

Appendix M - Aquatic Ecology Memorandum

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Our Reference: 2242.001V2

26 August 2022

RE: Rustlers Roost and Quest 29, Aquatic Ecology Flow Assessment

Project Background

Hanking Australia Investment Pty Ltd, through its subsidiary Primary Gold Pty Ltd, are proposing the Rustlers Roost and Quest 29 Mine Redevelopment Project (the Project). The Project is an existing brownfield sites on Mineral Leases (ML) located within pastoral leases near Mount Bunday, approximately 85 km south-east of Darwin. Open-cut gold mining (at three pits) and processing will recommence at Rustlers Roost Mine. Five satellite pits at Quest 29 Mine will also be mined and ore transported to be processed at Rustlers Roost. The Project also includes construction of a new process plant, workers accommodation, administration buildings, haul roads, Tailings Storage Facility (TSF), waste dumps and other mining infrastructure. The proposal is being assessed at the level of Environmental Impact Statement (EIS) by the Northern Territory Environmental Protection Authority (NT EPA) and Primary Gold has received comments on the Draft EIS that was submitted for assessment.

This memo has been prepared for CDM Smith on behalf of Primary Gold to contribute to the Supplementary EIS for the re-development of Rustlers Roost and Quest 29. Specifically, it contributes to the response to the NT EPA comments on the Draft EIS outlined in Table 1, by assessing potential impacts to aquatic ecology associated with changes in flow regimes from the Project.

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Table 1 NT EPA comments

NT EPA Comment
<p>Comment</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>Additional Information Required</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>
<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>
<p>Comment</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>Additional Information Required</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 National Water Quality Management Strategy.</p>

Scope of Work

The objective of this memo is to provide a concise assessment of the potential impacts to aquatic ecology associated with alterations to flow regimes as a result of the Project. This includes:

- assessment of the existing downstream aquatic ecosystem values
- summary of potential impacts to aquatic ecosystems associated with flow, including a risk assessment framework

- brief summary of the proposed project, particularly the expected changes in flow regimes
- assessment of the potential impacts to aquatic ecology associated with alterations to the flow regime as a result of the Project, including a risk assessment, and
- outline of assumptions or limitations of the assessment.

This memo is based on a desktop review only, with the following information reviewed for the assessment:

- CDM Smith (2021) *Draft Environmental Impact Statement (EIS) Section 7.5 Aquatic Ecosystems*. Prepared pursuant to the *Environmental Protection Act 2019*
- Aquatic Ecological Services (2020) *Toms Gully Aquatic Ecology Baseline Studies*, Final report prepared for Hanking (presented as Appendix S of the Draft EIS)
- EcOz Environmental Consultants (2021) *Sediment and macroinvertebrate results April 2021 Rustlers Roost*, Final report prepared for Primary Gold Pty Ltd (presented as Appendix Q of the Draft EIS)
- Surface Water and Erosion Solutions (2022) *Assessment of broader catchment surface water impacts of redevelopment of the Rustler's Roost mine and the Quest 29 mining precinct*. Report prepared for Hanking Mining
- various email threads provided by Surface Water and Erosion Solutions and CDM Smith outlining Project information and details of changes in flow from the Project, and
- reports and literature available outlining the influence of flow on aquatic ecology (as referenced throughout).

This assessment does not include potential impacts to water quality (including contaminants), groundwater and riparian vegetation.

Aquatic Ecosystem Values

The Project is located in two drainage basins, the Adelaide River basin and the Mary River basin. Rustlers Roost Mine is at the catchment boundary of Marrakai Creek, which flows to the Adelaide River, and Mount Bunday Creek, which flows via Hardies Creek to the Mary River. Quest 29 Mine is at the catchment boundary of Mount Bunday Creek and Charles Creek, which flows via McKinley River to the Mary River (CDM Smith 2021).

Three reports from the Draft EIS were used to assess the aquatic ecosystem values of downstream waterways (i.e. CDM Smith 2021, Aquatic Ecological Services 2020 and EcOz Environmental Consultants 2021). The aquatic ecosystem values were categorised using the criteria outlined in Table 2, which was based on the *Guidelines for Identifying High Ecological Values Aquatic Ecosystems* (Aquatic Ecosystems Task Group 2012). The waterways downstream of the mines were divided into reaches for the assessment based on the aquatic ecosystem values and potential impacts to flow. Specifically, these were:

- drainage channels and upper ephemeral tributaries (stream order 1 and 2) within and directly downstream of Rustlers Roost and Quest 29, including:
 - upper ephemeral tributaries of Mount Bunday Creek
 - upper ephemeral tributaries of Charles Creek
 - upper ephemeral tributaries of Marrakai Creek

- Mount Bunday Creek main branch (stream order 3 and above), downstream of Rustlers Roost and Quest 29
- Charles Creek main branch (stream order 3) downstream of Quest 29
- Marrakai Creek main branch (stream order 3 and above), downstream of the confluence with the upper ephemeral tributaries
- Hardies Creek (stream order 5 and above; approximately 30 km downstream of the Rustlers Roost), McKinley River main branch (stream order 5 and above; approximately 15 km downstream of the Quest 29) and the Mary River (downstream of the confluence with McKinlay River and Hardies Creek, approximately 35 km downstream of the Project), and
- Adelaide River main branch downstream of the confluence with Marrakai Creek (approximately 37 km downstream of Rustler’s Roost).

Table 2 Criteria used to assess aquatic ecosystem value

Criteria ^a	Low	Moderate	High
Diversity	Low biodiversity of aquatic flora and fauna Low habitat diversity	Moderate to good biodiversity of aquatic flora and fauna Moderate habitat diversity	High biodiversity of aquatic flora and fauna High habitat diversity
Distinctiveness	Species, communities and processes common Available habitat types common No habitat for protected species No listed protected aquatic areas, habitats or species High tolerance to change or highly adaptive communities	Species, communities and processes moderately common Available habitat types relatively common No core habitat for protected species Listed protected aquatic areas, habitats or species, but unlikely to provide significant habitat (e.g. breeding area) Moderate tolerance to change or moderately adaptive communities	Species, communities and processes rare Available habitat types rare Core habitat for protected species Listed protected aquatic areas, habitats or species Sensitive or poorly adaptive communities
Vital Habitat	Poor refuge or breeding area Supports low numbers of native species Little fisheries value Poor connectivity and fish passage	Limited refuge or breeding area Supports moderate numbers of native species Moderate fisheries value Limited connectivity and fish passage	Important refuge or breeding area Supports high numbers of native species High fisheries value High connectivity and important corridor for fish passage

Criteria ^a	Low	Moderate	High
Naturalness	Highly disturbed Poor riparian condition Poor habitat condition	Moderately disturbed Moderate to good riparian condition Moderate to good habitat condition	Undisturbed, pristine Excellent riparian condition Excellent habitat condition
Representativeness	Highly disturbed Poor example of ecosystem type	Moderately disturbed Average example of ecosystem type	Undisturbed Outstanding example of ecosystem type

^a Source: Aquatic Ecosystems Task Group 2012

The aquatic ecological values of waterways are outlined in Table 2. In summary:

- upper drainage channels and ephemeral tributaries had low to moderate aquatic ecosystem value
- Mount Bunday Creek, Charles Creek and Marrakai Creek main branches had moderate aquatic ecosystem values, except within the Mary River and Adelaide River floodplains where the aquatic ecosystem value was high, and
- Hardies River, Mary River, McKinley River and Adelaide River had high aquatic ecosystem values.

Table 3 Aquatic ecosystem values downstream of Rustler’s Roost

Criteria	Diversity	Distinctiveness	Vital Habitat	Naturalness	Representativeness	Value
Drainage channels and upper ephemeral tributaries (stream orders 1 and 2)	Moderate variety of instream habitat types that are dry for several months of the year No natural permanent waterbodies, but an artificial dam located on Marrakai Creek, 2.5 km downstream of Rustlers Roost	Species, communities and processes common No regionally, nationally, or internationally important habitat No mapped GDEs High proportion of non-pollution tolerant macroinvertebrate taxa	Unlikely that any significant aquatic fauna will occur due to highly ephemeral characteristics Limited potential to provide connectivity or fauna passage to upstream habitats, except during brief periods of high rainfall and flow	Highly disturbed, previous mining impacts within the MLs (including artificial permanent water bodies); pastoral land use outside the MLs	Flora and fauna likely typical of ephemeral systems in the region	Low to moderate
Mount Bunday Creek main branch	Likely to have a moderate to good diversity of habitat and species Refuge pools occur in reach (permanent water features located approximately 7.5 km from Rustlers Roost and 11 km from Quest 29) Alluvial groundwater likely to extend sub-surface flow in the dry season	Mary River coastal floodplain, Mary Floodplain system and mapped surface expression GDEs in the lower reaches Presence of turtles, monitors and saltwater crocodiles (unlikely to be core habitat) Low sensitivity macroinvertebrate taxa, often in high abundances Variety of common fish species caught	Potential breeding habitat for some aquatic species Provision of connectivity and fauna passage to upstream and downstream habitats during periods of high rainfall and flow (disconnected during the dry season)	Livestock access to the downstream water features and other pastoral impacts Mining activities associated with Tom’s Gully mine. Several domesticated or introduced species observed Clearing is greater in the downstream area	Moderately disturbed and moderate example of intermittent waterway in the region	Moderate (although high within the Mary River coastal floodplain)

Criteria	Diversity	Distinctiveness	Vital Habitat	Naturalness	Representativeness	Value
Charles Creek main branch	Permanent water feature approximately 3 km downstream of Quest 29 may provide dry season refuge.	Mary River coastal floodplain in downstream reach	Potential breeding habitat for some aquatic species Provision of connectivity and fauna passage to upstream and downstream habitats during periods of high rainfall and flow (disconnected during the dry season)	Livestock access to water features and other previous mining and pastoral impacts	Moderately disturbed and moderate example of intermittent waterway in the region	Moderate (although high within the Mary River coastal floodplain)
Marrakai Creek, main branch	Likely to have a moderate to good diversity of habitat and species. Semi-permanent pools located approximately 5.5 km downstream of Rustlers Roost may provide dry season refuge.	Part of Adelaide River floodplain system (nationally important wetland), located approximately 8 km downstream of Rustlers Roost Mapped GDEs in the lower reaches (surface expression)	Potential breeding habitat for some aquatic species Provision of connectivity and fauna passage to upstream and downstream habitats during periods of high rainfall and flow (disconnected during the dry season)	Some disturbance from pastoral activities, although riparian vegetation is generally good, generally less disturbed than other waterways in the region	Moderate example of intermittent waterway in the region	Moderate (although high within the Adelaide River floodplain system)
Hardies Creek, McKinley River and Mary River main branches	Supports a wide diversity of flora, fauna and habitat	Mary River coastal floodplain and Mary River floodplain system - wetlands of national and international importance Provides a reliable breeding site for Magpie	Essential ecosystem services and support a wide diversity of flora and fauna, including breeding habitat Important connectivity and fauna passage to	Major tourist attraction for recreational fishing and wildlife viewing in the region	Unique to the region as it lacks a single major river channel through the floodplain to the ocean	High

Criteria	Diversity	Distinctiveness	Vital Habitat	Naturalness	Representativeness	Value
		Goose and for many fish species, notably Barramundi. Twelve threatened species are known to occur in the floodplain Mapped surface expression GDEs in some areas	upstream and downstream habitats		Outstanding natural, cultural and visitor values	
Adelaide River main branches	Supports a wide diversity of flora, fauna and habitat	Adelaide River Foreshore Conservation Area - wetlands of national and international importance Habitat for a number of significant and threatened species Mapped surface expression GDEs in some areas	Essential ecosystem services and support a wide diversity of flora and fauna, including breeding habitat Important connectivity and fauna passage to upstream and downstream habitats	Major tourist attraction for recreational fishing in the region	Good example of ecosystem type and of natural and cultural importance	High

General Impacts of Flow on Aquatic Ecology

Water flow is an essential component shaping riverine ecosystems (Poff et al. 1997; Bunn and Arthington 2002). Significant changes to the natural flow regime (defined as the patterns of water flow that sustains riverine ecosystems by Poff et al. 1997), such as modification of the major flood flows, reversal of the timing of flow events, and consistent flow in systems that are naturally variable, can cause substantial ecological impacts to riverine systems (Poff et al. 1997; Bunn and Arthington 2002).

Altered flows can impact on aquatic systems in the following general ways (Bunn and Arthington 2002; Poff and Zimmerman 2010; Rolls et al. 2012):

- Riverine flow is a major determinant of the diversity and structure of instream physical habitats, which impacts on the composition of biotic communities.
- Aquatic species are adapted to natural flow regimes and have evolved life history traits in response to natural variation. Rapid changes to these flow regimes can influence the success of the life cycles.
- Natural flow regime allows for variation in connectivity along the length of rivers and between rivers and floodplains.
- Maintaining natural flow regimes can decrease the successful invasion of exotic and pest species.

Postel and Richter (2003) provide recommendations, illustrated in Figure 1, that seek to maintain natural flow regimes and therefore ecologically relevant properties and processes of riverine ecosystems that include:

- Allowing for flood flows, as these will impact on the degree of bed scouring, instream vegetation and recharge riparian banks and floodplains.
- Maintain base flows to support aquatic communities during drier periods.
- Retaining spring flushing flows to maintain ecological processes as these can be a cue triggering reproductive and migratory cycles.
- Varying some peak flows during the wet season as this period can sustain greater extraction.

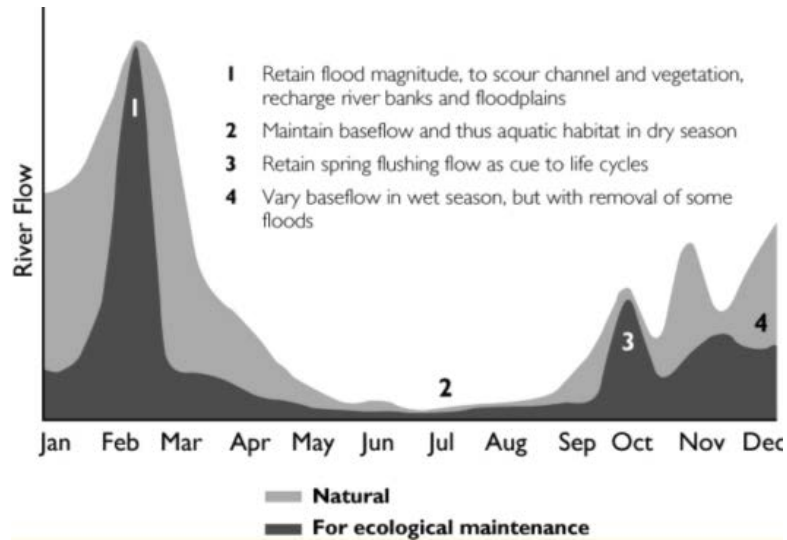


Figure1 Environmental flow recommendations provided to maintain key ecological processes throughout the year (Postel and Richter 2003)

The Postel and Richter (2003) recommendations have been further refined to incorporate general presumptive standards to provide moderate to high protection of riverine ecosystems as illustrated in Figure 2 (Richter et al. 2011). As the ecological risk is related to a proportion of natural flows, a greater volume of water can be extracted or released during periods of high natural flow, with extraction and release decreasing during periods of natural low flow (Figure 2).

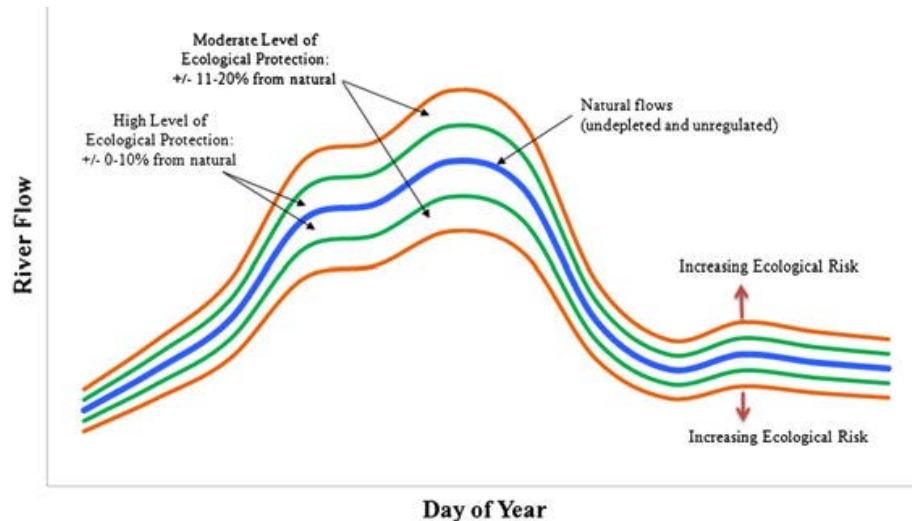


Figure 2 Presumptive river flow standards over time to maintain moderate and high levels of ecological protection in riverine systems (Richter et al. 2011)

While these recommendations and presumptive standards are based on perennial streams with an emphasis on baseflow, they also provide good general guidance for the Project area (i.e. ephemeral waterways with limited baseflows) in the absence of available standards for these types of waterways. However, there are a number of factors that are particularly important to consider for ephemeral waterways, including the duration and timing of flow as well as the presence of dry season refugia.

The duration and timing of flow and no flow events, and as such the presence of surface water in ephemeral waterways, is highly unpredictable and linked to erratic seasonal rainfall patterns. Because of this, aquatic species in these areas have evolved traits that enable them to persist throughout spates and dry periods (Bond et al. 2008; Bond and Cottingham 2008). These traits enable them to either recolonise from elsewhere if local populations are eradicated (resilience traits), or else survive the disturbance in situ (resistance traits) (Bond et al. 2008). For example, several species in the region use wet season flows as a cue for migration and / or breeding (Erskine et al. 2003). These traits may also give native species a competitive advantage compared to introduced species that are not adapted to the harsh environmental conditions of ephemeral waterways.

A key component of ephemeral systems is the presence of dry season refugia (Bond and Cottingham 2008). Dry season refugia are remnant pools (e.g. waterholes, dams, floodplain lagoons, riverine pools) that are subjected to reduced desiccation stress during periods of no flow and therefore contain water for the majority of the year. These habitats provide food resources, refuge, shelter and breeding habitat for aquatic flora and fauna long after other sections of the waterway may have dried. Aquatic flora and fauna inhabiting refugia during dry periods are then able to recolonise disturbed sections of waterways and other off-stream wetlands via a variety of dispersal mechanisms once flows commence following rainfall. The mortality of fauna caused by spells without flow is diminished if they utilise refugia and it has been suggested that the presence of refugia may be critical to the persistence of aquatic fauna in ephemeral systems (Bond et al. 2008).

Risk Assessment Framework

Key functions of downstream flow were identified with guidance from the presumptive standards in Postel & Richter (2003); interim flow objectives for Darwin Harbour Region waterways (Fortune 2020) and the Daley River (Eskerine et al. 2003); key hydrological indicators set for waterways in Queensland (Brizga et al. 2002); and Project information regarding changes to flow available (outlined in the section below). Key functions include:

- maintain water availability for native flora and fauna
- maintain instream habitat (channel maintenance, sediment and organic matter transport, riparian condition)
- protect natural flow regimes (wet season flow) / Seasonality (timing and duration of flow)
- maintain natural variability (a system should retain its perennial or seasonal nature)
- manage groundwater for ecosystems
- protect important rises in water levels – important wet season flows
- maintain seasonal wetland/floodplain inundation / protect natural low flows (perennial systems)
- minimise the effect of weirs/dams or other structures on flow
- emulate natural drying in seasonal waterways, and
- maintain flow requirements for aquatic biota.

The general presumptive standards developed to provide riverine ecosystems protection, indicate less than a 10% change in flows is likely to achieve a high level of ecosystem protection; and that an 11 to 20% change in flows is likely to achieve a moderate level of ecosystem protection (Richter et al. 2011). For the indicators available in outputs from hydraulic and hydrology models for the Project (Appendix A and B), a basic risk assessment framework was developed as outlined in Table 4.

Table 4 Criteria for assessing potential impacts to flow for the Project (based on the presumptive standards outlined in Richter et al. 2011)

Aquatic Ecosystem Value	Required Level of Protection	Acceptable Change in Flow
Low	Low	> 20% reduction
Moderate	Moderate	11 – 20% reduction
High	High	< 10% reduction

Changes in Flow from the Project

There are no proposed surface water extractions from waterways or major catchment modifications (e.g. diversions of rivers) as part of the Project. With the exception of controlled site dewatering (outlined below), the proponent will not be actively discharging to surface water during the life of mining. However, surface water will be incidentally captured within various structures (e.g. within the TSF, Waste Rock Dumps (WRDs) and the processing area etc.). Given both the Rustlers Roost and Quest 29 sites are at the very tops of the catchments, surface water collection in site drainage and storage features is limited to overland flow from small headwater catchments and direct rainfall captured within the various structures. As such, there is likely to be passive release during high flow periods from the following:

- Surface runoff from the existing and proposed WRD at Rustlers Roost and Quest 29
- Surface runoff from exiting heap leach pads at Rustlers Roost and Quest 29
- Overflow from existing leach ponds at Rustlers Roost and Quest 29, and
- Overflow from existing pit lakes (Taipan and Zamu pit) at Quest 29.

The majority of these are existing features from historic mining that currently overflow and passively release regularly during high rainfall events. Significant impacts to downstream flow from surface runoff and overflow are not expected, and as such are not considered further.

The largest potential impacts to downstream flow as a result of the Project are expected to be related to:

- changes in the catchment area in the upper reaches of waterways, and
- releases of water from dewatering the pits.

These are discussed further below.

Change in Catchment Area

Changes in catchment size as a result of the Project are relatively minor. Specifically:

- Marrakai Creek catchment is currently 330.1 km² and will be reduced to 328.3 km² following the Project (i.e. loss of 0.6% due to the proposed TSF removing the catchment)
- Bunday Creek catchment is currently 196.7 km² and will be 198.6 km² following the Project (i.e. increase of 0.9% as some of the Marrakai catchment will become part of this catchment due to the proposed TSF), and
- Charles Creek catchment downstream of the precinct is 77.1 km² and the catchment will not change as a result of the Project.

Changes in stream flow and velocity from a change in catchment area that may occur due to the Project were assessed in Surface Water and Erosion Solutions (2022), with long-term hydrologic modelling (incorporating a climate change component) and hydraulic modelling completed (for details refer to Surface Water and Erosion Solutions 2022).

For Marrakai Creek, the results of long-term hydrologic modelling indicated little change in long-term peak flow, total volume and average annual flow (<1%) at the mid-way point (approximately 20 km downstream of the Project) and outlet of the catchment (Surface Water and Erosion Solutions 2022; Appendix A). These changes were suitable for the protection of the moderate (Marrakai Creek, main branch) to high (Adelaide River floodplain system) ecological value waterways in this area. The hydraulic modelling of the 1% Annual Exceedance Probably (AEP) and 0.1% AEP design rainfall events also indicated changes in peak flow, total volume and velocity (<1%) are suitable for the protection of the moderate to high ecological value waterways at the mid-way point and outlet of the catchment. Changes in modelled water depth are less than 3% at the mid-way point and outlet of the Marrakai Creek catchment, except for the 1% AEP modelled water depth at the midway point which is predicted to decrease by 19% (i.e. from 31 cm to 25 cm). This 6 cm reduction in water level is considered acceptable / unlikely to result in significant impacts to Marrakai Creek, main branch (moderate ecosystem value).

For the Bunday Creek and Charles Creek catchments, long-term hydrologic modelling indicated changes in peak flow, total volume and average annual flow (<7%) at the confluences of the upper tributaries that receive direct runoff from the Project and main branches are suitable for the protection of these moderate ecological value waterways. The hydraulic modelling of the 1% AEP and 0.1% AEP design rainfall events also indicated changes in peak flow, total volume and velocity (<8%) are suitable. Changes in modelled water depth in the main branches are less than 6%, except for the 0.1% AEP modelled water depth where flow from the upper tributary that receive direct runoff from Quest 29 joins Charles Creek, which will increase from 2.5 cm to 7 cm. These increases in water depth will result in inundation of a greater area of aquatic habitat, which is not expected to result in negative impacts to aquatic flora and fauna.

Overall for the locations assessed, changes in long-term peak flow, total volumes, average annual flow, as well as peak flow, total volume and velocity during 1% and 0.1% AEP rainfall events resulting from changes in catchment are expected to be relatively minor (i.e. < 10%; Appendix A), and within an acceptable level of change for these low to high aquatic ecosystem value waterways.

Releases

There are currently two existing Authorised Discharge Points (ADPs) for releases from Rustlers Roost. ADP1 on Marrakai Creek and ADP2 on Mount Bunday Creek. All releases for Rustlers Roost are expected to be via ADP2 on Mount Bunday Creek and as such releases to ADP1 on Marrakai Creek are not assessed here. The location of ADP2 will need to be moved (a few hundred metres downstream to the boundary of the ML) through operation as it is currently in the area of the proposed TSF. For Quest 29, releases will be into Charles Creek, which flows into the McKinley River then the Mary River.

Both the Rustlers Roost and Quest 29 sites contain previously mined pits that have filled with water over time. The bases of these pits are below the groundwater table and groundwater flows into the pits. Dewatering will be required prior to mining at Rustlers Roost and during mining at both sites. There will be no releases during the dry season. Seasonal releases would only commence after natural creek flow has begun and cease when natural creek flow ends (i.e. releases will likely commence in December and end during recessional creek flows in April). The rate of release will be variable, determined on analysis of wet season rainfall recorded at Old Mount Bunday Station and available forecasts. In general, during times of low to no rainfall in the wet season, the pump release rate will be reduced to a minimum of 50 L/s, with the objective that the creek systems are not overwhelmed by the influx of water. As the rainfall volume increases, the rate of release will increase up to 200 L/s. On occasions where the rainfall is expected to be large (i.e. monsoon or cyclone events), the pump is expected to be turned on to its maximum capacity of approximately 300 L/s. Controlled releases for the dewatering during the wet season will comply with water quality release criteria outlined in the Water Management Plan (WMP) and operational Waste Discharge Licence (WDL), with a new WDL for ongoing controlled releases required post-2023 when the current WDL expires. The current WDL specifies releases to only occur when natural flow is present in the watercourse (as such the proposed release regime is slightly more stringent as they will be restricted to the wet season regardless of downstream flow).

Mount Bunday Creek Catchment

Flow in Mount Bunday Creek is spatially and temporary variable. The upper tributaries are generally dry during the dry season and flow during and following rainfall in the wet season. During the dry season, there are generally permanent pools and reaches (refuge) in the main branch of Mount Bunday Creek that are disconnected by dry sandy areas. Some areas in the main branch are also fed by alluvium groundwater extending wet season flows.

There will be no releases to Mount Bunday Creek during the dry season, and as such potential impacts to flow as a result of releases are restricted to the wet season. During the wet season, releases to Mount Bunday Creek (via ADP2) will vary depending on rainfall. A hydrology model for the releases to Mount Bunday Creek has been completed (Appendix B). The modelled scenario assumes all releases from Rustlers Roost go to the Mount Bunday catchment. The release volumes in the model are based entirely on the storage parameters and parameters to maximise storage while excluding dry season (April to July) releases.

In the upper ephemeral channels of Mount Bunday Creek (1.1 km downstream of the mine), the releases will result in an increase in the total volume of water discharged through the creek three-fold. However, peak discharges will only increase by 7% and velocity will only increase by 9% within this reach, which is within acceptable levels for the low to moderate ecosystem value of the upper Mount Bunday Creek tributaries.

Further downstream on the main branch of Mount Bunday Creek, total discharges increase by up to 6%, which will cause a very minor change in peak discharges and velocity (<1%). At the outlet of Mount Bunday Creek, near the confluence of Hardies Creek and the Mary River, releases from the mine will only result in a 2% increase in total discharge volume, resulting in a very minor increase in flow (<1%). These changes in flow are within acceptable limits for these moderate to high aquatic ecosystem waterways. Modelling results indicate that releases are expected to result in a 4 cm (36%) increase in water depth near the release point, but only minor increases in water depth (<1% and <1 cm) on the main branch of Mount Bunday Creek. These increases in water depth will result in inundation of a greater area of aquatic habitat, which is not expected to result in negative impacts to aquatic flora and fauna. Minor changes to stream bed reshaping are also expected, which naturally occurs during high flow events in ephemeral and seasonal streams in this region (Appendix B).

Charles Creek Catchment

Flow in Charles Creek is variable, it is largely ephemeral (dry / no flow) during the dry season.

There will be no releases to Charles Creek during the dry season, and as such potential impacts to flow as a result of releases are restricted to the wet season. During the wet season, the Quest 29 releases to Charles Creek will vary, with a lower release during low rainfall and higher release during high rainfall periods. A hydrology model for the releases to Charles Creek has been completed (Appendix B). The modelled scenario release volumes are based entirely on the storage parameters and parameters to maximise storage while excluding dry season (April to July) releases.

At the release point to the upper ephemeral channels of Charles Creek, total discharge (volume of water) is expected to increase by 33% as a result of the releases, with peak discharges increasing by 29%, and velocity will increase by 12%. This is within the acceptable levels for the low ecosystem value of the waterway at the release point adjacent to the mine.

Further downstream on the main branch of Charles Creek, total discharges increase by up to 7%, which will cause a minor change in peak discharges and velocity (<6%). At the outlet of Charles Creek, near the confluence of the McKinney River, releases from the mine will only result in a 0.1% increase in total discharge volume, resulting in a very minor increase in flow and velocity (<1%). These changes in flow are within acceptable limits for these moderate to high aquatic ecosystem waterways. Modelling results indicate that releases are expected to result in only minor increases in water depth (<5% and 1 cm or less) on the main branch of Charles Creek. This is not expected to result in negative impacts to aquatic flora and fauna.

Monitoring

Ongoing monitoring (including reactive measures) should be completed to assess the impacts of changes in flow on the downstream aquatic ecosystems during operation of the Project. Comparative sites not affected by the operation should also be assessed, and the results can also be compared to the results of surveys completed prior to recommencement of mining operations. Monitoring indicators should include habitat assessments (including stream bed erosion) and biological indicators (macroinvertebrate sampling).

Risk Assessment

An assessment of the changes to the ecological functions of flow as a result of the Project is outlined in Table 5. Overall, for flow indices available from hydrology models, changes in flow are expected to be within acceptable limits for each waterway. Restricting releases to the wet season and varying the release volume based on rainfall will help protect the natural water availability and variability in the system, which is important to maintain habitat and flora and fauna in the waterways (including maintaining migration and breeding cues for fauna).

From available Project information, hydrology models and a desktop assessment of aquatic ecosystem values, potential impacts to aquatic ecology associated with changes in flow regimes from the Project are expected to be low and within acceptable limits for downstream waterways. Ongoing monitoring and managing of impacts will further reduce the risk of changes to flow on aquatic ecosystem values.

Table 5 Assessment of ecological functions of flow from the Project

Function of downstream flow	Potential impact of the Project
Water availability for native flora and fauna	Changes in flow are relatively minor in the main branches of waterways given the small area of catchment removed and the predicted impacts of releases during the wet season (when compared to the discharge in the catchment). As such, permanent pools and reaches are expected to be available in the main branches, with no substantial reductions in water availability.
Instream habitat (channel maintenance, sediment and organic matter transport, riparian condition)	Modelling results indicate minor stream bed reshaping, which is common in ephemeral and seasonal streams in the region during large flow events. As such, changes in flow are not expected to significantly impact instream habitat. Slight increases in water depth during releases will increase the area of habitat available to aquatic flora and fauna.
Protect natural flow regimes (wet season flow) / Seasonality (timing and duration of flow)	No releases are proposed during the dry season when many of the waterways are dry. The release regime will be dependent on rainfall, to maintain seasonality in waterway flows.
Maintain natural variability (a system should retain its perennial or seasonal nature)	The ephemeral stream character will be maintained given no releases will occur during the dry season, and seasonality of flow will be maintained by varying release volumes depending on rainfall in the region.
Manage groundwater for ecosystems	No groundwater dependant ecosystems occur within the Project area. Given there are expected to be minor changes in flow in downstream waterways, potential GDEs in downstream reaches are expected to be maintained during operation of the Project. Impacts to groundwater were not assessed here.

Function of downstream flow	Potential impact of the Project
Protect important rises in water levels – important wet season flows.	Given water releases will not occur in the dry season and releases will be variable depending on rainfall, impacts to rises in water levels (during the wet season) are expected to be minor during operation of the Project. Despite the small loss of catchment area, important wet season flows will still occur.
Maintain seasonal wetland/floodplain inundation / protect natural low flows in perennial systems	Given the relatively small changes in flow compared to the large flows of main branch waterways, important wetland and floodplain habitat in downstream reaches of Mount Bunday Creek, Charles Creek, Marrakai Creek, Hardies Creek, McKinley River, Mary River and Adelaide River are expected to be maintained.
Minimise the effect of weirs/dams or other structures on flow	No dams or weir are proposed on waterways. All infrastructure will be within the ML in the upper reaches of the catchments.
Emulate natural drying in seasonal waterways	There will be no dry season releases; as such natural drying in waterways during the dry season will be maintained.
Maintain flow requirements for aquatic biota.	<p>The onset of stream flow at the beginning of the wet season and changes in water levels are expected to be maintained by adjusting the volume of releases based on rainfall in the region. This will maintain breeding cues for fish and fish use off-channel habitats during flooding.</p> <p>Peak floods and minimum flows that are vital to the connectivity of streams and provide stimulus for breeding and dispersal are expected to be maintained.</p>

Assumptions and Limitations

This assessment was desktop only and as such is limited by the accuracy of available information, including details of the Project and impacts to flow provided via email. Predicted impacts to flow are subject to the information and accuracy of the hydrological models.

For Marrakai Creek, pre- and post-redevelopment values for discharge, velocity and depth are provided for assessment point J9, which is 20 km downstream of the Project. As such, the impacts of the Project to the reaches of this waterway that are closer to the Project have not been quantitatively assessed (i.e. to determine the percentage change for risk assessment purposes). However, it is noted that the graphs provided for the section along the length of Marrakai Creek (thalweg) are not indicative of any substantial changes to the water depth or flow velocity (Appendix A).

This memo does not consider the water quality of proposed releases, and the potential impacts of this on aquatic ecology. This is an important consideration that we assume is being assessed by others.

This memo does not consider the potential impacts of the Project on groundwater. It therefore only considers the potential impacts of changes in surface water flows to groundwater-dependent ecosystems.

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Appendix A Changes in Flow due to Catchment Loss (from Surface Water and Erosion Solutions (2022))

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 ³ /s)	Total discharge (TL)	Average annual discharge (GL)	Peak discharge (m ³ /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 ³ /s)	Total discharge (GL)	Average annual discharge (GL)	Peak discharge (m ³ /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 ³ /s)	Total discharge (TL)	Average annual discharge (GL)	Peak discharge (m ³ /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

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

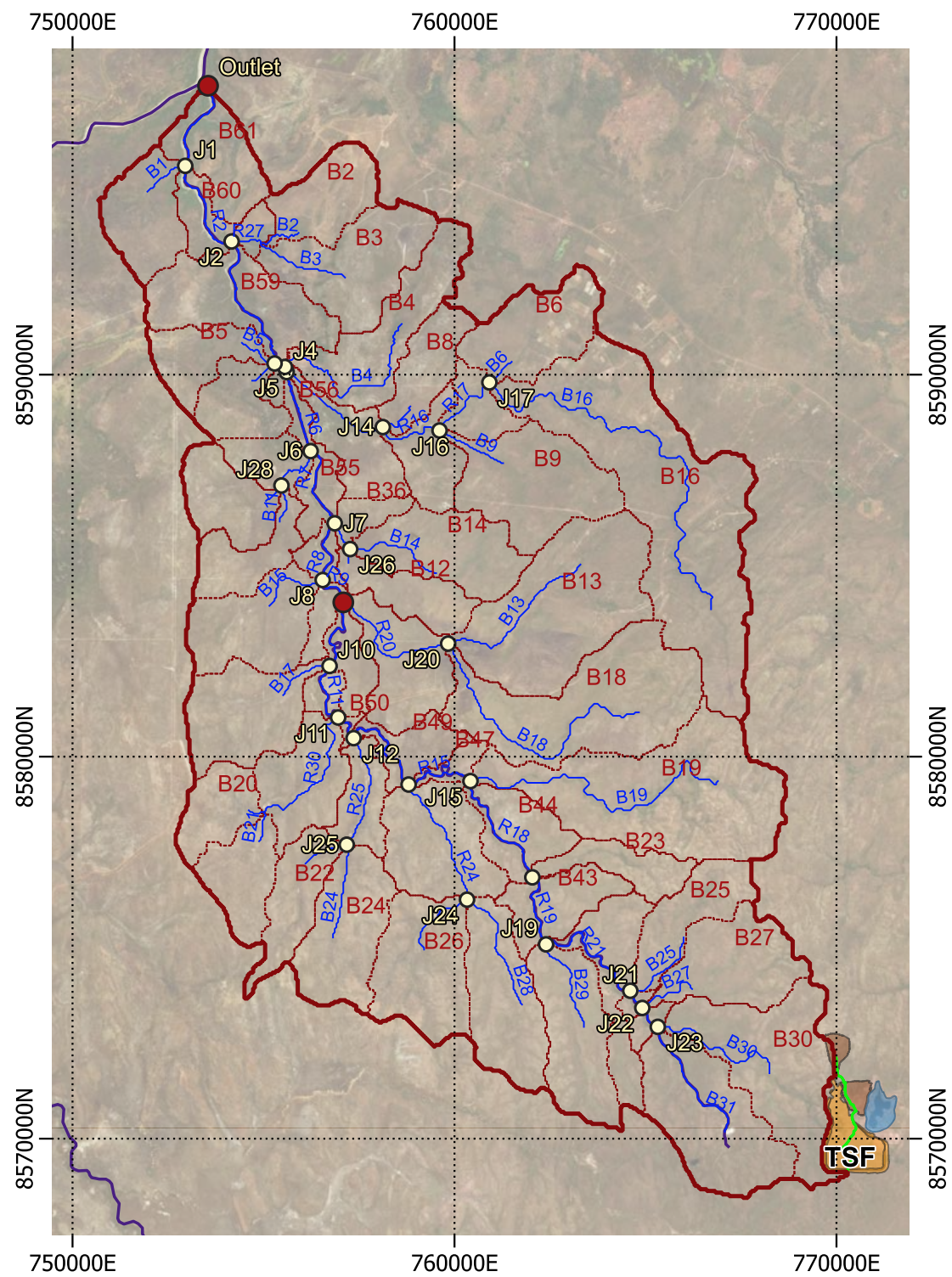
1% AEP									
Element	Pre-redevelopment				Post-redevelopment				Nash-Sutcliffe
	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	
J9	328.7	36.3	0.2	0.31	328.7	36	0.2	0.25	1
Outlet	374.8	64.9	1.16	3.37	374.8	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 ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m ³ /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

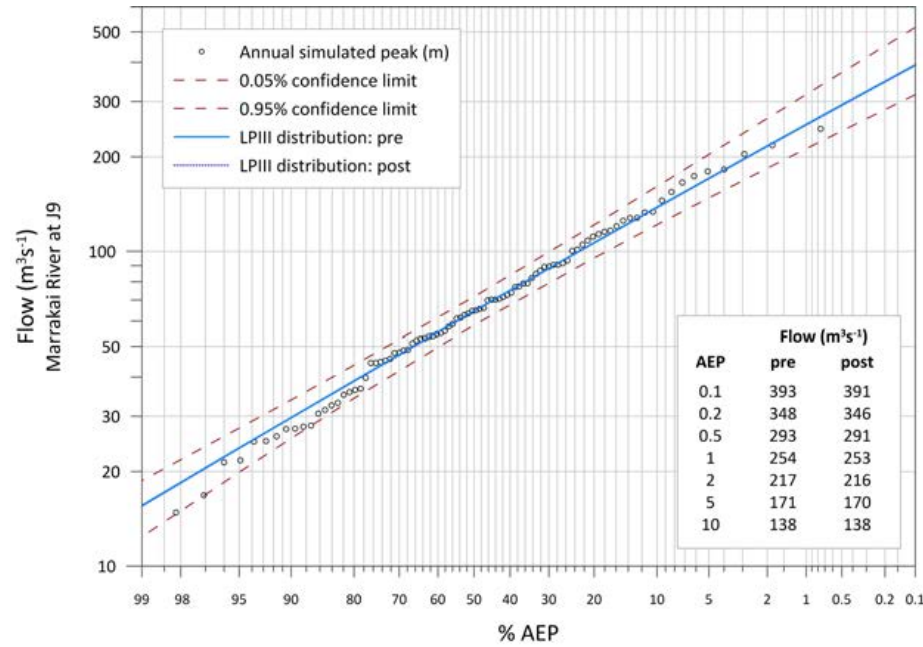
Table 3-6 Comparison of the differences in 1% AEP and 0.1% AEP rainfall events in the Charles Creek catchment pre- and post-redevelopment of the Quest 29 mining precinct.

1% AEP									
Element	Pre-redevelopment				Post-redevelopment				Nash-Sutcliffe
	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m ³ /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

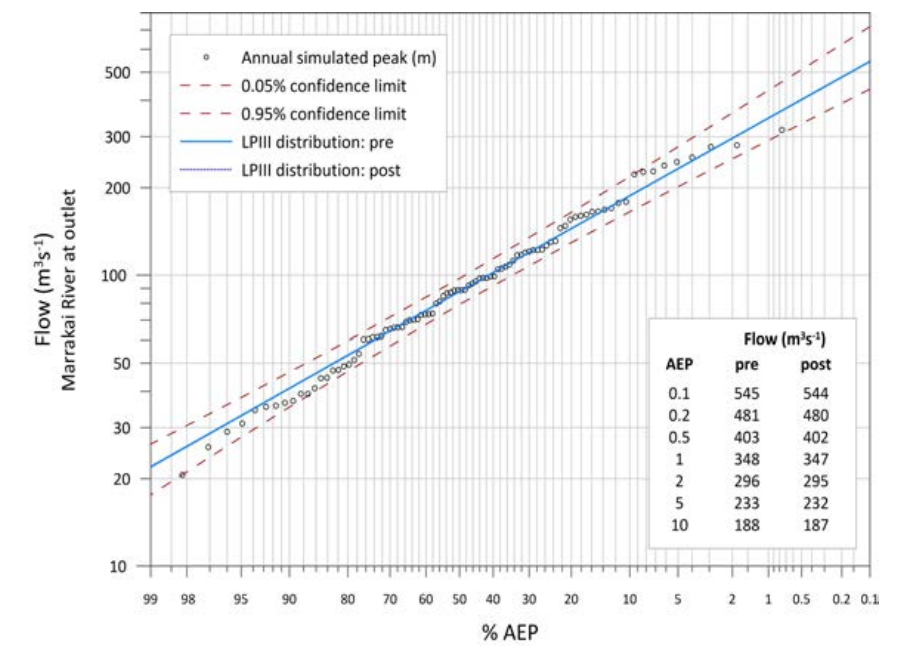


- Proposed tailings storage facility
- Hydrograph & LP3 Junctions
- WRD
- Pit_1_Final
- HEC-HMS Junctions
- HEC-HMS sub-basins
- Marrakai HEC-HMS reaches
- Adelaide_River
- Marrakai HEC-HMS boundary
- Marrakai cathment pre-redevelopment

Above. Marrakia Creek HEC-HMS model (sub-basins, junctions and reaches). The pre-redevelopment catchment loses 1.85 km² 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

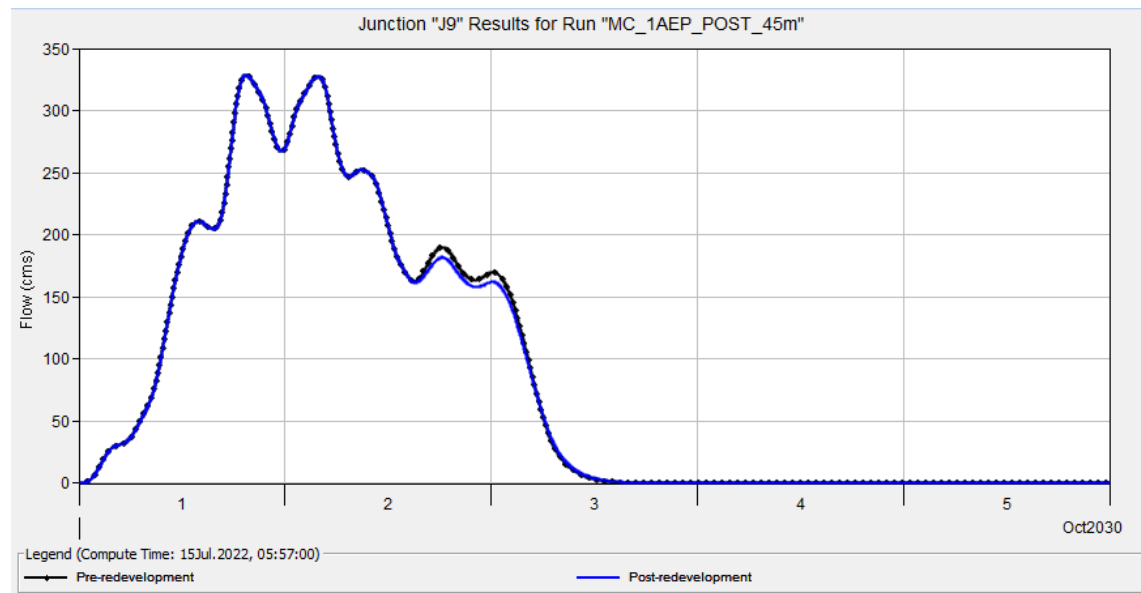
SURFACE WATER & EROSION SOLUTIONS
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



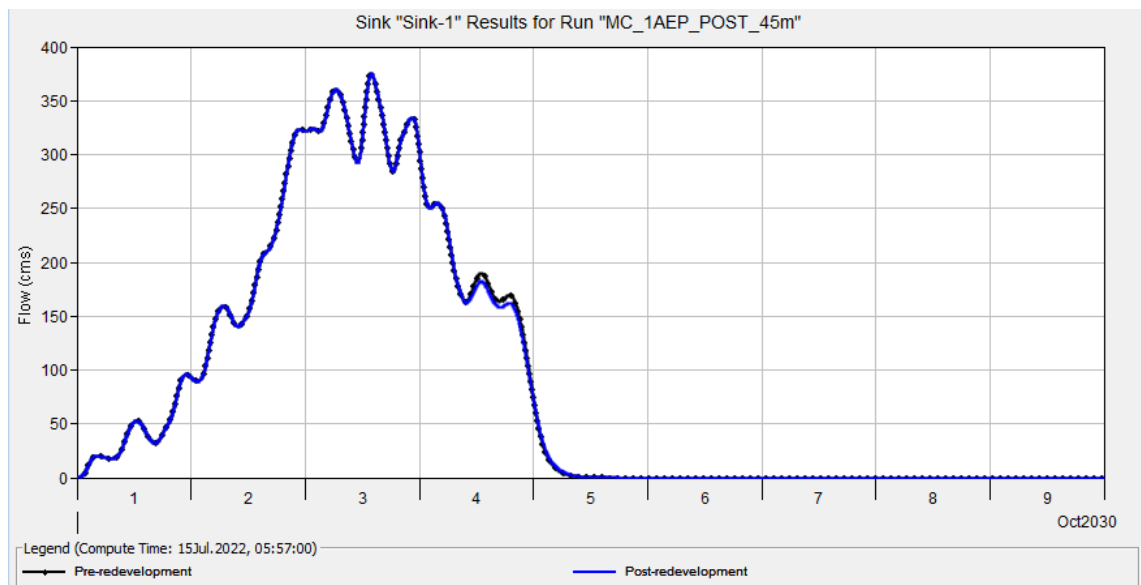
Project **Rustler's Roost & Quest 29**
EIS Supplementary
Information

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

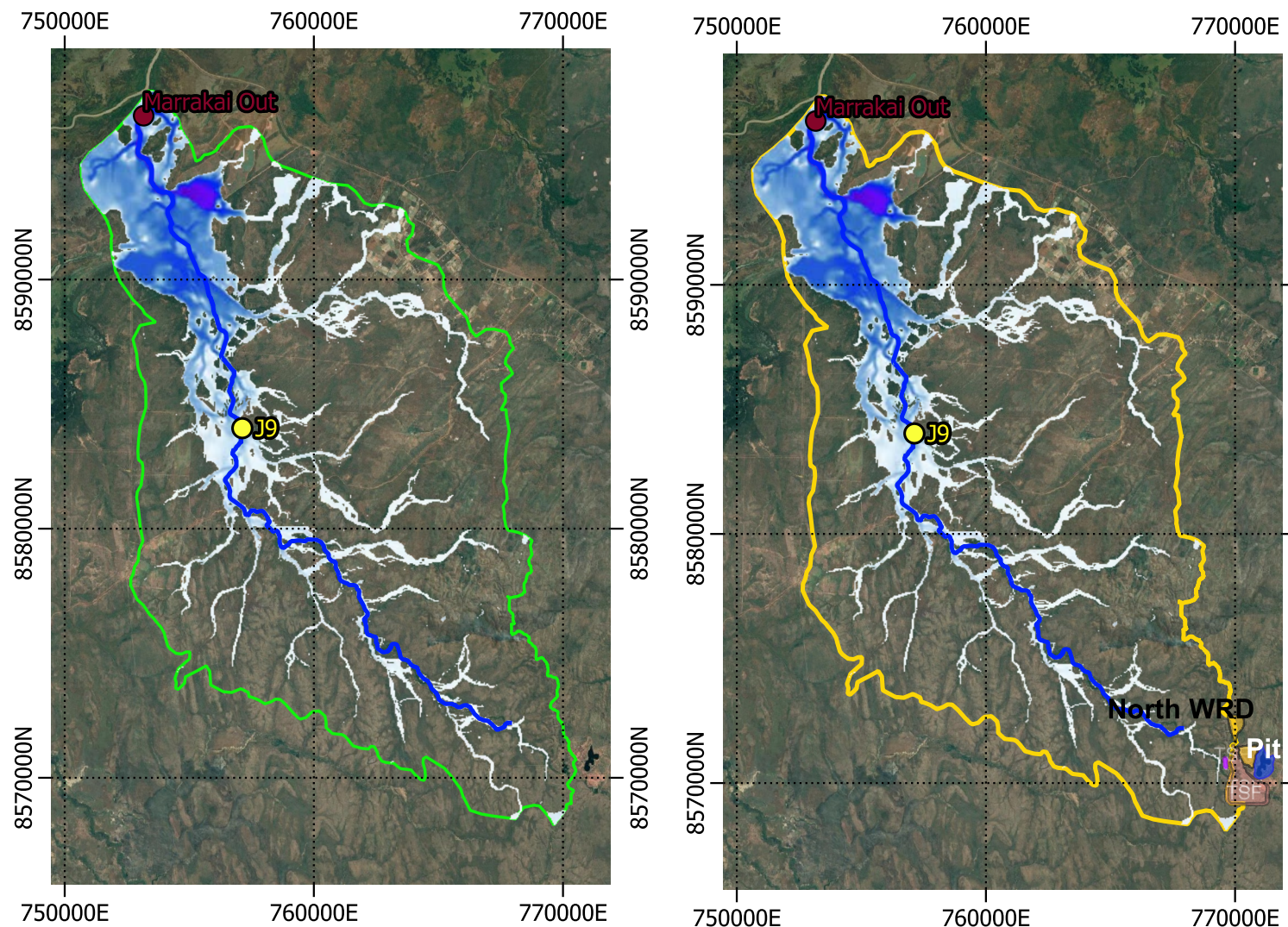
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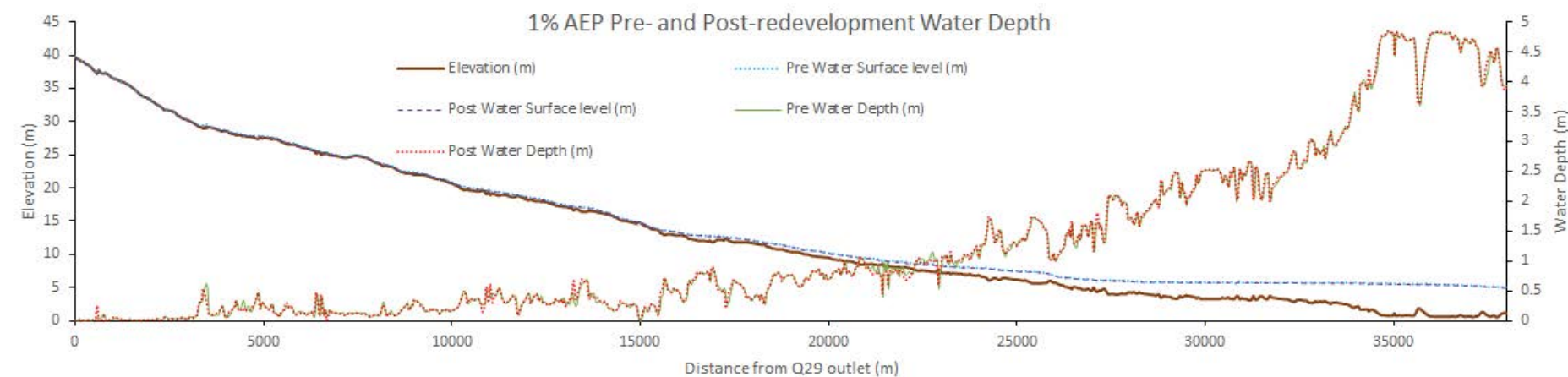
Above: Discharge at J9. There is only minor difference in pre- and post redevelopment conditions with slightly lower flows in the receding limb of the hydrograph



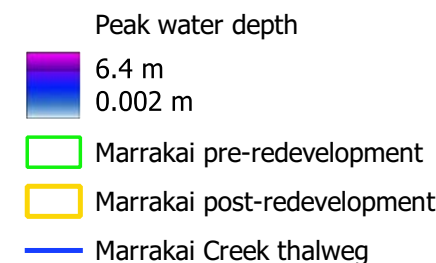
Above: Discharge at Marrakai Creek outlet. There is only minor differences in pre- and post redevelopment conditions with slightly lower flows in the receding limb of the hydrograph.



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



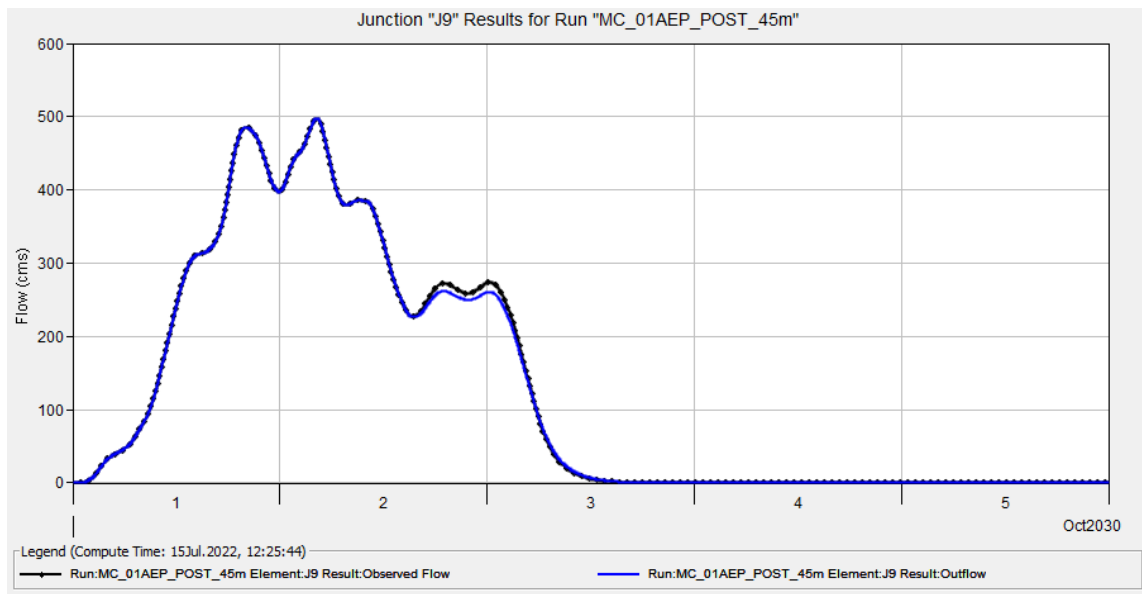
Above: Section along the thalweg of Marrakai Creek (see maps right) from Ruslter's Roost (left) to near confluence with Adelaide River (right) for the simulated peak flood level. There is little difference between pre- and post- with the average difference in depth of the post-redevelopment event = -0.011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



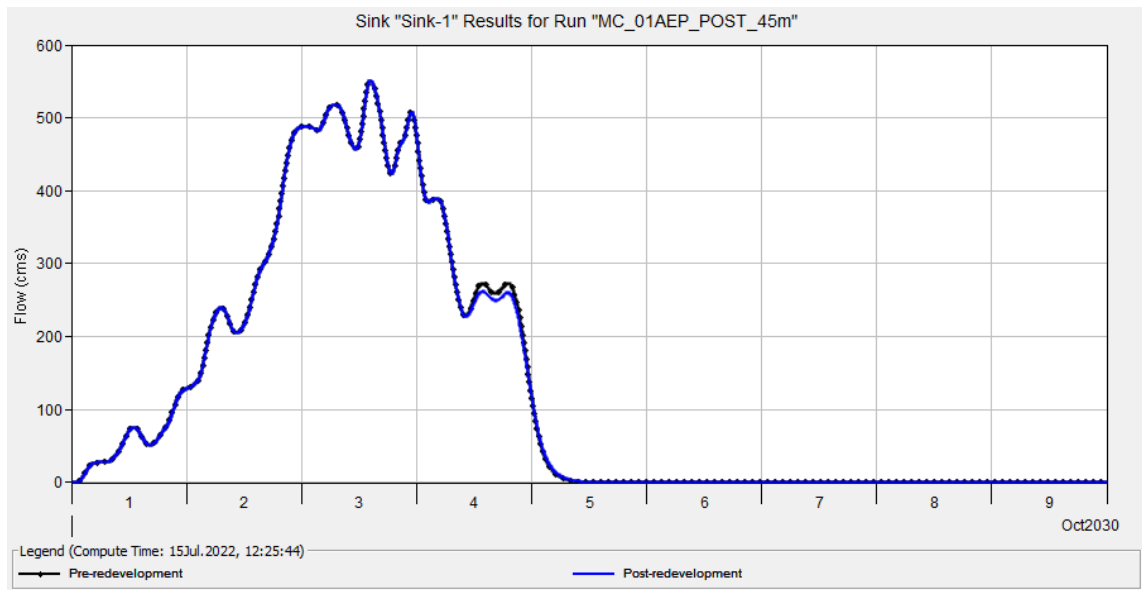
Notes

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.

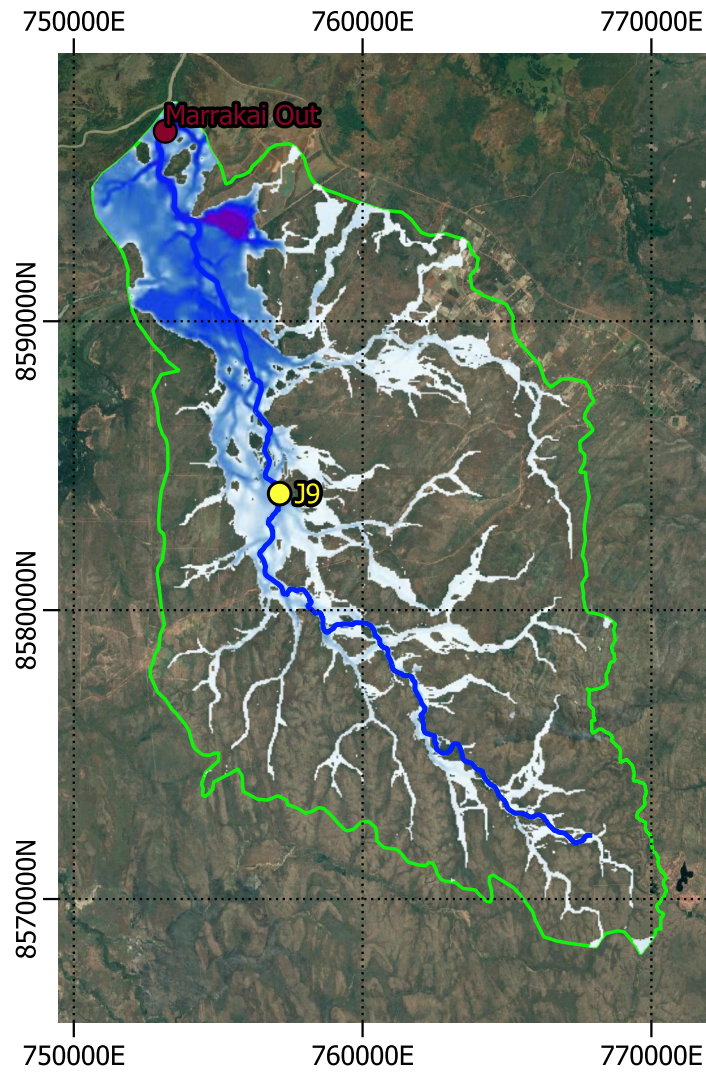
Drawing No MC-02	<p>SURFACE WATER & EROSION SOLUTIONS ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT</p>	Project Rustler's Roost & Q29 EIS Supplementary Information	Title Marrakai Creek: Pre- and Post- Redevelopment 1% AEP Rainfall Event Water Depths	Designed	Drawn	Checked	Sheet size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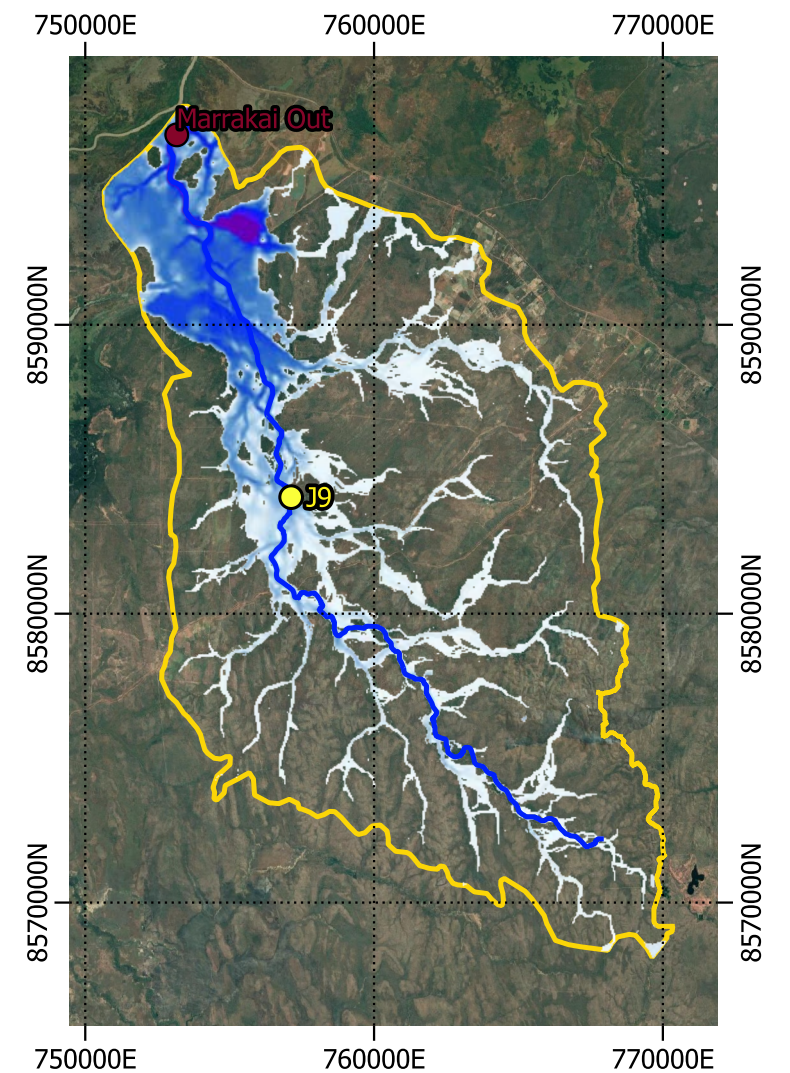
Above: The pre- and post-redevelopment discharges for the 0.1% AEP J9. There are only insignificant difference in the receding hydrograph.



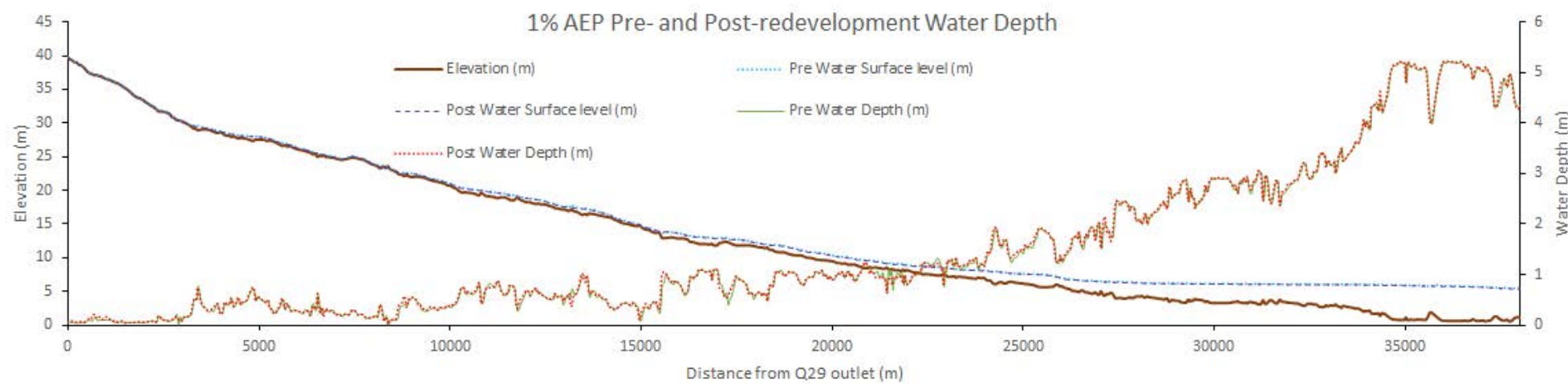
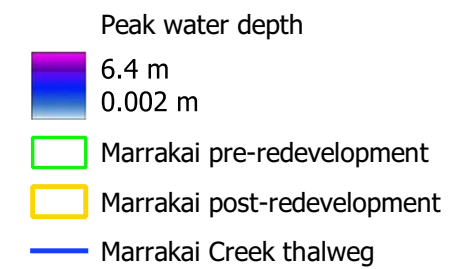
Above: The pre- and post-redevelopment discharges for the 0.1% AEP at the MC outlet. There are only insignificant difference in the receding hydrograph.



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



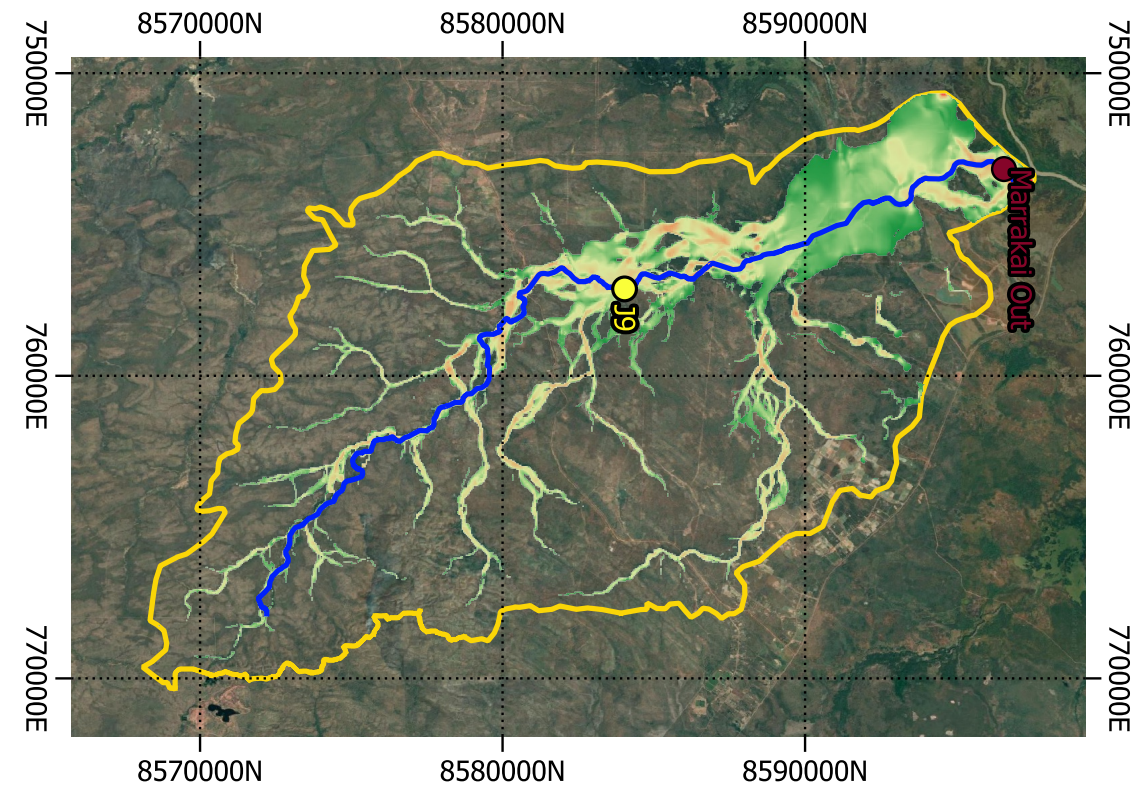
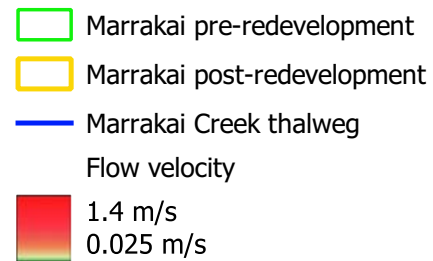
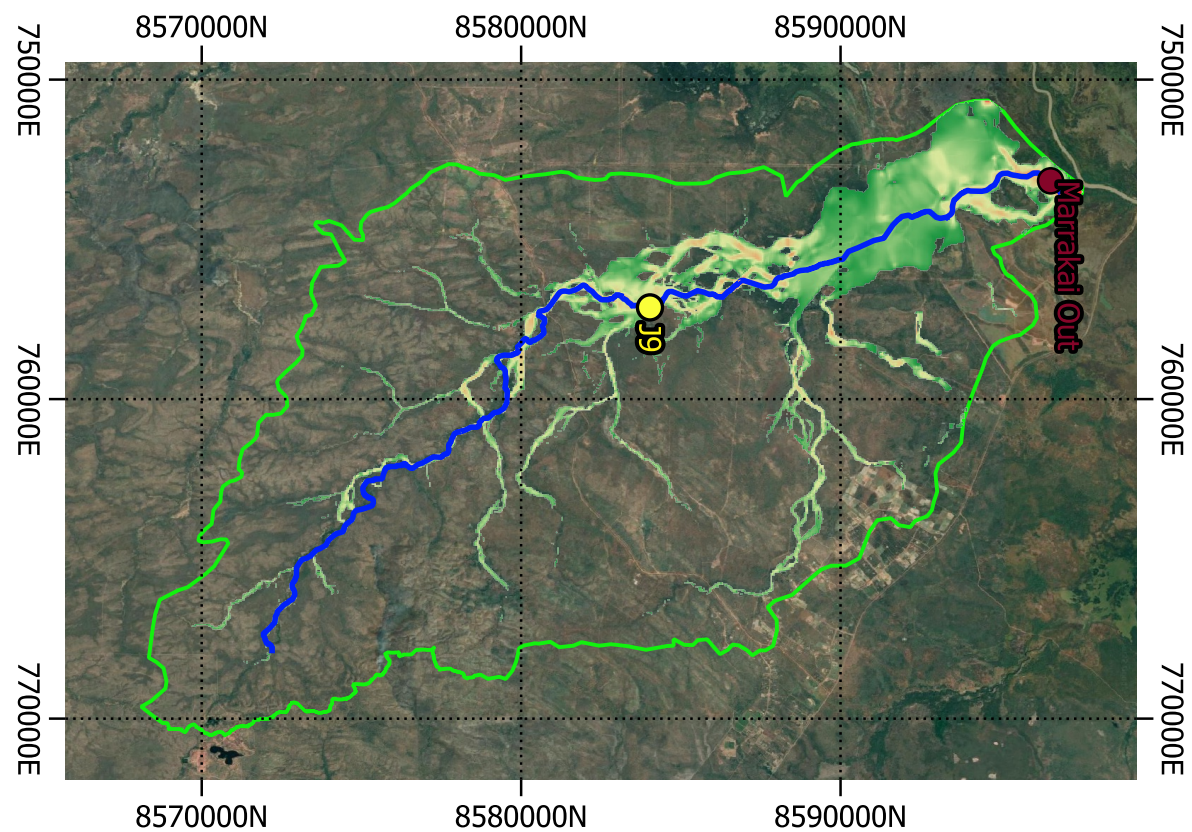
Above: Post-redevelopment 0.1% AEP flood water levels.



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.

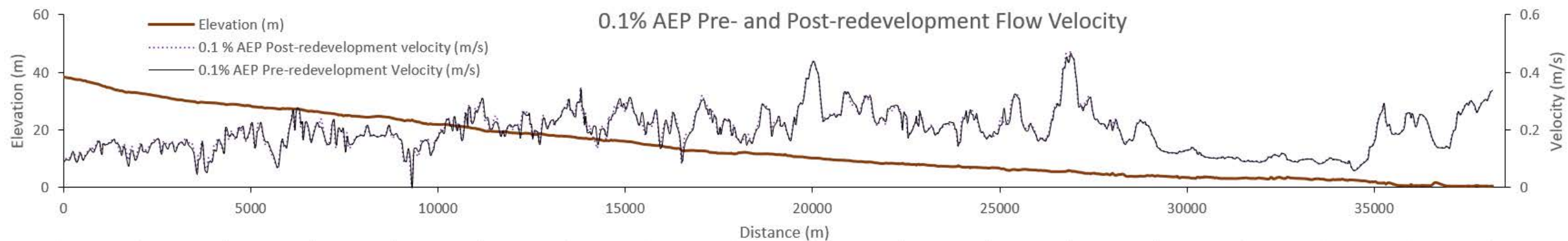
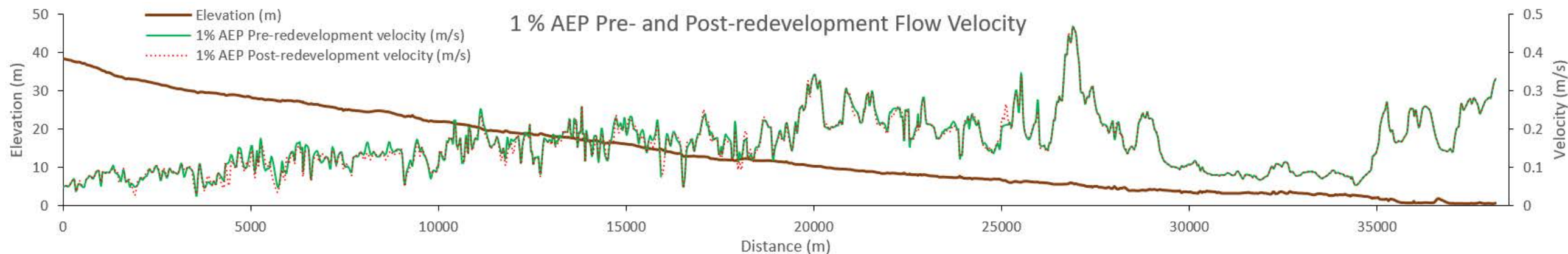
Notes

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.



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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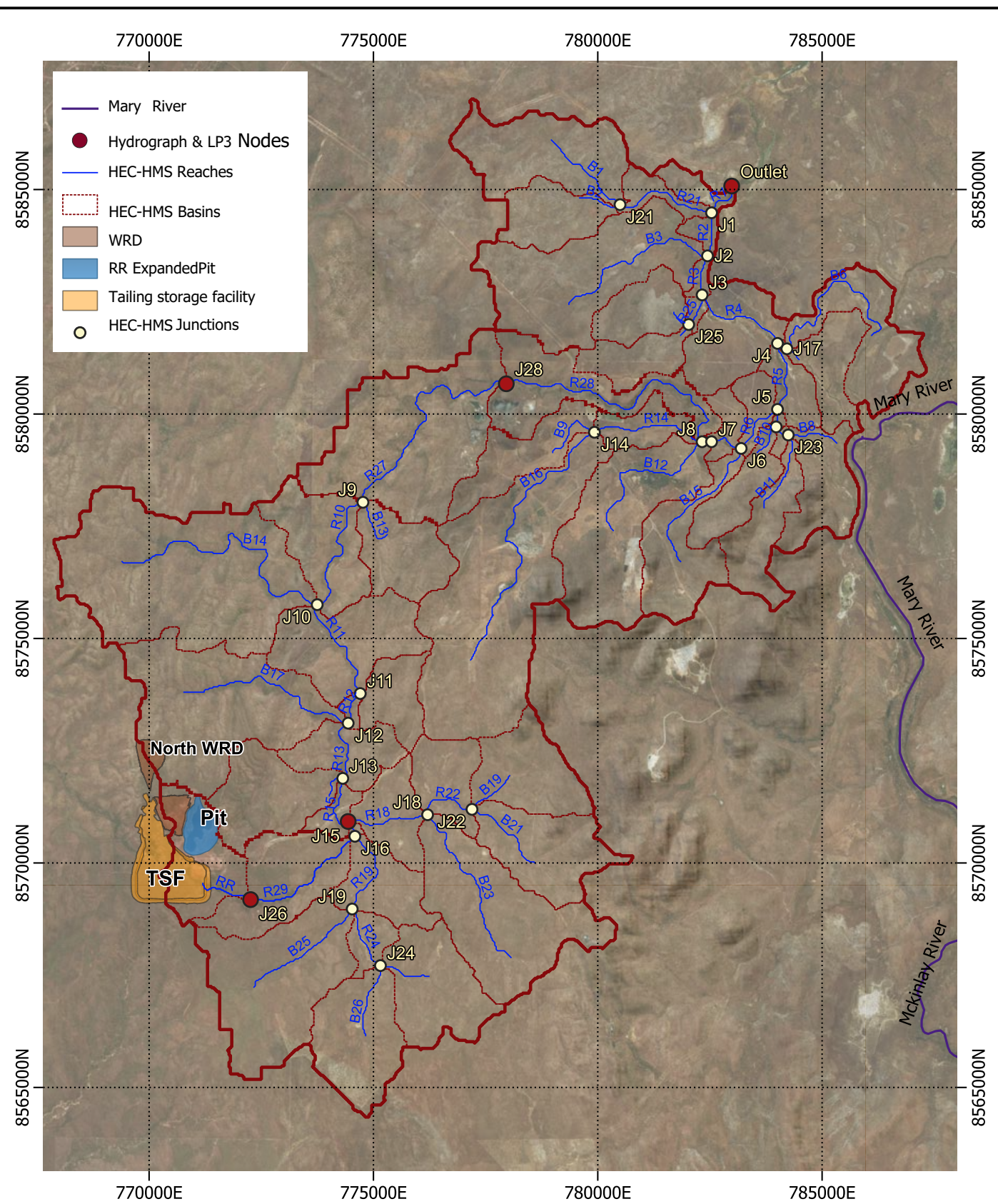
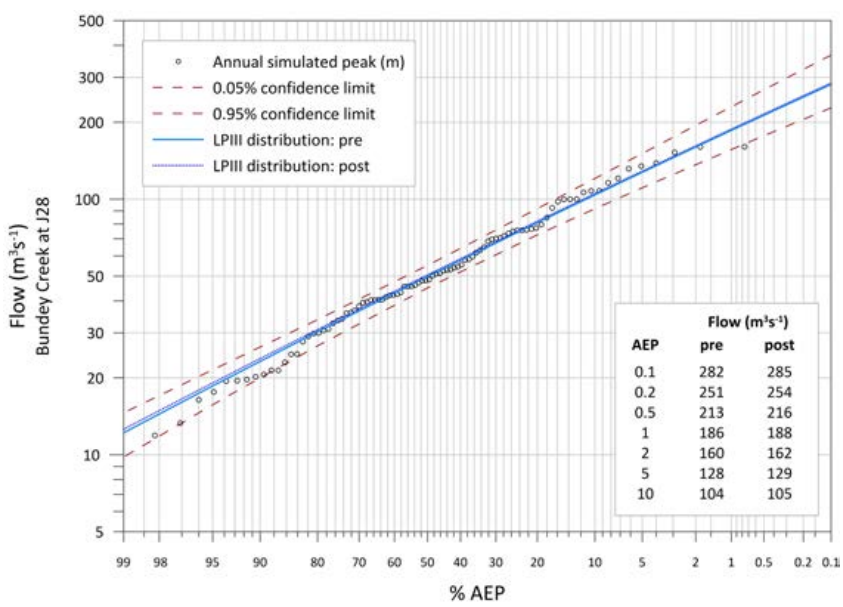
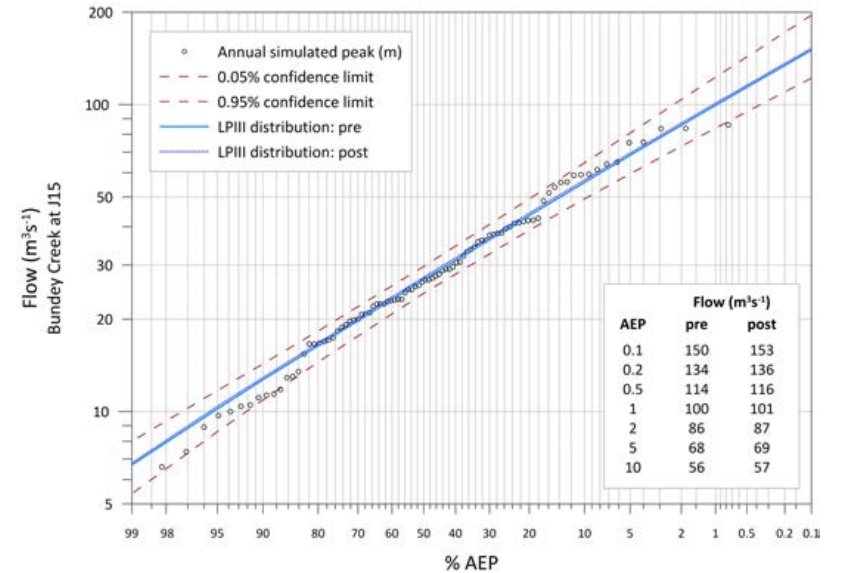


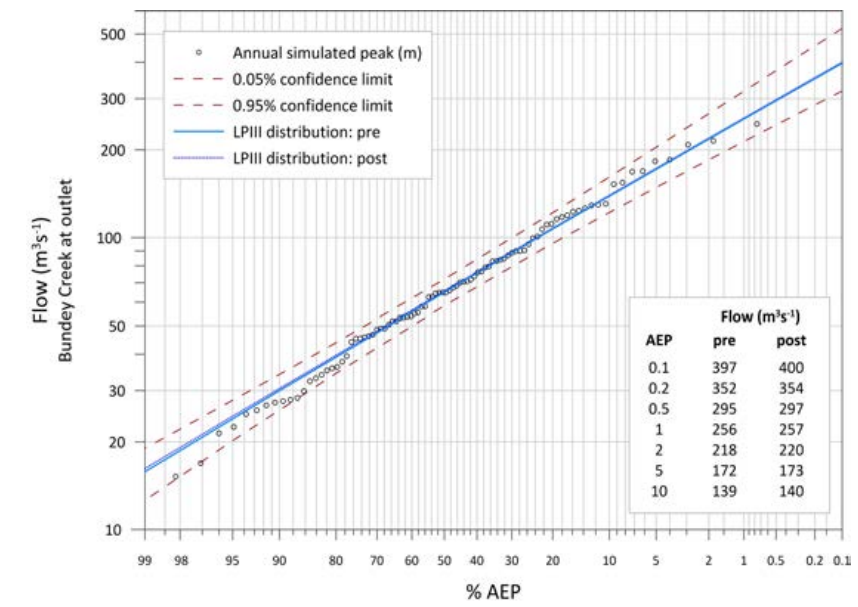
Figure 1. Mt Bunday Creek HEC-HMS model (sub-basins, junctions and reaches) showing the LP3 nodes.. The model is adjusted to incorporate redevelopment infrastructure such as the tailing storage facility, expanded pit and waste rock dumps.

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.



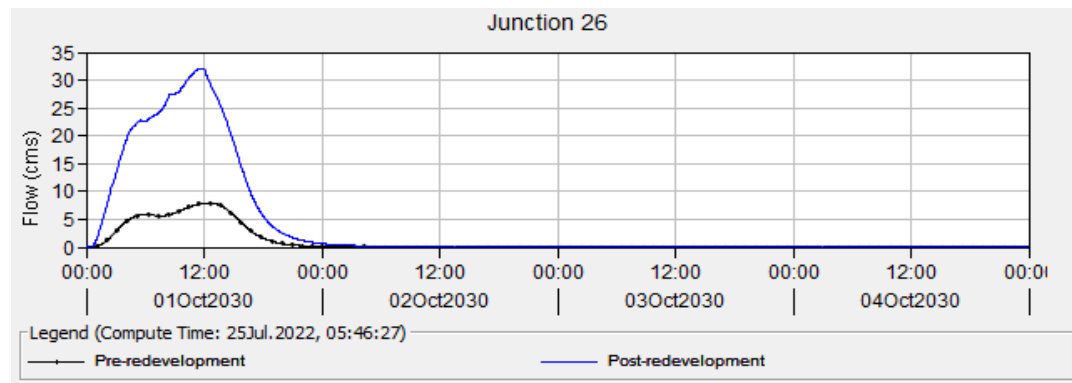
Left: Log Pearson distribution pre- and post-mine expansion at Junction J28 in the lower half of the Mt Bunday Creek catchment. Tom's Gully site debouches in to the main channel at this point. There is an increase in total discharge of 3.1% in the post-mine expansion scenario.

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

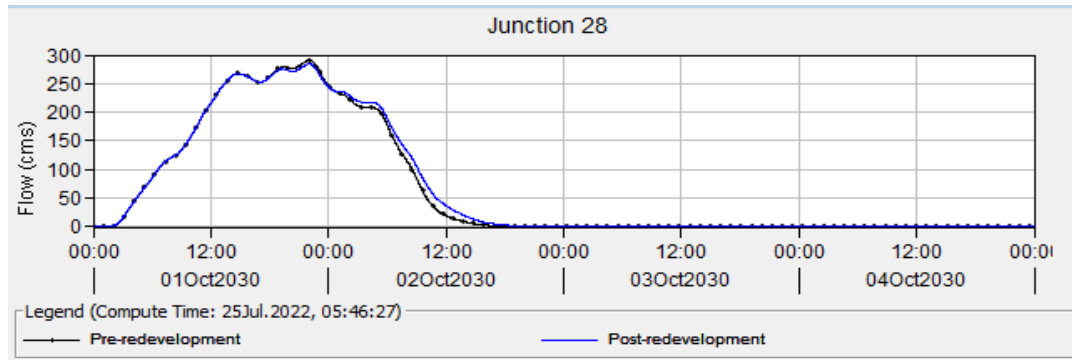
1. This is an assessment of changes in hydrology of the Mt Bunday Creek catchment due to the Rustler's Roost redevelopment in the upper catchment using the HEC-HMS model.
2. A 91 year simulation was conducted from 2030 applying climate change using the RCP 4.5 model.
3. A log-Pearson 3 distribution was 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 .



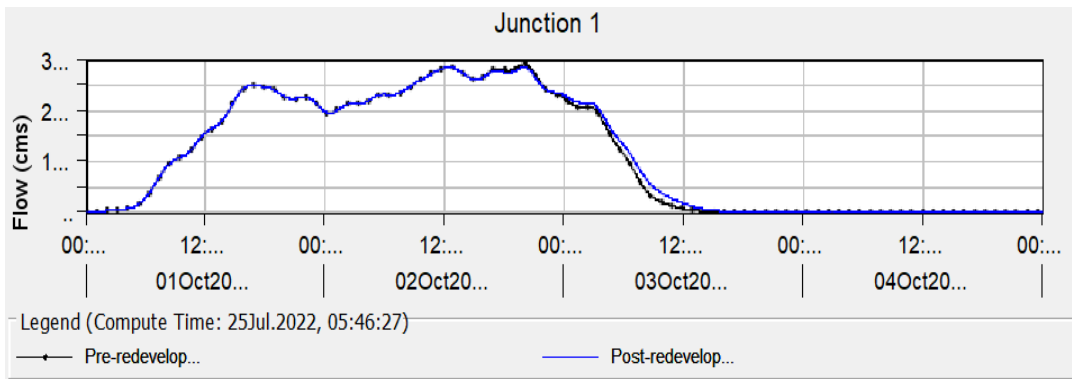
Above: Flow at Junction 26. The TSF has added 2 km² to this part of the catchment causing higher flows in this part of the catchment when water is released from the TSF. This higher flow reduces relative to other catchment flows as it move downstream.



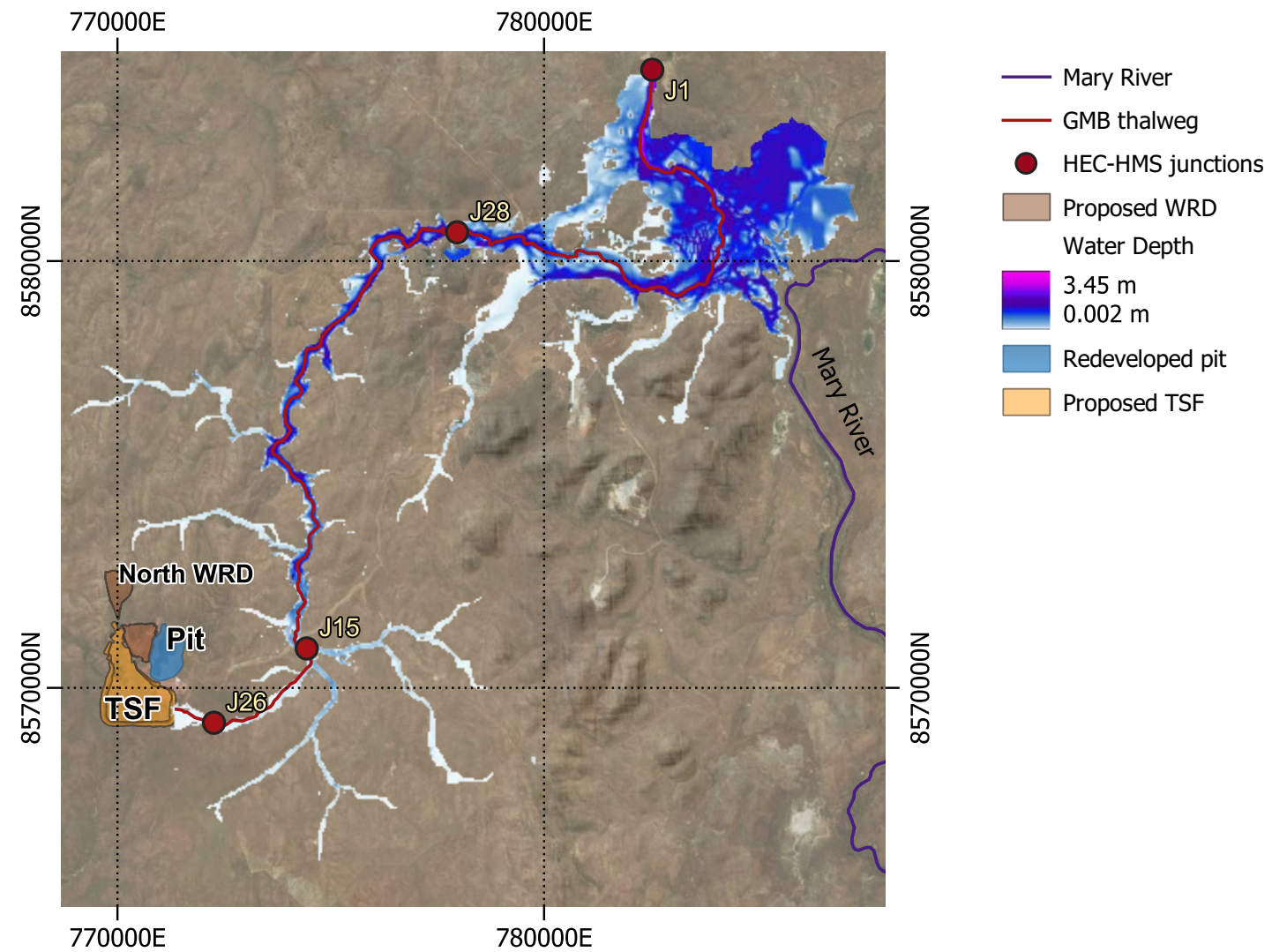
Above: Flow at Junction 15. There is little difference in the pre- and post-redevelopment hydrographs as TSF flow are absorbed with other catchment flows.



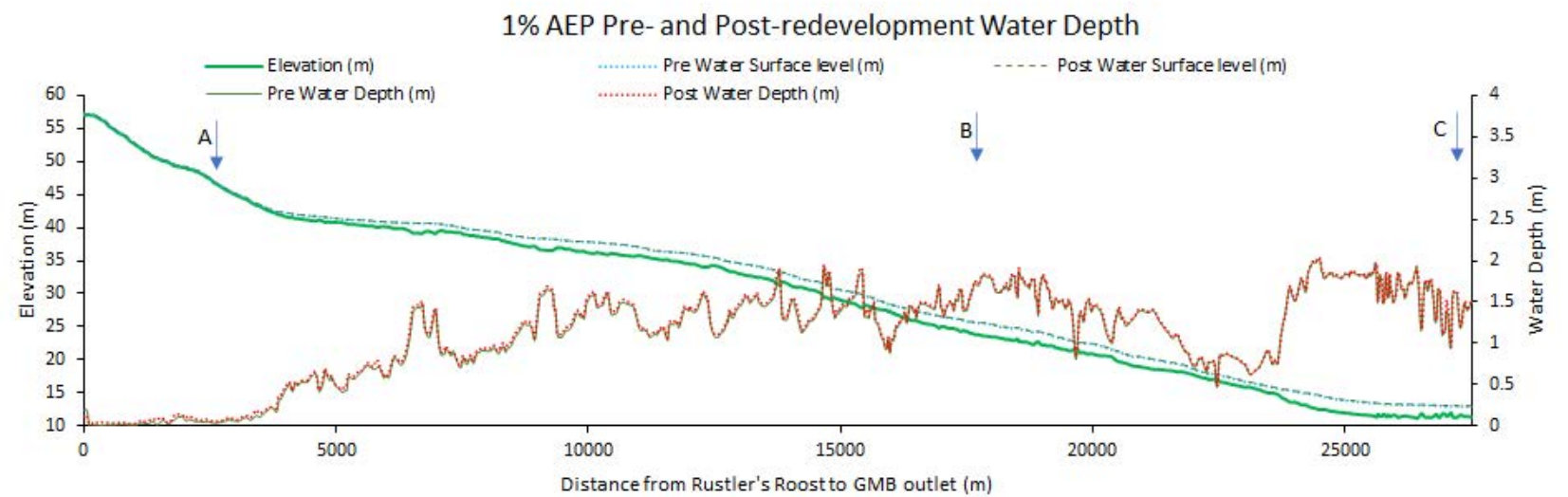
Above: Flow at Junction 28 (Tom Gully pit). There is little difference in the pre- and post-redevelopment hydrographs.



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

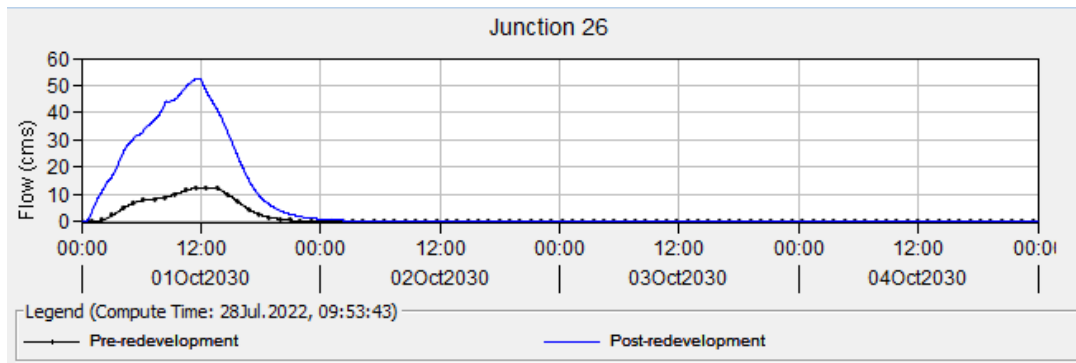
SURFACE WATER & EROSION SOLUTIONS
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



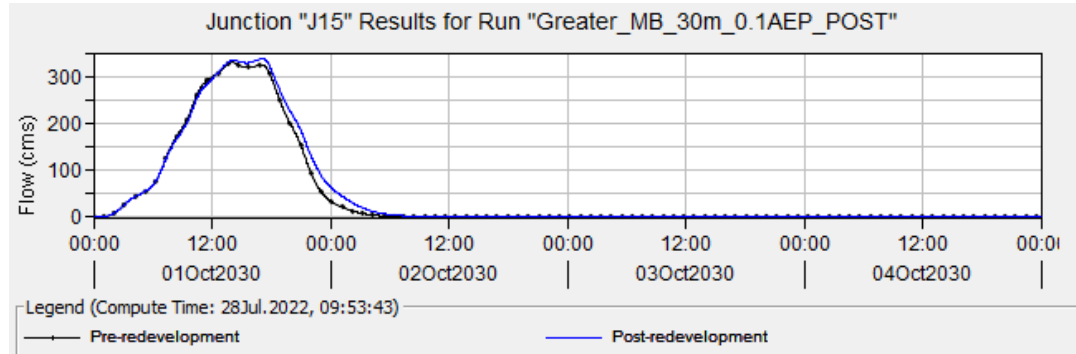
Project
**Rustler's Roost & Q29 EIS
Supplementary Information**

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

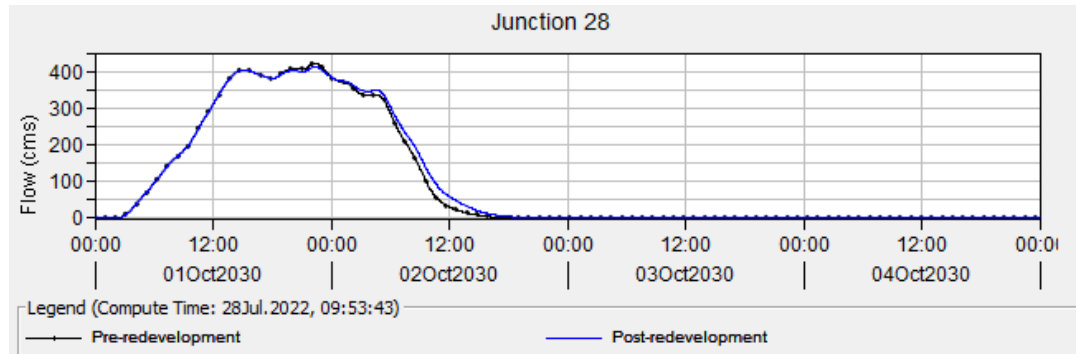
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Date	18/05/2022		Sheet No. 2
			Sheet 2 of 6



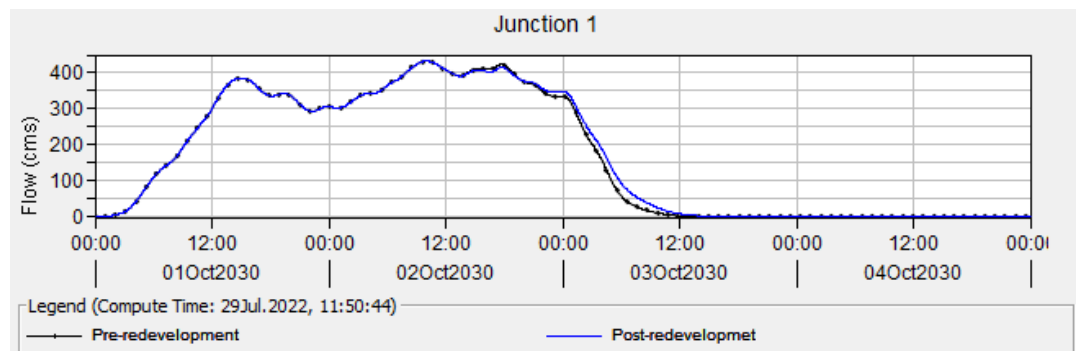
Above: Flow at Junction 26. The TSF has added 2 km² to this part of the catchment causing higher flows in this part of the catchment when water is released from the TSF. This higher flow reduces relative to other catchment flows as it move downstream.



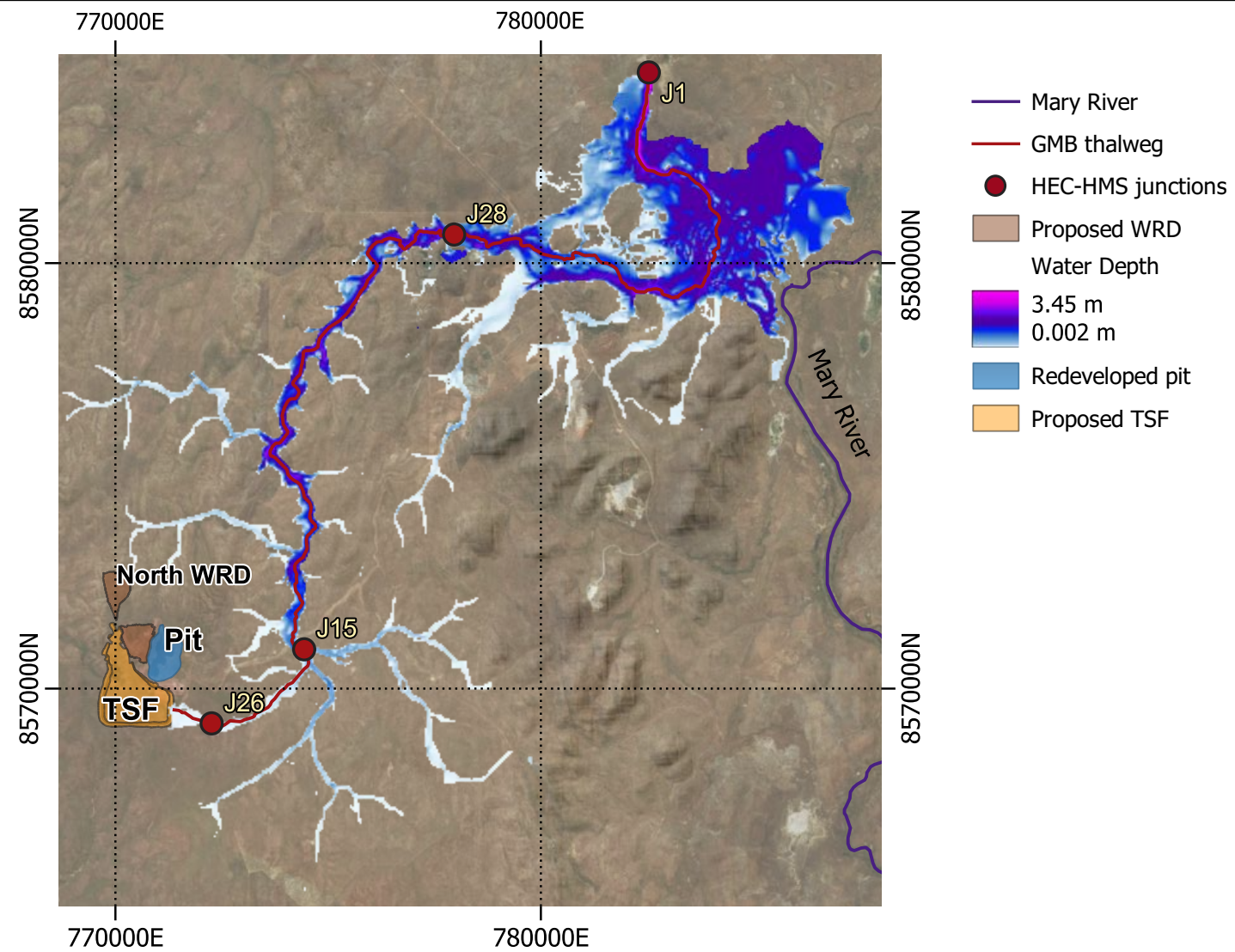
Above: Flow at Junction 15. There is little difference in the pre- and post-redevelopment hydrographs as TSF flow are absorbed with other upstream catchment flows from the southwest.



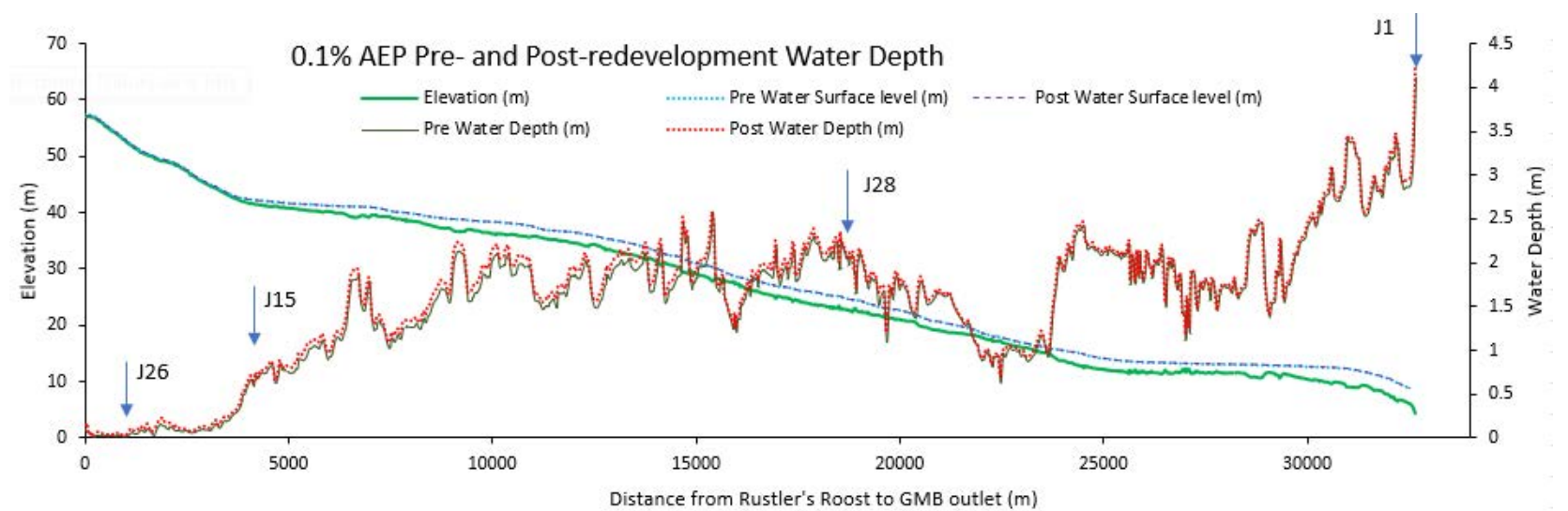
Above: Flow at Junction 28 (Tom's Gully pit). There is little difference in the pre- and post-redevelopment hydrographs.



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
GMB-03

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



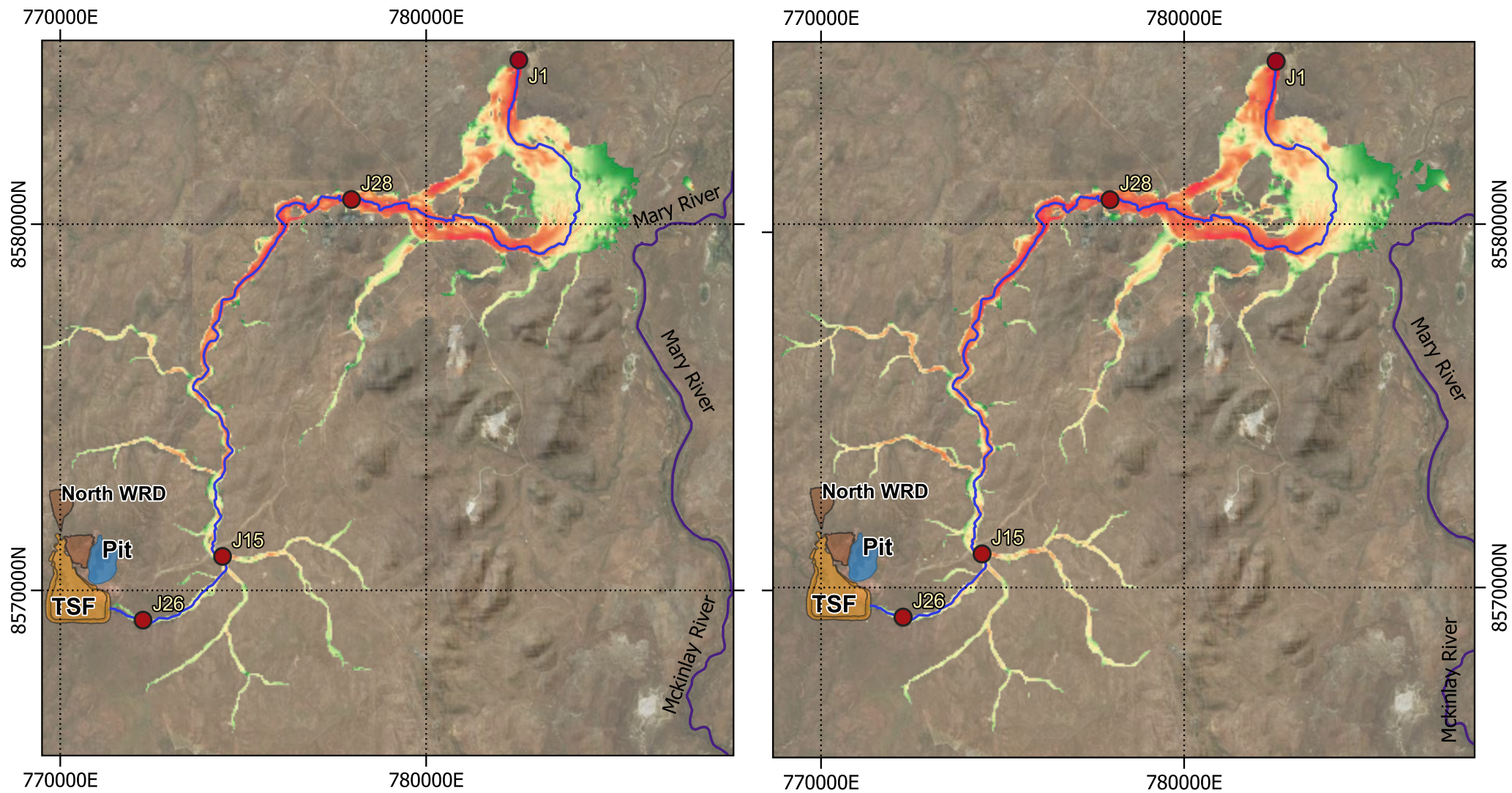
Project

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

Title

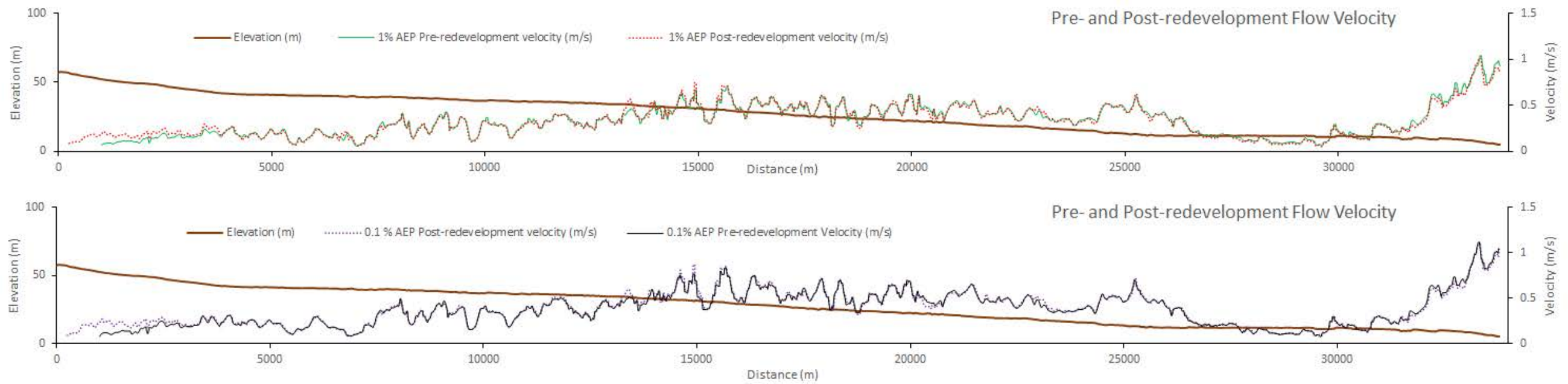
**Mt Bunday Creek: Pre- and Post-
Redevelopment 1% AEP Rainfall Event
Discharge & Water Depths**

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Date	Sheet No. 3		
18/05/2022	Sheet 3 of 6		



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.

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.

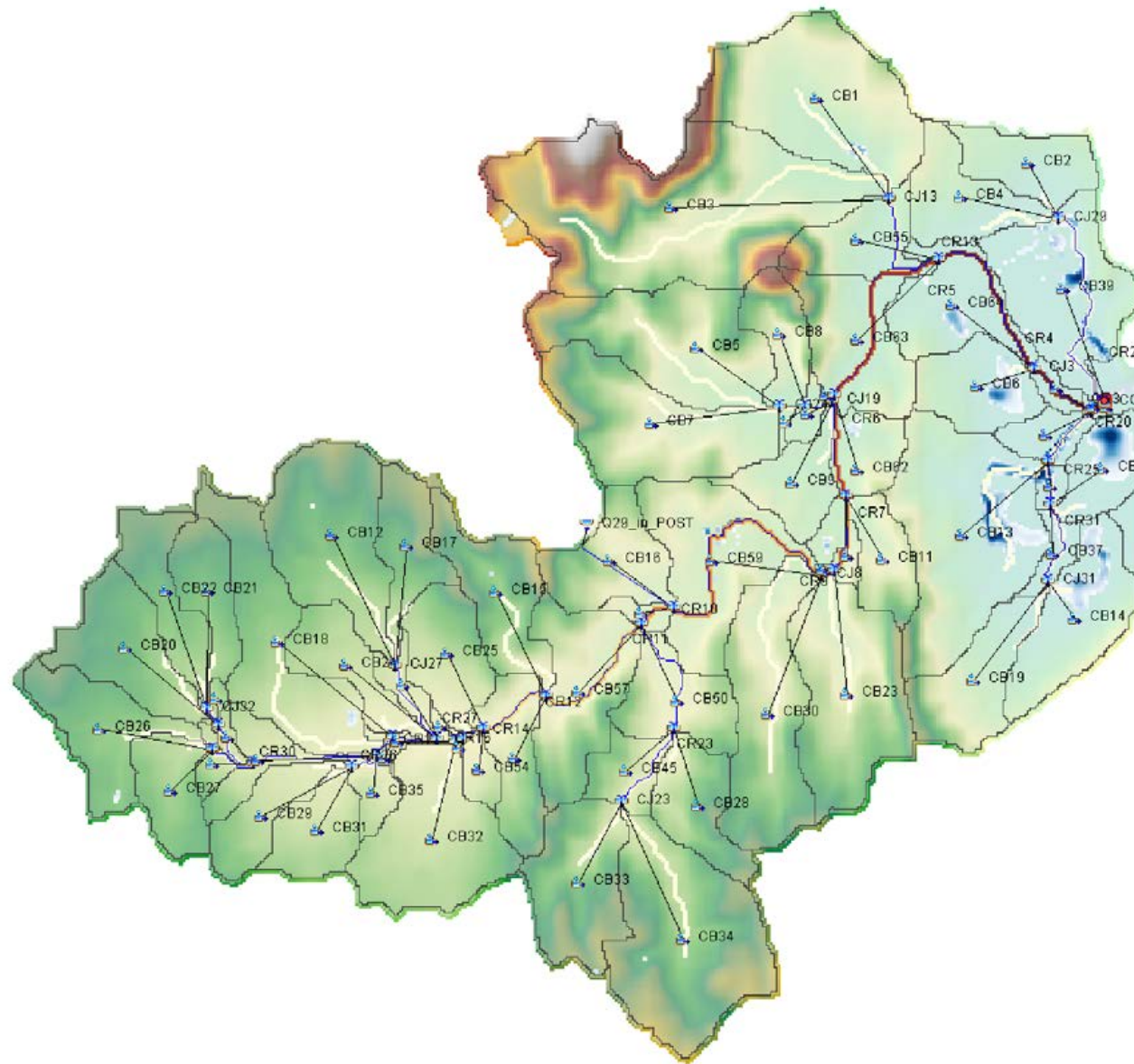


Figure 4. Charles Creek receiving catchment HEC-HMS model.

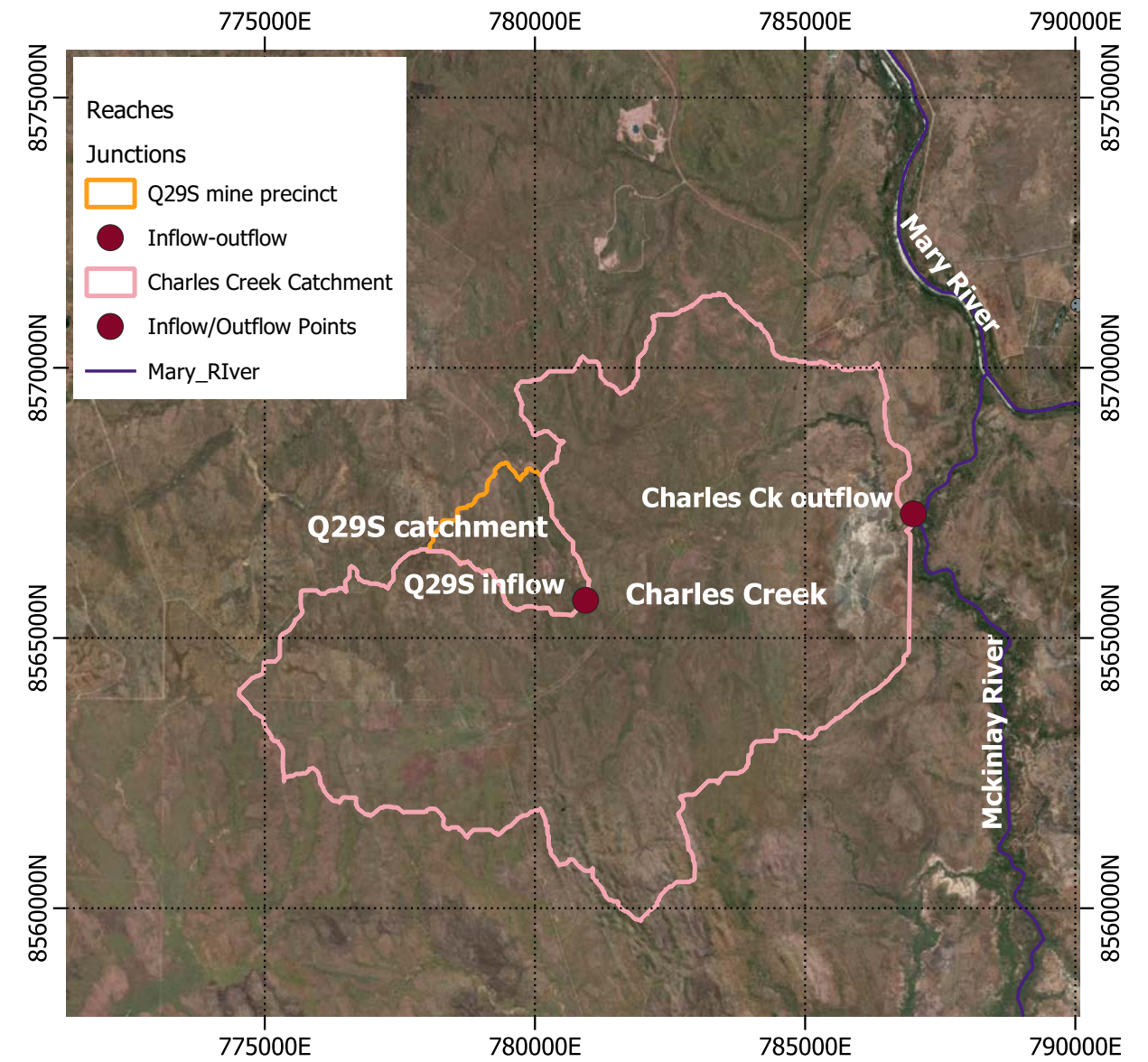


Figure 3. Q29S post-redevelopment catchment HEC-HMS model.

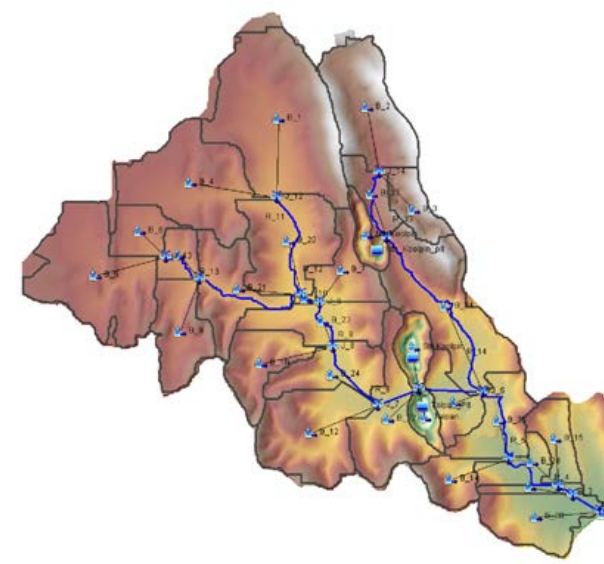


Figure 3. Q29S post-redevelopment catchment HEC-HMS model.

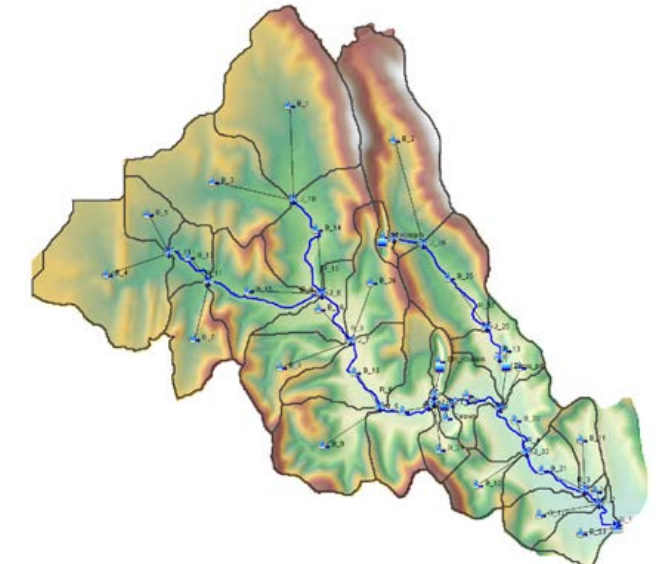


Figure 2. Q29S pre-redevelopment catchment HEC-HMS model.

Drawing No
CC-01

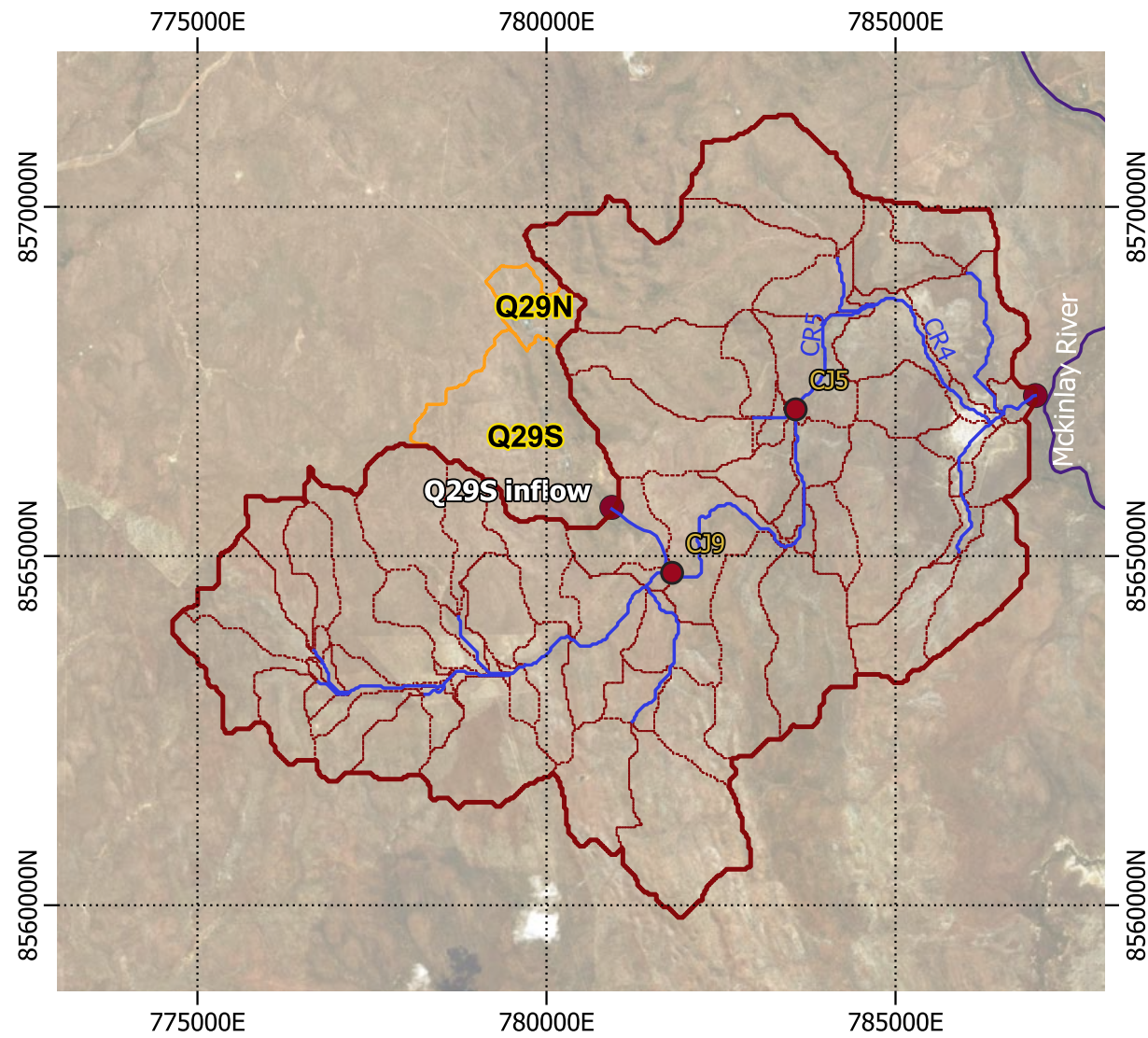
SURFACE WATER & EROSION SOLUTIONS
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



Project
Rustler's Roost & Quest 29
EIS Supplementary
Information

Title
Charles Creek Catchment HEC-HMS
models

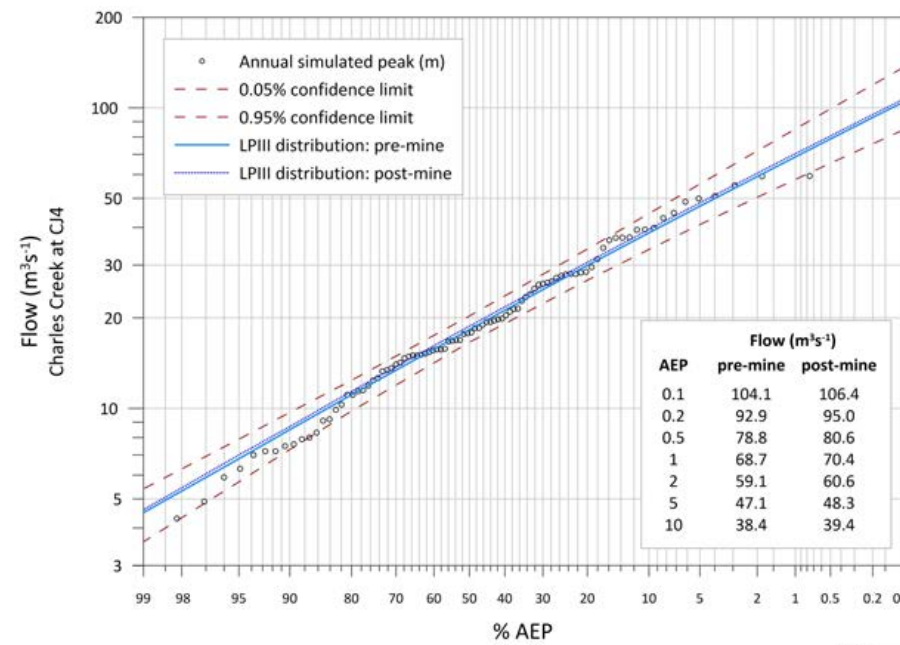
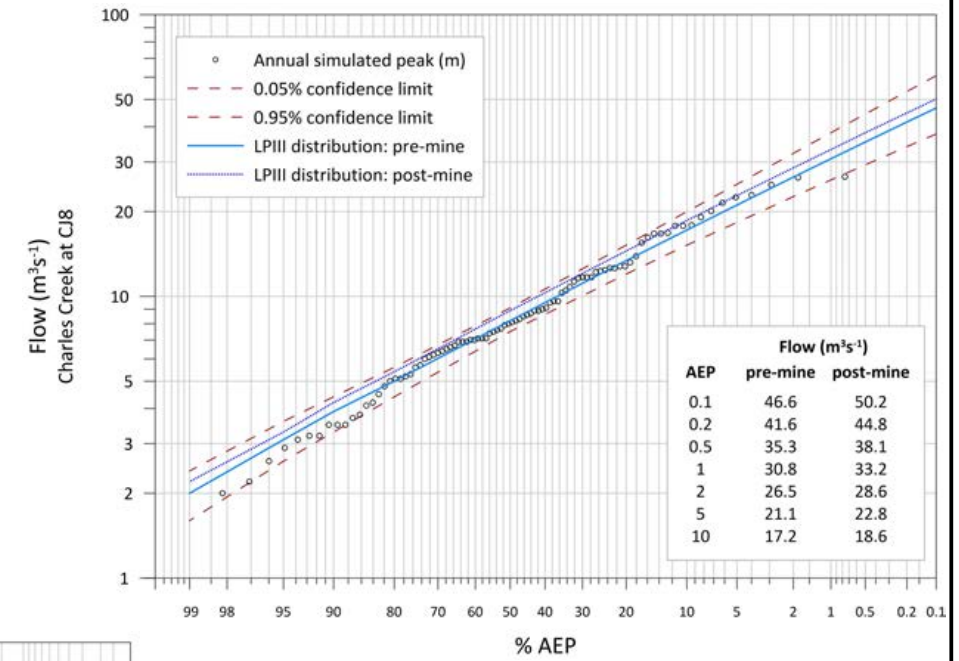
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Date	04/05/2022		Sheet No. 1
			Sheet 1 of 7



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.

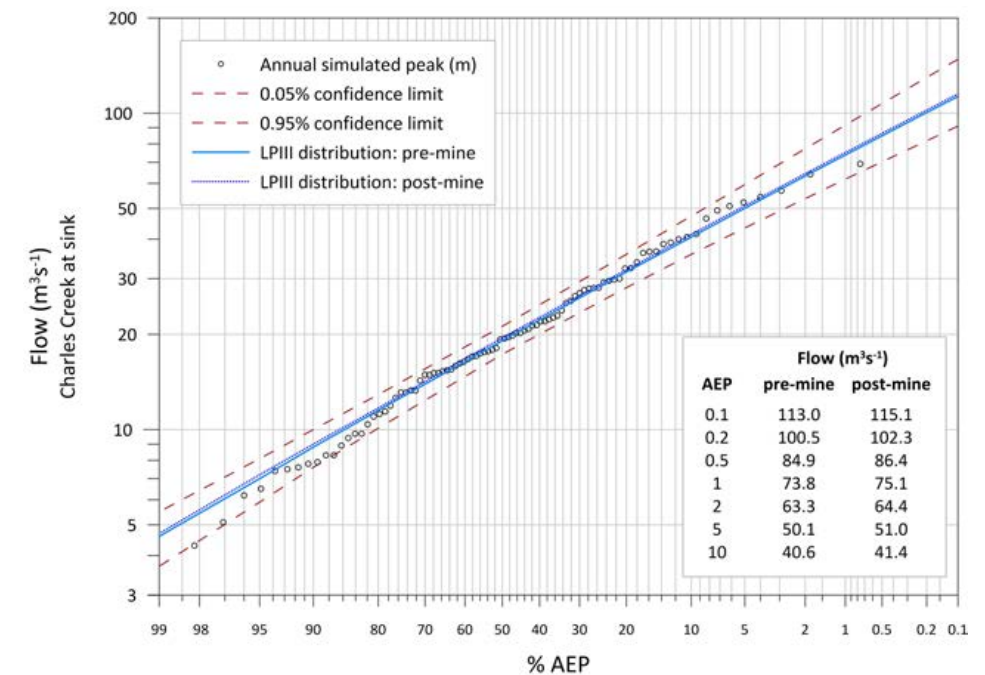
Right: Log Pearson distribution pre- and post-mine expansion at Junction CJ9 in the lower third of the Charles Creek catchment. There is a decrease in total discharge of -0.6% in the post-mine expansion scenario.

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



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.

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.



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

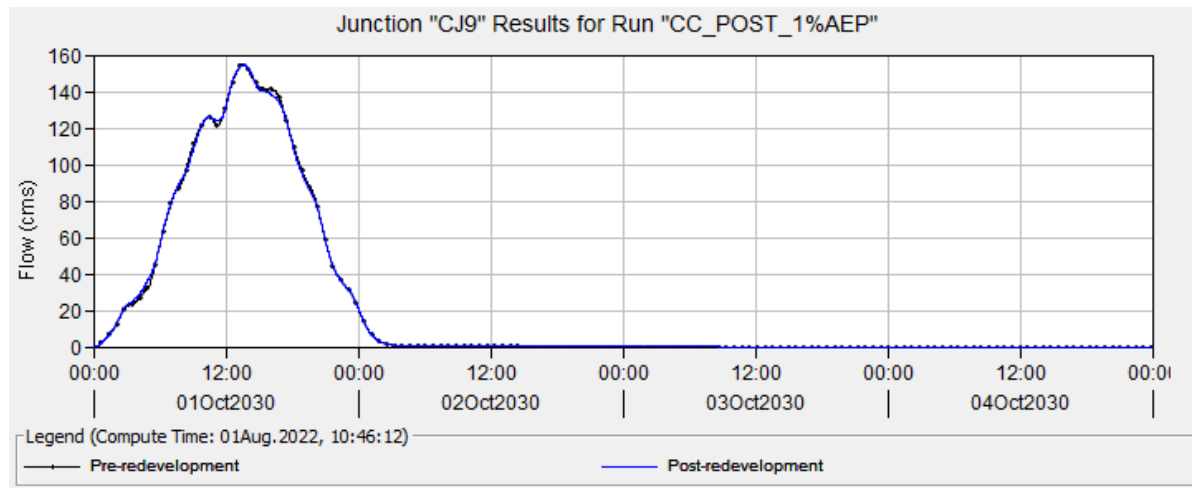
SURFACE WATER & EROSION SOLUTIONS
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



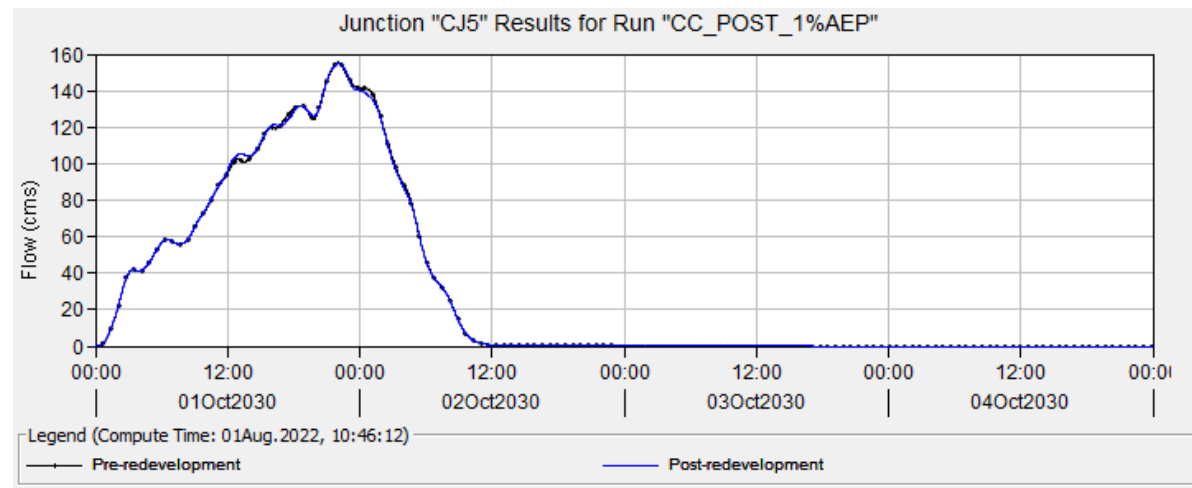
Project **Rustler's Roost & Quest 29**
EIS Supplementary
Information

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

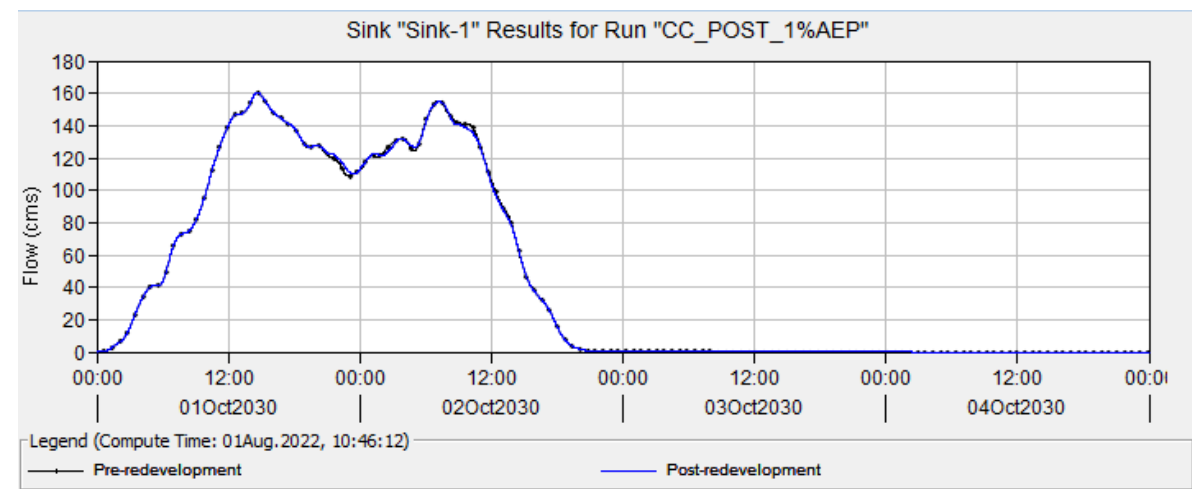
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Date		Sheet No. 2	
04/05/2022		Sheet 2 of 7	



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.

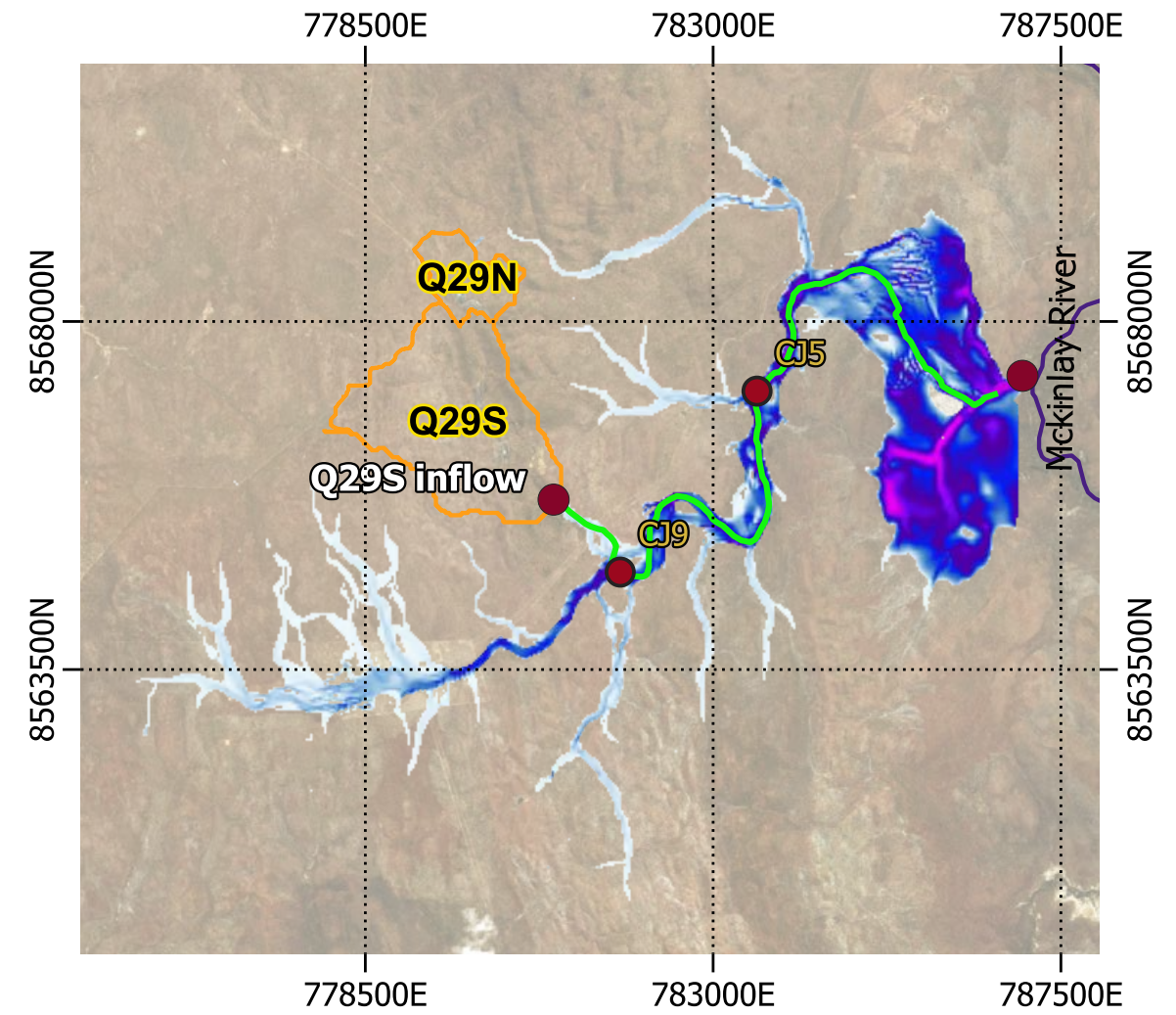


Above: The pre- and post-redevelopment discharges for the 1% AEP event CJ5 (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.



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.

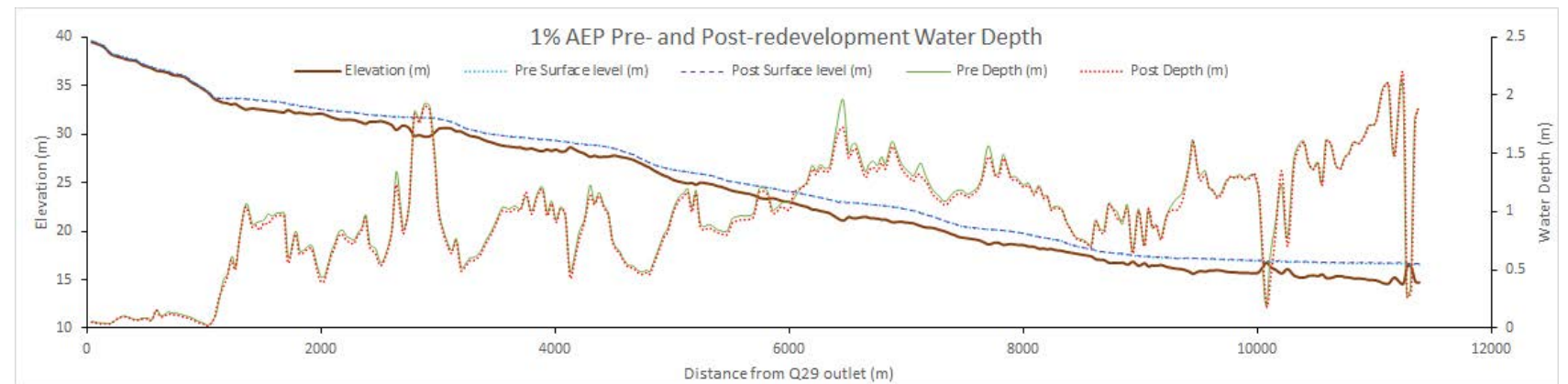
- Charles Creek Thalweg
- HEC-HMS Junction
- Mary River
- Q29 catchments
- Water depth
- █ 2.5 m
- █ 0.002 m



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

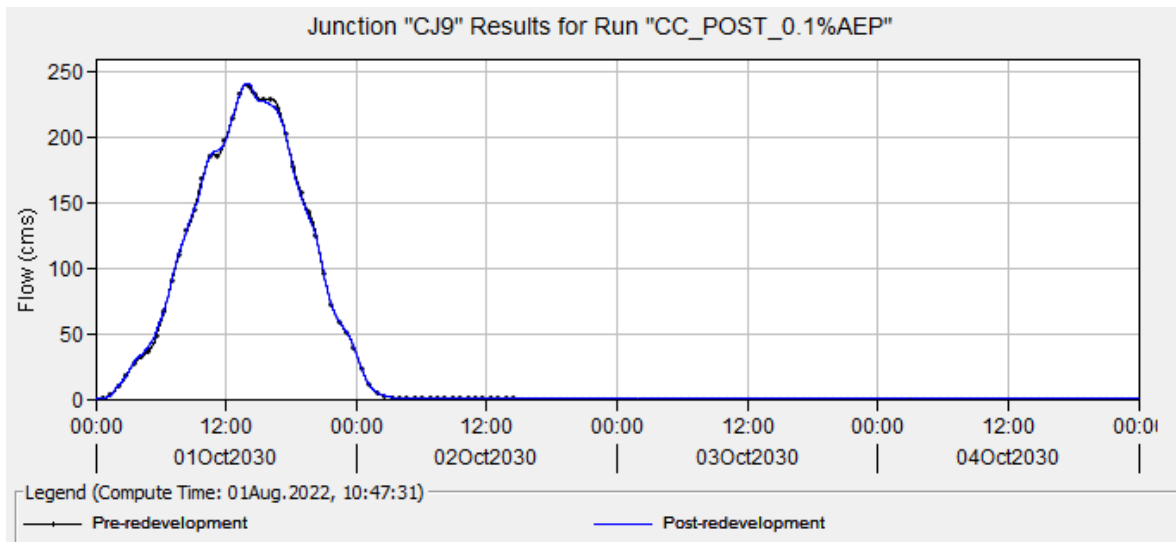
Notes

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.

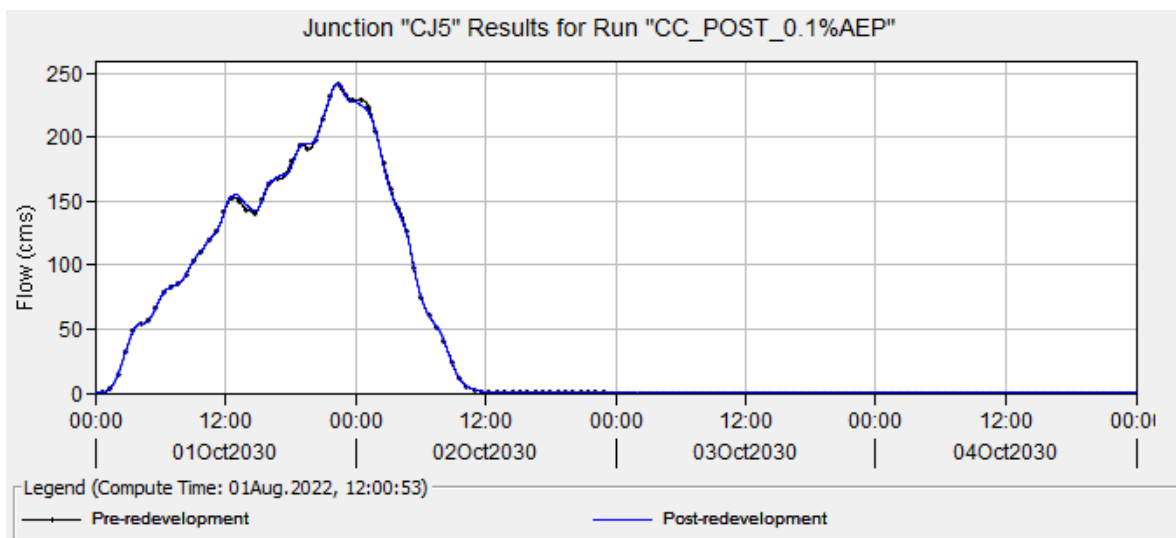


Above: Section along the thalweg of Charles Creek (see map above) from Q29 outlet (left) to near confluence with McKinley River (right). There is little difference between pre- and post- with the average difference in depth of the post-redevelopment event = -0.024 m.

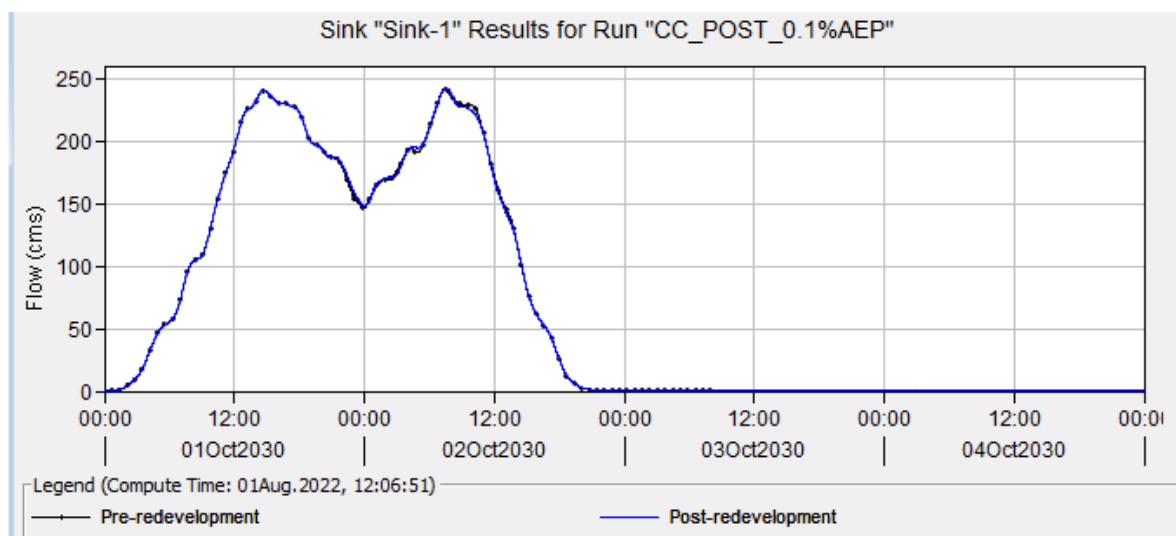
Drawing No CC-03	 ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT	Project Rustler's Roost & Q29 EIS Supplementary Information	Title Charles Creek: Pre- and Post-Redevelopment 1% AEP Rainfall Event Water Depths	Designed	Drawn	Checked	Sheet size
					KGE	DRM	A3
				Date			Sheet No. 3
				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.

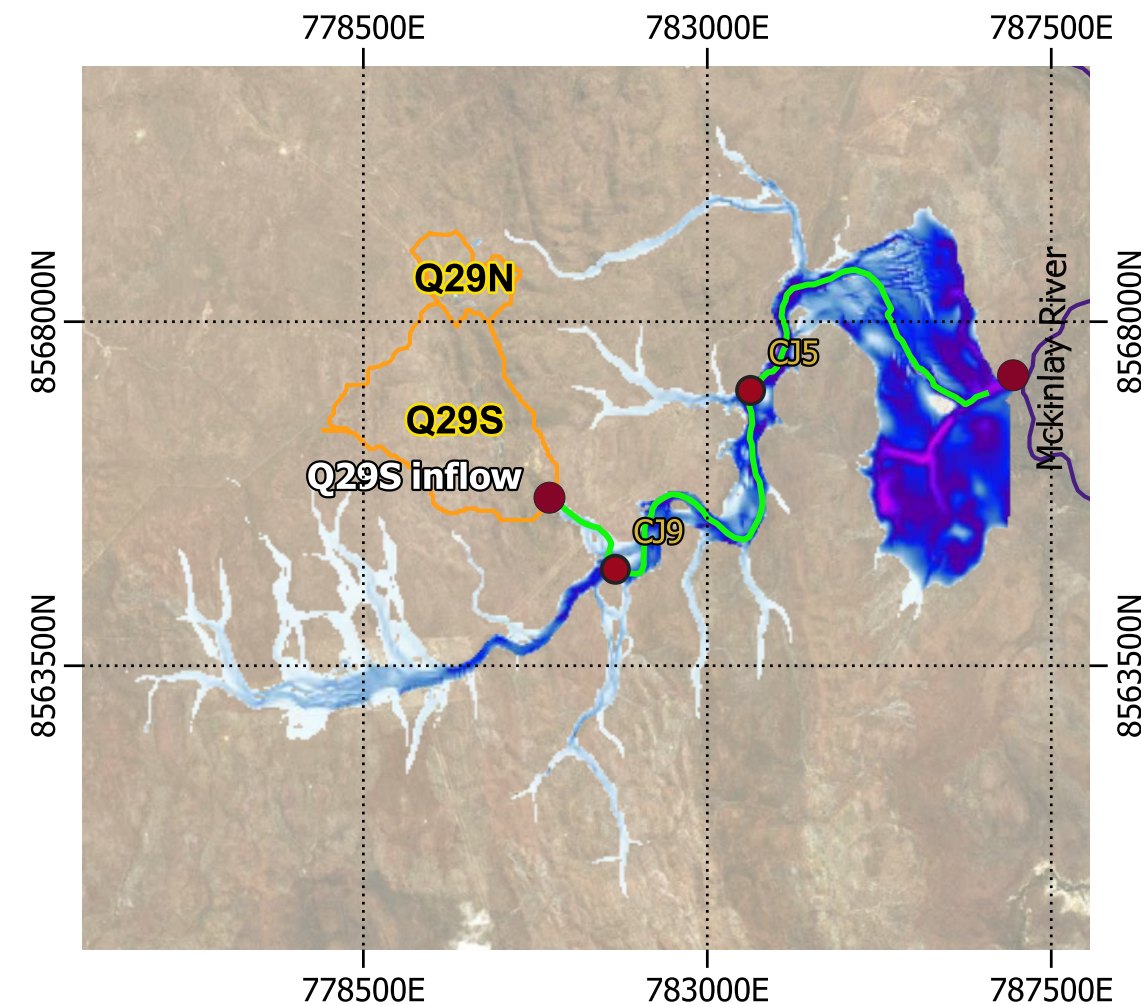


Above: The pre- and post-redevelopment discharges for the 0.1% AEP event CJ5 (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.



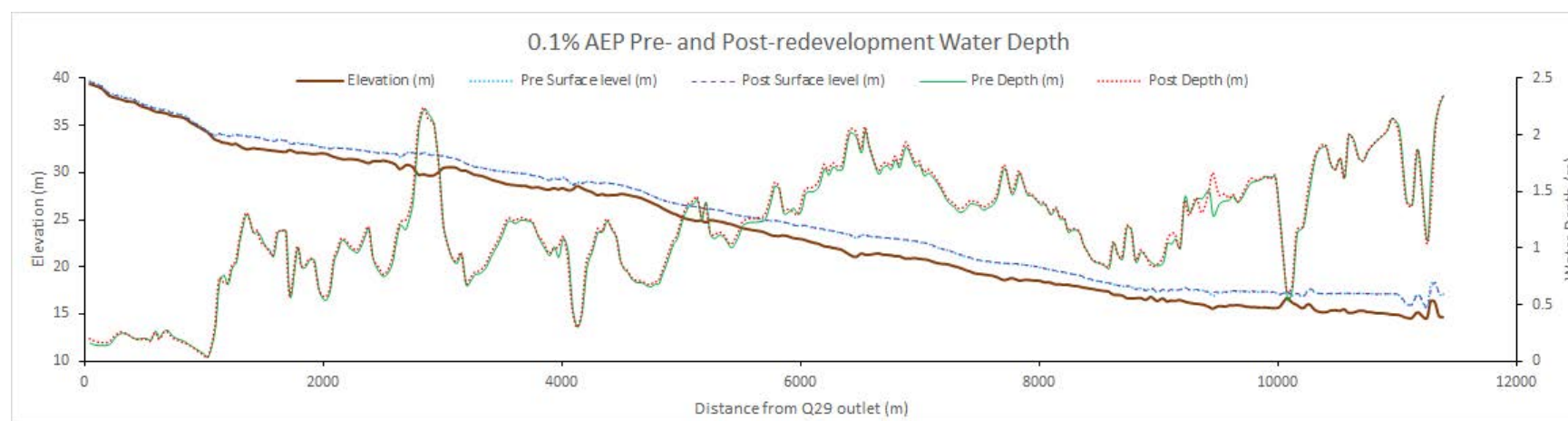
Above: The pre- and post-redevelopment discharges for the 0.1% AEP event at the catchment outlet (see map right). There is little difference between pre- and post-redevelopment discharges with NSS = 1.

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

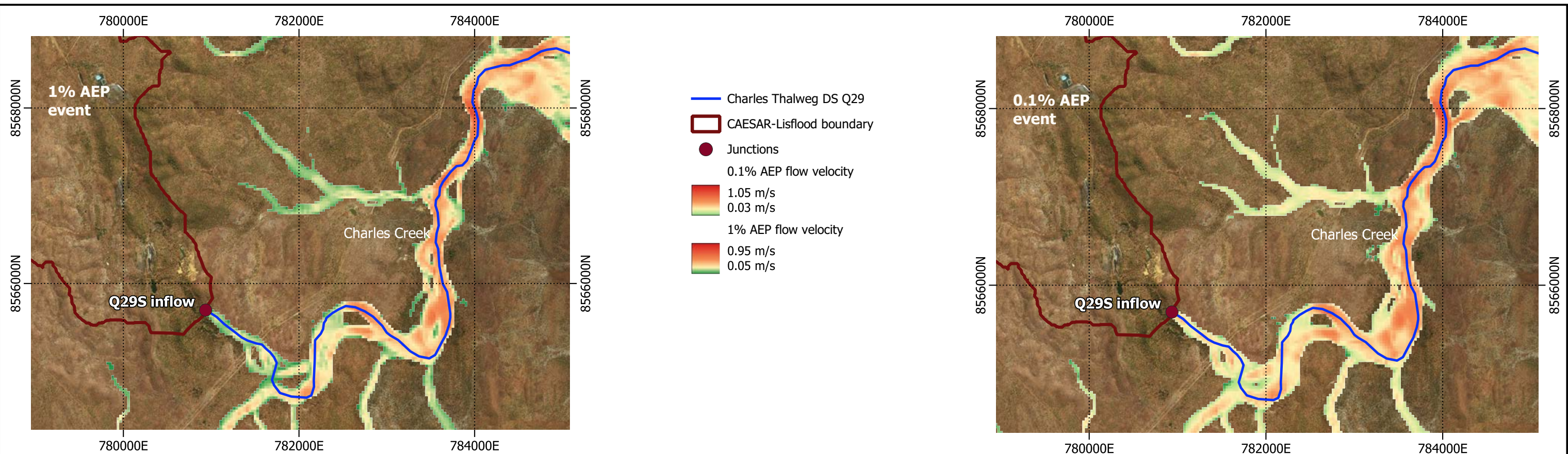


Above: 0.1% AEP flood inundation in Charles Creek between the Q29S outlet and the McKinley River confluence.

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.

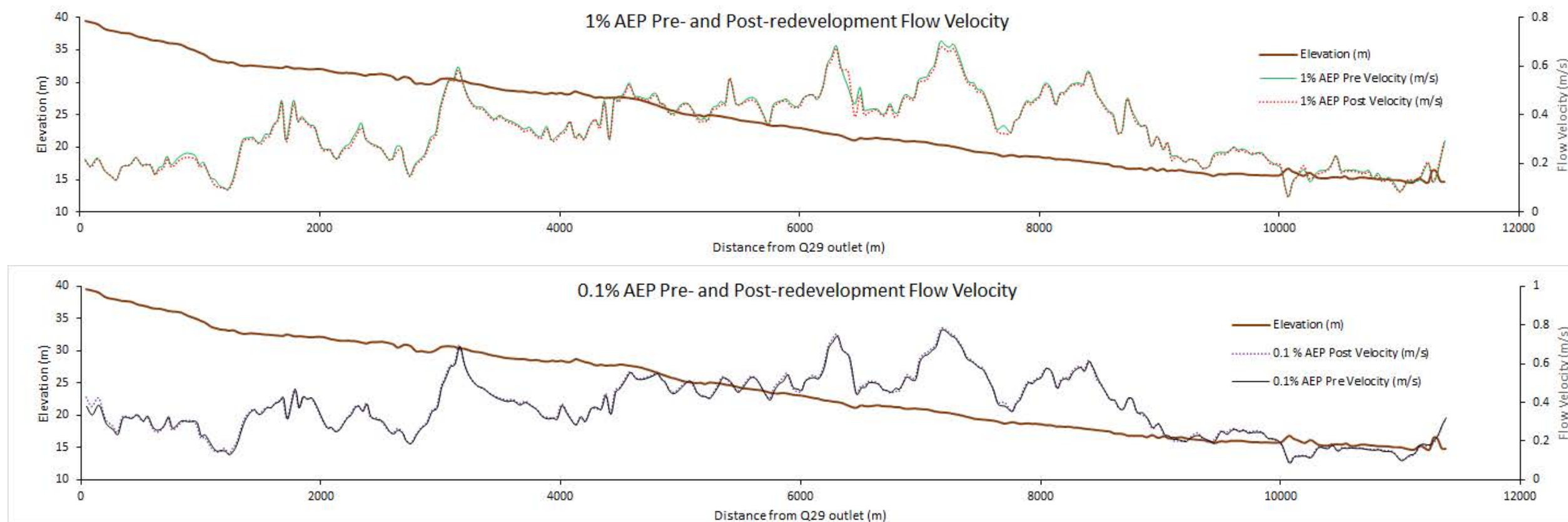


Above: Section along the thalweg of Charles Creek (see maps right) from Q29 outlet (left) to near confluence with McKinley River (right). There is little difference between pre- and post- with the average difference in depth of the post-redevelopment event = -0.023 m.



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
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				Date			Sheet No. 5
				18/05/2022			Sheet 5 of 7

Appendix B Changes in Flow Due to Releases (from Surface Water and Erosion Solutions (2022))

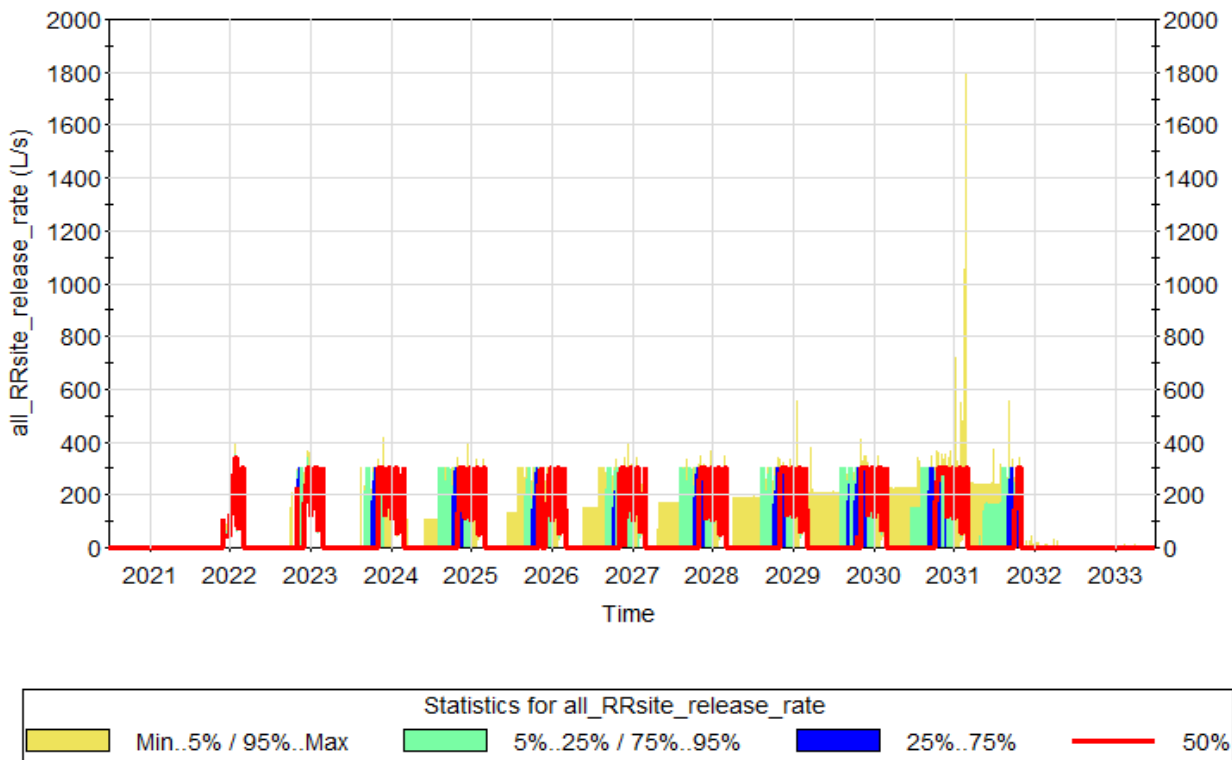


Figure 4-1 Environmental water release series distribution for Rustler's Roost. Figure provided by CDM Smith.

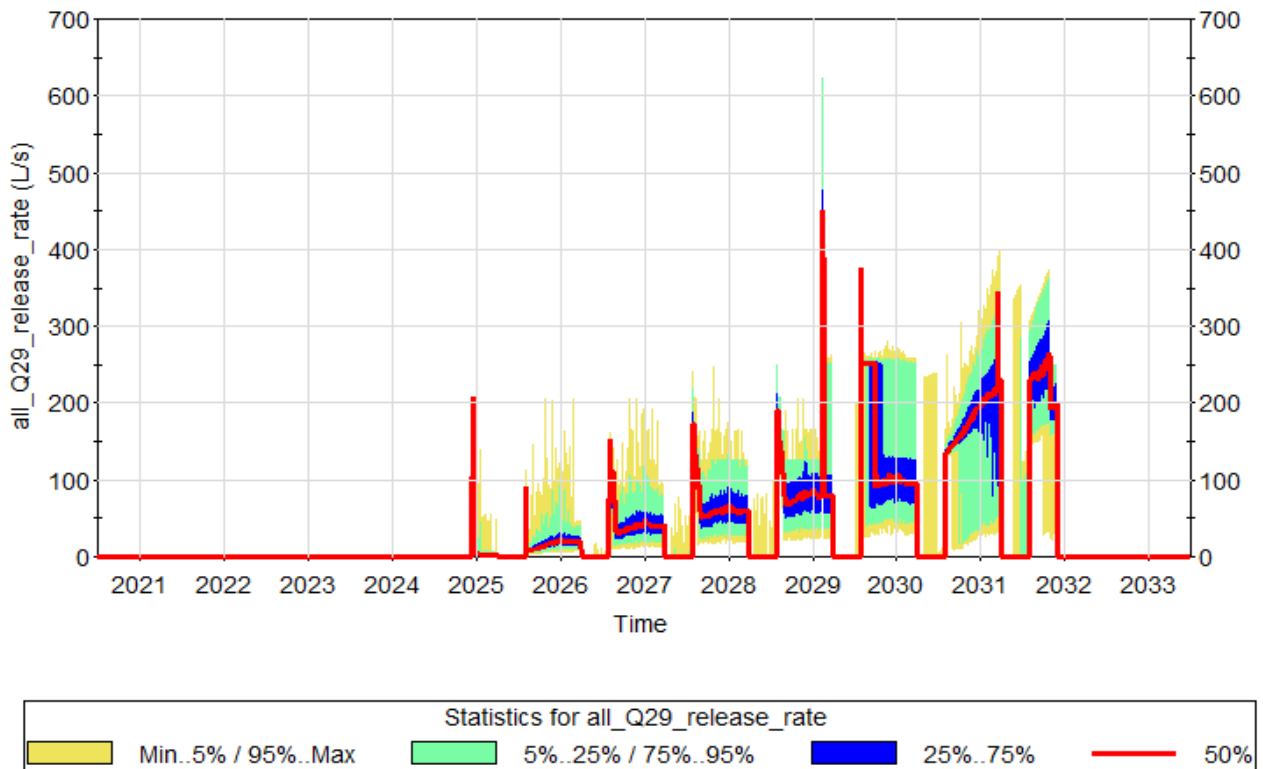


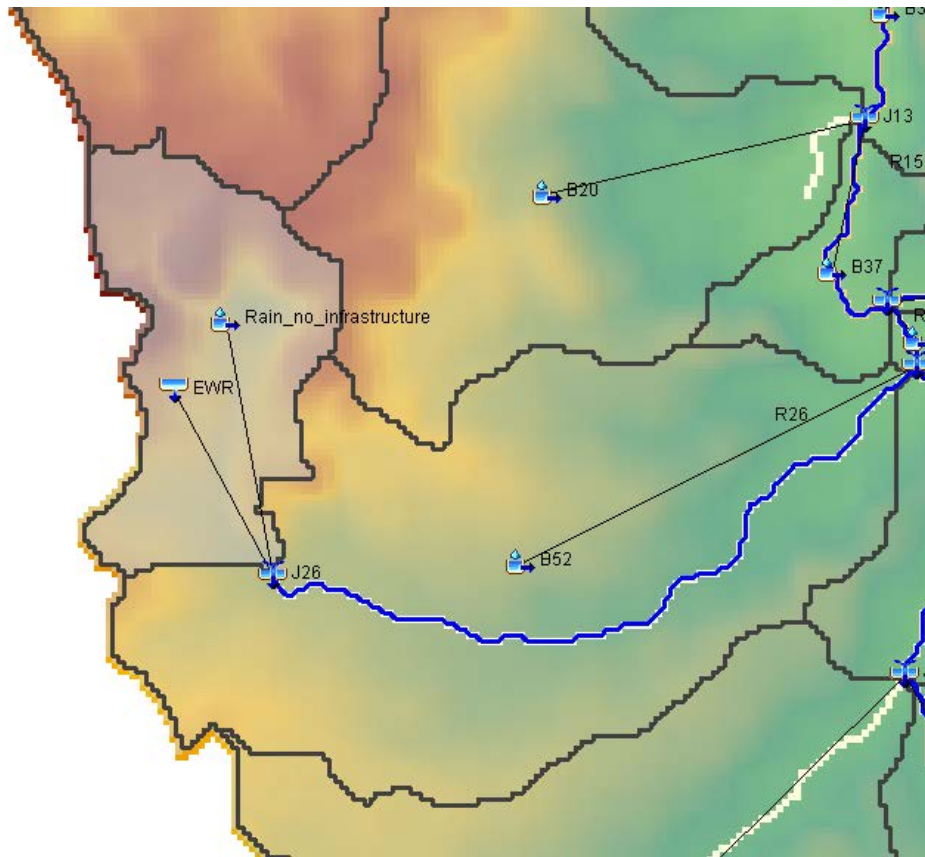
Figure 4-2 Environmental water release series distribution for Quest 29. Figure provided by CDM Smith

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

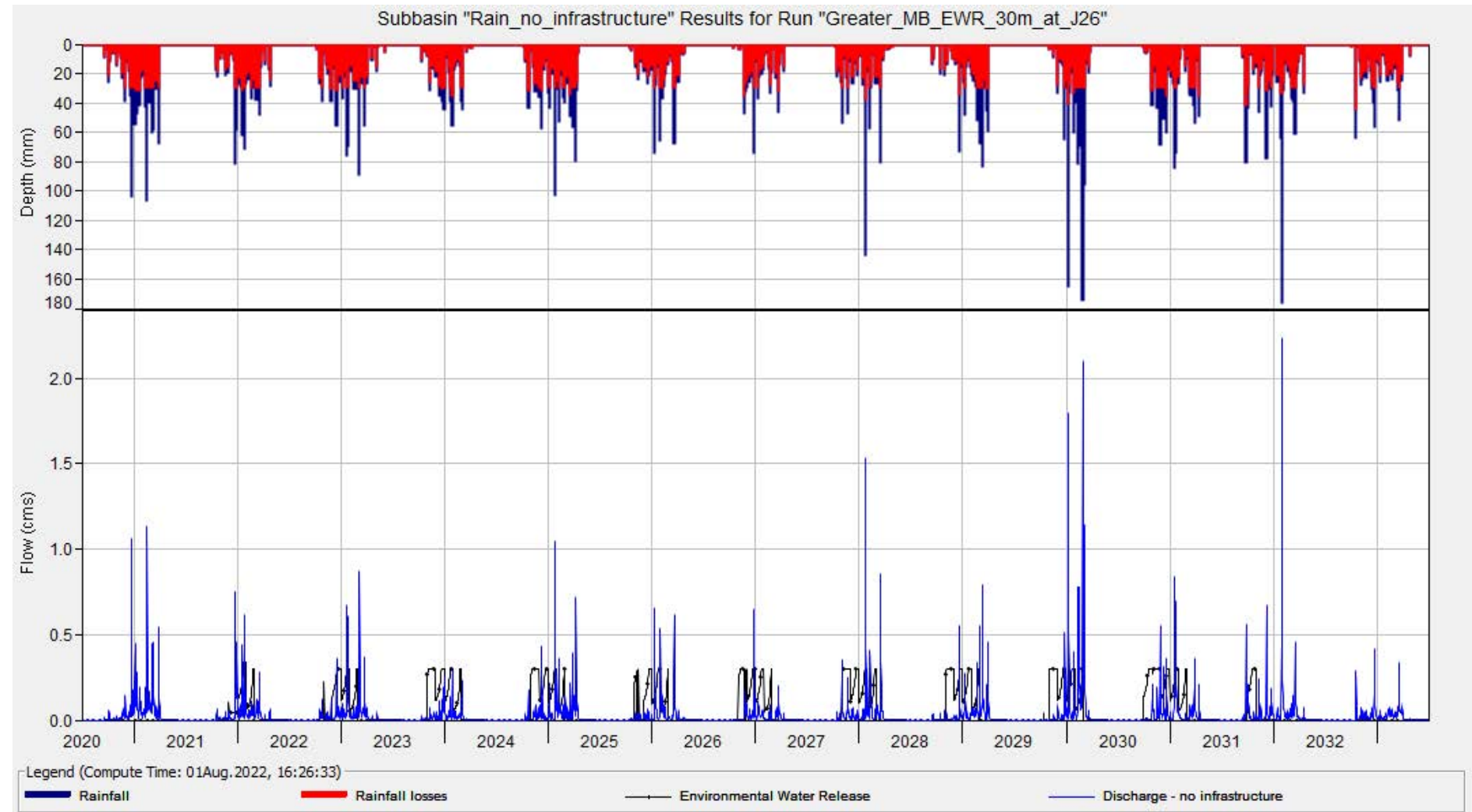
Element	Environmental Water Release				No Environmental Water Release				Nash-Sutcliffe	Distance from mine (km)
	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)		
J26	2.4	32.03	0.37	0.15	2.23	10.82	0.34	0.11	-0.38	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.

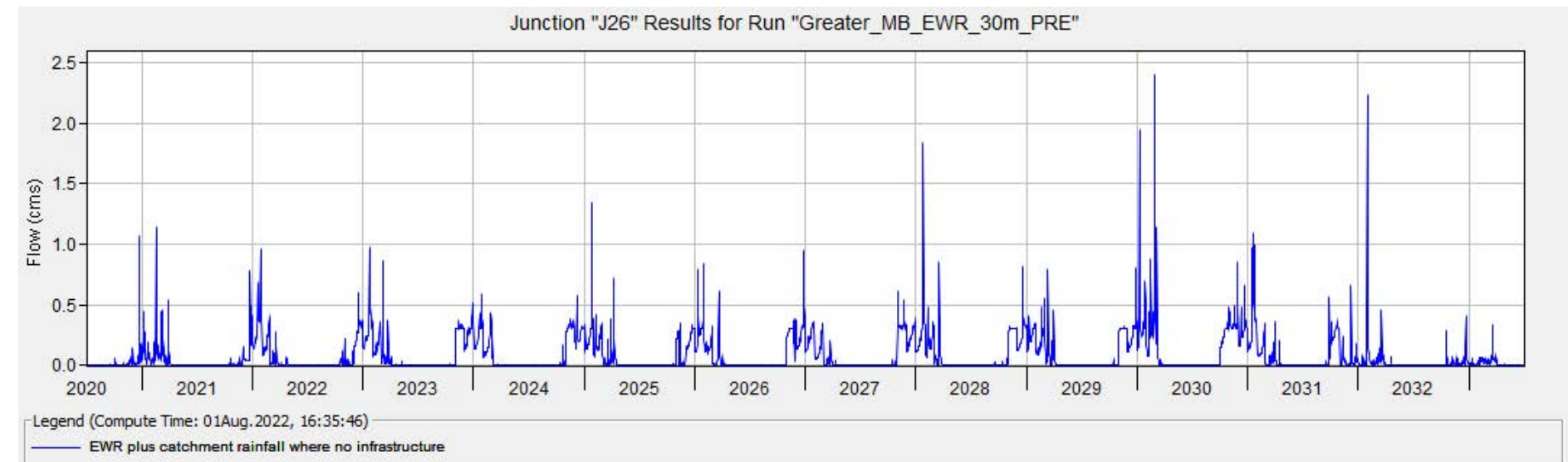
Element	Environmental Water Release				No Environmental Water Release				Nash-Sutcliffe	Distance from mine (km)
	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)	Peak Discharge (m ³ /s)	Total Discharge (GL)	Velocity (m/s)	Depth (m)		
Q29S in	5.3	38.2	0.64	0.51	3.75	25.6	0.59	0.45	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



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

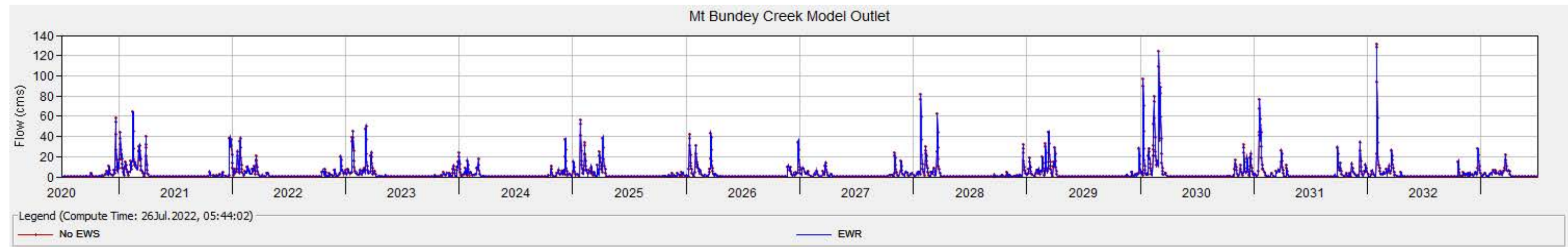
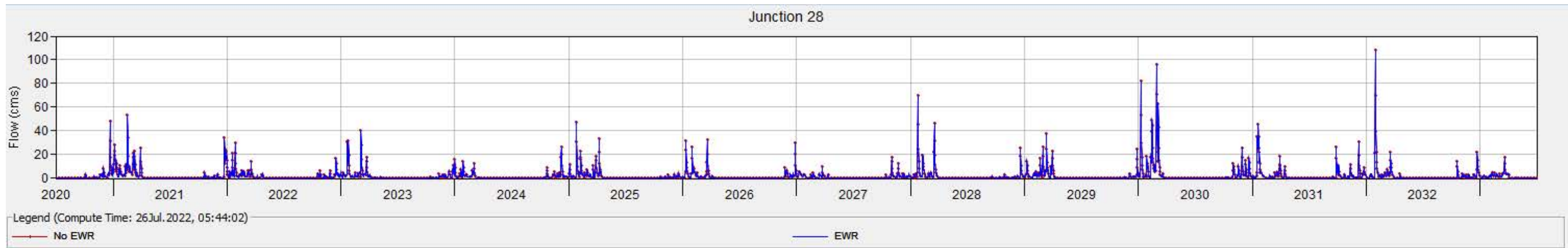
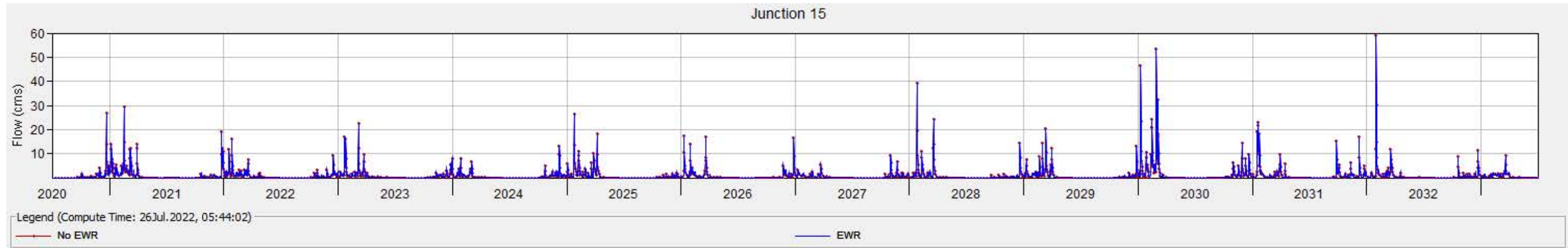
SURFACE WATER & EROSION SOLUTIONS
ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT



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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Date		Sheet No. 5	
26/06/2022		Sheet 5 of 6	

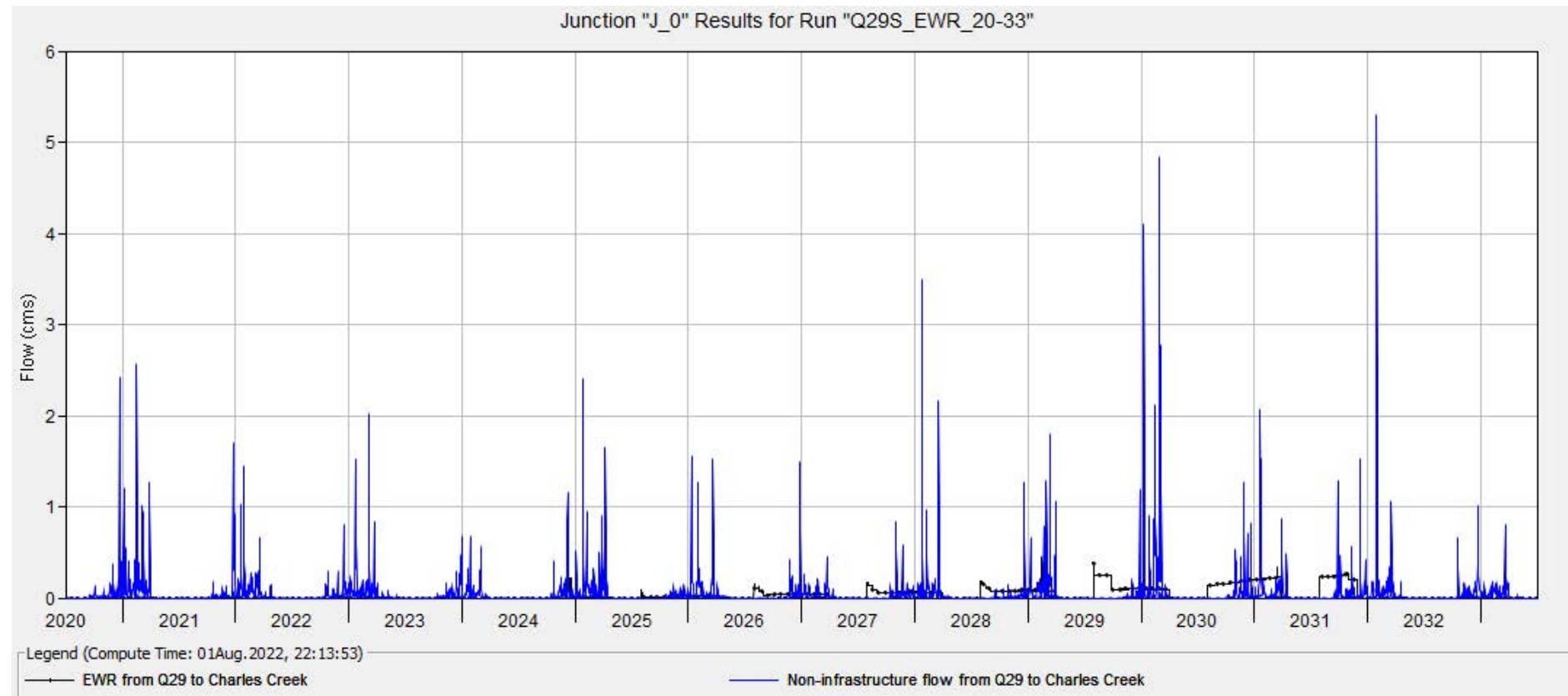


Above. Mt Bunday Creek HEC-HMS model hydrographs for environment water releases from the Rustler's Roost compared with no environmental water releases. There is little difference in EWR and No EWR hydrographs as they progress downstream.

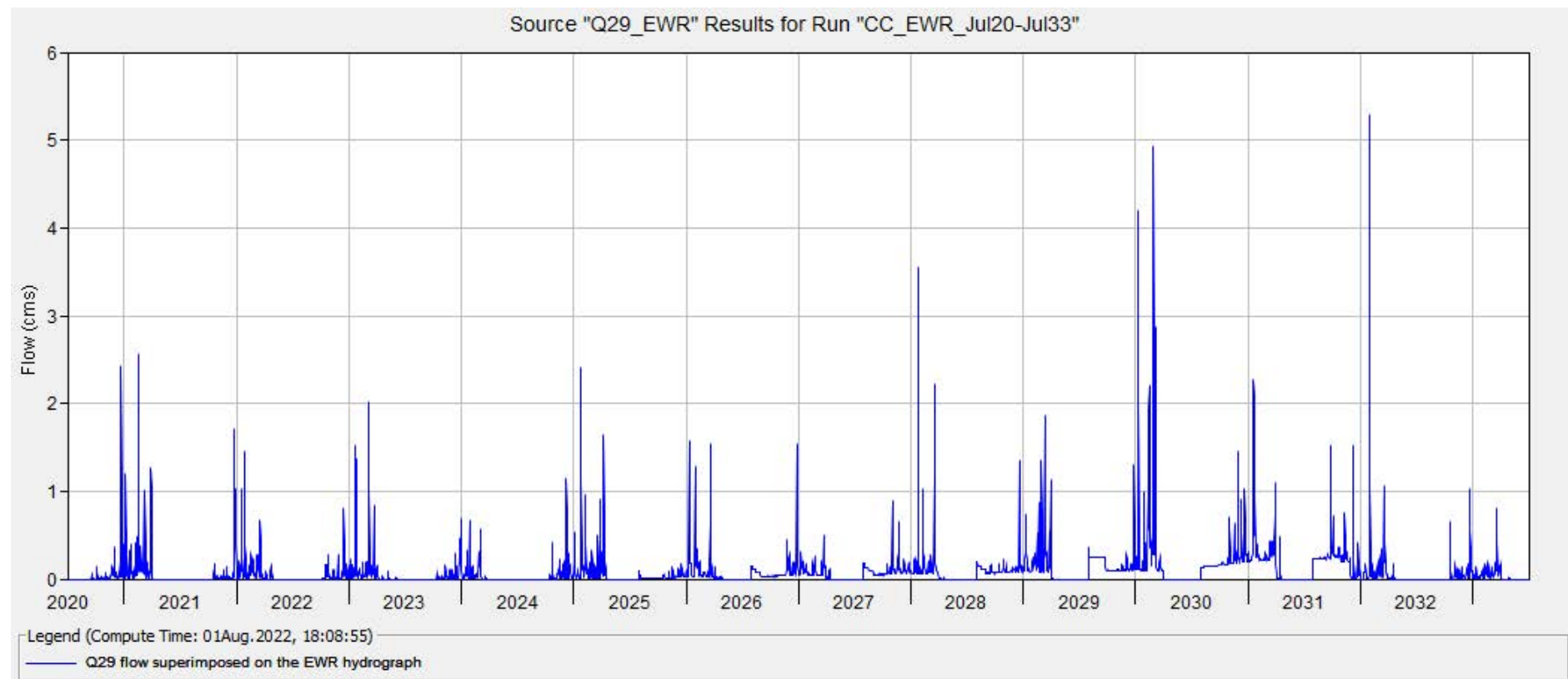
Drawing No GMB-06	 SURFACE WATER & EROSION SOLUTIONS ALL SITE & SOIL EVALUATIONS FOR SEPTIC & WASTEWATER MANAGEMENT	Project Rustler's Roost & Quest 29 EIS Supplementary Information	Title Rustler's Roost Environmental Water Releases: HEC-HMS Hydrographs in Mt Bunday Creek	Designed	Drawn	Checked	Sheet size
					KGE	DRM	A3
				Date			Sheet No. 6
				26/06/2022			Sheet 6 of 6



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.

Drawing No
CC-06

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

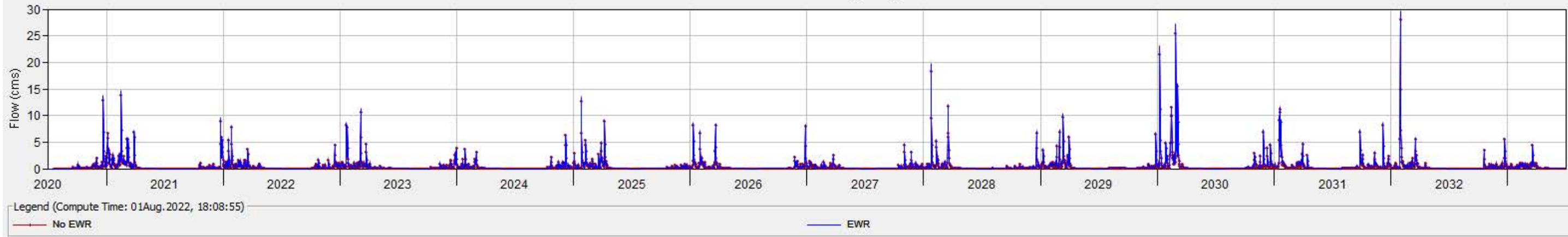


Project **Rustler's Roost & Quest 29**
EIS Supplementary
Information

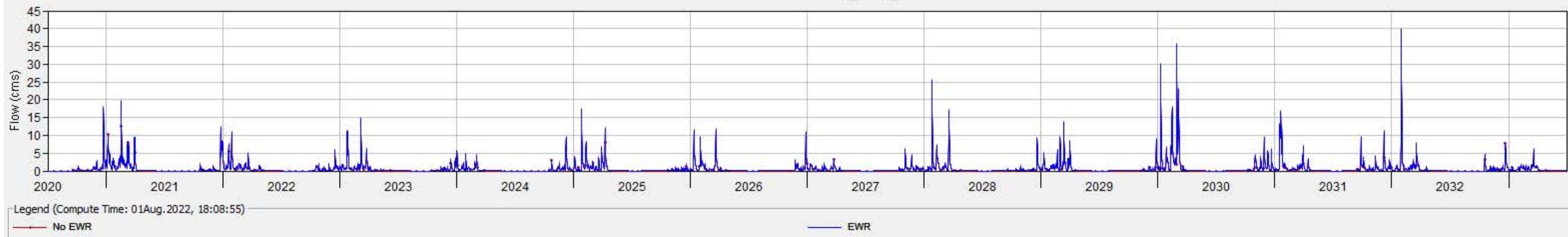
Title **Quest 29 Environmental Water Releases:**
HEC-HMS Hydrographs at Inflow to Charles
Creek

Designed	Drawn	Checked	Sheet size
	KGE	DRM	A3
Date		Sheet No. 6	
26/06/2022		Sheet 6 of 7	

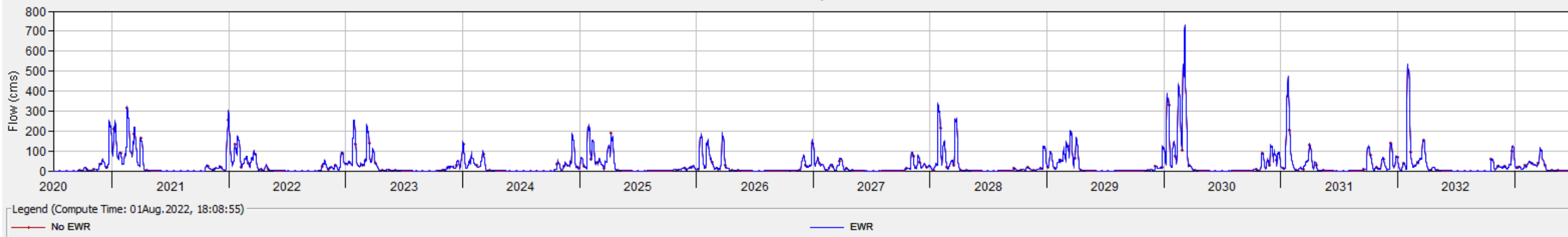
Junction "CJ9" Results for Run "CC_EWR_Jul20-Jul33"



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

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



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

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

Designed	Drawn	Checked	Sheet size
	KGE	DRM	A3
Date	26/06/2022		Sheet No. 7
			Sheet 7 of 7