Eramurra Salt Project

Hydrologic Assessment for Scenario 7.2.1

Leichhardt Salt

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Table of Contents

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Meaning
1D	One-Dimensional
2D	Two-Dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARR	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
EPA	Environmental Protection Authority
EV	Environmental Values
EY	Exceedance per Year
FMBR	Forty Mile Beach Road
IFD	Intensity-Frequency-Duration
KP	Kilometre Point
LiDAR	Light Detection and Ranging
LWC	Land and Water Consulting
m	Metres
m/s	Metres per Second
MS	Ministerial Statement
MSL	Mean Sea Level
Mtpa	Million Tonnes per Annum
NaCl	Sodium Chloride
RCP	Representative Concentration Pathway
SR	Sea Level Rise case
SS	Storm Surge case
SSP	Shared Socioeconomic Pathway
RFFE	Regional Flood Frequency Estimation
USACE	United States Army Corps of Engineers

1.0 INTRODUCTION

Surface Water Solutions (SWS) were engaged by Geosyntec Consultants Pty Ltd (Geosyntec) on behalf of Leichhardt Salt Pty Ltd (Leichhardt) to provide hydrological support to the environmental studies being undertaken to address the queries outlined in the Western Australian Environmental Protection Authority's (EPA) response to Leichhardt's project proposal submission to the EPA. Additional works were required to inform risks associated with the proposed development, and surface water modelling has been updated to address 12 Dec 2024 updates to the May 2023 Scenario 7.2 design pond configuration and to incorporate climate change updates adopted by Australian Rainfall and Runoff (ARR) in August 2024.

This document presents a hydrological and hydraulic assessment of the existing and proposed conditions for the Eramurra Salt Project, including the modelling approach, results, and recommendations.

1.1 Background

Leichhardt proposes to construct and operate the Eramurra Solar Salt Project (the Project), located in the western Pilbara region of WA, approximately 55 km west-south-west of Karratha (**Figure 1-1**). The Project will extract an average of 5.2 million tonnes per annum (Mtpa) of high-grade salt (sodium chloride (NaCl)) from seawater, using a series of evaporation and crystallisation ponds, a processing plant, transport corridor, and stockpiling for export from the Cape Preston East Port. The concentration ponds and crystallisers will be located on two Mining Leases.

The export of salt is proposed to be via a trestle jetty. The jetty and associated stockpiles will be located at the Cape Preston East Port approved by Ministerial Statement (MS) 949. Dredging of the proposed channel and berth pocket will be undertaken as part of this Proposal to remove high points at the Cape Preston East Port. Dredged material will either be disposed of at one or more offshore disposal locations, or onshore within the Ponds and Infrastructure Development Envelope. Bitterns will be transported by pipeline attached to the trestle jetty structure and discharged via a diffuser located off the trestle jetty. The Cape Preston East Port jetty and associated stockpiles are excluded from the Proposal.

The Western Australian Government Environmental Protection Agency (EPA) has a 5 stage approvals process:

- Stage 1 – Referral – submission of an environmental scoping document
- Stage 2 - EPA to decide on whether to assess the proposal
- Stage 3 – Assessment of proposal
- Stage 4 – EPA report on assessment of a proposal
- Stage 5 – Implementation of proposal

As part of the approval requirements a number of environmental studies have been conducted across the site and surrounds. These studies include (but are not limited too) study of the receiving environment (terrestrial and marine), the installation of a groundwater monitoring network; five groundwater elevation and gauging events; development of a numerical groundwater model with scenario modelling to assess groundwater effects from seepage and climate change/sea level changes. Surface water modelling has also been completed to assess the projects impact to surface water flows and drainage.

This hydrological assessment documents the outcomes of the surface water modelling. The outcomes of these investigations are assisting with ongoing characterisation of baseline hydrogeological regimes and water quality both in a local and regional context. The findings have been used to develop the management measures described in this hydrologic assessment.

The Project is located east of Cape Preston East Multi-Commodity Port on land parcels between Eramurra Creek along western edge and Devil Creek on eastern edge. The current design of the project development area will contain 90 km^2 of concentrator area, 20 km^2 of crystalliser area and 2 km^2 of bitterns ponds in addition to the plant processing area. **Figure 1-2** shows the current project layout (Scenario 7.2.1 Rev 5).

To produce salt, rows of concentrator evaporation ponds will be constructed. The perimeter embankment around the concentrator ponds and the pad for crystalliser area may alter existing waterways flowing towards the Indian Ocean as well as tidal flooding of the project land parcels.

The highly saline water within the concentration pond area has potential to increase salinity of local surface water, as well as potentially impacting groundwater quality. In addition to the direct impacts from the addition of salinity to the groundwater and surface water environments, the construction of the evaporation ponds and associated infrastructure (bunds, roads, pipelines and culverts) may disturb acid sulfate soils, which in turn will provide an additional salinity source.

Leichhardt's proposal has been submitted to the WA Government EPA where a decision was made to assess the project. The Environmental Scoping Document (ESD) was approved in June 2023. The current program of work is based on the requirement presented in the ESD which formed the basis of the scope of studies required to inform an update of the Environmental Review Document (ERD). It was noted by the EPA that the development of environmental management plans is required to manage and or mitigate any identified or perceived environmental concerns.

Currently the project is classed as being at Stage 3 of the approvals process, Leichhardt's current schedule has the ERD for the proposal being submitted for acceptance for public comment by the West Australian Government EPA in Q2 of 2025.

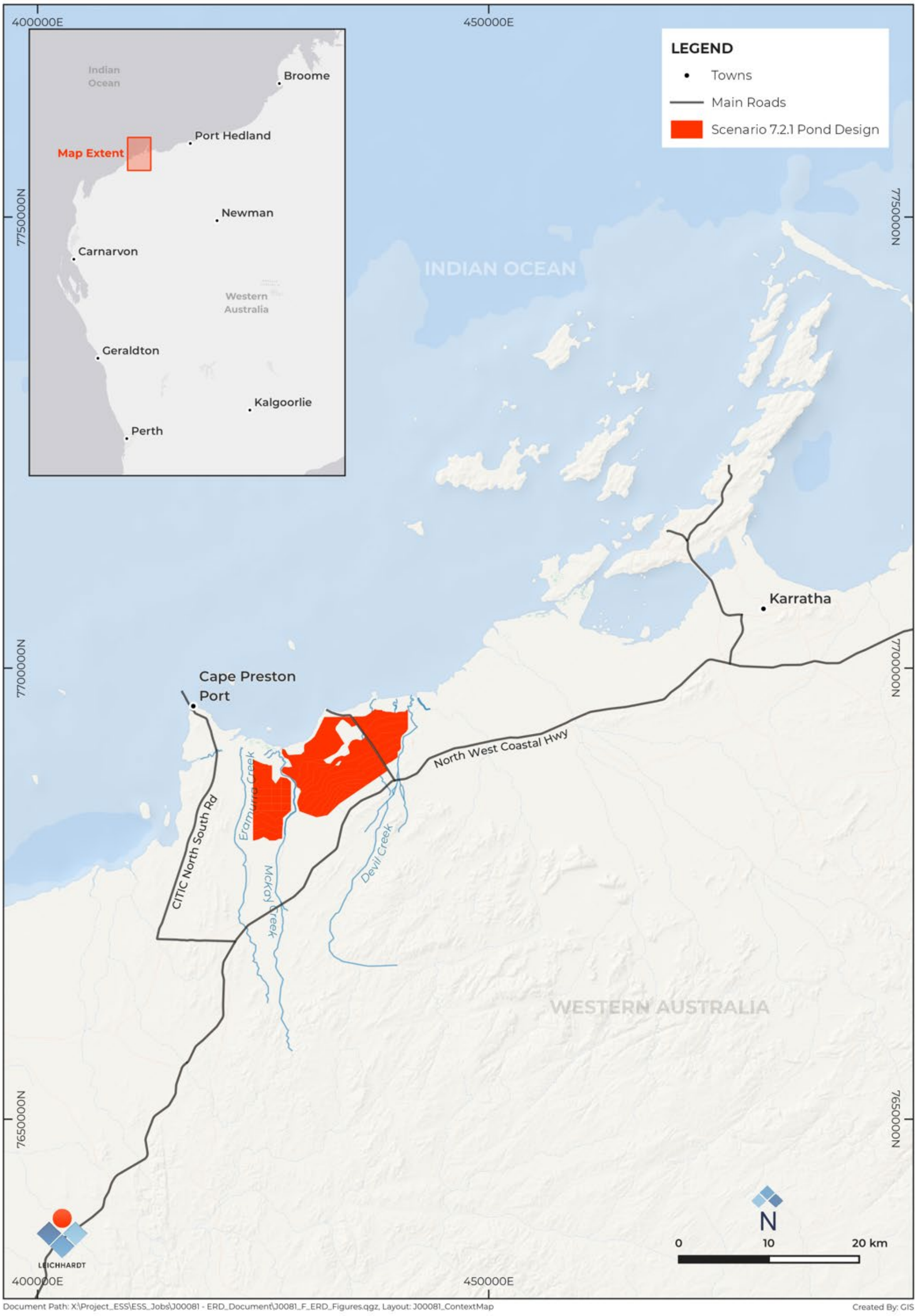

Figure 1-1: Proposed pond locations for the Eramurra Salt Project

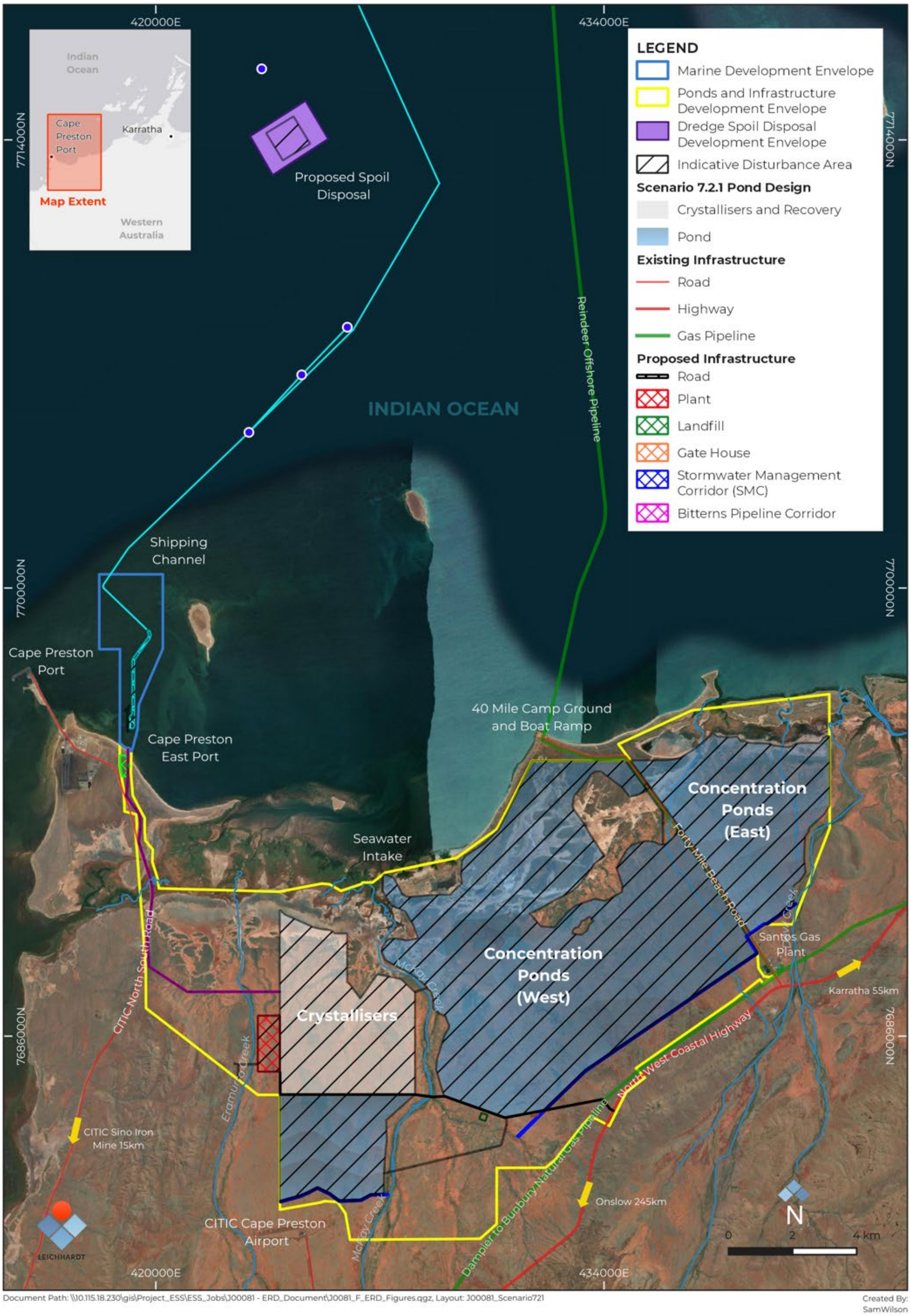

Figure 1-2: Proposed Scenario 7.2.1 layout

1.2 Report Contents

This report summarises the results of two-dimensional (2D) flood modelling for the Eramurra Salt Project under the following ten scenarios:

1. 63% Annual Exceedance Probability (AEP) or 1 Exceedance per Year (EY) rainfall event for existing condition
2. 63% AEP project condition
3. 10% (1 in 10) AEP event existing condition
4. 10% AEP event project condition
5. 5% (1 in 20) AEP event project condition
6. 2% (1 in 50) AEP event project condition
7. 2% AEP event project condition with 10% AEP storm surge (coastal attack)
8. 1% (1 in 100) AEP event project condition
9. 1% AEP event project condition with 5% AEP storm surge
10. 1% AEP event project condition with 5% AEP storm surge and 0.9 m climate change sea level rise

This report presents inundation extents, water levels, flow paths, and velocities along with implications for erosion and sedimentation for existing and project conditions. Project conditions models are based on the May 2023 Scenario 7.2 design pond configuration, with adjustments received 12 Dec 2024. Pond designs are expected to change as the project proceeds; hydraulic modelling updates should accompany any significant future changes to the pond designs.

1.3 Previous Reports and Supporting Data

The following reports and supporting data were provided by Leichhardt as background for the hydrological assessment:

- Eramurra Solar Salt Project Preliminary Metocean Study, RPS, 7 Sep 2021. Doc No. 100-CN-REPO-1960 RevA.
- Eramurra Solar Salt Project, 2021: A preliminary hydraulic modelling for the Cyclone Damien event, 21 Jan 2020.
- Eramurra Solar Salt Project February 2022 LiDAR Survey, MNG. 4 April 2022. Doc No. 104 578-008A.
- Eramurra Solar Salt Project Hydrologic Assessment for Scenario 7.2. Prepared by LWC Pty Ltd. 19 Jul 2023. W-AO-04_R_Hydrology_FR002.
- Eramurra Solar Salt Project Hydrologic Assessment. 14 Nov 2022. W-AO-04_R_Hydrology_FR001.
- Eramurra Solar Salt Project Surface Water Assessment to Inform Proposed Location of a Flood Levee. 24 Nov 2022. ESSP-NP-13-TRPT-0002.
- Eramurra Solar Salt Project Surface Water Assessment to Inform Surface Water Management and Drainage. 25 May 2023. ESSP-NP-13-TRPT-0004.

This report, provided by Surface Water Solutions, forms the update to the 2023 hydrologic assessment for Scenario 7.2 report reference W-AO-04_R_Hydrology_FR002.

2.0 HYDROLOGY

2.1 Catchment

The proposed ponds are located in three primary catchment areas as shown in **Figure 2-1**: Eramurra Creek, McKay Creek, and Devil Creek. The total contributing catchment area of the three creeks is approximately 704 km^2. The proposed ponds cover an area of approximately 118 km^2. Catchment delineations and area tabulations are indicative only as there is some cross-flow between the catchments that varies by flood event. In particular, there are some conjoined floodplains and anabranches connecting Eramurra Creek and McKay Creek south of the Cape Preston Airport. **Figure 2-2** shows the locations of the individual ponds based on the May 2023 general arrangement with minor Dec 2024 updates to the perimeter around McKay Creek. The ponds are generally separated into three areas; the central area is separated from the western area by McKay Creek, and from the eastern area by the Reindeer onshore gas pipeline easement along Forty Mile Beach Road (FMBR). For the purpose of the hydrologic and hydraulic modelling, all direct rainfall on the pond areas is considered to be internally contained with no influence from external flows.

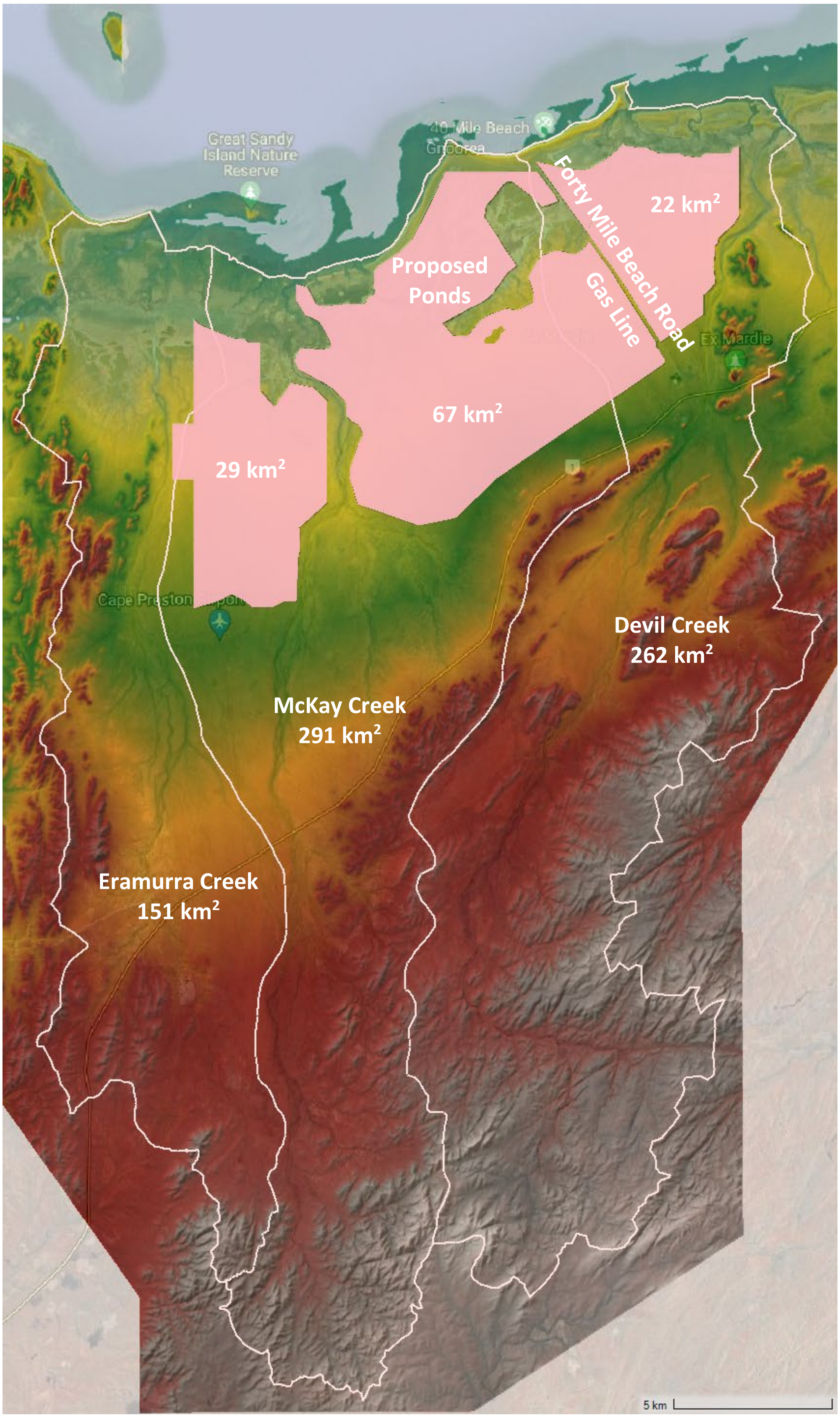

Figure 2-1: Eramurra Salt Project and contributing catchment areas

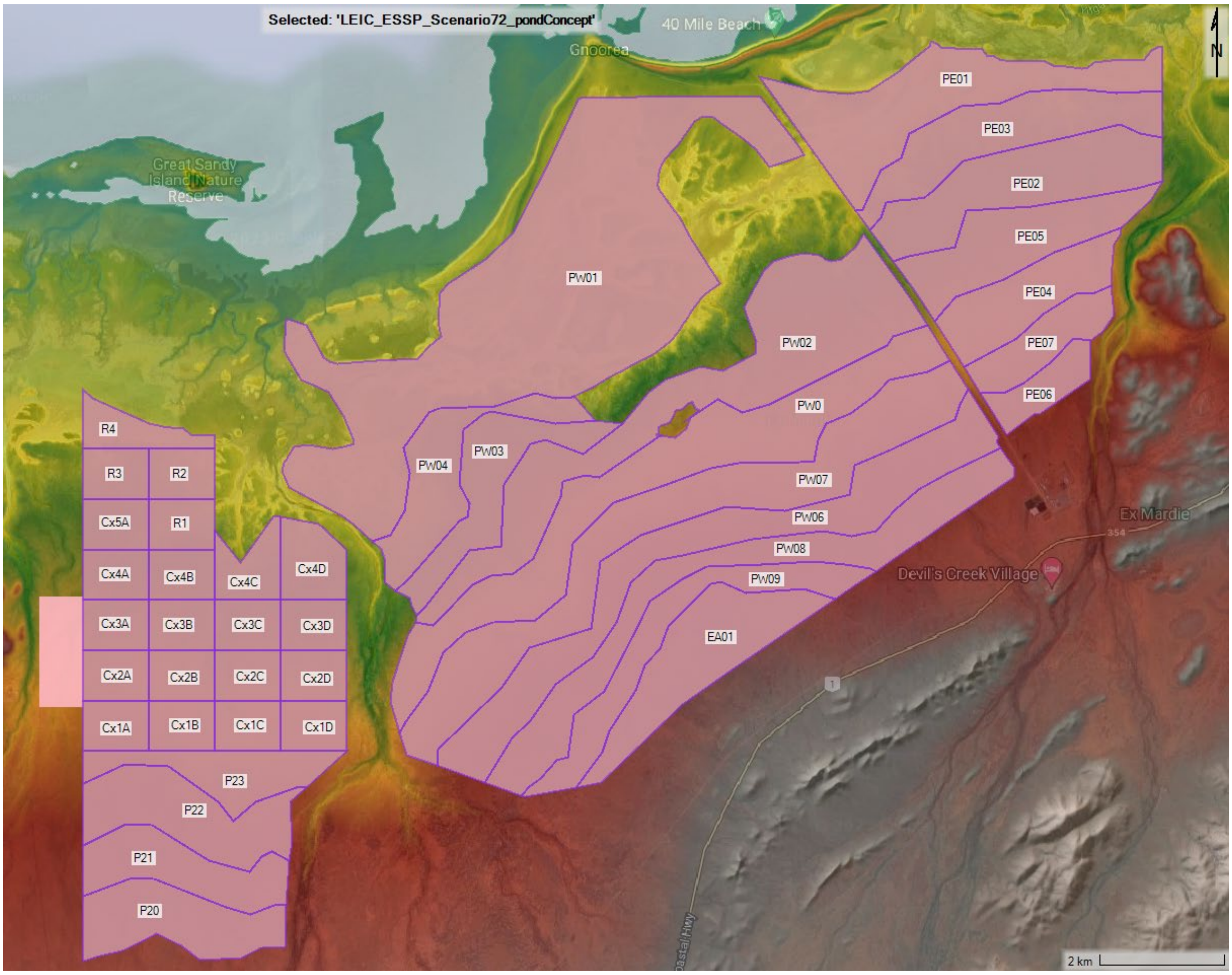

Figure 2-2: Proposed pond locations for the Eramurra Salt Project

2.2 Precipitation

Figure 2-3 and **Figure 2-4** show Bureau of Meteorology (BoM) precipitation details for the Eramurra Salt Project area (2016). Tabulated Intensity-Frequency-Duration (IFD) values are shown in **Table 2-1**. Additional precipitation data extracted from the Australian Rainfall and Runoff (ARR) data hub are included in Appendix A.

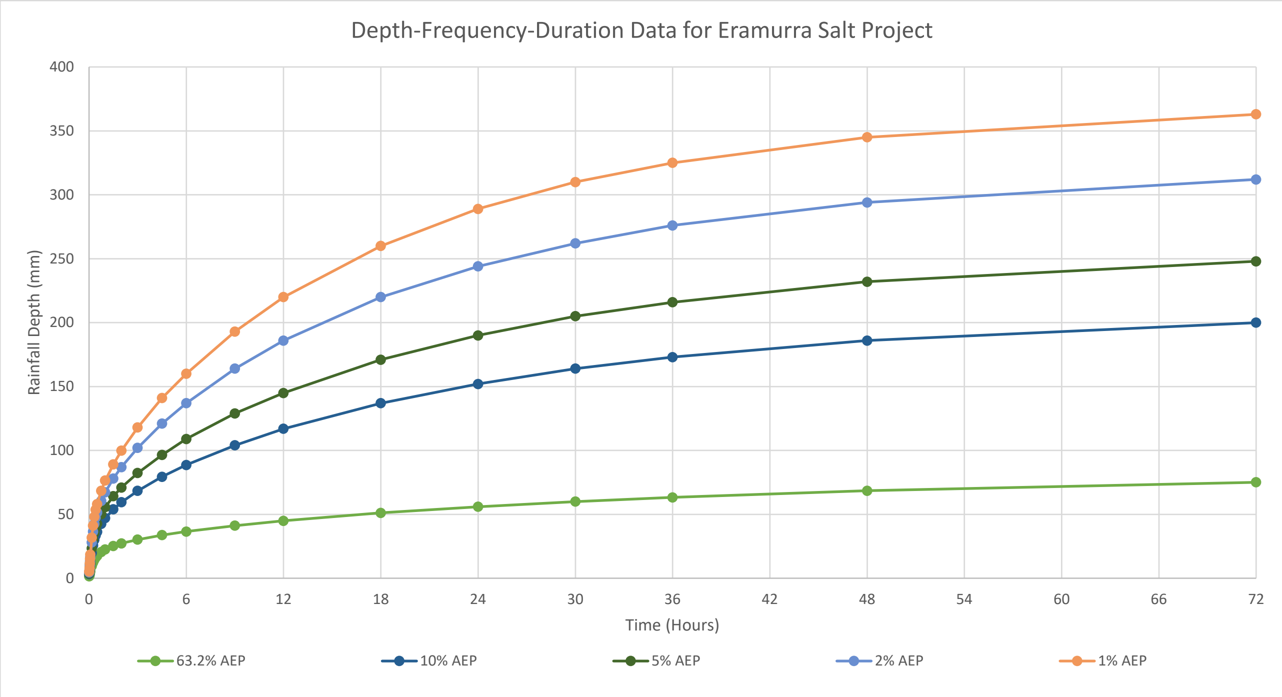

Figure 2-3: Depth-Frequency-Duration data for Eramurra Salt Project (BoM 2016)

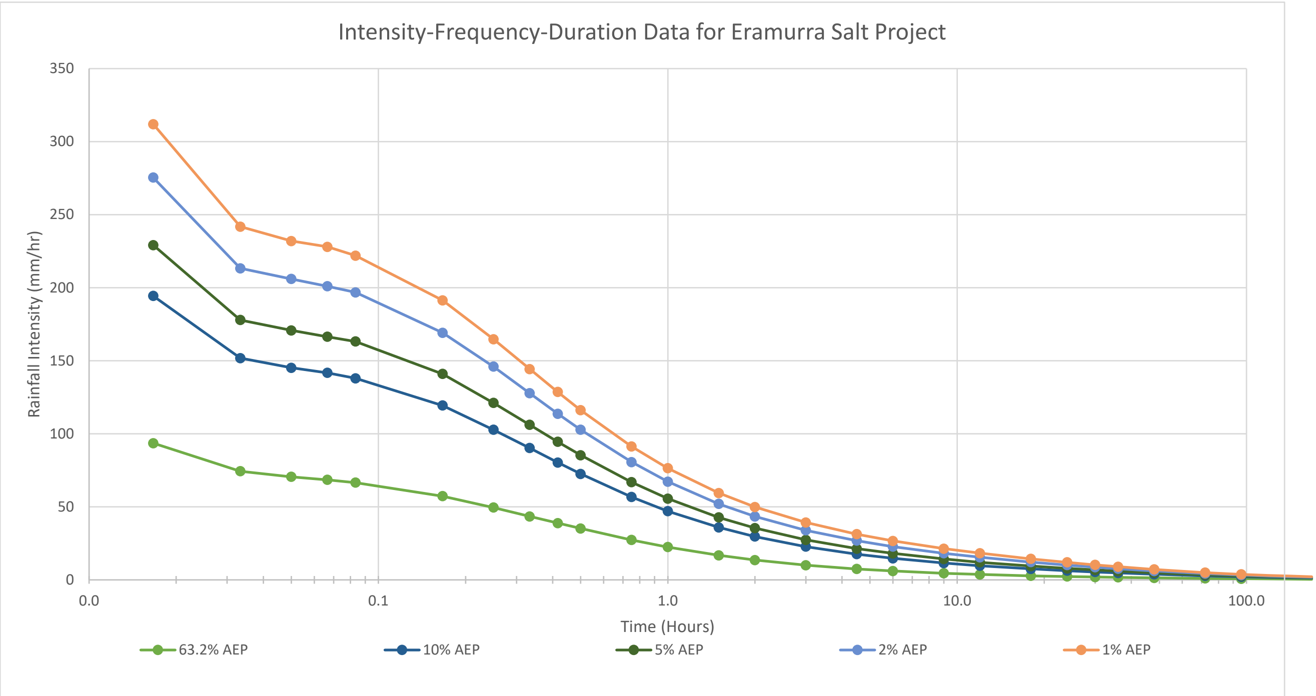

Figure 2-4: Intensity-Frequency-Duration data for Eramurra Salt Project (BoM 2016)

Table 2-1: IFD values for Eramurra Salt Project location

Duration	Rainfall Depth in mm				
	63.2% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1 min	2	3	4	5	5
5 min	6	12	14	16	19
10 min	10	20	24	28	32
15 min	12	26	30	37	41
30 min	18	36	43	51	58
1 hour	23	47	56	67	77
2 hour	27	60	71	87	100
3 hour	30	68	82	102	118
6 hour	37	89	109	137	160
12 hour	45	117	145	186	220
24 hour	56	152	190	244	289
48 hour	69	186	232	294	345
72 hour	75	200	248	312	363

2.3 Climate Change

Australian Rainfall and Runoff (ARR) guidelines were updated in August 2024 to incorporate revised climate change guidance. The guidance includes recommended uplift factors to be applied to rainfall intensities and soil infiltration losses. ARR data hub details are included in Appendix A for the Eramurra Creek, McKay Creek, and Devil Creek catchment areas. The ARR data hub summaries include the recommended national climate change uplift factors based on the August 2024 ARR updates (Version 4.2, Book 1, Chapter 6, dated 27 Aug 2024). The recommended uplift factors vary by the adopted Shared Socioeconomic Pathways (SSP) model, the project design life, and the duration of the assessed rainfall event.

Intensity-Frequency-Duration (IFD) data provided by the Bureau of Meteorology (BoM) are based on historical gauge data compiled through the year 2016. Current climate change guidance suggests that these IFD values are no longer relevant for present-day applications (2025), and the published trends imply that uplift factors should be applied to all projects regardless of the project inception date.

There is some flexibility in the selection of an SSP model, and the design life and relative risk of individual project elements may vary. SSP values include the following range based on Riahi, et al. (2017):

- SSP1: a world of sustainability-focused growth and equality
- SSP2: a “middle of the road” world where trends broadly follow their historical patterns
- SSP3: a fragmented world of “resurgent nationalism”
- SSP4: a world of ever-increasing inequality (SSP4)
- SSP5: a world of rapid and unconstrained growth in economic output and energy use

An adopted climate change strategy that confirms the preferred SSP model and considers the latest guideline revisions has not yet been finalised by Leichardt Salt. In light of the inherent uncertainties, a conservative interim uniform uplift factor of 20% has been applied to all model runs presented in this report, with the increased precipitation intensity offset by an assumed 10% increase in initial and continuing loss rates for natural catchments.

A 20% uplift factor is consistent with Year 2050 values for the SSP5 model (the most conservative model referenced by ARR) for a 12-hour precipitation event. The same 20% uplift factor would apply to Year 2075 values for the SSP2 model (the “middle-of-the-road” model). The corresponding soil infiltration uplift factor for the SSP2 2075 scenario is 10%.

These factors may be adjusted for future design phases. The current conceptual design condition presented in Chapter 4 below includes selected bridges and culverts that are designed to convey flows with the uniform adopted climate change uplift factors applied. Detailed designs of drains, levees, culverts, bridges, overflow spillways, and other infrastructure features may require separate uplift factors for consistency with adopted risk factors

Uplift factors increase significantly for shorter-duration storms. The 12-hour event is appropriate for external catchments; however, the internal ponds will have shorter critical rainfall durations and may require the adoption of higher climate change uplift factors for water balance calculations and hydrologic modelling. In addition, increased precipitation over ponded areas cannot be offset by higher soil losses, so the effects of the increased precipitation intensity on water balance calculations are more pronounced.

The project condition assessed in this hydraulic study is conservatively based on complete blockage of the project footprint. Earthworks and other design details have not been provided for assessment. This hydraulic assessment presents results from a limited number of precipitation events; additional modelling efforts will be required to refine the hydrotechnical understanding of the plans as detailed designs are incorporated into the modelled surfaces in future design stages. Specific climate change guidance for Western Australia may be developed in the future and may differ from the national averages used in the current guidance. As detailed designs progress, adopted climate change factors should be confirmed.

2.4 Regional Flood Frequency Estimation

Regional Flood Frequency Estimation (RFFE) procedures were applied to each of the three catchments upstream of the proposed pond locations using the basin size, outlet location, and centroid of each catchment (Ball et al., 2019). The project area is located approximately 80 km from the nearest gauged catchments, which include several catchments with drainage areas approximately equal to the site catchments. Due to the elongated, linear shape of the Eramurra catchments, however, the RFFE results state that the applicability of the predicted peak flow rates may be limited.

Table 2-2 shows the results for Eramurra Creek, **Table 2-3** shows the results for McKay Creek, and **Table 2-4** shows the results for Devil Creek. The RFFE results indicate substantial uncertainty, with peak flow estimates from 5% and 95% confidence limits varying by greater than an order of magnitude. The level of uncertainty is related to the lack of available gauge data in close proximity to the site catchments along with variations in loss rates and other hydrological parameters within the closest gauged catchments. Results in this report provide indicative estimates of flood conditions; as additional local gauge data become available, the results can be calibrated with increased confidence. Sensitivity analyses (as presented in Appendix B) should be referenced to provide acceptable contingency recommendations for design implementation.

2.5 Observed Events

In February 2020, Severe Tropical Cyclone Damien resulted in substantial rainfall across the project area catchments. Gauge results from loggers onsite were compiled and assessed against rainfall records for the period from 8-10 February 2020. The maximum recorded 24-hour rainfall depth of 150 mm was found to be equivalent to the 1 in 10 AEP event. Some calibration of results was undertaken, with stage hydrograph results and additional recommendations for further gauging efforts issued in the document “Preliminary Hydraulic Modelling for the Cyclone Damien Event” (LWC 2021).

Table 2-2: RFFE results for Eramurra Creek

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	27.0	5.31	138
20	77.5	15.3	397
10	126	24.9	647
5	184	36.2	942
2	267	52.6	1370
1	333	65.6	1710

Table 2-3: RFFE results for McKay Creek

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	26.0	5.10	134
20	74.6	14.6	383
10	122	23.8	624
5	177	34.7	909
2	257	50.4	1320
1	321	62.9	1650

Table 2-4: RFFE results for Devil Creek

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	33.8	6.70	171
20	96.9	19.2	490
10	158	31.3	798
5	230	45.6	1160
2	334	66.3	1690
1	417	82.7	2110

3.0 EXISTING CONDITIONS MODEL

An existing conditions flood model was set up using HEC-RAS Version 6.7 (USACE, 2025) with the following input parameters. Existing conditions model runs were developed for the 63% and 10% AEP events.

3.1 Terrain

The underlying terrain for the HEC-RAS model is based on a 0.5-metre by 0.5-metre resolution digital elevation model (DEM) developed from LiDAR data acquired by MNG on 18, 19, and 20 January 2022. Priority coastal areas were captured during times aligning with low tide windows. The horizontal datum for the terrain is GDA2020 MGA Zone 50, and the vertical datum is the Australian Height Datum (AHD), based on 1966-1968 Mean Sea Level (MSL). The survey used seventeen ground control grids and was tied into standard survey marks. The DEM has a stated accuracy of +/-100mm. The DEM covers the entirety of the catchment areas contributing to the Eramurra Salt Project and includes Indian Ocean coastal topographic data to an elevation of approximately -1.0 to -1.5m AHD. Inundated areas at the time of survey were excluded from the DEM surface, and bathymetric levels have been manually estimated for use in the hydraulic model. Metadata for the survey are included in the Aerial Survey Report (MNG, 2022).

3.2 2D flow area

A 725 km^2 2D flow area was delineated to cover the contributing catchment area and Cape Preston. A computational mesh spacing of 50 metres by 50 metres was applied to floodplain areas, with a mesh spacing of 10 metres applied along break lines for concentrated flow paths (see example in **Figure 3-1**). HEC-RAS recognises sub-grid terrain resolution, and the computation of flow transfer between individual grid cells accounts for the geometry of the underlying surface at the terrain resolution of 0.5-metre by 0.5-metre.

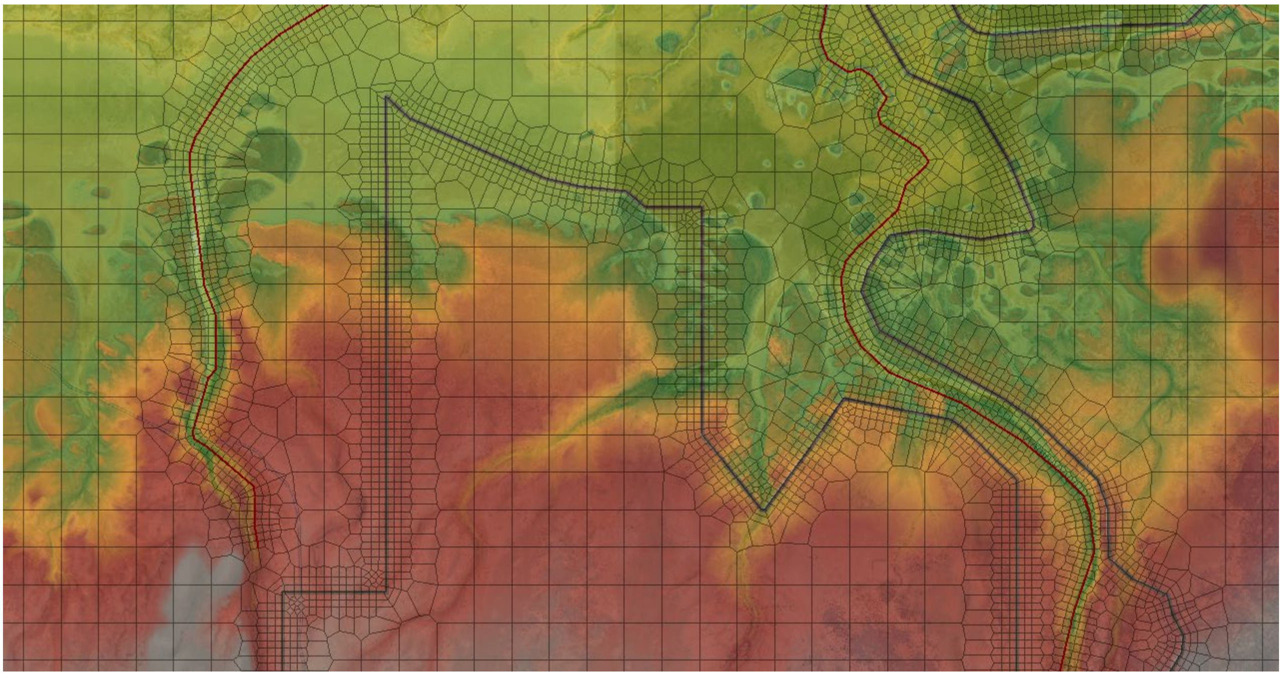

Figure 3-1: Example of mesh alignment

3.3 Roughness

Spatially varying Mannings roughness coefficients were assigned to the modelled areas. Applied roughness coefficients range from 0.05 for channels to 0.20 for floodplains. The relatively high floodplain roughness coefficients account for shallow flow characteristics in the sheet flow areas of the rain-on-grid model extents. A range of uniform roughness coefficients was applied to the model as a sensitivity analysis to account for potential differences arising from variable flow depths, vegetation coverage and other uncertainties. Roughness coefficient sensitivity analyses were conducted for the Cyclone Damien event modelling in 2020. Selected sensitivity analysis results are included in Appendix B.

3.4 Loss rates

Initial and continuing loss rates are not available from the Australian Rainfall and Runoff data hub for this region. Based on a comparison to the Cyclone Damien modelling results, an initial loss of 20 mm was selected for the 1EY event, increasing to 50 mm for the 1% AEP event. Initial loss rates were interpolated for intermediate events. A continuing loss rate of 5 mm/hr was added to the resulting initial loss rates. In accordance with ARR guidance, median pre-burst depths were removed from the initial losses. The final total loss rates removed from the precipitation estimates are intended to account for all infiltration, evaporation, and transpiration losses. Sensitivity analyses were conducted for varying loss rates, including completely saturated conditions, initial loss only, continuing loss only, and spatially distributed losses. Selected sensitivity analyses results are included in Appendix B.

3.5 Precipitation

BoM rainfall depths were applied to the direct rainfall model for durations ranging from 1 hour to 24 hours to aid the selection of a critical duration. The resulting critical duration for the upstream extent of the pond areas was found to be 12 hours. Ensemble temporal rainfall patterns for Rangelands West (**Figure 3-2**) were extracted for the critical duration event and applied to the model using areal results for a 100-km^2 catchment.

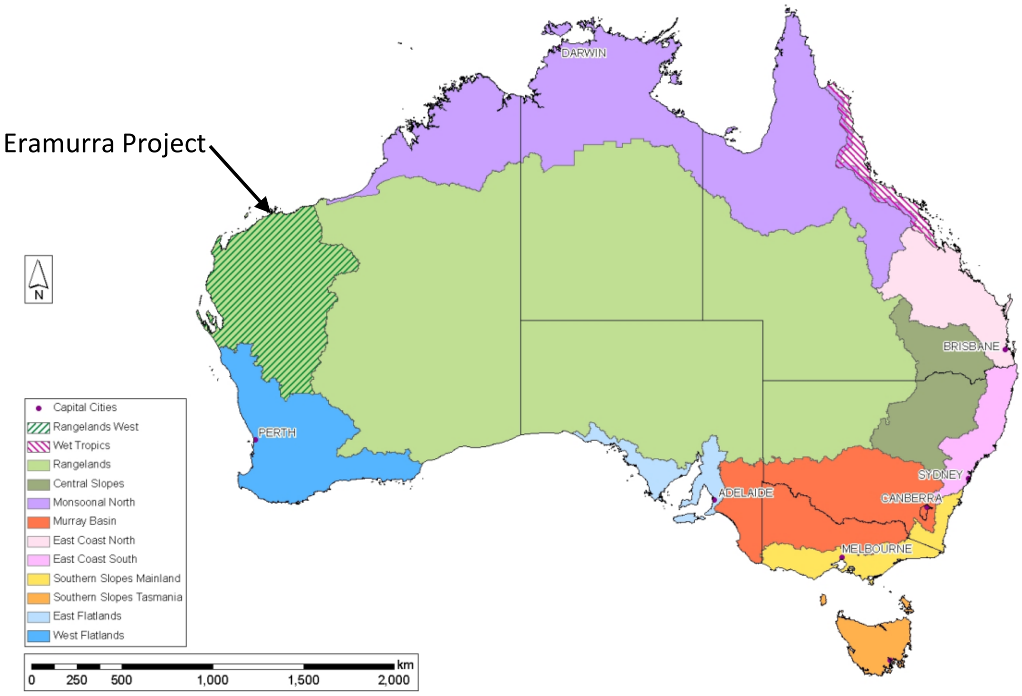

Figure 3-2: Australian temporal pattern locations (from ARR Book 2 Figure 2.5.7)

Figure 3-3 shows the applied 12-hour rainfall hyetographs, and **Figure 3-4** shows the resulting runoff hydrographs. Additional precipitation data extracted from the Australian Rainfall and Runoff (ARR) data hub are included in Appendix A.

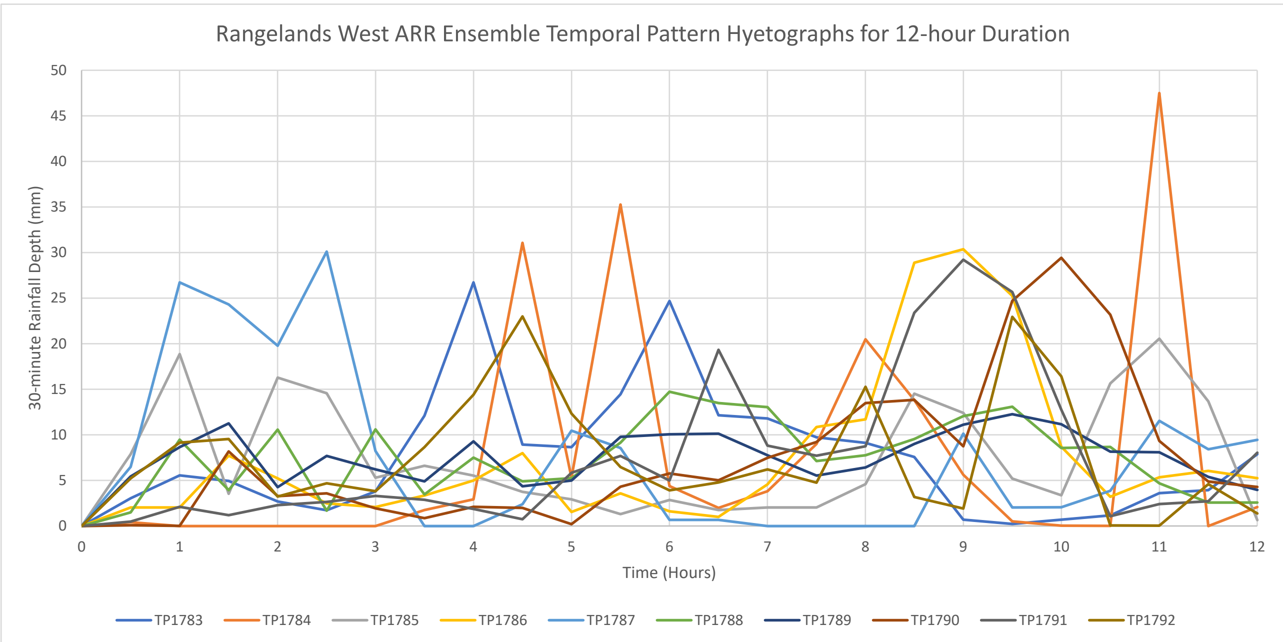

Figure 3-3: Applied precipitation hyetographs for Eramurra Salt Project

Based on recommended ARR methodologies (Ball et al., 2019), the first temporal pattern resulting in a peak discharge rate exceeding the mean of the ten ensemble results was selected for use in the hydraulic model as an unsteady time series inflow boundary condition. The flow hydrograph from the selected temporal pattern, TP#1786, is highlighted in **Figure 3-4**.

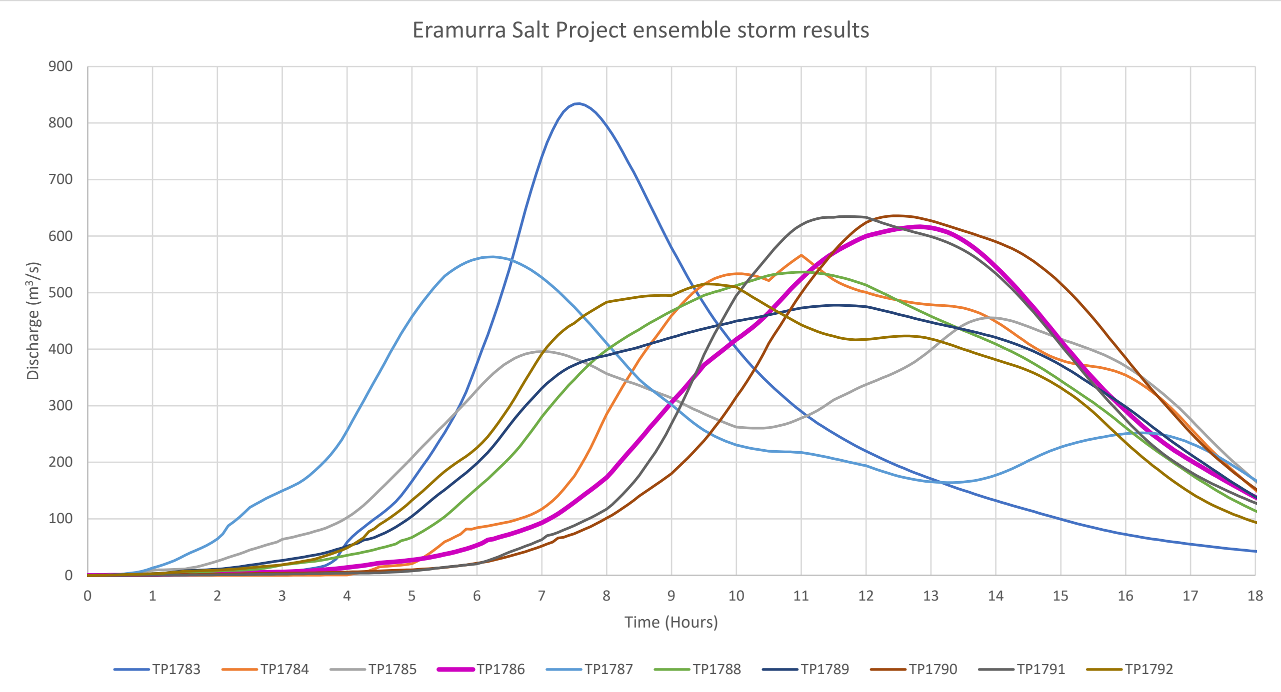

Figure 3-4: Applied precipitation hyetographs for Site G1

3.6 Boundary conditions

The downstream boundary condition was assigned a constant stage hydrograph for a sea level of 0.0 relative to the Australian Height Datum (AHD) throughout each simulation window. The AHD datum is based on the 1966-1968 Mean Sea Level (MSL). Sensitivity analyses were performed for 10% AEP and 5% AEP storm surge levels using an average of the RPS Metocean report values shown in **Table 3-1** and **Figure 3-5**. Project conditions impacts relative to the existing conditions were found to be reduced during storm surge conditions.

Table 3-1: Combined tide and storm surge levels (m AHD) from Eramurra Metocean report (RPS 2021)

Location\AEP	1 in 10	1 in 20	1 in 25	1 in 50	1 in 100	1 in 500
Average Jetty+Bays	**2.69**	**2.85**	**2.89**	**3.04**	**3.19**	**3.50**
Jetty Head	2.63	2.76	2.80	2.92	3.03	3.30
Bay 1	2.69	2.85	2.90	3.05	3.19	3.50
Bay 2	2.71	2.87	2.92	3.07	3.22	3.54
Bay 3	2.71	2.89	2.94	3.11	3.27	3.63
Bay 4	2.70	2.86	2.91	3.07	3.22	3.54
Anchorage 2	2.53	2.64	2.67	2.77	2.87	3.07

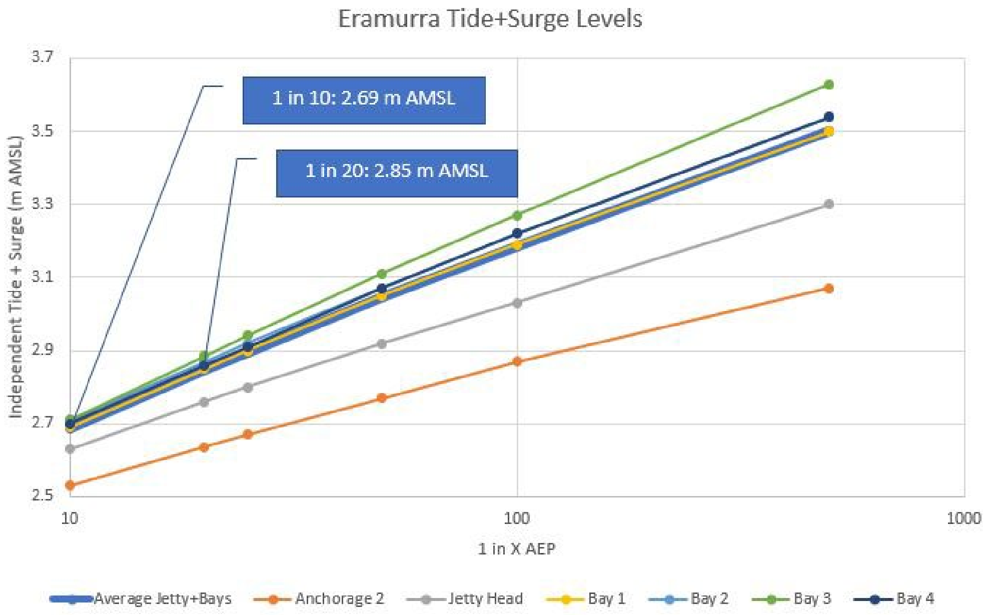

Figure 3-5: Tide and storm surge level interpolation

3.7 Simulation window

A 48-hour simulation window was applied to the model to allow complete propagation of the flood wave. Results were checked to confirm that the simulation time adequately captured the rise and recession of peak flows throughout the modelled areas.

3.8 Computational time step

A variable time step was assigned based on a maximum Courant Number of 2.0. Using this option, HEC-RAS selects an adaptive time step based on the assigned computational mesh size and computed velocities. The adopted time step generally ranged between 5 and 10 seconds. Mass balance errors and water surface elevation convergence errors were checked to ensure model stability and that imbalances remained below reasonable thresholds, confirming compliance with Courant Number criteria.

3.9 Structures

A 125-metre span bridge opening was included over Bangemall Creek along the Cape Preston access road as shown in **Figure 3-6**.

No other culverts or bridge structures were included in the existing conditions model. This approach assumes that any low-flow culverts along existing features are blocked or ineffective at the modelled flood stages.

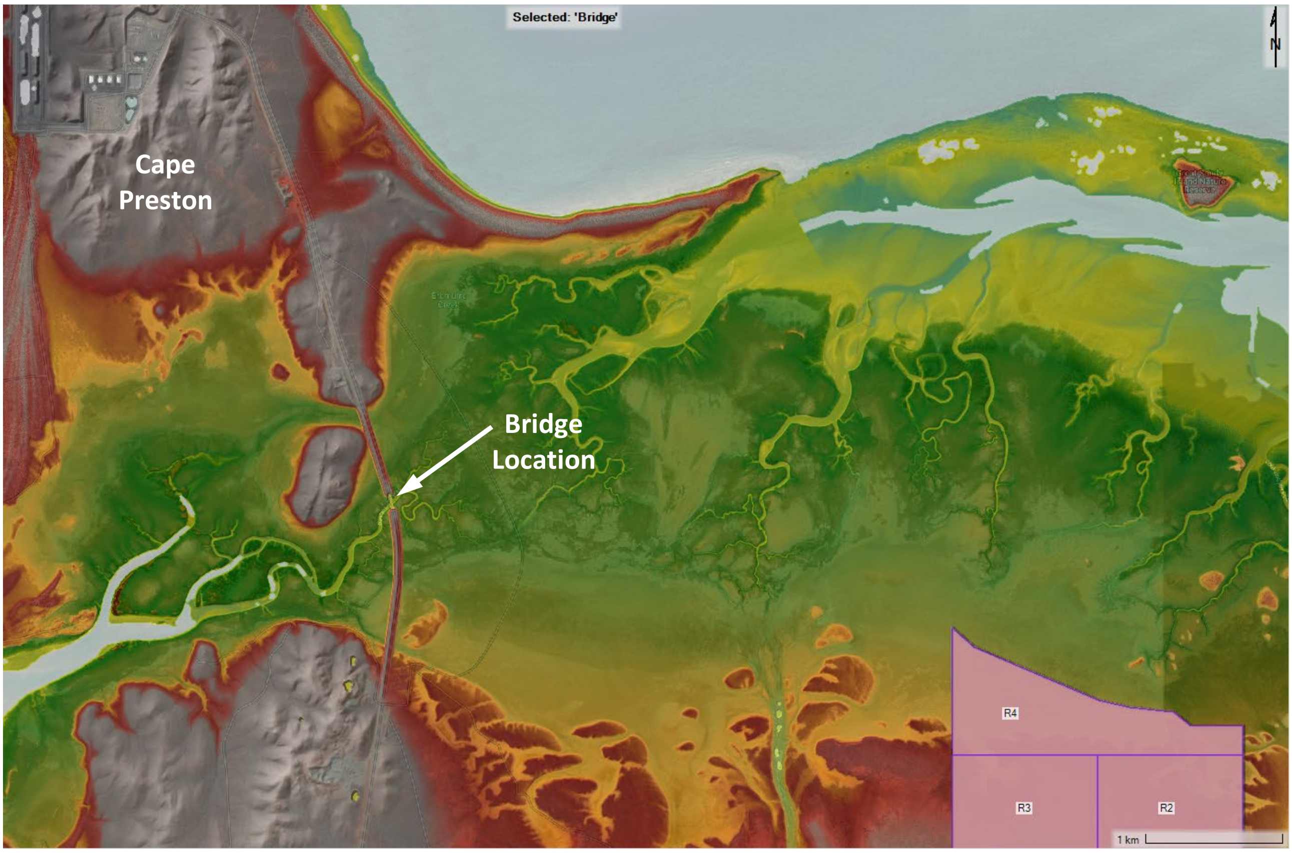

Figure 3-6: Modelled bridge location

3.10 Calculation options and tolerances

The full momentum shallow water equation set was applied in order to account for inertial terms that become significant with the changes in flow direction and other characteristics of the flow across the sites. Except where otherwise noted, program defaults have been applied to all remaining coefficients, options, tolerances, and model settings.

3.11 Summary

Table 3-2 summarises the model parameters used for the existing conditions model runs.

Table 3-2: Summary of model parameters

Model Parameter	Value
Inflow	12-hr 1EY-1% AEP precip
Outflow	Constant stage tidal hydrographs
Simulation window	48 hours
Computational time step	5-10 seconds
Computational mesh grid	5-50 metres
Roughness	0.05 to 0.20
Equation set	Full momentum
DEM grid resolution	0.5 x 0.5 metres

4.0 PROJECT CONDITIONS MODEL

Project conditions hydraulic models were set up identically to the existing condition model, with the adjustments listed below applied to the proposed model geometry. The proposed features were merged with the DEM to create a proposed raster grid terrain surface with a horizontal resolution of 0.5 metre by 0.5 metre.

4.1 Ponds

For the project conditions hydraulic models, levees were placed around each of the three pond area perimeters to completely separate pond areas from all external runoff for events up to the 1% AEP flood event. Some of the obstructed areas are understood to be located on raised pads without levees; the entire project footprint is conservatively blocked from external flood flows in the hydraulic modelling.

4.2 Drains, Culverts, and Levees

Drains are required around the outside of the ponds to facilitate drainage and prevent standing water against the bunds. One major drain with a bottom width ranging from 5 m to 20 m was added to the project conditions model terrain surface. **Figure 4-1** shows the drain location. In order to conservatively reflect maximum impacts, minor drains have not been included in the current project conditions model. Haul road crossings are assumed to be at grade without obstructions to creek flow profiles and are not included in project conditions earthworks models.

A series of box culverts was added to the project conditions model with a total span of 30 m as indicated in **Figure 4-1**. Separate, higher resolution hydraulic models were developed for the Santos Devil Creek Gas Plant (DCGP) area, incorporating a range of options with gated culverts serving as valved openings. Due to the differing scales of the adopted computational mesh resolution, the valved openings are not incorporated into the hydraulic model presented in this report; the FMBR area is separated from external inflows by a levee that prevents inflow up to the 1% AEP event. Drain dimensions and flood levee details are included in Surface Water Assessment to Inflow Surface Water Management and Drainage – Technical Memorandum ESSP-NP-13_TRPT-0004 Rev B (LWC 2023).

All other model parameters, including applied precipitation events and other boundary conditions, are consistent with the existing conditions model. The recommendations in this report are based on the 4 July 2023 configuration for the drain, levee, and culvert, with 12 Dec 2024 updates to reflect revisions to provide additional offset between the pond perimeter and Mackay Creek.

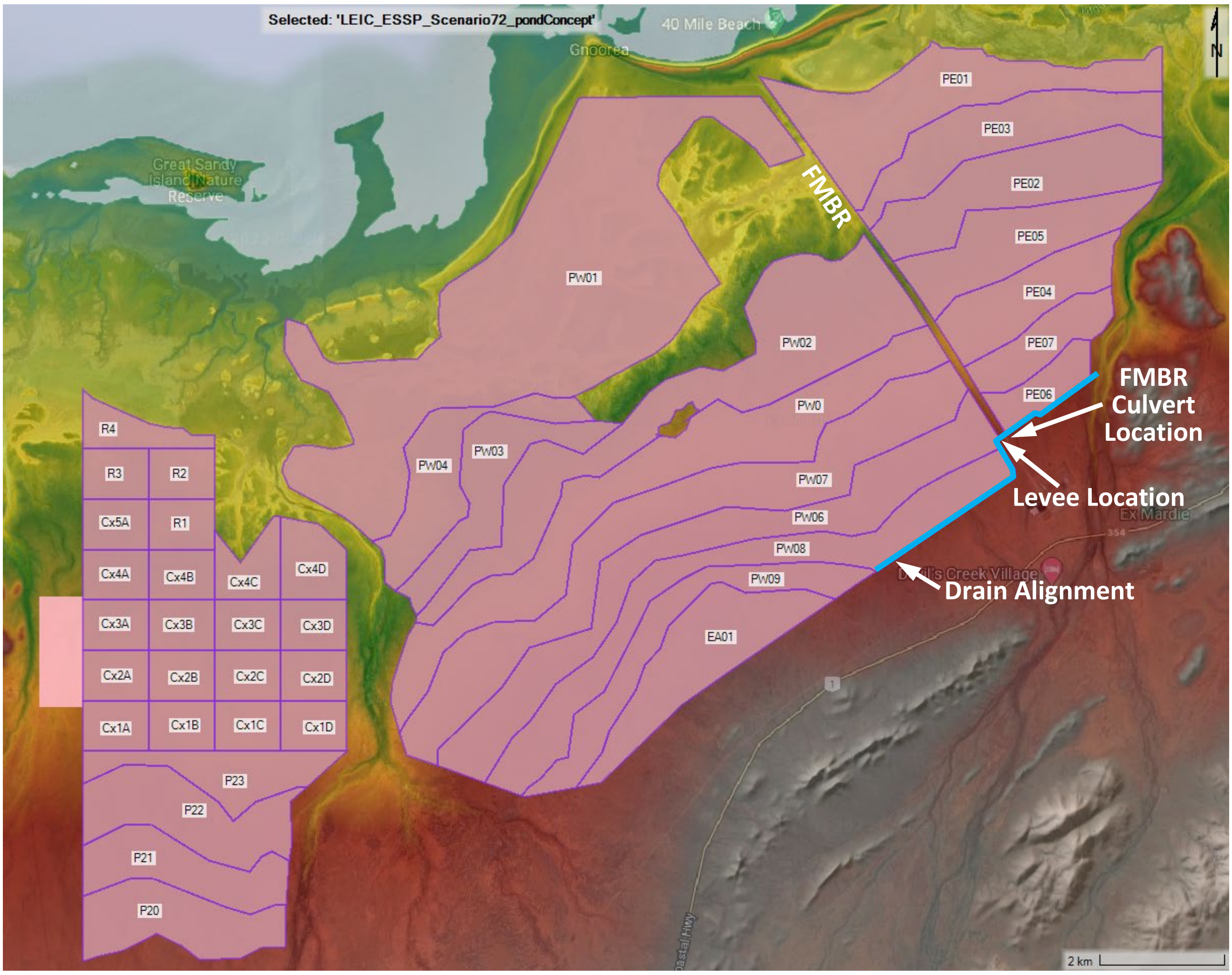

Figure 4-1: Location of drain added to model terrain

5.0 MODEL RESULTS

Results are presented below in terms of discharge hydrographs, cumulative flow volumes, maximum flood depths, and velocities.

5.1 Discharge

Figure 5-1 compares the total discharge to the ocean from all three tributaries during a 10% AEP event for existing and project conditions. **Figure 5-2** shows the corresponding cumulative flow hydrograph.

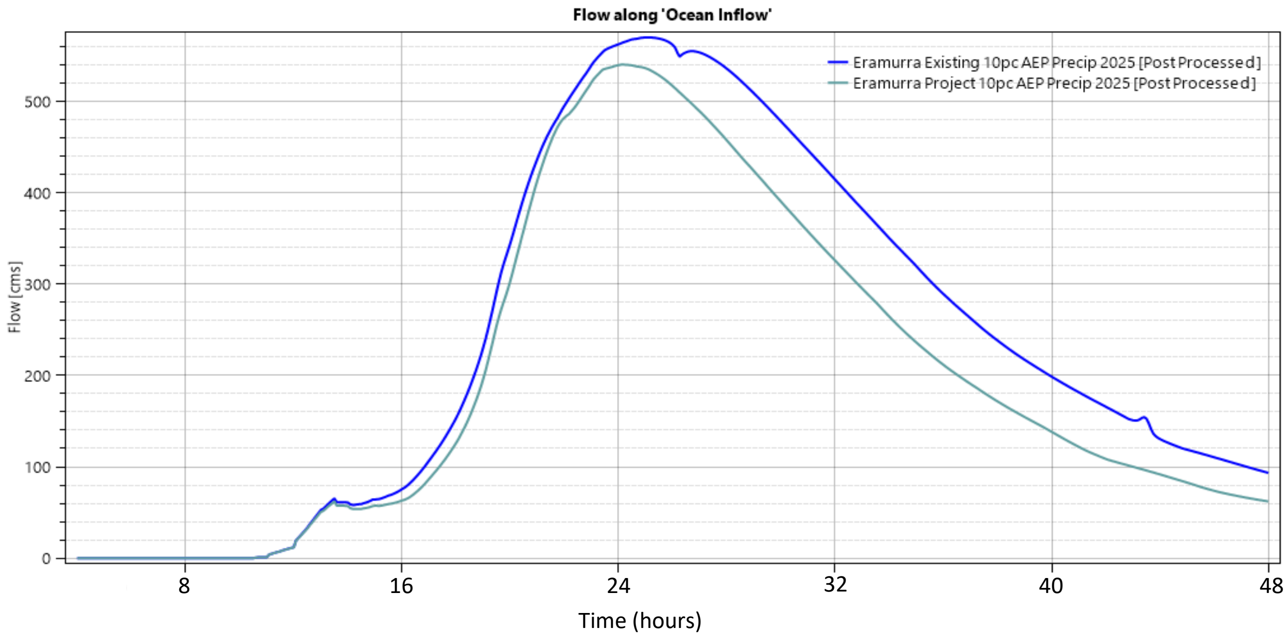

Figure 5-1: Comparison of existing and project conditions flow hydrographs for 10% AEP event

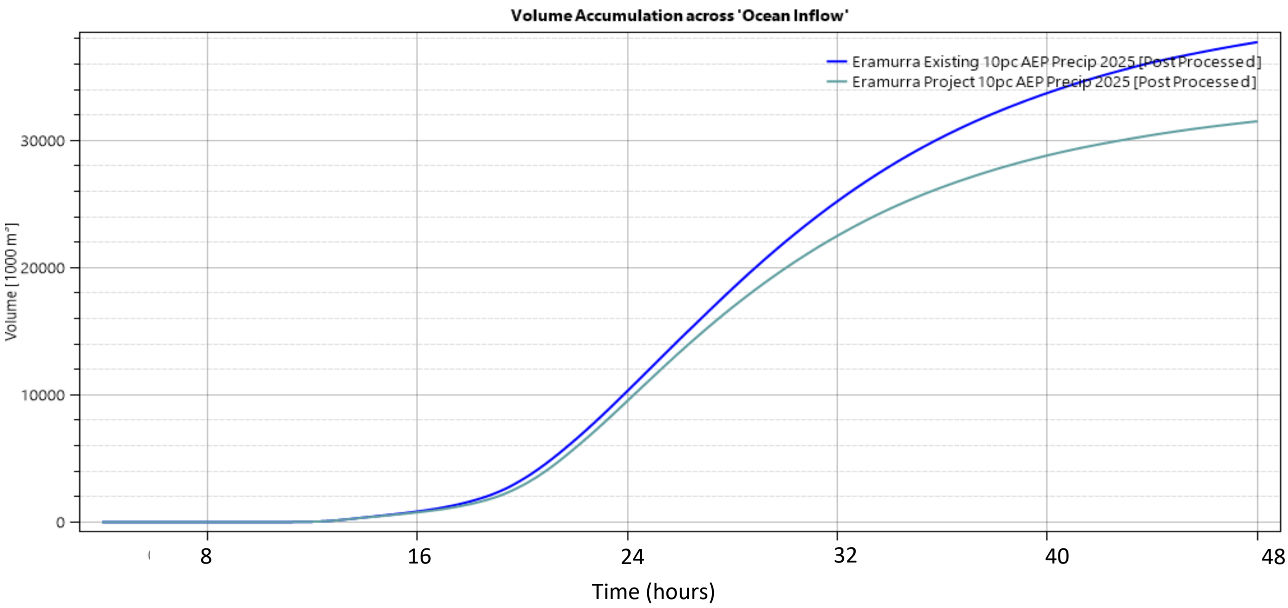

Figure 5-2: Comparison of existing and project conditions cumulative flow volumes for 10% AEP event

As shown in the figures, the peak flow rate released to the ocean is reduced by approximately 5%. The total volume of flow released to the ocean during the 10% AEP event is reduced by approximately 14% over a 2-day simulation window. The total volume of freshwater delivered to the ocean is reduced in the project conditions scenario because of the 17% reduction in catchment area resulting from runoff capture in the proposed pond area.

Evaluation of the impact of changes in flow rate or volume to any identified environmental value (EV) has not been conducted. An effects assessment has been completed where impacts from changes to groundwater levels and quality by the development were presented (CDM Smith 2023). The groundwater study did not account for surface water interaction. The results presented here do not account for groundwater inputs; the levels reported are entirely due to changes in surface water inputs.

5.2 Depths and Velocities in Creeks

Figure 5-3 shows the maximum existing conditions inundation depths and extents for the 63% AEO event. **Figure 5-4** shows the corresponding velocities. **Figure 5-5** shows the maximum inundation depths and extents with the pond areas blocked. **Figure 5-6** shows the resulting velocities. **Figure 5-7** shows the difference in maximum water surface elevation (afflux) between the existing and project conditions.

Figure 5-8 shows the existing conditions maximum inundation in the 10% AEP event. **Figure 5-9** shows the corresponding maximum velocities. **Figure 5-10** shows the project conditions depths, and **Figure 5-11** shows the project conditions velocities. **Figure 5-12** shows an afflux map for the 10% AEP water surface elevations. **Figure 5-13** summarises the affected areas with increased and decreased maximum water surface elevations.

Figure 5-14 shows the maximum inundation depths and extents for project conditions for the 5% AEP event. **Figure 5-15** shows the 2% AEP event with a downstream boundary condition of 0.0 mAHD. **Figure 5-16** shows the 2% AEP event with a 20% AEP storm surge of 2.69 mAHD. **Figure 5-17** shows the 1% AEP maximum inundation depth and extents for project conditions with a downstream boundary condition of 0.0 mAHD. **Figure 5-18** shows the 1% AEP precipitation event with a 10% AEP storm surge (2.85 mAHD). **Figure 5-19** shows the 1% AEP event with a 5% AEP storm surge and 0.9 m of sea level rise due to climate change.

The adopted sea level rise is based on recommended 2110 levels outlined in the WA Environmental Protection Authority's Environmental Factor Guideline for Coastal Processes (WA EPA, 2016).

Figure 5-20 shows the chainages along each of the three creeks for reference in the profile figures. **Figure 5-21** and **Figure 5-22** show the maximum water surface elevation profiles along Eramurra Creek for existing and project conditions. Both the 1EY and 10% AEP profiles are included; 5% AEP and larger events are shown in **Figure 5-23**. Differences between existing and project conditions are generally not discernible in the full profile plots. The zoomed in views show the downstream areas where the differences are greatest.

Figure 5-24, **Figure 5-25, and Figure 5-26** show the maximum water surface elevation profiles along McKay Creek. **Figure 5-27, Figure 5-28**, and **Figure 5-29** show the profiles along Devil Creek.

Afflux maps are shown with a 10 cm threshold for display. Project conditions model runs do not account for local drainage inside the ponds or constructed drains to facilitate drainage along the external pond perimeter, with the exception of the drain near the gas plant. Depth differences are limited to the immediate vicinity of the ponds, with all observable upstream increases in water surface elevation located within 500 m of the proposed bund locations.

Maximum depth differences within Eramurra Creek are indiscernible between existing and project conditions. Differences in McKay Creek are limited to the area downstream of Chainage 7000, with the maximum difference in the 10% AEP event being approximately 350 mm. Differences in Devil Creek are limited to the area downstream of Chainage 3000, with the maximum difference in the 10% AEP event being approximately 58 mm.

Areas downstream of the ponds are subject to reductions in maximum water surface elevation. The area with a maximum depth reduction is located west of the McKay Creek outlet. The maximum reduction in the 10% AEP event is approximately 520 mm, extending approximately 1.5 km from the ponds to the ocean.

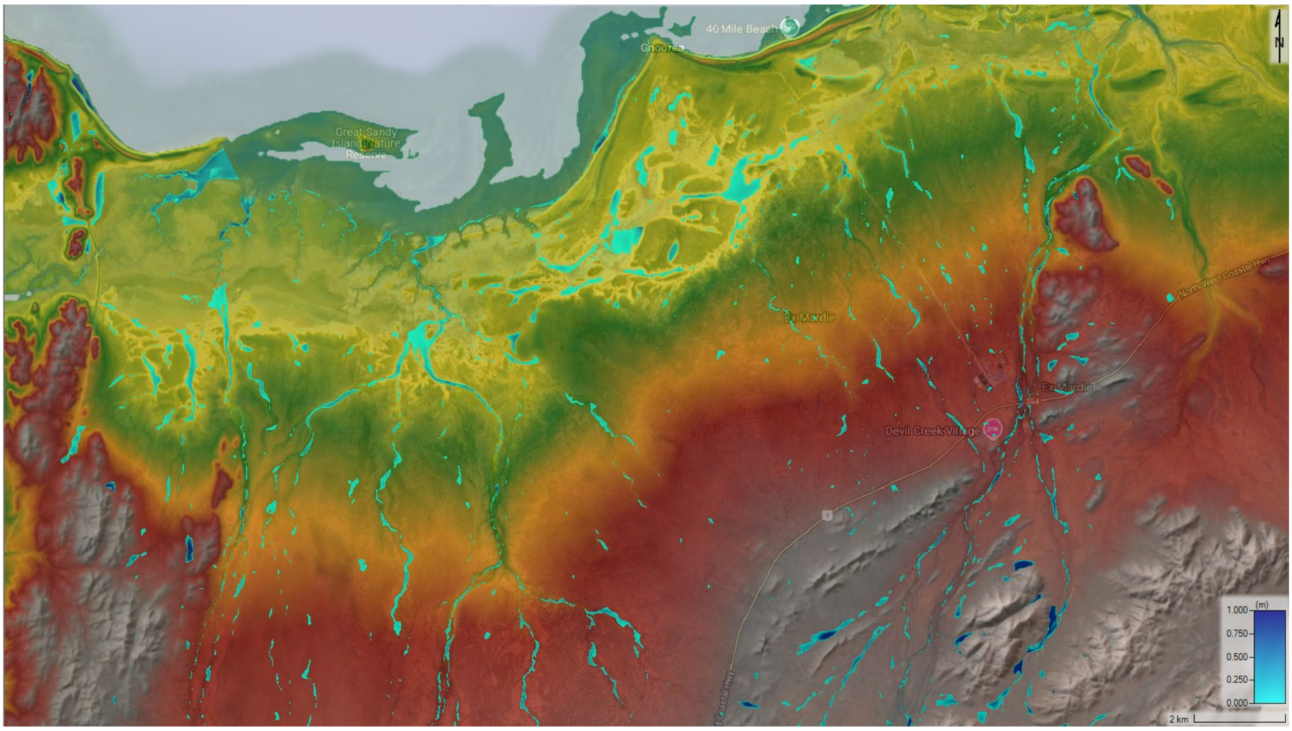

Figure 5-3: 1EY existing conditions maximum depth (metres)

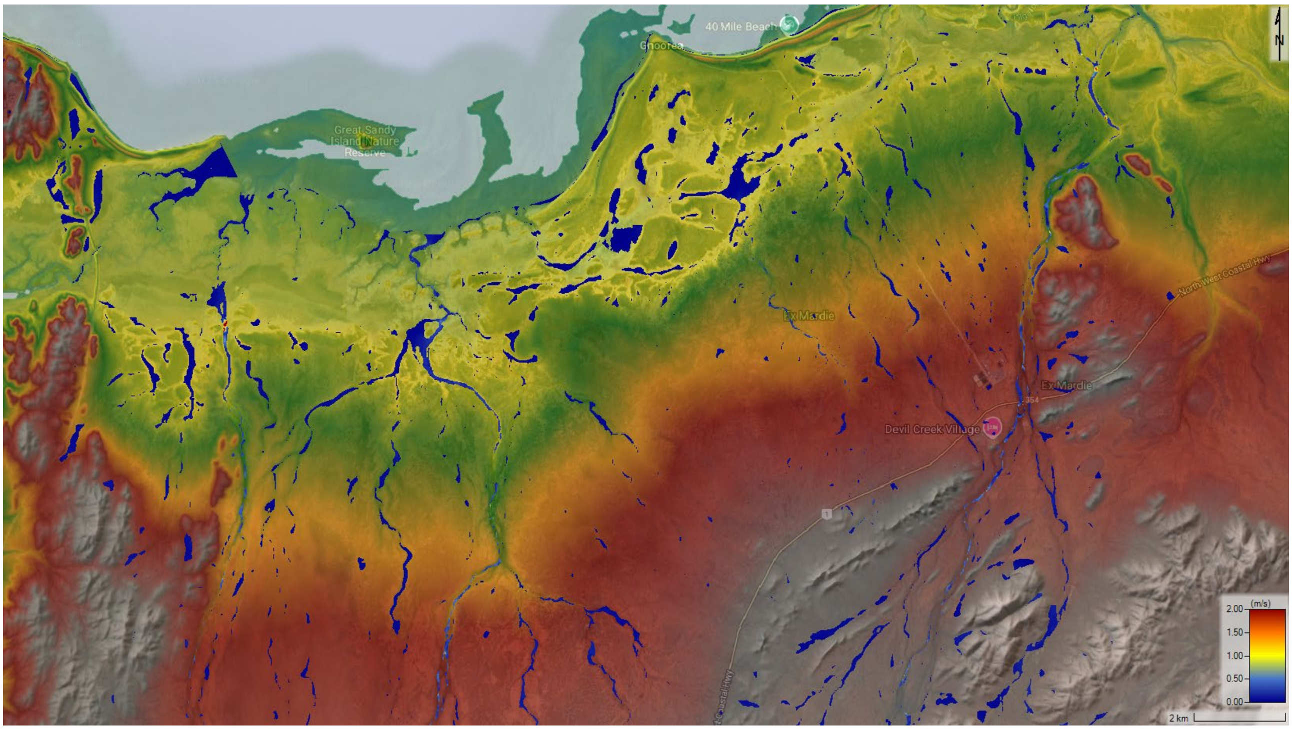

Figure 5-4: 1EY existing conditions maximum velocity (metres per second)

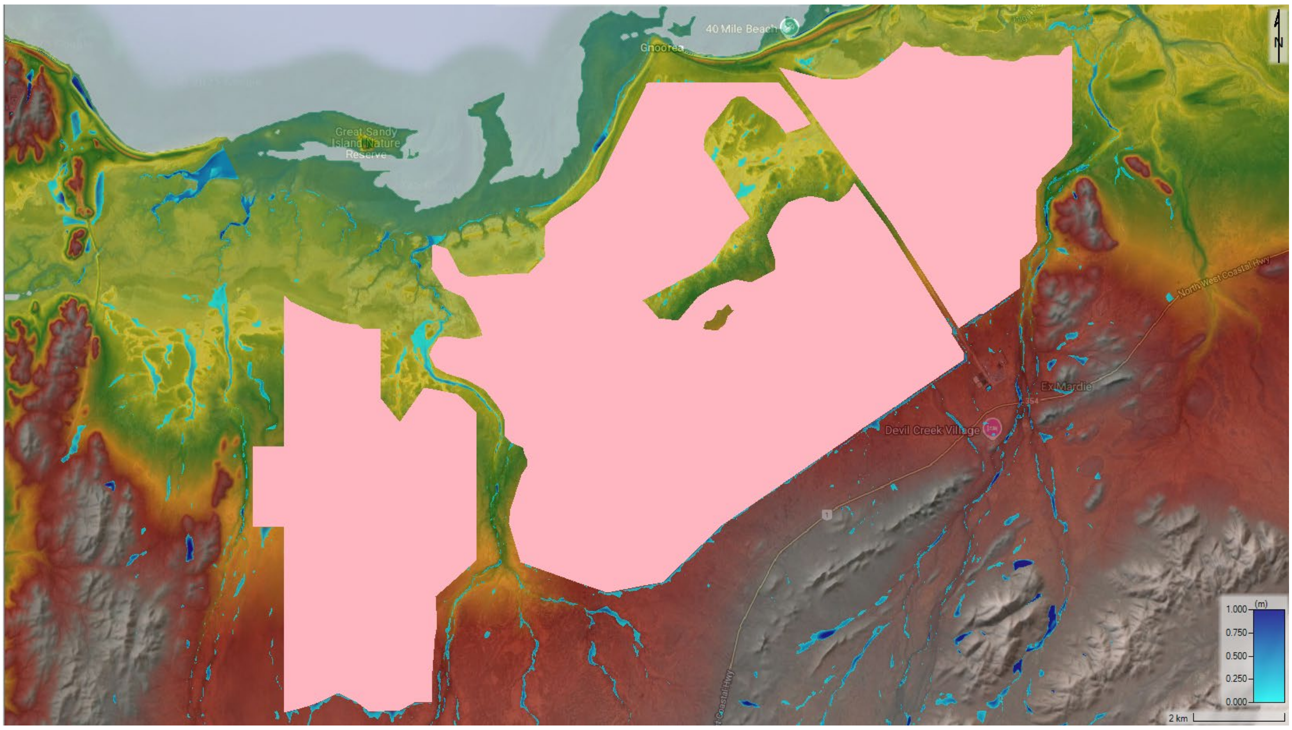

Figure 5-5: 1EY project conditions maximum depth (metres)

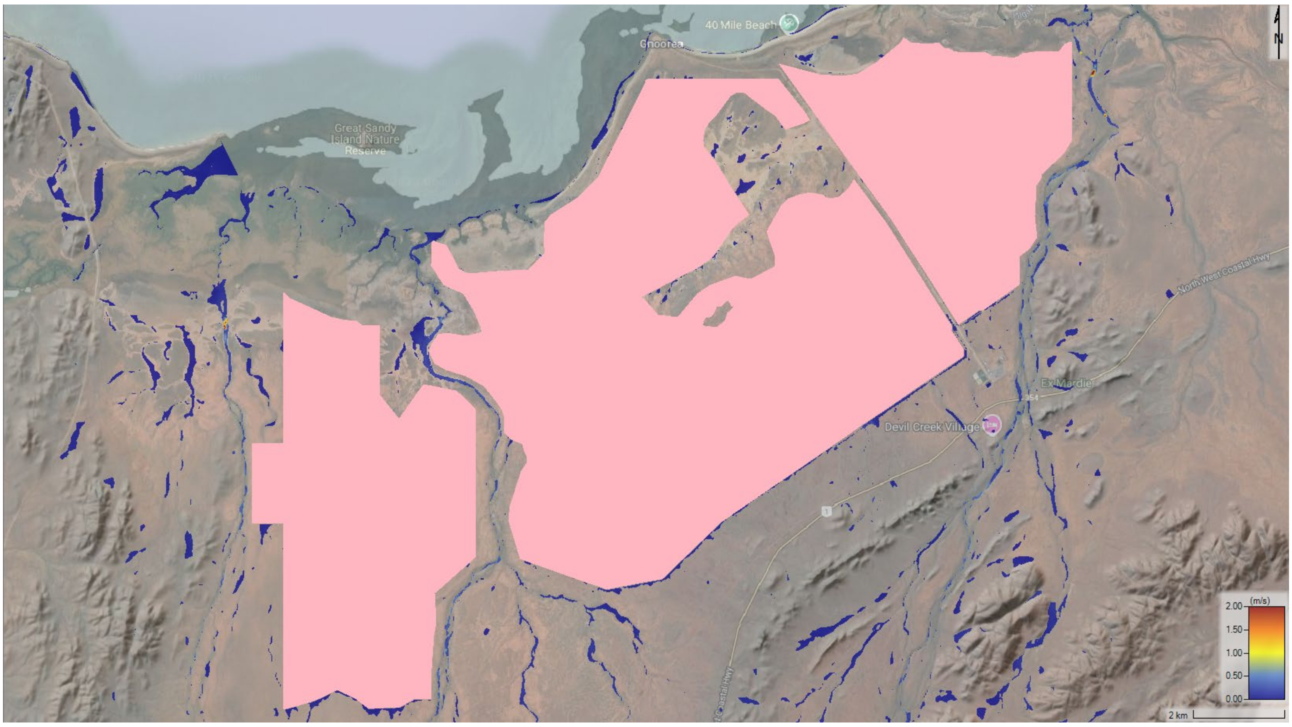

Figure 5-6: 1EY project conditions maximum velocity (metres per second)

Figure 5-7: 1EY maximum water surface elevation afflux (metres)

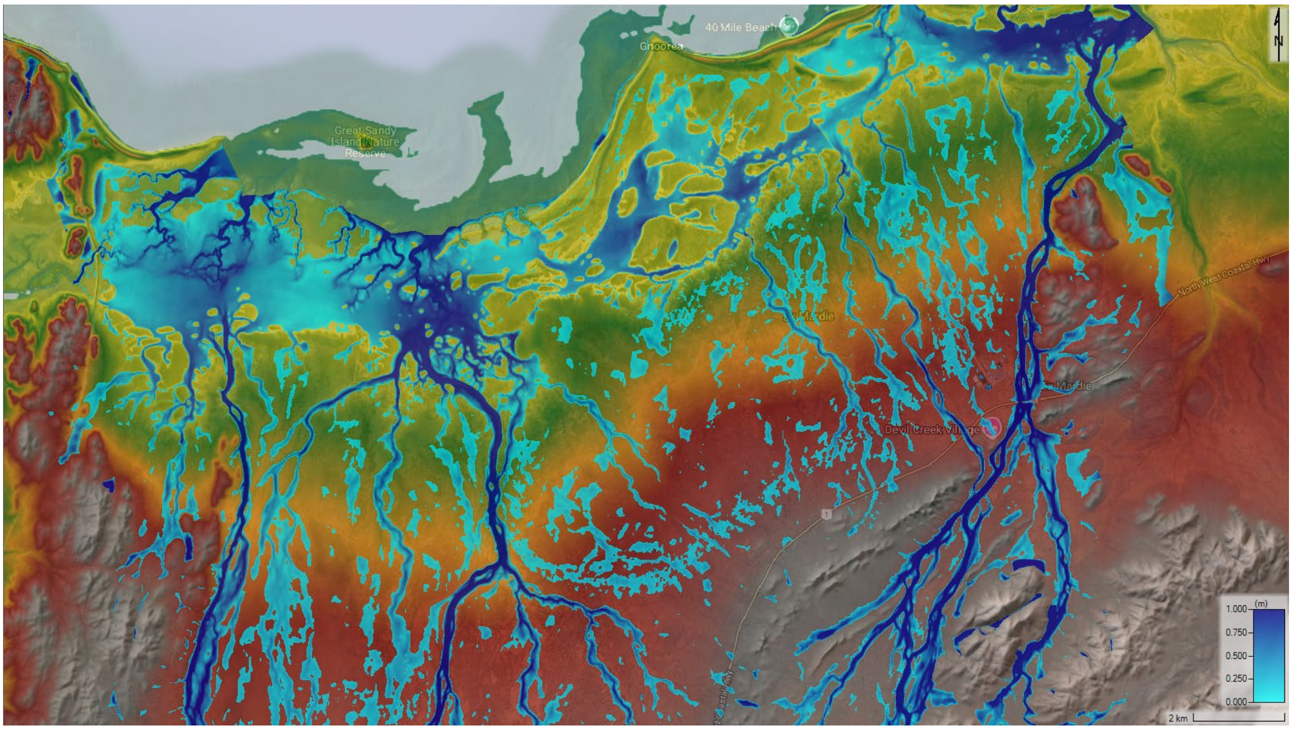

Figure 5-8: 10% AEP existing conditions maximum depth (metres)

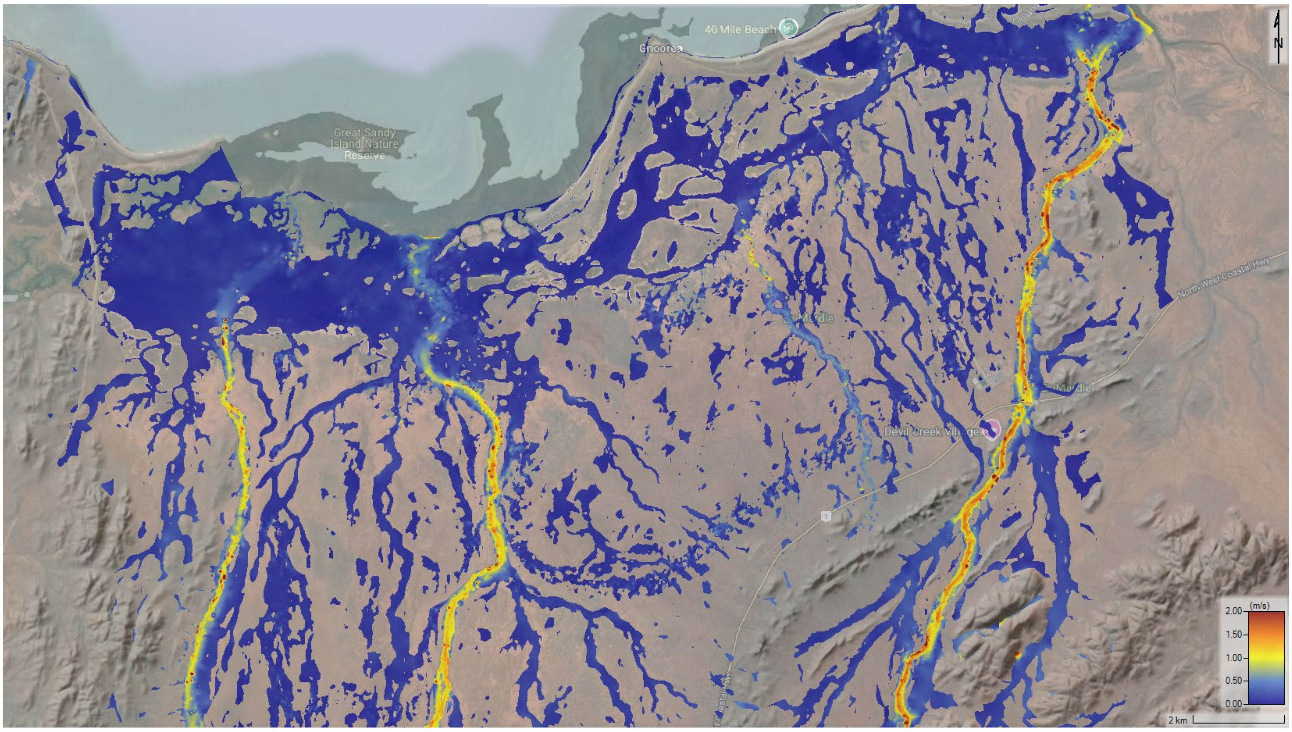

Figure 5-9: 10% AEP existing conditions maximum velocity (metres per second)

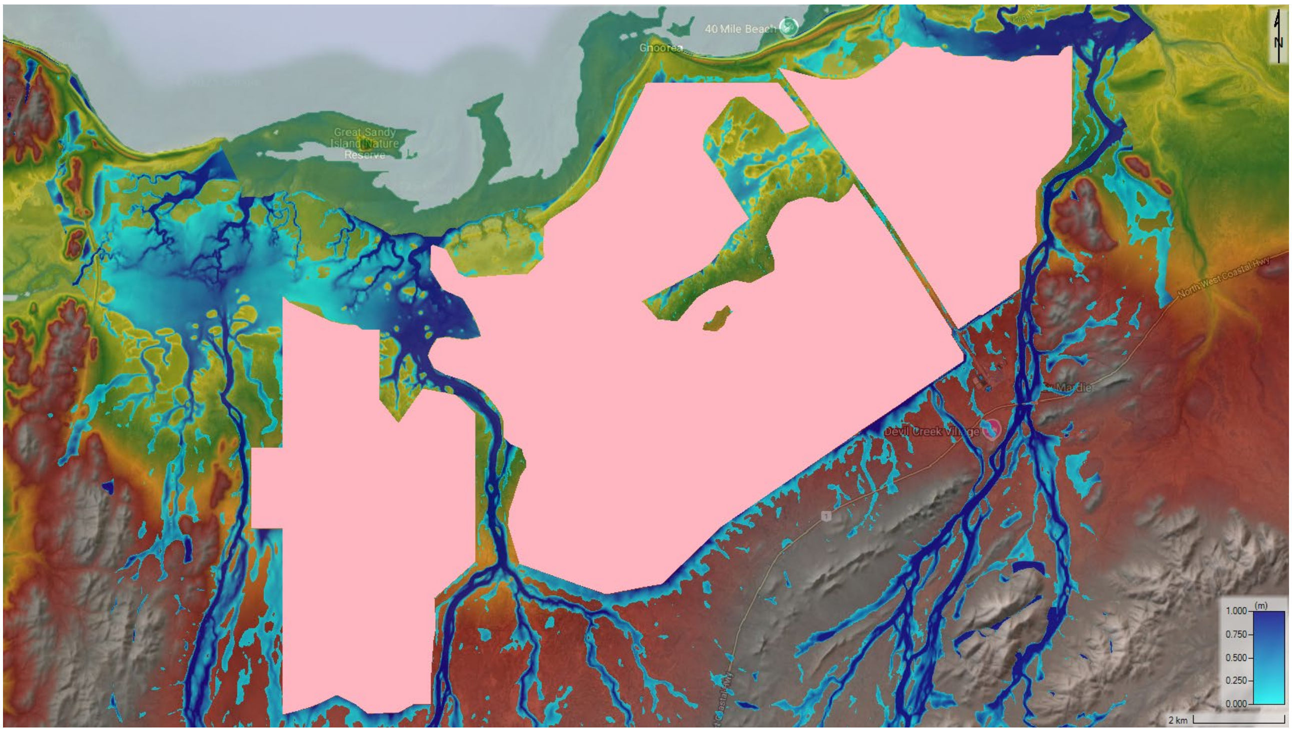

Figure 5-10: 10% AEP project conditions maximum depth (metres)

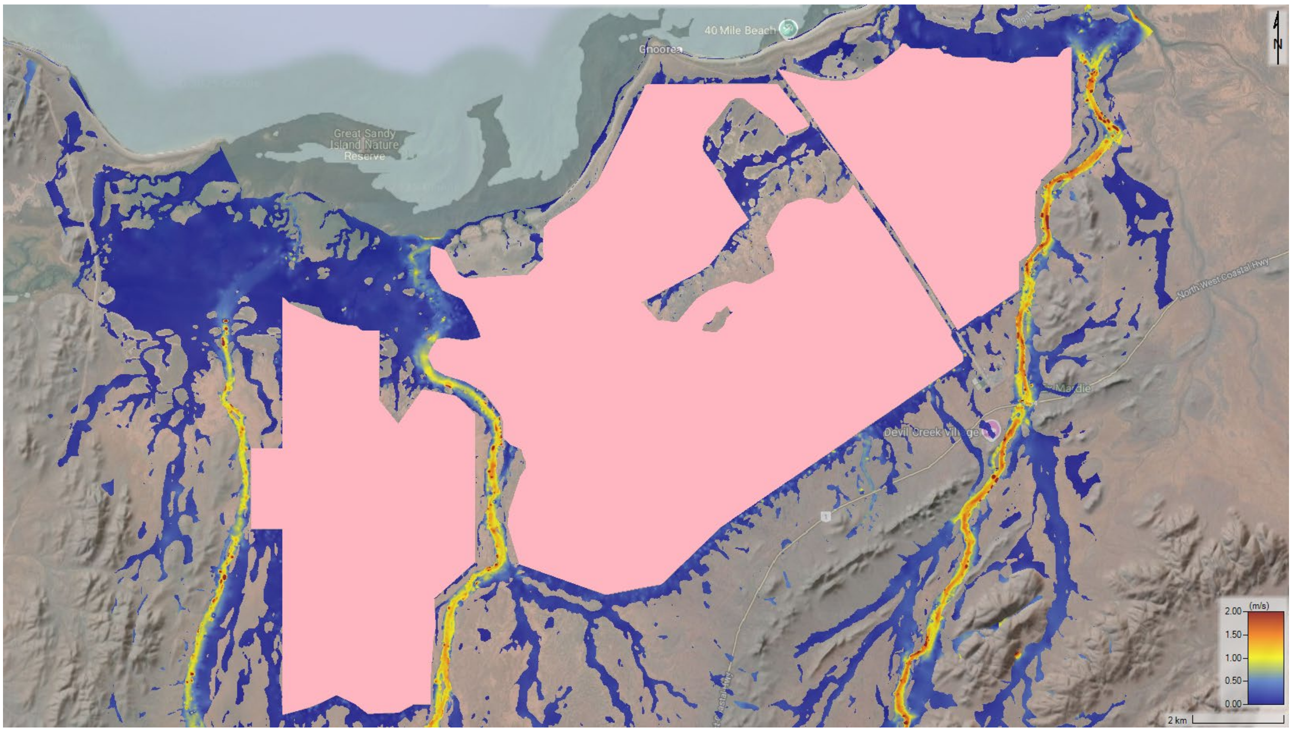

Figure 5-11: 10% AEP project conditions maximum velocity (metres per second)

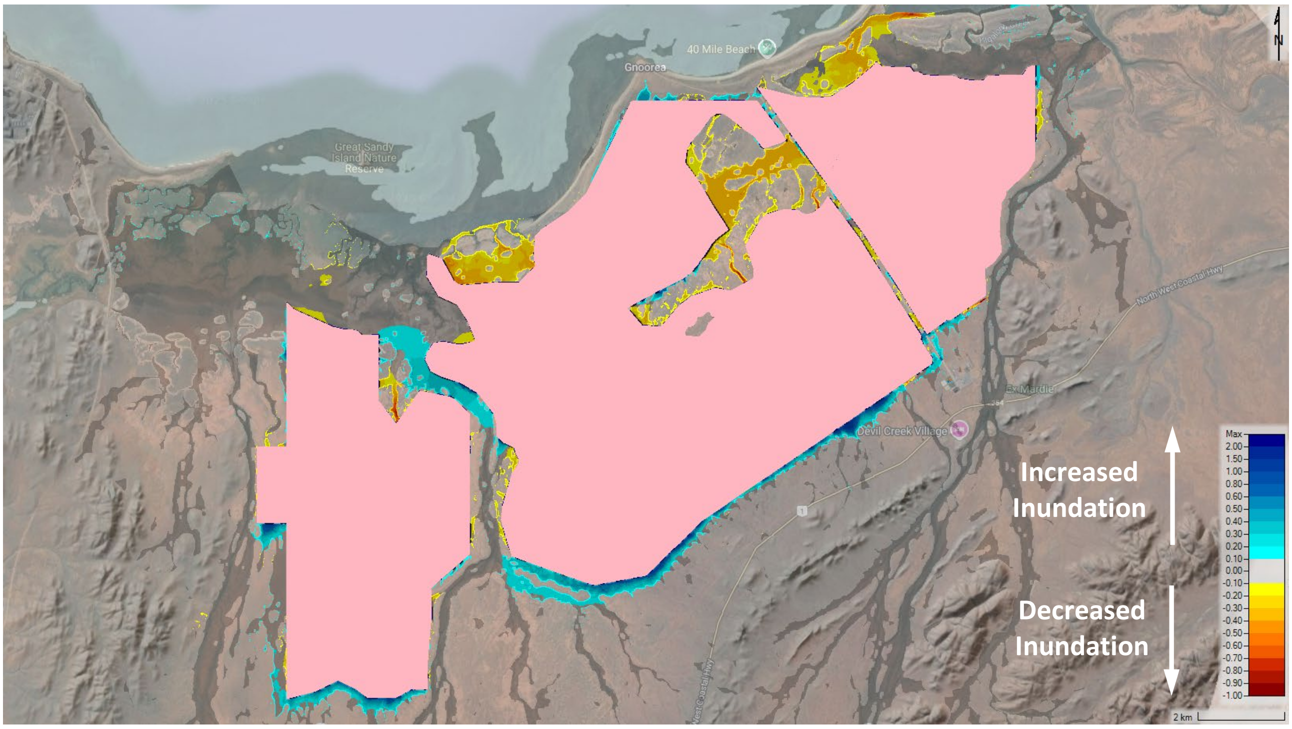

Figure 5-12: 10% AEP maximum water surface elevation afflux (metres)

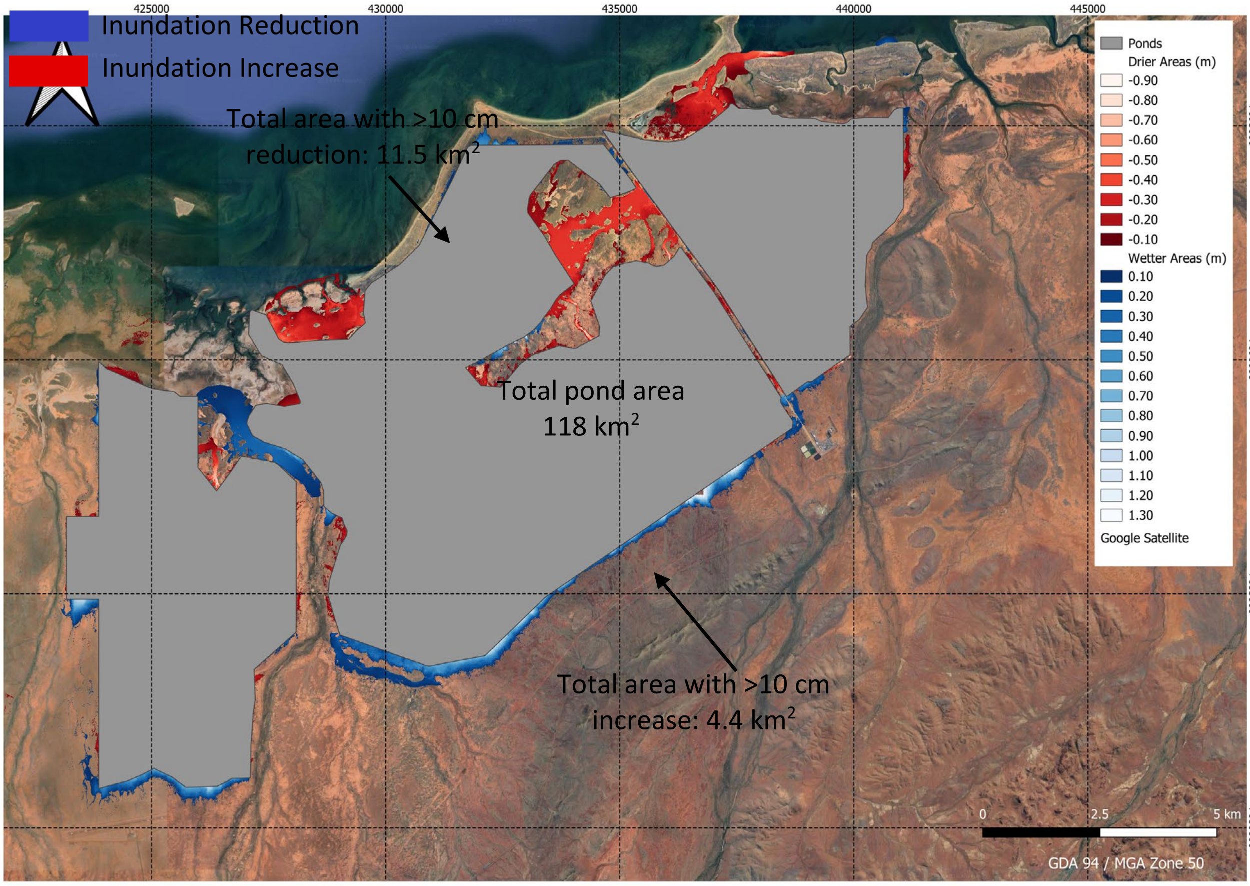

Figure 5-13: 10% AEP maximum water surface elevation afflux area tabulation

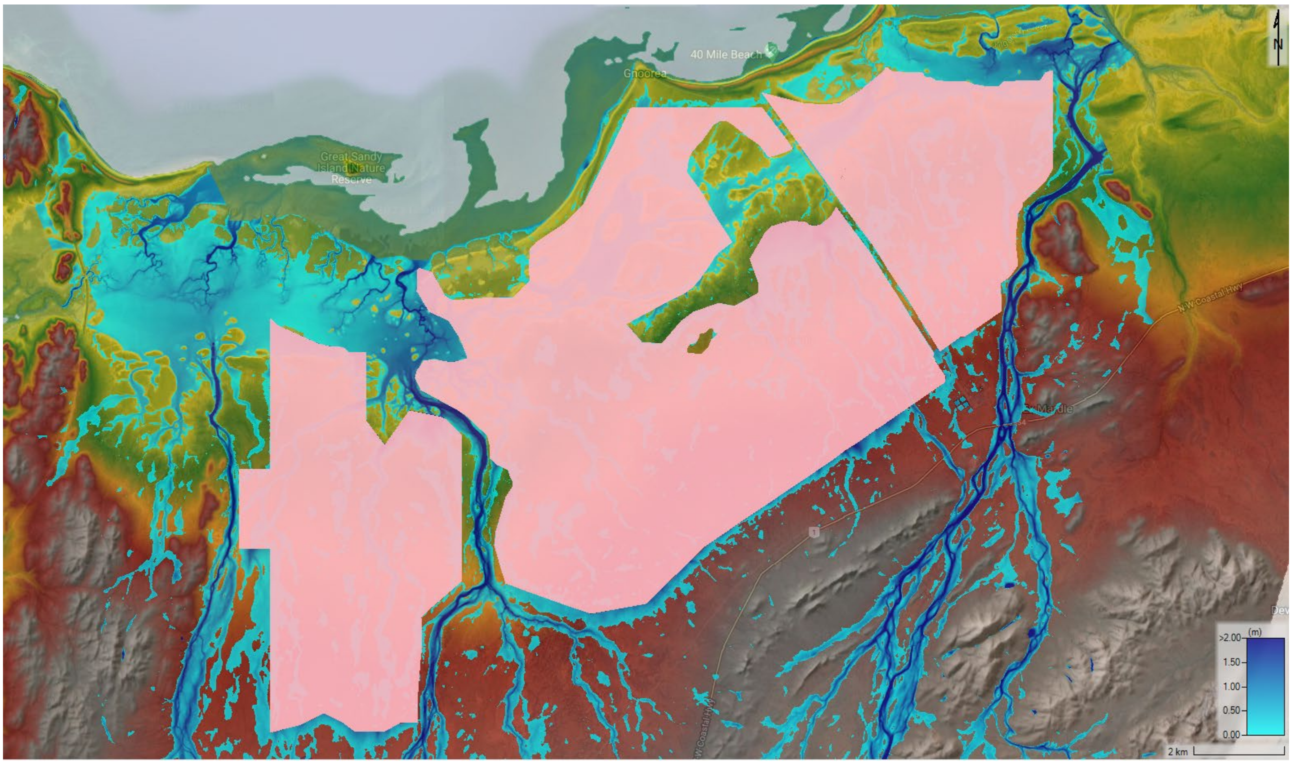

Figure 5-14: 5% AEP project conditions maximum depth (metres)

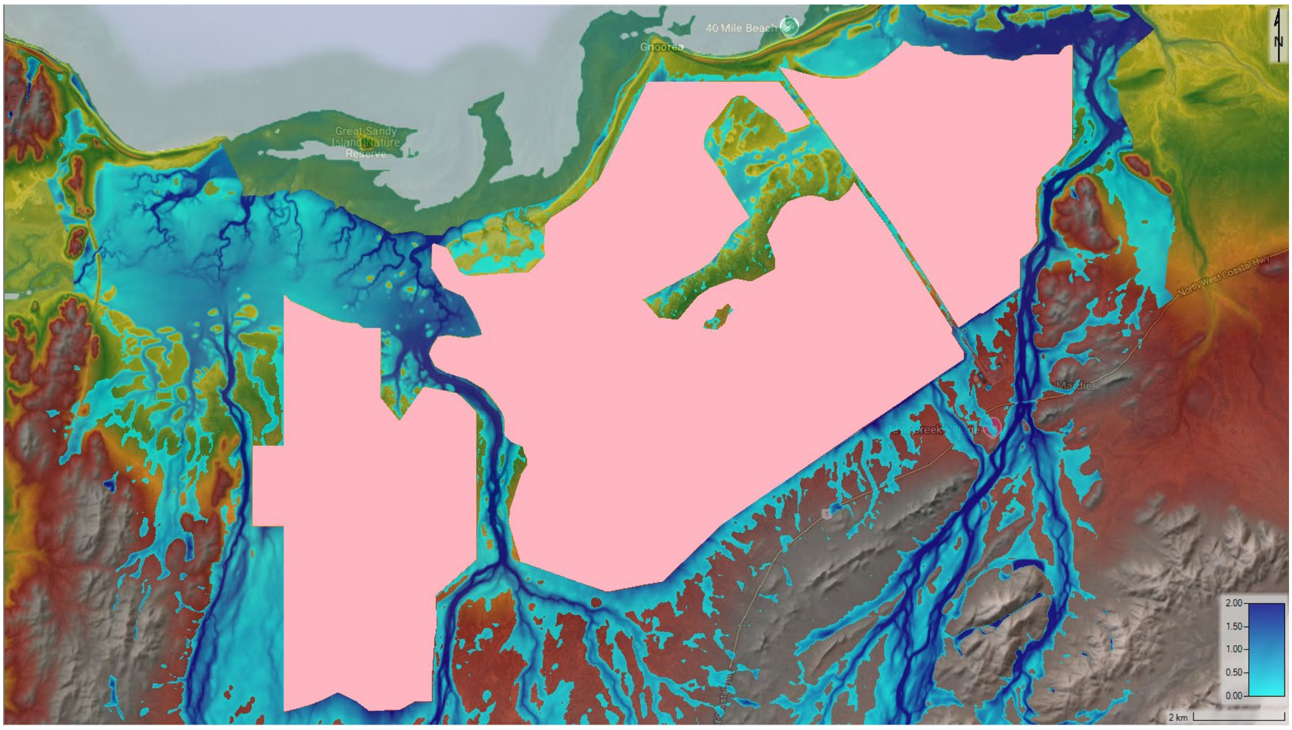

Figure 5-15: 2% AEP project conditions maximum depth (metres)

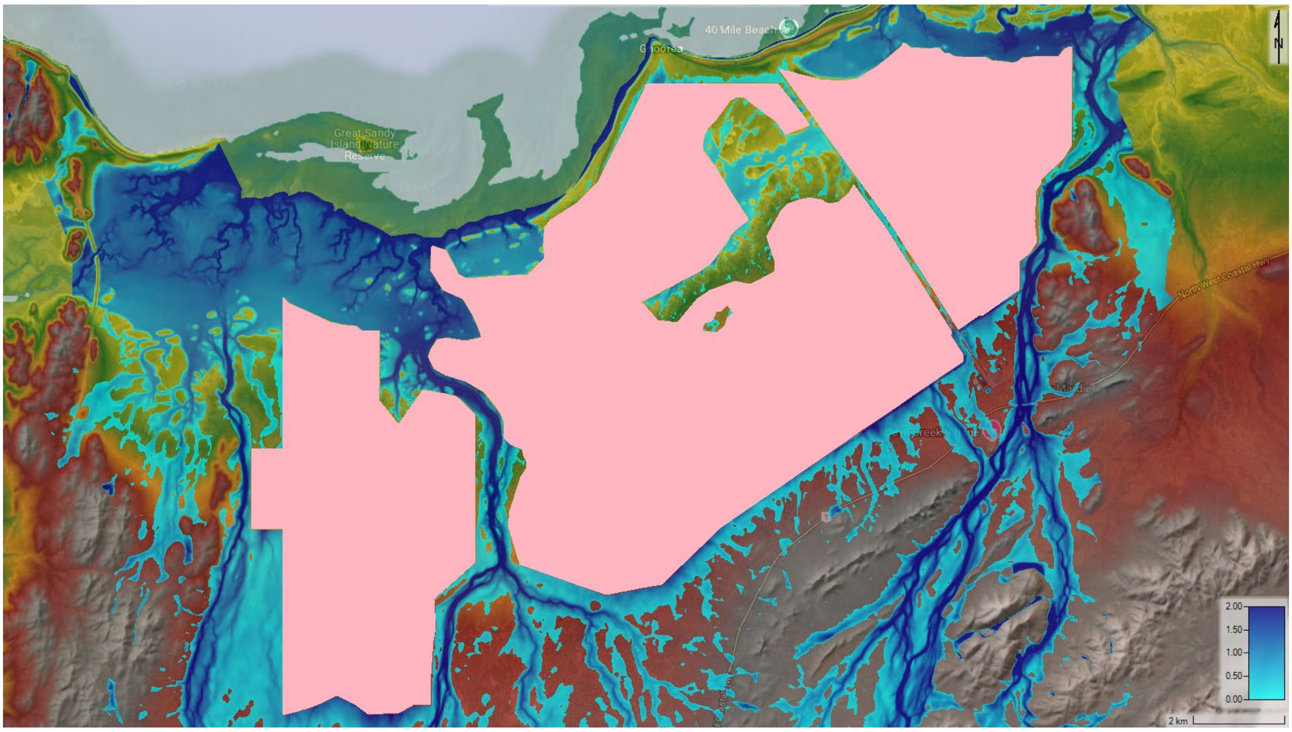

Figure 5-16: 2% AEP project conditions maximum depth with 10% AEP storm surge (metres)

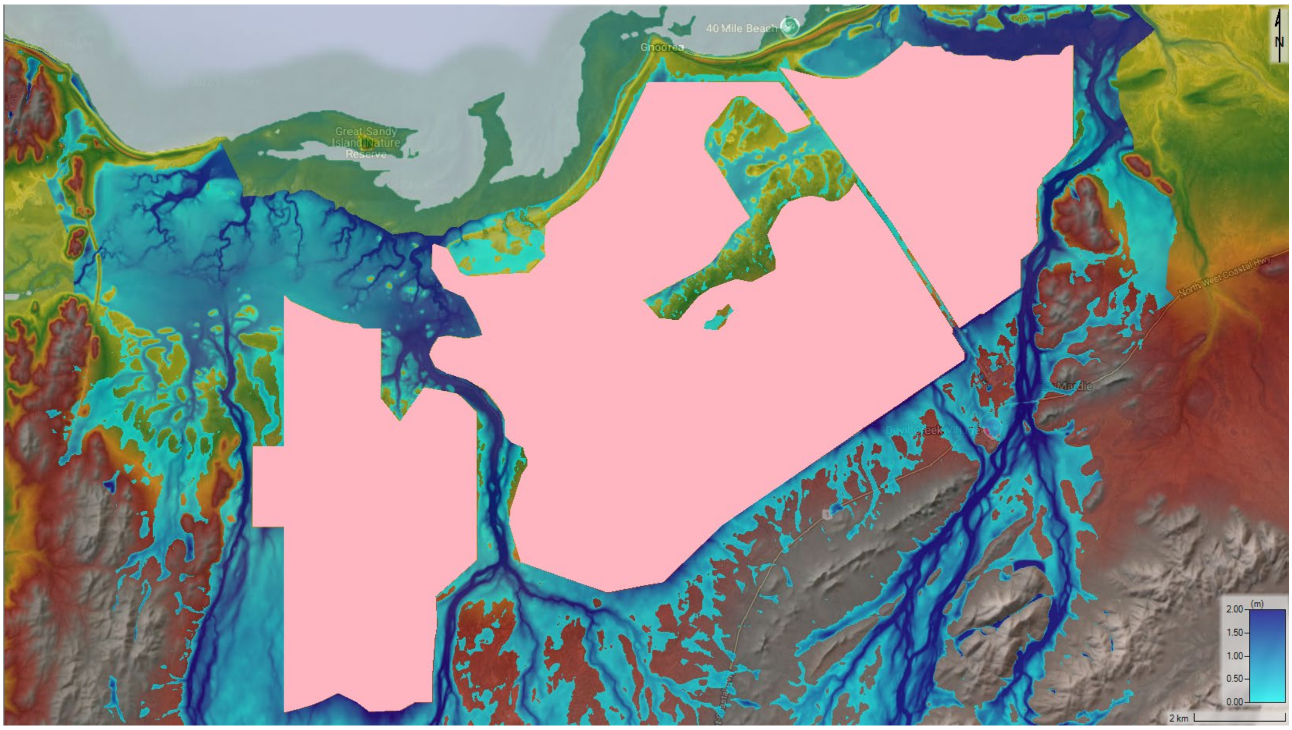

Figure 5-17: 1% AEP project conditions maximum depth (metres)

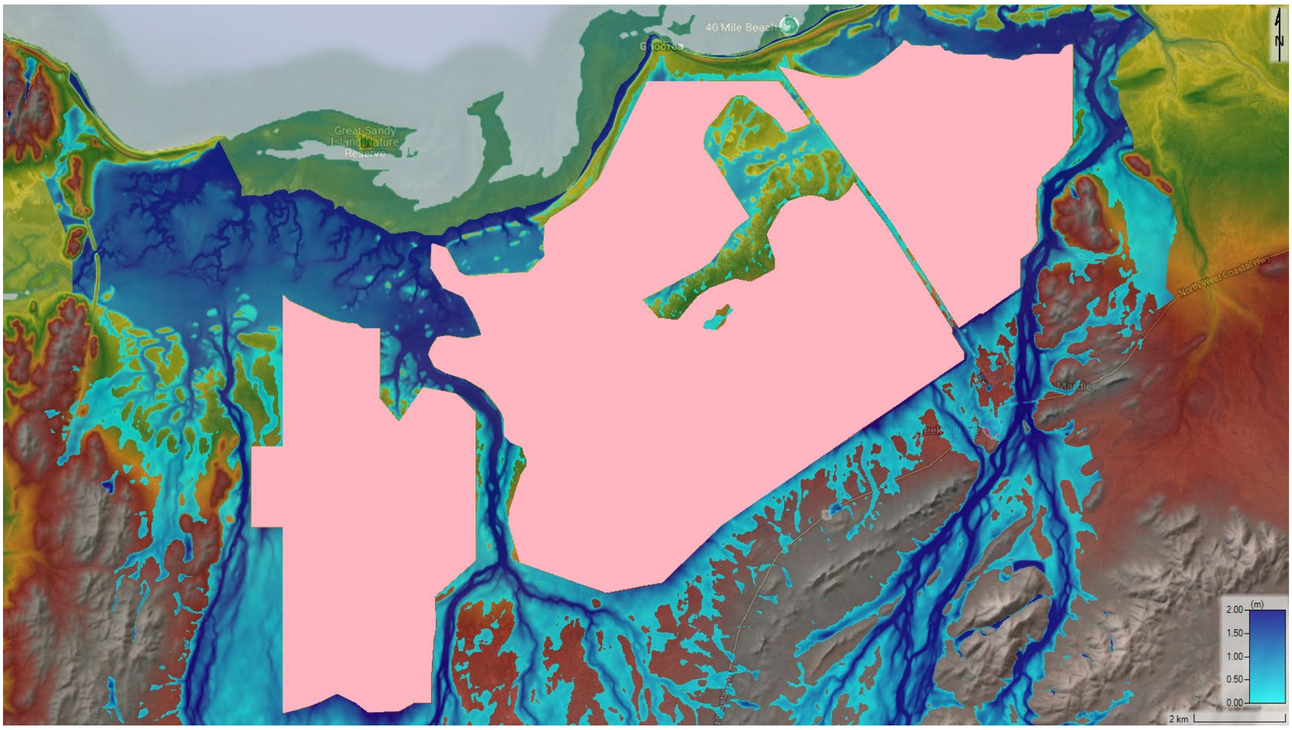

Figure 5-18: 1% AEP project conditions maximum depth with 5% AEP storm surge (metres)

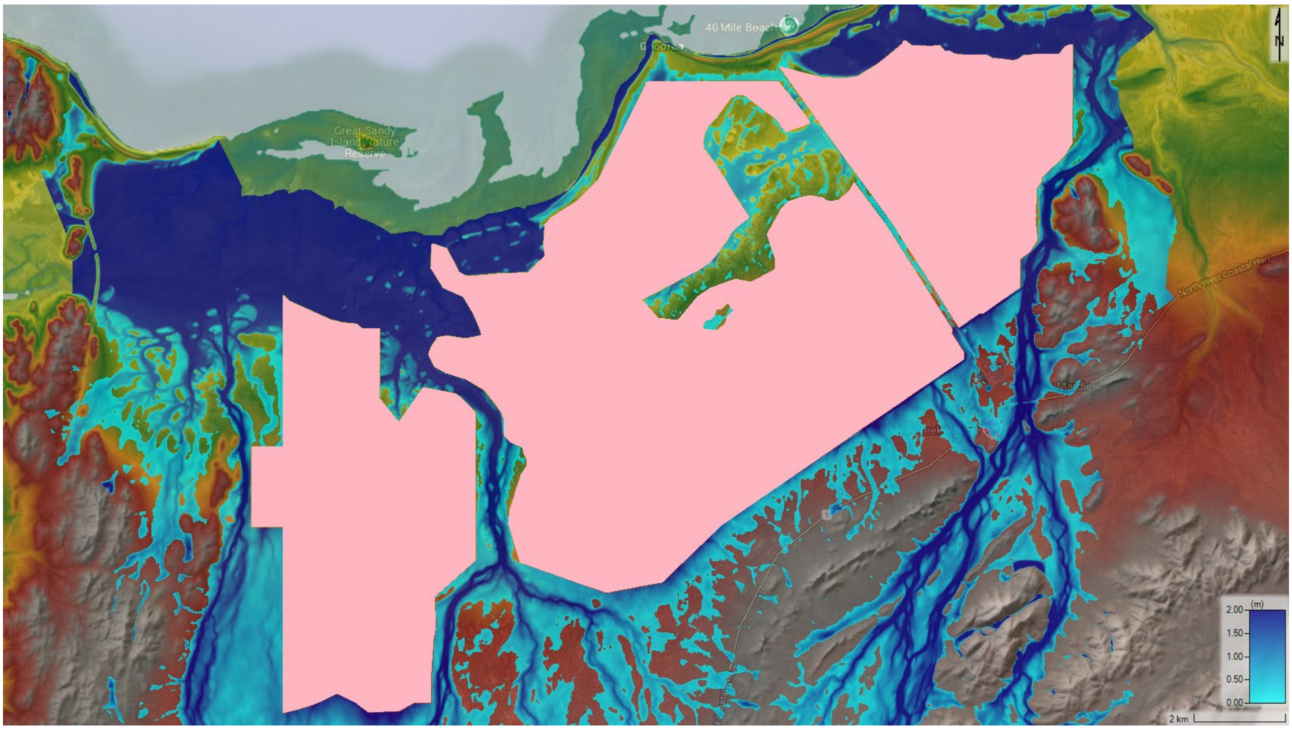

Figure 5-19: 1% AEP project conditions depth with 5% AEP storm surge and climate change (metres)

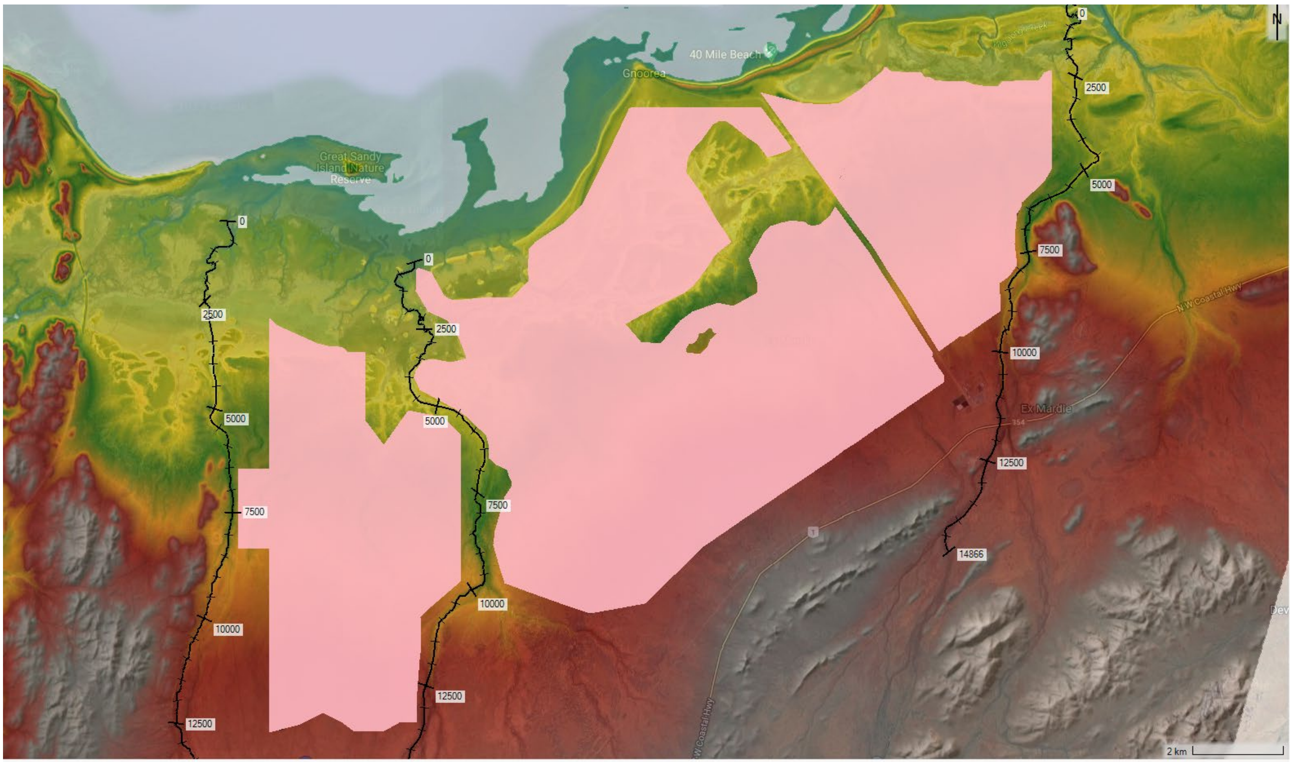

Figure 5-20: Chainage reference for profile figures

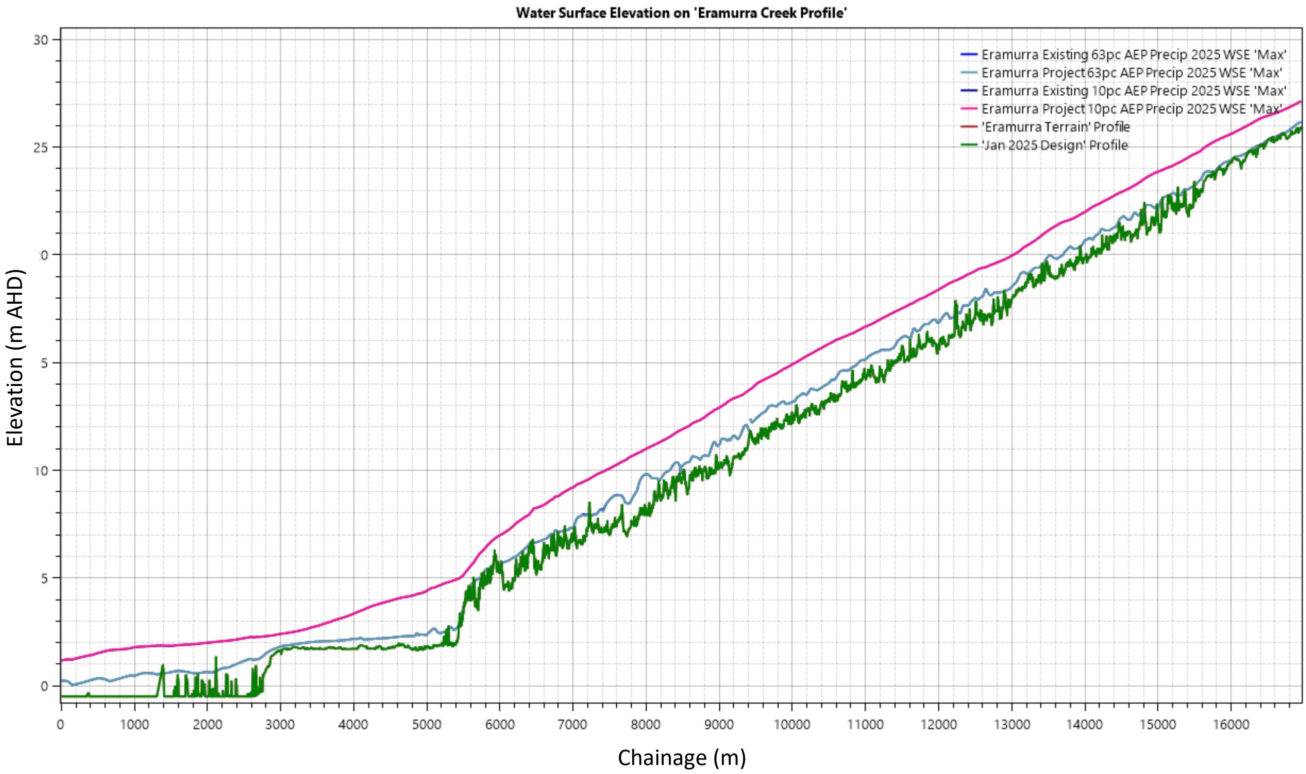

Figure 5-21: 1EY and 10% AEP maximum water surface elevation profiles along Eramurra Creek

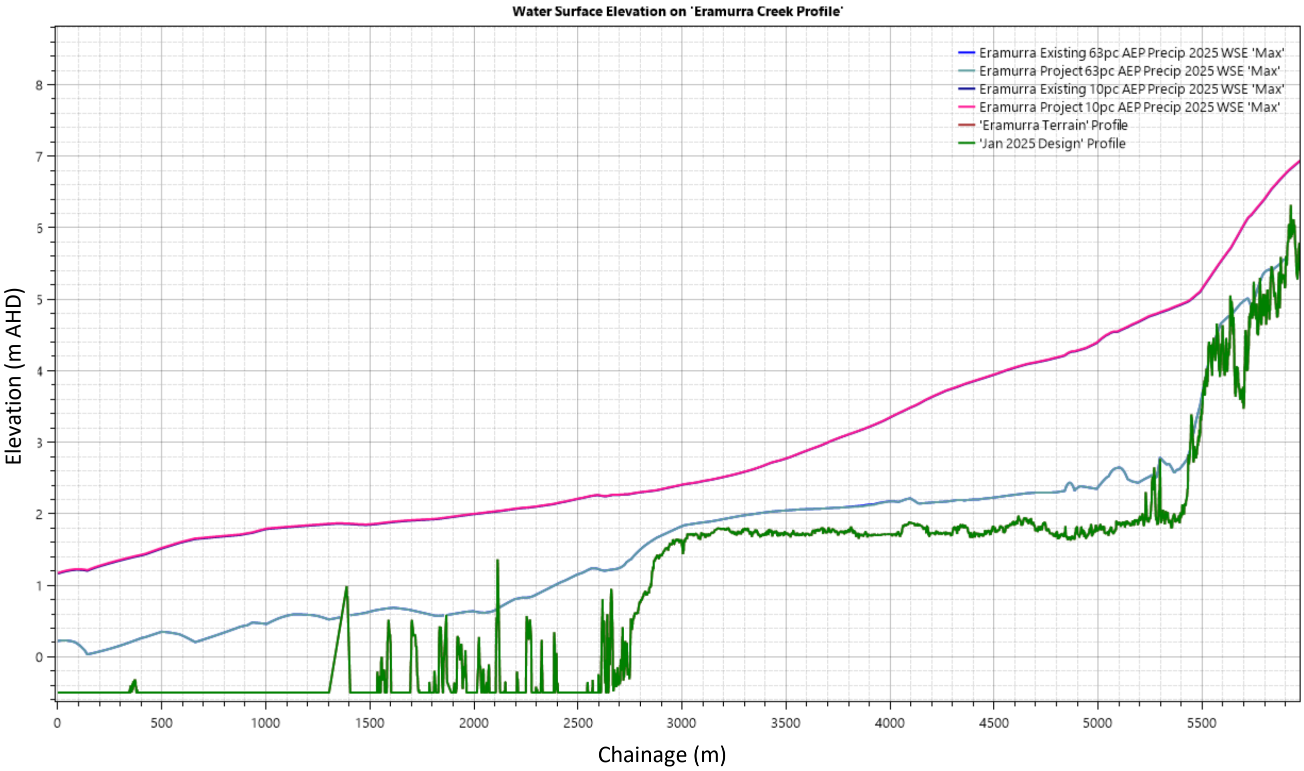

Figure 5-22: 1EY and 10% AEP max water surface elevation profiles along Eramurra Creek (zoomed in)

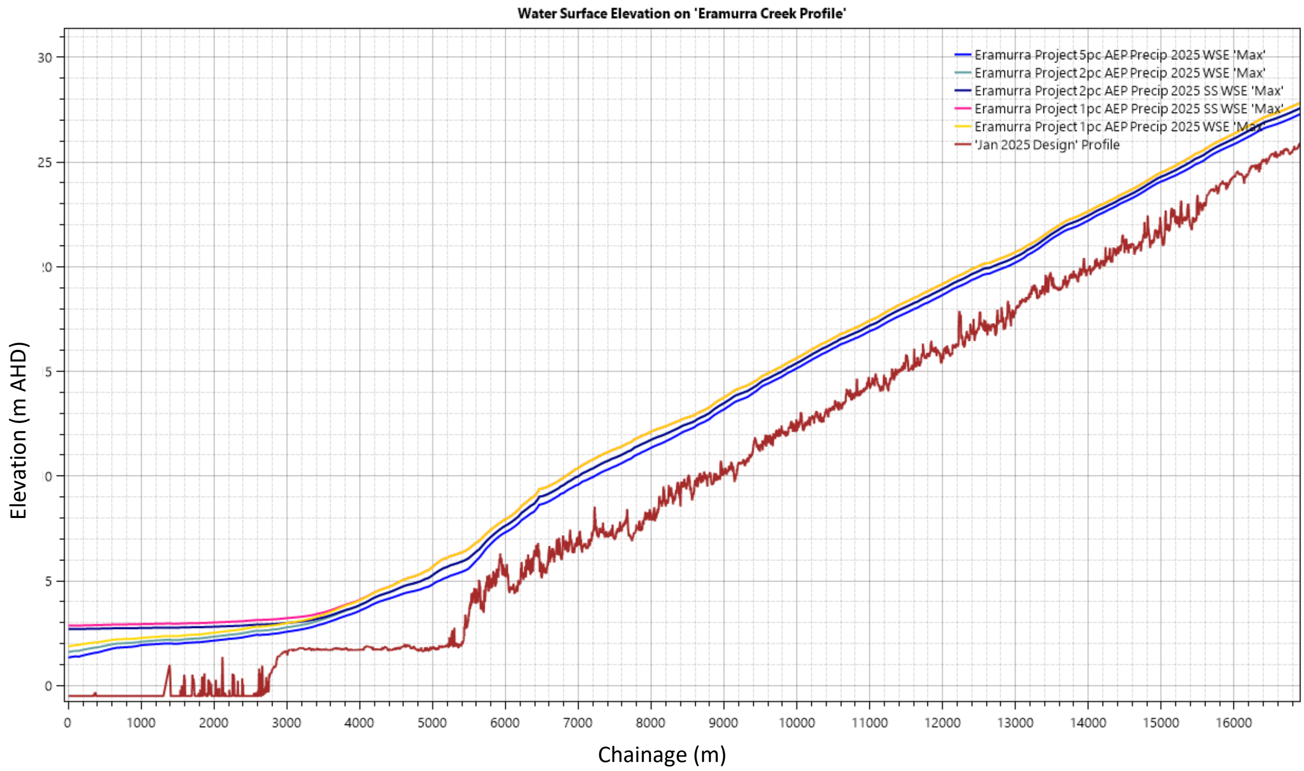

Figure 5-23: 5%, 2%, and 1% AEP maximum water surface elevation profiles along Eramurra Creek

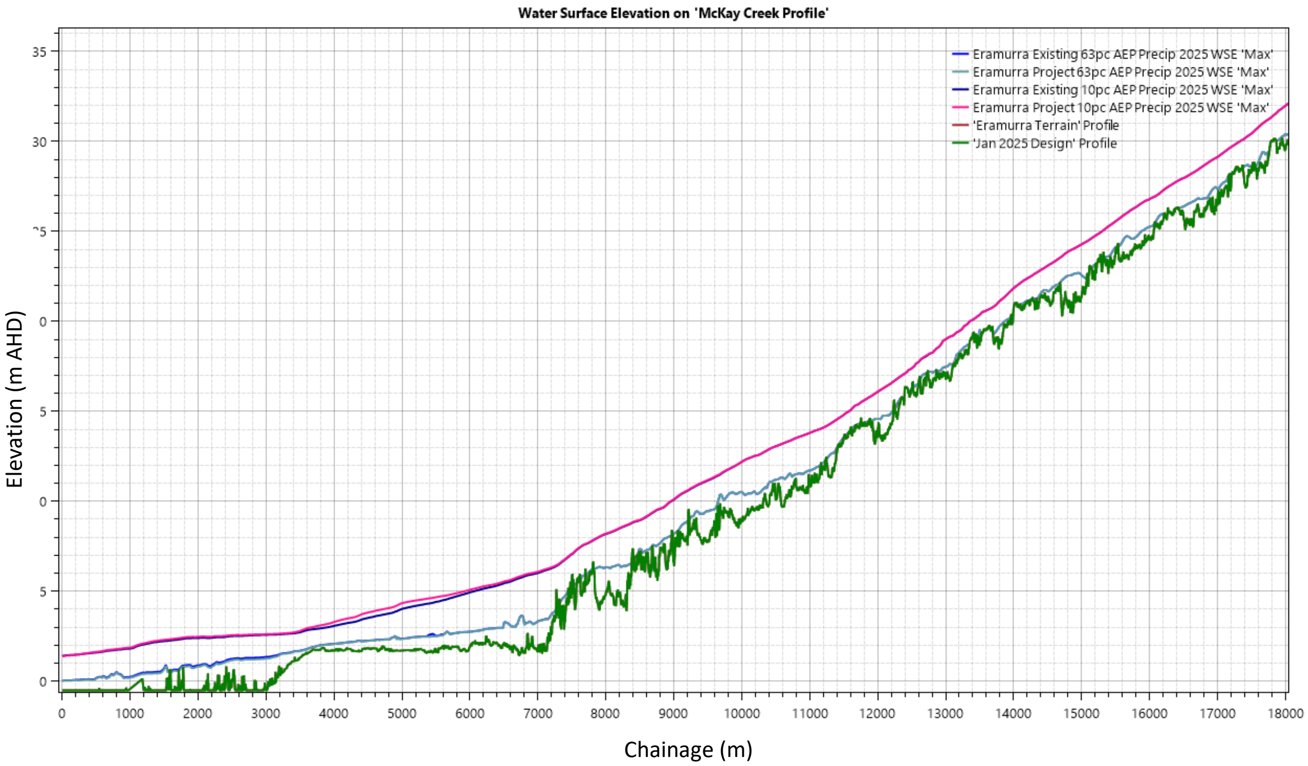

Figure 5-24: 1EY and 10% AEP maximum water surface elevation profiles along McKay Creek

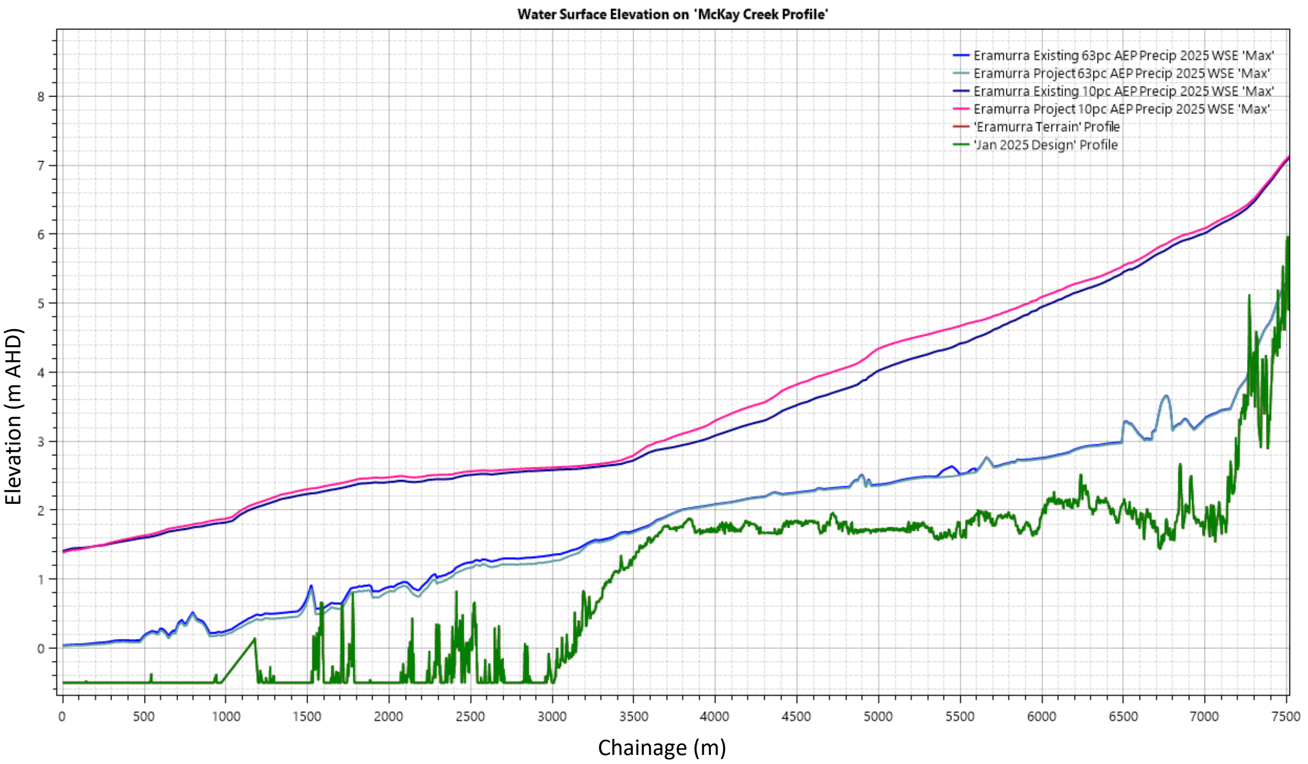

Figure 5-25: 1EY and 10% AEP max water surface elevation profiles along McKay Creek (zoomed in)

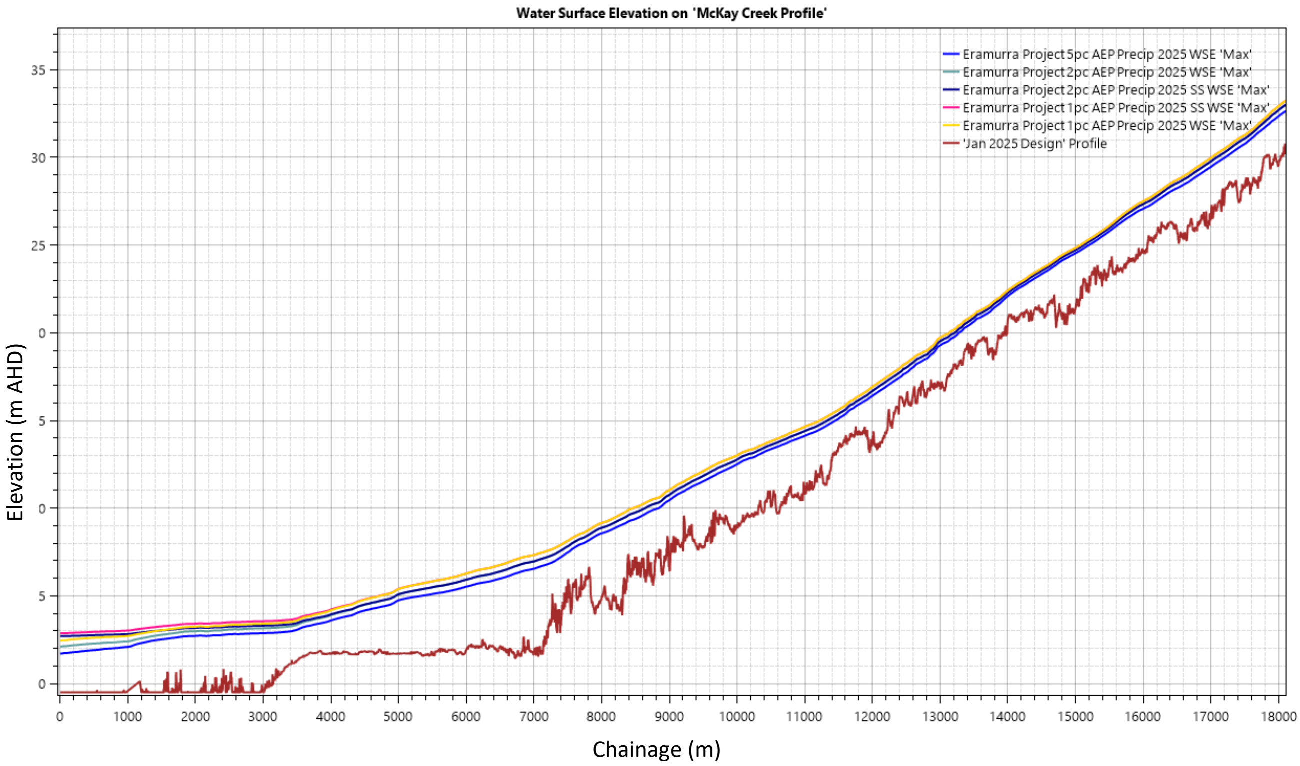

Figure 5-26: 5%, 2%, and 1% AEP max water surface elevation profiles along McKay Creek

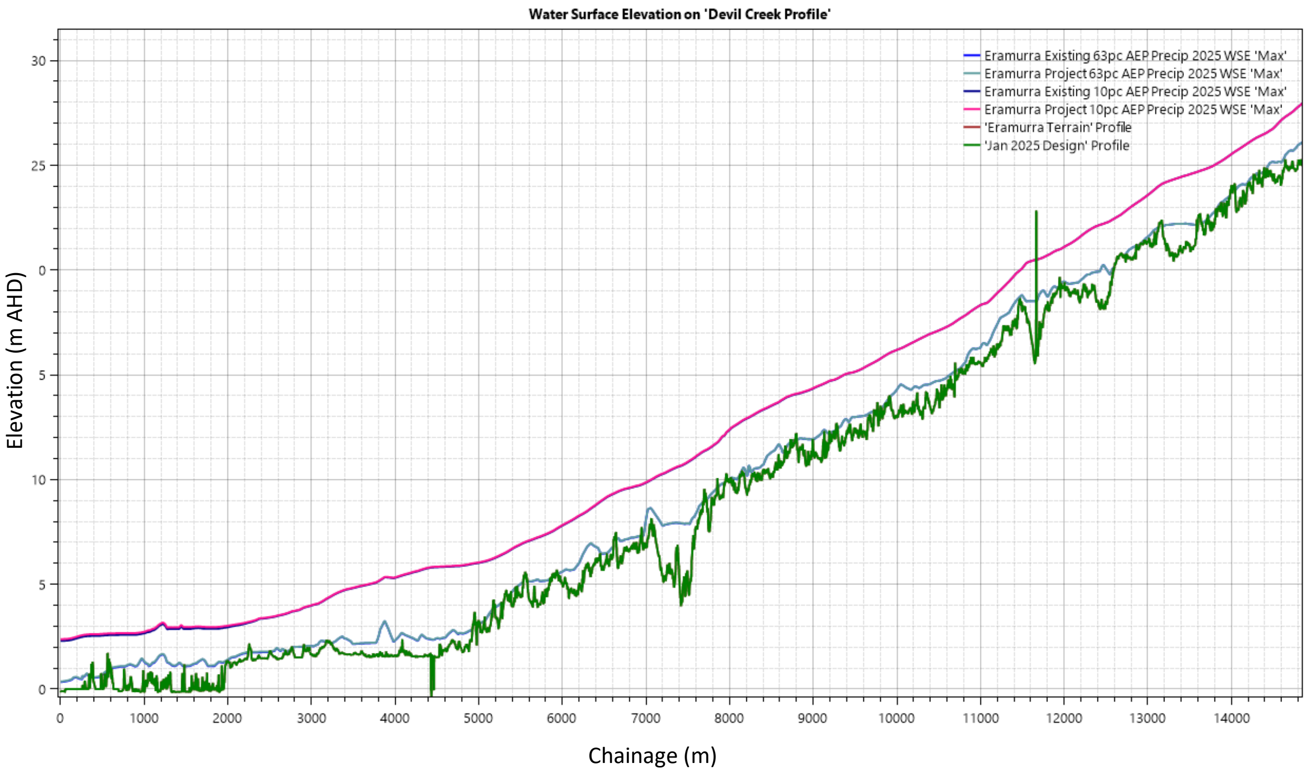

Figure 5-27: 1EY and 10% AEP maximum water surface elevation profiles along Devil Creek

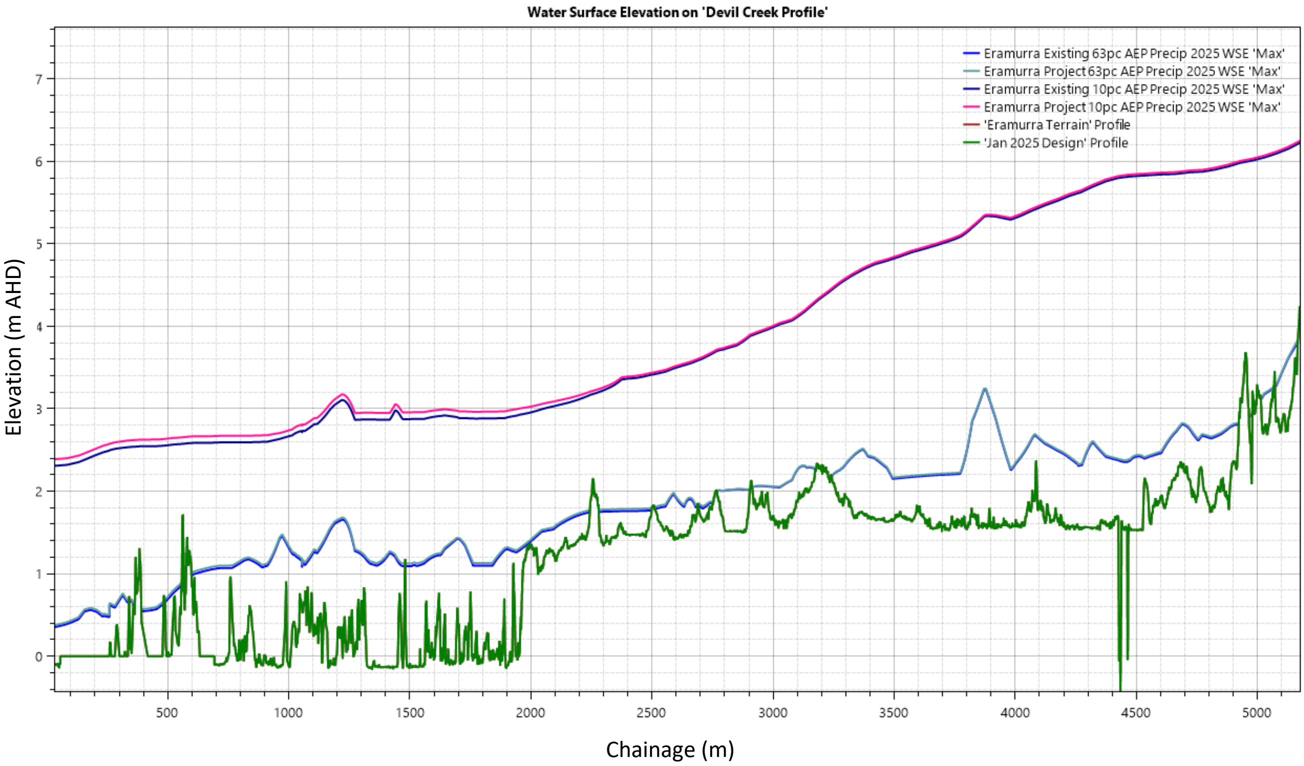

Figure 5-28: 1EY and 10% AEP max water surface elevation profiles along Devil Creek (zoomed in)

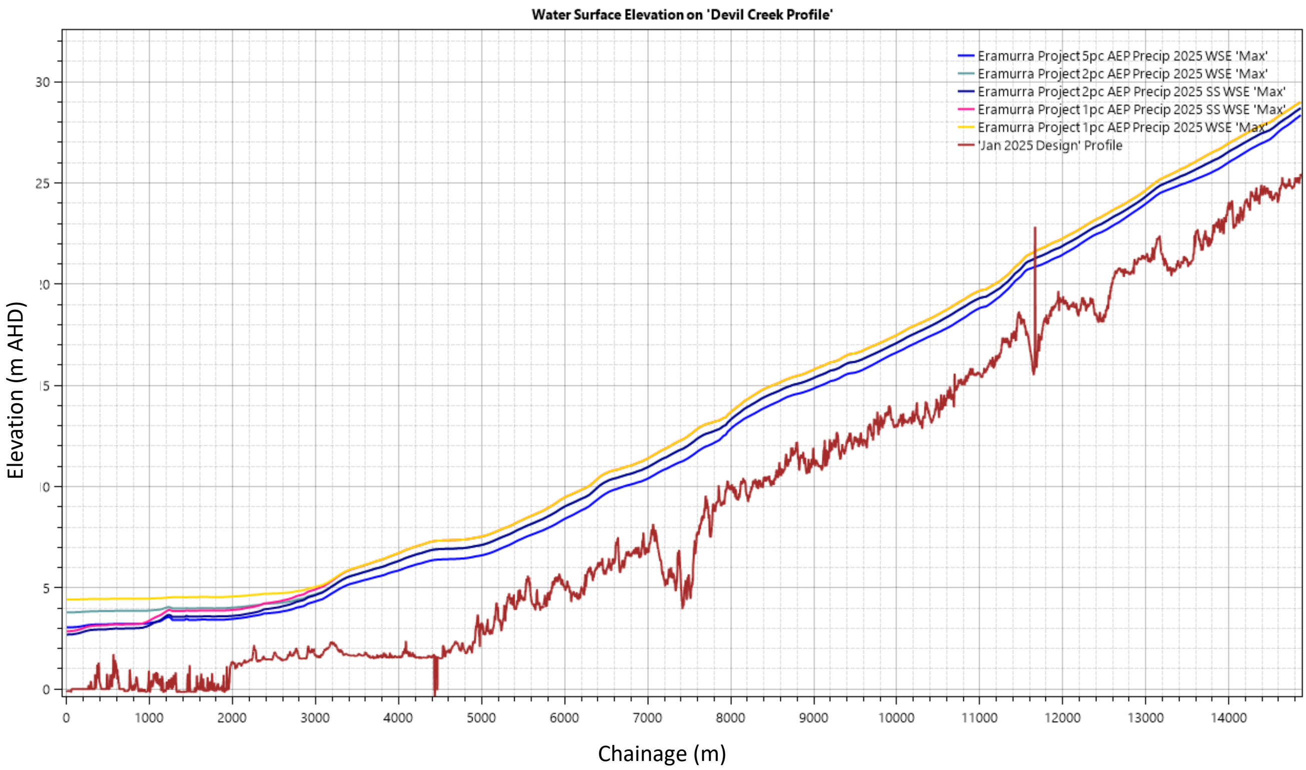

Figure 5-29: 2%, 5%, and 1% AEP max water surface elevation profiles along Devil Creek

5.3 Perimeter Drainage

Maximum inundation depths were extracted around the external perimeters of each of the pond areas for the eight project conditions model runs. **Figure 5-30** shows the chainage reference for the eastern and western pond areas, and **Figure 5-31** shows the central ponds. Chainage zero is located at the southwest corner of each pond area, and chainages increase in a clockwise direction around the perimeter of each pond area.

5.3.1 Western Ponds

Figure 5-32 shows the maximum water surface elevation profiles for the 1EY, 10% AEP, and 5% AEP events around the western ponds. **Figure 5-33** shows the 2% and 1% AEP events, including storm surge and climate change scenarios. **Figure 5-34** and **Figure 5-35** show the depth profiles, and **Figure 5-36** and **Figure 5-37** show the velocities.

5.3.2 Central Ponds

Figure 5-38 shows the maximum water surface elevation profiles for the 1EY, 10% AEP, and 5% AEP events around the central ponds. **Figure 5-39** shows the 2% and 1% AEP events. **Figure 5-40** and **Figure 5-41** show the depth profiles for the central ponds perimeter, and **Figure 5-42** and **Figure 5-43** show the velocities.

5.3.3 Eastern Ponds

Figure 5-44 shows the maximum water surface elevation profiles for the 1EY, 10% AEP, and 5% AEP events around the eastern ponds. **Figure 5-45** shows the 2% and 1% AEP events. **Figure 5-46** and **Figure 5-47** show the depth profiles for the eastern ponds perimeter; **Figure 5-48** and **Figure 5-49** show the velocities.

The perimeter profile figures provide an indication of areas where excavated drains and flood control levees would be needed to facilitate positive drainage and avoid standing water following runoff events. In particular, the southern perimeter of each pond area would collect water unless properly drained. The Santos gas plant, the Santos helipad and the Reindeer onshore gas pipeline easement areas require mitigation controls including a flood control levee, road crossing culverts, and an excavated drain to reduce ponding as described in Technical Memorandum ESSP-NP-13-TRPT-0004 (LWC 2023). Within that report, the depths indicate the minimum crest elevations to protect the embankments from overtopping from external flooding, with an appropriate freeboard applied, taking into account long-term water balance analyses and any updated flood modelling to reflect design refinements. Velocity profiles indicate areas where erosion may be likely and rock armouring or other scour countermeasures may be warranted.

5.3.4 Summary

Table 5-1 summarises the depths and velocities around each of the pond perimeters, with average and maximum values tabulated. The areas with the greatest depths are near the coast, and the areas with highest velocities are along the channel reaches where confined by the pond embankments. The maximum 1% AEP inundation depth is 4.1 m, and the maximum 1% AEP velocity is 1.1 m/s. Maximum depths occur with storm surge and climate change scenarios, whilst the maximum velocities occur without storm surge. The tabulated results reflect project conditions with levees and drains described in Section 4.2.

Table 5-1: Summary of maximum and average depths and velocities around pond perimeters

Pond Area	1EY	10% AEP	5% AEP	2% AEP	2% AEP + Storm Surge	1% AEP	1% AEP + Storm Surge	1% AEP + Storm Surge & Sea Level Rise
Maximum Depth around Pond Area Perimeter (metres)								
Western	0.66	1.53	2.01	2.46	2.46	2.68	2.69	2.88
Central	0.78	2.79	3.28	3.80	3.80	4.07	4.07	4.28
Eastern	0.62	1.66	2.20	2.80	2.80	3.11	3.11	3.33
Average Depth around Pond Area Perimeter (metres)								
Western	0.02	0.18	0.29	0.50	0.52	0.64	0.67	0.84
Central	0.03	0.34	0.44	0.59	0.64	0.68	0.74	0.89
Eastern	0.01	0.12	0.19	0.34	0.42	0.46	0.55	0.77
Maximum Velocity around Pond Area Perimeter (metres per second)								
Western	0.08	0.76	0.86	1.00	1.00	1.08	1.08	1.17
Central	0.29	0.89	0.93	1.05	0.97	1.10	1.00	1.04
Eastern	0.05	0.76	0.92	1.05	1.05	1.13	1.13	1.23
Average Velocity around Pond Area Perimeter (metres per second)								
Western	0.00	0.03	0.05	0.07	0.07	0.09	0.09	0.10
Central	0.01	0.08	0.08	0.09	0.09	0.10	0.09	0.09
Eastern	0.00	0.03	0.03	0.05	0.04	0.05	0.05	0.06

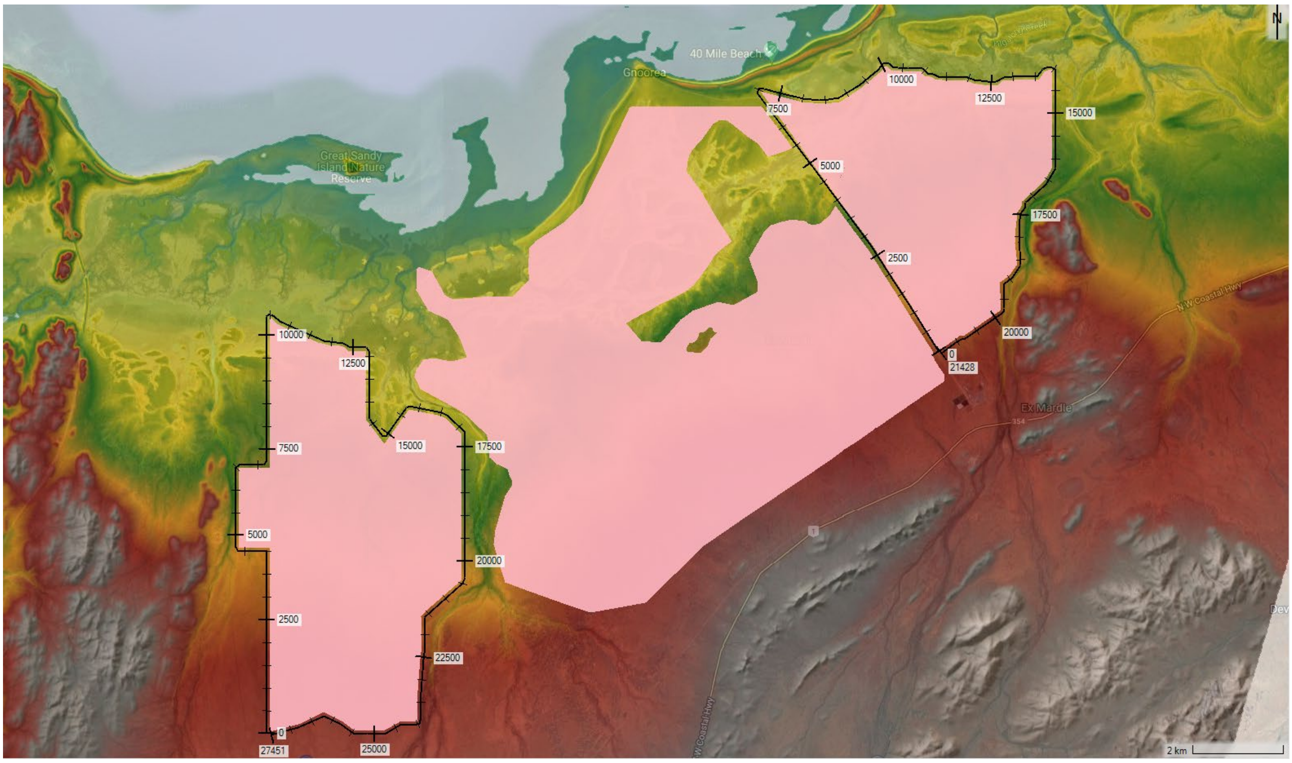

Figure 5-30: Chainage reference for western and eastern ponds perimeter drainage

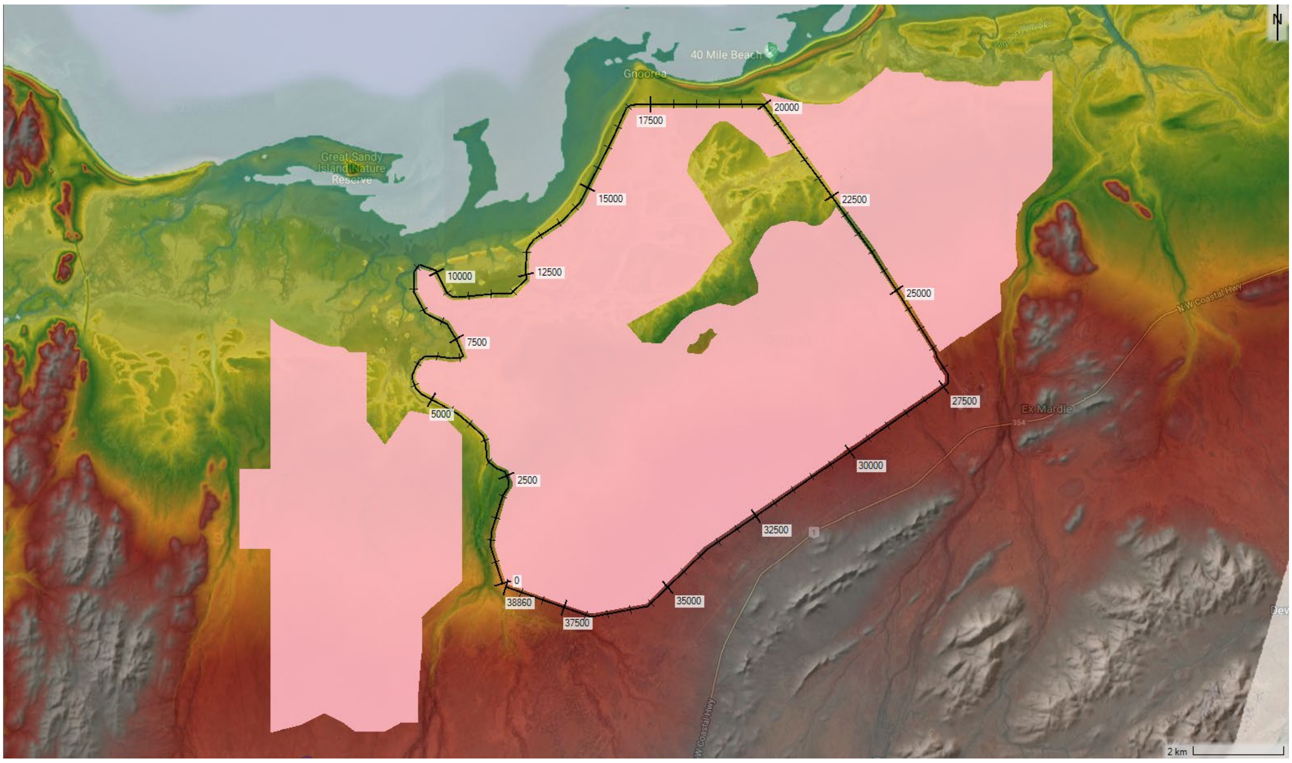

Figure 5-31: Chainage reference for central ponds perimeter drainage

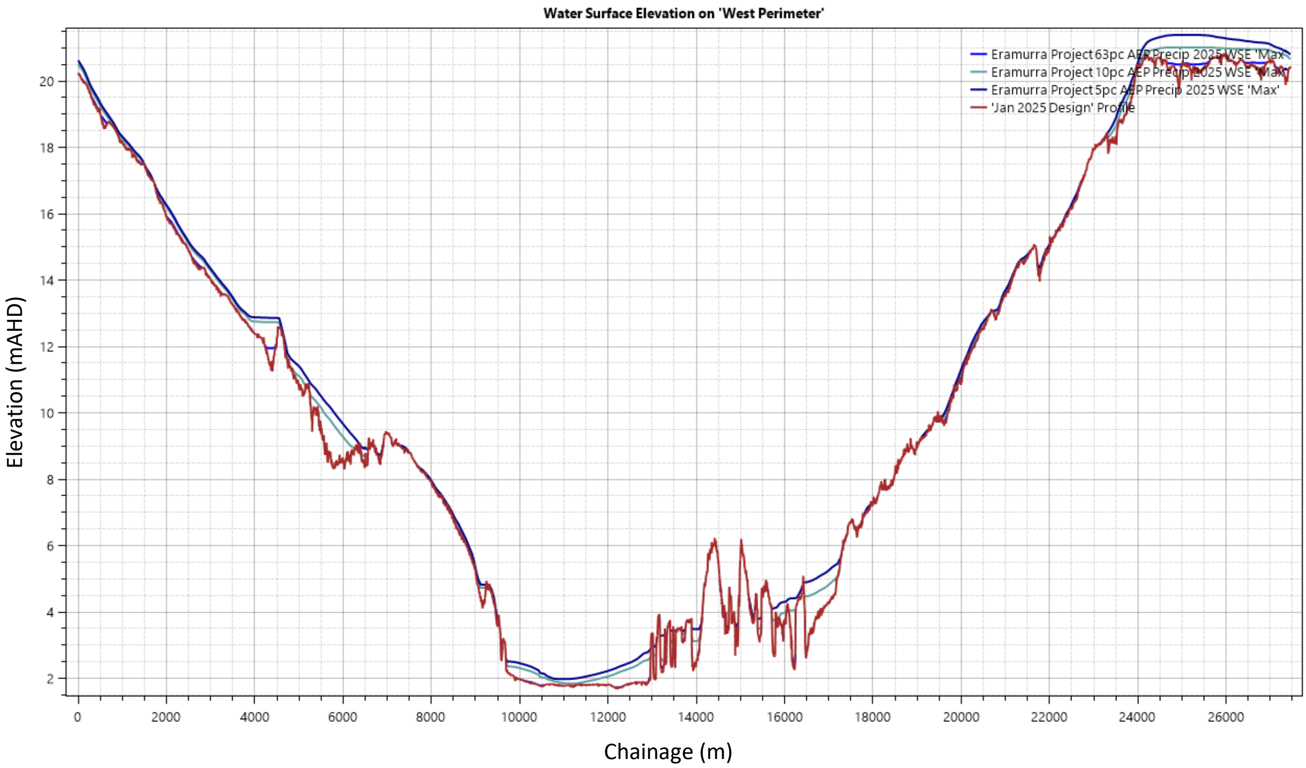

Figure 5-32: Water surface elevations around western ponds for 1EY, 10% AEP, and 5% AEP events

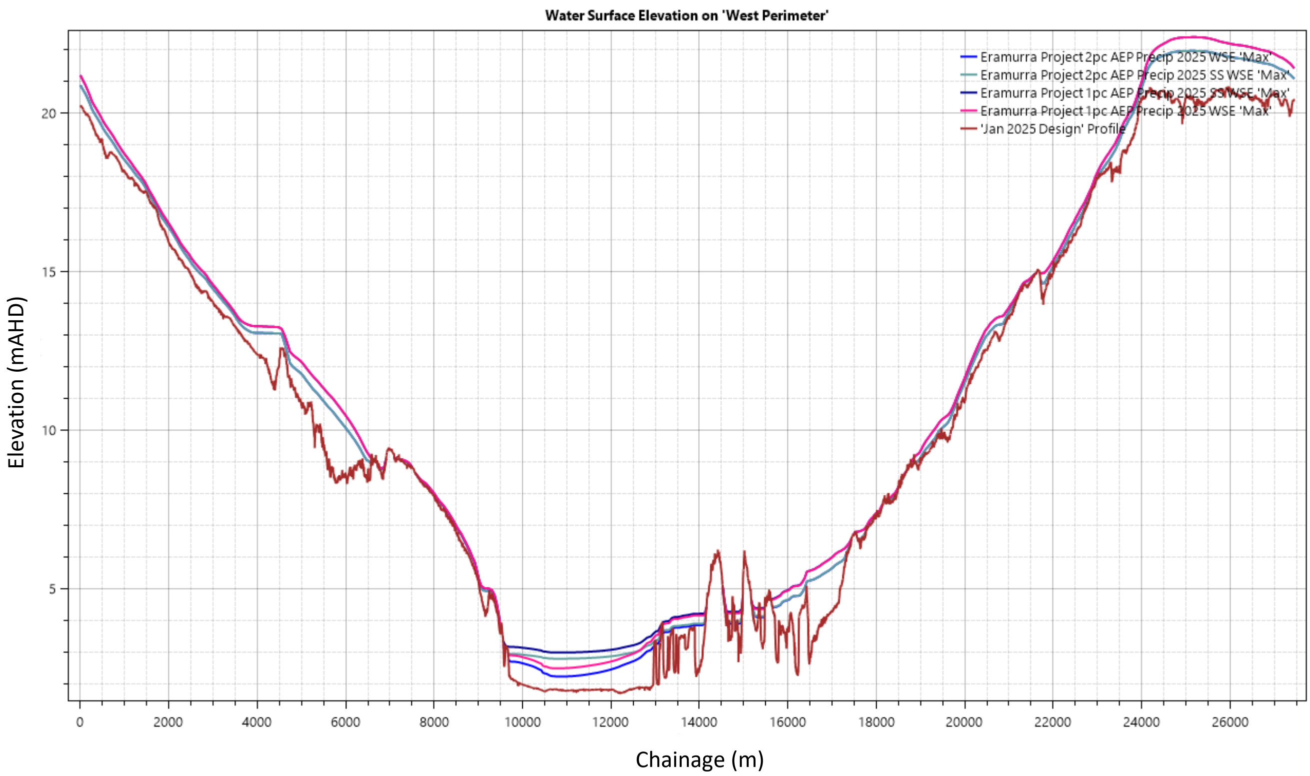

Figure 5-33: Water surface elevations around western ponds for 2% and 1% AEP events

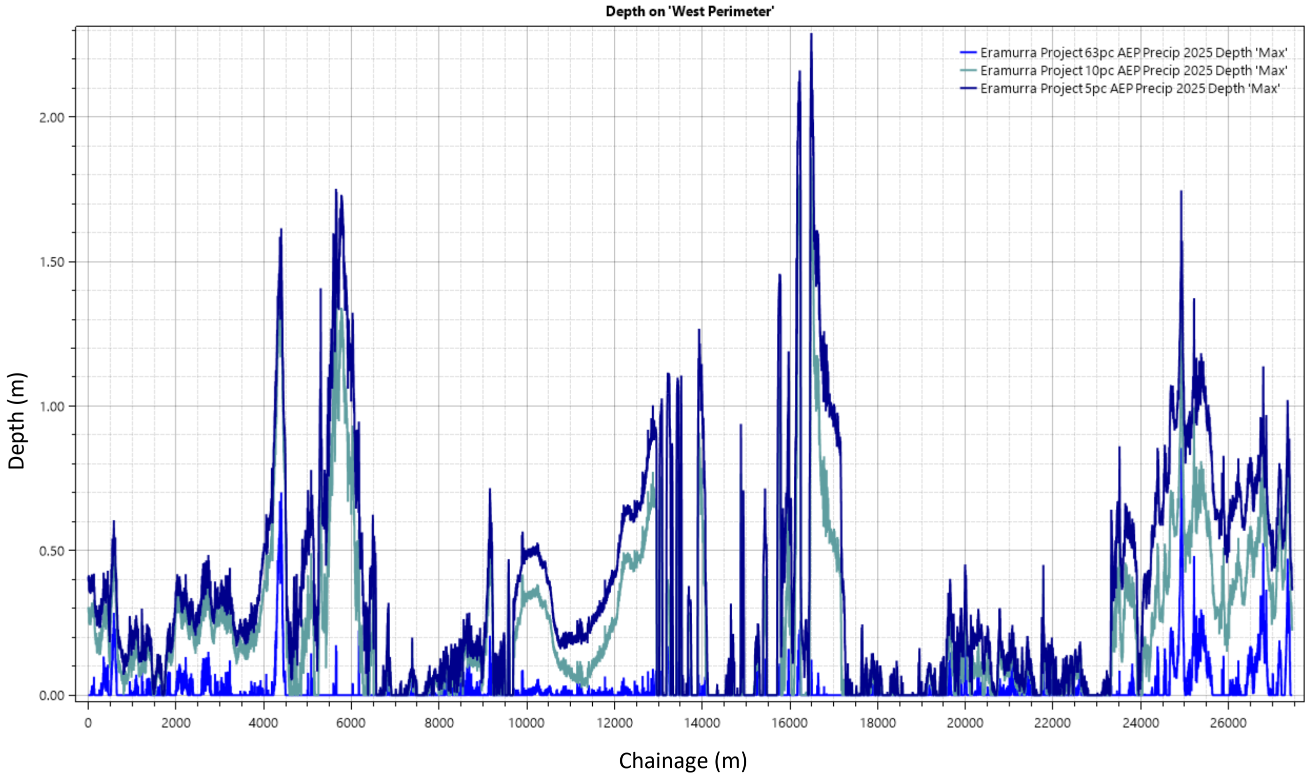

Figure 5-34: Flow depths around western ponds for 1EY, 10% AEP, and 5% AEP events

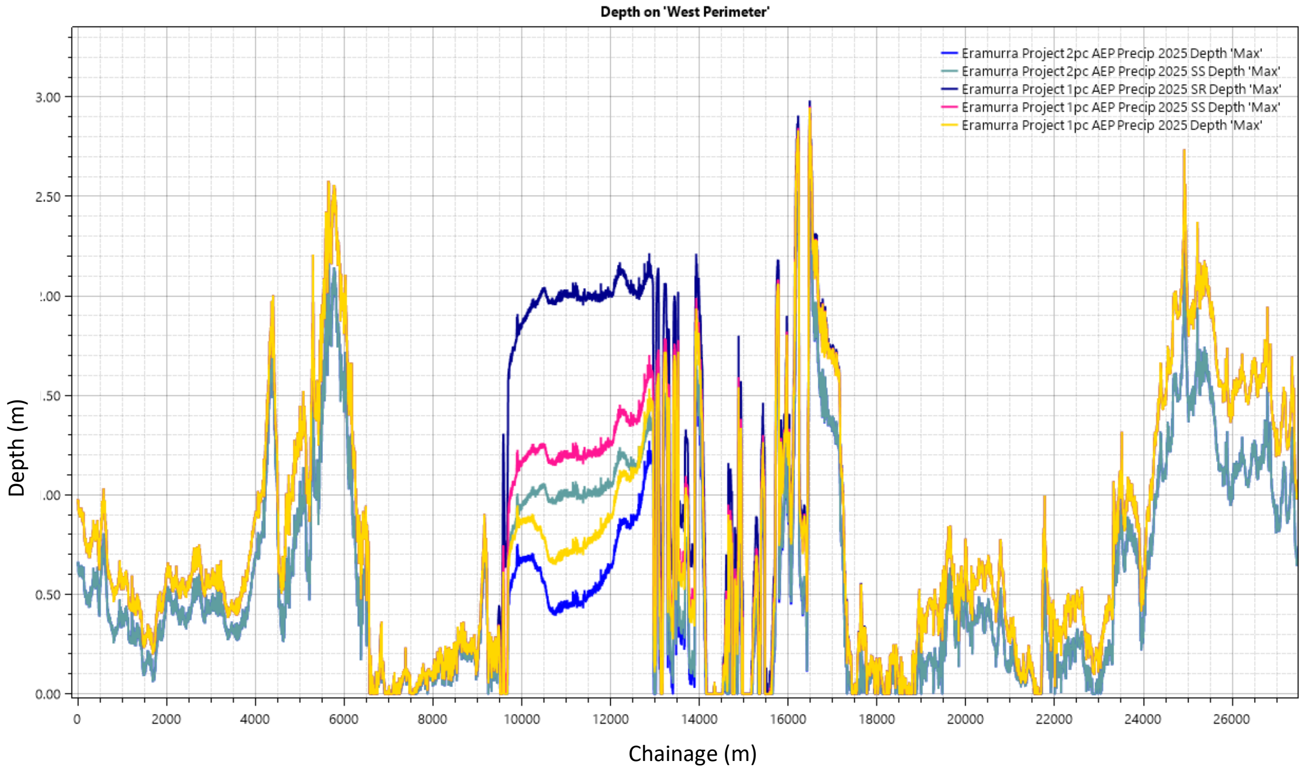

Figure 5-35: Flow depths around western ponds for 2% and 1% AEP events

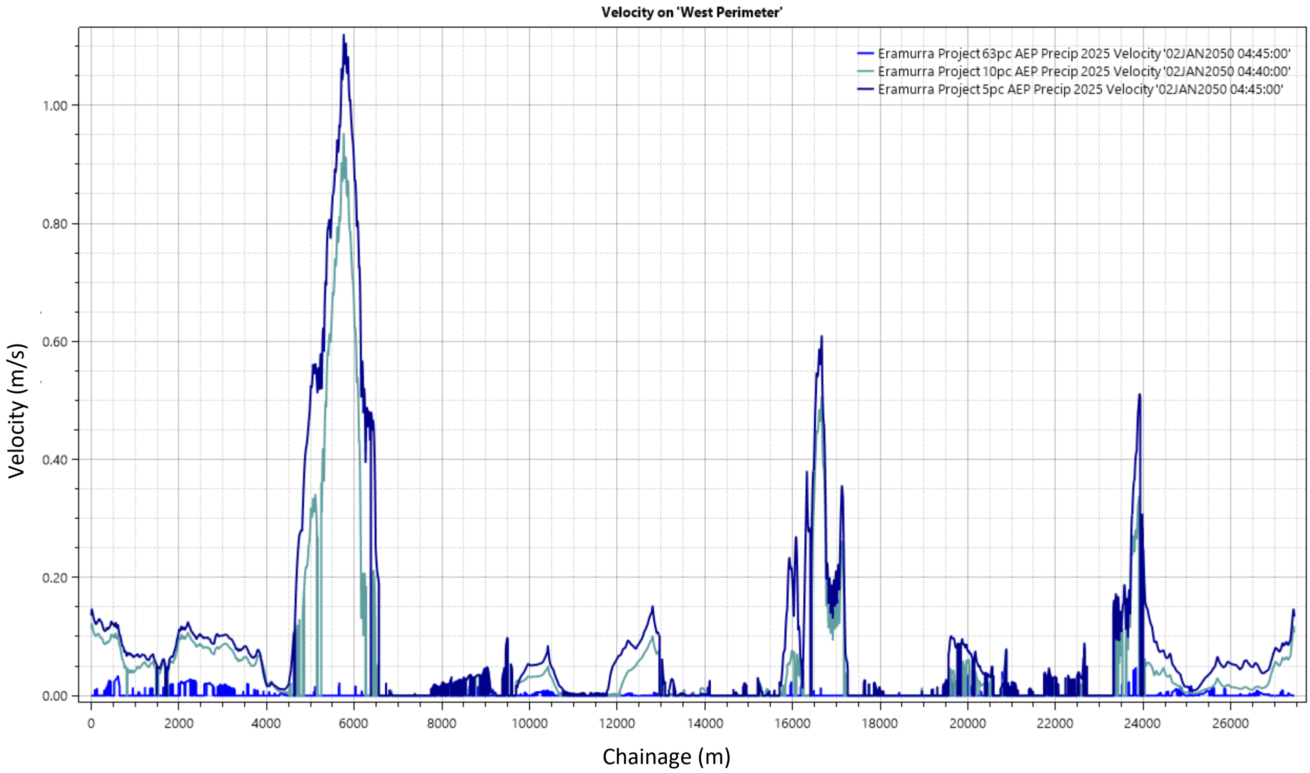

Figure 5-36: Flow velocities around western ponds for 1EY, 10% AEP, and 5% AEP events

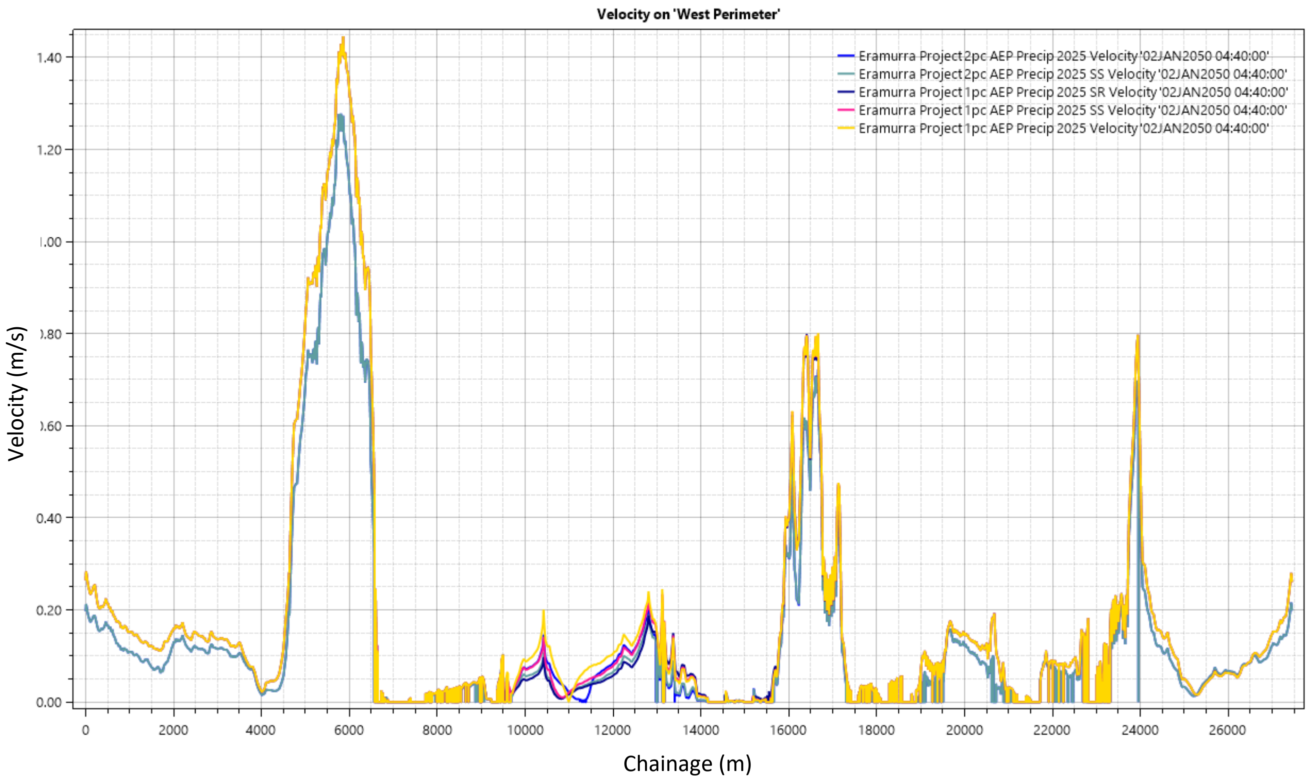

Figure 5-37: Flow velocities around western ponds for 2% and 1% AEP events

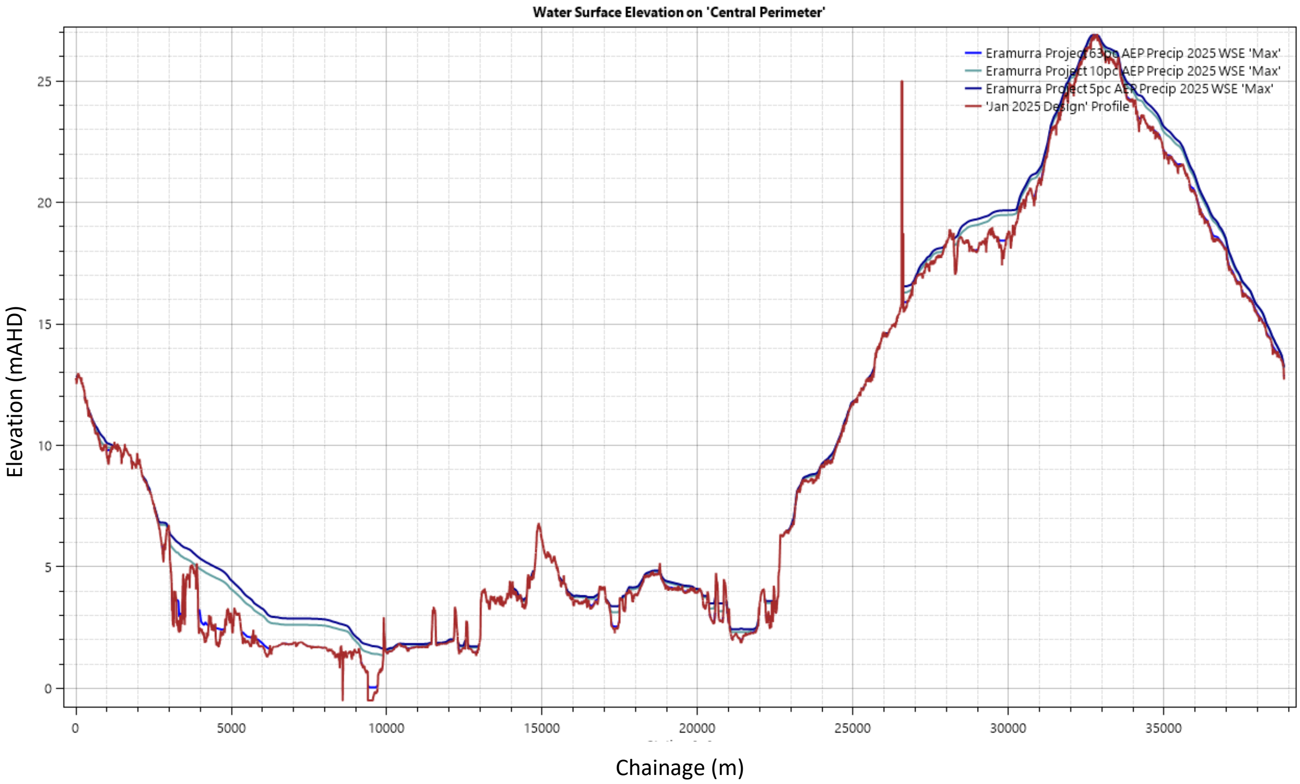

Figure 5-38: Water surface elevations around central ponds for 1EY, 10% AEP, and 5% AEP events

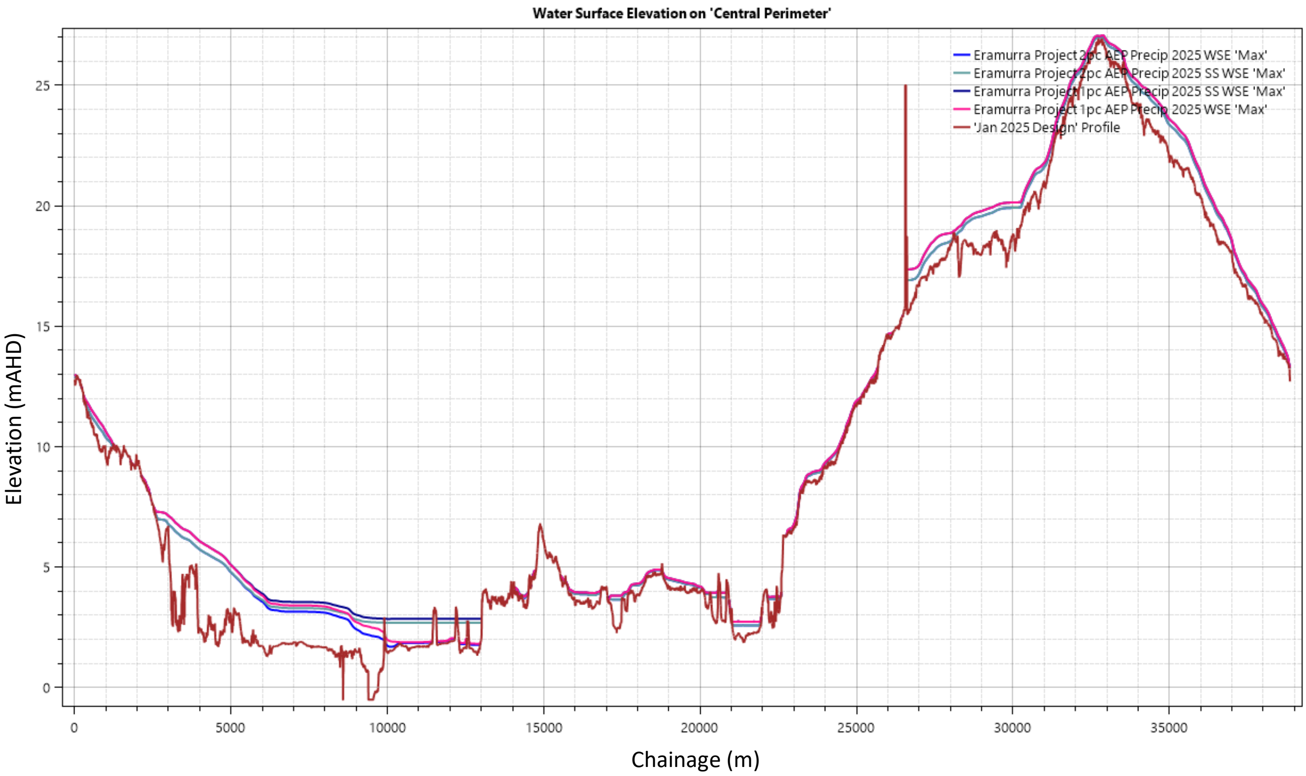

Figure 5-39: Water surface elevations around central ponds for 2% and 1% AEP events

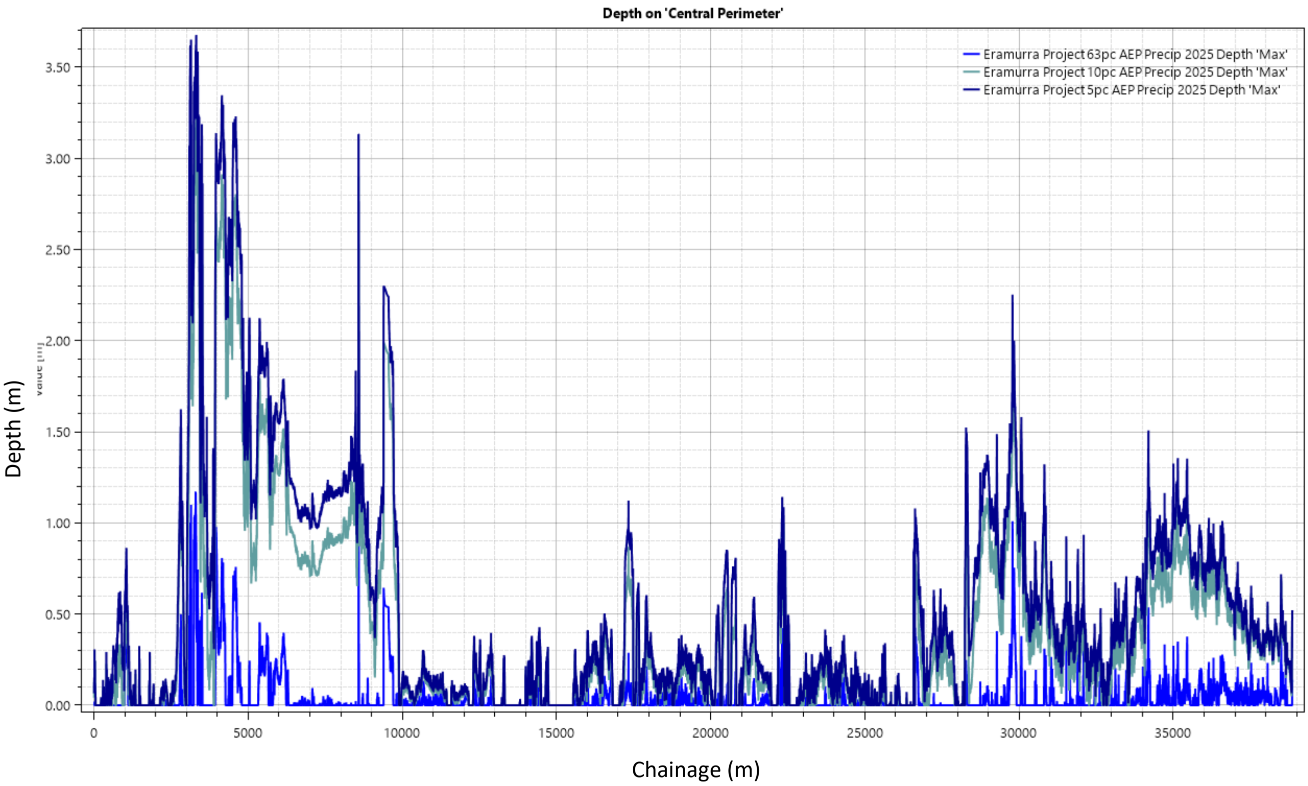

Figure 5-40: Flow depths around central ponds for 1EY, 10% AEP, and 5% AEP events

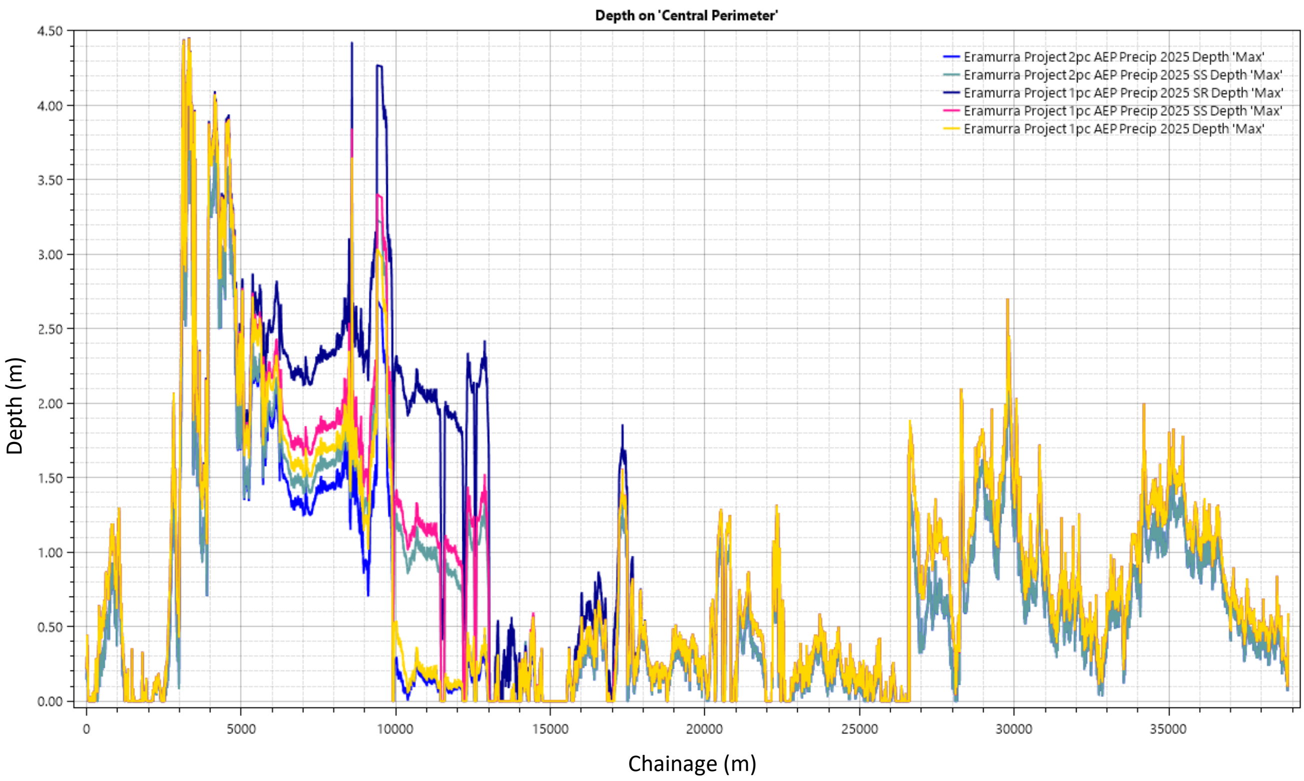

Figure 5-41: Flow depths around central ponds for 2% and 1% AEP events

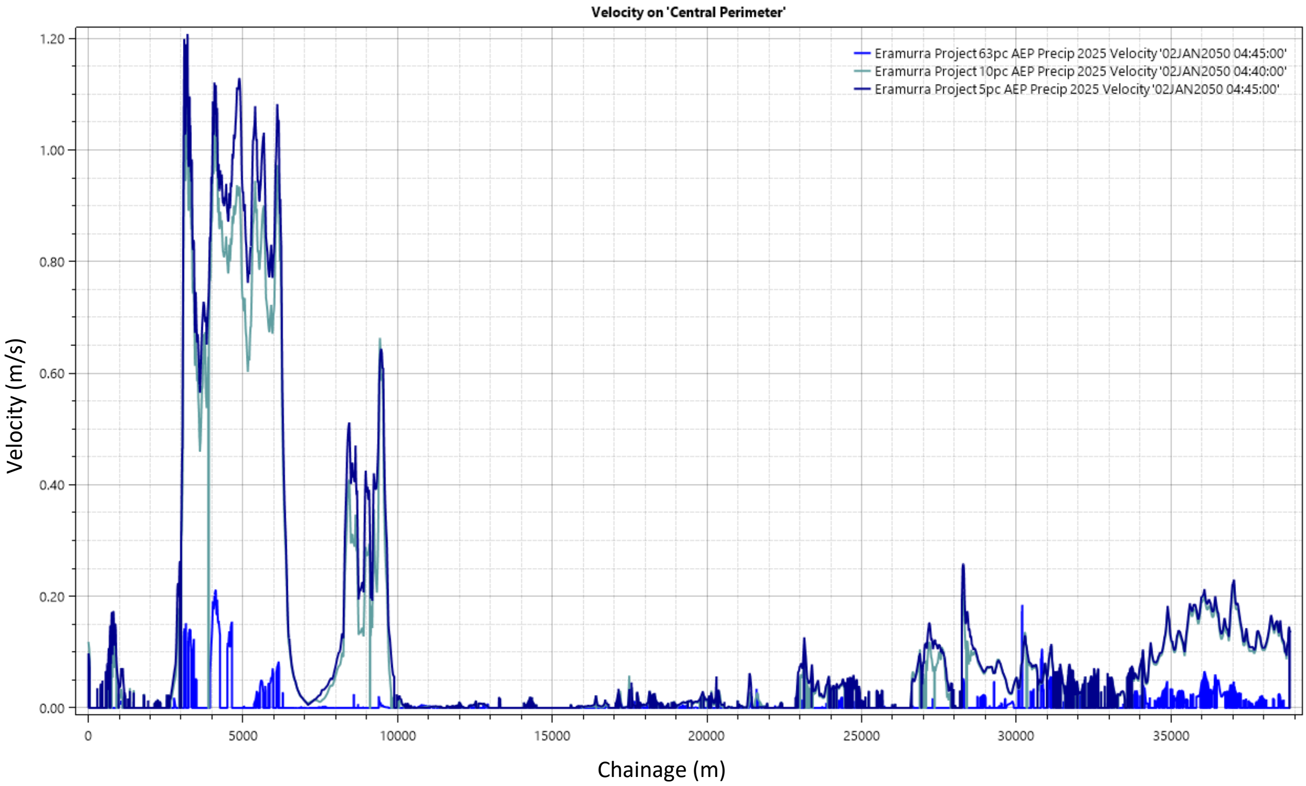

Figure 5-42: Flow velocities around central ponds for 1EY, 10% AEP, and 5% AEP events

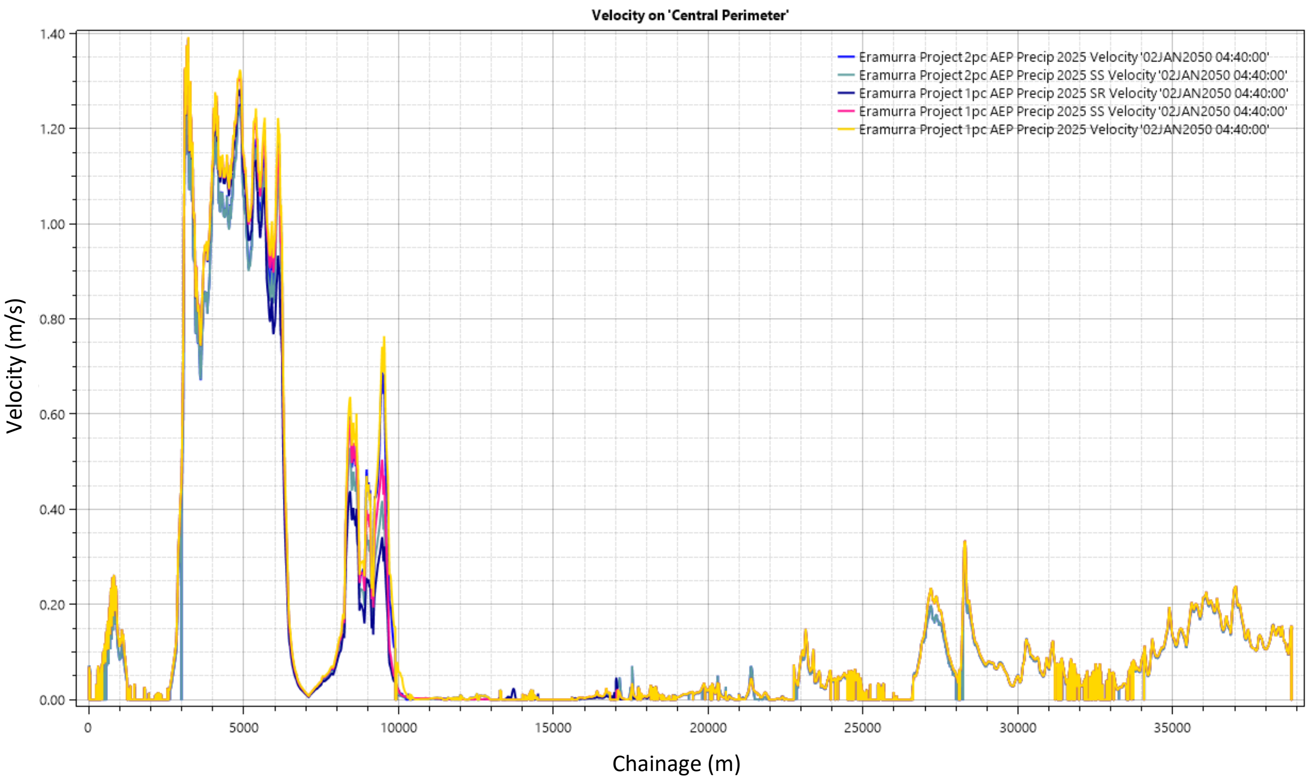

Figure 5-43: Flow velocities around central ponds for 2% and 1% AEP events

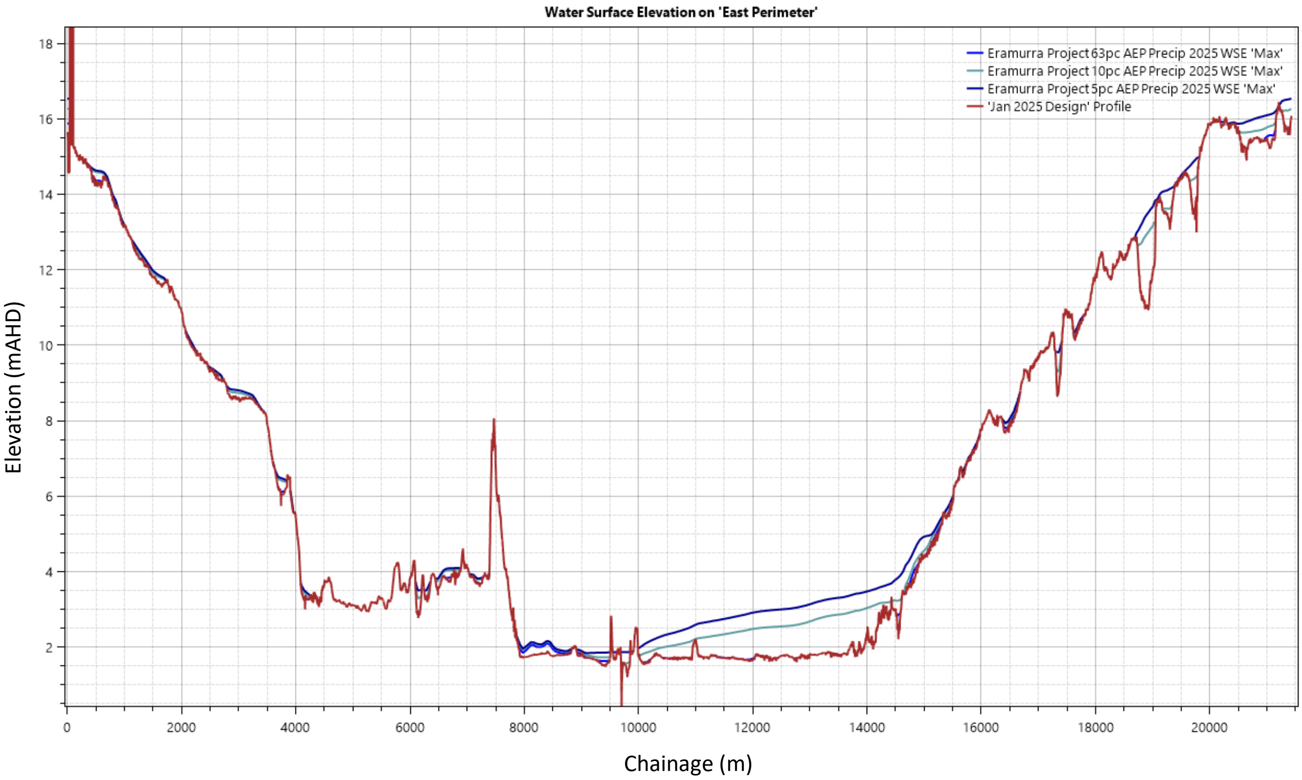

Figure 5-44: Water surface elevations around eastern ponds for 1EY, 10% AEP, and 5% AEP events

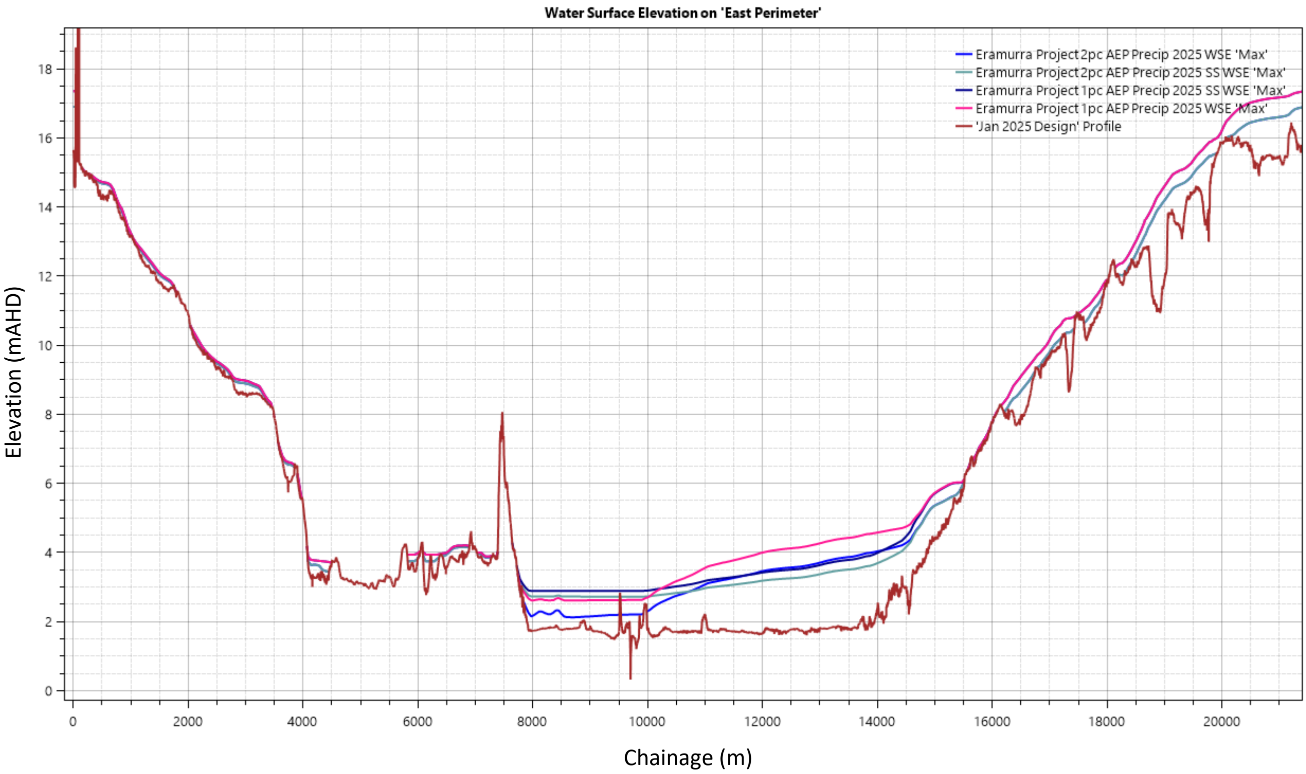

Figure 5-45: Water surface elevations around eastern ponds for 2% and 1% AEP events

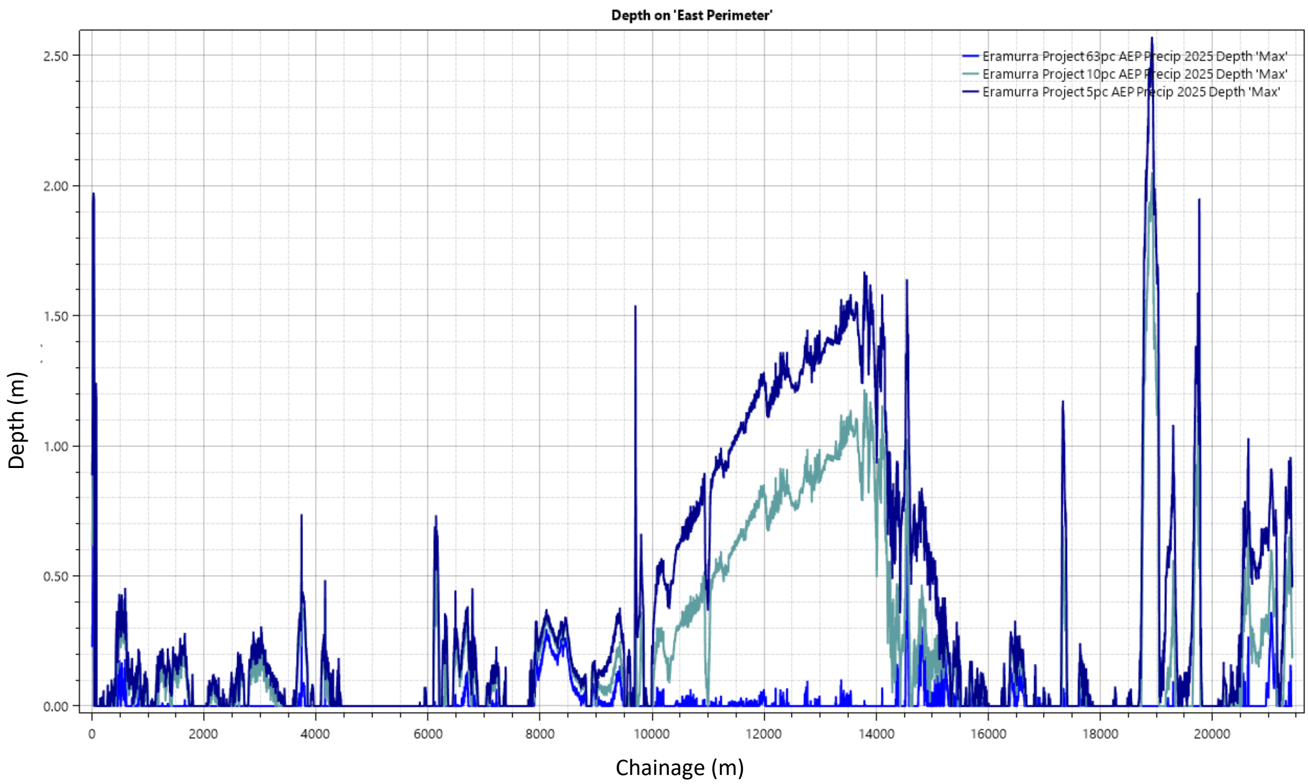

Figure 5-46: Flow depths around eastern ponds for 1EY, 10% AEP, and 5% AEP events

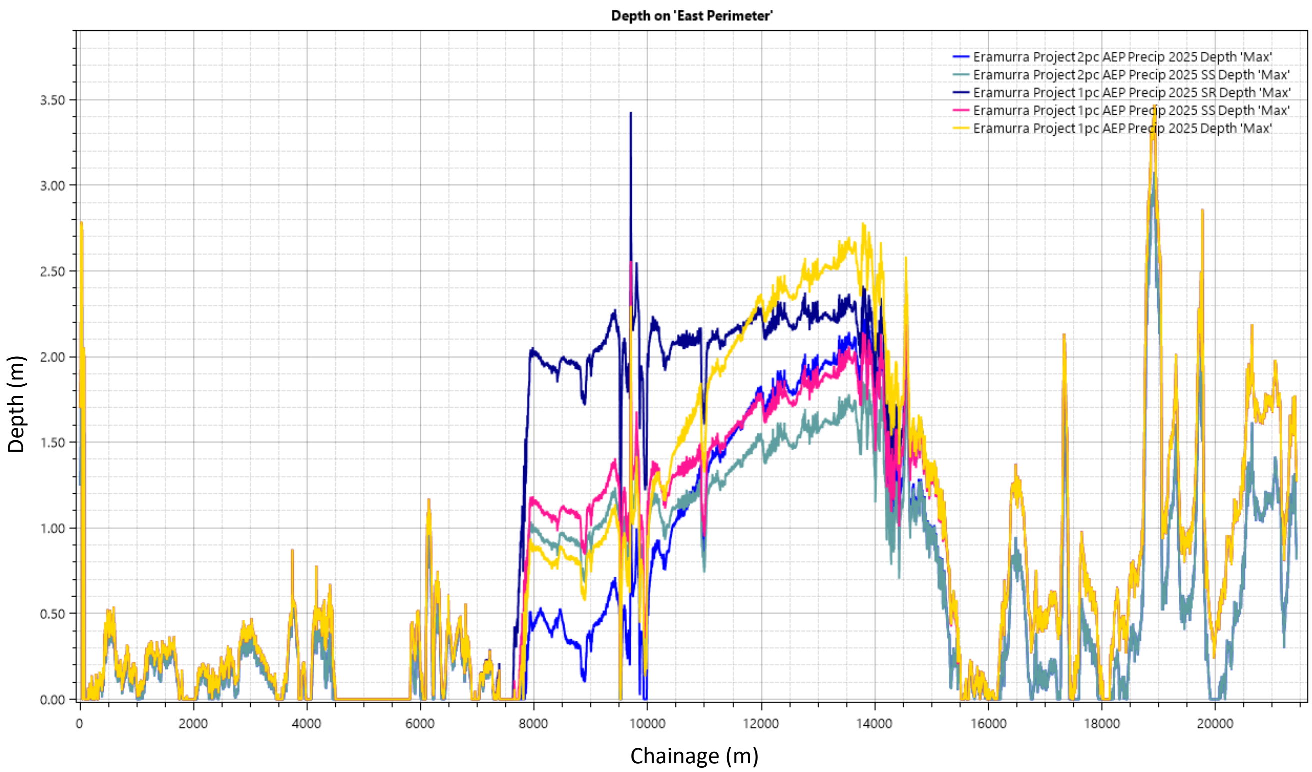

Figure 5-47: Flow depths around eastern ponds for 2% and 1% AEP events

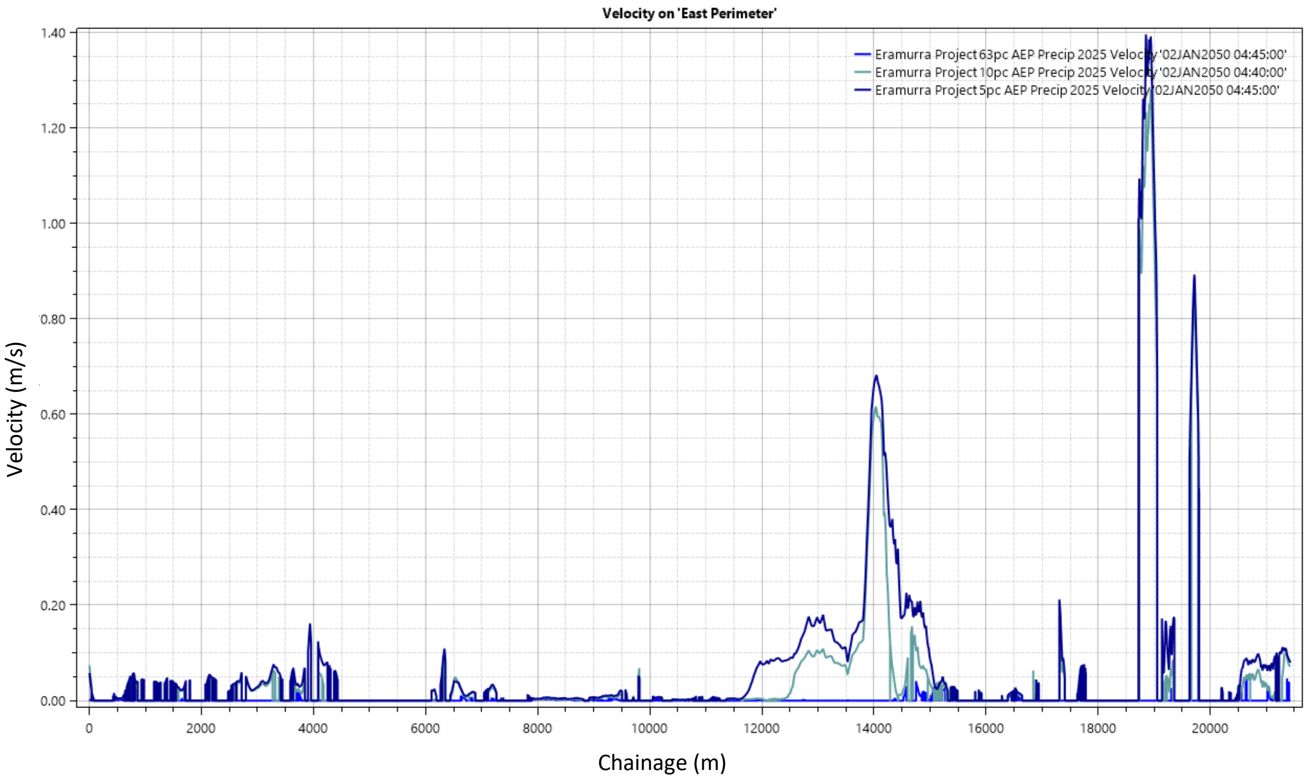

Figure 5-48: Flow velocities around eastern ponds for 1EY, 10% AEP, and 5% AEP events

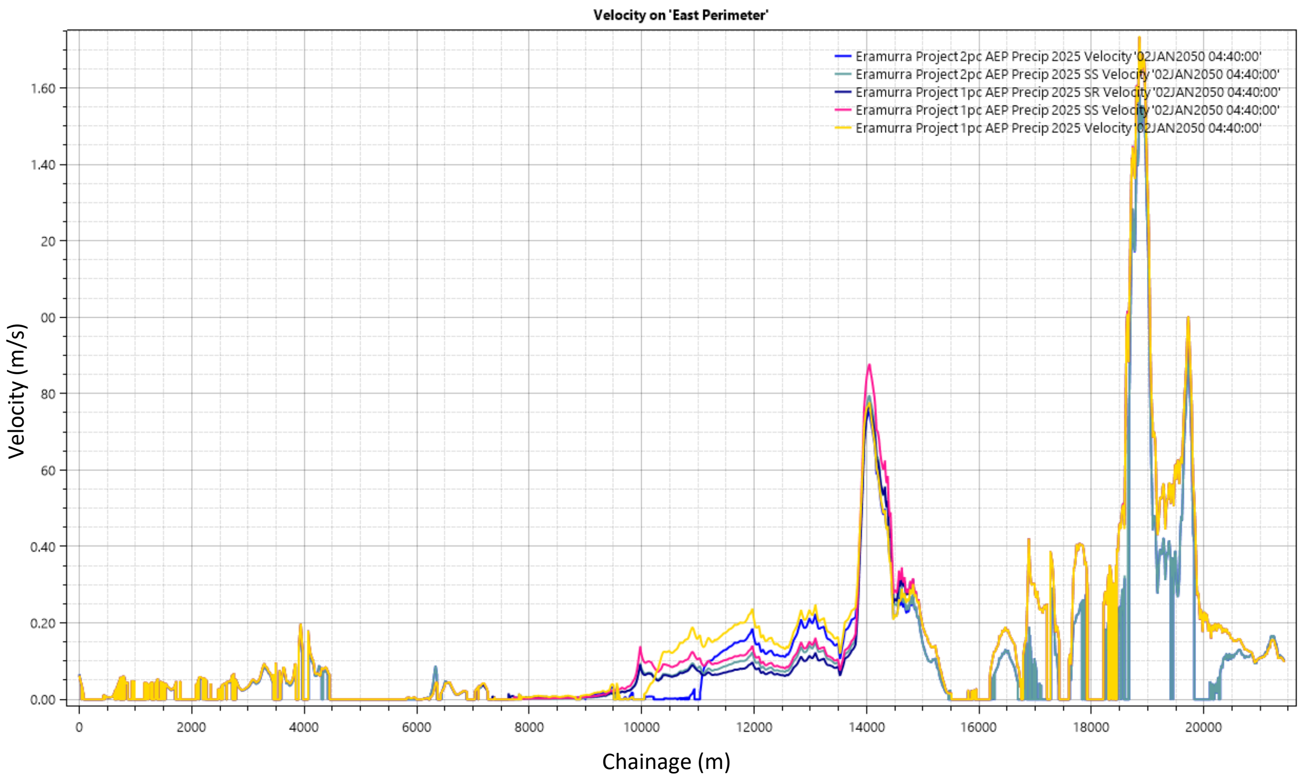

Figure 5-49: Flow velocities around eastern ponds for 2% and 1% AEP events

5.4 Forty Mile Beach Road

Figure 5-50 shows the location of the 130 m wide corridor between the proposed pond areas that encompasses Forty Mile Beach Road (FMBR). The Santos Devil Creek Gas Plant (DCGP) is located approximately 1 km south of the eastern ponds, and the corridor includes a 10 m wide easement for the Reindeer onshore gas pipeline. Chainages along the alignment and selected pipeline kilometre point (KP) values are shown for reference. KP 3.999 represents the low point in the adjacent topography, and KP 5.693 represents the end point for the existing concrete weight-coat on the gas pipeline.

Figure 5-51 compares existing and project conditions maximum water surface elevation profiles for the 1EY and 10% AEP flood events. **Figure 5-52** shows the maximum water surface elevation profiles along the alignment for the 2% and 1% AEP scenarios, including storm surge and climate change.

Figure 5-53 compares the water surface stage hydrographs for existing and project conditions in the 1EY and 10% AEP flood events. Hydrographs are extracted at the KP 3.999 location. **Figure 5-54** shows the water surface stage hydrographs for project conditions in the 5% to 1% AEP events at the same KP location.

Figure 5-55 compares the water surface stage hydrographs for existing and project conditions in the 1EY and 10% AEP flood events at KP 5.693. **Figure 5-56** shows the 5% to 1% AEP stage hydrographs. As reflected in the figures, water levels at the KP locations are unaffected by the downstream tide levels.

Under project conditions, a levee with a gated culvert structure prevents external runoff from entering the FMBR corridor. Relative to the existing condition, project conditions depths and velocities along the FMBR corridor are reduced during flood events. When gates are opened to drain the upstream ponding following a flood event, there is some increased standing water inside the easement relative to the existing condition. The project conditions hydraulic model incorporates a series of box culverts crossing the FMBR with a total span of 30 m.

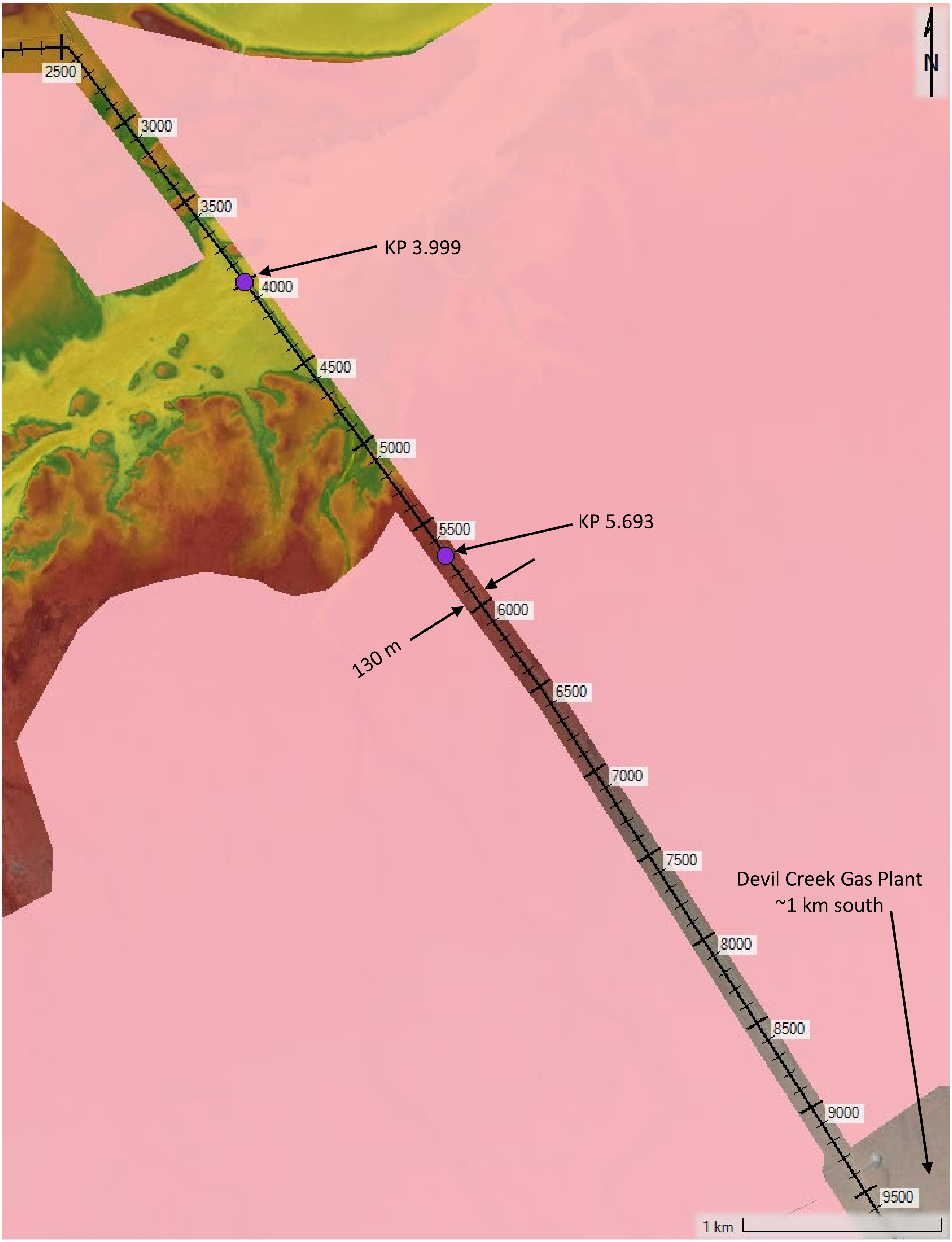

Figure 5-50: Reindeer onshore gas pipeline easement and chainage with selected KP locations

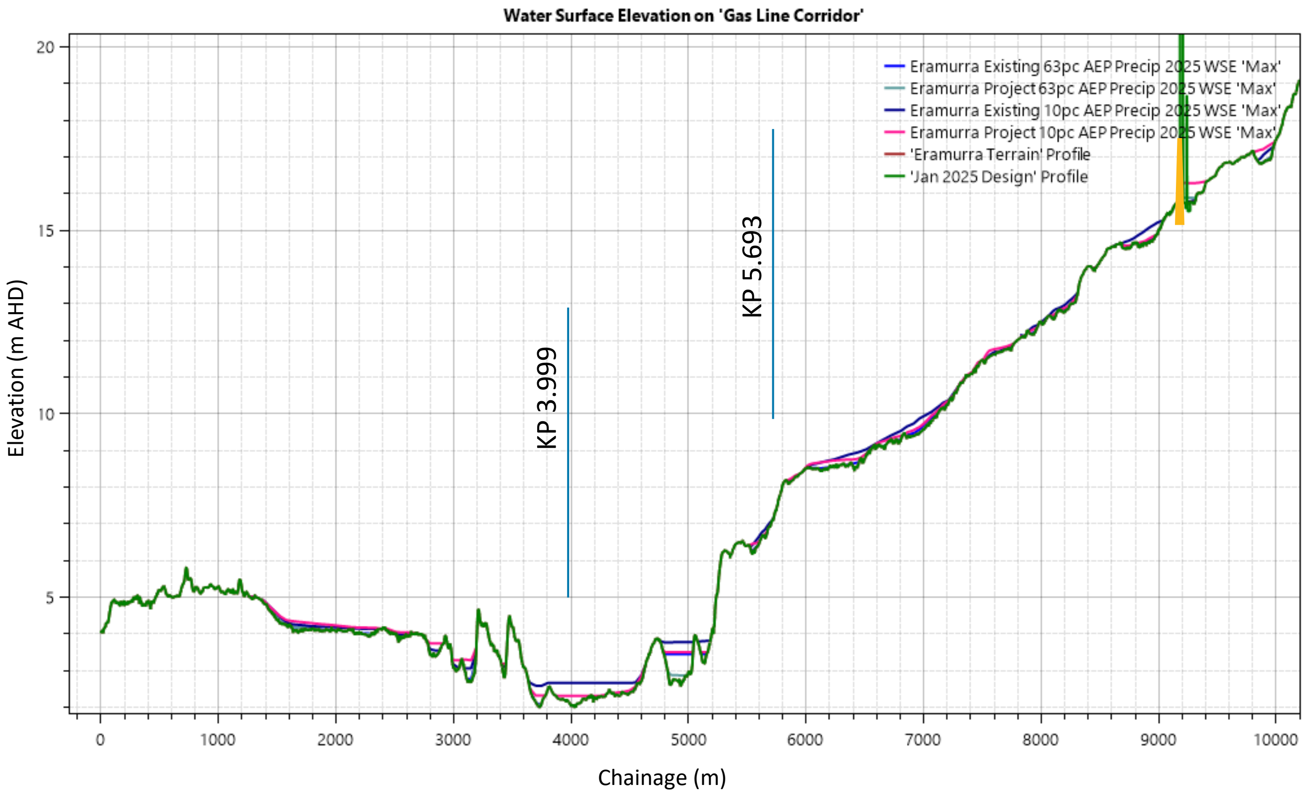

Figure 5-51: Reindeer onshore gas pipeline easement 1EY and 10% AEP water surface elevation profiles

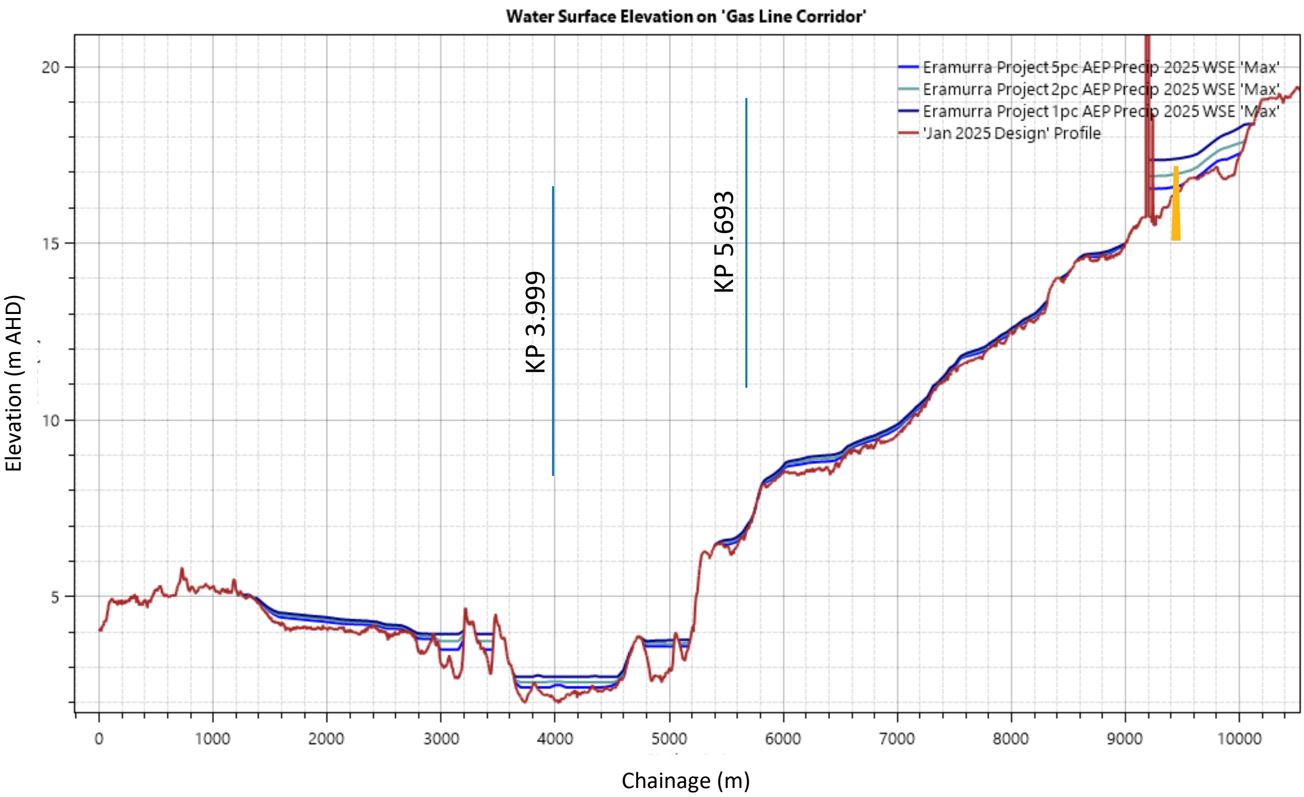

Figure 5-52: Reindeer onshore gas pipeline easement 2% and 1% AEP water surface elevation profiles

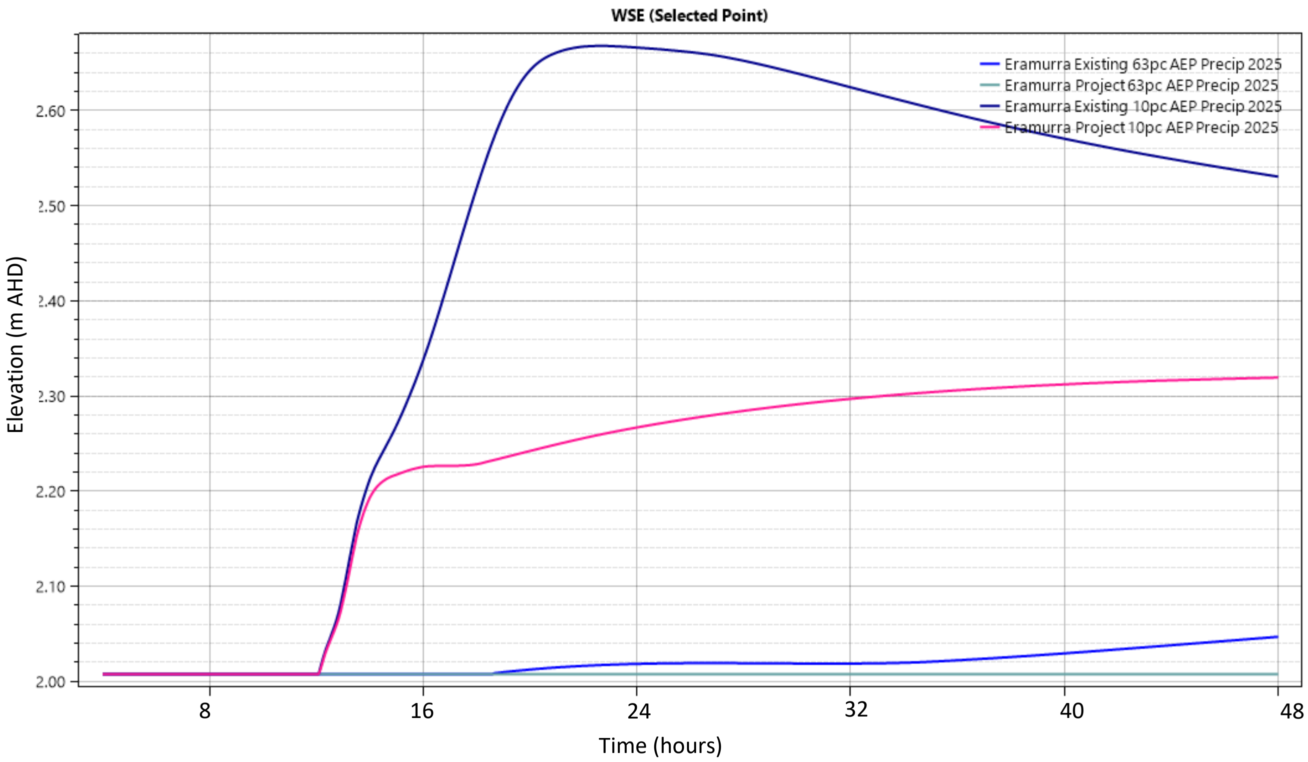

Figure 5-53: Reindeer onshore gas pipeline easement existing vs project water surface KP 3.999

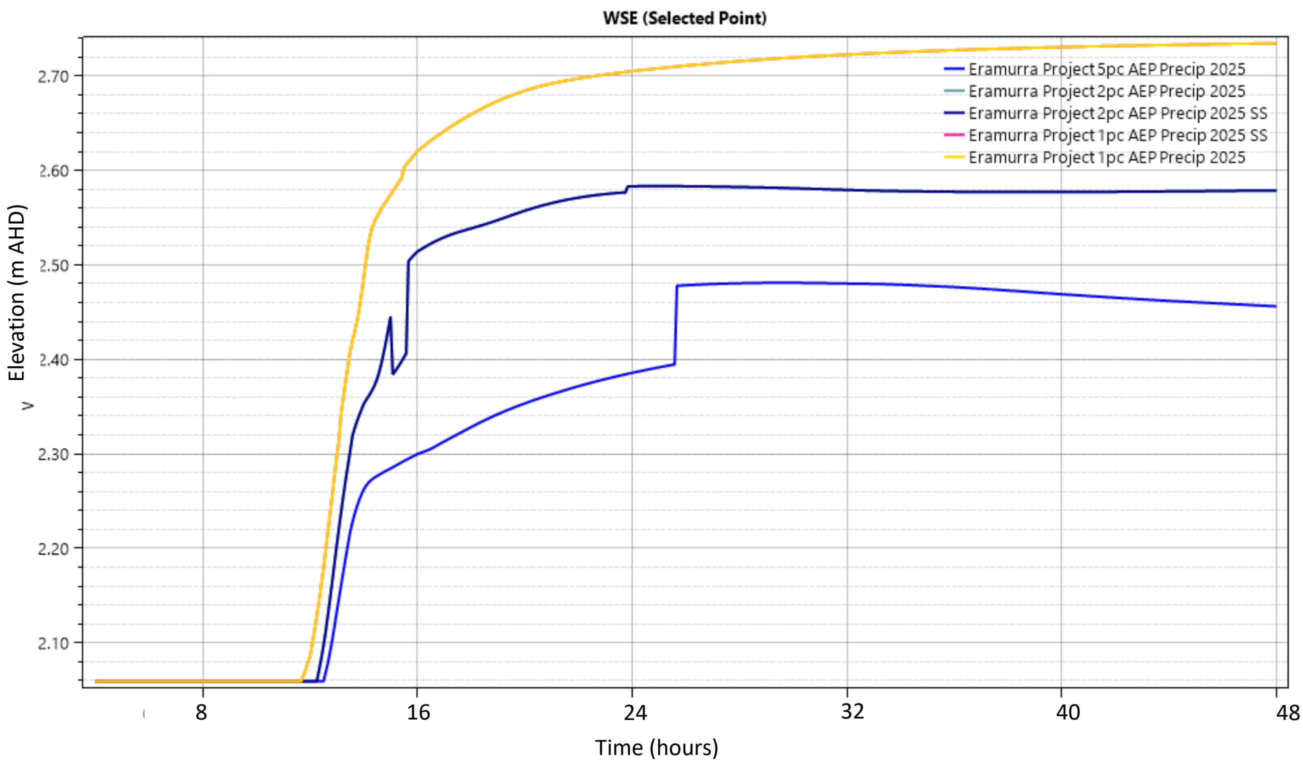

Figure 5-54: Reindeer onshore gas pipeline easement project conditions water surface KP 3.999

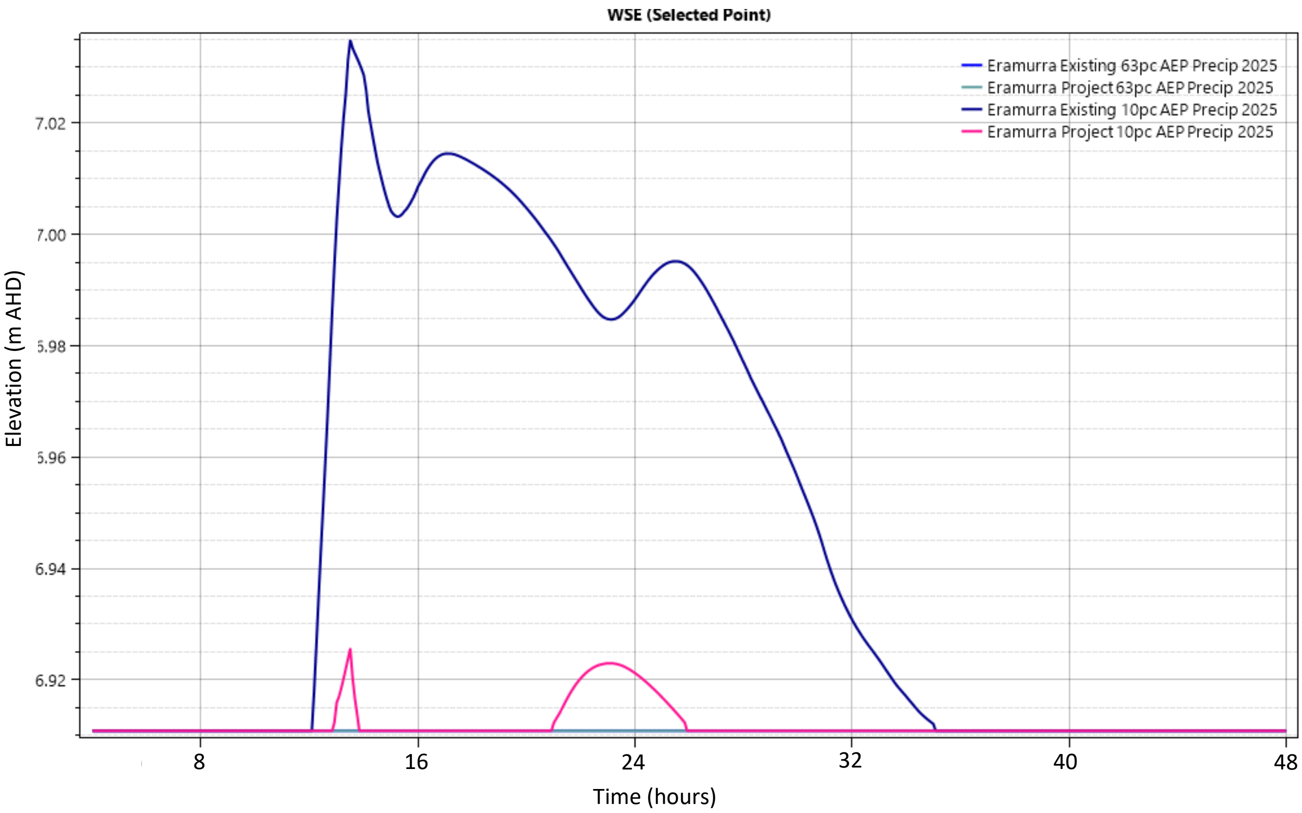

Figure 5-55: Reindeer onshore gas pipeline easement existing vs project water surface KP 5.693

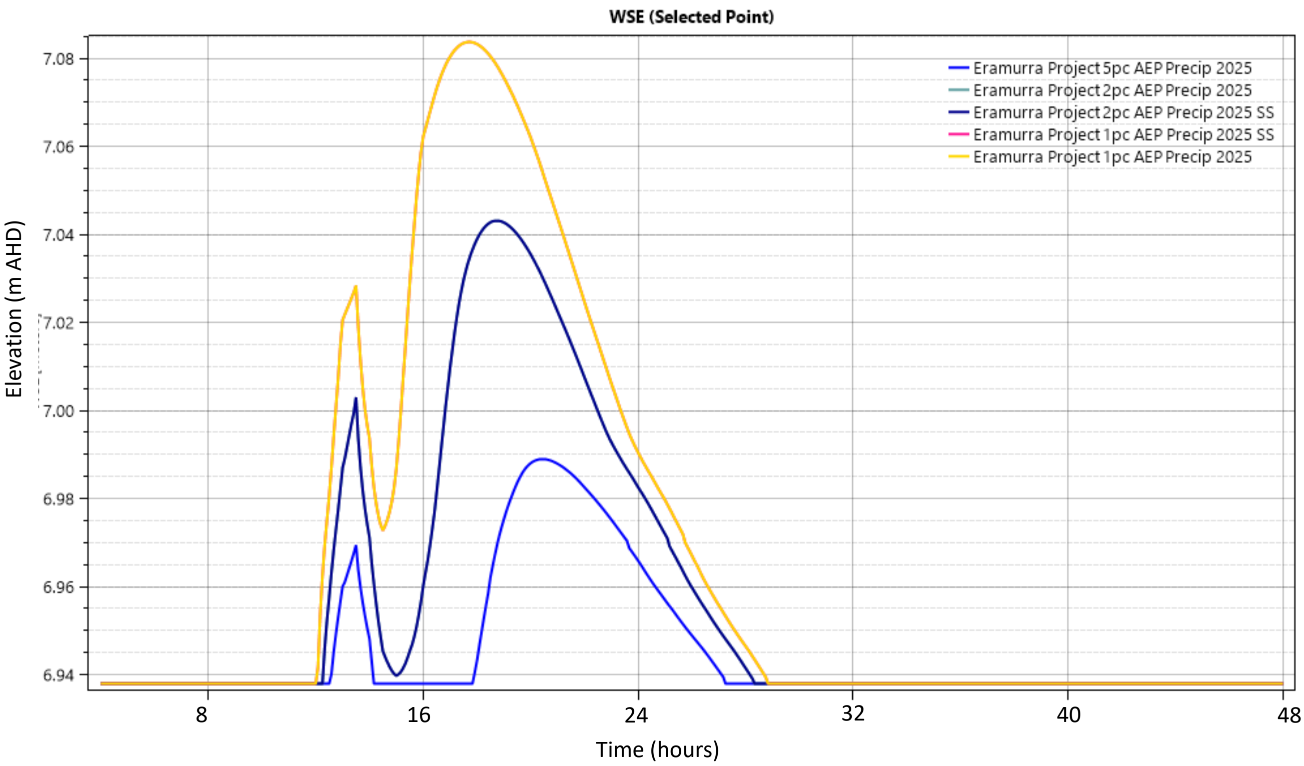

Figure 5-56: Reindeer onshore gas pipeline easement project conditions water surface KP 5.693

6.0 EROSION AND SEDIMENTATION

Figure 6-1 shows a comparison of existing and project conditions velocities along the McKay Creek profile, where the maximum constriction of existing conditions flow takes place. In this area, the 10% AEP maximum flow velocities are generally less than 1.5 m/s, with one localised area reaching 2 m/s. The velocity increase resulting from the constriction is approximately 5%-10%.

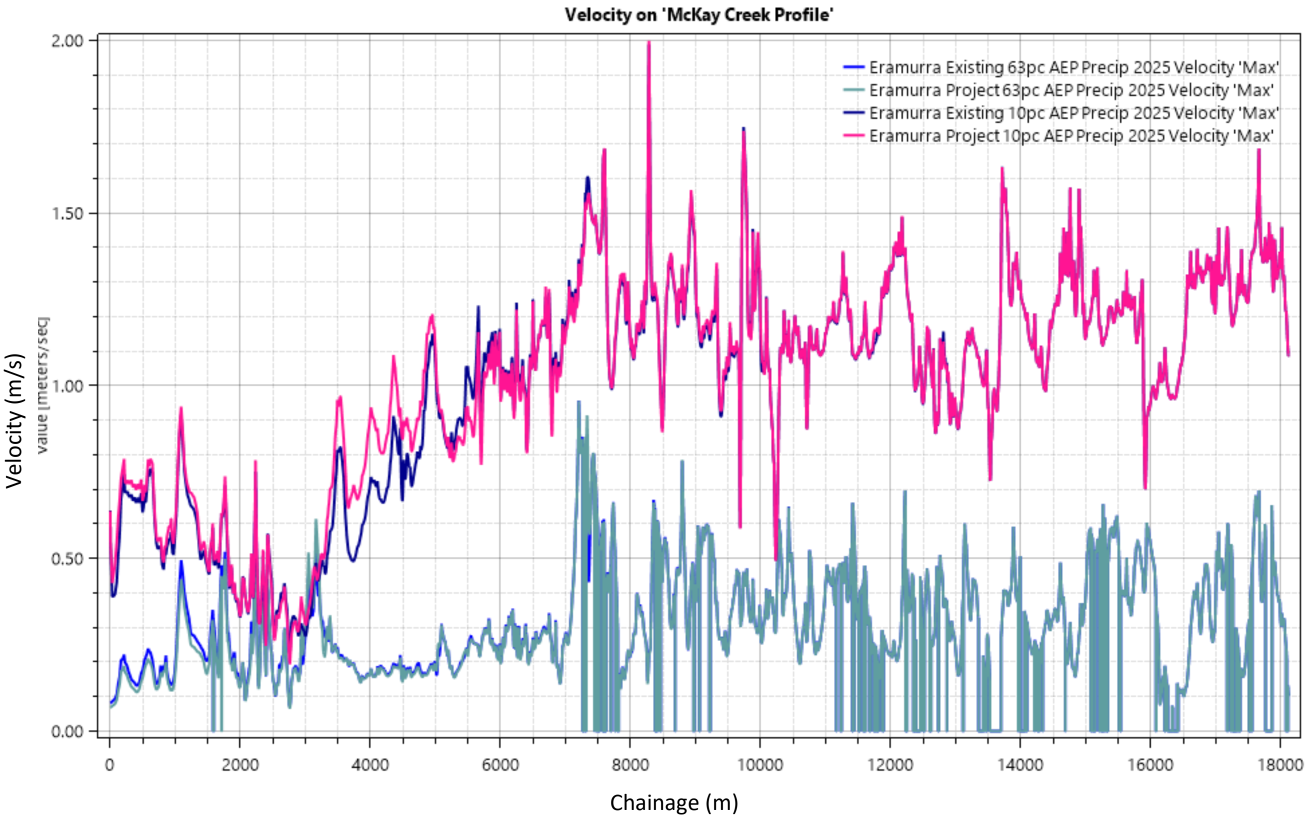

Figure 6-1: McKay Creek velocity profile

Figure 5-51 shows the maximum water surface elevation profiles along the gas line easement; **Figure 6-2** and **Figure 6-3** show the corresponding maximum velocities. As shown in these figures, the maximum 10% AEP inundation depth is approximately 1 m, and the maximum 10% AEP velocities are approximately 0.25 m/s.

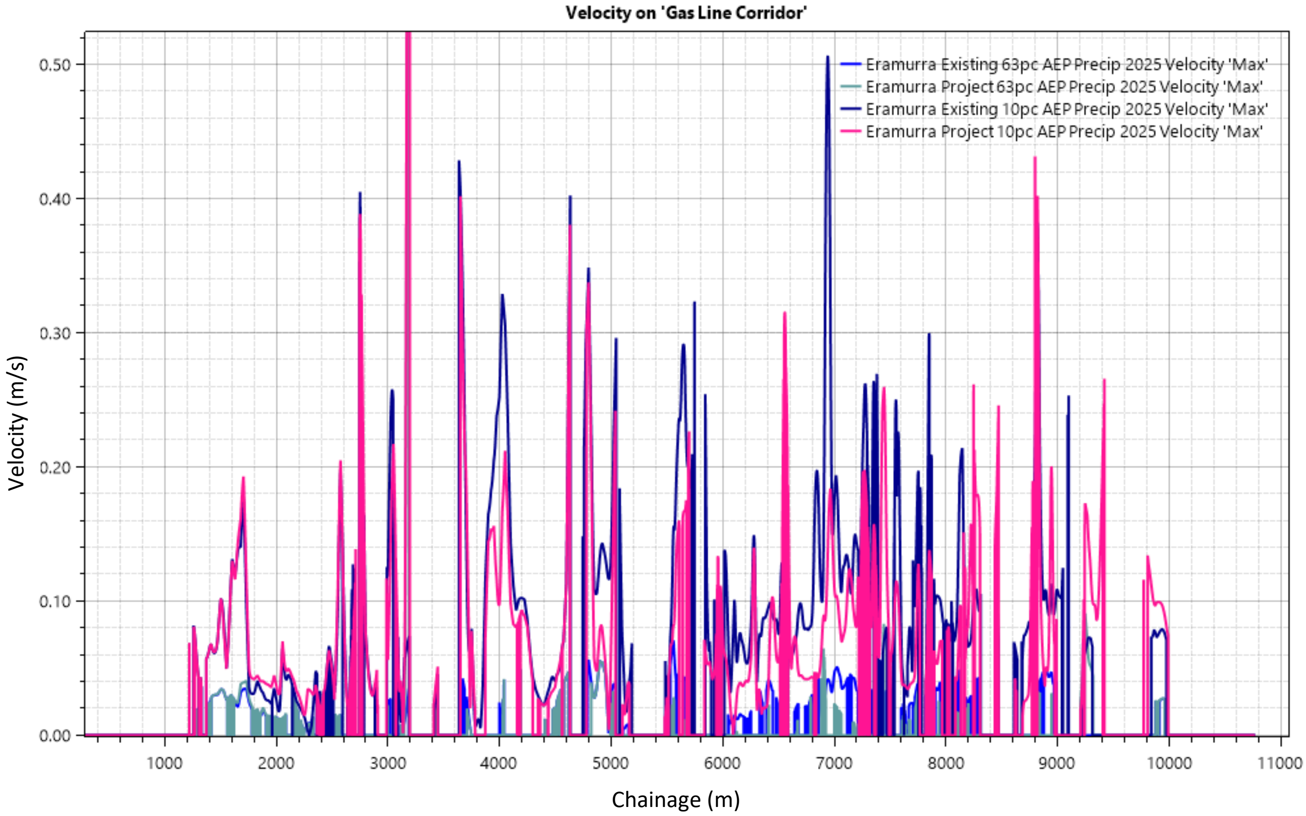

Figure 6-2: Reindeer onshore gas pipeline easement existing vs proposed 1EY and 10% AEP velocities

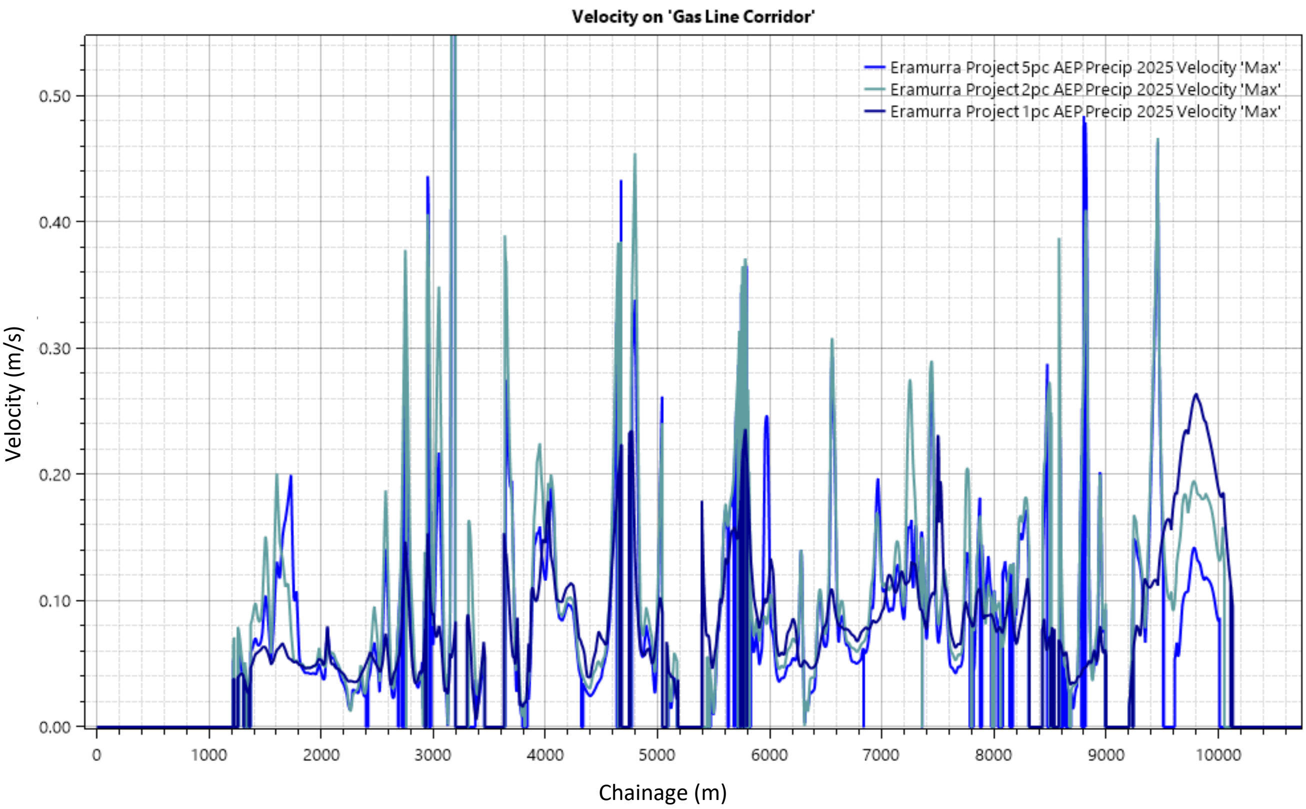

Figure 6-3: Reindeer onshore gas pipeline easement project velocities for 5%, 2%, and 1% AEP

Table 6-1 below shows an excerpt from Austroads 2013 highlighting the recommended rock class and section thicknesses associated with specified velocity ranges. Austroads references Main Roads Western Australia (MRWA, 2006) as the data source for the tabulated values. **Table 6-2** defines the gradation and size ranges for standard rock classes. **Figure 6-4** shows the tabulated values graphically. Under the specified hydraulic conditions, smaller rock sizes would risk being mobilised during flood events, with unprotected embankments subject to scour.

As shown in the velocity maps and profiles above, peak velocities in the 10% AEP flood are generally below 1.2 m/s, which falls below Austroads thresholds for rock protection in both the existing and project condition. Although these velocities fall below the Austroads threshold for requiring armour rock, the placement of coarser material such as Class A or B1 rock may be beneficial in preventing erosion of the bunds and preventing adverse impacts, particularly along areas where the flow path has been constricted or where localised runoff concentrates on embankment slopes.

Differences in velocity and water surface elevation related to the main creek channels are not expected to significantly alter the sediment dynamics of the creek systems.

Table 6-1: Rock protection (from Table 3.11, Austroads 2013)

Velocity (m/s)	Class of rock protection (tonne)	Section thickness, *T* (m)
< 2	None	–
2.0–2.6	Facing	0.50
2.6–2.9	Light	0.75
2.9–3.9	¼	1.00
3.9–4.5	½	1.25
4.5–5.1	1.0	1.60
5.1–5.7	2.0	2.00
5.7–6.4	4.0	2.50
> 6.4	Special	–

Table 6-2: Standard rock classes (from Table 3.12, Austroads 2013)

Rock class	Rock size[(1)] (m)	Rock mass (kg)	Minimum percentage of rock larger than
Facing	0.40 0.30 0.15	100 35 2.5	0 50 90
Light	0.55 0.40 0.20	250 100 10	0 50 90
¼ tonne	0.75 0.55 0.30	500 250 35	0 50 90
½ tonne	0.90 0.70 0.40	1000 450 100	0 50 90
1 tonne	1.15 0.60 0.55	2000 1000 250	0 50 90
2 tonne	1.45 1.15 0.75	4000 2000 500	0 50 90
4 tonne	1.80 1.45 0.90	8000 4000 100	0 50 90

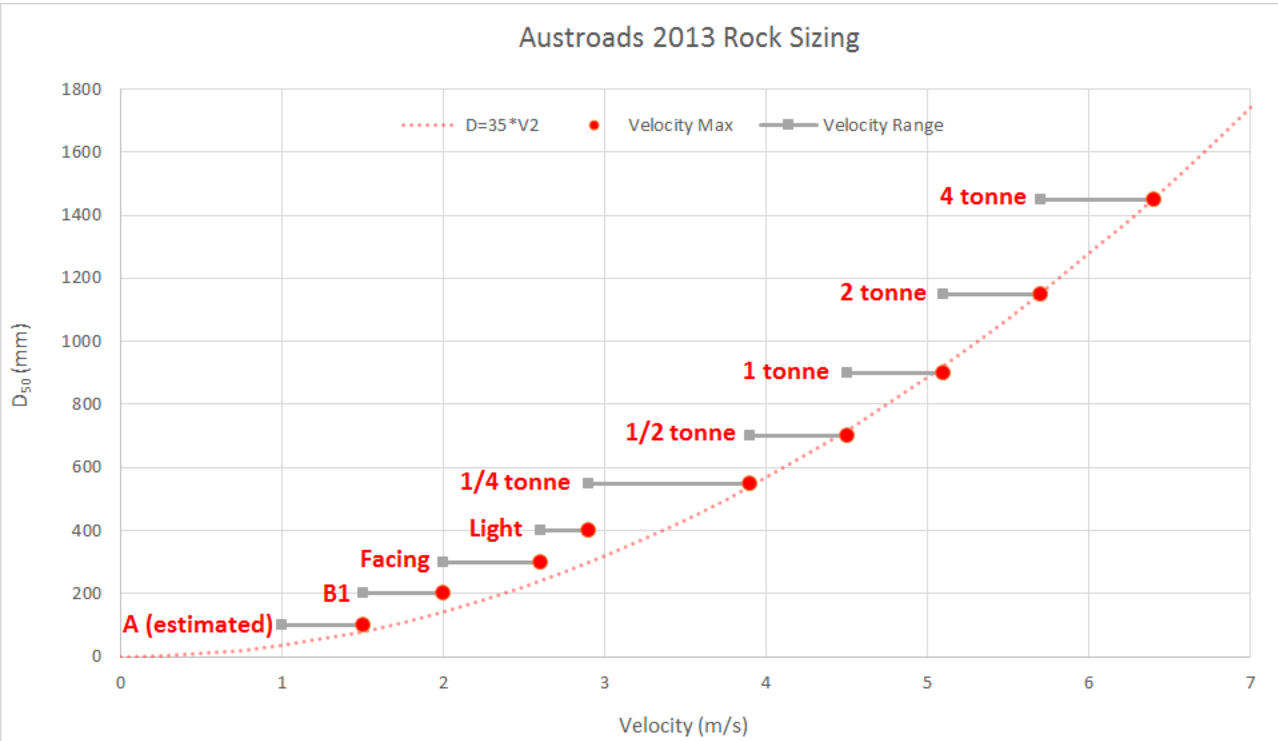

Figure 6-4: Velocity vs. median stone size (based on Austroads 2013)

7.0 CONCLUSIONS

7.1 Limitations

The results presented in this report are limited to the accuracy of the topographic mapping provided. Bathymetry below the water level at the time of survey has been estimated for the purpose of this study. If more recent or more detailed terrain data become available for the inundated areas in the LiDAR survey, the results of this study should be revisited.

The flood models account for minor changes to the pond configuration reflected in the 2023 Scenario 7.2 design iteration. Pond areas are assumed to be internally draining for the purpose of this modelling exercise; interior drainage design details have not been assessed. This assessment covers individual storm events with durations up to 12 hours; the determination of freeboard levels for the design of bund heights and water quality assessments require long-term water balance analyses that are beyond the scope of this flood study and will be addressed in accompanying reports.

Hydraulic structures incorporated into the flood model include a bridge along the Cape Preston Access Road, a flood control levee at the FMBR, and a series of box culverts across the FMBR.

The modelled results do not account for groundwater interaction; however, saturated conditions without initial or continuous losses have been assessed in the accompanying sensitivity analyses.

There is some inherent uncertainty in the adopted loss rates. Under the assumption of completely saturated antecedent conditions (no initial or continuing losses), predicted water levels increase relative to the modelled scenarios with losses applied. The potential increase is highest (up to 500 mm) in the confined corridors between pond embankments. The higher flow rates associated with saturated conditions result in higher velocities; however, the nominal increase does not change the scour rock recommendations presented above. Sensitivity results are shown in Appendix B.

Refining loss estimates would require additional gauging and calibration efforts. The currently available onsite gauge data are insufficient to allow for model calibration at this time. The study may benefit from any local historical flood observations or gauge data that may become available in the future.

Additional modelling efforts will be required to refine the hydrotechnical understanding of the plans as detailed designs are incorporated into the modelled surfaces in future design stages. As detailed designs progress, adopted climate change factors should be confirmed. The current conceptual design condition presented in this assessment includes selected bridges and culverts that are designed to convey flows with the uniform adopted climate change uplift factors applied. Detailed designs of drains, levees, culverts, bridges, overflow spillways, and other infrastructure features may require separate uplift factors for consistency with adopted risk factors

7.2 Summary and Recommendations

This study has assessed ten scenarios covering a range of precipitation events under existing and project conditions for the Scenario 7.2 design. Several changes have been made to the extents of the ponds since the previous design iteration addressed under the July 2023 W-AO-04 Hydrology Report FR002. The primary changes are related to a reduction of pond area in the vicinity of McKay Creek.

Under the revised Scenario 7.2 the maximum rise in water surface elevation is approximately 300 mm in the 10% AEP event. Increased water surface elevations are exhibited in a 7 km reach of McKay Creek and in a 3 km reach of Devil Creek. Water surface elevation increases along the perimeter of the proposed ponds are limited to within approximately 500 m of the proposed pond embankments.

Decreased water surface elevations are exhibited downstream of the ponds, over a maximum lineal extent of approximately 1.5 km. The maximum decrease in the 10% AEP event is approximately 500 mm.

A summary of depths and velocities around the perimeter of each of the ponded areas is provided (**Table 5-1**). The associated profile plots represent hydraulic conditions at the toe of the pond embankments. The areas with the greatest depths are near the coast, and the areas with highest velocities are along the channel reaches where confined by the pond embankments. The maximum 1% AEP inundation depth is 4.4 m, and the maximum 1% AEP velocity is 1.5 m/s. The maximum 2% AEP inundation depth is 3.9 m, and the maximum 2% AEP velocity is 1.3 m/s. Maximum depths correspond to model runs that incorporate storm surge and climate change scenarios, whereas the maximum velocities occur in model runs without storm surge applied.

Armouring of embankments subject to inundation may be required in some localised areas to prevent scour and related adverse impacts. The differences between existing and project conditions hydraulic characteristics within the main creek channels is not expected to significantly alter the sediment dynamics of the systems. The proposed ponds reduce the contributing catchment area draining freshwater runoff to the ocean by approximately 16%.

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APPENDIX A:
ARR DATA HUB AND RFFE RESULTS

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	116.256
Latitude	-21.006
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Climate Change Factors	show
Baseflow Factors	show

+
−
Dampier
Karratha
McKay Creek
Leaflet (http://leafletjs.com) | Map data © OpenStreetMap (https://www.openstreetmap.org/) contributors, CC-BY-SA (https://creativecommons.org/licenses/by-sa/2.0/), Imagery © Mapbox (https://www.mapbox.com/)

+
−
Dampier
Karratha
Devil Creek
Leaflet (http://leafletjs.com) | Map data © OpenStreetMap (https://www.openstreetmap.org/) contributors, CC-BY-SA (https://creativecommons.org/licenses/by-sa/2.0/), Imagery © Mapbox (https://www.mapbox.com/)

Data

River Region

Division	Pilbara-Gascoyne
River Number	9
River Name	Port Hedland Coast
Shape Intersection (%)	99.3

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i	Shape Intersection (%)
Northern Coastal	0.326	0.223	0.442	0.323	0.0013	0.58	-0.374	0.013	-0.0015	99.6

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Storm Initial Losses (mm)	-50.0
Storm Continuing Losses (mm/h)	-50.0

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/Rwest.zip)

code	Rwest
Label	Rangelands West
Shape Intersection (%)	100.0

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_Rwest.zip)

code	Rwest
arealabel	Rangelands West
Shape Intersection (%)	100.0

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-20.9972725228&longitude=116.333008933&sdmin=true&sdhr=true&sdday=true&user_labe
to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	25 May 2022 12:58PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.3 (0.010)	0.7 (0.018)	1.0 (0.020)	1.2 (0.022)	2.4 (0.035)	3.2 (0.042)
90 (1.5)	0.0 (0.000)	0.2 (0.005)	0.4 (0.007)	0.5 (0.008)	2.2 (0.028)	3.5 (0.039)
120 (2.0)	0.0 (0.000)	0.3 (0.006)	0.5 (0.009)	0.7 (0.010)	3.8 (0.044)	6.2 (0.062)
180 (3.0)	0.0 (0.000)	2.3 (0.042)	3.9 (0.056)	5.4 (0.065)	11.2 (0.110)	15.6 (0.132)
360 (6.0)	0.0 (0.000)	2.5 (0.036)	4.2 (0.047)	5.7 (0.053)	23.4 (0.171)	36.7 (0.229)
720 (12.0)	0.0 (0.000)	3.2 (0.035)	5.3 (0.045)	7.3 (0.050)	10.6 (0.057)	13.1 (0.060)
1080 (18.0)	0.0 (0.000)	0.7 (0.007)	1.2 (0.009)	1.7 (0.010)	7.8 (0.035)	12.4 (0.048)
1440 (24.0)	0.0 (0.000)	0.6 (0.005)	1.0 (0.006)	1.4 (0.007)	6.6 (0.027)	10.4 (0.036)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.4 (0.005)	2.5 (0.008)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.1 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**1.010 (5.1%)**	0.854 (4.3%)	**1.022 (5.1%)**
2040	**1.262 (6.3%)**	1.185 (6.0%)	**1.524 (7.7%)**
2050	**1.519 (7.7%)**	1.490 (7.5%)	**2.009 (10.3%)**
2060	**1.755 (8.9%)**	1.787 (9.1%)	**2.504 (13.0%)**
2070	**1.943 (9.9%)**	2.094 (10.8%)	**3.036 (16.0%)**
2080	**2.056 (10.6%)**	2.428 (12.6%)	**3.632 (19.4%)**
2090	**2.067 (10.6%)**	2.808 (14.7%)	**4.318 (23.5%)**

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	764.547136
Catchment Number	3554
Volume Factor	0.053971
Peak Factor	0.019481
Shape Intersection (%)	98.0

Layer Info

Time Accessed	25 May 2022 12:58PM
Version	2016_v1

Download TXT (downloads/43d2c7d7-ebda-4755-86aa-6327d651bf45.txt)

Download JSON (downloads/9108e8e9-c489-4bcf-a501-a454c88716e8.json)

Generating PDF... (downloads/1a3e2e13-17e7-472e-94c3-5e4d8020c951.pdf)

Climate Change Factors

Rainfall Factors

SSP1-2.6

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	1.22	1.2	1.18	1.17	1.15	1.15	1.14	1.13	1.12	1.11
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	1.29	1.26	1.24	1.22	1.2	1.19	1.18	1.17	1.16	1.15
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	1.59	1.53	1.49	1.44	1.4	1.38	1.35	1.33	1.3	1.29
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.05**	**1.05**	**1.05**	**1.06**
2040	1.06	1.06	1.07	1.08
2050	**1.07**	**1.08**	**1.08**	**1.1**
2060	1.07	1.09	1.1	1.12
2070	1.07	1.1	1.12	1.14
2080	1.07	1.1	1.14	1.17
2090	**1.07**	**1.11**	**1.16**	**1.19**
2100	1.07	1.11	1.17	1.22

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.07**	**1.07**	**1.07**	**1.07**
2040	1.08	1.08	1.09	1.09
2050	**1.08**	**1.09**	**1.1**	**1.12**
2060	1.09	1.11	1.12	1.15
2070	1.09	1.12	1.15	1.18
2080	1.09	1.13	1.17	1.21
2090	**1.08**	**1.14**	**1.2**	**1.24**
2100	1.08	1.14	1.22	1.27

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	07 March 2025 03:23PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Baseflow Factors

Downstream	0
Area (km2)	764.547136
Catchment Number	3554
Volume Factor	0.053971
Peak Factor	0.019481
Shape Intersection (%)	99.2

Layer Info

Time Accessed	07 March 2025 03:23PM
Version	2016_v1

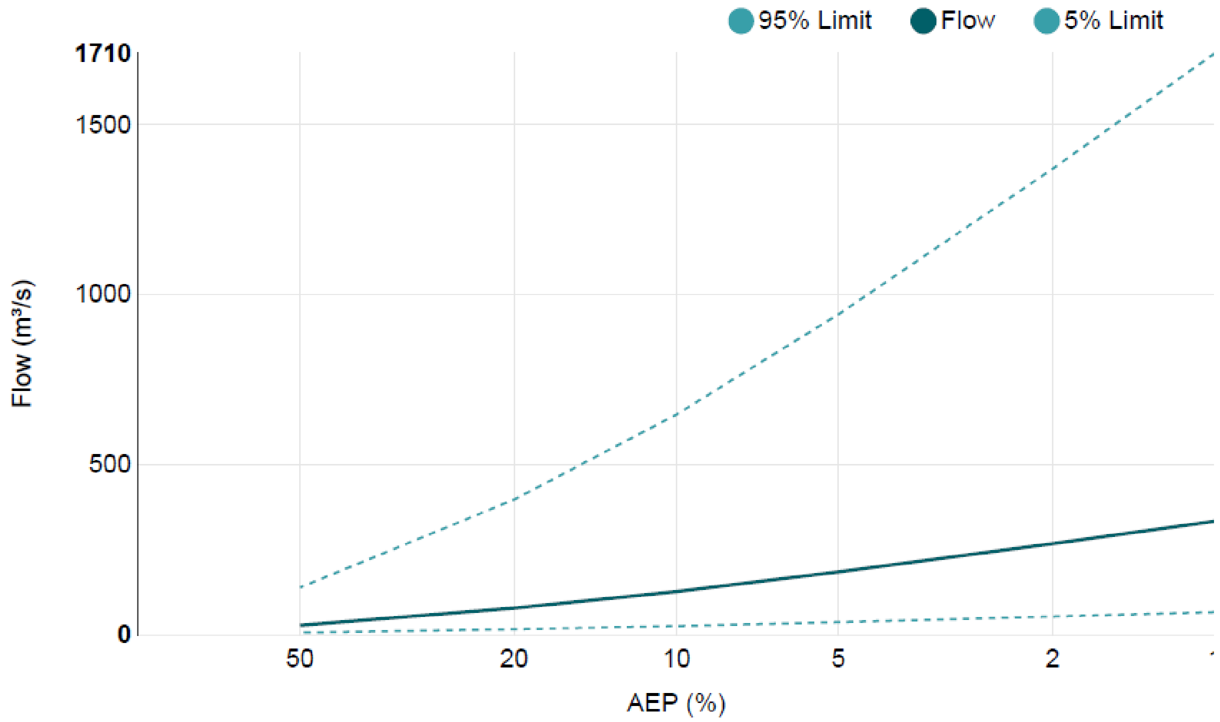
Download TXT (downloads/8cf5630e-75a7-4df9-94de-9f6294029c44.txt)

Download JSON (downloads/97e72ef2-7cd1-4c0f-9ce8-ebf5e18c2a46.json)

Generating PDF... (downloads/6d39c6ed-ac0d-4ec2-8eb4-1aa84bcc0019.pdf)

Eramurra Creek

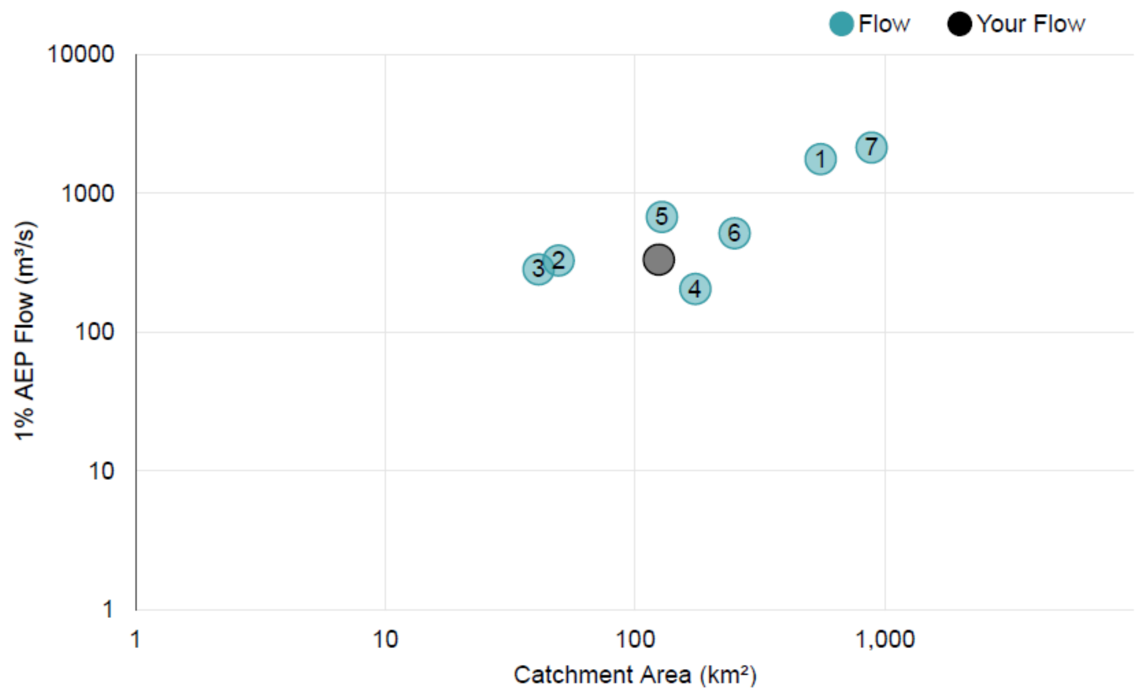
Results | Regional Flood Frequency Estimation Model



*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

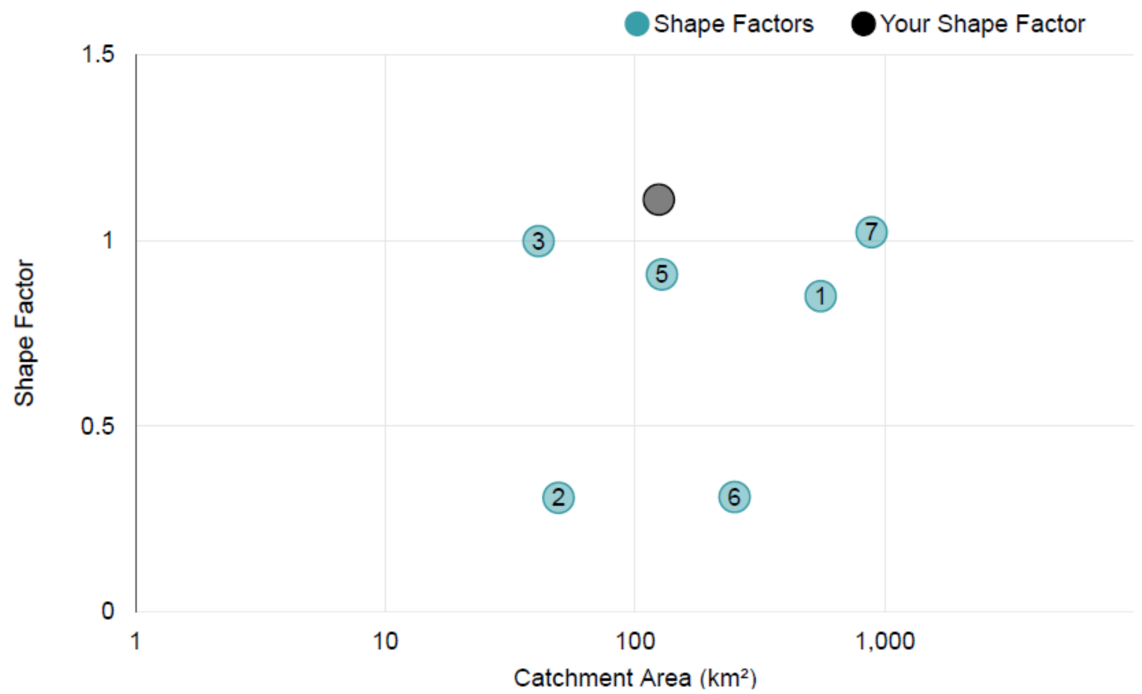
AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	27.0	5.31	138
20	77.5	15.3	397
10	126	24.9	647
5	184	36.2	942
2	267	52.6	1370
1	333	65.6	1710

1% AEP Flow vs Catchment Area

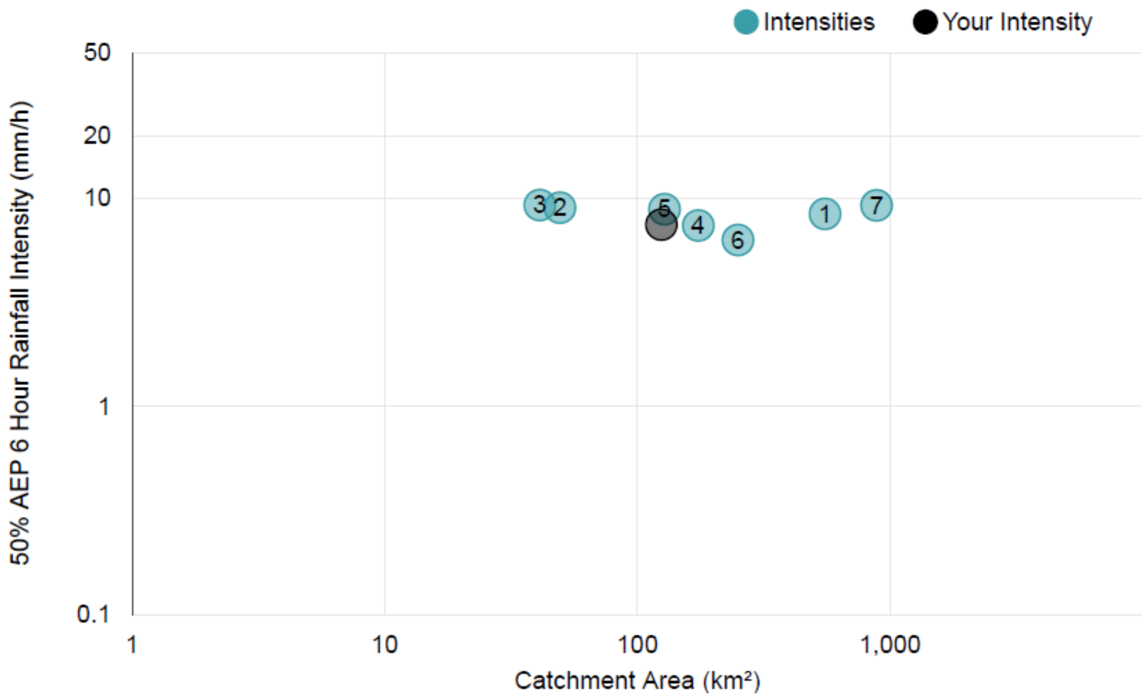


Shape Factor vs Catchment Area

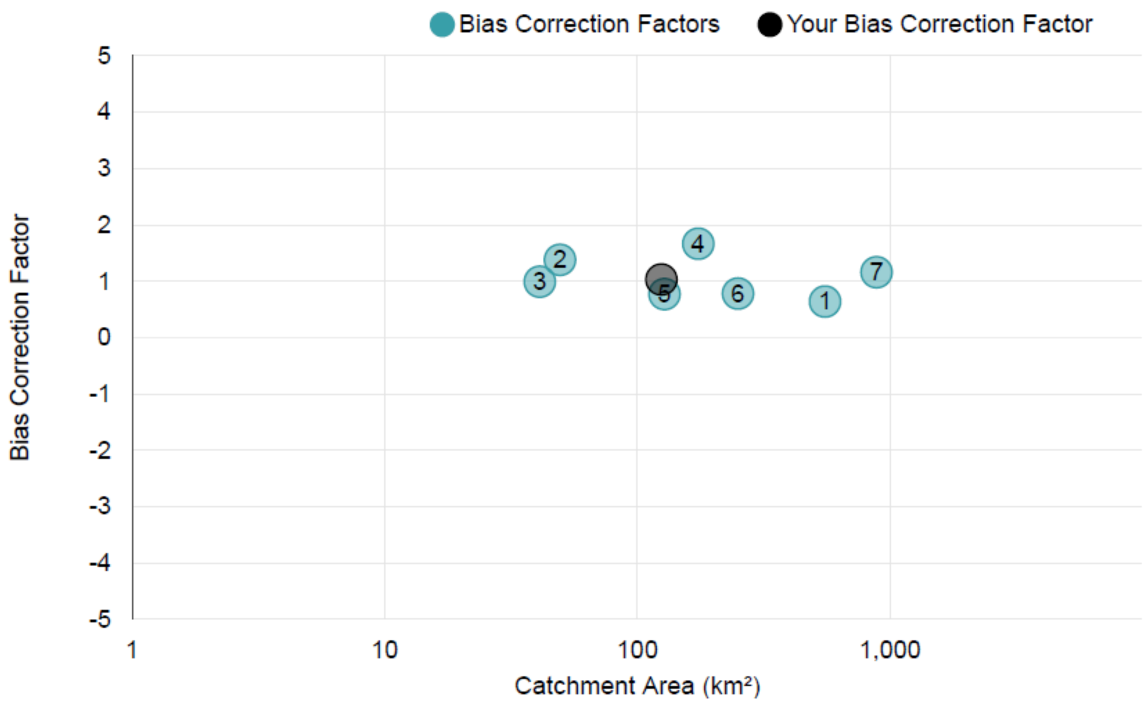
Note: This region does not use shape factors



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

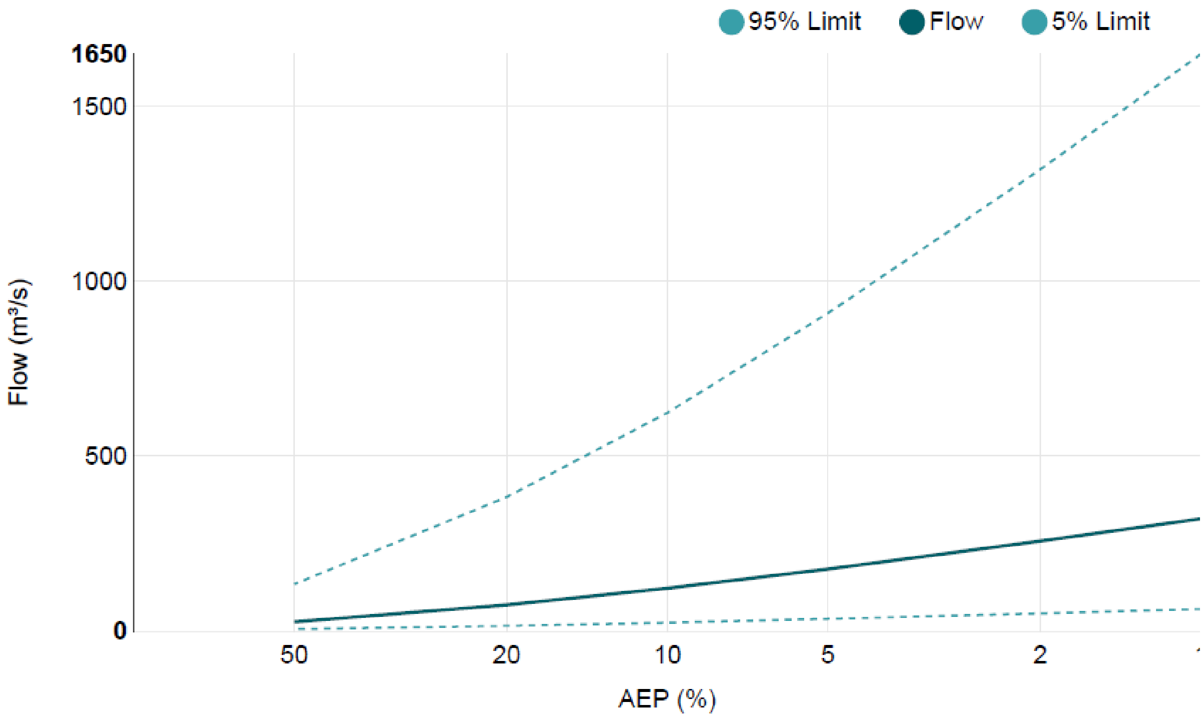
TXT Nearby JSON

Input Data

Date/Time	2022-06-04 06:16
Catchment Name	Eramurra West
Latitude (Outlet)	-20.927465
Longitude (Outlet)	116.260683
Latitude (Centroid)	-21.03897
Longitude (Centroid)	116.25893
Catchment Area (km^2)	124.5
Distance to Nearest Gauged Catchment (km)	86.6
50% AEP 6 Hour Rainfall Intensity (mm/h)	7.48815
2% AEP 6 Hour Rainfall Intensity (mm/h)	23.407269
Rainfall Intensity Source (User/Auto)	Auto
Region	Pilbara
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	1.11*
Interpolation Method	Natural Neighbour
Bias Correction Value	1.032

McKay Creek

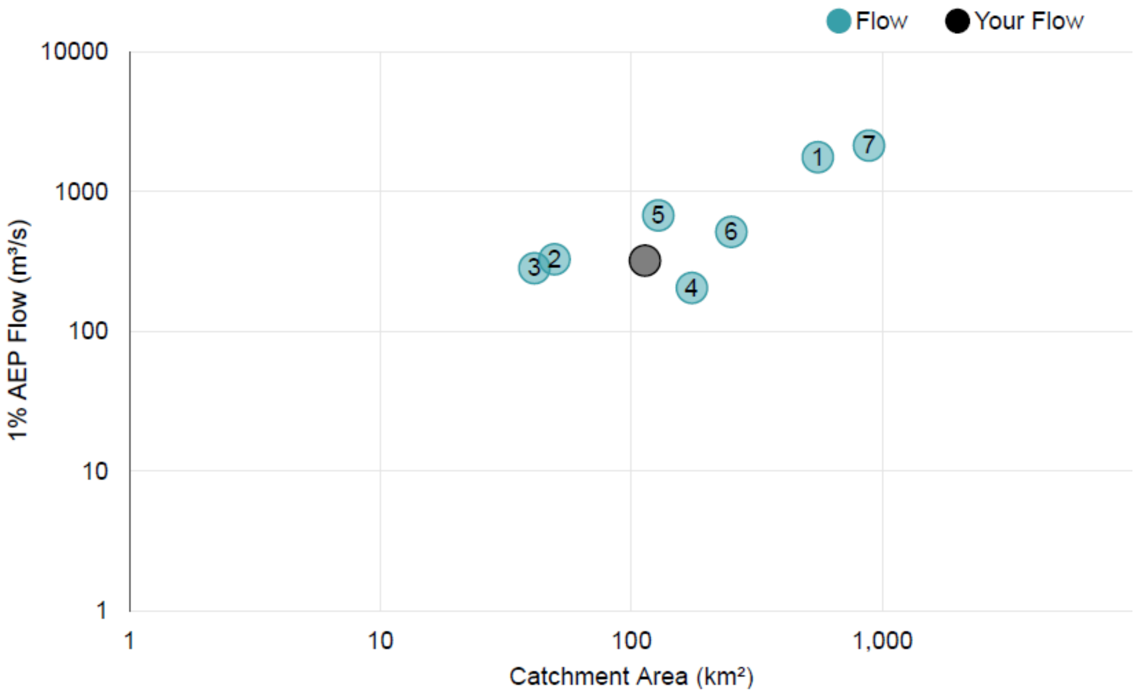
Results | Regional Flood Frequency Estimation Model



*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

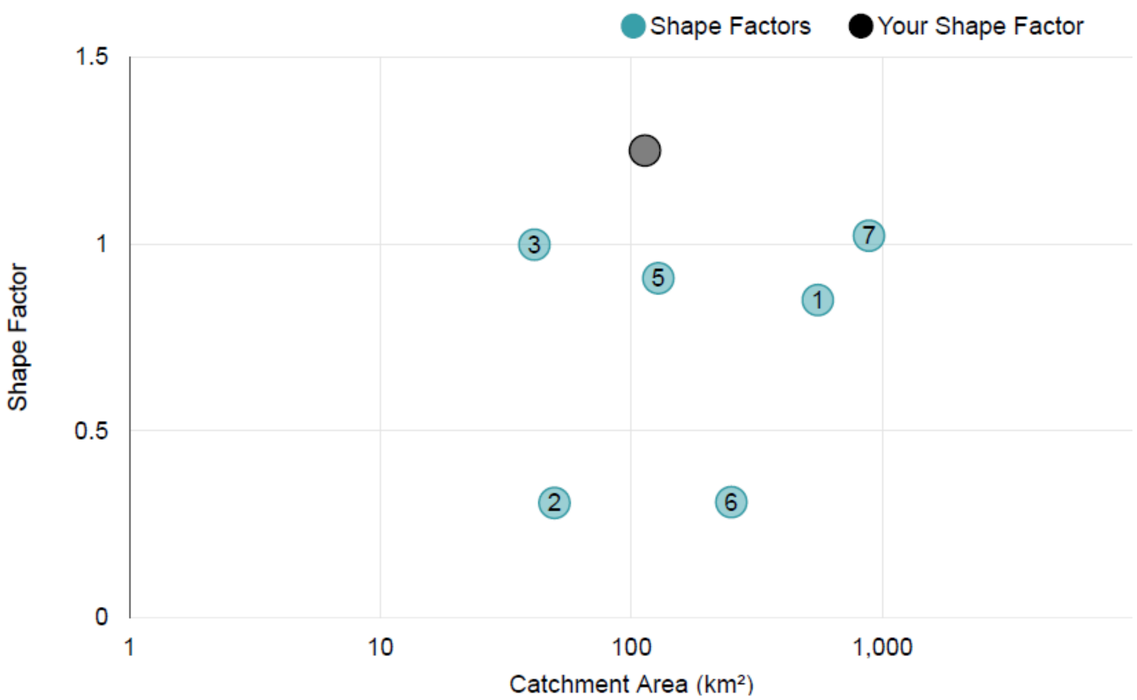
AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	26.0	5.10	134
20	74.6	14.6	383
10	122	23.8	624
5	177	34.7	909
2	257	50.4	1320
1	321	62.9	1650

1% AEP Flow vs Catchment Area

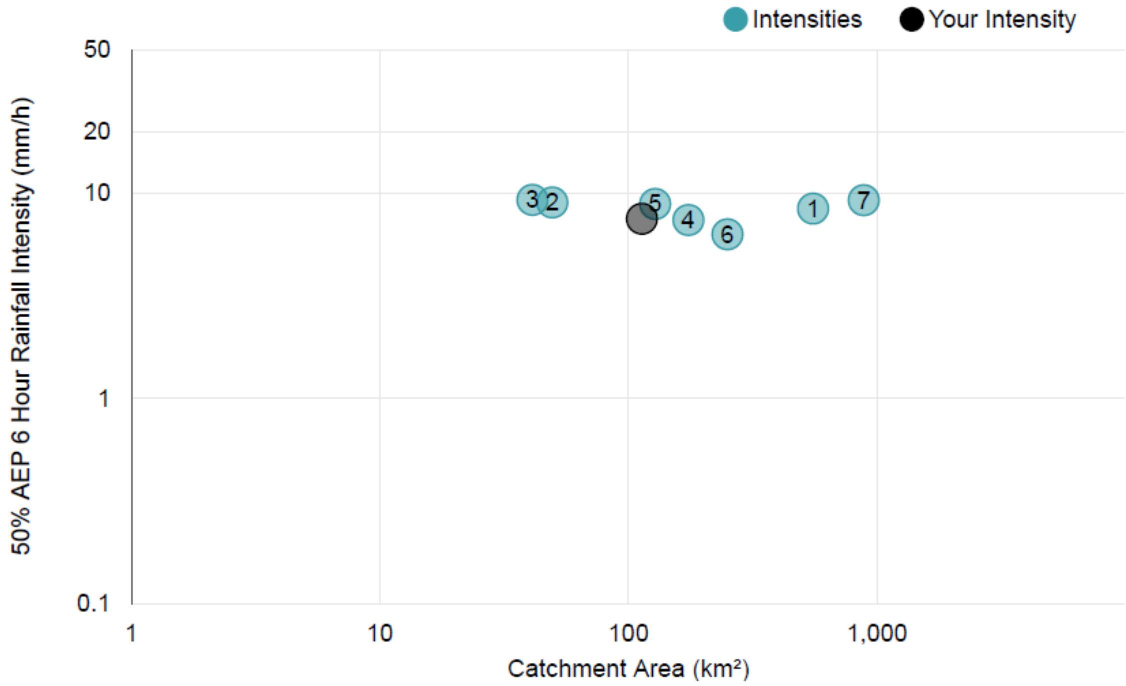


Shape Factor vs Catchment Area

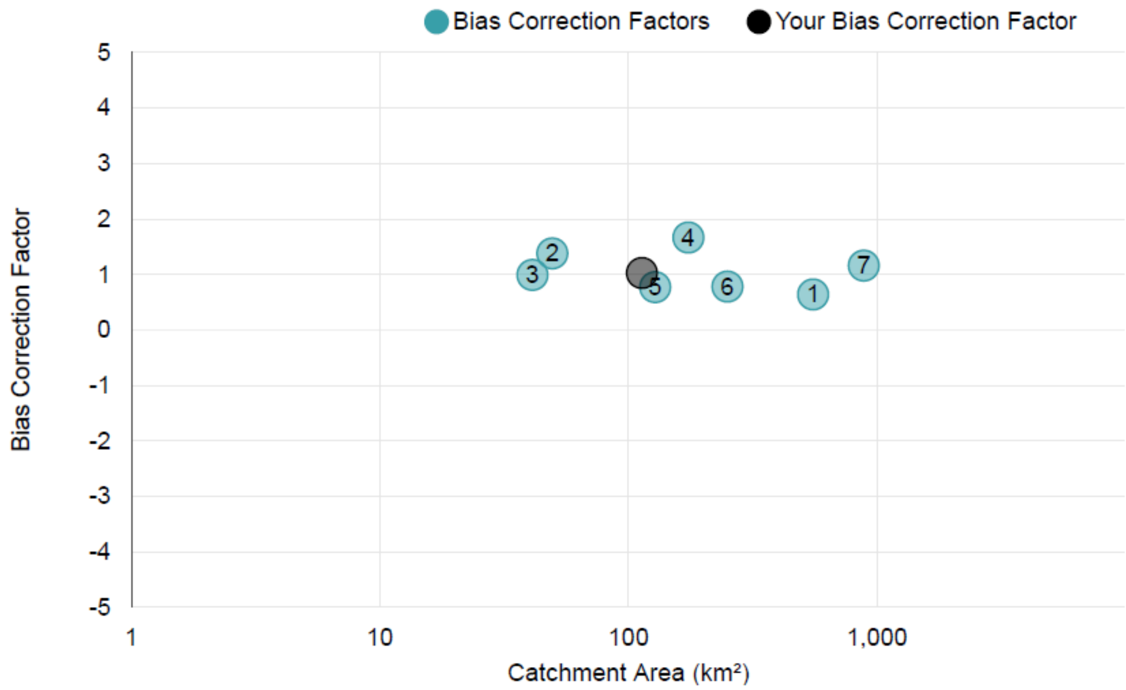
Note: This region does not use shape factors



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



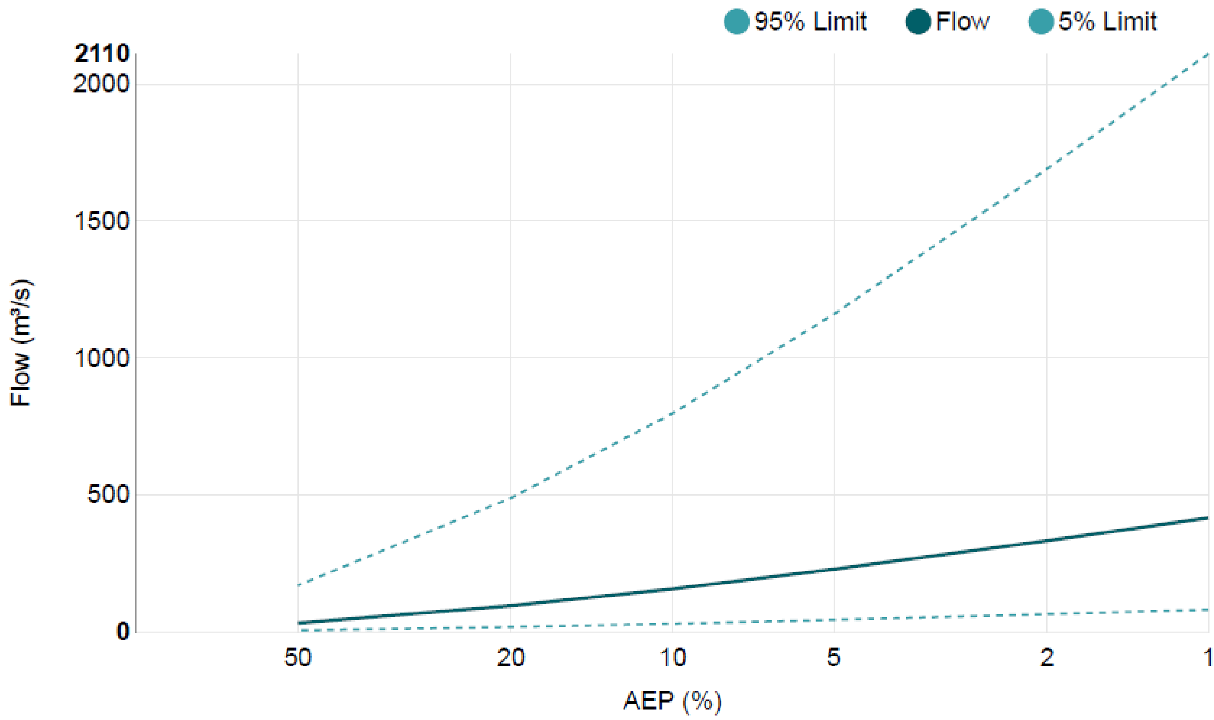
Download

TXT Nearby JSON

Input Data

Date/Time	2022-06-04 06:18
Catchment Name	McKay Creek
Latitude (Outlet)	-20.970712
Longitude (Outlet)	116.301104
Latitude (Centroid)	-21.090412
Longitude (Centroid)	116.309139
Catchment Area (km^2)	113.3
Distance to Nearest Gauged Catchment (km)	80.26
50% AEP 6 Hour Rainfall Intensity (mm/h)	7.522755
2% AEP 6 Hour Rainfall Intensity (mm/h)	23.402285
Rainfall Intensity Source (User/Auto)	Auto
Region	Pilbara
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	1.25*
Interpolation Method	Natural Neighbour
Bias Correction Value	1.028

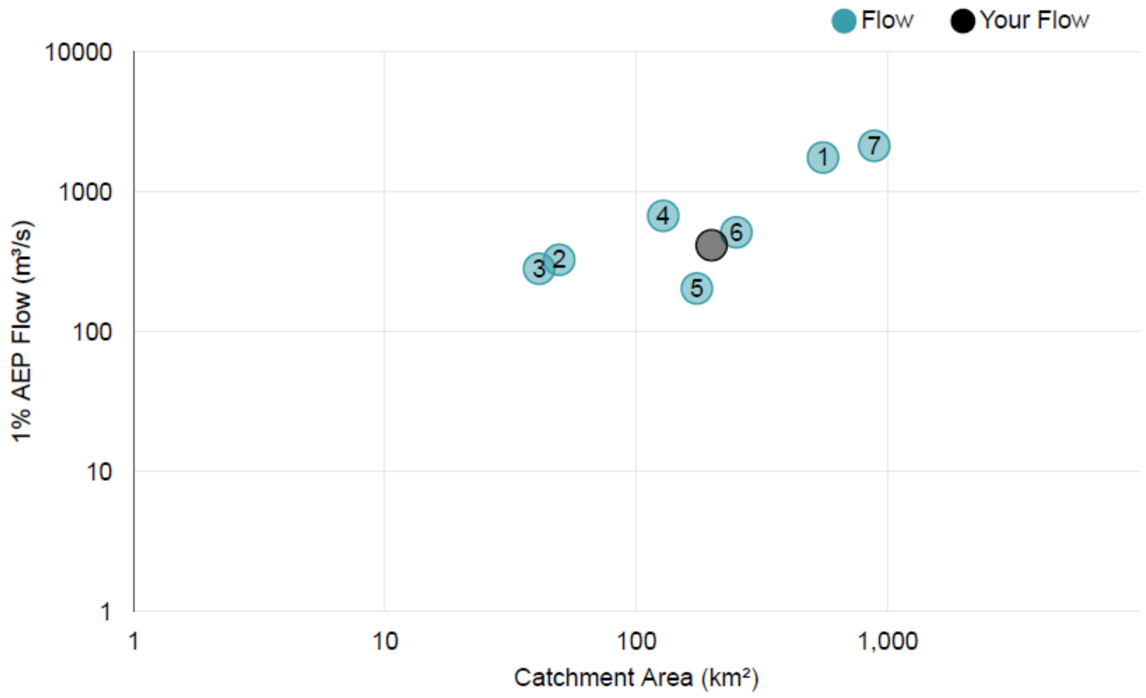
Results | Regional Flood Frequency Estimation Model



*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

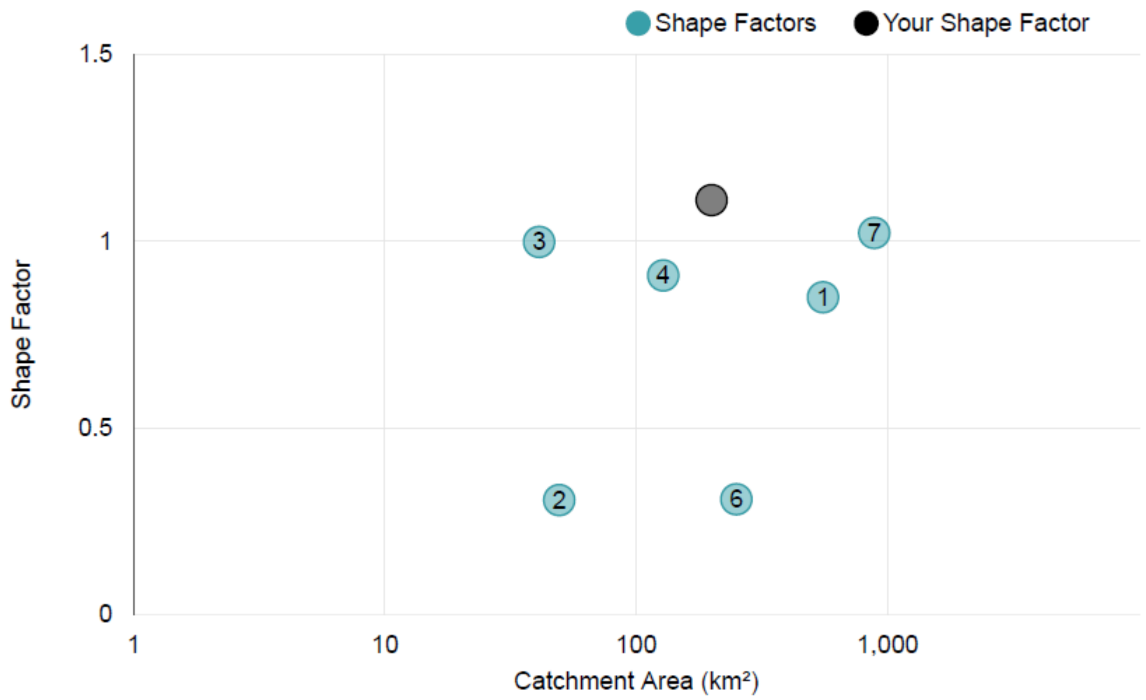
AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	33.8	6.70	171
20	96.9	19.2	490
10	158	31.3	798
5	230	45.6	1160
2	334	66.3	1690
1	417	82.7	2110

1% AEP Flow vs Catchment Area

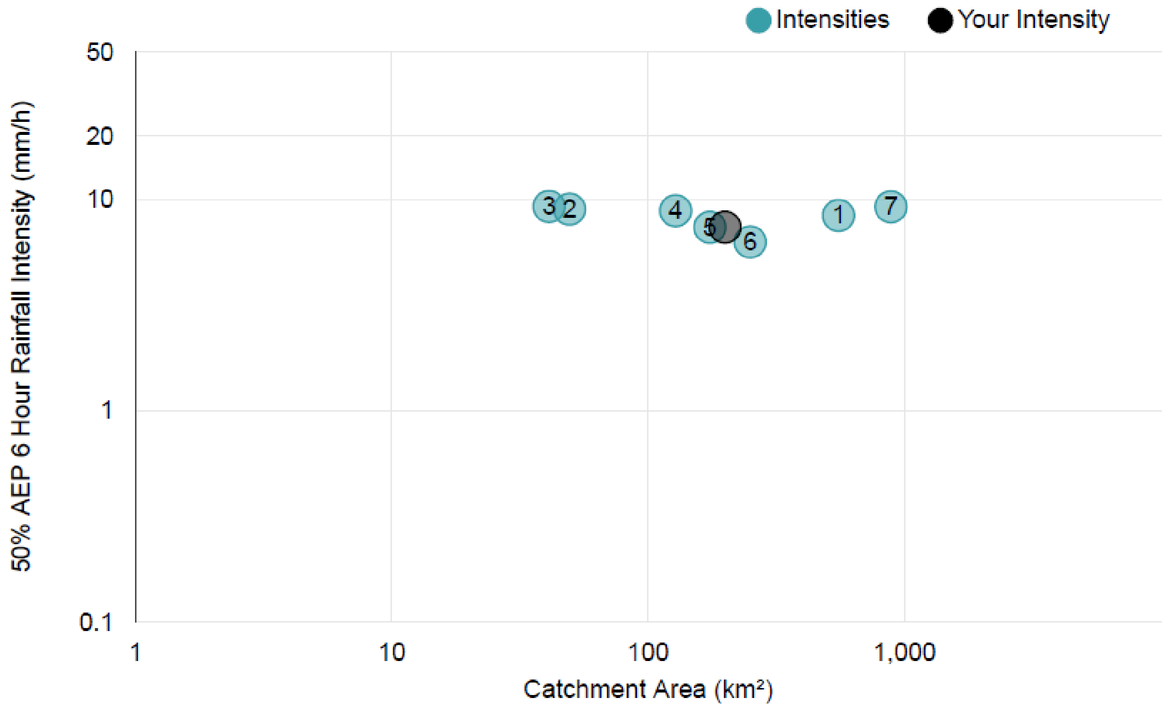


Shape Factor vs Catchment Area

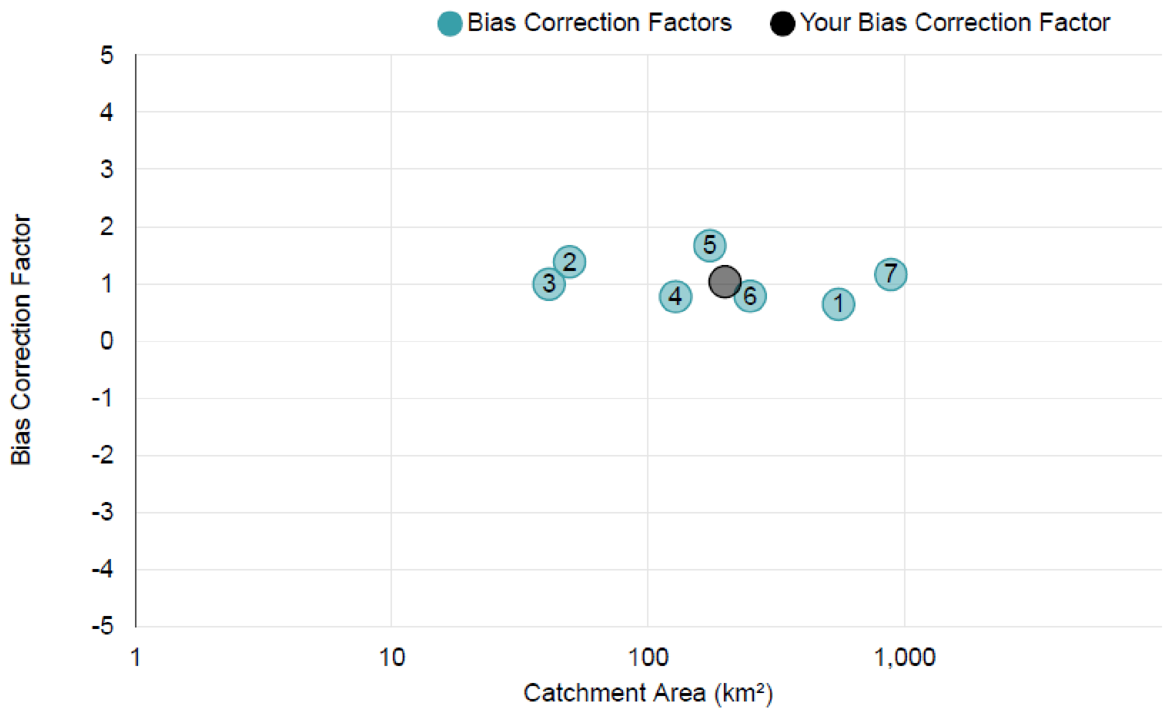
Note: This region does not use shape factors



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

TXT | Nearby | JSON

Input Data

Date/Time	2022-06-04 06:19
Catchment Name	Devil Creek
Latitude (Outlet)	-20.899322
Longitude (Outlet)	116.42253
Latitude (Centroid)	-21.036321
Longitude (Centroid)	116.38757
Catchment Area (km^2)	199.5
Distance to Nearest Gauged Catchment (km)	77.46
50% AEP 6 Hour Rainfall Intensity (mm/h)	7.422366
2% AEP 6 Hour Rainfall Intensity (mm/h)	22.815964
Rainfall Intensity Source (User/Auto)	Auto
Region	Pilbara
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	1.11*
Interpolation Method	Natural Neighbour
Bias Correction Value	1.033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APPENDIX B: SENSITIVITY RESULTS

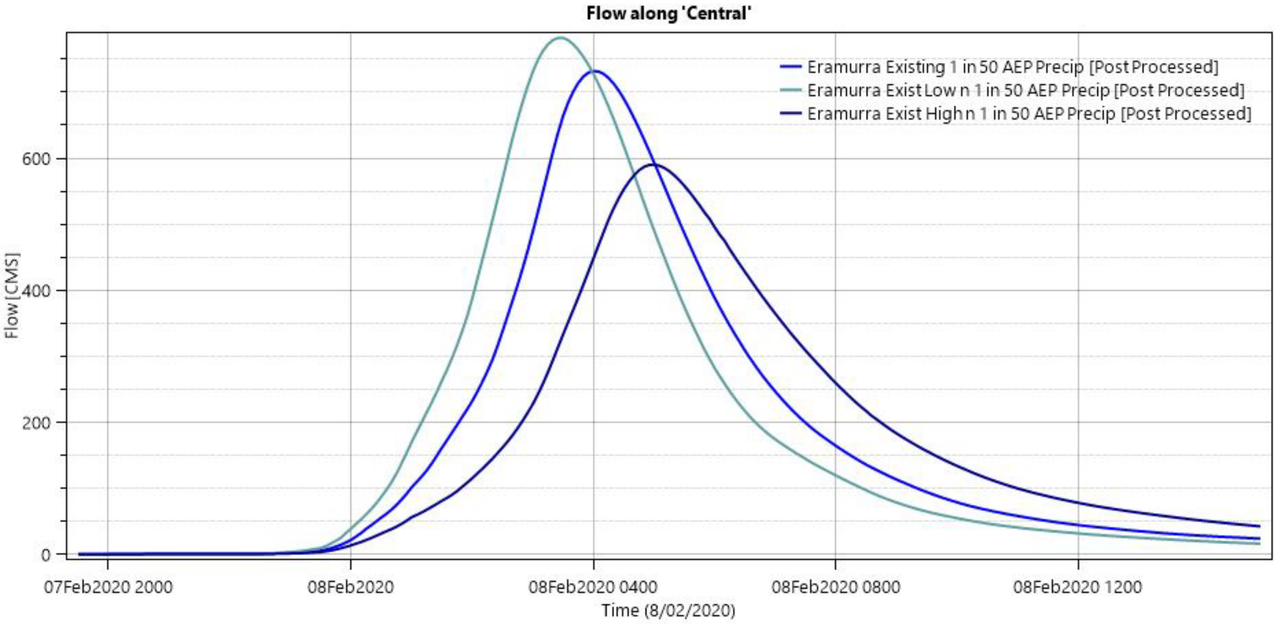

Figure B-1: Sensitivity of flow hydrographs in McKay Creek to adopted roughness coefficient

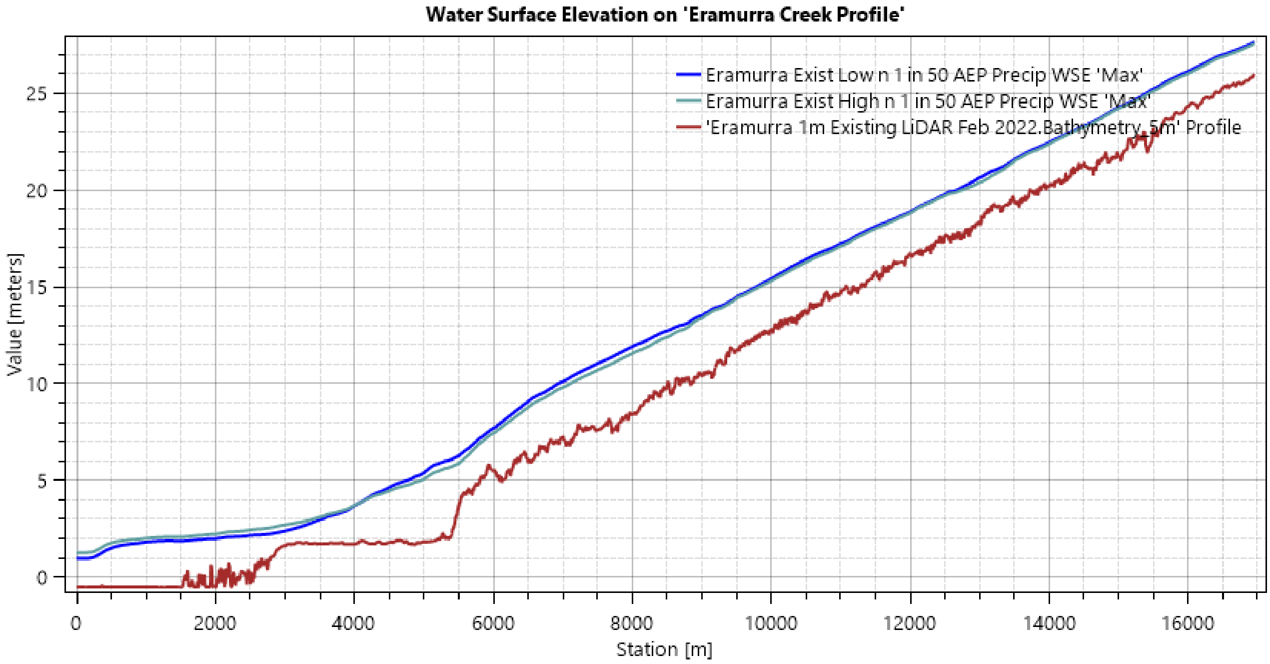

Figure B-2: Sensitivity of water surface elevation profiles in Eramurra Creek to adopted roughness coefficient

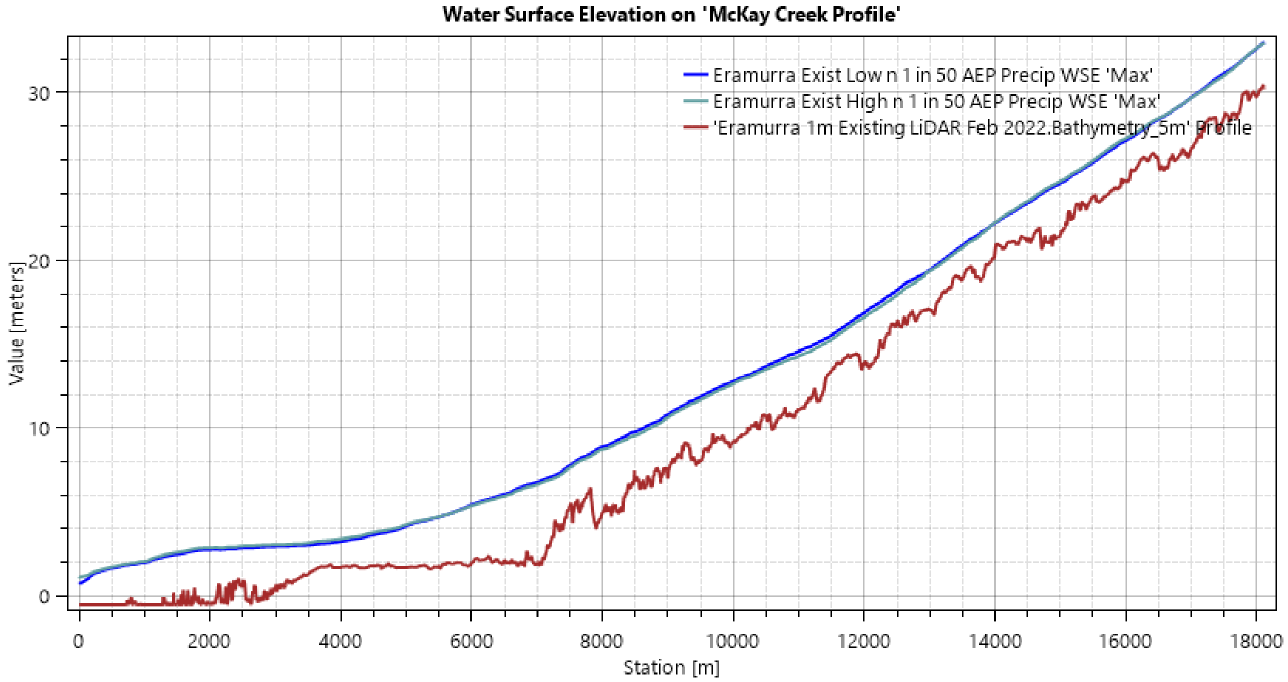

Figure B-3: Sensitivity of water surface elevation profiles in McKay Creek to adopted roughness coefficient

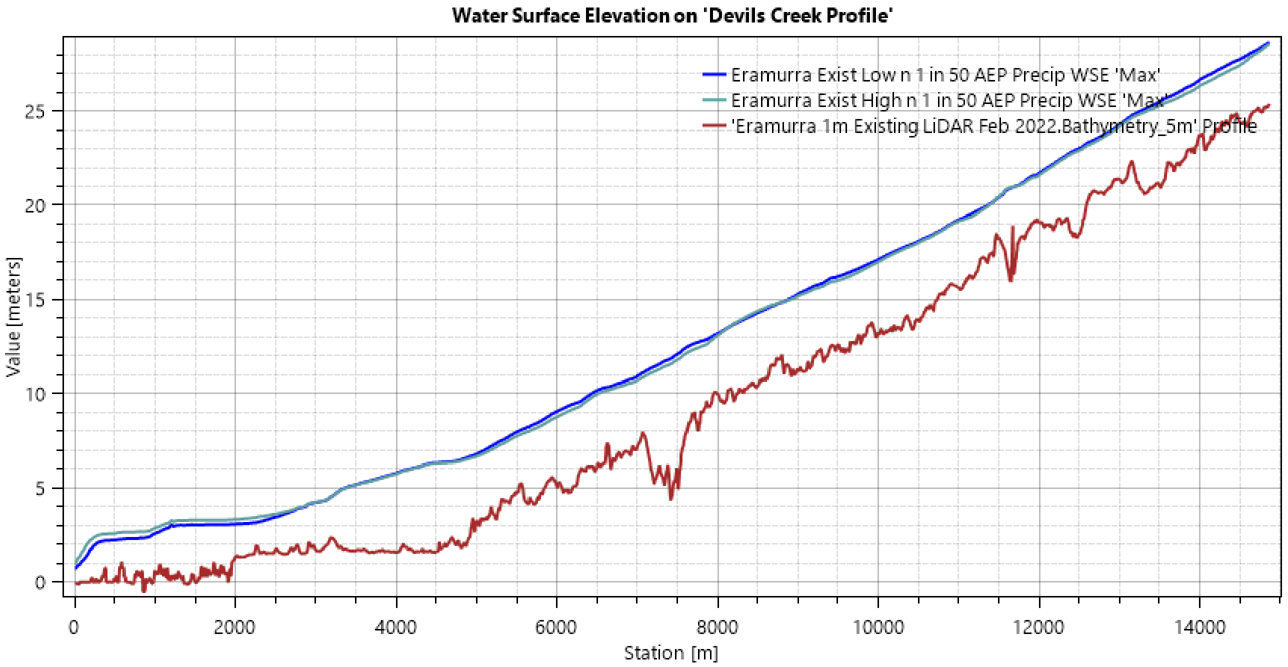

Figure B-4: Sensitivity of water surface elevation profiles in Devils Creek to adopted roughness coefficient

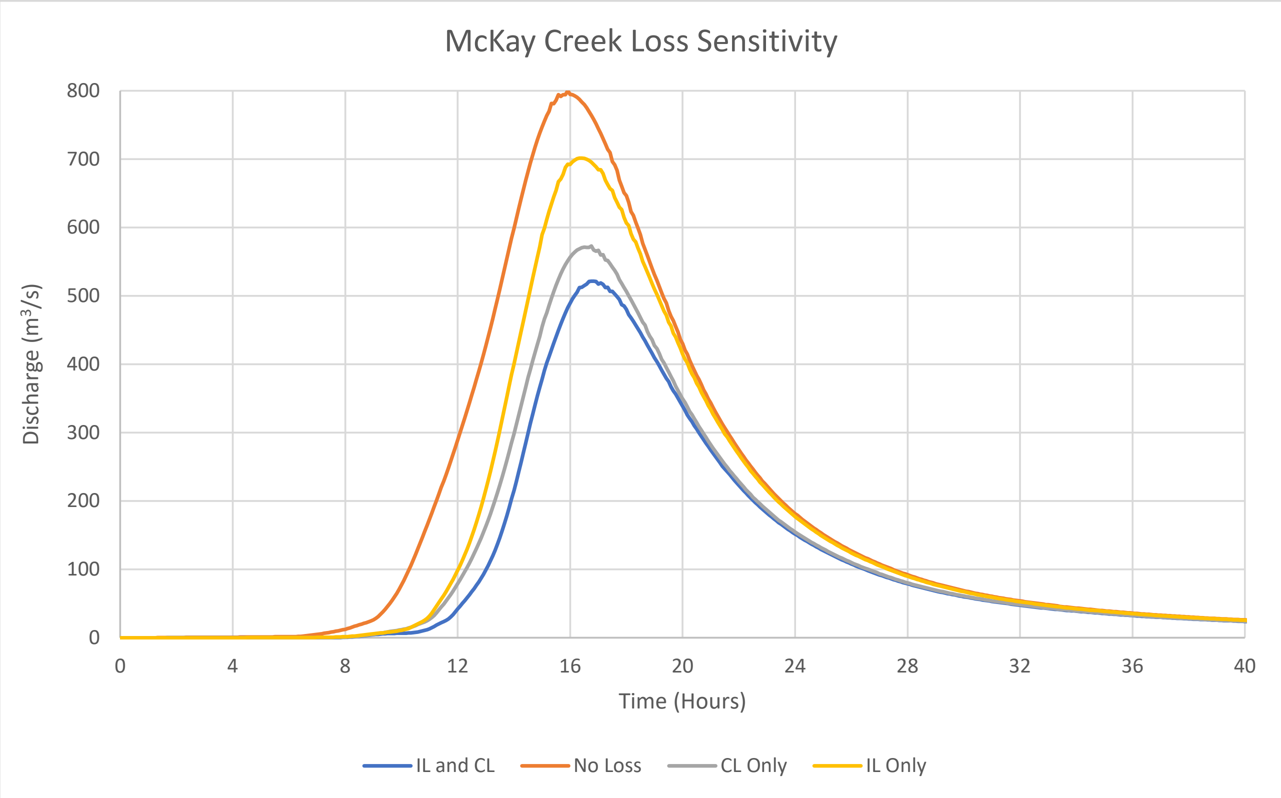

Figure B-5: Sensitivity of runoff hydrographs in McKay Creek to adopted loss rates

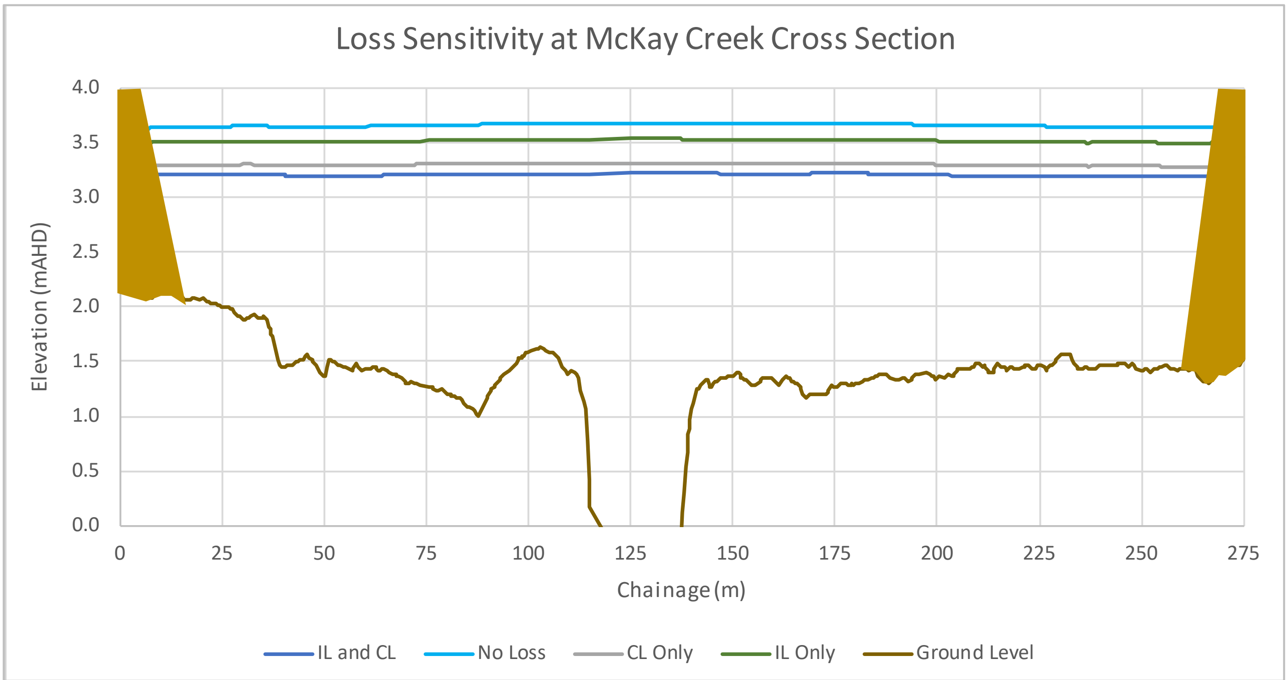

Figure B-6: Sensitivity of water surface elevation to adopted loss rates in McKay Creek cross section

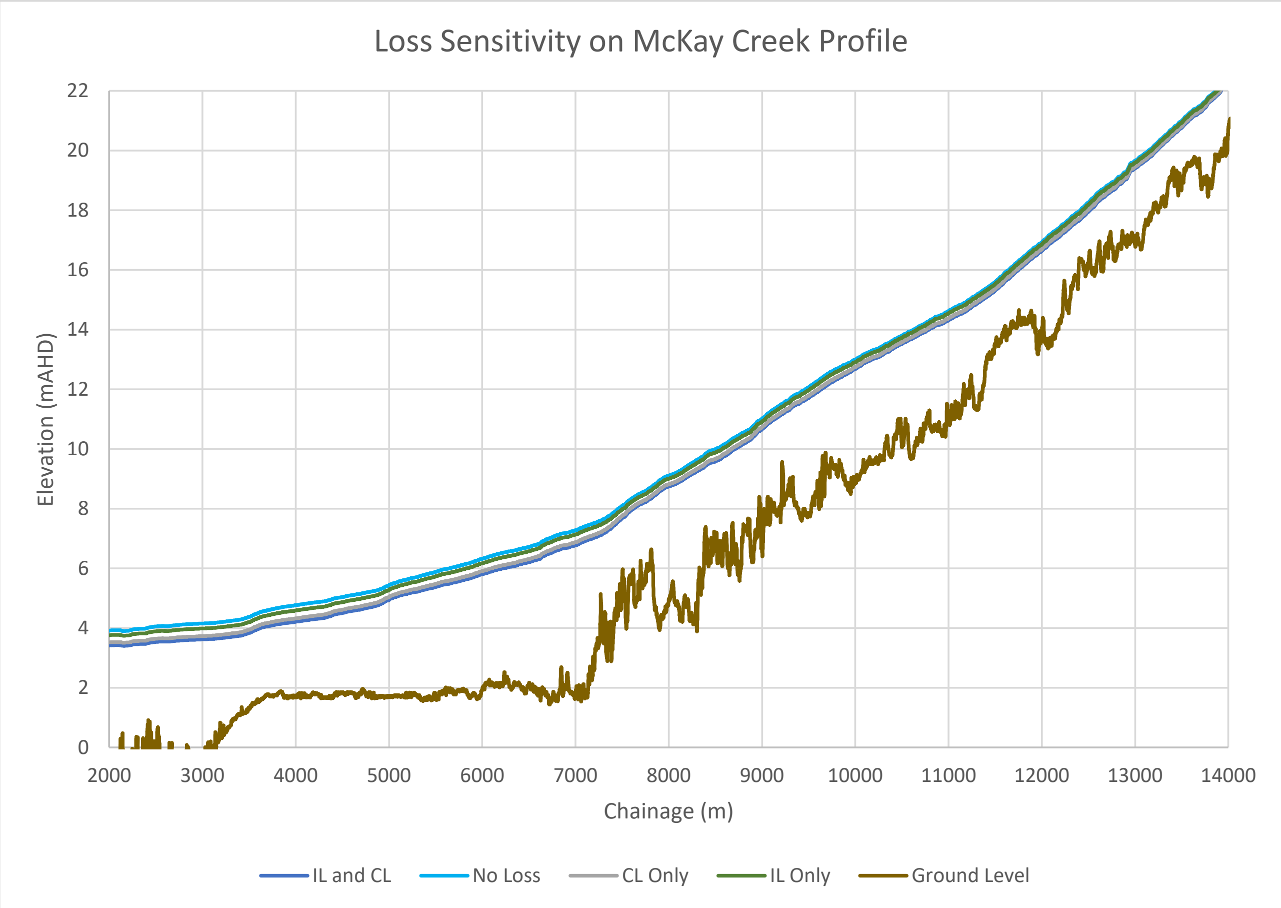

Figure B-7: Sensitivity of water surface elevation to adopted loss rates along McKay Creek profile