ENGENY

WHITEHAVEN COAL

PRCP Concept Design Report

Sirius Creek Diversion

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1. INTRODUCTION

1.1 Context

The purpose of this report is to detail the concept design developed for the closure and ultimate relinquishment of the SIrius Creek Diversion which satisfies the conditions under Environmental Authority (EA) EPML00717813. The watercourse diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Blackwater Mine (BWM)

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (As per EA requirements outlined in Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for BWM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964, Version 3- 4 April 2023).*

1.2 Purpose and Scope

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options Assessment.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion remediation option (outcome from Stage 1) to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology approach was adopted:

- A desktop geomorphic assessment of Sirius Creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP.

Design Process

1.3 Design Process

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2. OVERVIEW

2.1 Location

Sirius Creek is an ephemeral tributary of the Comet River, situated within the Fitzroy River basin. The creek originates in a relatively low relief range to the east of Blackwater Mine. The creek flows from east to west through the southern part of Blackwater Mine operations and south of Laleham Pit and Ramp 74, eventually joining Comet River some 47 km west of Blackwater Mine. The catchment upstream of the diversion is approximately 100 km^2 and currently flows through "Old Cut 4" Dam. The diversion was likely constructed in 1977-1978 (Alluvium, 2010), at a length of approximately 2.7 km, to allow mining in Laleham Pit and form part of the flood mitigation for this pit. Refer to Figure 2.1 for the location of the Sirius Creek Diversion.

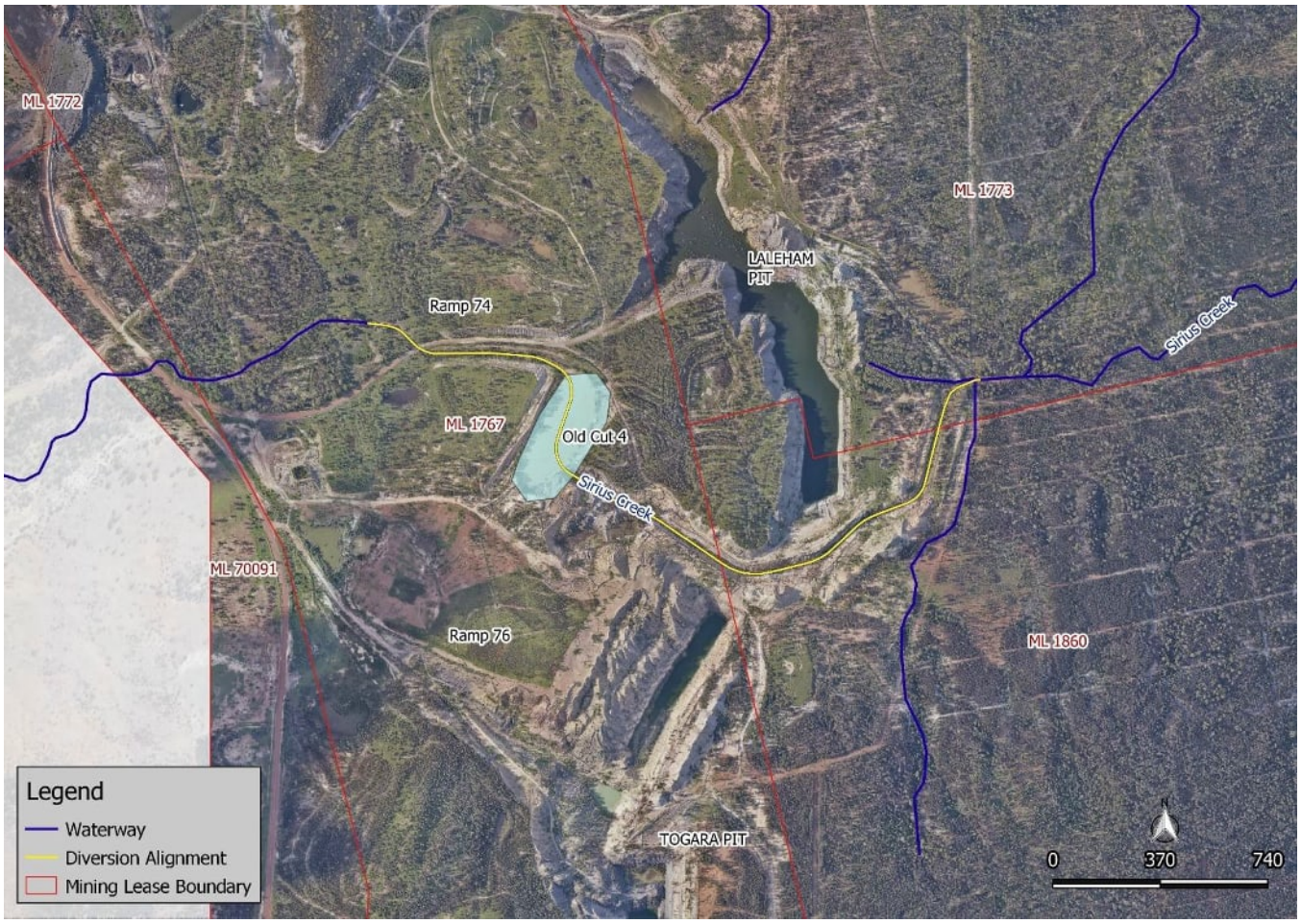


Figure 2.1:Location of the Sirius Creek Diversion at Blackwater Mine

2.2 Natural Reaches

The upstream, downstream and diversion reaches of Sirius Creek have been described as follows (Alluvium, 2010):

- **Upstream reach –** The upstream reach of the Sirius Creek diversion is a moderate sinuosity channel with low capacity, channel depths varying between 1-4 m and top width between 8-20 m. The channel does not have an excess supply of bedload sediment with native vegetation and habitat diversity enhanced due to woody debris. Some minor clearings have resulted in erosion heads along parts of the upstream channel. Generally, the upstream reach is representative of the natural environment of the surrounding land.
- **Downstream reach –** The downstream channel of the Sirius Creek diversion comprises of a moderate sinuosity low flow channel of low capacity, set within a broad floodplain. The riparian vegetation along the reach is subject to grazing and mining influences, with "Old Cut

4" dam impacting the sediment flow regime within the diversion. The dam is not allowing sediments to pass through the system freely and as a result sediment is accumulating within the diversion. The downstream reach is approximately 1-3 m deep with the low flow channel top width ranging from 10-20 m.

- **Diversion reach (pre-mining)** - The Sirius Creek diversion reach (pre-mining) was approximately 2.5 km long. It was gently meandering across the southern extent of what is now Laleham Pit.

The upstream, downstream and diversion reaches of the Sirius Creek diversion at Blackwater Mine are shown in Figure 2.2.

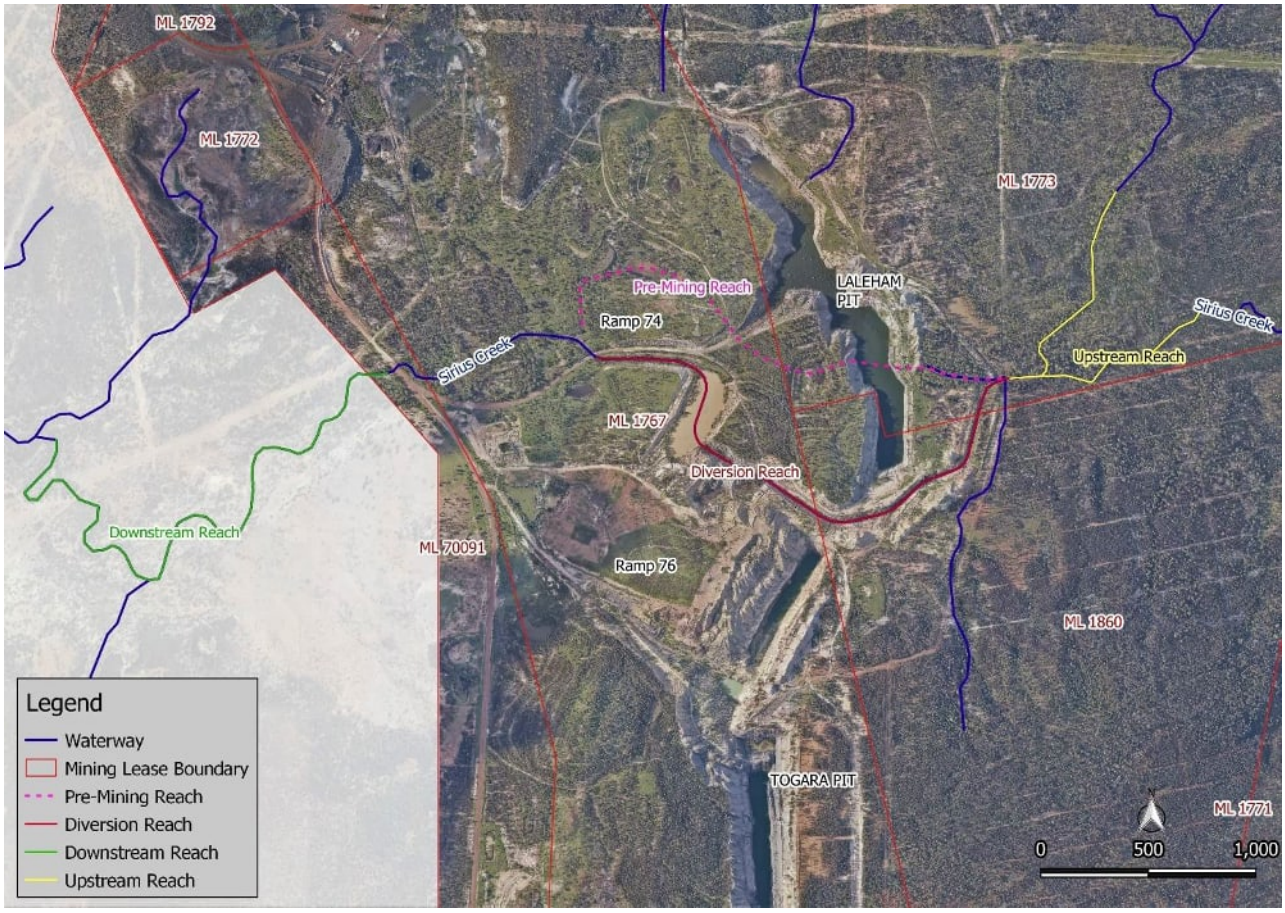


Figure 2.2: Upstream, Downstream and Diversion Reaches of the Sirius Creek Diversion

2.3 Diversion Reach

Monitoring of Sirius Creek diversion has been undertaken since 2010 and was last completed in 2017. As part of the major monitoring, the latest condition of the Sirius Creek diversion has been described as follows (Engeny, 2017):

- The upstream reach and downstream reach have remained relatively stable overall with a minor improvement in riparian vegetation condition. Prior to the last minoring assessment, the riparian condition was deteriorating steadily.
- There is an existing dam within the diversion reach, called "Old Cut 4" which is influencing the flow regime within the diversion as well as sediment supply of the reach.
- The diversion reach continues to remain in poor condition due to the nature of the diversion, the inability to function as a natural system and excess supply of sediment from spoil dumps and bank erosion.

Based on the current condition of the Sirius Creek diversion, it is highly unlikely that the diversion will achieve the water license relinquishment criteria prior to mine closure without intervention.

3. BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions. Details of the guidelines that have been used to design the Sirius Creek diversion are summarised below.

3.1 DNRME Guideline

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Sirius Creek diversion:

- Outcome 1 - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 - The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 - The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 - The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 - The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Sirius Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.1 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.

- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

TABLE 3.1: DNRME 2019 HYDRAULIC DESIGN CRITERIA

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
2-year ARI (no vegetation) (39% AEP)	<35	<1.0	<40
2-year ARI (vegetated) (39% AEP)	<60	<1.5	<40
50-year ARI (2% AEP)	<150	<2.5	<80[1]

1. DNRME values are taken from ACARP 2002 as the <50N/m^2 value in DNRME 2019 is incorrect.

3.2 ACARP Guidelines

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, which included an analogous approach, where channel dimensions are selected from a reference reach; a hydraulic geometry approach where dimensions are determined from regression relationships; and an analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be represented of stable watercourses within the Bowen Basin and are summarised in Table 3.2.

TABLE 3.2: ACARP 2014 ALLUVIAL CHANNEL DESIGN PARAMETERS

Stream Type	Stream Power (W/m^2)	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.3.

TABLE 3.3: ACARP 2014 RECOMMENDED VEGETATION SHEAR STRESS THRESHOLDS

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass	40
Structurally diverse suite of established native vegetation	120

The long-term performance of the diversion under both operating and closure scenarios is assessed with the following objectives, based on industry standard closure objectives:

- The diversion demonstrates to be in a safe, stable, non-polluting and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Reference rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining landuse of the 'Watercourses' which is applicable for the watercourse diversion.
- Existing water licence diversion objectives generally align with the objectives under the DNRME Guidelines (2019).

3.3 Environmental Authority EPML00717813

The land schedule within the Blackwater Mine EA (EPML00717813) requires that all areas significantly disturbed by mining activities must be rehabilitated in accordance with specified Rehabilitation Requirements. The EA provides the rehabilitation landform criteria for the post mining land use of watercourses (refer to Figure 3.1). Some indicators reference the Index of Diversion Condition (IDC) method, which is a component of ongoing diversion monitoring.

Table E1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

Figure 3.1: Blackwater Mine EA EPML00717813 Rehabilitation Requirements for Watercourses

4. OPTIONS IDENTIFICATION

Engeny identified four potential remediation options for the Sirius Creek diversion based on the current alignment, final landform consideration and the future mine plan. To inform the remediation concept design, the geomorphic features of the pre mining drainage path were incorporated and utilised as well as the upstream and downstream channel geometry and grade.

The objective was to identify suitable options for the permanent remediation of the Sirius Creek diversion and identify a preferred option to carry though to concept design. A maximum of three options were required, where four options were identified for Sirius Creek and taken forward into further assessment. The process to define the options includes a review of the natural waterway geometry, the existing creek diversion geometry, original design reports and current diversion design parameters.

Each option was defined with a concept cross section, longitudinal profile and meandering characteristics, if applicable. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of floodplain.
- Proposed tie-in locations to the existing waterway.
- Development Class 5 capital cost estimate.

Where applicable, the earthworks quantities include the filling quantity for existing dams or depressions which would be ultimately remediated in closure.

The options identification also includes the assessment of key risks and opportunities regarding potential staging, possible impacts to downstream infrastructure, reinstating the flood plain and post mining land-use risks in the context of closure. The main focus for each option was to determine the impacts and interaction between the PRCP final landform and the proposed diversion. Refer to Figure 4.1 for the potential options identified and Table 4.1 for further details.

TABLE 4.1: OPTIONS IDENTIFICATION DETAILS

Statistic	Option 1	Option 2	Option 3	Option 4
Description	Re-instating natural alignment of the creek	Remediation of existing diversion channel	Diverting channel south through spoil and final landform	Diverting channel north around final void
Likelihood that diversion will achieve state of dynamic equilibrium	High – stream length similar to natural	Low – stream length increased >10%	Medium – stream length increased <10%	Low- stream length increased >10%
Diversion constructed through spoil	No	Yes	Yes	No
Order of magnitude cost estimate*	$10.6 M	$19.2 M	$190 M	$40 M
Ability to isolate diversion from flows during establishment period	Yes	No	Yes	Yes

*Cost estimate based on average $10/m^3 and Option 2 including quantities to fill 'Old Cut 4 Dam'

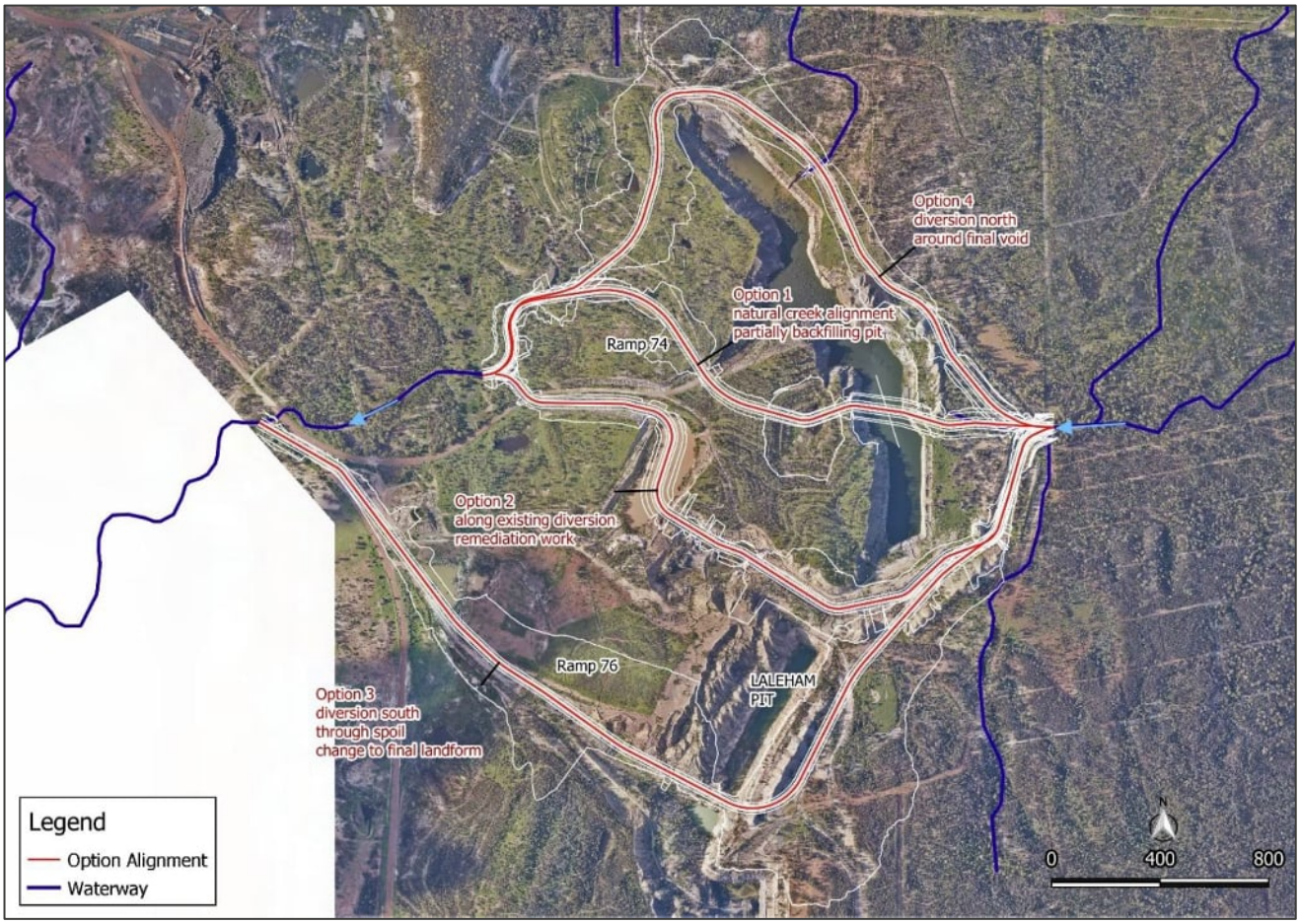


Figure 4.1: Sirius Creek Diversion Remediation Options

5. OPTIONS ANALYSIS

5.1 Multi-Criteria Analysis Framework

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criteria was determined and agreed upon with a BHP and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criteria against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

TABLE 5.1: WEIGHTING FOR INDIVIDUAL SCREENING CRITERIA

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	40%
Diversion constructed through spoil	30%
Order of magnitude cost estimate	20%
Ability to isolate diversion from flows during establishment period	10%

5.2 Multi-Criteria Analysis

The MCA resulted in Option 2 to be carried forward into concept design as a preferred option, since it scored highest out of all three options without a fatal flaw and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

TABLE 5.2: MULTI-CRITERIA ANALYSIS OUTCOMES

Item	Option 1	Option 2	Option 3	Option 4
Overall Weighted Score	-0.6	-0.9	-1.0	-1.2
Relative Risk	Highest Risk	High Risk	Highest Risk	High Risk
Fatal Flaw	Yes	No	Yes	No

6. CONCEPT DESIGN

6.1 Design Parameters

Table 6.1 describes the parameters within each outcome described in Section 3 forming the design plan for the permanent diversion, aligning with DNRME and ACARP Guideline requirements.

TABLE 6.1: DNRME AND THE AUSTRALIAN COAL ASSOCIATION RESEARCH PROGRAM (ACARP) PARAMETERS ADOPTED

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral dysconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] Hydrologic models were originally developed as part of the Saraji Mine Flood Study (Engeny, 2018).	☐ ☒	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	*Outcome 5 –* Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine.	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME, 2019. Stream power benchmark values were adopted from ACARP, 2014 due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 Diversion Alignment

Option 2 was identified to be the preferred option alignment using the MCA, retaining and remediating the diversion on its current alignment due to the voids north and south. The alignment was further refined to optimise quantities and is consistent with pre-mining stream length and grade.

Previously, a design was provided for an early revision of the final landform. The design has now been updated to be consistent with Final Landform 3.6.1. Figure 6.1 shows the proposed permanent diversion alignment design and general arrangement. The preferred option design is included in Appendix C and the concept design and interaction with the PRCP landform in Appendix D.

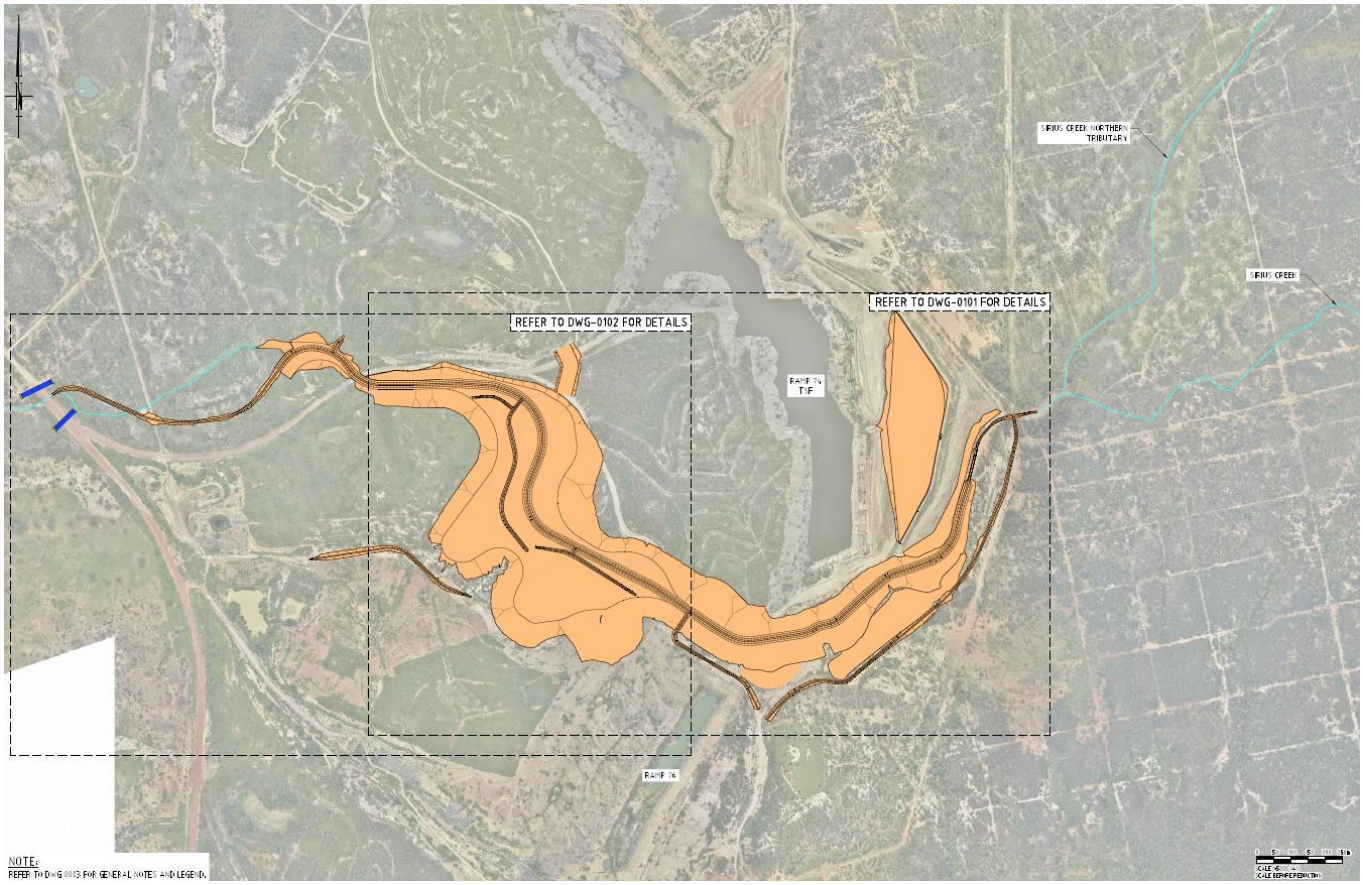


Figure 6.1: Option 2 General Arrangement

6.3 Channel Geometry and Grade

The typical upstream and downstream channel geometries are presented in Figure 6.3 and Figure 6.4 below. These dimensions were based on the average natural upstream and downstream channel geometry topographic data and aerial imagery were used to evaluate the planform and cross section parameters of multiple reference reaches of Sirius Creek. Cross-sectional dimensions were compared and evaluated for a total of 10 cross-section locations. The locations of the cross-sections taken for the analysis are provided in Figure 6.2. The accuracy of the survey used at the time of writing is defining the accuracy of the natural channel cross sections and the final cross section used for the concept design. Table 6.2 and Appendix C show the detailed geometry and typical cross section of the concept design with longitudinal profile, respectively.

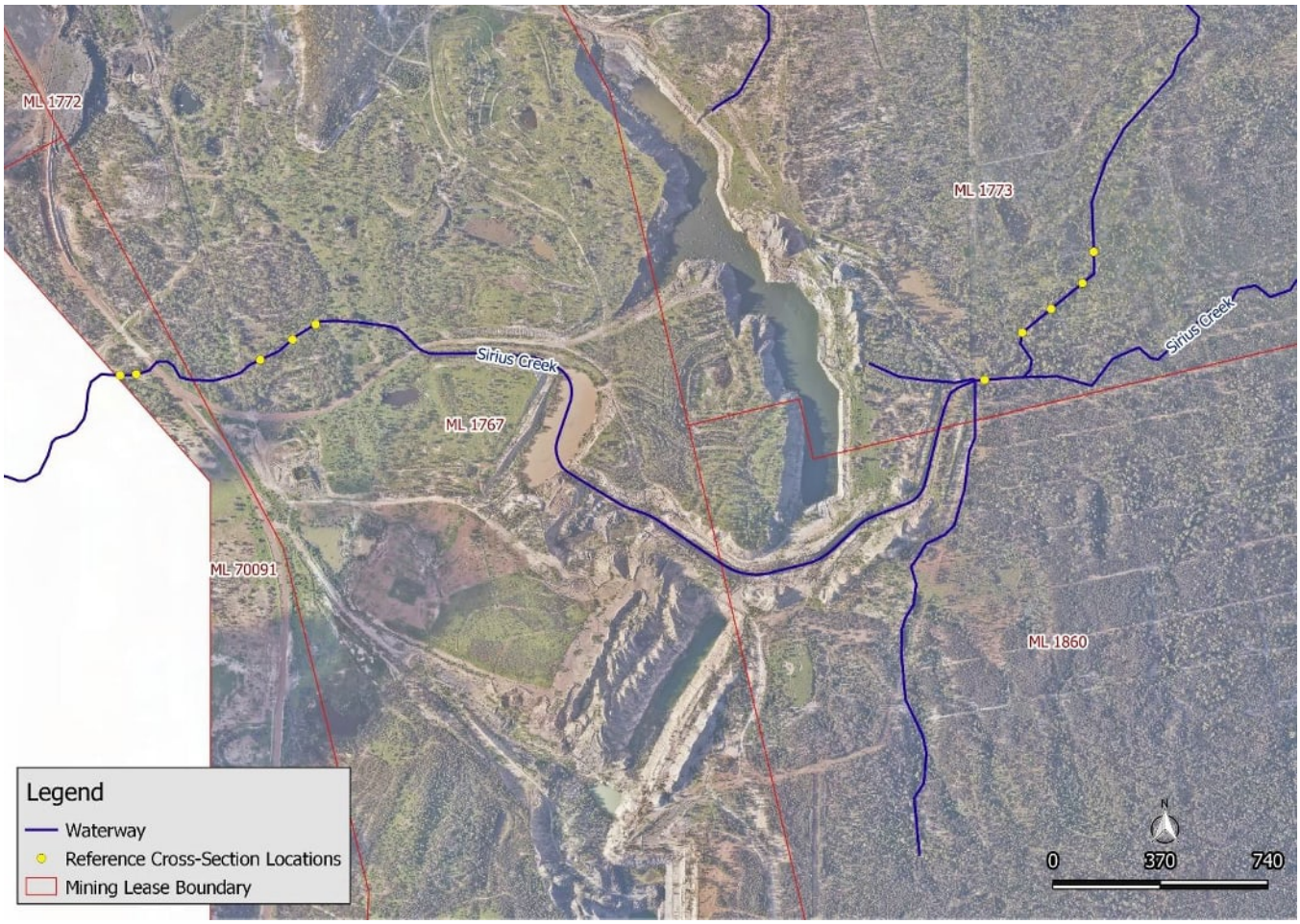


Figure 6.2: Locations of Reference Cross-Sectional Areas

TABLE 6.2: DETAILED CHANNEL CROSS SECTION GEOMETRY

Channel Geometry	Quantity	Comments
Channel Bed Width	4 m	Based on the upstream reference reaches scaled by total catchment area
Batter Slope	1V:4H	Adopted based on scaled cross sectional area and construction safety. 1V:4H batters adopted over the majority of the diversion with 1V:3H batters adopted from approximate chainage 1000m to 1700m to reduce cut volume where the largest batters are present and reduce impact to certified rehab areas.
Channel Depth	2 m	Consistent depth of low flow channel at 2m
Bench Width	5 m	Bench only present between low flow and high flow channel

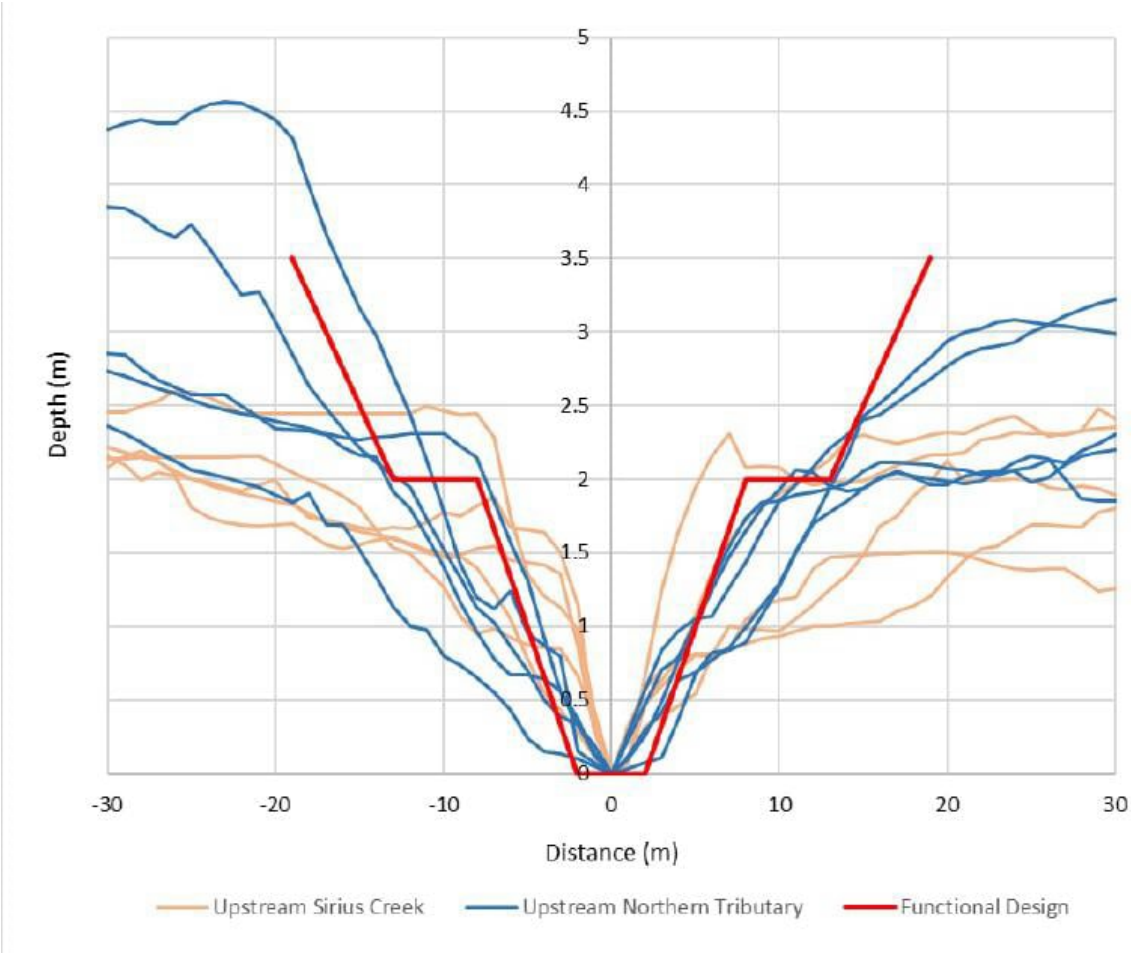


Figure 6.3: Typical Upstream Channel Cross Section and Design Cross Section

6.4 Hydrology

Peak flows for frequent events (39% AEP and2% AEP) for the Sirius Creek diversion remediation were estimated using the ACARP (2002) methods and are presented in Table 6.3. As described in Section 3, The hydraulic outcomes for diversion designs are only prescribed for frequent events (39% AEP and2% AEP). As such, hydraulic modelling of rare event (1% and 0.1% AEP) has not been undertaken as part of the diversion concept design. The Rehabilitation Flood Assessments undertaken separately as part of the PRCP should be referred to for the hydrologic and hydraulic modelling for the 1% AEP and 0.1% AEP flood events of Sirius Creek.

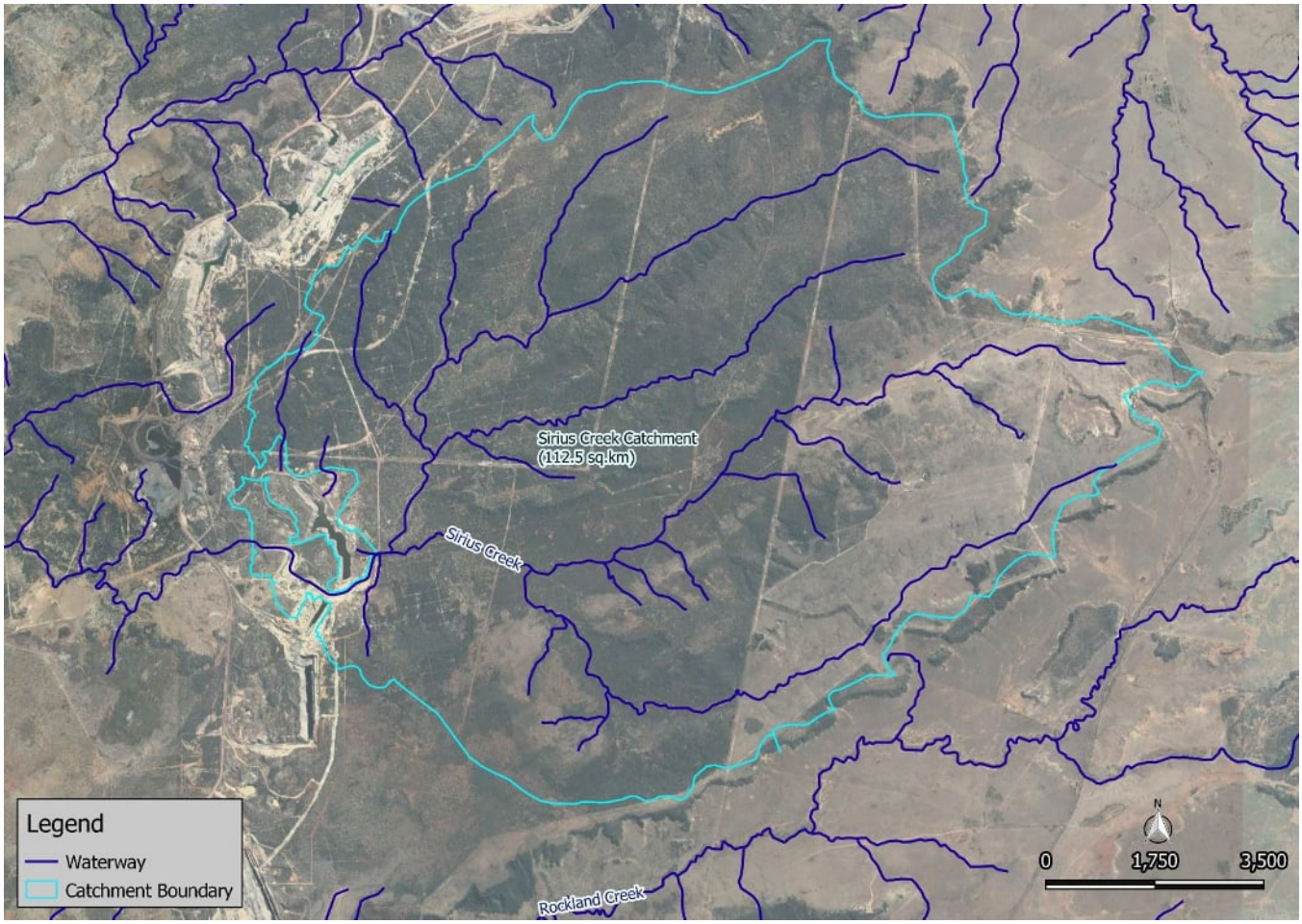


Figure 6.4: Map of Catchments

6.4.1 Frequent Events

The hydrologic model (Engeny, 2017) mentioned above was used to estimate flows through the diversion for the 39% AEP and 2% AEP flow events (refer toTable 6.3) in accordance with the ACARP (2002) method.

The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% AEP and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity. This approach has been adopted to determine the flows within the proposed Sirius Creek diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters.

TABLE 6.3: SIRIUS CREEK DIVERSION DESIGN FLOWS

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
39% AEP	61
2% AEP	141

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform will be summarized within the Rehabilitation Flood Assessments undertaken as part of the PRCP.

6.5 Hydraulics

The HEC-RAS hydraulic model was developed for assessing the diversion hydraulic results for the mine closure scenario against the hydraulic performance criteria in the DNRME hydraulic performance criteria. The HEC-RAS model was utilised for this assessment based on the fact that the criteria were originally developed by assessing existing diversions and Bowen Basin streams using 1-dimensional steady state modelling. Therefore, the performance criteria are based on cross section average values. The hydraulic model input parameters are summarised below:

- Manning's n: 0.06 for the left and right banks, 0.05 for the main channel.
  - Upstream boundary condition: 2-year ARI (39% AEP) peak discharge (refer Table 6.3).
  - 50-year ARI (2% AEP) peak discharge (refer Table 6.3).
- Downstream boundary condition – normal depth based on downstream channel grade.

Stream power is the product of channel slope and discharge. It represents the excess energy available to do work in and on the channel. If there is too much excess energy, then channel erosion may occur. Stream velocity is calculated by dividing the flow by the cross-sectional area (based on flow depth in the channel). The higher the velocity, the greater the erosive force of a stream and therefore more sediment will be freed and move through the system. Shear stress is an indication of the size of granular material that will begin to move at a particular flow within the diversion reach.

Average values were derived from the HEC-RAS model for the stream powers, stream velocity and shear stress in a 39% AEP and 2% AEP rainfall event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

TABLE 6.4: DIVERSION DESIGN CRITERIA COMPARED TO DNRME (2019) GUIDELINE PARAMETERS

	39% AEP		2% AEP	
Design Criteria	Diversion	DNRME Design Parameter (2019)	Diversion	DNRME Design Parameter (2019)
Stream Power (W/m^2)	24	<60	35	<150
Stream Velocity (m/s)	0.9	<1.5	1.0	<2.5
Shear Stress (N/m^2)	19	<40	23	<80[1]

[1]DNRME values are taken from ACARP 2014 as the <50N/m^2 value in DNRME 2019 is incorrect.

All diversion concept design parameters for stream power, stream velocity and shear stress for both 29% AEP and 2% AEP storm events, are within acceptable limits and below DNRME (2019) guideline values.

Appendix B illustrates the variability along the diversion channel for each design parameter.

6.6 Additional Design and Construction Considerations

6.6.1 Levee Design

The existing Ramp 74 levee was constructed in 2020 and was designed to provide 0.1% AEP flood protection to Ramp 74 but is not considered a permanent feature under a closure scenario due to ongoing maintenance requirements above and beyond the surrounding final land use. It is proposed that the existing landform levee modified to act as a landform levee by widening to sufficient width maintain a hydraulic gradient less than 5%, such that there is no credible piping failure mechanism through the embankment.

An additional low height flood levee is also required, as shown in the concept design drawings, to prevent inflows in the 0.1% AEP design flood event into Ramp 74 via the old access ramp. Based on preliminary analysis both levees are proposed to be constructed with a 120 m top width to manage long term piping failure risk. Further detailed analysis will be completed during the detailed design phase of the project.

6.6.2 Backfilling of Old Cut 4 Pit

In order to mitigate the risks associated with construction of a diversion through a backfilled pit it is proposed that the backfilling of Old Cut 4 will be completed using engineered fill as opposed to uncontrolled filling which could result in significant settlement and ongoing performance issues with the diversion. The decision to utilise engineered fill is based on the limited depth which is a maximum of 14 m and averages 2-3 m across the overall footprint of Old Cut 4 which is substantially less then would typically be associated with backfilling of a pit. Prior to execution of the works Old Cut 4 will need to be dewatered and silt removed from the base to expose a firm foundation. Filling will occur using select material placed in nominal 500 mm lifts with exact placement requirements determined following the geotechnical investigation with the intent to utilise material excavated from the diversion as the suitable fill material.

6.6.3 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, which potentially include dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- An appropriately qualified person to assess the growth media for the diversion banks and recommend required ameliorants, fertilisers and surface treatments. Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.6.4 Revegetation

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed as part of the function design for Sirius Creek as it will be critical to prevent uncontrolled erosion in the early years following construction.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.

The watercourse revegetation species should be based on selecting key framework trees, woody understory and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the BWM Progressive Rehabilitation and Closure Plan (PRCP).

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to changing climatic conditions.

- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

Further, hydraulic modelling has demonstrated that the 39% AEP shear stress is within the ACARP (2014) guideline values for the vegetation establishment within a transport limited system. To ensure vegetation has sufficient time for establishment it is suggested to keep the diversion offline for 1 to 2 wet seasons. Revegetation will reflect the dominant ecosystem of *Eucalyptus populnea* (poplar box) and *Eucalyptus melanophloia* (silver-leaved ironbark) woodland on alluvial plains.

6.6.5 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational phase should be conducted in accordance with Whitehaven's watercourse diversion monitoring program and following construction and rehabilitation of the new diversion alignment, it will be required to be conducted in accordance with the PRCP. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable),and following periods of high flow in the diversion.

6.7 Risks and Mitigation Measures

The Table 6.5 below summarises the main risks for the diversion remediation design and construction. The risks were assessed in accordance with BHPs Risk Framework.

TABLE 6.5: DIVERSION RISKS AND MITIGATION MEASURES

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to extreme flood event	Probable	2	9	Diversion channel constructed during dry season	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, topsoil availability on site and construction during dry season (low chance of flood)	Unlikely	1	1
Significant erosion of channel due to extreme flood event	Probable	2	9	Construction of channel during dry season including a watering program for sufficient vegetation establishment prior to wet season	Unlikely	1	1
Vegetation establishment interrupted by extreme flow event (wash away of seeds and damage of plants)	Probable	2	9	Choosing a seed mix similar to the surrounding environment and apply topsoil treatment allowing for effective plant growth, construction during dry season with watering program	Unlikely	1	1

7. CONCLUSION

To develop a PRCP Chapter for the Sirius Creek diversion, a concept design for remediation of the Sirius Creek diversion will be developed. This report illustrates the concept design details and has been prepared in accordance with the requirements of the Department of Natural Resources, Mines and Energy (DNRME) Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (DNRME,2019).

The concept design was developed based on three guidelines, two of which are currently recognised guidelines for design of watercourse diversions within Queensland. These guidelines have been developed by DNRME and the Australian Coal Association Research Program (ACARP):

- Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).
- Criteria for functioning river landscape units in mining and post mining landscapes (ACARP, 2014).
- EA condition for specified rehabilitation requirements.

Four options for the remediation of Sirius Creek were identified and the second option was selected to be carried forward into concept design, utilising the Multi-Criteria Analysis outlined in Section 5. The selected option has been further optimised following the final landform update (Landform 3.6.1). The final concept option design, typical cross sections and longitudinal section are presented in Section 6 and Appendix C. The main risks to the successful performance of the diversion are vegetation establishment and erosion which can be mitigated by construction timing, during dry season, the seed mix used and topsoil treatments to improve quality of the soil where necessary.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8. QUALIFICATIONS

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(g) This Report does not provide legal advice.

9. REFERENCES

ACARP (2014) 'Criteria for functioning river landscape units in mining and post mining landscapes'.

Alluvium (2010) 'Sirius Creek Diversion Baseline Monitoring 2010, Blackwater Mine'.

DES (Department of Environment and Science) (2019) 'Environmental Authority EPML00717813'.

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Engeny (2017) 'Sirius Creek Diversion Major Monitoring Assessment'.

Engeny (2017) 'Flood Model and Water Balance Model Update; Blackwater Mine'.

Engeny (2025) 'Sirius Creek Closure Design Functional Design Report'

U.S. Department of Interior Bureau of Reclamation (USBR) (2014) 'Reclamation Managing Water in the West – Design Standard No. 13, Embankment Dams' Chapter 8: Seepage.

APPENDIX A: MULTI-CRITERIA ANALYSIS DETAILS

Multi-Criteria Analysis - Sirius Creek Diversion

Project: PRCP Diversions FY21 (BWM)
Workshop Date: 2/11/2020

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Option 4	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and natural stream length. Ideally diversion length = natural stream length.	40%	1	-1	0	-1	Option 1 is the same length as natural stream. Other options are all longer by varying degrees.
Diversion constructed through spoil	For options that interact with the LoA mine plan, it is assumed that mining will occur (even if currently unapproved) then the diversion will be constructed through rehabilitated spoil. It is assumed that the PRCP final landform can be revised to achieve the required offset distances from rehabilitated spoil dumps (although the PRCP final landform would not show spoil dumps associated with currently unapproved mining).	25%	-1	-1	-1	-1	Options 1, 2 and 4 would be constructed through existing rehabilitated spoil. Option 3 would be constructed through a combination of existing and future rehabilitated spoil (associated with currently approved mining). For Options 2 and 3, the PRCP final landform would need to me revised to acheive the required offset distances from the future rehabilitated spoil dumps to the south.
Order of magnitude cost estimate	**Assumes $10/m3 of cut.** Includes cost to backfill voids as not proposing to backfill voids as part of the PRCP (so as not to lose grandfathering provisions under the EA).	25%	-3	0	-3	-2	Option 1 includes cost to backfill Ramp 74 TSF - fatal flaw. Option 3 excessive amount of earthworks due to topography - fatal flaw. Option 2 includes cost to backfill Old Cut 4 based on recent storage curve.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	10%	0	-2	0	0	Not possible to isolate Option 2 as constructed on same alignment as the existing diversion. Risk of high flow events washing away topsoil during diversion establishment period.
	Overall Weighted Score		-0.6	-0.9	-1.0	-1.2	
	Is there a Fatal Flaw?		Fatal Flaw	No	Fatal Flaw	No	
	Relative Risk		Highest Risk	High Risk	Highest Risk	High Risk	

Figure A.1: Multi-Criteria Analysis Details

APPENDIX B: HYDRAULIC PARAMETER MODELLING RESULTS

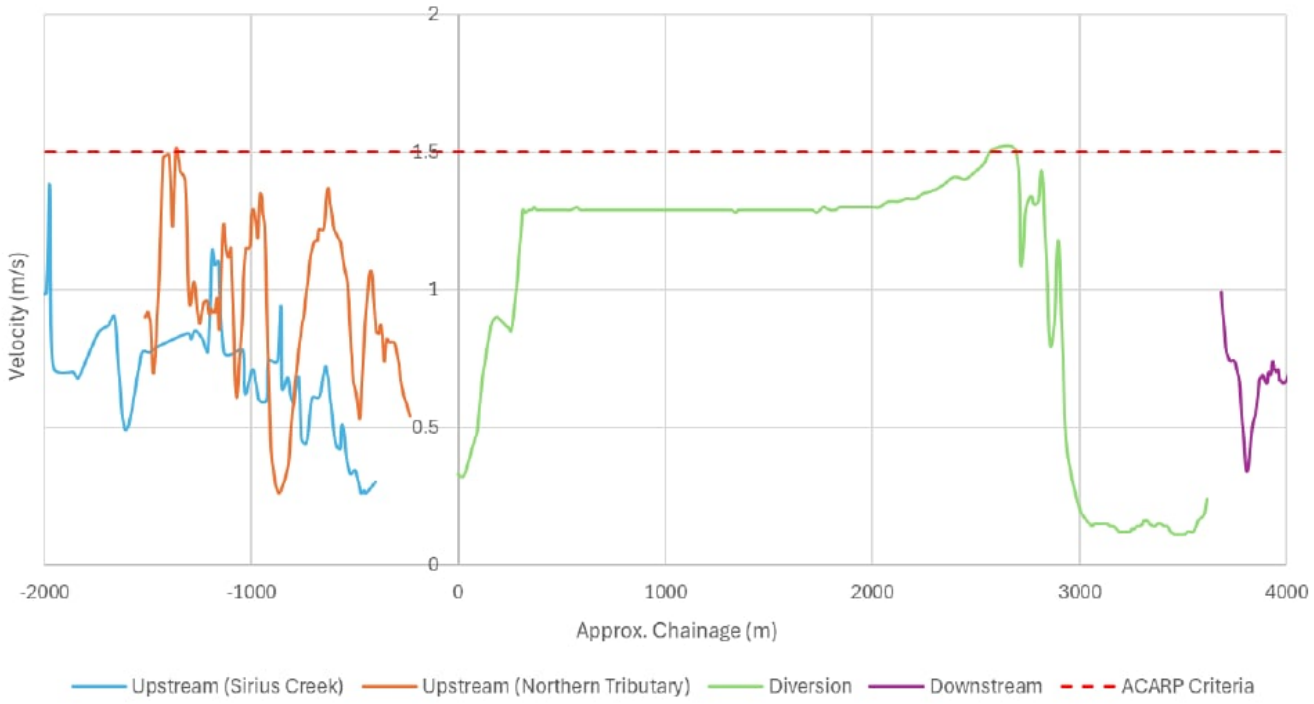


Figure B.1: YR ARI (39%AEP) Velocity Longitudinal Profile

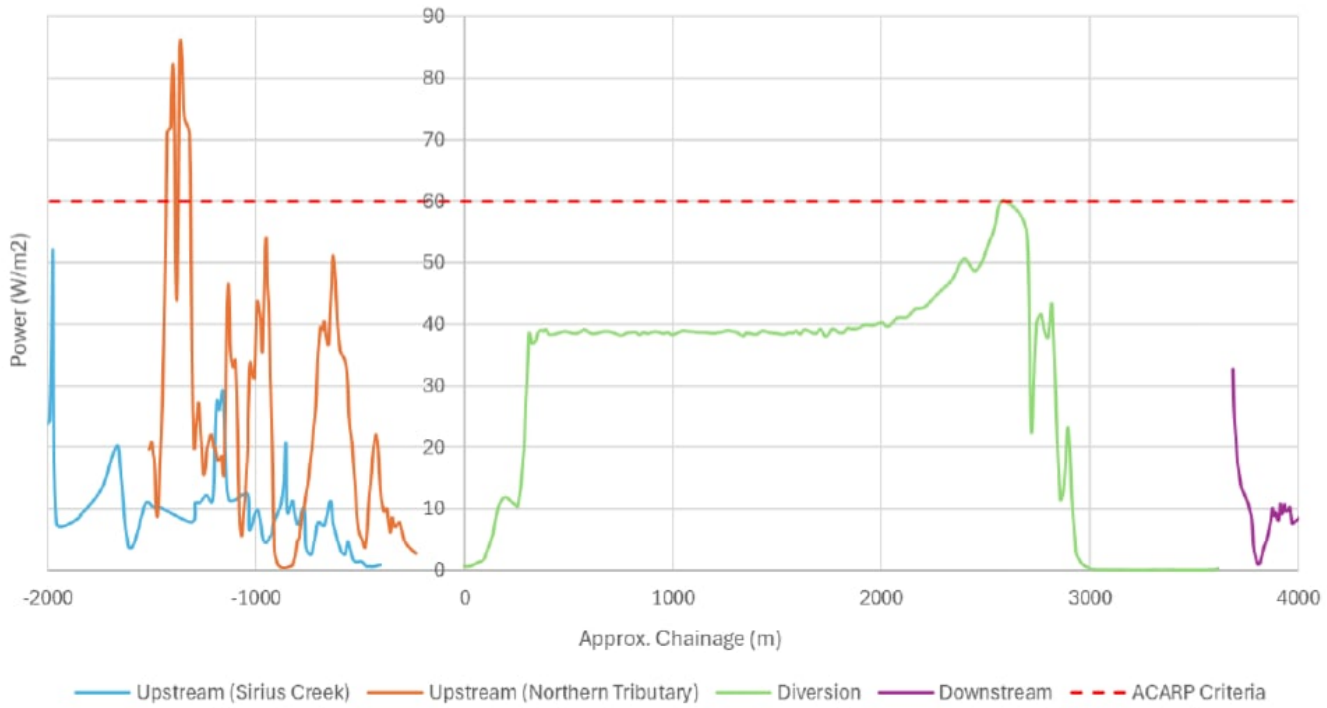


Figure B.2: 2-YR ARI (39%AEP) Stream Power Longitudinal Profile

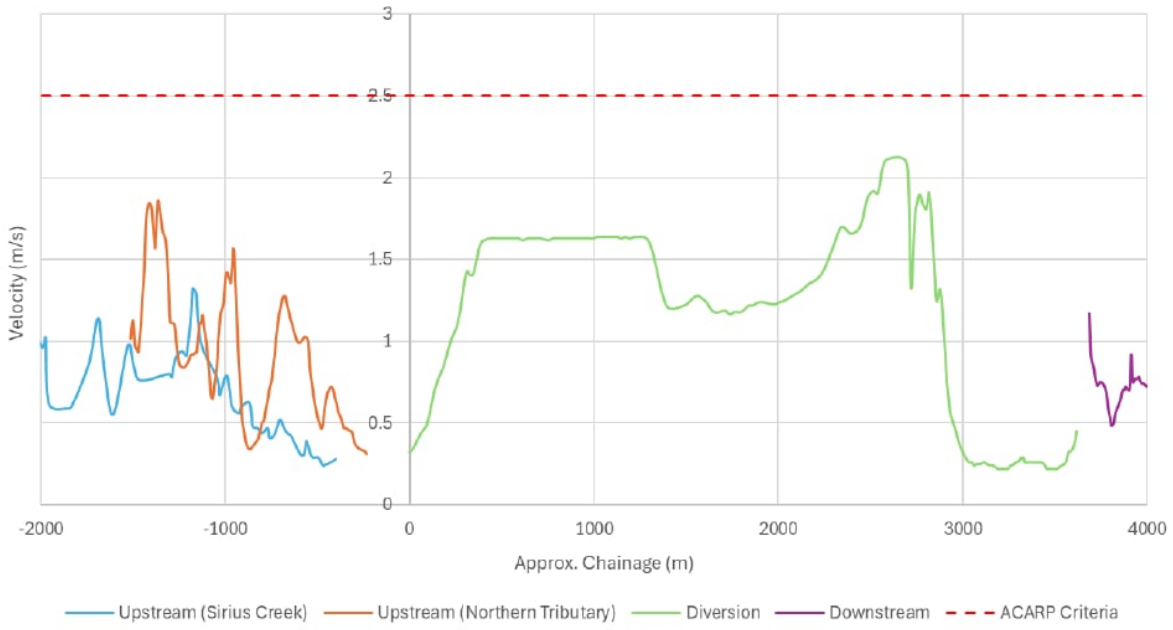


Figure B.3: 50-YR ARI (2%AEP) Shear Stress Longitudinal Profile

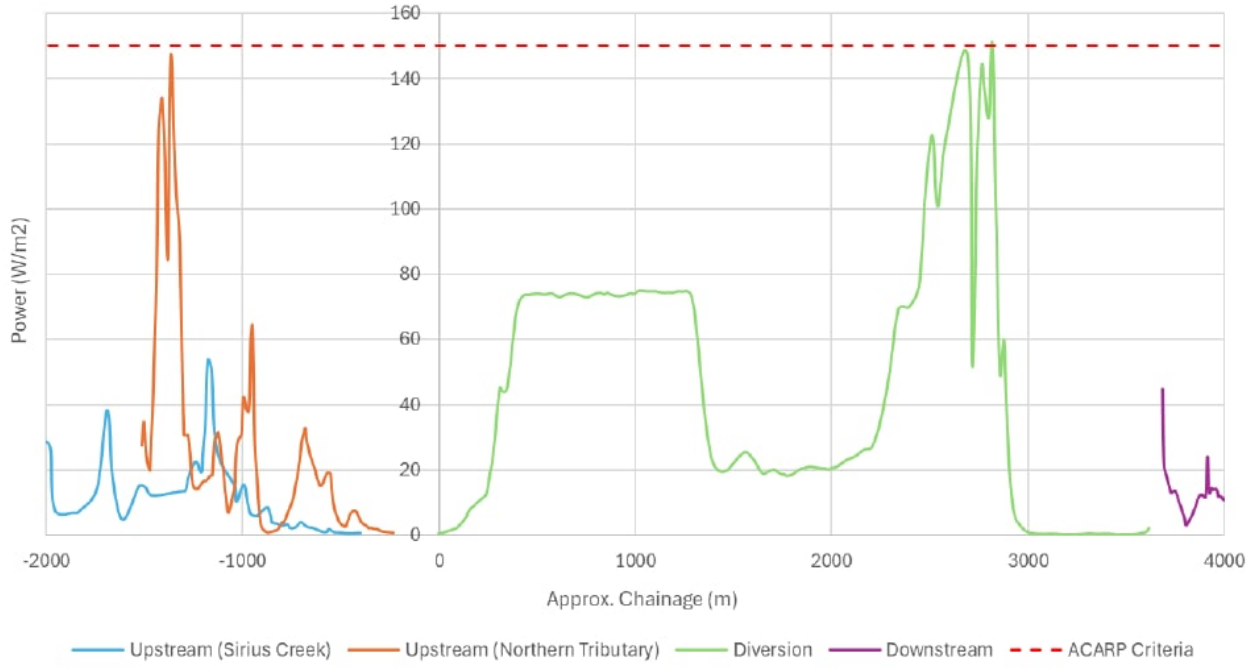


Figure B.4: 50-Yr ARI (2%AEP) Stream Power Longitudinal Profile

APPENDIX C: PREFERRED OPTION DESIGN SKETCHES

WHITEHAVEN COAL
SIRIUS CREEK CLOSURE



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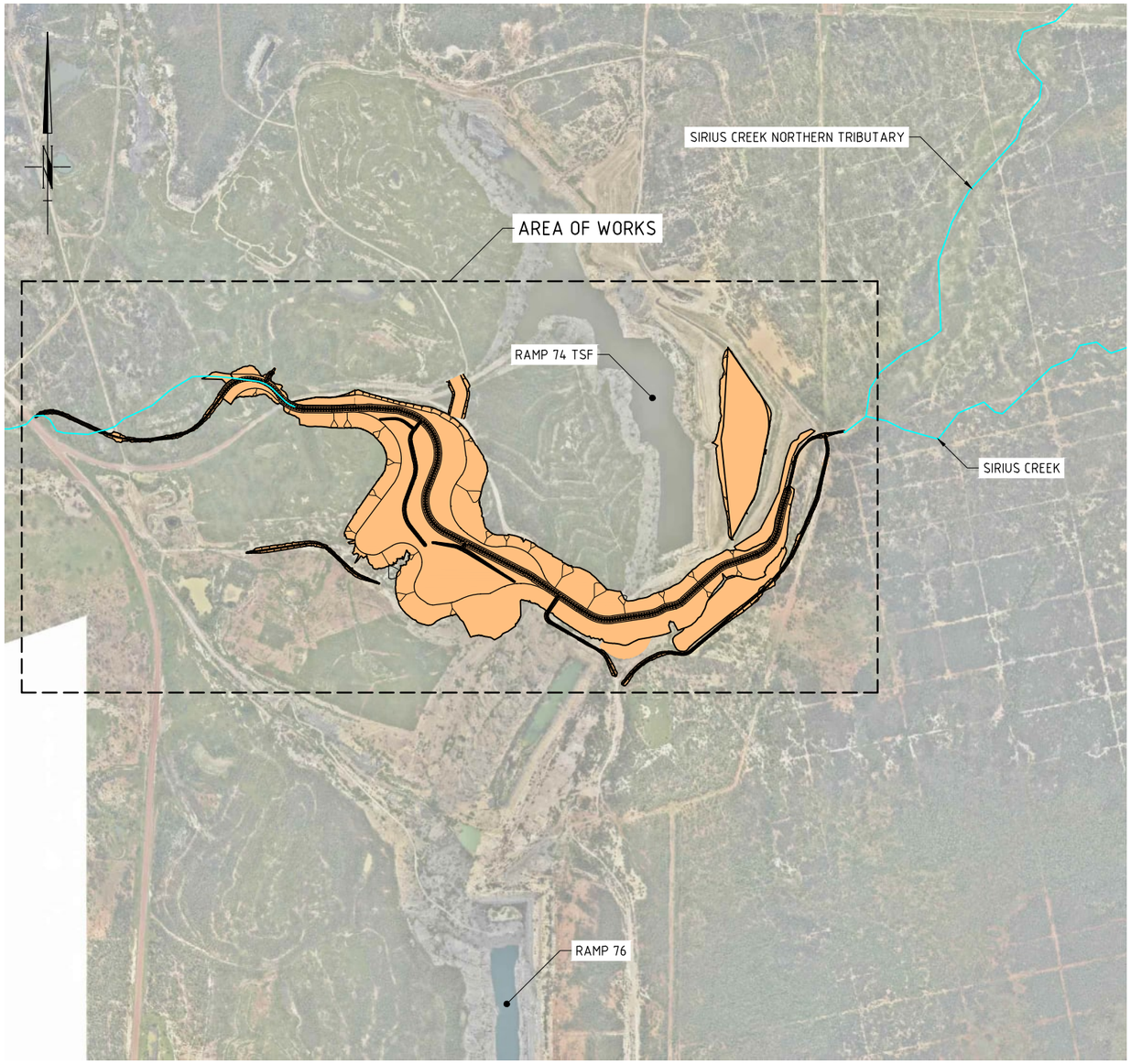
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WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
COVER SHEET

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LOCALITY PLAN
SCALE 1:10000 m

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BNE04877-0045-DWG-0002	LOCALITY PLAN, DRAWING INDEX - GENERAL NOTES & LEGEND	D
BNE04877-0045-DWG-0100	KEY PLAN	E
BNE04877-0045-DWG-0101	GENERAL ARRANGEMENT PLAN - SHEET 1 OF 2	E
BNE04877-0045-DWG-0102	GENERAL ARRANGEMENT PLAN - SHEET 2 OF 2	E
BNE04877-0045-DWG-0201	TYPICAL SECTIONS AND DETAILS - SHEET 1 OF 4	D
BNE04877-0045-DWG-0202	TYPICAL SECTIONS AND DETAILS - SHEET 2 OF 4	D
BNE04877-0045-DWG-0203	TYPICAL SECTIONS AND DETAILS - SHEET 3 OF 4	D
BNE04877-0045-DWG-0204	TYPICAL SECTIONS AND DETAILS - SHEET 4 OF 4	D
BNE04877-0045-DWG-0207	REHABILITATION - SECTIONS AND DETAILS - SHEET 1 OF 2	C
BNE04877-0045-DWG-0208	REHABILITATION - SECTIONS AND DETAILS - SHEET 1 OF 2	C
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BNE04877-0045-DWG-0304	LONGITUDINAL SECTIONS - LEVEES - SHEET 1 OF 1	D

LEGEND - EXISTING FEATURES

- 240 240 CONTOUR LABEL
- CONTOUR MAJOR (1.0m)
- CONTOUR MINOR (0.2m)
- WATERWAY

LEGEND - PROPOSED

- 240 240 CONTOUR LABEL
- CONTOUR MAJOR (1.0m)
- CONTOUR MINOR (0.2m)
- CIVIL WORKS EXTENT
- ENGINEERED FILL
- DUMPED ROCK EXTENTS
- SLOPE INDICATORS
- CONTROL LINE

0 200 400 600 800 1000m
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SCALE BEFORE REDUCTION

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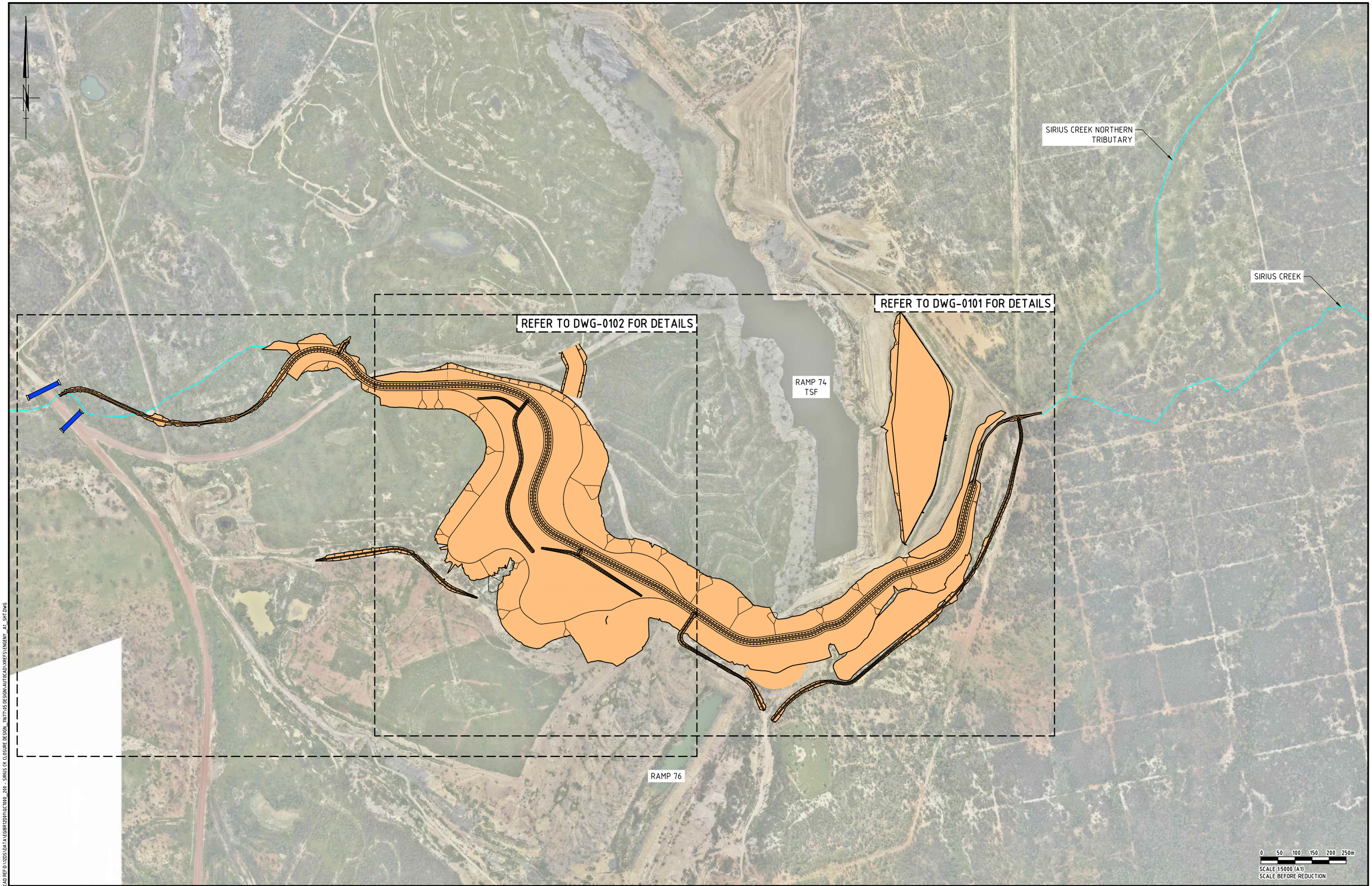
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WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
LOCALITY PLAN, DRAWING INDEX
GENERAL NOTES & LEGEND

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WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
KEY PLAN

ORIGINAL SIZE A1

DWG NO. BNE04877-0045-DWG-0100

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CONTROL LINE MCE02
(OLD CUT 4 LEVEE)

CONTROL LINE MCE01
(RAMP 74 LANDFORM LEVEE)

RAMP 74 TSF

EXISTING RAMP 74 LEVEE

CONTROL LINE MCD01
(SIRIUS CREEK DIVERSION)

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

STOCKPILE REMOVAL

STOCKPILE REMOVAL

A 0201

B 0201

F 0203

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RPEQ	-	RPEQ No.	-	

WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
GENERAL ARRANGEMENT PLAN
SHEET 1 OF 2

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0101
REV. E

CATCH DRAIN

CONTROL LINE MCD01
(SIRIUS CREEK DIVERSION)

CONTROL LINE MCE02
(OLD CUT 4 LEVEE)

5x1800 CMP'S
DETAILS TBC

FLOODPLAIN WIDENING

3300

3750

3832.335

3500

3250

2750

2500

2250

2000

1750

1500

0000

50

100

1424.000

G
0202

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

CATCH DRAIN

5x1800 CMP'S
DETAILS TBC

REFER TO DWG-0103 FOR CONTINUATION

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D	SSA	31.07.25	FUNCTIONAL DESIGN	SW
C	SSA	01.05.25	ISSUED FOR INFORMATION	BK
B	SSA	27.02.25	30% DESIGN REVIEW	SW
A	SSA	23.08.24	ISSUED FOR REVIEW	SW

DOC. NUMBER	DOCUMENT TITLE
REFERENCE DOCUMENTS	

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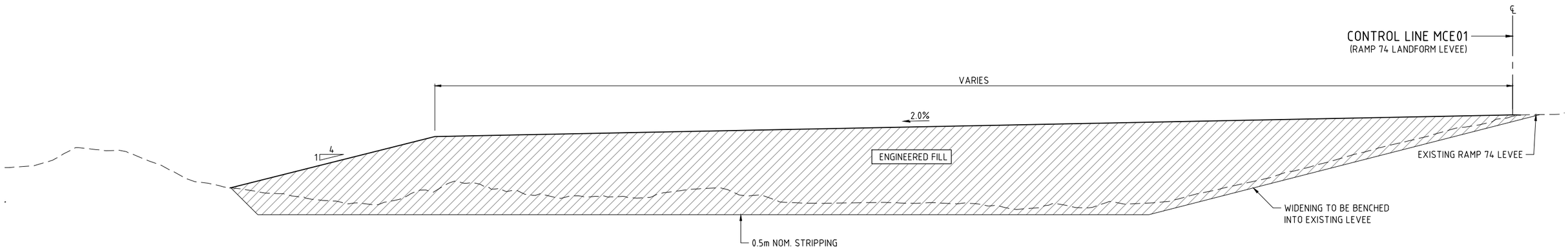
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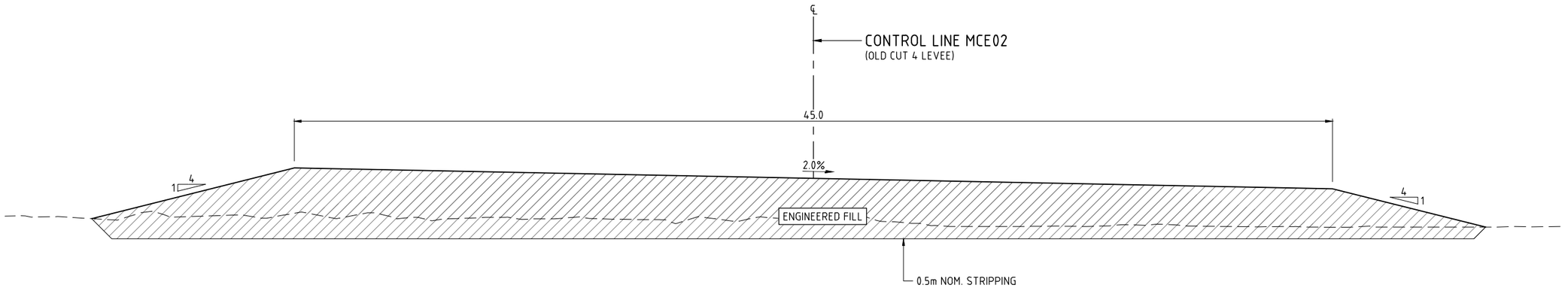
WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
GENERAL ARRANGEMENT PLAN
SHEET 2 OF 2

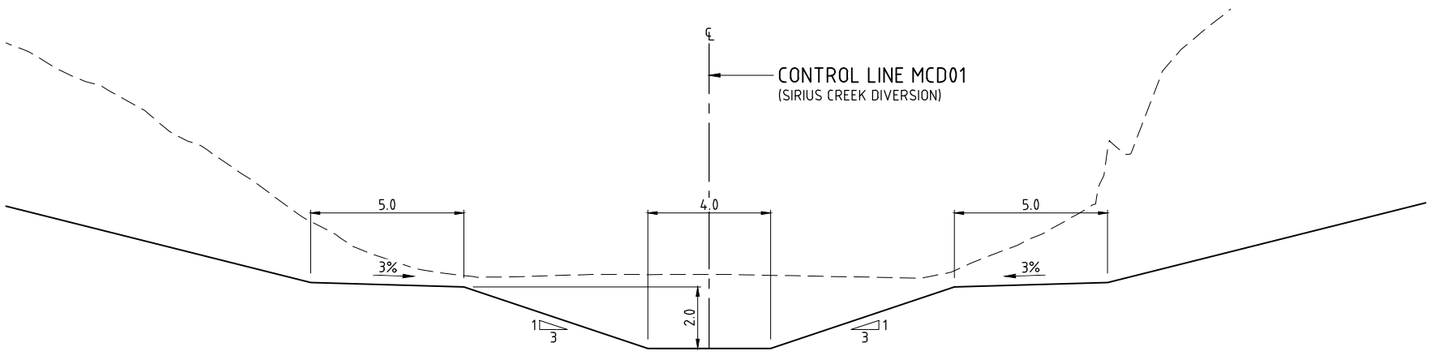
ORIGINAL SIZE	DWG NO.	REV.
A1	BNE04877-0045-DWG-0102	E



SECTION A
SCALE 1:200
0101



SECTION B
SCALE 1:100
0101



LEGEND

EXISTING SURFACE

DESIGN SURFACE

SIRIUS CREEK DIVERSION LOW FLOW TYPICAL DETAIL
SCALE 1:100

0 1 2 3 4 5m
SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

0 2 4 6 8 10m
SCALE 1:200 (A1)
SCALE BEFORE REDUCTION

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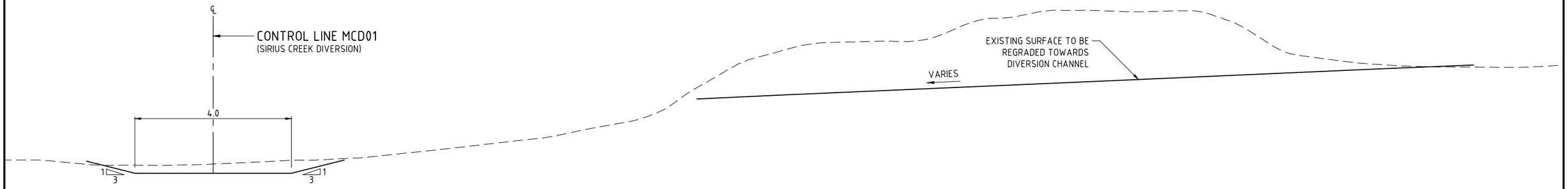
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WHITEHAVEN COAL

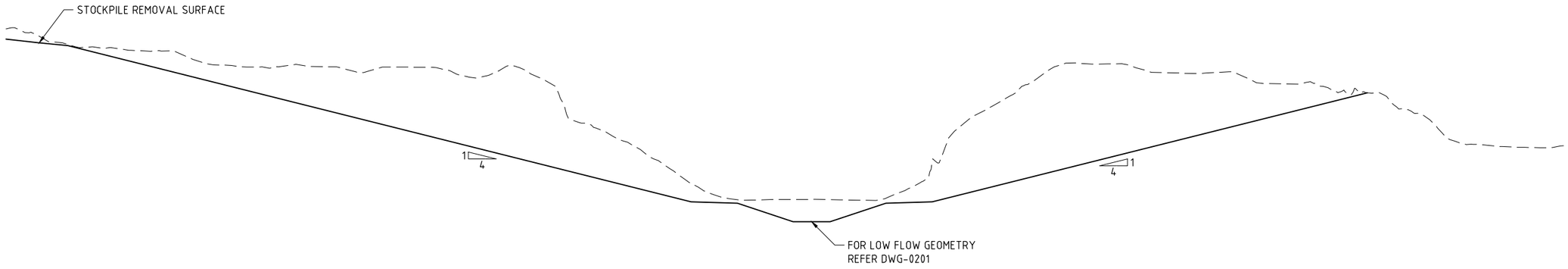
SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 1 OF 4

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0201
REV. D

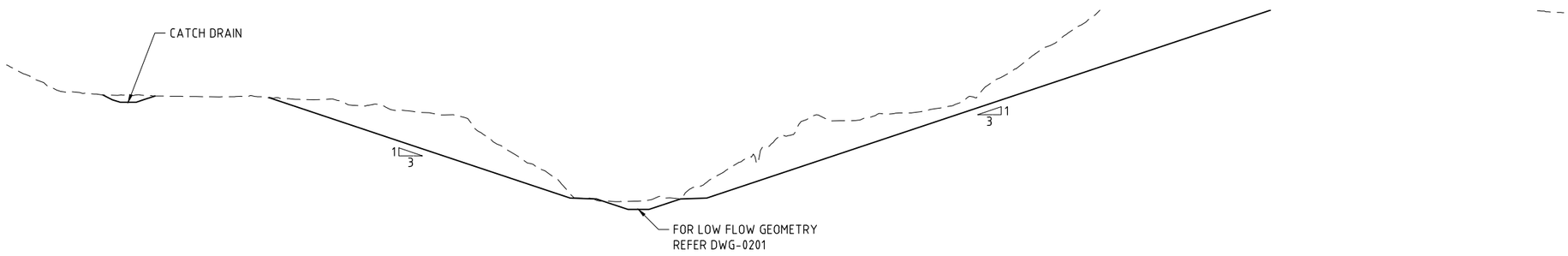
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SECTION C
SCALE 1:50 0101



SECTION D
SCALE 1:250 0101



SECTION E
SCALE 1:500 0101

LEGEND

EXISTING SURFACE

DESIGN SURFACE

0 0.5 1.0 1.5 2.0 2.5m
SCALE 1:50 (A1)
SCALE BEFORE REDUCTION

0 2.5 5.0 7.5 10.0 12.5m
SCALE 1:250 (A1)
SCALE BEFORE REDUCTION

0 5 10 15 20 25m
SCALE 1:500 (A1)
SCALE BEFORE REDUCTION

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LAST MODIFIED: 7/8/2025 11:11 AM

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REV	BY	DATE	REVISION DESCRIPTION	PM APPD.
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C	SSA	31.07.25	FUNCTIONAL DESIGN	SW
B	SSA	27.02.25	30% DESIGN REVIEW	SW
A	SSA	23.08.24	ISSUED FOR REVIEW	SW

DOC. NUMBER	DOCUMENT TITLE
REFERENCE DOCUMENTS	

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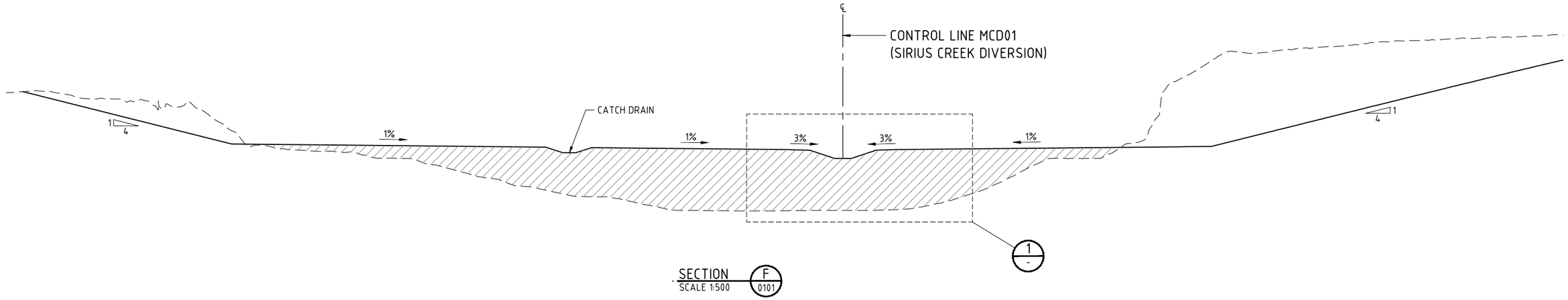
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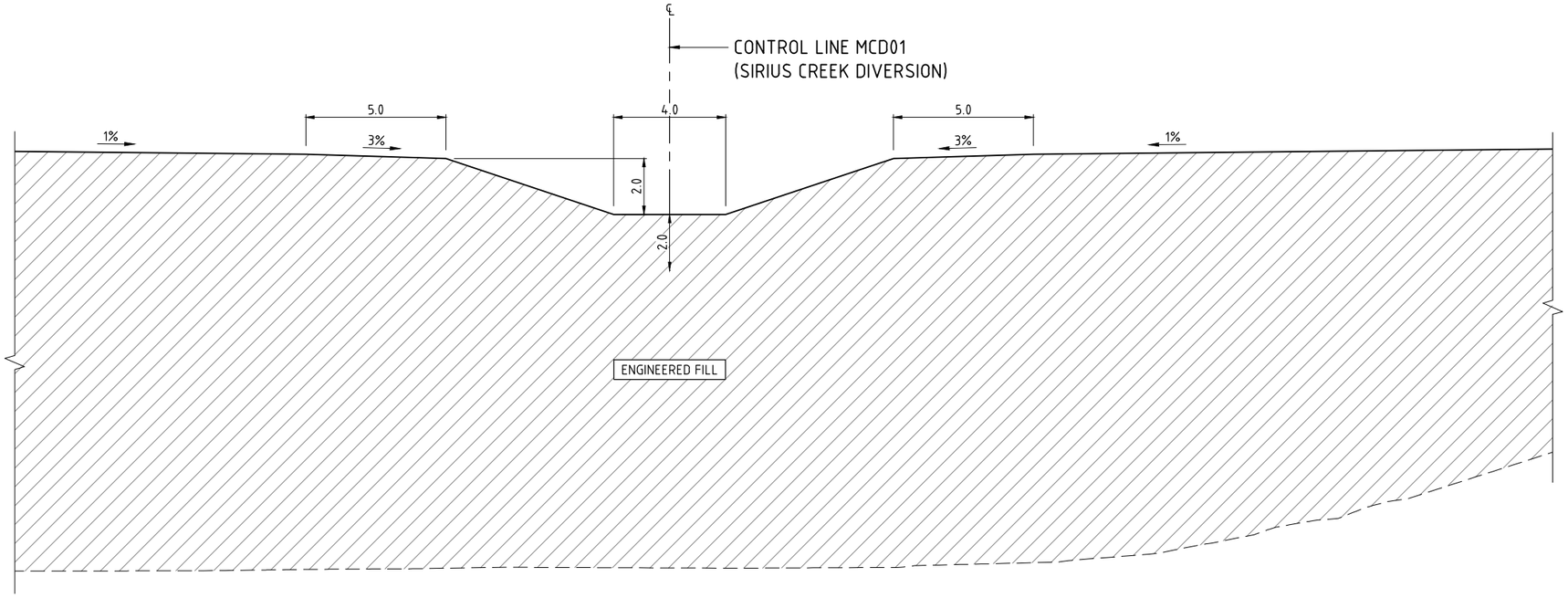
WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 2 OF 4

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0202
REV. D



SECTION F
SCALE 1:500 0101



LEGEND

EXISTING SURFACE

DESIGN SURFACE

DETAIL 1
SCALE 1:100 -

SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

SCALE 1:500 (A1)
SCALE BEFORE REDUCTION

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A	SSA	23.08.24	ISSUED FOR REVIEW	SW

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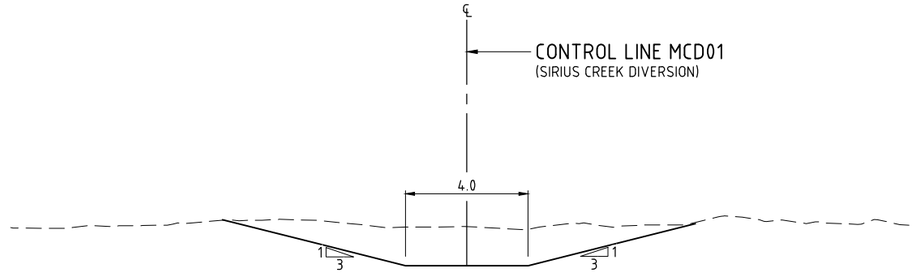
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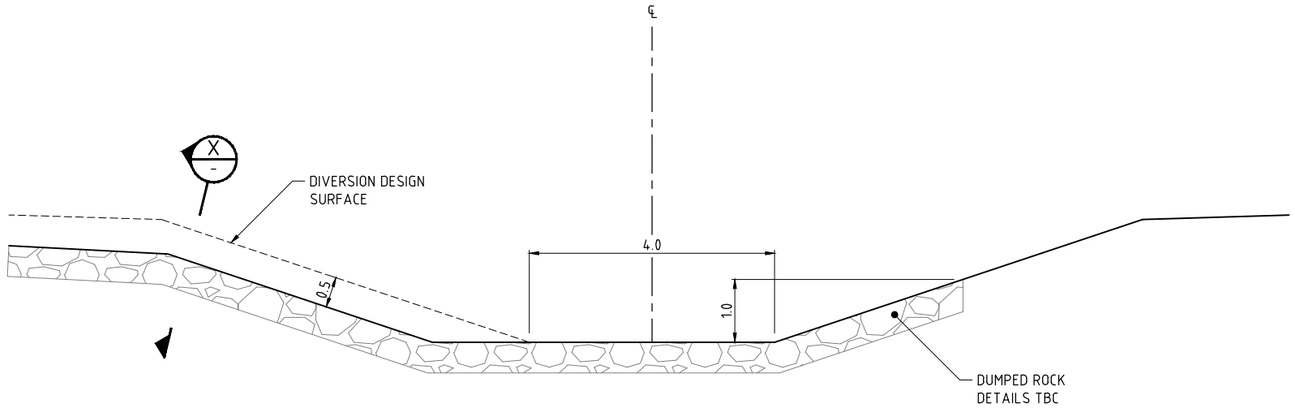
SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 3 OF 4

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0203
REV. D

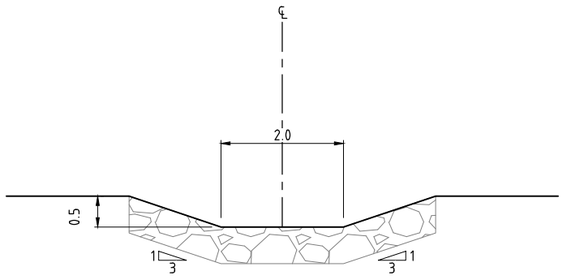
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LAST MODIFIED:1/10/2025 11:11 AM



SECTION G
SCALE 1:100



ROCK CHUTE TYPICAL SECTION
SCALE 1:100



SECTION X
SCALE 1:100

LEGEND

EXISTING SURFACE

DESIGN SURFACE

0 1 2 3 4 5m
SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

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LAST MODIFIED:7/8/2025 11:11 AM

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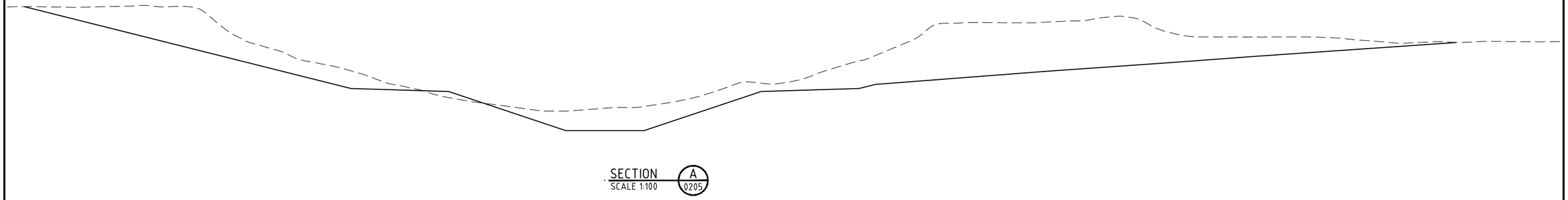
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DRAWN	SSA	CHECKED	RJM	
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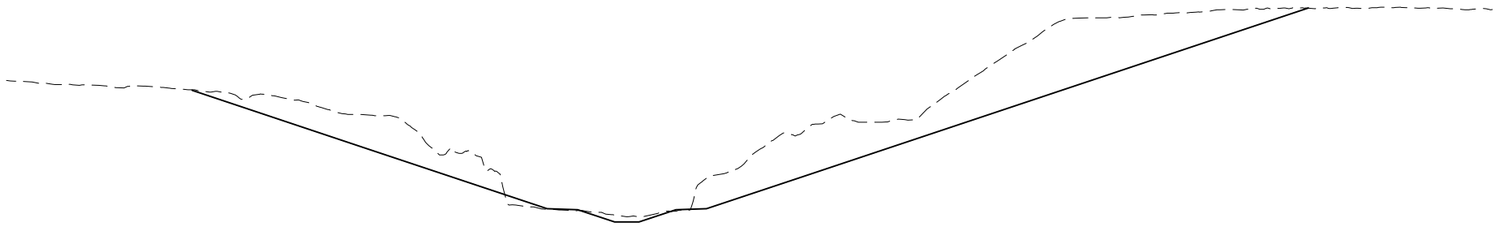
WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
TYPICAL SECTIONS AND DETAILS
SHEET 4 OF 4

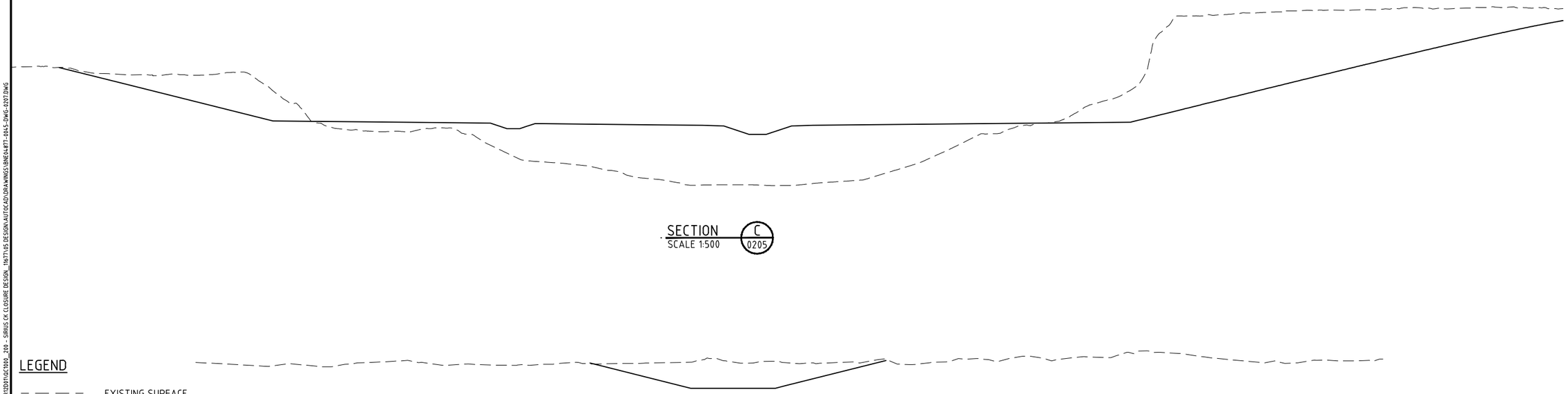
ORIGINAL SIZE	DWG NO.	REV.
A1	BNE04877-0045-DWG-0204	D



SECTION A
SCALE 1:100
0205



SECTION B
SCALE 1:500
0205



SECTION C
SCALE 1:500
0205

LEGEND

EXISTING SURFACE

DESIGN SURFACE

SECTION D
SCALE 1:100
0206

0 1 2 3 4 5m
SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

0 5 10 15 20 25m
SCALE 1:500 (A1)
SCALE BEFORE REDUCTION

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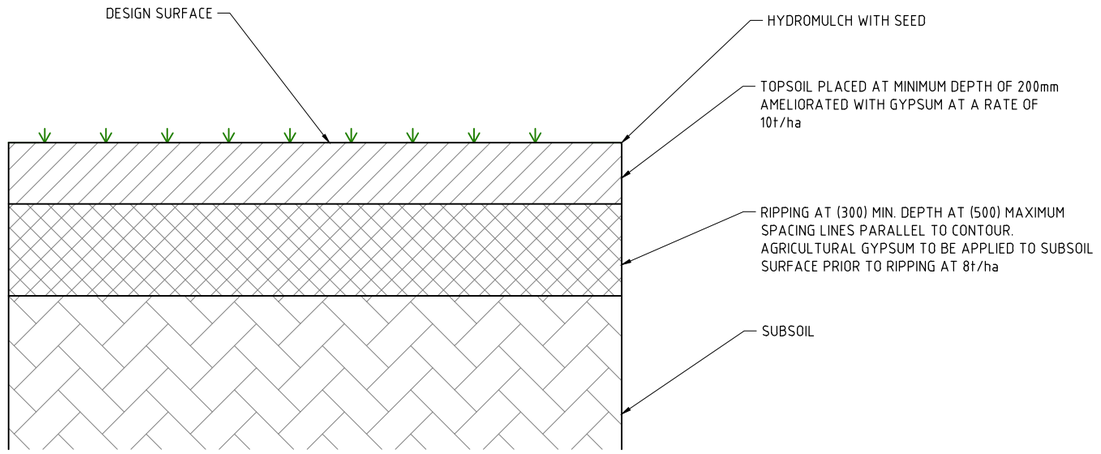
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WHITEHAVEN COAL

SIRIUS CREEK CLOSURE REHABILITATION SECTIONS AND DETAILS - SHEET 1 OF 2

ORIGINAL SIZE A1
DWG NO. BNE04877-0045-DWG-0207
REV. C

LAST MODIFIED: 7/10/2025 11:13 AM
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REHABILITATION DETAIL
SCALE 1:10

0 0.1 0.2 0.3 0.4 0.5m
SCALE 1:10 (A1)
SCALE BEFORE REDUCTION

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REV	BY	DATE	REVISION DESCRIPTION	PM APPD.
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A	ON	23.08.24	ISSUED FOR REVIEW	SW

DOC. NUMBER	DOCUMENT TITLE
REFERENCE DOCUMENTS	

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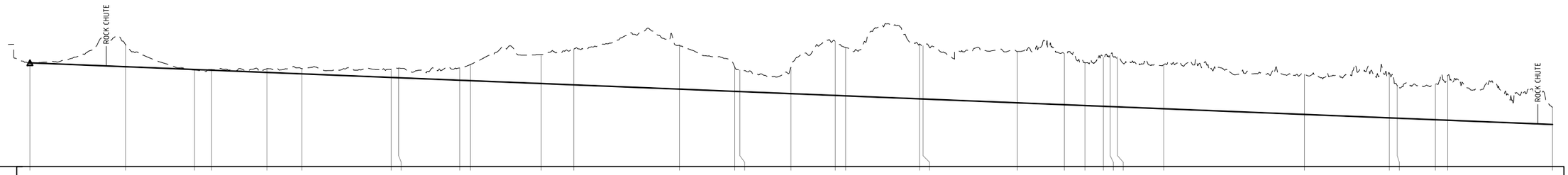
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WHITEHAVEN COAL

SIRIUS CREEK CLOSURE
REHABILITATION
SECTIONS AND DETAILS - SHEET 1 OF 2

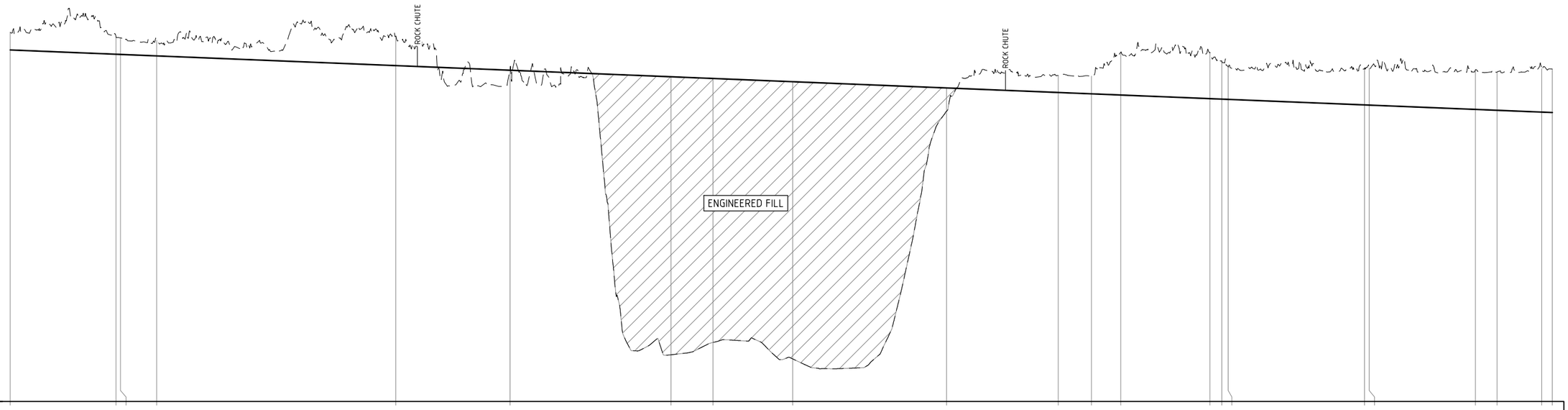
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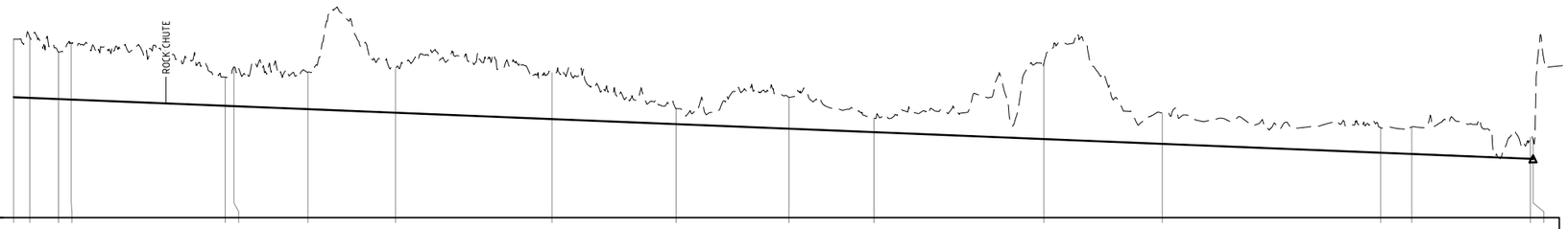
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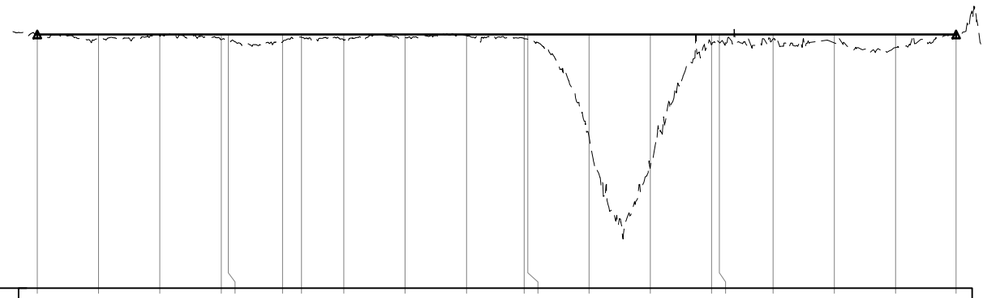
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DATUM 249.0

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DATUM 264.0

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APPENDIX D: CONCEPT DESIGN WITH PRCP LANDFORM INTERACTION

ML 1772

ML 1773

ML 1767

ML 1771

ML 70091

ML 1860

Sirius Creek

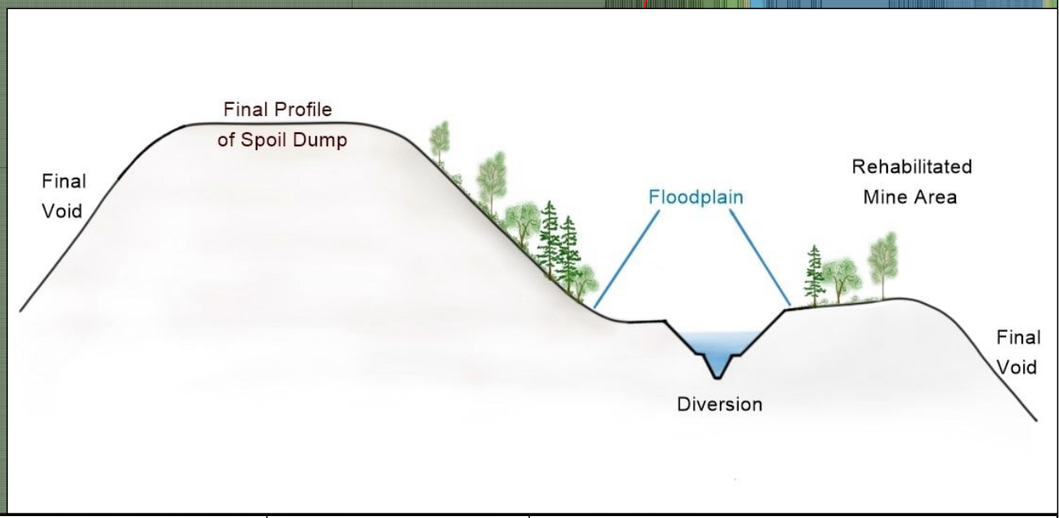
Sirius Creek

Legend

Mining Lease Boundary

PRCP Final Landform (m AHD)

- 255
- 260
- 265
- 280
- 300
- 320



ENGENY WATER MANAGEMENT

Whitehaven

0 260 520

Scale in metres (@ A4) 1:13,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

DATE	3/10/2025
DRAWN	LN
JOB NO.	BNE04877_0045

BHP Coal

Blackwater Mine
Conceptual Diversion Design and Closure Landform Interaction

A4 C