

## **Appendix E - Hydrology Analysis**



Assessment of broader catchment  
surface water impacts of redevelopment  
of the Rustler's Roost mine and the  
Quest 29 mining precinct.



Surface Water & Erosion Solutions

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# ACRONYMS & ABBREVIATIONS

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<b>AEP</b>	Annual Exceedance Probability
<b>ARR-DH</b>	Australian Rainfall and Runoff Data Hub
<b>BOM</b>	Bureau of Meteorology
<b>CPEng</b>	Chartered Professional Engineer
<b>CPESC</b>	Certified Professional in Erosion and Sediment Control
<b>DEM</b>	Digital Elevation Model
<b>ESCP</b>	Erosion and Sediment Control Plan
<b>IECA</b>	International Erosion Control Association
<b>IFD</b>	Intensity Frequency Duration
<b>LOM</b>	Life of Mine
<b>LP3</b>	Log Pearson 3 statistical distribution
<b>ML</b>	Mineral Lease
<b>MMP</b>	Mining Management Plan
<b>NSE</b>	Nash-Sutcliffe model efficiency coefficient
<b>NT</b>	Northern Territory
<b>Q29</b>	Quest 29 Project Area
<b>RPC</b>	Representative Concentration Pathway
<b>RRPA</b>	Rustler's Roost Project Area
<b>SILO</b>	Scientific Information for Landowners
<b>TSF</b>	Tailing Storage Facility
<b>WRD</b>	Waste rock dump

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# 1 INTRODUCTION

As a result of review of the draft EIS for Rustler's Roost (RR) and Quest 29 (Q29) mines, the comments and additional information requirements in Table 1 were received.

**Table 1-1. Specific comments on Draft EIS**

Section 7.5.7	Aquatic ecosystems	<p><b>Comment</b></p> <p>The TOR refers to hydrological processes and requires an assessment of potential impacts and risks as a result of alteration of surface water flow volumes associated with mine site discharges and surface water extraction.</p> <p>The Draft EIS does not consider the impacts of increased flows on aquatic ecosystems, despite modelling indicating that discharges could double or potentially triple surface flow volumes in receiving waterways.</p> <p><b>Additional Information Required</b></p> <p>1. Provide an analysis that demonstrates aquatic ecosystems downstream of the proposal will not be significantly impacted by increased surface water flow volumes from mine discharges.</p>
Section 7.5.7	Aquatic Ecosystem	<p>Section 7.5.7 states: "Section 7.3 states that the Project is unlikely to significantly affect surface water flows and therefore the aquatic ecosystem assessment has assumed that there is unlikely to be any significant impact to aquatic ecosystems from runoff quantity/flow changes". This statement appears inconsistent with the results of the modelled discharge scenarios in the EIS which suggests that the volume of surface water will double and potentially triple to 13.3GL/year.</p> <p>As the modelling suggests that there will be a change in the volume of surface water due to the proposal, it is unclear why the draft EIS has not considered the change as a risk to aquatic ecosystems and riparian vegetation. It is recommended that further information is requested by the NT EPA including an assessment of how increased surface flows may impact on riparian vegetation and aquatic ecosystems.</p>
Cumulative impact assessment	Whole of environment considerations	<p><b>Comment</b></p> <p>The EIS and the modelling work presented in Appendix H suggests around 5,800 ML/annum (or 78%) of the water produced on site will accumulate and require storage, or treatment and disposal.</p> <p>With the location of Toms Gully and other mining activity downstream of Rustlers Roost and Quest 29, there is a potential for successive, incremental, and combined impacts to sensitive receptors in the Mary River catchment.</p> <p><b>Additional Information Required</b></p> <p>1. Conduct a cumulative impact assessment of potential significant environmental impacts to environmental values and beneficial uses of the Mary River system as a result of both controlled and uncontrolled discharges from mine sites (Rustlers Roost, Quest 29 and Toms Gully).</p> <p>2. The assessment should focus on maintaining or improving catchment sediment and water quality consistent with the <b>National Water Quality Management Strategy</b>.</p>

This report addresses the comments in Table 1-1 in 3 parts. These are the impacts of:

1. The effect of changes in flows between the pre- and post-redevelopment landforms on downstream catchments,
2. Environmental Water Releases (EWR) on Mt Bundey Creek (Rustler's Roost) and Charles Creek (Quest 29), and

3. A whole-of-catchment hydrologic analysis of the Mary River catchment, including hydrologic, hydraulic and water quality modelling.

## **1.1 The effect of changes in flow regimes between the pre- and post-redevelopment landforms**

Hydraulic models were developed for the pre- and post-conditions for the Marrakai, Mt Bunday, Charles Creek and Mary River catchments. Two methods of analysis were used to assess effects. These were:

1. Long-term simulations were conducted for a simulated period of 91 years for the pre- and post-redevelopment conditions with the incorporation of a climate change factor in each simulation. Annual peak discharges were extracted, and Log Pearson 3 (LP3) distributions fitted for the pre- and post-conditions to assess change in flow regimes, and
2. Changes in flow velocities and flood inundation depth resulting from a 1% annual exceedance probability (AEP) and a 0.1% AEP rain event on the pre- and post-redevelopment catchment were assessed using the CAESAR-Lisflood hydrogeomorphic model (CLHM).

## **1.2 Environmental water releases**

A Goldsim Model (CDM Smith 2022) was developed by CDM Smith for the period 1 July 2020 to 1 July 2033 to simulate water management on site at Rustler's Roost and Quest 29. As part of the water balance modelling water exits the system as EWRs to maintain the operational network as a nett loss/gain of water. The EWRs are conceptualised as releases in Mt Bunday Creek and Charles Creek. A separate hydrology model was developed for Mt Bunday Creek to an outlet on the Mary River floodplain and a separate model for Charles Creek to its confluence with the McKinley River. Flow velocities, based on hydrologic model outputs, were determined along the stream thalwegs to assess changes in stream flow velocity and flood depth.

## **1.3 Mary River whole-of catchment impact assessment**

A whole-of-catchment (WoC) model was developed for the Mary River including inputs from the McKinley River, Mt Bunday Creek, Charles Creek and the Mary River extending to the Mary River flood plain. The modelling framework combined,

1. A hydrologic model, and
2. A 1-D hydraulic flow and water quality model.

This is a large model so several parts were required: a) Charles Creek to its confluence with the McKinley River, b) the McKinley River to its confluence with the Mary River, c) Mt Bunday Creek to its confluence with the Mary River and 4) Mary River to its lower floodplain reaches.

## 2 STUDY AREA

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The Rustler's Roost mine lays at the catchment boundary of the Mt Bunday Creek in the Adelaide River and the Mt Bunday Creek in the Mary River. Details of the site are provided in Surface Water & Erosion Solutions (2021a).

The Quest 29 mining precinct lays across the catchment boundary of Charles Creek and Mt Bunday Creek in the Mary River catchment. Details of the site are provided in Surface Water & Erosion Solutions (2021b).

The location of the catchments, and rainfall and evaporation rates for the region are given in Drawing no. MR-AR-01.

# 3 HYDROLOGIC CHANGES IN CATCHMENTS PRE- AND POST-REDEVELOPMENT

This section addresses changes in stream flows regimes and flow velocity that may result from mine redevelopment in the Mary and Adelaide Rivers. It does not assess the effects of change on aquatic ecosystems or riparian vegetation, but the results can be used to assess change.

## 3.1 Rainfall Inputs

We obtained continuous rainfall inputs from SILO for the nearby Beatrice Hill Bureau of Meteorology rain gauge no. 14086. We used the rainfall period 1930-2021 as future rain from 2030 to 2121 and applied the RCP 4.5 model to apply a climate change factor to the rainfall.

Design rainfall for a 1% AEP and 0.1% AEP were determined and an aerial reduction factor was applied (Coombes & Roso, 2019). These rainfalls were used in HEC-HMS.

For CLHM, excess rainfall from HEC-HMS was used as CLHM does not apply rainfall losses so losses must be applied to the rainfall pre-model.

The derived rainfall events are shown in Figure 3-1 and Figure 3-2.

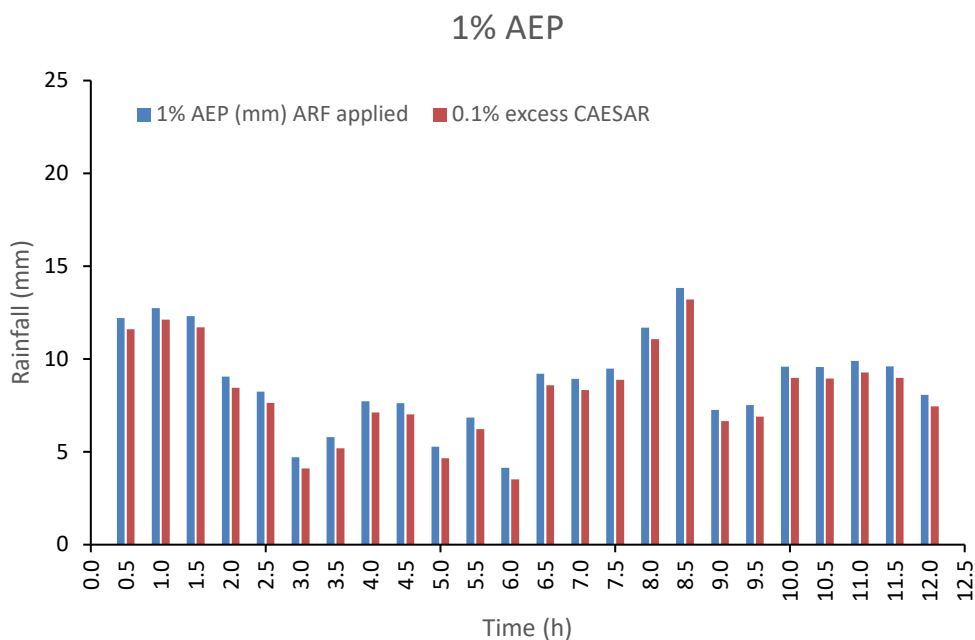
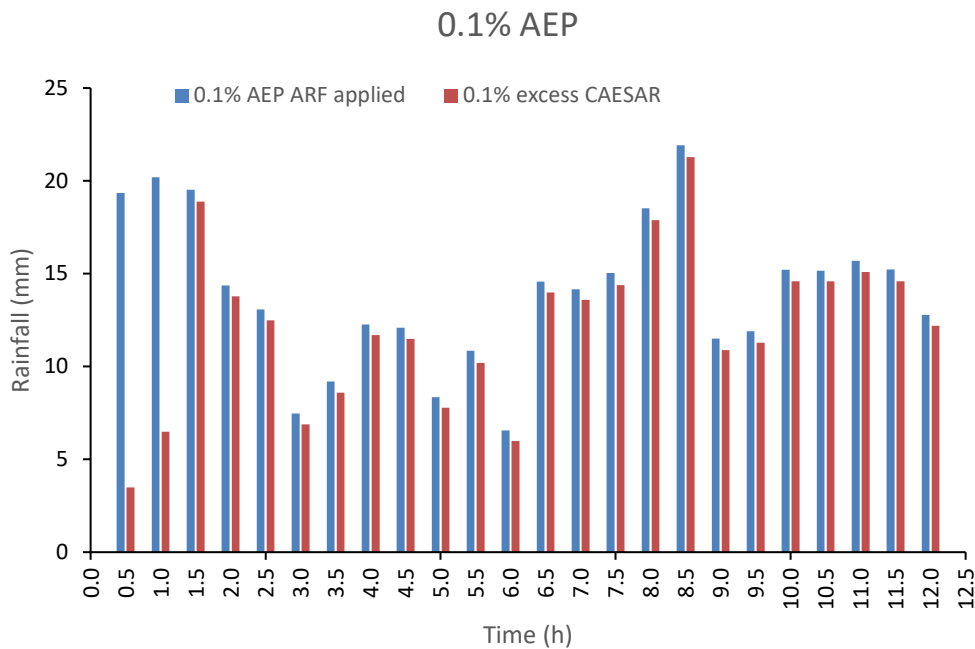


Figure 3-1 Derived 1% AEP rainfall event for Beatrice Hill.



**Figure 3-2 Derived 0.1% AEP rainfall event for Beatrice Hill.**

## 3.2 Digital Elevation Models

The study address whole-of-catchment hydrologic changes.

For the large model areas, we used the 30m x 30m hydrologically correct digital elevation models (DEM) available from the Australian Government.

## 3.3 Long-Term Hydrologic Modelling

Long-term hydrologic modelling was conducted to assess the effects of mine redevelopment on the Murrumbidgee, Mt Bunday, Charles Creek and the Mary River. Two simulations for the period from 1 October 2030 to 30 September 2121 were run for the catchments with inputs from the mining areas in their present condition before the redevelopment and in the post-redevelopment condition. A climate change component using the RCP 4.5 model (Surface Water & Erosion Solutions, 2021b) was applied to both scenarios. The HEC-HMS model used in previous reports in these catchments was used with the same parameter values for rainfall losses, catchment lag and channel lag derived as described in the previous reports (Surface Water and Erosion Solutions, 2021a).

The main approach was to assess changes in flow regimes of the creeks pre- and post-redevelopment. Two statistical methods were used to assess changes:

1. **Log Pearson 3 distribution:** The annual peak discharges were assessed at intervals down the creek using the 2030 to 2121 simulations. Annual peak discharges for the simulated pre- and post-mining conditions we extracted, and log-Person 3 (LP3) distributions were. For all catchments, the relationships showed little change in frequency distributions between the pre- and post-mining condition.
2. **Nash-Sutcliffe statistic (NSS):** This the statistic used in HEC-HMS to assess fits of predicted to observed hydrographs. In this study the pre-redevelopment hydrographs were used as observed hydrograph and the post-redevelopment compared and the statistic noted.

### **3.3.1 Results**

#### ***Marrakai Creek Catchment***

The HEC-HMS model domain for Marrakai Creek is shown Drawing MC-01.

The pre-redevelopment area of the Marrakai Catchment is 330.13 km<sup>2</sup>. During redevelopment, the catchment loses 1.85 km<sup>2</sup> to the proposed tailing storage facility (TSF) which will debouche to Mt Bunday Creek (Drawing MC-01).

The LP3 analysis shows no significant difference between peak annual discharge (Drawing MC-01) for the pre- and post-redevelopment conditions at the mid-way point of the catchment (J9) and the outlet of the catchment).

There is no significant difference in pre- and post-redevelopment peak discharge, total discharge and mean annual discharge at J9 (NSS = 1.0) (Table 3-1).

#### ***Mt Bunday Creek Catchment***

The HEC-HMS model domain for Mt Bunday Creek is shown Drawing GMB-01.

The pre-redevelopment area of the Mt Bunday Creek Catchment is 196.7 km<sup>2</sup>. During redevelopment, the catchment gains 1.85 km<sup>2</sup> to the proposed tailing storage facility (TSF) which will debouche to Mt Bunday Creek (Drawing GMB-01).

The LP3 analysis shows no significant difference between peak annual discharge (Drawing GMB-01) for the pre- and post-redevelopment conditions at the selected model junctions and the outlet of the catchment). Junction 15 was chosen because it is the first point after mine runoff enters the model through Reach 26 and enters the main Mt Bunday Creek catchment. Junction 28 is where discharges from Tom's Gully enters Mt Bunday Creek, and the outlet is at the confluence of Mt Bunday Creek and Mary River.

There is no significant difference in pre- and post-redevelopment peak discharge, total discharge and mean annual discharge at the studied junctions (NSS = 1.0) (Table 3-2) apart from J26 which is the entry point of changed flow. This change in flow is fully absorbed in the greater catchment.

#### ***Charles Creek Catchment (Quest 29)***

The HEC-HMS model domain for Charles Creek is shown Drawing CC-01.

The Charles Creek Catchment downstream of Q29S is 77.13 km<sup>2</sup>. There is no change to the model domain area pre- and post-redevelopment.

The LP3 analysis shows no significant difference between peak annual discharge (Drawing CC-02) for the pre- and post-redevelopment conditions at the selected model junctions and the outlet of the catchment). Junction CJ9 is where flow from the outlet of Q29S joins Charles Creek.

There is no significant difference in pre- and post-redevelopment peak discharge, total discharge and mean annual discharge at the studied junctions (NSS = 1.0) (Table 3-3).

### **3.3.2 Conclusions**

This analysis showed that in the long term there will be no significant change to flow regimes in the broader catchments.

**Table 3-1 Comparison of pre- and post-redevelopment long-term hydrology (2030-2121) in the Marrakai Creek catchment**

Junction	Change in drainage area (%)	Pre-redevelopment			Post-redevelopment			Nash-Sutcliffe statistic	Change in total volume (%)
		Peak discharge (m <sup>3</sup> /s)	Total discharge (TL)	Average annual discharge (GL)	Peak discharge (m <sup>3</sup> /s)	Total discharge (TL)	Average annual discharge (GL)		
J9	0.73	245.6	9.10	100.0	244.3	9.03	99.3	1	-0.7
Outlet	0.61	316.3	16.27	178.8	315.6	16.21	178.1	1	-0.4

**Table 3-2 Comparison of pre- and post-redevelopment long-term hydrology in the Mt Bunday Catchment**

Junction	Change in drainage area (%)	Pre-redevelopment			Post-redevelopment			Nash-Sutcliffe statistic	Change in total volume (%)
		Peak discharge (m <sup>3</sup> /s)	Total discharge (GL)	Average annual discharge (GL)	Peak discharge (m <sup>3</sup> /s)	Total discharge (GL)	Average annual discharge (GL)		
J26	-	3.4	82.5	0.91	9.9	340.8	3.75	-	
J15	6.5	85.8	2611.3	28.7	86.9	2784.3	30.6	0.99	6.6
J28	3.3	160.4	5520.6	60.7	162.1	5693.6	62.6	1	3.1
Outlet	1.8	245.7	9735.9	107.0	246.7	9908.9	108.9	1	1.8

**Table 3-3 Comparison of pre- and post-redevelopment long-term hydrology in the Charles Creek catchment**

Junction	Change in drainage area (%)	Pre-redevelopment			Post-redevelopment			Nash-Sutcliffe statistic	Change in total volume (%)
		Peak discharge (m <sup>3</sup> /s)	Total discharge (TL)	Average annual discharge (GL)	Peak discharge (m <sup>3</sup> /s)	Total discharge (TL)	Average annual discharge (GL)		
CJ9	0	55.6	1.76	19.4	57.1	1.75	19.3	0.998	-0.6
CJ5	0	74.4	2.53	27.8	75.0	2.52	27.6	0.999	-0.4
Outlet	0	106.2	3.78	41.6	107.1	3.77	41.5	1	-0.3

## 3.4 Hydraulic Modelling

Hydraulic modelling along the stream reaches provided pre- and post-redevelopment flow velocities and flood depth for the 1% AEP and 0.1% AEP rainfall events. The Lisflood model embedded in the CHLM was used for this analysis. The CHLM was previously calibrated to this region (Surface Water & Erosion Solutions, 2019). A recalibration was conducted to match the CLHM peak discharge to the HEC-HMS peak discharges derived in this study for the design events.

The catchment mode was used for Marrakai Creek and CLHM was run in the catchment and reach mode for Mt Bunday Creek and Charles Creek which both had upstream inputs.

HEC-HMS was used to simulate discharges at the outlets of Rustler's Roost and Quest 29 for the 1% AEP and 0.1% AEP design events. The discharges were used as upstream reach inputs to the CLHM model for Mt Bunday Creek and Charles Creek. The HEC-HMS excess rainfall, the rainfall converted to stream flow after losses, was applied as rain-on-grid in the CLHM catchment mode (Figure 3-1 & Figure 3-2).

Peak discharges and total flows were determined using HEC-HMS. Flow velocities and flow depths determined from the CLHM simulations and plotted along the thalweg of the stream channels to assess changes between the pre- and post-redevelopment conditions down the catchment.

### 3.4.1 Results

#### ***Marrakai Creek (Rustler's Roost)***

The CLHM model domain for Marrakai Creek is the same as the HEC-HMS model domain for the pre- and post-redevelopment condition (Drawing MC-01).

Pre- and post-redevelopment peak discharge, total discharge, peak depth, and peak velocity for both the 1% AEP and 0.1% AEP events are given in Table 3-4. Although different for each event, both pre- and post-redevelopment peak discharges are the same for same event (Table 3-4).

Flood inundation depths and discharge hydrographs are shown in Drawings MC-02 and MC-03 for the 1% AEP and 0.1% AEP events respectively. There is little difference in flood inundation depth along the thalweg of the stream for both events.

Flow velocities are shown in Drawing MC-4. There are only minor differences in pre- and post-redevelopment flow velocities along the thalweg of the stream for both events.

#### ***Mt Bunday Creek (Rustler's Roost)***

The CLHM model domain for Mt Bunday Creek is the same as the HEC-HMS model domain for the pre- and post-redevelopment condition (Drawing GMB-01).

Pre- and post-redevelopment peak discharge, total discharge, peak depth, and peak velocity for both events are given in Table 3-5. There is minor difference in pre- and post-redevelopment peak discharge (Drawings GMB-02 & GMB\_03), and apart from J26 which receives directed runoff from the mine infrastructure (Table 3-5). The higher parameter values for J26 are due to the increase catchment area due to the TSF and pit expansion.

Flood inundation depths and discharge hydrographs are shown in Drawings GMB-02 and GMB-03 for the 1% AEP and 0.1% AEP events respectively. There is little difference in flood inundation depth along the thalweg of the stream for both events.

Flow velocities are shown in Drawing GMB-4. There are only minor differences in pre- and post-redevelopment flow velocities along the thalweg of the stream.

### ***Charles Creek (Quest 29)***

The CLHM model domain for Charles Creek is the same as the HEC-HMS model domain for the pre- and post-redevelopment condition (Drawing CM-02).

Pre- and post-redevelopment peak discharge, total discharge, peak depth, and peak velocity for both events are given in Table 3-6. There are only minor differences in pre- and post-redevelopment peak discharge, total discharge and mean annual discharges at the studies junctions (NSS = 1.0) (Table 3-6).

Flood inundation depths and discharge hydrographs are shown in Drawings CC-03 and CC-04 for the 1% AEP and 0.1% AEP events respectively. There is little difference in flood inundation depth along the thalweg of the stream for both events.

Flow velocities are shown in Drawing CC-05. There are only minor differences in pre- and post-redevelopment flow velocities along the thalweg of the stream (Table 3-6).

### **3.4.2 Conclusions**

Two design storms were used in this assessment, the 1% AEP event and the 0.1% AEP event. The events were applied to the catchments for both the pre- and post-redevelopment condition of the sites. Visual inspections of simulated water depth and velocity plotted along the thalweg of the stream channels showed little difference in the hydraulic parameters for the the pre- and post-redevelopment conditions.

Peak discharges and hydrographs were determined using HEC-HMS. The Nash-Sutcliffe statistic used to test difference between conditons was generally  $\approx 1$  indicating no significant difference in the hydrology of the pre- and post-redevelopment conditions.

**Table 3-4 Comparison of the differences in 1% AEP and 0.1% AEP rainfall events in the Marrakai Creek catchment pre- and post-redevelopment of the Rustler's Roost Mine**

1% AEP									
Element	Pre-redevelopment				Post-redevelopment				Nash-Sutcliffe
	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	
J9	328.7	36.3	0.2	0.31	328.7	36	0.2	0.25	1
Outlet	374.8	64.9	1.16	3.37	374.8	64.6	1.15	3.46	1
0.1% AEP									
J9	498	53.9	0.19	1.21	498	53.5	0.19	1.2	1
Outlet	551	96.4	1.41	6.45	551	96	1.43	6.28	1

**Table 3-5 Comparison of the differences in 1% AEP and 0.1% AEP rainfall events in the Mt Bunday Creek catchment pre- and post-redevelopment of the Rustler's Roost Mine**

1% AEP									
Element	Pre-redevelopment				Post-redevelopment				Nash-Sutcliffe
	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	
J26	7.9	0.33	0.1	0.02	32.1	1.32	0.15	0.03	-
J15	206.7	10.2	0.21	0.53	211.6	10.9	0.21	0.51	0.99
J28	290.7	21.8	0.52	1.76	284.7	22.5	0.52	1.76	0.997
J1	292.41	38.4	1.14	3.43	287.39	39.1	1.14	3.41	0.997
0.1% AEP									
J26	12.7	0.50	0.13	0.025	52.4	2.10	0.18	0.07	-
J15	329.6	15.2	0.22	0.73	337.8	16.4	0.23	0.77	0.991
J28	421.2	32.4	0.66	2.11	413	33.5	0.67	2.17	0.996
J1	432.9	57.1	1.25	4.13	432.8	58.2	1.26	4.21	0.997

**Table 3-6 Comparison of the differences in 1% AEP and 0.1% AEP rainfall events in the Charles Creek catchment pre- and post-redevelopment of the Quest 29 mining precinct.**

1% AEP									
Element	Pre-redevelopment				Post-redevelopment				Nash-Sutcliffe
	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	
Q29S	21.4	0.93	0.2	0.06	21	0.92	0.2	0.06	-
CJ9	155.5	7.15	0.31	1	154.6	7.14	0.31	0.98	1
CJ5	155.5	10.19	0.57	1.5	155	10.18	0.57	1.47	1
Outlet	160.3	15.2	0.95	2.24	160.3	15.19	0.95	2.24	1
0.1% AEP									
Q29s	34.8	1.38	0.38	0.14	38.4	1.38	0.42	0.17	-
CJ9	240.3	10.63	0.36	0.025	241.3	10.63	0.36	0.07	1
CJ5	241.3	15.14	0.52	0.73	241.7	15.14	0.53	0.77	1
Outlet	241.3	22.59	1.04	2.11	241.7	22.59	1.04	2.17	1

# 4 ENVIRONMENTAL WATER RELEASES

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Environmental water releases (EWR) were provided by CDM Smith for the life-of-mine (LOM) from 1 July 2020 to 1 July 2033. A range of distributions were provided for the Rustler's Roost Mine (Figure 4-1) and the Quest 29 precinct (Figure 4-2). The analysis in this report was conducted using the 50<sup>th</sup> percentile distribution.

Hydrologic analysis was conducted using HEC-HMS and hydraulic analysis conducted using Manning's equation (Manning, 1891).

## 4.1 EWR Hydrologic Analysis

Simulations were run applying the EWR hydrograph to the Mt Bundy HEC-HMS model at junction J26 (Drawing GMB-01). The EWR covers water released from the mine infrastructure to Mt Bundey Creek and Charles Creek between 1 July 2020 to 1 July 2033 (life-of-mine). The mine site infrastructure will vary in size, so the simulation comprises input from the EWRs and rainfall runoff from the area of the infrastructure catchment where no infrastructure is located.

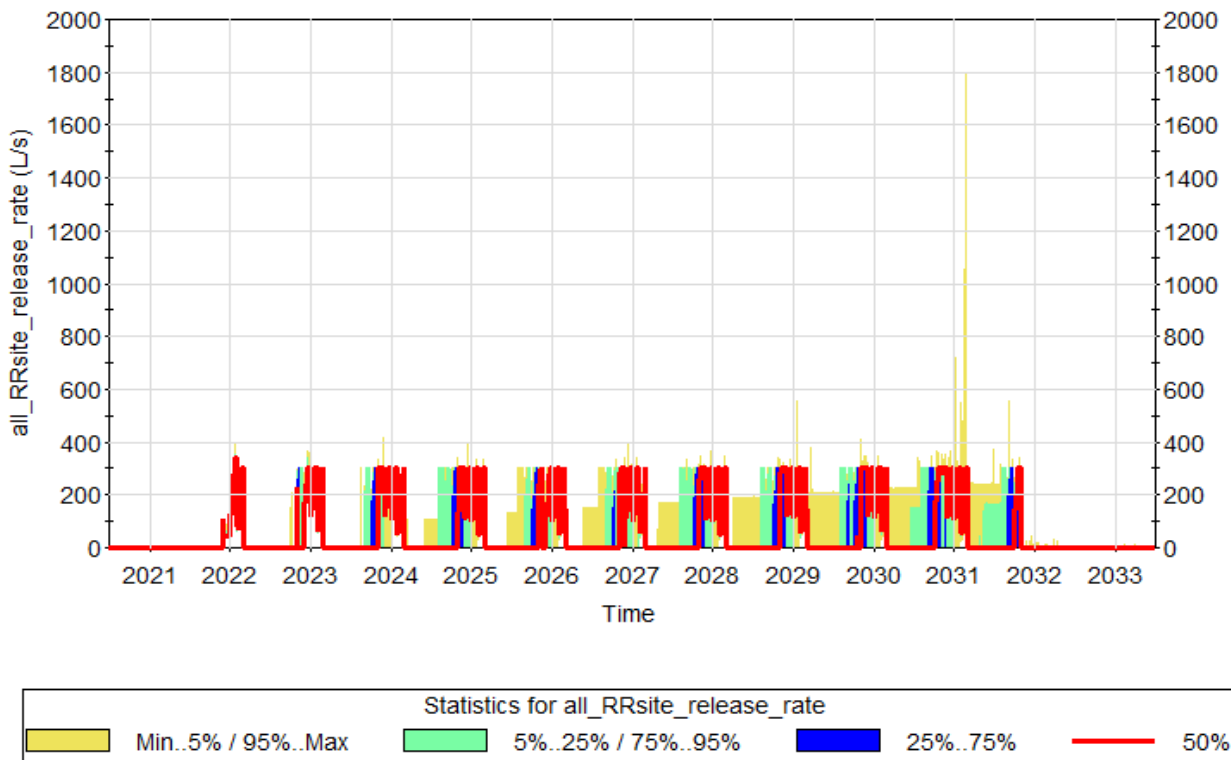
The rainfall applied for this was the Beatrice Hill record with the climate change factor for the RCP 4.5 model applied.

Simulations were run for EWRs and no EWRs.

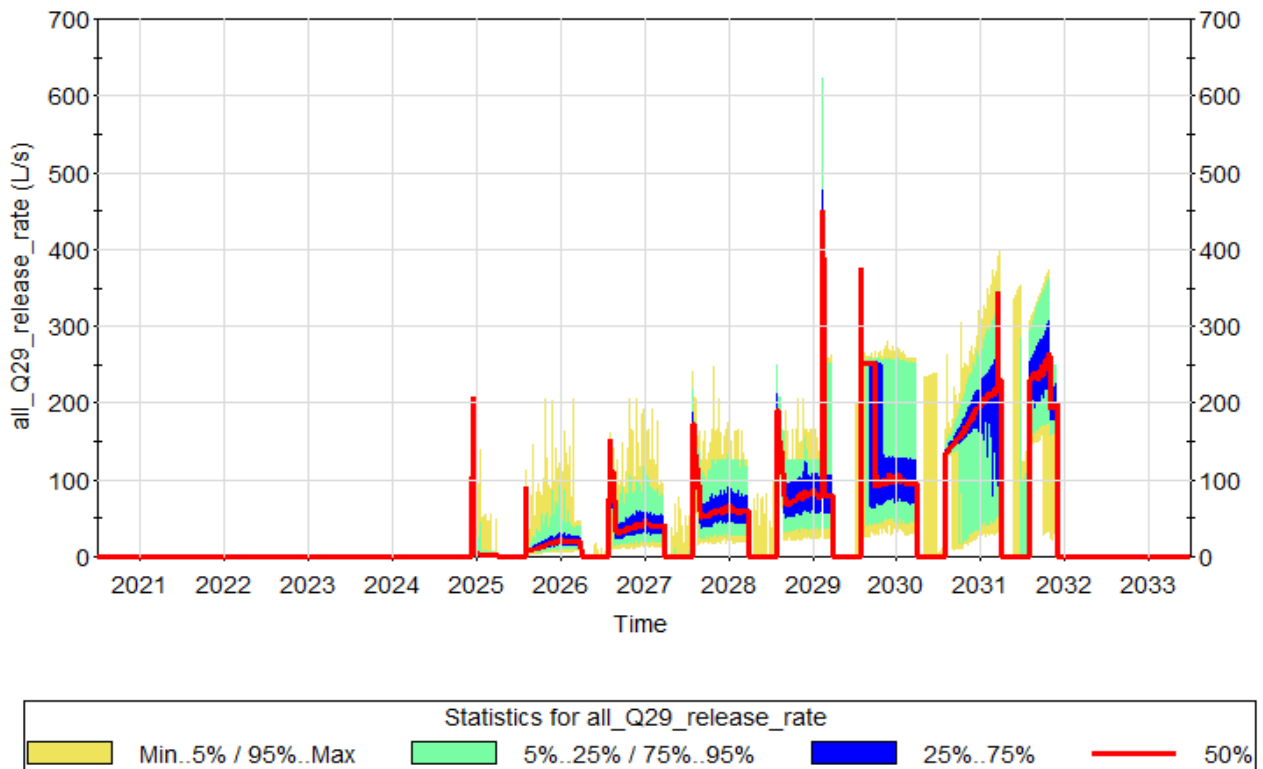
Inputs to Mt Bundey Creek at J26 for EWR simulations were the EWR hydrograph and rainfall runoff from the part of the Rustler's Roost infrastructure catchment (rain\_no\_infrastructure sub-basin, HEC-HMS model, Drawing GMB-05). For no EWR the pre-redevelopment model was used.

Inputs to Charles Creek at the Q29S outlet for EWR simulations were the EWR hydrograph and rainfall runoff from the part of the Q29S catchment without mining infrastructure (Drawing CC-06). For no EWR the pre-redevelopment model was used.

Velocities and depth were calculated using Manning's equation using the 30m hydrologically correct DEM. Because of the low resolutions of the DEM, the results are estimates and the DEM channels generally have a trapezoidal or 'V' cross section form.



**Figure 4-1 Environmental water release series distribution for Rustler's Roost. Figure provided by CDM Smith.**



**Figure 4-2 Environmental water release series distribution for Quest 29. Figure provided by CDM Smith**

### **4.1.1 Results**

The results for Rustler's Roost EWR analysis are provided in Table 4-1 and Drawings GMB-05 and GMB-06.

The results for Quest 29 EWR analysis are provided in Table 4-2 and Drawings CC-06 and CC-07.

Apart from the inflow elements, J26 for Rustler's Roost (Table 4-1) and Q29S in (Table 4-2) the remaining junction flows were not significantly different with respect to peak discharge and total discharge (NSS > 0.99).

The estimated peak velocities and depth for the pre- and post-redevelopment condition are generally equal but have not been tested statistically.

**Table 4-1 Comparison of the differences in EWR and no EWR from Rustler's Roost in Mt Bunday Creek.**

Element	Environmental Water Release				No Environmental Water Release				Nash-Sutcliffe	Distance from mine (km)
	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)		
J26	2.4	32.03	0.37	0.15	2.23	10.82	0.34	0.11	-0.38	1.1
J15	58.9	364	0.75	0.55	58.9	342.7	0.75	0.55	0.998	3.16
J28	108.3	865.8	1.04	0.85	108.3	844.6	1.04	0.85	1	5.7
J1 near outlet to Mary River	139.4	1292.2	1.29	1.47	139.4	1271	1.29	1.47	1	30.3

**Table 4-2 Comparison of the differences in EWR and no EWR from Quest 29 to Charles Creek.**

Element	Environmental Water Release				No Environmental Water Release				Nash-Sutcliffe	Distance from mine (km)
	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)		
Q29S in	5.3	38.2	0.64	0.51	3.75	25.6	0.59	0.45	0.735	-
CJ9	29.7	171.3	0.98	0.46	28.1	158.7	0.93	0.45	0.993	1.41
CJ5	40.2	269.8	0.55	0.21	39.1	257.1	0.54	0.20	0.998	6.19
Downstream of McKinley River confluence	734.6	11.516 TL	1.32	0.86	743.5	11.504 TL	1.32	0.86	1	11.7

# 5 WHOLE-OF-CATCHMENT MODEL

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A whole of catchment model (WOCM) for the Mary River was developed to assess changes in hydrology and water quality that may be caused by operations at Rustler’s Roost and Quest 29 redevelopments.

## 5.1 Hydrology

The Mt Bunday Creek and Charles Creek catchments were used as inputs because the resolutions of the WOCM was too low to incorporate the required detail of the two smaller catchments.

The average sub-basin characteristics are given in Table 5-1 and Table 5-2.

**Table 5-1 Whole-of-catchment model HEC-HMS sub-basin average parameters values.**

Area (km <sup>2</sup> )	Flow path Length (km)	Flow path Slope (%)	Time of Concentration (min)	Lag Time (min)
101.9	24	0.42	1033	619

**Table 5-2 Wole-of-catchment model HEC-HMS reach average parameter values.**

Length (km <sup>2</sup> )	Slope (%)	Lag Time (min)
101.9	0.07	1466

The HEC-HMS model is shown in Drawing MR-01.

Hydrologic analysis was conducted at junctions downstream of the Charles Creek confluence and the Mt Bunday confluence.

### 5.1.1 Results

The results are presented in Drawings MR-02 and MR-03 and Table 5-1, Table 5-2, and Table 5-3.

In all scenarios there was no significant difference between the pre- and post-redevelopment conditions. In all cases the Nash-Sutcliffe statistic = 1 and the total discharge difference is <0.1% with the majority <0.05%.

### 5.1.2 Conclusions

This analysis showed that it is likely there will be no significant change to stream flows in the Lower Mary River due to redevelopment of the Rustler’s Roost and Quest 29 mines.

**Table 5-3 Comparison of pre- and post-redevelopment long-term hydrology (2030-2121) in the Lower Mary River.**

Junction	Pre-redevelopment			Post-redevelopment			Nash-Sutcliffe statistic	Total Discharge Difference (%)
	Peak discharge (m <sup>3</sup> /s)	Total discharge (TL)	Average annual discharge (TL)	Peak discharge (m <sup>3</sup> /s)	Total discharge (TL)	Average annual discharge (TL)		
McKinlay-Mary River confluence	2527.9	279.3	3.07	2529.1	279.1	3.07	1	-0.04
Mt Bundy-Mary River confluence	2496.3	292.0	3.21	2496.0	292.0	3.21	1	-0.02
J3	2539.9	332.6	3.66	2539.9	332.6	3.65	1	-0.02
Mary River outlet	2584.0	354.0	3.89	2584.0	353.9	3.89	1	-0.01

**Table 5-4 Comparison of the differences in EWR and no EWR from Rustler's Roost and Quest 29 in the lower Mary River**

Element	Environmental Water Release		No Environmental Water Release		Nash-Sutcliffe	Total Discharge Difference (%)
	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (TL)	Peak Discharge (m <sup>3</sup> /s)	Total Discharge (TL)		
McKinlay-Mary River confluence	1949	36.09	1954	36.07	1	0.044
Mt Bundy-Mary River confluence	1943	37.79	1951	37.76	1	0.091
J3	1927	43.01	1933	42.98	1	0.079
Mary River outlet	1912	45.78	1918	45.75	1	0.074

**Table 5-5 Comparison of the differences in 1% AEP and 0.1% AEP flow events in the lower Mary River for Rustler's Roost and Quest 29 pre- and post-redevelopment conditions**

<b>1% AEP</b>					
Element	Pre-redevelopment		Post-redevelopment		Nash-Sutcliffe
	Peak Discharge (m <sup>3</sup> /s)	Total discharge (TL)	Peak Discharge (m <sup>3</sup> /s)	Total discharge (TL)	
McKinlay-Mary River confluence	2464	1.12	2464	1.12	1
Mt Bundy-Mary River confluence	2464	1.17	2464	1.17	1
J3	2464	1.34	2464	1.34	1
Mary River outlet	2464	1.42	2462	1.42	1

<b>0.1% AEP</b>					
McKinlay-Mary River confluence	3687	1.66	3687	1.66	1
Mt Bundy-Mary River confluence	3685	1.74	3685	1.74	1
J3	3682	1.99	3682	1.99	1
Mary River outlet	3677	2.11	3677	2.11	1

## 5.2 Water quality

In this study, the HEC-RAS model suite was used to assess contaminant dispersion from hypothetical releases from mine pits in the Quest 29, Rustler's Roost, and Tom's Gully mining areas during a high-rainfall event. The corresponding downstream contaminant concentrations were assessed against the Tom's Gully 80th percentile i.e. the site specific trigger value (SSTV).

Water releases from the Quest 29, Rustler's Roost, and Tom's Gully mining areas flow into the Mt Bunday and Charles creeks. Both creeks are tributaries of the Mary River. A 1-D hydraulic model was fitted in HEC-RAS to estimate flow velocities in the Mt Bunday Creek, Charles Creek, and Mary River main channels during a 1% and 0.1% AEP rainfall event. The water quality component of the HEC-RAS model was used to estimate the corresponding contaminant concentrations in these main channels during these events.

## 5.3 Hydraulic model

The HEC-RAS hydraulic model used the 30m digital elevation model (DEM) described in Section 3.2.

A single river reach was used in the 1-D hydraulic model to define the main channel. The extent of the main channels in the model were as follows:

- Mt Bunday Creek: Rustler's Roost mine area to the catchment outlet
- Charles Creek: Quest 29 mine area to the catchment outlet
- Mary River: Upstream of the confluence of Charles Creek to the catchment outlet.

In the 1-D model, cross-sections were established along the main channels at approximately 200–400m intervals for the Mt Bunday and Charles creeks and at 1500m intervals for Mary River. The widths of the cross-sections were set wide enough to capture most of the flood extent in the main channels during these high-rainfall events. The Manning's n value in the channel was assumed to be 0.03, which is within the typical range provided in the Australian Rainfall and Runoff for channels and floodplains (Ball, et al., 2019).

Flows from the mine areas during the 1% and 0.1% AEP rainfall events, as well as flows into the main channel from major tributaries, were estimated from the HEC-HMS model (Section 3). Flow outputs from the HEC-HMS model were extracted at a 30-minute timestep.

Drawings WQ-01, WQ-04 and WQ-07 show the maximum velocities that occur within the main channels during a 1% and 0.1% AEP rainfall event.

## 5.4 Mine site concentrations

The concentrations of contaminants leaving the mining areas and entering the main channels of Mt Bunday and Charles creeks are given in Drawings WQ-01, WQ-04 and WQ-07. These values are considered conservative. It is assumed that the creeks are dry prior to the rainfall event, which is unlikely. It is also assumed that there is no dilution of contaminants from the pit before entering the creek channels. These conditions give a conservative estimation.

### 5.4.1 Rustler's Roost

Contaminants from Rustler's Roost enter Mt Bunday Creek via a small left-bank tributary. Contaminant concentrations from Rustler's Roost used in the model were based on data collected between 2016–2022 at eight sampling sites within the mine area. Average concentrations were derived at each sampling site and the maximum average value was used as the input concentration into Mt Bunday Creek.

### 5.4.2 Quest 29

Contaminants from Quest 29 enter Mt Bunday Creek via a relatively large right-bank tributary. The contaminant concentrations used in the model were based on data collected at site Q29SW4 (located along the tributary downstream of the mining area). The median concentration was used as the input concentration into Mt Bunday Creek.

Contaminants from Quest 29 also enter Charles Creek via a small left-bank tributary. The contaminant concentrations used in the model were based on data collected between 2016–2022 at eight sampling sites within the mine area. Average concentrations were derived at each sampling site and the maximum average value was used as the input concentration into Charles Creek.

### 5.4.3 Tom's Gully

Contaminant concentrations from Tom's Gully were based on the original data used in the Tom's Gully Closure Plan.

## 5.5 Water quality model

The water quality component of the HEC-RAS model was used to estimate contaminant concentrations along the main channels of Mt Bunday Creek, Charles Creek, and Mary River during a 1% and 0.1% AEP rainfall event.

The following contaminants were used in the model:

- Aluminium
- Arsenic
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Manganese
- Nickel
- Lead
- Zinc
- Fine suspended sediment

Many studies have used turbidity as an indirect measure of fine suspended sediment concentration. Studies in small tropical rivers in northern Australia have shown that fine suspended sediment concentration is around 0.5–1.0 of the *in-situ* turbidity reading (Molier, Saynor, & Evans, 2005). Therefore, in this study, it is assumed that the fine suspended sediment concentration is equal to the turbidity values measured around the mining areas.

It is assumed that water released from the mining areas occurs over a 12-hour period. That is, water overflows from the pits for 12 hours, equivalent to the duration of the rainfall event. During the 12-hour release, the contaminant concentrations are constant. The concentration of contaminants in all non-mining impacted tributaries entering the main channels were assumed to be 0 mg/L.

Drawings WQ-02, WQ-03, WQ-04, WQ-05, WQ-06, WQ-08 and WQ-09 show the predicted contaminant concentrations during a 1% and 0.1% in Mt Bunday Creek, Charles Creek, and Mary River.

## 5.6 Results and Conclusions

Simulations showed that only Cadmium exceeded the SSTV at the outlet of the Mt Bunday Creek catchment. This occurred during the 0.1% AEP event.

At the outlet of the Charles Creek catchment, no concentrations exceeded the SSTVs due to contaminant releases from the Quest 29 mining area during a 1% or 0.1% AEP event.

The model showed that after Mt Bunday and Charles Creeks flow into the Mary River main channel during a 1% and 0.1% AEP event, contaminant concentrations were well below the SSTVs.

## 6 REFERENCES

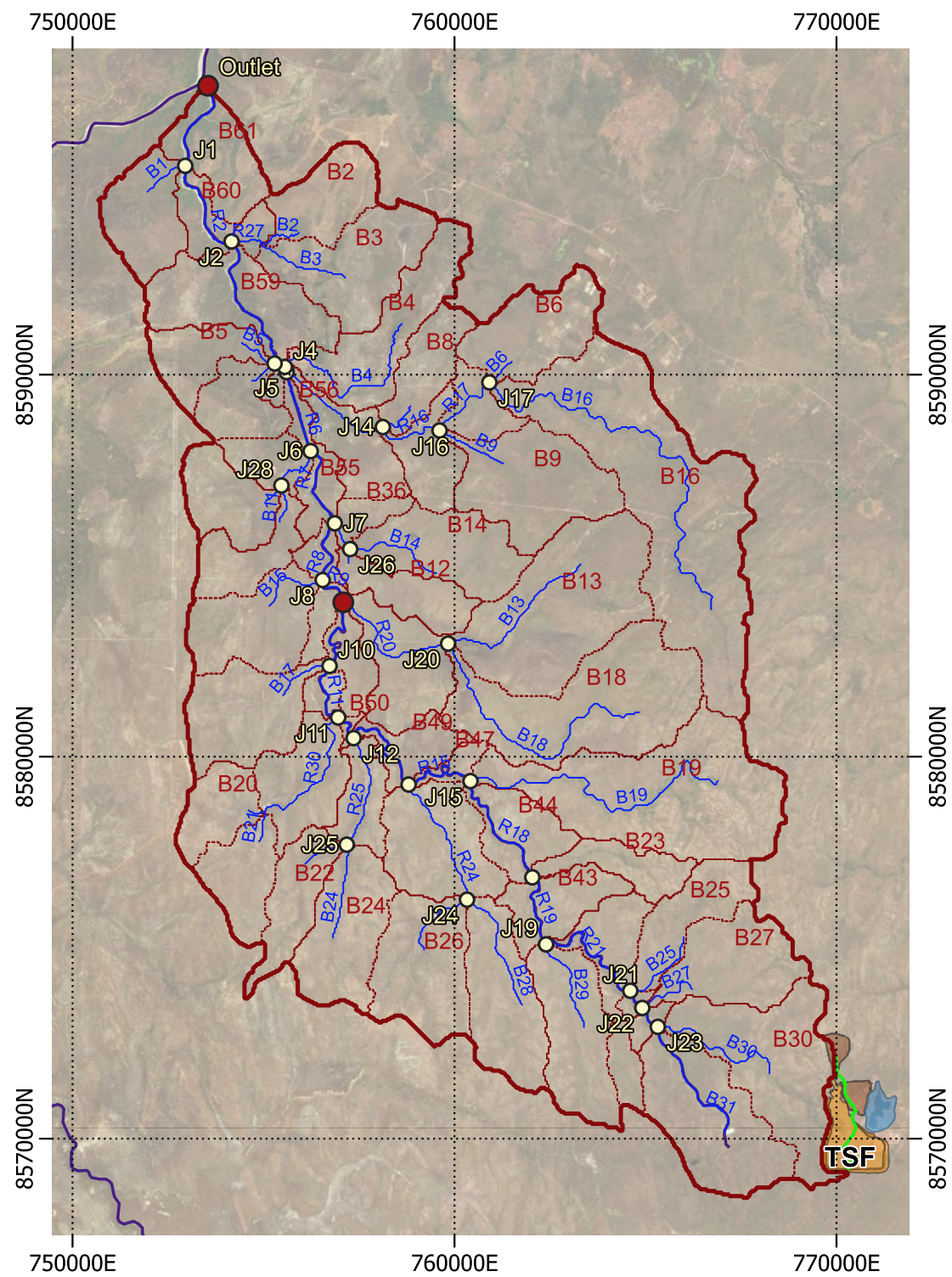
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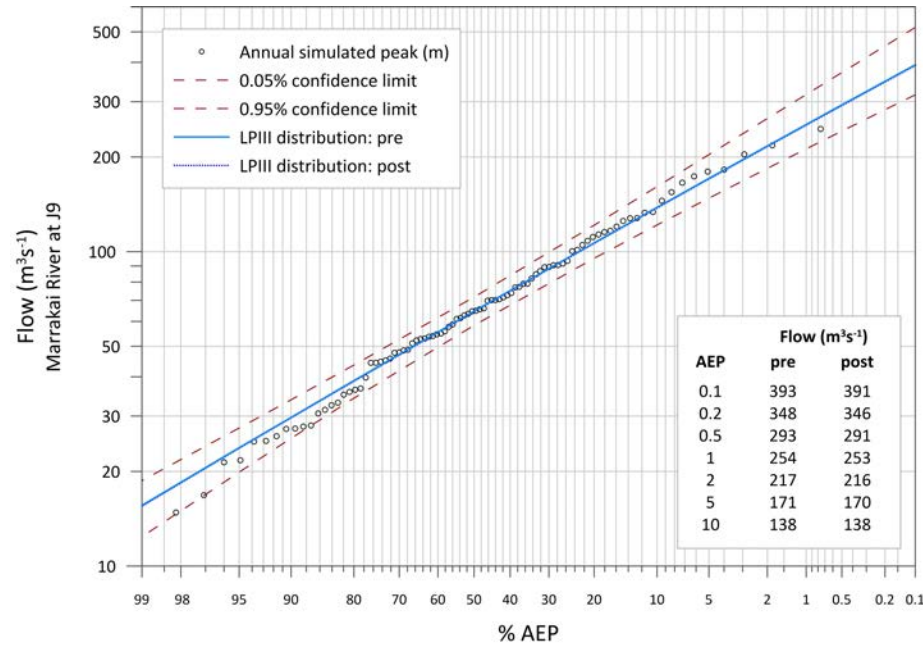
# 7 DRAWINGS

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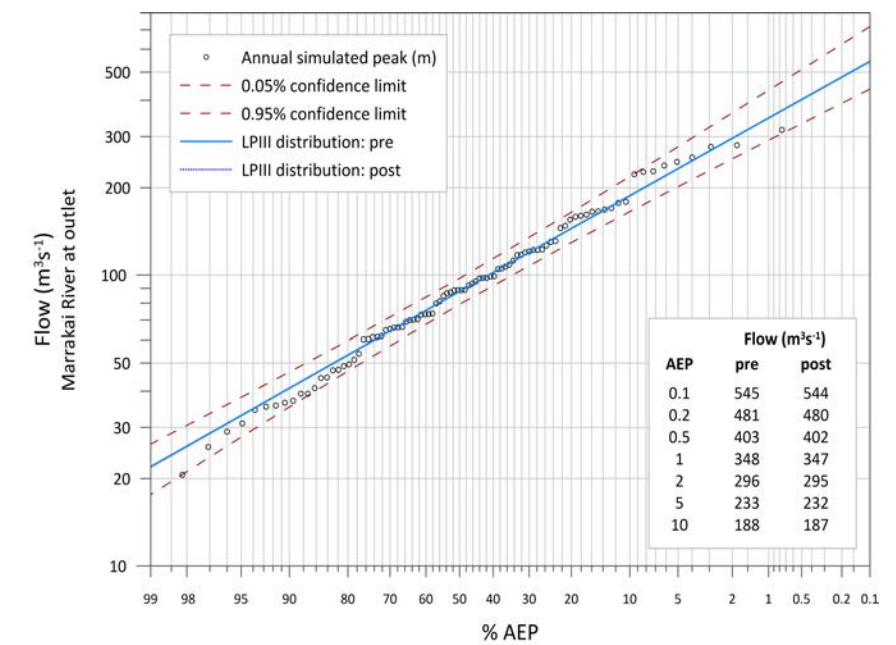
## Marrakai Creek



Above. Marrakia Creek HEC-HMS model (sub-basins, junctions and reaches). The pre-redevelopment catchment loses 1.85 km<sup>2</sup> to the proposed tailings storage facility which will debouch to the Mt Bunday catchment.



Above: Log Pearson distribution pre- and post-mine redevelopment at Junction J9 (see left) at about the mid-point of the catchment.



Above: Log Pearson distribution pre- and post-mine redevelopment at the Marrakai out node. There is no significant difference.

Notes

1. This is an assessment of changes in hydrology of the Marrakai Creek catchment due to Rustler's Roost redevelopment in the upper catchment using the HEC-HMS model.
2. A 91-year simulation was conducted from 2030 applying climate change using the RCP 4.5 model.
3. A log-Pearson 3 distribution was created using the annual peak discharges for the pre- and post-mining condition at HEC-HMS junctions down the catchment .
4. The results indicate that there is no significant change in the long-term flow regimes.
5. The pre-redevelopment simulated discharge was used as observed data in the post-redevelopment simulations. This resulted in a Nash-Sutcliffe statistic = 1.0. This indicates no discernable change of stream flows pre- and post-redevelopment in the downstream portion of Marrakai Creek.

Drawing No  
MC-01

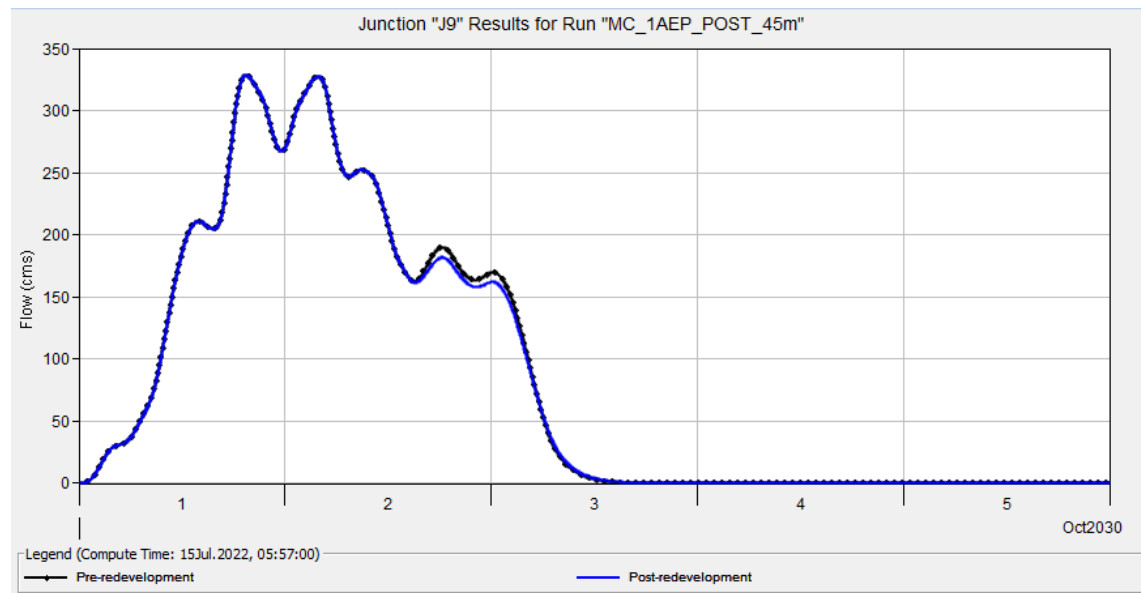
**SURFACE WATER & EROSION SOLUTIONS**  
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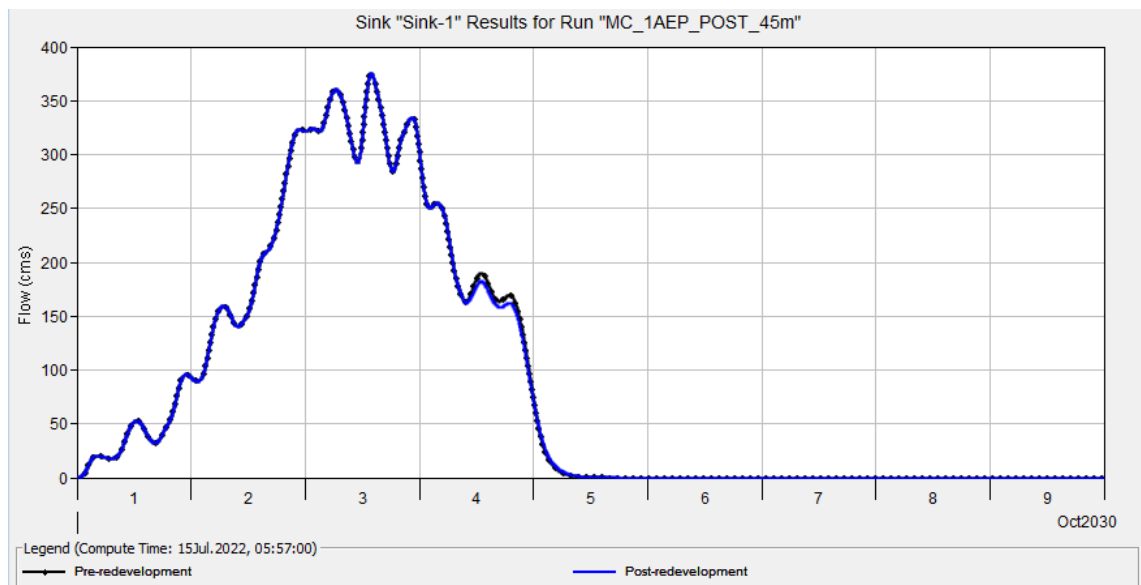
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EIS Supplementary  
Information

Title **Rustler's Roost Hydrologic Changes:  
Effects on Marrakai Creek Flows**

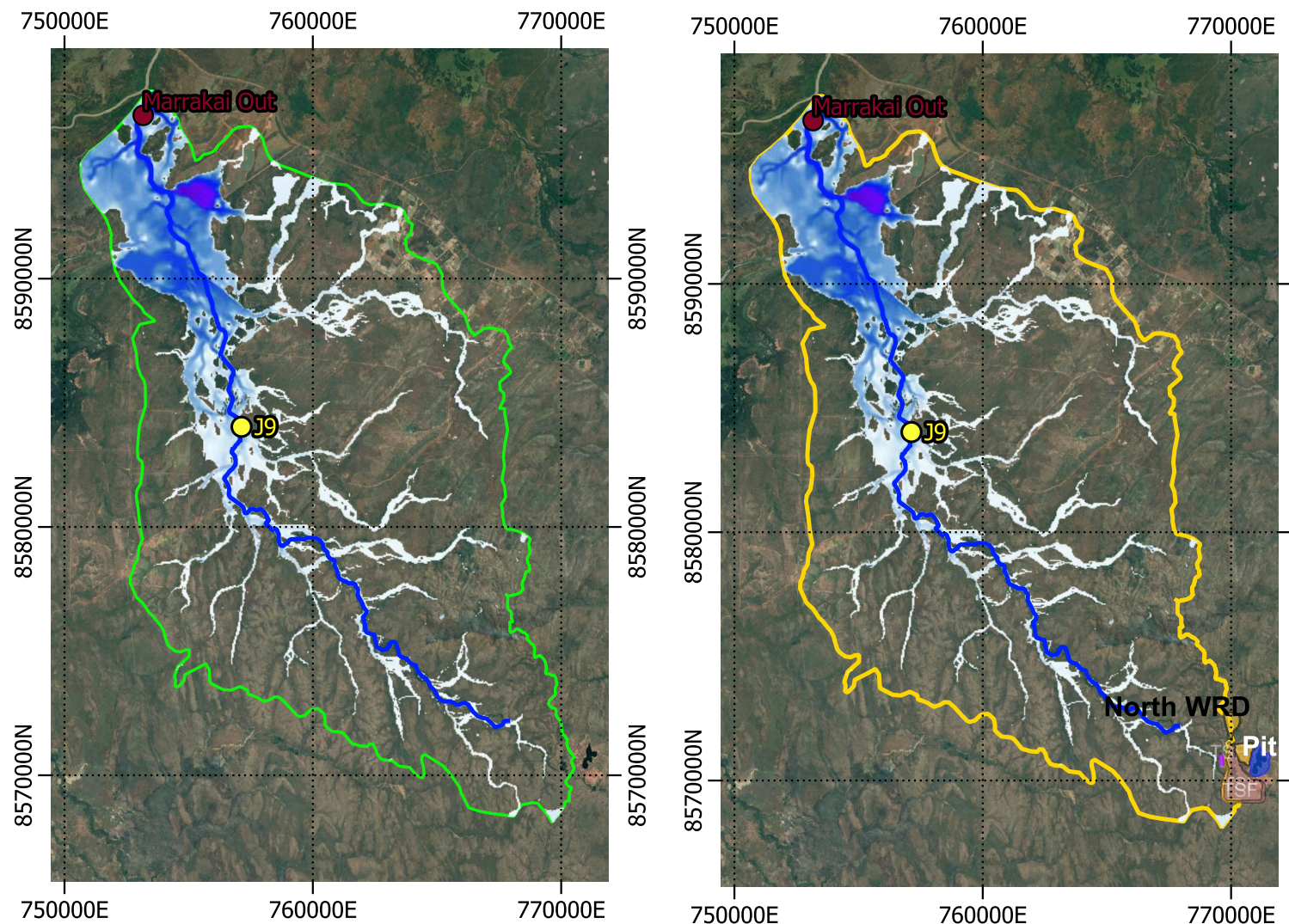
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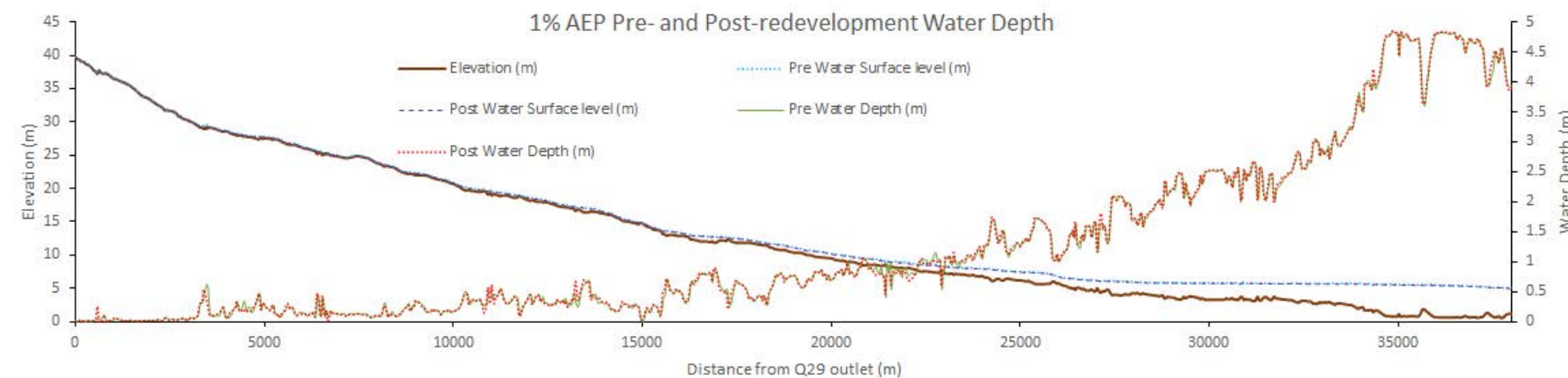
Above: Discharge at J9. There is only minor difference in pre- and post redevelopment conditions with slightly lower flows in the receding limb of the hydrograph



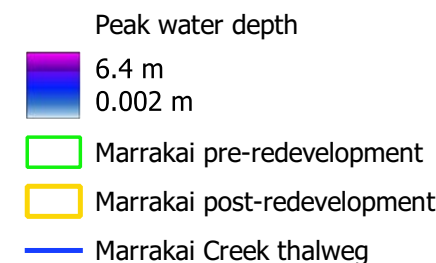
Above: Discharge at Marrakai Creek outlet. There is only minor differences in pre- and post redevelopment conditions with slightly lower flows in the receding limb of the hydrograph.



Above: Pre-redevelopment 1% AEP peak flood water levels. Above: Post-redevelopment 1% AEP peak flood water levels.



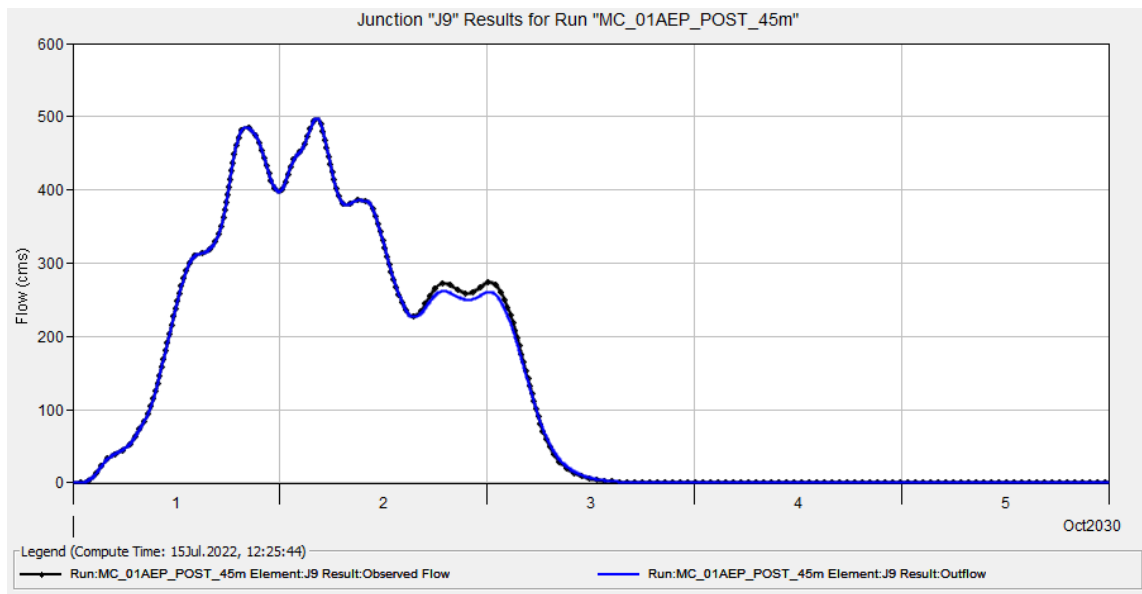
Above: Section along the thalweg of Marrakai Creek (see maps right) from Ruslter's Roost (left) to near confluence with Adelaide River (right) for the simulated peak flood level. There is little difference between pre- and post- with the average difference in depth of the post-redevelopment event = -0.011 m.



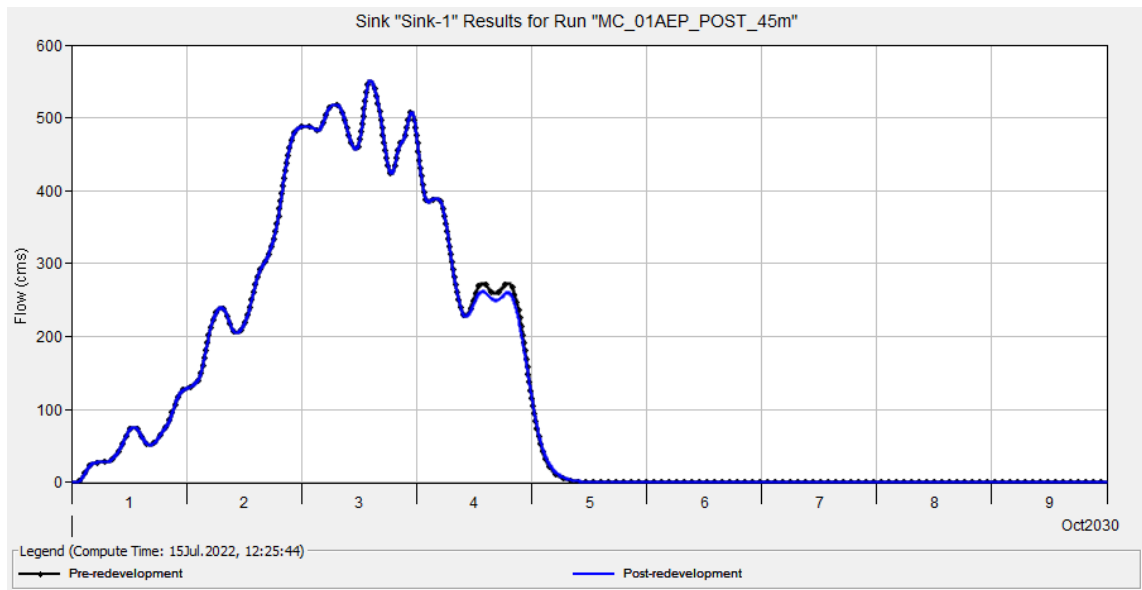
Notes

1. The simulations were conducted using the Lisflood model embedded in the CAESAR-Lisflood hydro-geomorphic model in reach mode and catchment mode to obtain water depth and HEC-HMS to obtain the design hydrographs.
2. The simulations show no evidence of significant change in peak flood levels pre- and post-redevelopment for the 1% AEP rainfall event.

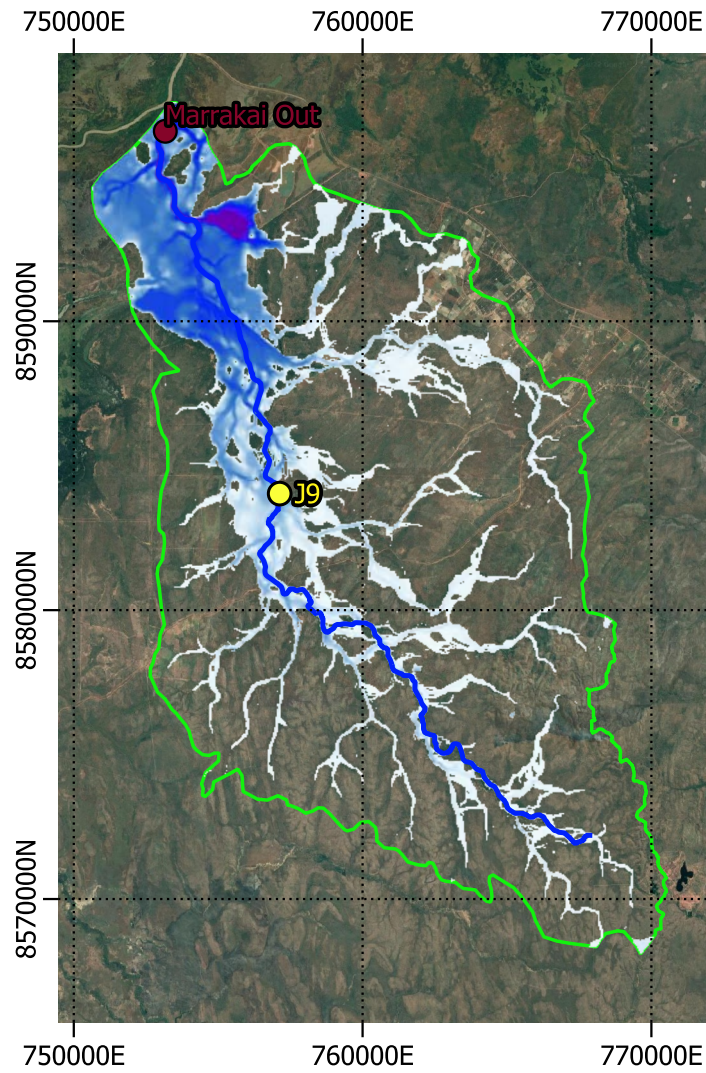
Drawing No MC-02	<p>SURFACE WATER &amp; EROSION SOLUTIONS ALL SITE &amp; SOIL EVALUATIONS FOR SEPTIC &amp; WASTEWATER MANAGEMENT</p>	Project Rustler's Roost & Q29 EIS Supplementary Information	Title Marrakai Creek: Pre- and Post- Redevelopment 1% AEP Rainfall Event Water Depths	Designed	Drawn	Checked	Sheet size
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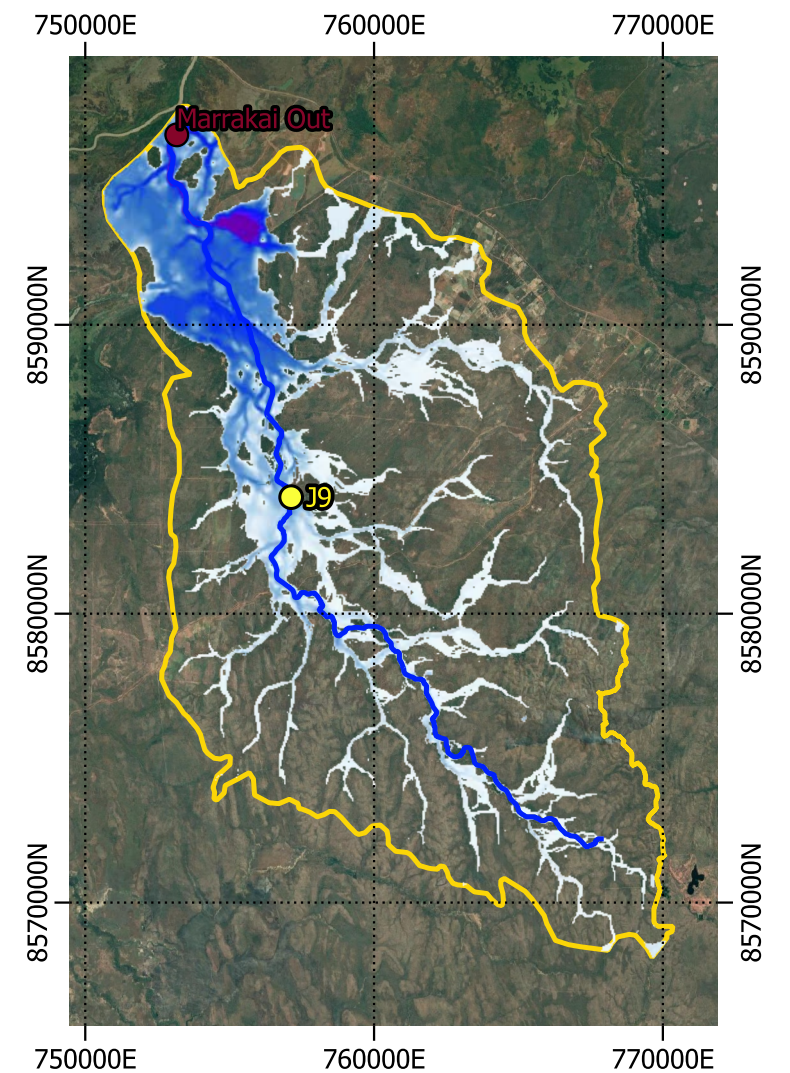
Above: The pre- and post-redevelopment discharges for the 0.1% AEP J9. There are only insignificant difference in the receding hydrograph.



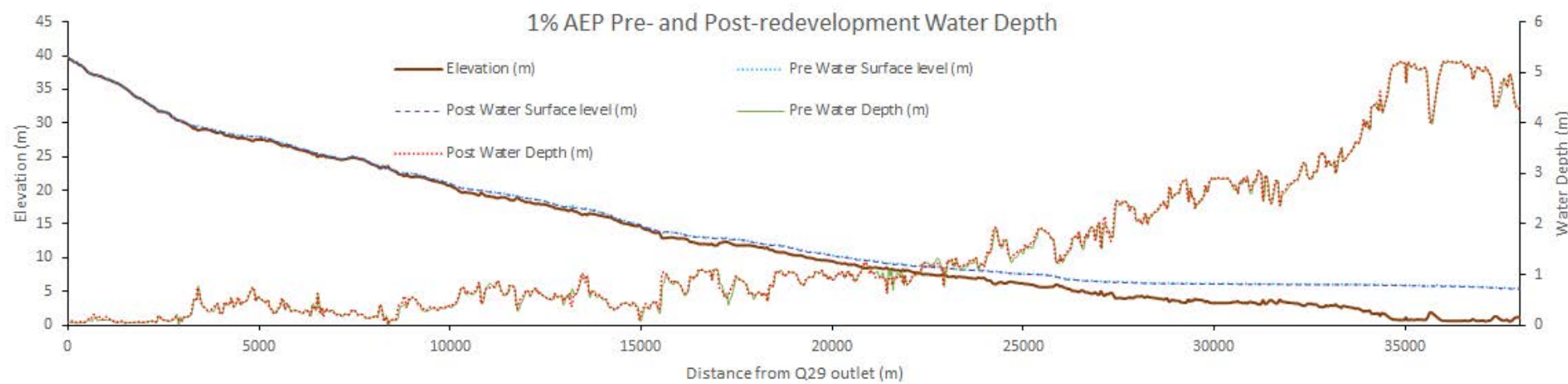
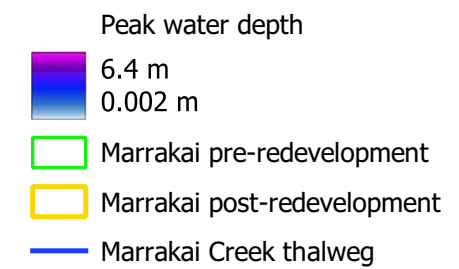
Above: The pre- and post-redevelopment discharges for the 0.1% AEP at the MC outlet. There are only insignificant difference in the receding hydrograph.



Above: Pre-redevelopment 0.1% AEP flood water levels.



Above: Post-redevelopment 0.1% AEP flood water levels.

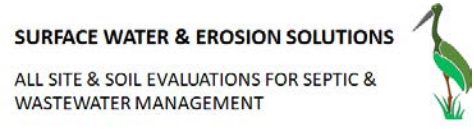


Above: Section along the thalweg of Marrakai Creek (see maps right) from Rusler's Roost (left) to near confluence with Adelaide River (right). There is little difference between pre- and post- with the average difference in depth the pre- and post-redevelopment event = -0.001 m.

Notes

1. The simulations were conducted using the Lisflood model embedded in the CAESAR-Lisflood hydro-geomorphic model in reach mode and catchment mode to obtain water depth and HEC-HMS to obtain the design hydrographs.
2. The simulations show no evidence of significant change in peak flood levels pre- and post-redevelopment for the 0.1% AEP rainfall event.

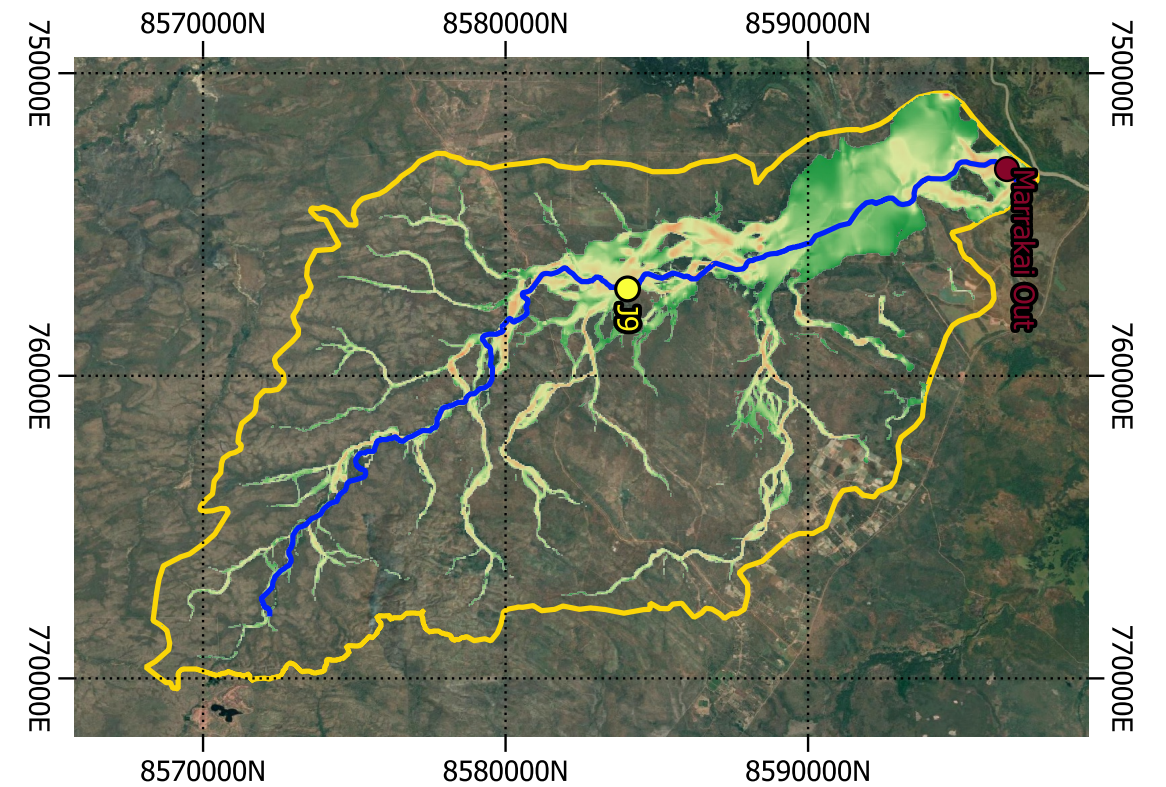
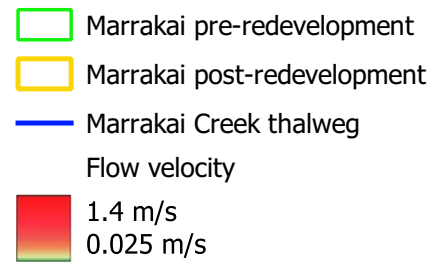
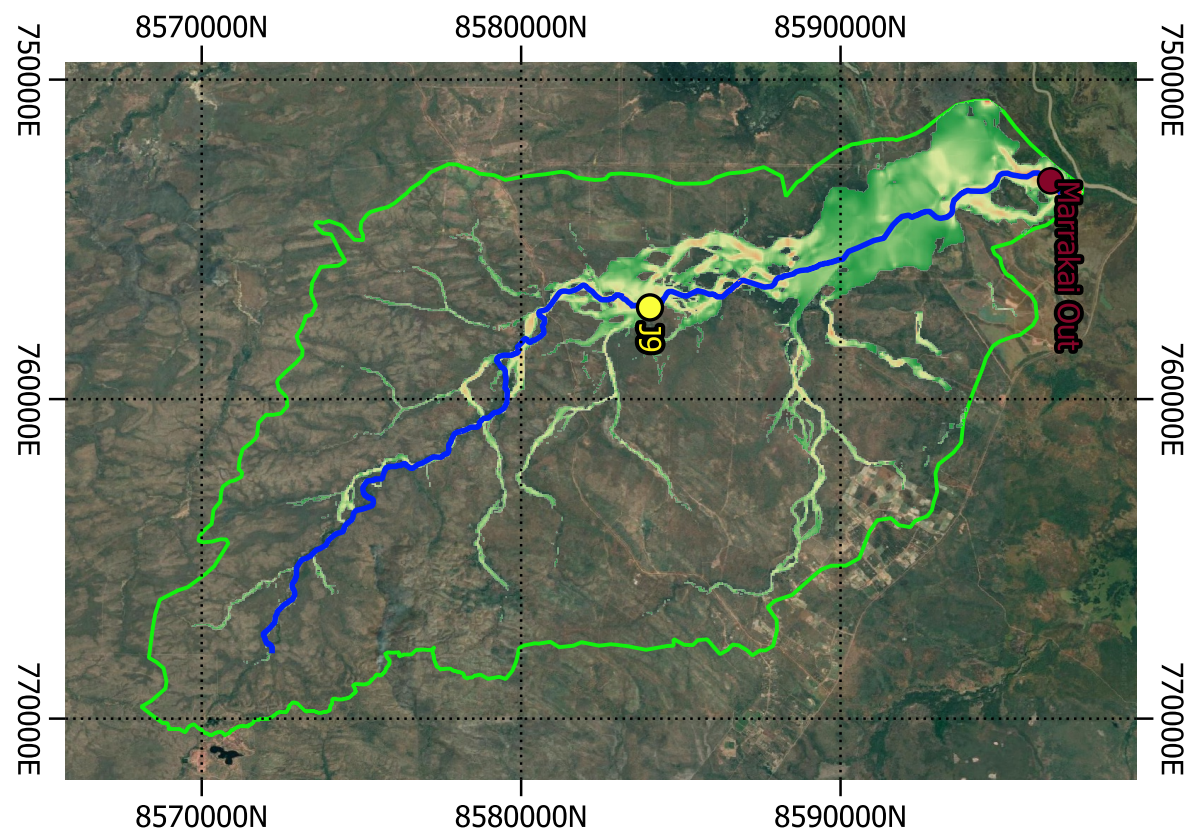
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MC-03



Project  
Rustler's Roost & Q29 EIS  
Supplementary Information

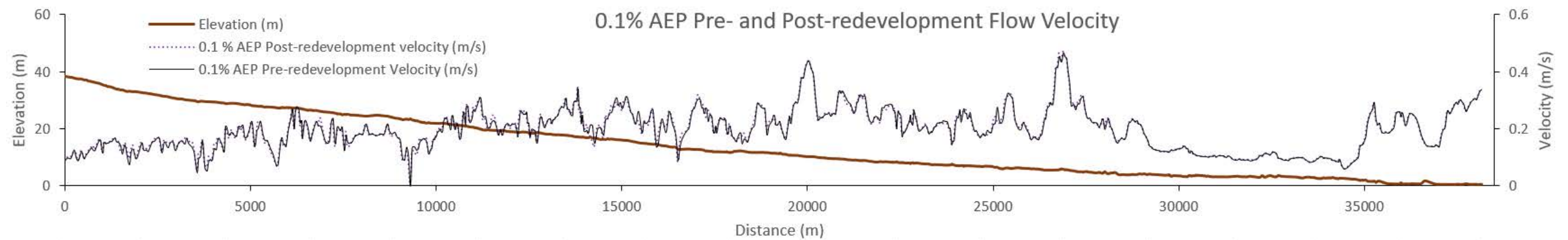
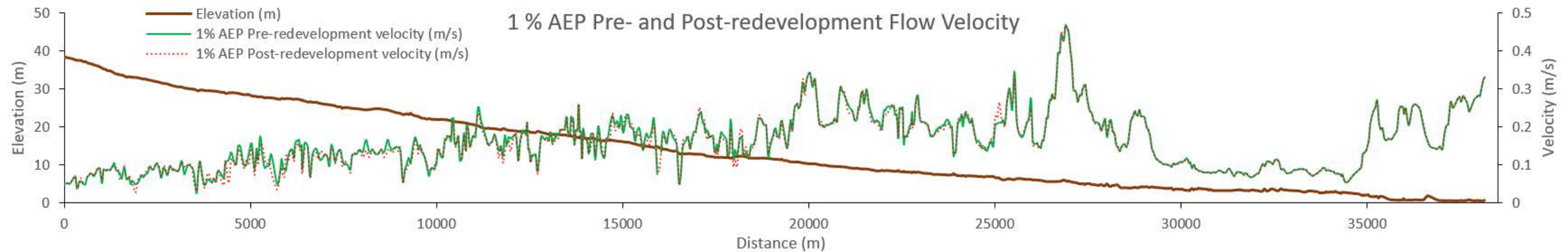
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Redevelopment 0.1% AEP Rainfall  
Event Water Depths

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Above: Stream flow velocities resulting from the 1% AEP rainfall event in Marrakai Creek. There is little difference between pre- and post- conditions (see below). Map rotate 90°.

Above: Stream flow velocities in Marrakai Creek for the 0.1% AEP rainfall event determined using the Lisflood hydraulic model. There is little difference between the pre- and post- conditions (see below). Map rotated 90°.



Top: Section along the thalweg of Marrakai Creek (see maps above) from Rustler's Roost to near confluence with Adelaide River (right) showing flow velocities for the 1% AEP (top) on the 0.1% AEP event (bottom). There is little difference pre- and post-redevelopment conditions.

Drawing No  
MC-04

**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT

Project  
**Rustler's Roost & Q29 EIS  
Supplementary Information**

Title  
**Marrakai Creek: Pre- and Post-  
Redevelopment 1% AEP & 0.1% AEP  
Rainfall Event Flow Velocities.**

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## **Mt Bunday Creek**

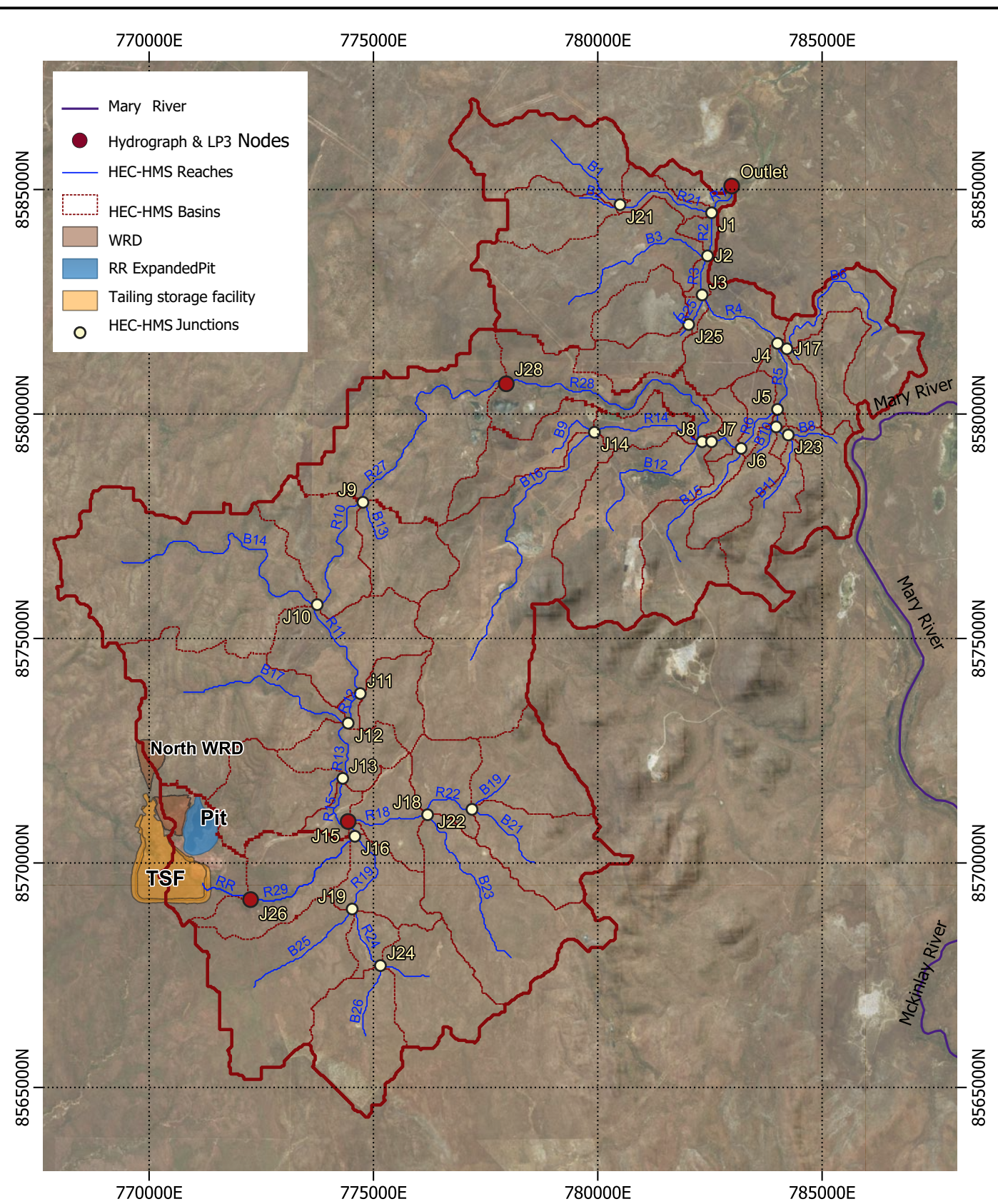
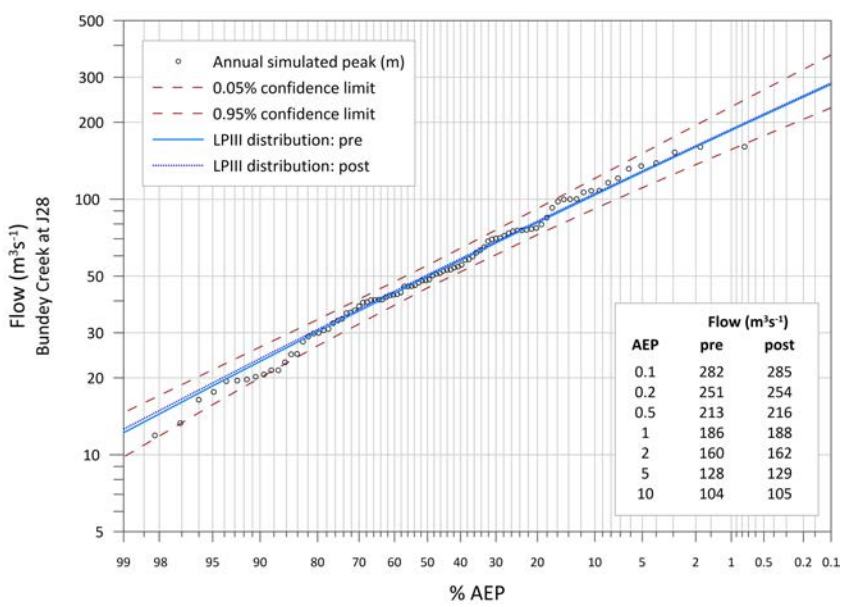
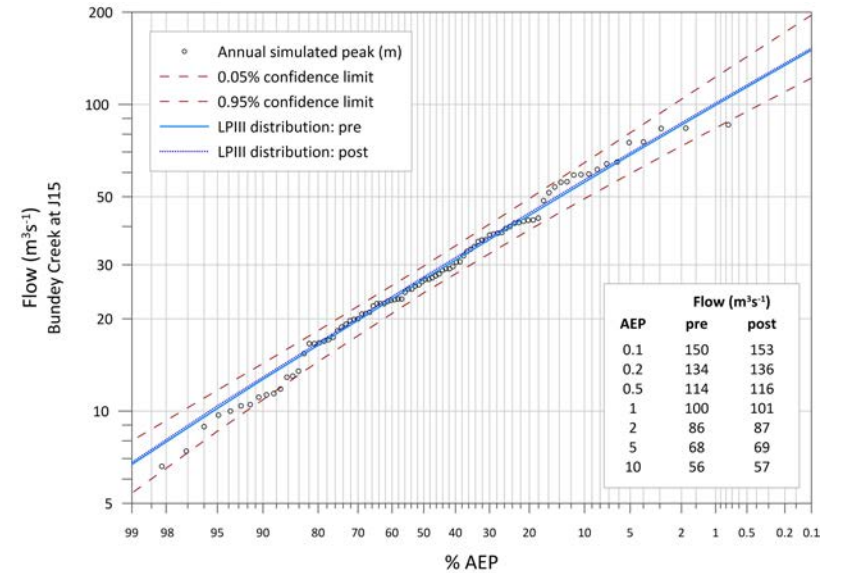


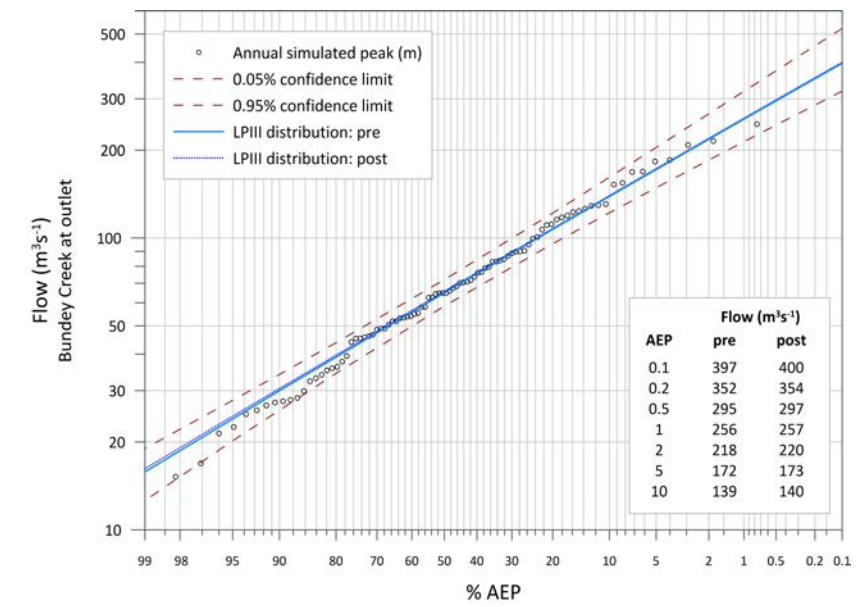
Figure 1. Mt Bunday Creek HEC-HMS model (sub-basins, junctions and reaches) showing the LP3 nodes.. The model is adjusted to incorporate redevelopment infrastructure such as the tailing storage facility, expanded pit and waste rock dumps.

**Right:** Log Pearson 3 distribution pre- and post-redevelopment at Junction J15 where Rustler's Roots discharges through R29 mix with main flows from the southwest part of the catchment. There is a long-term increase in total discharge of 6.6% post-mine redevelopment.



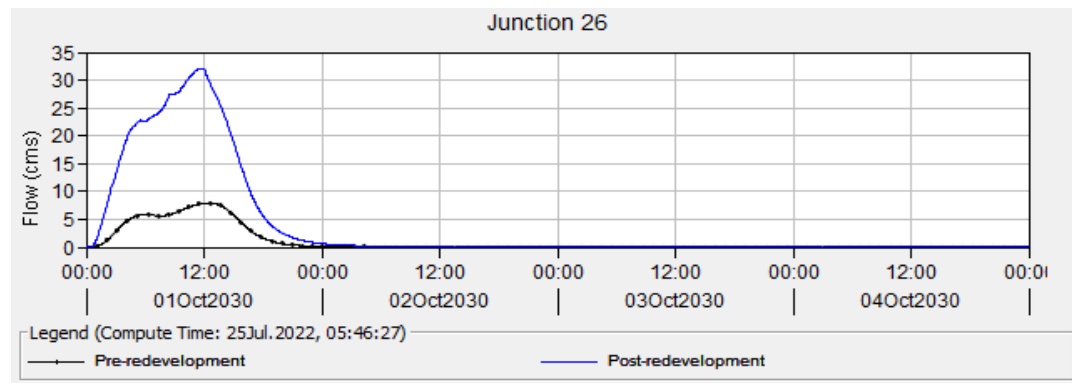
**Left:** Log Pearson distribution pre- and post-mine expansion at Junction J28 in the lower half of the Mt Bunday Creek catchment. Tom's Gully site debouches in to the main channel at this point. There is an increase in total discharge of 3.1% in the post-mine expansion scenario.

**Below:** Log Pearson distribution pre- and post-mine expansion at the catchment outlet at its confluence with the Mary River. There is an increase in total discharge of 1.8% in the post-mine expansion scenario.

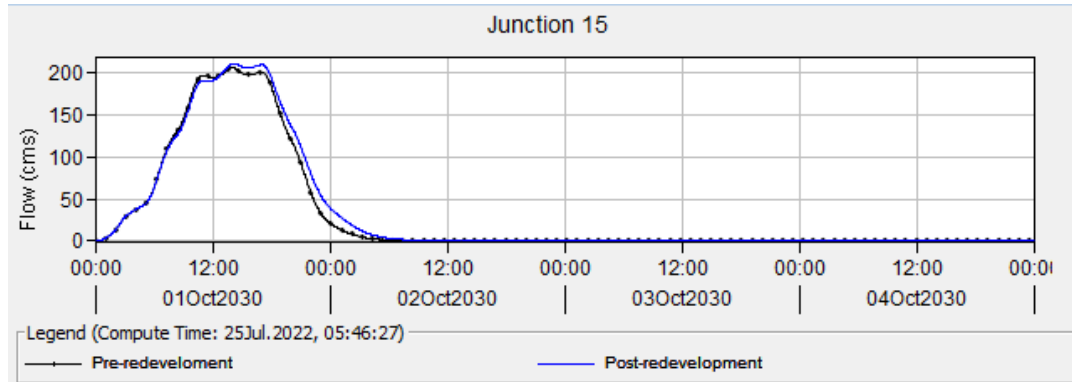


**Notes**

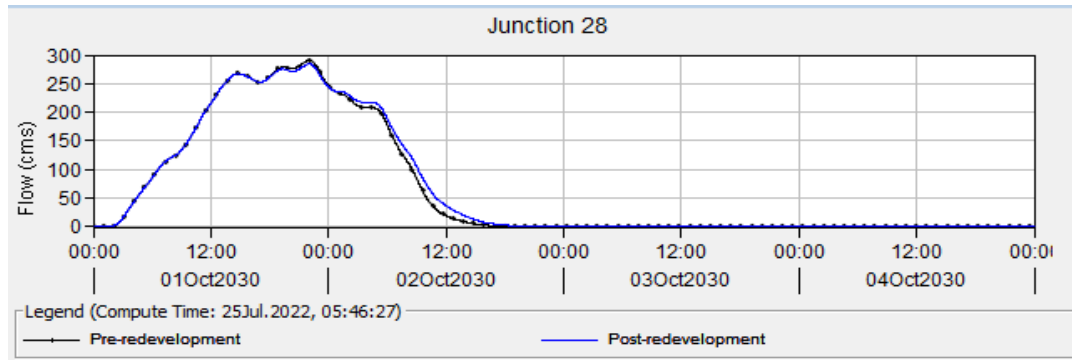
1. This is an assessment of changes in hydrology of the Mt Bunday Creek catchment due to the Rustler's Roost redevelopment in the upper catchment using the HEC-HMS model.
2. A 91 year simulation was conducted from 2030 applying climate change using the RCP 4.5 model.
3. A log-Pearson 3 distribution was created using the annual peak discharges for the pre- and post-mining condition at HEC-HMS junctions down the catchment using the 91-year simulation data .



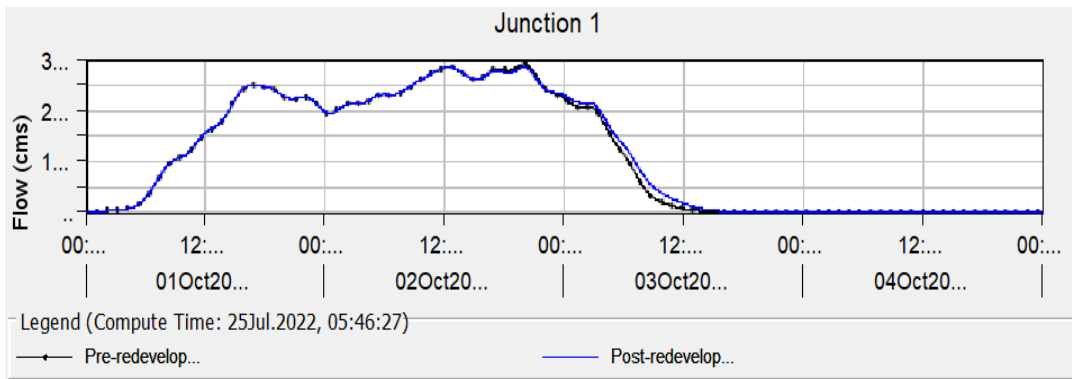
Above: Flow at Junction 26. The TSF has added 2 km<sup>2</sup> to this part of the catchment causing higher flows in this part of the catchment when water is released from the TSF. This higher flow reduces relative to other catchment flows as it move downstream.



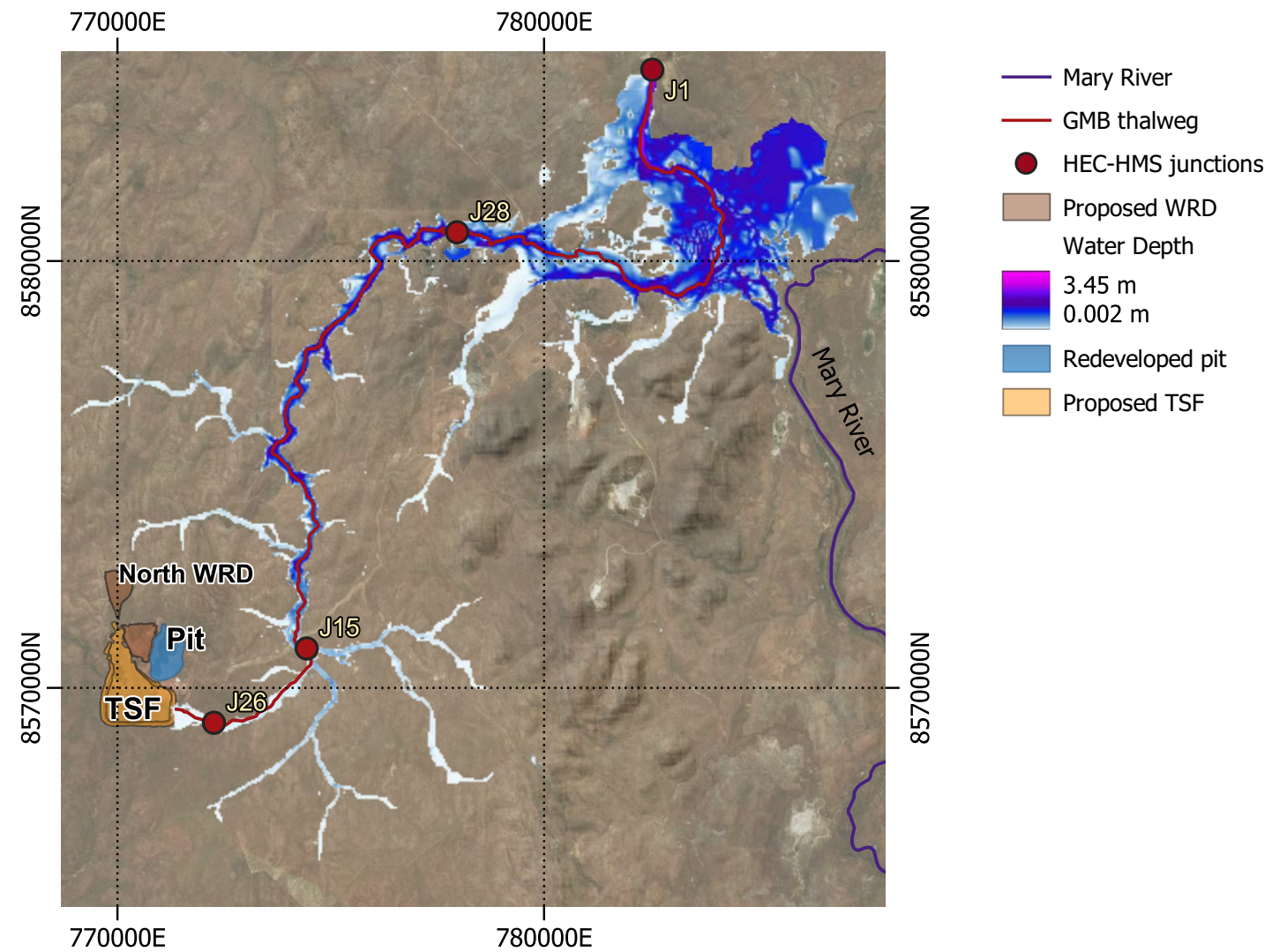
Above: Flow at Junction 15. There is little difference in the pre- and post-redevelopment hydrographs as TSF flow are absorbed with other catchment flows.



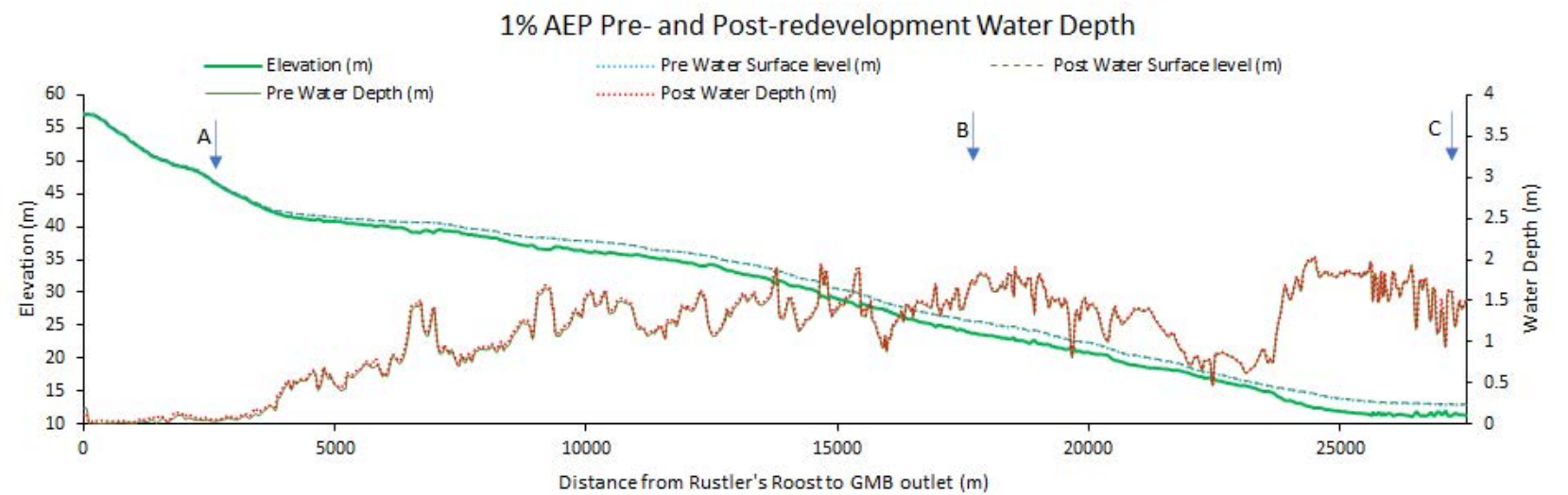
Above: Flow at Junction 28 (Tom Gully pit). There is little difference in the pre- and post-redevelopment hydrographs.



Above: Flow at Junction 1 near the outlet of Mt Bunday Creek. There little difference between the pre- and post-development hydrographs apart from a slight lag in the receding tail of the hydrograph.



Above: Post-redevelopment 1% AEP flood water inundation using the Lisflood hydraulic model embedded in the CAESAR-Lisflood hydrogeomorphic model. There is little discernible difference between the pre- and post-redevelopment conditions.



Above: Section along the thalweg of Mt Bunday Creek (see map above) from Rustler's Roost (left) to near confluence with the Mary River (right). There is little difference between pre- and post-redevelopment inundation depths with the average difference in depth of the post-redevelopment event = 0.029 m. Arrows show location of sections. Simulations conducted assuming the TSF and pit water levels are at the decant level.

Drawing No  
GMB-02

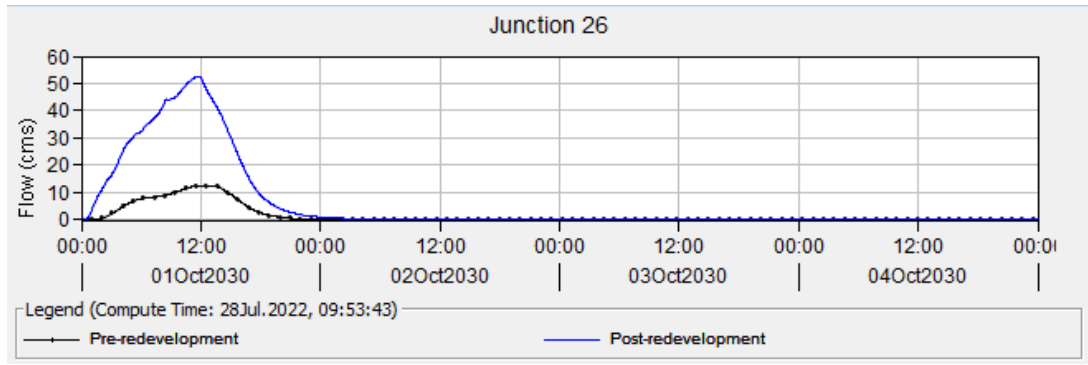
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



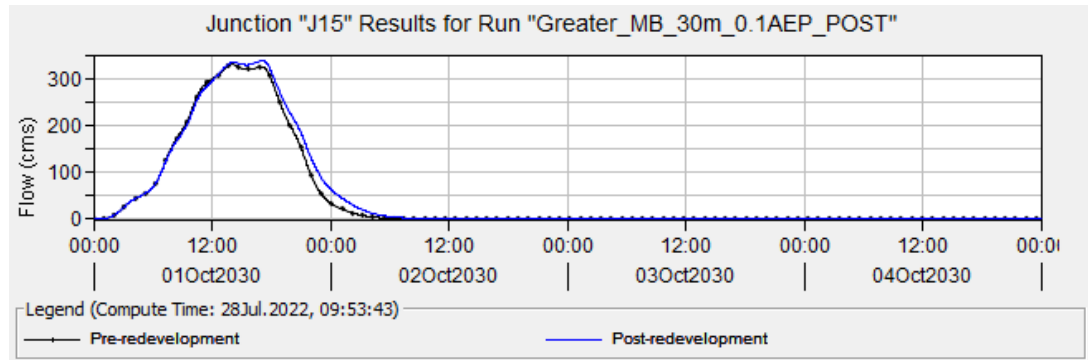
Project  
**Rustler's Roost & Q29 EIS  
Supplementary Information**

Title  
**Mt Bunday Creek: Pre- and Post-  
Redevelopment 1% AEP Rainfall Event  
Discharge & Water Depths**

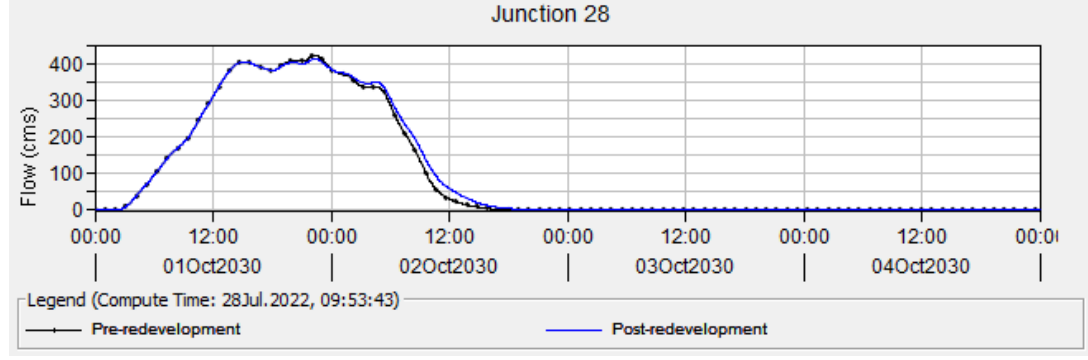
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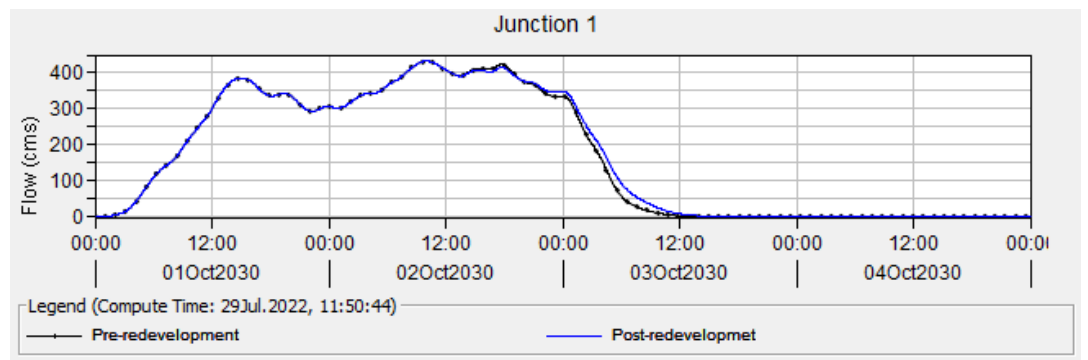
Above: Flow at Junction 26. The TSF has added 2 km<sup>2</sup> to this part of the catchment causing higher flows in this part of the catchment when water is released from the TSF. This higher flow reduces relative to other catchment flows as it move downstream.



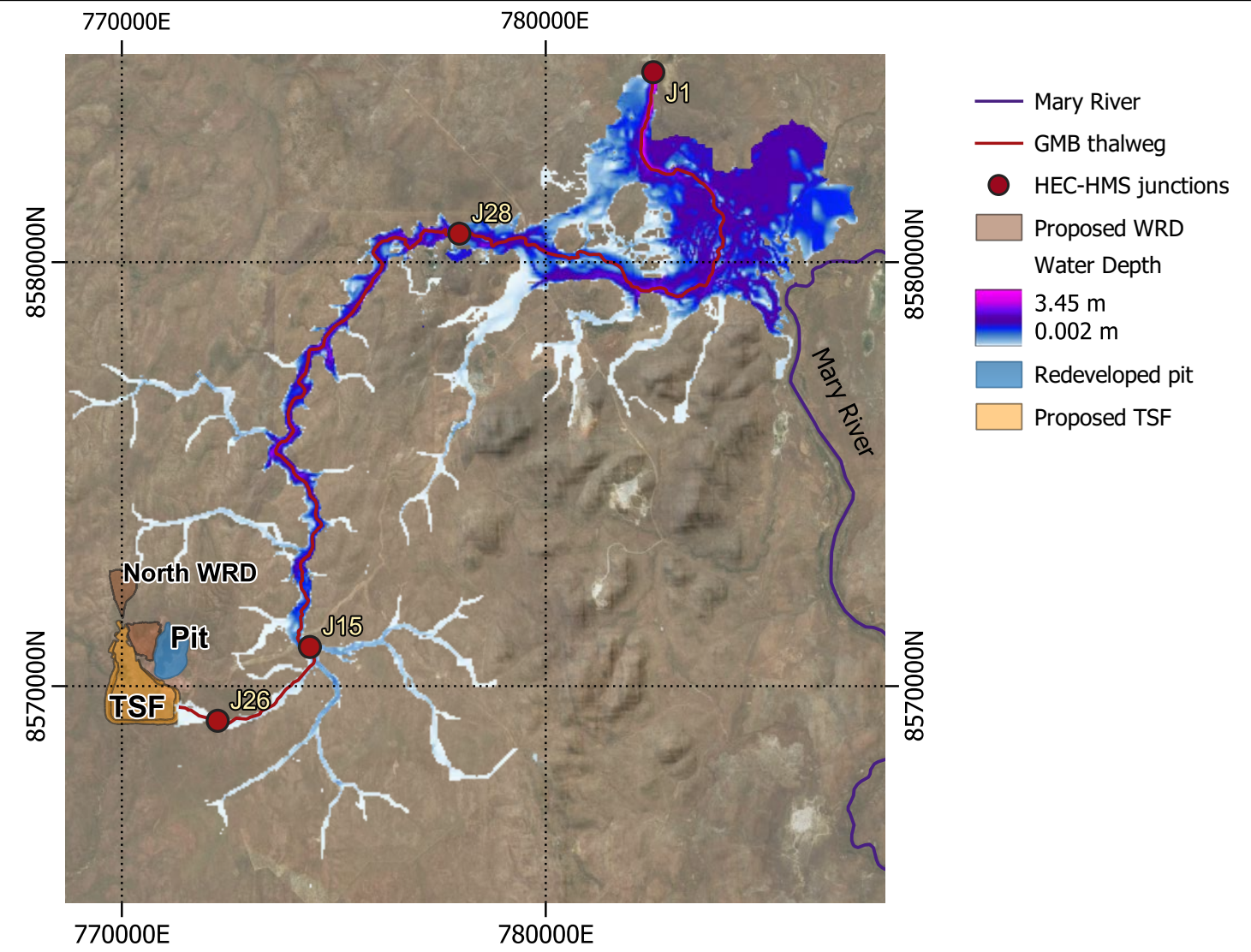
Above: Flow at Junction 15. There is little difference in the pre- and post-redevelopment hydrographs as TSF flow are absorbed with other upstream catchment flows from the southwest.



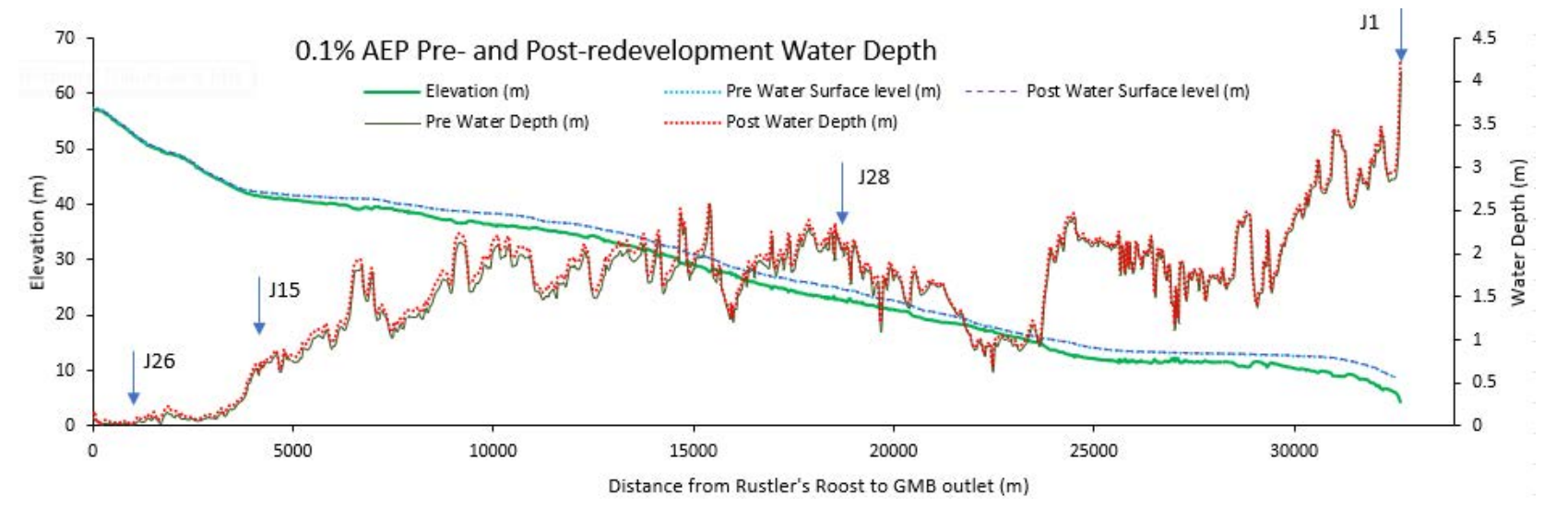
Above: Flow at Junction 28 (Tom's Gully pit). There is little difference in the pre- and post-redevelopment hydrographs.



Above: Flow at Junction 1 near the outlet of Mt Bunday Creek. There little difference between the pre- and post-development hydrographs apart from a slight lag in the receding tail of the hydrograph.

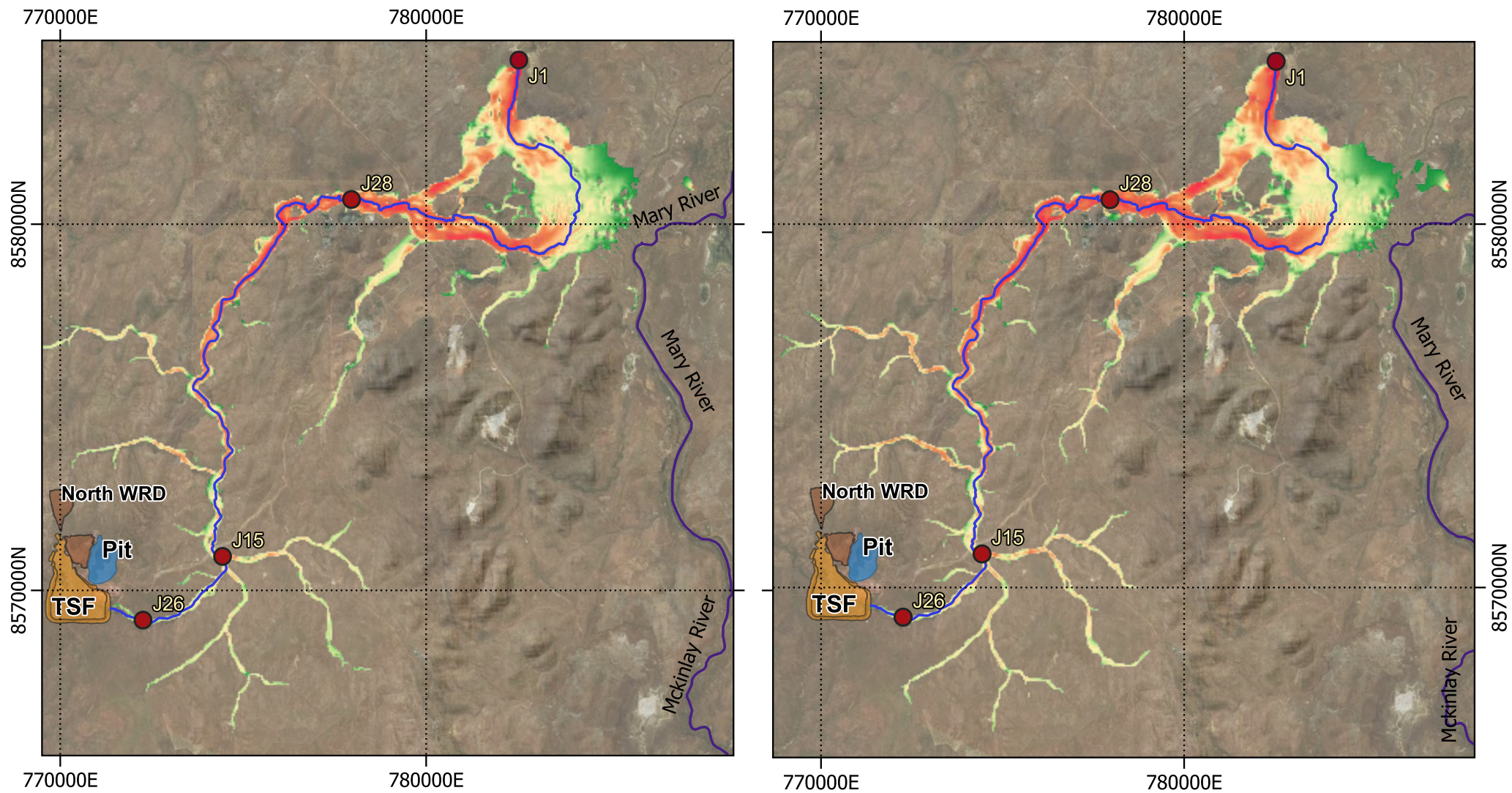


Above: Post-redevelopment 0.1% AEP flood water inundation using the Lisflood hydraulic model embedded in the CAESAR-Lisflood hydrogeomorphic model. There is little discernable difference between the pre- and post-redevelopment conditions.



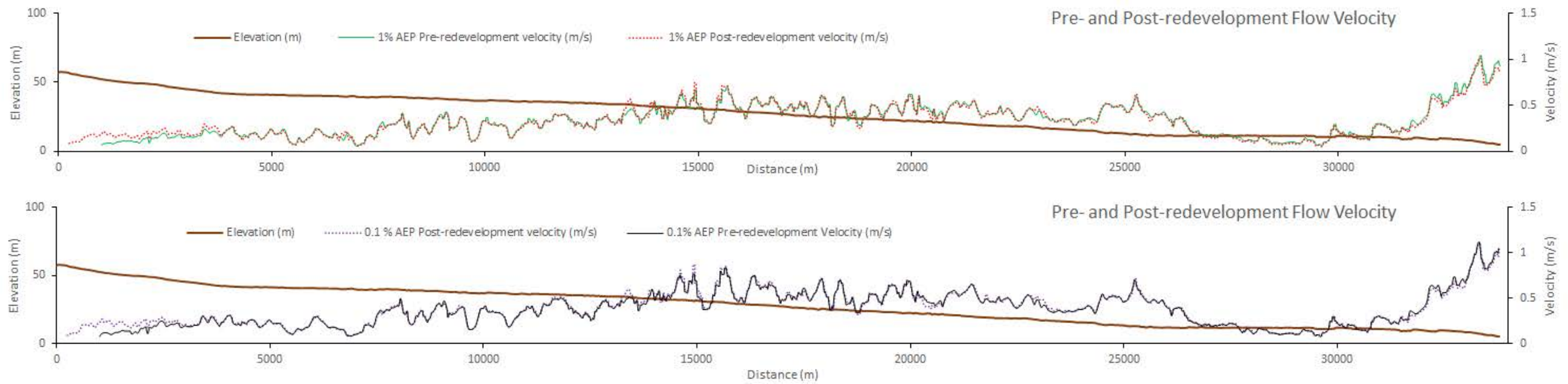
Above: Section along the thalweg of Mt Bunday Creek (see map above) from Rustler's Roost (left) to near confluence with the Mary River (right). There is little difference between pre- and post-redevelopment inundation depths with the average difference in depth of the post-redevelopment event = 0.061 m. Arrows show location of sections. Simulations conducted assuming the TSF and pit water levels are at the decant level.

Drawing No <b>GMB-03</b>	 ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT	Project <b>Rustler's Roost &amp; Q29 EIS Supplementary Information</b>	Title <b>Mt Bunday Creek: Pre- and Post- Redevelopment 1% AEP Rainfall Event Discharge &amp; Water Depths</b>	Designed	Drawn	Checked	Sheet size
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Far left: Stream flow velocities resulting from the 1% AEP rainfall event in Mt Bunday Creek. There is little difference between pre- and post-redevelopment velocities (see below).

Left: Stream flow velocities in Mt Bunday Creek for the 0.1% AEP rainfall event determined using the Lisflood hydraulic model. There is little difference between the pre- and post-redevelopment velocities (see below).



Above: Sections along the thalweg of Mt Bunday Creek (see maps above) from Rustler's Roost (left) to near the confluence with Mary River River (right). Upper - For the 1% AEP event (top), there is little difference between pre- and post-redevelopment velocities. For the 0.1% AEP event there is little difference pre- and post-redevelopment velocities.

Drawing No  
GMB-04

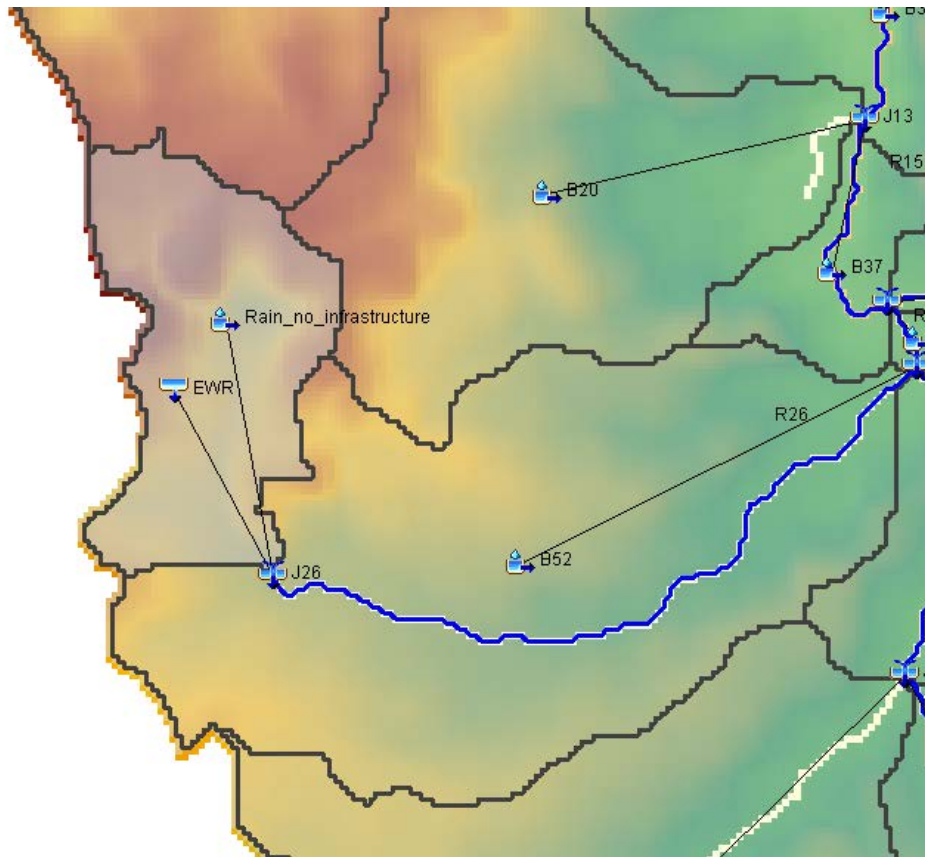
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



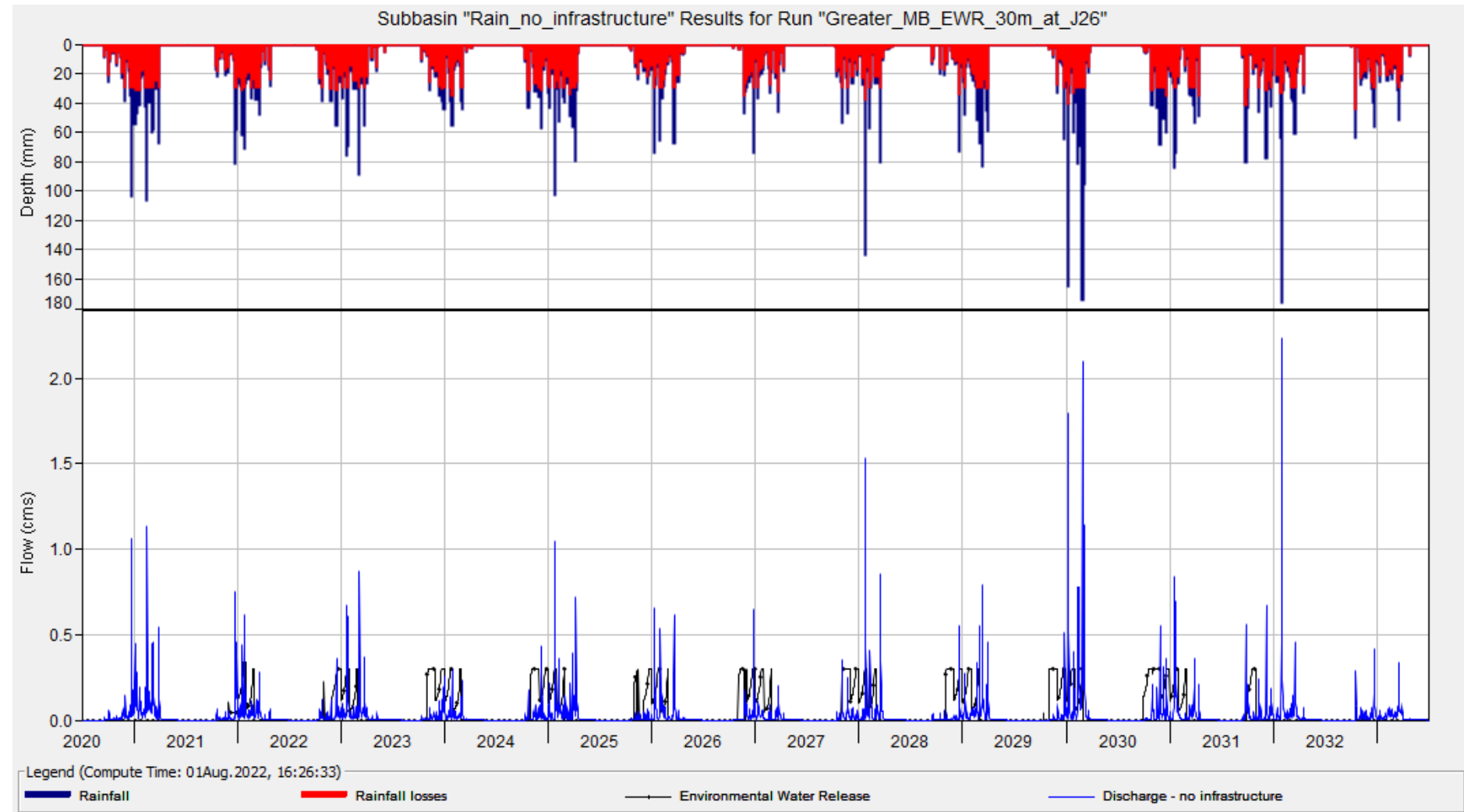
Project  
**Rustler's Roost & Q29 EIS  
Supplementary Information**

Title  
**Mt Bunday Creek: Pre- and Post-  
Redevelopment 1% AEP & 0.1% AEP  
Rainfall Event Flow Velocities.**

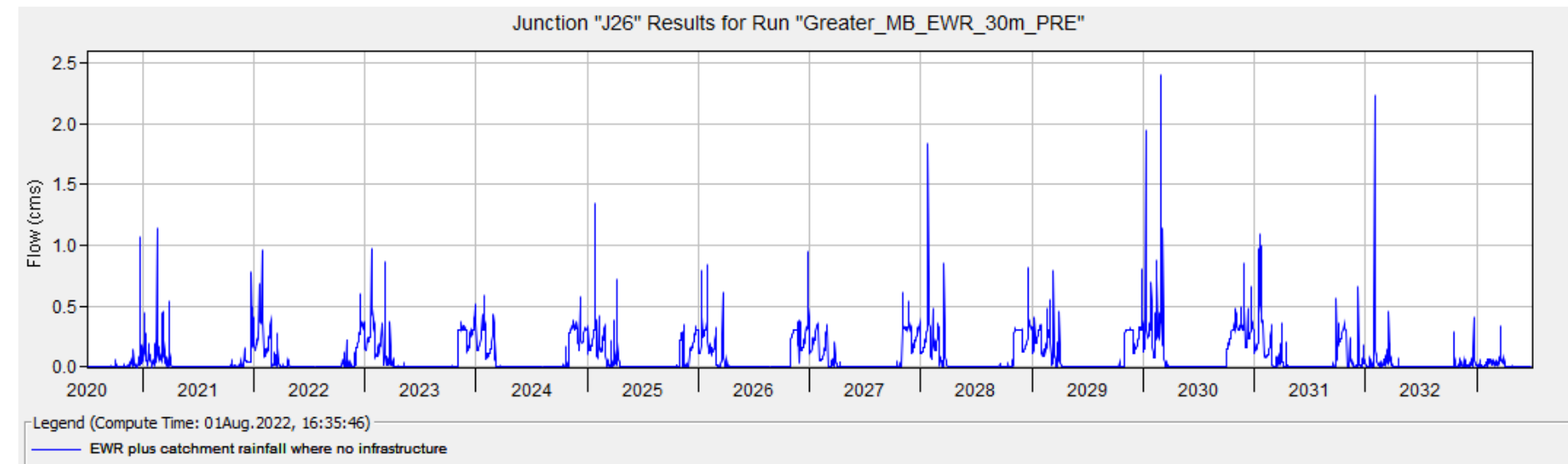
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Above: Extract of Mt Bunday Creek HEC-HMS model showing the mine infrastructure catchment with environmental water release (EWR) to J26. The EWR covers water released from the mine infrastructure to Mt Bunday Creek between 1 July 2020 to 1 July 2033 (life-of-mine). The mine site infrastructure will vary in size so the simulation comprises input from the EWRs and rainfall runoff from the area of the infrastructure catchment where no infrastructure are located.



Above: Discharge from the Rustler's Roost mine infrastructure catchment. The top panel shows the rainfall sequence during LOM with rainfall losses. The bottom panels shows the discharge resulting from the rainfall from only that area where there is no infrastructure. The EWR is shown separately from the rainfall discharge.



Above: Combined rainfall runoff discharge and EWR as input to J26 of the HEC-HMS model. Annual peak discharges have increased slightly relative to the Mt Bunday Creek catchment.

Drawing No  
GMB-05

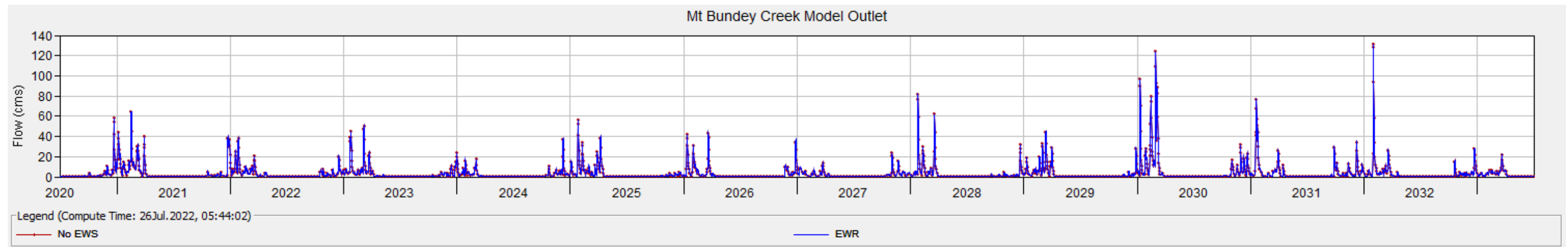
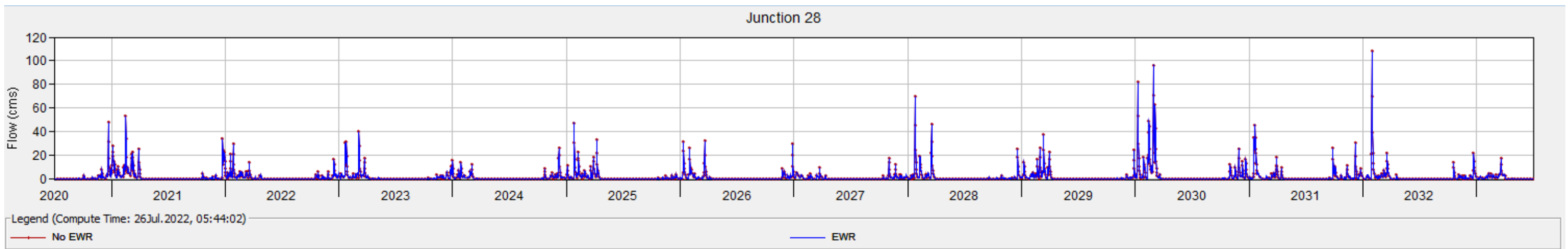
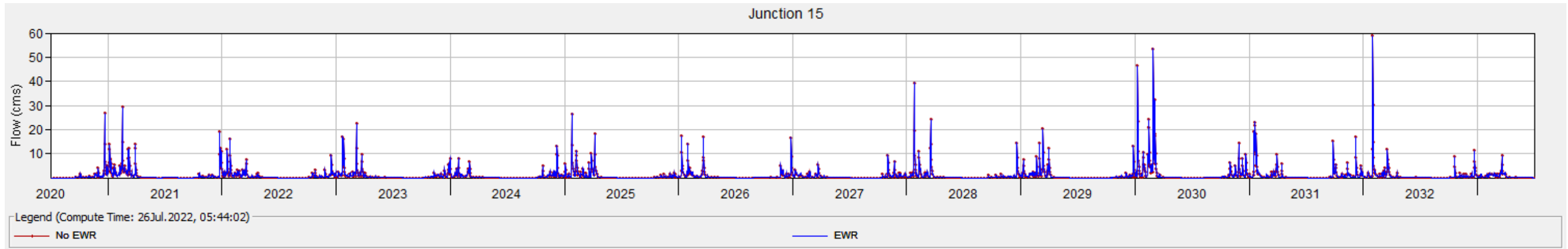
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC &  
WASTEWATER MANAGEMENT



Project  
**Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title  
**Rustler's Roost Environmental Water  
Releases: HEC-HMS Hydrographs at  
Mt Bunday Creek Junction 26**


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26/06/2022		Sheet 5 of 6	



Above. Mt Bunday Creek HEC-HMS model hydrographs for environment water releases from the Rustler's Roost compared with no environmental water releases. There is little difference in EWR and No EWR hydrographs as they progress downstream.

Drawing No  
**GMB-06**

**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



Project **Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title **Rustler's Roost Environmental Water Releases: HEC-HMS Hydrographs in Mt Bunday Creek**

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Date		Sheet No. 6	
26/06/2022		Sheet 6 of 6	

## **Charles Creek**

Notes

1. This is a preliminary assessment of changes in hydrology of the Charles Creek catchment (Figure 1) due to the Quest 29 redevelopment in the upper catchment using the HEC-HMS model to assess stream discharge changes and the CAESAR-Lisflood landform evolution model to assess stream flow velocity and channel erosion.
2. A HEC-HMS model was developed for the pre- and post-redevelopment Q29S catchments and the receiving Charles Creek catchment Figures 2-4 below.
3. A 91-year simulation was conducted from 2030 applying climate change using the RCP 4.5 model for each model with outflow from the Q29S catchment used as inflow to the Charles Creek catchment for the pre- and post-redevelopment conditions. This was used to assess changes in long-term flow regime (Drawing CC-02).
4. For this analysis the BOM Beatrice Hill daily rainfall data was used and not the BOM Middle Park Rangers gauge. Beatrice Hill is closer to the study site resulting in high peak discharges and total flow.
5. A CAESAR-Lisflood model was developed for the Charles Creek receiving catchment (Drawing CC-03). The effect on flow velocity and channel erosion for the 1% AEP and 0.1% AEP design rainfalls for the pre- and post-redevelopment conditions and de-watering pump rates was assessed.

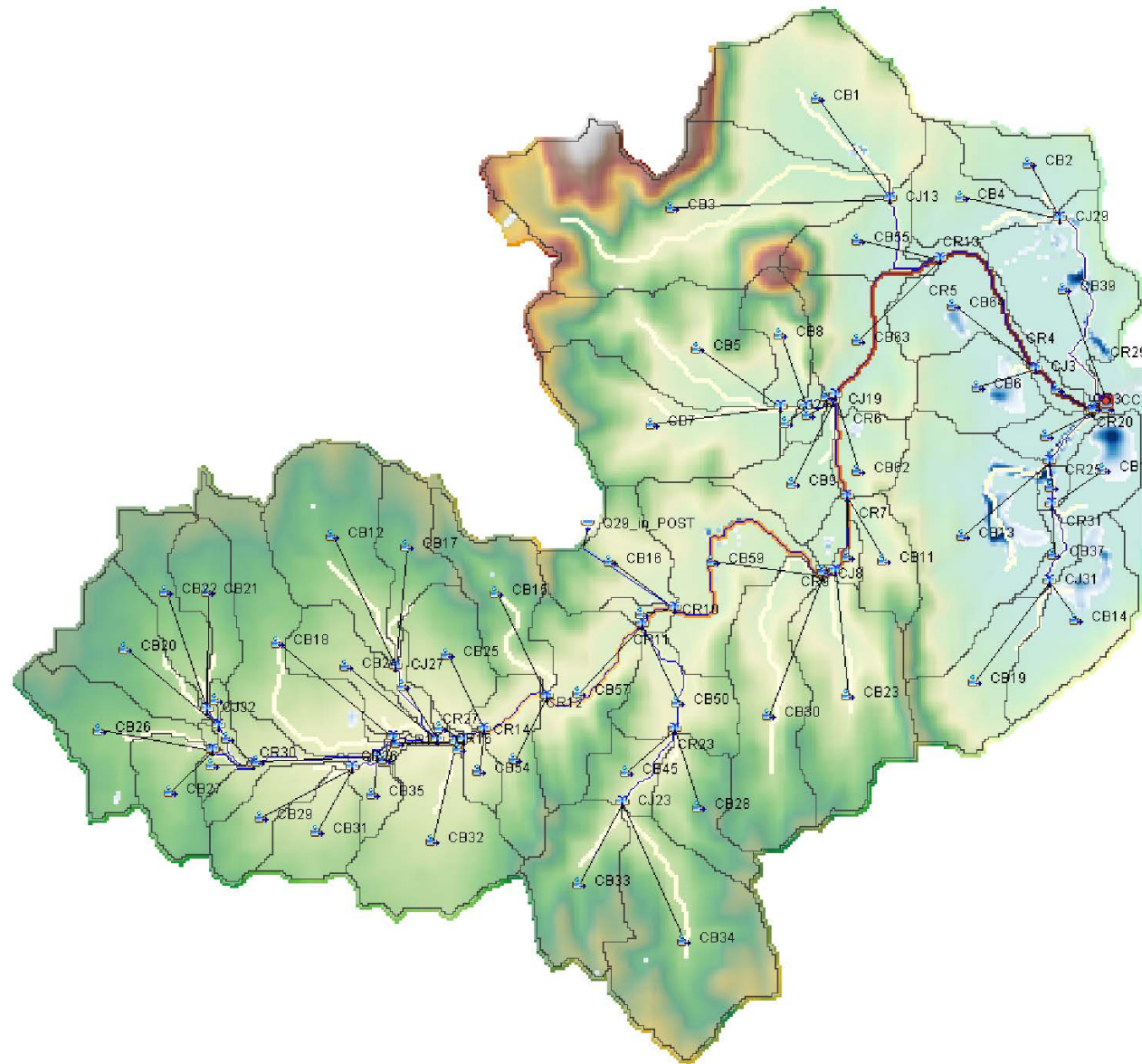


Figure 4. Charles Creek receiving catchment HEC-HMS model.

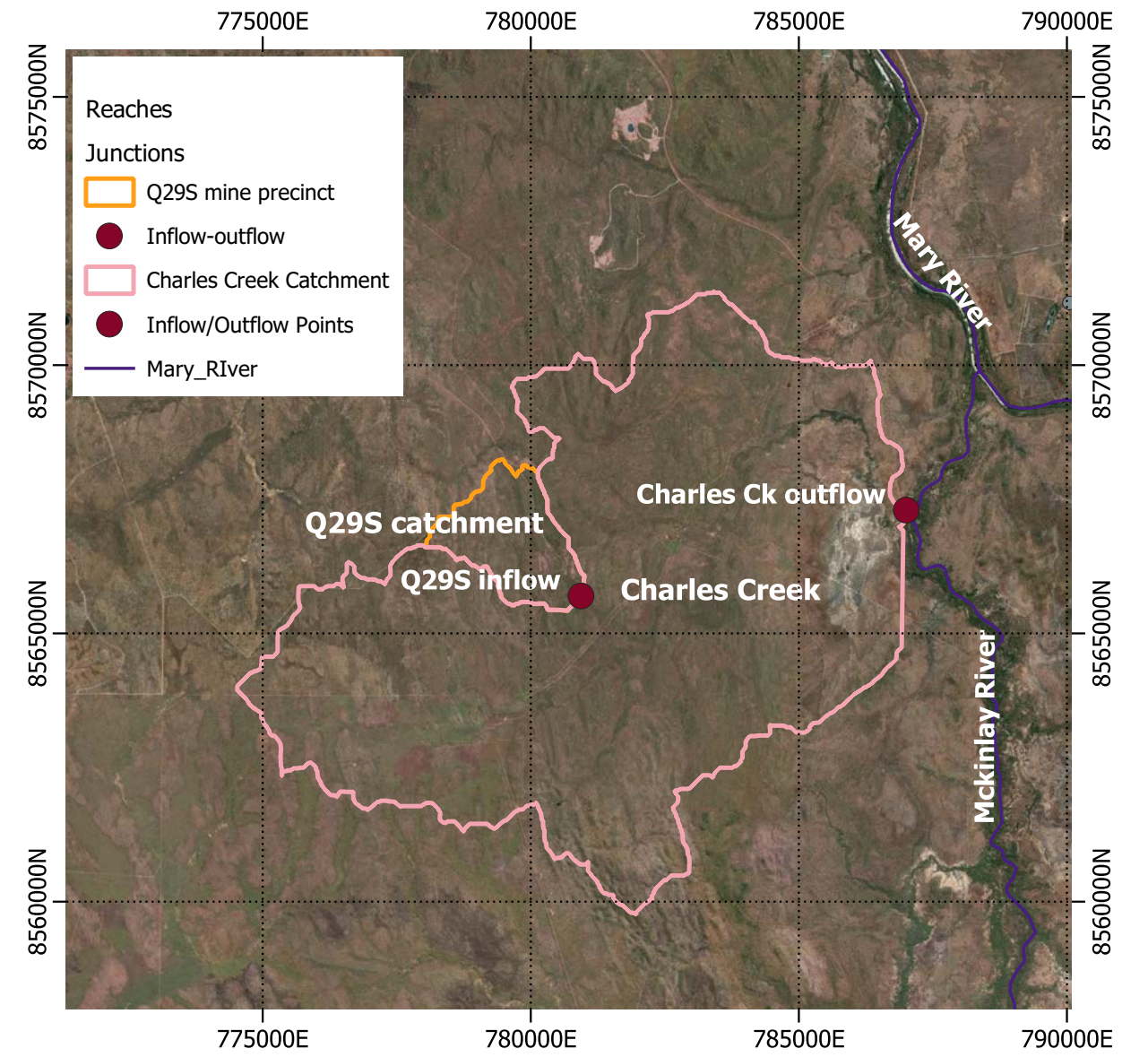


Figure 3. Q29S post-redevelopment catchment HEC-HMS model.

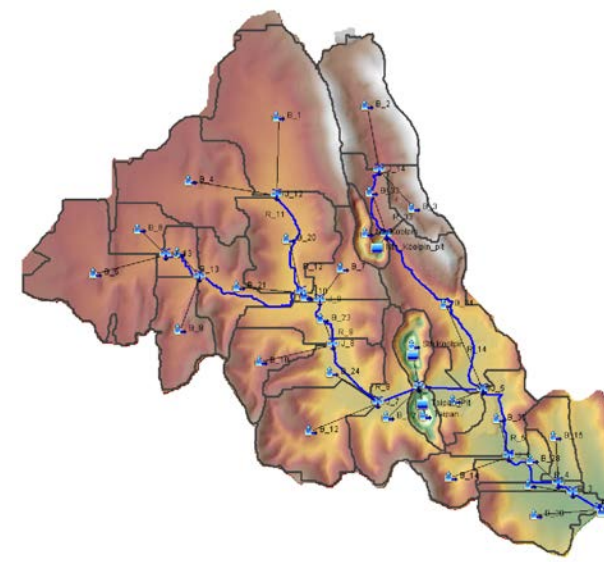


Figure 3. Q29S post-redevelopment catchment HEC-HMS model.

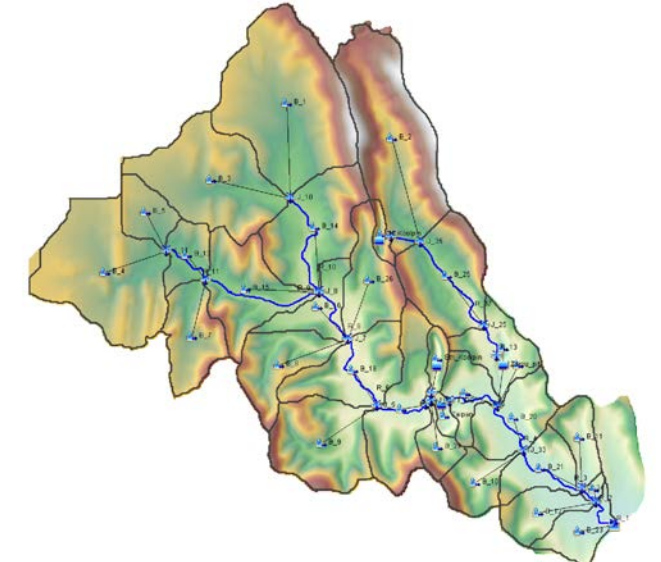


Figure 2. Q29S pre-redevelopment catchment HEC-HMS model.

Drawing No  
CC-01

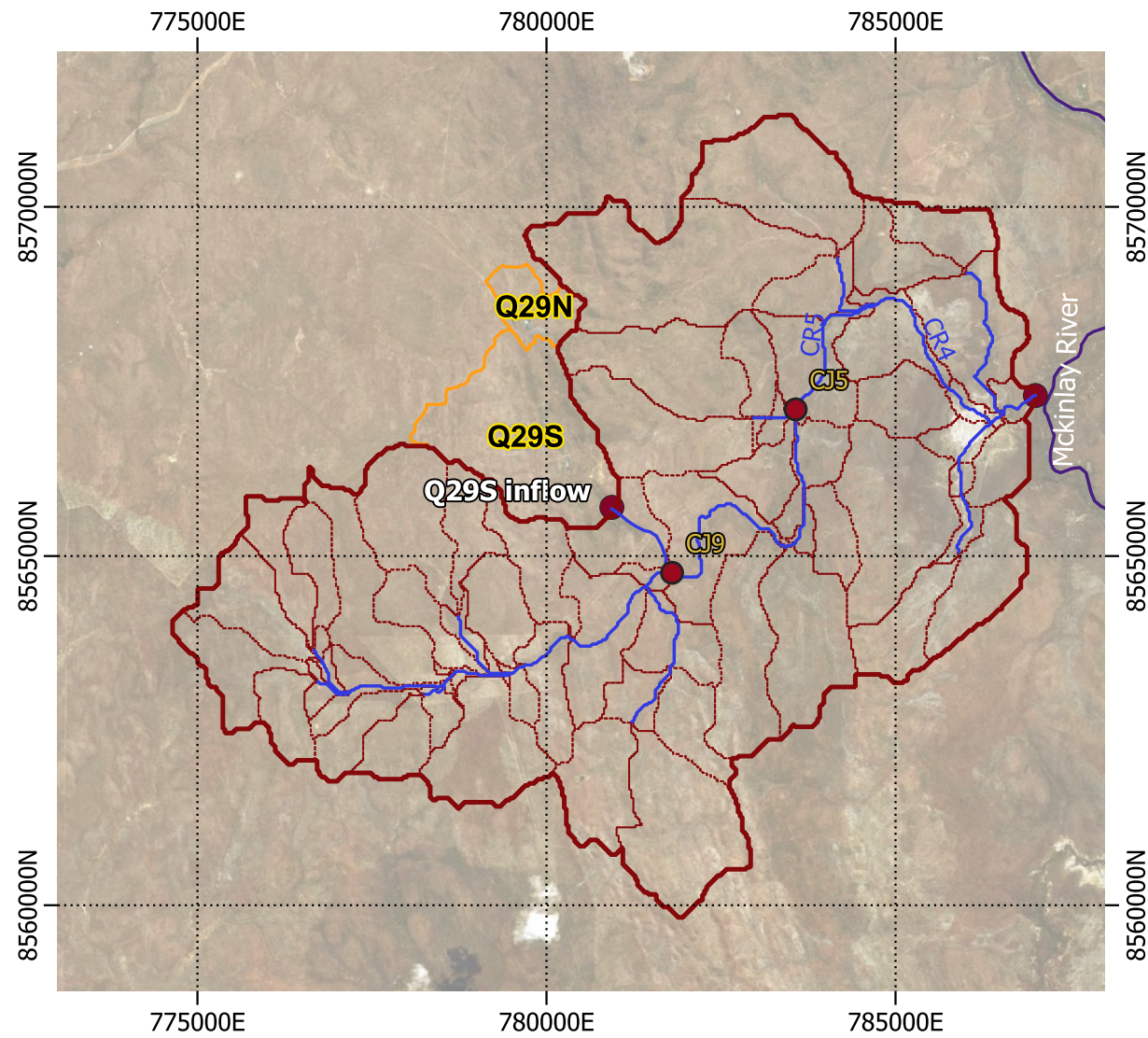
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



Project **Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title **Charles Creek Catchment HEC-HMS**  
models

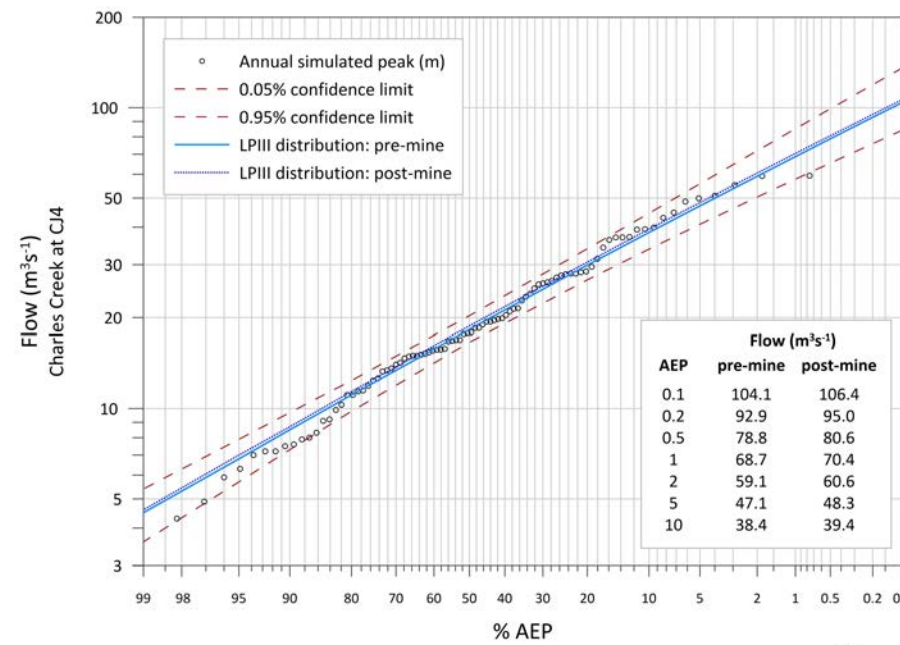
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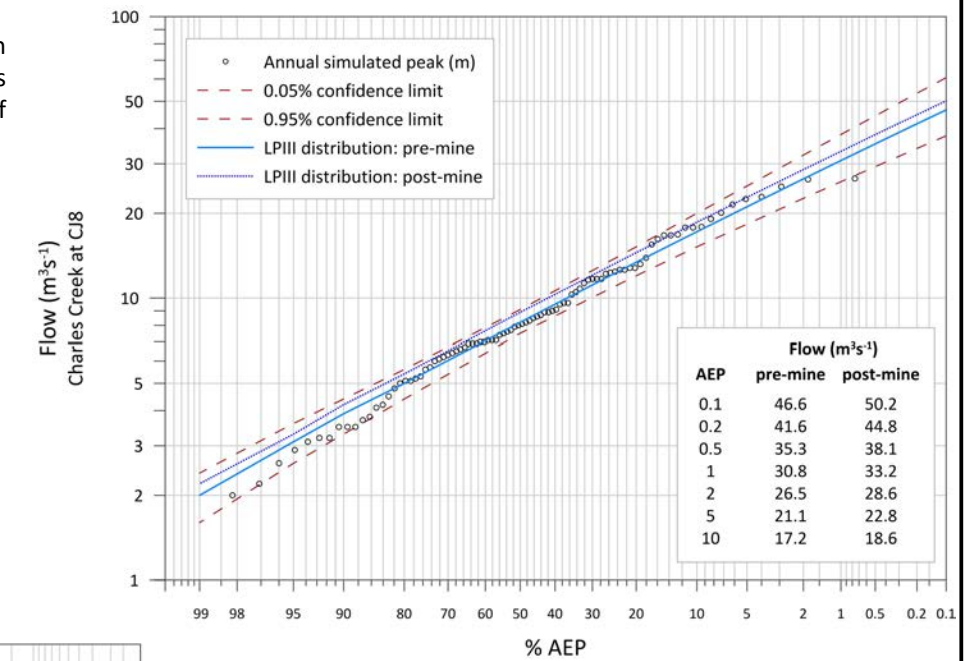
**Above:** The Charles Creek catchment below the Quest 29 South precinct and the CAESAR-Lisflood model domain with stream reaches. The LP3 distributions were determined at the nodes shown above.

**Right:** Log Pearson distribution pre- and post-mine expansion at Junction CJ9 in the lower third of the Charles Creek catchment. There is a decrease in total discharge of -0.6% in the post-mine expansion scenario.

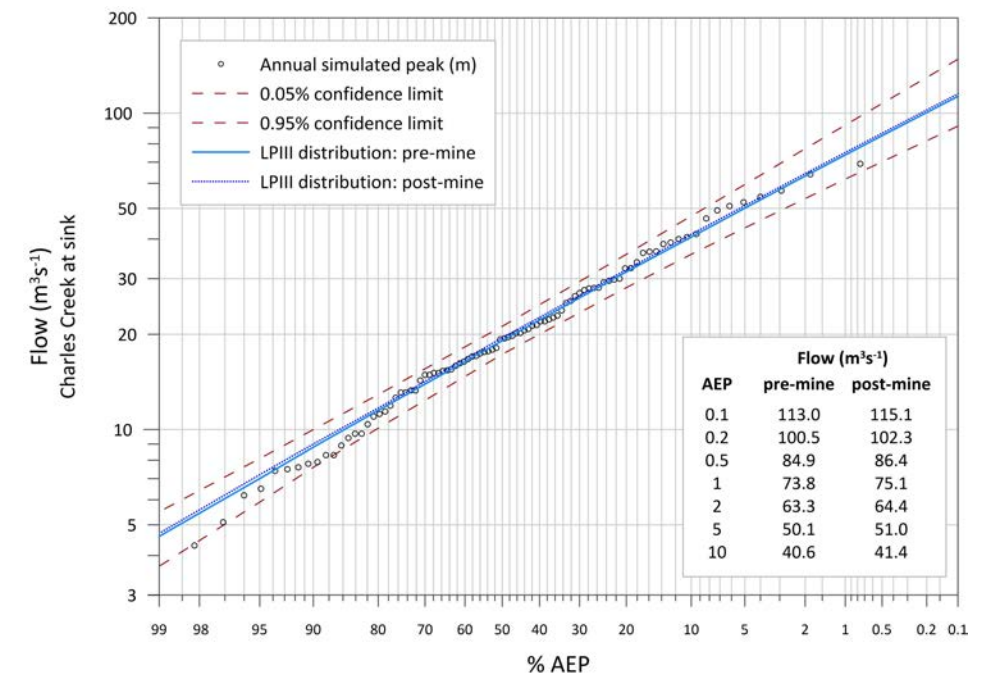
- Q29S mine precinct
- HEC\_HMS nodes
- Charles Creek Catchment/ CAESAR-Lisflood domain
- McKinley River
- Charles Creek reaches.



**Right:** Log Pearson distribution pre- and post-mine redevelopment at the Charles Creek outlet at the confluence with the McKinley River. There is a decrease in total discharge of -0.3% in the post-mine expansion scenario.



**Left:** Log Pearson distribution pre- and post-mine expansion at Junction CJ5 in the lower third of the Charles Creek catchment. There is a decrease in total discharge of -0.4% in the post-mine expansion scenario.



**Notes**

1. This is an assessment of changes in hydrology of the Charles Creek catchment due to the Quest 29 redevelopment in the upper catchment using the HEC-HMS model.
2. A 91-year simulation was conducted from 2030 applying climate change using the RCP 4.5 model.
3. A log-Pearson 3 distribution was created using the annual peak discharges for the pre- and post-mining condition at HEC-HMS junctions down the catchment using the 91-year simulation data.
4. The results indicate that there is a decrease in the long term total flows, with the amount of reduction reducing downstream. There is a 0.3% decrease in total flow at the Charles Creek and McKinley River confluence for the post-redevelopment condition.
5. The Nash-Sutcliffe statistic (Table right) indicates no significant difference between pre- and post-redevelopment.

Drawing No  
CC-02

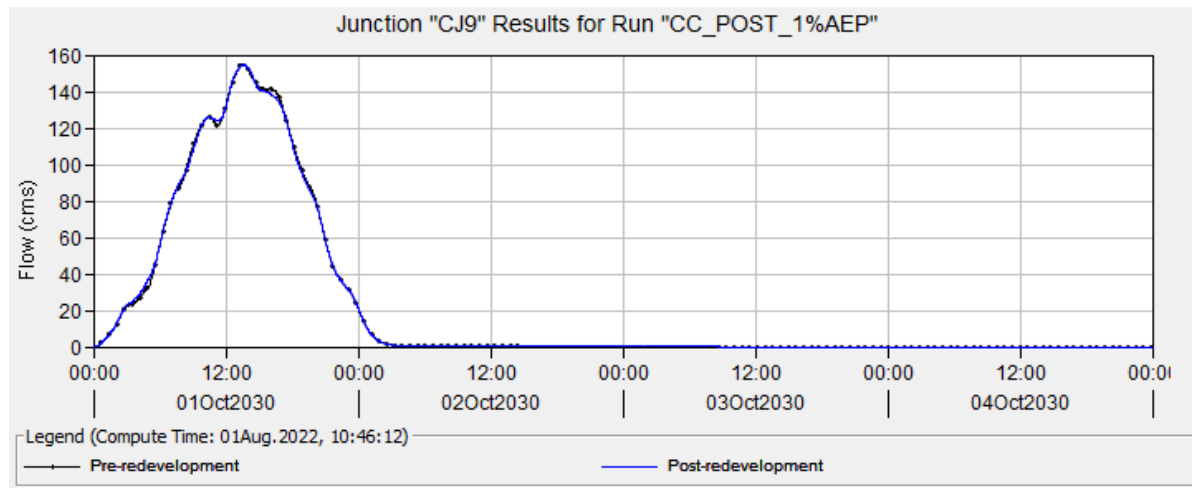
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



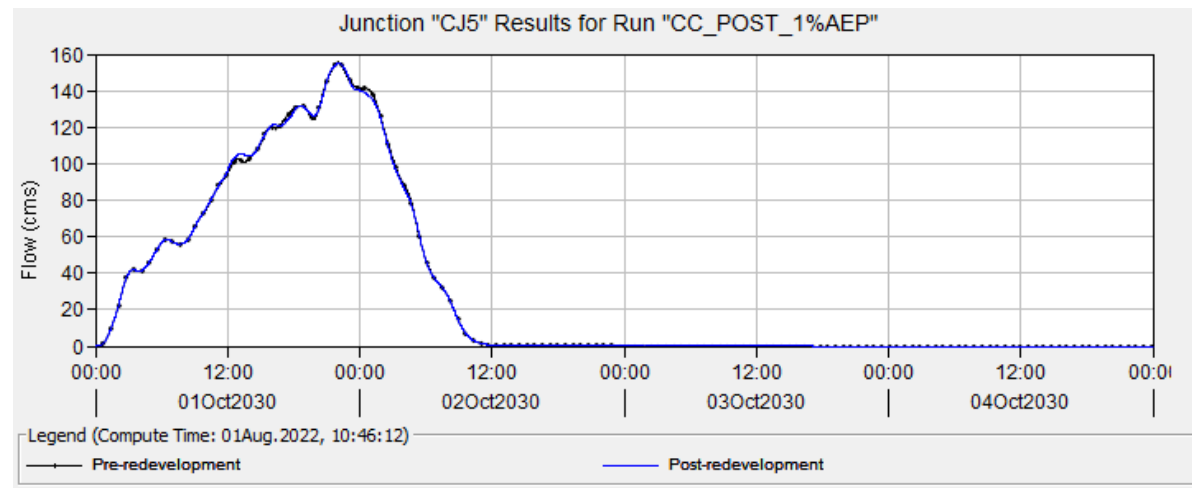
Project **Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title **Charles Creek Catchment Hydrology**  
Pre- & Post-mining - Longterm Flow  
regime comparison

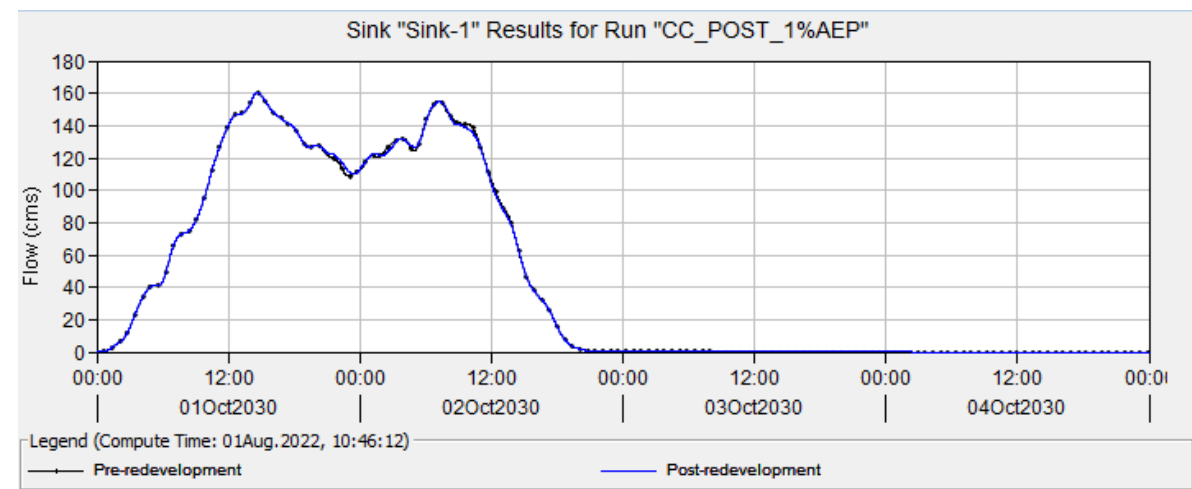
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Above: The pre- and post-redevelopment discharges for the 1% AEP event entering the CAESAR-Lisflood model domain from the outlet of the Quest 29 mine precinct. There is little difference between discharge with NSS = 1.

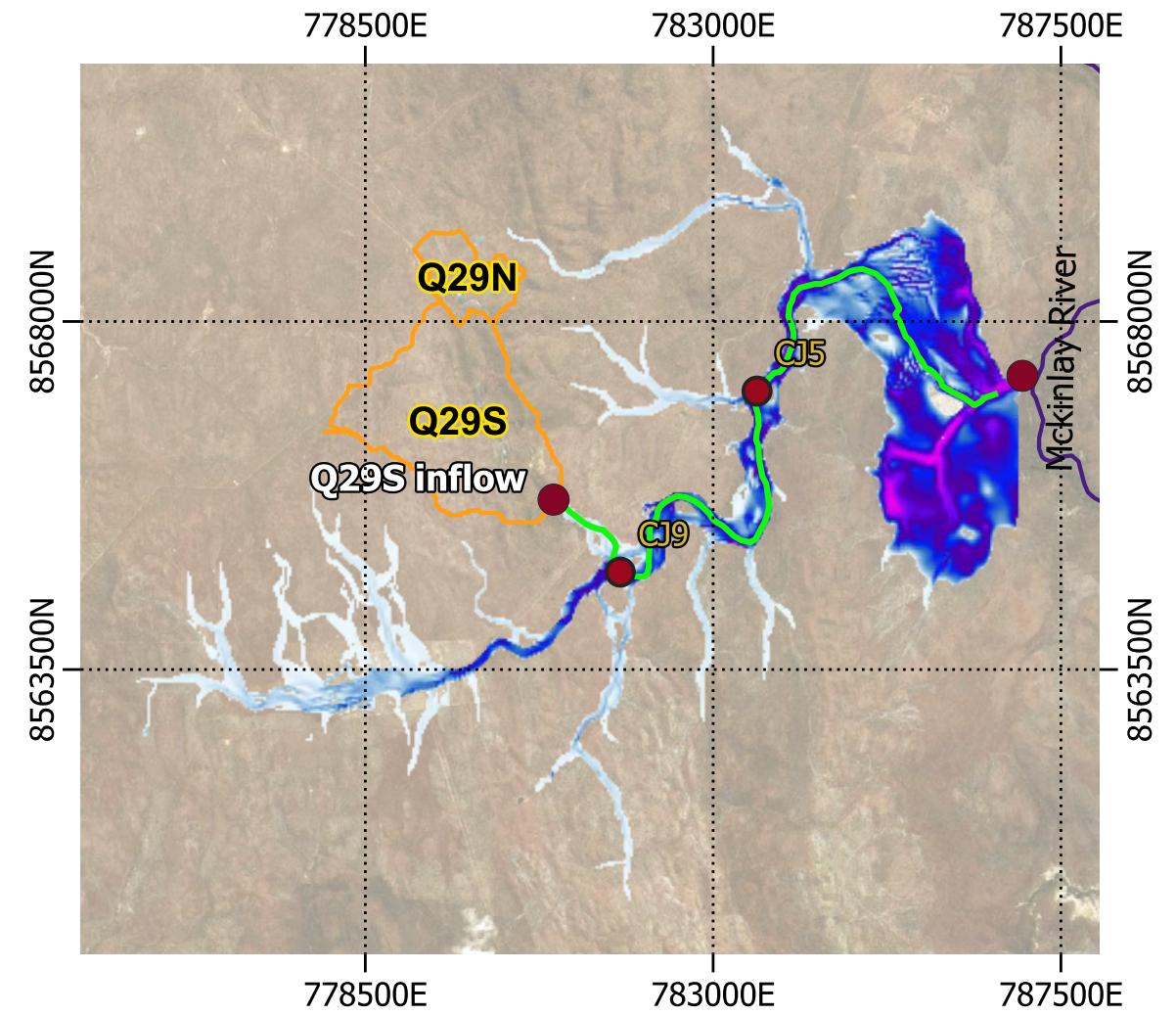


Above: The pre- and post-redevelopment discharges for the 1% AEP event CJ5 (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.



Above: The pre- and post-redevelopment discharges for the 1% AEP event at the catchment outlet (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.

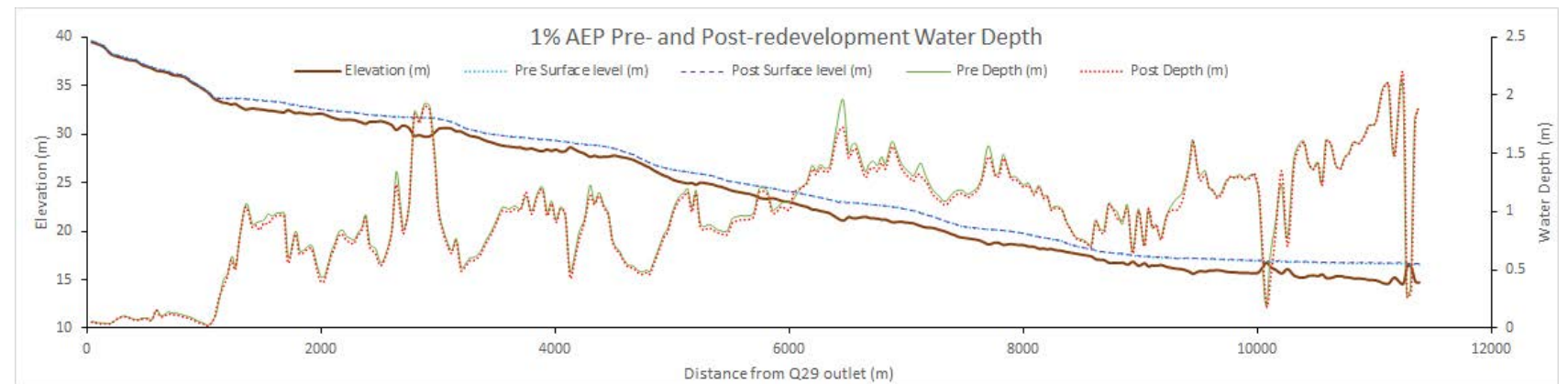
- Charles Creek Thalweg
- HEC-HMS Junction
- Mary River
- Q29 catchments
- Water depth
- █ 2.5 m
- █ 0.002 m



Above: Post-redevelopment 1% AEP flood water levels. Q29N debouches into Mt Bunday Creek to the north.

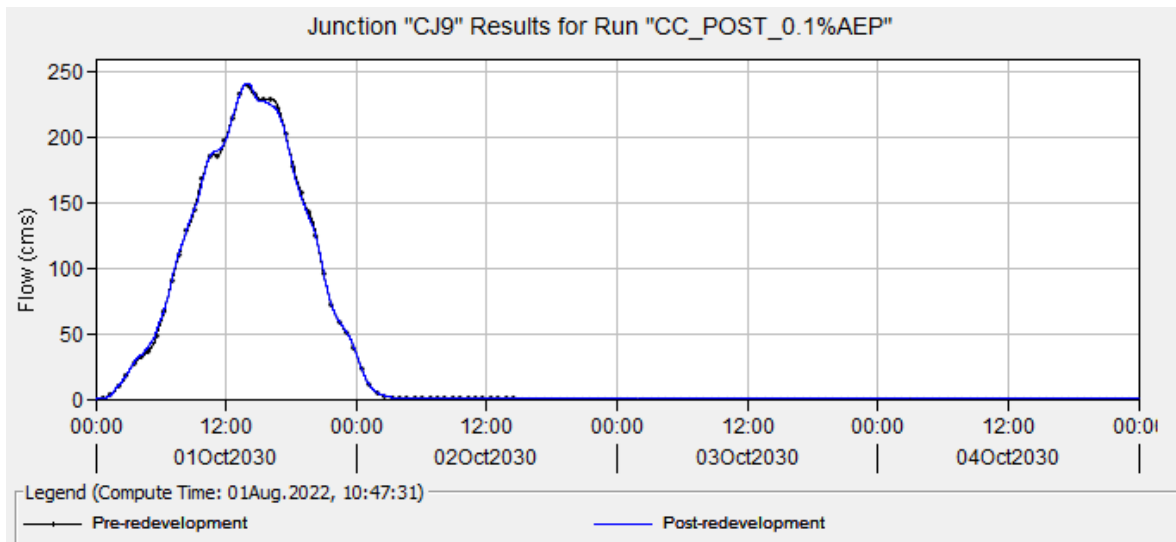
Notes

1. The simulations were conducted using the Lisflood model embedded in the CAESAR-Lisflood hydro-geomorphic model in reach mode and catchment mode.
2. The simulations show no evidence of significant change in flood levels for the 1% AEP rainfall event.

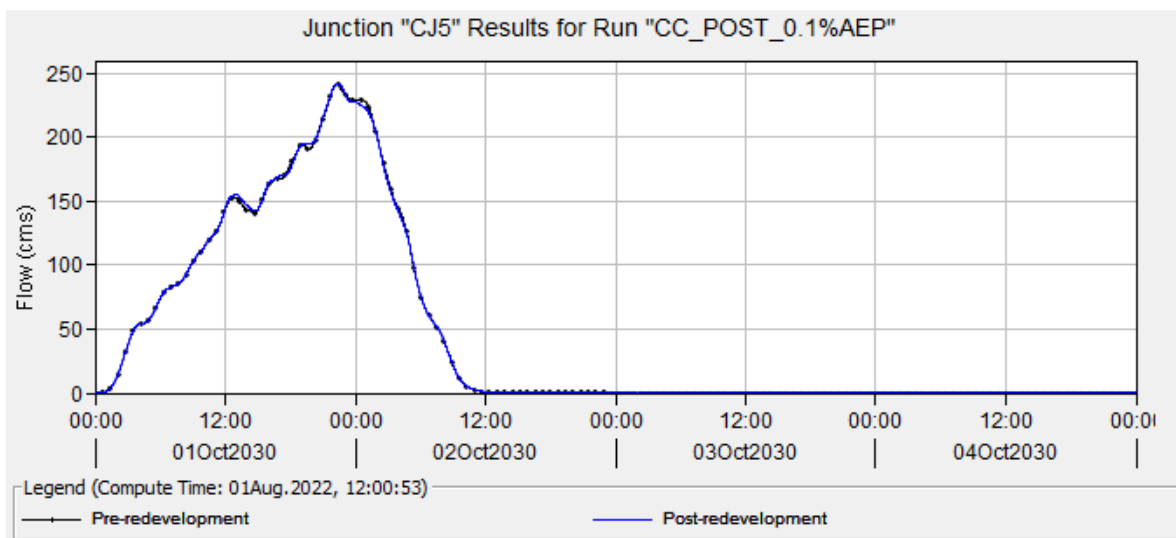


Above: Section along the thalweg of Charles Creek (see map above) from Q29 outlet (left) to near confluence with McKinley River (right). There is little difference between pre- and post- with the average difference in depth of the post-redevelopment event = -0.024 m.

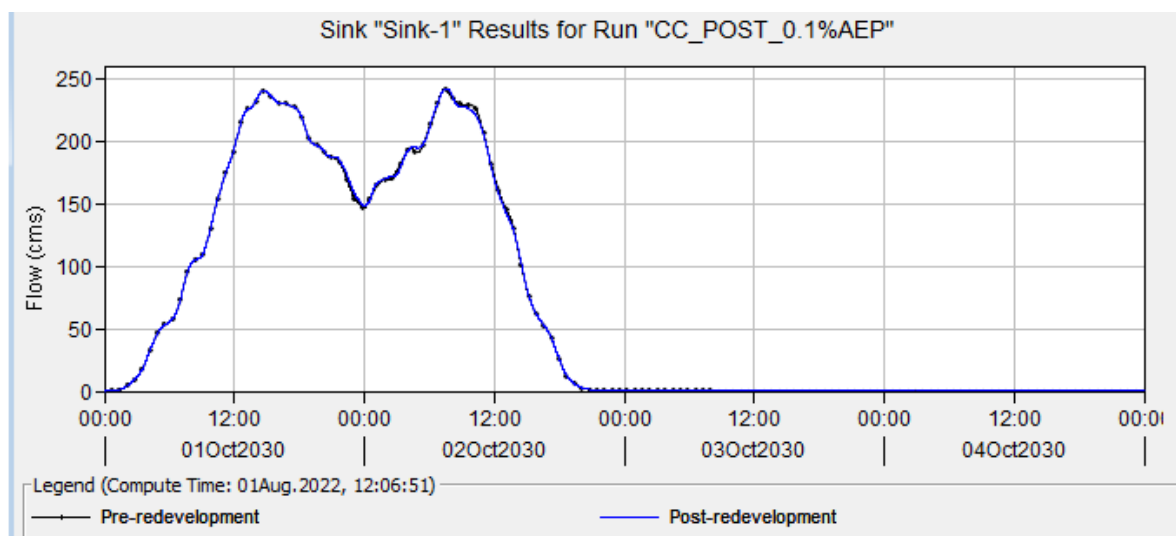
Drawing No CC-03	 SURFACE WATER & EROSION SOLUTIONS ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT	Project Rustler's Roost & Q29 EIS Supplementary Information	Title Charles Creek: Pre- and Post-Redevelopment 1% AEP Rainfall Event Water Depths	Designed	Drawn	Checked	Sheet size
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				Date			Sheet No. 3
				18/05/2022			Sheet 3 of 7



Above: The pre- and post-redevelopment discharges for the 0.1% AEP event entering the CAESAR-Lisflood model domain from the outlet of the Quest 29 mine precinct. There is little difference between discharge with NSS = 1.

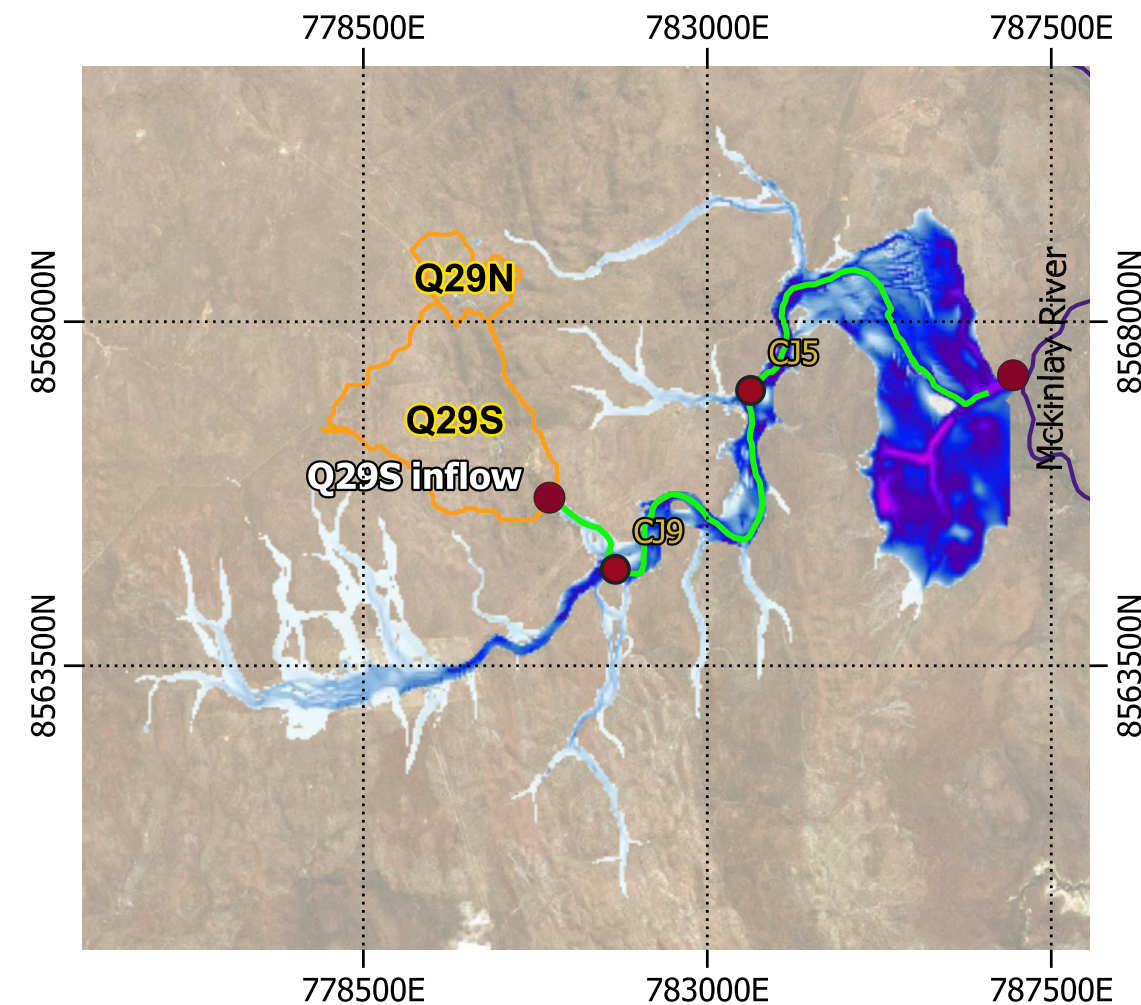


Above: The pre- and post-redevelopment discharges for the 0.1% AEP event CJ5 (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.



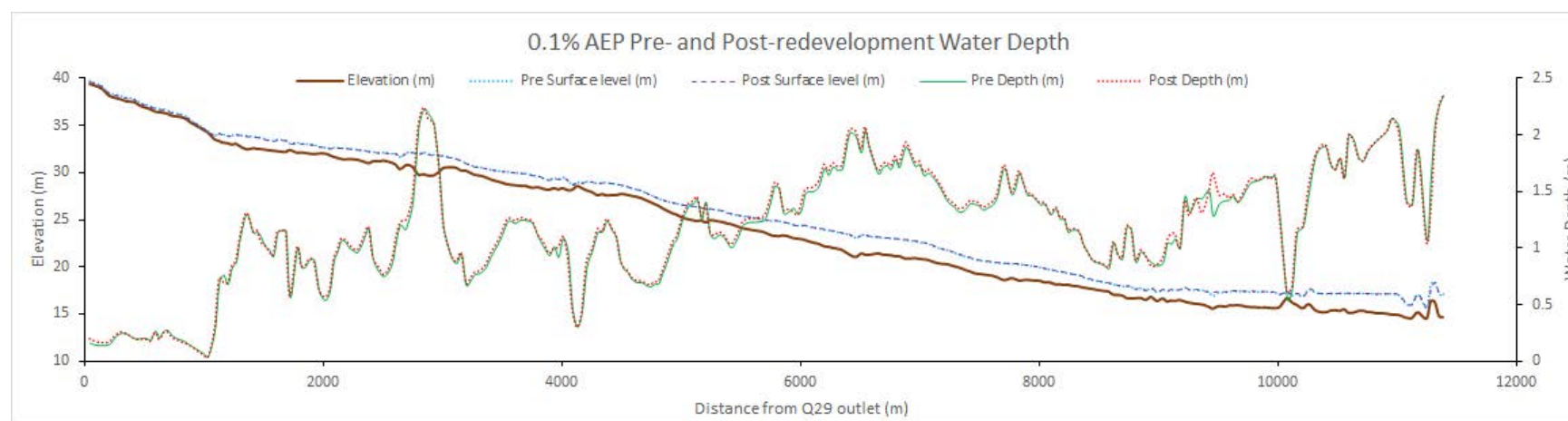
Above: The pre- and post-redevelopment discharges for the 0.1% AEP event at the catchment outlet (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.

- Charles Creek Thalweg
- HEC-HMS Junction
- Mary River
- Q29 catchments
- Water depth
- 2.5 m
- 0.002 m

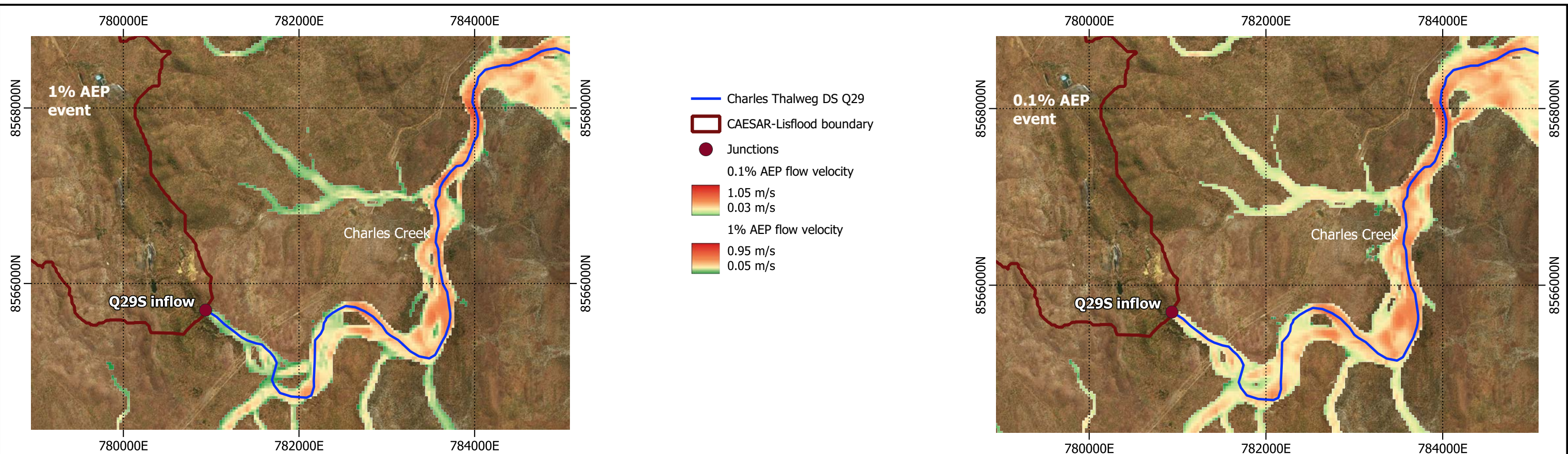


Above: 0.1% AEP flood inundation in Charles Creek between the Q29S outlet and the McKinley River confluence.

1. The simulations were conducted using the Lisflood model embedded in the CAESAR-Lisflood hydro-geomorphic model in reach mode and catchment mode to obtain water depth and HEC-HMS to obtain the design hydrographs.
2. The simulations show no evidence of significant change in flood levels for the 0.1% AEP rainfall event.

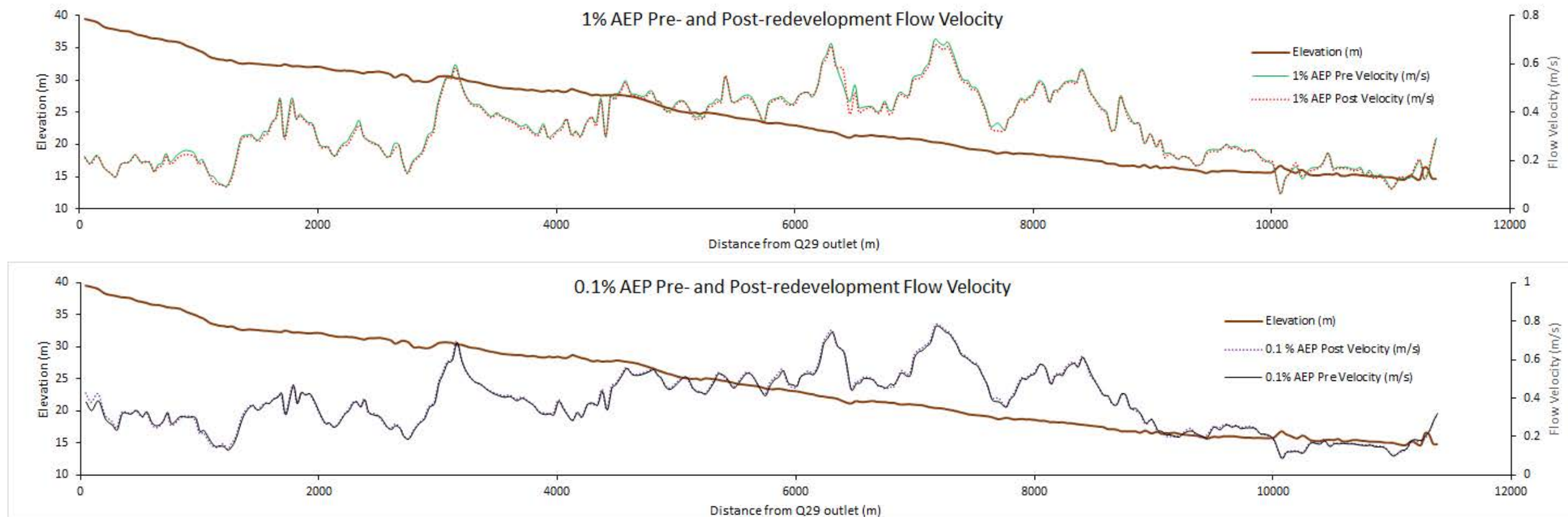


Above: Section along the thalweg of Charles Creek (see maps right) from Q29 outlet (left) to near confluence with McKinley River (right). There is little difference between pre- and post- with the average difference in depth of the post-redevelopment event = -0.023 m.



Above: Stream flow velocities resulting from the 1% AEP rainfall event in Charles Creek downstream of Quest 29. There is little difference between pre- and post- conditions.

Above: Stream flow velocities in Charles Creek downstream of Quest 29 for the 0.1% AEP rainfall event determined using the Lisflood hydraulic model. There is little difference between the pre- and pro- conditions.

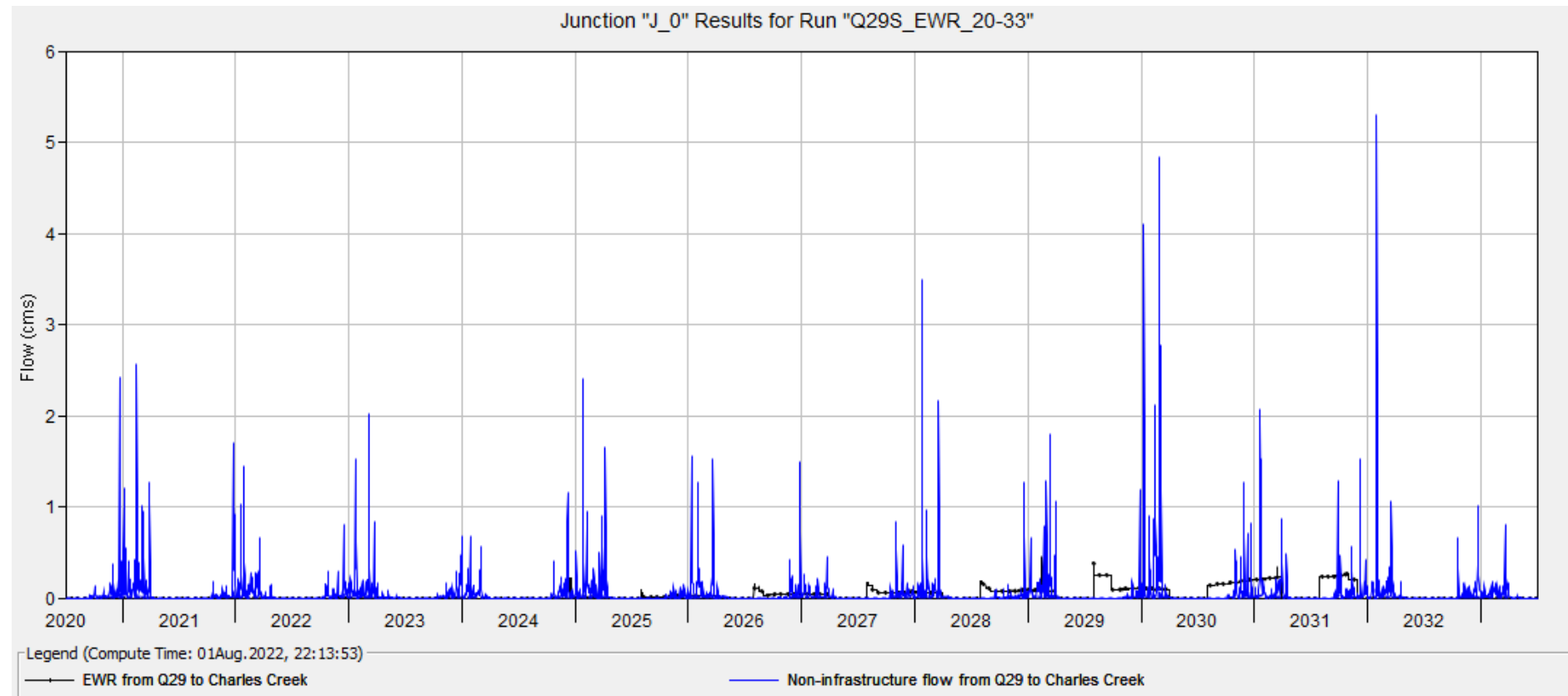


Above: Section along the thalweg of Charles Creek (see maps above) from Q29 outlet (left) to near confluence with McKinley River (right). There is little difference pre- and post-, with the average difference in velocity of the post-redevelopment event = -0.01 m/s.

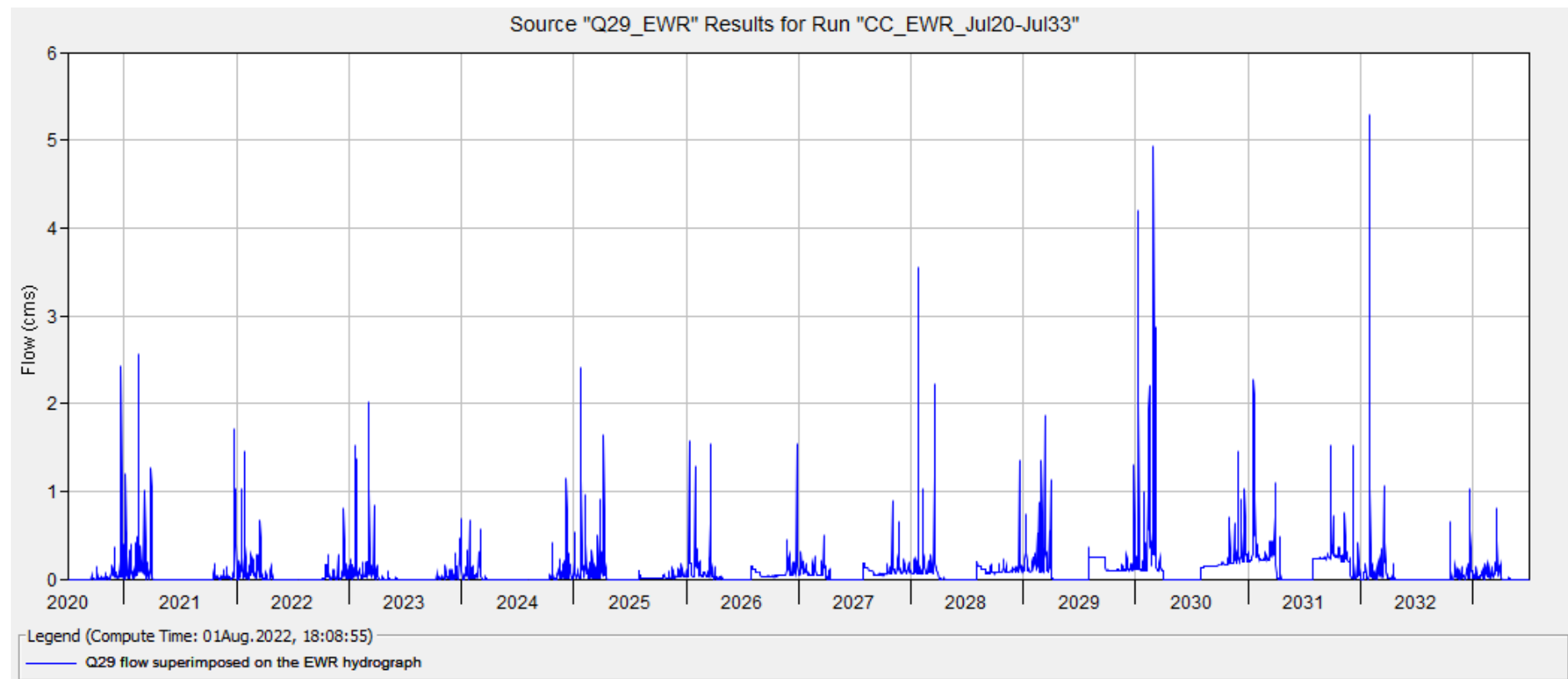
Drawing No CC-05	 ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT	Project Rustler's Roost & Q29 EIS Supplementary Information	Title Charles Creek: Pre- and Post-Redevelopment 1% AEP & 0.1% AEP Flow Velocities.	Designed	Drawn	Checked	Sheet size
					KGE	DRM	A3
				Date			Sheet No. 5
				18/05/2022			Sheet 5 of 7



Above: Extract of Q29S HEC-HMS model (Drawing CC-01) showing the mine infrastructure catchment with environmental water release (EWR) to Charles Creek. The EWR is covers water released from the mine infrastructure to Charles Creek between 1 July 2020 to 1 July 2033 (life-of-mine). The mine site infrastructure will vary in size so the simulation comprises input from the EWRs and rainfall runoff from the area of the infrastructure catchment where no infrastructure are located.

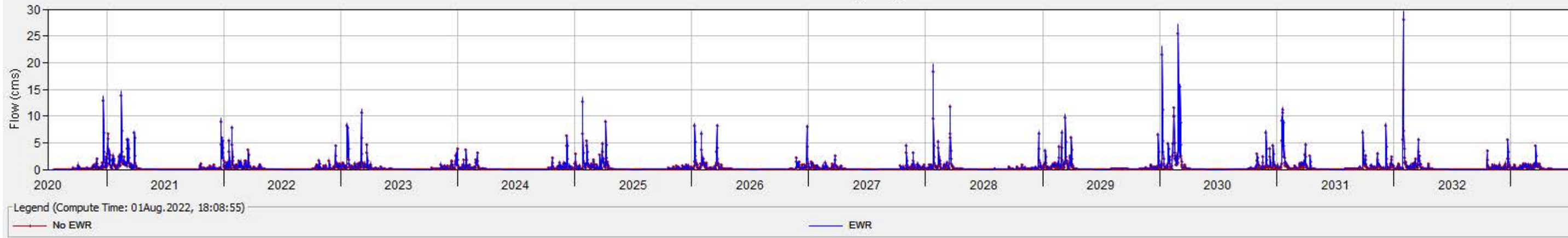


Above: Discharge from the Rustler's Roost mine infrastructure catchment. The top panel shows the rainfall sequence during LOM with rainfall losses. The bottom panels shows the discharge resulting from the rainfall from only that area where there is no infrastructure. The EWR is shown separately from the rainfall discharge.

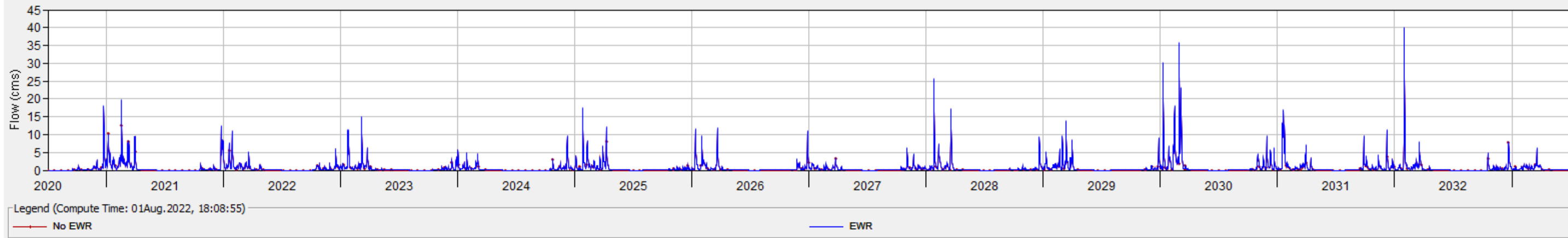


Above: Combined rainfall runoff discharge and EWR as input to J26 of the HEC-HMS model. Annual peak discharges have increased slightly relative to the Mt Bunday Creek catchment.

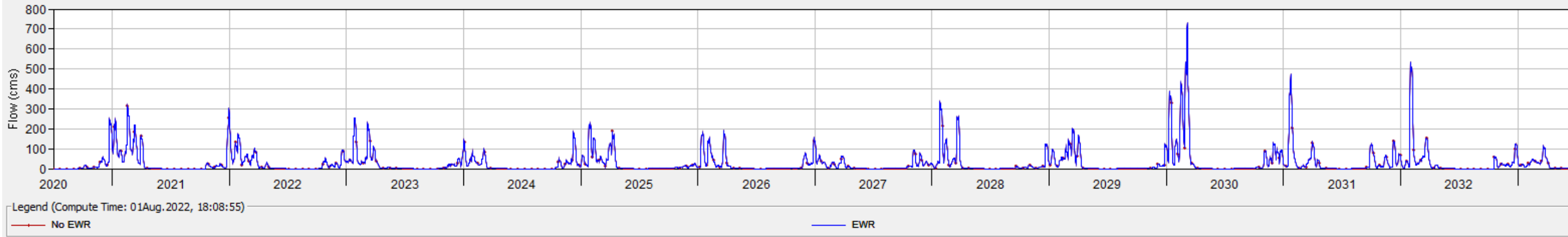
Junction "CJ9" Results for Run "CC\_EWR\_Jul20-Jul33"



Junction "CJ5" Results for Run "CC\_EWR\_Jul20-Jul33"

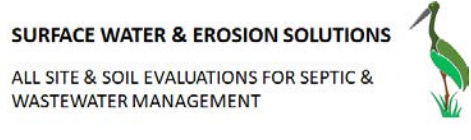


Charles Creek - McKinley River Confluence



Above. Charles Creek HEC-HMS model hydrographs for environment water releases from the Quest 29 mining precinct compared with no environmental water releases. There is little difference in EWR and No EWR hydrographs as they progress downstream.

Drawing No  
CC-07

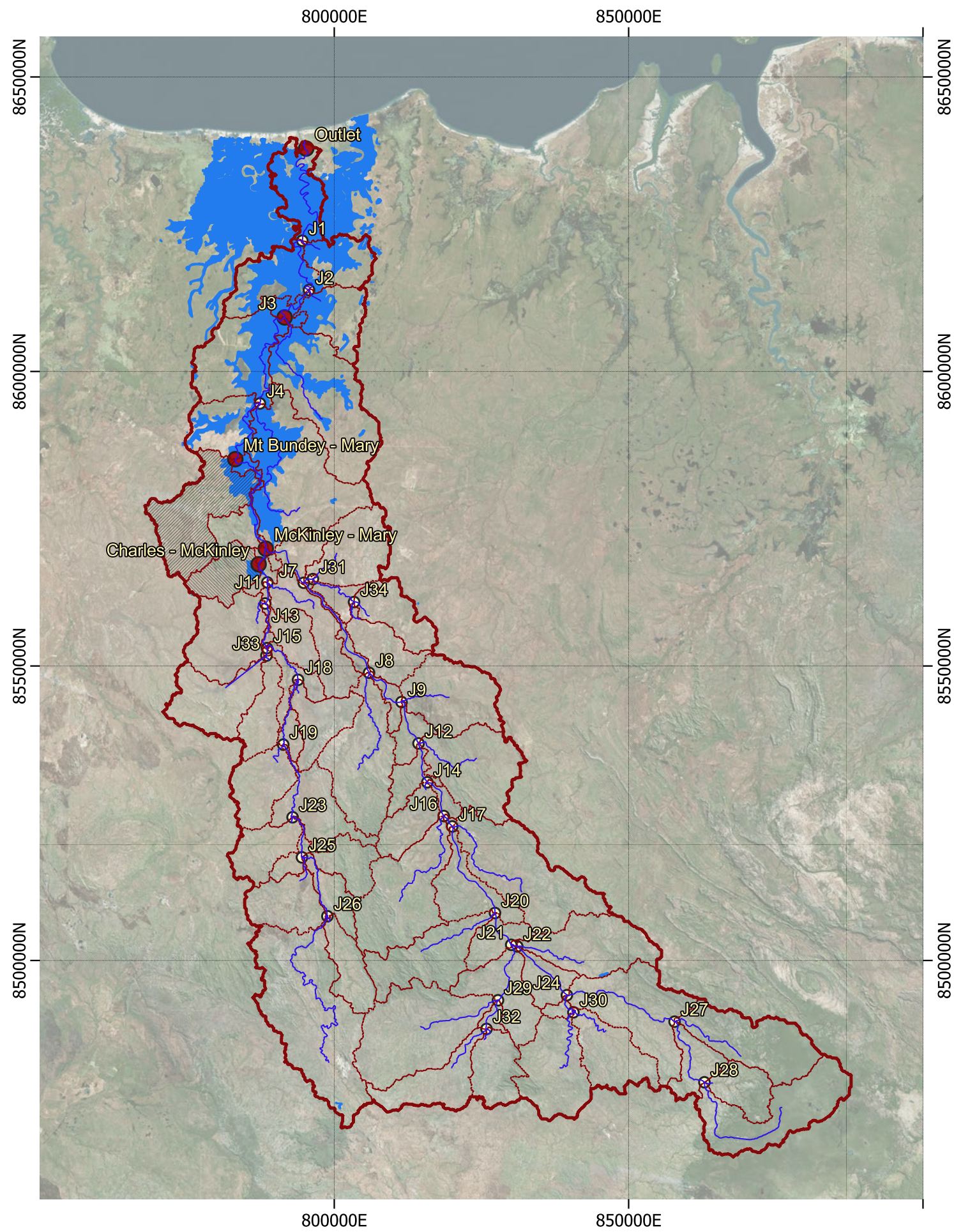


Project  
Rustler's Roost & Quest 29  
EIS Supplementary  
Information

Title  
Quest 29 Environmental Water Releases to  
Charles Creek: HEC-HMS Hydrographs at  
selected sections

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	KGE	DRM	A3
Date		Sheet No. 7	
26/06/2022		Sheet 7 of 7	

## **Mary River**



- Mary River Inundation
- HEC-HMS reach
- HEC-HMS junction
- Analysis junction
- ⋯ HEC\_HMS Basin
- ▨ Mt Bunday Catchment
- ▩ Charles Creek Catchment

Left: Mary River whole-of-catchment model showing HEC-HMS components and the location of analysis junctions. The blue inundation area is Northern Territory Government data. It gives an indication of what areas may be inundated.

Drawing No  
MR-01

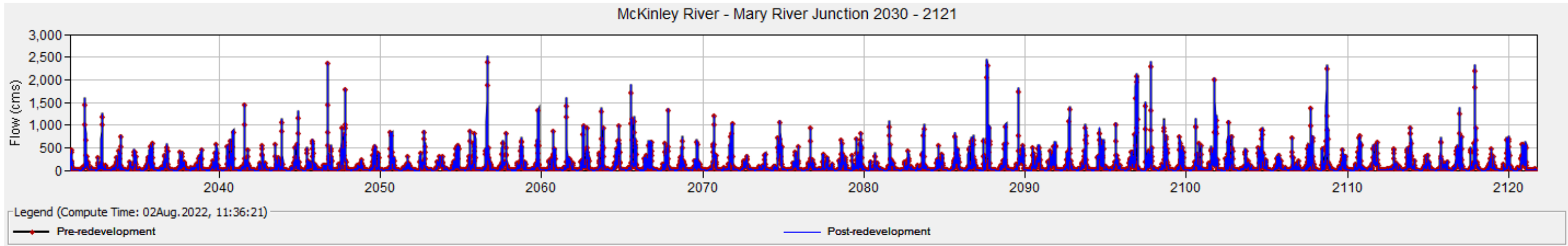
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC &  
WASTEWATER MANAGEMENT



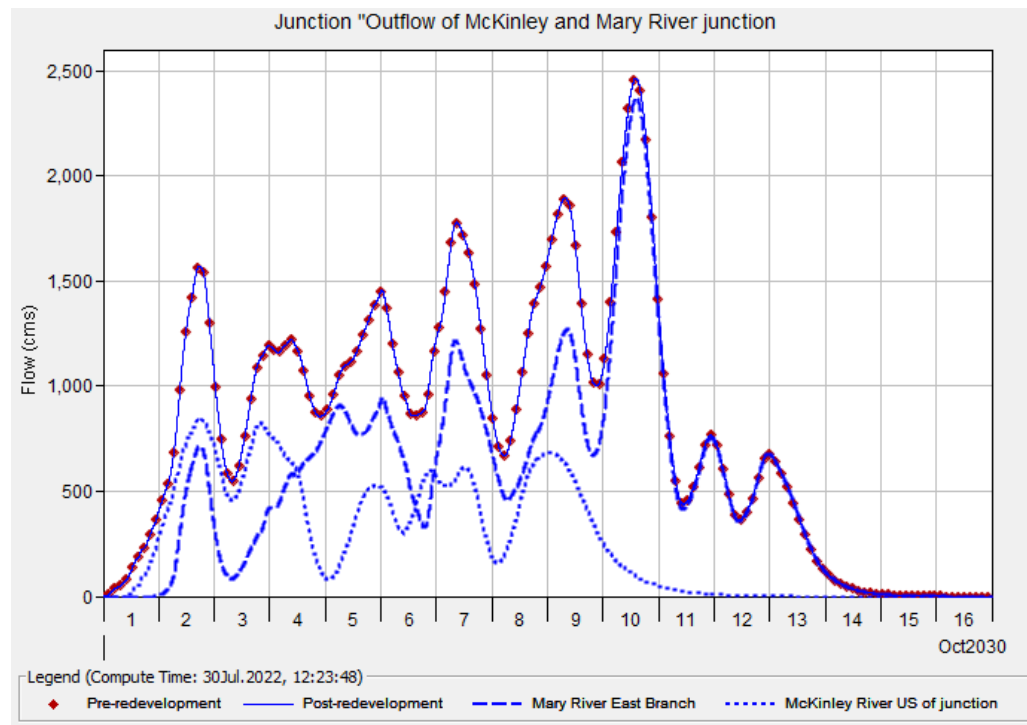
Project **Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title **Mary River Whole-of-Catchment**  
HEC-HMS Model

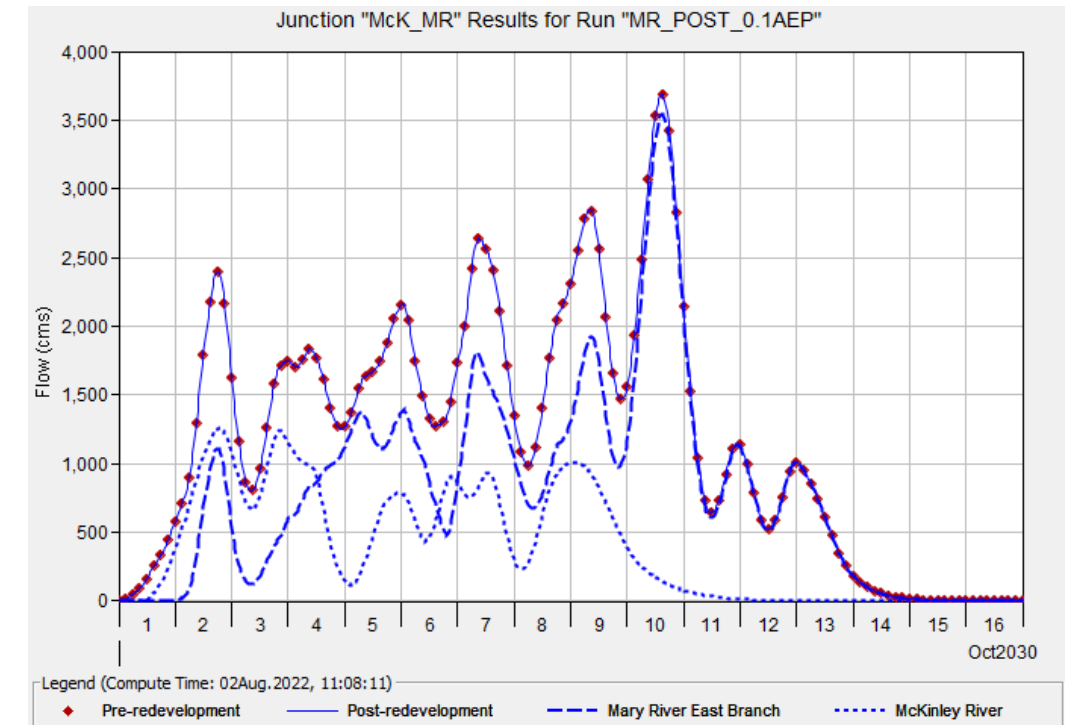
Designed	Drawn	Checked	Sheet size
	KGE	DRM	A3
Date		Sheet No. 1	
26/06/2022		Sheet 1 of 3	



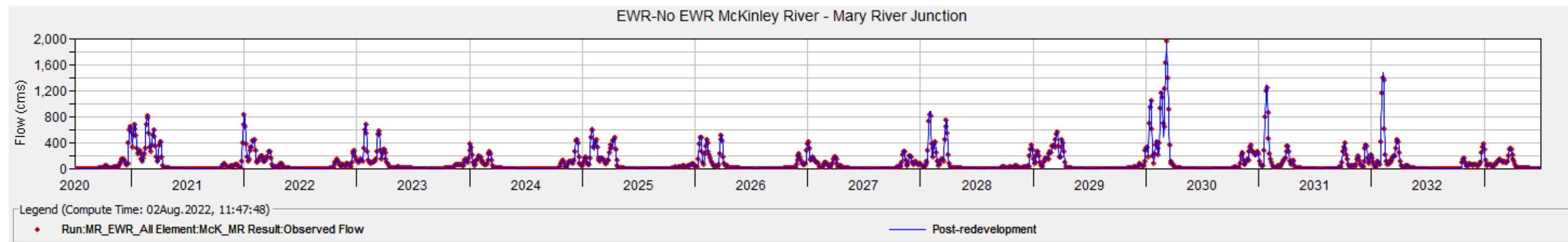
Above: Mary River whole-of-catchment model for 2030 to 2121 comparison of pre- and post-redevelopment condition at the McKinley-Mary River confluence. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.



Left: The 1% AEP event comparison of pre- and post-redevelopment condition McKinley-Mary River confluence. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.



Right: The 0.1% AEP event hydrograph comparison of pre- and post-redevelopment condition at McKinley-Mary River confluence. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.



Above: EWR hydrograph no EWR hydrograph at McKinley-Mary River confluence. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.

Drawing No  
MR-02

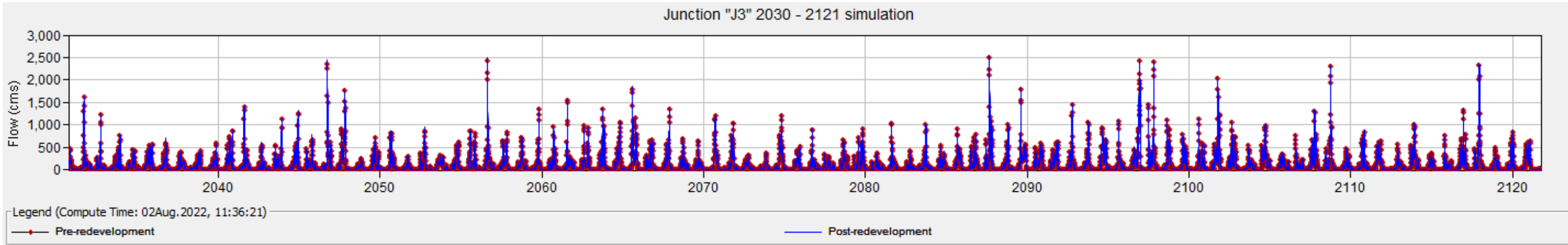
**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



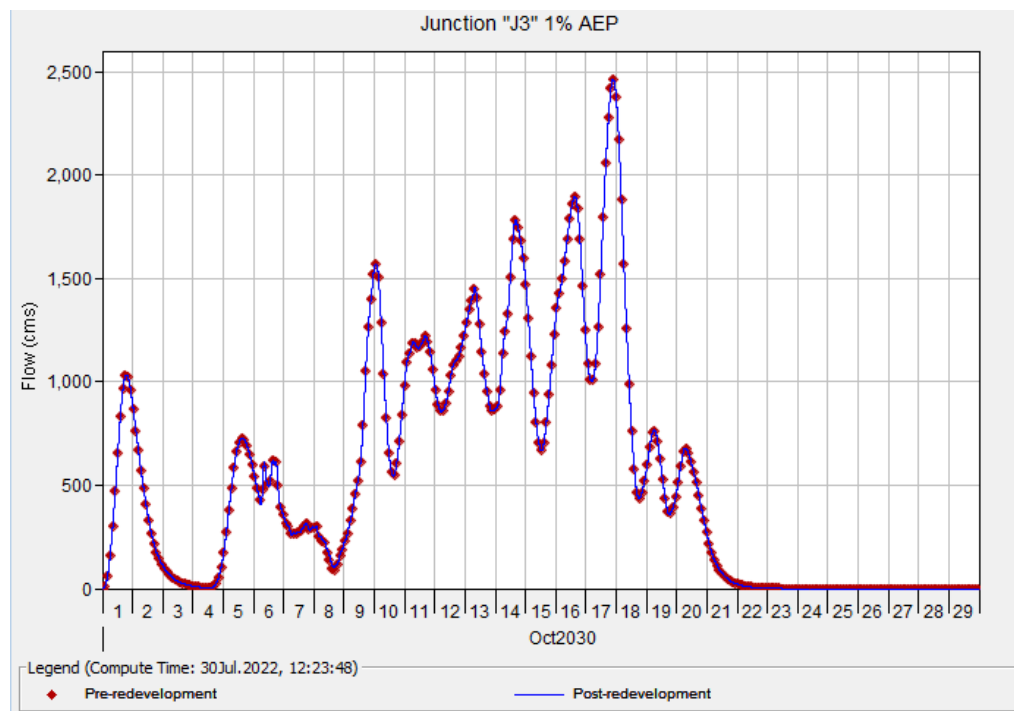
Project **Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title **Mary River Whole-of-Catchment HEC-HMS**  
Model Hydrographs McKinley R. & Mary  
R. Confluence

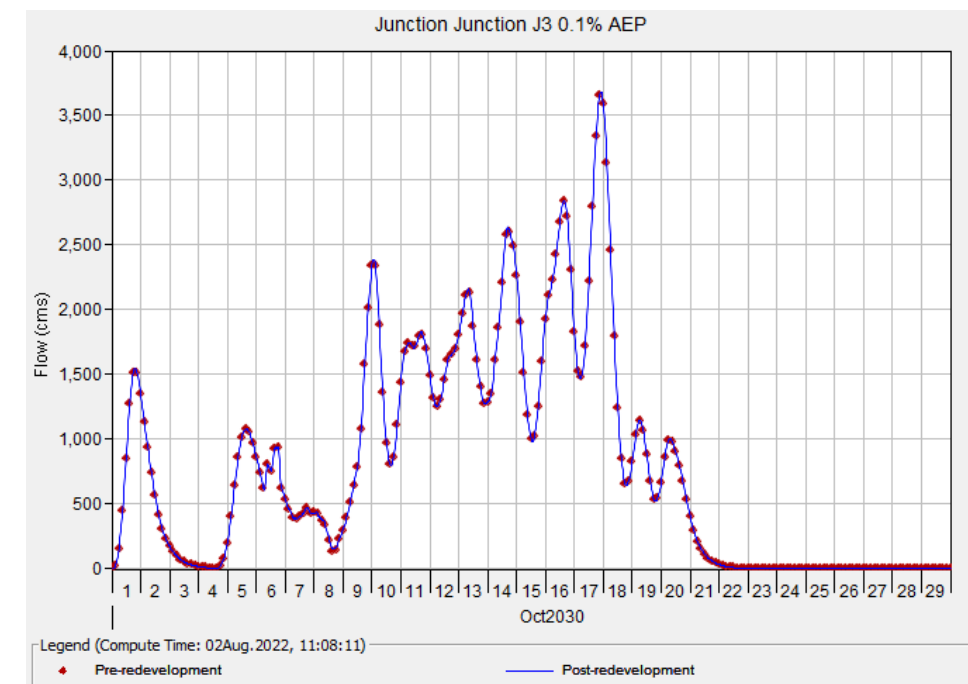
Designed	Drawn	Checked	Sheet size
	KGE	DRM	A3
Date	26/06/2022		Sheet No. 2
			Sheet 2 of 3



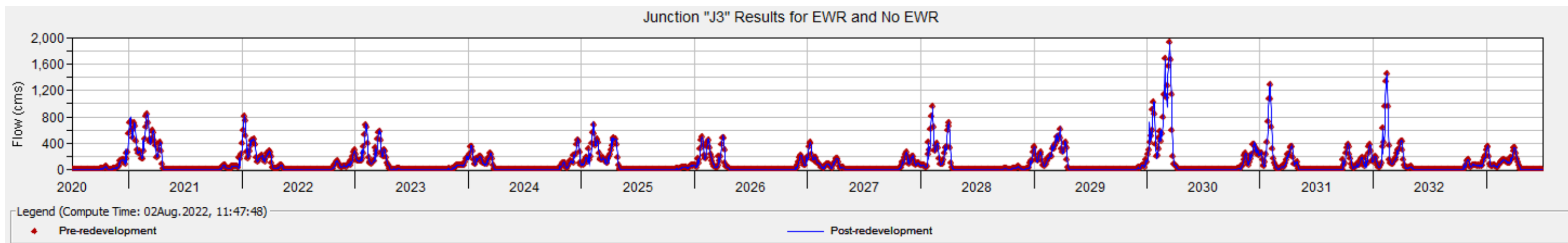
Above: Mary River whole-of-catchment model for 2030 to 2121 comparison of pre- and post-redevelopment condition at Junction 3 on the lower Mary River floodplain. Visually there is no difference between pre- and post-redevelopment flows and the Nash-Sutcliffe statistic = 1.0.



Left: The 1% AEP event hydrograph comparison of pre- and post-redevelopment condition at Junction 3. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.



Right: The 0.1% AEP event comparison of pre- and post-redevelopment condition at Junction 3. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.



Above: EWR no EWR hydrographs at Junction 3 on the floodplain. Visually there is no difference and the Nash-Sutcliffe statistic = 1.0.

Drawing No  
MR-03

**SURFACE WATER & EROSION SOLUTIONS**  
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT

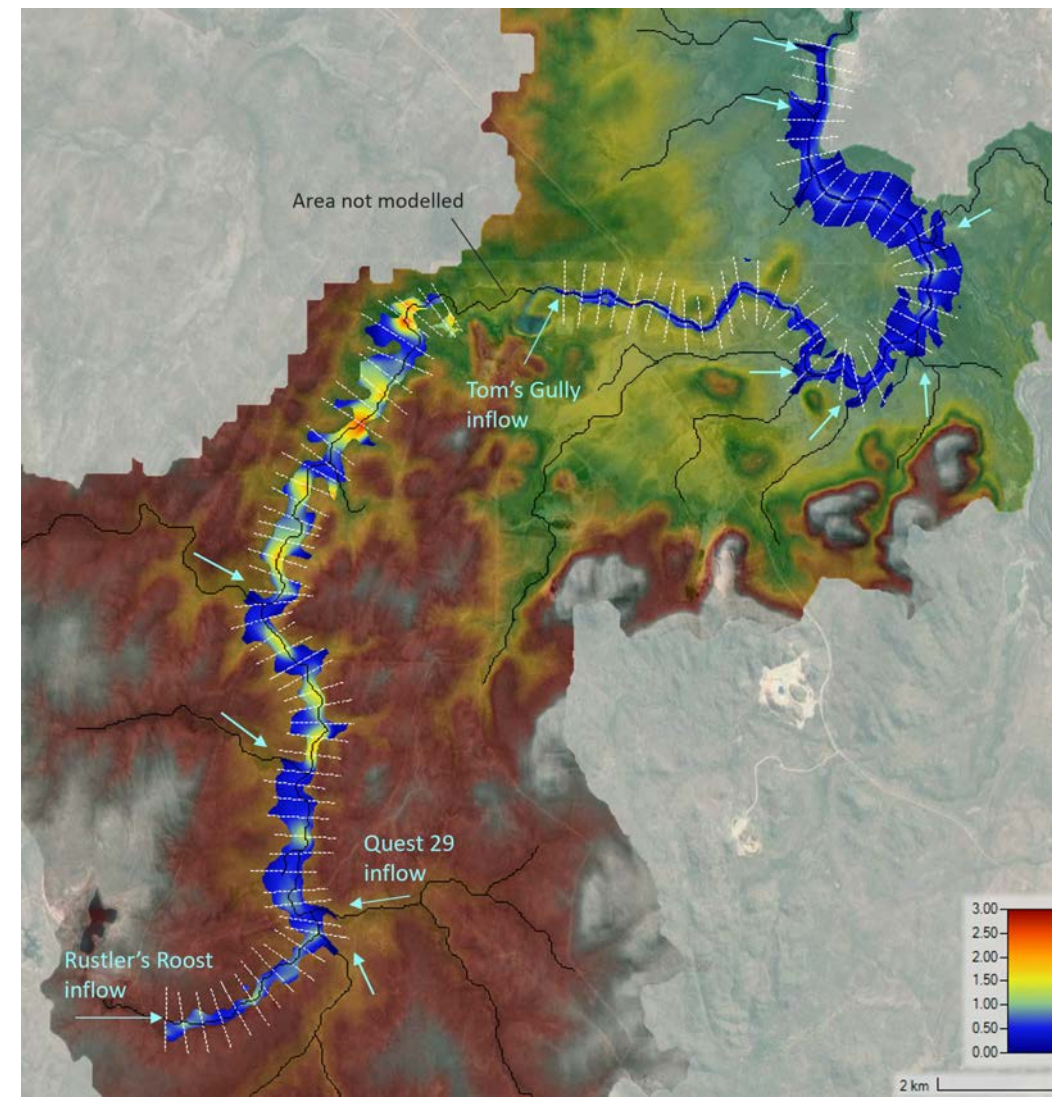
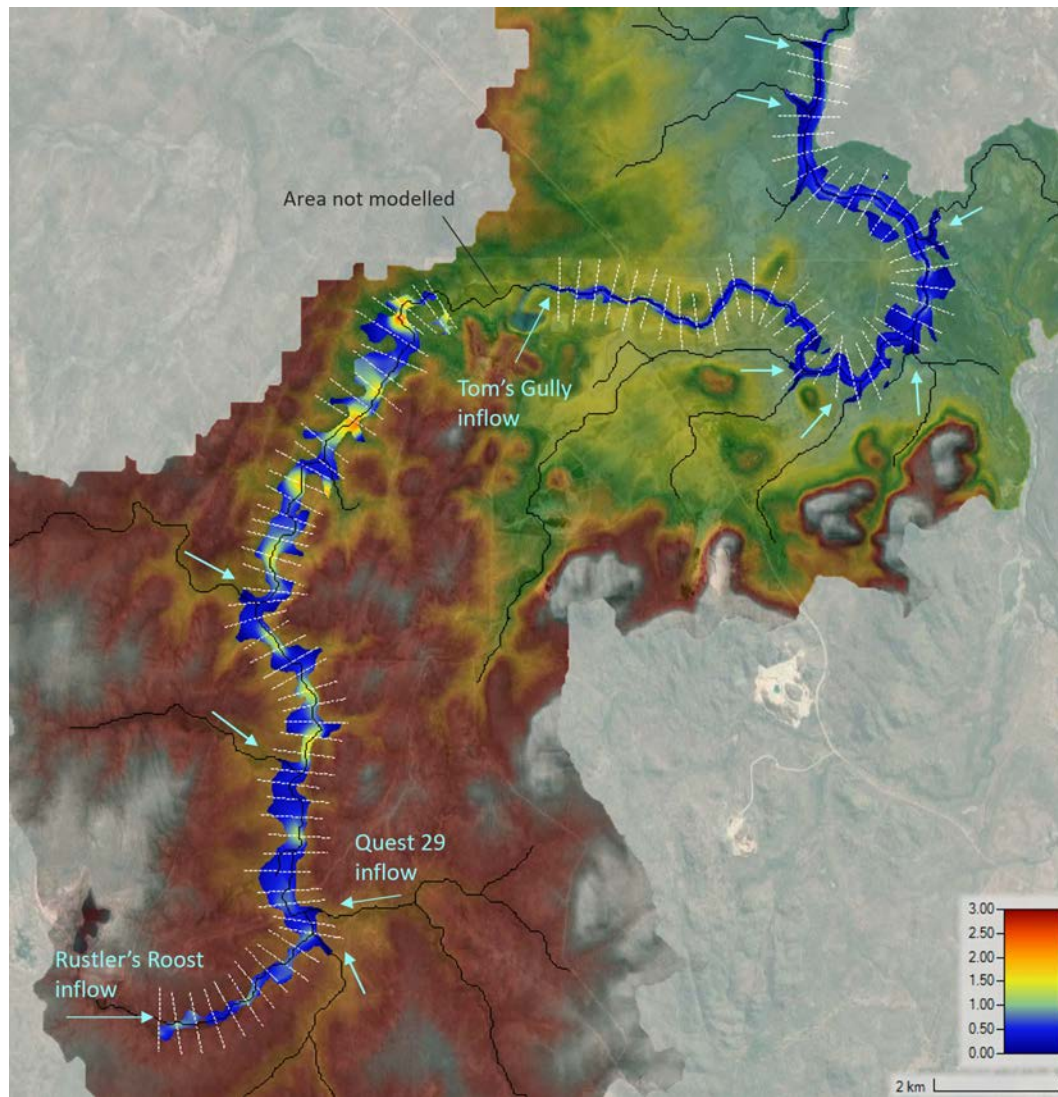


Project **Rustler's Roost & Quest 29**  
EIS Supplementary  
Information

Title **Mary River Whole-of-Catchment HEC-HMS**  
Model Hydrographs at Junction 3 on the  
floodplain

Designed	Drawn	Checked	Sheet size
	KGE	DRM	A3
Date		Sheet No. 3	
26/06/2022		Sheet 3 of 3	

# Water Quality



**Figure 1.** Maximum velocities within the main channel of Mt Bunday Creek during a 1% AEP (left) and a 0.1% AEP (right) rainfall event. White dashed lines are the cross sections used in the HEC-RAS 1-D model. Blue arrows indicate inflows into the main channel from major tributaries. Metal concentrations in these tributaries are assumed to be 0 mg/L.

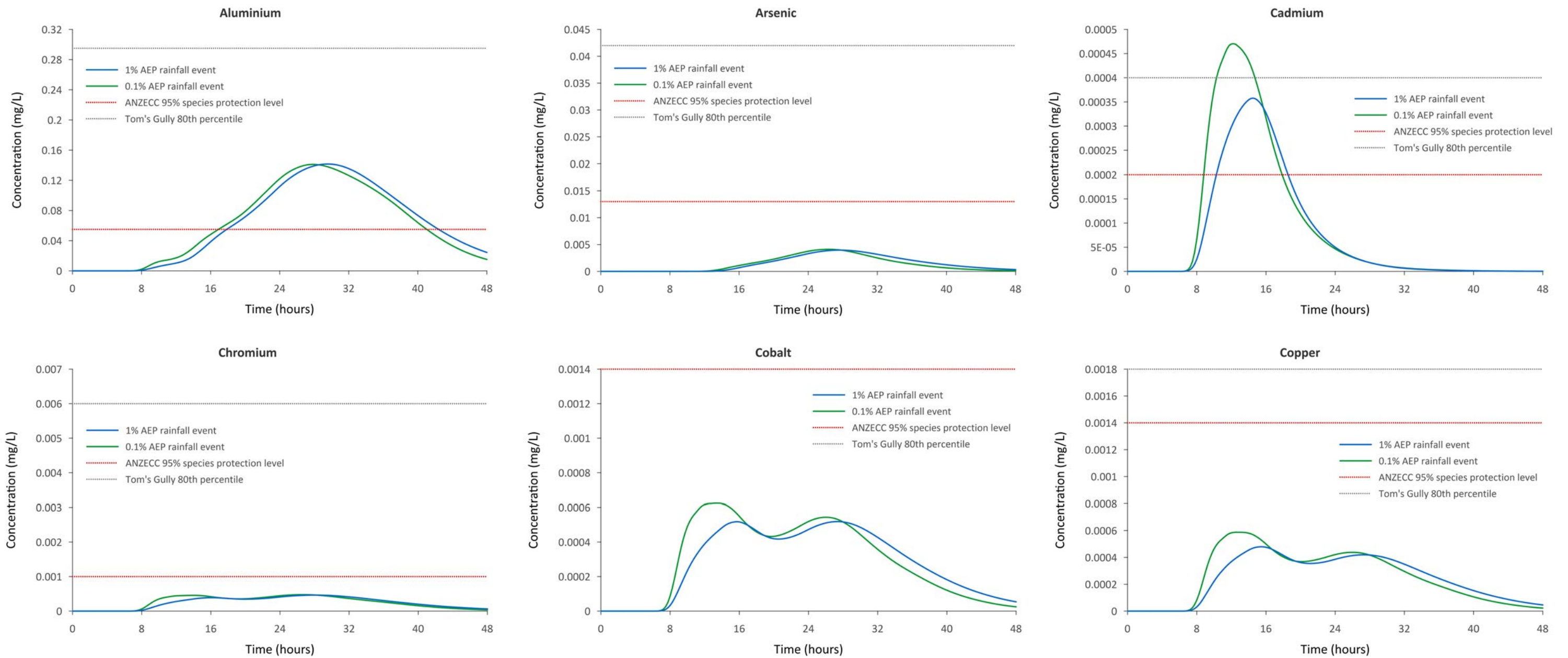
Contaminant concentrations (mg/L)					
Metal	Inflow from Rustler's Roost	Inflow from Quest 29	Inflow from Tom's Gully	Trigger value: Tom's Gully 80 <sup>th</sup> percentile (SSTV)	Trigger values: ANZECC 95% species protection
Aluminium	0.3954	0.4900	14.0	0.2950	0.0550
Arsenic	0.0350	0.0005	0.0050	0.0420	0.0130
Cadmium	0	0	0.4300	0.0004	0.0002
Chromium	0.0023	0.0010	0.4000	0.0060	0.0010
Cobalt	0.0036	0.0005	0.5600	0.0014	0.0014
Copper	0.0027	0.0005	0.5300	0.0018	0.0014
Iron	1.9958	0.9800	1.4200	2.7	0.3000
Manganese	0.5153	0.0260	7.6000	2.5	1.9000
Nickel	0.0017	0.0005	1.1200	0.0130	0.0110
Lead	0.0007	0.0020	0.4000	0.0056	0.0034
Zinc	0.0448	0.0020	4.4800	0.0150	0.0080
FSS*	128	54	1	87	15

\* FSS = fine suspended sediment, which is based on field turbidity data

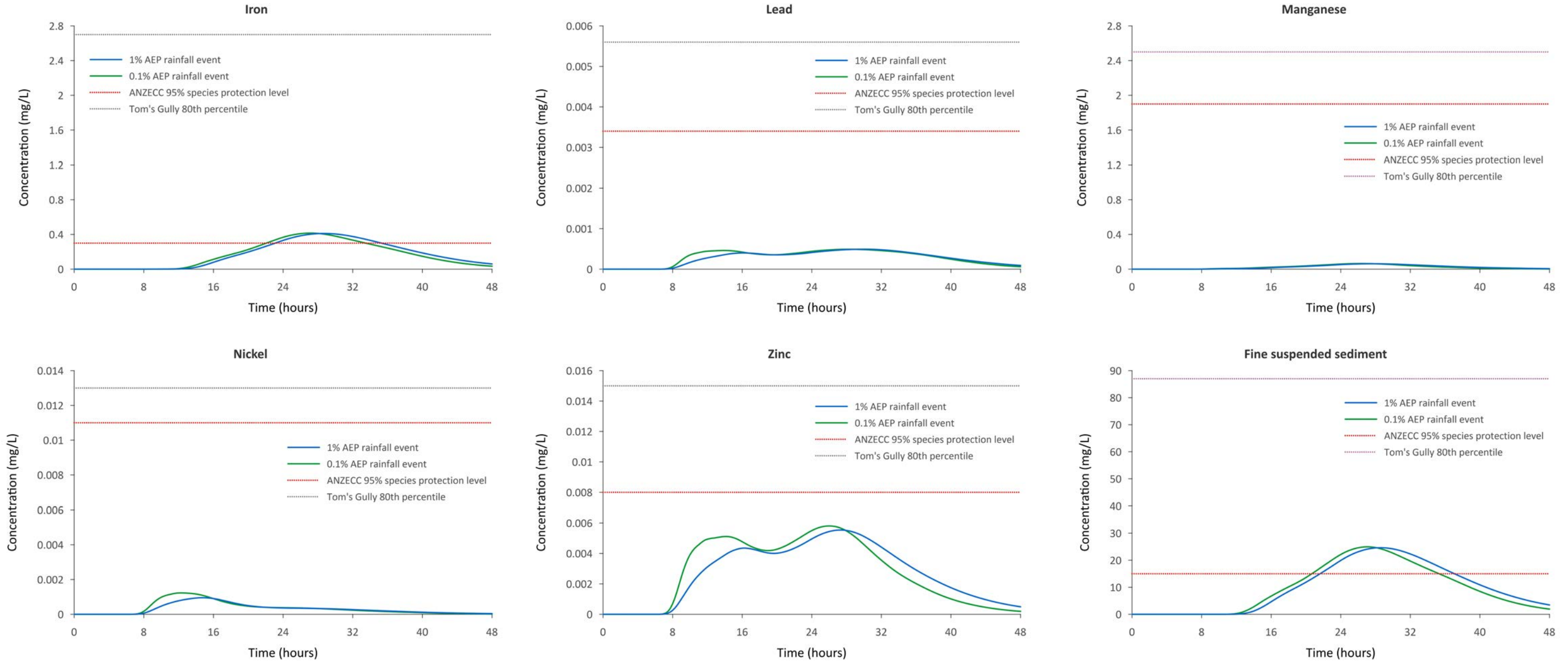
**Table 1.** Contaminant concentrations that enter the Mt Bunday Creek main channel from the mining areas. The Tom's Gully SSTV and ANZECC 95% species protection trigger values are also shown.

**Notes:**

- The WQ component of the HEC-RAS model was used to determine the contaminant concentrations along the Mt Bunday Creek main channel.
- The model was separated into an upper and lower channel. The predicted contaminant concentrations at the upper channel outlet were assumed to equal the concentrations entering the top of the lower channel.
- Contaminant concentrations entering the Mt Bunday Creek main channel are conservative. It is assumed that there is no dilution of contaminants from the mining area to the channel, and no settling out of metals or sediment in the flow.



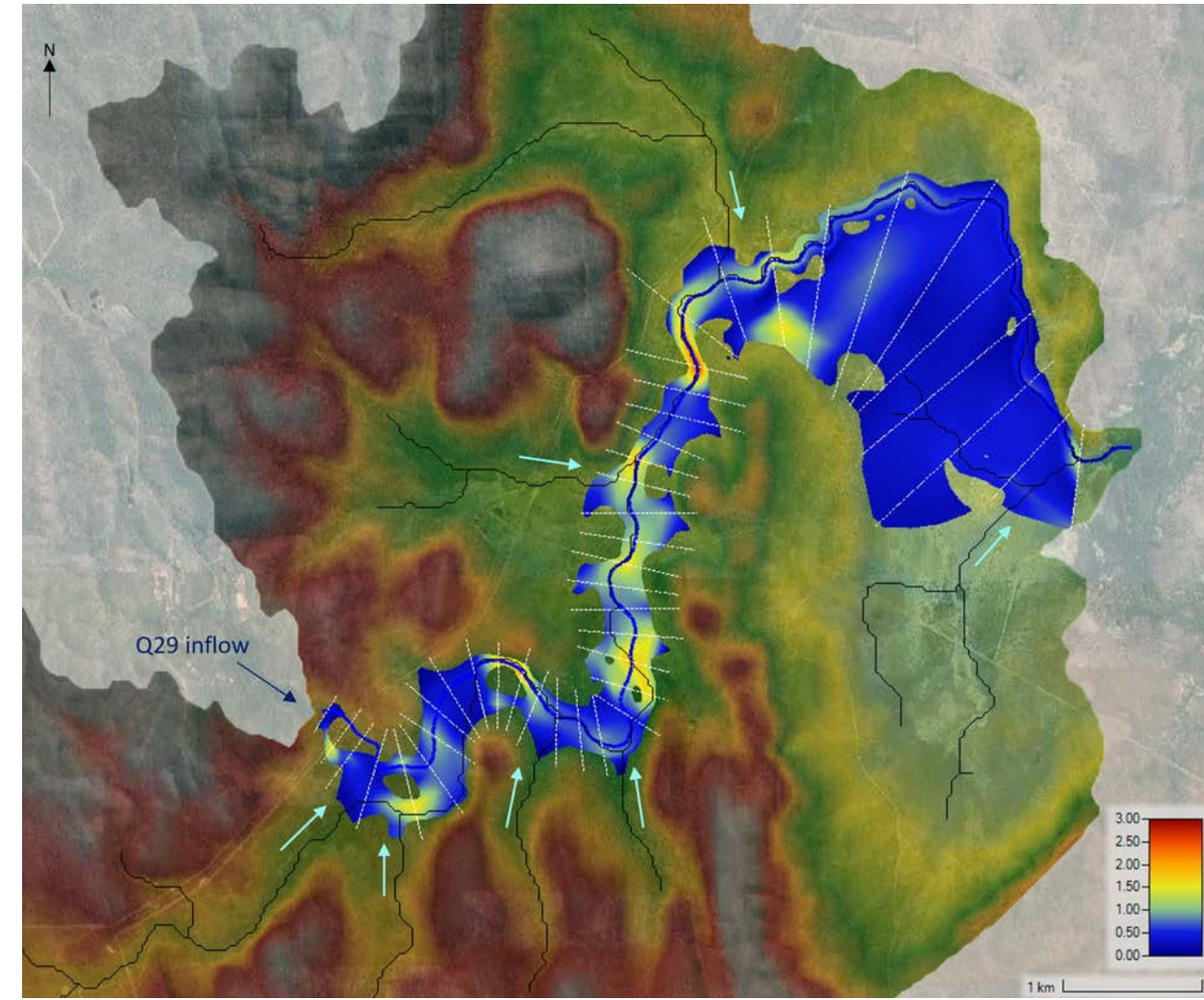
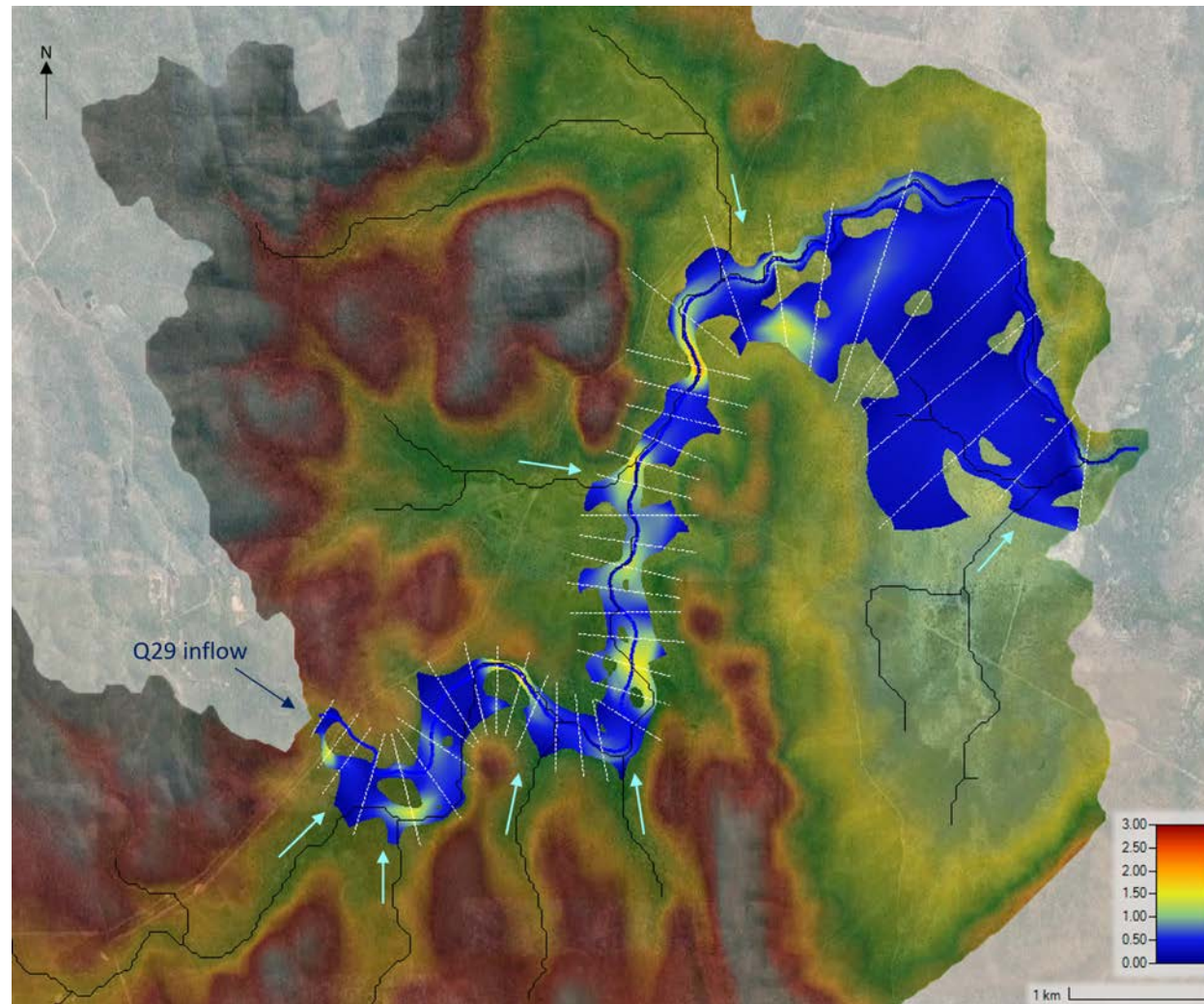
**Figure 1.** Predicted contaminant concentrations at the outlet of Mt Bunday Creek during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).



**Figure 1.** Predicted contaminant concentrations at the outlet of Mt Bunday Creek during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).

**Notes:**

- # [unclear], and fine suspended sediment, [unclear] V--## [unclear] but not the SSTV, [unclear] -h [unclear]. Cadmium may exceed the SSTV during the 0.1% AEP.
- The concentrations of Cadmium are predicted to exceed the SSTV for less than 8 hours during the 0.1% AEP event.
- All other contaminant concentrations are well below the SSTVs.



**Figure 1.** Maximum velocities within the main channel of Charles Creek during a 1% AEP (left) and a 0.1% AEP (right) rainfall event. White dashed lines are the cross sections used in the HEC-RAS 1-D model. Blue arrows indicate inflows into the main channel from major tributaries. Metal concentrations in these tributaries are assumed to be 0 mg/L.

Contaminant concentrations (mg/L)			
Metal	Inflow from Quest 29	Trigger value: Tom's Gully 80 <sup>th</sup> percentile (SSTV)	Trigger value: ANZECC 95% species protection
Aluminium	1.1745	0.2950	0.0550
Arsenic	0.2236	0.0420	0.0130
Cadmium	0	0.0004	0.0002
Chromium	0.0043	0.0060	0.0010
Cobalt	0.0046	0.0014	0.0014
Copper	0.0074	0.0018	0.0014
Iron	1.5620	2.7	0.3000
Manganese	0.1273	2.5	1.9000
Nickel	0.0064	0.0130	0.0110
Lead	0.0176	0.0056	0.0034
Zinc	0.0738	0.0150	0.0080
FSS*	36	87	15

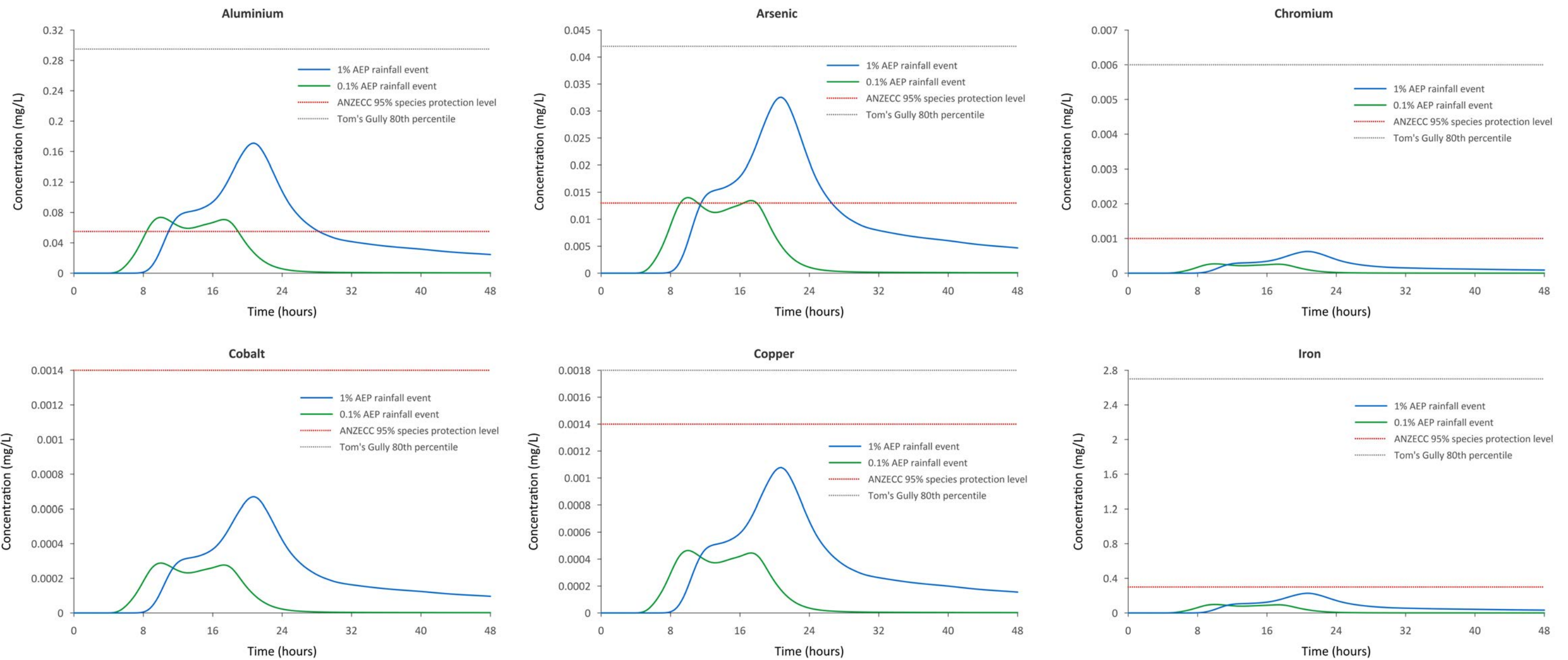
\* FSS = fine suspended sediment, which is based on field turbidity data

**Table 1.** Contaminant concentrations that enter the Charles Creek main channel from the Quest 29 mining area. The Tom's Gully SSTV and ANZECC 95% species protection trigger values are also shown.

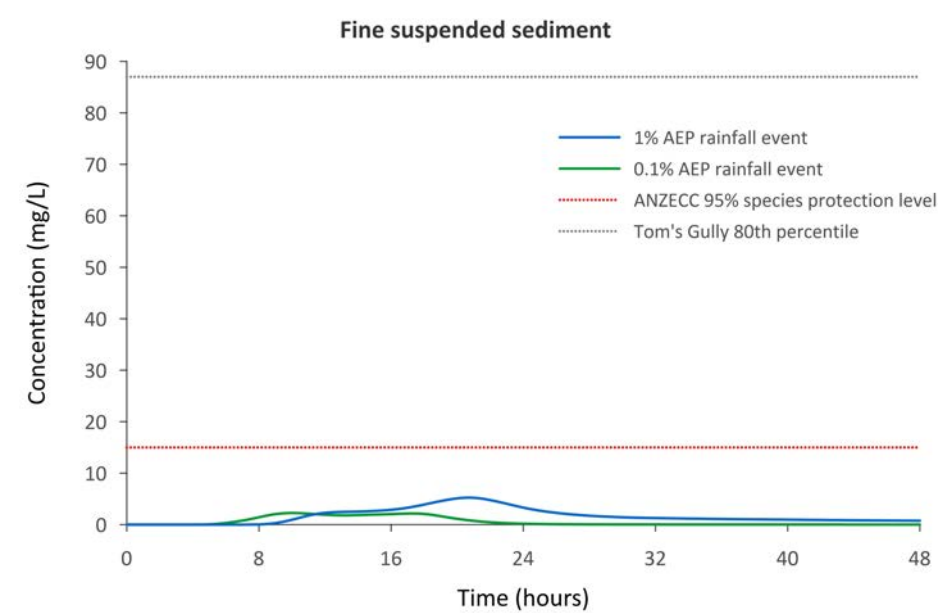
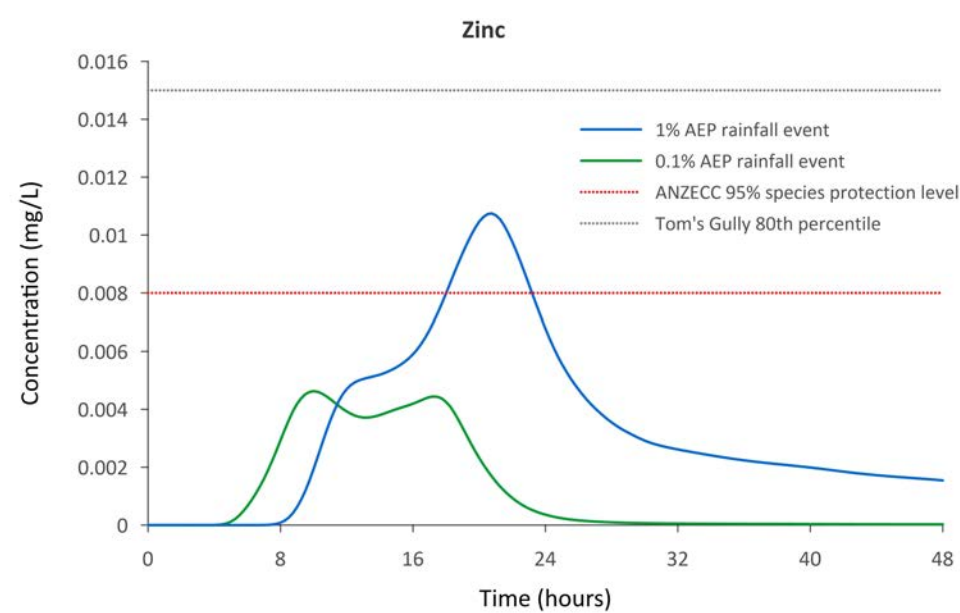
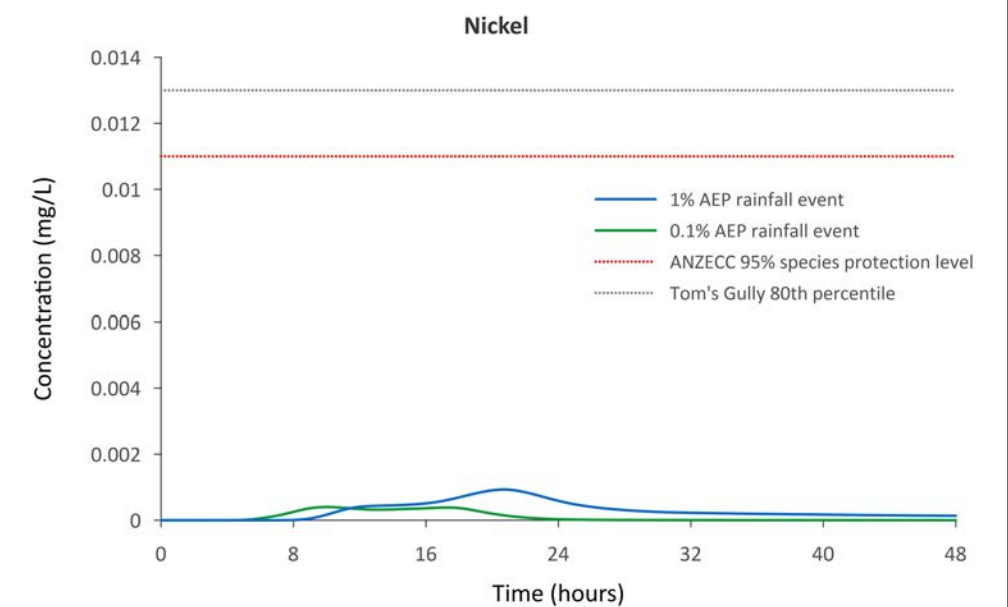
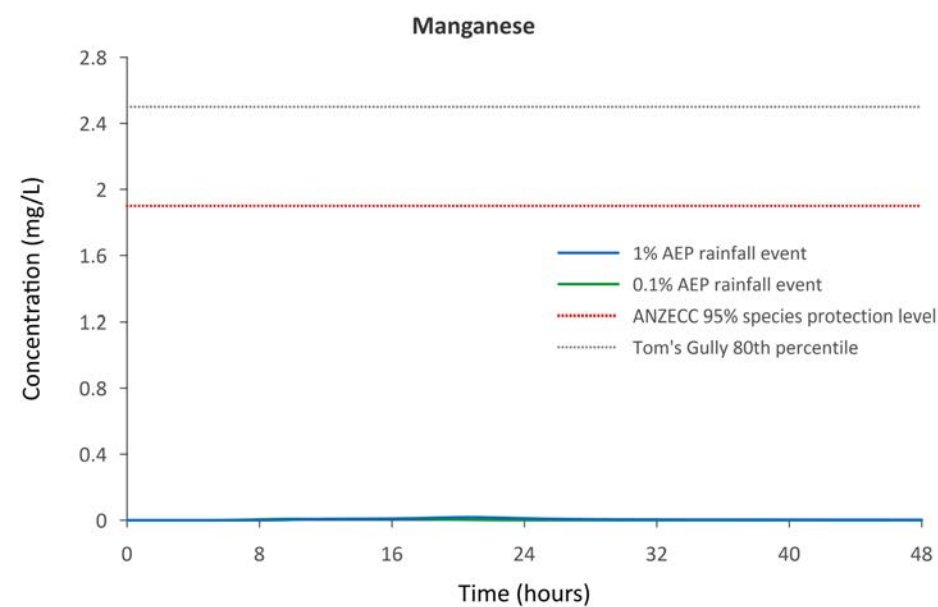
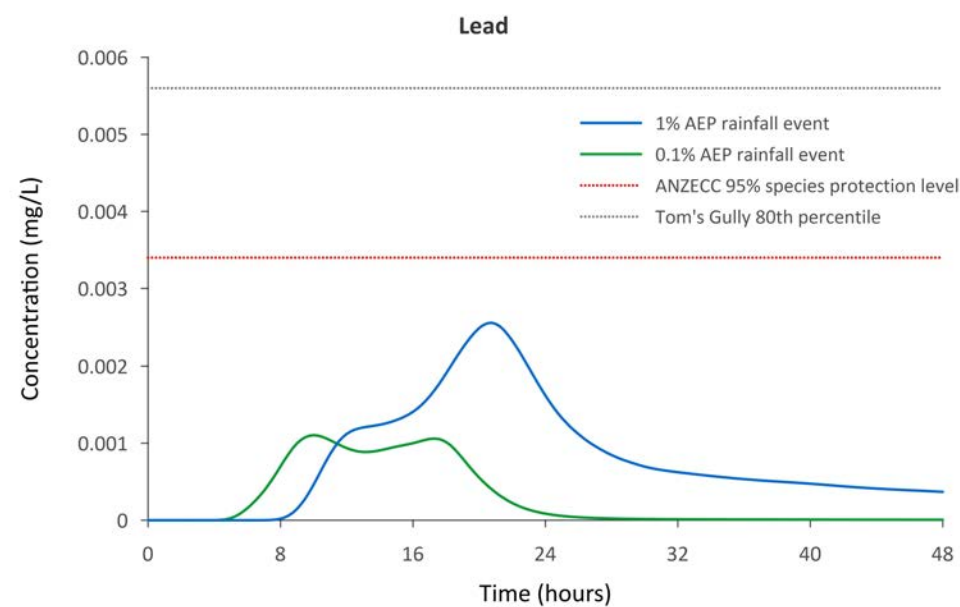
**Notes:**

- The WQ component of the HEC-RAS model was used to determine the contaminant concentrations along the Charles Creek main channel.
- Some contaminant concentrations entering the main channel from Quest 29's Zamu Pit area are orders of magnitude higher than the ANZECC trigger value.
- Contaminant concentrations entering the Charles Creek main channel are conservative. It is assumed that there is no dilution of contaminants from the mining area to the channel, and no settling out of metals or sediment in the flow.





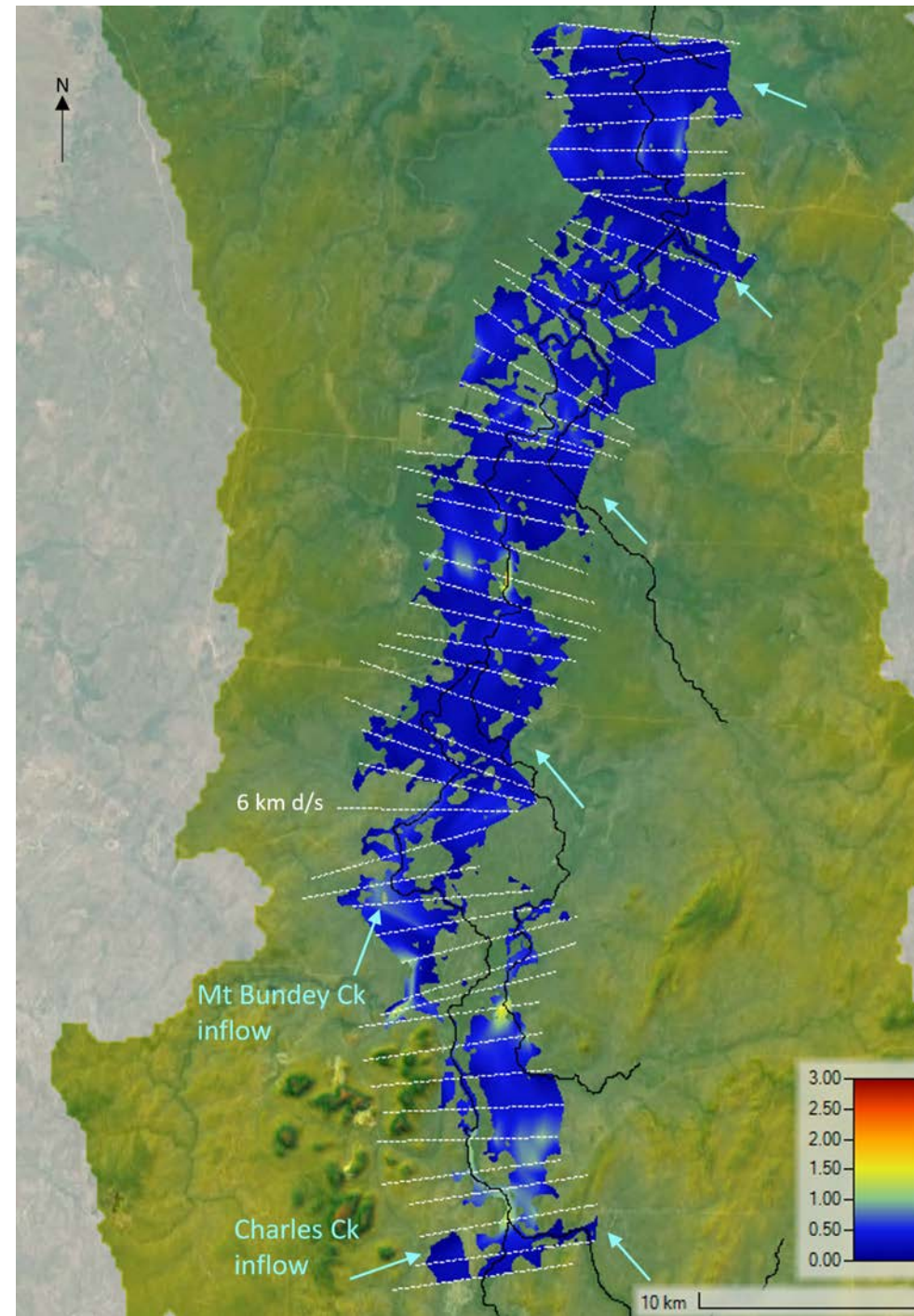
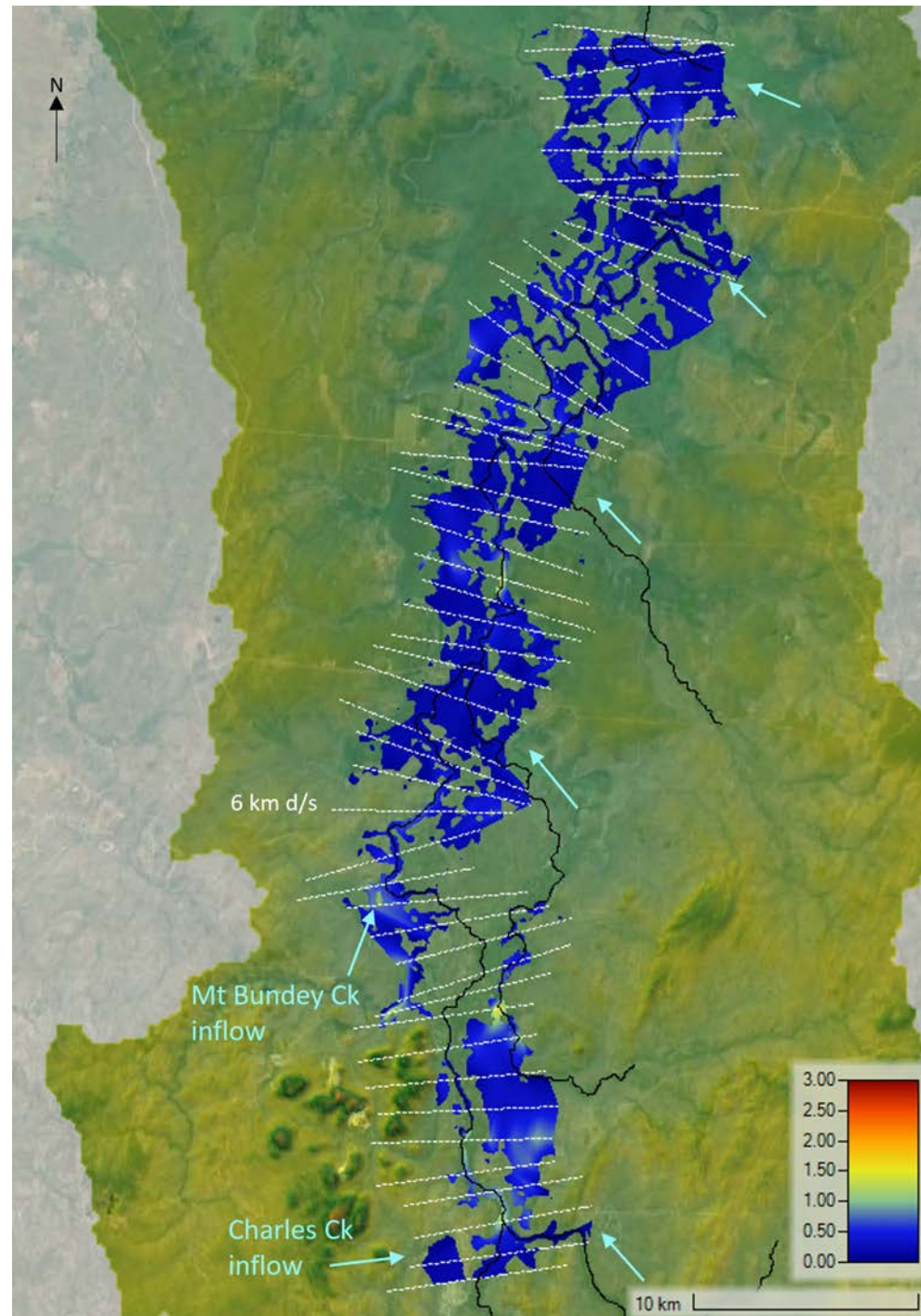
**Figure 1.** Predicted contaminant concentrations at the outlet of Charles Creek during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).



**Figure 1.** Predicted contaminant concentrations at the outlet of Charles Creek during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).

**Notes:**

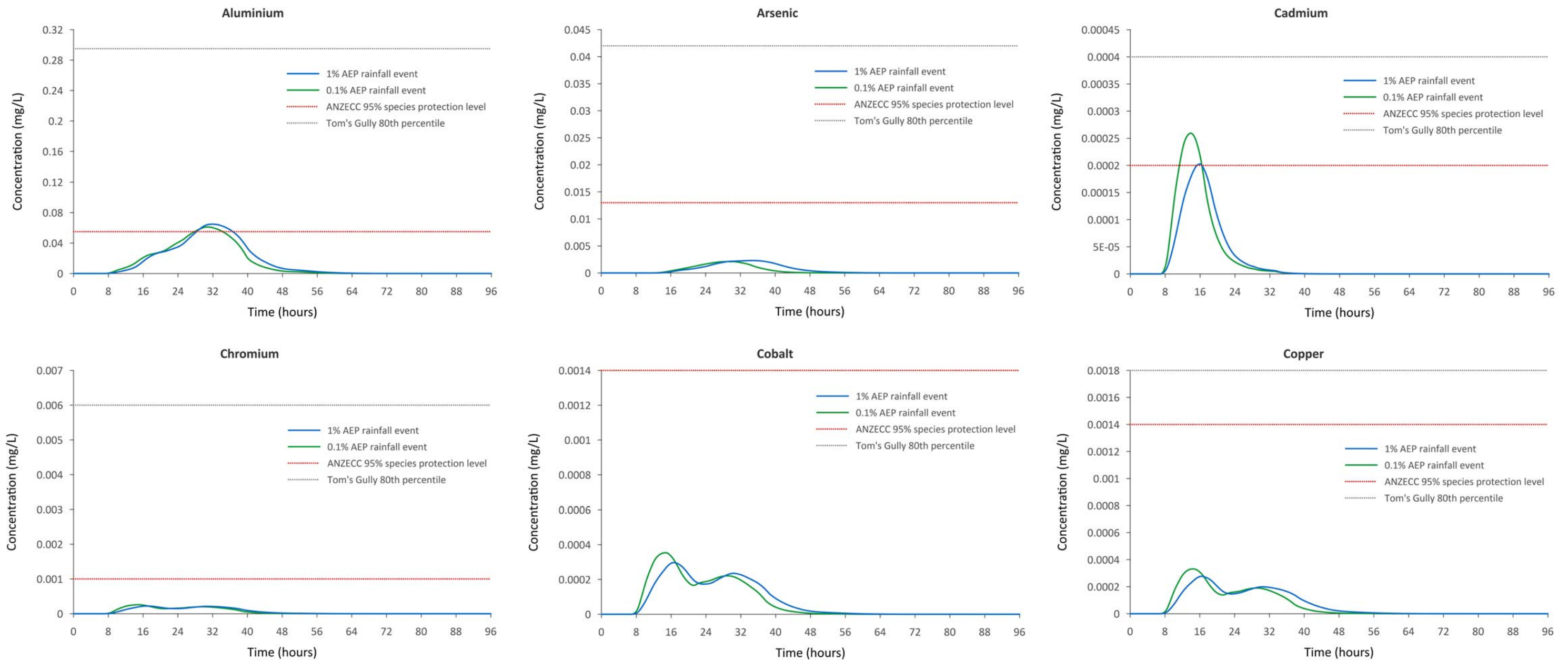
- All contaminant concentrations in Charles Creek were below the Tom's Gully 80th percentile values (SSTV) during the 1% and 0.1% AEP rainfall events.
- Concentrations of Aluminium, Arsenic, and Zinc are predicted to exceed the ANZECC trigger value at the catchment outlet for less than 24 hours during the 1% or 0.1% events.



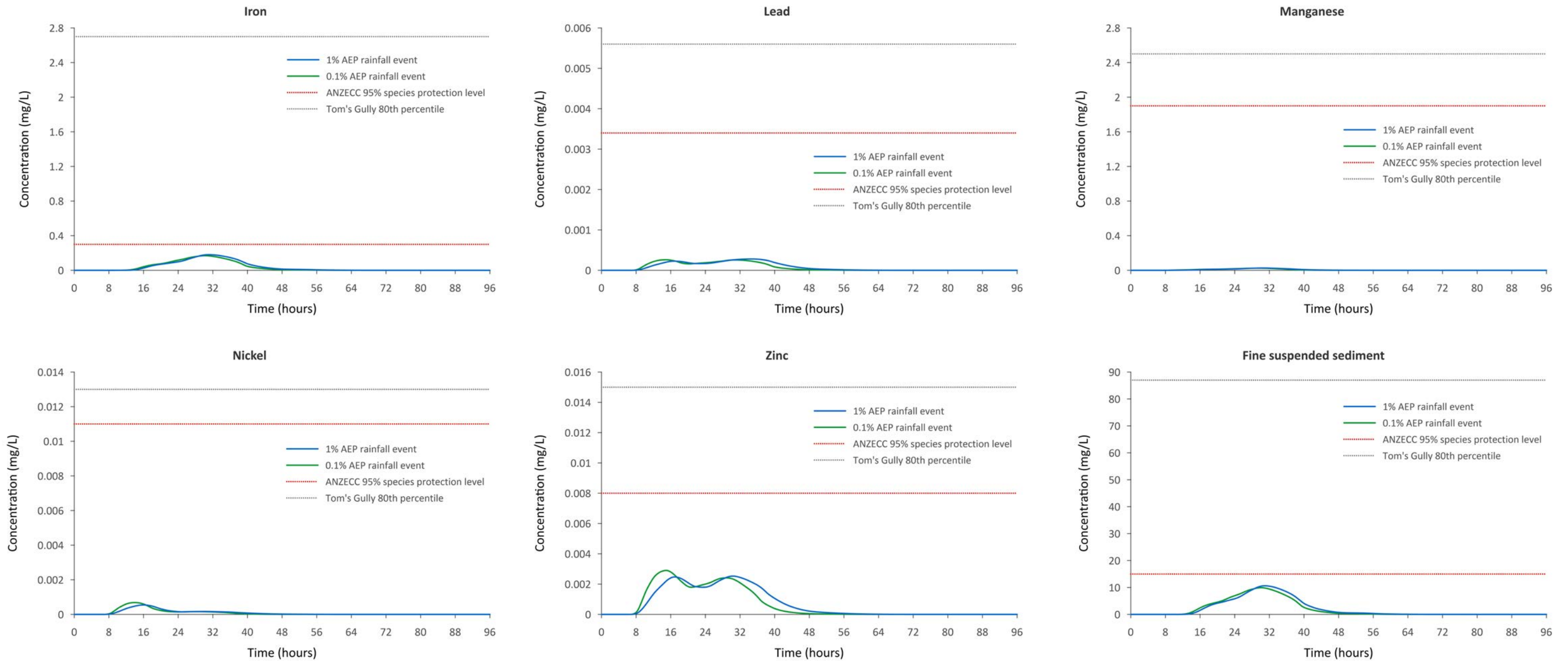
**Notes:**

- The WQ component of the HEC-RAS model was used to determine the contaminant concentrations along the Mary River main channel.
- The area of interest is just downstream of where the Mt Bundey Creek enters the Mary River.
- The time-series data for contaminant concentrations in the Mt Bundey and Charles creeks entering Mary River during a 1% and 0.1% AEP rainfall event are presented in drawings 02–03 and 05–06 respectively.

**Figure 1.** Maximum velocities within the main channel of Mary River during a 1% AEP (left) and a 0.1% AEP (right) rainfall event. White dashed lines are the cross sections used in the HEC-RAS 1-D model. Blue arrows indicate inflows into the main channel from major tributaries. Metal concentrations in these tributaries are assumed to be 0 mg/L.



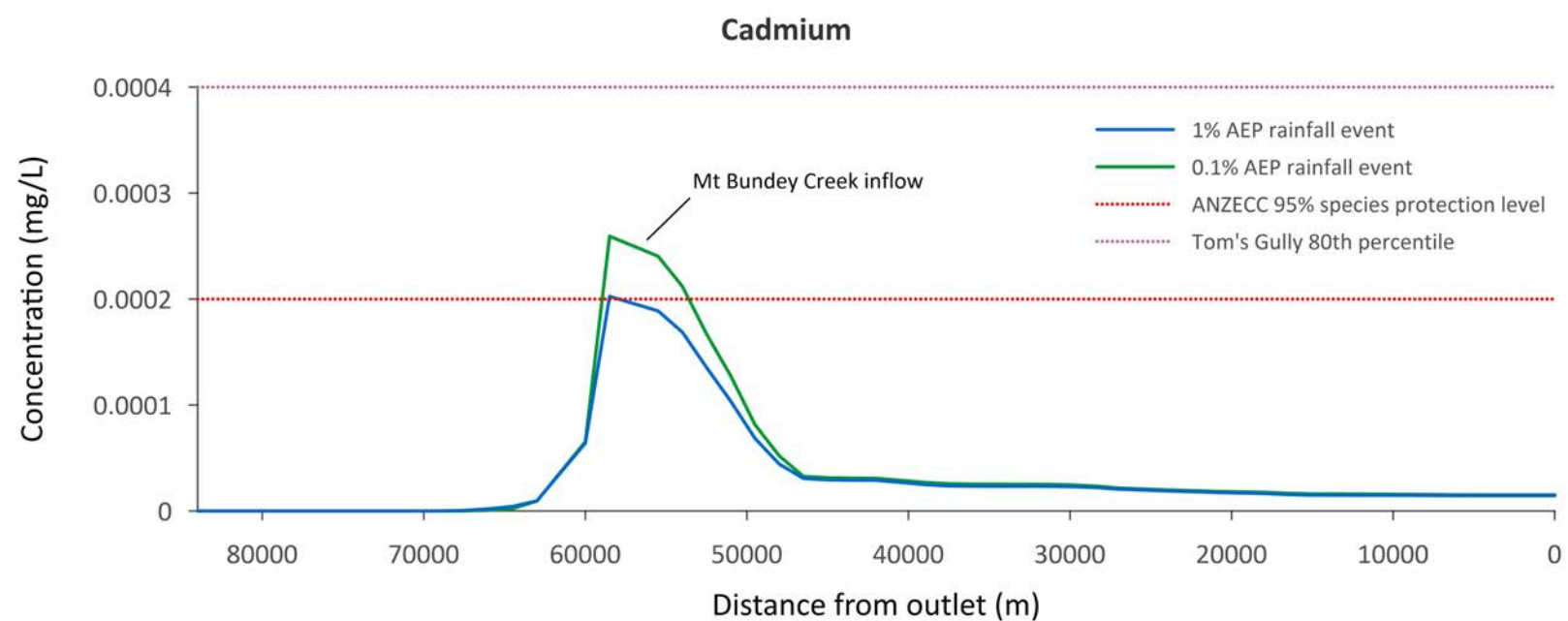
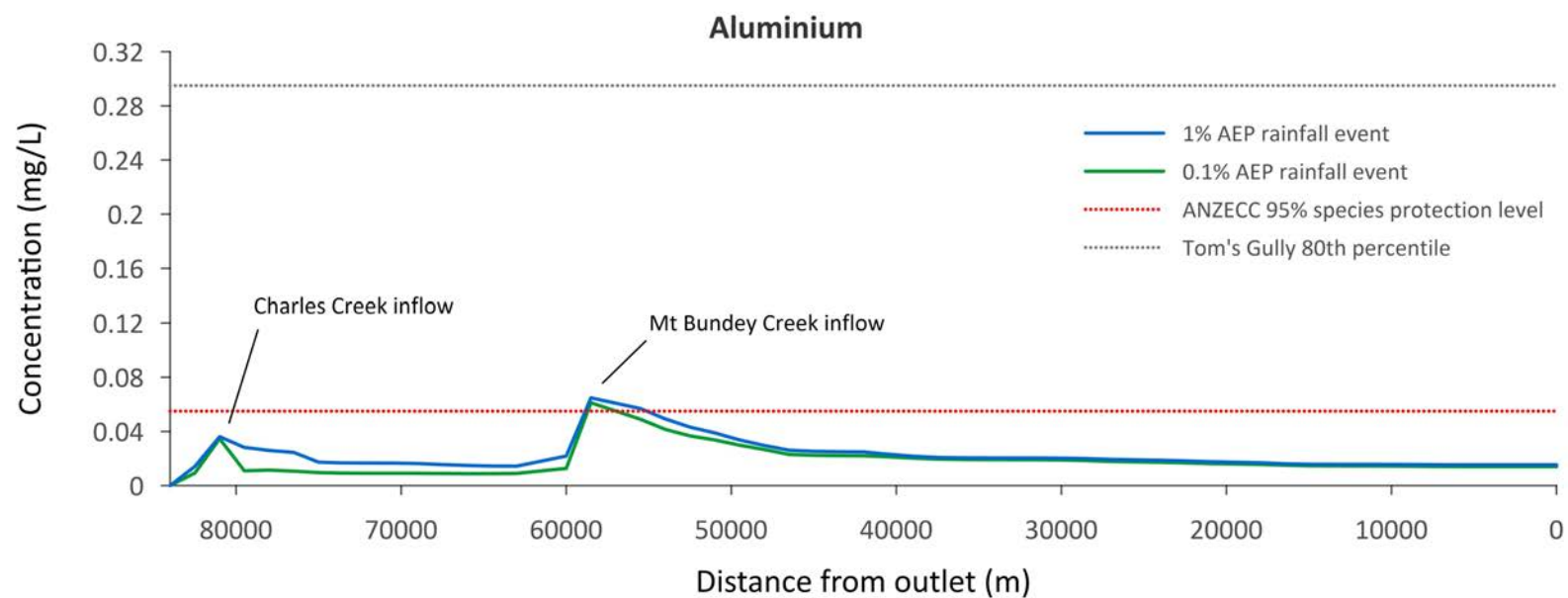
**Figure 1.** Predicted contaminant concentrations in the Mary River just downstream of the confluence with Mt Bunday Creek during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).



**Figure 1.** Predicted contaminant concentrations in the Mary River just downstream of the confluence with Mt Bundey Creek during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).

**Notes:**

- All contaminant concentrations in the Mary River, just downstream of where Mt Bundey Creek flows into the main channel, were well below the Tom's Gully 80th percentile values during the 1% and 0.1% AEP rainfall events.
- # and Cadmium were predicted to be slightly above the ANZECC trigger value for several hours during these s.



**Notes:**

- Elevated concentrations of Aluminium at the outlet of Charles Creek are below SSTV values once the creek enters the Mary River.
- The model predicts that Aluminium concentrations are well below the SSTV and will drop below the ANZECC trigger value within 2–4 km downstream of where Mt Bunday Creek flows into the Mary River.
- Cadmium concentrations are below the SSTV and are expected to drop below the ANZECC trigger value approximately 6 km downstream of where Mt Bunday Creek flows into the Mary River during the 0.1% AEP event (see Drawing WQ-07).
- Cadmium concentrations that exceeded the Tom's Gully 80th percentile value at the Mt Bunday Creek outlet were diluted to well below this value once flow entered the Mary River.

**Figure 1.** Predicted maximum concentrations of Aluminium (top) and Cadmium (bottom) along the main channel of the Mary River during a 1% and 0.1% AEP rainfall event compared against the ANZECC 95% species protection trigger value, as well as the Tom's Gully 80th percentile value (SSTV).

Drawing No WQ-10	 <p><b>SURFACE WATER &amp; EROSION SOLUTIONS</b> ALL SITE &amp; SOIL EVALUATIONS FOR SEPTIC &amp; WASTEWATER MANAGEMENT</p>	Project <b>Rustler's Roost &amp; Q29 EIS Supplementary Information</b>	Title <b>Mary River: metal concentration at outlet during 1% and 0.1% AEP rainfall events</b>	Designed	Drawn	Checked	Sheet size
					KGE	DRM	A3
				Date			Sheet No. 10
				29/07/2022			Sheet 9 of 10