including the 0.1% AEP event. The results also show that there are negligible impacts along Drainage line 8 and Hughes Creek for the 10% and 1% AEP events and small impacts for the 0.1% AEP event.

There will be some areas that will require erosion control measures such as where existing natural drainage paths enter constructed drains and at the upstream and downstream ends of constructed drains. Hence, the proposed surface water drainage infrastructure for the Project will result in a very low risk of changes to the existing erosion and sedimentation process in the receiving waters.

Table 8.7 – Changes in peak water levels (m) and peak velocities (m/s) under Post-closure Conditions at reporting locations in the vicinity of the Project

Location ID	Modelled change in peak water level (m)			Modelled change in peak velocities (m/s)		
	10%	1%	0.1%	10%	1%	0.1%
RP1	0.00	0.00	0.01	0.00	0.00	0.01
RP2	0.00	0.00	0.00	0.00	0.00	0.00
RP3	0.00	0.00	0.00	0.00	0.00	0.00
RP4	0.00	0.00	0.00	0.00	0.00	0.00
RP5	0.00	0.00	0.00	0.00	0.00	0.00
RP6	0.01	0.02	0.02	0.00	0.00	-0.01
RP7	0.00	0.04	0.05	0.01	0.00	0.03
RP8	-0.01	0.04	0.04	0.00	0.01	0.01
RP9	0.01	0.03	0.05	0.00	0.00	-0.01
RP10	-0.01	0.02	0.04	-0.04	-0.04	0.00
RP11	0.00	0.03	0.04	0.01	0.01	0.01

8.8.2 East Creek

Key findings on potential Post-closure Conditions flooding impacts along East Creek in the vicinity of the project include:

- For the 10% AEP event (see Figure D.1 and Figure D.4) and 1% AEP event (see Figure D.2 and Figure D.5):
  - there are no increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor;
  - downstream of the railway corridor, there are no modelled increases in peak water levels and peak velocities; and
  - within the Project MLA area, there are no increases in peak water levels and peak velocities.
- For the 0.1% AEP event (see Figure D.3 and Figure D.6):
  - there are no increases in peak water levels within the Norwich Park Branch Railway corridor. There are minor increases in peak velocities of up to 0.1 m/s within the railway corridor;
  - downstream of the railway corridor, there are no modelled increases in peak water levels and peak velocities; and
  - within the Project MLA area, there are no increases in peak water levels. There are generally no increases in peak velocities, except along the toe of the proposed Vulcan Main pit final landform at Drainage line 6 where maximum velocities are up to 0.9 m/s.

8.8.3 Hughes Creek

Key findings on potential Post-closure Conditions flooding impacts along Hughes Creek in the vicinity of the project include:

- For the 10% AEP event (see Figure D.1 and Figure D.4):
  - there are no increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor;

- downstream of the railway corridor, there are no modelled increases in peak water levels and peak velocities; and
- within the Project MLA area, there are generally no increases in peak water levels and peak velocities except for at the proposed Vulcan South pit final landform along Drainage line 8. Localised impacts occur where the Post-closure Conditions reinstates the natural topography. Rehabilitation of Post-closure Conditions topography in this area will be undertaken to replicate a Drainage line 8 channel and mitigate these impacts.

- For the 1% AEP event (see Figure D.2 and Figure D.5):
  - there are no increases in peak water levels and generally only localised areas of increase in peak velocities within the Norwich Park Branch Railway corridor;
  - downstream of the railway corridor, there are minor increases in peak water levels and peak velocities along Hughes Creek and at the downstream boundary of generally up to 0.1 m and 0.1 m/s, respectively; and
  - within the Project MLA area, there are generally no increases in peak water levels and peak velocities, except for along the toe of the proposed Vulcan Main and Vulcan South pit final landforms where it is recommended for erosion and scour protection to be implemented.
- For the 0.1% AEP event (see Figure D.3 and Figure D.6):
  - there are no increases in peak water levels and generally only localised areas of increase in peak velocities within the Norwich Park Branch Railway corridor;
  - downstream of the railway corridor, there no increases in peak water levels and minor increases in peak velocities along Hughes Creek and at the downstream boundary of generally up to and 0.2 m/s; and
  - within the Project MLA area, there are generally no increases in peak water levels and peak velocities, except for along the toe of the proposed Vulcan Main and Vulcan South pit final landforms where it is recommended for erosion and scour protection to be implemented.

8.9 SUMMARY

The hydrologic (XP-RAFTS) model design discharge hydrographs for the Boomerang Creek and Hughes Creek catchments were input to hydraulic (TUFLOW) model. Peak water levels and peak velocities were compared to assess the potential flood impacts in the vicinity of the Project for the 10%, 1% and 0.1% AEP events. The three scenarios assessed were:

- Existing Conditions;
- Life of mine (Operational) Conditions; and
- Post-closure Conditions.

The results of the comparison between Operational Conditions peak flood levels and Existing Conditions peak flood levels show that flood impacts as a result of the proposed mine water infrastructure are generally within the Project MLA area. The impacts that extend into the Norwich Park Branch Railway corridor and downstream of the Project boundary may require mitigation measures. These could include erosion protection in locations of increased flood velocities, staged flood protection levee construction (acknowledging this may impact on mine plan scheduling), limit the timeframe that the proposed infrastructure is in place, and additional road/rail culverts, etc. Where impacts cannot be fully mitigated, consent may be required from impacted neighbouring landowners/stakeholders (e.g., Aurizon, council, BMA).

The results of the comparison between Post-closure Conditions peak flood levels and Existing Conditions peak flood levels show that generally there are only minor impacts under the final landform configuration. These impacts are generally confined within the Project MLA area. Existing conditions natural topography will be reinstated within the Hughes Creek floodplain as well as Drainage line 6 and Drainage line 8 Post-closure to replicate the existing drainage line channels to minimise the impacts associated with the Post-closure Conditions landform.

9 Surface water monitoring

9.1 OVERVIEW

Monitoring of surface water quality both within and external to the mine site will form a key component of the surface water management system. Monitoring of upstream, onsite and downstream water quality will assist in demonstrating that the site water management system is effective in meeting its objective of minimal impact on receiving water quality and will allow for early detection of any impacts and appropriate corrective action.

The surface water monitoring protocols will:

- provide valuable information on the performance of the water management system;
- ensure compliance with the Project EA; and
- facilitate adaptive management of water resources on the site.

Details of the receiving water quality monitoring, mine affected water quality monitoring and sediment dam water monitoring program are outlined in Sections 9.2, 9.4 and 9.5 respectively. Locations of the proposed surface water monitoring locations and mine affected dam monitoring locations are shown in Figure 9.1 and Figure 9.2 and summarised in Table 9.1. Note that the mine water release points are the same as the mine water monitoring locations (i.e. at the spillway).

Table 9.1 – Proposed surface water and mine water dam quality monitoring locations

Station ID	Catchment Area	Easting*	Northing*	Description
		Receiving water monitoring sites		
Upstream sites				
VESW3	Harrow Creek	615,316	7,528,175	Harrow Creek upstream of the Project
VESW4	Boomerang Creek	623,621	7,531,088	Drainage line 4 upstream of Saraji Road
VSW5	Hughes Creek	626,062	7,522,834	Hughes Creek approximately 5.0 km upstream of Saraji Road
VSW6	Hughes Creek	630,659	7,521,084	Barrett Creek upstream of Saraji Road
Downstream sites				
VESW1[1]	Harrow Creek	614,134	7,543,160	Harrow Creek downstream of Highwall mining area
VSW4[1]	Hughes Creek	630,357	7,524,021	Hughes Creek upstream of Saraji Road
VSW7[1]	East Creek	626,767	7,528,677	Drainage line 7 upstream of Saraji Road
VSW9	East Creek	625,830	7,529,606	Drainage line 6, upstream of Saraji Road
VSW10	Hughes Creek	630,541	7,523,648	Drainage line 8, upstream of Saraji Road
VSW11	Boomerang Creek	622,511	7,533,708	Minor drainage line, upstream of confluence of Drainage line 2
		Mine water dam monitoring locations/release points		
MWD6	-	626,383	7,526,338	MWD6 spillway to MWD8
MWD7	-	626,719	7,526,640	MWD7 spillway to MWD8
MWD8	-	626,637	7,526,256	MWD8 spillway to Hughes Creek
MWD9	-	628,860	7,524,968	MWD9 spillway to Hughes Creek

* Projection – MGA94 (Zone 55)
[1] Remote logger location

9.2 REEF DISCHARGE STANDARDS

Section 3.2.3 of DES (2021) states that "triggers for assessment under section 41AA do not include diffuse sources of contaminated stormwater that contains sediment only. This will allow for an exclusion for stormwater proposed to be managed through erosion and sediment control measures."

Erosion and Sediment Control measures have been outlined in this EA (Section 5) using the Best Practice Erosion and Sediment Control document (IECA, 2008) and addresses:

- the fullest separation possible of diverted, surface and mine-affected water runoff;
- the diversion of upstream runoff from disturbed areas;
- the stabilisation of soils in disturbed areas; and
- the installation and maintenance of control measures such as sediment and erosion control devices (e.g., silt fences, swales, settling basins, energy dissipaters and vegetated buffers).

A detailed ESCP can be prepared for the Project, however, as outlined in this EA, surface water and diverted water releases from the Project do not trigger the need for an assessment under Section 41AA of EPR 2019.

9.3 RECEIVING WATER QUALITY MONITORING

The proponent has undertaken a round of baseline monitoring at a number of surface water locations in the Project vicinity (as detailed in Section 4.5.2). Vitrinite will monitor the receiving water locations at a number of these sites for surface water flows and water quality upstream and downstream of the Project, as well as the addition of a number of sites. Locations of the proposed surface water monitoring locations are shown in Figure 9.1 and summarised in Table 9.1.

Sampling for the surface water monitoring locations will be undertaken monthly and following any rainfall event greater than 50 mm in a 24-hour period. Monitoring will be also be undertaken downstream of any spill following a release event. Field and laboratory sampling will be undertaken. Note that sampling may only be possible during brief periods of runoff immediately following rainfall due to the ephemeral nature of the natural surface water system.

The surface water quality monitoring points have been designated as upstream and downstream monitoring points in Table 9.1. Upstream monitoring points, which are not influenced by releases from the Project, will be used to analyse the background surface water quality in the vicinity of the Project. This information can be used to develop site specific trigger levels for contaminant releases when sufficient data is available.

Downstream monitoring points will be used to assess the water quality of the receiving waters in the context of the Project. In addition to routine monitoring, these sites will be monitored directly after release events to assess the effect of Project releases.

Electrical Conductivity and pH can vary between the time of sampling and analysis in the laboratory. Therefore, field testing of samples will be undertaken for the following parameters:

- Electrical Conductivity;
- pH;
- Dissolved Oxygen; and
- Temperature.

In lieu of field testing of turbidity, the laboratory result for total suspended sediment should be used to inform on turbidity. In addition, the suite of laboratory analyses shown in Table 9.2 will be collected for the water quality monitoring locations.

The receiving water locations will be monitored against the WQOs for the Project (outlined in Table 3.1). In addition, preliminary release contaminant trigger investigation levels have been proposed for downstream monitoring sites.

9.3.1 Release contaminant trigger investigation levels

A set of initial proposed receiving water contaminant triggers levels have been developed, based on conditions at nearby operating coal mines, preliminary baseline results and the WQOs for the Project vicinity. These trigger levels are presented in Table 9.3 and are proposed to be measured against at the downstream water monitoring locations (i.e. VESW1, VSW4, VSW7, VSW9, VSW10 and VSW11). Monitoring at these locations will allow for an accurate evaluation of the impact of any releases from the Project.

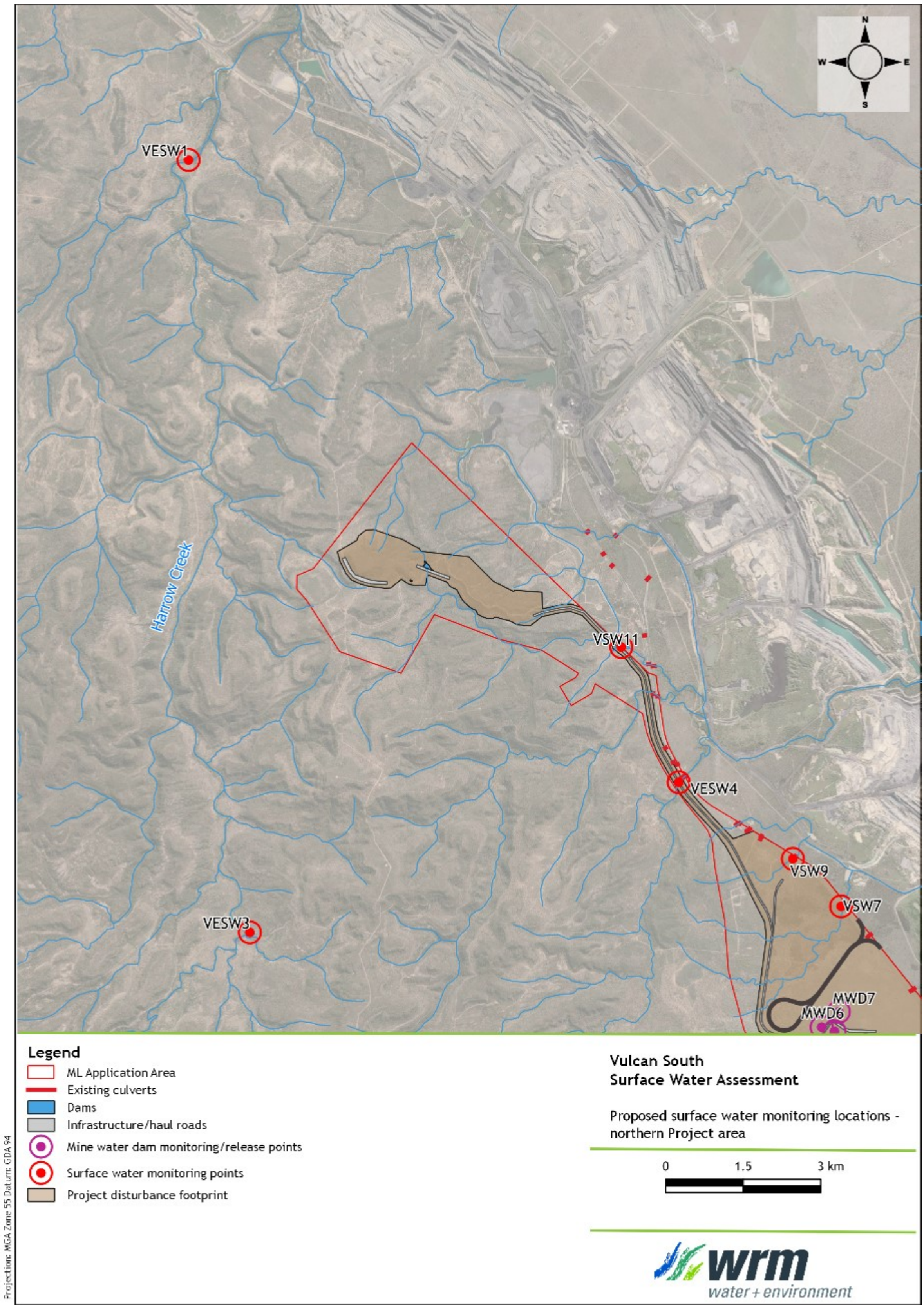

Figure 9.1 – Proposed surface water monitoring locations – northern Project area

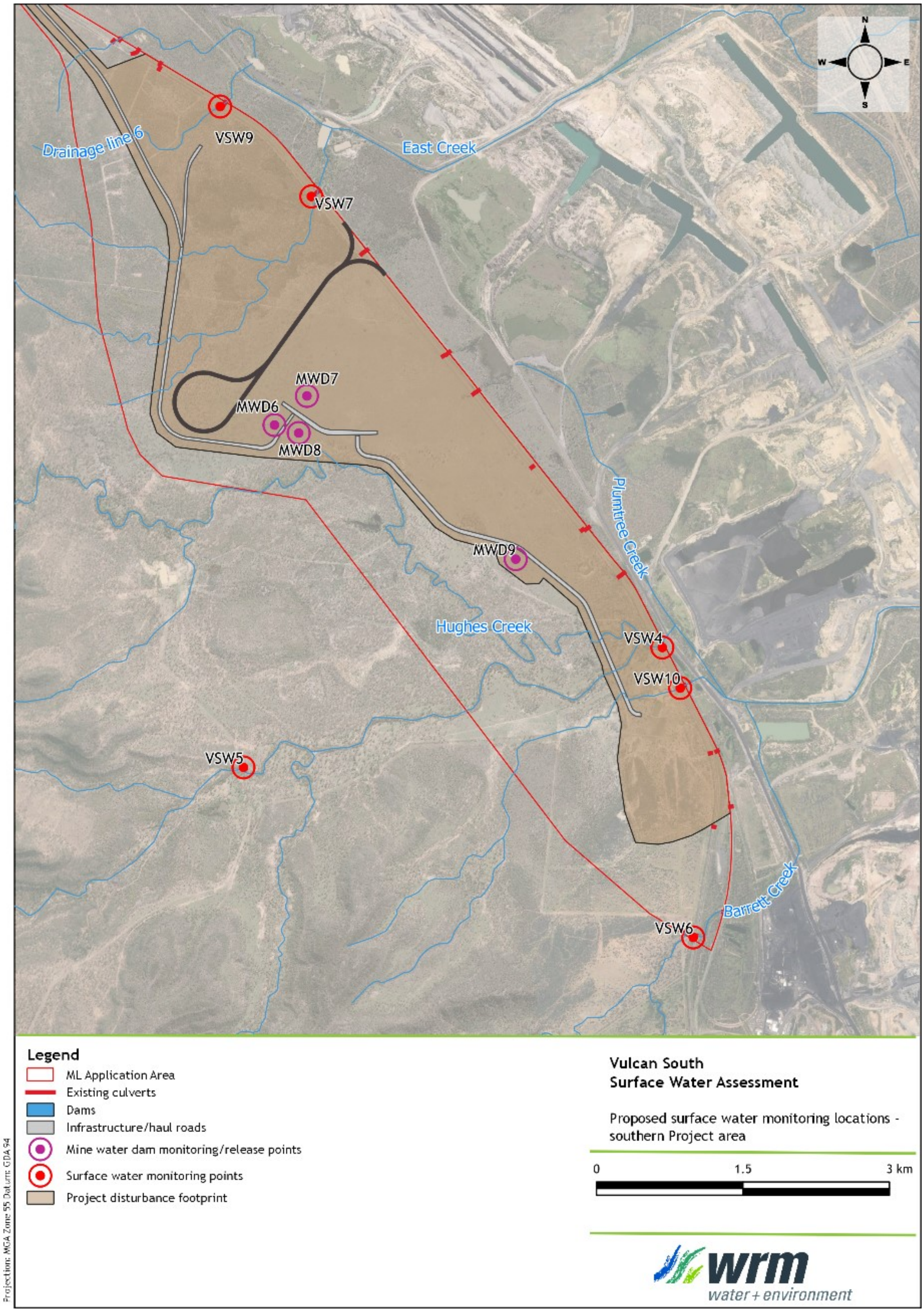

Figure 9.2 – Proposed surface water monitoring locations – southern Project area

It is noted that only limited baseline water monitoring has been undertaken and therefore the receiving water contamination water levels may need to be refined following further monitoring. Total suspended solids (TSS) levels will be updated once sufficient baseline monitoring has been collected. These levels will be update progressively as part of the Water Management Plan for the Project.

Table 9.2 - Receiving waters water quality laboratory analysis parameters

	Analyte		Analyte
Physico-chemical		*Metals and metalloids (total and filtered)*	
1	Electrical conductivity	17	Aluminium
2	pH	18	Arsenic
3	Turbidity	19	Cadmium
4	Total Suspended Solids	20	Chromium
5	Dissolved Oxygen	21	Copper
Major cations and anions		22	Iron
6	Sulfate	23	Lead
7	Calcium	24	Mercury
8	Fluoride	25	Nickel
9	Chloride	26	Zinc
10	Sodium	27	Boron
Nutrients		28	Cobalt
11	Total Phosphorus	29	Manganese
12	Filterable Reactive Phosphorus	30	Molybdenum
13	Total Nitrogen	31	Selenium
14	Oxidised Nitrogen	32	Silver
15	Total Kjeldahl Nitrogen	33	Uranium
16	Ammonium	34	Vanadium
		Hydrocarbons	
		35	Total Petroleum Hydrocarbon (C6-C36)
		Biological	
		36	Chlorophyll-a

Table 9.3 - Receiving water contaminant trigger levels

Quality characteristic	Units	Trigger level	Monitoring locations	Monitoring frequency
pH	-	6.5 - 8.0	VESW4, VSW4, VSW5, VSW6 & VSW7	Monthly, following any rainfall event greater than 50 mm in a 24-hour period and following a release event
Electrical conductivity	(µS/cm)	1,500		
TSS or TDS	(mg/L)	*TBC*		
Sulfate (SO_4^{2-})	(mg/L)	1,000		

9.4 MINE AFFECTED WATER QUALITY MONITORING

The water quality monitoring program will also include monitoring at all dams which contain mine affected water with the potential to discharge to the receiving waters. This includes the following dams:

- MWD6;
- MWD7;
- MWD8; and
- MWD9.

Locations of the proposed mine water monitoring locations are shown in Figure 9.1 and Figure 9.2 and summarised in Table 9.1.

Sampling for the mine water dam monitoring locations will be undertaken quarterly, as well as daily during a release event.

As outlined in Section 5.6.1, Vitrinite are not currently planning any mine affected controlled releases to the environment. Therefore, any releases from the mine water system would be uncontrolled from the dam spillways. The release locations for mine affected water would therefore be located on the spillway on the mine water dams, as outlined in Table 9.1.

Water quality parameters which will be collected for the mine water dams are outlined in Table 9.4. Note that the metals listed in Table 9.4 will be analysed for both total and dissolved concentrations.

Table 9.4 - Dam laboratory analysis parameters

Location	Parameter	Monitoring frequency
MWD6, MWD7, MWD8 & MWD9	pH, EC, sulfate, fluoride, aluminium, arsenic, cadmium, cobalt, copper, lead, nickel and zinc	Quarterly and daily during a release event

Preliminary mine affected water release limits have been proposed based upon similar surrounding mines for the mine affected water releases, as outlined in Table 9.5. Note that maximum EC, TSS and Sulphate water release limits will be outlined once sufficient baseline monitoring data has been collected. These release limits will be generated progressively as part of the Water Management Plan for the Project. Mine affected water releases would occur only during times of sufficient natural flow in the receiving waters to provide adequate dilution so that the receiving waters triggers given in Table 9.3 are not exceeded.

Table 9.5 - Mine affected water release limits

Quality Characteristic	Units	Minimum	Maximum
Electrical Conductivity (EC)	µs/cm	n/a	TBC
pH	pH units	6.5	9.0
Total Suspended Solids (TSS)	mg/L	n/a	TBC
Sulphate (SO_4^{2-})	mg/L	n/a	TBC

9.5 SEDIMENT DAM MONITORING

Surface runoff and seepage from spoil piles, including any rehabilitated areas, would be monitored for 'standard' water quality parameters including, but not limited to pH, EC, major anions (sulfate, chloride and alkalinity), major cations (sodium, calcium, magnesium and potassium), TDS and a broad suite of soluble metals/metalloids. This monitoring would be undertaken at all Project sediment dams (as listed in Table 5.2 and shown in Figure 1.3 - Figure 1.10).

The sediment dam monitoring would be used to validate the anticipated quality of water runoff reporting to sediment dams and haul road runoff dams. Initially, the sediment dam monitoring would occur on a regular (e.g. monthly) basis to demonstrate the water quality of stored waters is consistent with the relevant operating parameters to allow releases from sediment dams to occur when required. Subject to demonstrating the water quality objectives can be met, the frequency of monitoring and suite of parameters for the sediment dam monitoring would be reviewed and updated accordingly (e.g. to occur only when releases occur).

9.6 RECEIVING ENVIRONMENT MONITORING PROGRAM (REMP)

A REMP document will be developed which describes in detail the proposed monitoring program for the local receiving waters. The REMP will incorporate the historical and proposed monitoring as described in Section 4.5.2 and in the sections above.

The main objective of the REMP will be to report against WQOs for local waterways potentially affected by discharge from the Project and will assist in assessing general aquatic ecosystem health.

10 Cumulative impacts

10.1 OVERVIEW

The objective of this assessment is to identify the potential for impacts from the Project to have compounding interactions with similar impacts from other projects, including activities proposed, under development or already in operation within a suitable region of influence of the Project.

There are two levels at which cumulative impacts have been assessed:

- Localised cumulative impacts – These are the impacts that may result from multiple existing or proposed mining operations in the immediate vicinity of the Project. Localised cumulative impacts include the effect from concurrent operations that are close enough to potentially cause additive effect on the receiving waters. For the purposes of this assessment, all existing and proposed projects located within the Isaac River catchment have been included.
- Regional cumulative impacts – These include the Project's contribution to impacts that are caused by mining operations throughout the Bowen Basin region or at a catchment level. Each coal mining operation in itself may not represent a substantial impact at a regional level; however, the cumulative effect on the receiving waters may warrant consideration.

10.2 EXISTING PROJECTS

Projects which are currently operating within the Isaac River catchment upstream of the Deverill gauging station and have been included in the cumulative impacts assessment for the project are listed in Table 10.1.

10.3 NEW OR DEVELOPING PROJECTS

Relevant projects that have been considered include:

- Projects within the predicted sphere of influence of the Project, as listed on the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) website that are undergoing assessment under the State Development and Public Works Organisation Act 1971 (SDPWO Act) for which an Initial Advice Statement (IAS) or an EIS are available.
- Projects within the predicted sphere of influence of the Project, which are listed on the website of the Department of Environment and Science (DES) that are undergoing assessment under the Environmental Protection Act 1994 (EP Act) for which an IAS or an EIS are available.
- Projects within the predicted sphere of influence of the Project, which are listed on the website of +-the Department of Infrastructure, Local Government and Planning (DILGP) that are undergoing assessment under the Regional Planning Interests Act 2014 (RPI Act) for which an Assessment Application is available.

Projects currently undergoing assessment or having recently completed assessment under these processes and included in the cumulative impact assessment for the Project are listed in Table 10.2.

10.4 CUMULATIVE IMPACTS – SURFACE WATER RESOURCES

10.4.1 Water quality

The Project is located in the Isaac River catchment, which is a major tributary within the Fitzroy basin. The Fitzroy basin is the largest catchment in Queensland draining into the Pacific Ocean and also the largest catchment that drains to the Great Barrier Reef, although it does not contribute significant freshwater flows to the coastal environment when compared to river systems further north.

In 2008, the Queensland Government undertook an investigation into the cumulative effects of coal mining in the Fitzroy River basin on water quality (EPA, 2009). The investigation found that:

- There were inconsistencies in discharge quality limits and operating requirements for coal mine water discharges as imposed through environmental authorities.
- In some cases, discharge limits and operating conditions of coal mines were not adequately protecting downstream environmental values.

These conclusions led to a number of inter-related actions by Queensland Government and other stakeholders:

- Water quality objectives were developed for the Fitzroy Basin and added to Schedule 1 of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (Water)) in October 2011.
- Model water conditions were developed for coal mines in the Fitzroy basin (DERM February 2012). These model water conditions are designed to manage water discharges to meet the water quality objectives set out in the EPP (Water) and to provide consistency between mining operations in the Fitzroy basin.
- Environmental authorities for a number of mining operations were amended to introduce conditions consistent with the model water conditions.
- A number of mining operations entered into Transitional Environmental Programs (TEP) under the EP Act. These TEPs were focussed on actions that would allow mines to achieve compliance with new environmental authority conditions and upgrade operating conditions.

With these measures in place, a strong strategic and policy framework is now in place for management of cumulative water quality impacts from mining activities. This framework allows for management of individual mining activities in such a way that overarching water quality objectives can be achieved.

Mine affected water from the proposed Project will be managed through a mine water management system which is designed to operate in accordance with proposed EA conditions that are based on Model Mining Conditions, and incorporated into the release criteria used in modelling the mine water management system in this report.

It is noted that the Project is located within the Boomerang Creek catchment, which has already been significantly disturbed by existing mining operations in the Project vicinity.

In addition, given that the proposed project water releases will be managed within an existing overarching strategic framework for management of cumulative impacts of mining activities, the proposed management approach for mine water from the project is expected to have negligible cumulative impact on surface water quality and associated environmental values.

Table 10.1 – Existing projects considered in the cumulative impact assessment

Project - Proponent	Description	Operational status	Relationship to the Project Mining Lease	
			Timing	Location
Burton Mine - Peabody Energy Australia	Open cut coal mine	Ceased production indefinitely	May have overlapping operational phases with the construction and operations of the project, although unlikely given the current operational status.	Located 75 km to the north of the Project area. Located within the Isaac River catchment (upstream).
Eaglefield Mine - Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 75 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
North Goonyella Mine - Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 75 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Goonyella Riverside Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 60 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Moranbah North Mine - Anglo American	Underground coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 50 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Grosvenor Mine - Anglo American	Underground coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 40 km to the north of the Project area. Located within the Isaac River catchment (upstream).
Broadlea Mine - Fitzroy Australia Resources	Open cut coal mine	Care and maintenance	May have overlapping operational phases with the construction and operations of the project.	Located 40 km to the north of the Project area. Located within the headwaters of Smoky Creek, within the Isaac River catchment.
Carborough Downs Mine - Fitzroy Australia Resources	Underground coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the northeast of the Project area. Located within the headwaters of Billy's Gully, within the Isaac River catchment.
Isaac Plains Mine - Stanmore Coal	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the north of the Project area. Located within the headwaters of Billy's Gully, within the Isaac River catchment.

Millennium Mine - Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the northeast of the Project area. Located within the headwaters of Southern Gully, within the Isaac River catchment.
Daunia Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 25 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Poitrel Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 20 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Caval Ridge Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the north of the Project area. Located within the Isaac River catchment (upstream).
Peak Downs Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located directly adjacent (i.e. less than 1 km to the north and east of the Project area. Located within the Isaac River catchment.
Moorvale Mine - Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the northeast of the Project area. Located within the headwaters of North Creek, within the Isaac River catchment.
Saraji Mine – BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the southeast of the Project area. Located within the Isaac River catchment.
Norwich Park Mine - BMA	Open cut coal mine	Ceased production indefinitely	May have overlapping operational phases with the construction and operations of the project, although unlikely given the current operational status.	Located 45 km to the southeast of the Project area. Located within the Isaac River catchment (downstream).
Lake Vermont Mine - Jellinbah Group	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the southeast of the Project area. Located within the Isaac River catchment (downstream).

Table 10.2 – Proposed projects considered in the cumulative impact assessment

Project - Proponent	Description	Project status	Relationship to the Project Mining Lease Timing	Location
Moranbah South Project - Anglo American	Underground coal mine	Approved project	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Moorvale South Project - Peabody Energy Australia	Open cut coal mine	Approved project	May have overlapping operational phases with the construction and operations of the project.	Located 25 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Eagle Downs Mine - Bowen Central Coal Joint Venture	Underground coal mine	Construction on hold - site on care and maintenance	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the north of the Project area. Located within the Isaac River catchment upstream).
Winchester South Project - Whitehaven Coal	Open cut coal mine	EIS active	May have overlapping operational phases with the construction and operations of the project.	Located 15 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Olive Downs Coking Coal Project - Pembroke Olive Downs Pty Ltd	Open cut coal mine	Approved with conditions	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the west of the Project area. Located within the Isaac River catchment (downstream).
Saraji East Mine - BMA	Open cut coal mine	EIS active	May have overlapping operational phases with the construction and operations of the project.	Located 15 km to the southwest of the Project area. Located within the Isaac River catchment (downstream).
Dysart East Coal Mine - Bengal Coal	Underground coal mine	ML granted	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the southwest of the Project area. Located within the Isaac River catchment (downstream).
Red Hill - BMA	Underground coal mine	Approved with conditions	May have overlapping operational phases with the construction and operations of the project.	Located 60 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Isaac Downs Project	Open cut coal mine	EIS active	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the north of the Project area. Located within the Isaac River catchment (upstream).

10.4.2 Loss of Catchment and Stream Flows in the Isaac River

The Project will result in a loss of catchment to the Isaac River during operations and post-mining. The surface runoff volume lost from the catchment will generally be in proportion to the loss of catchment area. The Project area is less than 0.2% of the catchment area of the Isaac River to the confluence of Phillips Creek. Of this, around 40% of this area is managed through the ESCP and then released to the downstream environment. An additional 50% would be collected and diverted around the Project through diversion drains or dam DD2.

There are approximately 18 existing coal mines in the vicinity of the Project that also capture runoff from the Isaac River catchment, as shown in Figure 10.1. The total estimated captured area of all these projects (including the Project) combined represents around 7.3% of the Isaac River catchment to the Phillips Creek confluence.

A comparison of the captured catchment areas of the existing mining projects considered in the cumulative impact assessment with the Isaac River catchment to the Phillips Creek confluence is provided in Table 10.3, which indicates the following:

- The combined total catchment area of the existing mines (including the Project) represents around 7.3% of the total catchment area of the Isaac River to the Phillips Creek confluence.
- The combined mine affected catchment area (estimated) represents less than 2.5% of the total Isaac River catchment area to the Phillips Creek confluence.

When taking into account potential discharges from the operating mines in accordance with their current approved release rules, the overall loss of catchment area and associated stream flow is relatively small. In practical terms, impacts on the volume of water flow in the Isaac River would be negligible.

Table 10.3 – Catchment area of existing projects considered in the cumulative impact assessment

Catchment	Total catchment area (km^2)	Estimated mine affected catchment area (km^2)
Vulcan South (the Project)	15.3	4.8
Other mines	551	182
Combined	566	187
Isaac River (to the Phillips Creek confluence)	7,731	-

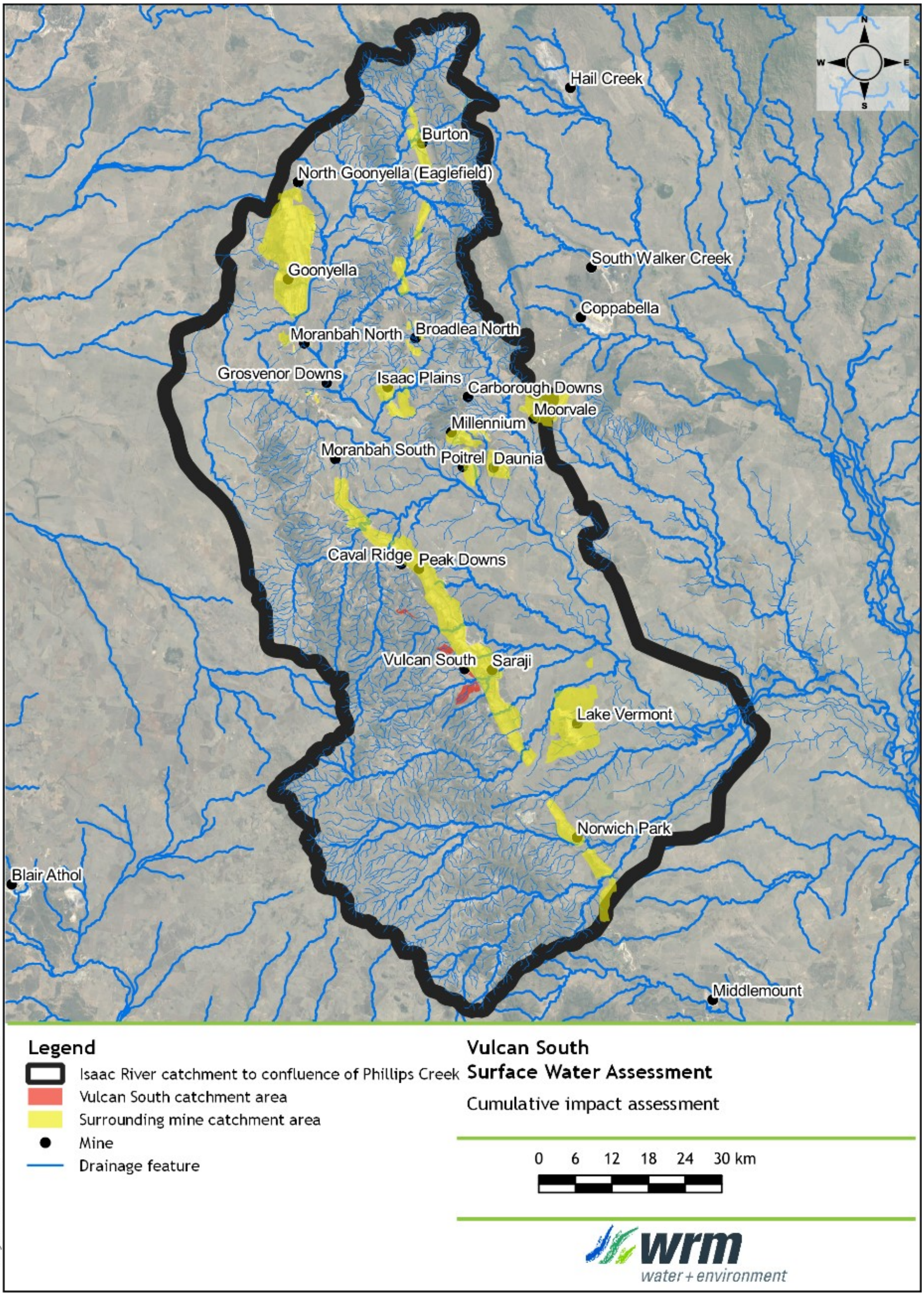

Figure 10.1 – Cumulative impact assessment

11 Summary of findings

11.1 OVERVIEW

The potential impacts of the Project on surface water resources will be mitigated through the implementation of a mine site water management system to control the flow and storage of water of different qualities across the site. A surface water monitoring program will be implemented to monitor potential environmental impacts and ensure that the site water management system is meeting its objectives.

11.2 WATER MANAGEMENT SYSTEM PERFORMANCE

The performance of the mine water management system has been investigated using a detailed site water balance model. The model simulated water inflows and outflows through the various stages of mine development, based on 122 realisations with different climatic sequences.

Water collected on the site will be used as first priority to satisfy site demands. Mine affected water from the infrastructure areas and open cut pit will be collected in MWD6, MWD7, MWD8 and MWD9 and reused to meet operational needs.

External water will be supplied to MWD8 when the site water inventory is at a low level, in order to meet site water demands.

The water balance results show that although water collected onsite will be used as a first priority to meet mine demands, the Project will frequently require external water to operate. Under 50%ile conditions, the Project is predicted to require up to 1,250 ML/annum in external water.

The water balance model was used to assess the risk of uncontrolled offsite spills from the mine affected water dams that can potentially overflow directly to the receiving waters (MWD6, MWD7, MWD8 and MWD9). There were no modelled overflows from the mine affected water dams to the receiving waters during any of the model realisations over the life of the Project.

11.3 FLOODING

The hydrologic (XP-RAFTS) model design discharge hydrographs for the Boomerang Creek and Hughes Creek catchments were input to hydraulic (TUFLOW) model. Peak water levels and peak velocities were compared to assess the potential flood impacts in the vicinity of the Project for the 10%, 1% and 0.1% AEP events. The three scenarios assessed were:

- Existing Conditions;
- Life of mine (Operational) Conditions; and
- Post-closure Conditions.

The results of the comparison between Operational Conditions peak flood levels and Existing Conditions peak flood levels show that flood impacts as a result of the proposed mine water infrastructure are generally within the Project MLA area. The impacts that extend into the Norwich Park Branch Railway embankment and downstream of the Project boundary may require mitigation measures. These could include erosion protection in locations of increased flood velocities, staged flood protection levee construction (acknowledging this may impact on mine plan scheduling), limit the timeframe that the proposed infrastructure is in place, additional road/rail culverts, etc. Where impacts cannot be fully mitigated, consent may be required from impacted neighbouring landowners/stakeholders (e.g., Aurizon, council, BMA).

The results of the comparison between Post-closure Conditions peak flood levels and Existing Conditions peak flood levels show that generally there are only minor impacts under the final landform configuration. These impacts are generally confined within the Project MLA area. It is recommended that erosion and scour protection options are considered along the proposed drainage corridor and existing channels where these increases occur as required to mitigate the risk of rapid geomorphic change.

Overall, the impact of the Project on the hydraulic characteristics of Boomerang Creek, Hughes Creek and their tributaries do not affect the existing conditions significantly. It is expected that the channel and floodplain will undergo little, if any, adjustment to the altered hydraulic conditions upstream or downstream of the Project as a result of the Project.

11.4 IMPACTS ON DOWNSTREAM WATER QUALITY

Preliminary baseline monitoring indicates that water quality in the surrounding environment is of poor quality. Notwithstanding, the water balance modelling indicates that no mine affected spills are predicted from mine operations. In addition, modelling predicts that spills from the sediment dams will be below the 720 µS/cm WQO for baseflows of the Project area.

In consideration of the already heavily disturbed nature of the surrounding catchment, it is unlikely that Project releases will have a measurable impact on receiving water quality or environmental values.

11.5 CUMULATIVE IMPACTS

The Project will reduce the catchment area draining to receiving waters due to capture of runoff from disturbed catchment areas within the water management system. The Project catchment area represents approximately 0.2% of the total catchment area of the Isaac River to its confluence with Phillips Creek. Of this, approximately 40% will be managed through the Project ESC and released back to receiving waters. The combined total catchment area of the existing mines (including the Project) represents around 7.3% of the total catchment area of the Isaac River to the Phillips Creek confluence.

The site water management system has been designed such that the risk of offsite release of mine affected water is very low (with no mine affected dam uncontrolled releases predicted under any modelled climatic conditions).

11.6 FINAL LANDFORM

A conceptual final landform water management plan for the Project under post-closure conditions has been developed. The key features of the final landform are:

- No final voids are proposed. All open cut pits will be backfilled with overburden material.
- Drainage structures will be implemented on and around the final landform to ensure that the landform is free draining.
- When sediment dam catchments are completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned.

In summary, the conceptual final landform is not considered likely to have a long-term significant impact on the receiving waters.

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Appendix A - Baseline surface water monitoring results

Parameter	Unit	VSW-1 1/02/20	VSW-2 1/02/20	VSW-3 1/02/20	VSW-2 5/03/20	VSW-3 5/03/20	VSW-4 4/03/20	VSW-6 4/03/20	VSW-7 4/03/20	VESW-1 5/03/20	VESW-2 5/03/20	VESW-5 18/03/20	VSW-1 19/03/20	VSW-2 19/03/20	VSW-3 19/03/20	VSW-4 19/03/20	VSW-6 19/03/20	VSW-7 19/03/20	VESW-1 19/03/20	VESW-2 19/03/20	VESW-3 19/03/20	VESW-4 19/03/20	WQO (see Table 3.1)
pH Value	-	7.42	6.74	6.54	7.38	6.92	7.16	7.12	7.57	7.79	8.41	6.78	7.53	7.04	6.57	7.11	6.89	7.57	7.89	7.74	7.00	7.13	6.5 - 8.5
Sodium Adsorption Ratio	-	6.64	2.92	1.69	3.86	0.55	0.61	0.26	0.34	0.82	0.93	0.68	9.17	1.86	1.10	0.37	0.77	0.42	0.87	0.58	0.37	0.51	-
Electrical Conductivity	µS/cm	1400	310	184	442	66	81	46	106	219	395	44	2440	346	104	74	80	124	306	280	70	129	> 720 (baseflow) > 250 (high flow)
Total Dissolved Solids (Calc.)	mg/L	910	202	120	287	43	53	30	69	142	257	29	1590	225	68	48	52	81	199	182	46	84	> 2,000
Suspended Solids (SS)	mg/L	10	55	20	100	293	296	379	1200	62	33	77	168	10	92	2050	386	51	<5	33	155	168	> 55
Turbidity	NTU	43	221	91	116	751	1590	503	1240	320	41	339	221	37	209	850	701	346	9	143	324	419	> 50
Total Hardness as CaCO3	mg/L	191	37	26	50	16	18	12	40	64	125	7	362	78	16	22	16	51	99	108	22	18	> 150
Hydroxide Alkalinity as CaCO3	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Carbonate Alkalinity as CaCO3	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	8.00	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Bicarbonate Alkalinity as CaCO3	mg/L	63	12	4	27	9	33	6	49	62	120	11	174	70	15	26	21	65	94	103	29	45	-
Total Alkalinity as CaCO3	mg/L	63	12	4	27	9	33	6	49	62	129	11	174	70	15	26	21	65	94	103	29	45	-
Sulfate as SO4 - Turbidimetric	mg/L	212	40	19	58	2	4	2	<1	7	13	2	340	33	6	6	4	1	11	6	3	2	> 25
Chloride	mg/L	275	54	34	80	10	6	3	6	25	40	5	528	40	17	5	9	6	30	19	6	7	-
Calcium	mg/L	27	5	4	7	3	4	3	8	14	32	1	46	10	3	4	3	9	20	27	4	4	-
Magnesium	mg/L	30	6	4	8	2	2	1	5	7	11	1	60	13	2	3	2	7	12	10	3	2	-
Sodium	mg/L	211	41	20	63	5	6	2	5	15	24	4	401	38	10	4	7	7	20	14	4	5	> 30
Potassium	mg/L	8	7	7	7	4	3	3	2	6	6	3	11	7	5	4	4	2	8	6	4	5	-
Dissolved Metals																							
Aluminium	mg/L	0.11	0.45	0.39	<0.01	0.28	0.26	0.2	0.07	<0.01	<0.01	1.11	0.01	<0.01	0.07	0.35	0.22	0.02	<0.01	<0.01	0.09	0.09	> 0.055
Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	0.002	0.004	> 0.024
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.0002
Chromium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.001
Cobalt	mg/L	<0.001	<0.001	<0.001	0.002	0.004	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.002	<0.001	0.001	<0.001	<0.001	<0.001	0.001	0.005	0.006	-
Copper	mg/L	0.003	0.001	0.002	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	> 0.0014
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.0034
Manganese	mg/L	0.039	0.019	0.015	0.141	0.278	0.125	0.04	0.066	0.089	0.102	0.011	0.443	0.201	0.028	0.192	0.026	0.002	0.012	0.362	0.309	0.295	> 1.9
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Nickel	mg/L	0.002	0.002	0.002	0.003	0.003	0.001	<0.001	0.001	0.002	0.002	<0.001	0.003	0.003	0.002	0.002	0.001	0.001	0.003	0.002	0.003	0.003	> 0.011
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.005
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Uranium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.1
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.5
Zinc	mg/L	0.024	<0.005	0.024	<0.005	0.014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	> 0.008
Boron	mg/L	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	> 0.37
Iron	mg/L	0.2	0.35	0.35	<0.05	0.38	0.18	0.13	0.15	<0.05	<0.05	0.63	1.83	<0.05	0.24	0.33	0.21	0.11	<0.05	<0.05	1.6	3.02	-

Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.00006
Total Metals																							
Aluminium	mg/L	0.89	3.38	1.56	1.71	12.8	22.8	6.62	21.8	5.42	0.72	7.97	3.61	0.94	3.76	16.5	10.3	9.22	0.38	3.94	6.56	6.36	> 5
Arsenic	mg/L	0.001	0.002	0.001	0.001	0.003	0.005	0.003	0.003	0.002	0.001	0.002	0.002	0.001	0.003	0.005	0.005	0.002	<0.001	0.002	0.003	0.005	> 0.5
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.01
Chromium	mg/L	<0.001	0.002	0.001	0.001	0.008	0.02	0.006	0.026	0.004	<0.001	0.005	0.003	<0.001	0.002	0.017	0.008	0.011	<0.001	0.004	0.006	0.004	> 1
Cobalt	mg/L	<0.001	0.001	<0.001	0.003	0.013	0.014	0.003	0.013	0.003	0.001	0.003	0.006	0.003	0.003	0.018	0.005	0.004	<0.001	0.003	0.008	0.01	> 0.1
Copper	mg/L	0.004	0.004	0.002	0.004	0.014	0.023	0.008	0.016	0.004	<0.001	0.006	0.003	0.002	0.003	0.02	0.009	0.005	0.001	0.003	0.006	0.012	> 1
Lead	mg/L	<0.001	0.004	0.002	0.003	0.016	0.032	0.009	0.022	0.007	<0.001	0.007	0.005	<0.001	0.004	0.028	0.011	0.006	<0.001	0.003	0.007	0.01	> 0.1
Manganese	mg/L	0.042	0.034	0.024	0.195	0.586	0.477	0.112	0.334	0.174	0.156	0.077	0.431	0.214	0.106	0.804	0.13	0.108	0.046	0.444	0.389	0.383	> 10
Molybdenum	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	> 0.05
Nickel	mg/L	0.002	0.004	0.003	0.006	0.016	0.028	0.006	0.022	0.008	0.004	0.006	0.005	0.004	0.004	0.025	0.012	0.008	0.003	0.007	0.009	0.009	> 1
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.02
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Uranium	mg/L	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01	0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.01	<0.01	<0.01	<0.01	<0.01	-
Zinc	mg/L	0.031	0.017	0.029	0.014	0.1	0.058	0.022	0.037	0.018	<0.005	0.024	0.021	0.015	0.018	0.059	0.031	0.022	<0.005	0.01	0.019	0.031	> 5
Boron	mg/L	0.06	<0.05	<0.05	0.05	0.38	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	> 5
Iron	mg/L	0.79	3.26	1.62	2.35	11.7	27.7	8.42	25.7	7.15	0.83	7.88	5.57	1.62	6.96	21.8	12.9	7.86	0.66	4.26	8.88	12.5	> 10
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	> 0.002
Fluoride	mg/L	<1.0	0.1	<0.1	0.1	<0.1	0.2	<0.1	0.2	0.1	0.2	<0.1	0.2	<0.1	<0.1	0.1	0.1	0.2	0.1	0.2	<0.1	0.1	< 2
Ammonia as N	mg/L	0.05	0.1	<0.01	0.1	0.99	0.11	0.07	0.11	0.1	0.02	0.1	0.17	0.13	0.21	0.09	0.21	0.12	0.16	0.55	0.22	6.95	> 0.02
Nitrite as N	mg/L	0.03	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	0.04	<0.01	0.62	<0.01	0.21	-
Nitrate as N	mg/L	1.7	1.57	1.19	0.08	<0.01	0.02	0.02	0.04	0.14	<0.01	0.14	0.07	0.05	<0.01	<0.01	0.08	0.03	<0.01	0.16	<0.01	0.1	-
Nitrite + Nitrate as N	mg/L	1.73	1.58	1.19	0.09	<0.01	0.02	0.02	0.04	0.17	<0.01	0.14	0.09	0.05	<0.01	<0.01	0.09	0.07	<0.01	0.78	<0.01	0.31	-
Total Kjeldahl Nitrogen as N	mg/L	1.6	1.3	0.9	2.7	1	1.8	0.8	0.6	0.7	0.9	1.3	2.1	0.7	0.9	2.6	2	1.1	0.7	1.3	1.2	9.9	-
Total Nitrogen as N	mg/L	3.3	2.9	2.1	2.8	1	1.8	0.8	0.6	0.9	0.9	1.4	2.2	0.8	0.9	2.6	2.1	1.2	0.7	2.1	1.2	10.2	> 0.5
Total Phosphorus as P	mg/L	0.04	0.09	0.05	0.18	0.2	0.43	0.19	0.18	0.17	0.21	0.12	0.09	0.02	0.08	0.58	0.37	0.1	0.02	0.09	0.12	0.41	> 0.05
Reactive Phosphorus as P	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	> 0.02
Total Anions	meq/L	13.4	2.6	1.43	4	0.5	0.91	0.25	1.15	2.09	3.98	0.4	25.4	3.21	0.9	0.78	0.76	1.49	2.95	2.72	0.81	1.14	-
Total Cations	meq/L	13.2	2.7	1.58	3.93	0.63	0.7	0.4	1.08	2.08	3.7	0.38	25	3.4	0.88	0.72	0.72	1.38	3.06	2.92	0.72	1.33	-
Ionic Balance	%	0.87	-	-	0.97	-	-	-	-	-	3.61	-	0.98	2.82	-	-	-	-	-	-	-	-	-
Chlorophyll a	mg/m³	<4	<4	<4	<2	-	<12	<4	<10	4	<2	-	<3	<1	<4	-	<8	<3	2	<2	<4	-	-
Dissolved Oxygen	mg/L	6.7	7.3	7.3	7	6.8	6.4	6.8	7.6	6.7	7.5	7.5	6.2	6.8	5.6	7.1	5.9	6.7	7.3	5.5	6.3	4.9	> 4

Note: Recorded exceedances of the WQOs have been shaded in grey.

Appendix B - **Existing Conditions flood maps and results**

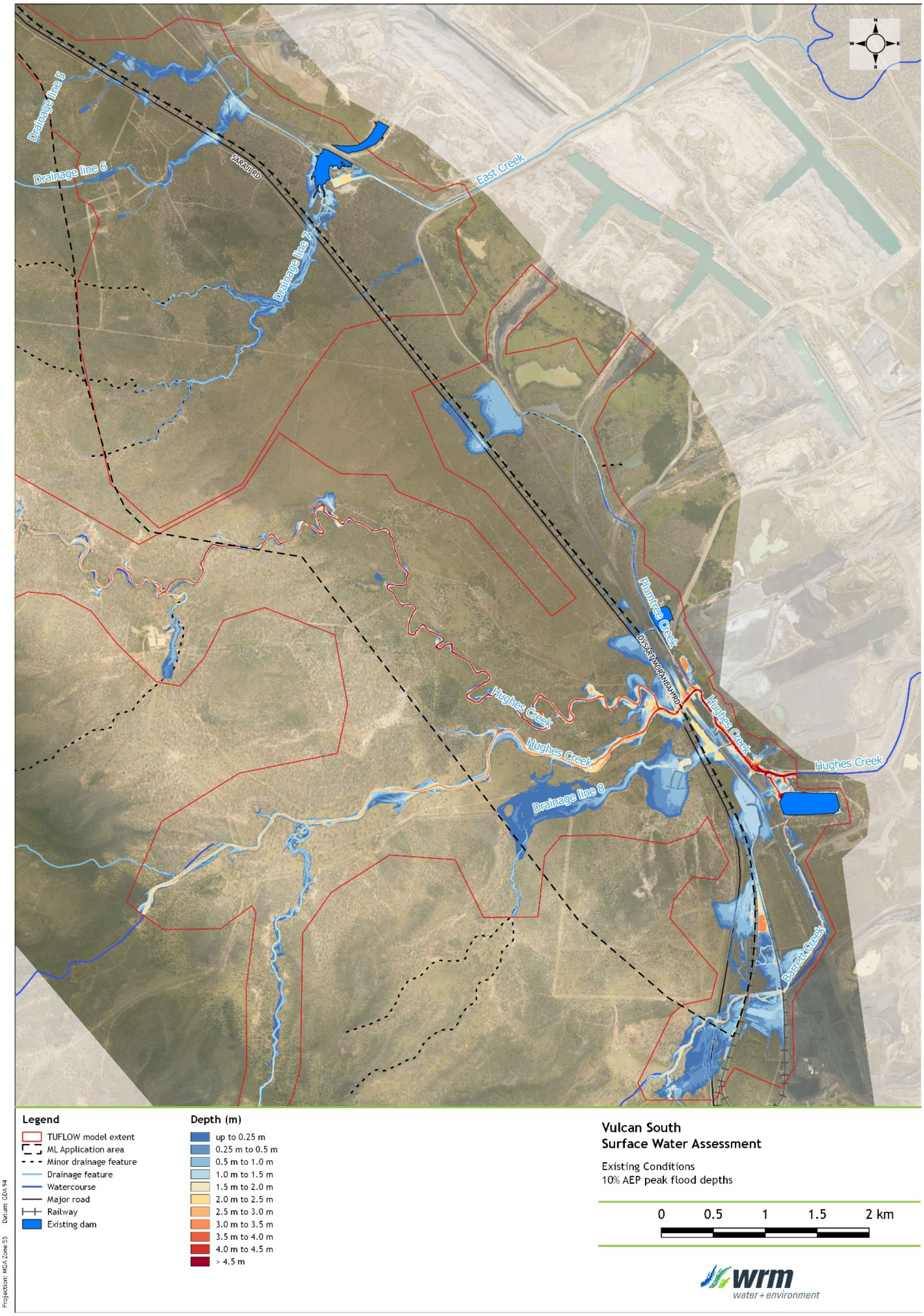
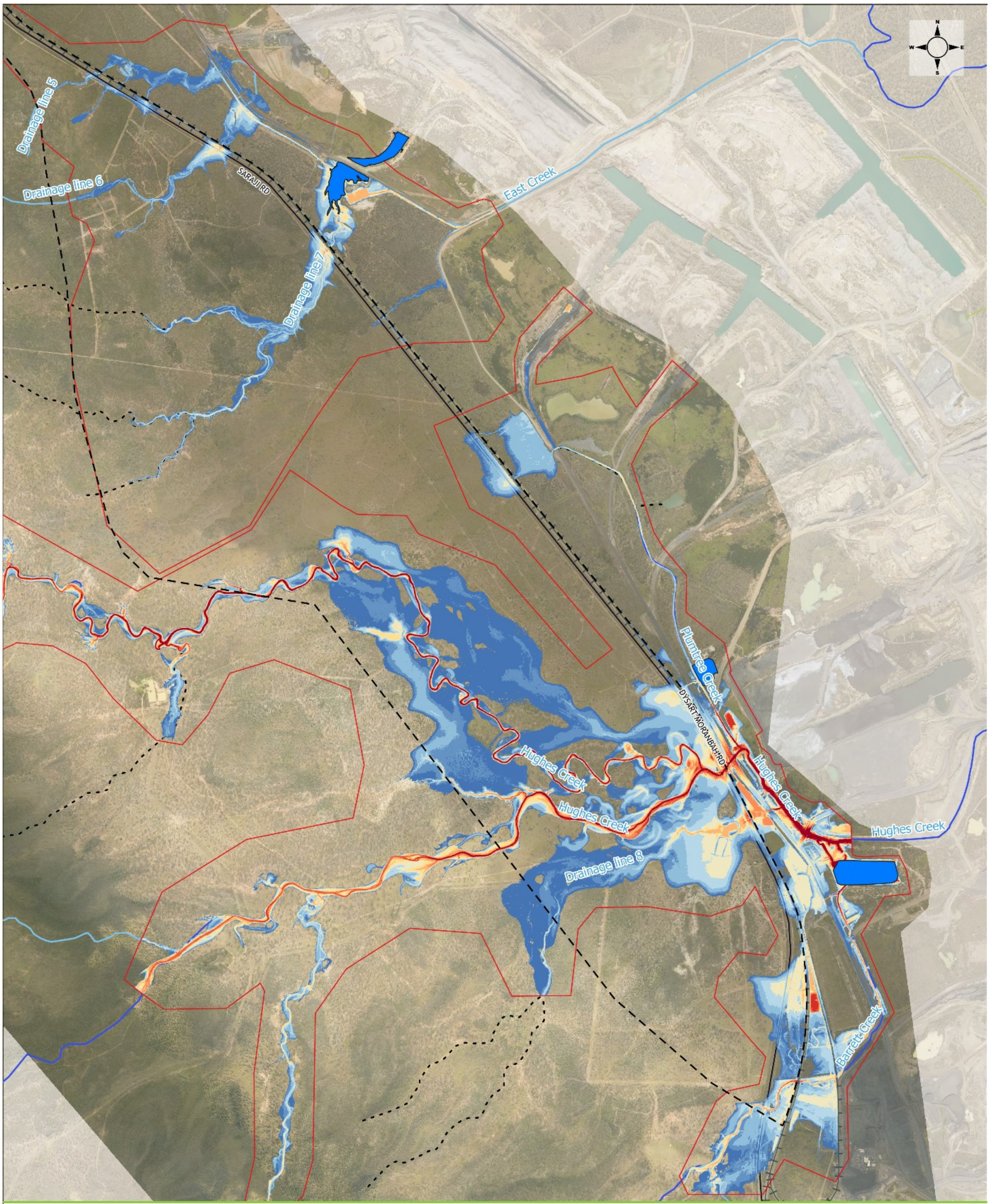


Figure B.1 – 10% AEP peak flood depths – Existing Conditions



Legend

- TUFLOW model extent
- ML Application area
- Minor drainage feature
- Drainage feature
- Watercourse
- Major road
- Railway
- Existing dam

Depth (m)

- up to 0.25 m
- 0.25 m to 0.5 m
- 0.5 m to 1.0 m
- 1.0 m to 1.5 m
- 1.5 m to 2.0 m
- 2.0 m to 2.5 m
- 2.5 m to 3.0 m
- 3.0 m to 3.5 m
- 3.5 m to 4.0 m
- 4.0 m to 4.5 m
- > 4.5 m

Projection: MGA Zone 55 Datum: GDA 94

Vulcan South
Surface Water Assessment

Existing Conditions
1% AEP peak flood depths

0 0.5 1 1.5 2 km

wrm water + environment

Figure B.2 – 1% AEP peak flood depths – Existing Conditions

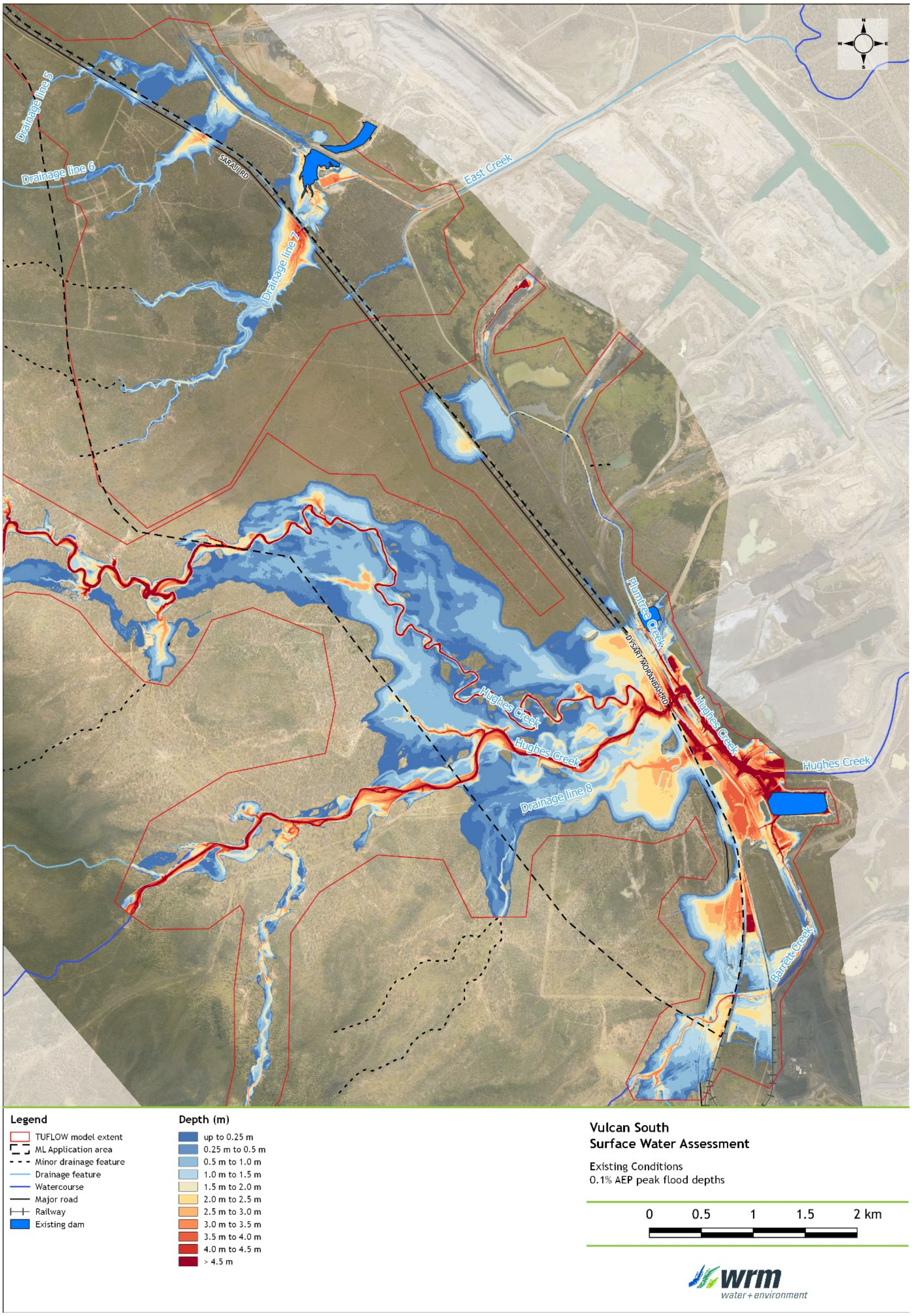


Figure B.3 – 0.1% AEP peak flood depths – Existing Conditions

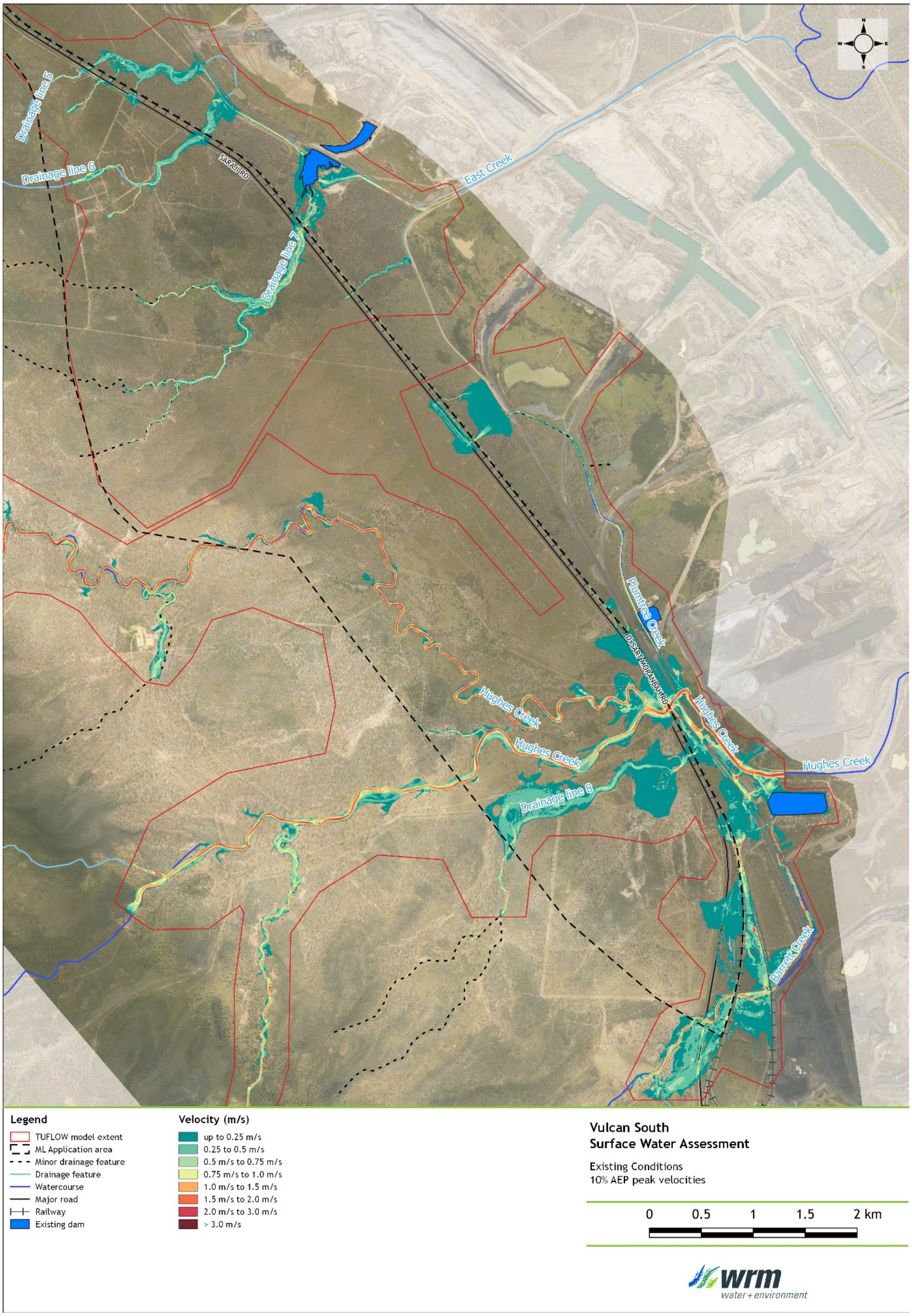


Figure B.4 – 10% AEP peak velocities – Existing Conditions

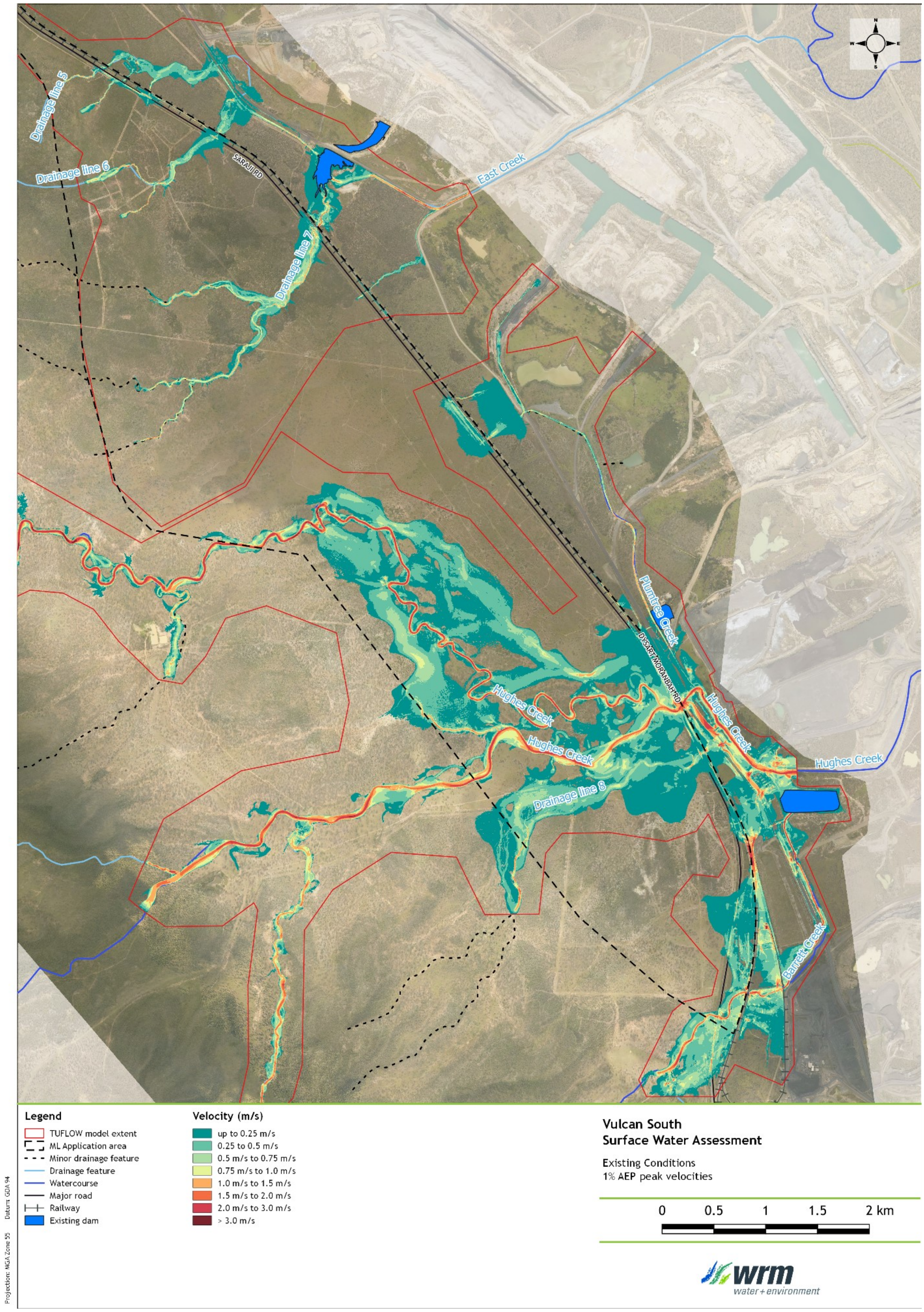


Figure B.5 – 1% AEP peak velocities – Existing Conditions

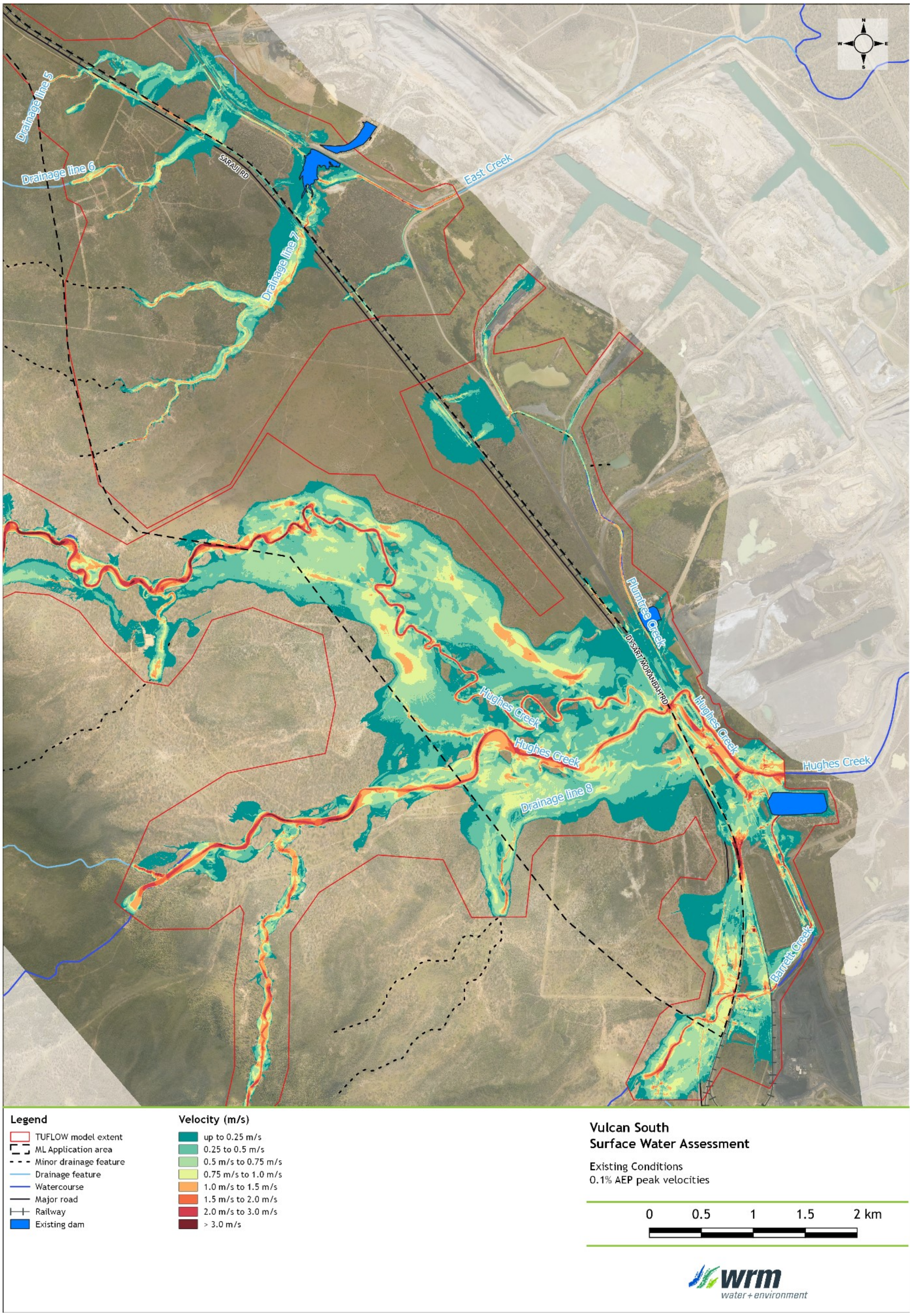


Figure B.6 – 0.1% AEP peak velocities – Existing Conditions

Appendix C - **Operational Conditions flood impact maps**

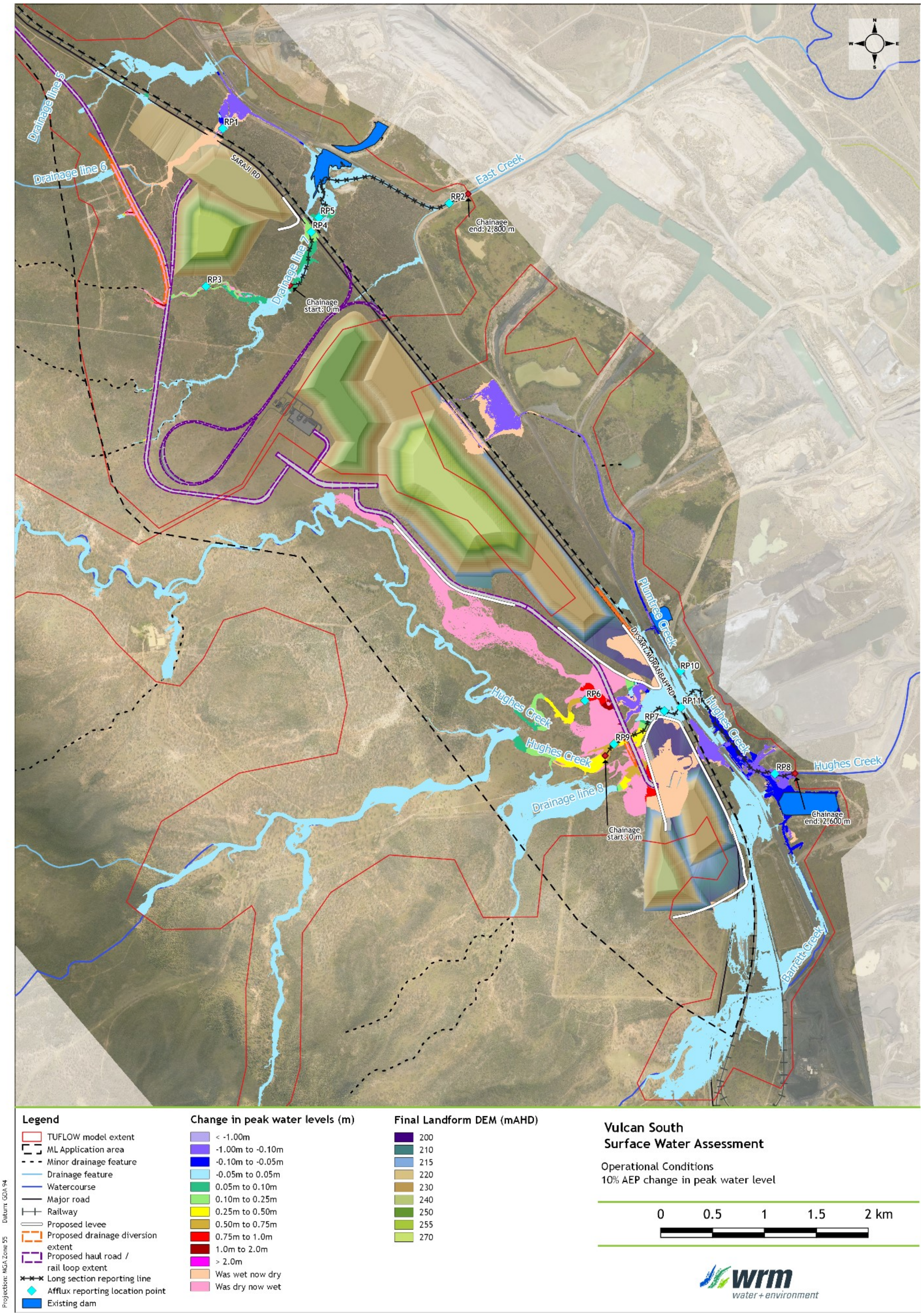


Figure C.1 - 10% AEP change in peak water levels - Operational Conditions impacts

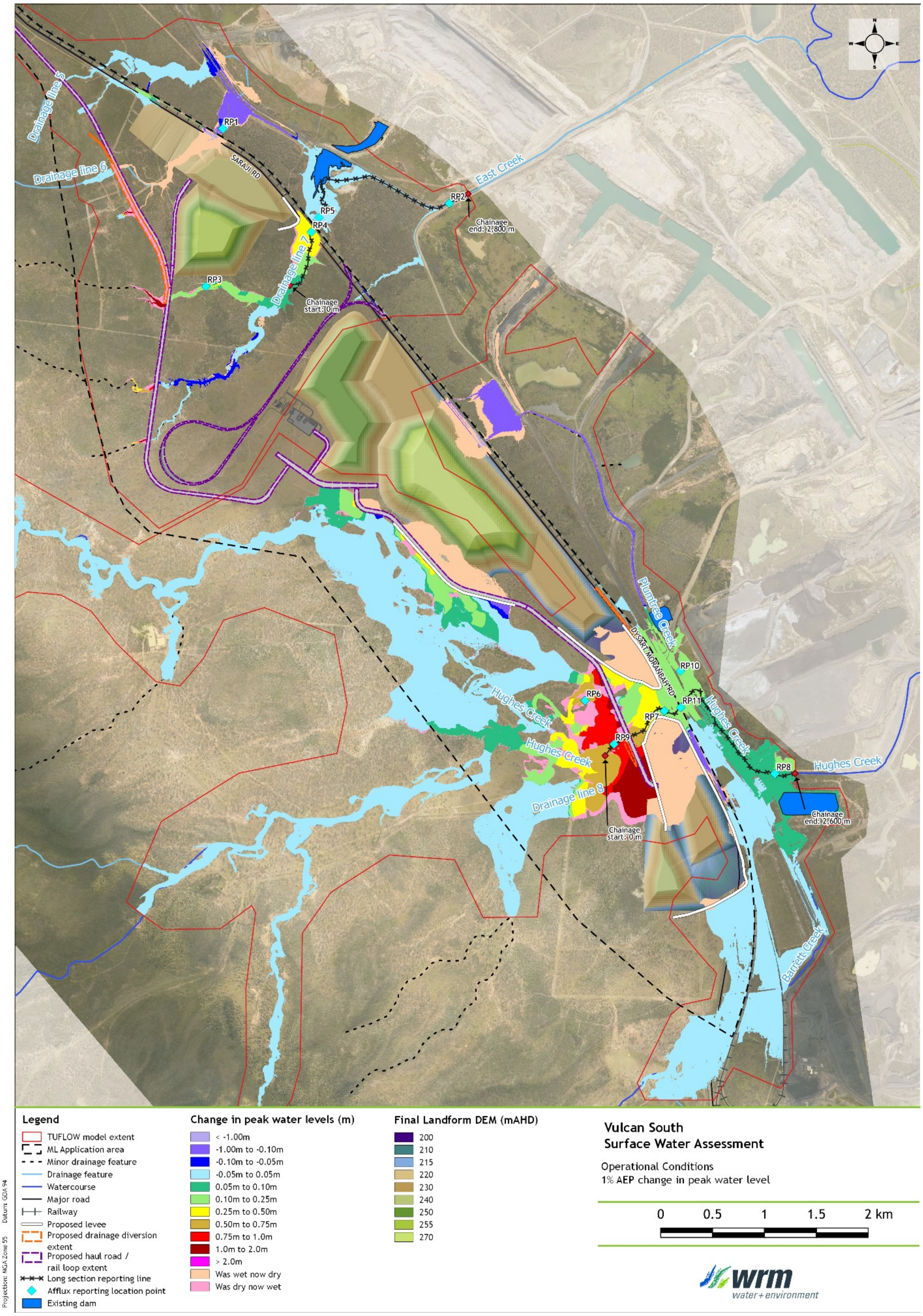


Figure C.2 - 1% AEP change in peak water levels - Operational Conditions impacts

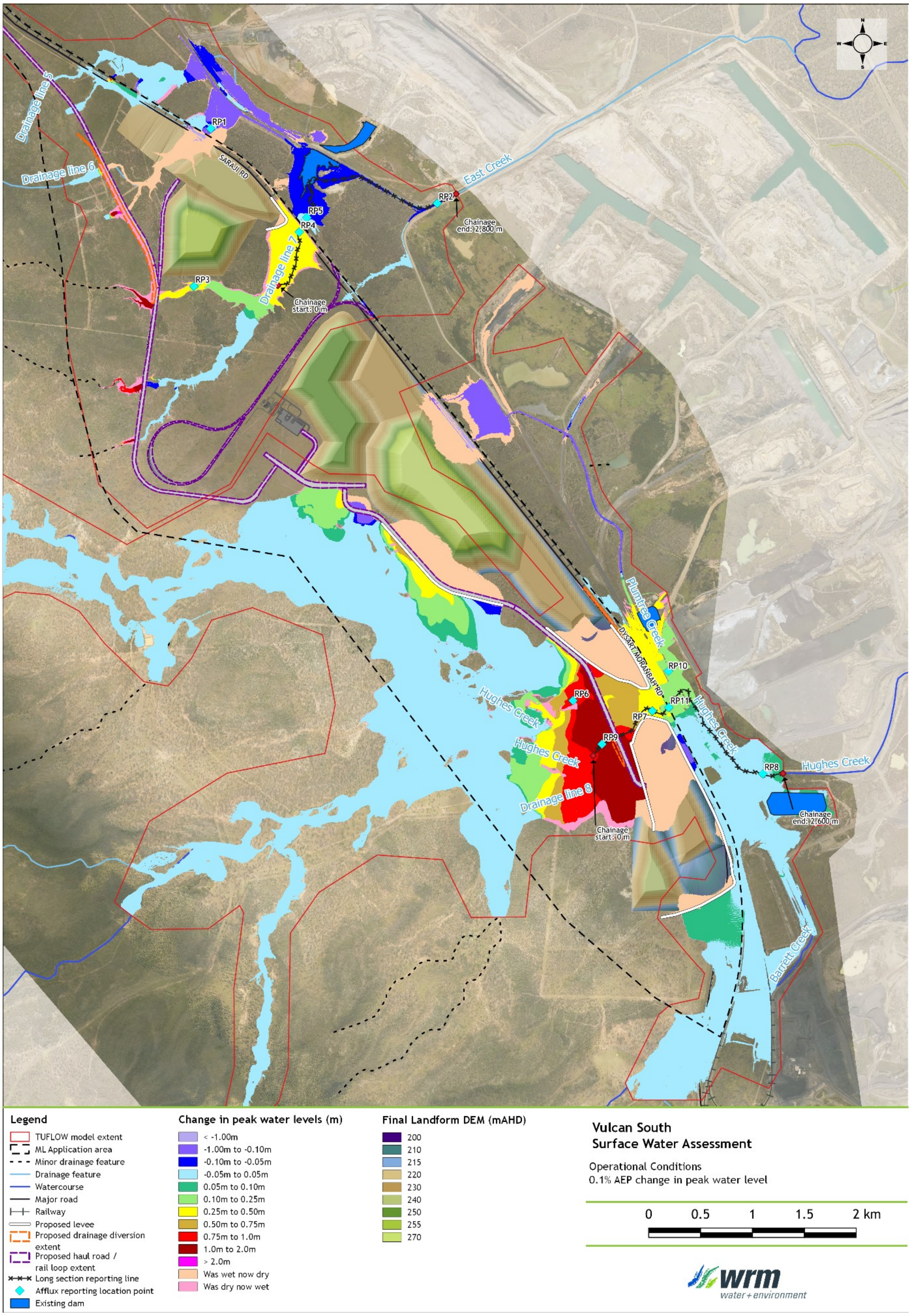


Figure C.3 - 0.1% AEP change in peak water levels - Operational Conditions impacts

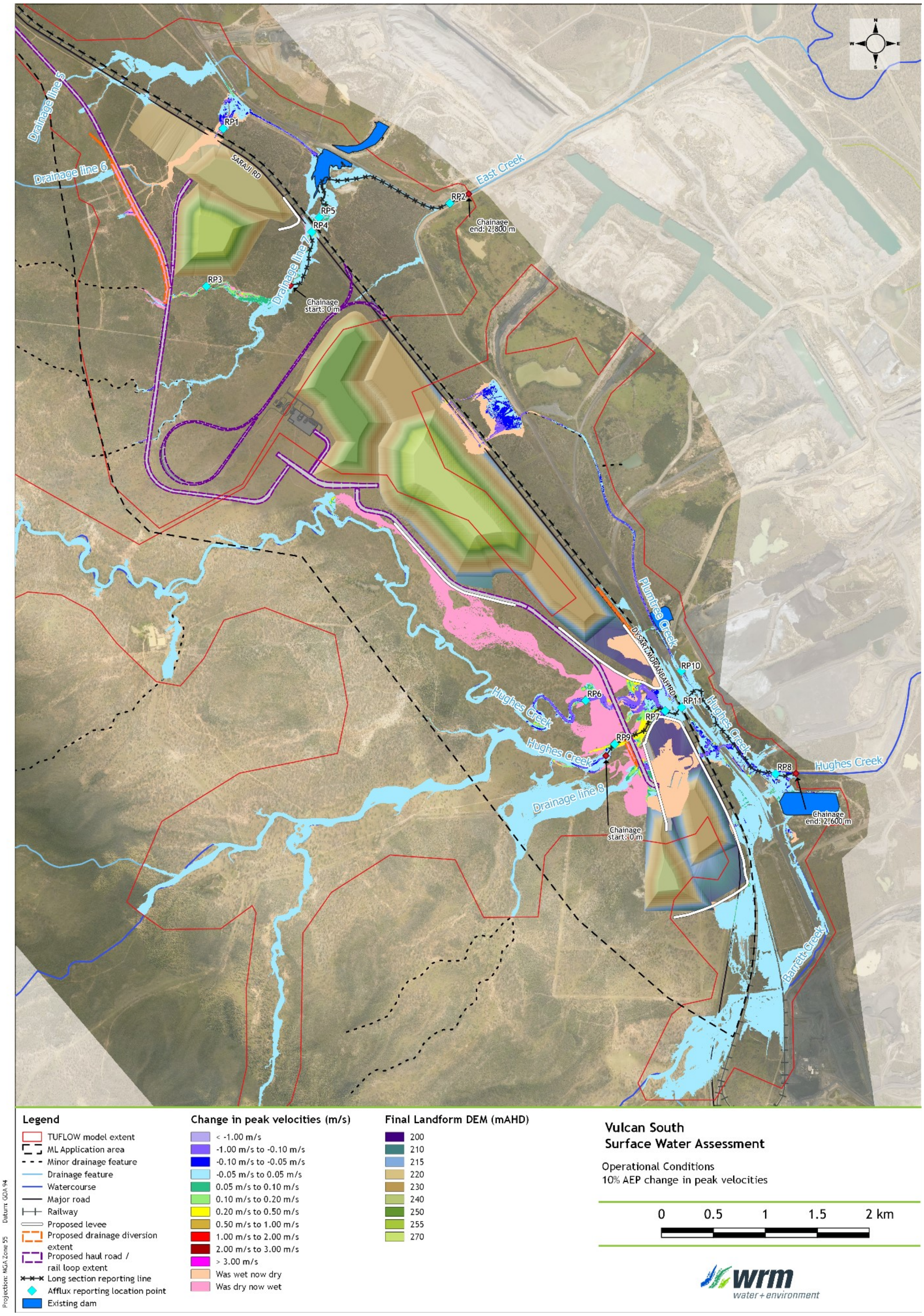


Figure C.4 - 10% AEP change in peak velocities - Operational Conditions impacts

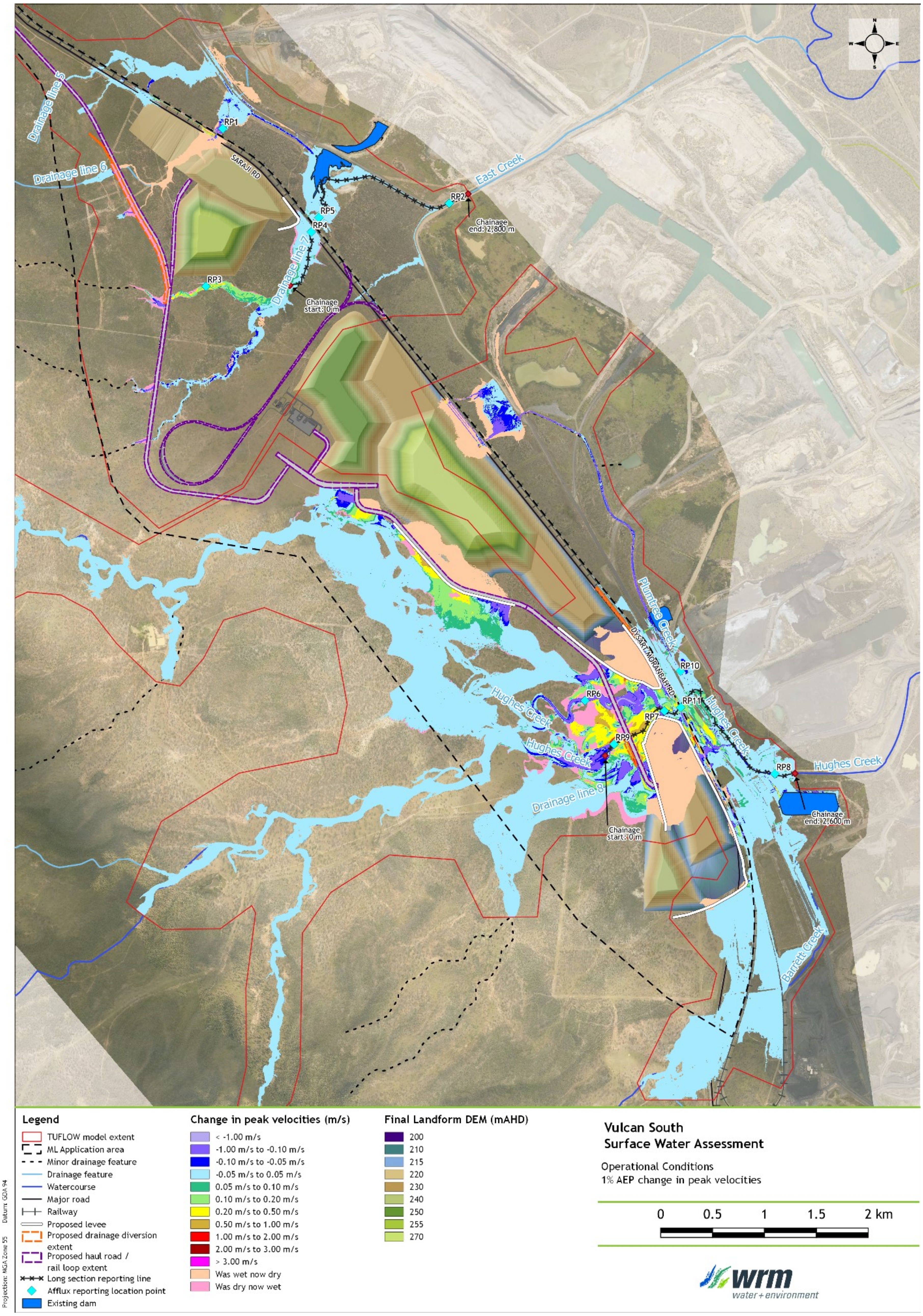


Figure C.5 - 1% AEP change in peak velocities - Operational Conditions impacts

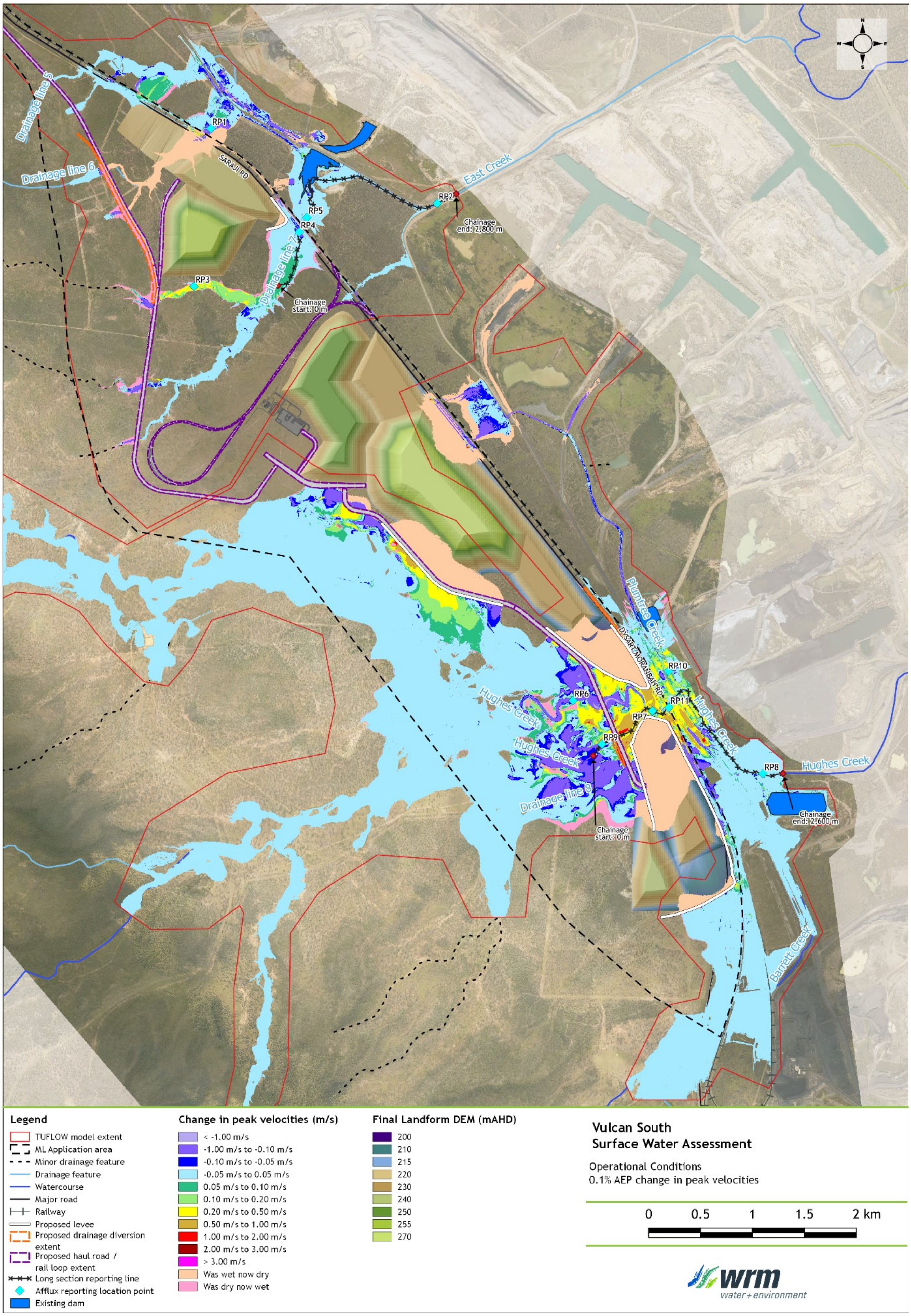


Figure C.6 - 0.1% AEP change in peak velocities - Operational Conditions impacts

Appendix D - Post-closure Conditions flood impact maps

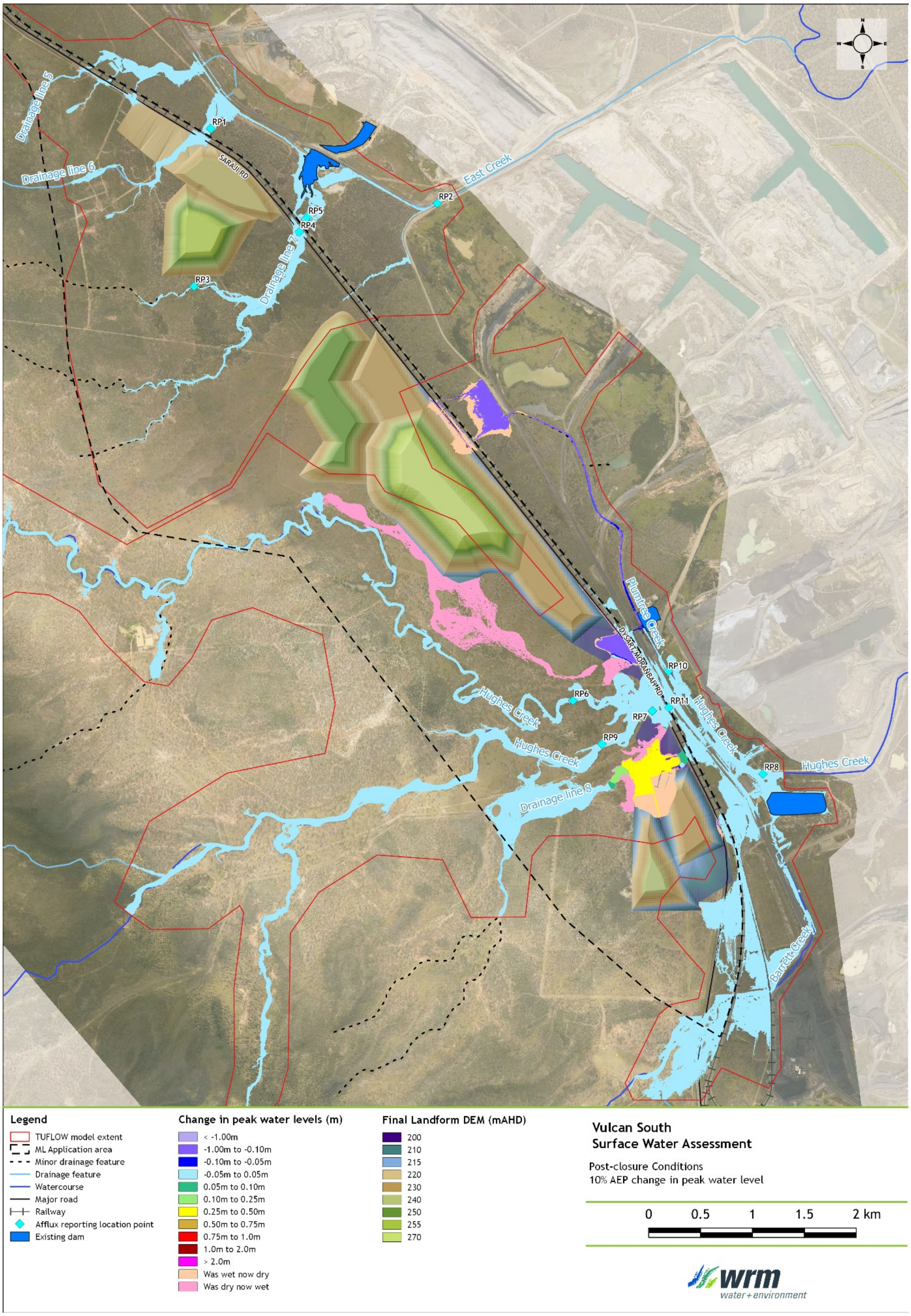


Figure D.1 – 10% AEP change in peak water levels - Post-closure Conditions impacts

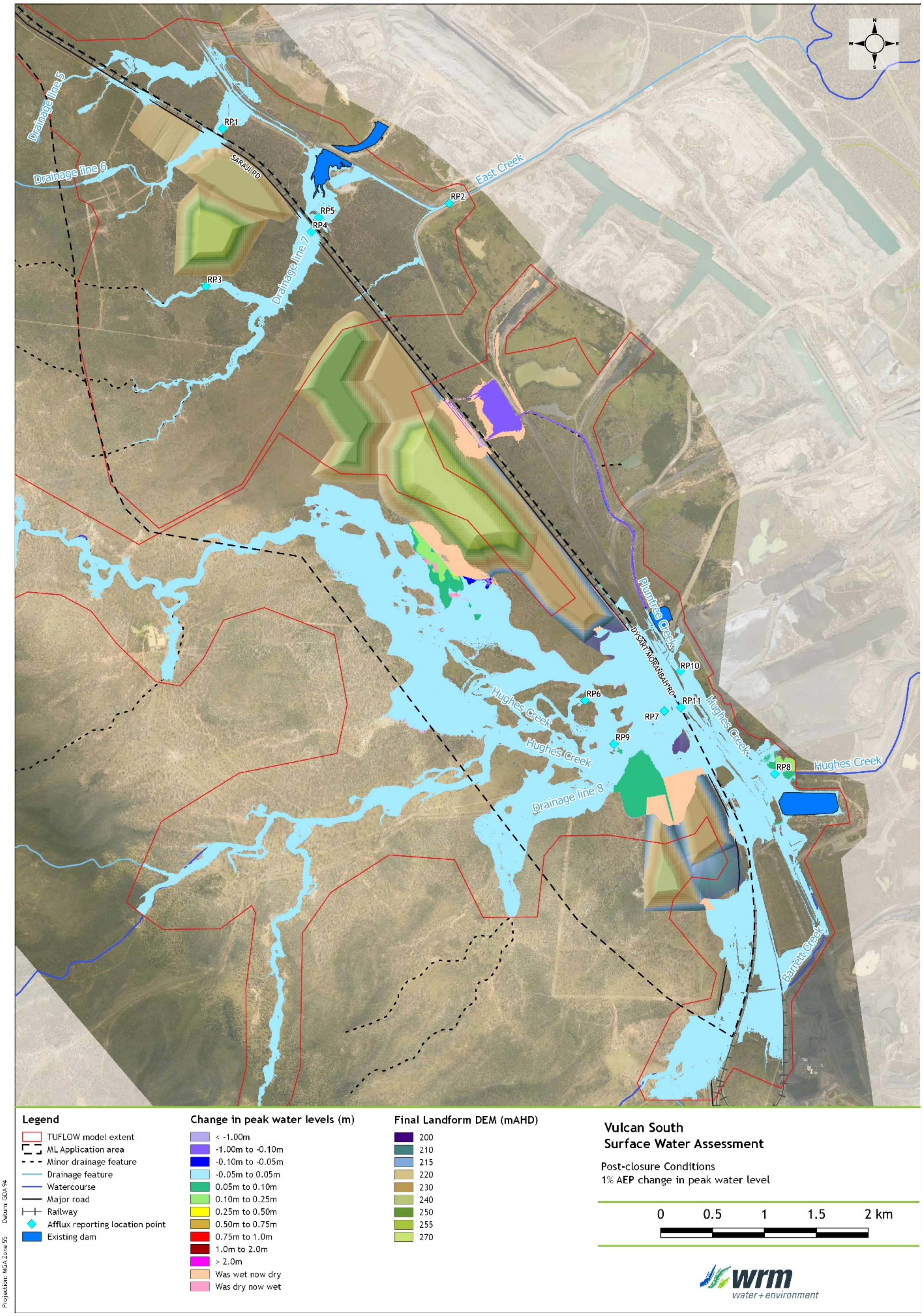


Figure D.2 - 1% AEP change in peak water levels - Post-closure Conditions impacts

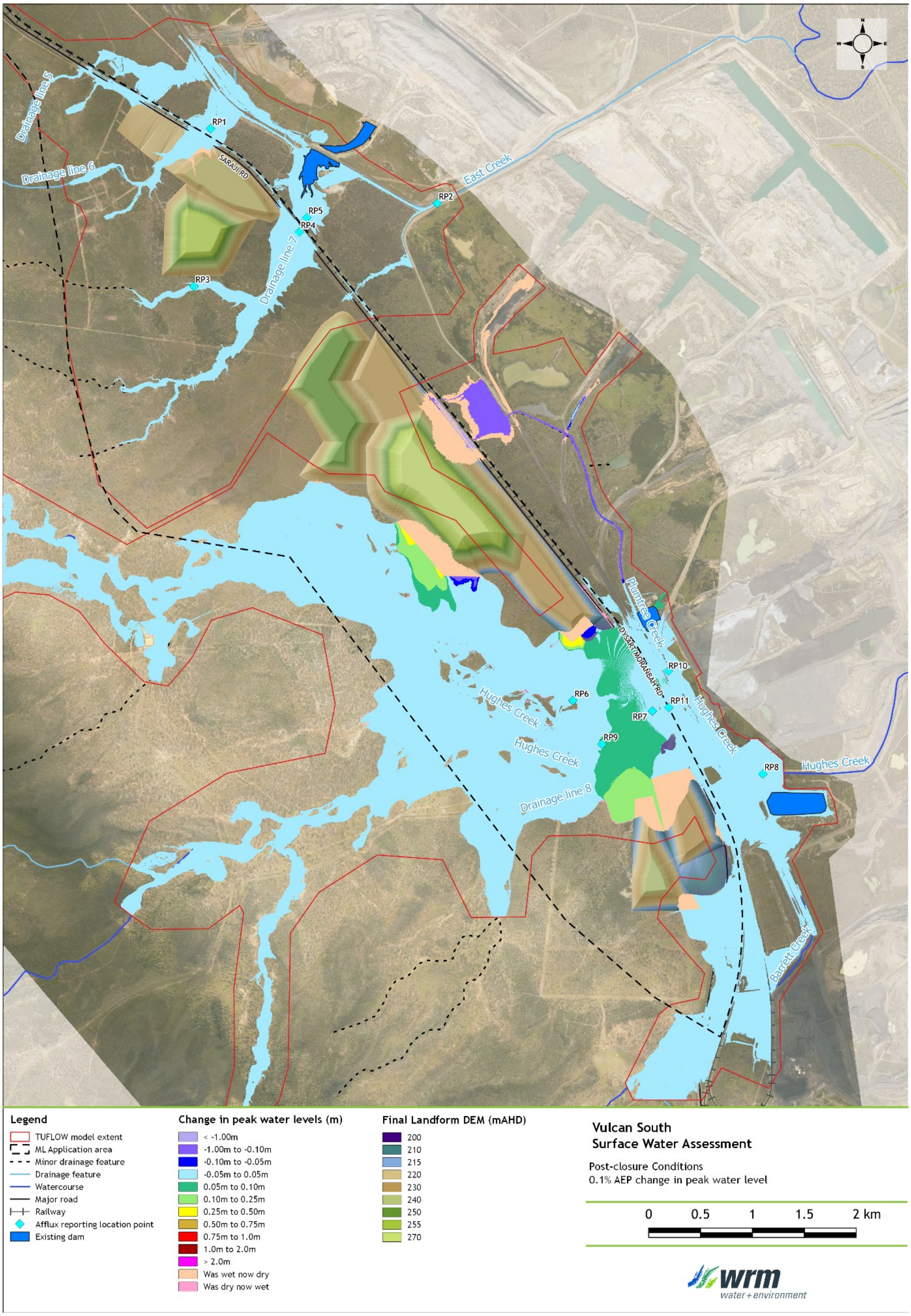


Figure D.3 - 0.1% AEP change in peak water levels – Post-closure Conditions impacts

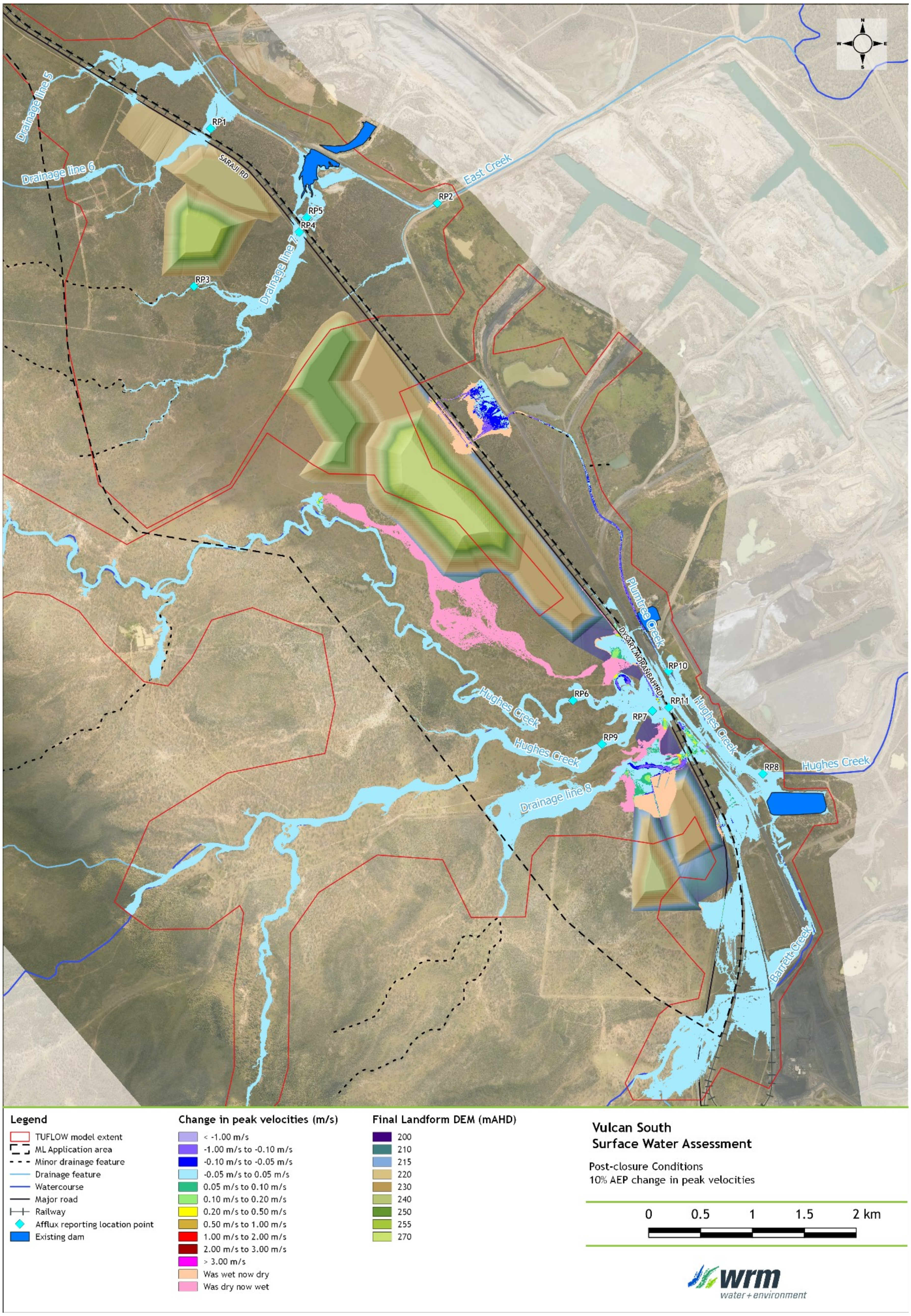


Figure D.4 - 10% AEP change in peak velocities – Post-closure Conditions impacts

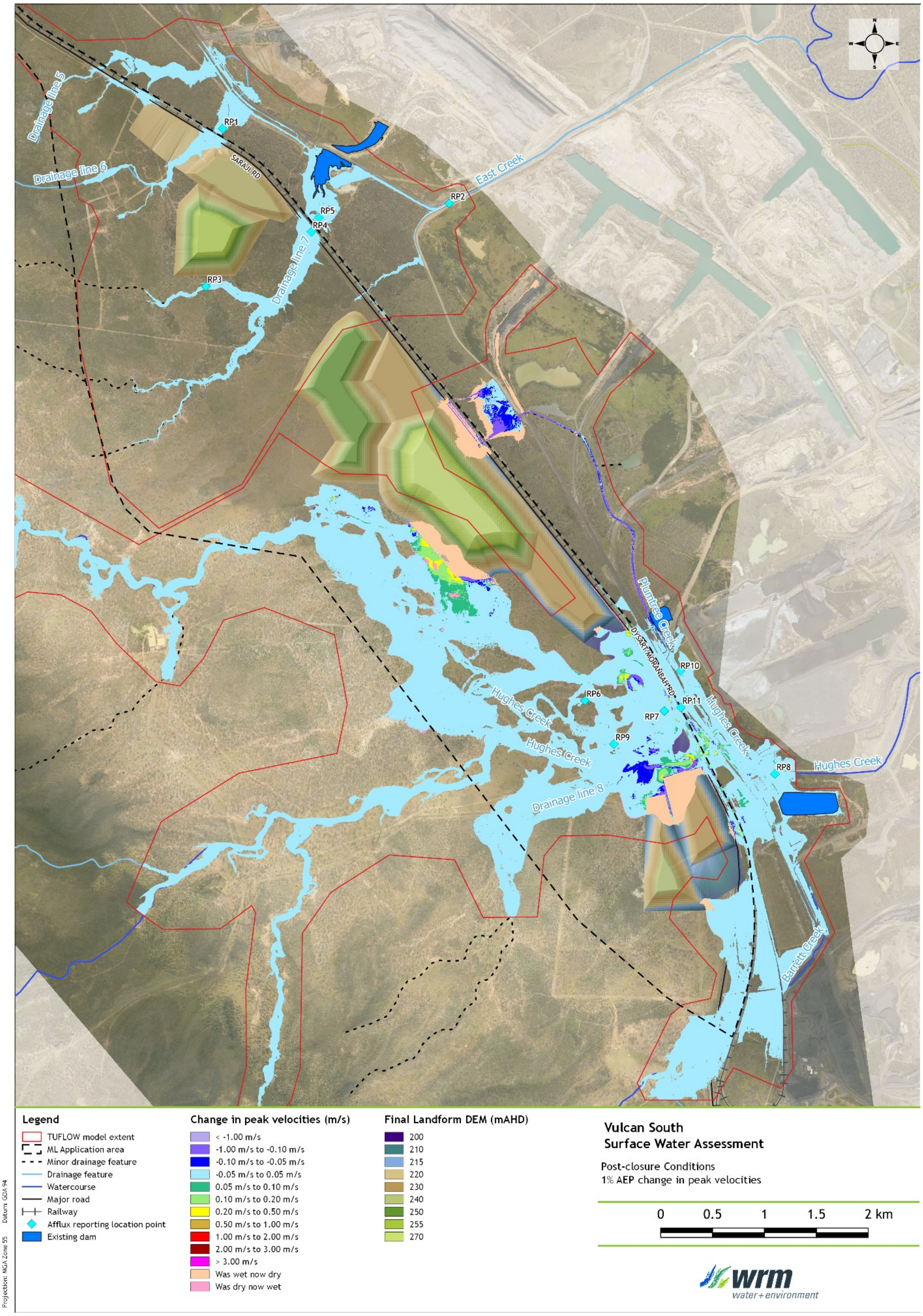


Figure D.5 - 1% AEP change in peak velocities – Post-closure Conditions impacts

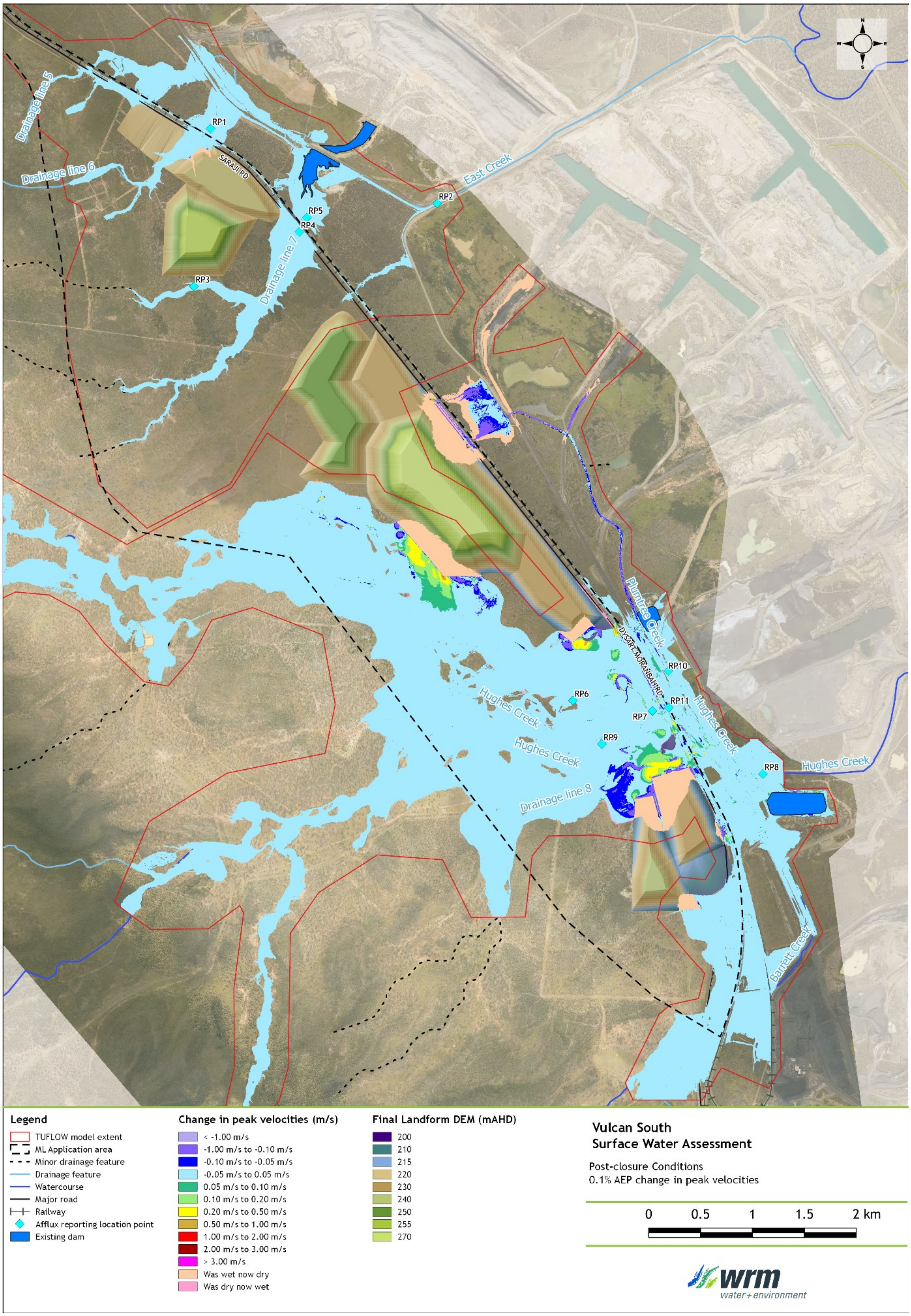


Figure D.6 - 0.1% AEP change in peak velocities - Post-closure Conditions impacts