Design
for a better
future /

BHP Western Australia Iron Ore

Update of South Flank Grand Central Overburden Storage Area Surface Water Management Plan and Surface Water Impact Assessment

July 2024

Question today

Imagine tomorrow

Create for the future

Update of South Flank Grand Central Overburden Storage Area Surface Water Management Plan and Surface Water Impact Assessment

BHP Western Australia Iron Ore

WSP
Lvl 3, Mia Yellagonga Tower 2, 5 Spring St
Perth WA 6000
PO Box 7181
Cloisters Square WA 6850

Tel: +61 8 9489 9700
Fax: +61 8 9489 9777
wsp.com

Rev	Date	Details
A	12/06/2024	Draft
0	30/07/2024	Final

	Name	Date	Signature
Prepared by:	Ajinkya Kemble	30/07/2024	Kemble
Reviewed by:	Leila Ang	30/07/2024	
Approved by:	Michele Zornitta	30/07/2024	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

Table of contents

List of tables

List of figures

List of appendices

Glossary

1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability. The probability that a design event (rainfall or flood) has of occurring in any one-year period.
ARR	Australian Rainfall and Runoff
BoD	Basis of Design
BoM	Bureau of Meteorology
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
CI	Confidence Interval
CL	Continuing Loss
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DTM	Digital Terrain Model
DWER	Department of Water and Environmental Regulation
FFA	Flood Frequency Analysis
GIS	Geographic information systems
GSDM	Generalised Short Duration Method
GC OSA	Grand Central Overburden Storage Area
GTSMR	Generalised Tropical Storm Method
Hydraulic model	A theoretical model used to provide representation of flow distribution and flood mechanisms at the area of interest.
Hydrological model	A theoretical model used to simulate the rainfall runoff flow and predict the runoff hydrographs.
IFD	Intensity–Frequency–Duration
IL	Initial Loss
ILCL	Initial Losses Continuing Losses
LoM	Life of Mine
LiDAR	Light Detection and Ranging
m AHD	Elevation in metres with respect to the Australian Height Datum.
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RFFE	Regional Flood Frequency Estimation

Runoff	The amount of rainfall that ends up as streamflow, also known as rainfall excess.
SGS	Sub Grid Sampling
SPS	Selection Phase Study
SSPs	Shared Socioeconomic Pathways
TUFLOW	TUFLOW is a suite of 1D/2D computer simulation software for hydraulic modelling.
WAIO	Western Australia Iron Ore
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).
WSP	WSP Australia Pty Limited

Executive summary

WSP Australia Pty Limited was engaged by BHP Western Australia Iron Ore to undertake a surface water impact assessment and develop a surface water management design for the South Flank Grand Central Overburden Storage Area (GC OSA) to a Selection Phase Study maturity level.

The GC OSA is located within the Mount Robinson Valley at the South Flank Mine, in the Central Pilbara approximately 90 km northwest of the town of Newman, Western Australia. The SPS level design will support fulfilment of requirements outlined under the State Environmental Protection Act 1986 Part IV approvals process. The study and design herein builds upon the South Flank Grand Central Overburden Storage Area – Surface Water Impact Assessment study undertaken in 2022 (WSP Golder 2022).

The GC OSA will intercept runoff conveyed in natural watercourses from the upstream catchments. Diversion channels upstream of the GC OSA are required to introduce a controlled interception of the runoff to prevent flood inundation of the downstream GC OSA. The surface water management at the GC OSA requires consideration for the South Flank Mine's operational and closure scenarios. The catchment delineation and the hydraulic model boundary schematisation was based on the 1 m LiDAR data provided by BHP (BHP, 2023a).

The two-dimensional rain-on-grid model to assess the surface water impact and hydraulically size the diversion channels was developed using TUFLOW. The site-specific rainfall data was sourced from Bureau of Meteorology for the current assessment. The hydraulic modelling was completed to analyse the flow and velocity for the existing and design scenarios.

The design scenario consists of GC OSA area, Pit area, diversion channel and the associated berm. The models were simulated for 10%, 1% AEP and 1 in 10,000 AEP events as per the design criteria specified in the projects Basis of Design memorandum. In addition, climate change sensitivity analysis was included to assess the incremental impacts on the diversion channel design for the medium-term (year 2041 to 2060) and long-term (year 2081 to 2100) time horizons for both the SSP 4.5 and SS8.5 emissions scenarios.

The existing conditions (baseline) scenario model results shows that the flow from Mount Robinson was prominent with significantly high velocities on the slopes of Mount Robinson. The results from the existing scenario were used to calculate the diversion channel dimensions and the associated berm height. The slope of the diversion channel was adjusted to achieve peak flow velocity below 2.3 m/s for 10% and 1% AEP event. The diversion channel minimum berm crest elevation was defined by the peak water level for the 1 in 10,000 AEP event.

The diversion channel and the associated design was modelled using Autodesk Civil3D. The design surface was then used in the hydraulic model to verify the hydraulic sizing. The modelling exercise demonstrated that the design was appropriate to protect the GC OSA area and divert the flood water towards downstream receptors

Peak flow velocities below 2.3 m/s were achieved within the diversion channel for the 10% and 1% AEP flood event with the exception of few areas in the west diversion channel where velocities are up to 3.5 m/s. Flow velocities are up to 4 m/s at the spillway locations of the east and west diversion channel for the 1 in 10,000 AEP flood event. For the 1 in 10,000 AEP event peak flow velocities in the channel are up to 3.7 m/s; erosion may be expected at areas of velocities higher than 2.3 m/s and should be further assessed during the next stage of design when more geotechnical information is available.

There are limitations on the hydrology model parameters, such as rainfall losses, which might affect the model results. Calibration and validation of these parameters at the site were not possible due to a lack of gauged data. The 2 years of water level records provided by BHP was not sufficient to complete a flood frequency analysis. An attempt to validate the model results was made by comparing the peak flow calculated at the site, peak flow obtained from the Regional Flood Frequency Estimation and Flood Frequency Analysis completed at Tarina station (Tarina station is located approximately 35 km from the site). The peak flow comparison revealed differences but highlighted that the values derived from the hydrology model generally fall between the Regional Flood Frequency Estimates and the Flood Frequency Analysis.

1 Introduction

1.1 Project background

BHP Western Australia Iron Ore (WAIO) appointed WSP Australia Pty Limited (WSP) to undertake a surface water impact assessment and develop a surface water management design for the South Flank Grand Central Overburden Storage Area (GC OSA) to a Selection Phase Study (SPS) maturity level.

The GC OSA is located within the Mount Robinson Valley at the South Flank Mine, in the Central Pilbara approximately 90 km northwest of the town of Newman, Western Australia. The SPS level design will support fulfilment of requirements outlined under the State Environmental Protection Act 1986 Part IV approvals process. The study and design herein build upon the South Flank Grand Central Overburden Storage Area – Surface Water Impact Assessment study undertaken in 2022 (WSP Golder 2022).

BHP is in the process of designing the GC OSA, which will be as a permanent structure to be used as a waste-material storage area. The surface water management design herein includes a 100 m standoff corridor from the GC OSA within the Mount Robinson Heritage exclusion area.

The GC OSA will intercept runoff conveyed in natural watercourses from the upstream catchments. Diversion channels upstream of the GC OSA are required to introduce a controlled interception of the runoff to prevent flood inundation of the downstream GC OSA. The surface water management at the GC OSA requires consideration for the South Flank Mine's operational and closure scenarios.

Appendices are included in the report which include:

- Basis of Design (BoD) adopted for the diversion channel designs as part of the surface water management is provided in Appendix A.
- Flood maps of the hydraulic modelling is provided in Appendix B.
- Design drawings developed to an SPS level is provided in Appendix C.

1.2 Aim and objectives

The aims of the study are as follows:

1. Assess flood conditions at the site for the existing conditions.
2. Develop a suitable design option to manage surface water runoff from the upstream catchments of the GC OSA.
3. Provide details for the preferred design solution.

The following objectives have been achieved:

- Prepared a BoD memorandum.
- Liaised with BHP to agree on hydrology and hydraulic methodology and a design solution.
- Developed a hydrology and hydraulic model to support the surface water management design option investigation.
- Tested different diversion channel alignment options with the flood model to predict surface water conditions and refine the surface water management design.

1.3 Basis of design

A BoD memorandum was prepared by WSP and agreed upon with BHP in March 2024 and is provided in Appendix A.

The BoD includes the design criteria, hydrology and hydraulic methodology, guidelines and documents, as well as assumptions used to inform this assessment. The analysis presented in this report should be read in conjunction with the BoD memorandum.

The flood model developed assessed one baseline scenario (i.e., existing conditions) and two design scenarios (i.e., operational scenario and post-closure scenario). Both the operational and post-closure design scenarios share the same design layout but differ in the events they represent.

A summary of the key design basis and civil design criteria from the BoD is included in Table 1.1.

Table 1.1 Design basis and design criteria (WSP 2024)

Item description	Design basis and criteria
Design Life Considerations	10-year Life of Asset during Operations.
Design Event for diversion channel	10% AEP Critical duration of peak flow determined as part of hydraulic modelling
Design Event for diversion berms	1% AEP with sufficient freeboard and to contain 1 in 10,000 AEP event without freeboard
Minimum freeboard for: 1. Diversion channel 2. Diversion berm	0.3 m A verification check will be undertaken on the energy head and any shifting flow conditions to confirm if 0.3 m is sufficient.
Maximum allowable velocities in diversion drains	2.3 m/s; however, 1.5 m/s will be targeted where possible to minimise the requirement for erosion protection.
Erosion Protection design	Material type and size to be determined based on the peak flow calculated (if considered necessary based on the targeted maximum velocity).
Diversion channel side slopes	To range between 1H:1V and 3H:1V based on in-situ material.
Minimum diversion channel depth	400 mm
Minimum berm crest width	5 m
Minimum horizontal offset distance between crest of diversion channel and toe of berm	1 m

1.4 Site locality

The South Flank Grand Central Overburden Storage Area (GC OSA) is located within the Mount Robinson Valley at the South Flank Mine in the Central Pilbara region approximately 90 km northwest of the town of Newman, Western Australia. A site locality map is included in Figure 1.1.

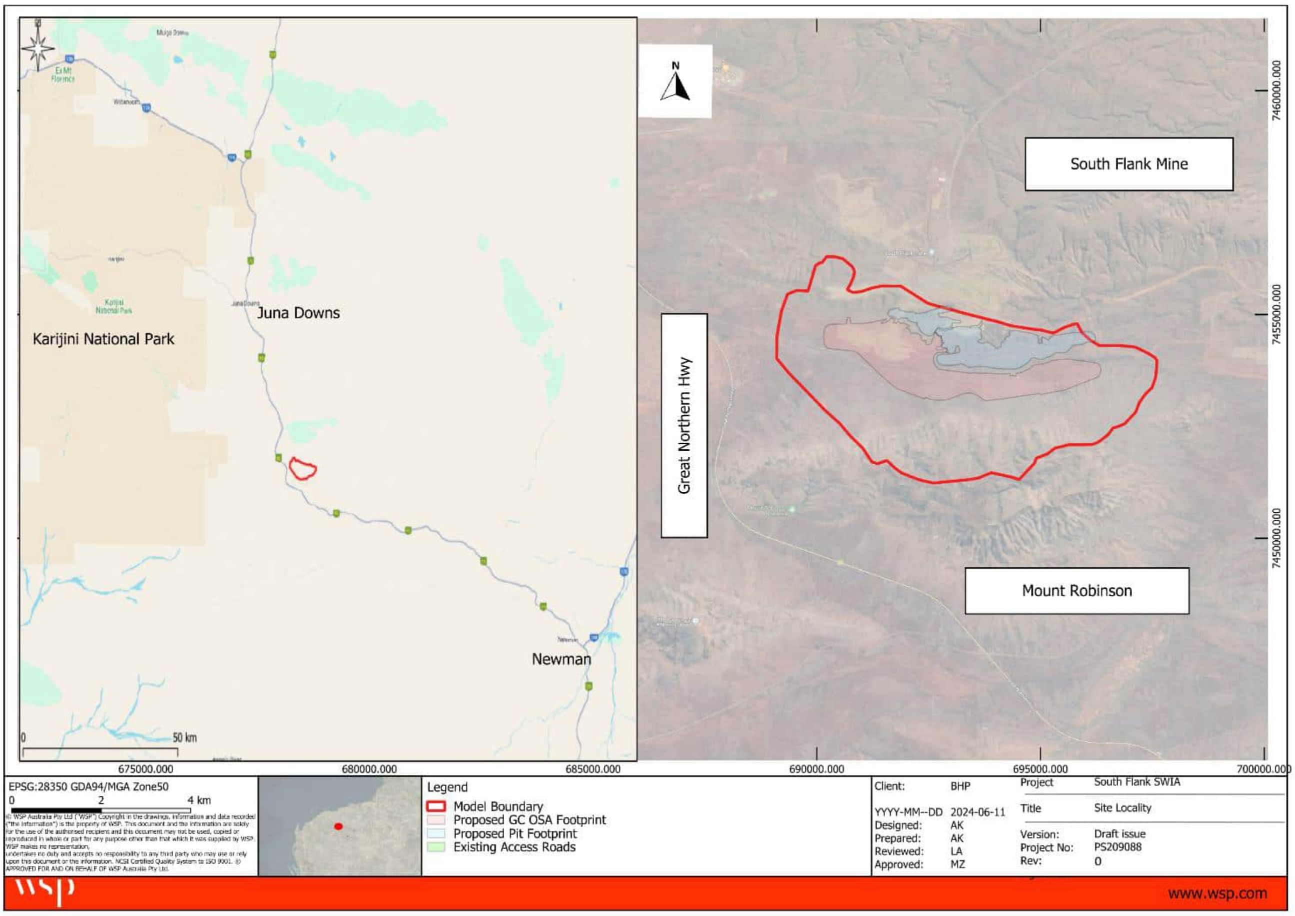


Figure 1.1 Site locality

2 Hydrology and hydraulic analysis

2.1 Catchment analysis

A catchment analysis has been completed to delineate the areas contributing to surface water runoff to the site, requiring consideration for surface water diversion for the GC OSA.

The catchments identified in Figure 2.1 indicates that a portion of the site lies within a catchment that drains in north-west direction as part of the Coondewanna catchment while another portion of the site lies within a catchment that drains in north-east direction as part of Weeli Wolli Creek Catchment.

Figure 2.1 also includes the two-gauge stations operating near the site; one is at Tarina and one is at South Flank DS (operated by BHP).

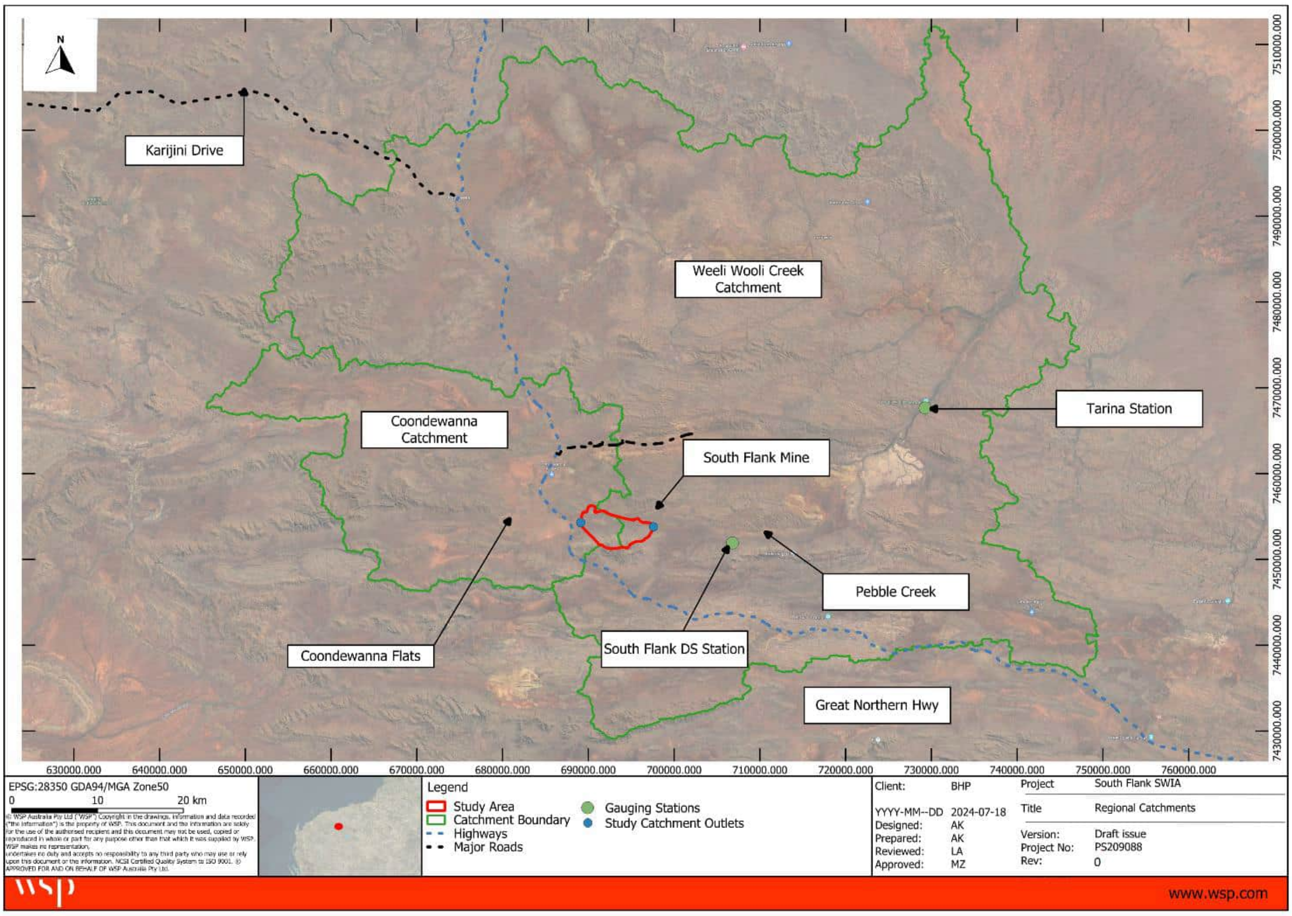


Figure 2.1 Regional catchment delineation

Although the regional catchments identified in Figure 2.1 were considered for hydrology validation, the hydrology model analysis was developed and focused on the catchments conveying surface water runoff to the site. The catchment area was extended approximately 2 km downstream of the site, both to the west and east, to assess the potential effects of the proposed surface water diversion on downstream receptors.

Figure 2.2 shows the catchments that have been considered in the hydrology and hydraulic model analysis, providing an overview of the main drainage lines within the site catchments.

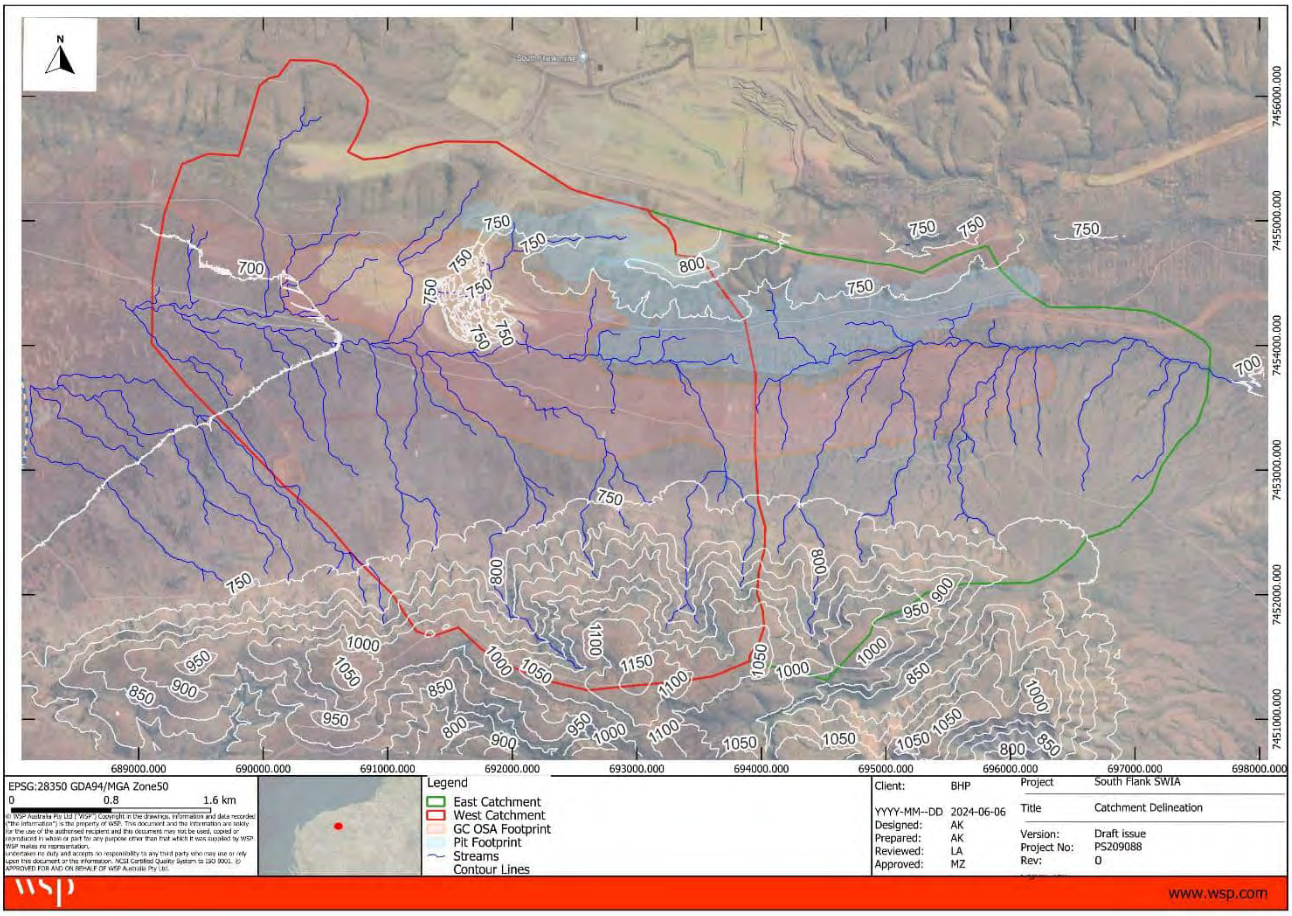


Figure 2.2 Site catchment delineation

2.2 Regional hydrology

Stream flow data were available for Tarina gauge station, Department of Water and Environmental Regulation (DWER) data, which is located approximately 35 km north east and South Flank DS station (BHP data) located 10 km south east from the site.

For Tarina station flow data were available for 38 years while for South Flank DS station 2 years of water level records were available.

2.2.1 Flood frequency analysis

The 2 years of water level records provided by BHP are an insufficient data population to complete a comprehensive flood frequency analysis (FFA). Due to the lack of data available at the time of writing this report, the 38 years of flow records at Tarina were used to undertake the FFA and therefore inform the hydrology analysis at the site. The purpose of undertaking a FFA at Tarina station is to provide a reference for comparison of peak flow value at the site. However, this comparison is limited by uncertainties related to differences in catchment characteristics, and location.

The stream flow data at Tarina were processed to define annual maxima flow data. Figure 2.3 shows the maximum peak flow at Tarina for each water year from 1985. Years with no flow recorded, or minimum flow were considered as outliers for the purpose of the FFA.

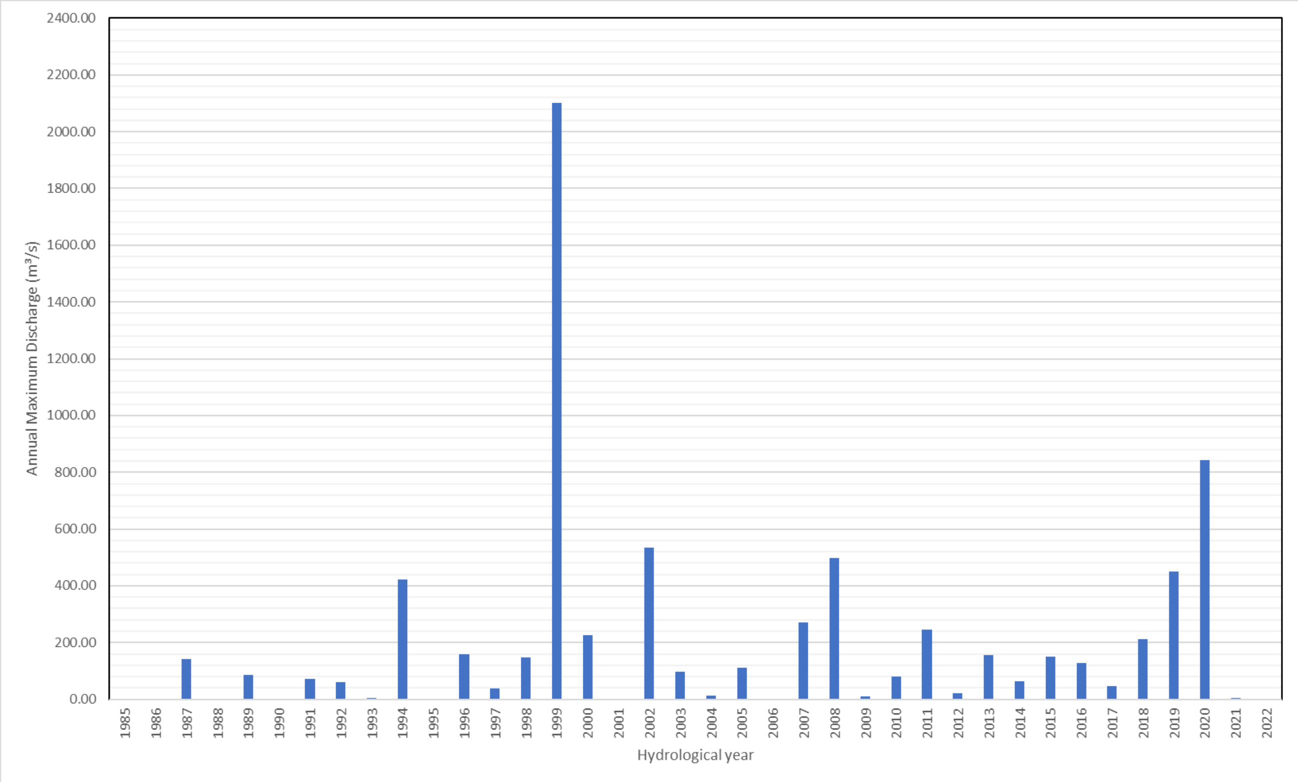


Figure 2.3 Annual maxima flow data at Tarina station

The FFA was completed using the Log Pearson III, Pearson III and Gumbel probability distribution. Log Pearson III is considered to provide the best fit for the flow data at Tarina. The results of the FFA for the different model distribution is included in Table 2.1.

Table 2.1 Flood frequency analysis at Tarina station

AEP (%)	**Predictive peak flow for different model distribution**								
	Log Pearson III			*Pearson III*			*Gumbel*		
	Predictive	95 % CI	5% CI	Predictive	95 % CI	5% CI	Predictive	95 % CI	5% CI
50	**93**	166	47	**149**	224	86	**116**	190	67
20	**367**	715	198	**415**	572	297	**360**	577	232
10	**714**	1609	365	**615**	834	440	**636**	1219	379
5	**1185**	3472	572	**816**	1097	577	**1052**	2490	552
1	**3405**	19356	1128	**1300**	1697	889	**3520**	12969	1065

2.2.2 Flood frequency analysis transposition

The peak flow derived from the FFA at Tarina were transposed to the site catchments using the method outlined by Grayson (1996). This transposition allowed the derivation of peak flow values for the 10% and 1% AEP flood events, which are included in Table 2.2.

Table 2.2 Flood frequency analysis transposition

Location	Catchment area (km^2)	10% AEP	1% AEP
Tarina station	1,512	714	3,405
Site – west catchment	10	30	141
Site – east catchment	16	20	94

The simplicity of the peak flow transposition method comes with inherent limitations that affect its reliability. These limitations include:

- The size of the catchments differs significantly. The area of the Tarina catchment is much larger than that of the site catchments.
- The catchment characteristics, both in terms of topography and surface flow runoff response, vary. The flow in the site catchment areas is primarily dominated by defined flow paths shaped by steep topography, whereas the Tarina catchments present generally more gentle slopes.
- Near the Tarina gauging station, Weeli Wolli Creek's lower reaches are typified by deep alluvial deposits that are likely to contribute to higher-than-normal transmission losses. Conversely, regional soil mapping (DPIRD, 2019) defines the study catchment as stony soils that would exhibit more normalised transmission losses typical of Pilbara catchments (Advisian, 2023).

2.2.3 Regional flood frequency estimation

A Regional Flood Frequency Estimation (RFFE) was conducted to provide an indication of the peak flow at both Tarina and the site. For the site analysis, both the eastern and western catchments were considered. The RFFE at Tarina and at the site is included in Table 2.3.

Table 2.3 RFFE at Tarina station

AEP (%)	Flow (m^3/s)								
	Tarina catchment (area: 1512 km^2)			*West catchment (area:16 km^2)*			*East catchment (area:10 km^2)*		
	Predictive	5% CI	95% CI	Predictive	5% CI	95% CI	Predictive	5% CI	95% CI
10	*418*	*85.1*	*2040*	*28.9*	*5.57*	*148*	*23.1*	*4.39*	*121*
5	*609*	*124*	*2960*	*42.1*	*8.11*	*216*	*33.5*	*6.38*	*176*
1	*1100*	*225*	*5370*	*76.3*	*14.7*	*391*	*60.8*	*11.6*	*319*

As noted in the Australian Rainfall and Runoff (ARR) guidelines, the accuracy of RFFE model estimates decreases under the following condition:

1. Catchment located further away than 300 km from the nearest gauged catchment location used to develop the RFFE
2. Catchments with an area greater that 1,000 km^2
3. Catchments in the arid areas since RFFE technique for the arid areas is based on a very small number of gauged catchments.

In addition to these limitations, the 95% to 5% confidence interval presented in the RFFE shows a wide range of possible values for the AEPs considered. Thus, the accuracy of the RFFE is limited, and its results should be regarded as indicative.

2.3 Hydrology and hydraulic model setup

As indicated in the BoD, a direct rain-on-grid modelling approach in TUFLOW was adopted for assessing the catchments surface water flow conditions. As part of the modelling approach, selected initial and continuing losses are incorporated in the TUFLOW to represent the catchment characteristics. Hydrology parameters adopted in the analysis are summarised in Table 2.4 and provided in the BoD in Appendix A.

Table 2.4 Hydrology parameters

Parameter	Description
Initial loss	18 mm
Continuous loss	4 mm/hr
Storm durations	Storm durations ranging from 15 minutes to 72 hours have been simulated for each event to determine the critical durations.
Temporal patterns	Ten temporal patterns were considered for each duration, as indicated in Australian Rainfall and Runoff 2019.
Pre-burst	Median pre-burst depths from ARR datahub.
Rainfall events	10%, 1% AEP and 1 in 10,000 AEP (as per the BoD)

2.3.1 Rainfall data

Design rainfall data in the form of intensity-frequency-duration (IFD) data were sourced from Bureau of Meteorology (BoM) at the location of Latitude: -23.015 and Longitude: 118.88. IFDs are included in Table 2.5.

Table 2.5 Intensity-frequency-duration (BoM)

Duration	Total rainfall (mm)			
	10% AEP	1% AEP	0.1% AEP	0.05% AEP
15 min	23.6	36.8	55.7	62.5
20 min	27.2	42.3	64	71.8
25 min	30	46.7	70.5	79.1
30 min	32.3	50.2	75.9	85
45 min	37.5	58.3	88.1	98.6
1 hour	41.3	64.6	97.5	109
1.5 hour	47.1	74.8	113	126
2 hours	51.9	83.5	126	141
3 hours	59.8	98.8	149	167
6 hours	77.9	135	205	230
9 hours	91.8	164	249	280
12 hours	103	188	284	319
18 hours	120	223	337	378
24 hours	133	247	373	418

Duration	Total rainfall (mm)			
	10% AEP	1% AEP	0.1% AEP	0.05% AEP
30 hours	143	265	403	452
36 hours	150	277	422	472
48 hours	161	294	442	492
72 hours	173	308	455	504

Derivation of 0.01 % AEP rainfall depth

To derive the rainfall depth for events beyond the 1 in 2,000 AEP, interpolation of very rare (1 in 2,000 AEP rainfall event) and extreme events (the PMP) was undertaken according to the methodology outlined in the ARR guidelines (Book 8, Chapter 3).

The PMP was derived considering the Generalised Short Duration Method (GSDM) for duration up to 6 hours and Generalised Tropical Storm Method (GTSMR) for storm durations beyond 6 hours.

Table 2.6 included the calculated PMP and the interpolated 1 in 10,000 AEP rainfall depths.

Table 2.6 Rainfall depth (mm): 1 in 10,000 AEP and PMP

Duration	1 in 10,000 AEP	PMP
15 min	82	190
30 min	111	270
45 min	130	350
1 hour	144	410
1.5 hour	167	530
2 hours	188	620
3 hours	224	750
6 hours	309	990
12 hours	422	1085
18 hours	497	1179
24 hours	547	1274
36 hours	617	1463
48 hours	641	1652

2.3.2 Hydraulic model parameters

Hydrology and hydraulic model parameters used for the assessment are included in Table 2.7

Table 2.7 Rain on grid model parameters

Model parameter	Description
Software package	TUFLOW version 2023-03-AC
Model approach	Rain-on-grid model (2d)

Model parameter	Description
Model extent	Refer to Figure 2.4
Cell size	— Cell size: a cell size 4 m — Sub-grid sampling (SGS): 1 m
Manning's *n* roughness coefficient	The following Manning's *n* values were adopted. The Manning's values are referenced from Open channel hydraulics (V T Chow, 1959): The buildings are modelled with higher roughness values to represent the blockage. — Brush and Trees: 0.065 — Roads: 0.022 — Buildings: 0.1
Inflow boundary conditions	IFD as anticipated in Section 2.3.1 were applied to the model domain
Outflow boundary conditions	HQ boundary (slope from terrain model)
Drainage structures	None
Simulated AEP events	10%, 1% AEP and 1 in 10,000 AEP
Simulated storm durations	15 minutes to 72 hours

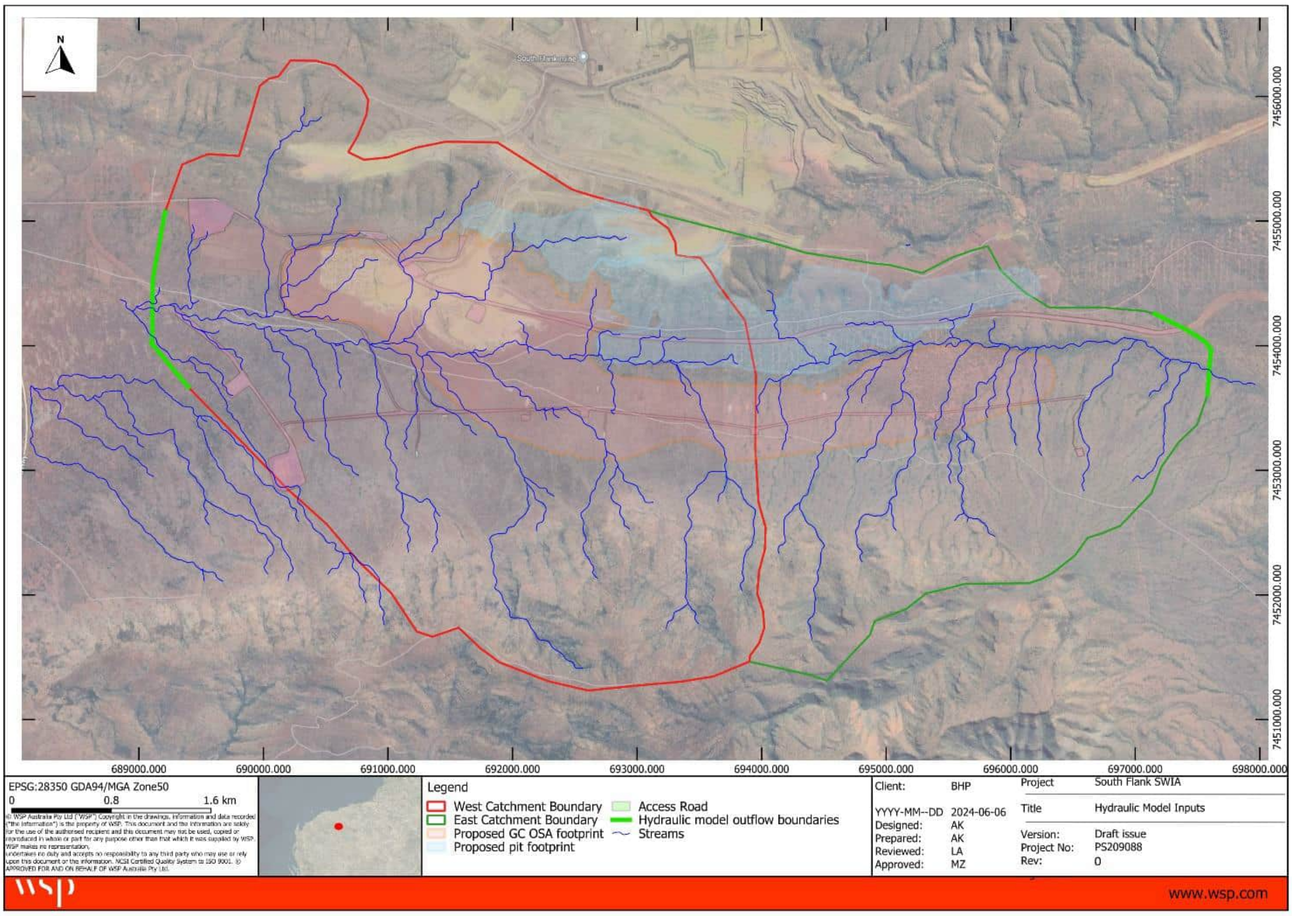


Figure 2.4 Hydraulic model extent

2.4 Hydraulic model results

2.4.1 *Critical storm durations*

The storm analysis identified that storm durations between 3 to 6 hours are critical for the catchments contributing to the surface water runoff at the site. The 6-hour storm duration was considered representative for the existing conditions (i.e., without the surface water diversion) as it generates the maximum water level and peak flow among the duration assessed.

Additional storm durations were assessed for the design conditions to account for changes in catchment response (refer to Section 3 for the design condition).

2.4.2 *Peak flow*

Peak flows were extracted at 9 locations representative of the flow paths that would be subject to surface water diversion. Refer to Figure 2.5 for location of peak flows estimated.

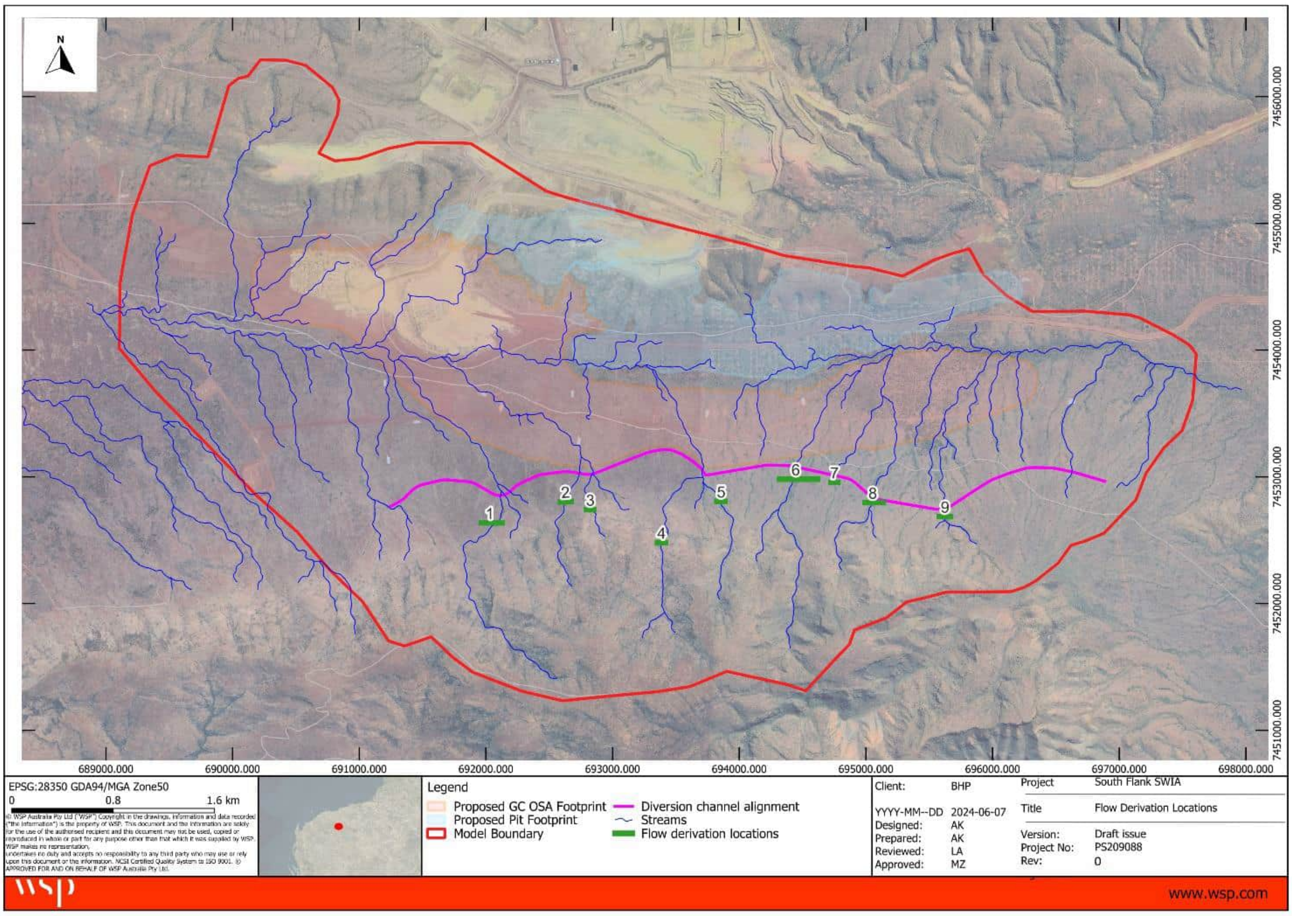


Figure 2.5 Location for peak flow analysis (existing conditions)

Peak flows for the different events are included in Table 2.8.

Table 2.8 Peak flow (m^3/s) – existing conditions

Location	10% AEP	1% AEP	1 in 10,000 AEP
1 (west catchment)	12.1	20.7	46.1
2 (west catchment)	5.1	11.9	34.8
3 (west catchment)	2.7	6.3	19.9
4 (west catchment)	11.3	26.6	73.3
5 (west catchment)	4.5	9.58	25.4
6 (East catchment)	12.6	24.9	75.5
7 (East catchment)	1.3	2.2	8.4
8 (East catchment)	6.5	14.2	45.9
9 (East catchment)	4.9	10.5	33.5

2.4.3 Flood depth

Figure 2.6, Figure 2.7, and Figure 2.8 show the maximum flood depths for the 10%, 1%, and 1 in 10,000 AEP flood events, respectively. Refer to Appendix B for high resolution flood maps.

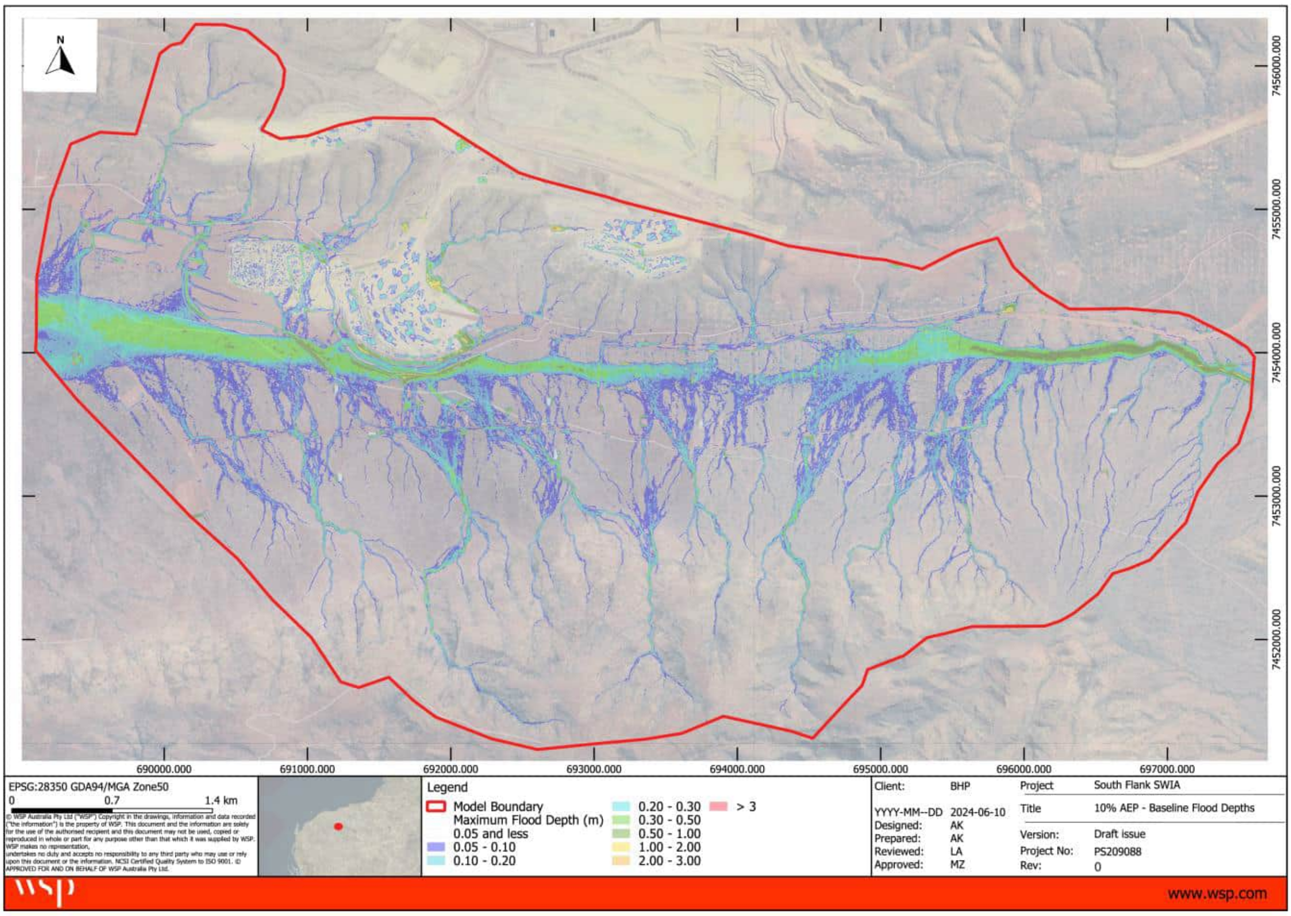


Figure 2.6 Flood depth 10% AEP – existing conditions

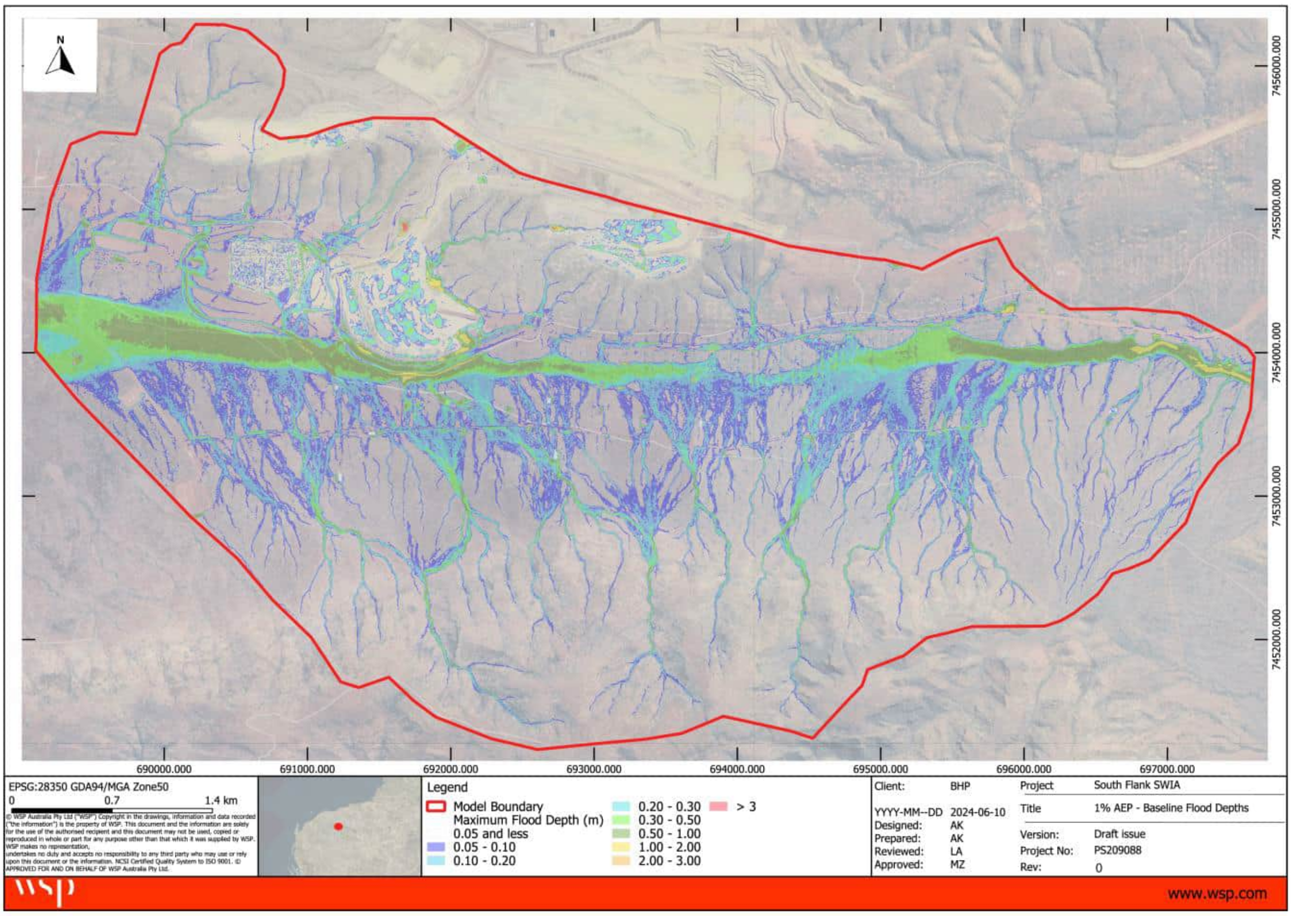


Figure 2.7 Flood depth 1% AEP – existing conditions

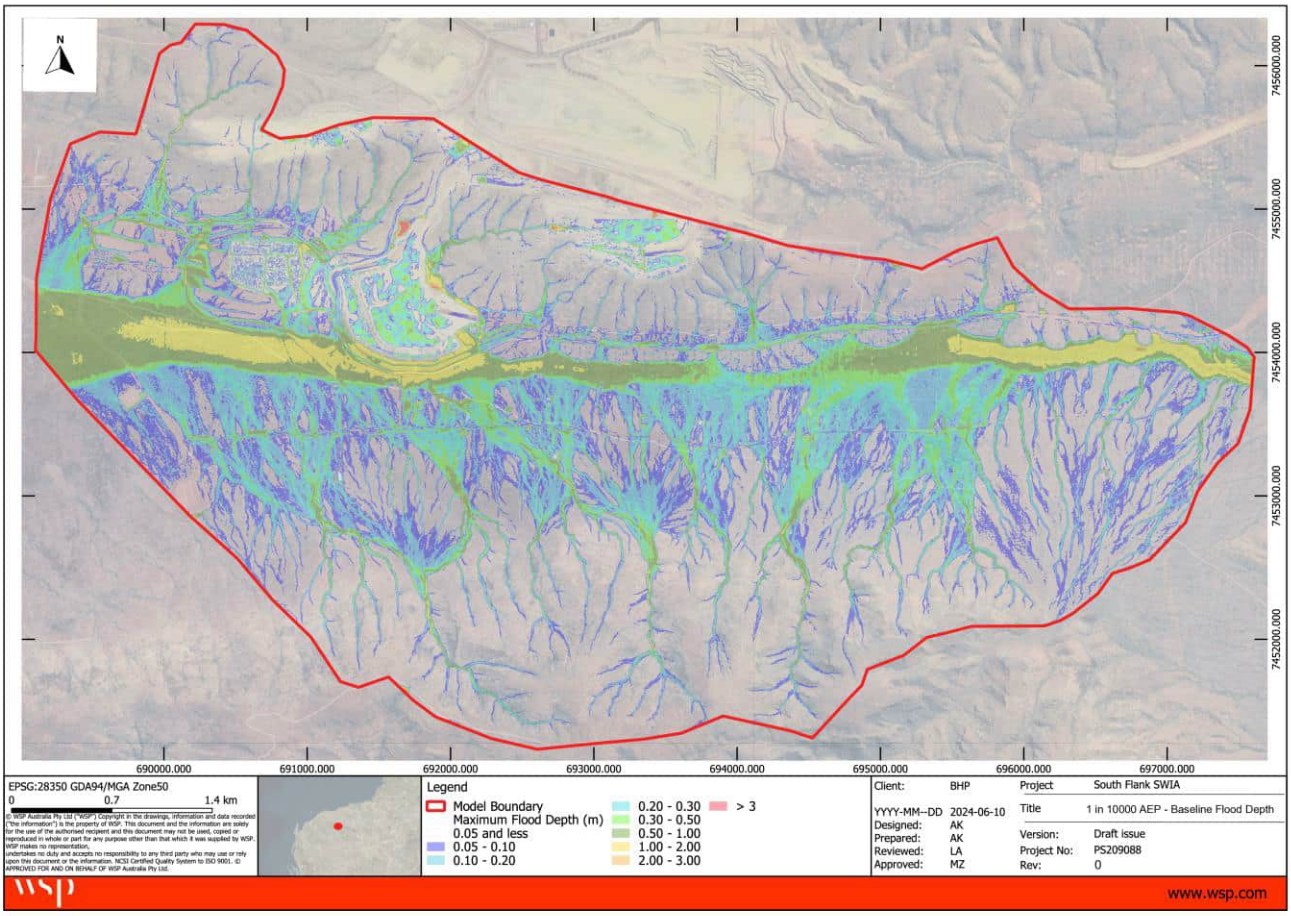


Figure 2.8 Flood depth 1 in 10,000 AEP – existing conditions

2.4.4 Flow velocities

Figure 2.9, Figure 2.10, and Figure 2.11 show the peak flood velocities for the 10%, 1%, and 1 in 10,000 AEP flood events, respectively. For high-resolution maps, please refer to Appendix B.

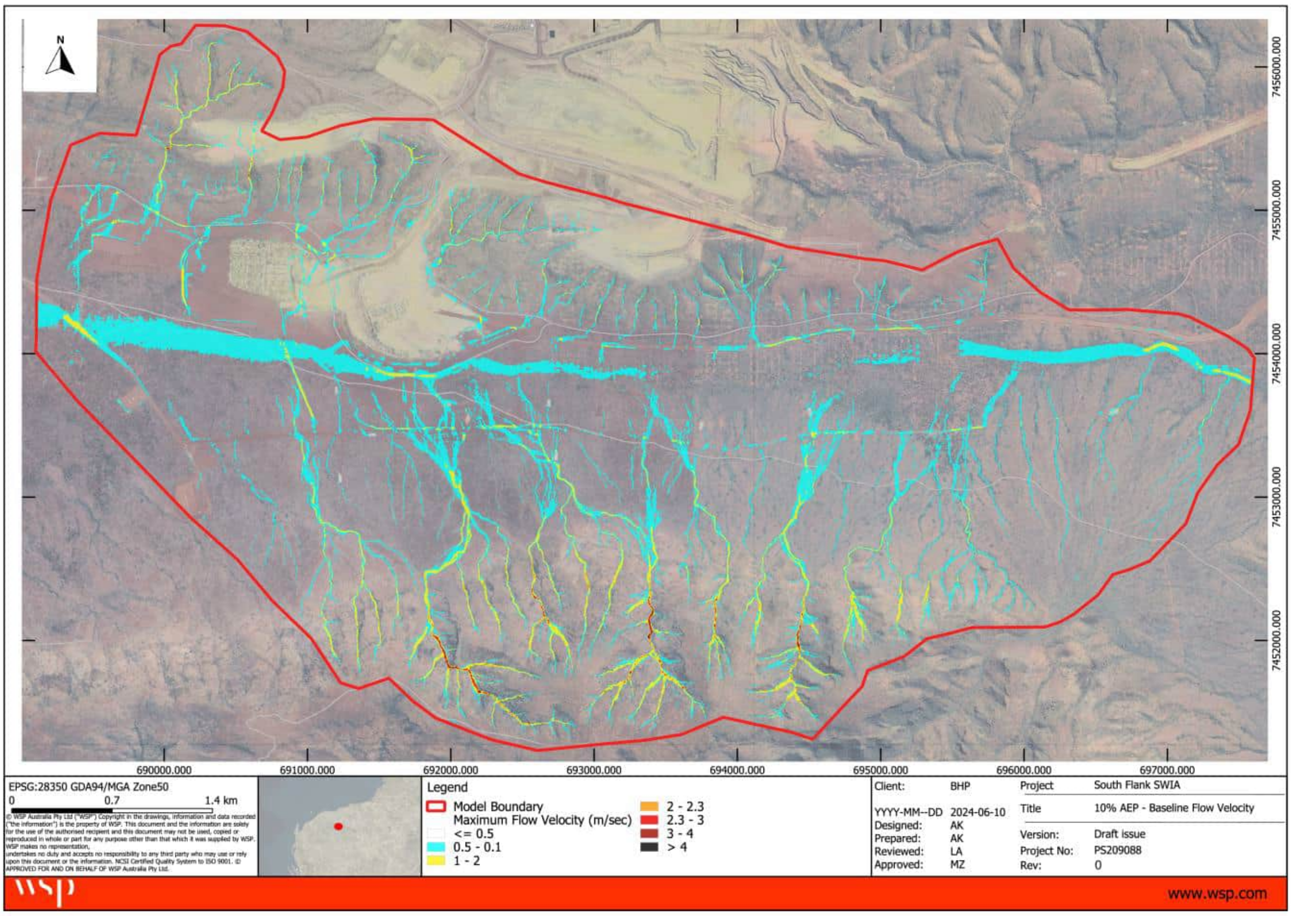


Figure 2.9 Peak flow velocities 10% AEP – existing conditions

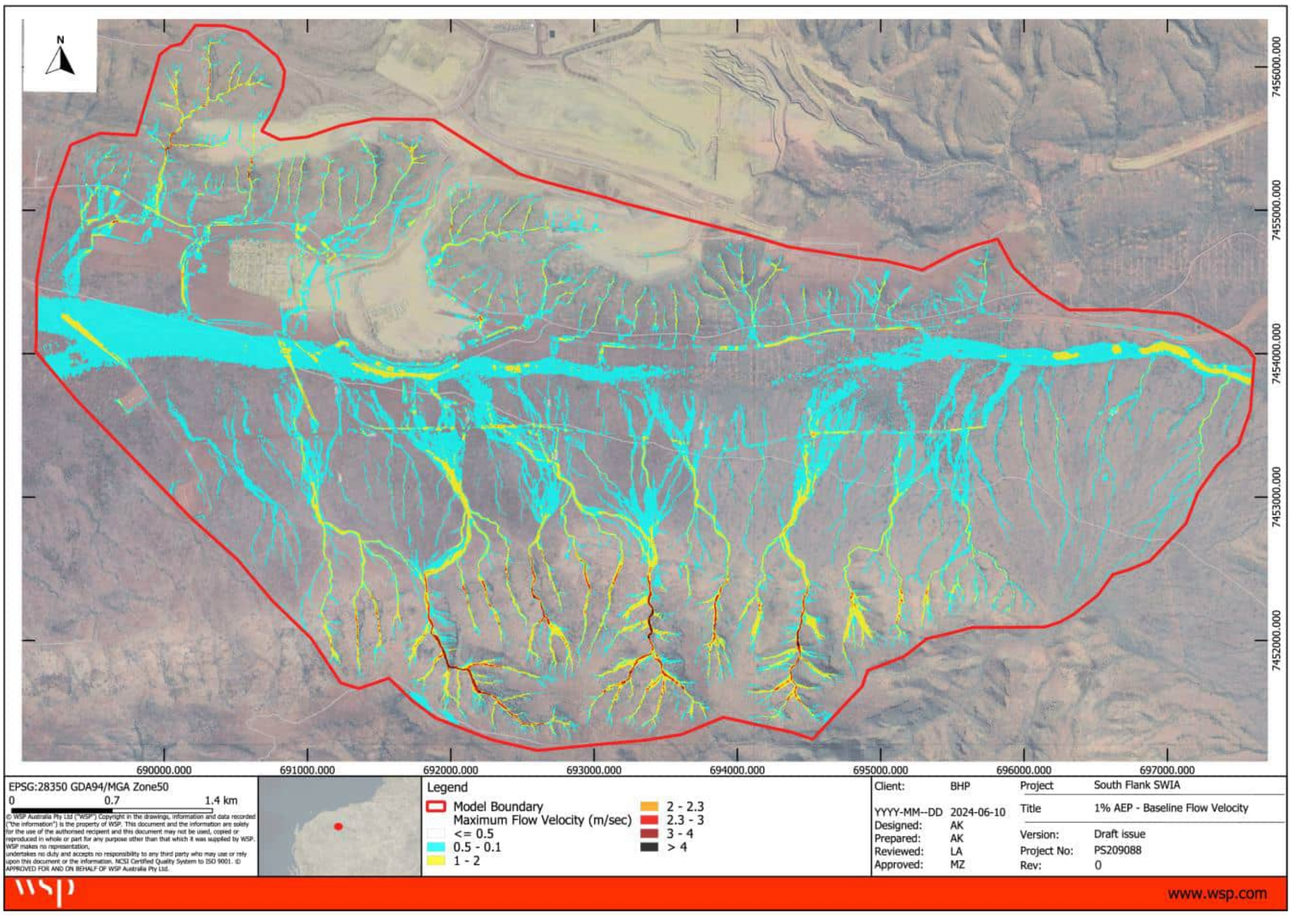


Figure 2.10 Peak flow velocities 1% AEP – existing conditions

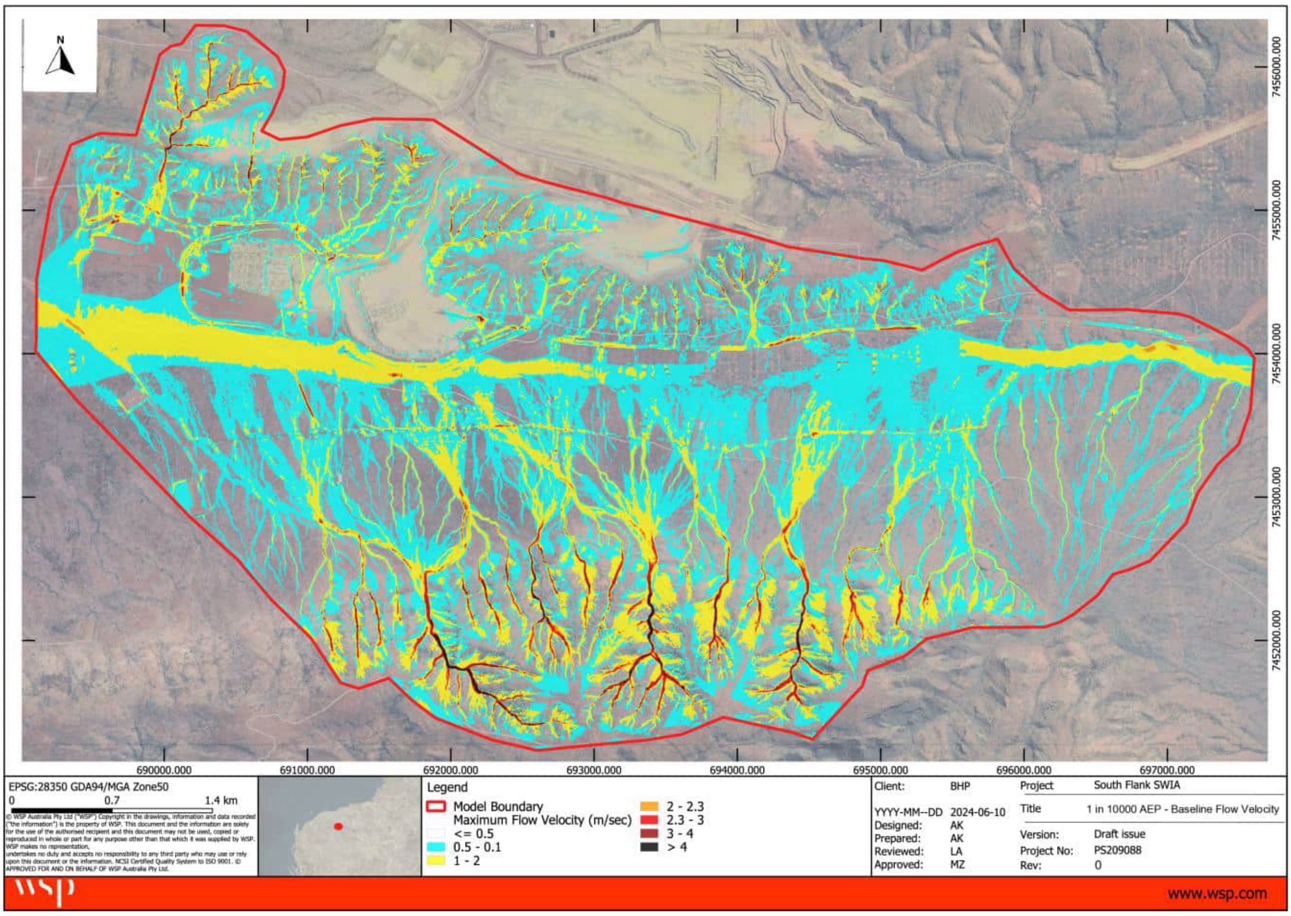


Figure 2.11 Peak flow velocities 1 in 10,000 AEP – existing conditions

2.5 Hydrology validation

Due to the lack of hydrology data, such as soil infiltration, stream flow, and rainfall data for the site catchments, it was not possible to complete a proper hydrology model calibration and validation.

An attempt to compare peak flows was made using the FFA conducted at the Tarina station (described in Section 2.2.1). This involved transposing and scaling the peak flow data derived from the catchments contributing to the Tarina station to the flow assessed at site catchments (west and east catchments) using the rain on grind hydraulic model.

2.5.1 Peak flow comparison

Peak flows derived from the FFA transposition, the RFFE and the hydrology model were compared as included in Table 2.9. The locations of the gauging stations used for the FFA and study area outlets are shown in Figure 2.1.

Table 2.9 Peak flow comparison

Location	Hydrology model (m^3/s)	RFFE (m^3/s)	FFA transposition (m^3/s)
10% AEP			
Site – west catchment	55	28.9	30
Site – east catchment	35.8	23.1	21

Location	Hydrology model (m^3/s)	RFFE (m^3/s)	FFA transposition (m^3/s)
1% AEP			
Site – west catchment	121.8	76.3	141
Site – east catchment	69.2	60.8	101

The comparison of peak flow for east and west site catchments indicates that the peak flow values at the site exceed those predicted by the RFFE and FFA in the 10% AEP flood event. The peak flow estimated with the hydrology model is approximately 60% higher than the FFA transposition and RFFE peak flow values.

It is to be noted that the peak flow values from the hydrology model are considering the GC OSA presence in the catchment area. The comparison of the peak flow values from the hydrology model with GC OSA presence and without GC OSA presence shows that the peak flow values are decreased by approximately 15% and 34% for 10% AEP and 1% AEP events, respectively.

For the 1% AEP flood event, the peak flow values from the hydrology model fall between the predictions of the RFFE and FFA transposition analysis. For the west catchment the peak flow estimated from the hydrology model is approximately 60% higher than the RFFE and 16% lower than the FFA transposition analysis. For the east catchment the peak flow from the hydrology model is approximately 15% higher than the RFFE analysis and 45% lower than the peak flow derived from the FFA transposition.

The peak flow comparison demonstrates that there are uncertainties in the peak flow estimations. These uncertainties are due to the lack of data and the attempt to compare peak flow of catchments that differ in size and characteristics. Additionally, the critical storm duration associated with the hydrology model is considered an element that could affect the peak flow comparison. Sensitivity tests on hydrology and hydraulic model parameters were completed (refer to Section 2 for further details) to assess the variability of model results due to changes in model parameters. Sensitivity analysis

Sensitivity tests were conducted on rainfall losses and Manning's roughness coefficients. The purpose of these tests was to investigate how changes in these model parameters might affect the model's output.

Manning's

Manning's roughness coefficients were adjusted by +/- 20% from their initial values. The modifications in roughness values demonstrated that the flood depths, flow velocities, and peak flows remained within the 10% tolerance level. Therefore, the model is considered to be not sensitive to changes in Manning's values within this +/- 20% range.

Rainfall losses

Initial loss and continuous loss values were adjusted by +/-25% and +/-50% from their initial values. The modifications in the ILCL values demonstrated that the flood depths remained within the 8% and 18% tolerance level for +/-25% and +/-50% ILCL values respectively.

2.5.2 Hydrology limitations

The hydrology and hydraulic analysis conducted to define the flood conditions at the site were completed using engineering judgment and good practice. The lack of data to properly calibrate and validate the model leaves uncertainties in the results. An attempt to compare the site peak flow conditions with the FFA at Tarina and the RFFE was made to compensate for the lack of calibration and validation data at the site and gain some confidence in the peak flow estimates. This however is a high-level comparison only.

The sensitivity test completed for the Manning's coefficient shows that uncertainties in roughness have limited effect on the model outcome. Rainfall losses and soil infiltration will require further investigation if better data becomes available, as these are relevant factors in defining surface water runoff at the catchments.

For the purpose of this analysis, rainfall losses were selected in consultation with BHP. The decision was made to adopt values that incorporates a level of conservatism producing a surface water management design that addresses hydrological limitations and uncertainties.

2.6 Climate change considerations

The addendum "Draft update to the Climate Change Considerations Chapter in Australia Rainfall and Runoff: A Guide to Flood Estimation – published in December 2023 by the Department of Climate Change, Energy, the Environment and Water" proposed changes in climate change estimation. It is acknowledged that the addendum is still in draft version and any material changes to the draft and final version may require a reassessment of the outcomes herein.

As discussed in the BoD provided in Appendix A, a climate change sensitivity analysis was completed by applying increase in rainfall intensity of 19% and 30% for medium-term (year 2041 to 2060) and long-term (year 2081 to 2100) for SSP 4.5 emissions scenario, and 55% for SSP 8.5 emissions scenario for the long-term time horizon. As noted in Appendix A, a 25% increase for SSP 8.5 is expected for the medium-term time horizon, but the results can be informed by and are expected to be comparable to the SSP 4.5 long-term increase. These climate change scenarios were assessed relative to baseline climate used for design to understand the potential incremental impact and hydrological risk during the post-closure phase.

3 Design flood model

The hydrology and hydraulic model introduced in Section 2 was used to explore different design options to divert flood water away from GC OSA and the Pit area.

This section presents the flood conditions for the preferred design solution (refer to Section 3.1) that was agreed with BHP.

3.1 Diversion channel

The alignment of the proposed surface water diversion and the heritage boundary (100 m standoff corridor) is shown in Figure 3.1. The design aims to maintain flow velocities below 2.3 m/s (or below 1.5 m/s where reasonably practicable) which necessitates keeping the channel slope below 0.002 m/m.

The diversion channel design criteria are presented in Appendix A (basis of design memorandum). As shown in Table 1.1, the diversion channel has been sized to convey the peak flow resulting from the 10% AEP event, with the berm height sized to either contain the water level resulting from the 1% AEP event with 0.3 m freeboard, or the 1 in 10,000 AEP event, whichever is greater.

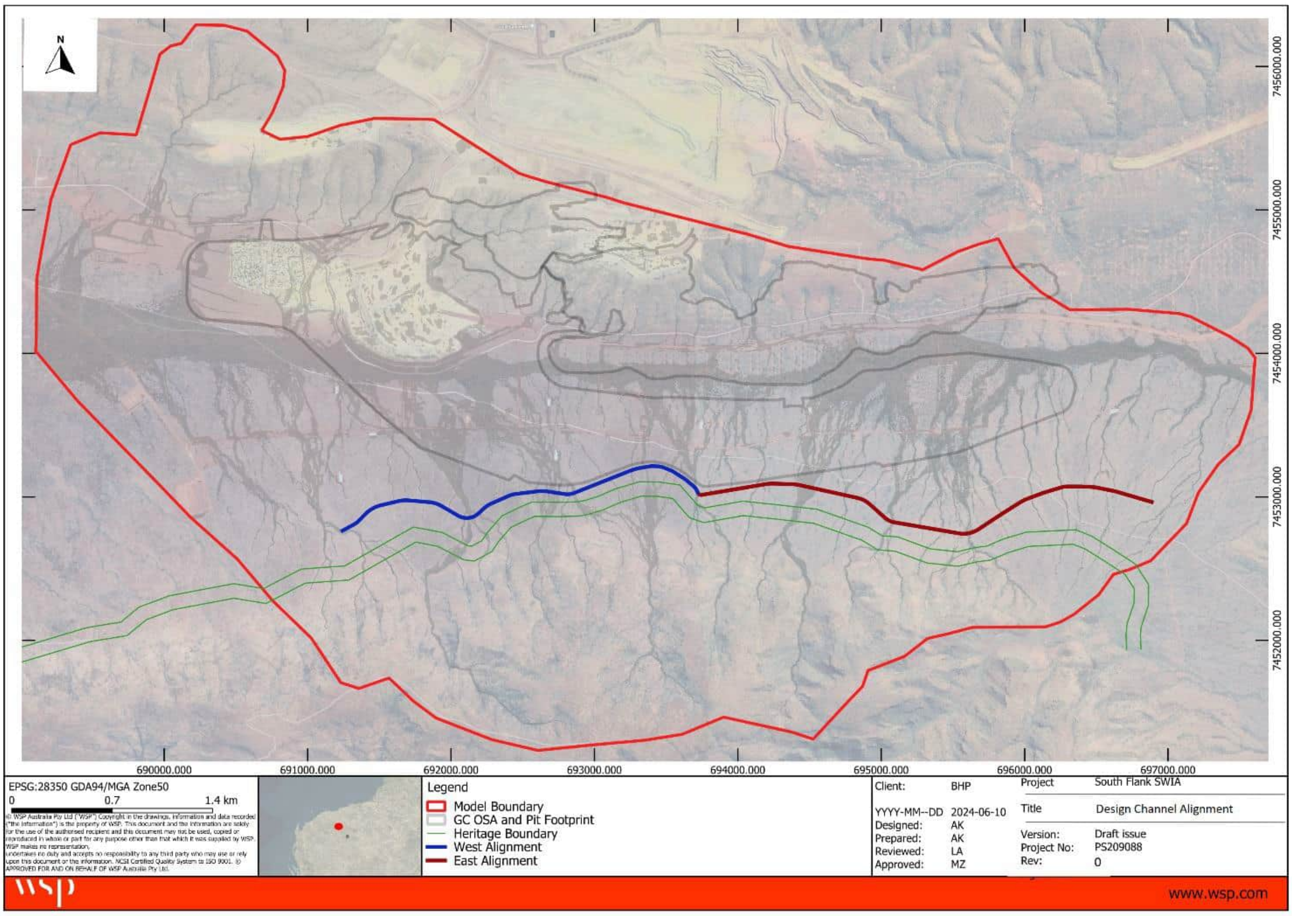


Figure 3.1 Diversion channel design alignment

3.2 Diversion channel hydraulic model results

The GC OSA and pit areas are included as inactive area for the hydraulic modelling purposes. The flood water is captured between the GC OSA and pit areas, and to the north of pit areas. This flood water should be considered during designing the toe drains for the GC OSA and the pit areas.

Model results were generated for the 10%, 1%, and 1 in 10,000 AEP flood events.

3.2.1 Peak flow and flow velocities

Peak flows and flow velocities were calculated at 13 locations along the proposed diversion channel. Refer to Figure 3.2 for location of peak flows and flow velocities estimated.

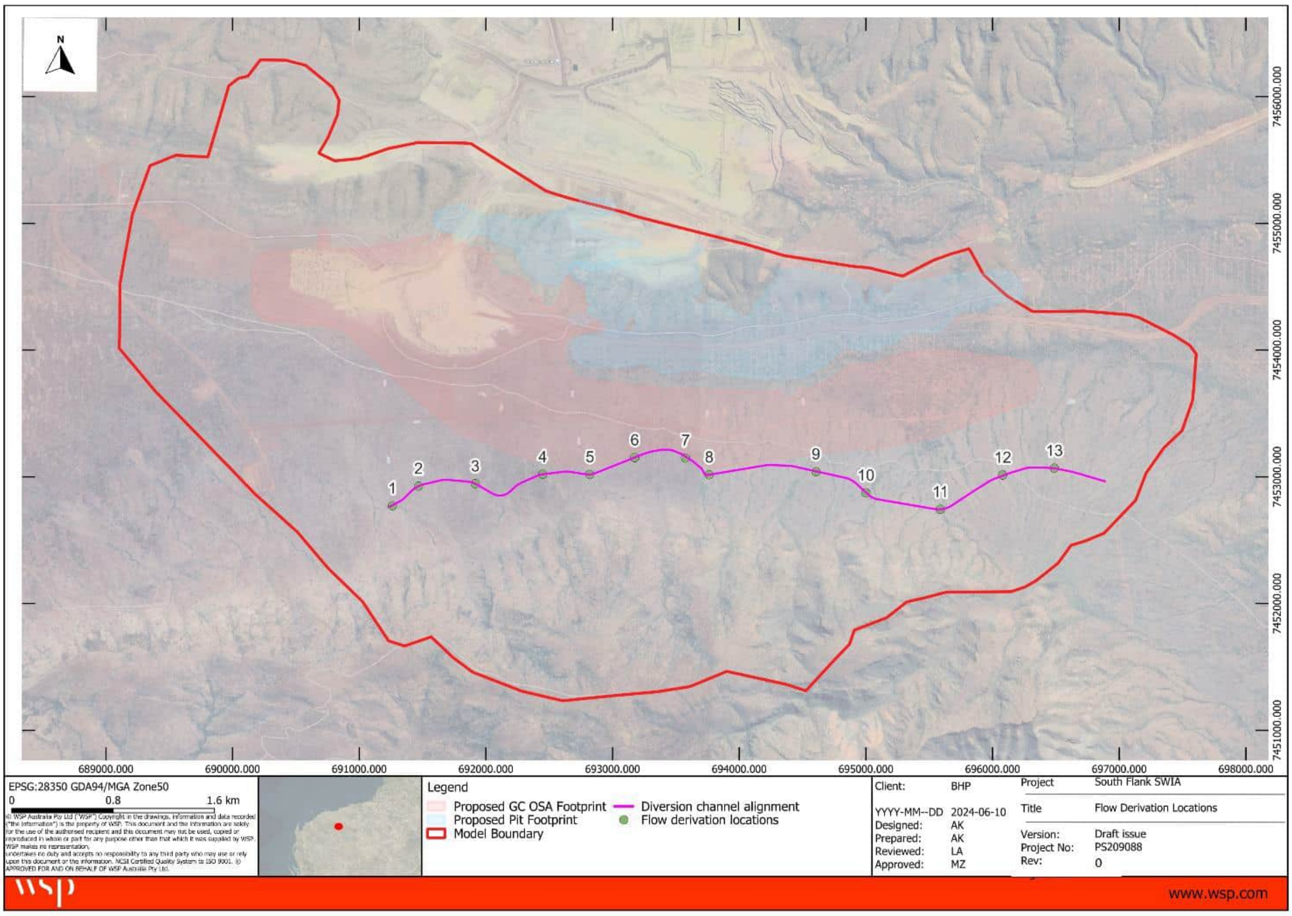


Figure 3.2 Location for peak flow analysis within diversion channels – design conditions

Peak flows within the diversion channel for the different events are included in Table 3.1.

Table 3.1 Peak flow and flow velocities within diversion channels – design conditions location

Location	**10% AEP**		**1% AEP**		**1 in 10,000 AEP**	
	Flow (m^3/s)	**Flow Velocity (m/s)**	**Flow (m^3/s)**	**Flow Velocity (m/s)**	**Flow (m^3/s)**	**Flow Velocity (m/s)**
1	29.2	1.6	52.9	2.1	148.3	3.3
2	33.1	1.4	61.2	1.8	165.0	2.5
3	32.8	1.3	60.4	1.7	160.0	2.3
4	22.8	1.6	40.6	1.9	115.0	2.5
5	15.5	1.4	21.4	1.5	43.7	1.5
6	12.3	1.4	19.2	1.5	52.3	1.6
7	7.9	1.3	11.5	1.5	30.5	1.9
8	0.3	0.3	0.7	0.5	2.8	0.8
9	13.7	1.2	22.4	1.4	68.7	1.9
10	14.9	1.1	25.0	1.3	74.9	1.7
11	19.0	1.2	34.9	1.4	95.0	1.8
12	21.6	1.3	40.9	1.6	103.8	2.0

Location	10% AEP		1% AEP		1 in 10,000 AEP	
	Flow (m^3/s)	Flow Velocity (m/s)	Flow (m^3/s)	Flow Velocity (m/s)	Flow (m^3/s)	Flow Velocity (m/s)
13	22.3	1.6	42.9	2.0	111.5	2.5

3.2.2 Flood maps

Flow velocities

Peak flow velocities for the different flood events are included in Figure 3.4, Figure 3.5, and Figure 3.6. The flood velocities are higher in the Mount Robinson slopes for all the modelled events. The velocities in the east and west diversion channels are within maximum allowable value of 2.3 m/s for 10% AEP event and 1% AEP event. The 1% AEP event shows small patches of high velocities in the west diversion channel at approximate chainage 800 m and 1500 m upstream from the discharge location. These are the locations where hydraulic jump was formed and would need additional level of protection against scouring.

The 1 in 10,000 AEP event shows velocities more than 2.3 m/s near the discharge location of east and west diversion channel for approximately 500 m and 400 m respectively. There are some small patches of high velocities (up to approximately 2.8 m/s) at the locations of watercourse inlets into the east and west diversion channels. Although velocities are escalated in these areas, it will require localised maintenance should a flood event up to the 1 in 10,000 AEP occur; however, overall diversion protection is still provided, and no critical infrastructure is severely impacted.

Figure 3.3 shows the key locations where watercourses are entering the diversion channel and Table 3.2 shows the peak velocities at these locations for 1 in 10,000 AEP flood event.

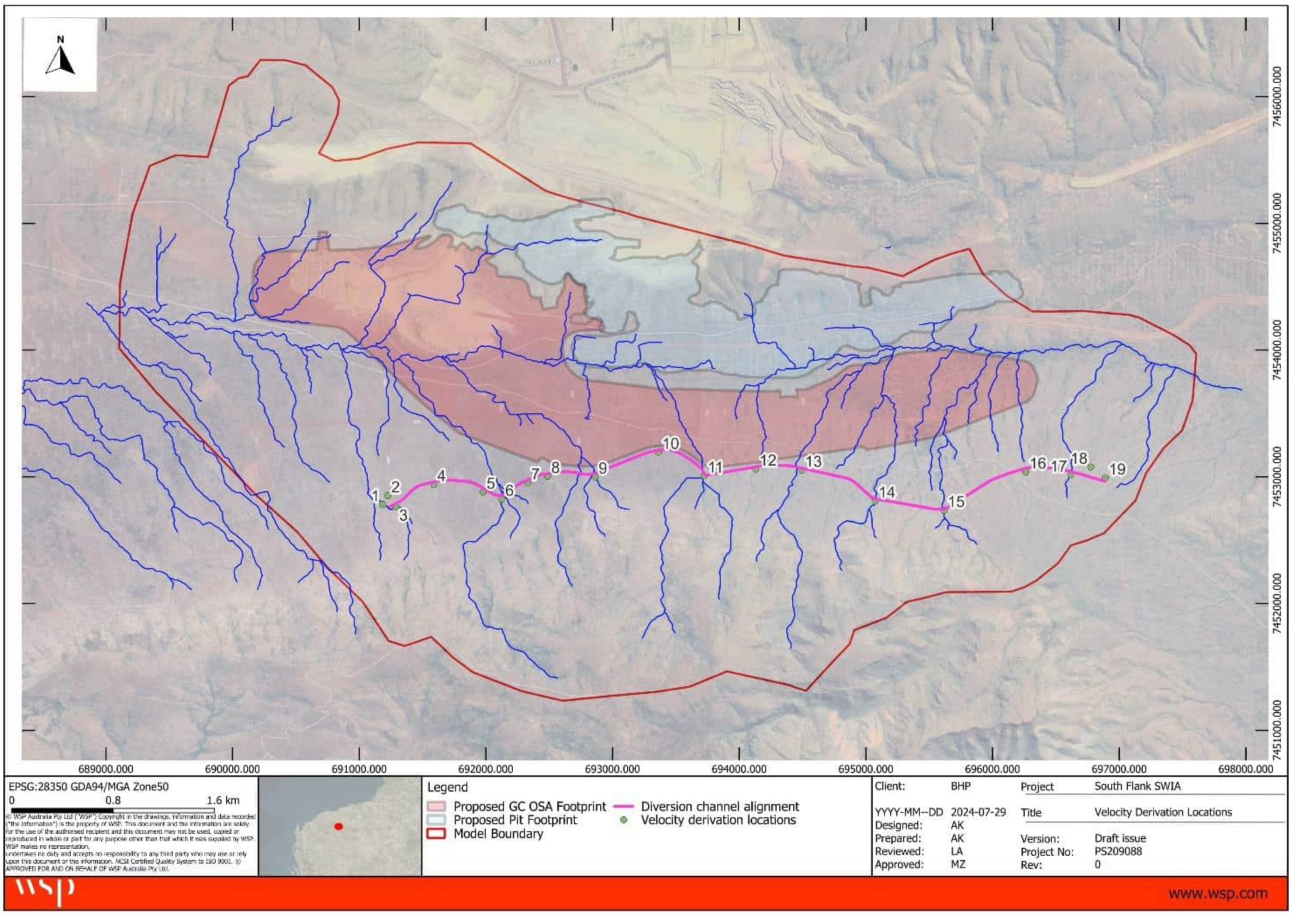


Figure 3.3 Location for peak velocity analysis at locations of watercourse inlets into the diversion channels - design conditions

Table 3.2 Peak velocities at watercourse inlets along diversion channels

Location	Peak flow velocity (m/s)
1	2.8
2	1.7
3	2.8
4	1.4
5	1.2
6	1.4
7	1.2
8	1.6
9	0.7
10	1.7
11	2.5
12	1.6
13	1.7

Location	Peak flow velocity (m/s)
14	2.7
15	2.3
16	1.6
17	1.0
18	1.8
19	2.3

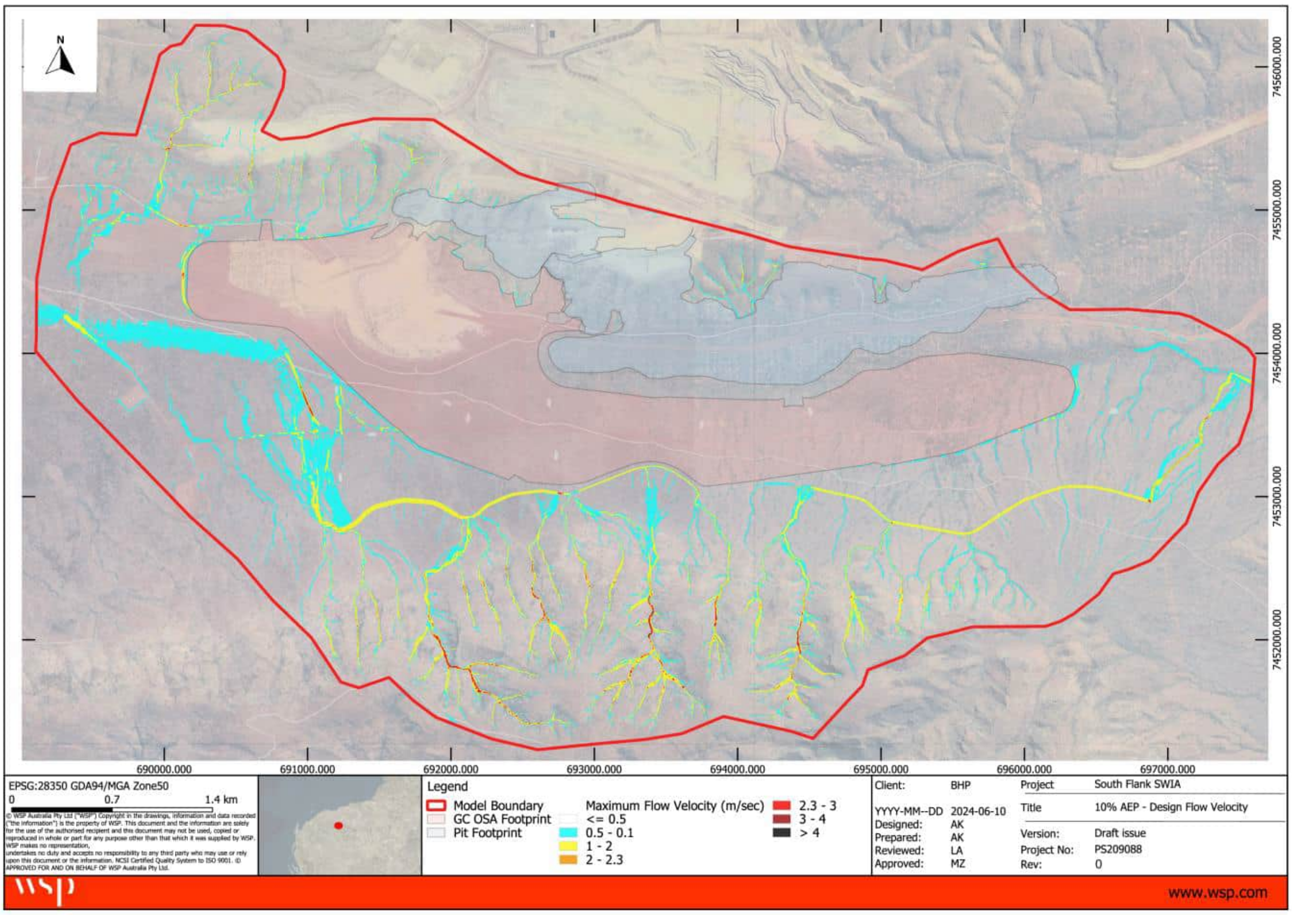


Figure 3.4 Peak flow velocities 10% AEP – design scenario

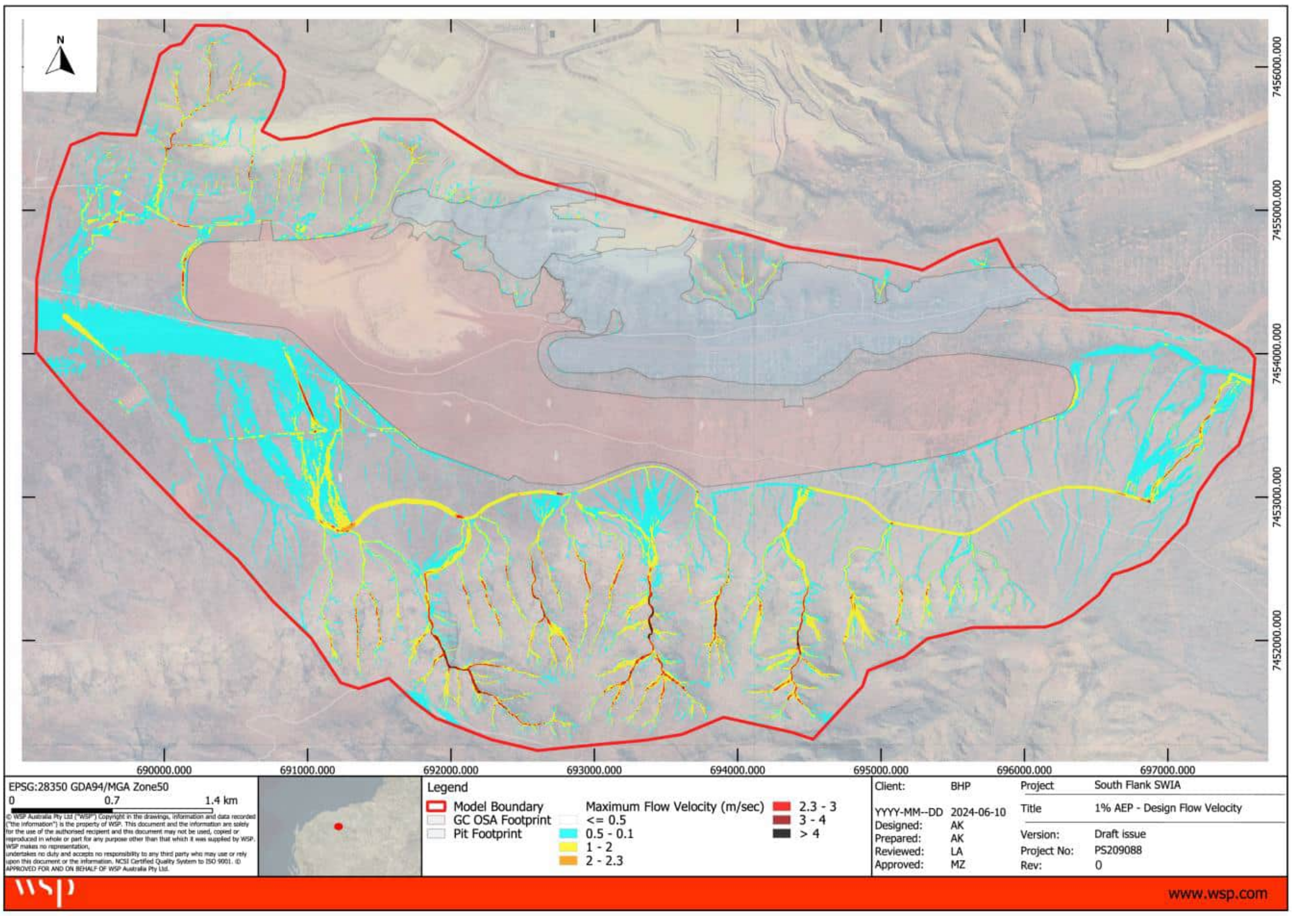


Figure 3.5 Peak flow velocities 1% AEP – design scenario

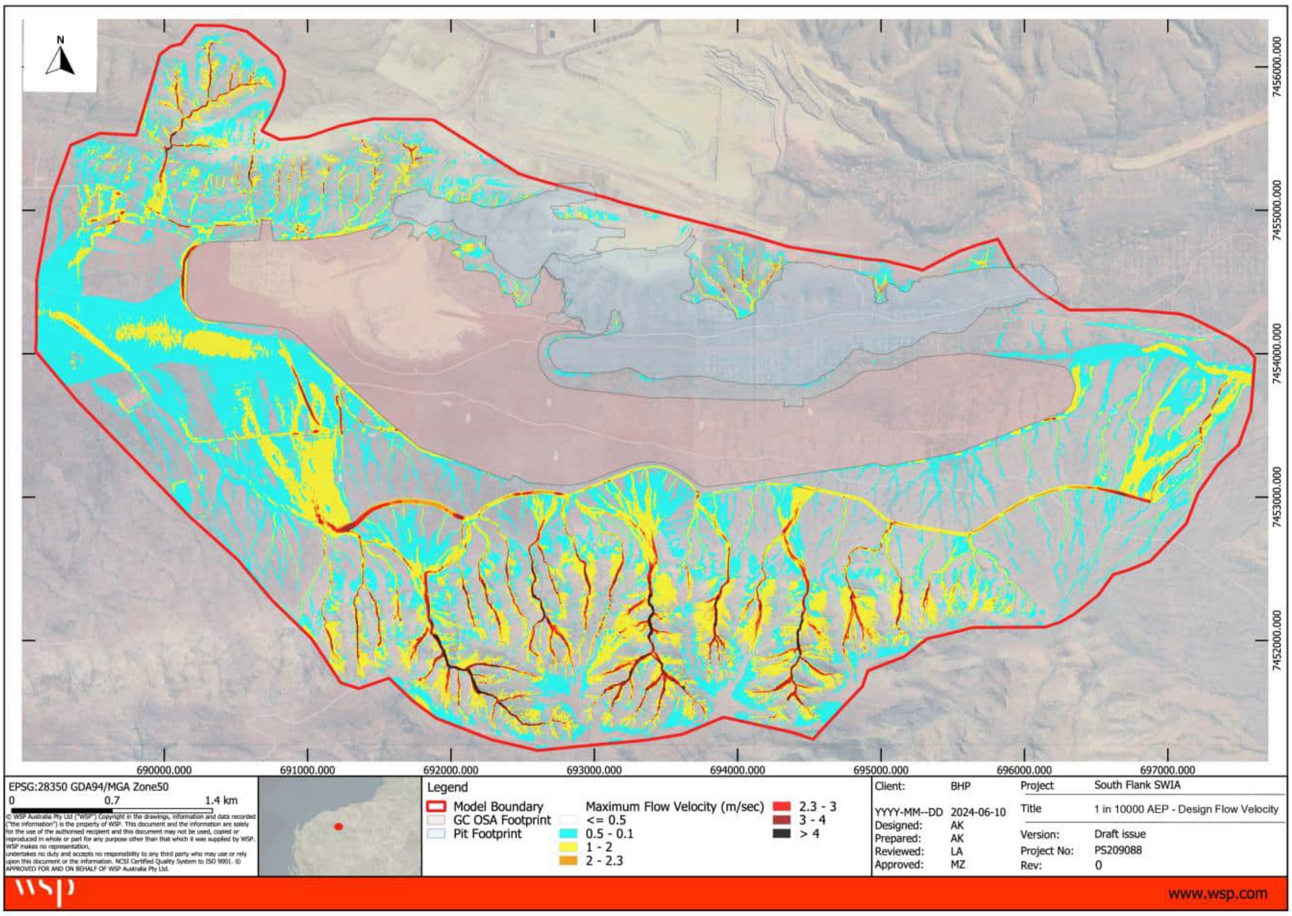


Figure 3.6 Peak flow velocities 1 in 10,000 AEP – design scenario

Flood depths

Peak flood depths for the different flood events are included in Figure 3.7, Figure 3.8, and Figure 3.9. The maximum flood depths within the diversion channels are up to 1 m, 2 m, and 3 m for 10% AEP, 1% AEP, and 1 in 10,000 AEP respectively. The berm height demonstrates that the water level is contained upstream of the GC OSA within diversion channels.

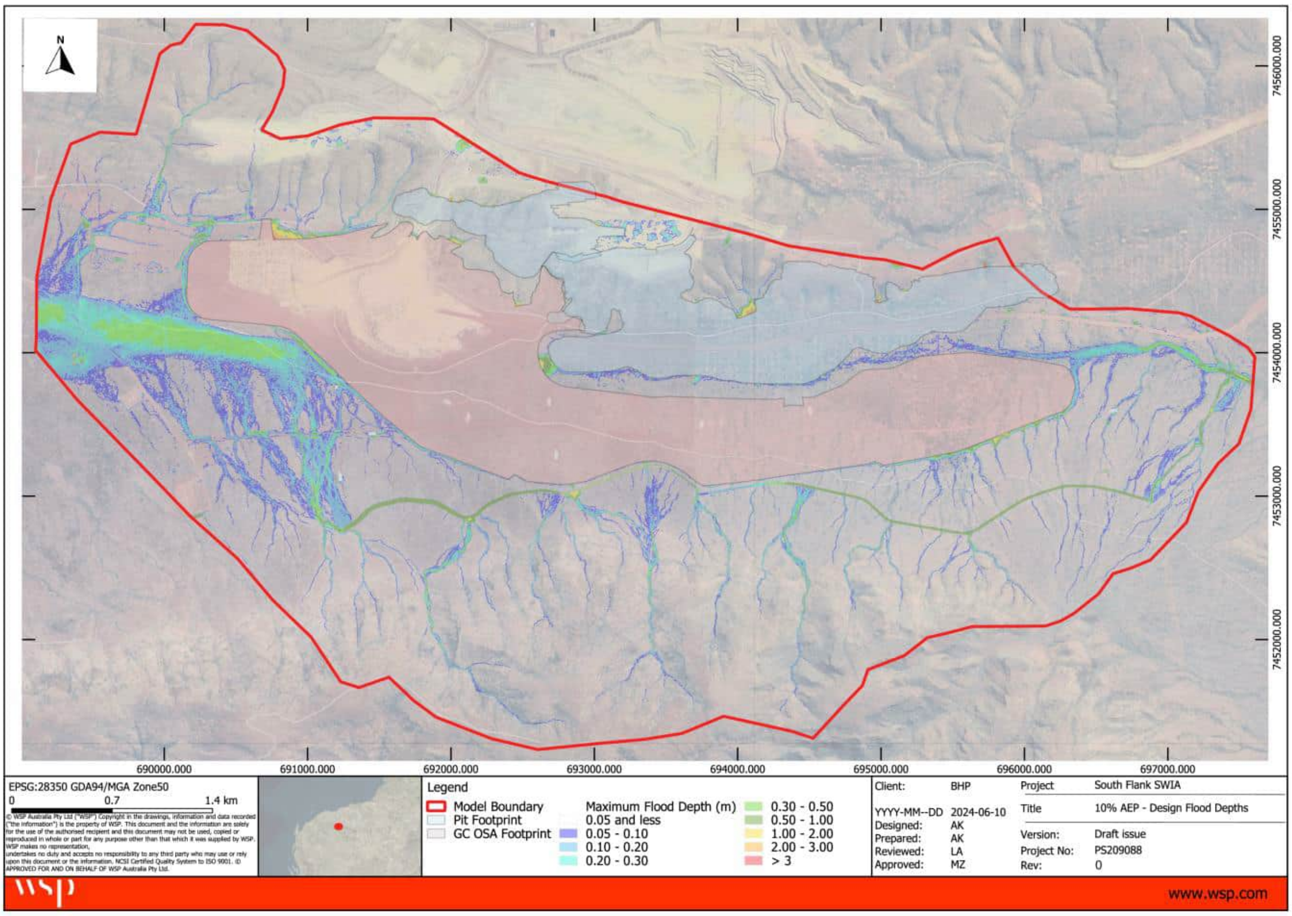


Figure 3.7 Peak flood depths 10% AEP – design scenario

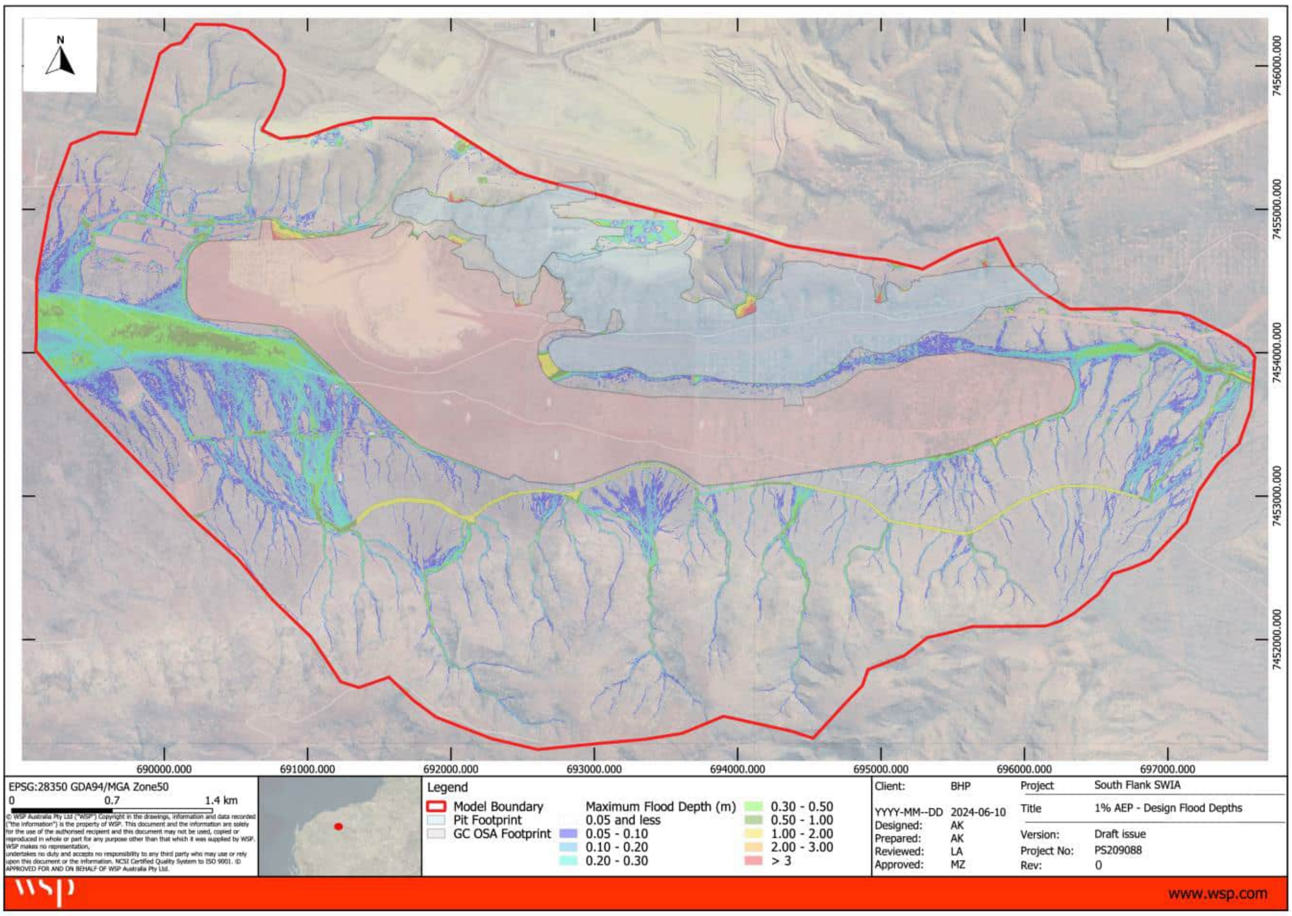


Figure 3.8 Peak flood depths 1% AEP – design scenario

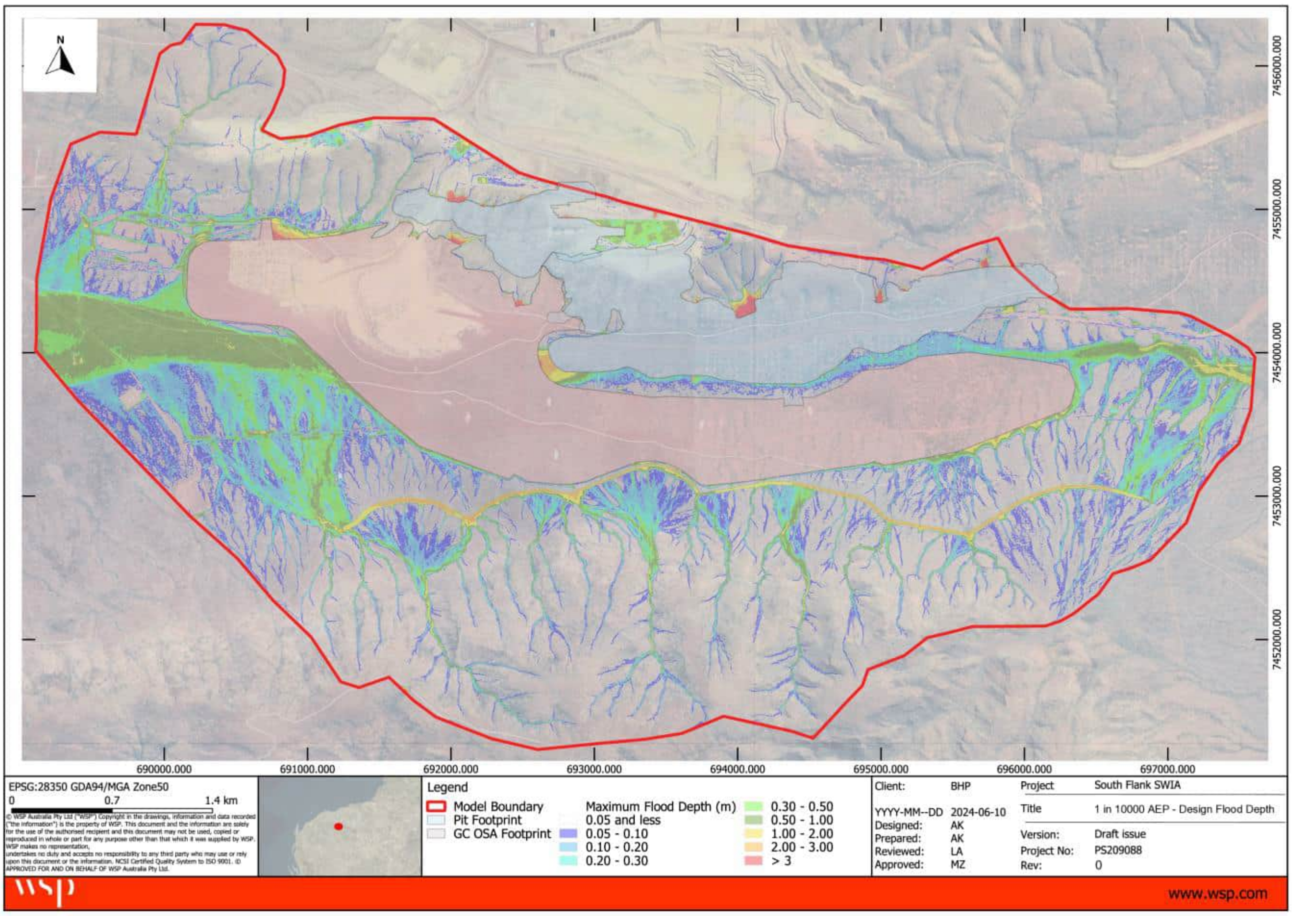


Figure 3.9 Peak flood depths 1 in 10,000 AEP – design scenario

3.3 Climate change sensitivity analysis

As discussed in Section 2.6, climate change scenarios were assessed as part of a sensitivity analysis relative to baseline climate used for design to understand the potential incremental impact and hydrological risk during the post-closure phase. The climate change sensitivity analysis was undertaken for 1 in 10,000 AEP event by increasing the rainfall intensity by 19% and 30% for the medium-term (2041 to 2060) and long-term (2081 to 2100) time horizons, respectively for the SSP 4.5 emissions scenario. In addition, an increase of 55% for SSP 8.5 emissions scenario for the long-term time horizon, respectively. As noted in Appendix A, a 25% increase for SSP 8.5 is expected for the medium-term time horizon, but the results can be informed by and are expected to be comparable to the SSP 4.5 long-term increase.

The change in hydraulic model result for the climate change are exported in Table 3.3 for the 13 locations along the surface water diversion as shown in Figure 3.2. The results show that the average water level increases by 250 mm, 310 mm, and 385 mm for increase in rainfall intensity of 19%, 30% and 55% respectively.

Table 3.3 Climate change analysis results

Location	19% Climate Change		30% Climate Change		55% Climate Change	
	Change in water level (mm)	Change in flow velocity (m/s)	Change in water level (mm)	Change in flow velocity (m/s)	Change in water level (mm)	Change in flow velocity (m/s)
1	91	0.3	135	0.3	197	0.4
2	204	0.2	251	0.2	321	0.3

Location	19% Climate Change		30% Climate Change		55% Climate Change	
	Change in water level (mm)	Change in flow velocity (m/s)	Change in water level (mm)	Change in flow velocity (m/s)	Change in water level (mm)	Change in flow velocity (m/s)
3	265	0.1	343	0.2	426	0.2
4	284	0.1	359	0.1	427	0.2
5	238	0	336	0	435	0
6	284	0.1	371	0.1	460	0.1
7	260	0.1	319	0.2	374	0.3
8	236	0.1	300	0.2	386	0.3
9	259	0	321	0.1	400	0.1
10	282	0	348	0	439	0
11	289	0	398	0	485	0
12	256	0.1	323	0.1	374	0.1
13	115	0.2	143	0.2	178	0.3

The change in water level has been provided to give a general indication on the potential increased berm height needed for containment when compared to the diversion channel design scenario further discussed in Section 4. In addition, the change in flow velocity may introduce design considerations of implementing erosion protection material in areas that are markedly impacted.

Table 3.3 provides supporting information for BHP to evaluate the potential contingencies to incorporate into the next stage of the diversion channel design to account for the incremental hydrological risk due to climate change.

4 Diversion channel civil design

4.1 Civil design summary

The east and west diversion channel alignments were modelled in Autodesk Civil3D and captured in the design drawings in Appendix C. The drawings consist of east and west diversion channel plan-profiles, as well as section details along the alignments.

The civil design of the diversion channels includes the following:

- The total length of the east and west diversion channels are approximately 3.3 km and 2.7 km, respectively.
- As shown on the general arrangement in Drawing D001, the alignments of the diversion channels are defined such that the maximum longitudinal slope is achieved (approximately 0.2%), meaning the alignments closely follow elevation contours of the topography. The east channel grades eastward, and the west channel grades westward.
- The diversion channel section details at certain chainages along the alignment are provided in Drawing D006 to D007. As shown, various section details of the diversion channel were defined in order to achieve the maximum permissible velocity criteria of 2.3 m/s for the 0.01 % AEP flood event such that erosion protection material is not required (therefore, the diversion channel is earth lined). This is achieved by increasing the diversion channel base widths along the diversion channel alignment until the spillway discharge points. The diversion channels are excavated to a maximum side slope of 3H:1V. The civil design of the diversion channels was developed using the outcomes of the hydraulic modelling. Refer to Section 3.2 for a summary of the hydraulic behaviour within the diversion channels.
- The section details show a 1 m horizontal offset (i.e., bench) between the crest of the diversion channel and toe of the berm which is reserved for construction access and constructability purposes. The berm heights vary based on the flow depths and freeboard requirements as determined from the hydraulic modelling (Section 3) as well as the topography and are constructed to a maximum side slope of 2H:1V. The berm crest widths are 5 m (minimum) for access of appropriate construction equipment to achieve the minimum requirements for fill compaction.
- The excavated material from the diversion channel will be used as fill for berm construction. BHP advised that a surplus in excavation compared to fill is preferred. Considering this, as well as the alignments defined, a cut fill balance for the east diversion channel is approximately 1 to 1 (cut: 59,850 m^3 to fill: 59,550 m^3), whereas the west diversion channel is approximately 2.2 to 1 (cut: 90,850 m^3 to fill: 41,450 m^3). Refer to Table 4.1 for a summary of the material take off quantities.
- The east and west spillways at the end of the diversion channels are approximately 100 m and 250 m long, respectively. The intent is to distribute the flow along the spillway lengths (as opposed to a single concentrated discharge point) to reduce discharge velocities thereby minimising the requirement for extensive erosion protection. As shown in Section A in Drawing D006 (west spillway) and Section J in Drawing D007 (east spillway), the berms are removed along the spillway lengths and the diversion channel crests are tied into existing ground. Refer to Table 4.2 for a summary of the various diversion channel dimensions.

Table 4.1 Summary of material take off quantities

Diversion Drain Section	Cut (m^3)	Fill (m^3)
Eastern Diversion Drain	59,850	59,550
Western Diversion Drain	90,850	41,450

Table 4.2 Design dimensions of the diversion channel

Diversion channel section (approximate chainage from – to)	Base width (m)	Average cut depth (m)	Average berm height (m)
0 m – 90 m	30	1.0	No berm (west spillway)
90 m – 850 m	30	1.0	2.1
850 m – 900 m	30-20	1.5	2.2
900 m – 1310 m	20	1	2.6
1310 m – 1360 m	20-15 (gradual transition)	0.7	2.5
1360 m – 1610 m	15	0.9	2.6
1610 m – 1660 m	15-5 (gradual transition)	1	2.7
1660 m – 2676 m	5	1.8	2.8
2676 m – 2730 m	N/A[a]	N/A	1.6
2730 m – 5795 m	15	1.8	2.4
5795 m – 6055 m	15	1.2	No berm (east spillway)

a) Length of diversion channel conveyed along existing ground and berm.

b) Refer to Drawing D006 (west spillway) and Section J in Drawing D007 (east spillway) for diversion channel cross sectional detail.

4.2 Civil design recommendations

As part of the next stage of design, the following can be considered:

- Undertake a geotechnical site investigation along the confirmed diversion channel alignments to:
  - Confirm the exposed soils within the diversion channel to inform the sediment incipient velocity and whether the targeted maximum velocity of 2.4 m/s for the 0.01 % AEP flood event is appropriate for the site conditions.
  - Confirm the depth of overburden material removal to competent ground to confirm bulk earthwork quantities.
  - Confirm any presence of shallow bedrock to estimate quantities of blasting as part of bulk excavation.
  - Undertake standard compaction testing on soil samples according to Australian Standard (AS 1289.5.1.1-2017) to determine the dry density moisture relationship. As the excavated material will be used for berm fill, the outcomes can be used to inform minimum achievable compaction, or to develop a method compaction specification for construction.
- Berm crest slope should be graded to a maximum slope of 2% toward the diversion drain.
- Further develop watercourse inlets and spillways rock armouring erosion protection design accounting for the peak velocities estimated for the 1 in 10,000 AEP event which is modelled to up to approximately 2.8 m/s. An alternative erosion protection method can be placed; however, as this diversion channel will remain until post-closure, the design life of the selected erosion protection material should be considered. Should a geosynthetic material type be selected (which have a finite design life), it may require replacement with rock material as closure approaches.

5 Hydrologic and hydraulic impact assessment

The effects on the overall catchment have been assessed for (i) the baseline catchment conditions (i.e., no development) and (ii) the proposed GC OSA/pit with the surface water diversion in place. Table 5.1 presents the impacts to both the local and regional catchments.

Table 5.1 Development impacts to local and regional catchments

Parameter	Local Catchments		Regional Catchments	
	West Catchment	East Catchment	Coondewanna Catchment	Weeli Wolli Catchment
Baseline Catchment Area (km^2)	16.38	8.97	860	4,150
Loss to Catchment Area (km^2) [1]	4.7	2.5	4.7	2.5
Percentage Reduction in Catchment Area (%)	29%	28%	0.55%	0.06%

(1) Due to the internally draining OSA, as well as pit. It is assumed that the majority of rainfall that reports to the OSA will be captured within the upper layers of the OSA lifts and subsequently be lost to evaporation. Any rainfall which falls within the pit will report as runoff to the base of the pit and be pumped out of the pit subsequent to the rainfall event.

This impact assessment from this study has been carried out for the range of AEPs and has been focused on the local West and East catchments. The impacts to peak flows in the West and East catchment outlets are summarised in Table 5.2.

Table 5.2 Impacts to flow rates in the local west and east catchments

AEP	Baseline Peak Flow Rates (m^3/s)		Development Peak Flow Rates (m^3/s)		Relative Change in Peak Flow Rates (%)	
	West	East	West	East	West	East
10%	55.01	35.84	46.75	32.26	-15%	-10%
1%	187.6	110.67	123.32	77.23	-34%	-30%
1 in 10,000	278.84	157.93	175.07	108.63	-37%	-31%

As shown in Table 5.2, a reduction in peak flows can be seen across both catchments, ranging between 15% and 37% reduction for the West Catchment, and 10% and 31% reduction for the East Catchment. Note that different temporal patterns were used for each AEP. Orographic effects on rainfall should be assessed (if any) during the next stage of the study due to Mt Robinson being an elevated landform and located inland.

Due to negligible reduction of regional catchment areas, no impacts to the overall hydrologic behavior of these regional catchments are anticipated.

The impacts to velocities in the West and East catchment outlets are summarised in Table 5.3. It should be noted that as the TUFLOW model extent for the West Catchment is approximately 1 km upstream of the catchment outlet. As such, the velocities presented for the West Catchment outlet are only approximations of the velocities of at the catchment outlet. Further modelling, taking into account useable LiDAR data for the entire catchment, would be required to estimate the velocities at the catchment outlet.

Table 5.3 Impacts to velocities in the local west and east catchments

AEP	Baseline Maximum Velocities (m/s)		Development Peak Flow Velocities (m/s)		Change in Peak Velocities (%)	
	West	East	West	East	West	East
10%	1.05	1.19	1.05	1.16	-0.2%	-2%
1%	1.40	1.60	1.25	1.44	-11%	-10%
1 in 10,000 AEP	1.54	1.74	1.36	1.56	-12%	-10%

As shown in Table 5.3, a reduction in estimated velocities can be seen across both catchments. It should be noted that the estimated velocities for baseline (existing conditions) compared to development (surface water diversion) conditions are still quite comparable, meaning that the sediment transport regime of both catchments would remain largely unchanged.

5.1 Discussion

5.1.1 *Expected changes in creek characteristics*

The proposed diversions (West and East) will intercept the parallel drainage lines which report to the main creeks along the valley bottom from the Mount Robinson north slopes. These parallel drainage lines are well-defined creek lines, which generally concentrate into a single flow line before reporting to the main creeks along the valley bottom. Evidence of alluvial deposition can be seen in the aerial imagery (BHP 2021b) along the valley floor, highlighting that sediment is produced in the upper reaches of the Mount Robinson hillslopes and transported in the channels towards the valley base. Evidence of alluvial fan formation along the eastern section of the East catchment has been observed from the aerial imagery (BHP 2021b).

The proposed diversions will intercept flows from the parallel drainage lines along the Mount Robinson slope and concentrate these flows into a single flow path perpendicular to the creek lines, before discharging the flows down the hillslopes through the spillways in each drain (West and East). The drains have been designed with flat slopes to reduce the velocities within the drain as much as practically possible, thereby reducing the risk of scour in the drains, yet still maintaining high enough velocities to mimic the velocities (and therefore sediment transport capacity) of the parallel drainage lines. The drains have also been designed to release the flows over as large an area as feasibly possible, thereby diffusing the flows as much as possible over the hillslope. The parallel drainage lines along the Mount Robinson slope are well-defined and confined to already established gullies, and so there is no need to reproduce a meandering system with the drain.

Although it is possible that the incorporation of the drains will reduce sediment transport to the main valley floor, the impact to sediment transport capacity is expected to be low.

5.1.2 *Potential unmitigated (residual) impacts to the hydrologic regimes*

The following residual impacts have been identified:

- Scour along the southern embankment of the western section of the OSA (in the West Catchment) in high-energy (low-frequency) flow events. The GC OSA during closure phase will be protected with 1 m thick rock armour.
- Areas of ponding against the northern toe of the OSA.
- Ponded areas along the southern toe of the eastern section of the OSA (in the East Catchment), expected in high and low-frequency events.

As such, there is some inherent uncertainty in the predictions. However, this uncertainty has been considered through the use of freeboard in the designs, and through the use of professional judgement in the selection of hydrologic and hydraulic parameters.

Further hydraulic modelling work in support of the Detailed Design phase (DPS) should consider sensitivity assessments of key hydrologic and hydraulic parameters to ensure that the full range of uncertainty (within reason) is captured.

5.1.3 Risk to environmental values should the predictions be incorrect

The largest risk to the downstream receptors is an increased transport of sediment to the Coondewanna Flats. However, this risk is offset by the following considerations:

- Flow to the Coondewanna Flats from the West Catchment takes place through existing culverts under the Great Northern Highway, which will act as a natural attenuator of larger (likely > 20%AEP) events. Sediment will likely be deposited in the flat area upstream of the culverts. The flow attenuation from these culverts for low-frequency events will be reduced, and as such it is key that any risk of scour within the catchment be reduced as much as practically possible.
- The diversions have been designed to reduce risk of scour, whether within the drain or along the embankments of the OSA, as much as practically possible for all events.

No specific mitigation or contingency measures have been considered, apart from the surface water management infrastructure already proposed. However, continued monitoring of the system will be critical during operation of the mine. This will ensure that any required remedial actions are carried out in a timely manner.

6 Monitoring and maintenance considerations

As the diversion channels will be in place throughout the operation, closure and post-closure phases, the following should be considered in the monitoring and maintenance plan for these structures:

- The diversion channel alignments should be inspected on an annual basis, as a minimum, particularly prior to the onset of the wet season. The diversion channels' inspections should also be undertaken after large rainfall events to document the following:
  - Signs of erosion and scour, or worsened erosion and scour, within the diversion channel and inlet locations of upstream watercourses due to the large rainfall event, which may require repair and maintenance to restore conveyance capacity of the design peak flow.
  - Signs of eroded, or slumped, berm material compromising the containment capacity of the peak flow being conveyed along the diversion channel. Restoration of any failed berm areas should be undertaken immediately after a rainfall event.
- Annual inspection should also identify any established vegetation within the diversion channel that may potentially obstruct flow or may be loosened causing debris conveyance to the spillway locations. Dislodged vegetation may cause blockage at the spillways causing uncontrolled upstream overtopping. Large established vegetation such as shrubs or trees should be removed.
- Monitoring sediment accumulation along the diversion channel inverts should also be undertaken on annual basis, as a minimum, to ensure the minimum channel depths are still achieved prior to the onset of any large rainfall event. Should sediment accumulation cause a reduction in the diversion channel depths, removal may be required.
- Monitor for animal activity such as established nesting, or dead animals, within the diversion channel invert that may potentially obstruct flow. These should be removed immediately upon identification.
- Infrastructure downstream of the spillway discharge locations should be monitored for progressive erosion or flooding. Erosion protection or localised surface water management should be implemented if erosion or flooding occurs during frequent rainfall events.

Access to continue monitoring and maintenance of these structures per the above items should remain into closure and post-closure. Inspections should continue, but could be converted to event-based monitoring rather than an annual basis. Event-based monitoring and the associated hydrological risk should be approved by BHP to form part of the final monitoring and maintenance plan. Frequency of monitoring may be adjusted into post-closure if deficiencies are identified. If subsequent inspections confirm unacceptable conditions, corrective repairs or modifications should be implemented, so the structure's performance becomes acceptable again.

7 Conclusions and recommendations

7.1 Conclusions

A surface water impact assessment was undertaken, along with diversion channel designs, for the 1 in 10,000, 1% and 10% AEP events to meet the design criteria as detailed in the BoD (refer to Appendix A). Three climate change scenarios for SSP 4.5 and SSP 8.5 for the medium term (year 2041 to 2060) and long term (year 2081 to 2100) were also analysed to understand the potential incremental impact and hydrological risk during the post-closure phase.

The existing conditions (baseline) scenario was established to represent the study area's existing flooding conditions for 1 in 10,000, 1%, and 10% AEP events. The critical duration for the baseline catchments ranged between 3 to 6 hours.

The design scenario included the proposed GC OSA and the pit area and were developed considering operations and post-closure phases. The operations scenario was assessed for 10% and 1% AEP event, whereas the 1 in 10,000 AEP event was tested to understand the flooding behaviour and the conveyance capacity of the diversion channel and the containment sizing of the associated berm for the post-closure scenario. The critical duration for the design scenarios ranged between 15 minutes to 3 hours throughout the study area.

Under all design scenarios, the model results revealed the following:

- The diversion channel alignments were designed to enable a 100 m standoff of all infrastructures from the Mount Robinson Heritage exclusion area and no land disturbance was required within this area.
- The diversion channels in combination with the associated berm could divert the contributing flow from the Mount Robinson with velocities less than 2.3 m/s for 1% and 10% AEP events. The 1 in 10,000 AEP event demonstrates higher velocities than 2.3 m/s near the discharge locations on the east and west diversion channels.
- Diverting the flow from the Mount Robinson via the east and west of the diversion channel has made several facilities downstream more vulnerable, including the access roads that connect the facilities internally. However, the diversion channel largely diverts peak flows and velocities still providing flood protection for these areas. Localised erosion may be experienced at areas of slightly higher velocities; therefore, some maintenance may be required based on inspections for storm events up to and including the 1 in 10,000 AEP.
- As shown in Table 3.3, the incremental impact due to climate change for the long-term time horizon when considering the effect on the diversion channel design into the post-closure phase is potentially an increased berm height of as much as approximately 300 mm for SSP 4.5, and as much as approximately 500 mm for SSP 8.5. Increase in velocities are also expected; however, may potentially be addressed during the next stage of design by adjusting the hydraulic sizing of the diversion channel.

7.2 Recommendations

For future hydraulic model development and the next stage of the diversion channel designs, the following recommendations are proposed:

- Complete soil infiltration tests to obtain the site's storm loss data. Including the site's storm loss data removes the uncertainty associated with using loss values taken from only a few literature sources.
- Aerial imagery and flood model results indicate the presence of culverts under the access roads downstream of the diversion channels which connects the various facilities within the South Flank mine site. Although the current results are unlikely to changes, it is recommended to include these details, so that the model would further improve the flood result accuracy.

- The GC OSA toe drains should be sized to accommodate the flood water accumulated to the south edge of the GC OSA boundary and should be conveyed away from the GC OSA boundary to the east and west directions respectively.
- Hydraulic modelling shows flood water intercepted and ponds locally at the edges of the Pit and GC OSA on the north side. During the next stage of the study, it is recommended to implement local surface water management as a mitigation and prevent flood impacts to the Pit and GC OSA.
- Consider orographic effects on rainfall during the next stage of the study due to Mt Robinson being an elevated landform and located inland.
- The civil design recommendations are summarised in Section 4.2.
- Undertake a climate change resilience and hydrological risk assessment on the diversion channel design to determine whether the next stage of the design and the associated increased costs is warranted (i.e., increased berm height, implementation of erosion protection material, change in hydraulic sizing to reduce velocities, etc.).

8 Limitations

This Report is provided by WSP Australia Pty Limited (WSP) for BHP in response to specific instructions from the Client and in accordance with WSP's proposal.

8.1 Permitted purpose

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (Permitted Purpose).

8.2 Qualifications and assumptions

The services undertaken by WSP in preparing this Report were limited to those specifically detailed in the Report and are subject to the scope, qualifications, assumptions, and limitations set out in the Report or otherwise communicated to the Client.

Except as otherwise stated in the Report and to the extent that statements, opinions, facts, conclusion and / or recommendations in the Report (Conclusions) are based in whole or in part on information provided by the Client and other parties identified in the report (Information), those Conclusions are based on assumptions by WSP of the reliability, adequacy, accuracy, and completeness of the Information and have not been verified. WSP accepts no responsibility for the Information.

WSP has prepared the Report without regard to any special interest of any person other than the Client when undertaking the services described in the Agreement or in preparing the Report.

8.3 Use and reliance

This Report should be read in its entirety and must not be copied, distributed, or referred to in part only. The Report must not be reproduced without the written approval of WSP. WSP will not be responsible for interpretations or conclusions drawn by the reader. This Report (or sections of the Report) should not be used as part of a specification for a project or for incorporation into any other document without the prior agreement of WSP.

WSP is not (and will not be) obliged to provide an update of this Report to include any event, circumstance, revised Information, or any matter coming to WSP's attention after the date of this Report. Data reported and Conclusions drawn are based solely on information made available to WSP at the time of preparing the Report. The passage of time; unexpected variations in ground conditions; manifestations of latent conditions; or the impact of future events (including (without limitation) changes in policy, legislation, guidelines, scientific knowledge; and changes in interpretation of policy by statutory authorities); may require further investigation or subsequent re-evaluation of the Conclusions.

This Report can only be relied upon for the Permitted Purpose and may not be relied upon for any other purpose. The Report does not purport to recommend or induce a decision to make (or not make) any purchase, disposal, investment, divestment, financial commitment or otherwise. It is the responsibility of the Client to accept (if the Client so chooses) any Conclusions contained within the Report and implement them in an appropriate, suitable, and timely manner.

In the absence of express written consent of WSP, no responsibility is accepted by WSP for the use of the Report in whole or in part by any party other than the Client for any purpose whatsoever. Without the express written consent of WSP, any use which a third party makes of this Report or any reliance on (or decisions to be made) based on this Report is at the sole risk of those third parties without recourse to WSP. Third parties should make their own enquiries and obtain independent advice in relation to any matter dealt with or Conclusions expressed in the Report.

8.4 Disclaimer

No warranty, undertaking or guarantee whether expressed or implied, is made with respect to the data reported or the Conclusions drawn. To the fullest extent permitted at law, WSP, its related bodies corporate and its officers, employees and agents assumes no responsibility and will not be liable to any third party for, or in relation to any losses, damages or expenses (including any indirect, consequential or punitive losses or damages or any amounts for loss of profit, loss of revenue, loss of opportunity to earn profit, loss of production, loss of contract, increased operational costs, loss of business opportunity, site depredation costs, business interruption or economic loss) of any kind whatsoever, suffered on incurred by a third party.

Bibliography

- Ball, J., Babister, M., Nathan, R., Weeks, W., Weinmann, E., Retallick, M., & Testoni, I. (2019). *The Australian Rainfall and Runoff: A guide to flood estimation (ARR).* Commonwealth of Australia (Geoscience Australia)
- Bureau of Meteorology. (2016). Intensity frequency duration (IFD)
- Chow, V. T. (1957). Open Channel Hydraulics. Mcgraw-Hill Book Co.
- WSP Golder. 2022. South Flank Grand Central Overburden Storage Area. Surface Water Impact Assessment. WSP document no.: 241
- WSP. 2024. Update of South Flank Grand Central Surface Water Impact Assessment. WSP document no.: PS209088-WSP-HYD-MEM-001_RevA_BoD_South Flank GC OSA. Dated 5 March 2024.
- BHP. 2021b. "South_Flank_Aerial_Imagery.tif". Provided to WSP Golder, October 2021
- BHP. 2023. "WAIO_South.xlsx". Provided to WSP, 2023
- BHP.2023a. "GC_OSA_2022_LiDAR.tif" and "GC_OSA_2022_LiDAR_Part_2.tif". Provided to WSP, November 2023BHP Billiton Iron Ore (BHP). 2014. WAIO Standards – Design Criteria – Earthworks and Drainage. Document No. DESC-000-C-00002/1
- Advisian. 2023. South Flank R Deposit Haul Road Hydrology SPS.
- Department of Water and Environmental Regulation (Government of Western Australia). 1986. *Environmental Protection Act 1986*.
- Visser J B, Kim S, Wasko C, Nathan R, Sharma A. 2022. The Impact of Climate Change on Operational Probable Maximum Precipitation Estimates
- Department of Climate Change, Energy, the Environment and Water (Australian Government). 2023. *Draft Update to the Climate Change Considerations Chapter in Australian Rainfall and Runoff: A guide to Flood Estimation*. *Book 1. Chapter 6. Climate Change Considerations*

Appendix A

Basis of design

DESIGN DRAWINGS FOR

DIVERSION CHANNEL
SURFACE WATER IMPACT ASSESSMENT

FOR

BHP SOUTH FLANK GRAND CENTRAL

GENERAL NOTES

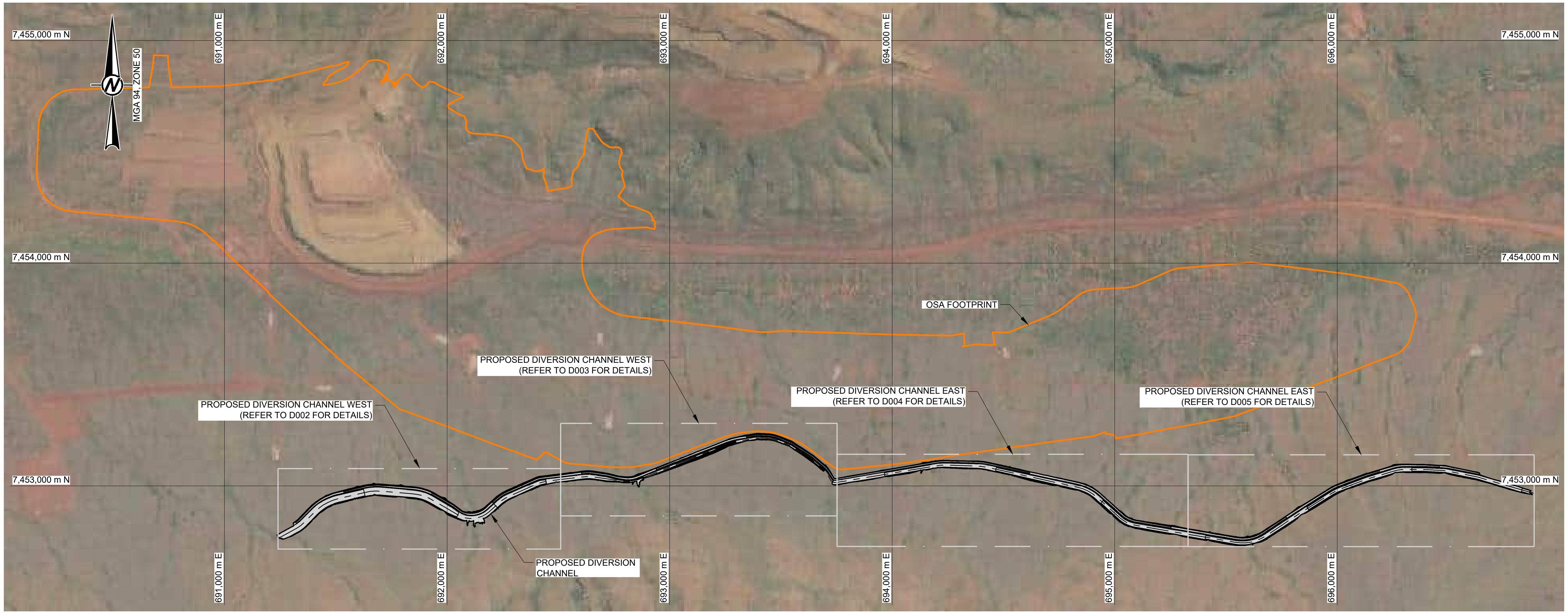
1. ALL LEVELS ARE IN METRES TO AUSTRALIA HEIGHT DATUM (AHD).
2. ALL CO-ORDINATES ARE IN METRES TO MAP GRID AUSTRALIA (MGA 94, ZONE 50).
3. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
4. DIMENSIONS SHALL NOT BE SCALED OFF DRAWINGS.
5. ALL DRAWINGS ARE A3 SHEET SIZE.
6. DRAWINGS SHOULD BE PRINTED IN COLOUR TO DISPLAY CORRECTLY.

REFERENCES

1. AERIAL IMAGE REPRODUCED WITH PERMISSION FROM www.bing.com/maps (© 2020 MICROSOFT CORPORATION) IN ACCORDANCE WITH THE SPECIAL SERVICES TERMS FOR AUTODESK® LIVE MAP DATA.
2. SURVEY DATA PROVIDED BY BHP, DATED 2022.

DRAWING LIST

DRAWING No.	DRAWING TITTLE	REVISION
D001	GENERAL ARRANGEMENT AND DRAWING LIST	0
D002	DIVERSION CHANNEL WEST LAYOUT PLAN AND LONGITUDINAL SECTION (1 OF 2)	0
D003	DIVERSION CHANNEL WEST LAYOUT PLAN AND LONGITUDINAL SECTION (2 OF 2)	0
D004	DIVERSION CHANNEL EAST LAYOUT PLAN AND LONGITUDINAL SECTION (1 OF 2)	0
D005	DIVERSION CHANNEL EAST LAYOUT PLAN AND LONGITUDINAL SECTION (2 OF 2)	0
D006	DIVERSION CHANNEL TYPICAL SECTIONS (1 OF 2)	0
D007	DIVERSION CHANNEL TYPICAL SECTIONS (2 OF 2)	0



DRAFT

NOT FOR CONSTRUCTION

DIVERSION CHANNEL EAST SECTION AT CHAINAGE

SCALE 1:20,000

0 500 1,000

1:20,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

CLIENT
BHP WAIO

CONSULTANT
wsp
MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

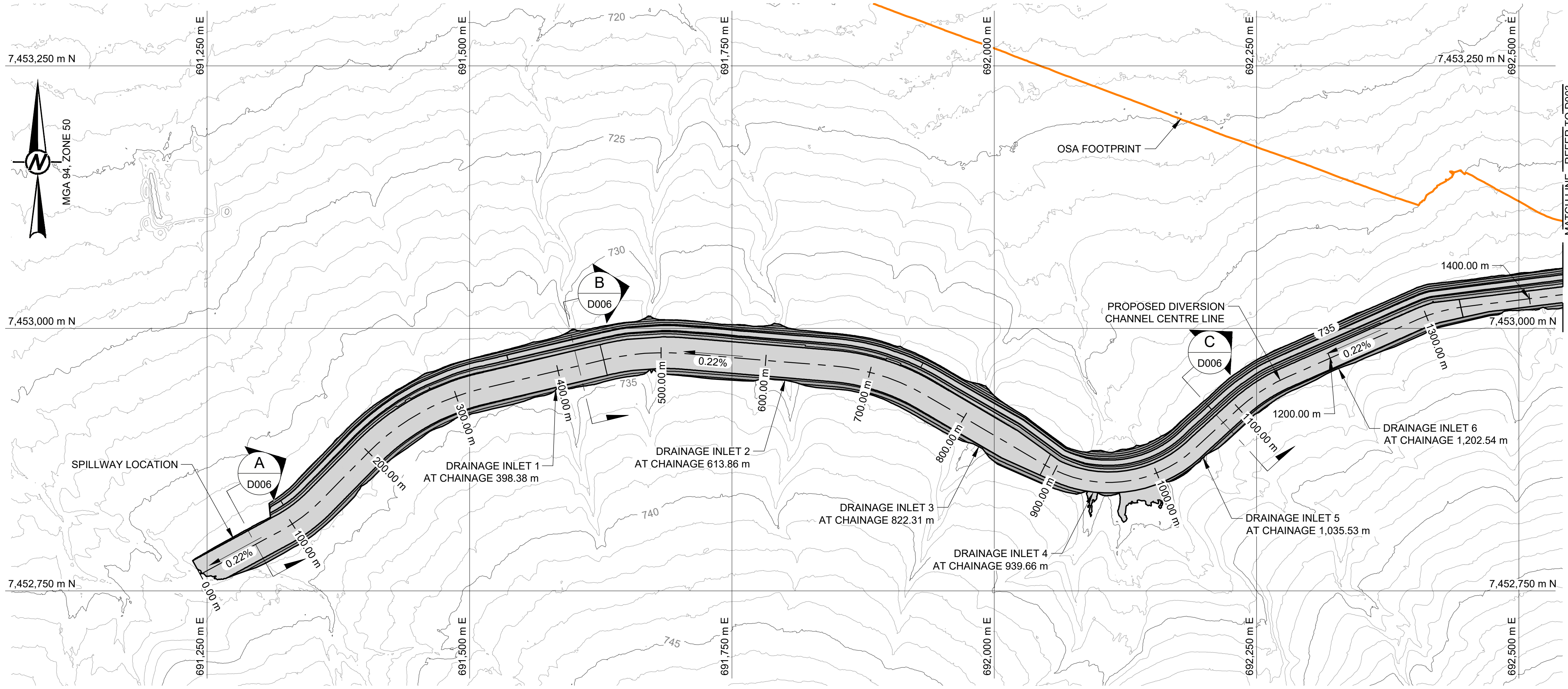
TITLE
GENERAL ARRANGEMENT AND DRAWING LIST

PROJECT NO.	DOCUMENT No.	REV.		DRAWING
PS209088	003-R	0	1 of 7	D001

Path: \\golder.gds\gap\Perth\Geomatics\BHP_WAIO\South_Flank\99_PROJECTS\PS209088_Surface_Water_Impact_Assessment\02_PRODUCTION\FIGURES\003-R\ | File Name: PS209088-003-R-F001-F007_Rev0.dwg | Last Edited By: aug506882 Date: 2024-06-04 Time:2:49:57 PM | Printed By: AUCJ506882 Date: 2024-07-10 Time:5:00:56 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

0 25 mm

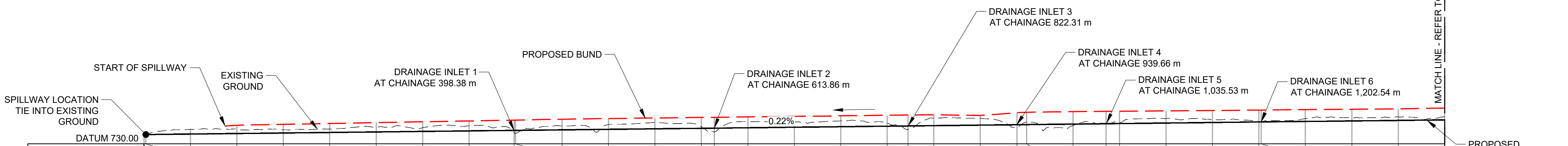


LEGEND

- 500 — EXISTING TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)
- 500 — DESIGN TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)
- OSA FOOTPRINT

DIVERSION CHANNEL WEST - LAYOUT PLAN (CH:00 m TO CH:1,400 m)

SCALE 1:5,000



PROPOSED DIVERSION CHANNEL		732.00	732.11	732.22	732.34	732.45	732.56	732.67	732.79	732.90	732.90	733.01	733.12	733.24	733.35	733.38	733.46
PROPOSED BUND				733.97	734.26	734.46	734.61	734.81	734.98	735.13	735.14	735.30	735.45	735.56	735.69	735.73	735.81
EXISTING GROUND	731.83	732.00	733.13	733.12	733.01	733.16	733.58	733.47	733.87	732.46	732.28	733.87	734.14	734.58	733.66	732.55	734.79
CUT AND FILL DEPTH (m)		0.00	-1.02	-0.89	-0.67	-0.72	-1.02	-0.80	-1.08	-0.44	0.62	-0.85	-1.01	-1.34	-0.31	-0.83	-1.33
CHAINAGE	0.00	2.03	50,00	100.00	150,00	200.00	250,00	300.00	350,00	398.38	400.00	450,00	500.00	550,00	600.00	613.86	650,00

PROPOSED DIVERSION CHANNEL	733.57	733.69	733.80	733.85	733.91	734.02	734.11	734.14	734.25	734.33	734.36	734.47	734.59	734.70	734.70	734.81	734.92	735.04	735.15
PROPOSED BUND	735.92	736.02	736.13	736.18	736.24	736.13	736.64	736.78	736.89	736.94	736.96	737.03	737.15	737.25	737.25	737.34	737.43	737.52	737.68
EXISTING GROUND	734.74	734.94	734.45	733.11	735.49	735.48	733.50	734.70	733.92	734.52	734.65	735.46	735.18	734.76	734.75	735.43	735.60	735.76	735.82
CUT AND FILL DEPTH (m)	-1.17	-1.25	-0.65	-0.74	-1.57	-1.46	-0.62	-0.56	0.32	0.20	-0.28	-0.99	-0.59	-0.07	0.05	-0.61	-0.67	-0.73	-0.68
CHAINAGE	700.00	750,00	800.00	822.31	850,00	900.00	939.66	950,00	1,000.00	1,035.53	1,050,00	1,100.00	1,150,00	1,200.00	1,202.54	1,250,00	1,300.00	1,350,00	1,400.00

DIVERSION CHANNEL WEST - LONGITUDINAL SECTION (CH:00 m TO CH:1,400 m)

HOR. SCALE 1:5,000
VER. SCALE 1:2,500

0 50 100
1:2,500 METRES

0 100 200
1:5,000 METRES

DRAFT

NOT FOR CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

CLIENT
BHP WAIO

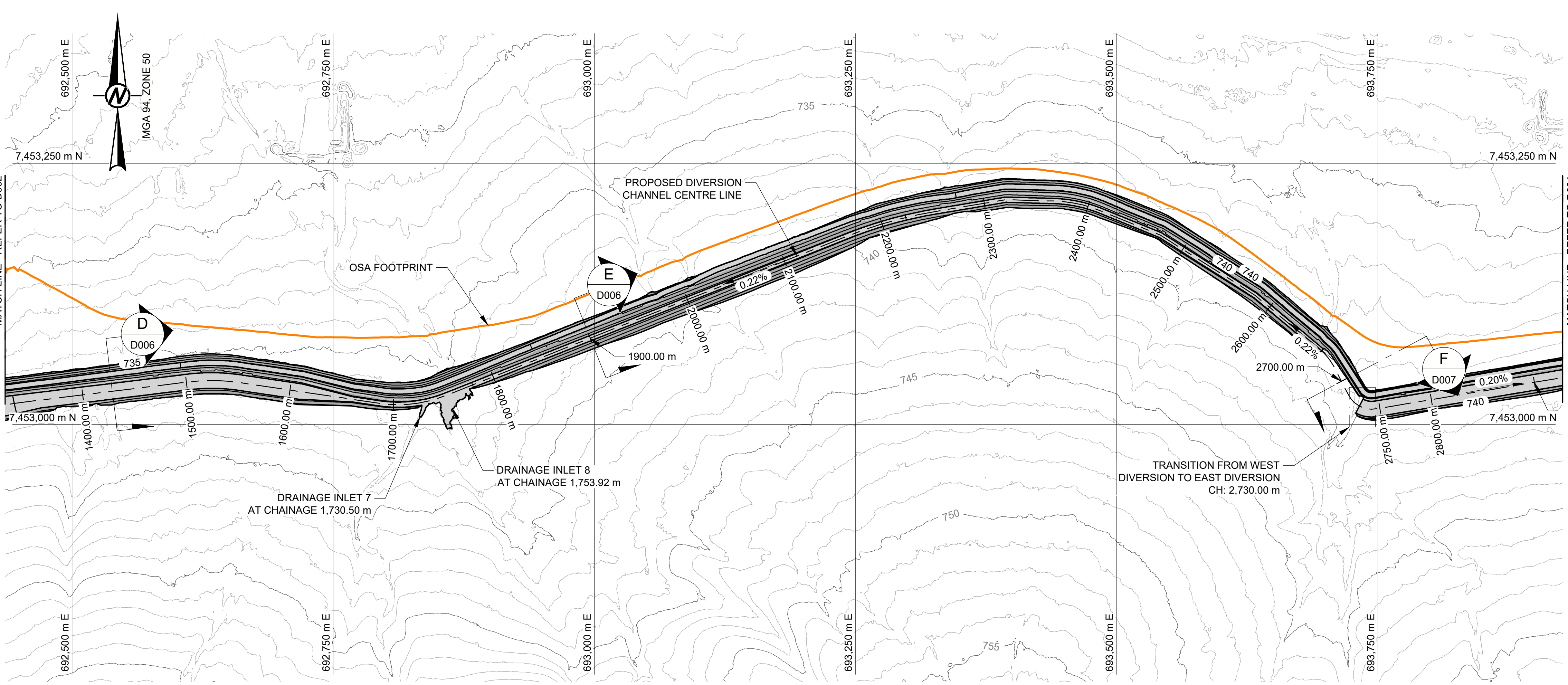
CONSULTANT
wsp

MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

TITLE
DIVERSION CHANNEL WEST
LAYOUT PLAN AND LONGITUDINAL SECTION (1 OF 2)

PROJECT NO.	DOCUMENT No.	REV.		DRAWING
PS209088	003-R	0	2 of 7	D002



LEGEND

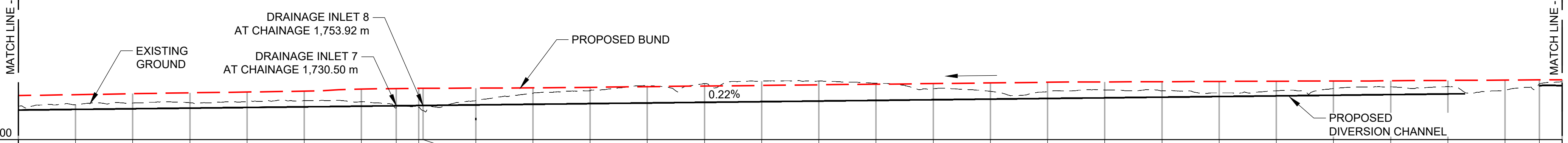
500 — EXISTING TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)

500 — DESIGN TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)

OSA FOOTPRINT

DIVERSION CHANNEL WEST - LAYOUT PLAN (CH:1,400 TO 2,750 m)

SCALE 1:5,000



CHAINAGE	PROPOSED DIVERSION CHANNEL	PROPOSED BUND	EXISTING GROUND	CUT AND FILL DEPTH (m)
1,400.00	735.15	735.15	735.82	-0.68
1,450.00	735.26	735.26	736.07	-0.81
1,500.00	735.37	735.37	736.36	-0.98
1,550.00	735.49	735.49	736.43	-0.94
1,600.00	735.60	735.60	736.62	-1.02
1,650.00	735.71	735.71	736.79	-1.08
1,700.00	735.82	735.82	736.60	-0.78
1,730.50	735.89	735.89	735.54	-0.35
1,750.00	735.94	735.94	735.63	0.31
1,753.92	735.94	735.94	735.07	-0.88
1,800.00	736.05	736.05	736.81	-0.76
1,850.00	736.16	736.16	738.10	-1.94
1,900.00	736.27	736.27	738.54	-2.27
1,950.00	736.38	736.38	739.42	-3.03
2,000.00	736.50	736.50	739.76	-3.26
2,050.00	736.61	736.61	740.20	-3.59
2,100.00	736.72	736.72	740.23	-3.51
2,150.00	736.83	736.83	739.84	-3.00
2,200.00	736.95	736.95	738.85	-1.90
2,250.00	737.06	737.06	738.42	-1.36
2,300.00	737.17	737.17	738.37	-1.20
2,350.00	737.28	737.28	738.65	-1.37
2,400.00	737.40	737.40	738.50	-1.10
2,450.00	737.51	737.51	738.19	-0.68
2,500.00	737.62	737.62	738.51	-0.89
2,550.00	737.73	737.73	738.91	-1.18
2,600.00	737.85	737.85	739.19	-1.35
2,650.00	737.96	737.96	739.24	-1.28
2,700.00			738.63	
2,730.00	739.39	739.39	739.73	0.34
2,750.00	739.43	739.43	740.10	0.67

DIVERSION CHANNEL WEST - LONGITUDINAL SECTION (CH:1,400 TO 2,750 m)

HOR. SCALE 1:5,000
VER. SCALE 1:2,500

0 50 100
1:2,500 METRES

0 100 200
1:5,000 METRES

DRAFT

NOT FOR CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

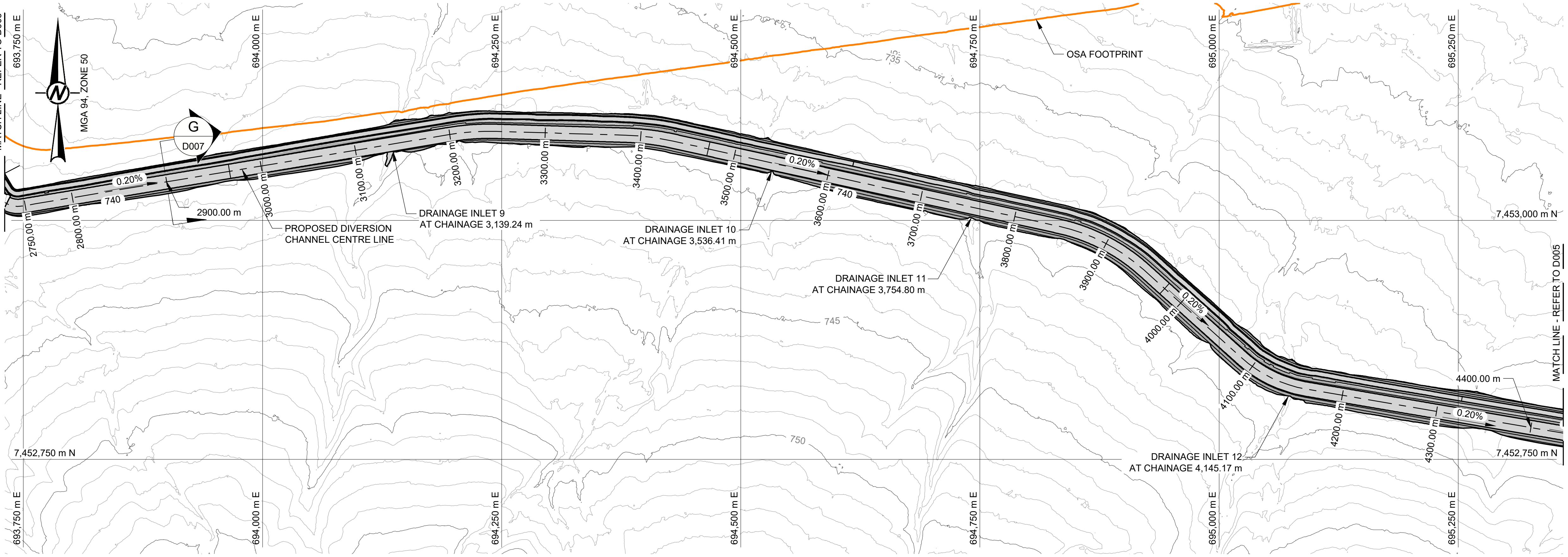
CLIENT
BHP WAIO

CONSULTANT
wsp
MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

TITLE
DIVERSION CHANNEL WEST LAYOUT PLAN AND LONGITUDINAL SECTION (2 OF 2)

PROJECT NO. PS209088 | DOCUMENT No. 003-R | REV. 0 | 3 of 7 | DRAWING D003

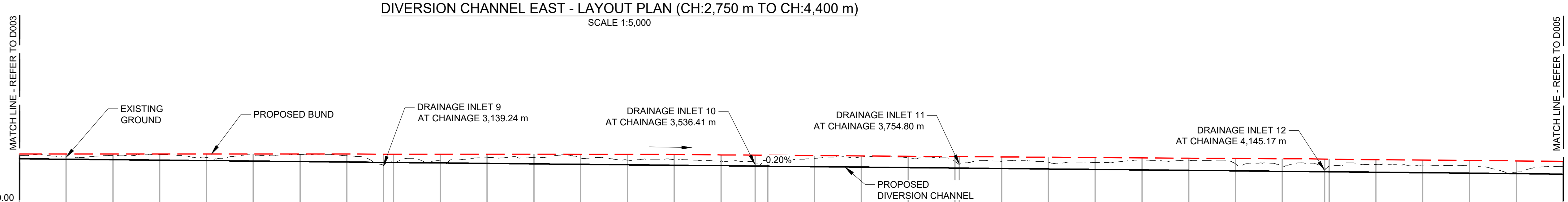


LEGEND

500 (thin line)	EXISTING TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)
500 (thick line)	DESIGN TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)
(orange line)	OSA FOOTPRINT

DIVERSION CHANNEL EAST - LAYOUT PLAN (CH:2,750 m TO CH:4,400 m)

SCALE 1:5,000



PROPOSED DIVERSION CHANNEL	739.43	739.33	739.23	739.13	739.03	738.93	738.83	738.74	738.66	738.64	738.54	738.44	738.34
PROPOSED BUND	740.45	740.44	740.44	740.44	740.44	740.43	740.43	740.43	740.43	740.43	740.42	740.41	740.40
EXISTING GROUND	740.10	739.78	740.14	740.27	739.70	740.16	740.32	740.05	737.98	738.75	739.12	739.65	739.70
CUT AND FILL DEPTH (m)	0.67	-0.45	-0.91	-1.14	-0.67	-1.23	-1.48	-1.32	-0.68	-0.11	-0.58	-1.21	-1.36
CHAINAGE	2,750.00	2,800.00	2,850.00	2,900.00	2,950.00	3,000.00	3,050.00	3,100.00	3,139.24	3,150.00	3,200.00	3,250.00	3,300.00

PROPOSED DIVERSION CHANNEL	738.24	738.14	738.04	737.94	737.87	737.85	737.75	737.65	737.55	737.45	737.44	737.35	737.25
PROPOSED BUND	740.39	740.38	740.33	740.25	740.15	740.12	740.03	739.97	739.91	739.85	739.84	739.77	739.71
EXISTING GROUND	739.64	739.13	739.23	738.95	738.31	739.13	739.51	739.82	739.69	738.90	738.30	738.90	738.68
CUT AND FILL DEPTH (m)	-1.40	-0.99	-1.18	-1.01	0.43	-1.28	-1.76	-2.17	-2.14	-1.45	0.86	-1.55	-1.43
CHAINAGE	3,350.00	3,400.00	3,450.00	3,500.00	3,536.41	3,550.00	3,600.00	3,650.00	3,700.00	3,750.00	3,754.80	3,800.00	3,850.00

PROPOSED DIVERSION CHANNEL	737.15	737.05	736.96	736.86	736.76	736.67	736.66	736.56	736.46	736.36	736.26	736.16
PROPOSED BUND	739.65	739.59	739.54	739.49	739.44	739.36	739.35	739.20	739.11	739.04	738.96	738.89
EXISTING GROUND	738.62	739.19	739.14	738.32	737.93	737.01	737.92	738.18	738.08	737.92	736.57	737.82
CUT AND FILL DEPTH (m)	-1.47	-2.14	-2.18	-1.46	-1.17	0.35	-1.26	-1.62	-1.62	-1.56	-0.31	-1.65
CHAINAGE	3,900.00	3,950.00	4,000.00	4,050.00	4,100.00	4,145.17	4,150.00	4,200.00	4,250.00	4,300.00	4,350.00	4,400.00

DIVERSION CHANNEL EAST - LONGITUDINAL SECTION (CH:2,750 m TO CH:4,400 m)

HOR. SCALE 1:5,000
VER. SCALE 1:2,500

0 50 100
1:2,500 METRES

0 100 200
1:5,000 METRES

DRAFT

NOT FOR CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

CLIENT
BHP WAIO

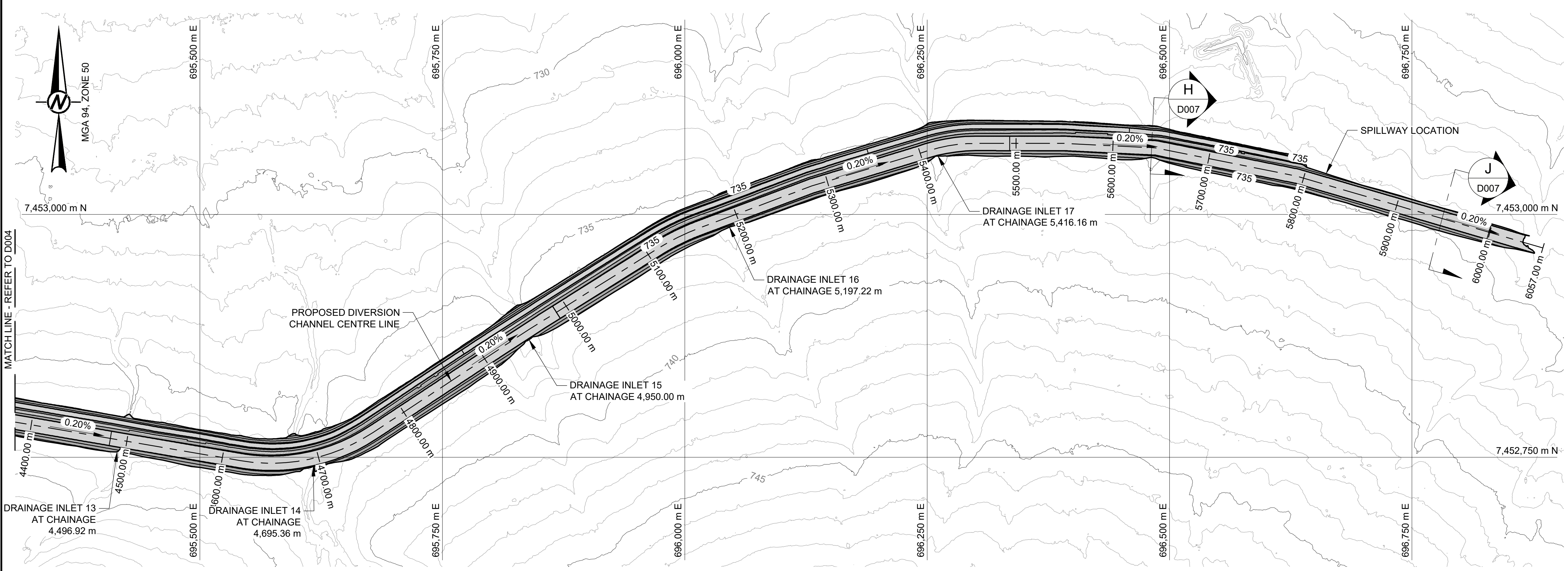
CONSULTANT
WSP

MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

TITLE
DIVERSION CHANNEL EAST LAYOUT PLAN AND LONGITUDINAL SECTION (1 OF 2)

PROJECT NO.	DOCUMENT No.	REV.		DRAWING
PS209088	003-R	0	4 of 7	D004

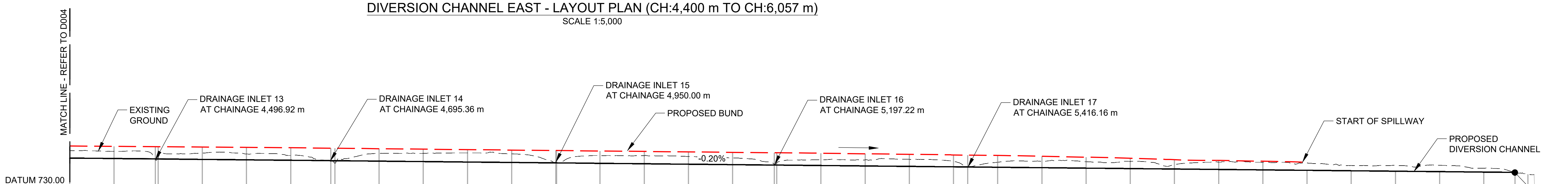


LEGEND

- 500 — EXISTING TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)
- 500 — DESIGN TOPOGRAPHICAL CONTOUR AND ELEVATION (mAHD)

DIVERSION CHANNEL EAST - LAYOUT PLAN (CH:4,400 m TO CH:6,057 m)

SCALE 1:5,000



CHAINAGE	4,400.00	4,450.00	4,496.92	4,500.00	4,550.00	4,600.00	4,650.00	4,695.36	4,700.00	4,750.00	4,800.00	4,850.00	4,900.00	4,950.00	5,000.00	5,050.00	5,100.00	5,150.00	5,197.22	5,200.00
PROPOSED DIVERSION CHANNEL	736.16	736.06	735.97	735.97	735.87	735.77	735.67	735.58	735.57	735.47	735.37	735.27	735.17	735.08	734.98	734.88	734.78	734.68	734.59	734.58
PROPOSED BUND	738.89	738.81	738.74	738.74	738.65	738.57	738.50	738.41	738.40	738.28	738.17	738.07	737.97	737.88	737.77	737.67	737.56	737.47	737.39	737.39
EXISTING GROUND	737.82	737.69	735.83	736.33	737.29	737.10	736.75	735.71	734.98	737.22	737.24	737.34	737.12	735.14	736.70	736.70	736.53	736.18	734.72	735.12
CUT AND FILL DEPTH (m)	-1.65	-1.63	-0.14	-0.36	-1.42	-1.33	-1.08	0.13	0.59	-1.75	-1.87	-2.06	-1.95	-0.07	-1.72	-1.82	-1.75	-1.50	0.13	-0.54

CHAINAGE	5,250.00	5,300.00	5,350.00	5,400.00	5,416.16	5,450.00	5,500.00	5,550.00	5,600.00	5,650.00	5,700.00	5,750.00	5,800.00	5,850.00	5,900.00	5,950.00	6,000.00	6,035.34	6,050.00	6,057.37
PROPOSED DIVERSION CHANNEL	734.48	734.38	734.28	734.19	734.15	734.09	733.99	733.89	733.79	733.69	733.59	733.49	733.39	733.29	733.20	733.10	733.00	732.93		
PROPOSED BUND	737.26	737.14	737.00	736.87	736.83	736.77	736.56	736.37	736.11	735.80	735.63	735.46								
EXISTING GROUND	735.79	735.76	735.87	735.42	734.02	735.23	735.43	735.33	735.41	734.68	735.23	735.21	735.04	734.49	734.49	734.55	733.88	732.93	732.50	732.50
CUT AND FILL DEPTH (m)	-1.31	-1.37	-1.59	-1.23	-0.14	-1.15	-1.44	-1.45	-1.62	-0.99	-1.64	-1.72	-1.65	-1.20	-1.29	-1.45	-0.88	0.00		

SPILLWAY LOCATION TIE INTO EXISTING GROUND

DIVERSION CHANNEL EAST - LONGITUDINAL SECTION (CH:4,400 m TO CH:6,057 m)

HOR. SCALE 1:5,000
VER. SCALE 1:2,500

0 50 100
1:2,500 METRES

0 100 200
1:5,000 METRES

DRAFT

NOT FOR CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

CLIENT
BHP WAIO

CONSULTANT
wsp
MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

TITLE
DIVERSION CHANNEL EAST LAYOUT PLAN AND LONGITUDINAL SECTION (2 OF 2)

PROJECT NO.	DOCUMENT No.	REV.		DRAWING
PS209088	003-R	0	5 of 7	D005

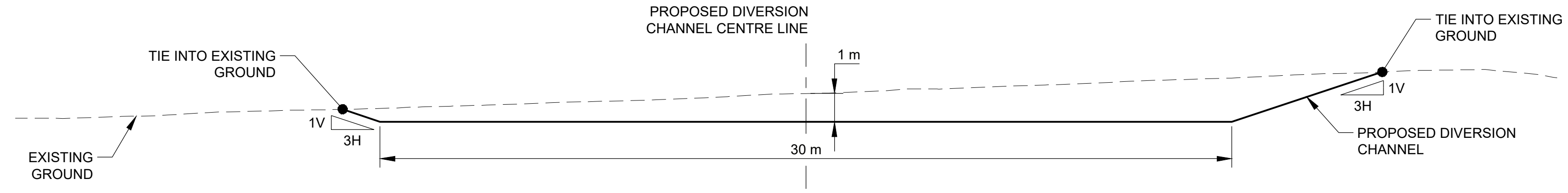
LEGEND

— — — EXISTING GROUND

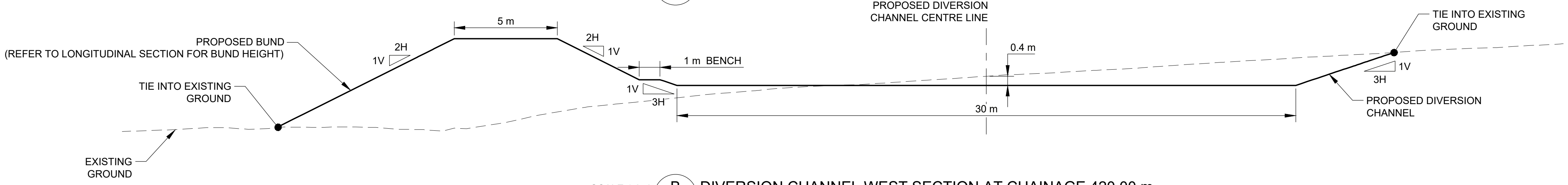
——— DESIGN

GENERAL NOTE(S):

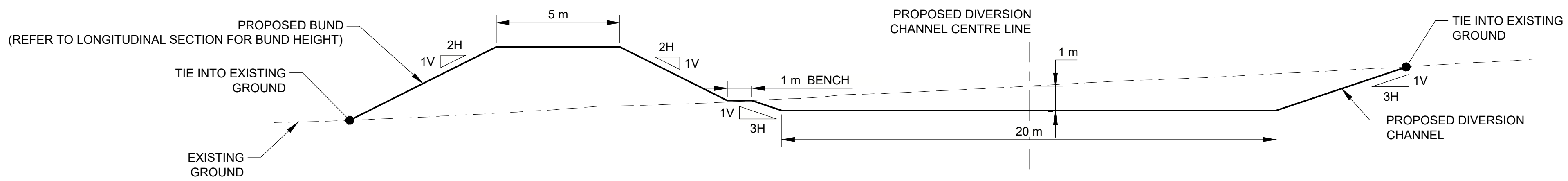
1. REFER TO DRAWINGS D002 TO D005 FOR PROPOSED BUND HEIGHTS ALONG DIVERSION ALIGNMENTS.



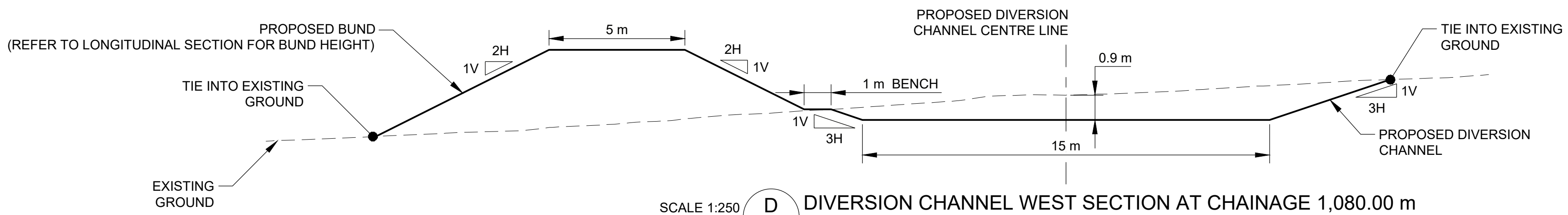
SCALE 1:250 A D002 WEST SPILLWAY SECTION AT CHAINAGE 60.00 m



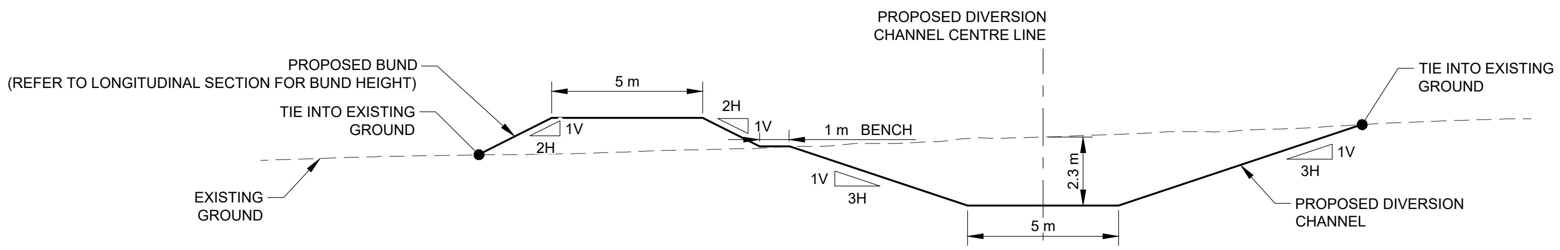
SCALE 1:250 B D002 DIVERSION CHANNEL WEST SECTION AT CHAINAGE 420.00 m



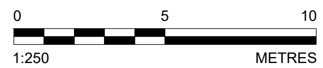
SCALE 1:250 C D002 DIVERSION CHANNEL WEST SECTION AT CHAINAGE 980.00 m



SCALE 1:250 D D003 DIVERSION CHANNEL WEST SECTION AT CHAINAGE 1,080.00 m



SCALE 1:250 E D003 DIVERSION CHANNEL WEST SECTION AT CHAINAGE 1,900.00 m



DRAFT

NOT FOR CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

CLIENT
BHP WAIO

CONSULTANT
wsp
MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

TITLE
DIVERSION CHANNEL
TYPICAL SECTIONS (1 OF 2)

PROJECT NO.	DOCUMENT No.	REV.		DRAWING
PS209088	003-R	0	6 of 7	D006

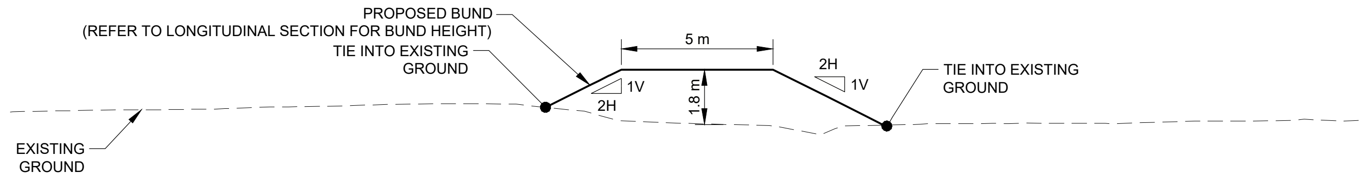
LEGEND

— — — — EXISTING GROUND

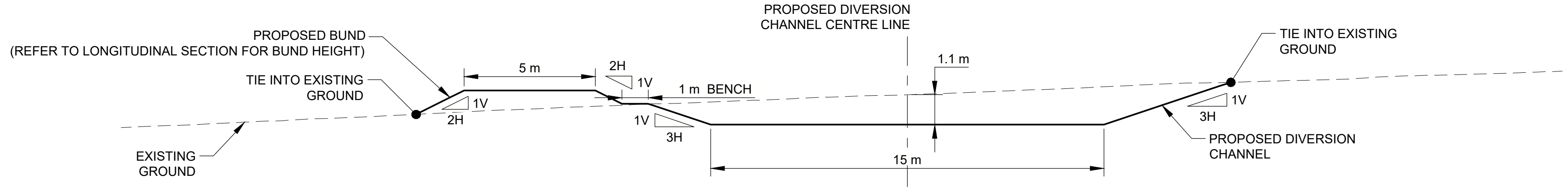
———— DESIGN

GENERAL NOTE(S):

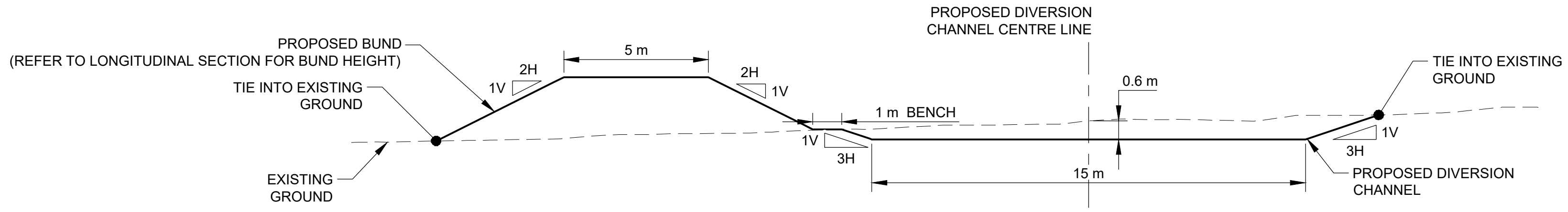
1. REFER TO DRAWINGS D002 TO D005 FOR PROPOSED BUND HEIGHTS ALONG DIVERSION ALIGNMENTS.



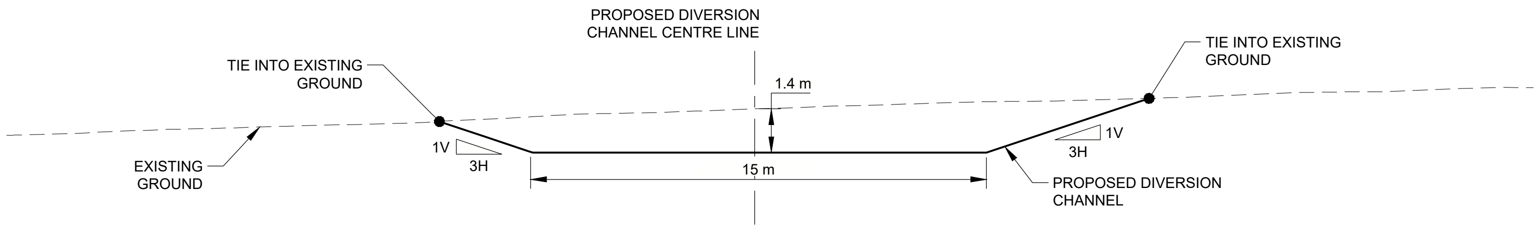
SCALE 1:250 F D003 DIVERSION CHANNEL WEST SECTION AT CHAINAGE 2,700.00 m



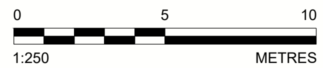
SCALE 1:250 G D004 DIVERSION CHANNEL EAST SECTION AT CHAINAGE 2,900.00 m



SCALE 1:250 H D005 DIVERSION CHANNEL EAST SECTION AT CHAINAGE 5,640.00 m



SCALE 1:250 J D005 EAST SPILLWAY SECTION AT CHAINAGE 5,950.00 m



DRAFT

NOT FOR CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2024-05-31	NOT FOR CONSTRUCTION	A.K	A.J	L.A	M.Z

CLIENT
BHP WAIO

CONSULTANT
wsp

MIA YELLAGONGA LEVEL 3 TOWER 2
5 SPRING STREET
WEST PERTH, WA 6000
AUSTRALIA
[+61] (8) 9213 7600

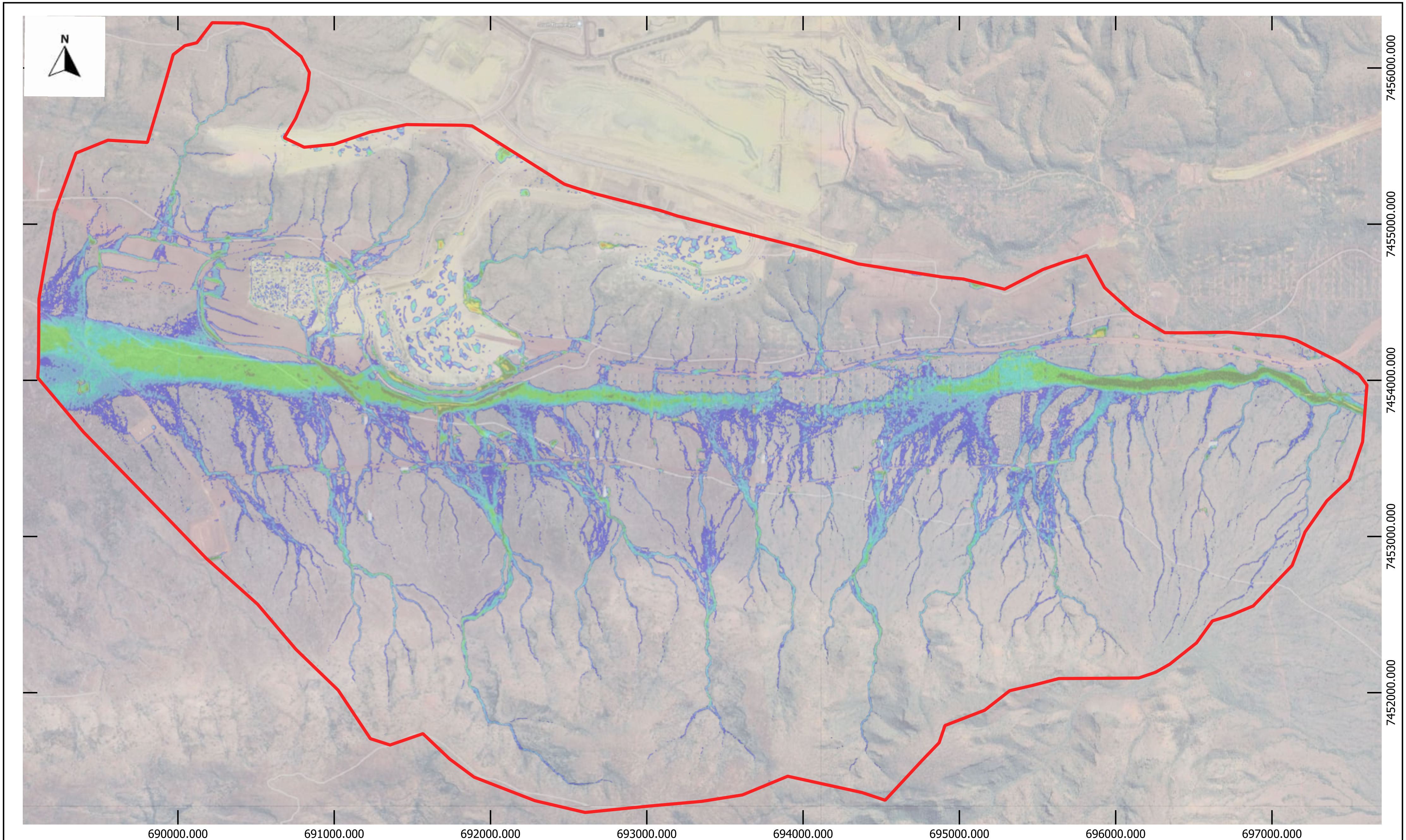
PROJECT
SOUTH FLANK GRAND CENTRAL
SURFACE WATER IMPACT ASSESSMENT

TITLE
DIVERSION CHANNEL TYPICAL SECTIONS (2 OF 2)

PROJECT NO.	DOCUMENT No.	REV.		DRAWING
PS209088	003-R	0	7 of 7	D007

Appendix B

Flood maps



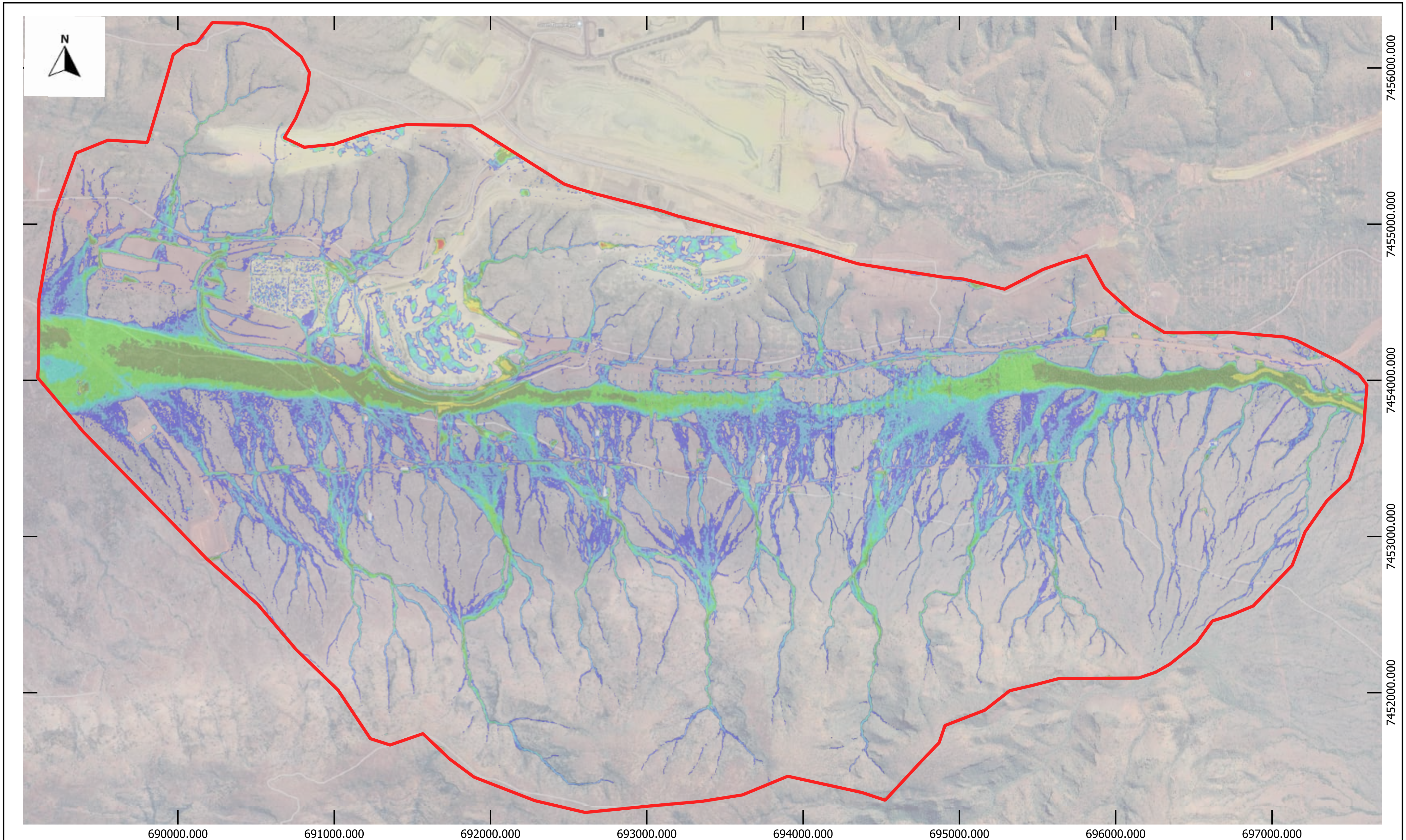
EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- Maximum Flood Depth (m)
- 0.05 and less
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	10% AEP - Baseline Flood Depths
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0



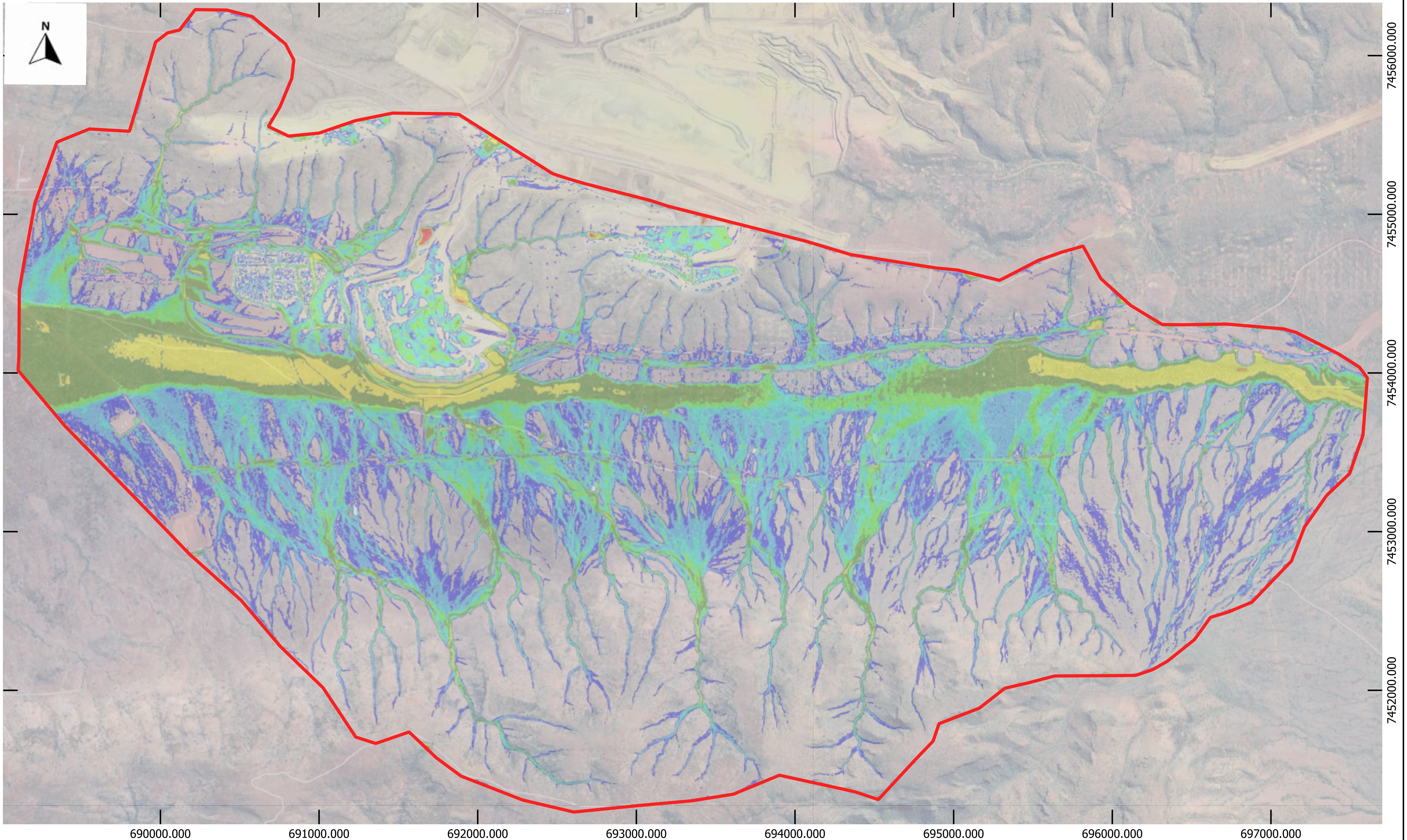
EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- Maximum Flood Depth (m)
- 0.05 and less
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1% AEP - Baseline Flood Depths
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

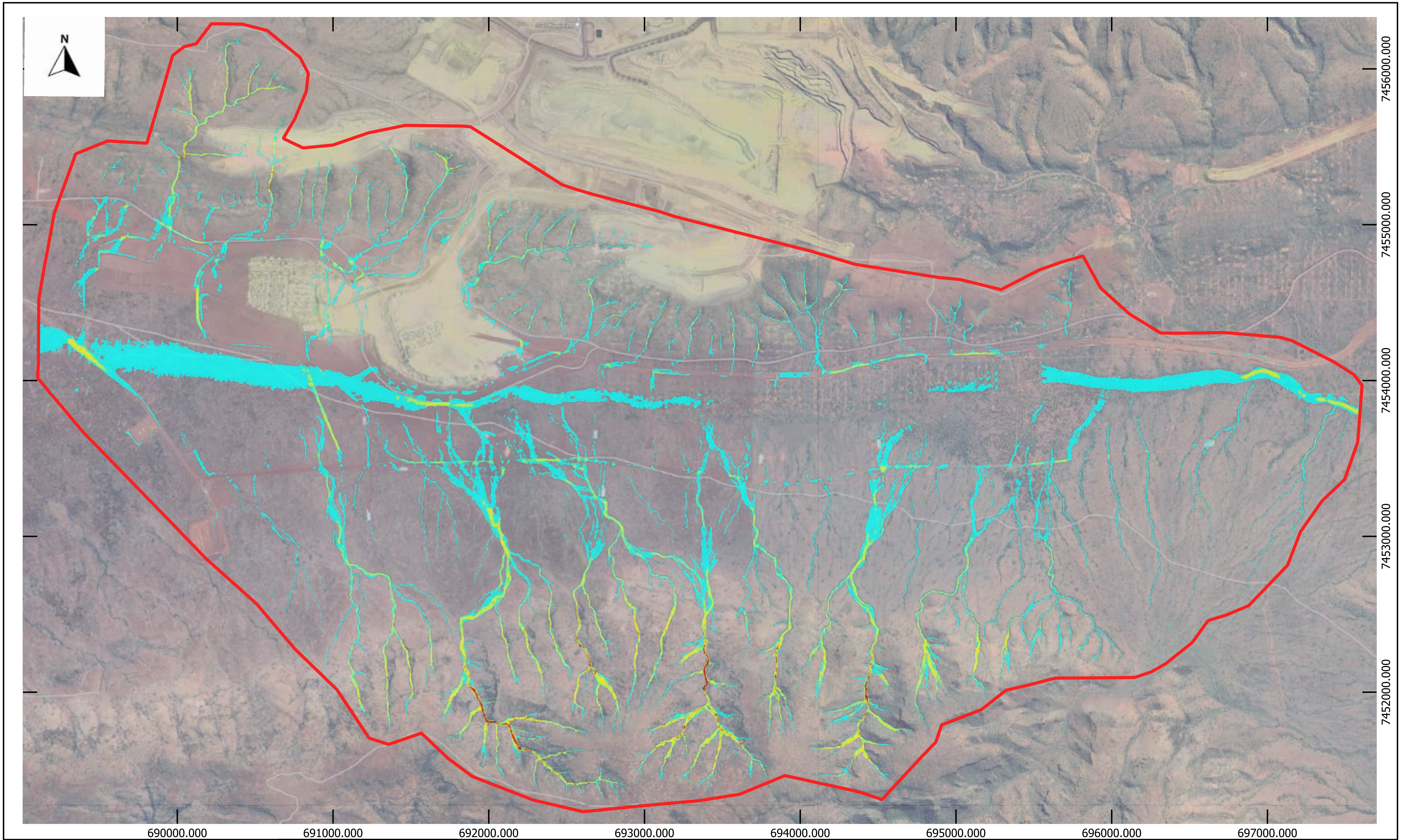
Legend

- Model Boundary
- Maximum Flood Depth (m)
  - 0.05 and less
  - 0.05 - 0.10
  - 0.10 - 0.20
  - 0.20 - 0.30
  - 0.30 - 0.50
  - 0.50 - 1.00
  - 1.00 - 2.00
  - 2.00 - 3.00
  - > 3

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1 in 10000 AEP - Baseline Flood Depth
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

wsp

www.wsp.com



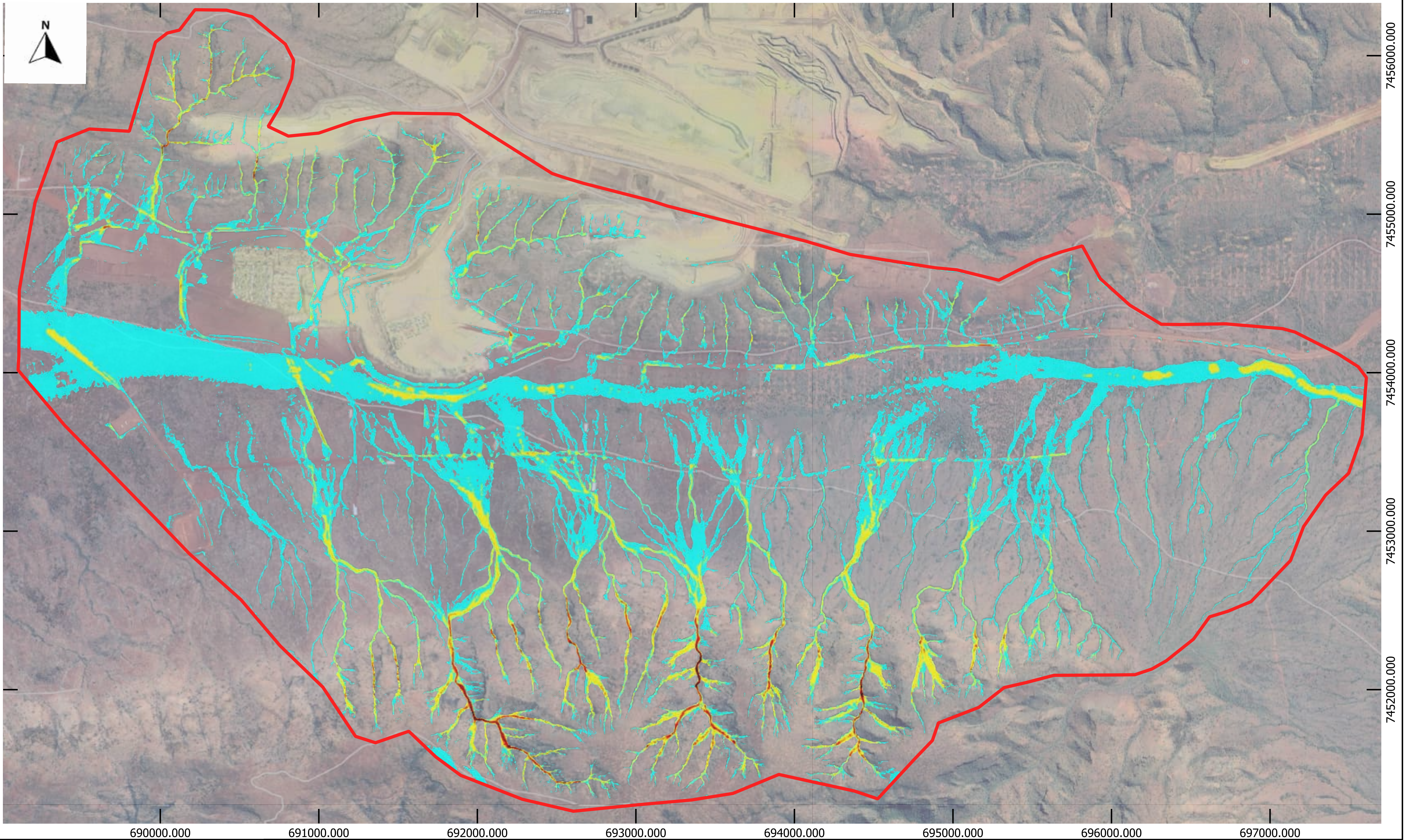
EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- Maximum Flow Velocity (m/sec)
  - <= 0.5
  - 0.5 - 0.1
  - 1 - 2
  - 2 - 2.3
  - 2.3 - 3
  - 3 - 4
  - > 4

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	10% AEP - Baseline Flow Velocity
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0



EPSG:28350 GDA94/MGA Zone50

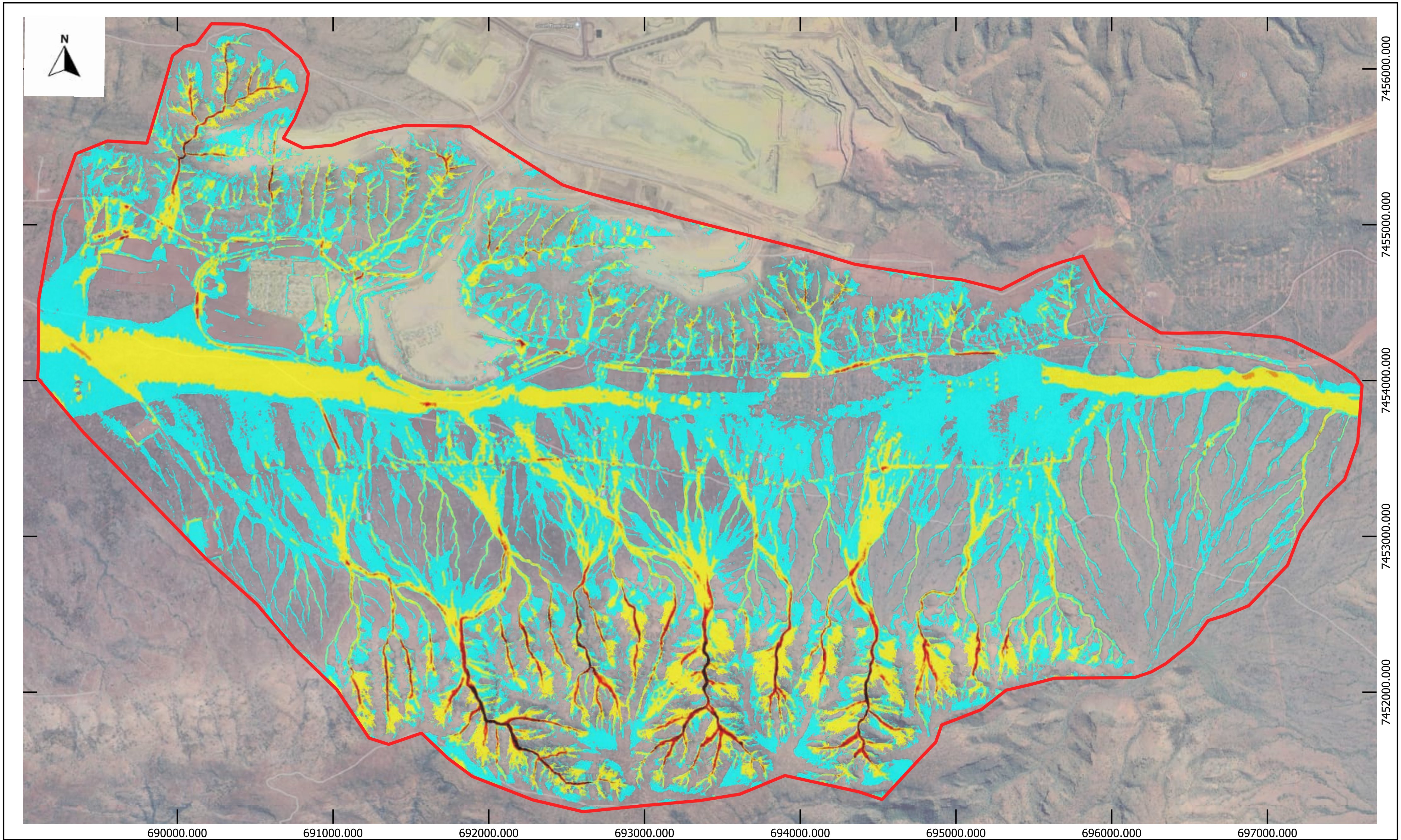
0 0.7 1.4 km

Legend

- Model Boundary
- Maximum Flow Velocity (m/sec)
  - <= 0.5
  - 0.5 - 0.1
  - 1 - 2
  - 2 - 2.3
  - 2.3 - 3
  - 3 - 4
  - > 4

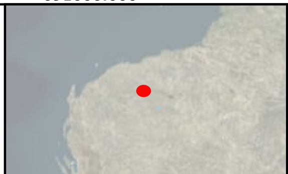
Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1% AEP - Baseline Flow Velocity
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

www.wsp.com



EPSG:28350 GDA94/MGA Zone50

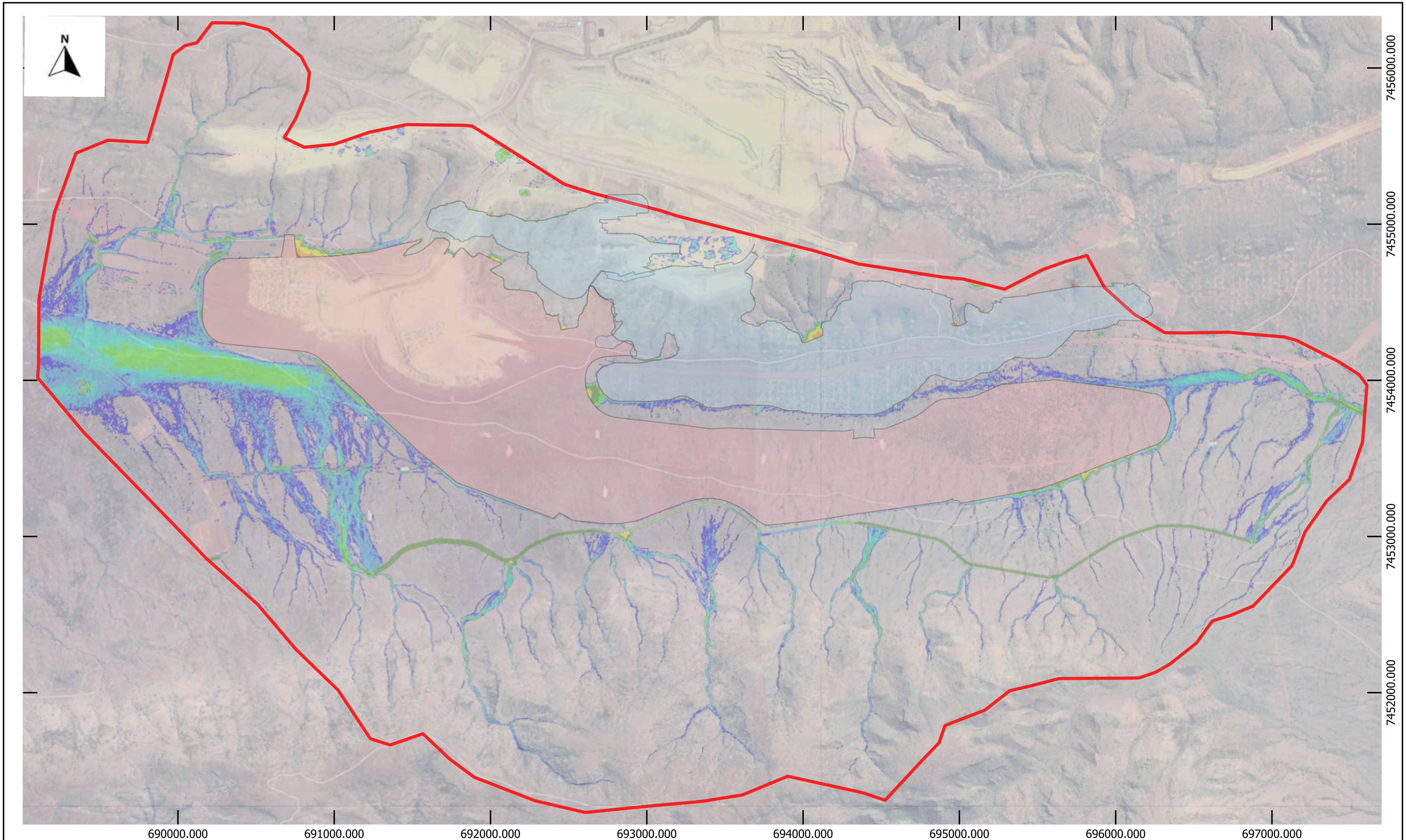
0 0.7 1.4 km



Legend

- Model Boundary
- Maximum Flow Velocity (m/sec)
  - <= 0.5
  - 0.5 - 0.1
  - 1 - 2
  - 2 - 2.3
  - 2.3 - 3
  - 3 - 4
  - > 4

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1 in 10000 AEP - Baseline Flow Velocity
Designed:	AK	Version:	Draft issue
Prepared:	AK	Project No:	PS209088
Reviewed:	LA	Rev:	0
Approved:	MZ		



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

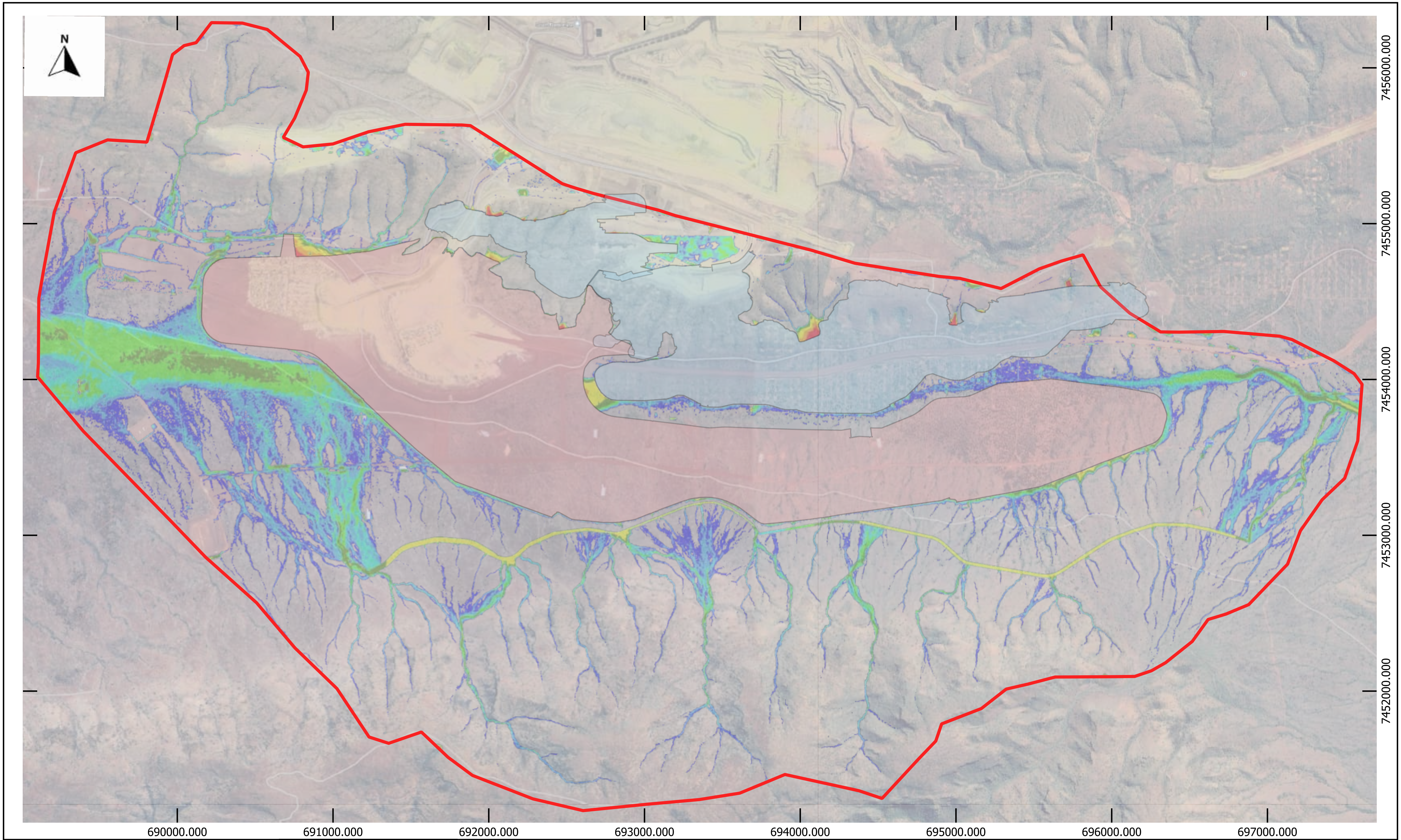
Legend

- Model Boundary
- Pit Footprint
- GC OSA Footprint

Maximum Flood Depth (m)

- 0.05 and less
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	10% AEP - Design Flood Depths
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- Pit Footprint
- GC OSA Footprint

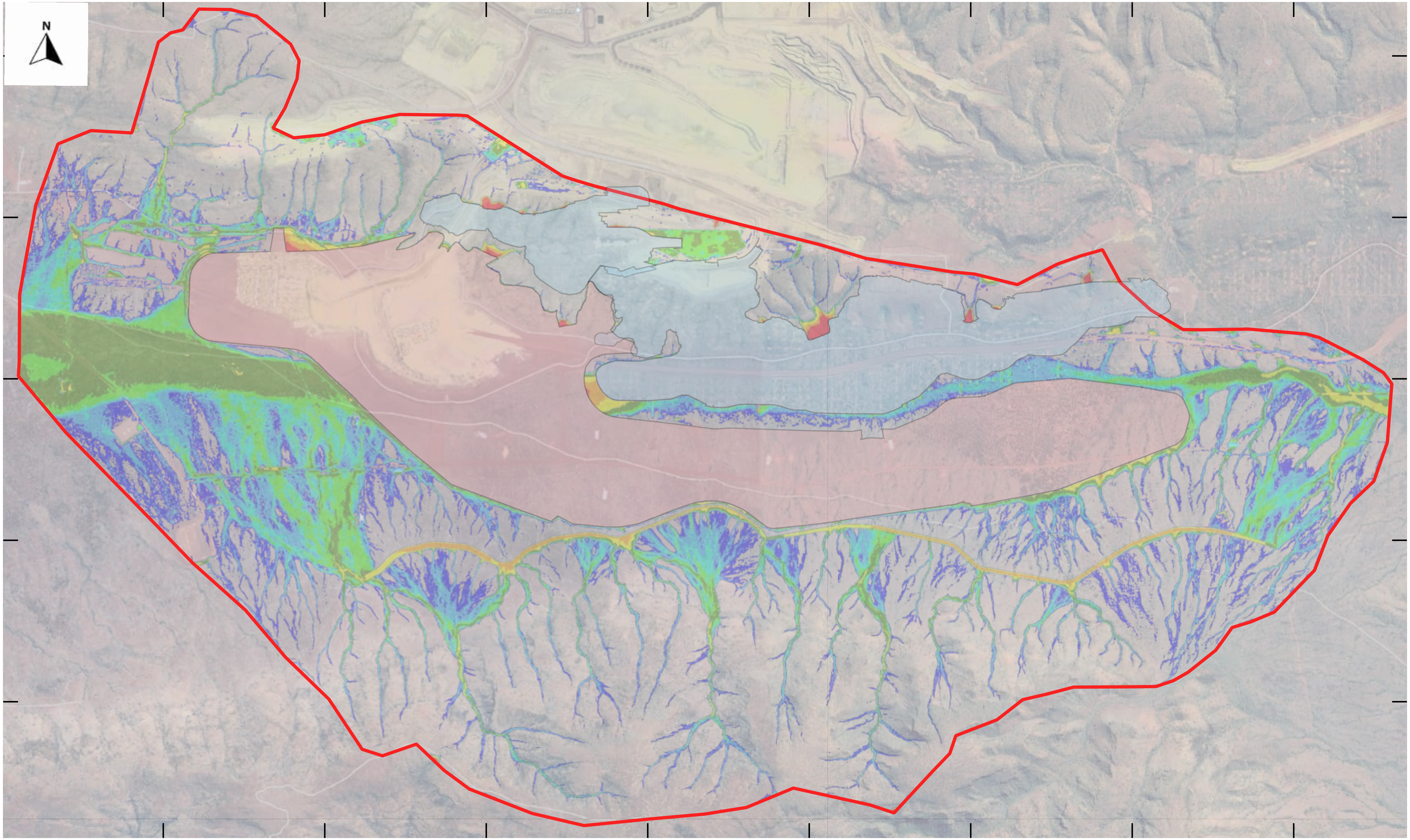
Maximum Flood Depth (m)

- 0.05 and less
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1% AEP - Design Flood Depths
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

wsp

www.wsp.com



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- Pit Footprint
- GC OSA Footprint

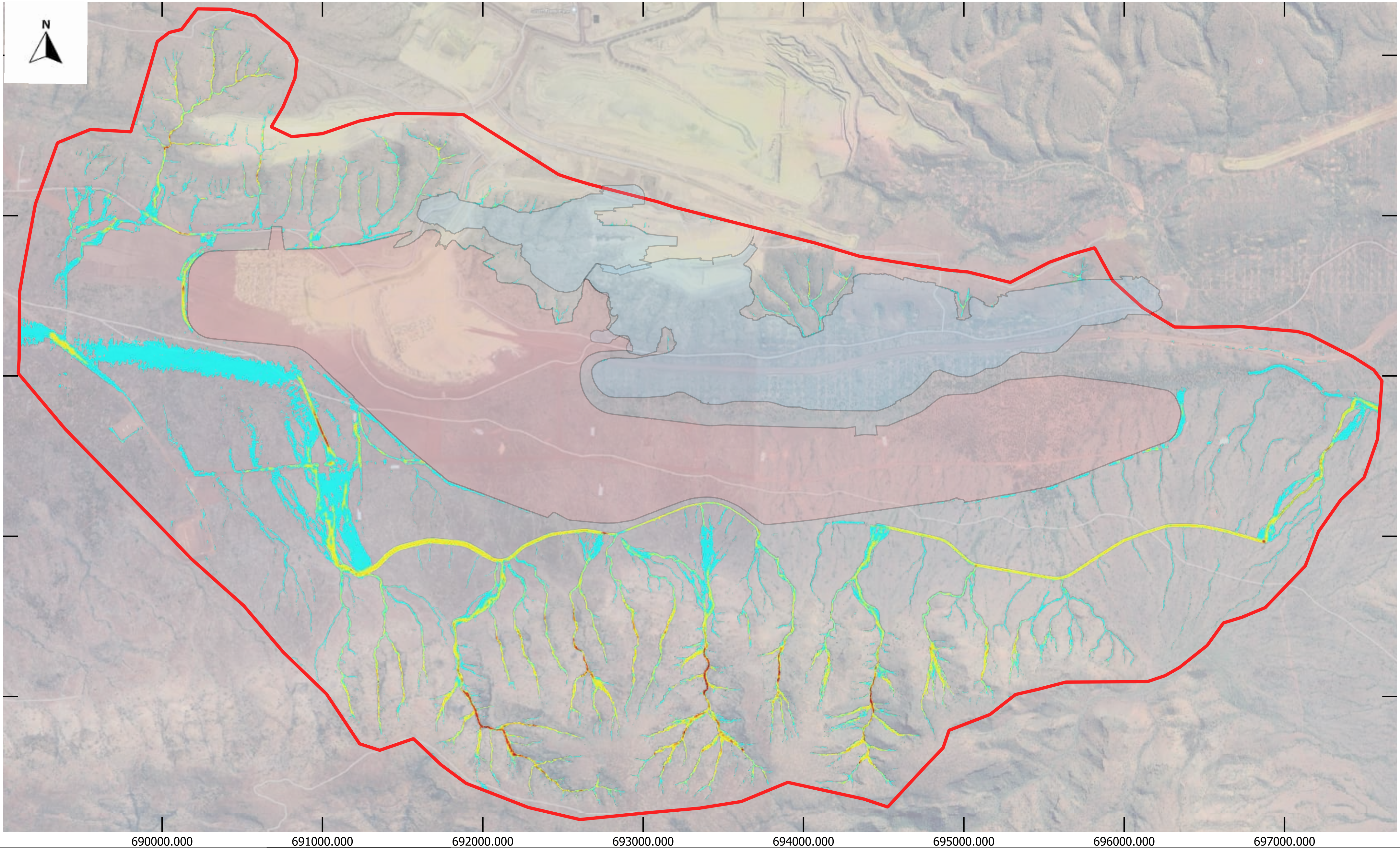
Maximum Flood Depth (m)

- 0.05 and less
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1 in 10000 AEP - Design Flood Depth
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

wsp

www.wsp.com



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- GC OSA Footprint
- Pit Footprint

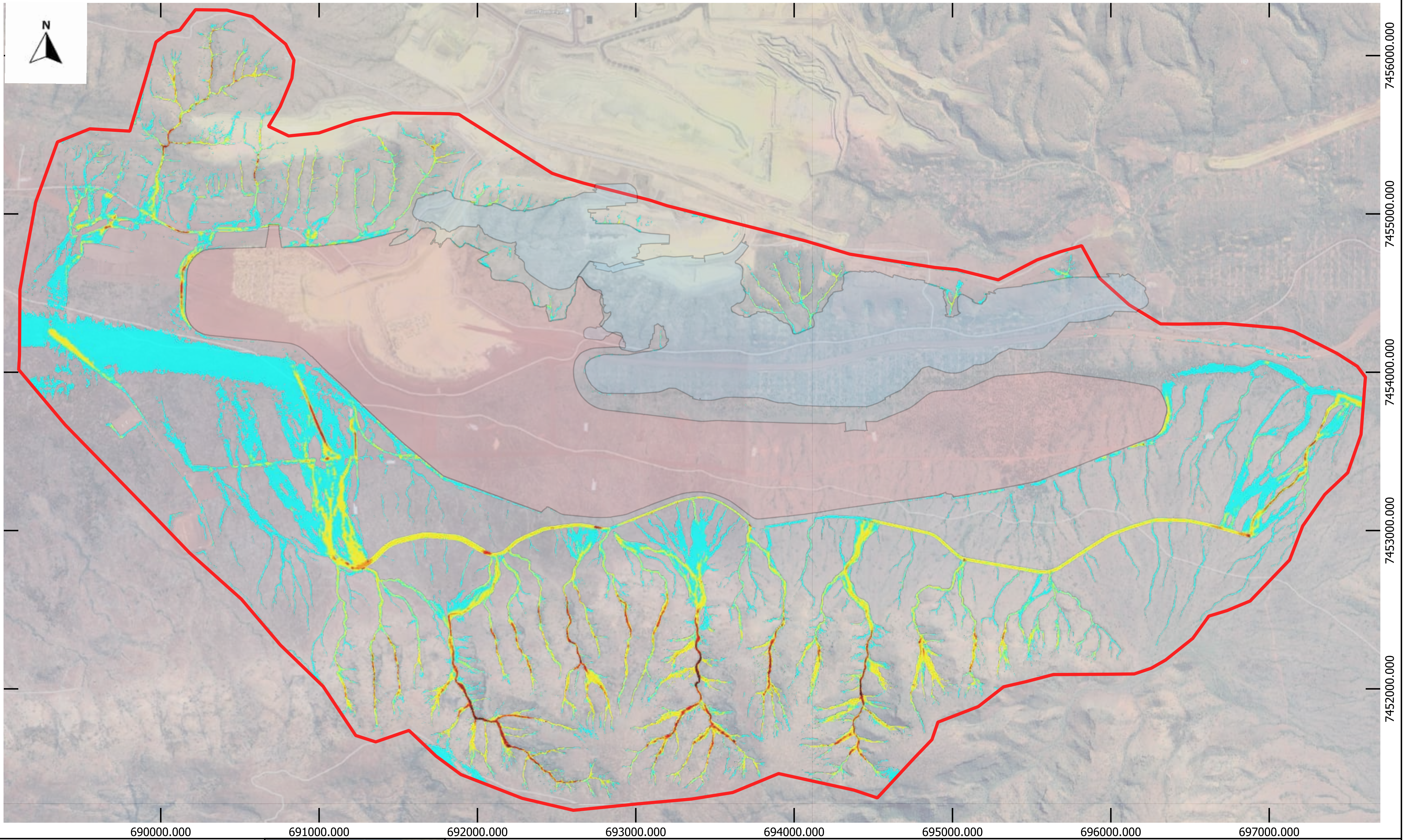
Maximum Flow Velocity (m/sec)

- <= 0.5
- 0.5 - 0.1
- 1 - 2
- 2 - 2.3
- 2.3 - 3
- 3 - 4
- > 4

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	10% AEP - Design Flow Velocity
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

wsp

www.wsp.com



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- GC OSA Footprint
- Pit Footprint

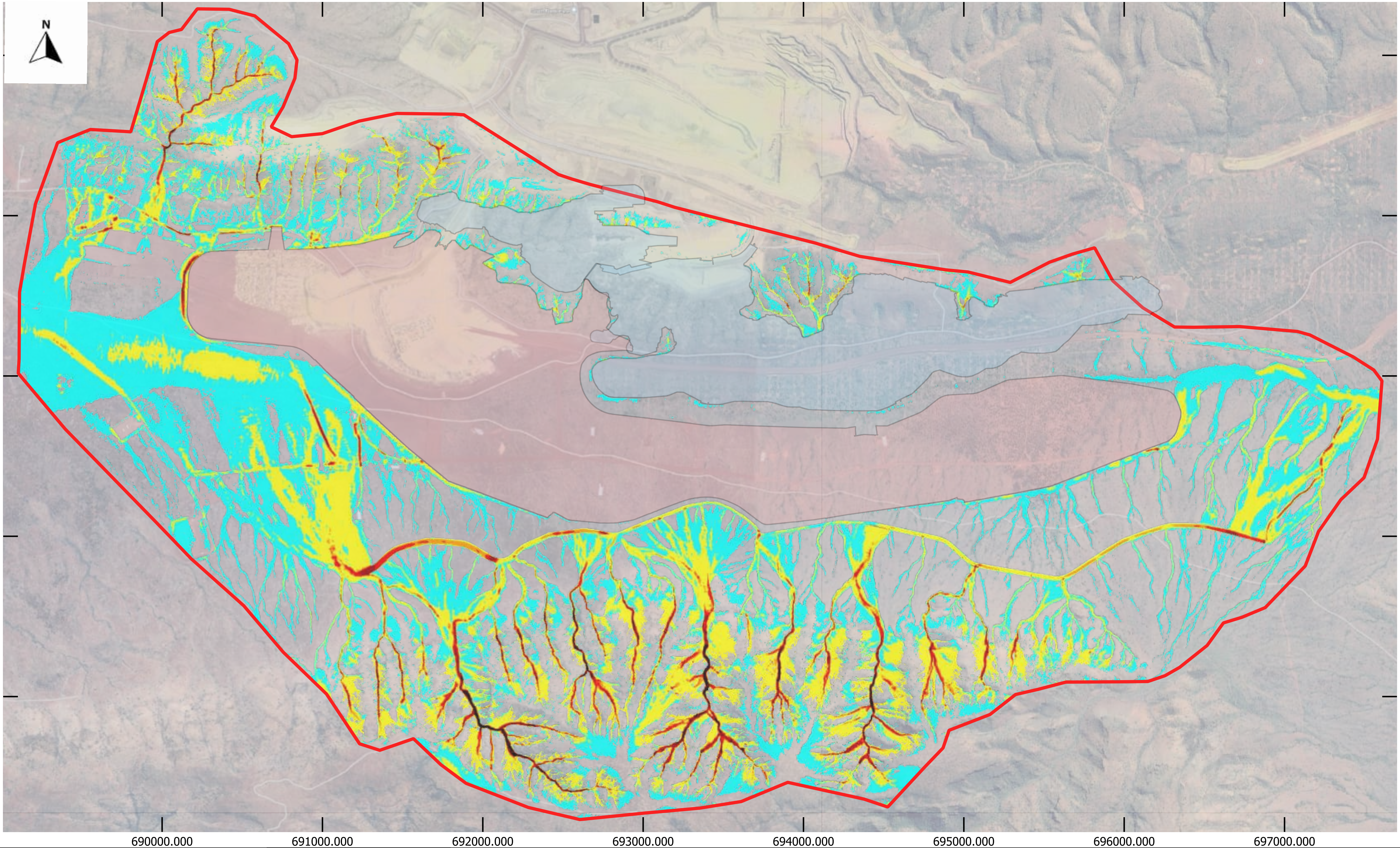
Maximum Flow Velocity (m/sec)

- <= 0.5
- 0.5 - 0.1
- 1 - 2
- 2 - 2.3
- 2.3 - 3
- 3 - 4
- > 4

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1% AEP - Design Flow Velocity
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

wsp

www.wsp.com



EPSG:28350 GDA94/MGA Zone50

0 0.7 1.4 km

Legend

- Model Boundary
- GC OSA Footprint
- Pit Footprint

Maximum Flow Velocity (m/sec)

- <= 0.5
- 0.5 - 0.1
- 1 - 2
- 2 - 2.3
- 2.3 - 3
- 3 - 4
- > 4

Client:	BHP	Project	South Flank SWIA
YYYY-MM--DD	2024-06-10	Title	1 in 10000 AEP - Design Flow Velocity
Designed:	AK		
Prepared:	AK	Version:	Draft issue
Reviewed:	LA	Project No:	PS209088
Approved:	MZ	Rev:	0

Appendix C

Design drawings

Memo

To:	Johanna Richards (BHP) – johanna.richards@bhp.com
From:	Prepared by: Ajinkya Kemble (WSP) – Ajinkya.Kemble@wsp.com Reviewed by: Leila Ang (WSP) – Leila.Ang@wsp.com and Michele.Zornitta@wsp.com
Subject:	Update of South Flank Grand Central Surface Water Impact Assessment
Our ref:	PS209088-WSP-HYD-MEM-001_RevB_BoD_South Flank GCA OSA
Date:	12 June 2024

1. Introduction

BHP Western Australia Iron Ore (WAIO) appointed WSP Australia Pty Limited (WSP) to undertake a surface water impact assessment and develop a conceptual surface water management design for the South Flank Grand Central Overburden Storage Area (GC OSA) within the Mount Robinson Valley at the South Flank Mine, located in the Central Pilbara approximately 90 km northwest of the town of Newman, Western Australia. The conceptual design will support fulfilment of requirements outlined under the State Environmental Protection Act 1986 Part IV approvals process.

The combined GC OSA and pit landforms, in addition to any supporting infrastructure (such as access roads) are referred to as the "Study Area" for the purpose of this assessment.

1.1 Background

BHP has completed the final design of the GC OSAs and will commence the environmental approvals process to fulfil requirements outlined under the State Environmental Protection Act 1986. The GC OSA will be sited immediately to the west and south of BHP's Grand Central Area, part of the existing South Flank Mine. The GC OSA landforms are intended for use as waste material storage areas for Acid and Metalliferous Drainage (AMD) material and will form permanent structures. The deposited AMD material will be covered with non-polluting material upon placement, thereby reducing the exposure of the AMD material to rainfall.

The GC OSA landforms will intercept runoff from various surrounding catchments, particularly of note natural creeks which capture runoff from the Mount Robinson range. As such, considerations for surface water management at the GC OSA landforms, both during operations and closure of the South Flank Mine, need to be considered.

WSP undertook surface water impact assessment for the site in June 2022 (WSP Golder, 2022). In support of these assessments, hydrologic assessments were undertaken using RORB, while 2D hydraulic assessments were undertaken using TUFLOW.

Lvl 3, Mia Yellagonga Tower 2, 5 Spring St
Perth WA 6000
PO Box 7181
Cloisters Square WA 6850

Tel: +61 8 9489 9700
Fax: +61 8 9489 9777
www.wsp.com

Various options were considered for the diversion of flow generated from the Mount Robinson and GC OSA slopes as part of an Options Assessment, with the preferred option consisting of two earth-lined drains (each combined with a bund on the north side), to divert flow either to the west or to the east, thereby maintaining the flows in their original catchments. Each drain will be constructed with an overflow area ("spillway") at the drain outlet, to facilitate diffuse outflow from the drains. This option concept is carried forward in this basis of design.

1.2 Objectives

The following objectives will be undertaken as part of this study:

- Consider GC OSA updated footprint and design to enable a 100 m standoff of all infrastructure from the Mount Robinson Heritage exclusion area. No land disturbance is to take place within the standoff corridor.
- Apply appropriate method to reconcile routed peak flows for baseline modelling conditions.
- Apply climate change uplift to PMP calculations due to the non-stationary nature of precipitation under a predicted warmer climate to estimate the update to the 1 in 10000 AEP rainfall.
- Account for depth-varied surface roughness coefficient in the hydraulic modelling.
- Undertake sensitivity analysis of relevant hydraulic and hydrologic parameters such as initial loss (IL), continuous loss (CL) and manning's roughness coefficients.

1.3 Abbreviations

Abbreviations	Description
1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall & Runoff (2019)
BoM	Bureau of Meteorology
CSP	Corrugated Steel Pipe
DTM	Digital Terrain Model
GSDM	Generalised Short Duration Method
GC OSA	Grand Central Overburden Storage Area
Hydraulic model	A theoretical model used to provide representation of flow distribution and flood mechanisms at the area of interest.

Abbreviations	Description
Hydrological model	A theoretical model used to simulate the rainfall runoff flow and predict the runoff hydrographs.
IFD	Intensity Frequency Duration
IL/CL	Initial Losses /Continuing Losses
LoM	Life of Mine
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RFFE	Regional Flood Frequency Estimation
SGS	Sub Grid Sampling
WAIO	Western Australia Iron Ore

2. Data review

This section provides an overview of the dataset utilised to inform the assessment.

Dataset

Data	Reference	Design basis
Digital Terrain Model (DTM)	BHP (2021a)	The DTM extent covers the entire catchment areas contributing to the surface water runoff at the site. There are some irregularities in the DTM data which were identified during the previous study as well. This DTM data will be used to inform the ground elevations in the hydraulic model.
Digital Terrain Model (DTM)	BHP (2022a)	To overcome the irregularities in the DTM, BHP captured new and recent survey. This DTM covers most of the catchment areas contributing to the surface water runoff at the site. The northern extent of model boundary is not covered by this data. This DTM data will be used to inform the ground elevations in the hydraulic model and will supersede the DTM data from 2021 in the areas having overlapped.

Data	Reference	Design basis
WAIO climate change data	BHP (2023)	The climate change data is specific to the study area and provides projection of change in temperature values. These temperature values will be used to derive the climate change application factor as discussed in Section 4.8.
GC OSA Footprint	BHP (2023a)	File name: *gcgd_os34c_wc001_005_fill_c.dxf* This is the updated GC OSA footprint to include the 100 m heritage standoff corridor. GC OSA are intended for use as a waste material storge area and will be a permanent structure.
Pit Footprint	BHP (2023b)	File name: *All Grand Central Pits.dxf* - This file covers all the pits in the GC area. File name: *ultimate_extents_gd02_and_ge_stages.dxf* – This file contains the pit area which will be considered for this study.
Heritage standoff corridor boundary	BHP (2023c)	File name: *HeritageBoundary.shp* – it contains the extent of the heritage standoff corridor.
Aerial imagery	BHP (2022b)	File name: *SouthFlank_r015_20231013_CPG94.ecw* – Aerial image covering the entire catchment area contributing to the GC OSA.

Hydrology studies

WSP reviewed available hydrology and hydraulic studies to inform this basis of design. In particular, South Flank Surface Water Environmental Impact Assessment report (MWH, August 2016) reflects an assessment for the entire South Flank mine site which has approximately 16 overburden storage areas. The initial loss and continuous loss values in this report will be used to inform the hydrology analysis.

WSP also reviewed the following documents; however, no useful data or information was available to inform the design and/or analysis:

1. Central Pilbara Water Resource Management Plan report (BHP IOMA, September 2021).
2. Weeli Wolli Spring Ecohydrological Framework Assessment (AQ2, 2016).
3. Coondewanna Flats Ecohydrological Conceptualisation (AQ2, 2016).

4. Coondewanna Flats Eco-Hydrology Review and Conceptual Model (AQ2, 2015).

Applicable Guidelines

The following guidelines will be used to inform the assessment:

- Australian Rainfall and Runoff 1987 (Institution of Engineers Australia, 1987)
- Australian Rainfall and Runoff 2019 (Ball, et al., 2019)
- Environmental Approvals: Water Information Checklist (Draft) (BHP Billiton Iron Ore, 2020).
- WAIO Standards – Design Criteria – Earthworks and Drainage. Document No. DESC-000-C-00002/1 (BHP, 2014).
- Department of Water and Environmental Regulation (Government of Western Australia). 1986. Environmental Protection Act 1986.
- State Environmental Protection Act 1986, Department of Water and Environmental Regulation (1986)
- The Impact of Climate Change on Operational Probable Maximum Precipitation Estimates (Visser et al. 2022).

3. Civil design criteria

Table 3.1 summarises the key parameters and assumptions for the civil design. This civil criterion is based on the previous study (WSP Golder, 2022) which uses the BHP WAIO civil standards.

Table 3.1 Surface water model assumptions

Item description	Assumptions	Reference
General Information		
Design Life Considerations	Estimated 10-year Life of Asset during Operations.	BHP (2021c)
Consideration for climate change	Climate change considerations are incorporated into the hydrologic and hydraulic assessment to understand the impact to surface water infrastructure due to the increased storm intensities over the design life.	WSP Golder (2022)
Design Considerations		
Design events for OSA toe bunds	10% AEP Critical duration of peak flow determined as part of hydraulic modelling.	Adopted, based on (i) BHP 2014 WAIO Standards (Minor Drain Diversion) (ii) Acceptable risk associated with expected 10-year Life of Asset.

Item description	Assumptions	Reference
Design Event for diversion channel	10% AEP Critical duration of peak flow determined as part of hydraulic modelling.	Adopted, based on (i) BHP 2014 WAIO Standards (Minor Drain Diversion) (ii) Acceptable risk associated with expected 10-year Life of Asset.
Design Event for diversion bunds	1% AEP with sufficient freeboard and to contain 1 in 10,000-year event without freeboard.	WSP Golder (2022) and adopted, based on risk level associated with permanence of OSA landforms (post-closure)
Minimum freeboard for: 1. Diversion channel 2. Diversion bund	0.3 m A verification check will be undertaken on the energy head and any shifting flow conditions to confirm if 0.3 m is sufficient.	Adopted, based on (i) BHP 2014 WAIO Standards (BHP 2014) and (ii) current best practice
Maximum allowable velocities in diversion drains	2.3 m/sec; however, 1.5 m/sec will be targeted where possible to minimize the requirement for erosion protection.	Adopted, based on BHP 2014 WAIO Standards (BHP 2014) for Gravels under peak flow conditions
Civil Criteria		
Erosion Protection design	Material type and size to be determined based on the peak flow calculated.	Adopted
Diversion channel side slopes	To range between 1H:1V and 3H:1V based on in-situ material.	As per BHP 2014 WAIO Standards (BHP 2014). Will be refined, if necessary, based on erosion protection requirements
Minimum diversion channel depth	400 mm	As per BHP 2014 WAIO Standards (BHP 2014)
Minimum berm crest width	5 m	Adopted for constructability purposes
Minimum horizontal offset distance between crest of diversion channel and toe of berm	1 m	Adopted for constructability purposes

4. Hydrology model methodology

This section describes the hydrology model methodology proposed for the assessment.

4.1 Hydrology and hydraulic model

A rain-on-grid modelling approach will be considered for assessing catchment surface water flow conditions. This modelling approach allows the identification of all flow paths that contribute to runoff at the catchment site.

4.2 Catchment delineation

A catchment analysis was conducted using 1 m DTM data through Global Mapper software package upon which catchment areas were delineated.

The catchment area relevant for the assessment is approximately 27 km^2. Figure 4.1 shows the catchment, sub catchments, drain lines, and the site area.

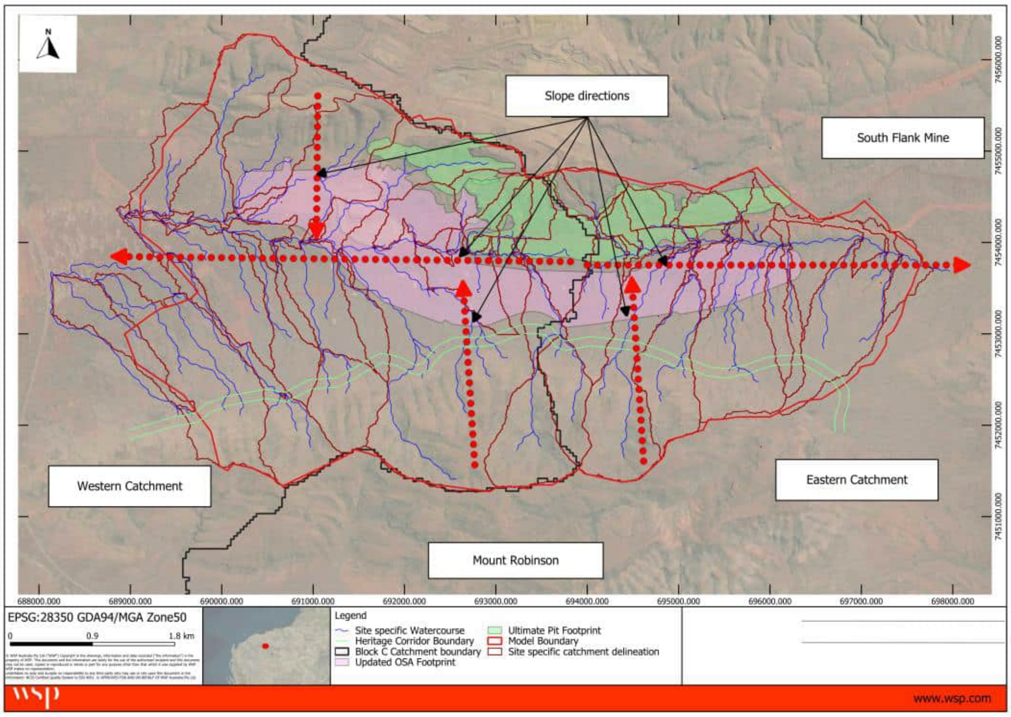


Figure 4.1 Catchments and drain lines

4.3 Intensity-frequency-duration

Design rainfall data in the form of intensity-frequency-duration (IFD) data were sourced from BoM (Lat: -23.015, Long: 118.88). The IFDs were extracted for a range of storm duration from 15 minutes up to 72 hours for the AEP events required for the assessment. The design rainfall values are presented in Table 4.1.

Table 4.1 Design rainfall data

Duration	Total rainfall (mm)			
	10% AEP	1% AEP	0.1% AEP	0.05% AEP
15 min	23.6	36.8	55.7	62.5

Duration	Total rainfall (mm)			
	10% AEP	1% AEP	0.1% AEP	0.05% AEP
20 min	27.2	42.3	64	71.8
25 min	30	46.7	70.5	79.1
30 min	32.3	50.2	75.9	85
45 min	37.5	58.3	88.1	98.6
1 hour	41.3	64.6	97.5	109
1.5 hour	47.1	74.8	113	126
2 hours	51.9	83.5	126	141
3 hours	59.8	98.8	149	167
6 hours	77.9	135	205	230
9 hours	91.8	164	249	280
12 hours	103	188	284	319
18 hours	120	223	337	378
24 hours	133	247	373	418
30 hours	143	265	403	452
36 hours	150	277	422	472
48 hours	161	294	442	492
72 hours	173	308	455	504

4.4 Rainfall losses

The site lies within an area classified as "arid" according to ARR 2019 guidelines. ARR 2019 does not provide storm losses for arid regions. In addition, no infiltration tests are available to inform the soil permeability. Therefore, to gather information on storm losses in an arid region, a literature review of the site location and surrounding areas was completed.

The MWH (2016) study provided indications on IL and CL based on ARR 1987. According to the study IL of 18 mm and CL of 4 mm/hr are appropriate for the site.

As there is no gaging station data available within the catchment area for calibrating the outcomes of hydraulic modelling results. Sensitivity tests on IL and CL will be completed to determine how sensitive the model is to a change in the loss parameters. In addition, a regional hydrological assessment will be carried out to provide a point of comparison for the key parameters (including infiltration); refer to Section 4.9 for further detail.

Based on the outcome of the sensitivity test, further investigation such as soil infiltration test may be recommended for the next stage of design.

4.5 Critical storm duration

Critical storm duration is defined as the storm duration which generates maximum of peak water levels (or peak flow for surface water infrastructure hydraulic sizing) among the durations analysed at the GC OSA. Critical storm durations for the site will be assessed as part of the flood modelling exercise.

A representative critical storm duration will be chosen for the assessment after discussion with BHP.

4.6 Temporal pattern

Ten temporal patterns will be considered for each storm duration as per ARR 2019 Guidelines (ARR, 2019). Point temporal patterns were obtained from the ARR Datahub (2019).

4.7 Probable Maximum Precipitation and 1 in 10,000-year rainfall depths

The Probable Maximum Precipitation (PMP) event will be analysed to derive the 1 in 10,000-year rainfall depth.

The Generalised Short Duration Method (GSDM method) will be used to derive the PMP value. The GSDM method has been chosen as it is applicable across Australia for tropical and subtropical coastal areas and for catchment areas less than 1,000 km^2 and durations up to 6 hours (Ball et al, 2019).

To derive the rainfall depths associated with the 1 in 10,000-year (0.01% AEP) event, interpolation procedure defined in ARR 2019 guideline (Book 8, chapter 3.5.2) will be used.

4.8 Climate change projection

The current edition of ARR 2019 lacks provisions for estimating climate change factors beyond the 1% AEP event.

At the time of writing this memo, the addendum “Draft update to the Climate Change Considerations Chapter in Australia Rainfall and Runoff: A Guide to Flood Estimation – published in December 2023 by the Department of Climate Change, Energy, the Environment and Water” suggests that current ARR guidelines on climate change will be updated later in the year.

This memo incorporates the proposed changes in climate change anticipated in the ARR addendum, noting that the addendum is still in draft version.

Shared Socioeconomic Pathways (SSPs) 4.5 will be used as the benchmark event for climate change impacts while the SSP8.5 will be used for sensitivity analysis, considering the uncertainty around climate projections.

The methodology for adjusting rainfall intensity is as follow:

$$\%\ \text{Rainfall Intensity Increase} = (1 + \frac{\text{alpha}}{100})\hat{}(\text{DT})$$

Where:

alpha: represents the rate of change as outlined in Table 1 of the ARR addendum.

DT: it is the estimated global temperature projection for design period of interest (obtained from Table 2 of the ARR addendum).

For the critical storm duration of 6 hours identified for the site, the anticipated increases in rainfall intensity under SSP 4.5 are 19% for the medium term (2041-2060) and 30% for the long term (2081-2100). Under the SSP 8.5 scenario for sensitivity analysis, increases of 25% and 55%, respectively, will be considered.

No changes to temporal patterns and losses will be considered in the analysis.

The changes in rainfall intensity will be considered in the model to evaluate the impact of flood results. This will focus on determining changes in flood levels, flow velocities, and flood depths for the different rainfall intensity increase.

The changes in the flood model results will be discussed with BHP to determine the implications on the design.

4.9 Hydrology calibration

We will review the catchment data available to locate appropriate gauge stations to calibrate the hydrology model.

In absence of calibration data, the calibration will be informed using,

- peak flow values derived from RFFE.
- stream flow gauge data from Tarina Station (site reference: 708014).

WSP will comment on this approach based on the outcome of the study.

5. Surface flow model

WSP proposes to develop and rain-on-grid TUFLOW model. The model extent would cover the entire catchments contributing to the surface water runoff at the site. Figure 5.1 shows the approximate extent of the hydraulic model.

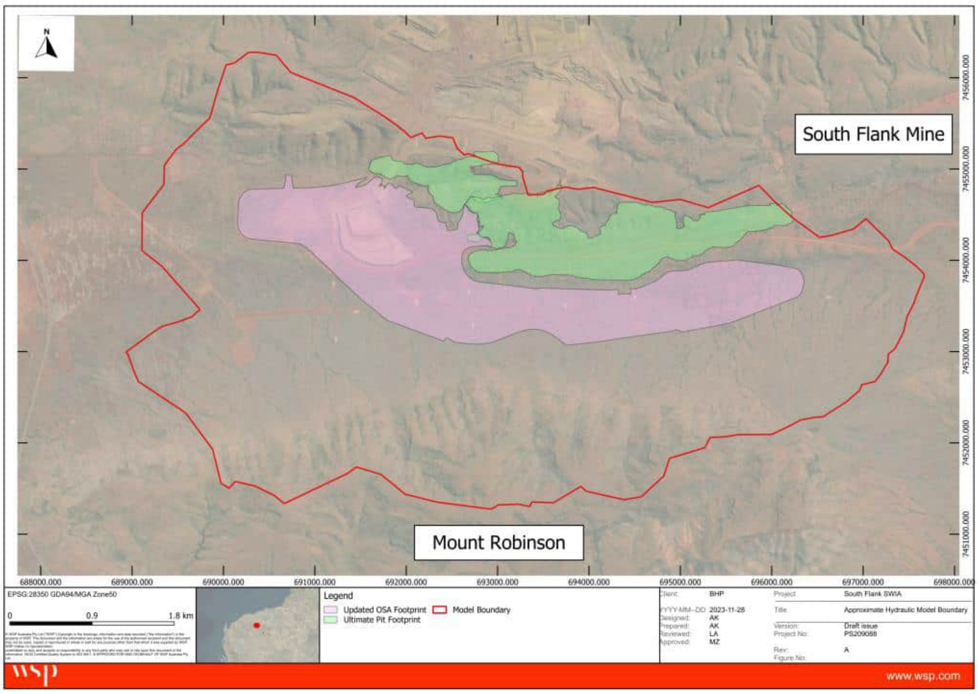


Figure 5.1 Hydraulic model extent

5.1 Model scenarios and annual exceedance probabilities modelled

The flood model will be developed for two scenarios:

1. Baseline scenario
2. Operational scenario
3. Post-closure scenario

The hydraulic model will assess flood levels, flood depths and flow velocities for 10%, 1%, and 0.01% AEP flood events.

Climate change will also be applied for each event.

5.2 Model resolution

We will conduct a sensitivity analysis on cell size to define the optimal model resolutions, striking a balance between precision and computational efficiency. This analysis aims to identify resolutions that deliver robust results while optimizing the overall run time of the model.

Sub grid sampling (SGS) and quadtree will be considered where appropriate to refine the accuracy of the model.

5.3 Manning's roughness coefficient

The site area falls under rural catchment category. The following roughness values will be used to inform the land use types in the catchment area.

- Representative roughness values:
  - Corrugated Steel Pipe (CSP) Culvert: 0.024
  - Riprap Lined Channel: 0.04
  - Non-vegetated, engineered channel (unlined earth channel): 0.03.
  - Natural streams: 0.05
  - Floodplain: 0.065
  - GC OSA Landforms: 0.05
  - Access roads: 0.02.

As per ARR 2019 guideline, the varying depth roughness values are used for the urban catchments and hence has not been considered for this study.

A sensitivity analysis will be undertaken to evaluate the response of hydraulic model to changes of roughness values.

6. References

- BHP. 2021a. "South_Flank_LiDAR_1_m.tif". Provided to WSP Golder, October 2021
- BHP. 2021b. "South_Flank_Aerial_Imagery.tif". Provided to WSP Golder, October 2021
- BHP. 2021c. Personal Communication – Richards J and Nick Taylor, October 2021
- WSP Golder. 2022. South Flank Grand Central Overburden Storage Area – Surface Water Impact Assessment Report, June 2022

- BHP. 2022a. “GC_OSA_2022_LiDAR.tif”and “GC_OSA_2022_LiDAR_Part_2.tif”. Provided to WSP, 2022
- BHP. 2022b. “SouthFlank_r015_20231013_CPG94.ecw”. Provided to WSP, 2022
- BHP. 2023. “WAIO_South.xlsx”. Provided to WSP, 2023
- BHP. 2023a. “gcgd_os34c_wc001_005_fill_c.dxf”. Provided to WSP, 2023
- BHP. 2023b. “All Grand Central Pits.dxf”. Provided to WSP, 2023
- BHP. 2023c. “HeritageBoundary.shp”. Provided to WSP, 2023
- BHP Billiton Iron Ore (BHP). 2014. WAIO Standards – Design Criteria – Earthworks and Drainage. Document No. DESC-000-C-00002/1
- Pilgrim, DH (ed). 1987. Australian Rainfall and Runoff – A Guide to Flood Estimation, Institution of Engineers, Australia, Barton, ACT, 1987.
- Ball J, Babister M, Nathan R, Weinmann E, Retakllick M, Testoni I (Editors). 2019. Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia)
- BHP. 2020. Environmental Approvals: Water Information Checklist (Draft)
- Department of Water and Environmental Regulation (Government of Western Australia). 1986. *Environmental Protection Act 1986*.
- Visser J B, Kim S, Wasko C, Nathan R, Sharma A. 2022. The Impact of Climate Change on Operational Probable Maximum Precipitation Estimates