Kerosene Camp Creek Diversion and Mine Surface Water Management

50% Level Design

PSM4809-016R REV1 19 July 2024

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Executive Summary

This Report presents analysis and design drawings to support a 50% level of design for the surface water infrastructure associated with the mine area and Kerosene Camp Creek Diversions for the Nolans Rare Earth Project (the **Project**), which is being developed by Arafura Resources Limited (**Arafura**).

The Project is located in the Central Region of the Northern Territory (NT), approximately 135 km north of Alice Springs and 10 km west of the Stuart Highway. The development footprint for the Project is almost wholly located within the boundary of the Aileron Station, with an expected mine life of 38 years. The Project includes a mining (pit) area, the Kerosene Camp Creek diversion, accommodation camp, Residue Storage Facility (RSF), site access road, mine access road and process plant area.

The focus of this report is on the Kerosene Camp Creek diversion and mining area, with aspects such as the RSF, site access road, mine access road, explosives area, infrastructure area and process plant area being addressed separately. A previous Definitive Feasibility Study (DFS) has been undertaken, Knight Piésold (2019), which has been reviewed and built upon as part of this study.

This report is aimed to aid development of a submission for a 'Form 6' *Application for a Permit to construct or alter works* application. The '*Form 6*' Permit to Interfere with a Waterway document is written in a way that is more relevant to a dam, as opposed to a diversion drain. However, there is a 'draft for consultation' *Interference with a Waterway Guideline* (2022) document, released by the NT Department of Environment, Parks and Water Security, that gives additional context on the requirements, including for a diversion drain.

As per the guideline, Kerosene Camp Creek and Nolans Creek, as well as the other tributaries are defined as waterways. The following examples are given as interference of a waterway:

- Dredging sand or gravel from a waterway
- Constructing a culvert crossing of a waterway
- Installing flood levees that may change the flood flow behaviour, and
- Diversion of a formed watercourse.

The Project includes each of the above examples, as such a Permit submission is required for the Project.

Four primary risks are highlighted as a result of interfering with a waterway:

1. Erosion and sedimentation.
2. Changes to water quality.
3. Changes to hydrology.
4. Changes to substrate.

The erosion and hydrology aspects are addressed within this report.

The Northern Territory Environmental Protection Authority (EPA) has previously provided an '*Assessment Report 84*' for the Nolans Project (NT EPA, 2017). The report highlighted that the following factors were to be addressed to aid Project approval:

- Demonstrate how the KCC diversion would maintain the existing regional hydrologic regime by effective delivery of natural flows of KCC to its downstream reaches
- Demonstrate how the KCC diversion would mitigate surface flows into the pit, even under a 1 in 1,000 Annual Exceedance Probability (AEP) event
- Demonstrate how the KCC diversion would maintain sediment transport and water quality regimes that allow the watercourse to be self-sustaining, and
- Demonstrate how the KCC diversion would maintain surface water quality (as informed by acid and metalliferous drainage testing of the basement rock).

The first three points are addressed as part of this report (with the exception of the specific impacts on water quality), whereas the fourth point is being addressed by others, separate to this report.

Details of the surface studies are presented in:

- Hydrology analysis in PSM4809-009L DRAFT
- Hydraulic Flood Mapping, including for the 1 in 1,000 AEP, in PSM4809-014L, and this report
- Diversion drain optioneering in this report
- Sediment basin design in this report
- Sediment erosion analysis in this report
- Earthworks philosophy and 50% Level of Design Drawings in PSM4809-017M REV1
- Future works recommended to achieve an "Issued For Construction" level of design in this report.

The hydraulic analysis has supported that the Stage 1 and Stage 2 Diversion Drains have sufficient capacity to transmit a 1 in 1,000 AEP flow, including an allowance for the impacts of climate change. The other clean and dirty water drains have been sized for a 1 in 100 AEP design event. The analysis has shown that in general that the downstream impacts in terms of flood depths and velocities relative to the current conditions are localised to:

- The mining area
- The reach of Kerosene Camp Creek between the mine and the confluence with the Nolans Creek for Stage 1
- The reach of Kerosene Camp Creek between the mine and the confluence with the unnamed creek that the Stage 2 Diversion Drain discharges into for Stage 2.

Otherwise, the hydraulic modelling has highlighted that there could be an opportunity to modify the location of some topsoil stockpile locations to improve surface water infrastructure design outcomes.

The sediment basins have been sized to be compliant with IECA requirements. Analysis of the sediment capture efficiency of the basins during a 1 in 100 AEP have shown:

- The basins allow virtually all the sand material to settle.
- Most of the medium and fine silts are captured, with all efficiencies greater than 80%.
- The performance of the sediment basin starts to drop for an 'incipient flow' case (i.e. a full basin before the critical storm event) for sediments that are as fine or finer than very fine silts, generally dropping below 80% retention of fines. Provided that the basins are operated as intended (i.e. the basins are flocculated and emptied within 5 days of an inflow event), then the chance of the 'incipient flow' case occurring is quite small, as it would need two significant rainfall events to occur within a 5 day period.
- The central basin is expected to perform the worst, but the critical case for this basin is during Stage 1. Regardless the basin is expected to be able to capture in excess of 60% of the very fine silts.

As a result of the adequate sediment capture efficiencies, it is not considered necessary to have an additional polishing pond to further capture any sediments that escape the sediment basins.

The creek lines around the Project area consist of loose sandy sediments, which would be expected to be transported under most flow events. However, as reported in PSM4809-009L DRAFT, there is evidence that both the Woodforde River at the location of the Arden Soak regional streamflow gauge, and the creek lines in the project catchment location, are in dynamic equilibrium in terms of their fluvial geomorphology. When a creek line is in dynamic equilibrium, there is an equilibrium balance of sediment erosion and deposition (sourced from upstream erosion) that occurs during flood events. As such, during an event, there is anticipated to be a naturally occurring movement of sand along the creek lines, but post an event, no significant changes are anticipated in the channel cross-section (except for extreme flood events, which can cause a geomorphological 'jump' in the fluvial environment). If this naturally occurring movement of sand is disrupted, then erosion would be expected downstream due to the reduction in sand coming from further upstream. Maintaining this naturally occurring movement of sand through the Project area is considered an important aspect of maintaining the fluvial geomorphology response of the existing natural creek lines.

HEC-RAS sediment transport modelling has been undertaken, the results of which suggest that:

- Sand moves in the natural system during most flood events and the natural creeks are likely in dynamic equilibrium.
- Both the Stage 1 and Stage 2 diversion drains can transmit sands sourced from the upstream creeks to the downstream environment, with the Stage 1 diversion drain performing better in this respect. There is

expected to be some capture of sand in the diversion drains though, which will over time likely have a net benefit of 'coating' the diversion drains and making them more similar to the natural creeks in their fluvial geomorphology.

- Inclusion of a polishing pond downstream of the Stage 1 diversion (as is included in the DFS design) is currently not recommended as it incepts a significant portion of the natural sands transported through the Stage 1 diversion. And modelling indicates that in the reach of KCC upstream of the confluence with Nolans Creek that the creek dynamic equilibrium would become unbalanced and that continual scour could occur over subsequent flood events in this reach of the creek.
- Depending on the cut materials exposed, there is a potential for significant suspended load, comprising of finer grained sediments, being eroded and sourced from the diversion drains. It is noted that these eroded materials are likely representative of the alluvial floodplain materials. Further investigation of this is recommended following additional site investigation to confirm the materials exposed in the base of the diversion drains. For example, the modelling presented in this report does not consider the likely benefit of cohesion in the sediments, which may be present, in reducing eroded volumes. This potential risk of higher erosion rates is likely to be more critical in the initial flood events (such as a 'first flush' event), before the natural sand 'coating' likely develops in the diversion drains. If the future investigations highlight an unacceptable erosion response in the diversion drains, then options to mitigate this could include:
  - Placing erosion protection, such as rip-rap lining, in the diversion drain, or
  - Placing a 'coating' of natural sand in the diversion drain low flow channel (as opposed to relying on it to be transported in via flood events).

The Stage 2 diversion drain is considered feasible, despite the flat longitudinal slope, during mining in conjunction with a management plan for potential clean out of the inlet if sand builds up over time (for example in excess of 0.5 m within the drain). The aggradation performance of the drain would require monitoring during the mining period to collect data and support decisions for mine closure. A monitoring plan and a Trigger-Action-Response-Pan (TARP) will be required to be developed to support operational decisions regarding sand clean out of the Stage 2 diversion drain inlet. The opportunity to collect additional information prior to the construction of Stage 2 diversion drain, such as erosion bed load monitoring and material grading, would also allow further development of the Stage 2 diversion drain design prior to implementation.

In the worst case, closure could require backfill of part of the pits, with the KCC drain alignment re-instated across the top of the backfilled pit area.

There are a number of recommendations for future work to support an 'Issued For Construction' level of design for the surface water infrastructure, the most significant of which are:

- Additional test pit sampling and lab testing along the diversion drain and bund alignments
- Geotechnical borehole investigation for the Stage 2 diversion drain to aid slope cut design and inform conditions at the drain base level, and
- It is recommended that the climate change assumptions are reviewed at the time of the Stage 2 diversion drain implementation to ensure it confirms with the most current streamflow information and climate change design advice.

1. Introduction

This Report presents analysis and design drawings to support a 50% level of design for the surface water infrastructure associated with the mine area and Kerosene Camp Creek Diversions for the Nolans Rare Earth Project (the **Project**), which is being developed by Arafura Resources Limited (**Arafura**).

The Project is located in the Central Region of the Northern Territory (NT), approximately 135 km north of Alice Springs and 10 km west of the Stuart Highway. The development footprint for the Project is almost wholly located within the boundary of the Aileron Station, with an expected mine life of 38 years. The Project includes a mining (pit) area, the Kerosene Camp Creek diversion, accommodation camp, Residue Storage Facility (RSF), site access road, mine access road and process plant area.

The focus of this report is on the Kerosene Camp Creek diversion and mining area, with aspects such as the RSF, site access road, mine access road, explosives area, infrastructure area and process plant area being addressed separately. A previous Definitive Feasibility Study (DFS) has been undertaken, Knight Piésold (2019)[(1)], which has been reviewed and built upon as part of this study.

The following regulatory considerations are applicable to the Project:

- 1992 Northern Territory Water Act
  - Which requires approval to interfere with a waterway.
- 'Form 6' *Application for a Permit to construct or alter works*
  - Includes requirements for a hydrological report, including assessment of the downstream receiving environment with regard to flooding.
- Mining Management Plan (MMP) requirements:
  - Flood immunity levels for waste rock dumps
  - Consideration of risks for construction and operation of haul/access roads (including runoff).
- Northern territory Environmental Protection Authority (EPA) 2021 *Environmental factors and objectives* to:
  - Protect the hydrological regimes and inland water quality of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are maintained
  - Consider cumulative impacts, pressures on environmental values and climate change.

Analysis to support a 50% level of design is presented within this Report, with a set of Design Drawings provided in PSM4809-017M. Additional work is anticipated to uplift the surface water design to an 'Issued for Construction' (IFC) level of design. This report is anticipated to aid submission of a draft 'Permit to Interfere with a Waterway' submission for the Kerosene Camp creek and mine area to the NT Water Resources Regulator for their review and comments.

The revision to this report includes additional commentary and results from additional analyses, as presented in Sections 3.2, 6, 7.4 and 9.4.2.

2. Background

2.1 Mine Layout Stages

The mine area will consist of an open pit that will be excavated in multiple stages. For this study, the pit stage development and associated mine infrastructures have been arranged into two main stages:

- Stage 1, and
- Stage 2.

2.1.1 Stage 1

The Stage 1 pits comprise of three starter pits (Pit 1, Pit 2 and Pit 3), each located several hundred meters from the others. They are interconnected via a haul road that also connects to the run-of-mine (ROM) pad and mine infrastructure area. The Stage 1 operation includes a single waste dump, the 'South' waste dump, located on the

[(1)] Knight Piésold, March 2019. *Nolans Project – Surface Water Management – Definitive Feasibility Study – Design Report*. PE801-00140/13 Rev0.

eastern part of the mine area, and several topsoil stockpiles which are distributed across the mine area. Figure 1 shows the Stage 1 mine layout.

Surface water management structures, as shown in Figure 1, considered for this report include:

- Diversion drain for Kerosene Camp Creek (KCC), which redirects the creek waters around 'Pit 1' and discharges back into the natural KCC creek line further downstream. These diverted flows are notionally not affected by the mining area and are classified as 'clean' water.
- Dirty water diversion and toe drains, which serve to reduce water ingress into the pits during flood events and to direct flows to the sediment basins. Pit 1 and Pit 2 will be accompanied by temporary diversion drains. Two toe drains will be designed for the waste dump, wrapping along the eastern and western footprint of the dump. All flows sourced from areas disturbed by mining areas are classified as 'dirty' and will be captured by sediment basins for storage and cleaning before discharging into the natural watercourse.
- Clean water diversion drains, which capture runoff from some localised sub-catchments at the south-west edge of the mining area and diverts them either into KCC ('Clean Water Drain 1') or Nolans Creek ('Clean Water Drain 2').
- Flood protection bunds:
  - A flood protection bund will be constructed along the eastern extent of the mine area to mitigate flooding from Nolans Creek encroaching into the mine area during flood events
  - An inflow control bund will also accompany the Stage 1 KCC diversion drain, which will divert flows into the diversion drain
  - A temporary contingency bund will be built north of Pit 1 to prevent water ingress in the event of water backing up from an existing local valley that is hydraulically connected to the Stage 1 KCC diversion.
- Sediment basins, which will be built downstream of the mining area to mitigate sediment laden discharge from the mine. Stage 1 operation comprise of two sediment basins, the 'Eastern' and 'Central' sediment basins which aim to capture and control all 'dirty' flows from the mine.

2.1.2 Stage 2

The Stage 2 operation layout expands on the Stage 1 layout, with the majority of the infrastructure in the eastern portion of the mine area being the same as during Stage 1, as shown in Figure 2. A 'North' waste dump will be included in Stage 2 which will be developed on the north-western boundary of the mining area. Two different footprint options for the North waste dump are currently possible. The footprint of the pit is based on the final design of the pit stage development, 'Pit 7'.

The overall philosophy of the surface water management system has remained consistent with Stage 1, however:

- The Stage 2 KCC diversion alignment redirects flows from KCC to an unnamed tributary located north-west of the site, which rejoins KCC several kilometres downstream of the Kerosene Camp Creek and Nolans Creek confluence. It is expected that the diversion channel will intersect rock as part of the cut:
  - Some backfilling of the Stage 1 diversion drain alignment is also required to mitigate flows into Pit 7.
- The alignment of the KCC diversion inflow control bund is modified so that it follows the alignment of the Stage 2 KCC diversion drain. The bund follows a 'dog-leg' design in plan to conform to the natural topography and has been designed with the objective to reduce the catchment area north of the KCC diversion inflow control bund, which drains into Pit 7.
- An additional 'Western' sediment basin will be constructed to capture 'dirty' water from the 'North' waste dump and all associated surface water structures.
- The construction of the 'North' waste dump will be accompanied by toe drains. It is anticipated that a French drain will be required along the southern section of the dump, which will discharge to the North Dump Toe Drain 2.

A general layout of the Stage 2 mine area operation is presented in Figure 2.

2.2 Hydrology and Catchment Setting

2.2.1 Catchment Setting

The Project is located within the Western Plateau Drainage Division, on the border of the Burt and Wiso river basins, as shown in Figure 3, with the basins separated along the Reynolds Range. The mine area is within the headwaters of the Wiso basin, which drains to the north. As shown in Figure 3, Kerosene Camp Creek is a Strahler order 3 creek at the mine location, transitioning to an order 4 stream further downstream of the mine, where ultimately it discharges to the Woodforde River. The general elevation of the valley floor around the Project area ranges between 650 and 700 m RL. The longitudinal slope of creek lines is typically less than 0.5 percent.

The arid region of the Project is typically characterised by a climate where evaporation exceeds rainfall, and as such, creek lines are ephemeral by nature, with runoff only occurring during or after high rainfall storm events. The mining area intercepts several minor tributaries of the ephemeral KCC with a catchment area of roughly 19.8 km^2 upstream of the KCC diversion drain, as shown in Figure 3. The eastern border of the mine is adjacent to Nolans Creek, a tributary of KCC, with a catchment area of 28 km^2 upstream of the confluence of Nolans Creek and KCC. The confluence of KCC and Nolans Creek is roughly a kilometre downstream of the mine area. These form a tributary of the Woodforde River and are fall within the Ti Tree water control district. The nearest regional streamflow gauge, Arden Soak, is stationed approximately 25 km downstream and north of the site along the Woodforde River.

The area of the Project catchment area shown in Figure 3, which is the area to the location where the unnamed creek that the Stage 2 diversion is discharging into reaches the confluence with KCC, is 118.8 km^2. The diversions are aimed at maintaining the overall catchment area draining to the downstream confluence. The area upstream of the Stage 1 and 2 diversions is 19.8 km^2, representing 16.7% of the total catchment. During the Stage 2 diversion, there is approximately 9.2 km^2 (representing 7.7% of the total catchment) that will receive less flow and 5.1 km^2 (representing a 4.3% of the total catchment) that will receive additional flow. The results presented in this report give information as to the impacts of the catchment diversion.

Further details of the catchment setting are presented in PSM4809-009L DRAFT.

2.2.2 Baseline Hydrology

The Project area is characterised by an arid and Grassland climate under the Köppen classification with a hot dry summer and cold winter. The mean annual rainfall is estimated to be 300 to 320 mm, with rainfall predominantly coming from frontal bands and storms during summer. The evaporation point potential (that is the evaporation that would occur under the condition of unlimited water supply from a small area) far exceeds the rainfall at approximately 2,800 mm/year, giving that the evaporation is water limited.

Local long-term climate data is available from the Bureau of Meteorology. Three (3) rainfall stations within 200 km of the project have been summarised, two (2) of which have long-term climate records:

1. Aileron (Station ID 015543): Located approximately 10 km to the west of the Project, with an elevation of 684 m. From the available 71-year record, the mean annual rainfall is estimated as 300 mm.
2. Territory Grape Farm (Station ID 015643): Located approximately 43 km to the north-east of the Project, with an elevation of 566 m. From the available 36-year record, the mean annual rainfall is estimated as 315 mm. This station provides the closest long-term climate data to the Project area.
3. Alice Springs Post Office (Station ID 015540): Located approximately 141 km to the south of the Project, with an elevation of 580 m. From the available 114-year record, the mean annual rainfall is estimated as 278 mm. This station provides the longest long-term climate data to the Project area.

These records show that:

- The wet season occurs over the summer months, with 'shoulder' months between the 'wet' and 'dry' seasons of March and November
- There is approximately 15°C variation in the mean air temperature between summer and winter.

The creek lines in the Project area are all ephemeral in nature, with typically high rainfall losses encountered before runoff results.

PSM4809-009L DRAFT, dated 2 May 2023, provides detailed background on the site hydrology and the basis for estimating design flows. Two main hydrologic zones are defined in PSM4809-009L DRAFT:

1. Rock outcrop areas (which typically consist of metamorphic and granite rocks).
2. Sandy alluvial floodplain.

Each zone is characterised by a unique rainfall-runoff response and the parameters adopted for design are presented in Table 1. The Initial Loss (IL) – Continuing Loss (CL) method was selected to characterise the site infiltration and rainfall losses. RORB routing parameters, represented as the $C_{0.8}$ value, are also presented in Table 1.

Table 1 – Design Hydrologic Zone

Hydrologic Zone	Initial Loss (mm)	Continuing Loss (mm/hr)	RORB $C_{0.8}$
Alluvial Floodplain	60	5	0.6
Rock Outcrop	35	1.7	0.4

As can be seen in Table 1, lower losses are associated with the rock outcrop hydrologic domain, with losses typically associated with depression storage, as opposed to soil infiltration losses that are more associated with the alluvial floodplain hydrologic domain.

The hydrologic zones within the Project catchment have been spatially defined, as illustrated in Figure 4. The zoning was delineated via judgement and reference to the Napperby 1:250k scale geological series map, as well as the high-resolution topography Digital Elevation Model (DEM).

As discussed in PSM4809-009L DRAFT, design flows are estimated via:

- Base Case: Parameters from Table 1 are applied to the hydrologic zones in Figure 4
- (Upper Bound) Sensitivity: All areas are modelled with the 'Rock Outcrop' parameters from Table 1.

The sensitivity analysis is included to acknowledge the uncertainties in the rainfall-runoff parameters, as well as an approach to capture the potential future impacts of climate change. The parameters have been based on analysis of regional streamflow records. There is scope to update/re-consider these parameters and the hydrologic basis of design following the capture of on-site streamflow records (based on the recently installed on-site gauges).

2.2.3 Climate Change Guidance Updates

An assessment of climate change impacts was presented in PSM4809-009L DRAFT, based on the current guidance in the Australian Rainfall and Runoff (Ball *et al.*, 2019). Since the time of that report, some updated climate change guidance has been presented to the industry as a draft update to the Australian Rainfall and Runoff guideline. Whilst this guidance is still under industry review, it is expected to become the recommended guidance presented in the Australian Rainfall and Runoff guideline by mid-2024. As such, it is considered prudent to consider the potential impacts of this update as part of this report.

To date, the approach to assess climate change impacts on design floods has been to modify the design rainfall Intensity-Frequency-Duration (IFD) curves. The concept is that storm extreme event rainfalls are expected to worsen in line with the Clausius-Clapeyron relationship, which explains that for every degree of warming in the air temperature, the atmospheric water holding capacity increases by 7%. This approach obviously increases rainfalls and thereby has a flow on effect of increasing flows.

As presented in PSM4809-009L DRAFT, this resulted in a 12 to 19% increase in rainfall IFD totals (across all durations) by 2060 to 2070.

However, this approach does not account for impacts of climate change that can potentially reduce flows. For example, as the mean temperatures get hotter, the mean antecedent moisture content in the catchment would be expected to get drier. Which could in turn increase storm event rainfall losses, thereby having a reducing impact on flows.

The updated draft climate change guidance presented in Department of Climate Change, Energy, the Environment and Water (2023[(2)]) provides:

- Updated IFD rainfall scaling factors, which vary with storm duration, and
- An approach to account for potential increases in rainfall losses as a result of climate change.

Table 2 presents the mean projected changes in storm rainfall intensity at 2060 to 2070 as a result of the RCP 8.5 climate change scenario from the updated draft guidance.

Table 2 – Mean change in rainfall intensity for Nolans Project for 2060 to 2070 (to RCP 8.5)

Storm Duration (hrs)	Mean rainfall intensity increase (%)
≤ 1	37 to 56
1.5	33 to 51
2	31 to 47
3	29 to 43
4.5	26 to 39
6	24 to 36
9	23 to 34
12	21 to 32
18	20 to 29
≥ 24	19 to 28

As can be seen from Table 2, the rainfall increases are larger than what was recommended previously. The critical duration for the catchment upstream of the diversion drains is between typically between 1.5 and 12 hrs (as presented in PSM4809-009L DRAFT). This indicates a potential 21 to 51% increase in storm rainfalls from Table 2. The estimates of the impact of the sensitivity scenario (as discussed in Section 2.2.2) on the peak flows for the diversion drains is an increase of 40%. As such, whilst the increase in flows from the sensitivity case does not entirely cover the potential range from the rainfall climate change impacts from Table 2, it does cover most of the potential range.

Due to the limited number of regional streamflow gauges within the arid region of Australia, there is no guidance provided in the draft update for changes in loss parameters as a result of climate change for Nolans project area.

At this time, it is not recommended that additional changes are made to the hydrology approach to account for the updated draft climate change guidance as:

- Less than 40% increases in critical rainfalls are predicted for the design life of the Stage 1 diversion
- Additional site based streamflow information will be collected prior to construction of the Stage 2 diversion, which may allow refinement of the hydrology design parameters (which are currently based on regional data)
- Climate change design advice is a rapidly updating field within the industry at the moment, as such, updated advice is possible by the time the Stage 2 diversion is to be implemented
- The adopted climate change scenario (RCP8.5) from Table 2 is typically considered a conservative carbon emission scenario
- There will be an opportunity to re-assess climate change assumptions at the time of the Stage 2 diversion drain implementation to ensure it confirms with the most current streamflow information and climate change design advice.

As such, the sensitivity scenario from Section 2.2.2 is considered a reasonable allowance to account for the possible impacts of climate change.

[(2)] Department of Climate Change, Energy, the Environment and Water, 2023. *Draft update to the Climate Change Considerations chapter in Australian Rainfall and Runoff: A Guide to Flood Estimation, Book 1, Chapter 6, Climate Change Considerations*.

2.3 Reliance Files

The following files, as provided by Arafura, have been relied upon for this report:

- Reports:
  - *Definitive Feasibility Study Geotechnical Interpretive Report* (Knight Piésold Consulting, 2020) – PE20-00272 - Geotechnical Interpretive Report Rev 2.pdf
  - *Nolans Project Geotechnical Site Investigation* (Knight Piésold Consulting, 2011) – PE801-00140_06 Geotechnical Site Investigation Rev B.pdf.
- General site layout inputs:
  - KMZ DEC 2022.kmz – General layout
  - MIN_TITLE_PROD_GRNT.shp – Tenement boundary
  - siteplan_layout-mga_v2.dxf – Stage 1 layout
  - site_layout-mga_28.dxf – Stage 2 layout
  - mine_roads_and_infra_a_mp_oct23_mga.dxf.
- Waste dumps:
  - asbuilt_southdump_mp_oct23_final_mga.dxf
  - nw_dump_expansion_temp.shp.
- Pit shells:
  - pit1_1811_gda94.dxf
  - pit2_1811_gda94.dxf
  - pit3_1811_gda94.dxf
  - pit7_200107_gda94.dxf.
- ROM:
  - rom_concept_alt_mp_oct23_mga_v3.dxf.
- Stockpiles:
  - lt_sp_mp_oct2023_mga_v3.dxf
  - top_soill_sp_mga.dxf.
- Digital Elevation Models (DEMs):
  - GDA94_MGA_Z53_Nolans_Project_2111_Submission (0.5 m resolution site-specific DEM).

2.4 Critical Aspects

The Northern Territory Environmental Protection Authority (EPA) has previously provided an '*Assessment Report 84*' for the Nolans Project (NT EPA[(3)], 2017). The report highlighted that the following factors were to be addressed to aid Project approval:

- Demonstrate how the KCC diversion would maintain the existing regional hydrologic regime by effective delivery of natural flows of KCC to its downstream reaches
- Demonstrate how the KCC diversion would mitigate surface flows into the pit, even under a 1 in 1,000 Annual Exceedance Probability (AEP) event
- Demonstrate how the KCC diversion would maintain sediment transport and water quality regimes that allow the watercourse to be self-sustaining, and
- Demonstrate how the KCC diversion would maintain surface water quality (as informed by acid and metalliferous drainage testing of the basement rock).

The first three points are addressed as part of this report (with the exception of the specific impacts on water quality), whereas the fourth point is being addressed by others, separate to this report.

[(3)] Northern Territory Environmental Protection Agency, December 2017. *Assessment Report 84, Nolans Project*.

The Nolans 2016 *Environmental Impact Statement*[4] presents that many geological units in the greater Reynolds Range region contain elevated Uranium (U) and Thorium (Th) values, which exceed the average values expected for the upper continental crust. Existing tributaries of Kerosene Camp Creek upstream of the mine area appear to exhibit a degree of radioactivity. Samples were taken from stream sediment along existing tributaries of KCC within and downstream of the mining lease boundary. Two assay sample sizes were tested which were based on the 3.3 mm and 180 μm fraction. Both classes indicated elevated U and Th concentrations above the average values, in particular the finer grained fraction exhibited greater U and Th concentrations. Whilst the radioactivity is naturally occurring, consideration of the radioactive nature of the sediments, both with respect to sediment basin performance for dirty water drains receiving runoff from the waste dumps and transport of sediment through the diversions, is considered an important aspect for the design approach.

The creek lines around the Project area consist of loose sandy sediments, which would be expected to be transported under most flow events. However, as reported in PSM4809-009L DRAFT, there is evidence that both the Woodforde River at the location of the Arden Soak regional streamflow gauge, and the creek lines in the project catchment location, are in dynamic equilibrium in terms of their fluvial geomorphology. When a creek line is in dynamic equilibrium, there is an equilibrium balance of sediment erosion and deposition (sourced from upstream erosion) that occurs during flood events. As such, during an event, there is anticipated to be a naturally occurring movement of sand along the creek lines, but post an event, no significant changes are anticipated in the channel cross-section (except for extreme flood events, which can cause a geomorphological 'jump' in the fluvial environment). If this naturally occurring movement of sand is disrupted, then erosion would be expected downstream due to the reduction in sand coming from further upstream. Maintaining this naturally occurring movement of sand through the Project area is considered an important aspect of maintaining the fluvial geomorphology response of the existing natural creek lines.

3. Permit to Interfere with a Waterway

3.1 Northern Territory

The '*Form 6*' Permit to Interfere with a Waterway document is written in a way that is more relevant to a dam, as opposed to a diversion drain. However, there is a 'draft for consultation' *Interference with a Waterway Guideline* (2022) document, released by the NT Department of Environment, Parks and Water Security, that gives additional context on the requirements, including for a diversion drain.

As per the guideline, Kerosene Camp Creek and Nolans Creek, as well as the other tributaries are defined as waterways. The following examples are given as interference of a waterway:

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- Constructing a culvert crossing of a waterway
- Installing flood levees that may change the flood flow behaviour, and
- Diversion of a formed watercourse.

The Project includes each of the above examples, as such a Permit submission is required for the Project.

Four primary risks are highlighted as a result of interfering with a waterway:

1. Erosion and sedimentation.
2. Changes to water quality.
3. Changes to hydrology.
4. Changes to substrate.

The erosion and hydrology aspects are addressed within this report.

The guideline includes a self-assessment tool as to the qualitative impact as High, Medium or Low. As shown in Figure 3, the creek lines adjacent to the Project are no more than a Strahler order 3, which can be associated with Medium impacts, but as the duration of impacts are greater than for 2 years, this indicates a High impact from the self-assessment tool.

[4] Arafura Resources Limited, 2016. *Nolans EIS Radiation Report – Appendix P*

Consultation with the Regulator has also highlighted that maintaining flow volumes to the downstream environment (as much as is possible) is also an important consideration.

This report, along with the design drawings presented in PSM4809-017M, are aimed to aid with the submission of the required Permit.

It is highlighted that there are access roads upstream of the mine area that will require culverts and/or floodways for local creek lines upstream of the KCC diversion. These features would also classify as interference with a waterway, but detailed design of these culverts or floodways is not yet available. As such, to allow progression of the KCC diversion assessment, nominal road crossing surface water infrastructure drainage features for the upstream roads have been included in the hydraulic modelling.

3.2 Queensland Requirements Context

The Department of Natural Resources, Mines and Energy (DNRME) in Queensland has a watercourse diversions specific guideline (OSW/2019/4599)[(5)], which provides additional context on diversion requirements in an adjacent jurisdiction. It is however not a requirement for the Project to comply with this guideline.

The Guideline has different minimum objectives for temporary and permanent watercourse diversions:

- Applicable to both temporary and permanent diversions:
  - Watercourse diversion is to maintain the existing hydrologic characteristics of the surface water systems
  - The hydraulic characteristics of the watercourse diversion are comparable with other local watercourses and suitable for the region in which the diversion is located
  - The watercourse diversion maintains equilibrium and functionality and are appropriate for all substrate conditions they encounter.
- Applicable only to temporary diversions:
  - The temporary watercourse diversion maintains a sediment transport regime that minimises any impacts to upstream and downstream reaches.
- Applicable only to permanent diversions:
  - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses
  - The permanent watercourse diversion maintains a sediment transport regime that allows the watercourse to be self-sustaining, while minimising any impacts to upstream and downstream reaches.

In the above context, permanent diversion drains are required to simulate the natural system as closely as possible and there is a higher requirement for sediment transport outcomes. The KCC Stage 1 diversion drain is a temporary diversion drain, whereas the Stage 2 diversion drain has the potential to be a permanent diversion drain.

As part of design documentation, geomorphic and vegetation assessments of existing watercourses is recommended, as well as details of the expected substrate within the diversion, a revegetation plan (where revegetation is planned) and operating and management plans. Section 6 discusses the geomorphic processes identified in existing watercourses, and Section 7.4.1 discusses the vegetation typically associated with natural creek lines.

For the hydraulic performance of a diversion, the guideline highlights the longitudinal grade, plan form and vegetation as key components to the management of stream energy. For a diversion, variation in the vegetation is expected over time, in particular immediately following construction where vegetation will be unlikely to have established. Sensitivity analysis in the hydraulic modelling is recommended to account for this variation. Limiting values for velocity, bed shear stress and stream power are recommended as guidance for conditions to maintain geomorphic processes in diversions, with the values reproduced in Table 3. It is highlighted that the values have been developed based on an ACARP study specific to the Bowen Basin in Queensland.

[5] Department of Natural Resources, Mines and Energy. 2019. *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (OSW/2019/4599), Version 2.00.

Table 3 – Bowen Basin Recommended Limits for Diversion to Maintain Geomorphic Processes

Scenario	Velocity Limit (m/s)	Bed Shear Stress Limit (N/m^2)	Stream Power Limit (W/m^2)
1 in 2 AEP (no vegetation)	< 1.0	< 40	< 35
1 in 2 AEP (vegetated)	< 1.5	< 40	< 60
1 in 50 AEP (vegetated)	< 2.5	< 50	< 150

Section 7.4 discusses the performance of the Stage 1 and 2 diversions against the limits from Table 3.

If the design allows for natural evolution (instead of construction) of geomorphic features present in the natural watercourses, then a design plan is required to identify how the diversion will develop these features and how any impacts will be managed during the feature development phase. This is particularly relevant for the development of a sand cover within the diversion drains, which is prevalent within the natural watercourses. Section 9 focusses on the sediment transport performance of the diversion drains and the potential to develop a sand coating over time.

Where a diversion route is unable to reflect the natural features of the watercourse to be diverted, the design is required to:

- Identify characteristics of the proposed watercourse diversion route that prevent the inclusion of identified features
- Justify that the watercourse diversion cannot be located along an alternate route that can reflect the features of the watercourse to be diverted.

The Stage 2 diversion, which will not maintain the route of Kerosene Camp Creek, is unlikely to be able to replicate all of the natural features of the existing watercourses. Section 6 discusses the limitations related to the Stage 2 diversion drain alignment.

4. Design Criterion

This section outlines the design criterion adopted for each of the surface water management structures discussed in Section 2.1.

4.1 Drains

The Stage 1 and Stage 2 KCC diversion drains have been designed to withstand the 1 in 1,000 AEP peak design flow estimate, with a minimum 500 mm freeboard. Assuming a 38 yr mine life, this would represent a 3.7% chance of a 1 in 1,000 AEP event (or a more extreme event) occurring over the duration of the Project.

Toe drains and the other clean and dirty water diversion drains have been sized for the 1 in 100 AEP peak design flow, with a minimum 300 mm freeboard.

The peak design flow is estimated as the larger of the base case and sensitivity hydrology scenarios presented in Section 2.2.2.

4.2 Flood Protection Bunds

The flood protection bunds have been designed to mitigate overtopping of floods up to the 1 in 1,000 AEP event. A freeboard allowance of 1 m has been allocated in addition to the design height as a contingency against the potential for wind waves, bund settlement and hydrologic uncertainty.

There is also potential for the bunds to erode where it may be subjected to high flow velocities. Erosion of the bunds can be mitigated by constructing a layer of rip-rap protection. Considerations for the application of rip-rap protection have been investigated by examining the local maximum velocity at each bund from the hydraulic model of the 1 in 1,000 AEP design event. The rip-rap protection has been designed based on the Austroads (2013) *AGRD05* manual. The manual provides rock protection requirements based on velocity for floodways, but which can also be extended in a conservative way to bund applications. Details of the rip-rap protection requirements as related to the flow velocity are provided in Tables 4 and 5.

Table 4 – Austroads Rock Slope Protection Design

Velocity (m/s)	Rock Protection Class	Layer Thickness (m)
< 2.0	None	–
2.0 – 2.6	Facing	0.50
2.6 – 2.9	Light	0.75
2.9 – 3.9	¼ tonne	1.00
3.9 – 4.5	½ tonne	1.25
4.5 – 5.1	1 tonne	1.60
5.1 – 5.7	2 tonne	2.00
5.7 – 6.4	4 tonne	2.50

Table 5 – Austroads Rock Slope Protection Rip-Rap Design

Rock Protection Class	D_{10} (mm)	D_{50} (mm)	D_{100} (mm)
Facing	150	300	400
Light	200	400	550
¼ tonne	300	550	750
½ tonne	400	700	900
1 tonne	550	900	1,150
2 tonne	750	1,150	1,450
4 tonne	900	1,450	1,800

4.3 Sediment Basin

Sediment basins are required to control sediment captured in the dirty water drains, primarily from the waste dumps. The characteristics of the sediment, both in terms of its grading and dispersity as well as its radioactivity are important aspects in the sediment basin design criteria.

The sediment basins are designed in accordance with the design procedure prescribed by the International Erosion Control Association (IECA) Australasia[(6)]. A *Type D* sediment basin was selected on the basis that basin operations are expected to exceed 12 months and fine sediment size particles (which may be dispersive) are anticipated.

The baseline soil assessment report by Landloch[(7)] suggests that the soil materials are non-sodic and not dispersive. However, it was noted that during field tests the materials exhibited a tendency to slake and go into suspension when disturbed. The Landloch report concludes that the soil may exhibit this behaviour during high rainfall events. Given the risk of the soil slaking and possibly being dispersive when disturbed, a conservative design was adopted, and the basins were designed for dispersive materials.

The Nolans 2016 *Environmental Impact Statement*[(8)] indicates that many geological units in the greater Reynolds Range region contain elevated uranium (U) and thorium (Th) values, which exceed the average values expected for the upper continental crust. Samples were taken from stream sediment along existing tributaries of KCC within and downstream of the mining lease boundary. Two assay sample sizes were tested which were based on the 3.3 mm (i.e. gravel) and 180 µm (i.e. sand) fraction. Both classes indicated elevated U and Th concentrations above the average values, with, in particular, the finer sand sized fraction exhibiting a greater U and Th concentration (i.e. the natural creek sands display radioactive particles).

Barrel leachate testing for the waste materials indicate that oxidised Gneiss and Schist are the most likely potential sources of radioactive particles. The Landloch report indicates that oxidised Gneiss rock fraction is expected to be reasonably durable, whereas the oxidised Schist is more susceptible to breakdown. The Landloch report recommends that the oxidised material not be used within the upper 1 m of the dump surface, but this does not

[(6)] International Erosion Control Association Australasia, 2016. *Sediment Basin Design and Operation – Appendix B*

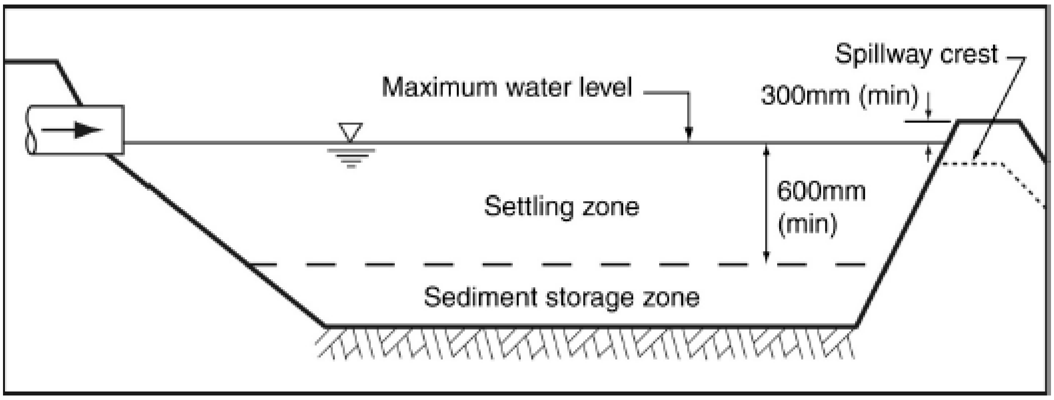
[(7)] Landloch, 2021. *Baseline Soil Assessment: Nolans Project*

[(8)] Arafura Resources Limited, 2016. *Nolans EIS Radiation Report – Appendix P* mitigate the risk of erosion during wate dump construction. It is indicated that the oxidised Gneiss and Schist rocks are only expected to make up to about 6.5% of the total expected waste. It is unknown to what sized particles the oxidised Gneiss and Schist would be expected to degrade to over time.

No other information, such as the radioactivity of silts and clays, is currently available. As such, it has not been possible to assess the risk radioactivity associated with finer particles, which can be more prone to escaping sediment basins during extreme events.

The sediment capture efficiency has been analysed for each of the sediments basins to understand the capture performance of each basin. Based in the baseline information, capture of sands, which display radioactivity, even during extreme flow events (such as the 1 in 100 AEP), is recommended.

A *Type D* sediment basin consists of an upper settling zone, a lower sediment storage zone, and an emergency spillway as shown in Inset 1. The sediment storage zone captures and stores the settled sediment and will require continuous maintenance to avoid significant build-up of sediment after storm events. For rarer storm events, flows are expected to discharge through the emergency spillway.



Inset 1: Long-section of a typical Type D sediment basin (IECA, 2016).

Type D basins are governed by a minimum volume requirement. The adopted design criteria are:

- Sediment basins are sized to capture the runoff volume expected from a 5-day 95th percentile rainfall event, which is to be catered for within the 'settling zone'
- The sediment storage zone has been designed as 50% of the settling zone volume
- The emergency spillway has been designed for 1 in 100 AEP design peak flow, with a minimum 500 mm freeboard.

Other general design rules prescribed by the IECA procedure include:

- The minimum length to width ratio of the basin is three times long as it is wide (to help increase sediment capture efficiency)
- The minimum recommended depth of the settling zone is 0.6 m.

It is highlighted that dispersive clays captured within a sediment basin will require flocculation before the captured water is discharged, in a controlled manner, to the downstream environment. The entire flocculation settling storage volume is to be pumped out within a maximum five-day period from the end of the runoff event.

4.4 Material Sizing

Understanding the Particle Size Distribution (PSD) of the site material is critical for assessing the sediment erosion potential of the Project area.

Two geotechnical reports from Knight Piésold Consulting in 2011[9] and 2020[10] inform the baseline PSD of the Project surficial materials. Sieve analysis of bulk samples collected from test pits was undertaken to measure the

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[9] Knight Piésold, 2011. *Nolans Project – Geotechnical Site Investigation*

[10] Knight Piésold, 2020. *Nolans Project – Definitive Feasibility Study Geotechnical Interpretative Report*

PSD. Limited hydrometer analyses of some samples are presented in the KP report (2020); however, they were either invalid samples or inapplicable to the Project area.

PSD from samples that were relevant to the study were identified and are shown in Figure 5. The KP (2020) report has grading information on samples taken from sand materials within the creek bed. The KP (2011) report took samples from different locations around the Project area. Samples taken from two areas were noted, including the proposed pit location and along the creek channels.

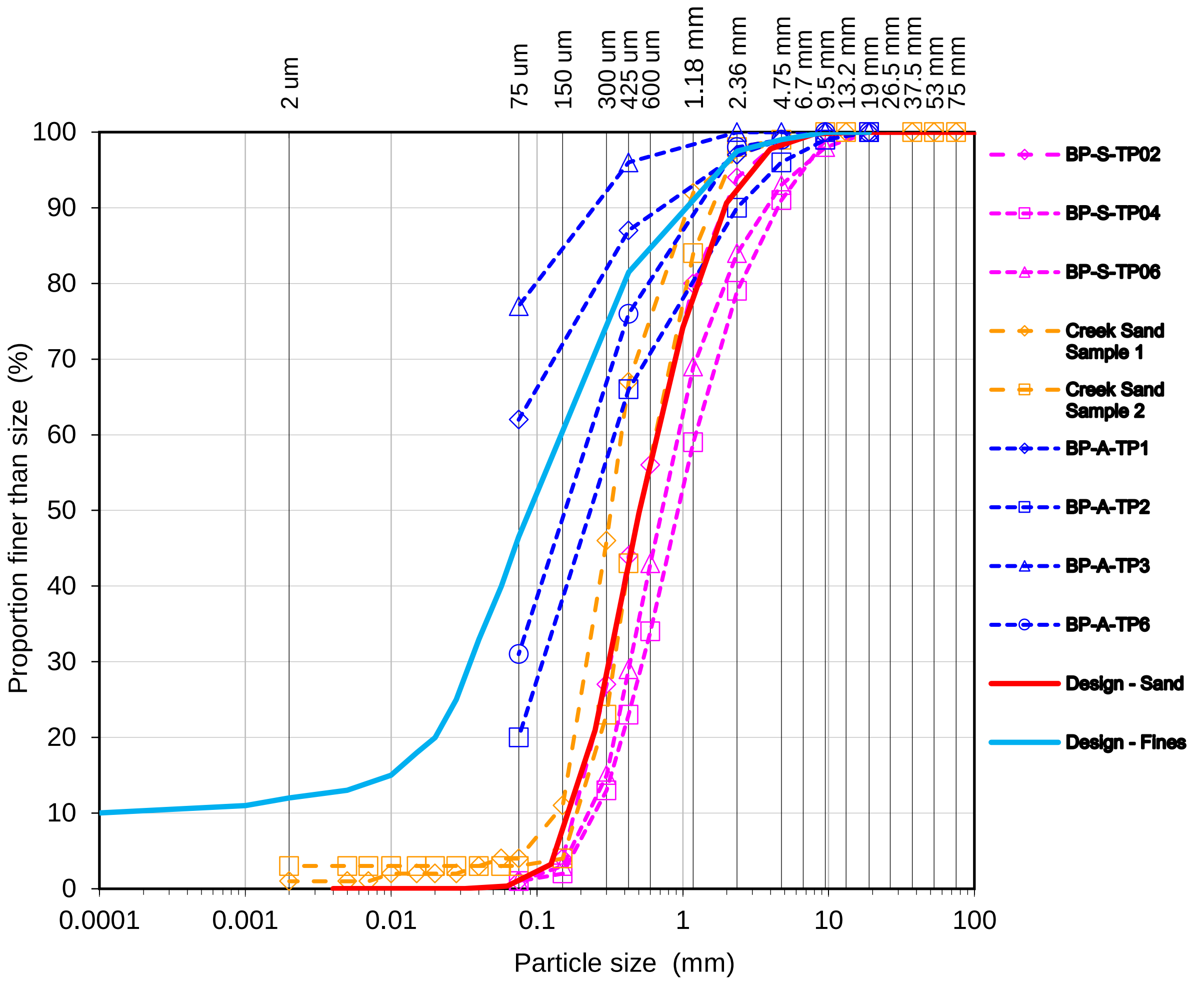
It was discovered that samples taken from the pit location were characteristic of lower permeability material, defined as predominantly clayey, silty sand. Test samples were taken at depth up to 2.3 m from this area.

Conversely, the samples extracted from the creek channels were defined as predominantly sand with traces of silt, with bulk samples taken at depth of up to 0.6 m.

Based on the baseline PSD sampling, the grading classification adopted for the sediment erosion assessment have been defined as either:

- 'Sand', which is predominantly sand representative of the natural surficial material and creek beds, or
- 'Fines', which is characteristic of the clayey, silty sand typical of the wider floodplain areas and weathered rock, and which is anticipated in cut areas, such as diversion drains.

Inset 2 presents the PSD curves of all the test samples presented in Figure 5 and the design PSD curves adopted for the erosion assessment. The adopted design curves were produced by 'averaging' the PSD test samples from KP investigations.



Inset 2: PSD test result and design curves.

Inset 2 shows that the design 'Fines' material (i.e. silts and clays) consists about 45% of fines (fraction less than 75 µm), whereas the creek bed sands are quite 'clean', with very little fines.

5. Design Storm Events and Flows

Based on the rainfall-runoff modelling summarised in Section 6.3 of PSM4809-009L and TUFLOW modelling from Section 2.2 of PSM4809-014L, a series of design storm events have been established, including:

- 1 in 5 AEP, 48 hours duration
- 1 in 10 AEP, 12 hours duration
- 1 in 20 AEP, 4.5 hours duration
- 1 in 50 AEP, 6 hours duration
- 1 in 100 AEP, 4.5 hours duration, and
- 1 in 1,000 AEP, 3 hours duration.

Table 6 presents the base case RORB predicted peak flows based on the above design storm durations at a number of critical 'print' nodes. The Sensitivity scenario flows are presented in Table 7, which is considered to account for a reasonable allowance for the potential impacts due to climate change.

The location of the print nodes is presented in Figure 27 of PSM4809-009L DRAFT. Some of these nodes have been taken as inflow hydrograph boundary conditions for the TUFLOW model discussed in Section 7.

Table 6 – Design Peak Flow Estimates (Base Case)

Locations	Peak Flow (m³/s)					
	1 in 5 AEP	1 in 10 AEP	1 in 20 AEP	1 in 50 AEP	1 in 100 AEP	1 in 1,000 AEP
N38 (western unnamed creek)	70.2	131.8	200.5	251.9	304.5	652.2
N65 (KCC at toe of Reynolds Range)	10.1	19.7	37.2	41.3	53.0	116.7
N67 (Nolans Creek western tributary)	8.9	17.2	32.1	35.7	45.9	101.0
N55 (Nolans Creek eastern tributary)	21.2	40.6	51.9	83.5	104.2	221.5
Diversion Drain Inlet (N46)	24.4	46.6	58.6	96.1	121.1	263.0
Nolans Creek, adjacent to pit (N57)	29.8	55.5	68.1	114.4	142.3	299.5

Table 7 – Design Peak Flow Estimates (Sensitivity)

Locations	Peak Flow (m³/s)					
	1 in 5 AEP	1 in 10 AEP	1 in 20 AEP	1 in 50 AEP	1 in 100 AEP	1 in 1,000 AEP
N38 (western unnamed creek)	70.2	131.8	200.5	251.9	304.5	652.2
N65 (KCC at toe of Reynolds Range)	10.1	19.7	37.2	41.3	53.0	116.7
N67 (Nolans Creek western tributary)	8.9	17.2	32.1	35.7	45.9	101.0
N55 (Nolans Creek eastern tributary)	27.9	54.3	84.8	105.2	127.9	274.1
Diversion Drain Inlet (N46)	32.7	64.1	103.9	123.4	152.5	336.1
Nolans Creek, adjacent to pit (N57)	41.0	76.8	119.0	147.2	180.2	386.6

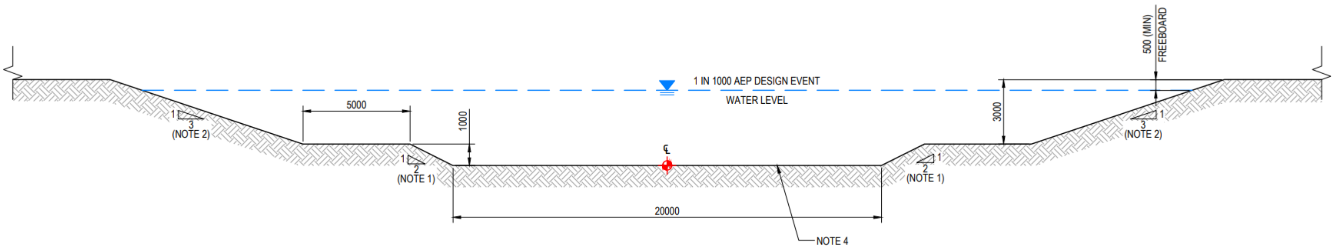
6. Diversion Drain Optioneering

The alignment of the Stage 1 KCC diversion drain diverts a segment of KCC to the west, as shown in Figure 1. To try and maintain the geomorphic response of KCC through the diversion, despite the diversion being temporary, there is benefit in matching the key planform, low flow channel and longitudinal slope characteristics of the diversion to those from the natural watercourses. For KCC and Nolans Creek, the natural low flow channels characteristics include:

- Sand lining
- Low flow channel of 1 m depth, and 20 to 30 m top width
- Longitudinal slope of 1V:333H (0.3%) to 1V:200H (0.5%).

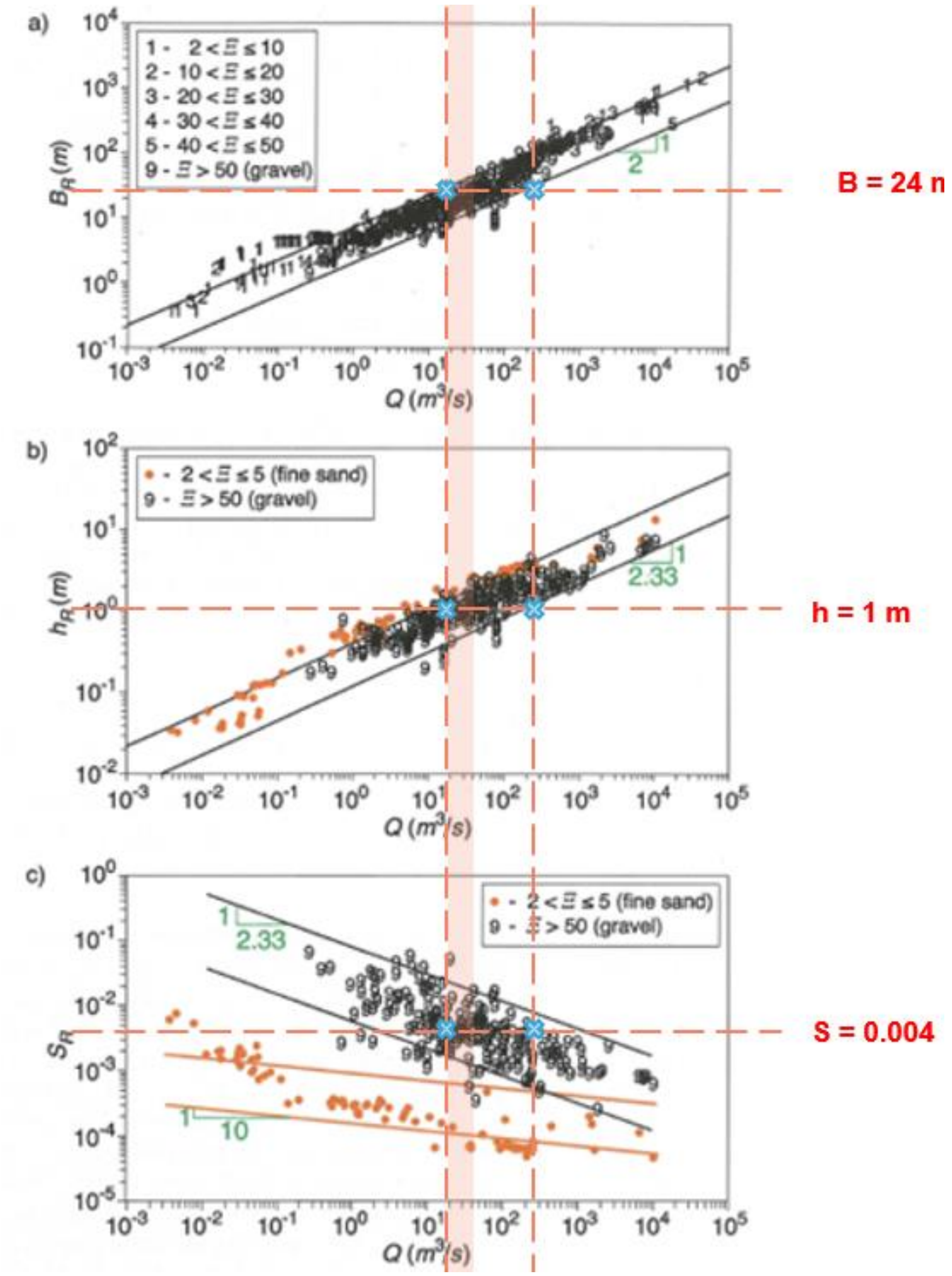
If a creek is in dynamic equilibrium, then the low flow channel would be expected to be a regime channel. A regional compilation of regime channel characteristics is presented in da Silva and Yalin (2017)[11]. As discussed in PSM4809-009L DRAFT, the Arden Soak low flow channel (downstream of KCC) is very likely a regime channel in dynamic equilibrium, with KCC showing similar characteristics.

The Stage 1 KCC diversion drain is required to convey a 1 in 1,000 AEP, whereas typical watercourse low flow channels will have bankfull flow between the 1 in 2 AEP and 1 in 10 AEP. To try and maintain the fluvial geomorphology of the system, the Stage 1 diversion cross-section has been designed with a low flow channel contained within a larger channel, as shown in Inset 3, with the low flow channel aimed to have similar characteristics to natural watercourse low flow channels, and the wider channel containing larger events up to the 1 in 1,000 AEP. The low flow channel has been designed with a 24 m top width, a 1 m depth and a longitudinal slope of 1V:250H (0.4%). These low flow channel dimensions agree well with those for a regime channel based on the chart from da Silva and Yalin (2017), as shown in Inset 4 (noting that the typical sand grading from Inset 2 classifies as $\Xi > 50$), with the orange bank showing the predicted range for 1 in 2 to 1 in 10 AEP, which also agrees with predicted bankfull flows (Q on Inset 4).



Inset 3: Stage 1 KCC Diversion Channel Design (Drawing PSM4809-010-39).

[11] da Silva, A. M. F. and Yalin, M.S. 2017. *Fluvial Processes – Second Edition*. International Association for Hydro-Environment Engineering and Research, IAHR Monograph. CRC Press, Taylor & Francis Group. London, UK.



Inset 4: **Stage 1 KCC Diversion Low Flow Channel Comparison as a Regime Channel.**

With the Stage 2 mine layout and the available mining lease, there are two main possibilities for the KCC Stage 2 diversion drain alignment:

1. Diverting flows to the west (as shown in Figure 2), which represents a 3 m elevation drop over a 3 km length (i.e. a 1V:2,000H, 0.05% slope).
2. Diverting flows to the east towards Nolans Creek, following an alignment sitting in between northern edge of the South Waste Dump and Pit 7, which would give an approximately 6.5 m elevation drop over a 2.8 km length (i.e. a 1V:500H, 0.2% slope).

Investigation of other creek lines in the nearby region shows that longitudinal slopes vary between 0.34% (1V:300H) at the flattest and are typically between 0.4% (1V:250H) and 0.6% (1V:167H). In this regional context, both possible alignments have a flatter longitudinal slope than regional analogues. And whilst the option to divert flows towards

Nolans Creek does give a steeper longitudinal slope, it does raise a number of factors that detract from the feasibility of this option, including:

- The outlet of the diversion would require a 'gap' in the Nolans Creek Flood Protection Bund, which would likely have a detrimental outcome for the ability of the Nolans Creek Flood Protection Bund to excluding extreme flood events from the mining area
- There is currently very limited space between Pit 7 and the South Waste Dump toe, such that the diversion drain would likely be required to be placed as close as possible to the Pit 7 crest, which could have implications for pit slope stability (due to seepage losses from the drain causing pore pressures in the adjacent pit slopes) and/or could require HDPE lining of the diversion drain
- The diversion drain alignment would prevent the South Dump Toe Drains from being able to drain to the Eastern Sediment Basin and would require an additional sediment basin to be created on the south side of the diversion drain alignment. Space for such a sediment basin is not currently available and would require a reduction in the size of the South Waste Dump.

Due to these factors, despite the flatter longitudinal slope, the Stage 2 KCC diversion drain alignment to the west (as shown in Figure 2) is considered the most feasible option within the available mining lease and current mine layout. However, the flatter longitudinal slope does represent a potentially serious change to the typical natural watercourse longitudinal slopes and requires analysis to understand the performance, in particular with respect to the risk for aggradation within the drain over time. Sections 7.4 and 9.4.2 discuss the hydraulic and sediment performance for the Stage 2 KCC diversion alignment respectively to quantify the expected performance.

The Stage 2 KCC diversion exceeds 3,000 metres in length and is required to divert flows up to the 1 in 1,000 AEP. Given these two factors, consideration has been given to assess options that are feasible and meet performance outcomes.

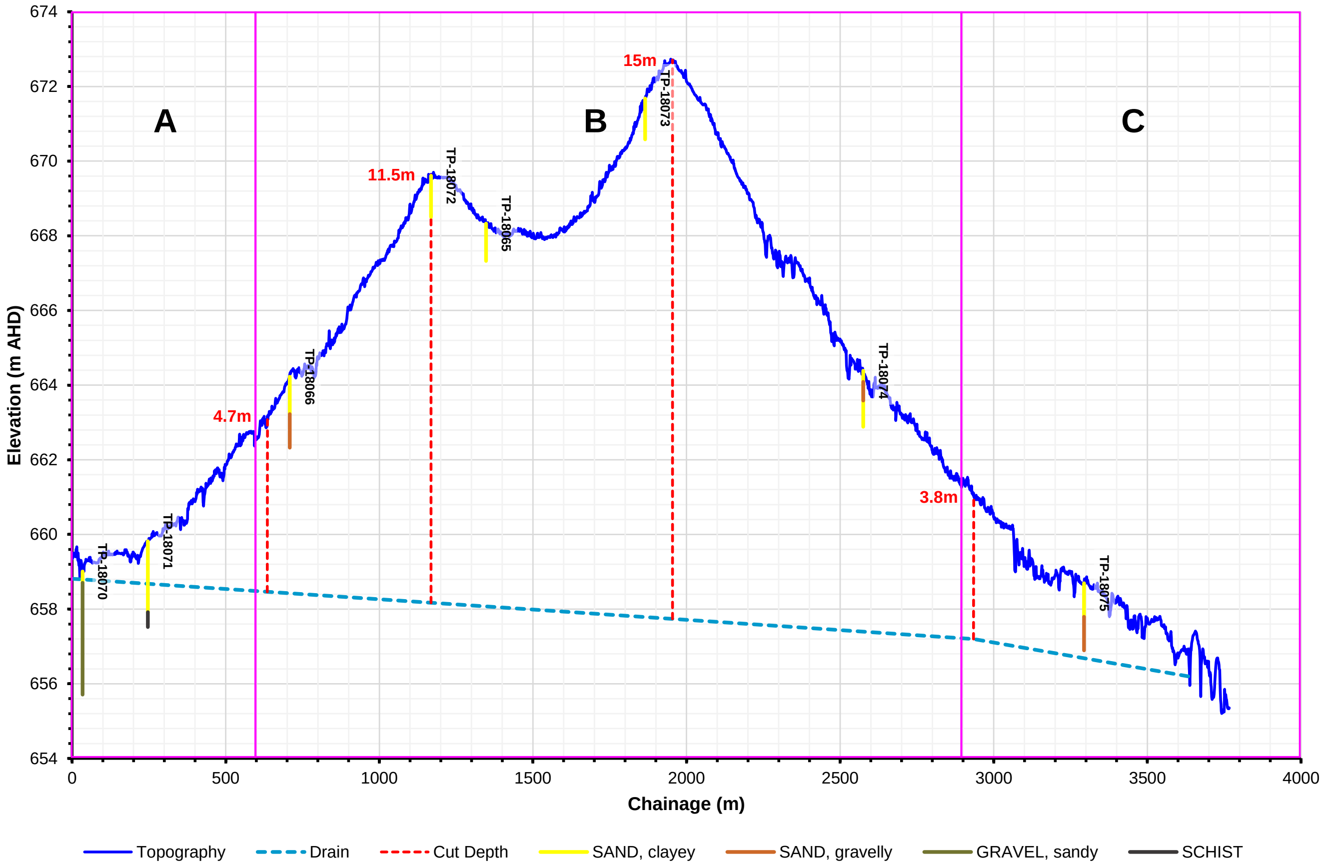
The longitudinal profile of the proposed drain is dictated by the inlet and outlet elevations in the natural topography. The elevation of the natural topography at the inlet and outlet of the drain is approximately 659 m and 656 m respectively, which is about 3 m drop over the drain length of more than 3,000 metres. For this longitudinal slope, initial investigation has highlighted that a drain with a 35 m base width and approximately 5 m depth would be required to have sufficient capacity to contain a 1 in 1,000 AEP design event.

The longitudinal cross-section of the diversion drain alignment in Inset 5 has been classified into three zones:

- Zone A: The available relief between the drain base and crest within the first 600 m of the drain is less than 5 m. This limits the excavation and available depth that can be allocated to the drain channel. As the natural topography is trending upslope within this region, it is anticipated that some degree of backwater conditions will occur, which will need to be managed by the inlet inflow control bund. The inflow control bund will act as a barrier and mitigate against ingress of floodwaters into the site, and as such, the anticipated backwater pooling is likely to be acceptable.
- Zone B: Most of the mid-section of the drain requires excavation that will exceed 5 m depth, providing a large degree of freeboard. In this area, it is expected that the channel will be excavated into rock. Aerial images indicate that the rock mass foliation typically runs sub-parallel to the drain alignment, which could potentially cause kinematic rock mass failures. Additional geotechnical investigation in the form of boreholes and ATV/OTV logging is recommended to aid design of the slope cuts for the diversion drain in this segment.
- Zone C: As the drain approaches its outlet, the natural topography results in the relief between the drain base and the crest reducing below 5 m. Control of flows is more complicated in this area, and it is not possible to preserve the flow capacity of the drain along the alignment with a uniform cross-section (as the available channel depth decreases). As such, in order to preserve flow capacity of the drain, either:
  - The width must increase to make up for the reduction in channel depth, or
  - The longitudinal slope of the channel steepens at the expense of higher velocities.

  Both aspects were considered in the optioneering. However, given the relatively small elevation difference between the drain inlet and outlet, there was only limited opportunity to steepen the slope in Zone C (without making the resulting slopes in Zones A and B very flat).

The adopted longitudinal slope of the drain is 0.05% up to a chainage of 2,900 m, which then steepens to 0.14% onwards.



Inset 5: Stage 2 KCC diversion drain alignment long-section profile.

Optioneering of the drain geometry was explored to determine the preferred design for Zone C. The downstream alignment of the drain is highlighted in Figure 6, showing the footprint of the different options in plan.

Three options were explored:

- Option 1, which incorporates a two-level channel design involving a lower 'low-flow' channel and upper 'high-flow' channel. The 'low-flow' channel was designed to manage flows up to the 1 in 100 AEP design peak flow. This resulted in a channel with a maximum top width of 246 m, as shown in Figure 7.
- Option 2, similar to Option 1 adopts the two-level channel design however, with the base of the 'low-flow' channel increased in an effort to reduce the total width of the channel. This yielded a maximum top-width of 136 m, as shown in Figure 7.
- Option 3, which was designed to only contain the 'lower-flow' conditions up to the 1 in 100 AEP event, with the channel dimensions show in Figure 7.

The possible drain height near the exit of the drain is very limited, consequentially the drain exits have focussed on transferring 1 in 100 AEP flows to the outlet, with higher flows being managed up to the edge of the 1 in 1,000 AEP floodplain that the diversion drain is discharging into, as shown in Figure 6. Both Options 1 and 2 have aimed to contain the 1 in 1,000 AEP, whereas Option 3 allows the drain to overtop for events that exceed the 1 in 100 AEP.

The selection of the preferred drain exit option is a balance between:

- The amount of land that would need to be cleared in order to contain the 1 in 1,000 AEP flood, and
- The consequence of letting events in excess of the 1 in 100 AEP spilling out of the Option 3 channel.

Modelling of Option 3 (as shown in Figure 13 and 14) found that the floodwater breakout of the drain near the extent was reasonably limited, with velocities typically less 1 m/s (which indicates a reasonably low risk of significant erosion following drain breakout). The extent flooded by Option 3 is less than the extent that would need to be cleared for either Options 1 or 2. As a result, Option 3 was adopted for the preferred Stage 2 diversion drain design.

7. Hydraulic Modelling

Hydraulic modelling of the Project area was undertaken to estimate flood depths, velocities, extents, and flows.

7.1 Model Details

Hydraulic modelling was undertaken with the TUFLOW HPC GPU (2023-03-AB version) hydraulic software. TUFLOW HPC provides an explicit solution to the 2D Shallow Water Equations (Saint-Venant equations) and utilises a finite volume scheme, conserving both volume and momentum.

The model adopted a direct rainfall (rain-on-grid) approach to simulate the site rainfall runoff response. Direct rainfall was applied to each cell across the model domain, excluding areas associated with the pit shell footprint. Four inflow source areas were also inputted to consider the upstream catchment, integrating design hydrograph outputs from the RORB hydrologic modelling for the Project area.

An initial / continuing loss (ILCL) approach was selected to represent the design storm losses. Within TUFLOW the losses were applied directly to the rainfall hyetograph before applying the rainfall to the 2D cells, which is comparable to the initial-continuing loss method adopted in the RORB hydrologic model. A uniform Manning's roughness coefficient value was applied.

7.2 Model Setup

The extent of the TUFLOW model encompasses the mine area, north of the confluence of Nolans Creek and Kerosene Camp Creek, and the immediate upstream catchments south of the site, as shown in Figure 8 and Figure 9 for the Stage 1 and Stage 2 TUFLOW model setups respectively. A global cell size of 16 m was selected to represent the site topography, sampled from the site-specific high-resolution DEM. Where there was no elevation data from the high-resolution DEM, the 1 second SRTM DEM-H was referenced. At main areas of flow or other critical areas, TUFLOW Quadtree meshing was utilised to refine cell sizes to 4 m.

Initial and continuing losses for the base case hydrology approach were classified as one of two rainfall-runoff loss parameters:

- Reynolds Range Rock: *IL* of 35 mm, *CL* of 1.7 mm/hr
- Sandy Alluvial Floodplain: *IL* of 60 mm, *CL* of 5 mm/hr.

The zoning was defined in accordance with Figure 4.

For the Sensitivity hydrology approach, the entire model was modelled with the Reynold Range Rock loss parameters.

An outlet boundary condition was modelled along the northern boundary of the model, downstream of the Nolans Creek and Kerosene Camp Creek confluence. Four areas of major inflow were identified upstream of the model domain. These were modelled as source areas ('N55', 'N67', 'N65' and 'N38'), which allow input of design hydrographs into the model. The hydrographs were extracted from the hydrologic RORB model of the Project area discussed in Section 6 of PSM4809-009L DRAFT. Figure 10 highlights a selection of design hydrographs used as source area inputs from different AEP events. Peak flows from these source areas are also summarised in Tables 6 and 7.

The model adopts a uniform roughness (Manning's n) of 0.05.

Rainfall hyetographs for the rain-on-grid were aligned with the critical design storms from the RORB modelling with rainfall taken from Intensity-Frequency-Duration (IFD) curves downloaded from Bureau of Meteorology and areal reduction factors and design temporal patterns as per the AR&R Datahub.

A series of PO (print-output) lines and points have been digitised to extract output hydrograph and time-series results at 5-minute intervals, some of which are shown in Figure 8 and Figure 9.

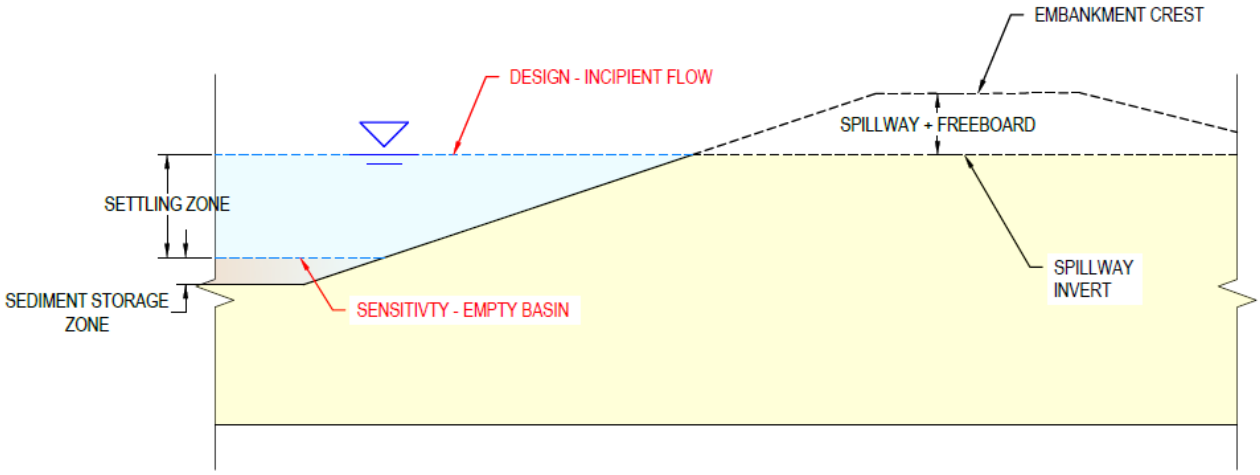
Three development scenarios were investigated for analysis:

1. Baseline or 'existing' conditions, referred to as the 'baseline' scenario, which all other scenarios will be compared against.
2. Stage 1 operational conditions based on the proposed Stage 1 layout.
3. Stage 2 operational conditions based on the proposed Stage 2 layout.

The setup of the TUFLOW model for the Stage 1 and Stage 2 operational scenarios are presented in Figure 8 and Figure 9 respectively. The 1 in 5 AEP, 1 in 10 AEP, 1 in 20 AEP, 1 in 50 AEP, 1 in 100 AEP and 1 in 1,000 AEP events were simulated for each development scenarios.

Sensitivity of different parameters were considered to account for uncertainties and a range of possible outcomes. Two sensitivity parameters were analysed:

- Storage of sediment basin: Runoff extent can vary depending on the available water storage of the sediment basins at the time of the storm. To capture the range of outcomes, two scenarios were considered, as illustrated in Inset 6:
  - Design events: incipient spill condition where the sediment basin is ‘full’ and water level is at the overflow spillway crest. This scenario represents the upper bound for downstream flow estimates, i.e., reduced impacts of sediment basin storage attenuation on downstream waterways.
  - Sensitivity events: empty basin condition where the sediment basin is ‘empty’ and water level is at the base of the settling zone. This scenario represents the ‘worst’ case impact to the downstream waterway, i.e., greatest impact from sediment basin storage attenuation to downstream flows.
- Loss parameters:
  - Design events: Both hydrologic domains (i.e., alluvial floodplain and rock) are assigned to the cells within the model as per Figure 4.
  - Sensitivity events: The rocky outcrop runoff parameter is applied globally, regardless of the anticipated surface geology/hydrologic domain. This scenario should notionally yield the ‘upper bound’ flow estimates, with the conservativism providing an allowance for climate change.



Inset 6: Spillway storage sensitivity.

7.3 Stage 1 and Stage 2 Diversion Results

Hydraulic model results are presented in:

- Stage 1 Operations conditions:
  - Figure 11 presents the 1 in 1,000 AEP design event maximum depth and difference to the baseline scenario
  - Figure 12 presents the 1 in 1,000 AEP design event maximum velocity and difference to the baseline scenario.
- Stage 2 Operations conditions:
  - Figure 13 presents the 1 in 1,000 AEP design event maximum depth and difference to the baseline scenario
  - Figure 14 presents the 1 in 1,000 AEP design event maximum velocity and difference to the baseline scenario.

Hydraulic modelling outputs for the other design and sensitivity events for Stage 1 and Stage 2 operational scenarios are presented in PSM4809-014L. The hydraulic modelling results show that:

- Stage 1 scenario:
  - The diversion drains have been adequately sized to capture and divert major flows away from key mining infrastructure.
  - Pit 1 is subject to water inflow for the 1 in 100 to 1 in 1,000 AEP event from potential water backing up from the floodplain north of the pit. The 'Pit 1 bund' has been added to the design drawings to mitigate this flood water from inflowing into the Pit for up to at least the 1 in 1,000 AEP.
  - The Stage 1 diversion inflow control bund for the main Stage 1 KCC diversion drain needs a minimum height of 2.5 m to avoid overtopping of the bund under the 1 in 1,000 AEP event. The Nolans Creek flood protection bund that borders along Nolans Creek on the eastern side of the mining area needs a minimum height of 1.5 m to avoid overtopping for the 1 in 1,000 AEP event.
  - Velocities within the main Stage 1 KCC diversion drain exceeds 2 m/s for the 1 in 1,000 AEP event, erosion modelling, presented in Section 9, has been undertaken to quantify the implications of this. Velocities at the (smaller) pit crest diversion drains and waste dump toe drains are typically less than 2 m/s, but does exceed 2 m/s in localised areas (such as near the outlet of the 'Pit 1 and Pit 2 drain').
  - Differences in flood depth are typically in the range of +0.1 to +0.3 m and -0.7 to -1.3 m/s for the velocity for the 1 in 1,000 AEP at Nolans Creek and Kerosene Camp Creek downstream of the mine tenement.
- Stage 2 scenario:
  - The 'North' waste dump toe drains have sufficient capacity for the 1 in 100 AEP event flows and allow transfer of flows to the 'Western' sediment basin without overspill. Velocities typically range between 0.3 and 1.3 m/s.
  - Ponding occurs at the southwestern corner of the 'North' waste dump against the haul road. A French drain has been included in the 50% level of design drawings to facilitate a drainage path for this water and to allow the catchment to remain connected to the downstream environment. The Extended North Waste Dump option has not been specifically modelled within the TUFLOW hydraulic model. If the extended waste dump option is pursued no significant differences to the currently modelled outcomes are anticipated, as the extended waste dump effectively covers the full valley catchment, and with the inclusion of toe drains, the full catchment area should remain connected to the downstream environment.
  - The Stage 2 KCC diversion drain is adequately sized to capture and divert major flows away from key mining infrastructure areas.
  - The pit area intercepts a creekline that drains an area between the Stage 2 diversion inflow control bund and the southern edge of the pit crest, which makes it prone to inflows over the pit crest. A potential to modify this area via earthworks to improve the drainage is discussed in Section 10.4.
  - The Stage 2 diversion inflow control bund for the main Stage 2 diversion drain needs to be a minimum height of 3 m to avoid overtopping of the bund under the 1 in 1,000 AEP event. The Nolans Creek flood protection bund needs a minimum height of 1.5 m to avoid overtopping for the 1 in 1,000 AEP event.
  - Velocities across most of the main Stage 2 diversion drain remains below 2 m/s for the 1 in 1,000 AEP event. The velocity on the downstream section border nears 2 m/s, erosion modelling, presented in Section 9, has been undertaken to quantify the implications of this.

Since the time of completing the hydraulic modelling, some adjustments to the Stage 1 and Stage 2 layout have occurred. This has led to some minor discrepancies between the modelled site layout and the 50% level of design layout. The following structures have been identified where there has been a change:

- Topsoil stockpile
- ROM pad
- Haul road, and
- Clean water drains.

Some of these changes have resulted in 'clashes', which are highlighted and presented in Insets 7 to 9. In these insets, the 50% level of design layout is presented in the foreground while the simulated layout is displayed as a hillshade in the background.

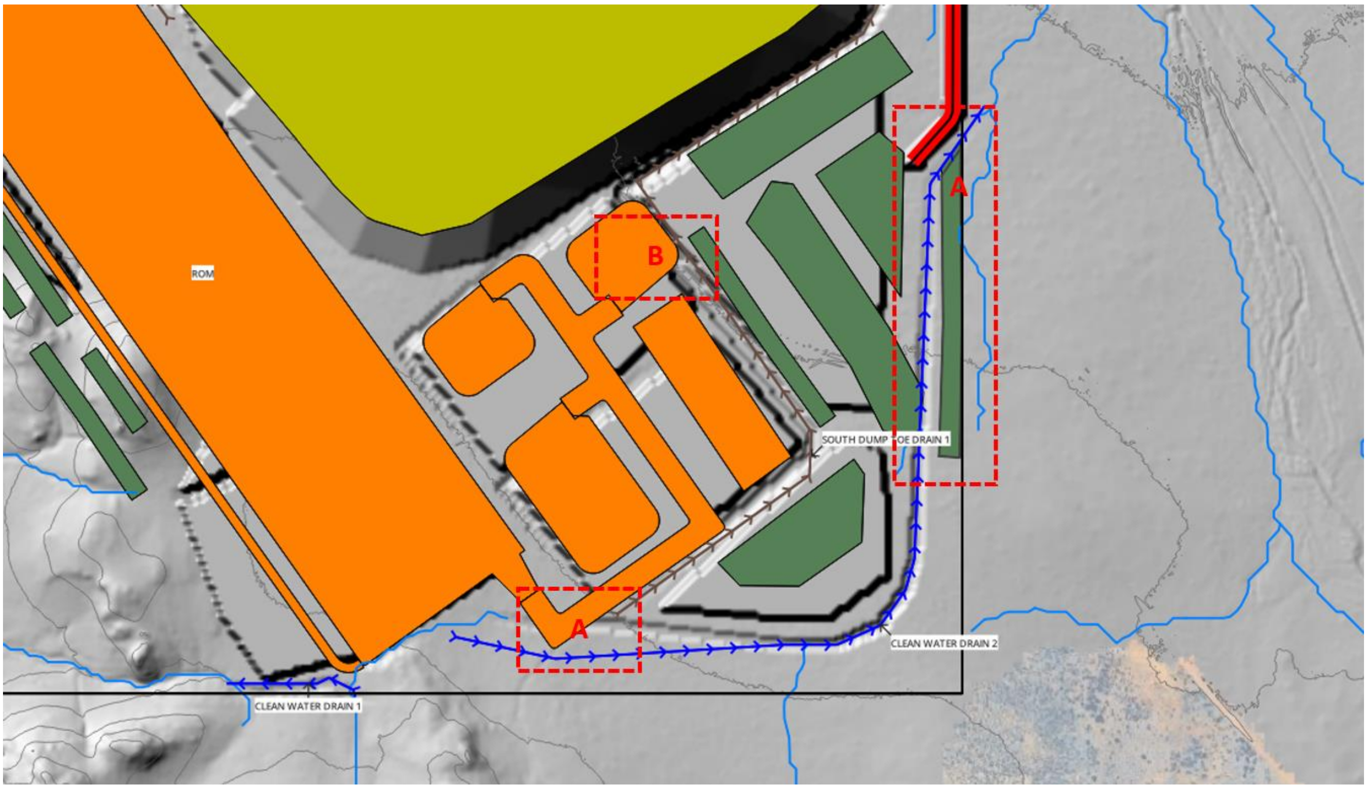
From Inset 7 it can be observed that:

- The simulated 'Clean Water Drain 2' alignment clashes with parts of the current proposed layout at the locations marked 'A', including the ROM pad and topsoil stockpile. In particular, there could be issues with access to the most eastern topsoil stockpile once the diversion drain has been constructed.
- The simulated 'South Dump Toe Drain 1' intercepts a proposed topsoil stockpile, marked 'B'.

From Inset 8, which applies to Stage 1, it can be observed that:

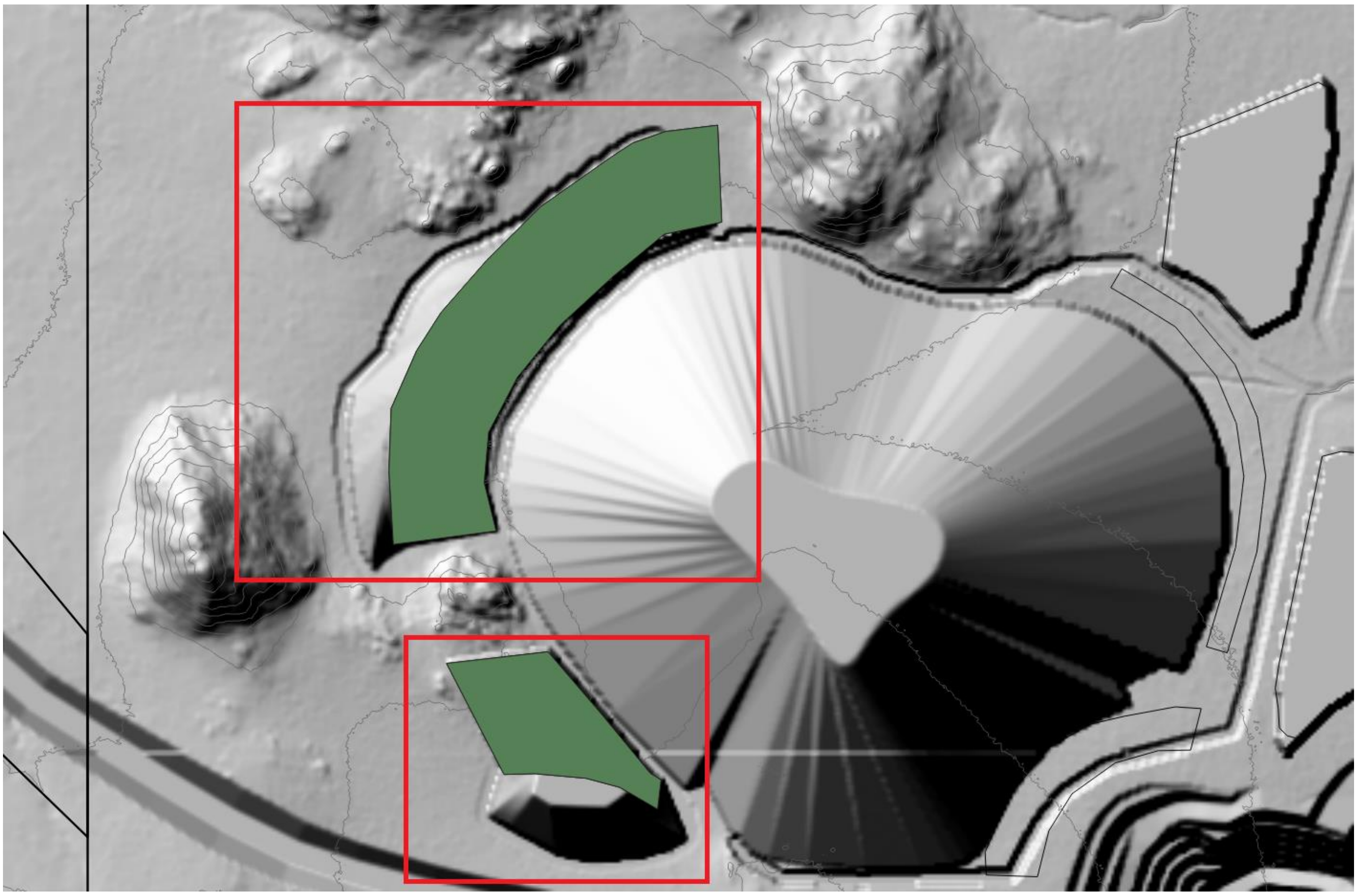
- The downstream section of the 'South Dump Toe Drain 2' intercepts a proposed topsoil stockpile, marked 'A'. There is not a significant separation between the Pit 3 crest and the topsoil stockpile. Adjustment of the stockpile locations in this area would be beneficial
- There is a clash between the 'Pit 1' diversion drain and a topsoil stockpile, marked 'B'. Adjustment of the stockpile locations in this area would be beneficial.

The footprint of the topsoil stockpiles west of the 'North' waste dump have been modified and merged with the natural topography in the hydraulic model in such a way that the toe of the topsoil stockpiles will act as a contour drain. The difference in the stockpile layout is highlighted in Inset 9.



Inset 7: Clashes between the hydraulic model and the 50% level of design: South-eastern section of the mine layout.

Inset 8: **Clashes between the hydraulic model and the 50% level of design: Pit area of the Stage 1 mine layout.**



Inset 9: **Clashes between the hydraulic model and the 50% level of design: Topsoil stockpiles west of the Stage 2 North Waste Dump.**

7.4 Hydraulic Sensitivities

7.4.1 Manning's n Values

Typically, the creeks within the project area have a sandy creek bed with minimal to no vegetation, with grass vegetation covering the low flow channel banks and floodplain areas and trees occasionally along the creek banks, as shown in Inset 10. This is similar for the Woodforde River at Arden Soak further downstream, with Inset 11 showing the grass cover during both wet and dry conditions.

Inset 10: Example of Creeks within the Project Area.

Inset 11: Example of Arden Soak Creek.

Based on the sand grading from Inset 2, the creek bed sand typically has a d_{50} between 1 and 3 mm, which gives an estimated Manning's n between 0.012 and 0.015 for the creek beds based on Strickler's equation. The typical grass cover is considered to be 'Class C' grass cover from Chow (1959)[12], which allows for variable Manning's n between 0.03 and 0.25 depending on the flow velocity. Accounting for the trees on the edges of the creek lines, overall Manning's n in the range of 0.04 to 0.05 would be expected.

The results presented in Section 7.3 have been based on an overall Manning's n of 0.05. This roughness is considered appropriate for the typical floodplain areas but is expected to be rougher than the typical creek bed conditions. The implication is that the results will predict conservative/higher water depths, but lower velocities in the channels. As the results have mostly been used to establish bund heights and drain freeboard allowances, the

[12] Chow, V.T. 1959. *Open-Channel Hydraulics*. McGraw Hill Book Company, The Blackburn Press, Caldwell, New Jersey.

adoption of a constant 0.05 Manning's n introduces a small conservatism. However, in the context of erosional performance, it could underestimate the localised velocities in the drain bed.

A series of hydraulic sensitivities have been undertaken to further investigate the localised drain velocities, bed shear stress and stream power results and allow comparison with the limits from Table 3. The adopted Manning's n parameters are:

- For Existing conditions (with the zones shown in Figure A1 of Appendix A):
  - Sand creek beds 0.013
  - Floodplain 0.05
  - Rock areas 0.05
- For Stage 1 diversion drain scenario (with the zones shown in Figure A2 of Appendix A):
  - For 1 in 2 AEP non-vegetated diversion channel:
    - Channel bed 0.013
    - Channel batters 0.013
  - For 1 in 2 AEP vegetated diversion channel and 1 in 50 AEP:
    - Channel bed 0.013
    - Channel batters Chow Class C vegetation
- For Stage 2 diversion drain scenario (with the zones shown in Figure A3 of Appendix A):
  - For 1 in 2 AEP non-vegetated diversion channel:
    - Channel bed 0.013
    - Channel batters 0.029 ('Soil Excavation' case)
  - For 1 in 2 AEP vegetated diversion channel and 1 in 50 AEP:
    - Channel bed 0.04
    - Channel batters 0.04
    - The 0.04 Manning's value ('Rock Excavation' case) is based on a rough blasted channel in rock.

The results for these different hydraulic sensitivities are presented in Section 7.4.2.

7.4.2 Results and Long Sections

The Queensland DRNME water course diversions guideline (OSW/2019/4599) provides a framework for assessment of diversion drains in the Bowen Basin of Queensland based on analysis of 1 in 2 AEP and 1 in 50 AEP flood events and comparing the hydraulic performance with velocity, bed shear stress and stream power limits, as shown in Table 3. The 1 in 2 AEP events also consider an unvegetated case (to represent conditions early in the diversion design life) and a vegetation case (to represent conditions later in the diversion design life). Figure A4 to Figure A21 in Appendix A present maximum velocity and maximum bed shear stress results for the different hydraulic sensitivities, including for existing, Stage 1 and Stage 2 diversion scenarios.

Long sections, the alignments of which are shown in Figure A26 of Appendix A, have been extracted along each of the main creeks and diversion drains for the different alignments to allow comparison of the TUFLOW velocity, bed shear stress and stream power results. Also shown on the long sections are outputs from the HEC-RAS erosion modelling for selected equivalent events and Manning's n conditions.

Figure A27 of Appendix A presents the long section for Nolans Creek for the 1 in 2 AEP, with the results showing:

- The TUFLOW and HEC-RAS model results are broadly consistent
- The different hydraulic sensitivities and the inclusion of the Nolans Creek Flood Protection Bund show little sensitivity in the maximum velocities, bed shear stresses or stream powers experienced in the Nolans Creek low flow channel, indicating that the Project does not significantly alter the existing conditions in Nolan Creek
- The maximum velocities typically exceed the limit for a non-vegetated channel and often exceed the limit for a vegetated channel from Table 3. However, this also occurs in the natural existing system and is an indication that sand in the creek beds is expected to move as part of the dynamic equilibrium system, even for the 1 in 2 AEP event

- The maximum bed shear stress and stream power results are typically below the limits from Table 3.

For the 1 in 50 AEP event, the long section in Figure A28 of Appendix A shows similar outcomes to the 1 in 2 AEP event, with values typically less than the limits in Table 3, with areas exceeding the limits also exceeding under existing/baseline conditions.

Figure A29 of Appendix A presents the long section for KCC for the 1 in 2 AEP and the Stage 1 diversion, with the results showing:

- The TUFLOW and HEC-RAS model results are broadly consistent
- The different hydraulic sensitivities and the inclusion of the Stage 1 diversion drain show little sensitivity in the maximum velocities, bed shear stresses or stream powers experienced in the KCC low flow channel upstream or downstream of the diversion, indicating that the Project does not significantly alter the existing conditions in KCC.
- The maximum velocities typically exceed the limit for a non-vegetated channel and often exceed the limit for a vegetated channel from Table 3. However, this also occurs in the natural existing system and is an indication that sand in the creek beds is expected to move as part of the dynamic equilibrium system, even for the 1 in 2 AEP event.
- The maximum velocity results within the Stage 1 diversion show a maximum velocity of approximately 2 m/s, whilst this plots towards the upper bound of velocities within KCC, it does match the velocities experienced in the natural KCC at the upstream end of the diversion drain, with the velocity maintained throughout the diversion length. Whilst there is some difference, the results are considered equivalent to the natural system and supports that the aim of the diversion low flow channel to maintain the watercourse low flow characteristics has been achieved.
- The maximum bed shear stress and stream power results are typically below the limits from Table 3, and show similar values within the diversion drain to those observed upstream and downstream within KCC.

For the 1 in 50 AEP event, the long section in Figure A30 of Appendix A shows similar outcomes to the 1 in 2 AEP event, with bed shear stress and stream power values typically less than the limits in Table 3, with areas exceeding the velocity limits in the diversion drain comparable to performance of the existing KCC watercourse.

Figure A31 of Appendix A presents the long section for the Stage 2 Diversion for the 1 in 2 AEP, with the results showing:

- The TUFLOW and HEC-RAS model results are broadly consistent
- The different hydraulic sensitivities and the inclusion of the Stage 2 diversion drain show minor sensitivity in the maximum velocities, bed shear stresses or stream powers experienced upstream or downstream of the diversion, indicating that the Project does not significantly alter the existing conditions
- The maximum velocity, bed shear stress and stream power results within the diversion drain are all below the limits from Table 3, however, the results within the diversion drain do indicate a reduction from those typically experienced upstream and downstream of the diversion drain. This is not unexpected as a result of the longitudinal slope of the diversion drain and could have implications for aggradation at the inlet of the channel, which is further explored in Section 9.4.2.

For the 1 in 50 AEP event, the Stage 2 diversion drain long section in Figure A32 of Appendix A shows:

- The bed shear stresses and stream powers are below the limits in Table 3, and similar to the values in the natural creeks upstream and downstream of the diversion
- The maximum velocity is also typically below the limits in Table 3, and similar to the values in the natural creeks upstream and downstream of the diversion. However, for the higher Manning's n scenario (representing a rough excavated/blasted rock channel) the maximum velocities do drop below those experienced in the creek lines upstream and downstream of the diversion. This would represent a high sediment deposition risk for an excavated diversion channel with higher roughness, even during larger events, such as the 1 in 50 AEP.

Figure A33 of Appendix A presents the long section for 'Western Tributary', downstream of the Stage 2 diversion, for the 1 in 2 AEP, with the results showing:

- The TUFLOW and HEC-RAS model results are broadly consistent, but with the HEC-RAS model predicting higher bed shear stresses and stream powers

- The different hydraulic sensitivities and the inclusion of the Stage 2 diversion drain show little sensitivity in the maximum velocities, bed shear stresses or stream powers experienced in the Western Tributary low flow channel, indicating that the Project does not significantly alter the existing conditions in creek line
- The maximum velocities typically exceed the limit for a non-vegetated and vegetated channel from Table 3. However, this also occurs in the natural existing system and is an indication that sand in the creek beds is expected to move as part of the dynamic equilibrium system, even for the 1 in 2 AEP event
- The maximum bed shear stress and stream power results are typically below the limits from Table 3 and inclusion of the Stage 2 diversion drain does not result in significant differences.

For the 1 in 50 AEP event, the long section in Figure A34 of Appendix A shows similar outcomes to the 1 in 2 AEP event, with values typically less than or at the limits in Table 3, with areas exceeding the limits also exceeding under existing/baseline conditions.

The findings from the hydraulic sensitivities support that the Stage 1 diversion is expected to be able to meet the aims of a 'temporary diversion' from the Queensland OSW/2019/4599 guideline. Whereas, for the Stage 2 diversion drain, consideration of the risk of aggradation at the drain inlet is required, which is further investigated in Section 9.4.2.

8. Sediment Basin Analysis

Several sediment basins have been designed on the downstream side of the mining area, into which the dirty water drains discharge, allowing sediment to be captured prior to discharging flows into the natural waterways. The sediment basin layout has been updated from the previous design proposed in the DFS. The most significant difference to the DFS design is that a proposed polishing pond in KCC has been removed from the design. This decision is justified through:

- Modelling of the sediment capture efficiency of the proposed sediment basins, as presented in this Section, and
- Investigation of the sediment transfer through the Stage 1 KCC diversion drain, as presented in Section 9. As discussed in Section 2.4, it is likely that KCC is in fluvial dynamic equilibrium. Placing a polishing pond at the outlet of the Stage 1 KCC diversion drain would capture any of the naturally transported sands from further upstream and thereby disrupt the existing dynamic equilibrium, causing erosion in the natural waterways downstream to 'make up' for the sediment not transported from further upstream.

Stage 1 will consist of two sediment basins, namely the:

- 'Eastern' sediment basin, which will receive inflows primarily from the southeast area of the site, comprising of the ROM, topsoil stockpiles, and south waste dump and associated toe drains, and
- 'Central' sediment basin, which will collect 'dirty' water flows from the pit area and Stage 1 temporary Pit 1 and 2 diversion drains.

Stage 2 preserves the Stage 1 sediment basin setup and includes one additional basin:

- 'Western' sediment basin, positioned to capture 'dirty' water from the north waste dump area.

8.1 Catchments Areas

The upstream catchment area of each sediment basin has been investigated for both the Stage 1 and Stage 2 layout. The catchments delineated based on the Stage 1 and Stage 2 layout are presented in Figure 15 and Figure 16 respectively. Table 8 summarises the catchment area of each sediment basin. The basins have been sized based on the scenario which yields the 'worst' case outcome, that is the greatest volume requirement, which in the case of the Central sediment basin is the Stage 1 layout.

Table 8 – Sediment Basin Upstream Catchment Area

Sediment Basins	Catchment Area (ha)	
	Stage 1	Stage 2
Western	-	149.9
Central	138.3	26
Eastern	314.1	314.1

The upstream area draining to the 'Central' basin decreases from Stage 1 to Stage 2. This is due to the pit development in Stage 2 intercepting a significant portion of the catchment area from Stage 1.

8.2 IECA Compliant Design

Calculation of the volume requirement of the *Type D* settling zone is a function of the:

- Effective upstream catchment area connected to the basin, *A* (hectare)
- 5-day, 'Y' percentile rainfall, $R_{Y\%,5-day}$ (mm), where 'Y' is taken as the 95th percentile
- Volumetric runoff coefficient, C_v.

A simple correlation equation for calculating the 5-day rainfall total has been prescribed by the IECA manual:

$$R_{Y\%,5-day} = K_1 * I_{1yr,\ 120hr} + K_2$$

Where:

- $I_{1yr,\ 120hr}$ is the average rainfall intensity for a 1 in 1 year ARI, 120-hour storm (mm/hr)
- K_1 and K_2 are constants that vary depending on the rainfall percentile chosen for design. A lookup table for K_1 and K_2 constants are provided in the manual.

The average rainfall intensity has been sourced from the 2016 IFD design rainfall curves from the Bureau of Meteorology (BoM) data portal for the Nolans Project area.

The volumetric runoff coefficient is included in the equation to represent the runoff generation response of the site material. A lookup table has been provided in the manual for selecting a typical volumetric runoff coefficient from four soil hydrologic groups, which have been classified based on their likely runoff generation, adopted from USDA(13). The soil groups are:

- Group A, which are typically well-drained sandy loams, sands or gravels characteristic of high infiltration rates
- Group B, which typically comprise of soils with moderately coarse loamy textures or clay loams with moderate structures. They are characteristic of soil with moderate infiltration rates
- Group C, which consists of clay loam to clay with moderately fine to fine texture and exhibit slow infiltration rates
- Group D, which are fine-textured clay with very slow infiltration rates.

Vegetation is excluded from this classification as it is not typically characteristic of the site setting for this sort of application. The IECA has specified that the selection of runoff coefficient via the table is limited '*only to the pervious surfaces with low to medium gradient, (i.e. <10% slope). Light to heavy clays compacted by construction equipment should attract a volumetric runoff coefficient of 1.0*'.

Referring to the test pit logs from the KP (2011) site investigation, it is understood that the surficial material around the pit area is largely characteristic of sand with silt and clay. This description is more fitting of a 'Group B' material, however given that a sizable portion of the catchment area contains runoff from the 'South' waste dump, which may contain clay material, a 'Group C' classification was adopted as an 'average representative' classification for the 'Central' and 'Eastern' basins.

The headwaters of the catchment area connected to the 'Western' sediment basin is typically situated on the ranges where outcropping rock areas are expected (which will have a higher runoff fraction), along with weathered soil

(13) USDA, 1993. *Soil Survey Manual. USDA Handbook No. 18*

materials. The catchment is also largely occupied by the 'North' waste dump and stockpiles. As such, a 'Group D' classification was adopted for the 'Western' basin.

The sediment basin design is summarised in Table 9. Detailed drawings of the sediment basin design are available in PSM4809-017M.

Table 9 – Type D sediment basin sizing as per IECA guidelines

Attributes	Western	Central	Eastern
Minimum Settling Zone Volume (ML)	52.2	40.5	91.9
Minimum Sediment Storage Volume (ML)	26.1	20.2	46.0
Total Storage (ML)	78.3	60.7	137.9
Embankment Crest (m RL)	657	656.6	656.9
Spillway Invert (m RL)	656.1	655.5	655.9
Top of Sediment Storage (m RL)	655.3	654.8	655.3

8.3 Spillway Sizing

A trapezoidal broad-crested weir was selected for the design of the emergency spillway to accommodate flows for up to the 1 in 100 AEP design event. A channel side slope of 1V:2H was selected. The flow capacity of the weir was calculated via the broad-crested weir equation:

$$Q = CLH^{1.5}$$

Where:

- C is the coefficient of discharge, adopted as 1.705
- L is the weir effective cross-sectional width (m)
- H is the water head above the weir crest (m).

The design peak flow was taken from the 'worst' outcome of the Stage 1 and Stage 2 base case hydraulic model, i.e. the highest flow. The dimensions of the spillways are summarised in Table 10. Detailed drawings of the spillway arrangement are also available in PSM4809-017M. It is highlighted that the spillways have been located so as to spill into minor creek lines that drain to Kerosene Camp Creek (in the case of the Western and Central basins) or Nolans Creek (in the case of the Eastern basin).

The weir channel has been rip-rap lined to mitigate erosion risks. The rip-rap has been sized so as to 'slow' flow velocities and achieve sub-critical flow conditions, with a stilling basin at the end of the spillway to further reduce velocities before discharge into the local creek lines.

Table 10 – Sediment Basin Emergency Spillway Sizing

Attributes	Western	Central	Eastern
Adopted 1 in 100 AEP Design Flow (m^3/s)	13.3	5.8	13.4
Spillway Side Slope (1V:XH)	2	2	2
Spillway Length (m)	8	8	8
Spillway Base Width (m)	30	30	30
Height of Spillway (m)(1)	0.9	0.8	1.0
Rip-rap D_{30} (mm)	150	120	150
Rip-rap D_{50} (mm)	250	200	250
Rip-rap D_{100} (mm)	500	400	500

(1) Spillway height is inclusive of a 500 mm freeboard.

It is highlighted that the Central sediment basin spillway is larger on the 50% Level of Design drawings, presented in PSM4809-017M, than that specified in Table 10, with a spillway height of 1.1 m. This is because the initial arrangement considered was to have the Eastern basin spill into the Central basin before spilling into the environment. The results from Section 8.4 supported that this was not necessary, and that the Eastern basin could achieve acceptable sediment capture efficiency when discharging directly to the environment. There is an opportunity to align the Central Basin spillway size on the design drawings with those in Table 10 for the final design drawings.

8.4 Sediment Capture Efficiency

The 5 day 95th percentile volume design allowance for the sediment basin provides that overtopping spills from the sediment basin would be expected a few times a year. The sediment capture efficiency of the basins was investigated for the 1 in 100 AEP design event to understand the capture performance of the basins under conditions where the basin spillway is engaged. The runoff hydrograph that produced the critical peak flow used for the sizing of the spillway was also adopted in this analysis. The hydrograph was routed through the stage volume curve of the sediment basin storage, using a 5-minute time step. The stage volume curve was calculated from a 3D geometrical model of the sediment basin embankments and storage.

The attenuated spillway outflow hydrograph is used to calculate the residence time for the basin at each timestep and the fraction of sediment retained in the basin for each sediment class based on their associated settling velocity, as summarised in Table 11. The Fair and Greyer (1954) equation below, has been used to calculate the fraction of a sediment class retained at each time step:

$$R = 1 - \left[1 + \frac{1}{n} * \frac{v_s}{Q/A} * \frac{(d_e + d_p)}{(d_e + d^*)}\right]^{-n}$$

Where:

- R is the fraction of the target sediment class retained in the basin
- n is a turbulence factor
- v_s is the settling velocity of the target sediment (m/s)
- Q is the basin outflow (m^3/s)
- A is the basin surface area (m^2)
- d_p is the depth of the permanent pool (m)
- d_e is the depth from the permanent pool to the spillway (m)
- d^* is the minimum of 1 and d_p (m).

The following assumptions were made for the analysis:

- Sediment concentration is constant throughout a storm event (i.e. the peak sediment load occurs at the peak flow)
- The sediment settling velocities are independent of the sediment concentration
- The hydraulic turbulence factor (*n*) for the basins range between 1.12 to 1.33, which has been assigned based on the plan area shape of the basins.

A sensitivity analysis was included, which investigated the performance of the sediment basins at different storage levels. The two bookend scenarios were considered, that is an:

- 'Empty Basin', where the water level is assumed to be at the top of the sediment storage zone before the storm event, i.e. the sediment storage is full and the settling zone is empty, or
- 'Incipient Flow', where the water level is assumed to at the spillway invert before the storm event, i.e. level just before the basin spillway is engaged.

Table 11 – Sediment Particle Size Settling Velocity

Particle Size Classification	Mean Particle Diameter (µm)	Settling Velocity (mm/s)
Very Coarse Sand	2,000	200
Coarse Sand	1,000	100
Medium Sand	500	53
Fine Sand	250	26
Very Fine Sand	125	11
Coarse Silt	62	2.3
Medium Silt	31	0.66
Fine Silt	16	0.18
Very Fine Silt	8	0.04
Clay (Non-dispersive)	4	0.011

The performance of the sediment basins is presented in Table 12. It can be observed that for the 1 in 100 AEP event:

- The basins allow virtually all the sand material to settle
- Most of the medium and fine silts are captured, with all efficiencies greater than 80%
- The performance of the sediment basin starts to drop for the 'incipient flow' case for sediments that are as fine or finer than very fine silts, generally dropping below 80% retention of fines. Provided that the basins are operated as intended (i.e. the basins are flocculated and emptied within 5 days of an inflow event), then the chance of the 'incipient flow' case occurring is quite small, as it would need two significant rainfall events to occur within a 5 day period
- The central basin is expected to perform the worst, but the critical case for this basin is during Stage 1. Regardless the basin is expected to be able to capture in excess of 60% of the very fine silts.

Inflows into the Central basin will significantly reduce once Stage 2 commences, as much of the effective catchment area from Stage 1 will be occupied by the development of the Stage 2 pit (i.e. 'Pit 7').

Referring to the design PSD of the site surficial materials in Inset 2, it can be observed that:

- The vast majority of the sediment is coarser than a medium silt, for which the performance of all basins is very good under a 1 in 100 AEP event
- The clay fraction makes up approximately 15% of the grading. If some of the clay fraction is dispersive, it is assumed the proportion of clay captured will be approximately equal to the portion of runoff contained in the basin.

As a result of the adequate sediment capture efficiencies, it is not considered necessary to have an additional polishing pond to further capture any sediments that escape the sediment basins.

Table 12 – Sediment Basin Capture Efficiency for 1 in 100 AEP Flow Event

Sediment Basin	Scenario	Sediment Class Retention (%)									
		Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Coarse Silt	Medium Silt	Fine Silt	Very Fine Silt	Clay
Western	Empty Basin	100%	100%	100%	100%	100%	99.9%	99.7%	99.0%	95.5%	88.2%
	Incipient Flow	100%	100%	100%	99.9%	99.9%	99.2%	96.8%	88.1%	62.3%	34.3%
Central	Empty Basin	100%	100%	100%	100%	99.9%	99.5%	97.8%	91.3%	70.9%	47.6%
	Incipient Flow	100%	100%	100%	100%	99.9%	99.2%	96.8%	87.9%	61.9%	34.6%
Eastern	Empty Basin	100%	100%	100%	100%	100%	100%	100%	100%	99.9%	99.4%
	Incipient Flow	100%	100%	100%	100%	100%	99.9%	99.5%	97.5%	86.8%	63.6%

9. Sediment Erosion Analysis

9.1 Analysis Aims

Sediment erosion and transport analysis was undertaken to:

- Confirm if the natural sand in the creek line would move in the natural system in a manner aligned with the expectation for dynamic equilibrium
- Confirm if the sand in the creek line would transfer through the KCC diversion drain and to the downstream environment. Similar to the current natural system
- Determine how much sediment could be potentially sourced (via flood erosion) from the KCC diversion drain cutting, for example in a ‘first flush event’
- Assess the impact of the inclusion of a polishing pond at the downstream end of the Stage 1 KCC Diversion Drain on the natural sand movement.

The above four questions are considered critical to support the design approach.

9.2 Sediment Erosion Functions

Sediment functions are typically used to relate the amount of bed and suspended sediment erosion transport in a creek relative to the creek flow conditions. There exist multiple published sediment equations that have been calibrated for a range of different conditions and sediment sizes. Based on the particle size information collected for the Project area, see Section 4.4, three sediment equations have been selected for analysis:

- Ackers-White
- Toffaleti, and
- Yang.

The Ackers-White equation was developed from flume data for non-cohesive and relatively uniform sediments ranging from sand to fine gravels less than 7 mm. The bed load is driven by the coarser particles and the suspended load is comprised of the fines, driven by turbulence. It is most suited for applications where sediment sizes range between 0.04 and 4 mm with sub-critical flow conditions. The Ackers-White equation is considered a good ‘base case’ function, most applicable to the erosion of the sands in the natural creek beds, but feasible (although likely conservative) to apply to the KCC diversion drain bases where finer material is anticipated.

The Toffaleti equation is a total load function developed primarily for sand and silt and usually applied to large rivers. It was calibrated to large suspended load systems with fine to medium sized sands ranging between 0.3 and 0.93 mm. The flow is split up into four different depth zones where the sediment transport is calculated independently. It typically does not perform well for larger particles or high gradient systems. The Toffaleti equation is considered as a possible equation for the KCC diversion drains, although it will likely still predict towards the upper bound, as it does not allow for the benefit of cohesive sediment in reducing erosion.

The Yang equation contains two separate equations, one for sand and the other gravels (grain classes between 2 and 10 mm). It is a total load transport equation which is dependent on the stream power as a product of velocity and shear stress. The equation was developed using flume and field data and is most applicable to grain sizes ranging between 0.015 and 1.71 mm and sediments with specific gravity of 2.65. The Yang equation is considered the most appropriate for predicting sand erosion in the natural creek lines.

9.3 Model Setup and Scenarios

9.3.1 HECRAS Model

Sediment erosion analysis was conducted using HEC-RAS. HEC-RAS performs 1D and 2D hydraulic calculations and offers options to predict sediment transport and scour by coupling hydrodynamic analysis with published sediment transport predictors. HEC-RAS solves the full 1D Saint Venant Equation using an implicit, finite difference method for unsteady flow analysis.

A 1D quasi-unsteady flow routing option was selected to perform the sediment transport analysis which functions as an ‘erodible-bed model’ (i.e. the model does not account for channel widening as a result of erosion well, and instead focusses on vertical changes as a result of erosion). This approach provides greater numerical stability by discretising the hydrograph time-series and modelling it as a series of steady state 'slices'. The caveat is that it does not necessarily conserve flow mass over the hydrograph, and hence can introduce unacceptable errors if there is significant channel storage in the system. However, due to use the high-resolution DEM and the geometry of the diversion drains, significant channel storage should not be a critical aspect, especially in the main creek lines and channels. As such, adopting the quasi-static solver is considered acceptable.

9.3.2 Terrain and Elevation Model

The elevation model integrated into HEC-RAS is similar to that adopted in the TUFLOW model which is a mosaic of the high-resolution Project DEM and custom-built elevation models of the proposed mine infrastructure. Three different terrain models were prepared, each representing a different development scenario. The development scenarios (i.e. Baseline, Stage 1 and Stage 2) are consistent with that adopted for the hydraulic model, as described in Section 7.2. The 1 in 5 AEP, 1 in 10 AEP, 1 in 20 AEP, 1 in 50 AEP, 1 in 100 AEP, 1 in 1,000 AEP events were simulated for each development scenarios.

The general setup of the HEC-RAS model is presented in:

- Figure 17 for the Baseline conditions (i.e. current topography)
- Figure 18 for the Stage 1 scenario, and
- Figure 19 for the Stage 2 scenario.

In addition, another version of the Stage 1 layout was setup which integrates the polishing pond proposed in the DFS design. This was setup to investigate the extent to which the polishing pond would disrupt the natural system.

The HEC-RAS uses a series of 1D cross-sections to capture the topography, the extents of the cross-sections have been selected to match the floodplain width. Each section of the creek is represented by a 'River Reach', with nodes at confluences between the different 'Reaches'.

The elevation profile of 1D cross-sections were extracted from the terrain model using the HECRAS *RASMapper* functionalities. Cross-sections were typically cut at intervals between 5 and 15 m, with finer spacing typically upstream and downstream of confluences between reaches to mitigate model instabilities.

Given the objective of the analysis is to investigate the sediment erosion along the drain, the model extent is smaller than that of the hydraulic model, terminating at the end of the high-resolution DEM at the downstream extents.

Flow was loaded into the model through upstream boundary conditions. Flow hydrographs were sourced either from the TUFLOW source areas or PO lines. As these models aim to investigate the mechanisms for the four 'critical' questions, the sensitivity hydrology case was not considered and only hydrographs from the base case hydrology case were considered in the analysis. Runoff was strictly loaded into the model via flow hydrographs, excluding precipitation. As such, infiltration was not simulated in this analysis. A normal depth condition was applied to the downstream boundary conditions with the average bed slope used as an estimate for the friction slope.

A Manning's *n* of 0.05 was applied globally to all cross-sections.

A base computational increment of 5 to 15 minutes was defined for the calculations. A finer increment was set for higher flows to assist with the sediment transport calculations.

9.3.3 Sediment Equations and Setup

The sorting method equation is used to explain the sediment armouring process and grain-class specific transport capacities. The sorting method adopted was based on the Copeland method, which was designed for sand bed river application, as it forms armour layers more slowly (and consequentially computes more erosion). The Rubey method was adopted to estimate the fall velocity of the different sediment classes.

The design PSD curves discussed in Section 4.4 were used in the sediment erosion analysis, with the design curves inputted summarised in Table 13. A specific gravity of 2.65 and sediment density of 1,489 kg/m^3 has been assumed for modelling.

Table 13 – HEC-RAS Material Particle Size Distribution

HEC-RAS Interval	Diameter (mm)	Sand (% passing)	Fines (% passing)
Clay	0.004	0	12.76
Very Fine Silt	0.008	0	14.37
Fine Silt	0.016	0	18.45
Medium Silt	0.032	0	28
Coarse Silt	0.0625	0.34	42.18
Very Fine Sand	0.125	3.21	56.81
Fine Sand	0.25	20.95	70.79
Medium Sand	0.5	49.66	83.02
Coarse Sand	1	74.13	89.49
Very Coarse Sand	2	90.66	95.96
Very Fine Gravel	4	97.77	98.63
Fine Gravel	8	99.75	99.75
Medium Gravel	16	100	100
Coarse Gravel	32	100	100
Very Coarse Gravel	64	100	100
Cobble	128	100	100

A bed change option was applied globally to the model which allowed both the banks and channels to deposit sediment, and only the channel to erode. A maximum erodible depth of 3 m was set below the pre-event cross-section invert elevation. For some cases a maximum erodible depth of 0 m was applied to cross-sections to limit erosion (for example to consider a rock section in the Stage 2 KCC diversion).

The sediment upstream boundary condition was controlled via a rating curve. The rating curve assumes a constant total load distribution regardless of flow of 100 tonnes/day, which is a small nominal sediment load to help prevent an initial scour hole at the upstream boundary.

9.3.4 Scenarios

Sensitivity options of the different sediment equations and bed gradation combinations were considered to understand the possible range of uncertainty in the results. Four main models were considered to help answer each of the 'critical questions' from Section 9.1:

- Model 1: Where the Ackers-White sediment transport equation was selected. The 'Sand' grading from Table 13 was assigned to cross-sections on the creek lines and 'Fines' grading from Table 13 defined along the Stage 1 and Stage 2 KCC diversion drains
- Model 2: Which uses the Toffaleti sediment transport equation with the Model 1 bed gradation setup (i.e. a Model 1 sensitivity)
- Model 3: Which adopts the Ackers-White transport equation. The 'Sand' grading from Table 13 was assigned to cross-sections on the creek lines, however, a 'no erosion' layer was applied to the diversion drains. This is to help confirm transport of the upstream derived sands through the diversion drains
- Model 4: Which uses the Yang transport equation with the bed gradation setup from Model 3 (i.e. a Model 3 sensitivity).

Models 1 to 4 are aimed to provided 'bookend' style results.

A different version of the Stage 1 layout was prepared which simulates the polishing pond proposed in the DFS. This was modelled as an embankment in HEC-RAS with a nominal discharge spillway.

9.4 Erosion Analysis Results

Erosion modelling outputs are presented in this section. A range of different scenarios have been simulated to investigate the analysis aims outlined in Section 9.1. The modelling outputs have been presented in the form of:

- Scour maps, which have been post-processed from the 1D cross-section elevations. These maps show the difference in elevation between the start and end of the simulated flood event. This visualisation should highlight if erosion (colour coded in red) or deposition (colour coded in blue) has occurred at a cross-section over the duration of the flood event.
- 'Mass in' time series plots, which quantify the estimated mass of sediment (in tonnes) flowing into the cross section, either from a lateral boundary or upstream cross-section, cumulated over the course of the flood event. Typically, a cross-section upstream and downstream are queried to visualise the change in sediment loading over the distance between the two cross-sections.

Table 14 presents a summary of the flood events and erosion and layout scenarios modelled. Results of these analyses are presented in Figure 20 to Figure 39, as well as in Appendix C.

Table 14 – Model Cases Summary

<table>
<tr><th>AEP (1 in X)</th><th>Development Scenario</th><th>Sediment Transport Scenario</th><th>Polishing Pond Included?</th></tr>
<tr><td>5</td><td rowspan="6">Baseline / Stage 1 / Stage 2</td><td rowspan="6">Model 1 / 2 / 3 / 4</td><td>No</td></tr>
<tr><td>10</td><td>Yes</td></tr>
<tr><td>20</td><td rowspan="4">No</td></tr>
<tr><td>50</td></tr>
<tr><td>100</td></tr>
<tr><td>1,000</td></tr>
</table>

Can the sand in the creek line move in the natural system?

Fluvial geomorphology concepts are often linked to the 'bankfull flow' event, which is the flow that fills the low flow channel. The bankfull flow is typically between the 1 in 2 AEP and the 1 in 10 AEP. If the channel is in dynamic equilibrium, then the shape of the low flow channel is referred to as a 'regime channel'. As such, given the expectation of a system in dynamic equilibrium, transport of sand in the low flow channel is expected for flood events as low as the 1 in 2 to 1 in 10 AEP.

Scour maps for the 'Baseline' scenario, that is based on existing topography, are presented in Figure 20 and Figure 21 for the 1 in 5 AEP and 1 in 10 AEP design events respectively. The scour extent predicted based on the Ackers-White equation is shown (i.e. 'Model 1' from Section 9.3.4). It can be seen from the figures that sediment moves through the overall system as indicated by alternating patches of deposition and erosion. Overall, though there is not widespread erosion or deposition, also supporting dynamic equilibrium in the natural channels.

9.4.1 Stage 1

Can sand in creek line transfer through the Stage 1 diversion and downstream?

The Stage 1 KCC Diversion Drain low flow channel has been sized to be similar in dimensions to the natural creek lines (as discussed in PSM4809-009L DRAFT). As such, it is anticipated that the diversion drain low flow channel should allow transfer of sand through the diversion drain in a similar manner to the natural system.

Figure 22 and Figure 23 present the scour maps of the 1 in 10 AEP and 1 in 100 AEP event respectively based on the Stage 1 layout under the 'Model 3' setting. With the 'Model 3' scenario, no erosion is simulated in the KCC Diversion drain, such that, the only way for sediment to transfer from the upstream end of the diversion to the downstream end is transportation as suspended or bed load through the diversion.

In comparison to the baseline scenarios from Figure 20 and Figure 21, it can be seen that the pattern of deposition and erosion along the creek lines downstream the Stage 1 KCC diversion are not too dissimilar to the baseline results and often manifest at similar areas, suggesting that sand can transfer through the diversion. Additionally, a significant scour hole does not develop at the downstream end of the diversion drain, indicating that sediment from upstream is making it to the downstream end of the diversion.

It is important to note though that both Figure 22 and Figure 23 show deposition occurring along the diversion and a risk of overall sediment loading decreasing downstream the diversion. The deposition within the channel can be beneficial, as it would 'coat' the diversion drain low flow channel in sand, making it more like a natural creek. The scour maps in Figure 22 and Figure 23 indicate that in the first flood event post construction, the sand 'coating' may only cover the first few hundred metres of the diversion drain. It is however important to note that there is some doubt that the model results are properly capturing the drop out of sediment that would occur at the end of the end of a flood event, which could 'coat' more of the drain alignment in sand. Regardless, the results do indicate that it could take a number of events for a 'coating' of sand to develop along the length of the diversion drain.

Figure 24 presents cumulative mass time series for cross-sections at the inlet and outlet of the Stage 1 diversion, chainages 2,725 m and 1,375 m respectively along 'River 8' (locations of which are shown in Figure 18). Figure 25 presents cumulative mass time series for cross-sections at the upstream and downstream end of the 'River 8' reach (which contains the Stage 1 diversion), chainages 3,374 m and 27 m respectively along 'River 8' (locations of which are shown in Figure 18).

The Figure 24 and Figure 25 plots are based on the 'Model 3' and 'Model 4' scenarios (from Section 9.3.4), which assume no erosion along the diversion drain and are aimed to capture the possible range of uncertainty in the sediment movement via two different sediment erosion functions.

The decrease in sediment load at the outlet of the diversion drain (CH. 1,375) in Figure 24 suggests that there is sediment deposition along the diversion drain, but also that between 50 and 70% of the sediment makes it through the diversion drain.

Figure 25 shows a mixture of responses:

- For 'Model 3' the sediment load is similar at the downstream end as to the upstream end for the 1 in 10 AEP event, but indicates higher sediment loads at the downstream end in the 1 in 100 AEP
- Conversely, for 'Model 4', the downstream end has lower sediment loads than the upstream end for both the 1 in 10 AEP and 1 in 100 AEP events.

These results do indicate that the system may not be in perfect dynamic equilibrium, but in general do support that sediment can make its way through the Stage 1 KCC Diversion Drain in a manner not dissimilar to the natural system.

How much sediment is sourced from the Stage 1 diversion?

As discussed above, it is possible that a 'coating' of sand depositing into the diversion drain could take a number of flood events to develop, as such there is a risk of sediment eroded from the diversion drain cut flowing to the downstream environment if the drain is unlined. This case can be considered analogous to a 'first flush' scenario. To investigate this aspect, erosion needs to be simulated for the Stage 1 KCC Diversion Drain, meaning either 'Model 1' or 'Model 2' from Section 9.3.4.

Figure 26 and Figure 27 present the scour maps of the 1 in 10 AEP and 1 in 100 AEP event respectively based on the Stage 1 layout for the Model 1 (i.e. Ackers-White) scenario. This setting assumes that the diversion cut consists of weathered rock and fine-grained material which can be subject to erosion. It can be observed that the model predicts typically between 0.1 m and 0.5 m of erosion along the diversion. Downstream of the diversion though, there is a reasonably widespread zone of deposition at the confluence between KCC and Nolans Creek, but otherwise, a portion of the eroded sediment is likely continuing to be transported to the downstream environment. It is anticipated that 'Model 1' results are likely conservative, as they do not account for the benefit of likely cohesion in the material exposed in the Stage 1 KCC Diversion Drain channel.

Figure 28 presents cumulative mass time series for cross-sections at the inlet and outlet of the Stage 1 diversion, chainages 2,725 m and 1,375 m respectively along 'River 8' (locations of which are shown in Figure 18). Figure 29 presents cumulative mass time series for cross-sections at the upstream and downstream end of the 'River 8' reach (which contains the Stage 1 diversion), chainages 3,374 m and 27 m respectively along 'River 8' (locations of which are shown in Figure 18).

The results of Figure 28 and Figure 29 show that the Ackers-White results from 'Model 1' are likely conservative, with significantly higher sediment volumes predicted than from the Toffaleti 'Model 2' results. The Toffaleti sediment erosion function is considered more appropriate for the anticipated sediment conditions in the diversion drain channel.

Focussing on the Toffaleti ‘Model 2’ results in Figure 28 and Figure 29:

- For a 1 in 10 AEP event:
  - There are approximately 2,200 tonnes eroded from the diversion drain
  - There are approximately 2,000 tonnes eroded from the full River 8 reach, indicating that there may have been 200 tonnes deposited between the KCC Diversion Drain outlet and the confluence with Nolans Creek.
- For a 1 in 100 AEP event:
  - There are approximately 11,000 tonnes eroded from the diversion drain
  - There are approximately 6,500 tonnes eroded from the full River 8 reach, indicating that there may have been 4,500 tonnes deposited between the KCC Diversion Drain outlet and the confluence with Nolans Creek.

Even with the ‘Model 2’ scenario, these results are still anticipated to be conservative due to the assignment of the ‘Fines’ PSD curve (from Table 13) in the diversion, but not accounting for the potential benefit of cohesion in the sediment.

In comparison with the Baseline erosion model results for ‘River 8’ under the 1 in 10 AEP event, the predicted sediment sourced from the diversion drain predicted by the Stage 1 Toffaleti ‘Model 2’ is in the order of three times that predicted by the Baseline scenario.

This definitely highlights an unsurprising risk of sediment erosion from the diversion drain cut going to the downstream environment during a ‘first flush’ style of event, with these sediments more representative of the alluvial sediments from the wider floodplain as opposed to the typical creek line sands. Mitigation options could include:

- Including a polishing pond at the downstream end of the diversion drain (however it is debateable how effective this could be as it would be best at capturing the sands, which are typically transported downstream in the natural system, and have worst performance for silts and clays, which are the more likely materials sourced from the diversion drain), or
- Including erosion protection, such as rip-rap lining, in the diversion drain, or
- Placing a ‘coating’ of natural sand in the diversion drain low flow channel (as opposed to relying on it to be transported in via flood events).

The benefit of such mitigation measures must be weighed up against the ‘length of exposure’. Once the drain as achieved a ‘coating’ of natural sands, the system is expected to be more analogous to the existing natural system.

It is recommended that the further test pit sampling be undertaken to better inform the materials anticipated in the base of the Stage 1 KCC Diversion Channel. Once this information is collected, then additional sediment erosion analysis could be undertaken to better inform this risk and investigate, for example, the beneficial impact of cohesion in the drain sediments (if found to be present).

How does the polishing pond impact the natural sand movement?

Placing a polishing pond at the downstream end of the diversion drain may be able to capture some of the sediment eroded from the diversion drain, but it is important to understand if:

- The polishing pond reduces the flow of natural sand to the downstream environment? And
- Does the reduction in sediment load downstream result in more significant erosion of the natural creek bed sand further downstream of the polishing pond (because the dynamic equilibrium in the system has been unbalanced)?

To investigate the first question, a bund has been placed in the model at the location of the potential polishing pond. Figure 30 presents the scour map prediction for the 1 in 10 AEP event based on the Stage 1 layout and the inclusion of a polishing pond at the downstream end of the diversion drain. The results in Figure 30 show a significant zone of deposition being captured by the polishing pond. Figure 31 shows the cumulative eroded mass timeseries plot with:

- Results provided for CH. 1,375 of River 8 (i.e. downstream end of the diversion drain) and CH. 776 of River 8 (i.e. simulated polishing pond location)
- Results for the Stage 1 KCC diversion drain with no polishing pond in red, which indicates in the order of 14,000 tonnes of sediment from a 1 in 10 AEP event at CH. 776

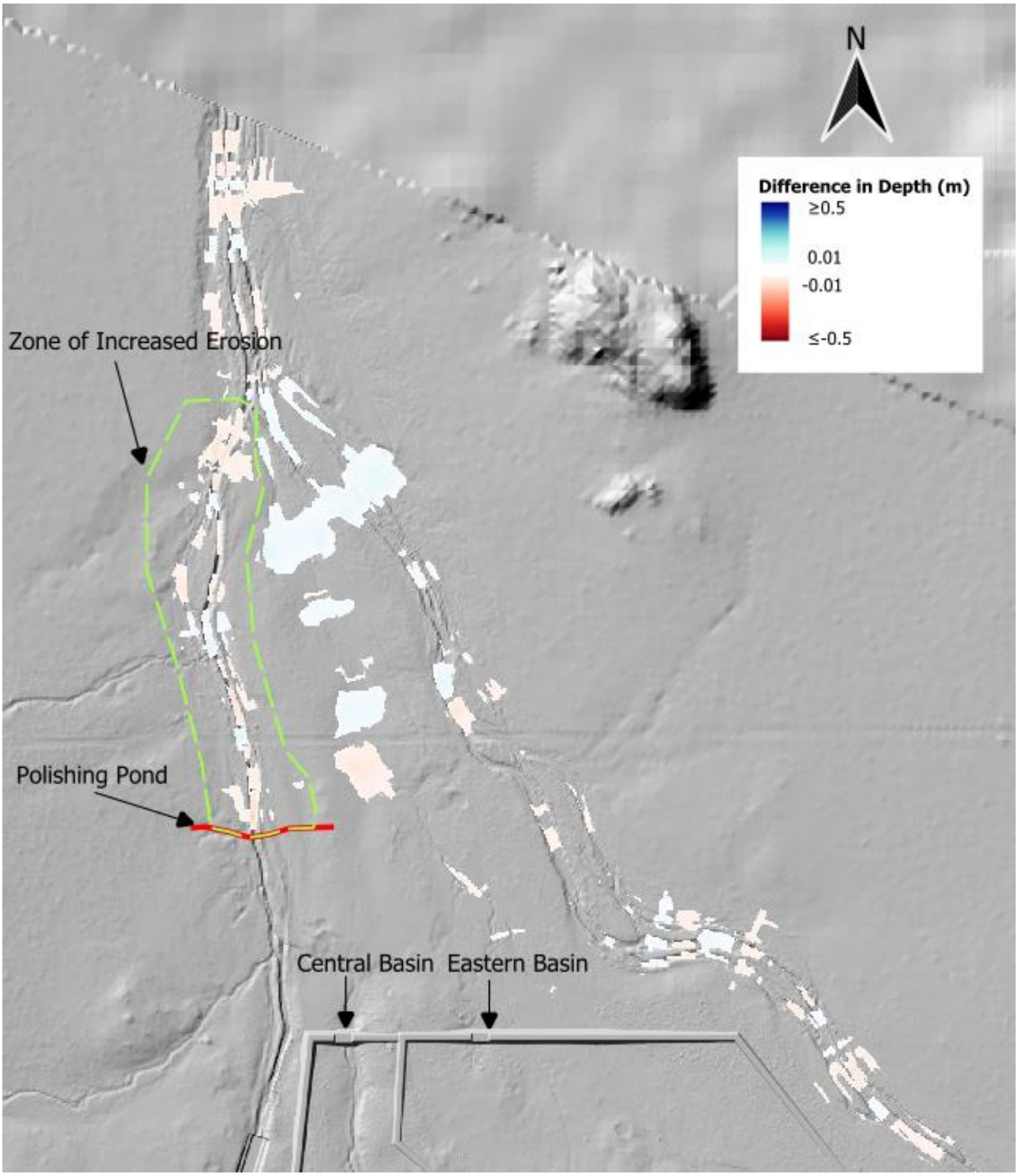
- Results for the Stage 1 KCC diversion drain with a polishing pond in green, which indicates in the order of 7,500 tonnes of sediment from a 1 in 10 AEP event at CH. 776. This indicates that in the order of half the sediment transported through the diversion drain could be captured on the polishing pond.

Additional sensitivity analyses indicate that the polishing pond could reduce the sediment going to the downstream environment by two to ten times. This is likely to cause a significant disruption to the dynamic equilibrium downstream of the polishing pond.

It is highlighted that the erosion results predicted by the 1D model downstream of the modelled polishing pond in Figure 30 are not considered realistic, as the model is not sophisticated enough to model the fact that the sands are more likely to be captured in the polishing pond (i.e. the model cannot capture the depth and sediment stratification properly). As such, the model is likely letting 'too much' sand downstream.

To investigate the second question as to how much impact the impact the reduced sediment load could have on the downstream environment, an alternate model set-up has been used where it is assumed that the polishing pond captures all upstream sediment (achieved in the model by allowing no erosion upstream of the polishing pond). Results of this analysis for the 1 in 10 AEP event are shown in Inset 12, which indicates:

- Increased erosion downstream of the polishing pond, in particular upstream of the confluence with Nolans Creek (in comparison to the Baseline model results in Figure 21), but not necessarily the formation of a significant scour hole developing (at least from a single event)
- Erosion depths typically less than 0.5 m downstream of the polishing pond. However, it is highlighted that this does indicate a deficit and disruption to the dynamic equilibrium that would likely accumulate and worsen over multiple flood events.



Inset 12: 1 in 10 AEP Scour Map for Ackers-White where no sediment passes the Polishing Pond.

It is considered that the addition of a polishing pond would alter the dynamic equilibrium in the natural system and therefore has not been considered as part of the default Stage 1 recommended design. The only anticipated benefit of including a polishing pond would be that it would reduce sediment flow downstream that is eroded from the diversion drain cut in the initial/'first flush' flood events, but this risk can be managed in other ways as discussed above.

9.4.2 Stage 2

The scour maps for the 1 in 10 AEP and 1 in 100 AEP based on the Stage 2 layout under the Model 3 setting are presented in Figure 32 and Figure 33 respectively. As the Stage 2 diversion re-routes the KCC flows, it disrupts the source of sediment to the mine area and reduces the sediment loading to the natural system downstream. It thus follows that sediment loading to the receiving creek line downstream the diversion to the west increases.

The results of Figure 32 and Figure 33 do indicate that whilst there is a reduced sediment load in ‘River 8’ (i.e. downstream of the mine area in KCC), the sediment load from Nolans Creek appears to maintain a system roughly in dynamic equilibrium downstream of the Nolans Creek and KCC confluence.

Can sand in creek line transfer through the Stage 2 diversion and downstream?

Figure 32 and Figure 33 present the scour maps of the 1 in 10 AEP and 1 in 100 AEP event respectively based on the Stage 2 layout under the ‘Model 3’ setting. With the ‘Model 3’ scenario, no erosion is simulated in the Stage 2 KCC Diversion drain, such that, the only way for sediment to transfer from the upstream end of the diversion to the downstream end is transportation as suspended or bed load through the diversion.

Figure 34 presents cumulative mass time series for cross-sections at the inlet and outlet of the Stage 2 diversion, chainages 3,743 m and 187 m respectively along ‘River 11’ (locations of which are shown in Figure 19). Figure 35 presents cumulative mass time series for cross-sections at the upstream and downstream end of the ‘River 11’ reach (which contains the Stage 2 diversion), chainages 3,871 m and 5 m respectively along ‘River 11’ (locations of which are shown in Figure 19).

The Figure 34 and Figure 35 plots are based on the ‘Model 3’ and ‘Model 4’ scenarios (from Section 9.3.4), which assume no erosion along the diversion drain and are aimed to capture the possible range of uncertainty in the sediment movement via two different sediment erosion functions.

The decrease in sediment load at the outlet of the diversion drain (CH. 187) in Figure 34 suggests that there is sediment deposition along the diversion drain, with in the order of 10 to 20% of the sediment sourced upstream making it through the diversion drain.

Figure 35 shows a mixture of responses:

- For ‘Model 3’ the sediment load is approximately 25% lower at the downstream end as to the upstream end for the 1 in 10 AEP event, but indicates approximately 33% higher sediment loads at the downstream end in the 1 in 100 AEP
- Conversely, for ‘Model 4’, the downstream end has approximately 10% lower sediment loads than the upstream end for the 1 in 10 AEP but indicates approximately 250% higher sediment loads at the downstream end in the 1 in 100 AEP event.

The increases in sediment at the downstream end from Figure 35 are likely sourced from the creek line downstream of the diversion outlet, associated with the increased flows. This is supported by the deeper scouring immediately downstream the diversion shown in Figure 32 and Figure 33, followed by bands of deposition.

These results do indicate that the system is unlikely to be in perfect dynamic equilibrium, at least initially, but in general does support that sediment can make its way through the Stage 2 KCC Diversion Drain, albeit that deposition of sand in the initial flood events is likely to create a ‘coating’ of sand, which will transition the diversion channel towards a ‘more natural’ erosion response over time.

Potential for Stage 2 inlet aggradation?

The flatter slope of the Stage 2 diversion drain, the natural watercourses in the region, as well as the results presented above indicate aggradation within the drain is possible. Aggradation at the inlet of the diversion drain has the potential to pose a risk to the performance and freeboard of the Stage 2 Diversion Inflow Control Bund during a flood event.

The HEC-RAS model results have been interrogated with a focus specifically on the Stage 2 diversion drain inlet, with results presented in Appendix B for the ‘Model 3’ scenario. For a 1 in 2 AEP and 1 in 50 AEP event, the results indicate that deposition occurs at the Stage 2 diversion drain inlet, with 870 tonnes and 1,450 tonnes of deposition predicted for the events respectively. This could represent in the order of 1,000 m^3 of sand. The HEC-RAS model predicts that this volume would be deposited as a ‘veneer’ of sand within the Stage 2 diversion channel, with 100 mm to 250 mm of sand cover. This level of aggradation is not expected to fundamentally change the performance of the Stage 2 diversion drain. However, it does highlight the potential for build up over subsequent events if intervention is not made (for example cleaning out of the sand).

To investigate the risks associated with an adverse build-up of sand at the Stage 2 diversion inlet, a ‘blockage’ representing 1,500 m^3 of sand within a 50 m segment of the diversion low flow channel has been assumed, as shown in Figure A22 of Appendix A. This blockage effectively fills the low flow channel fully in this segment and is considered to be positioned in the worst location for the hydraulic performance of the diversion drain.

During lower flow events, such as a 1 in 2 AEP, there may not be sufficient stream power to erode this blockage. Figure A23 and Figure A24 of Appendix A show the maximum velocity and bed shear stress respectively for a 1 in 2 AEP event with the assumed blockage in place. This scenario is also plotted on the long section of Figure A31 of Appendix A showing:

- A drop in velocity, shear stress and stream power in the diversion low flow channel upstream of the blockage (which would represent pooling upstream of the blockage)
- A sharp increase in velocity, shear stress and stream power at the location of the blockage, indicating that erosion could likely initiate, at least during the hydrograph rising limb
- No significant changes in results further downstream in the Stage 2 diversion.

In this theoretical case, additional aggradation could occur in the diversion channel upstream of the 'blockage', but additional aggradation 'on top' of the existing blockage would be less likely. Simulation of the 1 in 1,000 AEP event with the inclusion of this blockage shows that the Stage 2 Diversion Inflow Control Bund maintains sufficient freeboard to not overtop. As such, the risk of aggradation due to a few flood events is not anticipated to reduce the ability of the diversion system to perform in line with the design intent. If sand does build up at the inlet (say in excess of 0.5 m), then there is expected to be sufficient opportunity to manage the build-up operationally by cleaning out the inlet.

As such, during mining, the diversion is considered feasible and is expected to be able to meet design aims in conjunction with a management plan for potential clean out of the inlet if sand builds up. There does however remain a question mark about the viability of the diversion drain as a permanent diversion drain post closure of the mine. For example, if the pit voids are not backfilled and sand aggrades over time at the diversion drain inlet, the Stage 2 Diversion Inflow Control Bund could potentially overtop in the longer term due to reduced freeboard and result in discharge into the pit. However, prior to closure, the performance of the diversion drain would be much better understood and further, more detailed analysis, would be recommended to support the mine closure design.

If the Stage 2 diversion is not considered feasible as a long-term diversion drain post closure, then there would still be options to backfill part of the pits, with the KCC drain alignment re-instated across the top of the backfilled pit area.

How much sediment is sourced from the Stage 2 diversion?

Even with the potentially higher deposition of sand along the diversion alignment (as discussed above), it is possible that a 'coating' of sand depositing into the diversion drain could take a number of flood events to develop, as such there is a risk of sediment eroded from the diversion drain cut flowing to the downstream environment if the drain is unlined. This case can be considered analogous to a 'first flush' scenario. To investigate this aspect, erosion needs to be simulated for the Stage 2 KCC Diversion Drain, meaning either 'Model 1' or 'Model 2' from Section 9.3.4.

Figure 36 and Figure 37 present the scour maps of the 1 in 10 AEP and 1 in 100 AEP event respectively based on the Stage 2 layout for the Model 1 (i.e. Ackers-White) scenario. This setting assumes that the diversion cut consists of weathered rock and fine-grained material which can be subject to erosion. It can be observed that the model predicts typically in excess of 0.5 m of erosion along the diversion, with a significant amount of suspended load being sourced from the diversion, especially as it spans more than 3,000 metres length. Downstream of the diversion though, there is a localised zone of deposition (due to slower velocities associated with the confluence between the drain and the existing creek line), but otherwise, a portion of the eroded sediment is likely continuing to be transported to the downstream environment. It is anticipated that 'Model 1' results are likely very conservative though, as they do not account for the benefit of likely cohesion in the material exposed in the Stage 2 KCC Diversion Drain channel or the likely presence of rock in the channel.

Figure 38 presents cumulative mass time series for cross-sections at the inlet and outlet of the Stage 2 diversion, chainages 3,743 m and 187 m respectively along 'River 11' (locations of which are shown in Figure 19). Figure 39 presents cumulative mass time series for cross-sections at the upstream and downstream end of the 'River 11' reach (which contains the Stage 2 diversion), chainages 3,871 m and 5 m respectively along 'River 11' (locations of which are shown in Figure 19).

The results of Figure 38 and Figure 39 show that the Ackers-White results from 'Model 1' are likely conservative, with significantly higher sediment volumes predicted than from the Toffaleti 'Model 2' results. The Toffaleti sediment erosion function is considered more appropriate for the anticipated sediment conditions in the diversion drain channel (although they will also over-estimate erosion in areas of the drain where rock is encountered).

The Toffaleti results indicate that between 6,000 and 20,000 tonnes of sediment could be sourced from the Stage 2 diversion drain for the 1 in 10 AEP and 1 in 100 AEP events respectively. If there are significant portions of rock and/or cohesive material exposed in the diversion drain channel, then these numbers are expected to be a significant over-estimate.

Additional sediment erosion analysis is likely to be beneficial to better assess the potential for erosion sourced from the Stage 2 diversion drain cutting following further site investigation, which will also help inform the rock conditions likely to be present in much of the Stage 2 diversion channel.

9.5 Outcomes

The results of the HEC-RAS sediment transport modelling suggests:

- Sand moves in the natural system during most flood events and the natural creeks are likely in dynamic equilibrium.
- Both the Stage 1 and Stage 2 diversion drains can transmit sands sourced from the upstream creeks to the downstream environment, with the Stage 1 diversion drain performing better in this respect. There is expected to be some capture of sand in the diversion drains though, which will over time likely have a net benefit of 'coating' the diversion drains and making them more similar to the natural creeks in their fluvial geomorphology.
- Inclusion of a polishing pond downstream of the Stage 1 diversion is currently not recommended as it incepts a significant portion of the natural sands transported through the Stage 1 diversion. And modelling indicates that in the reach of KCC upstream of the confluence with Nolans Creek that the creek dynamic equilibrium would be unbalanced, and that continual scour could occur over subsequent flood events in this reach of the creek.
- The Stage 2 diversion drain is considered feasible, despite the flat longitudinal slope, during mining in conjunction with a management plan for potential clean out of the inlet if sand builds up over time (for example in excess of 0.5 m within the drain). The aggradation performance of the drain would require monitoring during the mining period to collect data and support decisions for mine closure. In the worst case, closure could require backfill of part of the pits, with the KCC drain alignment re-instated across the top of the backfilled pit area.
- Depending on the cut materials exposed, there is a potential for significant suspended load comprising of finer grained sediments being eroded and sourced from the diversion drains. It is noted that these eroded materials are likely representative of the alluvial floodplain materials. Further investigation of this is recommended following additional site investigation to confirm the materials exposed in the base of the diversion drains. For example, the modelling presented in this report does not consider the likely benefit of cohesion in the sediments, which may be present, in reducing eroded volumes. This potential risk of higher erosion rates is likely to be more critical in the initial flood events (such as a 'first flush' event), before the natural sand 'coating' likely develops in the diversion drains. If the future investigations highlight an unacceptable erosion response in the diversion drains, then options to mitigate this could include:
  - Placing erosion protection, such as rip-rap lining, in the diversion drain, or
  - Placing a 'coating' of natural sand in the diversion drain low flow channel (as opposed to relying on it to be transported in via flood events).

10. Other Surface Water Design Aspects

10.1 Western Waste Dump French Drain

Figure 2 shows the location of a proposed French Drain under the North waste dump. The catchment along the southern side of the North waste dump footprint currently drains through a valley that will be buried by the waste dump. Given the topography along the south edge of the proposed North waste dump footprint, using a French Drain would require less cut to place, as opposed to a toe drain.

The French Drain size is currently nominal, with an allowance for a 2 m deep and 10 to 20 m wide zone of rockfill (with a D_{50} greater than 300 mm) currently specified. This zone of rockfill would not be expected to cater for the 1 in 100 AEP peak flow and some degree of temporary ponding at the inlet of the French Drain would be expected. There is, however, a decent amount of temporary storage ponding area available at the French Drain inlet and therefore it is expected to be able to facilitate a drainage path through the southern section of the North waste dump, linking it with the downstream catchment. It is anticipated that some degree of cut will be required to excavate the

French Drain channel to facilitate a downslope from the inlet to the outlet. More detailed design for the French Drain is anticipated prior to 'Issued for Construction' drawings being provided, for example relating to options to mitigate clogging of the French Drain during placement of the overlying waste dump.

10.2 Waste Dump Toe Drain Sizing

The waste dump toe drains have been nominally sized to contain flows from the 1 in 100 AEP. Peak flows have been queried from the TUFLOW hydraulic model. Currently, the drains have been sized using Manning's equation, which assumes prismatic open channel flow conditions, with a side slope of 1V:2H and a Manning's *n* of 0.015 adopted.

Some degree of erosion within the drains is expected, especially during rarer flood events where flow velocities are likely to be above the erosion initiation threshold. All toe drains discharge to sediment basins, as such, there is minimal risk to the environment associated with this. Locations where the drain erosion is likely to be the worst will be at bends in the drains, in these areas rip-rap lining is likely to be beneficial. However, the amount of acceptable erosion and/or consequences of drain alignment adjustment at bends due to erosion will be related to the mining operational criterion that Arafura set. Sizing of rip-rap for the toe drains is an aspect that has been left as an aspect for future works if Arafura is keen to pursue this risk mitigation.

Some of the waste dump toe drains (South Dump Toe Drain 2 and North Dump Toe Drain 2) cross proposed haul road alignments in the current mine layout. These locations will require culvert crossings to be designed as future works once the haul road locations are confirmed.

South Dump Toe Drain 2 is quite close to the 'Pit 3' and 'Pit 7' crests. There may be an opportunity to increase the drain offset to the pit crest via adjustment of the topsoil stockpile locations. Otherwise, there may be a need to consider lining the drain cross-section with HDPE to reduce seepage into the pit slope and mitigate potential slope instabilities. Further geotechnical and seepage analysis would be required to assess if HDPE lining would be recommended.

10.3 Other Minor Drain Designs

The temporary pit diversion drains for the Stage 1 pits and the clean water drains have been designed using Manning's equation. The channels were designed with a side slope of 1V:2H and a Manning's *n* of 0.015. Erosion may be expected at the outlet of the 'Pit 1 & Pit 2' drain, the location of which shown in Figure 1, and rip-rap lining could be beneficial in this area. Use of rip-rap in this area is however considered at the discretion of Arafura given it is a temporary diversion drain that will be decommissioned once Stage 2 pit development commences and that the drain also discharges to a sediment basin.

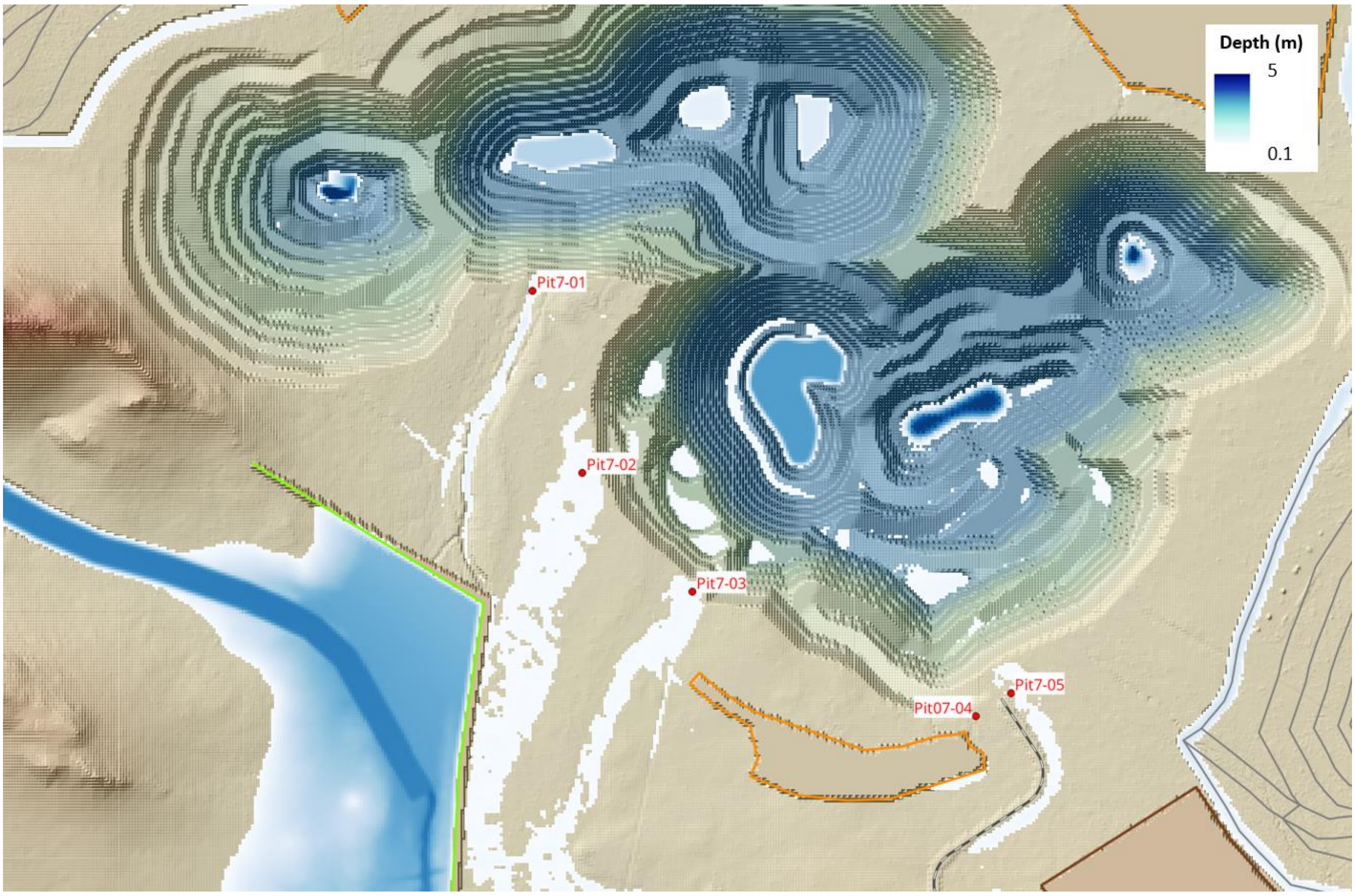
The 'Pit 1 & Pit 2 Drain' crosses a proposed haul road alignment in the current mine layout. This location will require a culvert crossing to be designed as future works once the haul road locations are confirmed.

The 'Pit 1 Drain', 'Pit 2 Drain' and 'Pit 1 & Pit 2 Drain' are all located close to the Stage 1 pits. There may be a need to consider lining parts of the drain cross-section with HDPE to reduce seepage into the pit slope and mitigate potential slope instabilities. Further geotechnical and seepage analysis would be required to assess if HDPE lining would be recommended.

10.4 Fill Areas

The topography between the Stage 2 Diversion Inflow Control Bund and the proposed Stage 2 pit, 'Pit 7', currently drains towards Pit 7. This is shown in Inset 13, highlighting the existing drainage paths that drain towards the pit. The topography does not lend itself to a diversion drain, as the 'Pit7-01' point in Inset 13 is the low point of the area.

As such, the implications of letting this area drain over the pit crest has been investigated. The inflow points from Inset 13 were interrogated to estimate the potential of erosion and the expected water ingress volumes during flow events if left unmanaged. As otherwise, filling of the area may be necessary to divert flow towards the eastern side of the pit where the diversion drain and sediment basins are located.



Inset 13: Pit 7 Query Locations (1 in 1,000 AEP maximum depth design flood extent).

The maximum velocity queried from the TUFLOW hydraulic model upstream of Pit 7 is typically less than 0.6 m/s for the base case hydrology scenario.

The total volume of water ingress was estimated by integrating the area under the flow hydrograph. The design and sensitivity event durations were investigated for the 1 in 10 AEP, 1 in 50 AEP, and 1 in 100 AEP. The maximum volume of water ingress into the pit at one inflow point is 10 ML. A summary of these values is presented in Table 15. It is highlighted that longer duration events could potentially lead to higher inflow volumes than those presented in Table 15.

Table 15 – Pit 7 Inflow Velocity and Volume

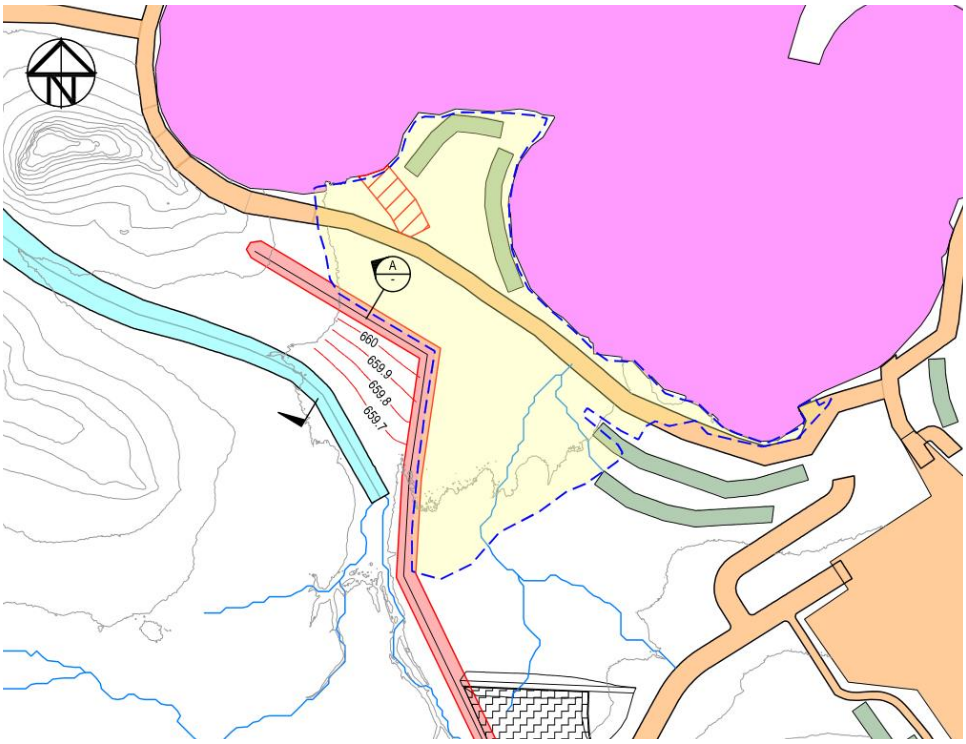
Location	AEP (1 in X)	Duration (hours)	Peak Velocity (m/s)	Volume (ML)
Pit7-01	100	4.5	0.6	3.6
		6	0.6	3.8
	50	4.5	0.5	2.2
		6	0.5	3.1
	10	4.5	0.2	0.1
		12	0.0	1.3
Pit7-02	100	4.5	0.3	6.5
		6	0.3	6.7
	50	4.5	0.3	3.8
		6	0.3	5.3
	10	4.5	0.0	0.1
		12	0.0	1.8
Pit7-03	100	4.5	0.5	9.1
		6	0.5	9.9
	50	4.5	0.4	6.2
		6	0.4	8.2
	10	4.5	0.2	0.5
		12	0.1	4.0
Pit7-04	100	4.5	0.5	1.7
		6	0.5	1.8
	50	4.5	0.5	1.0
		6	0.5	1.5
	10	4.5	0.1	0.0
		12	0.0	0.6
Pit7-05	100	4.5	0.6	7.5
		6	0.6	7.8
	50	4.5	0.5	4.5
		6	0.5	6.4
	10	4.5	0.2	0.2
		12	0.0	2.4

The modelling suggests that peak velocities upstream the pit crest are not excessive, but at the pit crest knickpoint, gully erosion initiation would remain feasible. If a gully erosion knickpoint were to form, it could likely be managed operationally. Combining the different inflow points, there is a total of 10.1 ML of estimated inflow under a 12 hr 1 in 10 AEP event. It is recommended that Arafura consider the potential additional pumping requirements associated with letting this area drain over the pit crest.

One possible option to mitigate the chance of this area draining into the pit could be to backfill the yellow area highlighted in Inset 14. Backfilling this area would be required to create an artificial drain slope and divert the flow to the east around the pit crest and towards the direction of the sediment basins.

Inset 14 also highlights that the area between the Stage 2 KCC diversion drain and Stage 2 Diversion Inflow Control Bund will need to be backfilled and a downslope created towards the Stage 2 Drain inlet to mitigate ponding and dead storage around the inlet of the diversion drain.

Backfilling of some of the Stage 1 KCC diversion drain indicated in Figure 2 is also recommended once Stage 2 development commences to mitigate against flows into the pit via the decommissioned Stage 1 diversion drain cross-section.



Inset 14: Back-fill footprint upstream Pit 7.

11. 50% Level Design

11.1 Earthworks Material Zoning

PSM4809-017M, dated 22 December 2023, presents the details regarding the earthworks material zoning for the sediment basin embankments, flood protection bunds and inflow control bunds. The objective has been to create a design where materials will be sourced mostly from the bulk earthworks local to the open pit and sediment pond area of the mine site (in the first instance) so as to limit haul distances and costs.

11.2 Design Philosophy

Consideration of risk was included in the assessment of the bund and embankment design. The prime risk is considered to be the potential for a piping failure to occur due to the presence of dispersive materials within the construction.

If a breach were to occur due to piping, the structures which are considered to present the prime risk to mine operation are:

- Inflow Control bund/s, which could potentially have a serious impact on pit operation, and
- Sediment control dam embankments at the northern edge of the open pit(s), which could result in environmental impact downstream, requiring cleanup, repair of the structures and impact on reputation.

Assuming that exclusion of potentially dispersive materials from the construction is not practical or feasible, prevention of piping could be achieved using natural materials to form an appropriate filter for a low permeability 'Zone A' material. A correctly designed natural filter would typically comprise a well graded sand, which is understood to be a product that will be in high demand on this project with limited availability and/or high cost. This style of work is typically required for permanent water storage structures.

It may also be possible to reduce the risk of piping through provision of well compacted, more clayey materials. However, the extent and location of the more clayey sands on site would also necessitate careful control on the selection of these materials in the field.

The alternative approach proposed in the designs presented in PSM4809-017M REV1 and here is to provide a positive control by utilising a welded HDPE liner to exclude water from entering the embankments that are likely to see long term impoundment of water or have the greatest risk with respect to impact on mine operation. The use of a HDPE liner would also allow earthworks to use almost any of the site derived materials in the works without restrictive selection requirements.

The other bunds at the mine area (Pit 1 and Pit 7 bunds and the Nolans Creek Flood Protection Bund) are not considered to present as significant a risk to either operations or the environment. These structures are typically at the downstream side of mining operations and the risk of piping through good compaction is expected to be sufficient. These structures are also relatively low in height and regular inspection and maintenance should also be able to be carried out without impact or restriction to ongoing operations.

The freeboard allowance has also been matched with the corresponding risk to the operations and/or environment, with:

- 0.5 m to 1 m freeboards provided for the sediment basin spillways, Stage 1/2 Diversion Drains, Inflow Control Bunds and Nolans Creek Flood Protection Bund, and
- 0.3 m freeboard for clean and dirty water drains.

11.3 Drawings

50% level of design drawings are provided within PSM4809-017M REV1 and have been based on the design concepts and criteria as presented in this report.

12. Future Work for IFC

In order to uplift the 50% Level of Design to an Issued for Construction (IFC) design the following additional work is currently recommended:

- Additional test pits, with bulk samples to be collected and lab testing undertaken. Indicative locations for these test pits are shown on drawings:
  - PSM4809-010-44, and
  - PSM4809-020-64.
- Particle Size Distribution (PSD) testing of the test pit bulk samples would further inform the grading of the creek beds and material in the base of the diversion drains. It is recommended that this then be used to update the sediment erosion analysis presented in this report
- The test pits will also help inform the layout of bund erosion toe protection measures
- For the Stage 2 Diversion Drain, two boreholes are recommended to be drilled and geotechnically logged, with downhole ATV/OTV also undertaken, which would be to support the slope cut design for the Stage 2 diversion drain as well as the potential risk of rock erosion during flood events. The indicative locations for these boreholes are shown on drawing PSM4809-020-64
- Where haul road cross diversion drains, culvert crossing designs will be required
- Section 7.3 presents a number of potential clashes between the proposed topsoil stockpiles and the proposed surface water infrastructure, these clashes will need to be resolved
- Section 10.1 presents preliminary details for a French Drain under the North Waste Dump, once the waste dump footprint is finalised, additional work will be required to confirm the drain sizing and recommendations to mitigate clogging of the French Drain
- Section 10.2 and 10.3 highlight that rip-rap lining and/or HDPE lining some areas of the drains may be required to manage localised erosion and/or seepage into the pit slopes, further interface with Arafura and design may be required on these aspects
- Section 10.4 highlights the implications of the topography between the Stage 2 Diversion Inflow Control Bund and the Pit, with water draining into the pit. Further interface with Arafura and design of this area is anticipated to establish a preferred approach to managing the runoff in this area
- Any adjustments to the mine layout will need to be factored into the surface water infrastructure layout
- Formal geotechnical stability analyses of the bunds and embankments has not been undertaken and is recommended. Lab testing on the bulk samples collected from the test pits is likely to be required to help support these analyses
- Additional technical specifications may be required to enable construction

- As discussed in Section 2.2.3 it is recommended that the climate change assumptions are reviewed at the time of the Stage 2 diversion drain implementation to ensure it confirms with the most current streamflow information and climate change design advice
- It is intended that this report will be used to initiate preliminary feedback from the NT Regulator, addressing any comments from the Regulator will be essential in achieving a successful Permit application.

It is also highlighted that the Stage 2 diversion drain is considered feasible, despite the flat longitudinal slope, during mining in conjunction with a management plan for potential clean out of the inlet if sand builds up over time (for example in excess of 0.5 m within the drain). The aggradation performance of the drain would require monitoring during the mining period to collect data and support decisions for mine closure. A monitoring plan and a Trigger-Action-Response-Pan (TARP) will be required to be developed to support operational decisions regarding sand clean out of the Stage 2 diversion drain inlet. The opportunity to collect additional information prior to the construction of Stage 2 diversion drain, such as erosion bed load monitoring and material grading, would also allow further development of the Stage 2 diversion drain design prior to implementation.

In the worst case, closure could require backfill of part of the pits, with the KCC drain alignment re-instated across the top of the backfilled pit area.

Yours Sincerely

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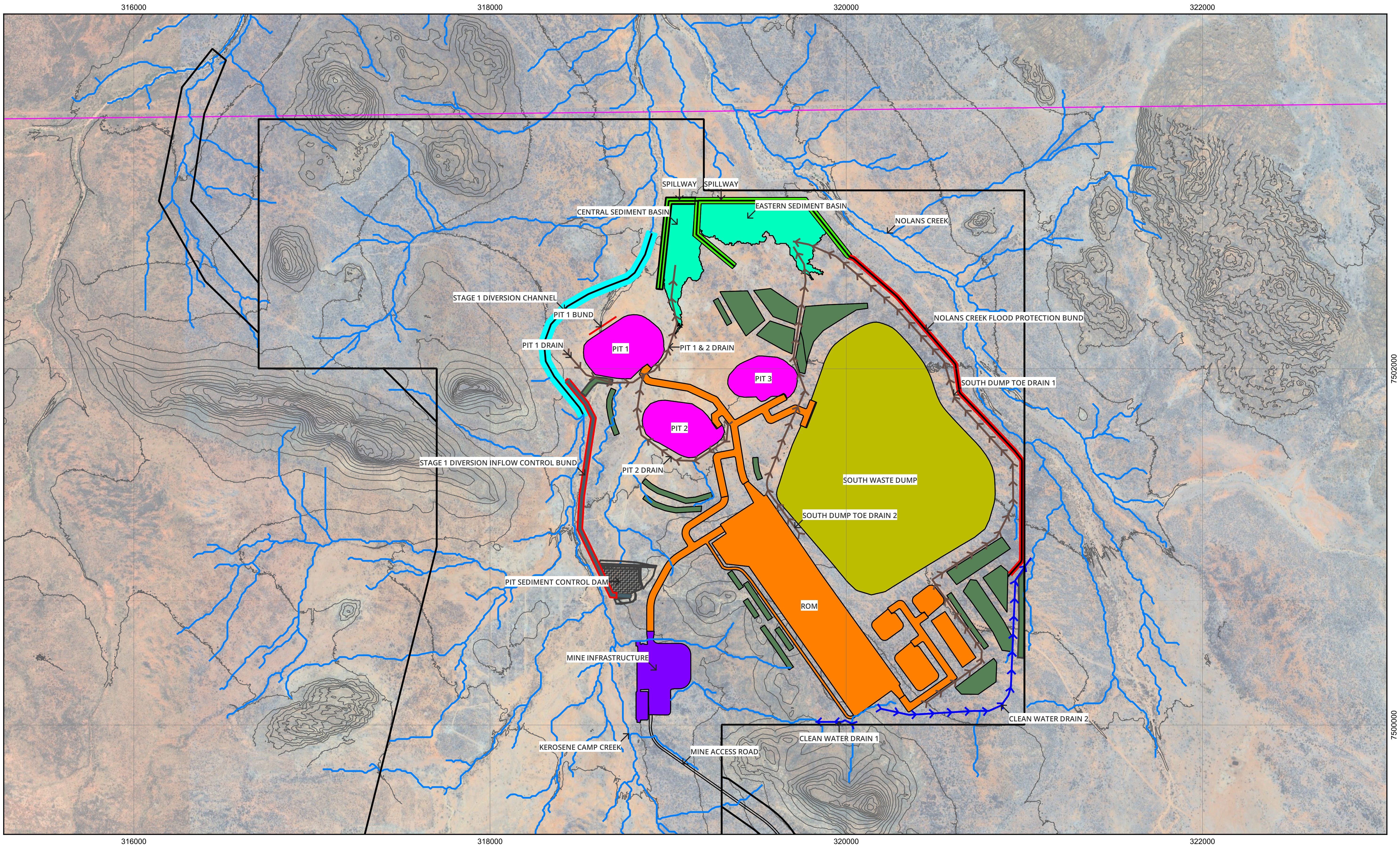

Legend

Contours - 5 m	Station Boundary	Sediment Basin Full Water Level
Clean Water Drains	Diversion Channel	Flood Protection Bunds
Creek Line	Pit Footprint	Waste Dump
Dirty Water Drains	Topsoil Stockpile	Mine Infrastructure Area
Lease Boundary	ROM, Haul Roads and Laydown Areas	Sediment Basin Embankment

Notes:
1. Aerial sourced from Google Satellite

Scale 1:20,000

100 0 100 200 300 400 m

N

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Revision: A
Date: 12 Jan 2024
Paper Size: A3

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 GENERAL LAYOUT

PSM4809-016R
Figure 1

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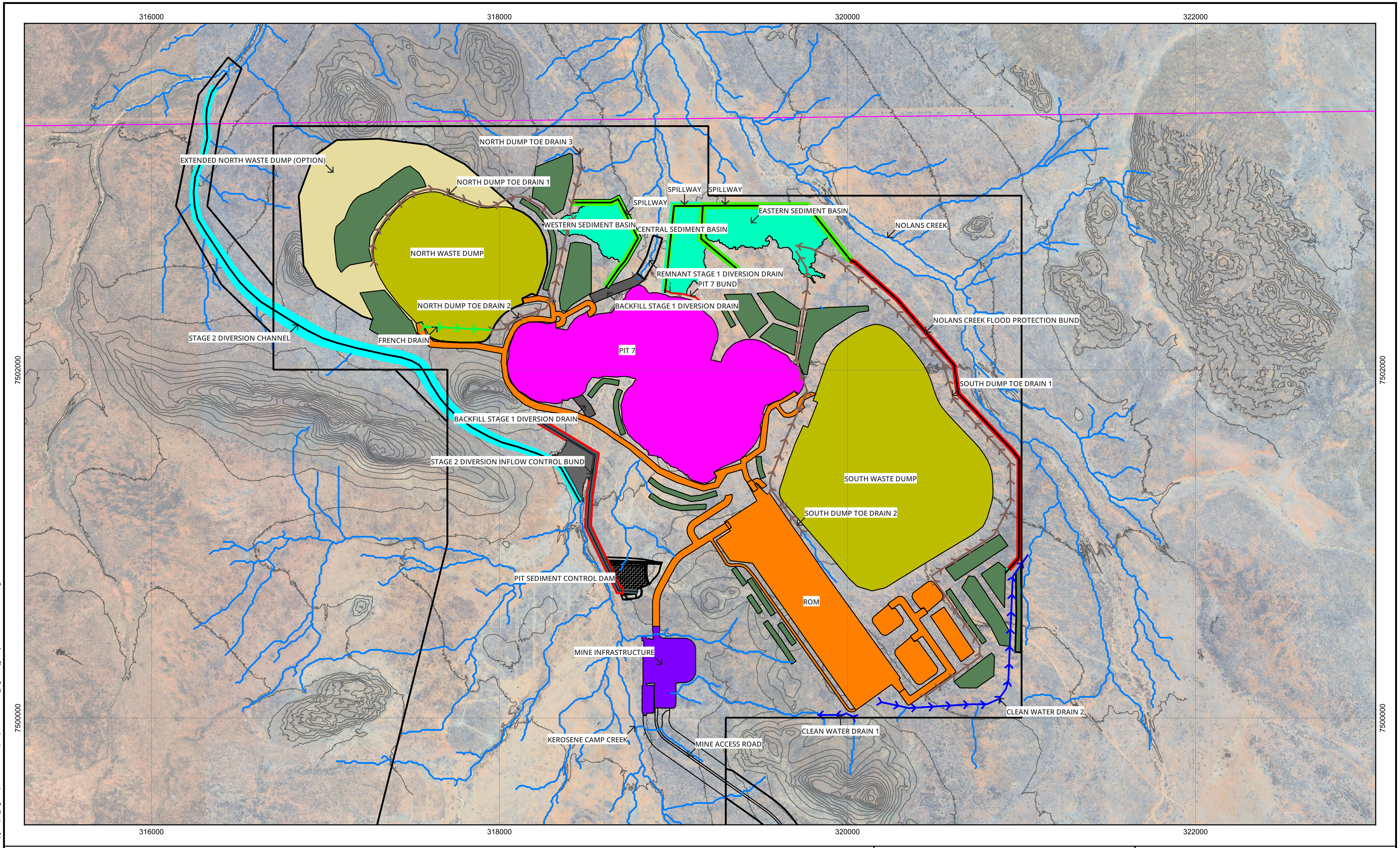

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Legend

- Contours - 5 m
- Clean Water Drains
- Creek Line
- Dirty Water Drains
- Lease Boundary
- Station Boundary
- French Drain
- Diversion Channel
- Pit Footprint
- Topsoil Stockpile
- ROM, Haul Roads and Laydown Areas
- Sediment Basin Full Water Level
- Flood Protection Bunds
- Waste Dump
- Mine Infrastructure Area
- Sediment Basin Embankment
- Backfill

Notes:
1. Aerial sourced from Google Satellite

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Scale 1:20,000

100 0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 53
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Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 GENERAL LAYOUT

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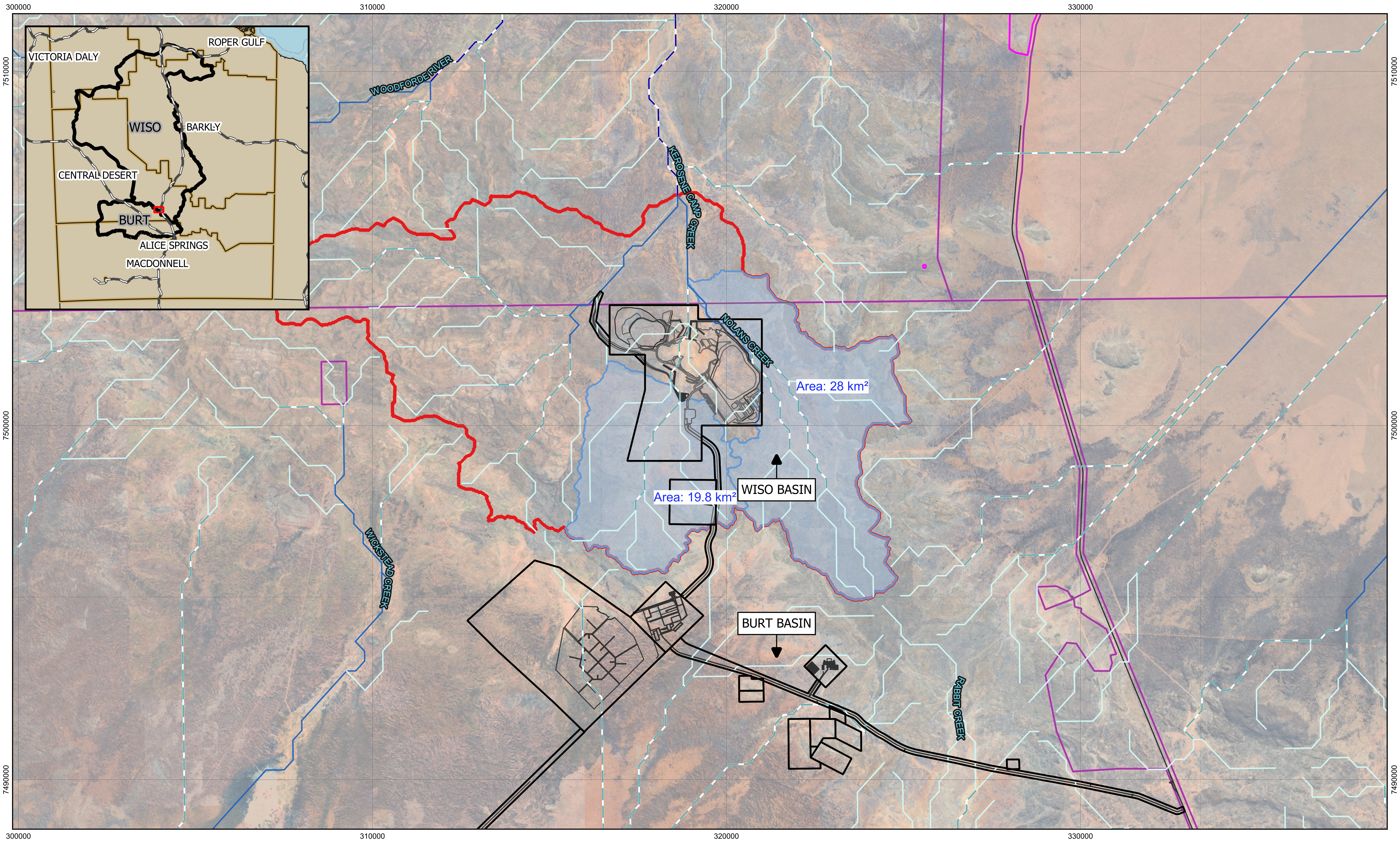
PSM4809-016R | Figure 2



Legend

- Lease Boundary
- Project Catchment
- Station Boundary
- Stage 2 General Layout
- Upstream Catchment

Strahler Stream Order

- 1
- 2
- 3
- 4

Notes:
1. Aerial sourced from Google Satellite
2. Strahler order sourced from NT Department of Environment, Parks and Water Security (NT DEPWS)

Scale 1:100,000

N

1,000 0 1,000 2,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

SITE CATCHMENT SETTING

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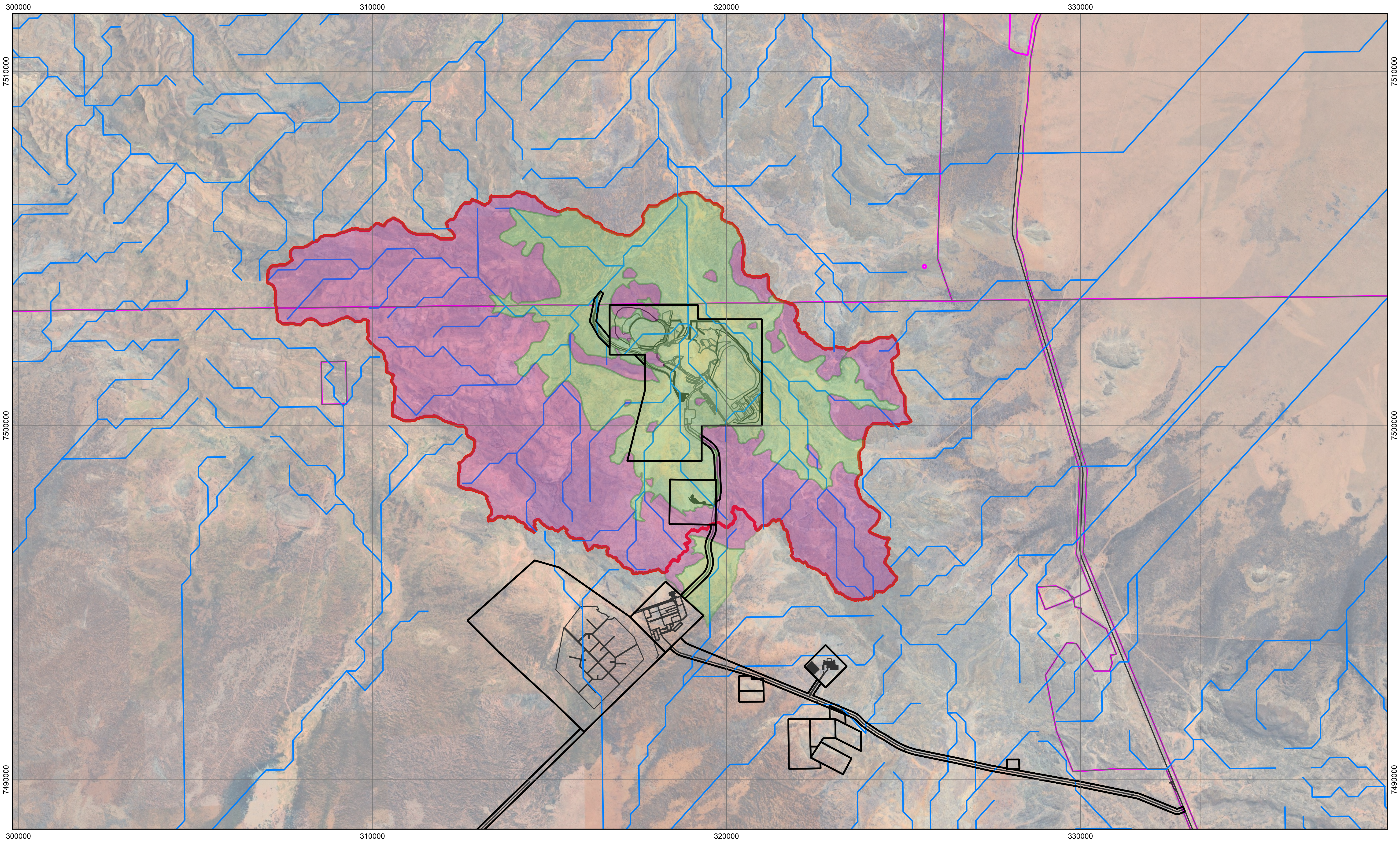
Date: 23 Jan 2024	Paper Size: A3	PSM4809-016R	Figure 3



Legend

- Lease Boundary
- Project Catchment
- Station Boundary
- Stage 2 General Layout
- Creek Line

Hydrologic Zones

- Alluvial Floodplain Region
- Rock Region

Notes:
1. Aerial sourced from Google Satellite
2. Hydrologic zones inferred from referencing the Napperby
1:250k scale geological series GIS version (NT GEMIS, 2014)

N

Scale 1:100,000

1,000 0 1,000 2,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

SITE CATCHMENT SETTING
HYDROLOGIC ZONES

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	Date: 12 Jan 2024	Paper Size: A3	PSM4809-016R Figure 4

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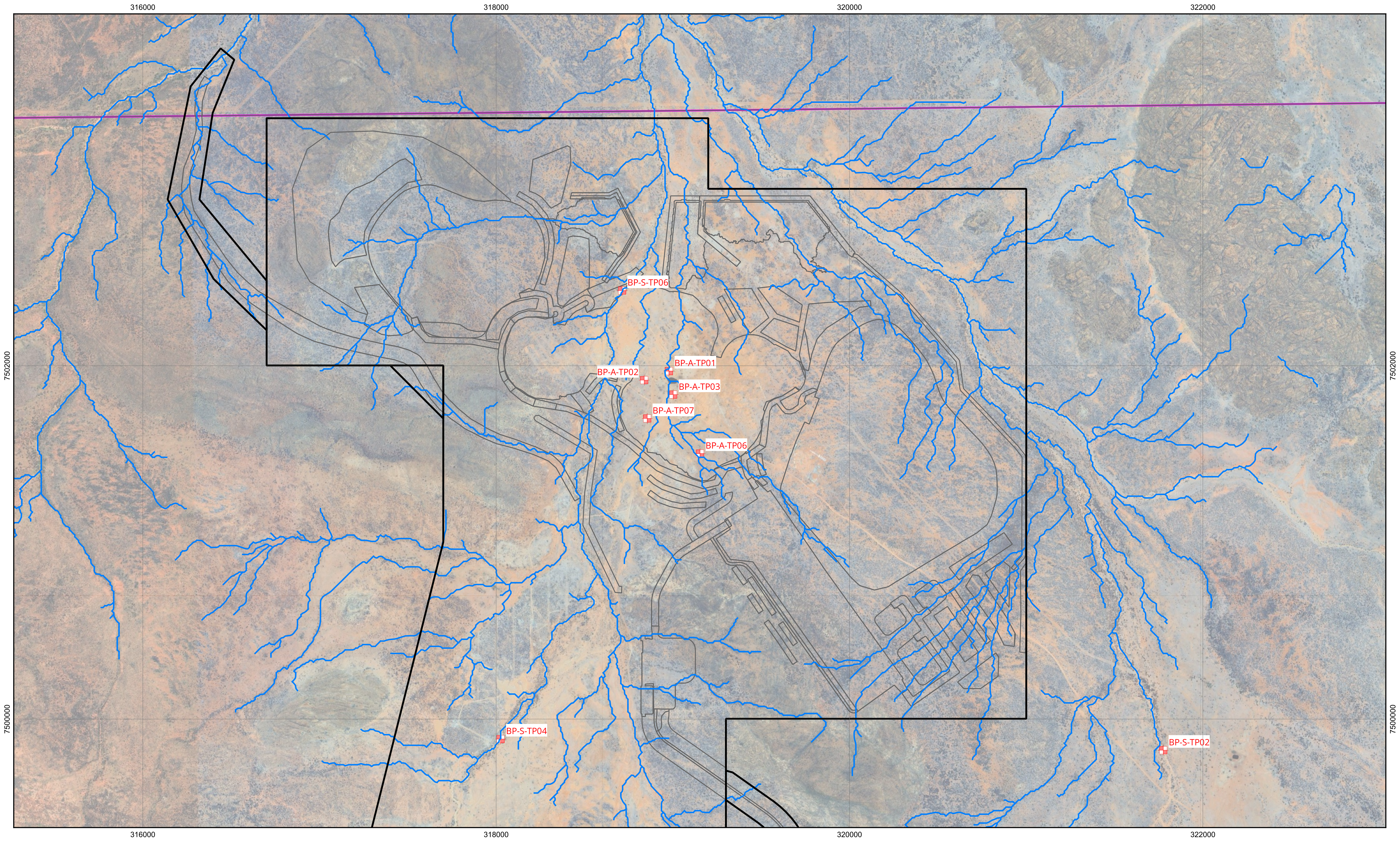

Legend

- Lease Boundary
- Station Boundary
- Stage 2 General Layout
- Creek Line
- PSD Test Pit Samples

Notes:
Aerial sourced from Google Satellite
1. Test pit locations referenced from Nolans Project Geotechnical Site Investigation (KP, 2011)

N

Scale 1:20,000

100 0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

PSD SAMPLING LOCATION

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Date: 06 Feb 2024	Paper Size: A3

PSM4809-016R | Figure 5

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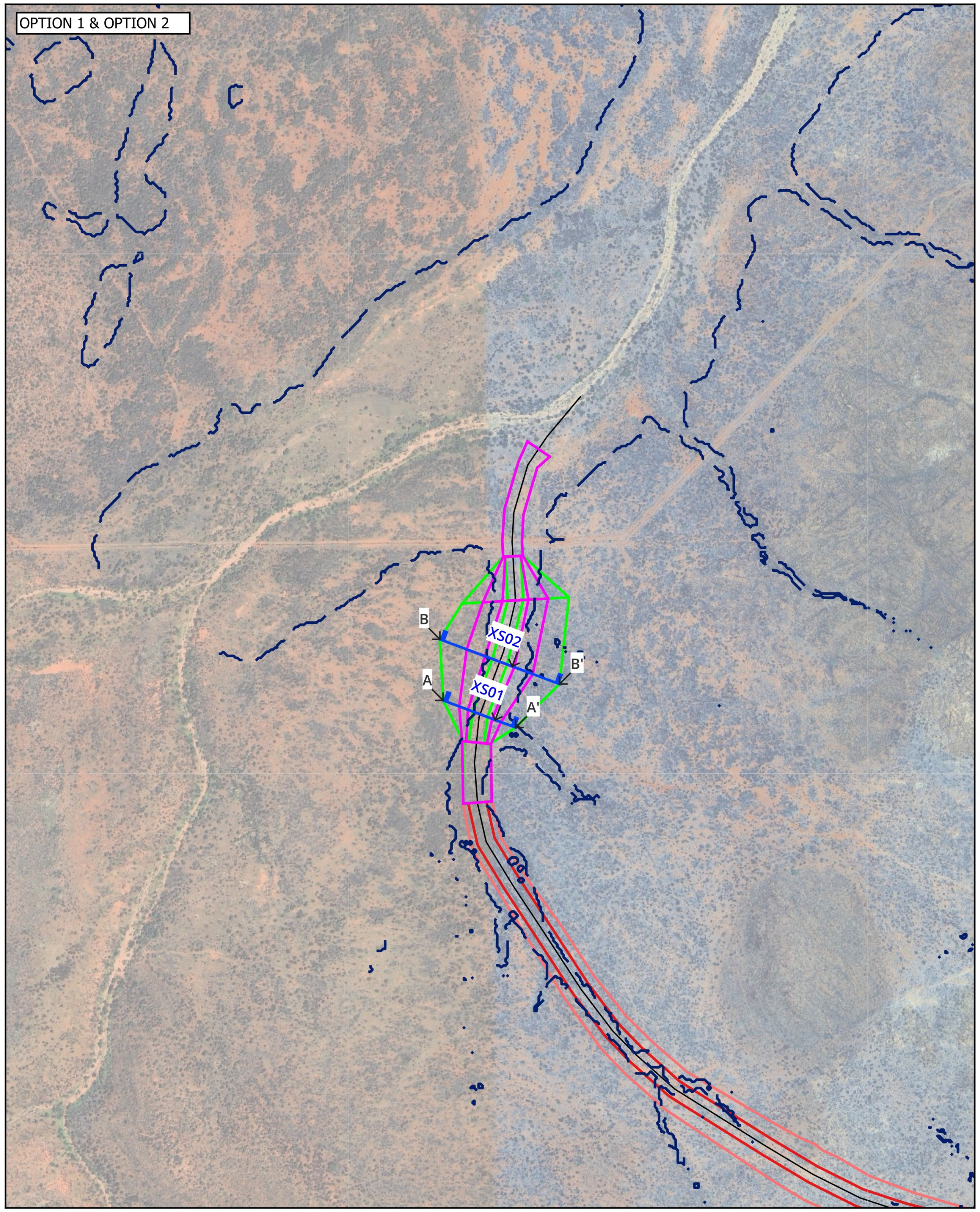

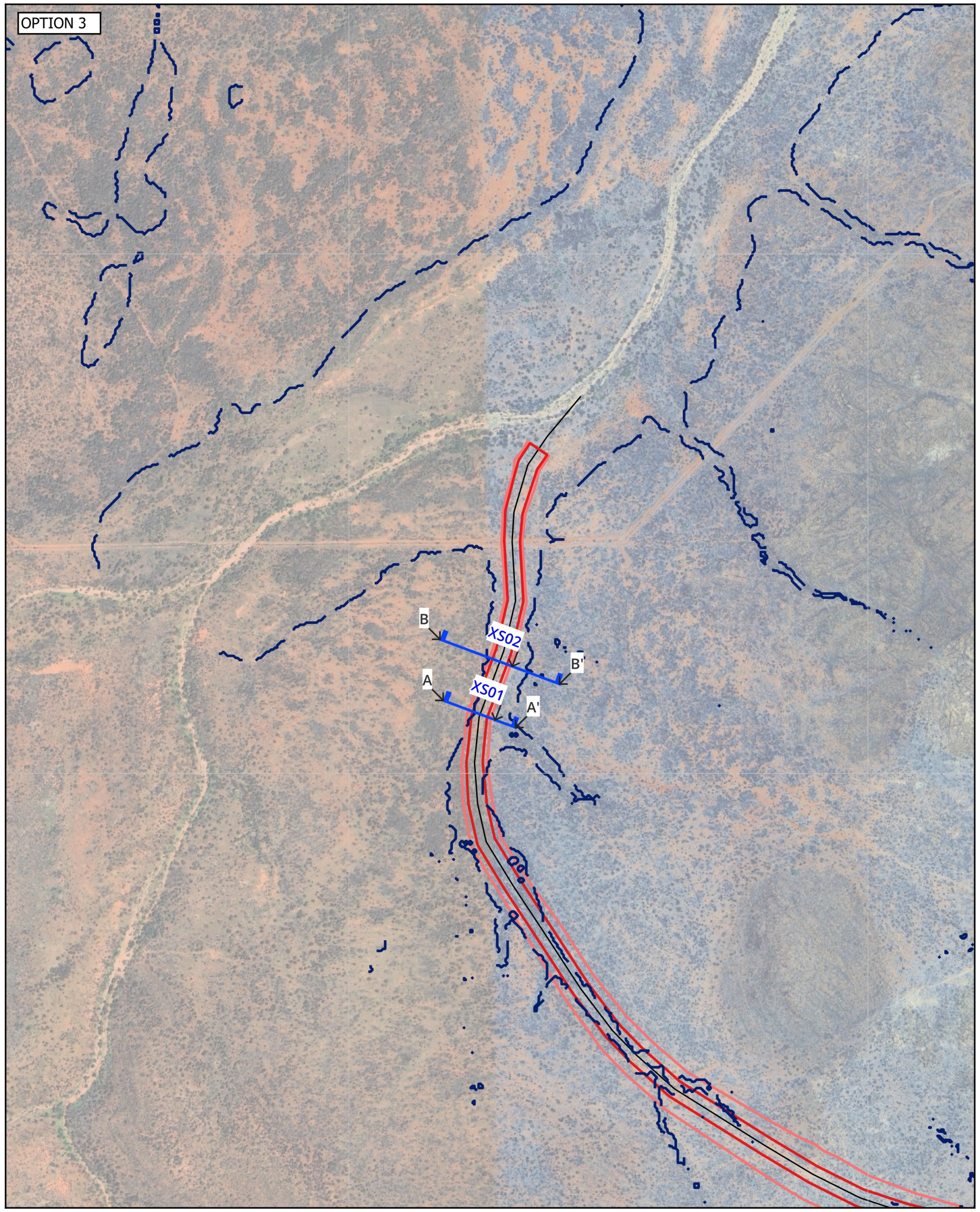

Legend

- Diversion Drain Centre Line
- Option 1
- Option 2
- Option 3 - Top Width
- Option 3 - Base Width
- 1 in 1,000 AEP Flood Extent

Notes:
1. Aerial sourced from Google Satellite
2. The 1 in 1,000 AEP flood contour is derived from the hydraulic modelling of the existing topography. The contours are extracted from the maximum depth output of the model.

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Scale 1:10,000

50 0 50 100 150 200 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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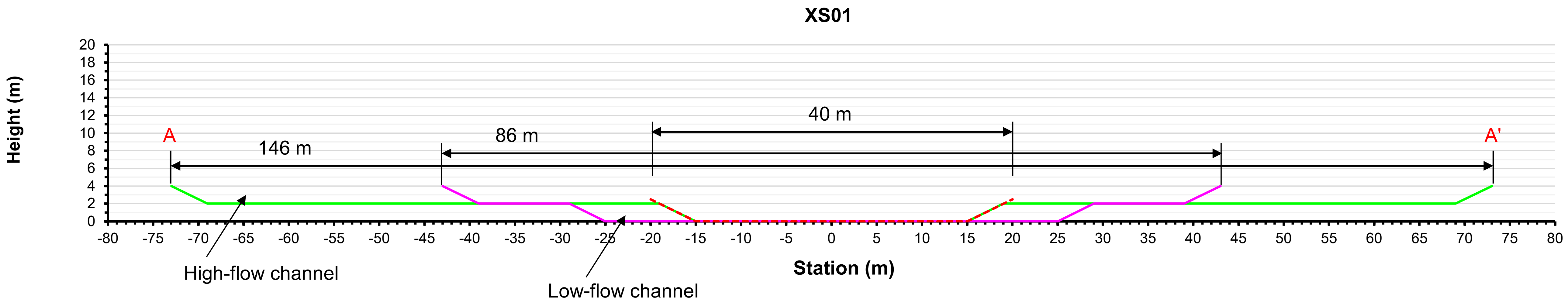
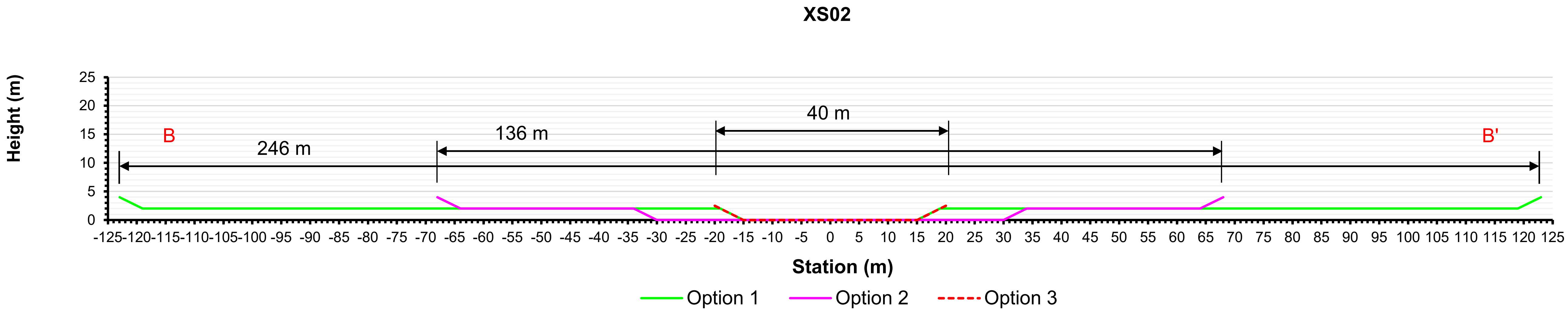
Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 DIVERSION DRAIN OPTIONEERING

PSM4809-016R | Figure 6

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01 GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure06





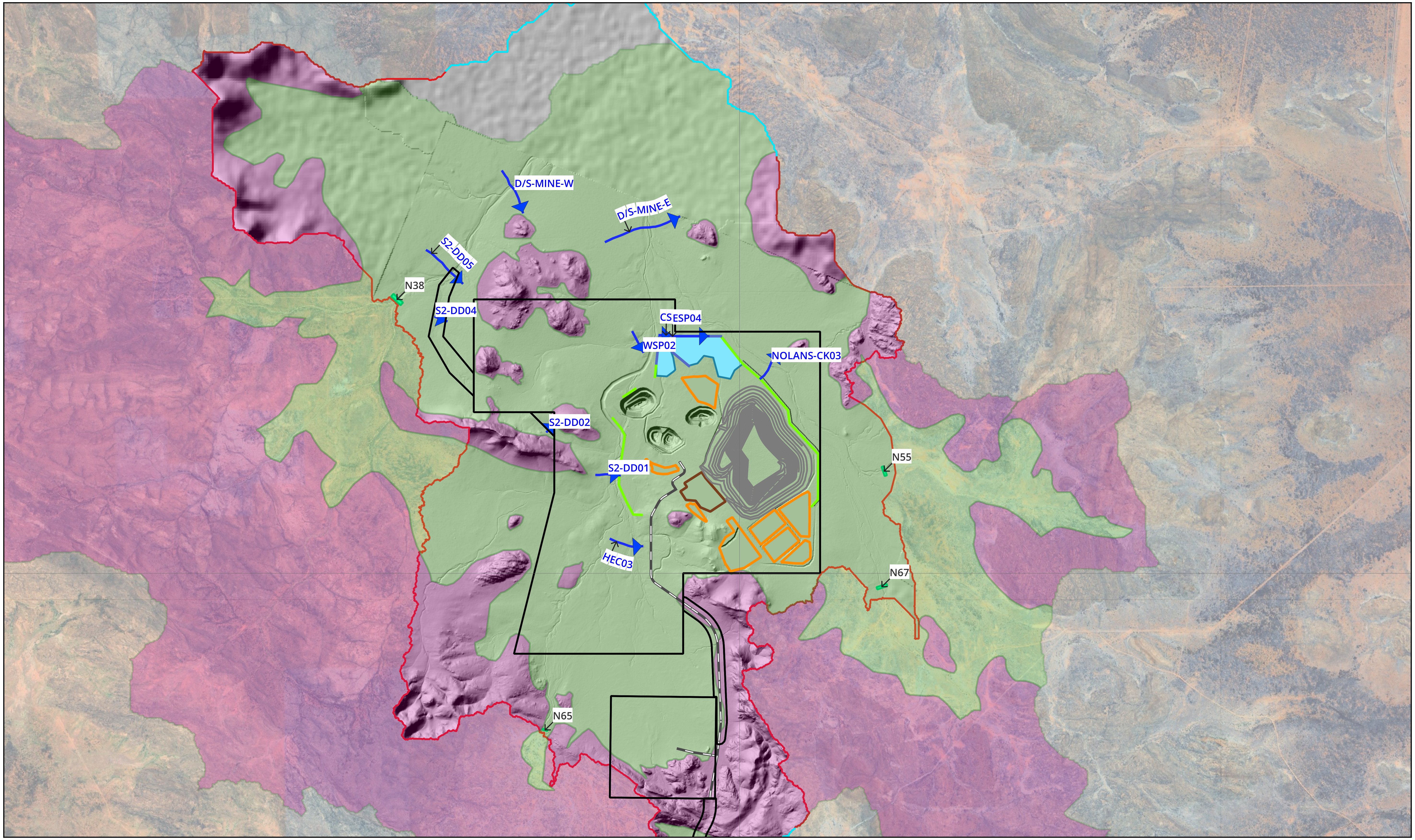
Notes:

1. Cross-section of 'XS01' and 'XS02' from Figure 6

2. Option 1 and Option 2 adopts a 'two-level' channel design - one for the 'lower' flows and the larger channel for the 'higher' flows

3. The 'low-flow' channel was designed to contain the 1 in 100 AEP expected flows and the 'high-flow' channel for the 1 in 1,000 AEP design flows

Arafura Resources Limited Nolans Rare Earth Project Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design STAGE 2 DIVERSION DRAIN OPTIONEERING CROSS-SECTIONS	
PSM4809-016R	FIGURE 7



Legend

- Lease Boundary
- Model Boundary
- Outlet Boundary Condition
- Initial Water Level Region
- Source Area
- Print-Output (PO) Lines
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Loss Zones

- Alluvial Floodplain Region
- Rock Region

Notes:
1. Aerial sourced from Google Satellite

Scale 1:45,000

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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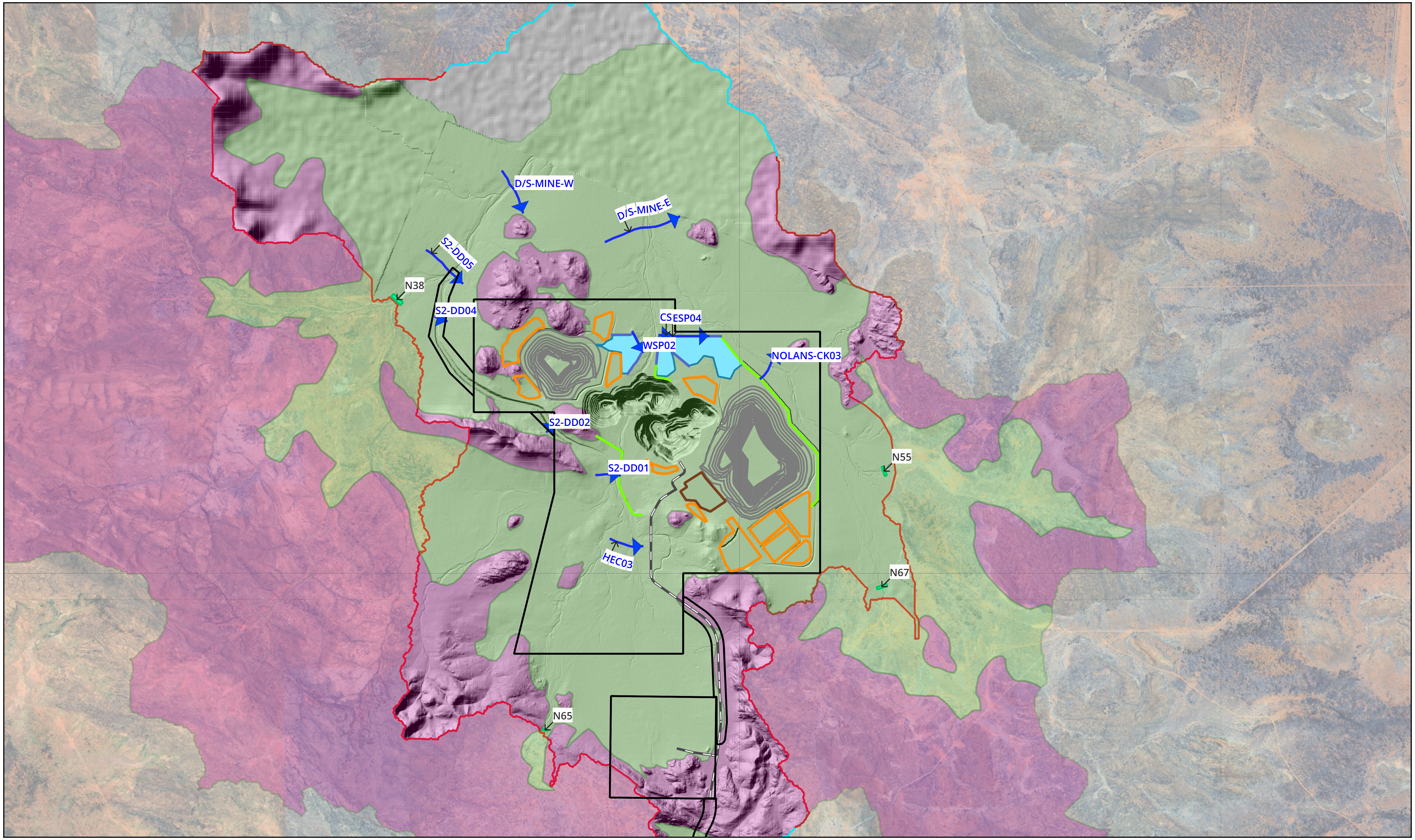
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1
TUFLOW MODEL SETUP

PSM4809-016R Figure 8



Legend

- Lease Boundary
- Model Boundary
- Outlet Boundary Condition
- Initial Water Level Region
- Source Area
- Print-Output (PO) Lines
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Loss Zones

- Alluvial Floodplain Region
- Rock Region

Notes:
1. Aerial sourced from Google Satellite

Scale 1:45,000

250 0 250 500 750 1,000 m

N

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2
TUFLOW MODEL SETUP

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	Date: 11 Jan 2024	Paper Size: A3	
	PSM4809-016R	Figure 9	

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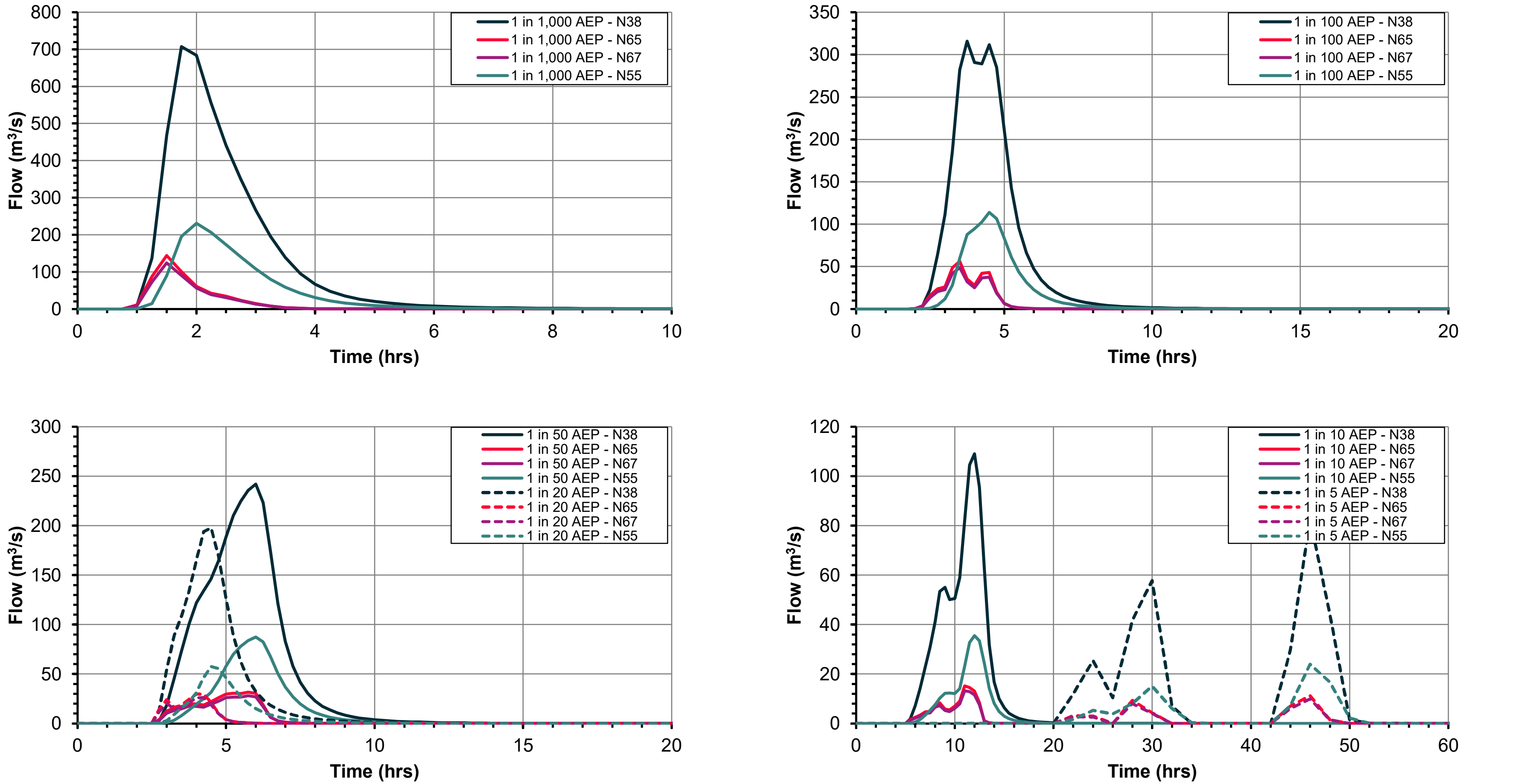


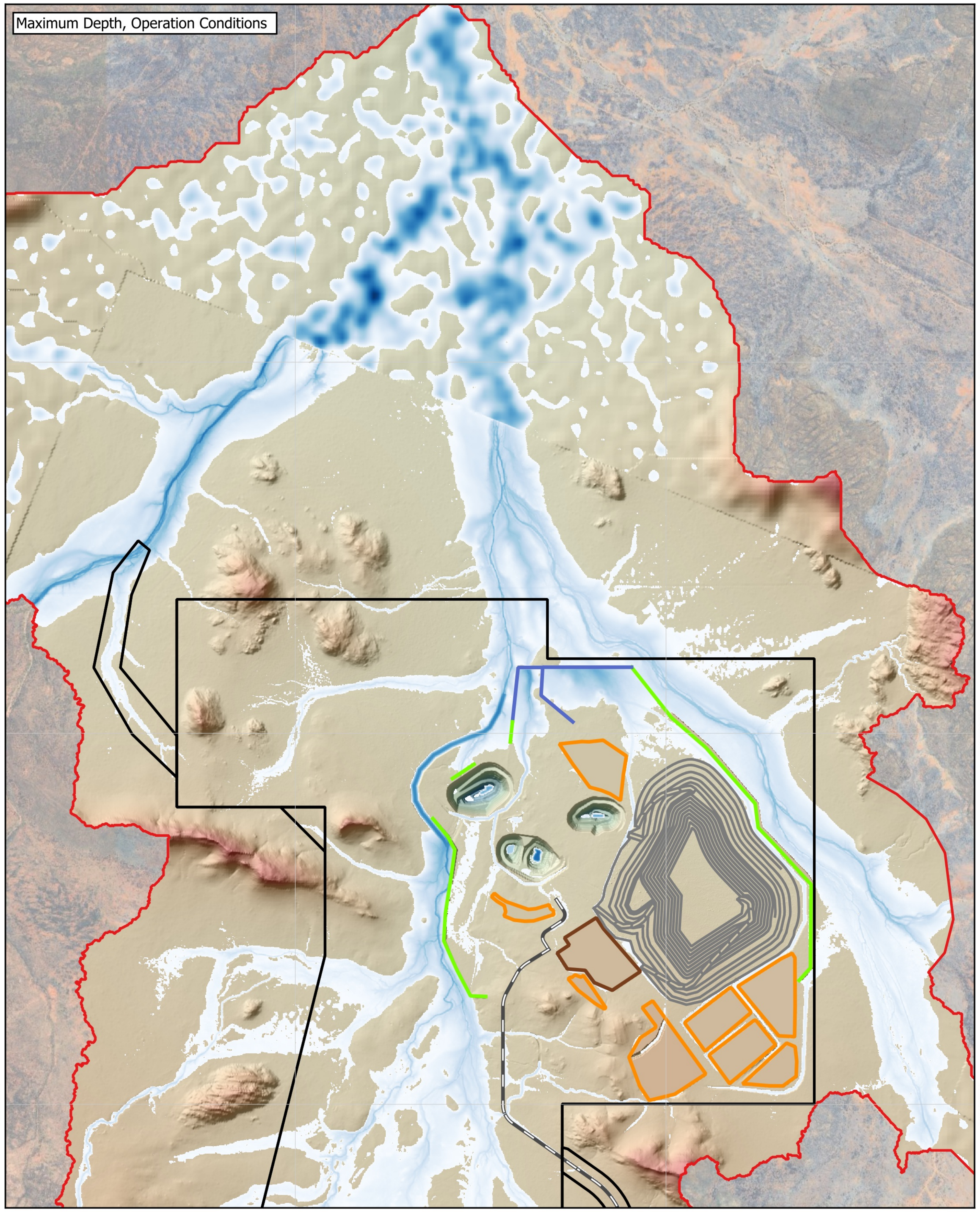
Notes:

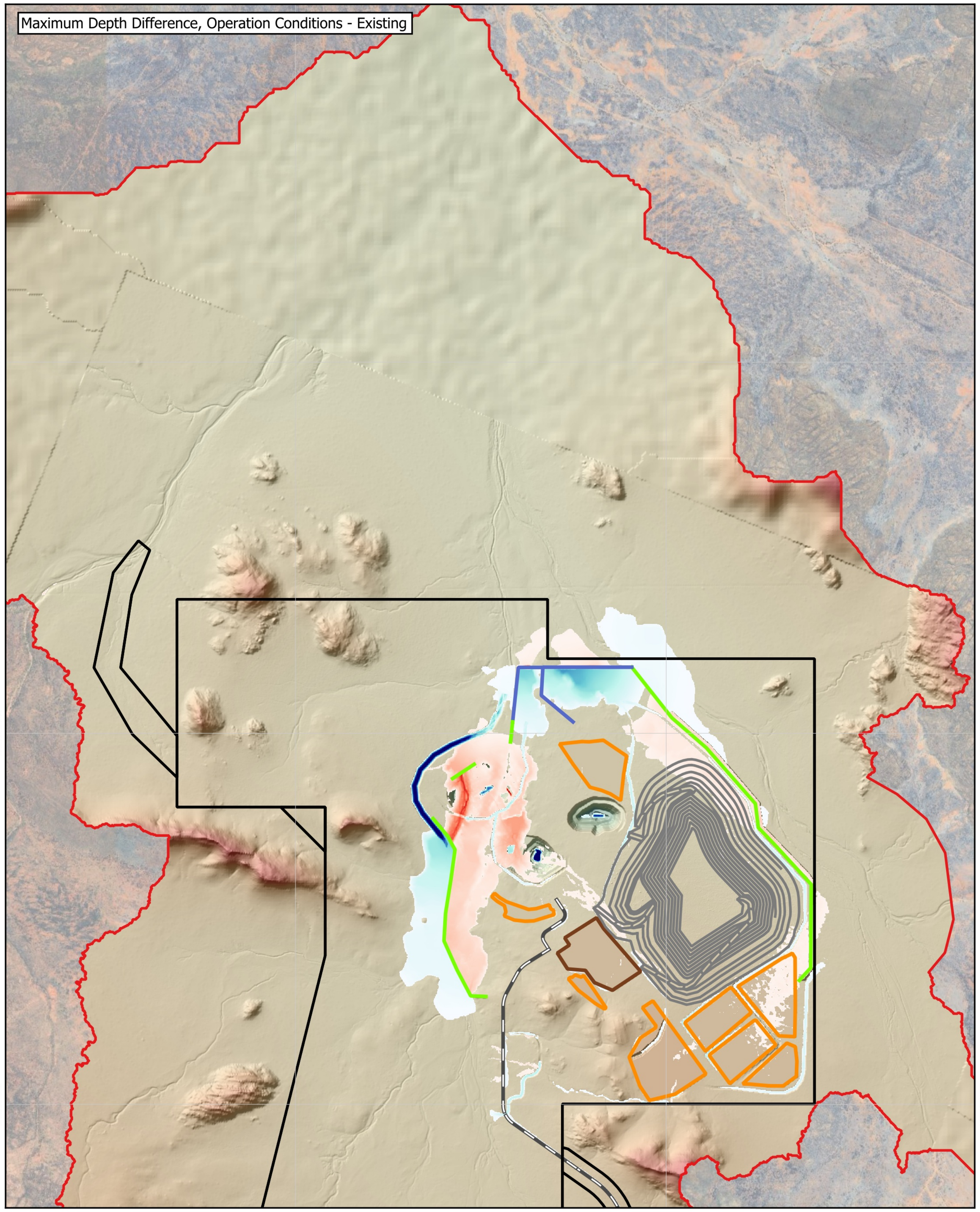
1. TUFLOW source area locations are presented in Figure 8 and 9
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

TUFLOW DESIGN HYDROGRAPH SOURCE AREAS

PSM4809-016R	Figure 10





Legend

- Lease Boundary
- Model Boundary
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Loss Classifications	Soil and Rock
Sediment Basin Initial Condition	Incipient Spill
Event Duration	3 Hour

Elevation (mAHD)
≥750
≤550

Maximum Depth (m)
≥5
0.1

Difference in Depth (m)
≥3
0.1
-0.1
≤-3

Scale 1:35,000

250 0 250 500 750 1,000 m

N

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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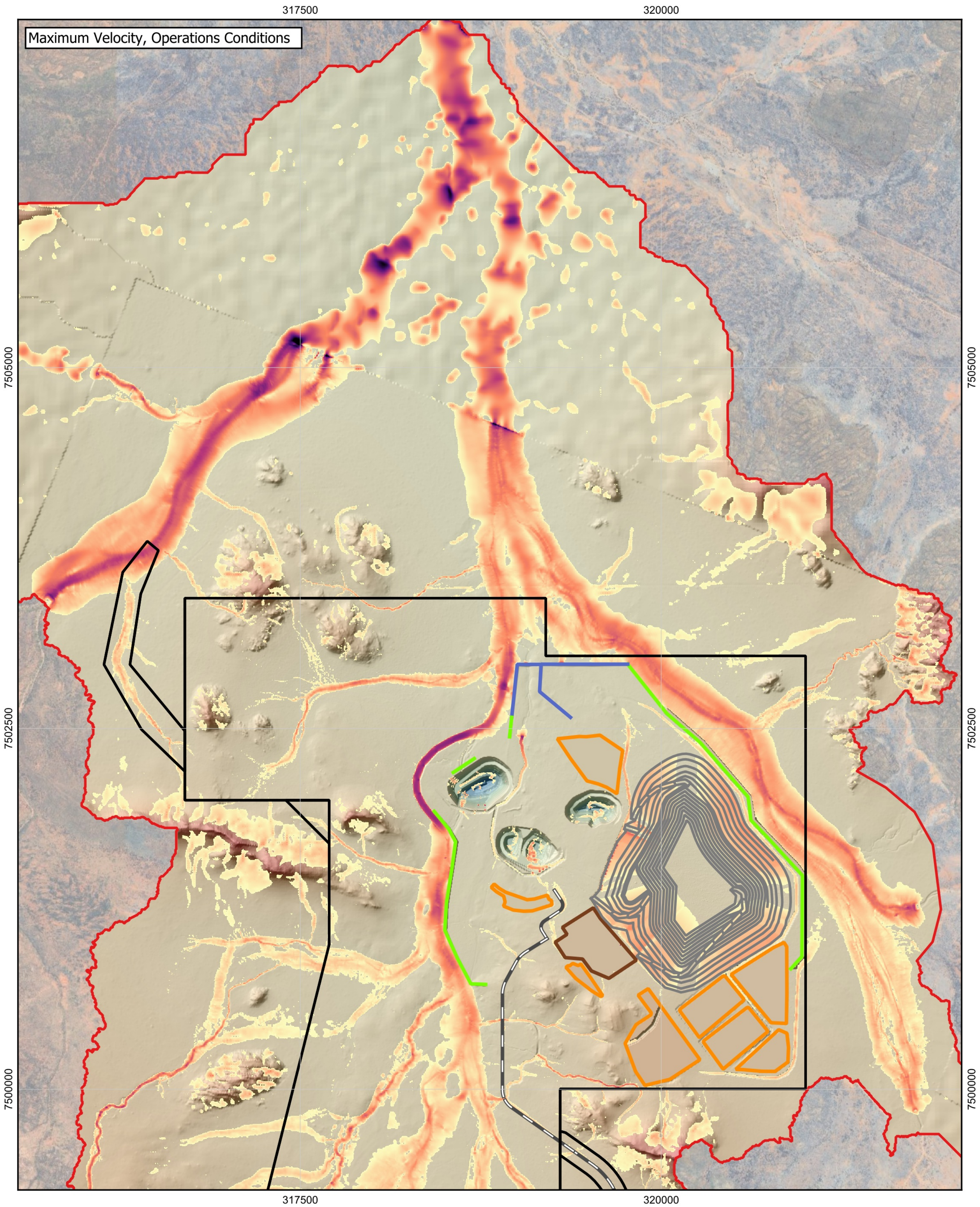
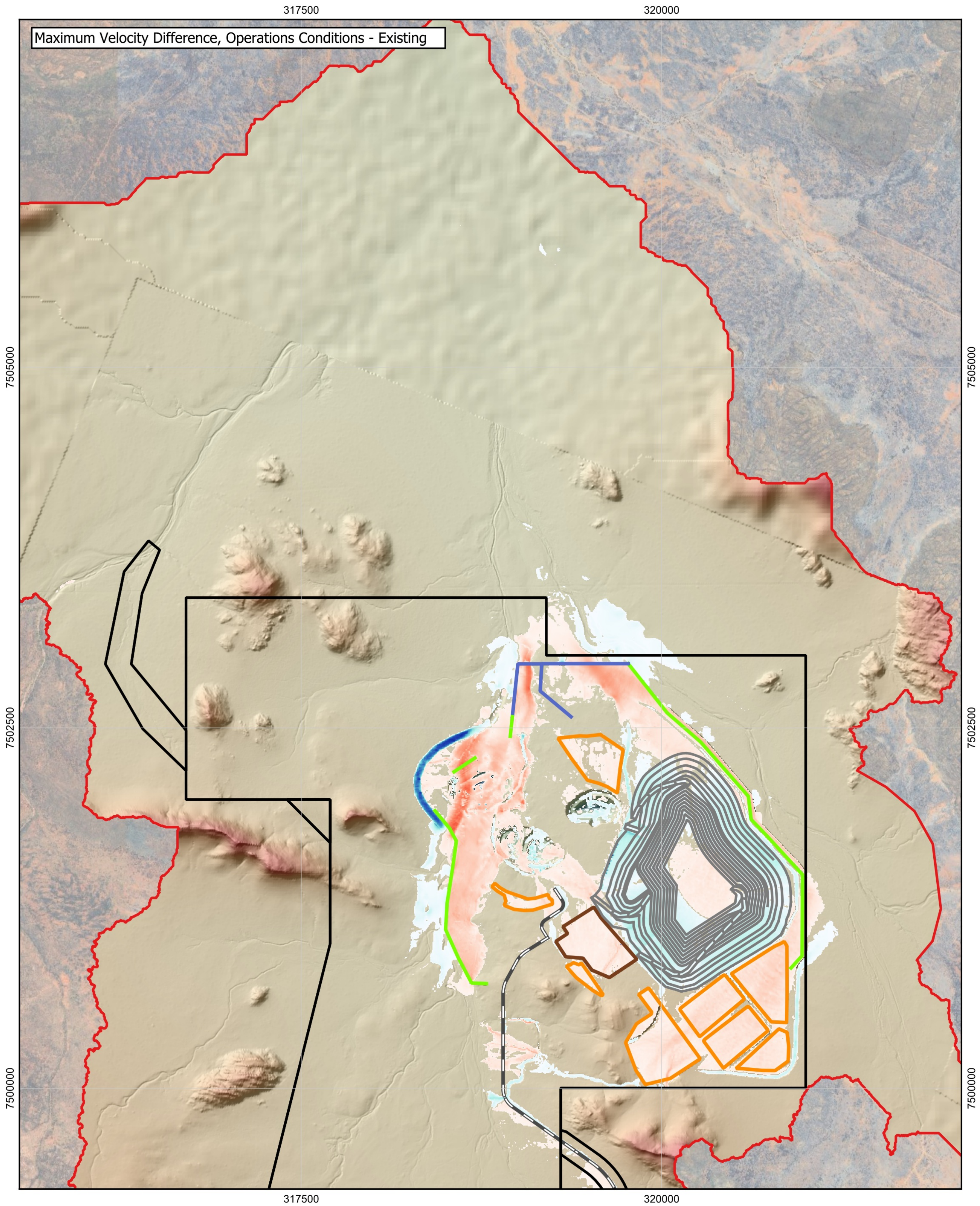
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 - 1 IN 1,000 AEP DESIGN EVENT MAXIMUM DEPTH AND DIFFERENCE

PSM4809-016R | Figure 11

\\anf.psm.local\anf-files\4000\PSM4809\PSM4809-016R\Eng\01 GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure11





Legend

- Lease Boundary
- Model Boundary
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Loss Classifications	Soil and Rock
Sediment Basin Initial Condition	Incipient Spill
Event Duration	3 Hour

Elevation (mAHD)
≥750
≤550

Maximum Velocity (m/s)
≥4
0.5

Difference in Velocity (m/s)
≥3
0.1
-0.1
≤-3

Scale 1:35,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 - 1 IN 1,000 AEP
DESIGN EVENT
MAXIMUM VELOCITY AND DIFFERENCE

PSM4809-016R

Figure 12

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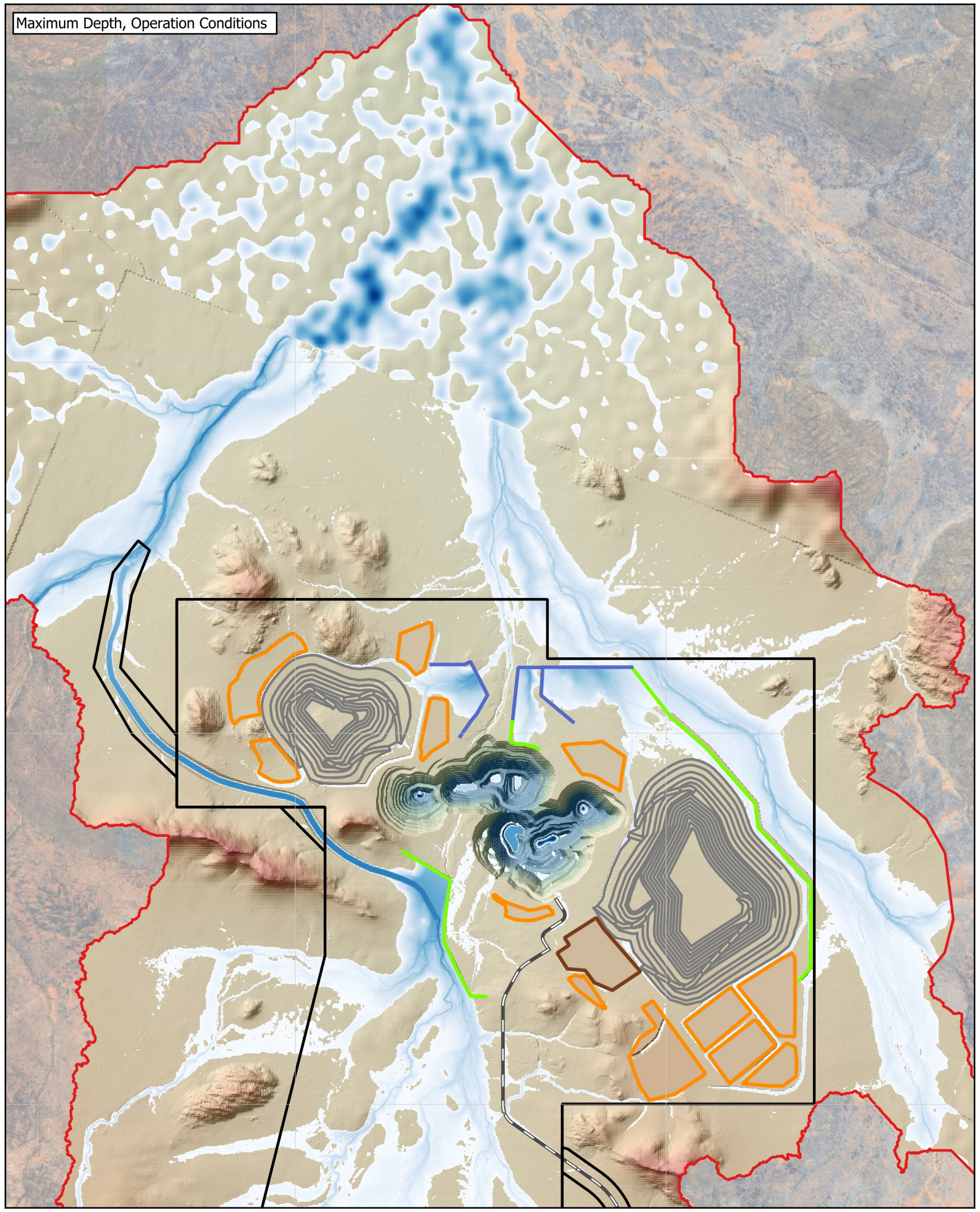

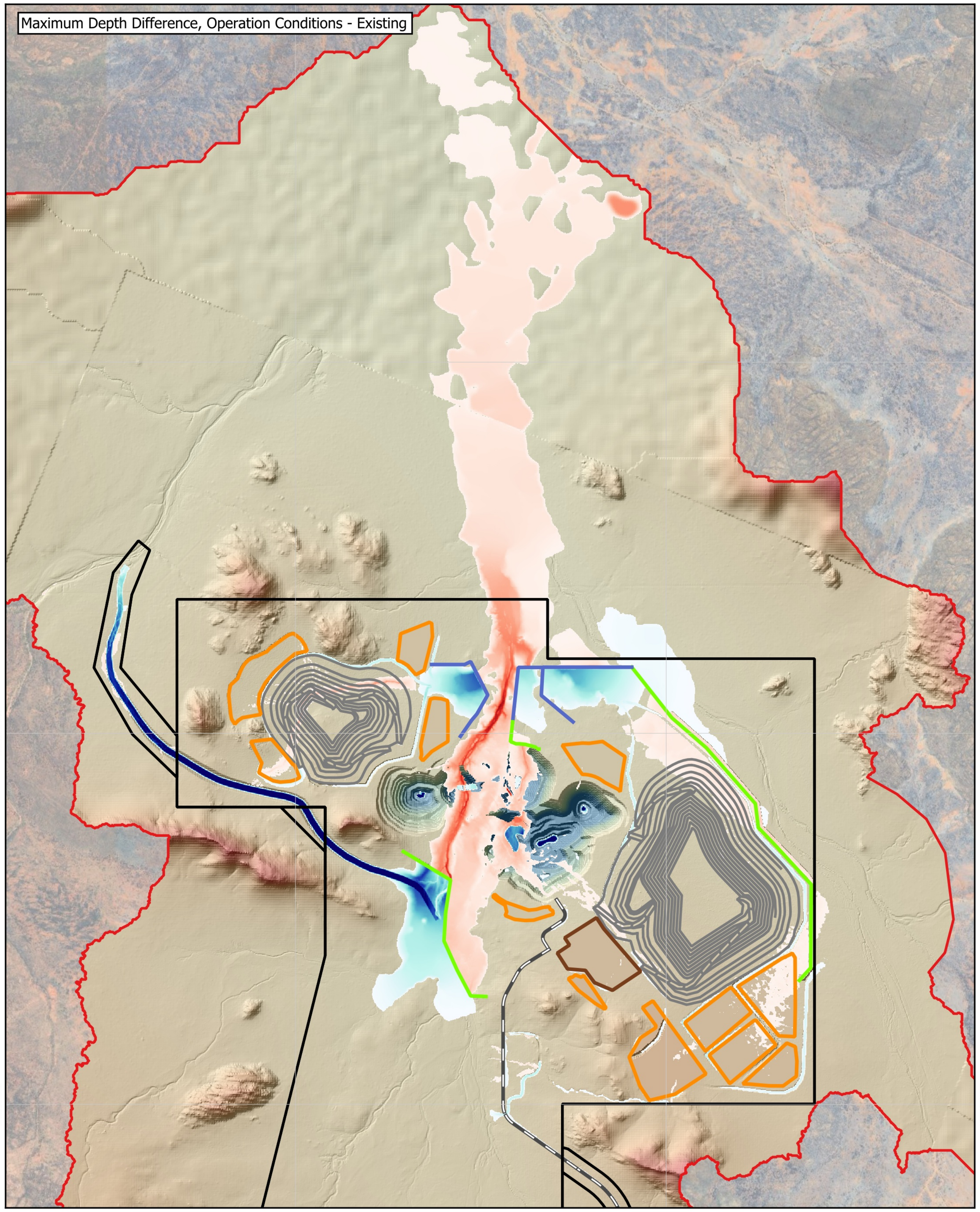

Legend

- Lease Boundary
- Model Boundary
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Loss Classifications	Soil and Rock
Sediment Basin Initial Condition	Incipient Spill
Event Duration	3 Hour

Elevation (mAHD)
≥750
≤550

Maximum Depth (m)
≥5
0.1

Difference in Depth (m)
≥3
0.1
-0.1
≤-3

Scale 1:35,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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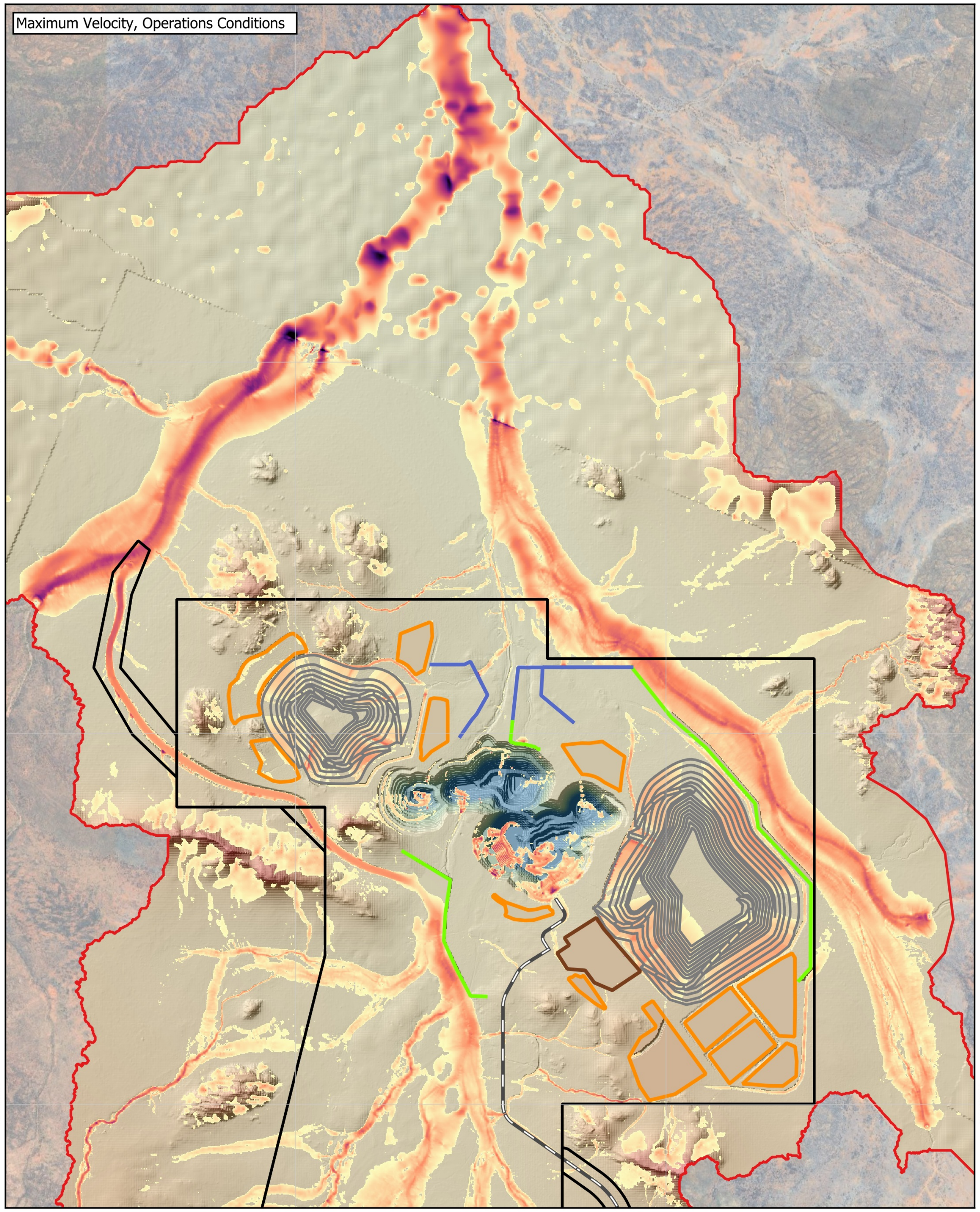
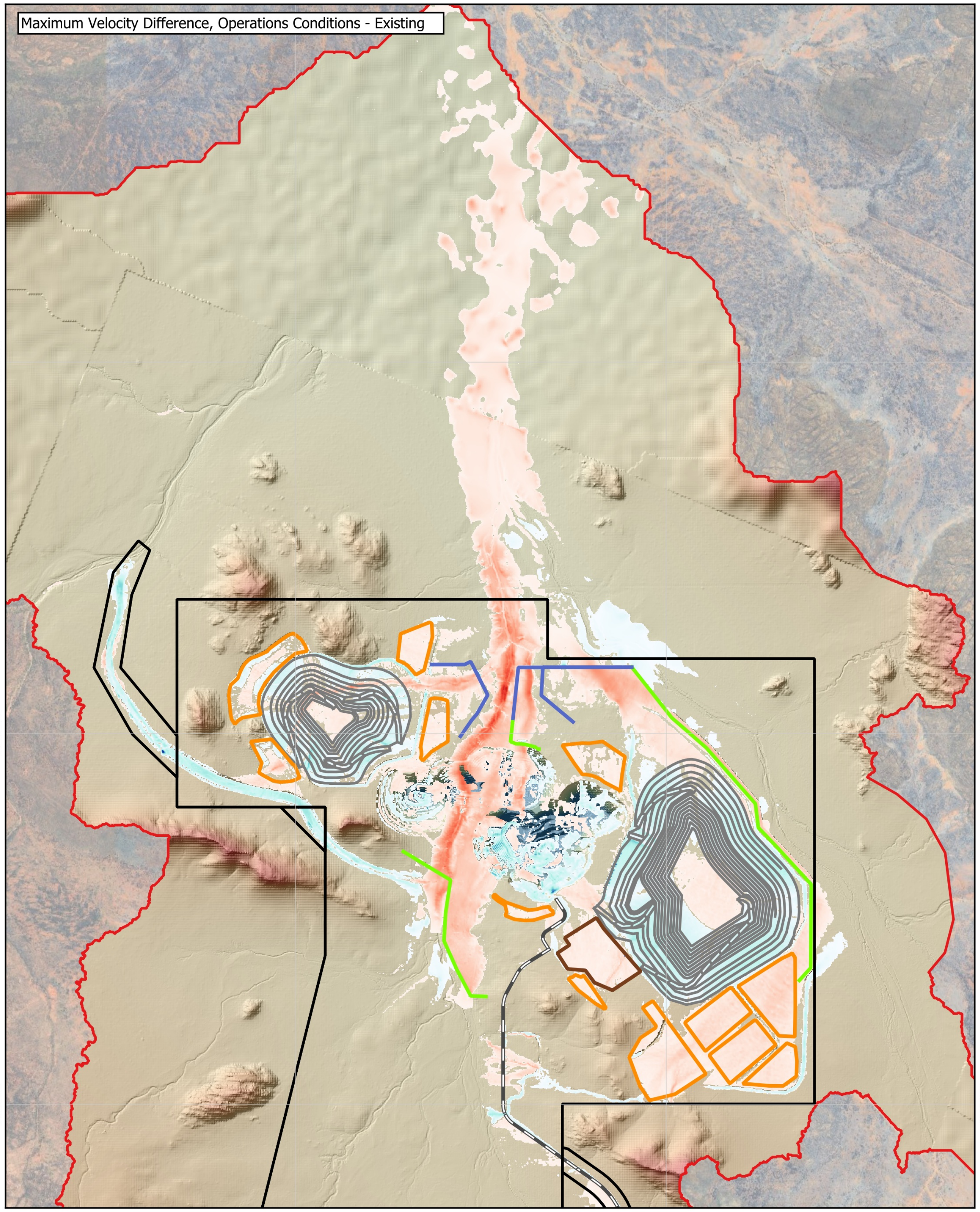
Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 - 1 IN 1,000 AEP
DESIGN EVENT
MAXIMUM DEPTH AND DIFFERENCE

PSM4809-016R | Figure 13

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01 GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure13





Legend

- Lease Boundary
- Model Boundary
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Loss Classifications	Soil and Rock
Sediment Basin Initial Condition	Incipient Spill
Event Duration	3 Hour

Elevation (mAHD) ≥750 ≤550

Maximum Velocity (m/s) ≥4 0.5

Difference in Velocity (m/s) ≥3 0.1 -0.1 ≤-3

Scale 1:35,000

N

250 0 250 500 750 1,000 m

Map Projection: GDA2020 / MGA zone 53 EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 - 1 IN 1,000 AEP DESIGN EVENT
MAXIMUM VELOCITY AND DIFFERENCE

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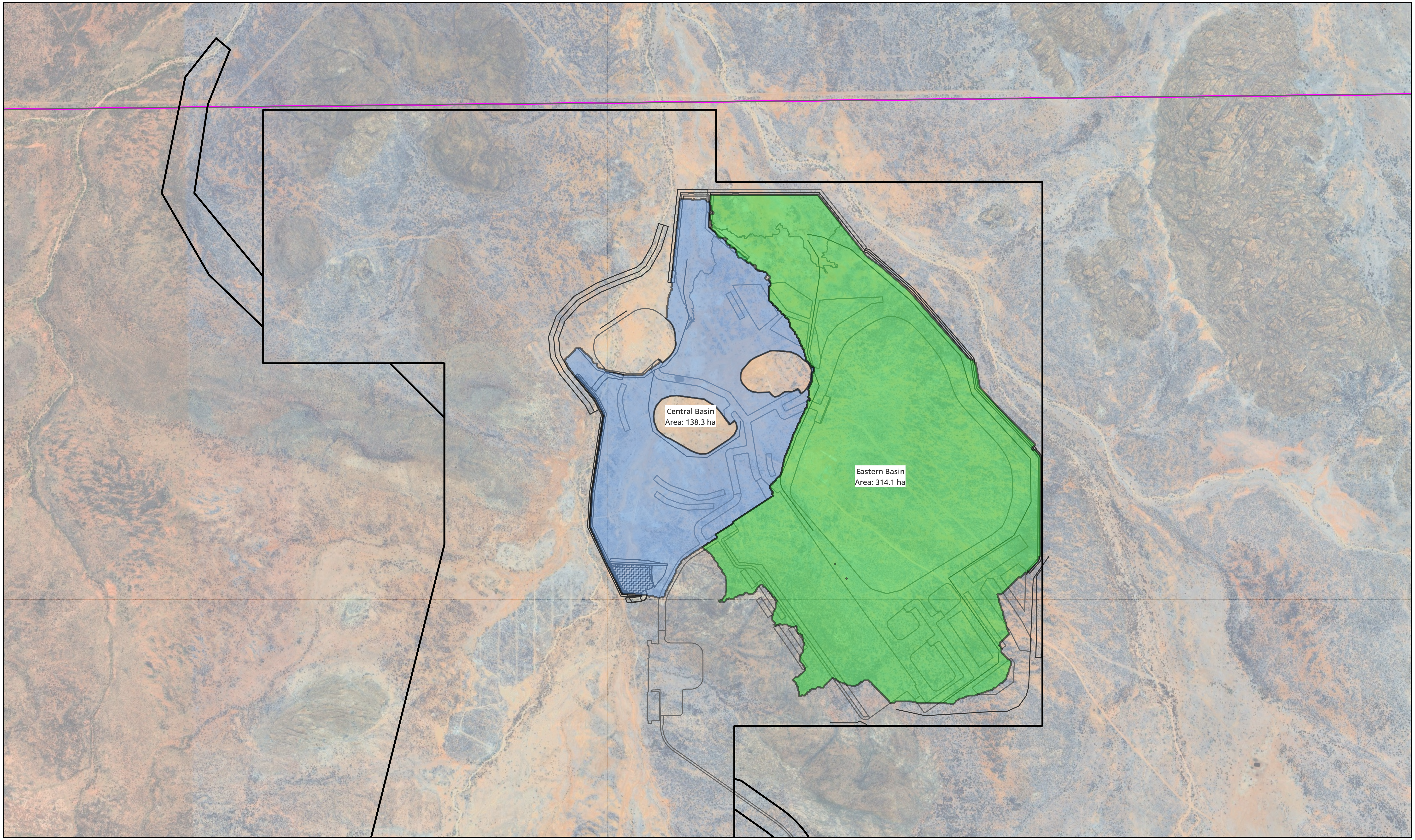
PSM4809-016R | Figure 14

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01 GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure14



Legend

- Lease Boundary
- Station Boundary
- Stage 2 General Layout

Catchment

- Central Basin
- Eastern Basin

Notes:
1. Aerial sourced from Google Satellite

Scale 1:20,000

100 0 100 200 300 400 m

N

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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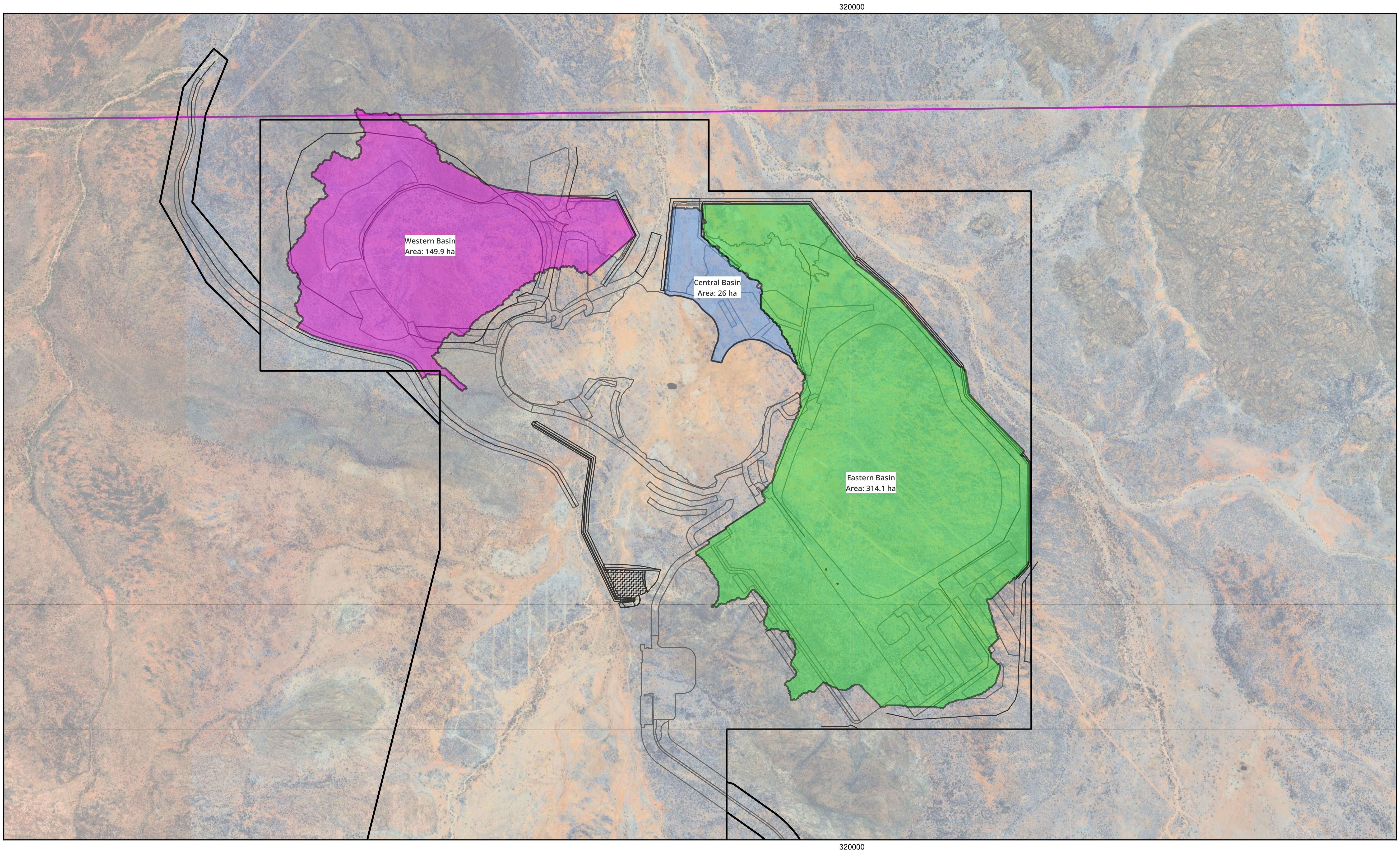
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1
SEDIMENT BASIN CATCHMENT

PSM4809-016R | Figure 15

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure15



Legend

Lease Boundary
Station Boundary
Stage 2 General Layout

Catchment

Central Basin
Eastern Basin
Western Basin

Notes:
1. Aerial sourced from Google Satellite

N

Scale 1:20,000

100 0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Revision: A

Date: 11 Jan 2024

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Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2
SEDIMENT BASIN CATCHMENT

PSM4809-016R

Figure 16

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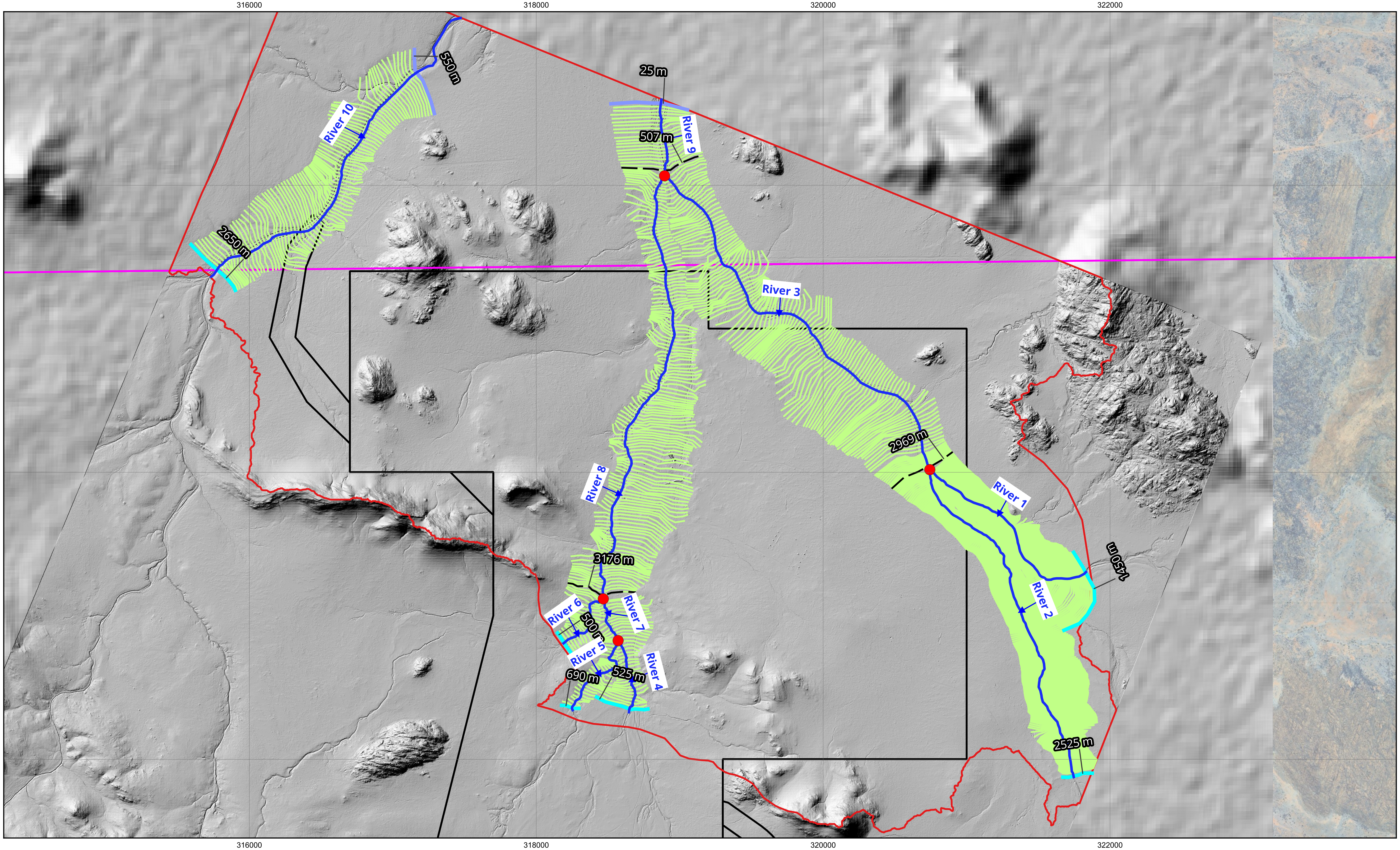

Legend

- Lease Boundary
- Station Boundary
- Model Boundary
- River Centreline
- 1D Cross-Section Lines
- Start of River
- Upstream Boundary Condition
- Downstream Boundary Condition
- Junction

Notes:
1. Cross-section chainage order descends from upstream to downstream

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection: GDA2020 / MGA zone 53 EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS BASELINE
1D MODEL SETUP

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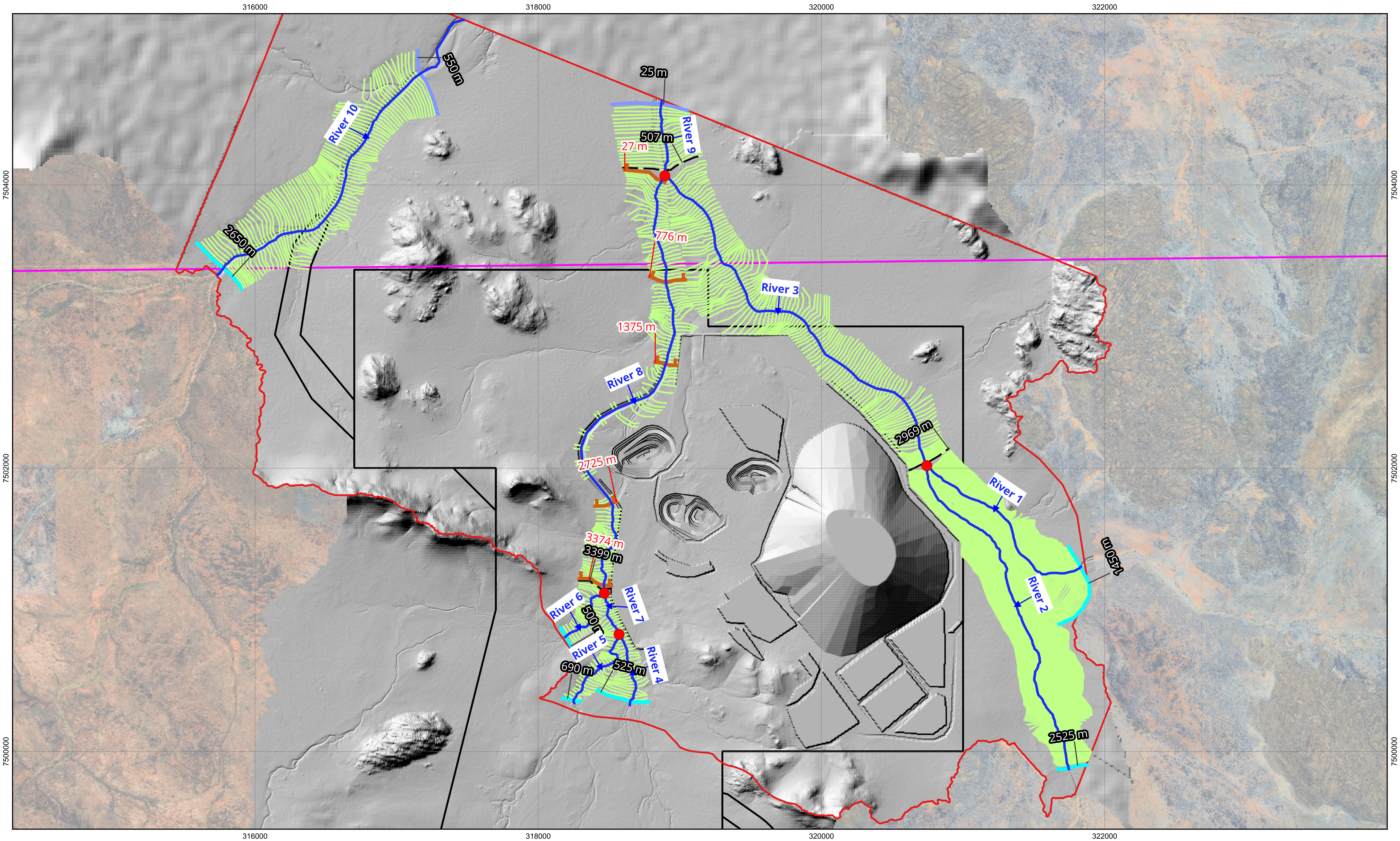
PSM4809-016R | Figure 17

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure17



Legend

- Lease Boundary
- Station Boundary
- Model Boundary
- River Centreline
- 1D Cross-Section Lines
- Start of River
- Upstream Boundary Condition
- Downstream Boundary Condition
- Junction
- Output Cross-Section

Notes:
1. Cross-section chainage order descends from upstream to downstream

N

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 1
1D MODEL SETUP

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Figure 18

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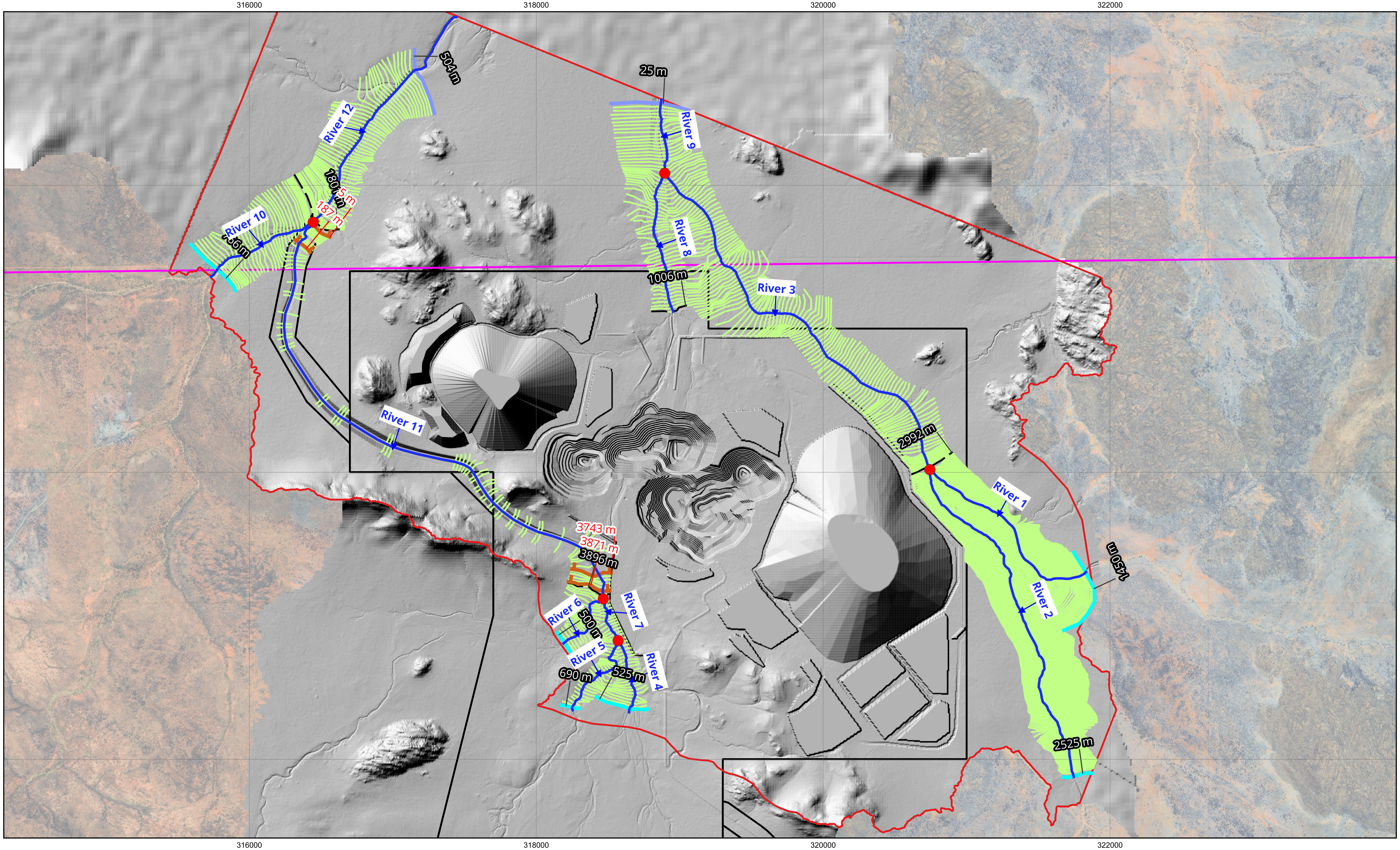

Legend

- Lease Boundary
- Station Boundary
- Model Boundary
- River Centreline
- 1D Cross-Section Lines
- Start of River
- Upstream Boundary Condition
- Downstream Boundary Condition
- Junction
- Output Cross-Section

Notes:
1. Cross-section chainage order descends from upstream to downstream

Scale 1:25,000

150 0 150 300 450 600 m

N

Map Projection:
GDA2020 / MGA zone 53
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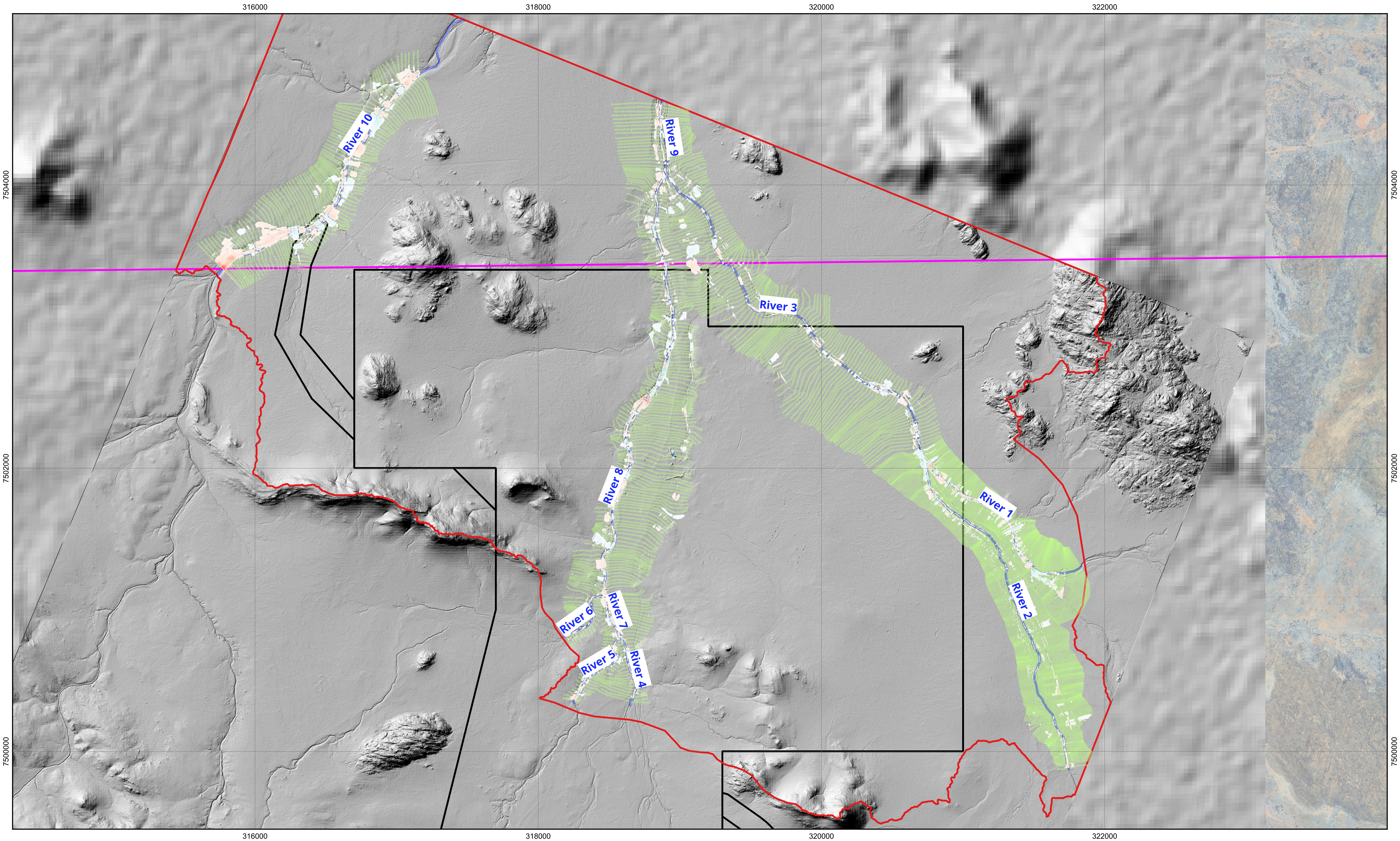
Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
1D MODEL SETUP

PSM4809-016R | Figure 19

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure19



Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

N

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
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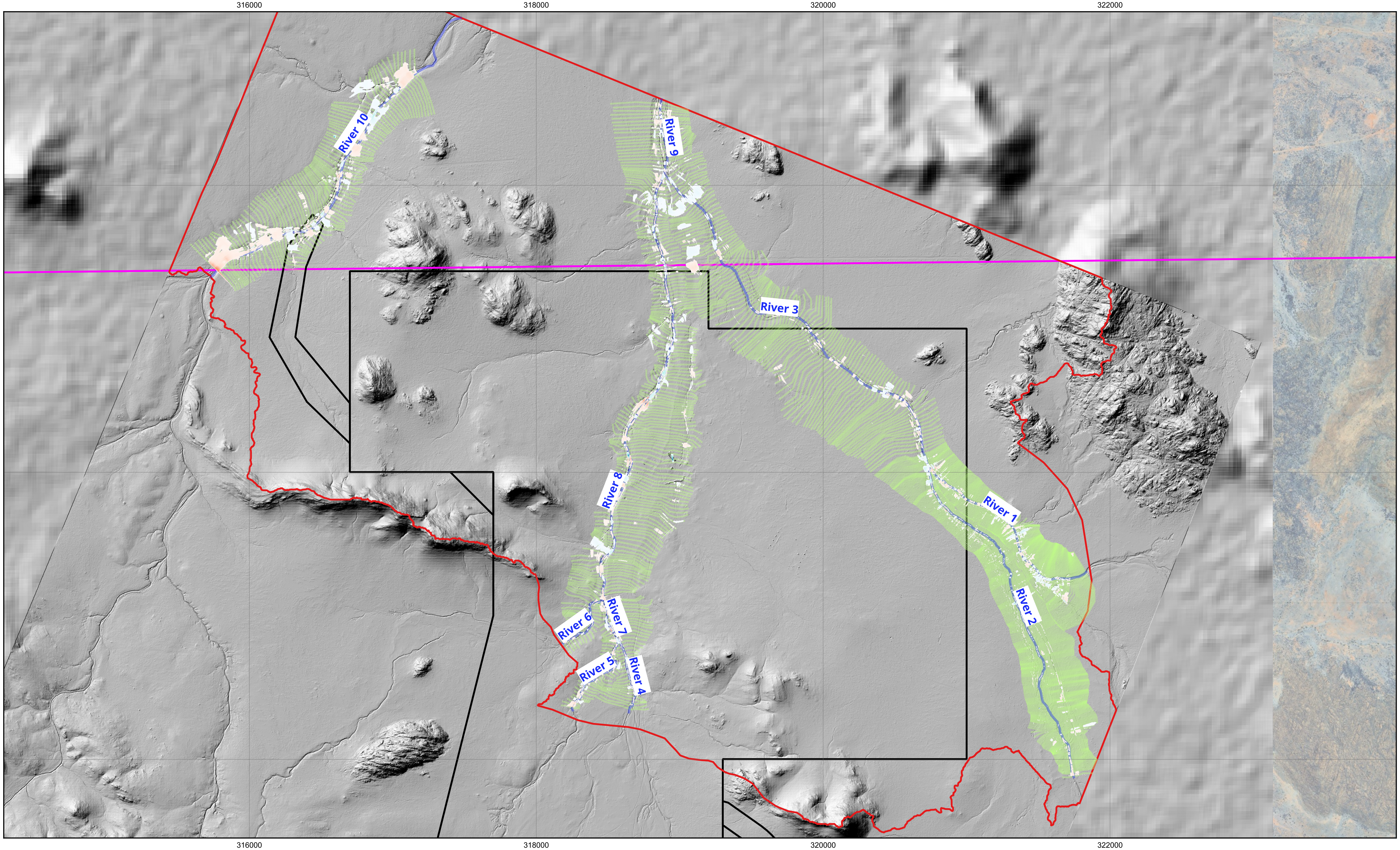
Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS BASELINE SCOUR MAP
1 IN 5 AEP - MODEL 1

PSM4809-016R | Figure 20



Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
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Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS BASELINE SCOUR MAP
1 IN 10 AEP - MODEL 1

PSM4809-016R

Figure 21

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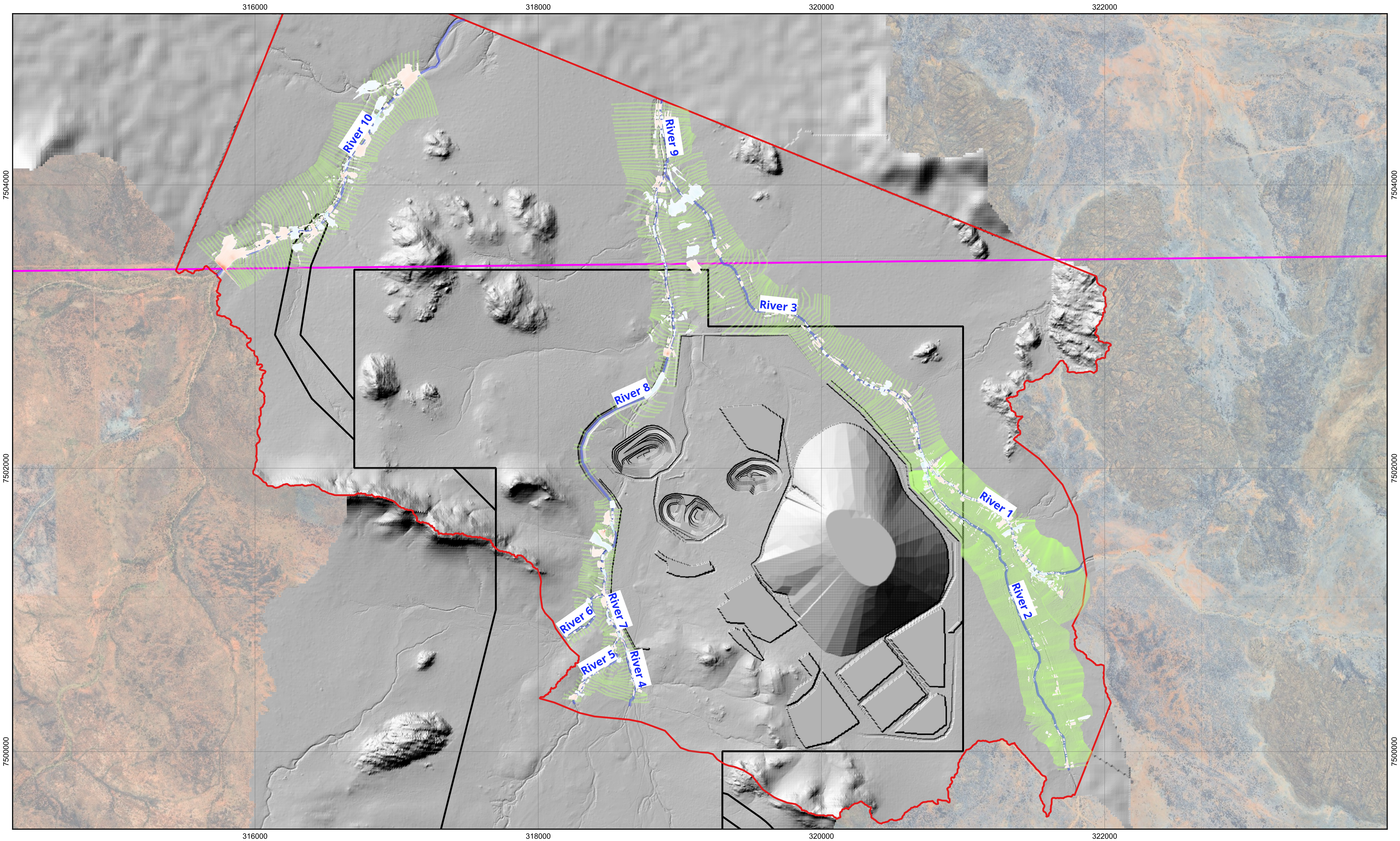

Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 1
SCOUR MAP
1 IN 10 AEP - MODEL 3

PSM4809-016R | Figure 22

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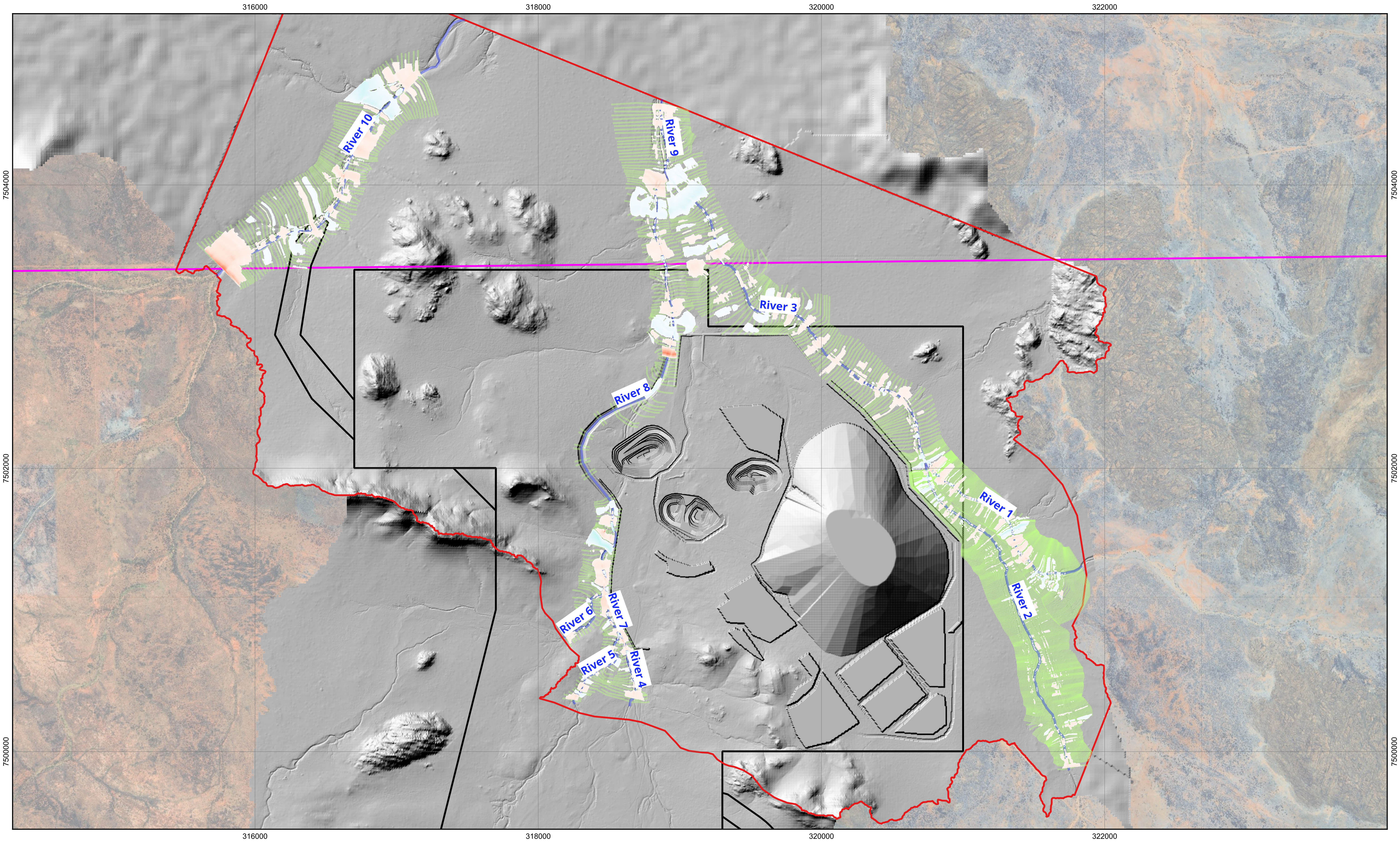


Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

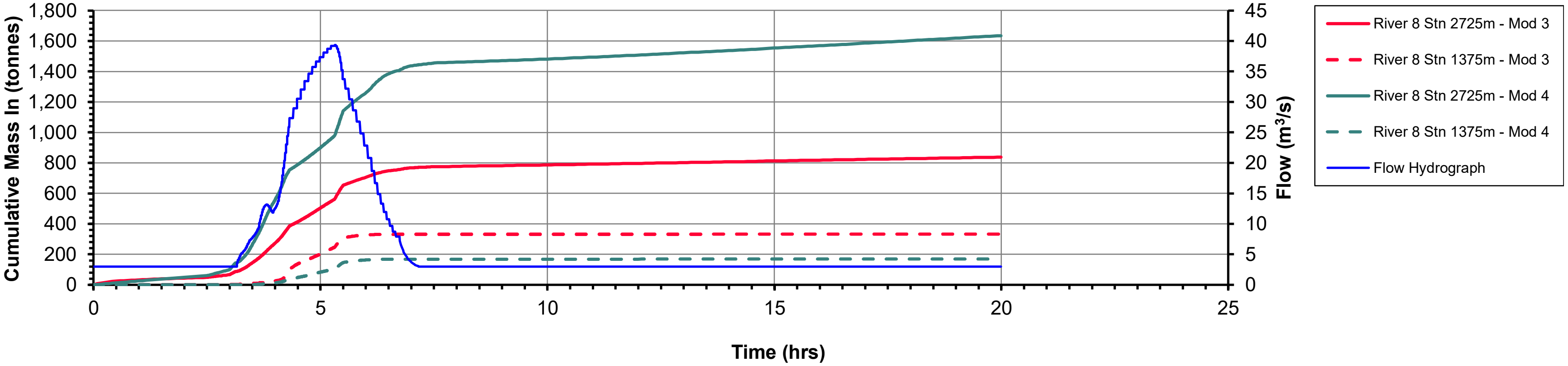
Created By:	Revision:
PSM	A
Date: 02 Feb 2024	Paper Size: A3

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

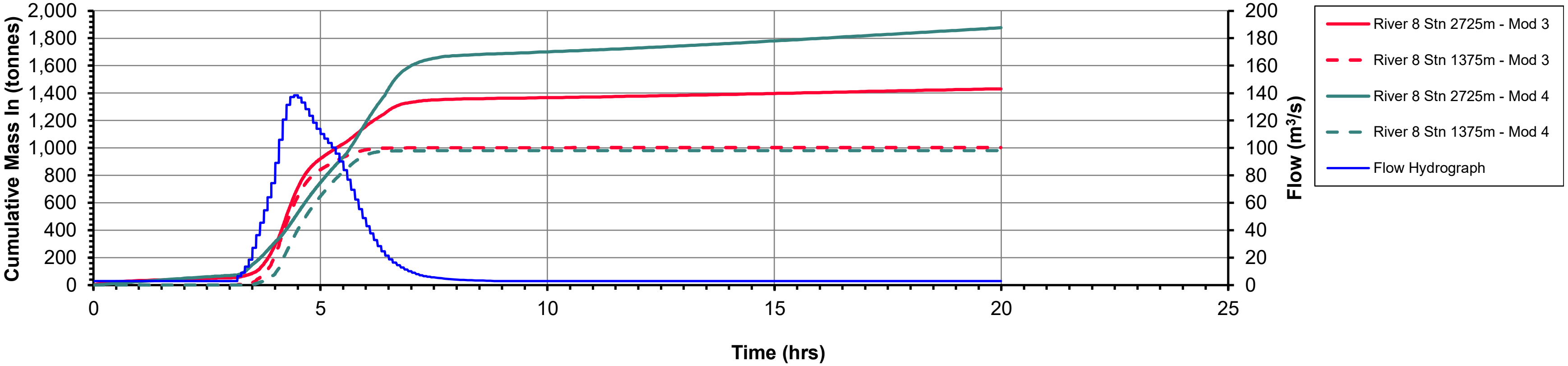
HEC-RAS STAGE 1
SCOUR MAP
1 IN 100 AEP - MODEL 3

PSM4809-016R | Figure 23

1 IN 10 AEP



1 IN 100 AEP



Notes:

1. Cross-section locations are highlighted in plan in Figure 18
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL

Arafura Resources Limited Nolans Rare Earth Project Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design	
HEC-RAS STAGE 1 DIVERSION DRAIN MASS IN - MODEL 3 & 4	
PSM4809-016R	Figure 24

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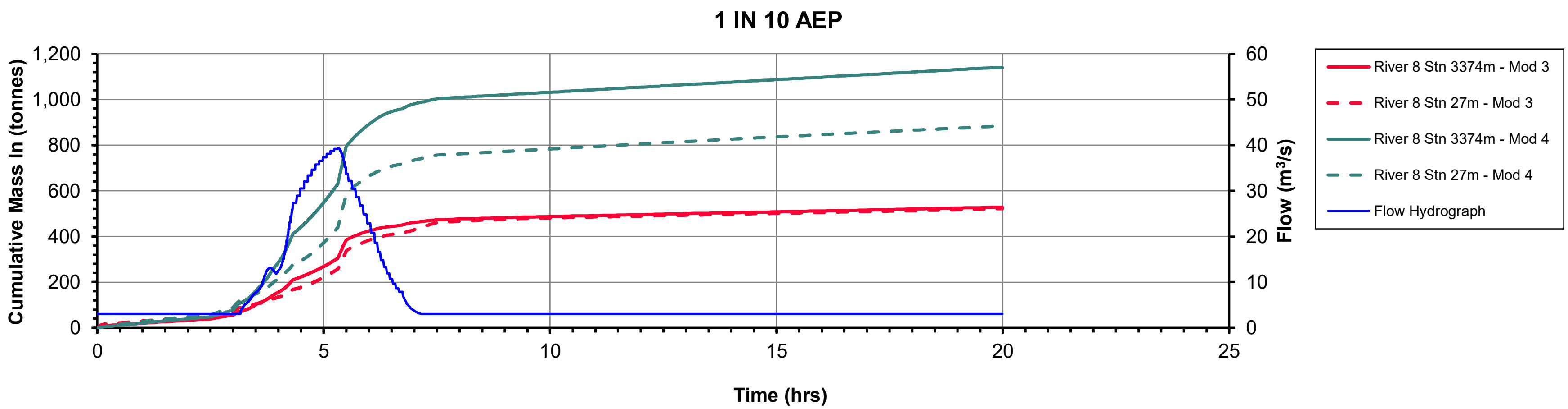

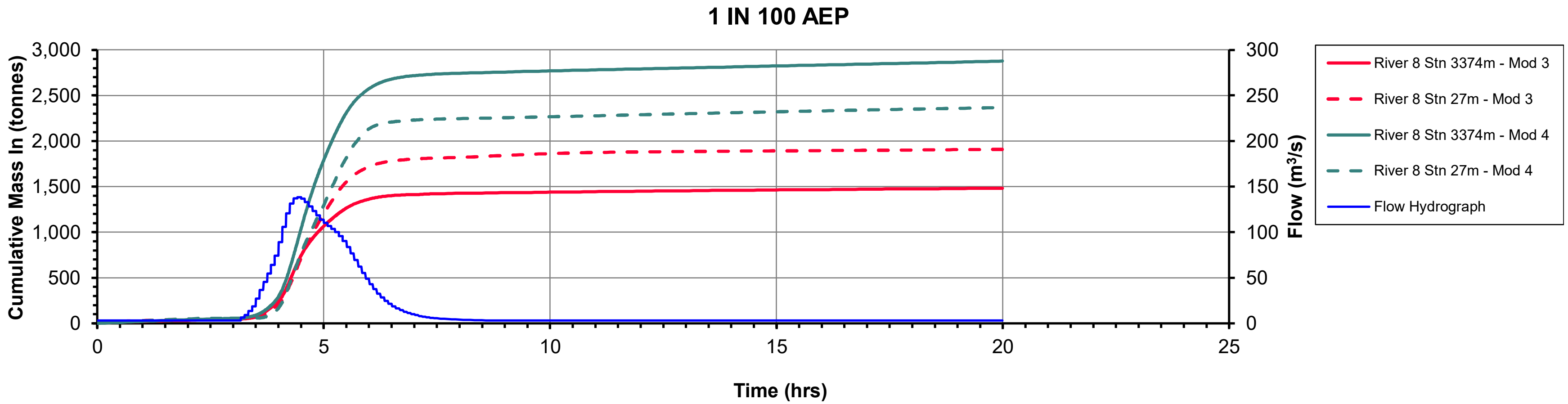

Notes:

1. Cross-section locations are highlighted in plan in Figure 18
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL

PSM

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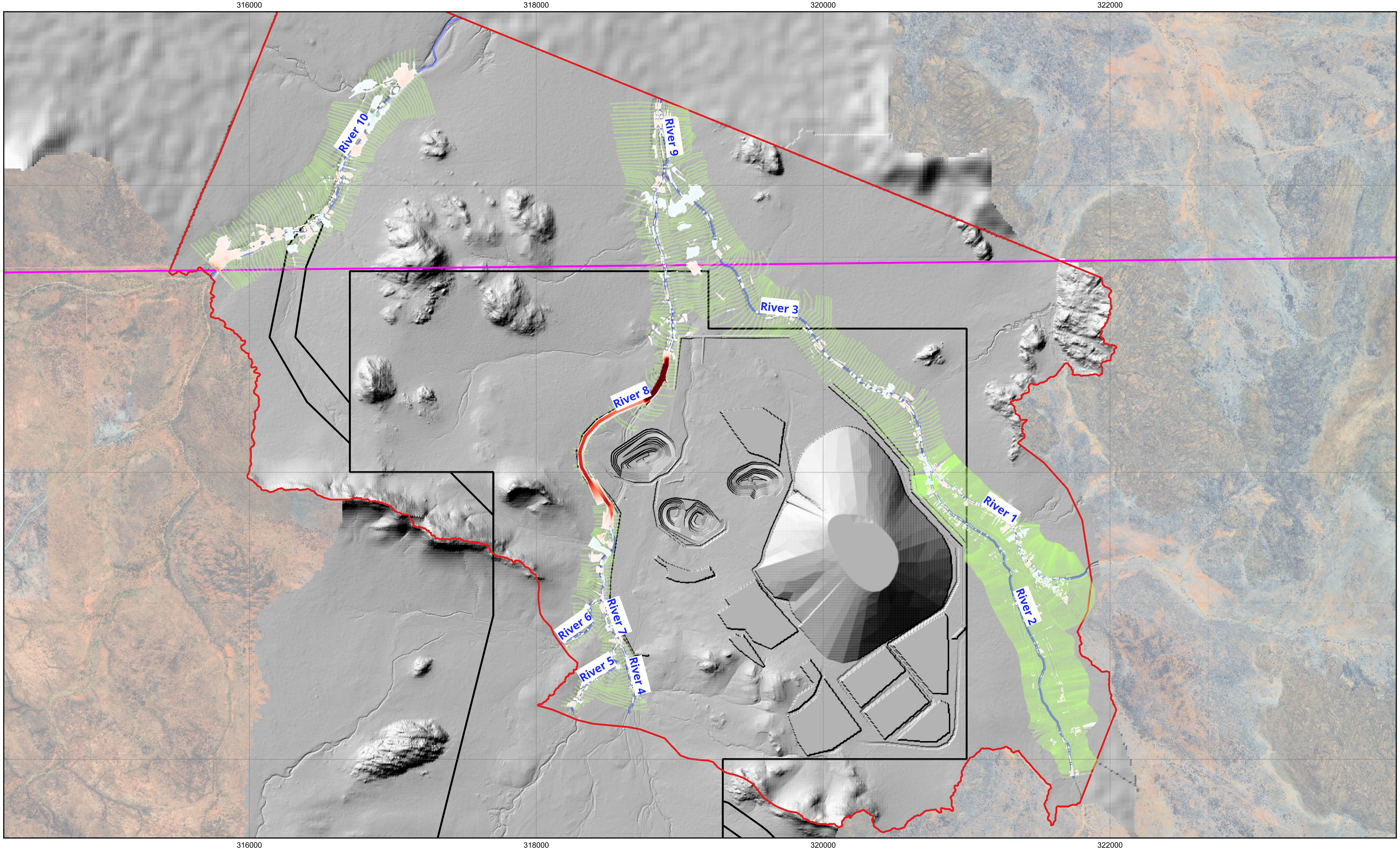
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 1
RIVER 8 MASS IN - MODEL 3 & 4

PSM4809-016R	Figure 25



Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)
≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

N

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 1
SCOUR MAP
1 IN 10 AEP - MODEL 1

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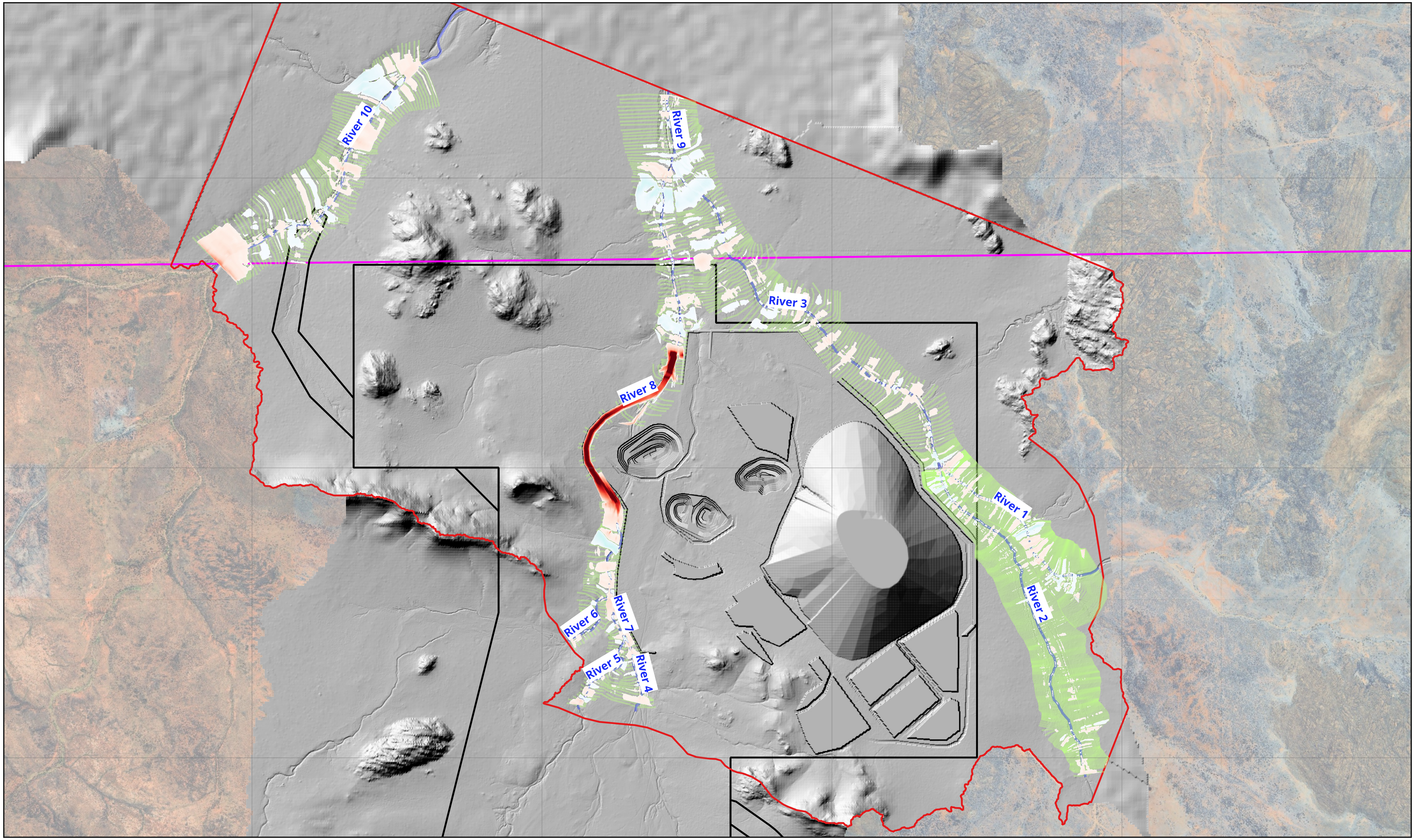
Date: 02 Feb 2024	Paper Size: A3

PSM4809-016R Figure 26

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure26



Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

N

PSM

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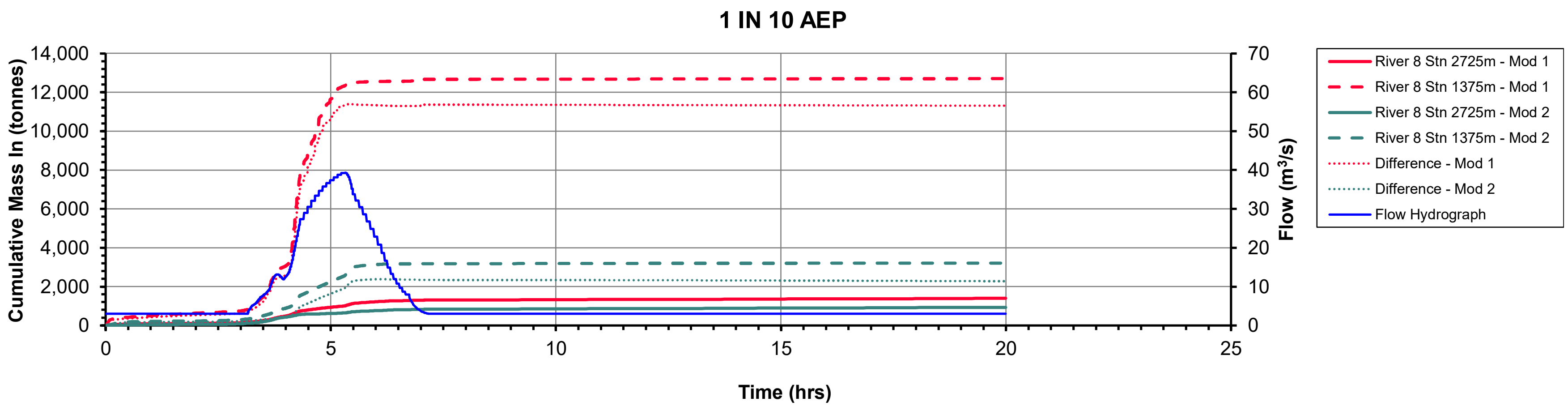
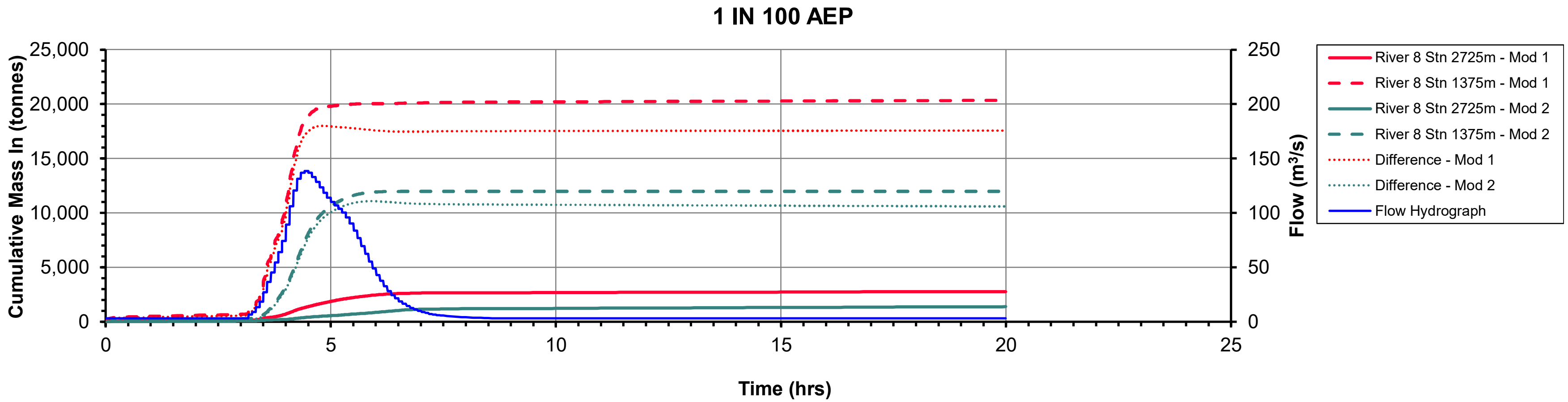
Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 1
SCOUR MAP
1 IN 100 AEP - MODEL 1

PSM4809-016R | Figure 27

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure27

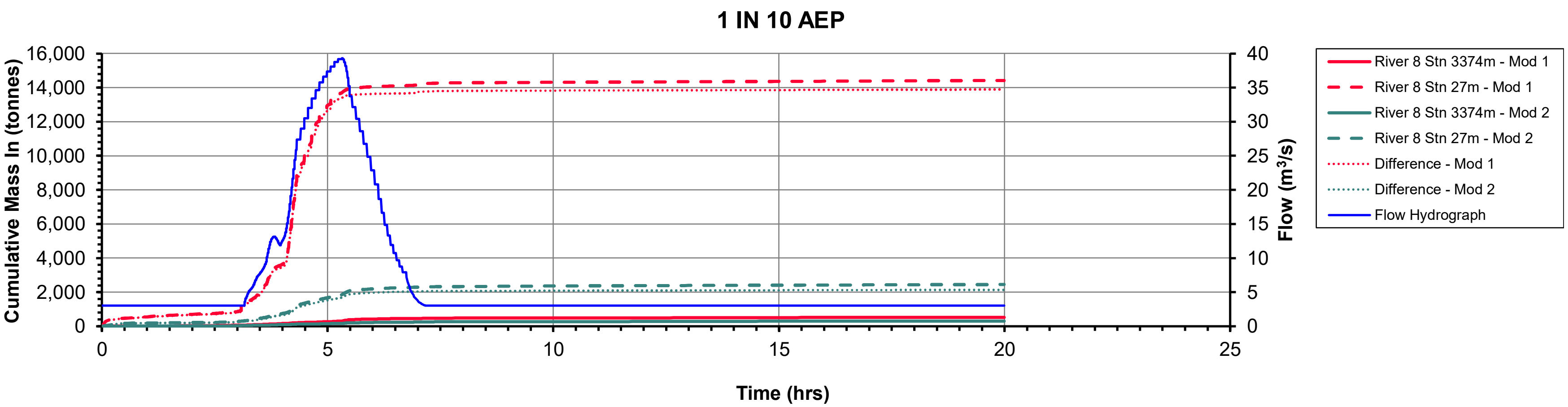


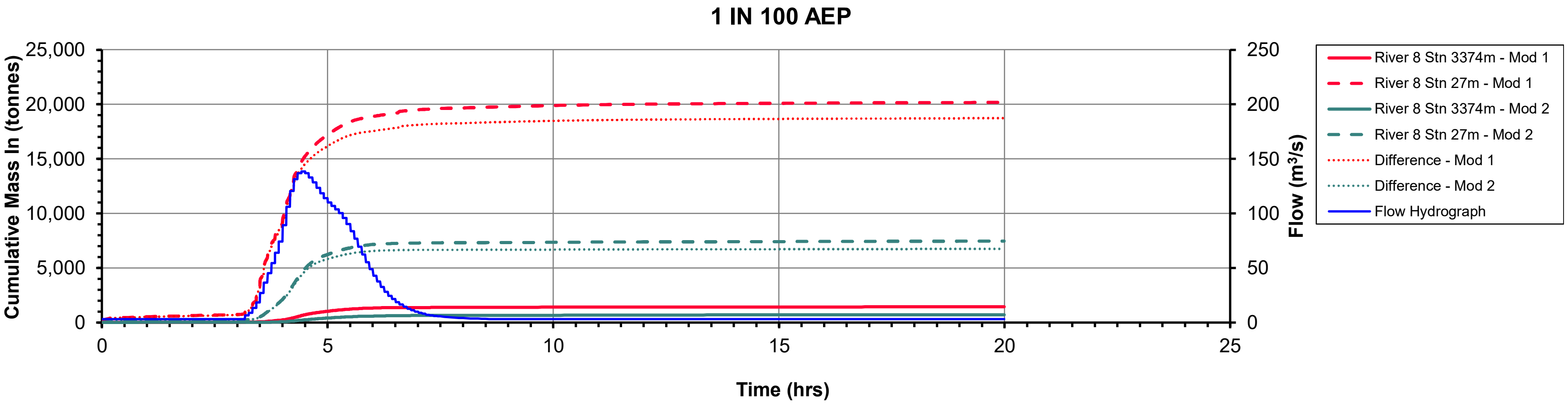


Notes:

1. Cross-section locations are highlighted in plan in Figure 18
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL
4. Difference = Downstream Mass - Upstream Mass

Arafura Resources Limited Nolans Rare Earth Project Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design	
HEC-RAS STAGE 1 DIVERSION DRAIN MASS IN - MODEL 1 & 2	
PSM4809-016R	Figure 28





Notes:

1. Cross-section locations are highlighted in plan in Figure 18
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL
4. Difference = Downstream Mass - Upstream Mass

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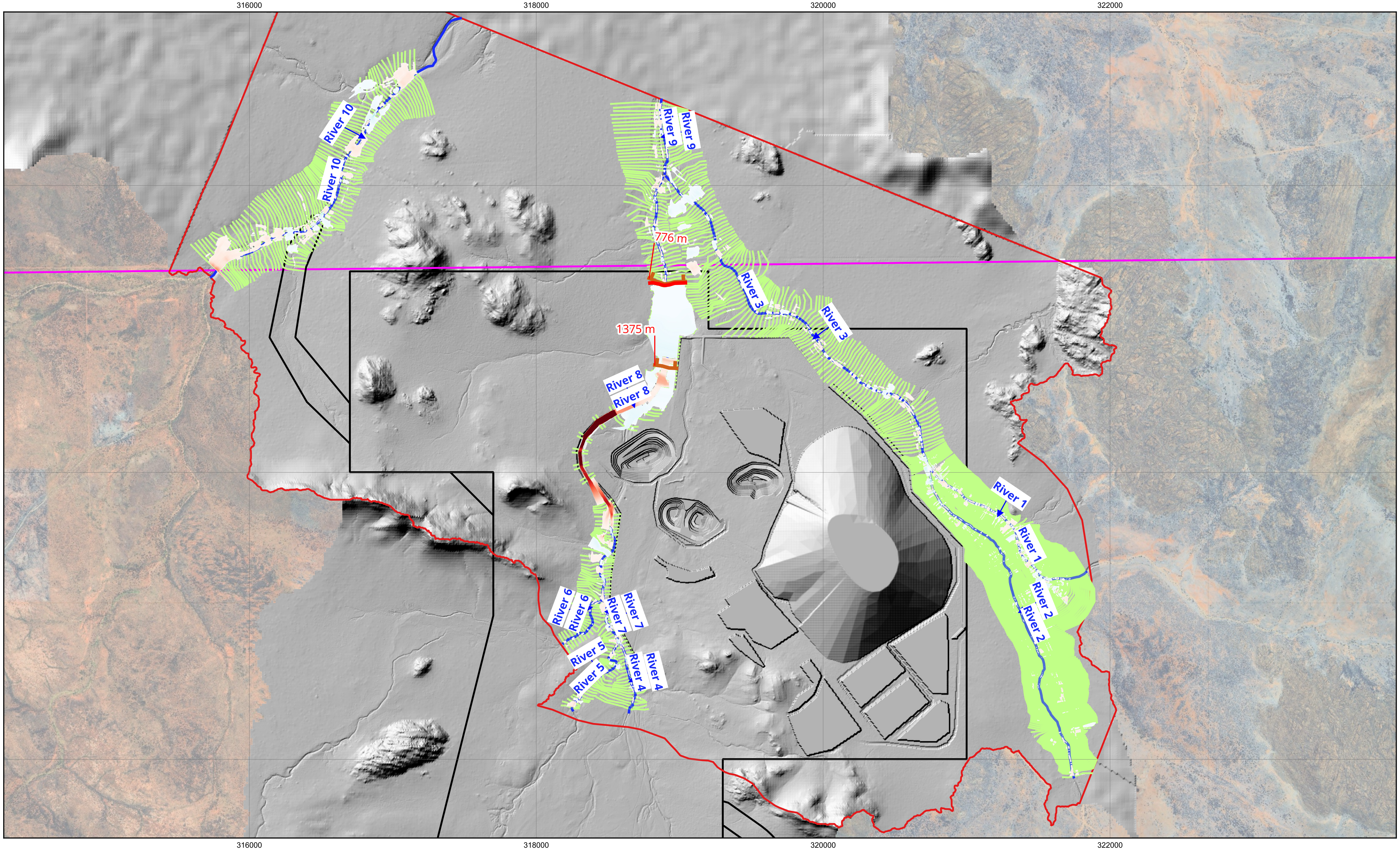
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 1
RIVER 8 MASS IN - MODEL 1 & 2

PSM4809-016R	Figure 29



Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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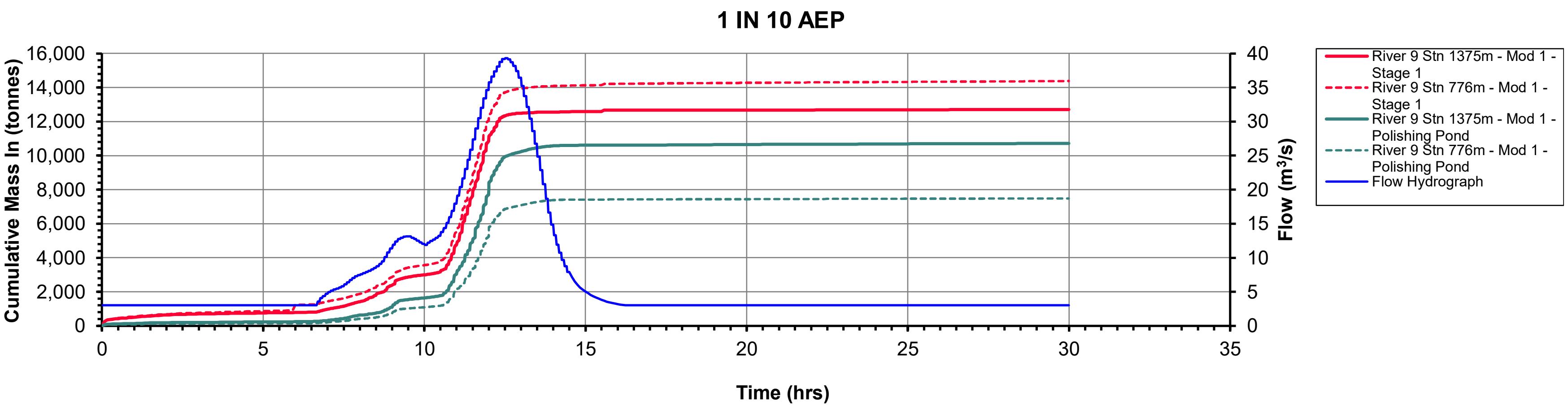
HEC-RAS STAGE 1
POLISHING POND SCOUR MAP
1 IN 10 AEP - MODEL 1

PSM4809-016R

Figure 30

\\anf.psm.local\anf-files\4000\PSM4809\Eng\01_GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure30



Notes:

1. Cross-section locations are highlighted in plan in Figure 30
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL

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HEC-RAS STAGE 1
MASS IN - POLISHING POND - MODEL 1

PSM4809-016R	Figure 31

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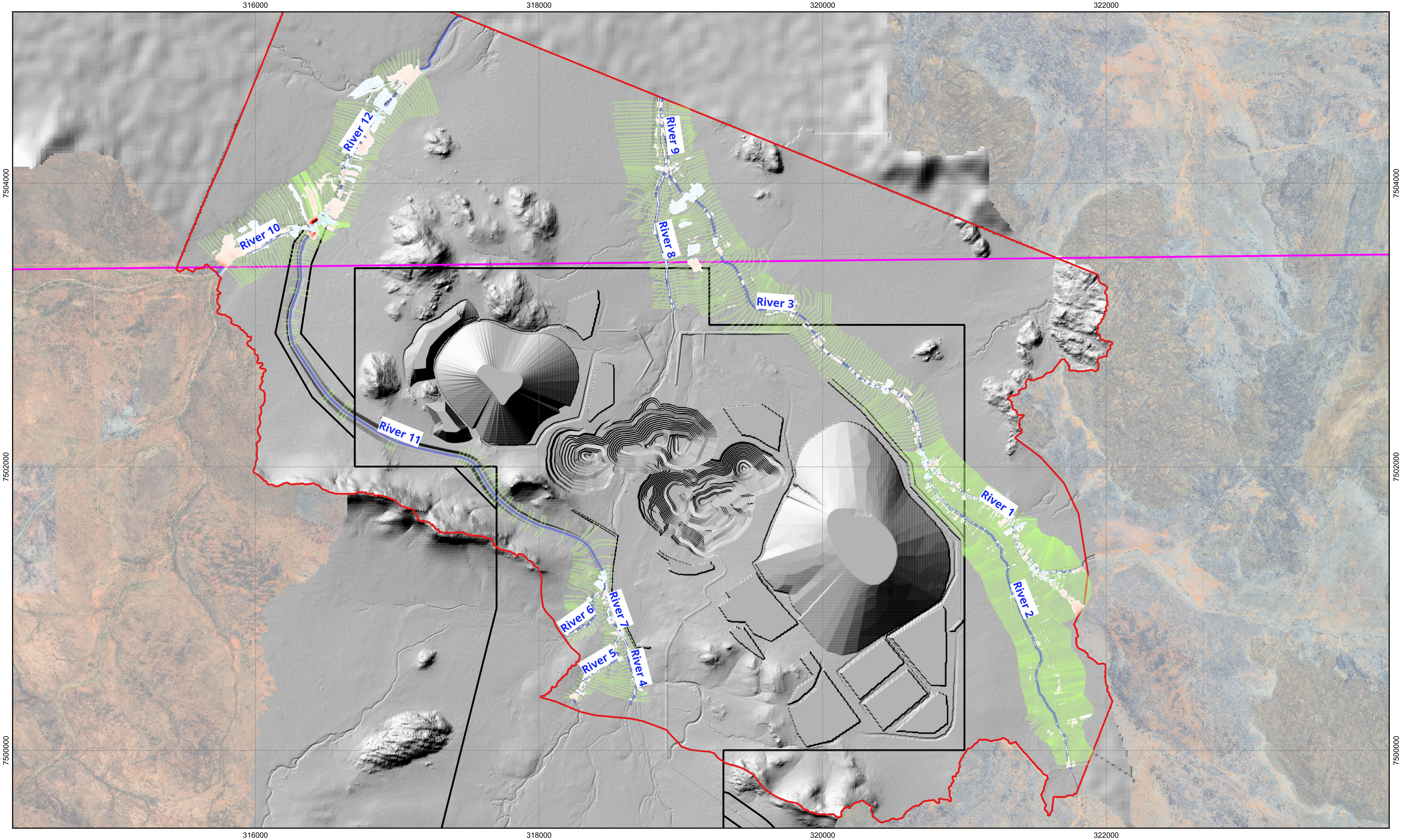

Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

N

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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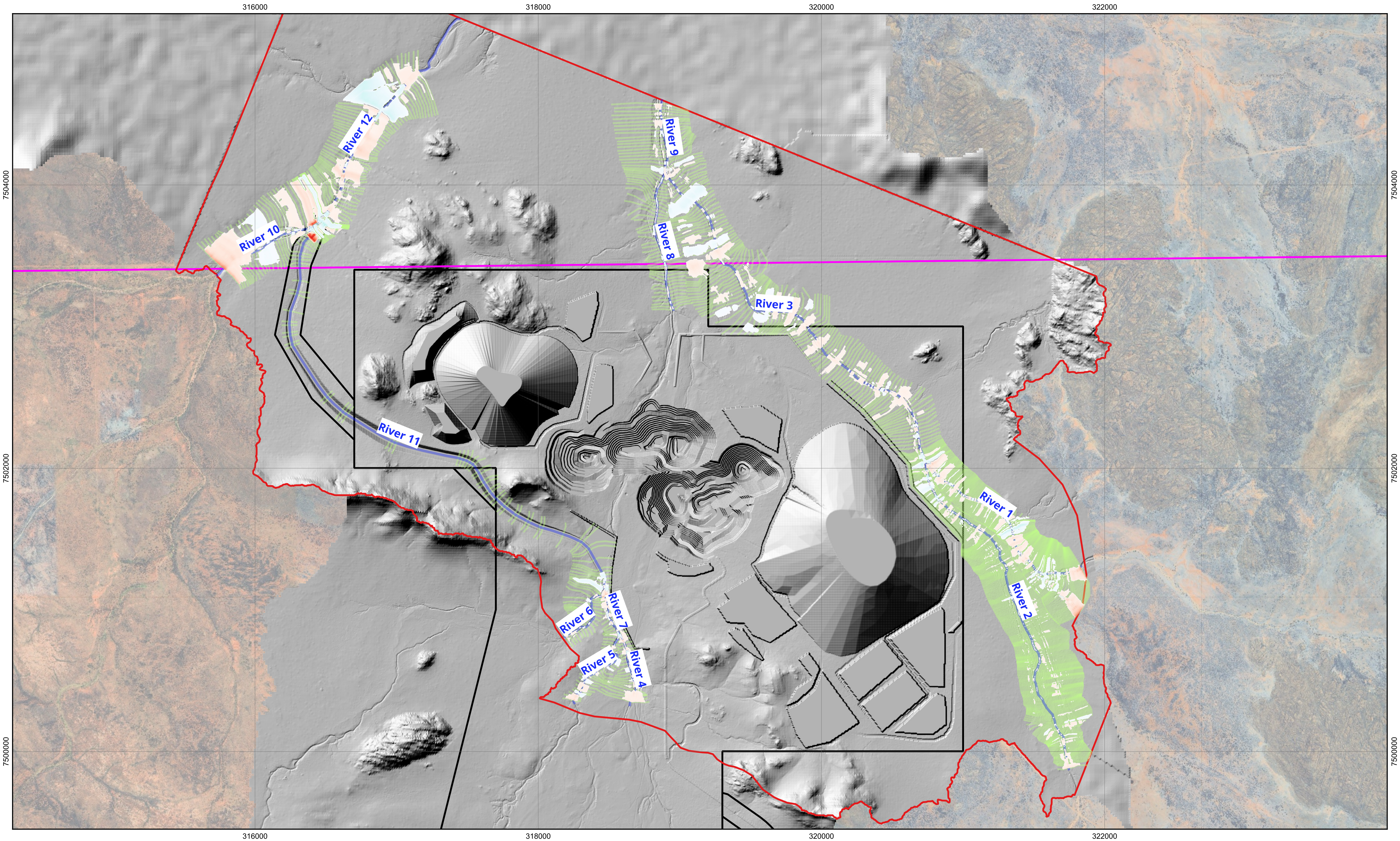
HEC-RAS STAGE 2
SCOUR MAP
1 IN 10 AEP - MODEL 3

PSM4809-016R | Figure 32



\\anf.psm.local\anf-files\4000\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures.qgz Layout: PSM4809-016R Figure33

Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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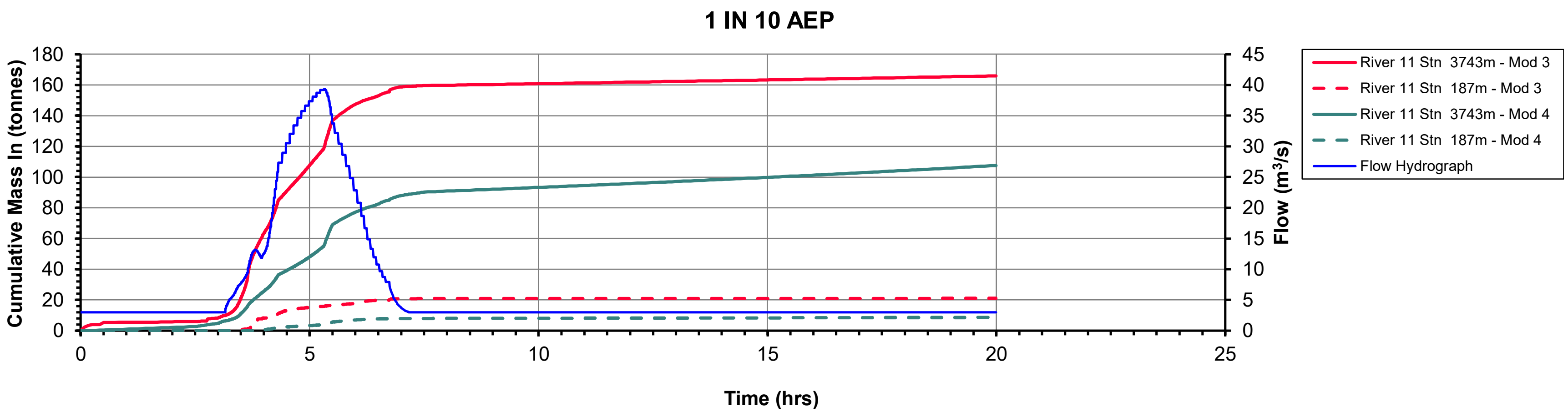
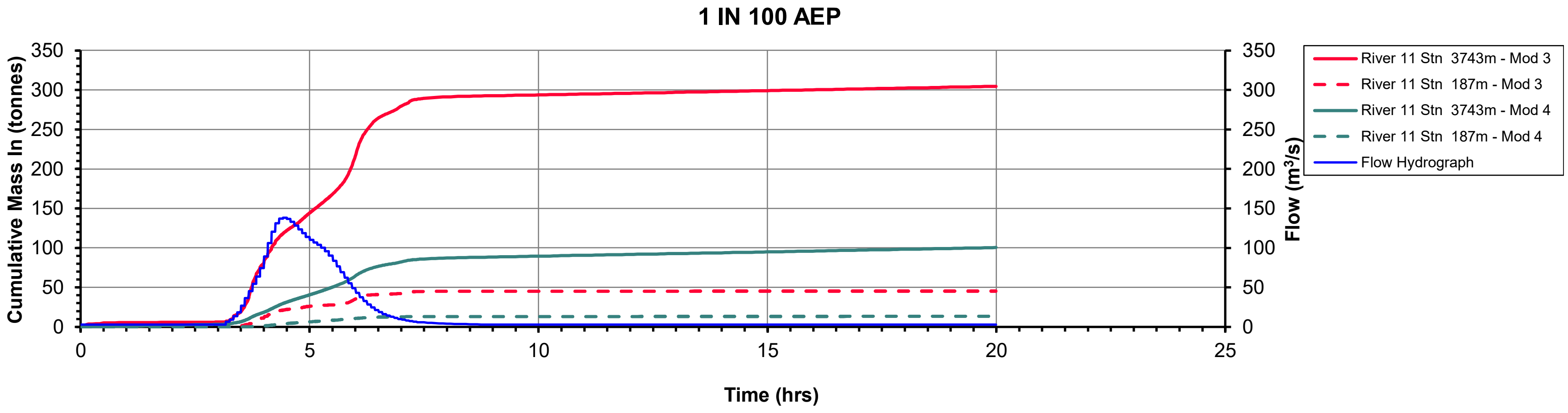
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
SCOUR MAP
1 IN 100 AEP - MODEL 3

PSM4809-016R

Figure 33





Notes:

1. Cross-section locations are highlighted in plan in Figure 19
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL

PSM

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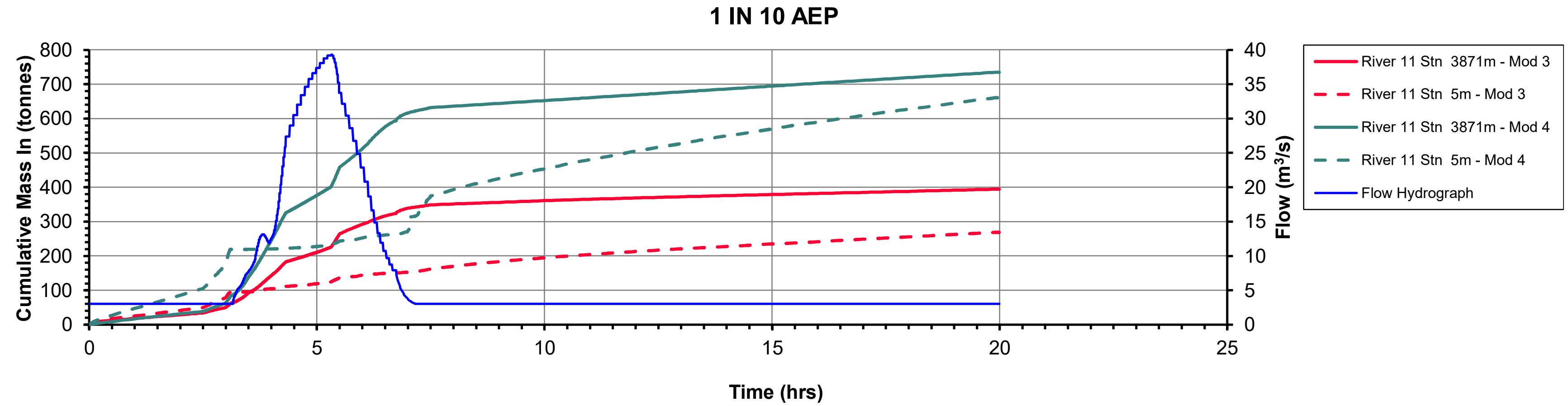
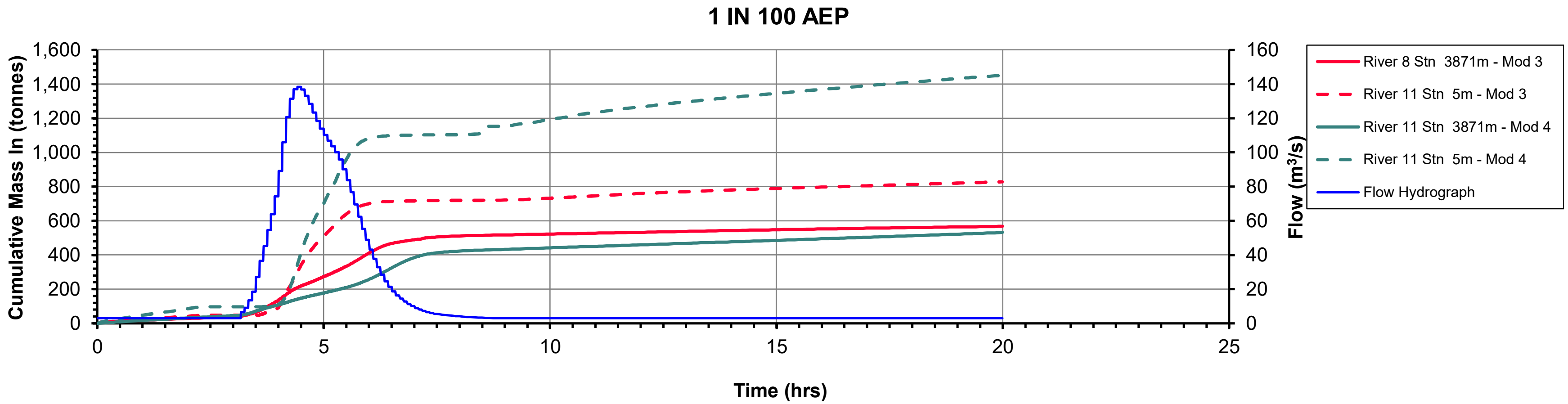
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
DIVERSION DRAIN MASS IN - MODEL 3 & 4

PSM4809-016R	Figure 34





Notes:

1. Cross-section locations are highlighted in plan in Figure 19
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL

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Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
RIVER 11 MASS IN - MODEL 3 & 4

PSM4809-016R	Figure 35

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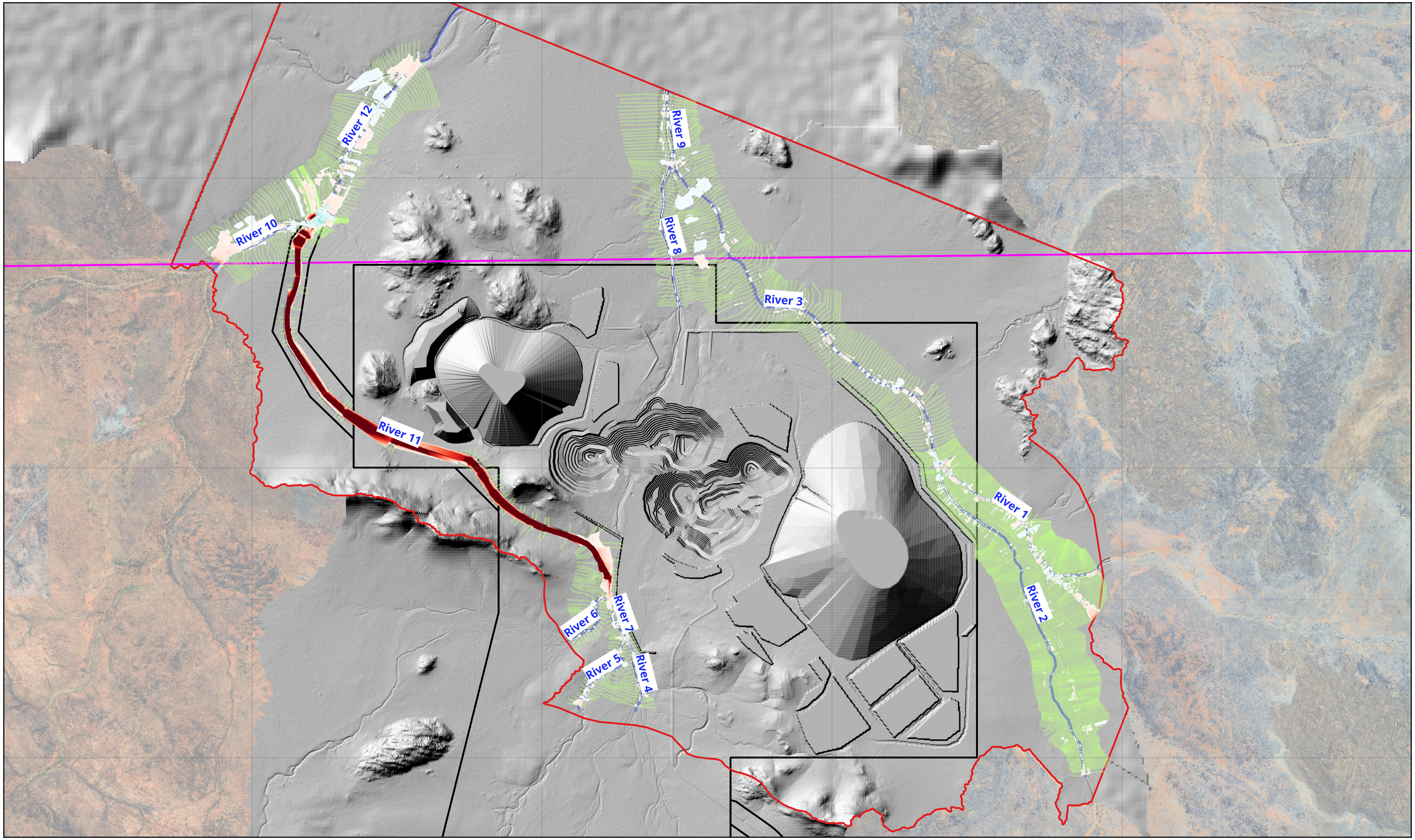

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Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

N

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Revision: A
Date: 02 Feb 2024
Paper Size: A3

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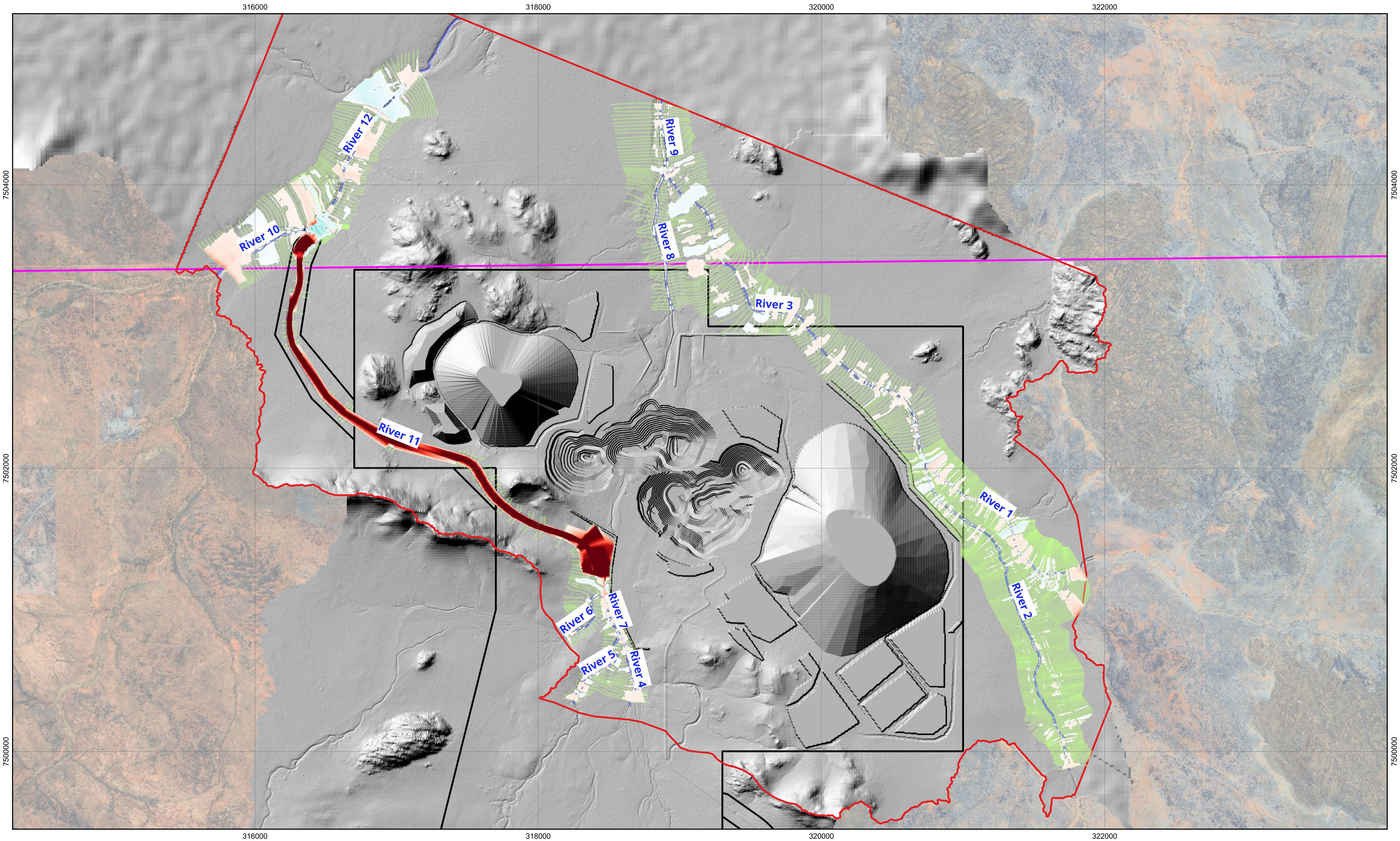
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
SCOUR MAP
1 IN 10 AEP - MODEL 1

PSM4809-016R | Figure 36



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Legend

- Lease Boundary
- Station Boundary
- River Centreline
- 1D Cross-Section Lines

Notes:
1. Positive depth difference indicates net deposition, whereas negative indicates net erosion over the duration of the flood text

Difference in Depth (m)

≥0.5
0.01
-0.01
≤-0.5

Scale 1:25,000

150 0 150 300 450 600 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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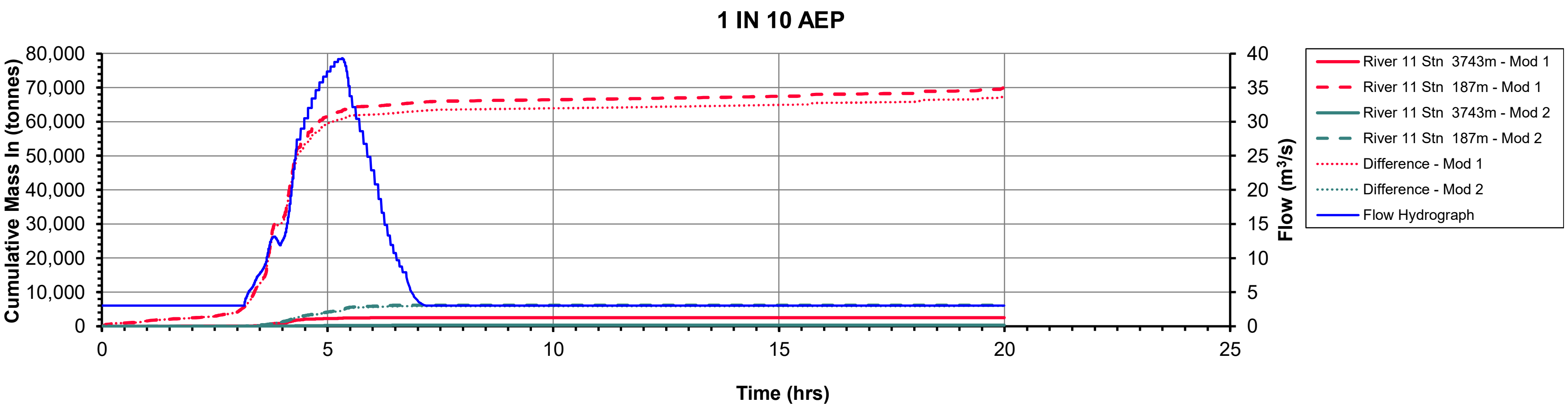
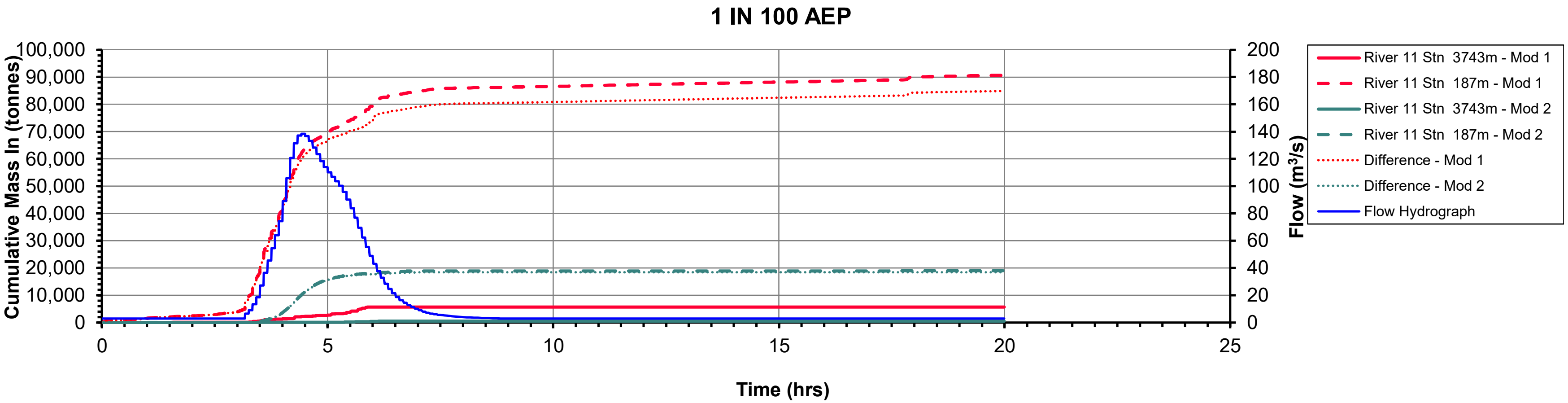
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
SCOUR MAP
1 IN 100 AEP - MODEL 1

PSM4809-016R | Figure 37





Notes:

1. Cross-section locations are highlighted in plan in Figure 19
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL
4. Difference = Downstream Mass - Upstream Mass

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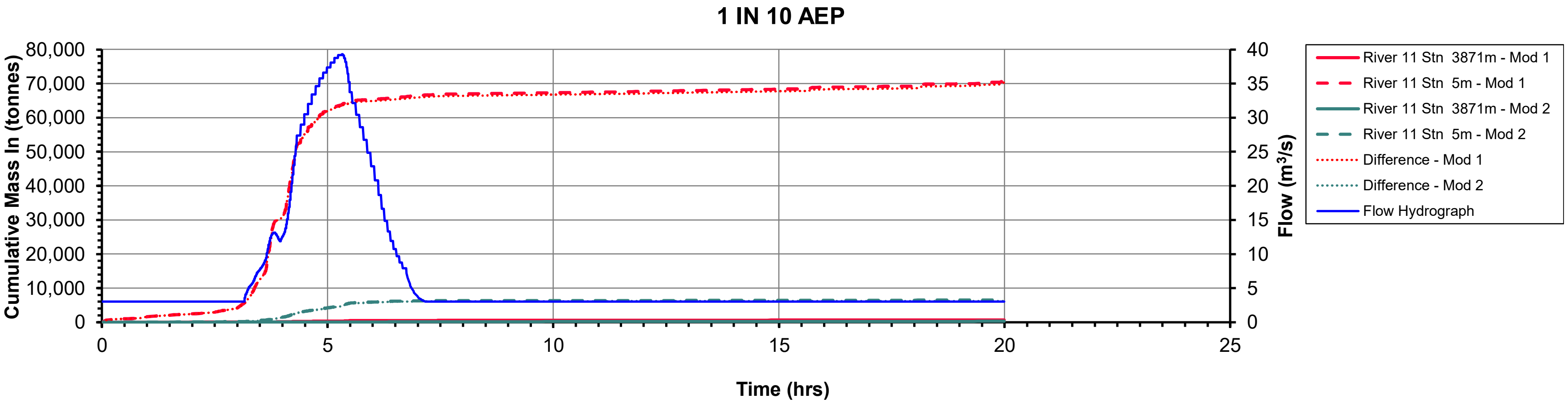
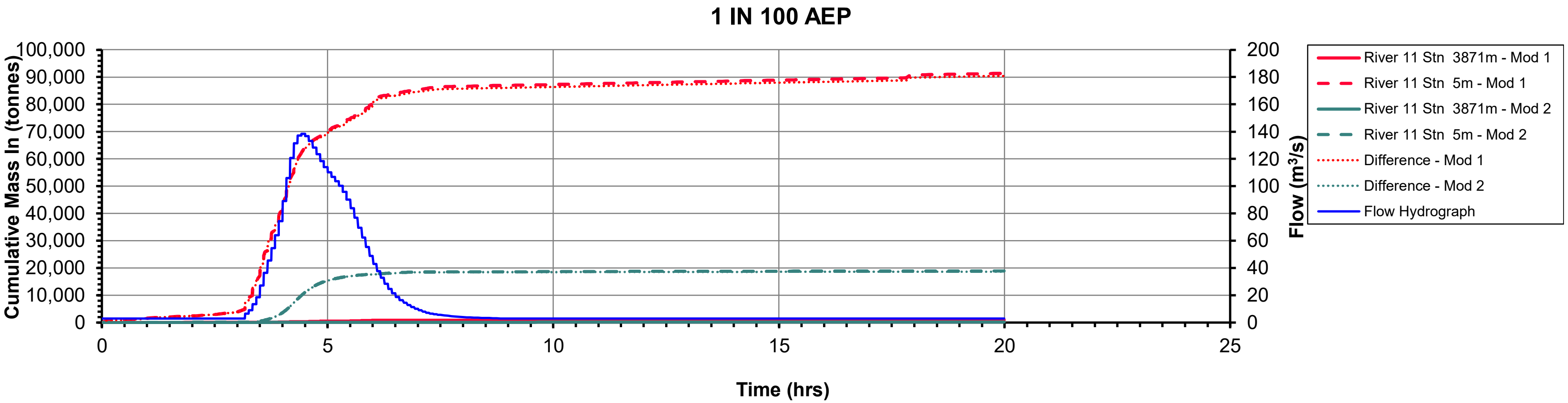
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
DIVERSION DRAIN MASS IN - MODEL 1 & 2

PSM4809-016R	Figure 38

\\anf.psm.local\anf-files\4000\PSM4809\Eng\03.Phase2\Figures\PSM4809-016R\[PSM4809-016R Figure24.xlsx]Fig39





Notes:

1. Cross-section locations are highlighted in plan in Figure 19
2. Time 0 hrs represent start of design storm event
3. AEP = Annual Exceedance Probability; Stn = Station; Mod = MODEL
4. Difference = Downstream Mass - Upstream Mass

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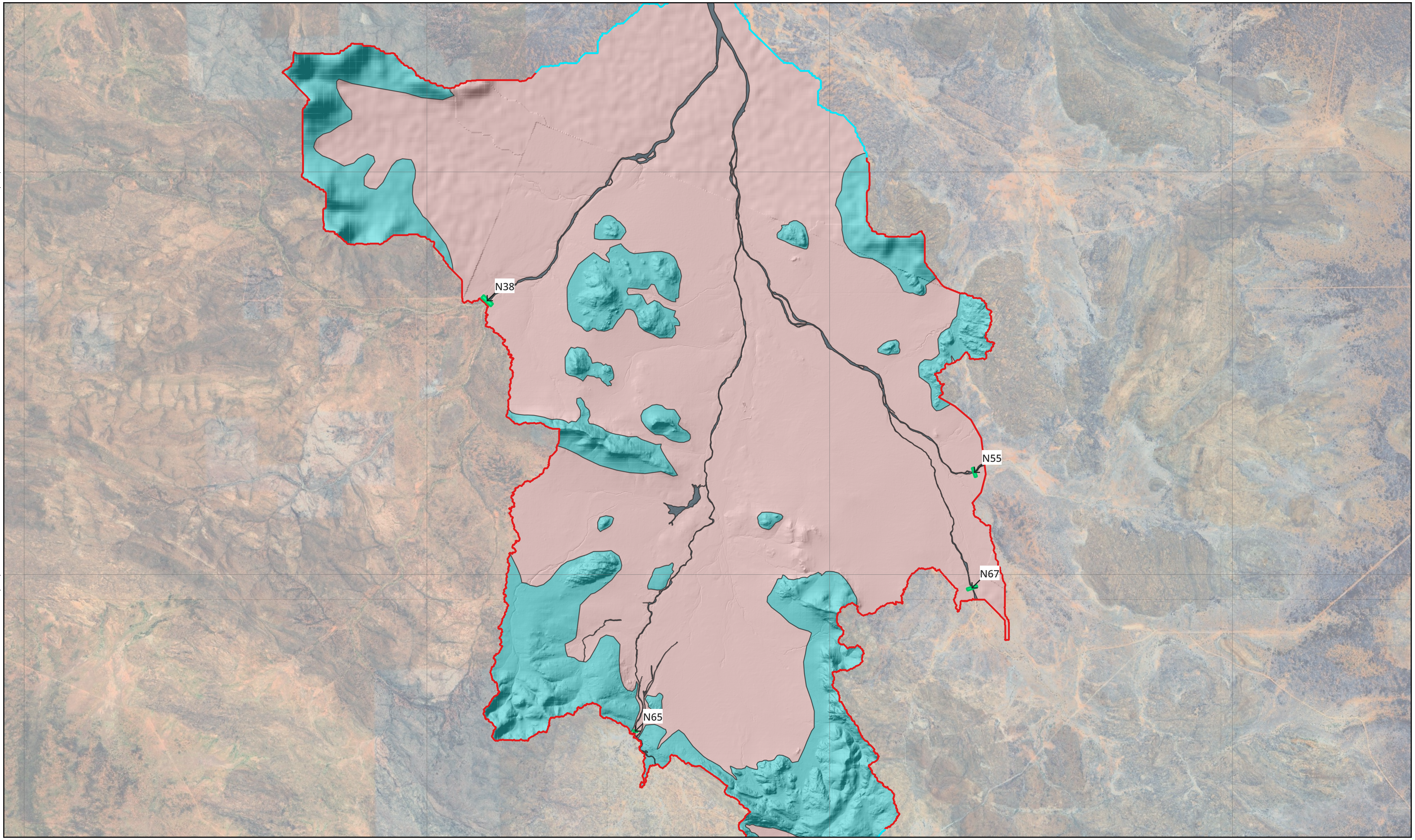
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HEC-RAS STAGE 2
RIVER 11 MASS IN - MODEL 1 & 2

PSM4809-016R	Figure 39

Appendix A
Modelling Sensitivities and Long Sections



Legend

- Model Boundary
- Outlet Boundary Condition
- Source Area

Land Classification

- Rock
- Floodplain
- Sand

Notes:
1. Aerial sourced from Google Satellite

Scale 1:45,000

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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EXISTING
TUFLOW MODEL SETUP

Created By:	Revision:
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PSM4809-016R | Figure A1

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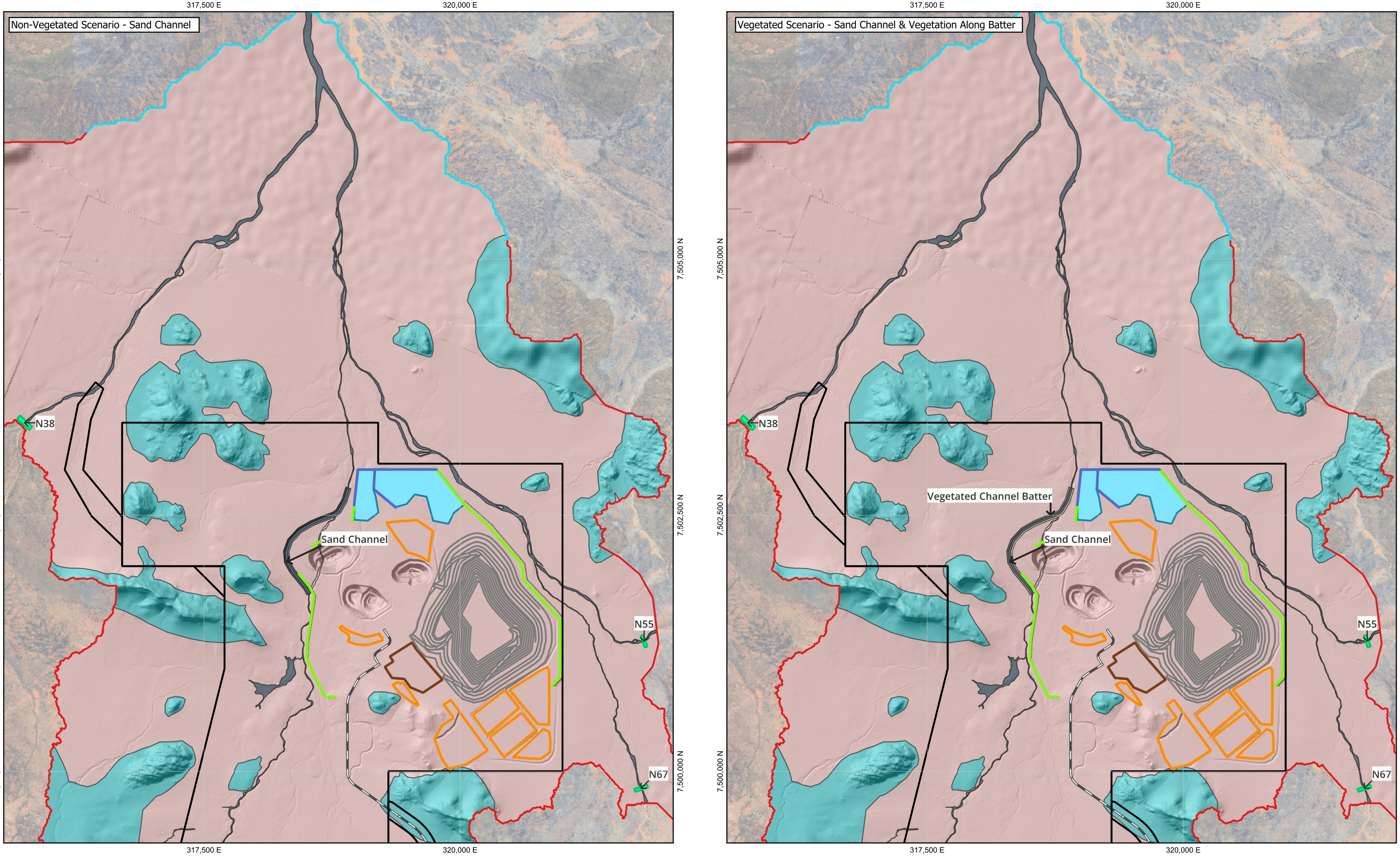

Legend

- Lease Boundary
- Model Boundary
- Outlet Boundary Condition
- Initial Water Level Region
- Source Area
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Land Classification

- Rock
- Floodplain
- Sand
- Vegetated Channel

Notes:
1. Aerial sourced from Google Satellite

Scale 1:35,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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STAGE 1
TUFLOW MODEL SETUP

PSM4809-016R

Figure A2

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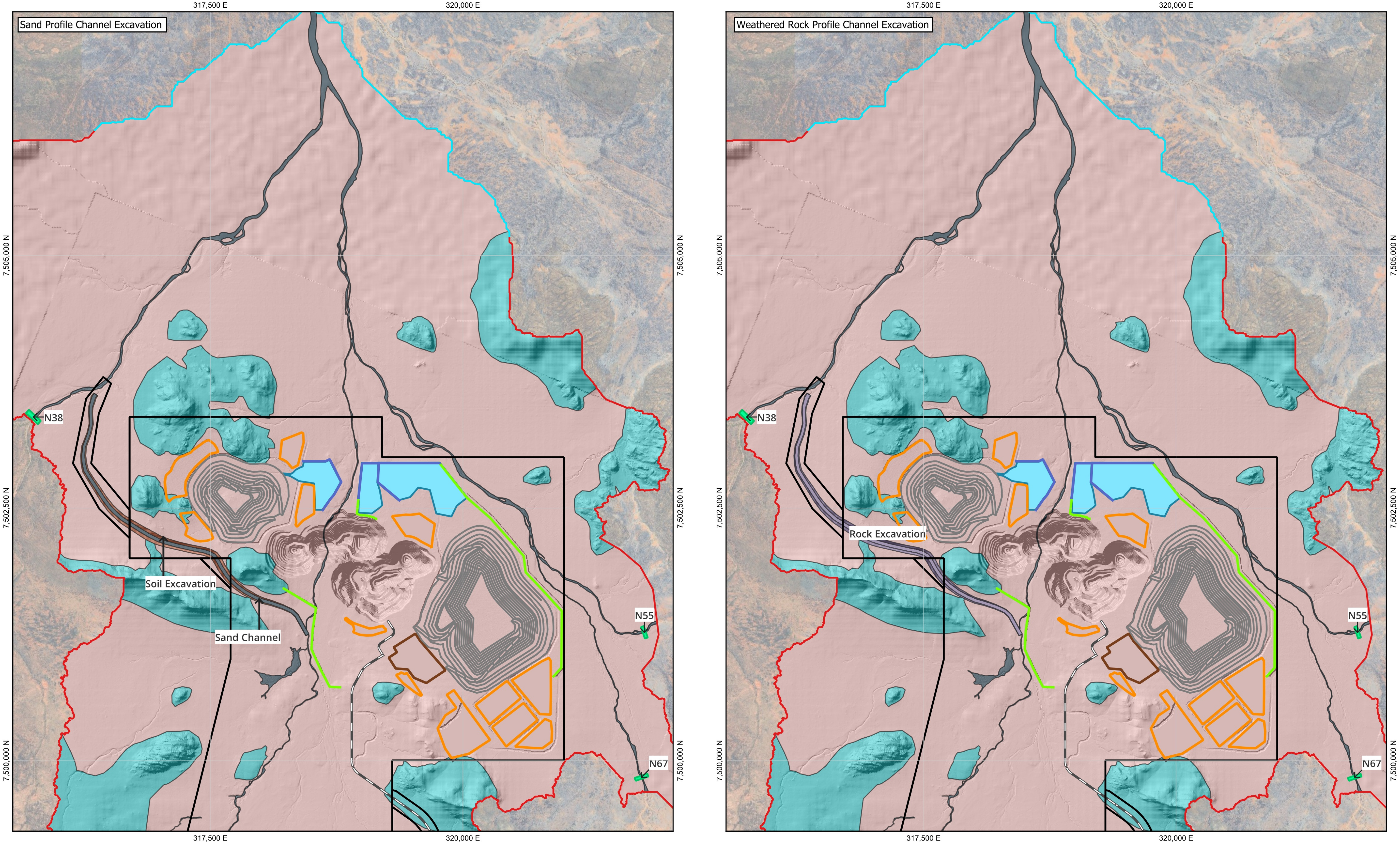

Legend

- Lease Boundary
- Model Boundary
- Outlet Boundary Condition
- Initial Water Level Region
- Source Area
- Modelled ROM
- Modelled Stockpile
- Waste Dump
- Modelled Bund
- Modelled Sediment Basin Embankment
- Modelled Road

Land Classification

- Rock
- Floodplain
- Sand
- Soil Excavation
- Rock Excavation

Notes:
1. Aerial sourced from Google Satellite

Scale 1:35,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2
TUFLOW MODEL SETUP

PSM4809-016R | Figure A3

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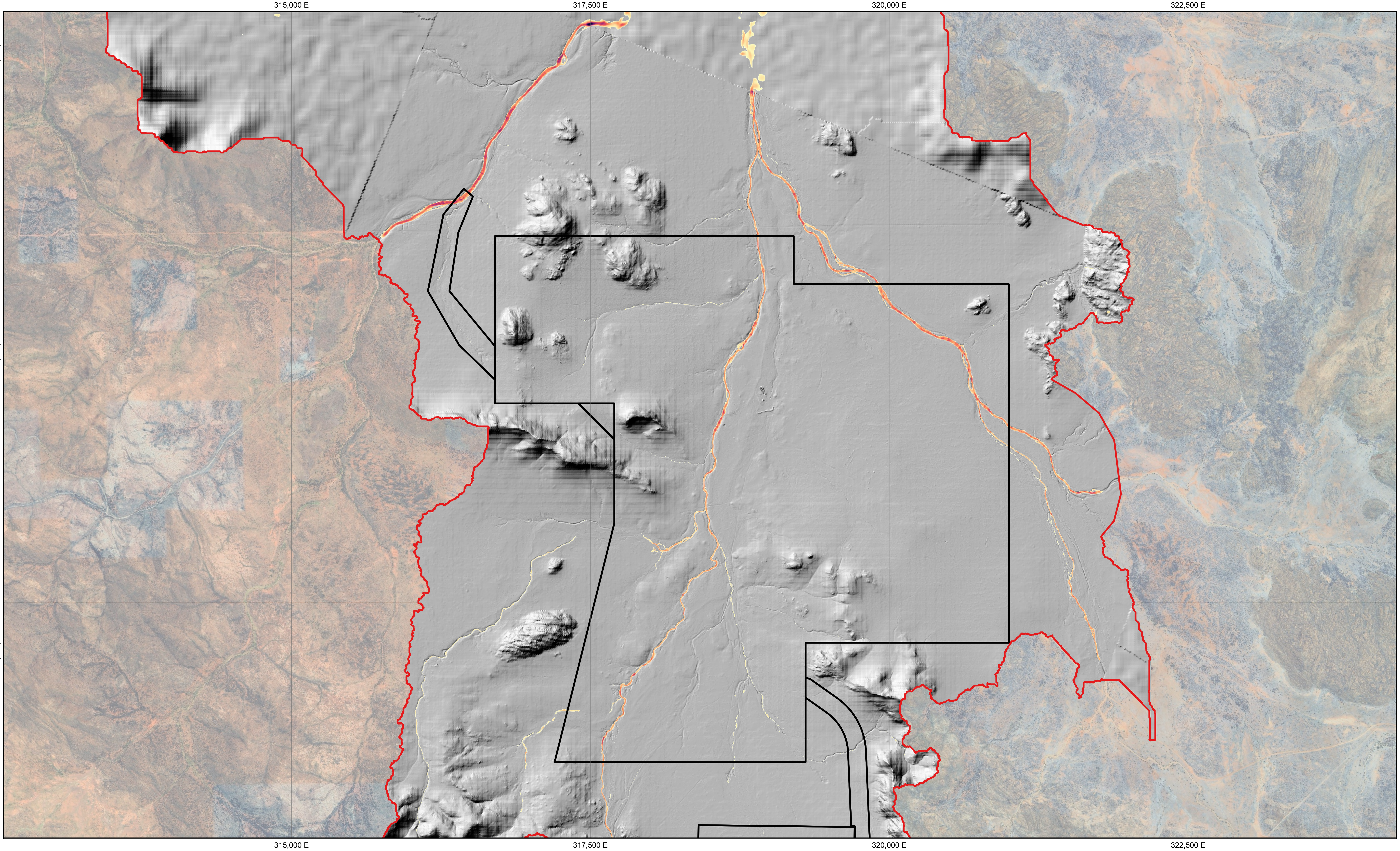

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

EXISTING
1 IN 2 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R

Figure A4

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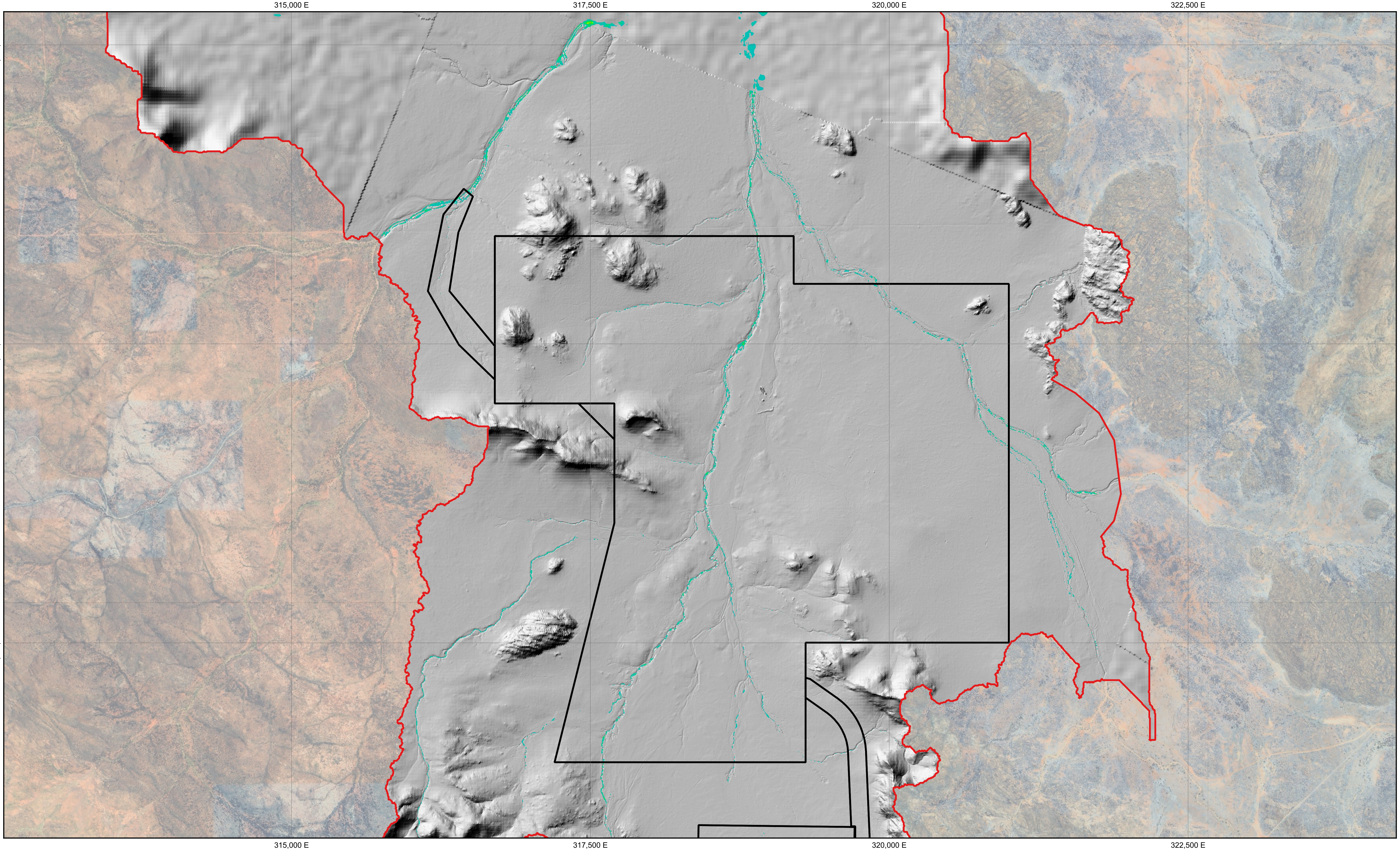

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)
≥500
10

Scale 1:30,000
N
250 0 250 500 750 1,000 m
Map Projection: GDA2020 / MGA zone 53 EPSG:7853

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Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

EXISTING
1 IN 2 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

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Date: 18 July 2024	Paper Size: A3

PSM4809-016R | Figure A5

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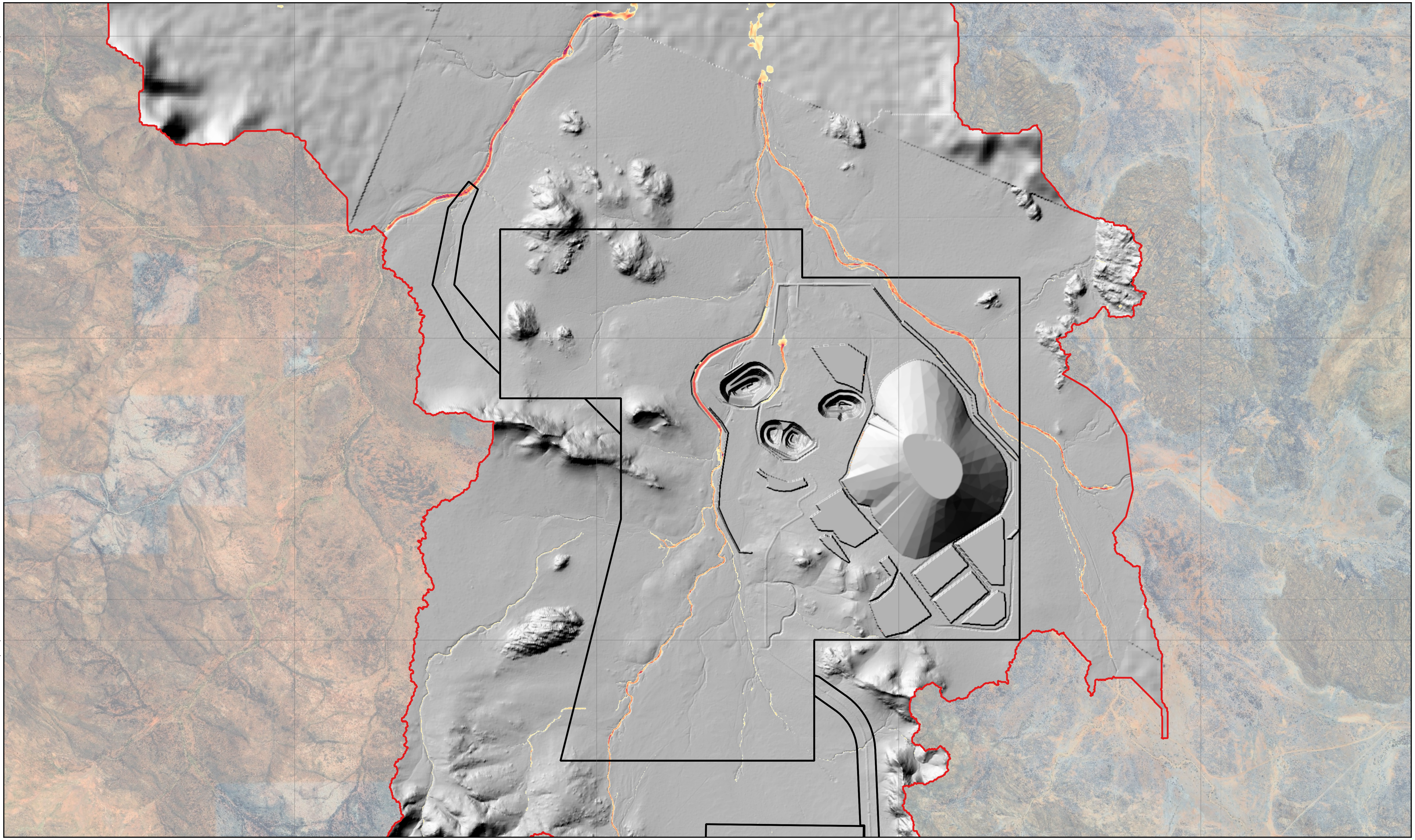

Legend

Lease Boundary

Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Date: 18 July 2024

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Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 NON-VEGETATED
1 IN 2 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R

Figure A6

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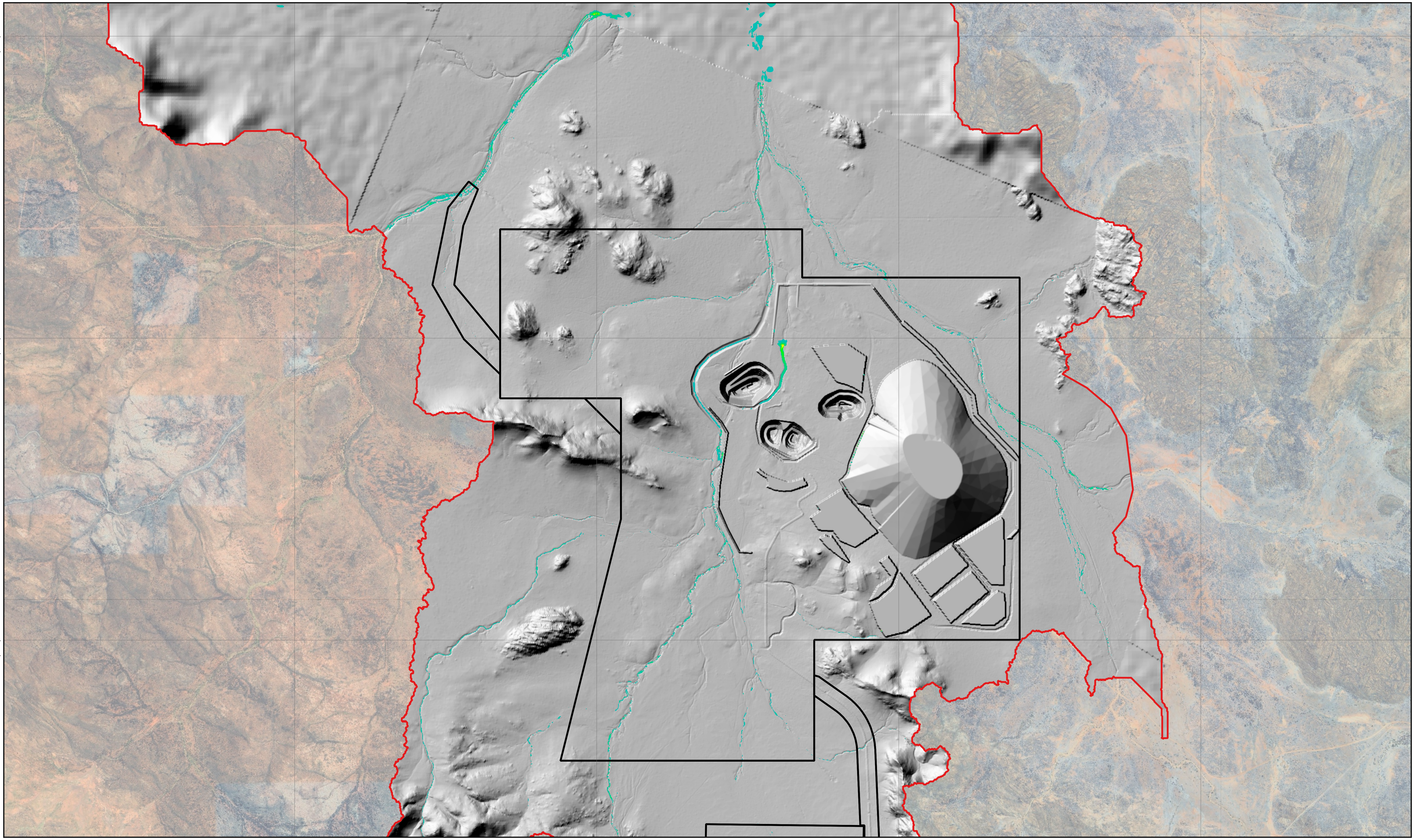

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m²)

≥500

10

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Date: 18 July 2024	Paper Size: A3

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 NON-VEGETATED
1 IN 2 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R | Figure A7

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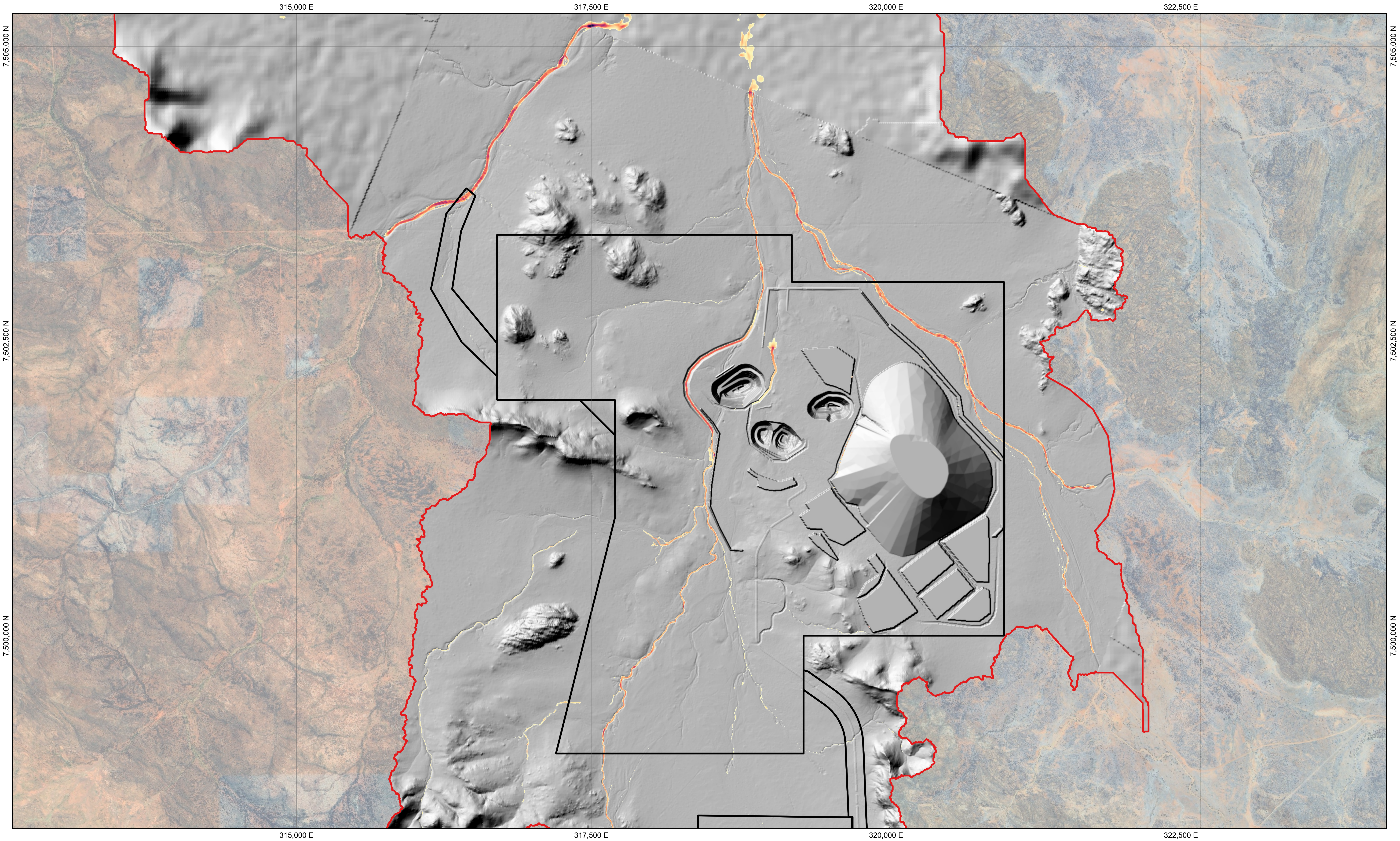

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 VEGETATED
1 IN 2 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R | Figure A8

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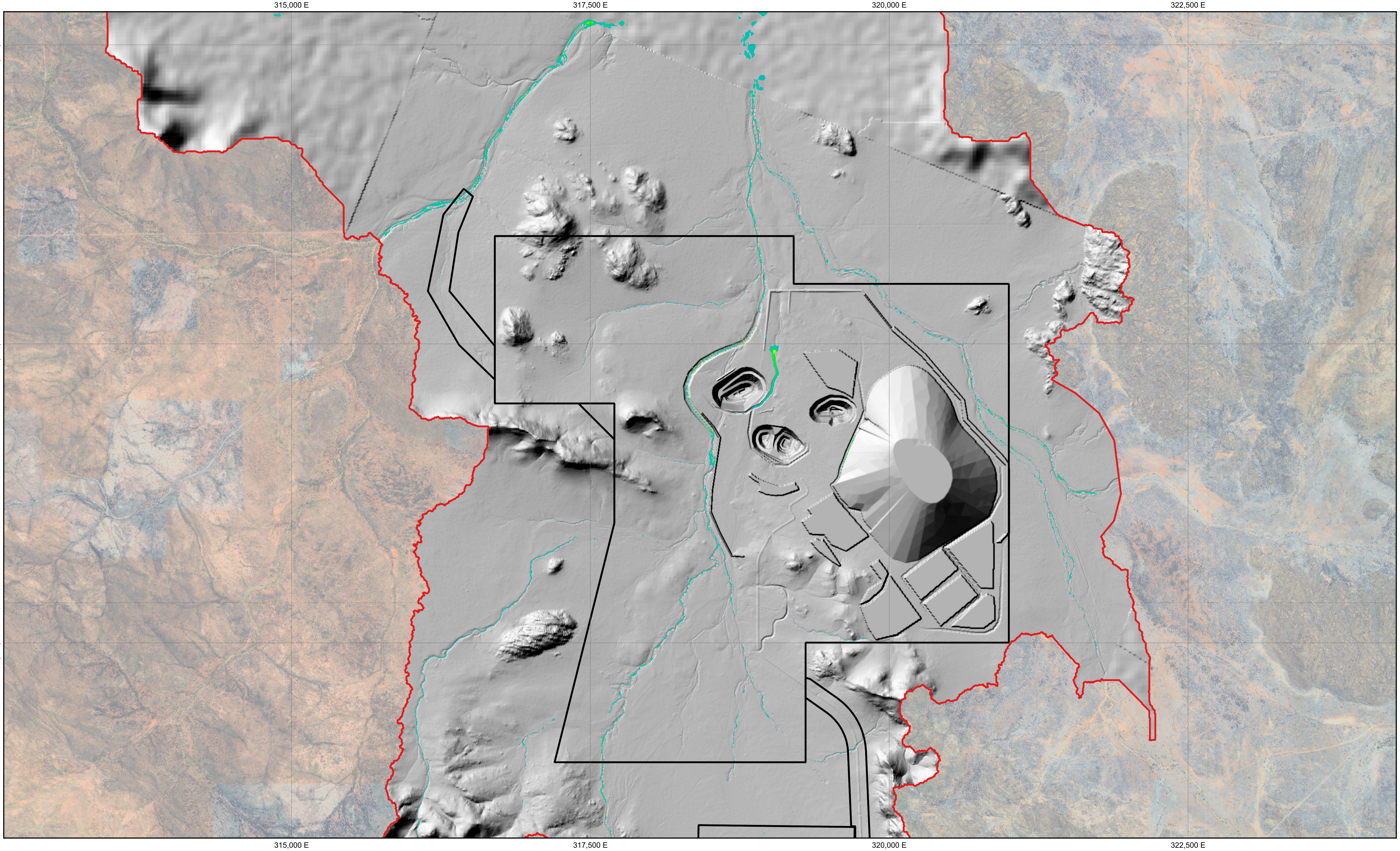

Legend
- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)
≥500
10

Scale 1:30,000
N
250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 VEGETATED
1 IN 2 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

Created By: PSM	Revision: A
Date: 18 July 2024	Paper Size: A3

PSM4809-016R | Figure A9

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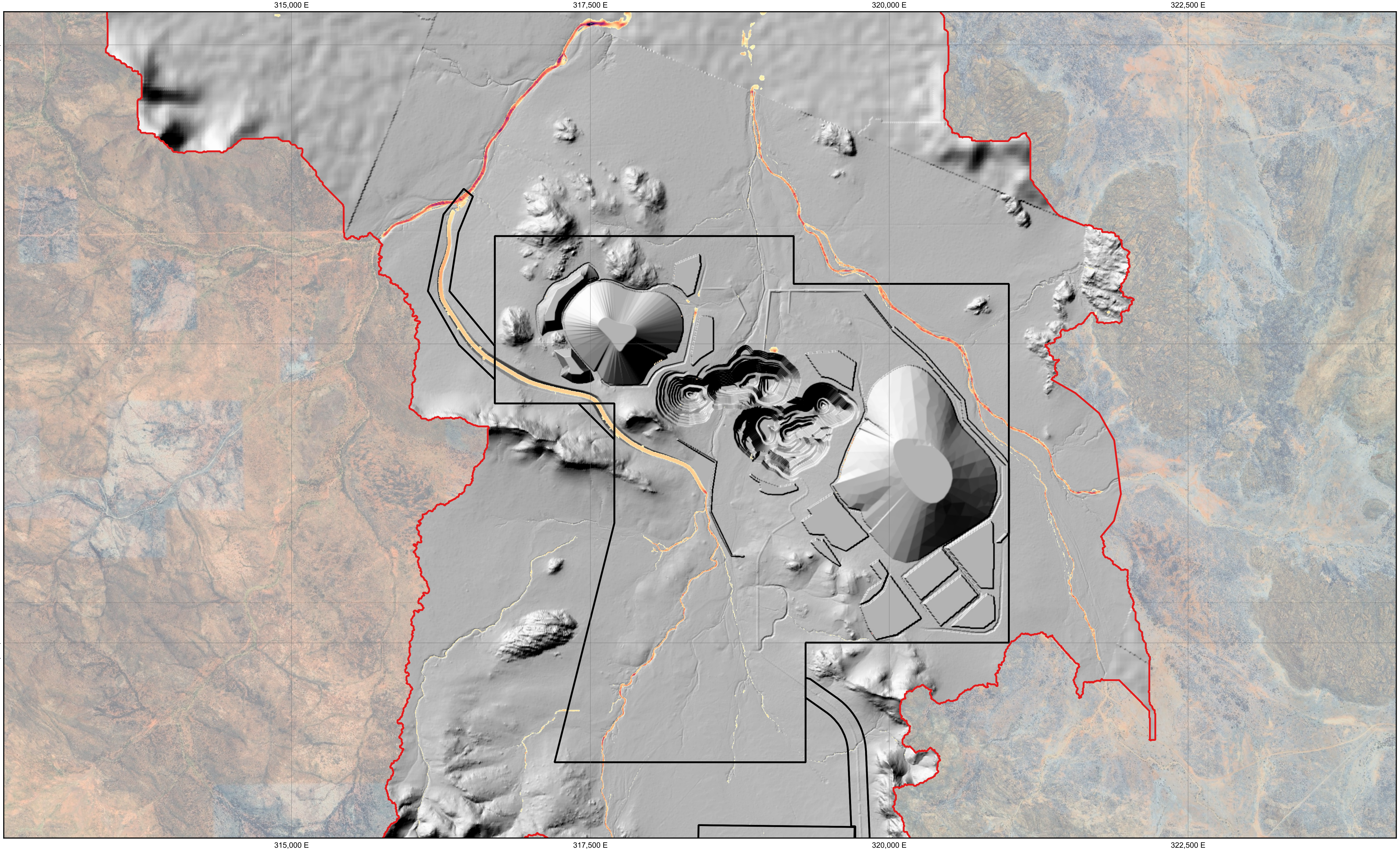

Legend

Lease Boundary

Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Revision: A

Date: 18 July 2024

Paper Size: A3

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 SOIL EXCAVATION
1 IN 2 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R

Figure A10

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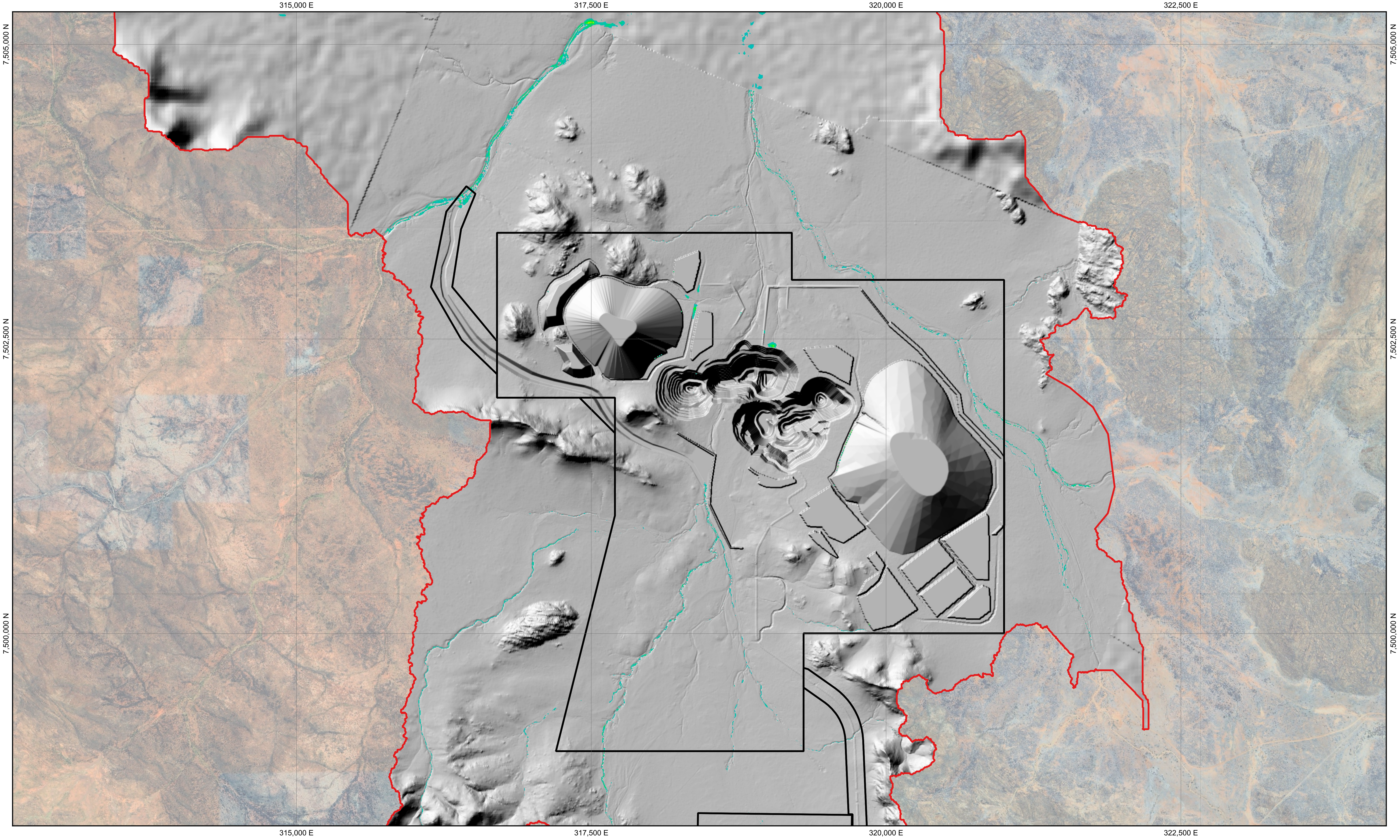

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)
≥500
10

Scale 1:30,000
N
250 0 250 500 750 1,000 m
Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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PSM	A
Date: 18 July 2024	Paper Size: A3

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 SOIL EXCAVATION
1 IN 2 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R | Figure A11

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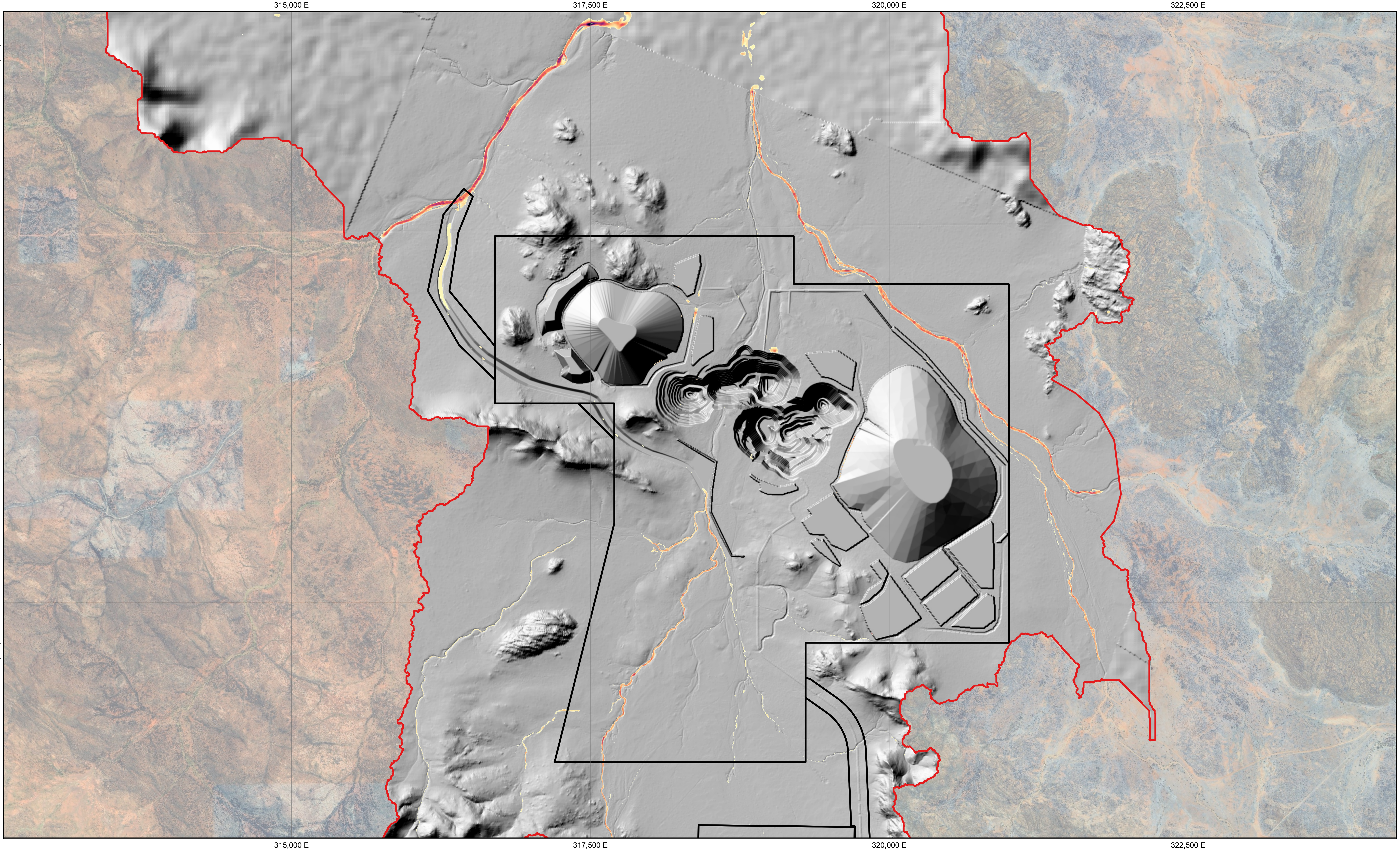

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA12

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

Created By: PSM

Revision: A

Date: 18 July 2024

Paper Size: A3

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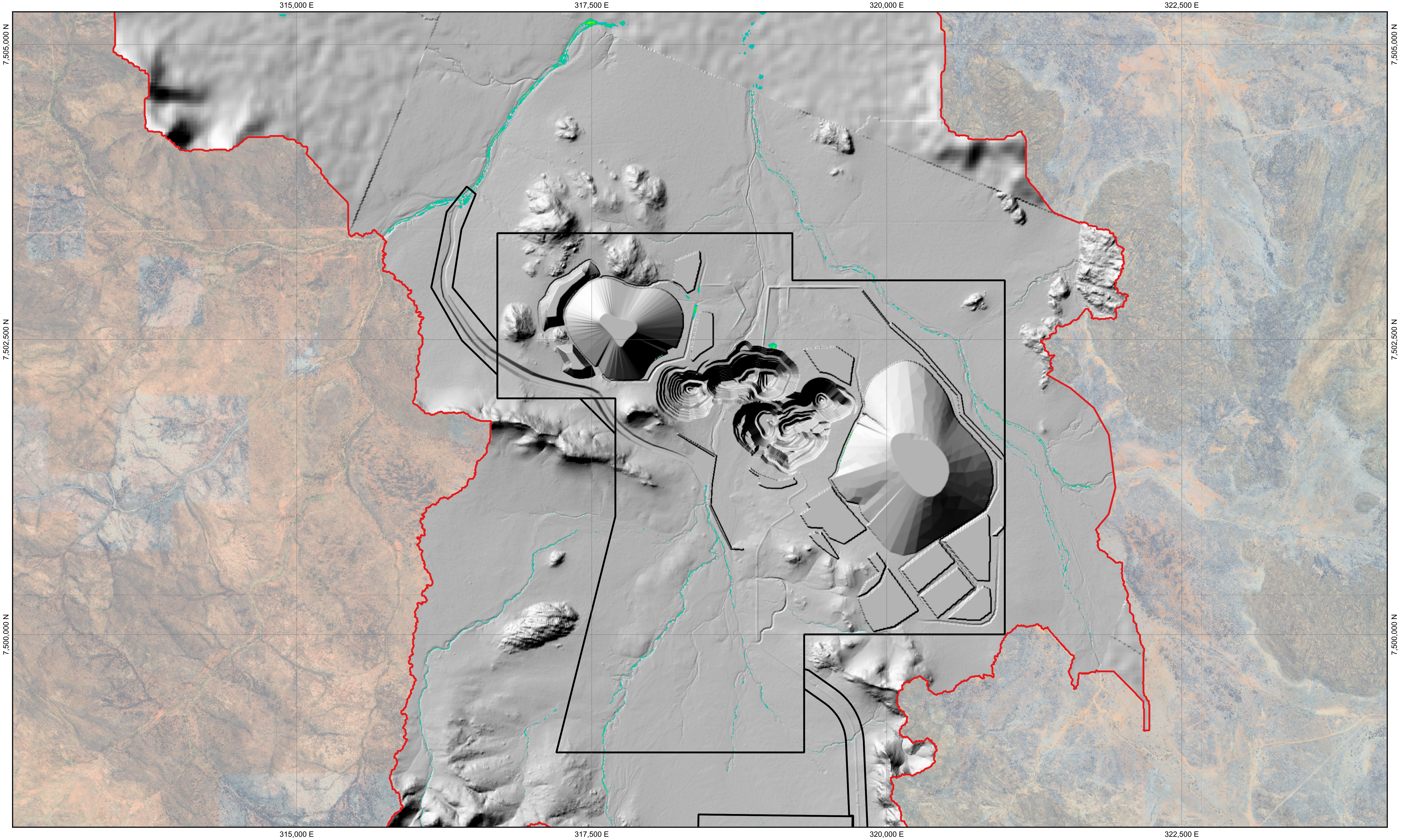
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 ROCK EXCAVATION
1 IN 2 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R

Figure A12



Legend

Lease Boundary

Model Boundary

Notes:

1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)

≥500

10

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Date: 18 July 2024	Paper Size: A3	

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 ROCK EXCAVATION
1 IN 2 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R

Figure A13

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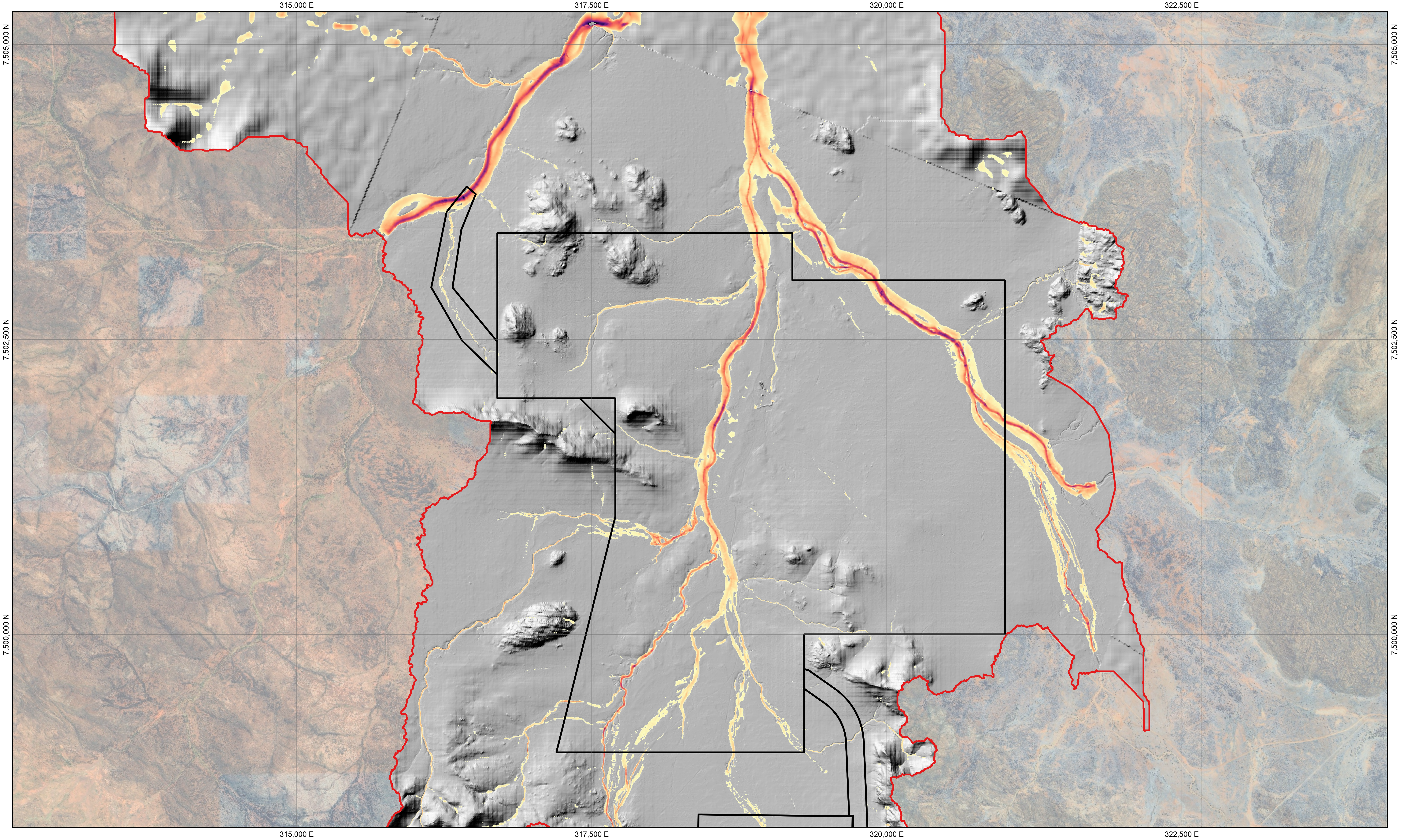

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

EXISTING
1 IN 50 AEP DESIGN EVENT
MAXIMUM VELOCITY

Created By: PSM	Revision: A
Date: 18 July 2024	Paper Size: A3

PSM4809-016R | Figure A14

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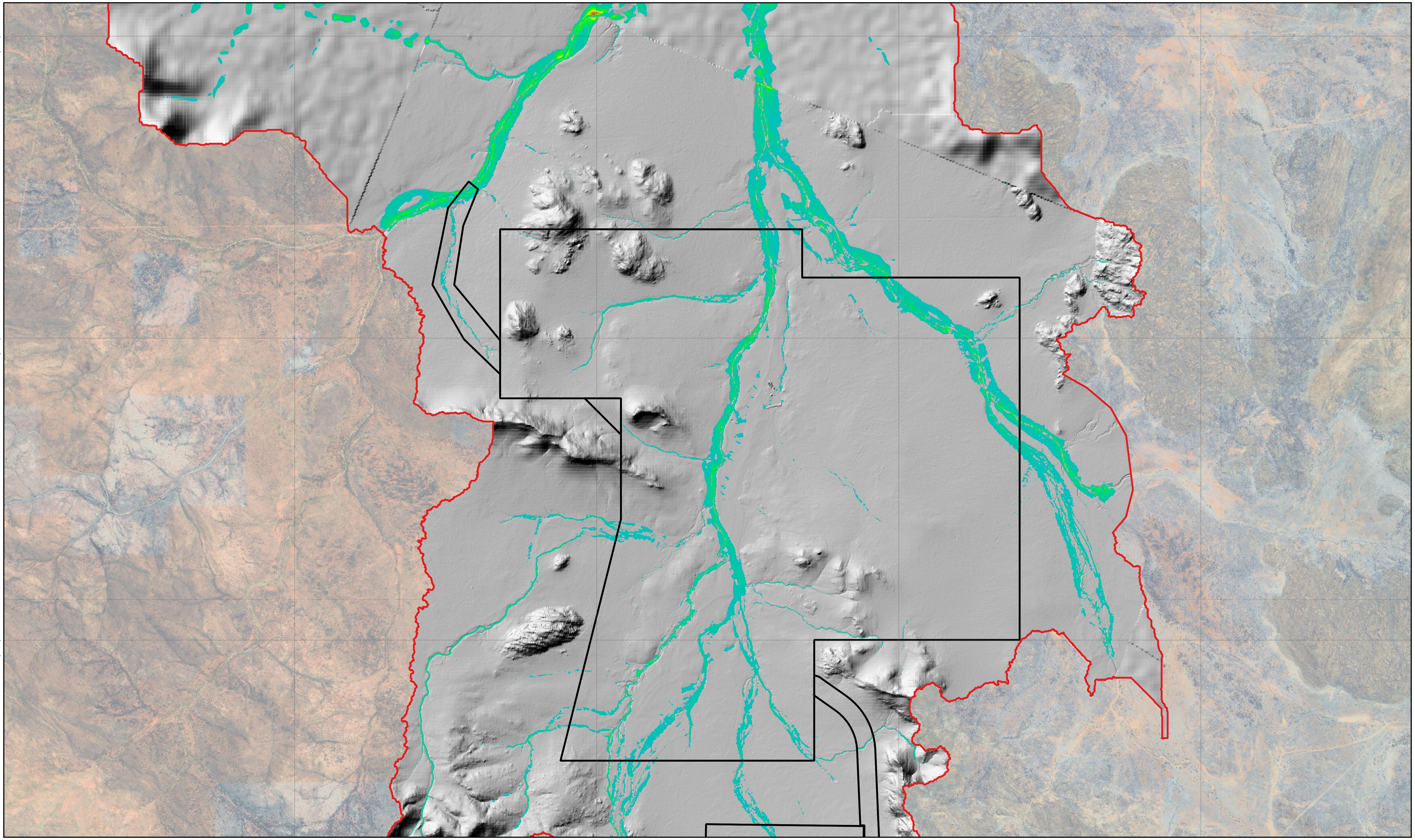

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA15

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)
≥500
10

Scale 1:30,000
N
250 0 250 500 750 1,000 m
Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Date: 18 July 2024	Paper Size: A3

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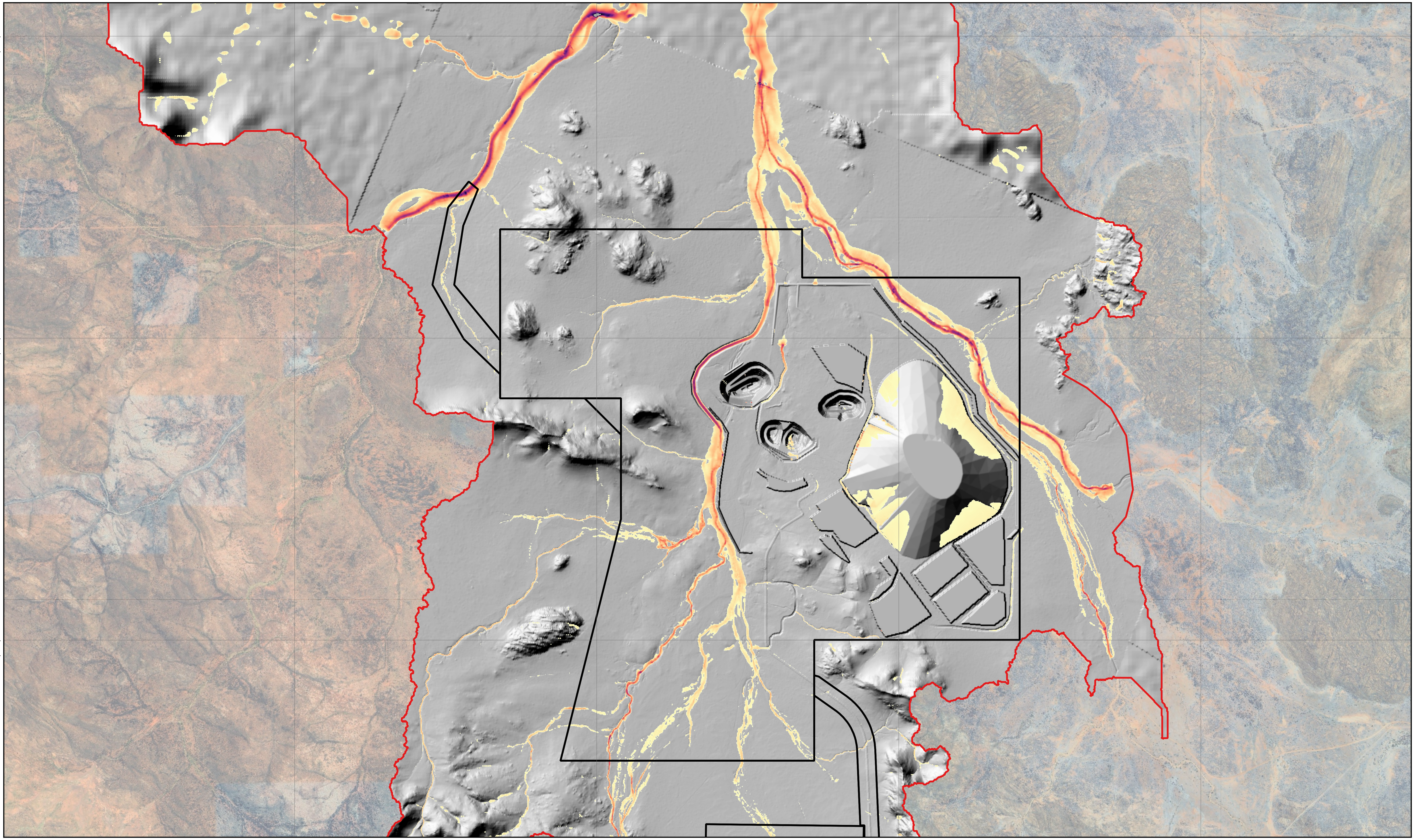
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

EXISTING
1 IN 50 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R | Figure A15



N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA16

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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PSM	A
Date: 18 July 2024	Paper Size: A3

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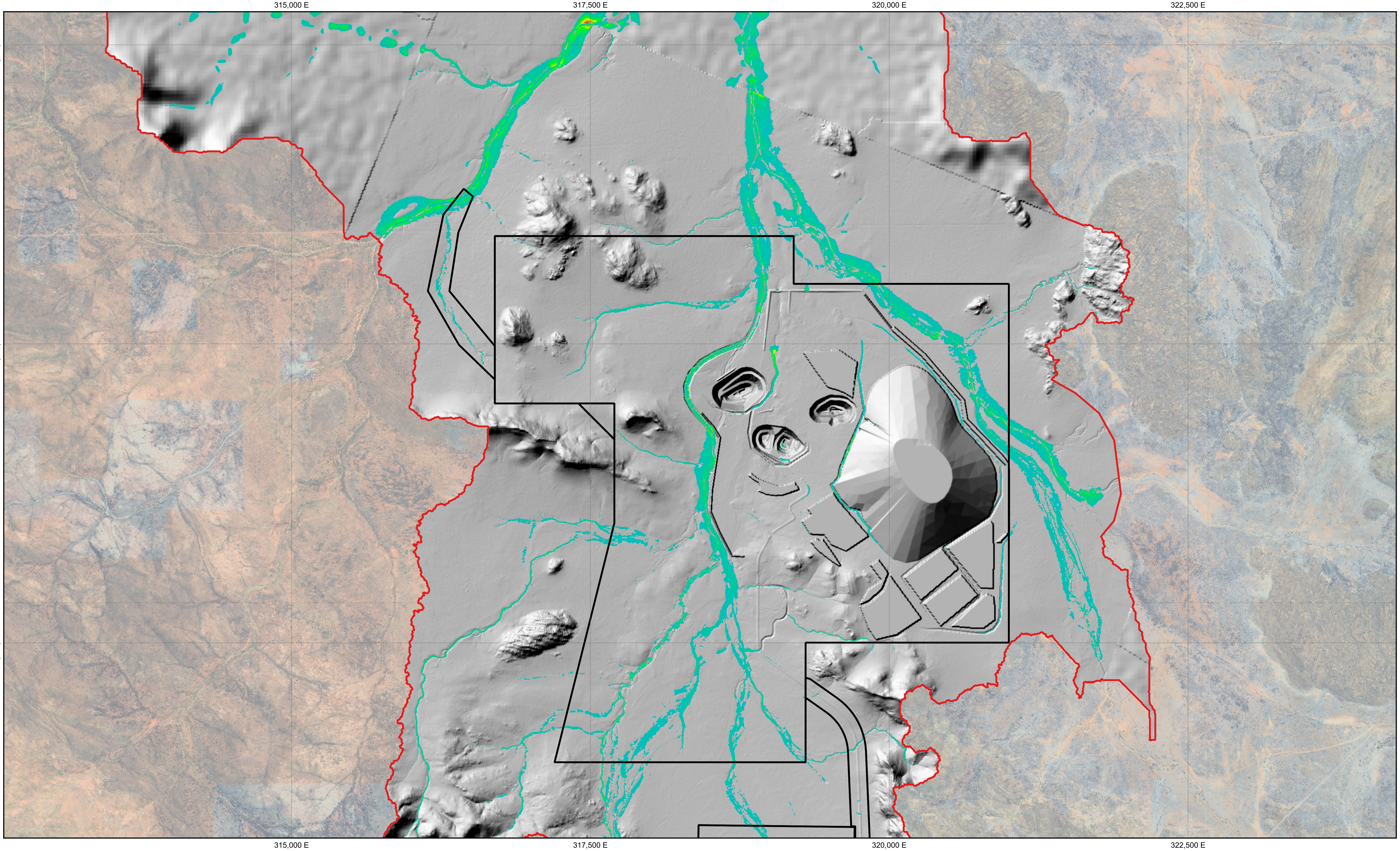
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 VEGETATED
1 IN 50 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R Figure A16



Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)

≥500

10

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Date: 18 July 2024	Paper Size: A3

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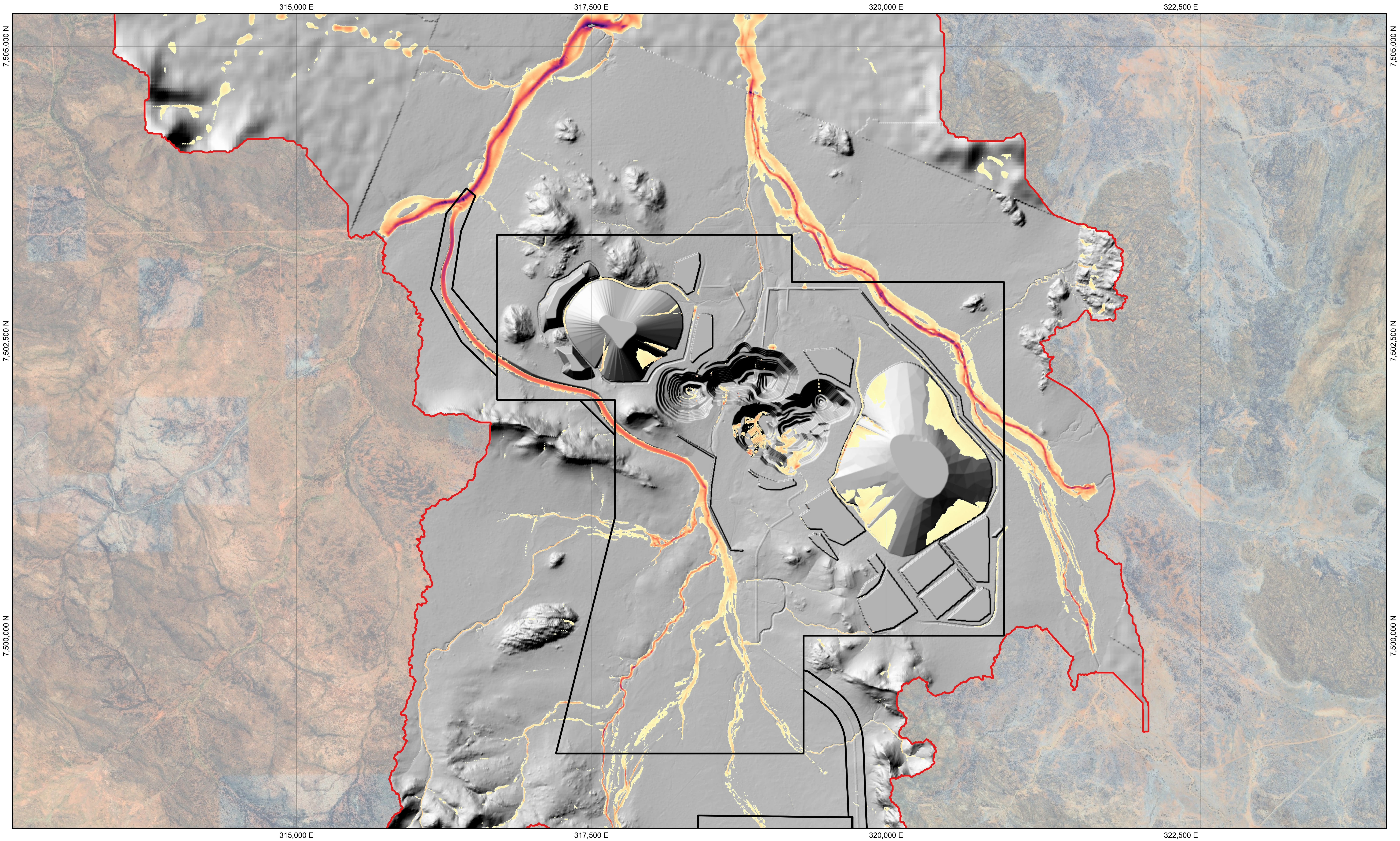
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 1 VEGETATED
1 IN 50 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R | Figure A17

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA17



Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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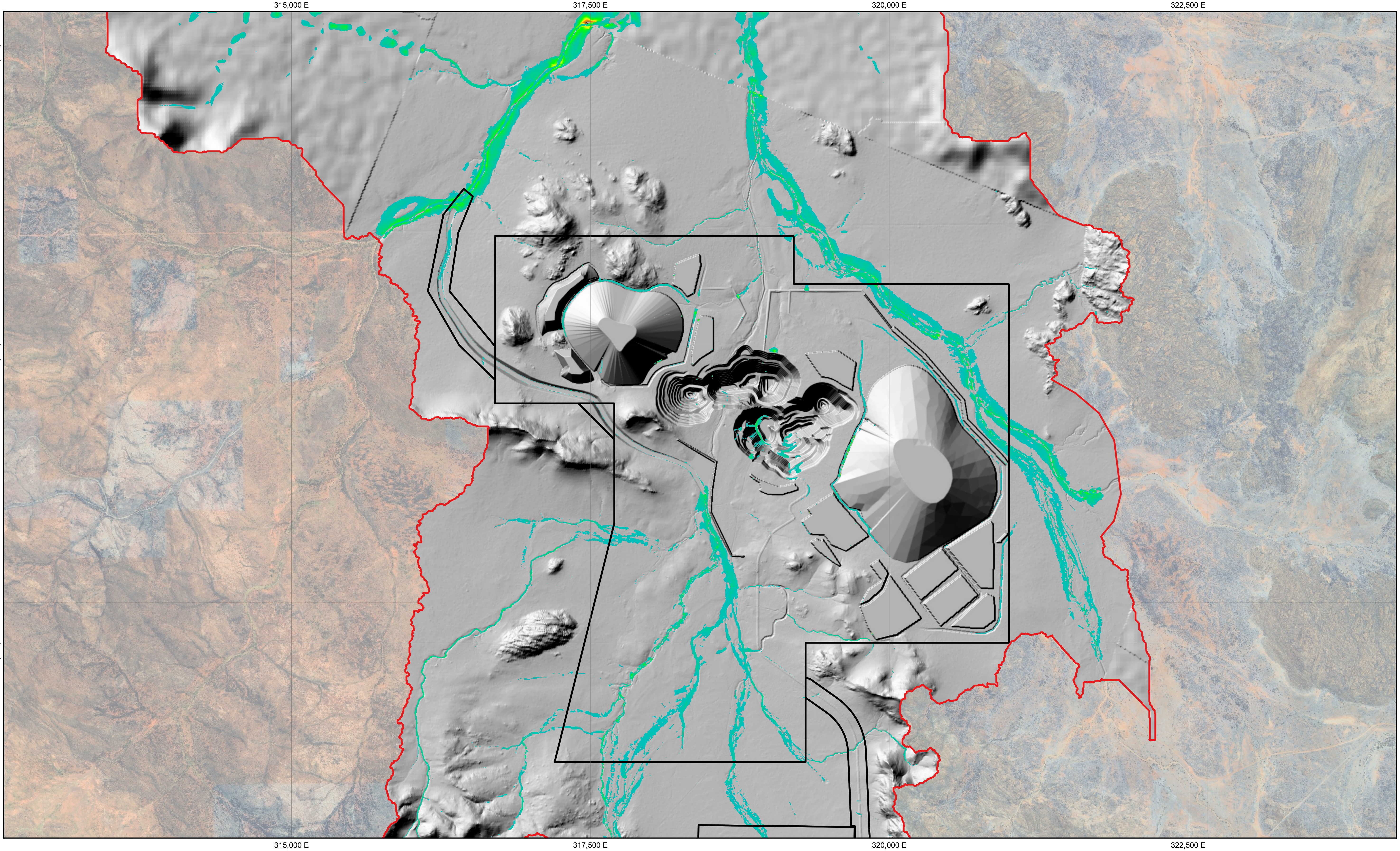
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 SOIL EXCAVATION
1 IN 50 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R | Figure A18

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA18



N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA19

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)
≥500
10

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Revision: A

Date: 18 July 2024

Paper Size: A3

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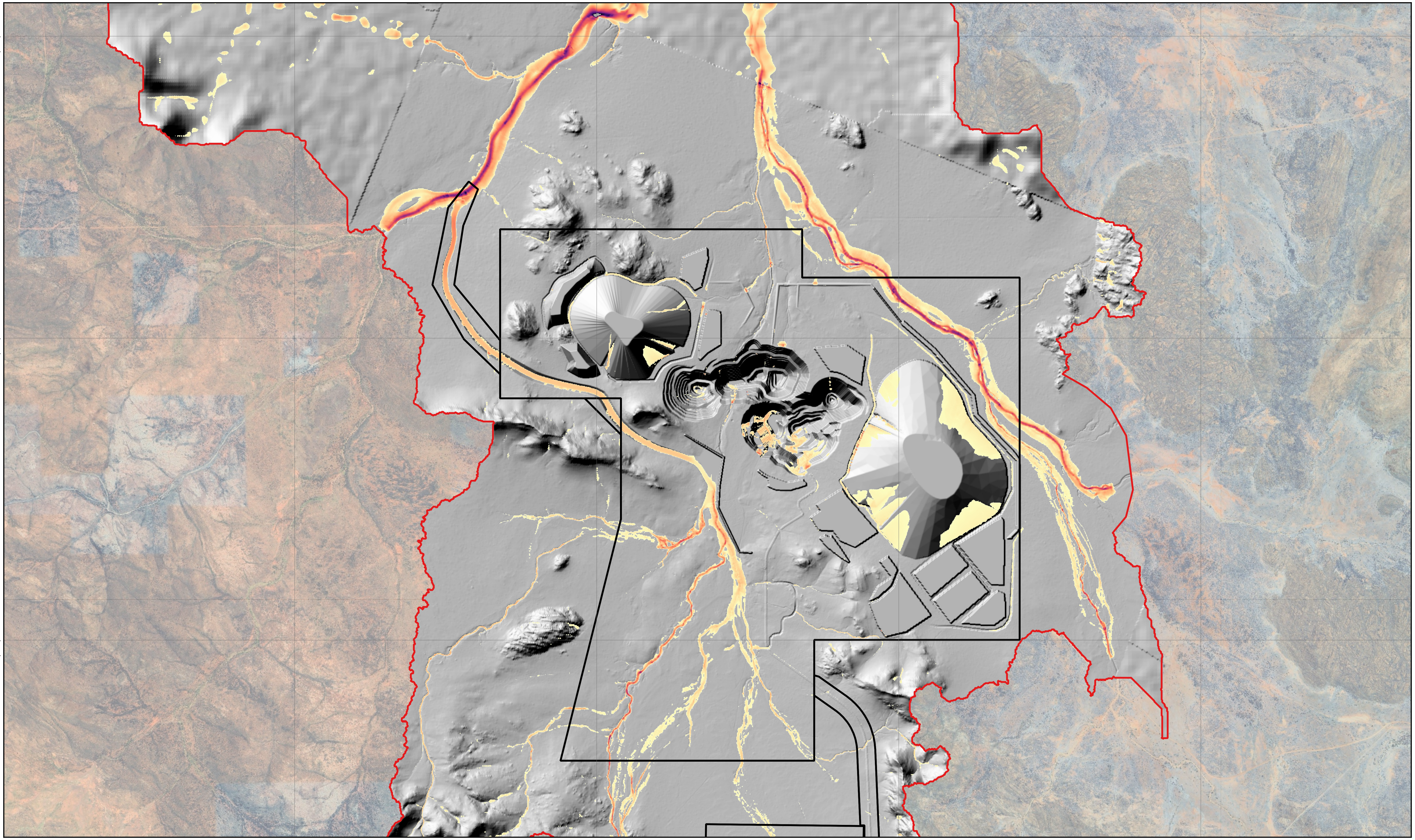
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 SOIL EXCAVATION
1 IN 50 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R

Figure A19



N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA20

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)
≥5
0.5

N

Scale 1:30,000

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Revision: A
Date: 18 July 2024
Paper Size: A3

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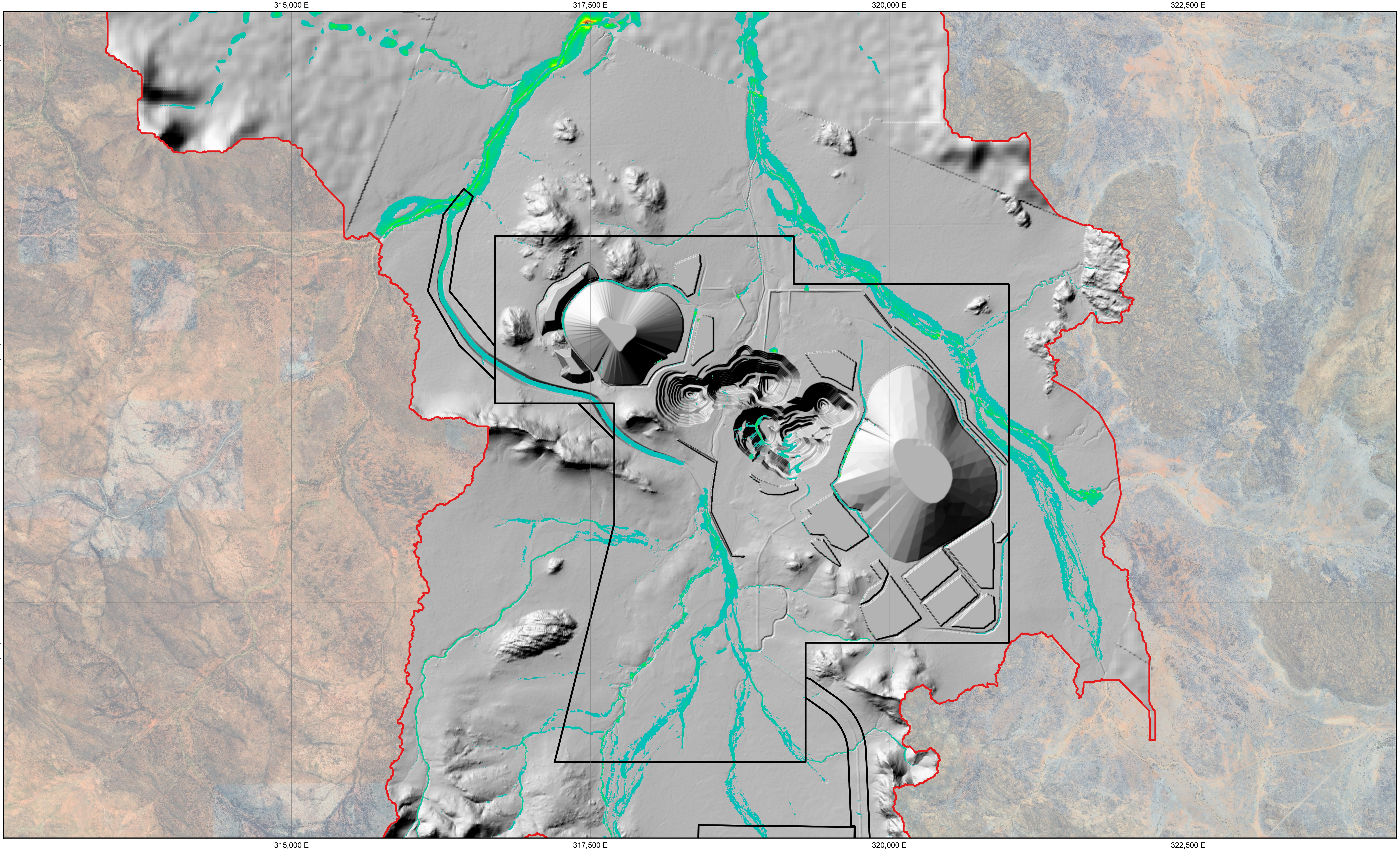
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 ROCK EXCAVATION
1 IN 50 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R
Figure A20



Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)
≥500
10

N

Scale 1:30,000

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 ROCK EXCAVATION
1 IN 50 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

Created By: PSM	Revision: A		
Date: 18 July 2024	Paper Size: A3	PSM4809-016R	Figure A21

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Legend

Lease Boundary

Simulated Aggradation

Notes:
1. Aerial sourced from Google Satellite
2. Sediment agradation assumed to be approximately equivalent to 1,500 m^3 of sediment to achieve a 1 m blockage/deposition of the low-flow channel

Scale 1:5,000

N 50 0 50 100 150 200 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 AGRADATION SENSITIVITY

PSM

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Date: 18 July 2024	Paper Size: A3

PSM4809-016R | Figure A22

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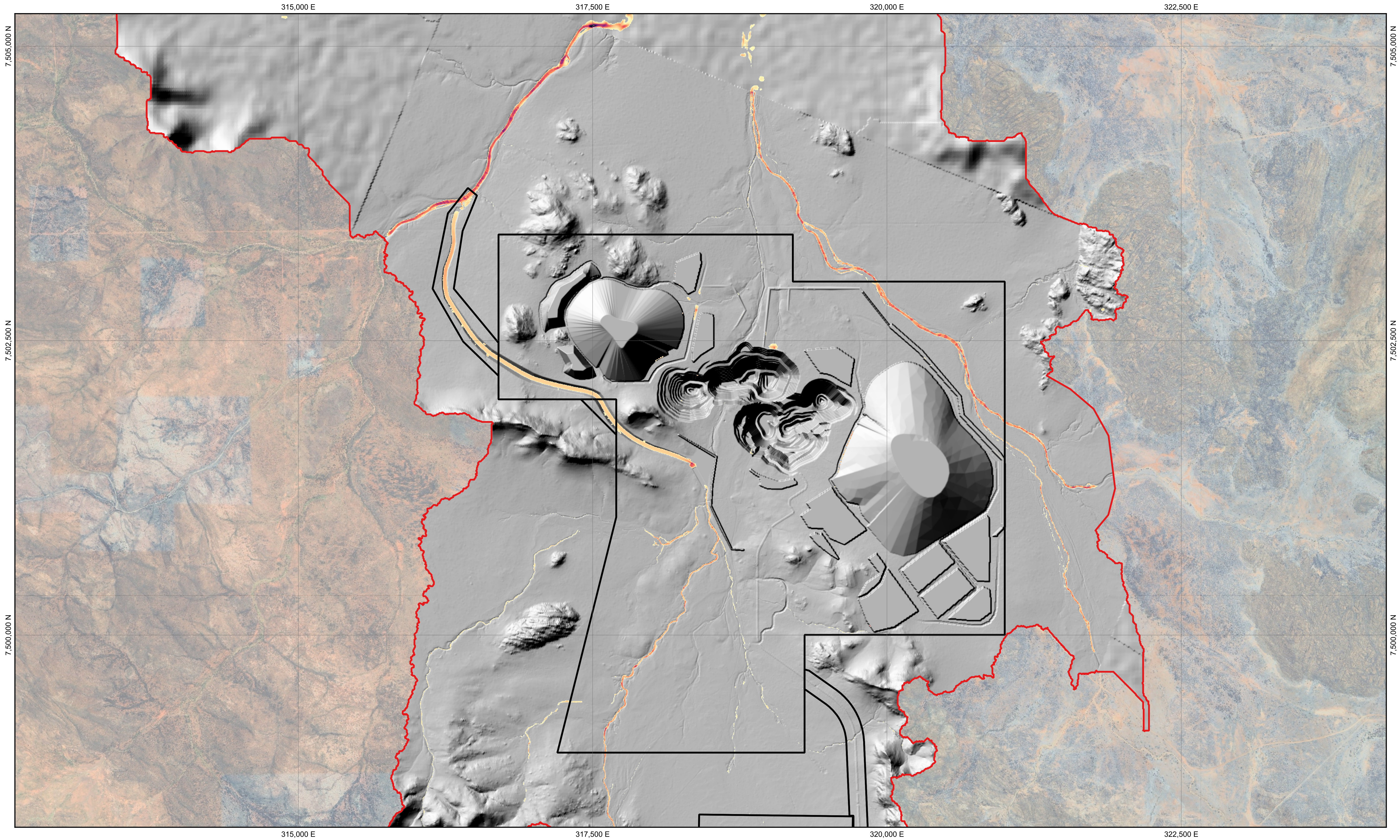

Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Velocity (m/s)

≥5

0.5

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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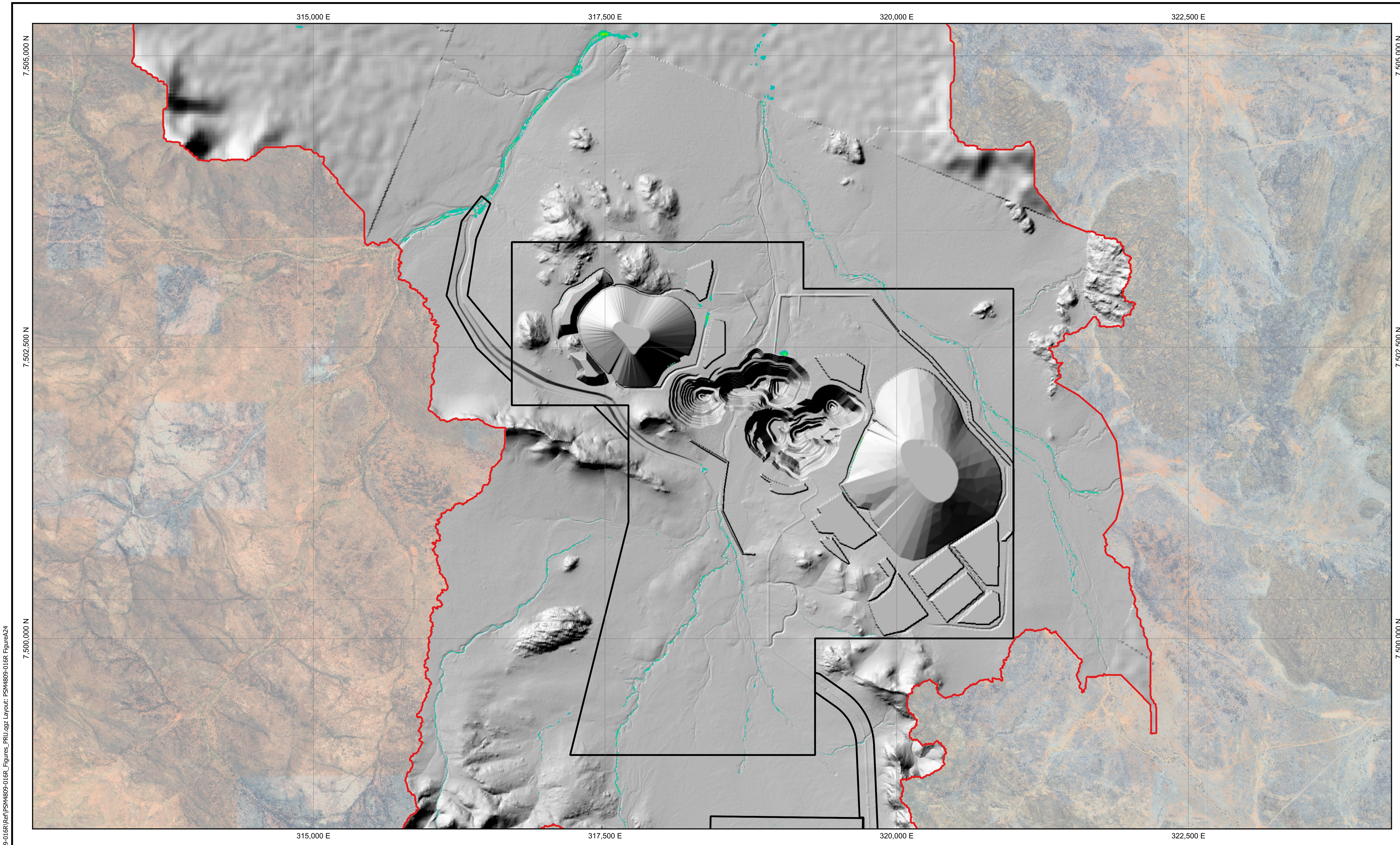
Date: 18 July 2024	Paper Size: A3

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 AGRADATION
1 IN 2 AEP DESIGN EVENT
MAXIMUM VELOCITY

PSM4809-016R | Figure A23

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA23



Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Shear Stress (N/m^2)

≥500

10

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

P S M

Created By: PSM

Revision: A

Date: 18 July 2024

Paper Size: A3

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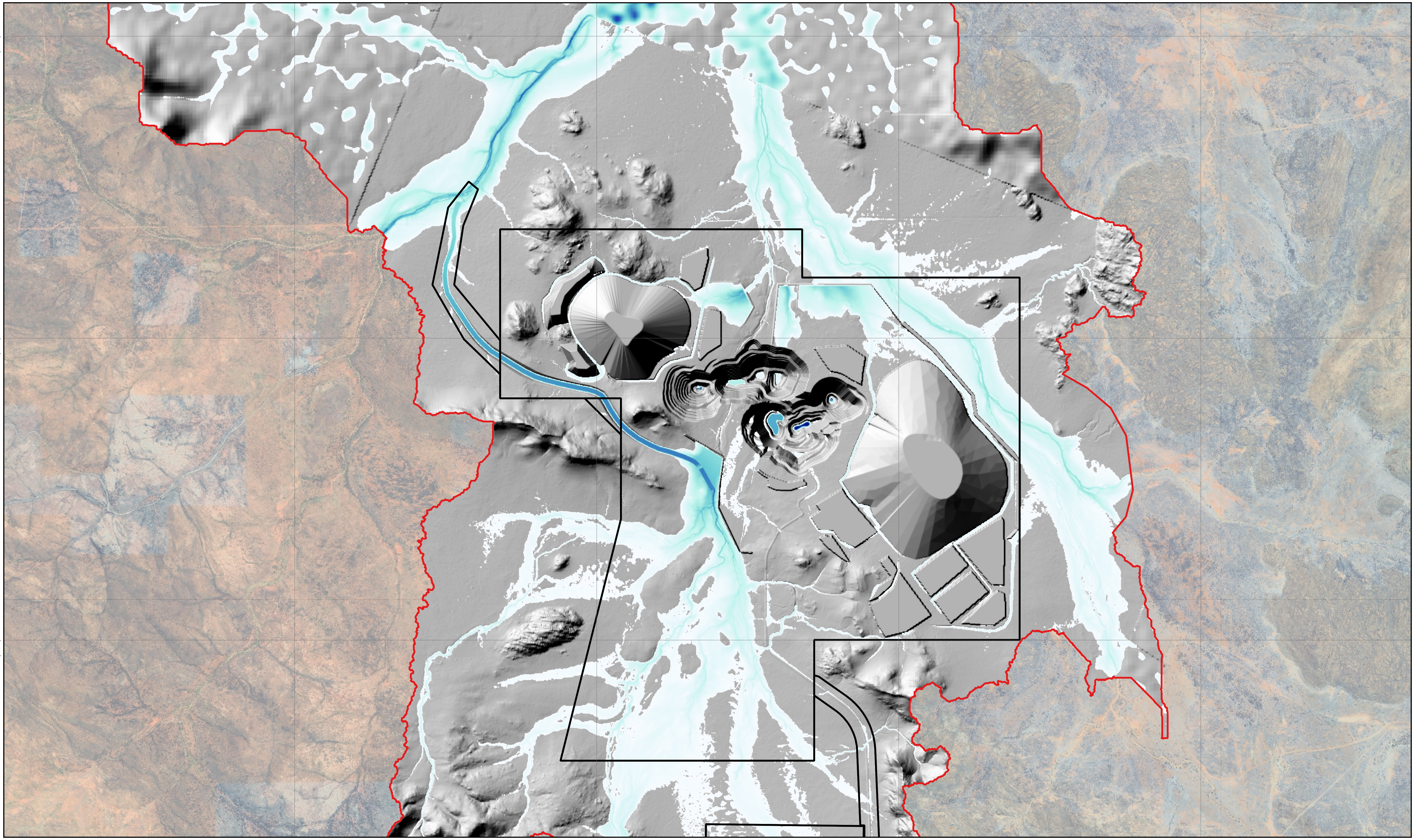
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 AGRADATION
1 IN 2 AEP DESIGN EVENT
MAXIMUM SHEAR STRESS

PSM4809-016R

Figure A24

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA24



Legend

- Lease Boundary
- Model Boundary

Notes:
1. Aerial sourced from Google Satellite

Maximum Depth (m)

≥5

0.1

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

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Date: 18 July 2024

Paper Size: A3

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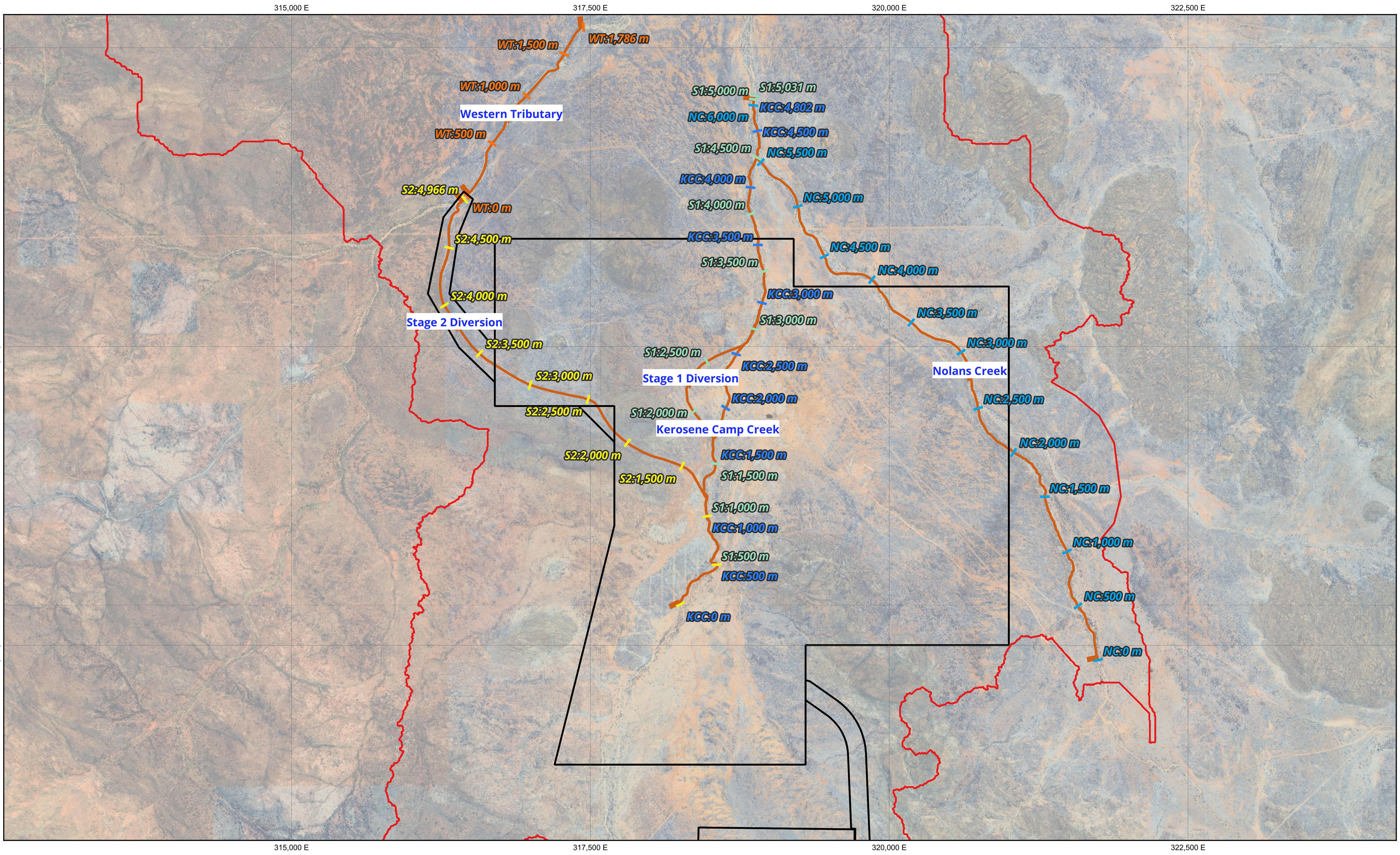
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 AGRADATION
1 IN 1,000 AEP DESIGN EVENT
MAXIMUM DEPTH

PSM4809-016R

Figure A25

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA25



Legend

- Lease Boundary
- Model Boundary
- Long Sections

Chainage Marks

- Kerosene Camp Creek
- Nolans Creek
- Stage 1 Diversion
- Stage 2 Diversion
- Western Tributary

Notes:
1. Aerial sourced from Google Satellite

Scale 1:30,000

N

250 0 250 500 750 1,000 m

Map Projection:
GDA2020 / MGA zone 53
EPSG:7853

PSM

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Revision: A

Date: 18 July 2024

Paper Size: A3

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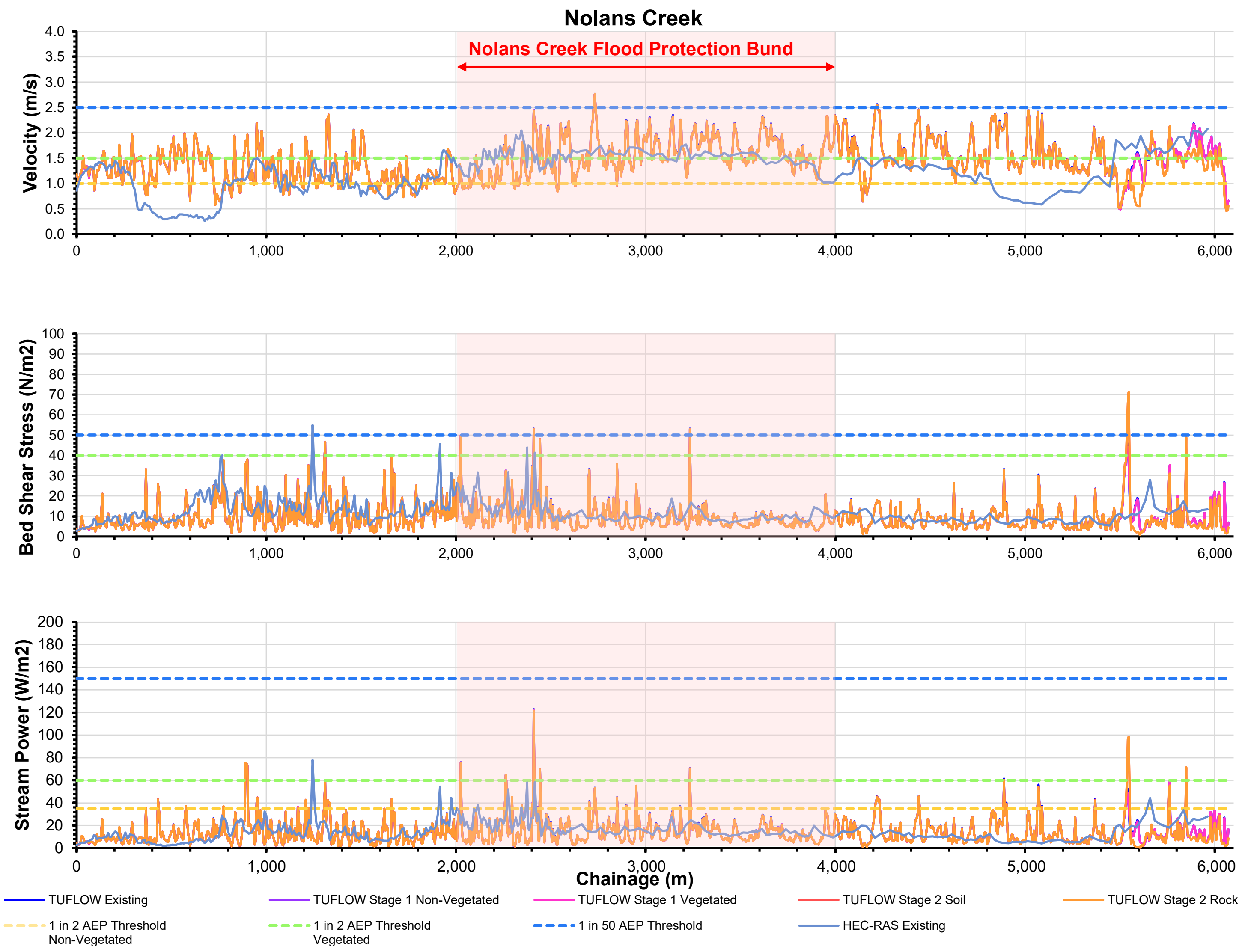
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

HYDRAULIC PARAMETER QUERY LONG SECTIONS

PSM4809-016R

Figure A26

N:\PSM4809\Eng\01.GIS\QGIS\08_Figures\PSM4809-016R\Ref\PSM4809-016R_Figures_PRU.qgz Layout: PSM4809-016R FigureA26



Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2

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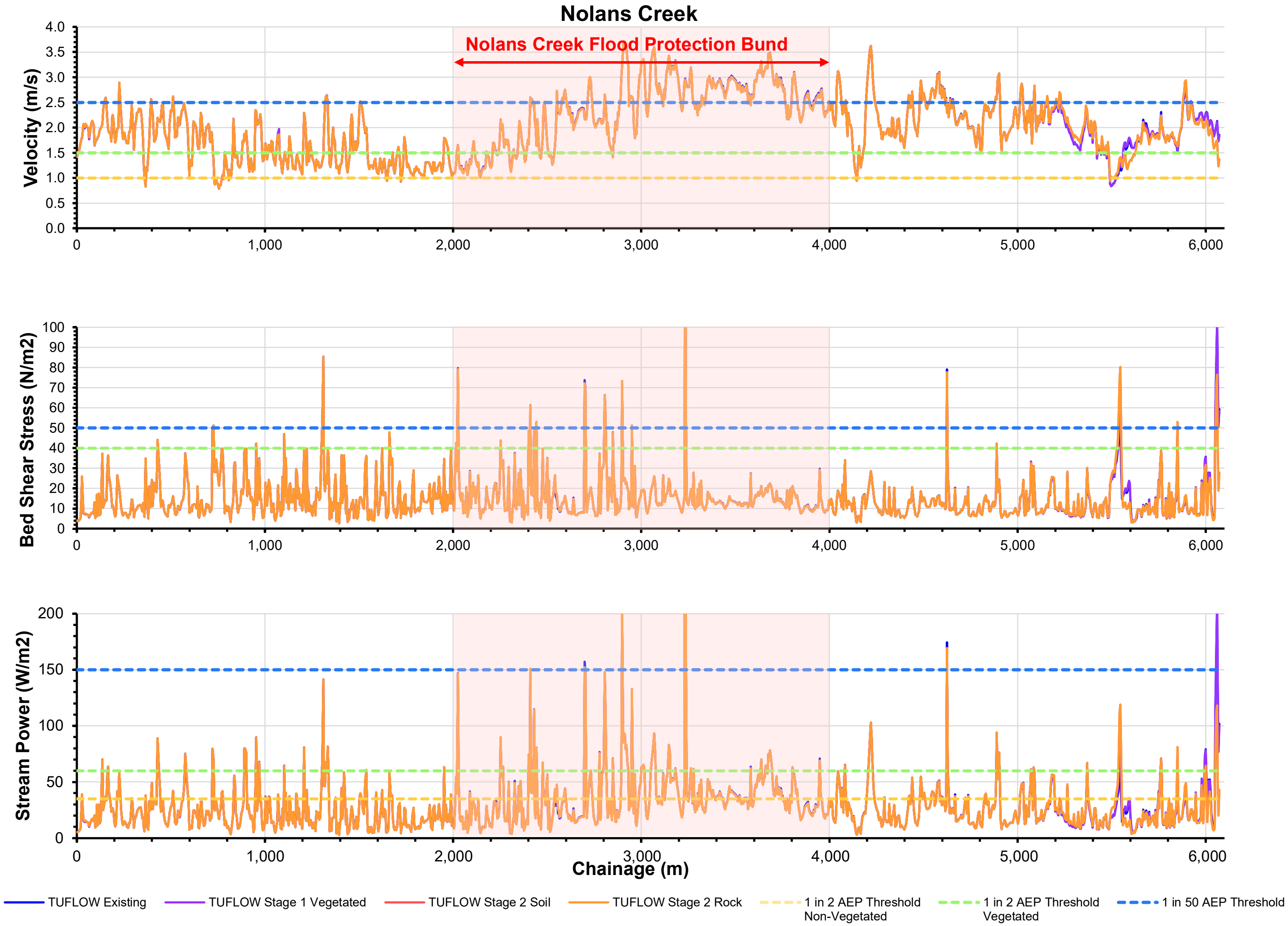
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

NOLANS CREEK 1 IN 2 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R | Figure A27



Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2

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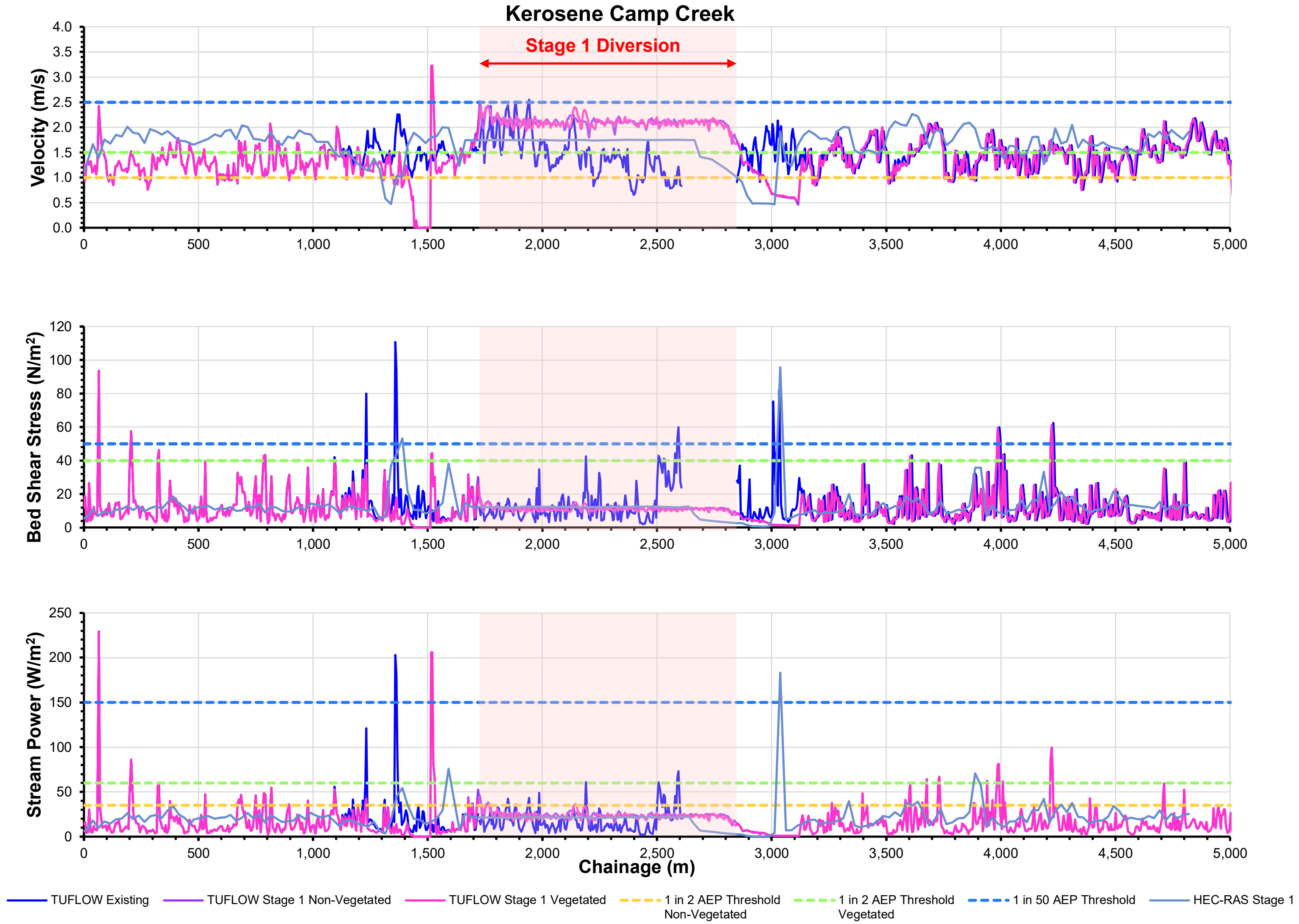
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

NOLANS CREEK 1 IN 50 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A28

N:\PSM4809\Eng\03.Phase2\TUFLOW\[PeerReview_TUFLOW_Extract.xlsx]S2DD



Notes:

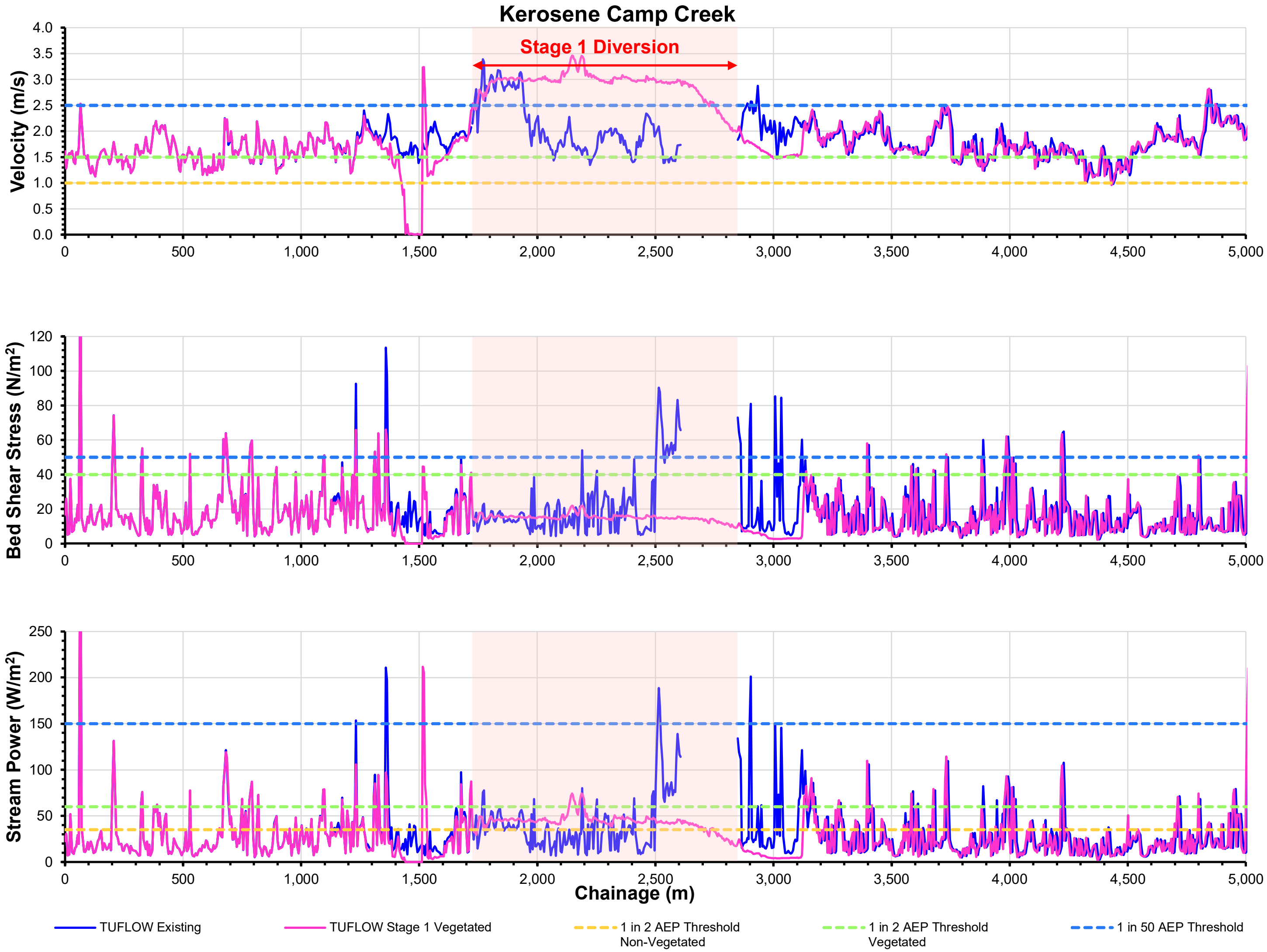
1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2
5. Includes both the Kerosene Camp Creek and Stage 1 Diversion long sections

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

KEROSENE CAMP CREEK 1 IN 2 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A29

N:\PSM4809\Eng\03.Phase2\TUFLOW\[PeerReview_TUFLOW_Extract.xlsx]S2DD



Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2
5. Includes both the Kerosene Camp Creek and Stage 1 Diversion long sections

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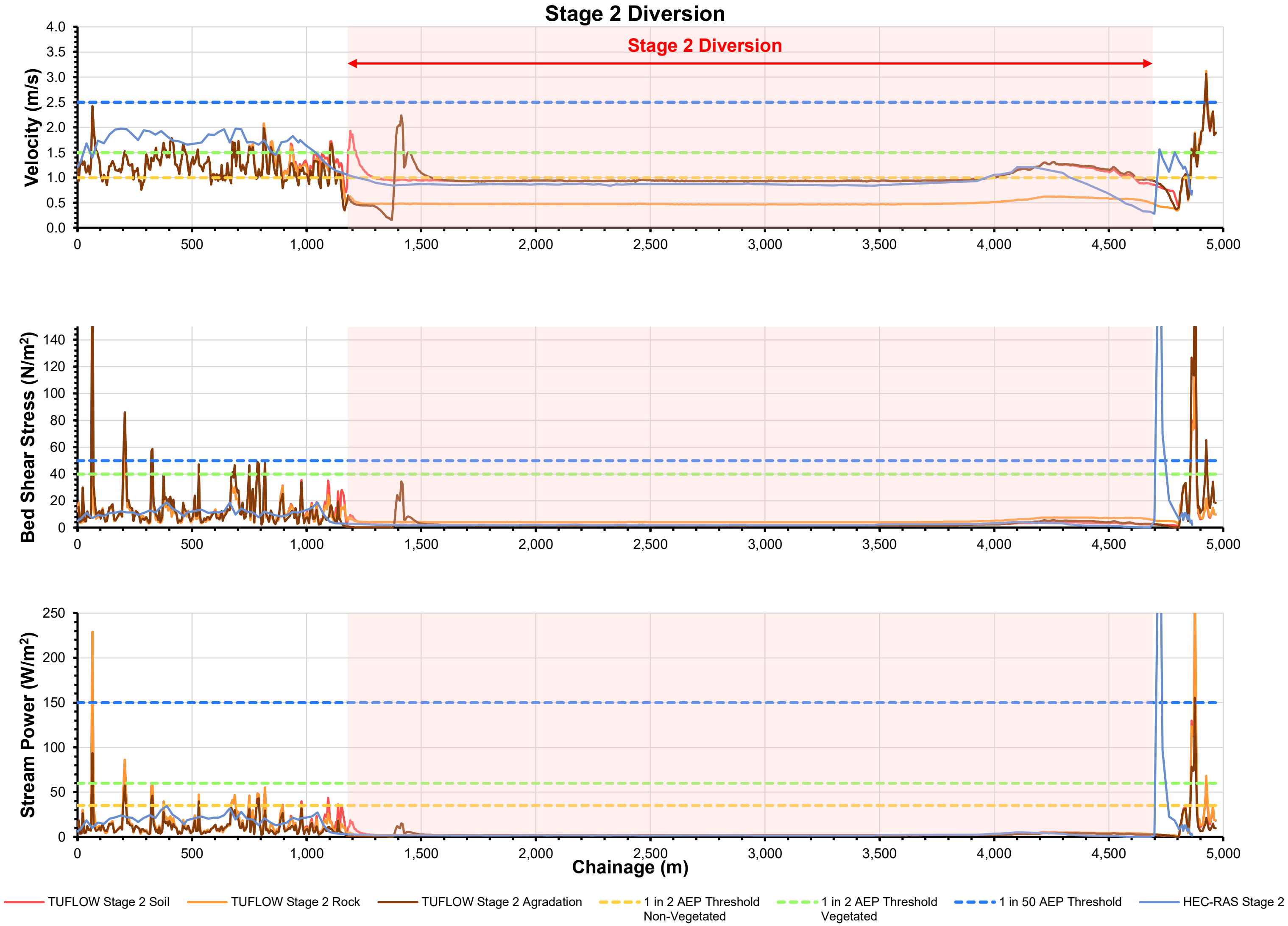
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

KEROSENE CAMP CREEK 1 IN 50 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A30

N:\PSM4809\Eng\03.Phase2\TUFLOW\[PeerReview_TUFLOW_Extract.xlsx]S2DD



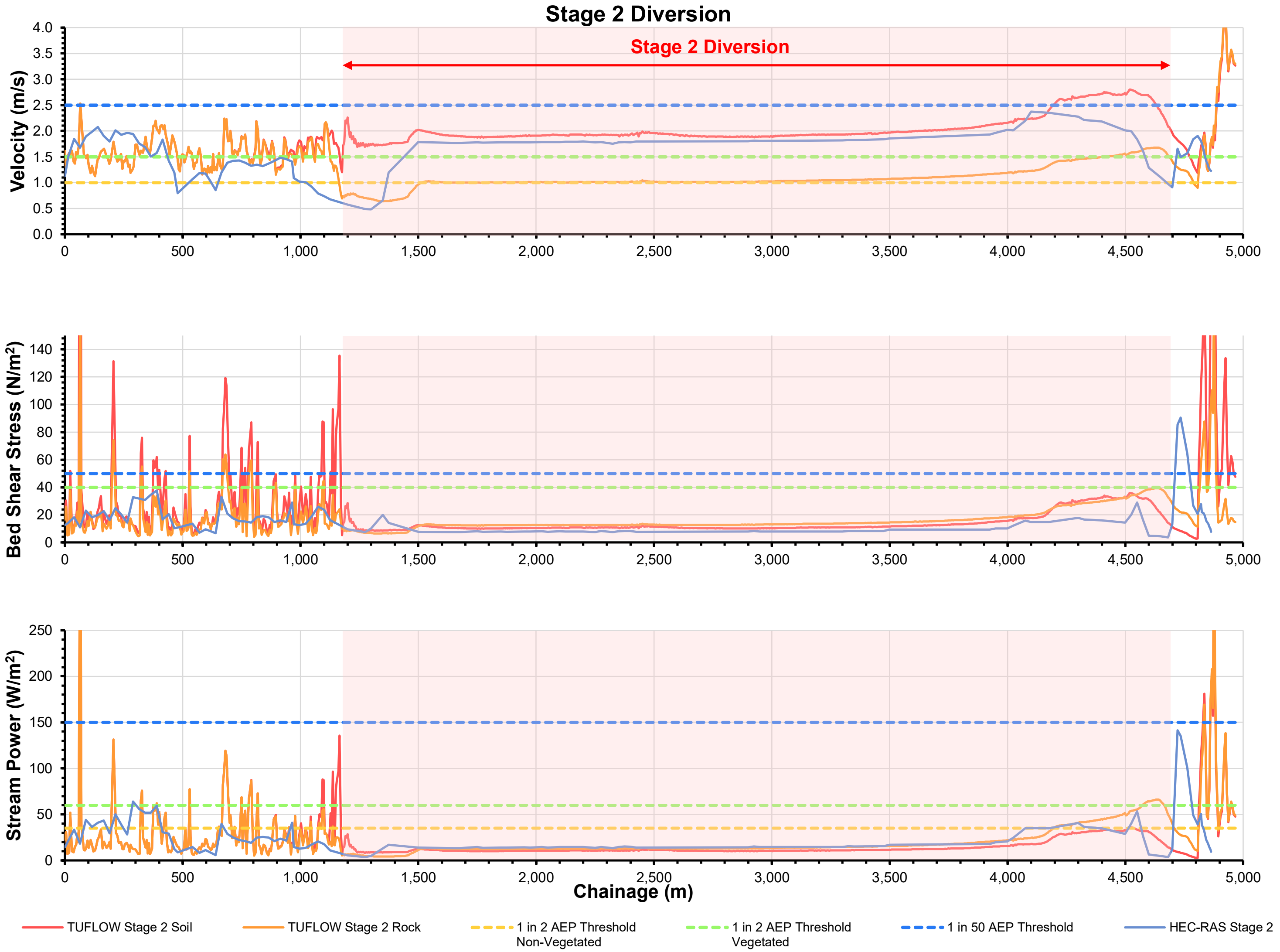
Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2

Arafura Resources Limited
Nolans Rare Earth Project
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 DIVERSION 1 IN 2 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A31



Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2

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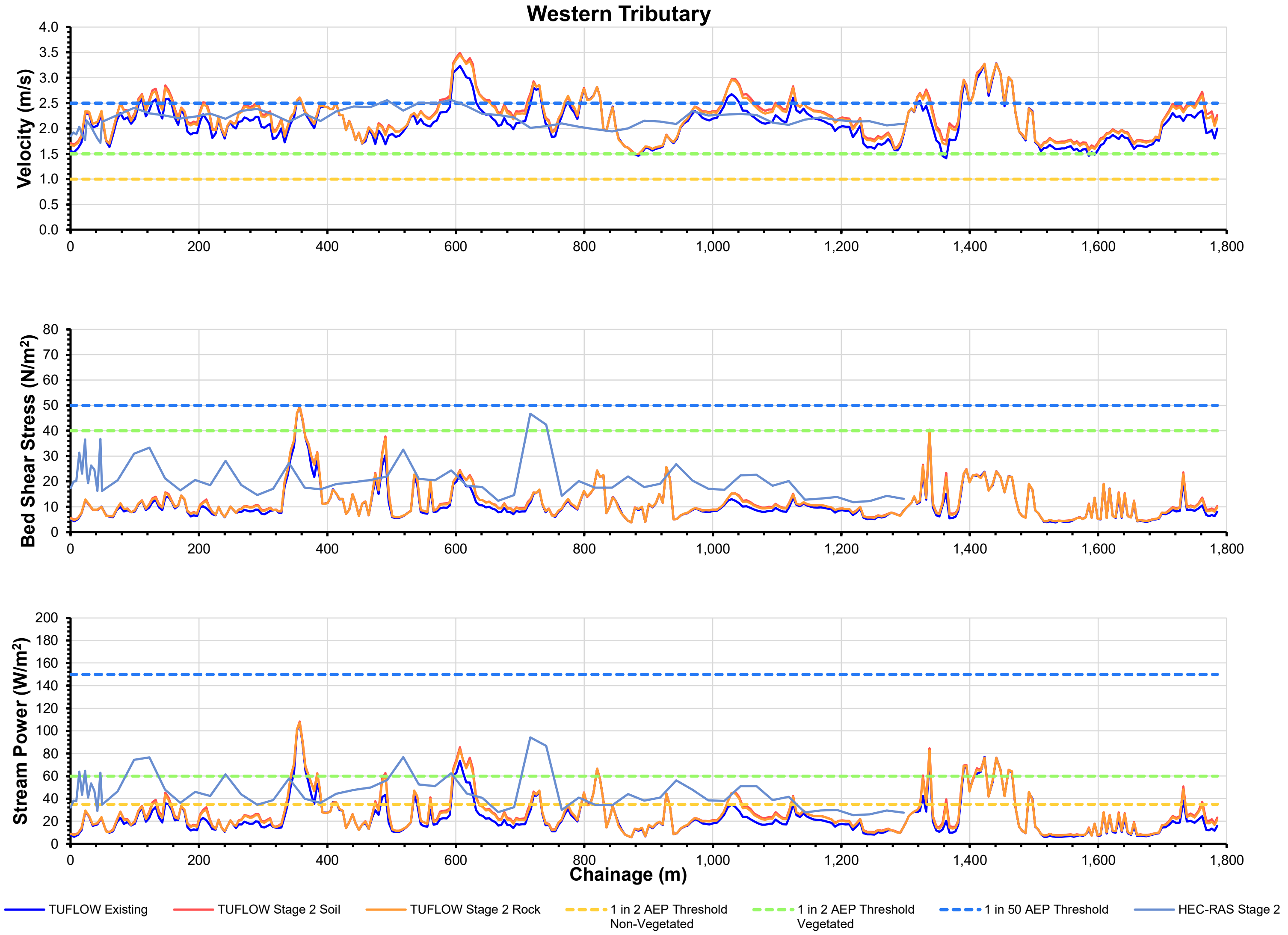
Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

STAGE 2 DIVERSION 1 IN 50 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A32



Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2

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Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

WESTERN TRIBUTARY 1 IN 2 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A33

Notes:

1. Hydraulic parameter thresholds based on the Queensland Government DNRME 2019 guideline for water course diversions authorised under the Water Act 2000
2. Velocity thresholds - 1 in 2 AEP non-vegetated = 1 m/s, 1 in 2 AEP vegetated = 1.5 m/s, 1 in 50 AEP = 2.5 m/s
3. Bed shear stress thresholds - 1 in 2 AEP non-vegetated = 40 N/m^2, 1 in 2 AEP vegetated = 40 N/m^2, 1 in 50 AEP = 50 N/m^2
4. Stream power thresholds - 1 in 2 AEP non-vegetated = 30 W/m^2, 1 in 2 AEP vegetated = 60 W/m^2, 1 in 50 AEP = 150 W/m^2

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Kerosene Camp Creek Diversion and Mine Surface Water Management - 50% Level Design

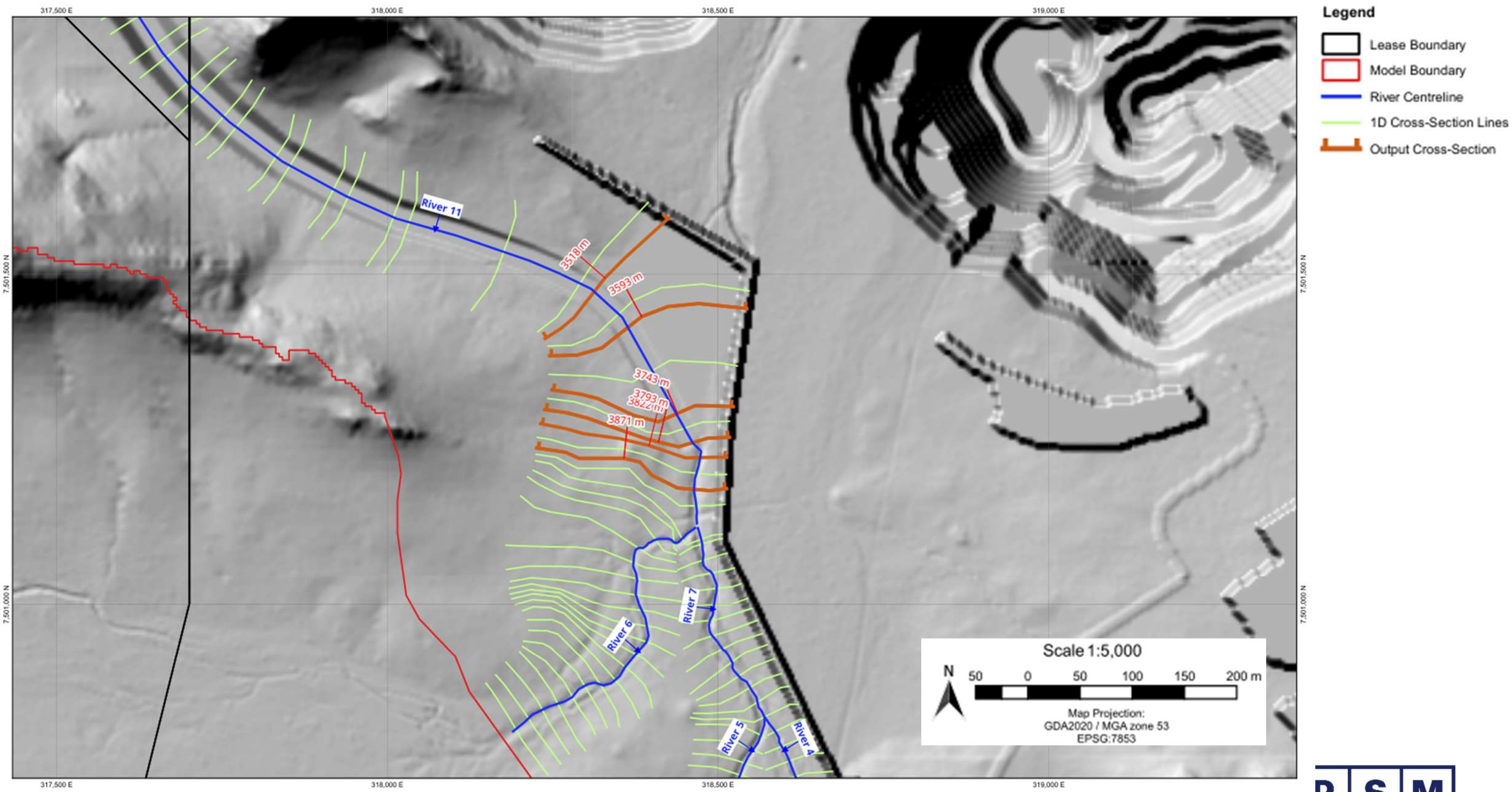
WESTERN TRIBUTARY 1 IN 50 AEP HYDRAULIC PARAMETER LONG SECTION PROFILE

PSM4809-016R	Figure A34

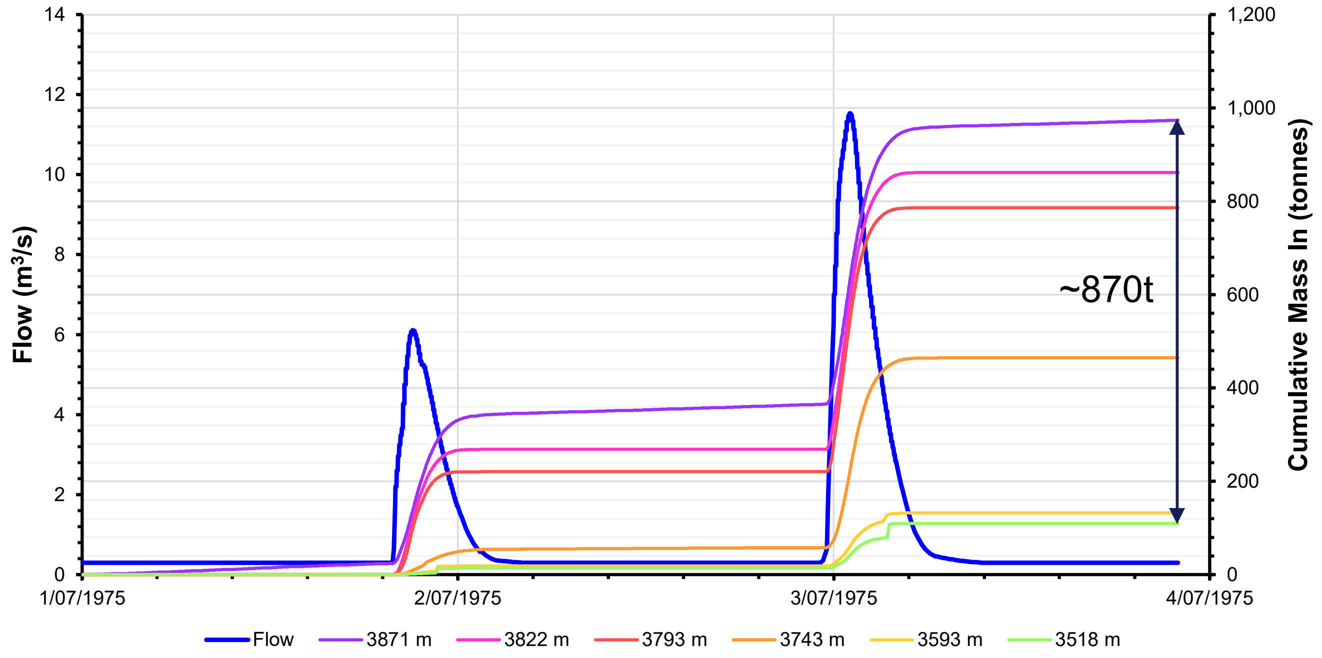
Appendix B
Stage 2 Diversion Drain Inlet Aggradation Sensitivties

Appendix B

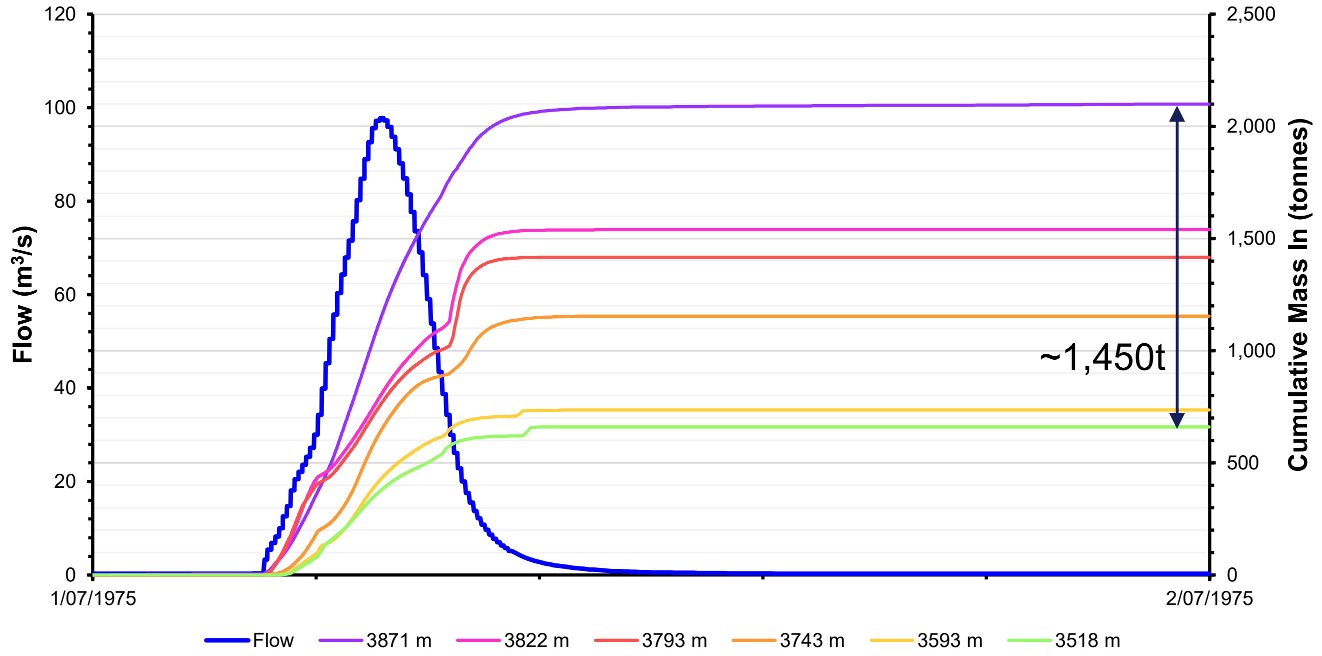
Cross-Sections



Cumulative Mass In



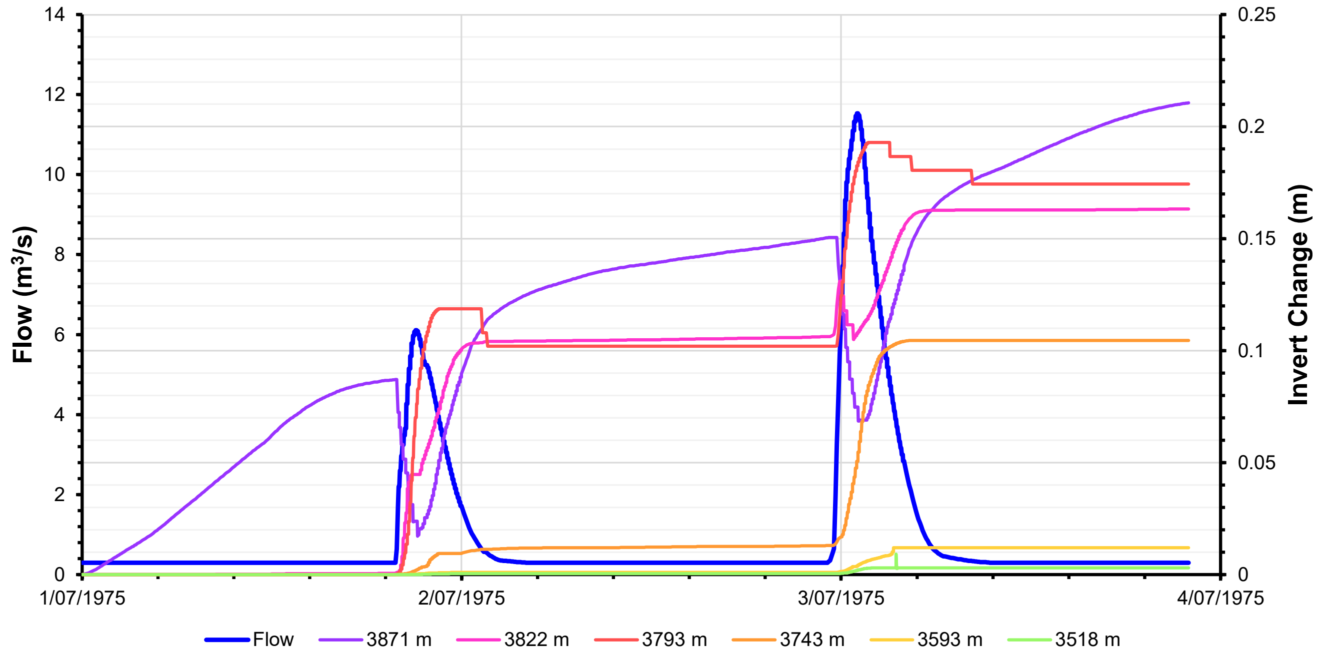
Stage 2 Soil Excavation Sensitivity
1 in 2 AEP Design Event



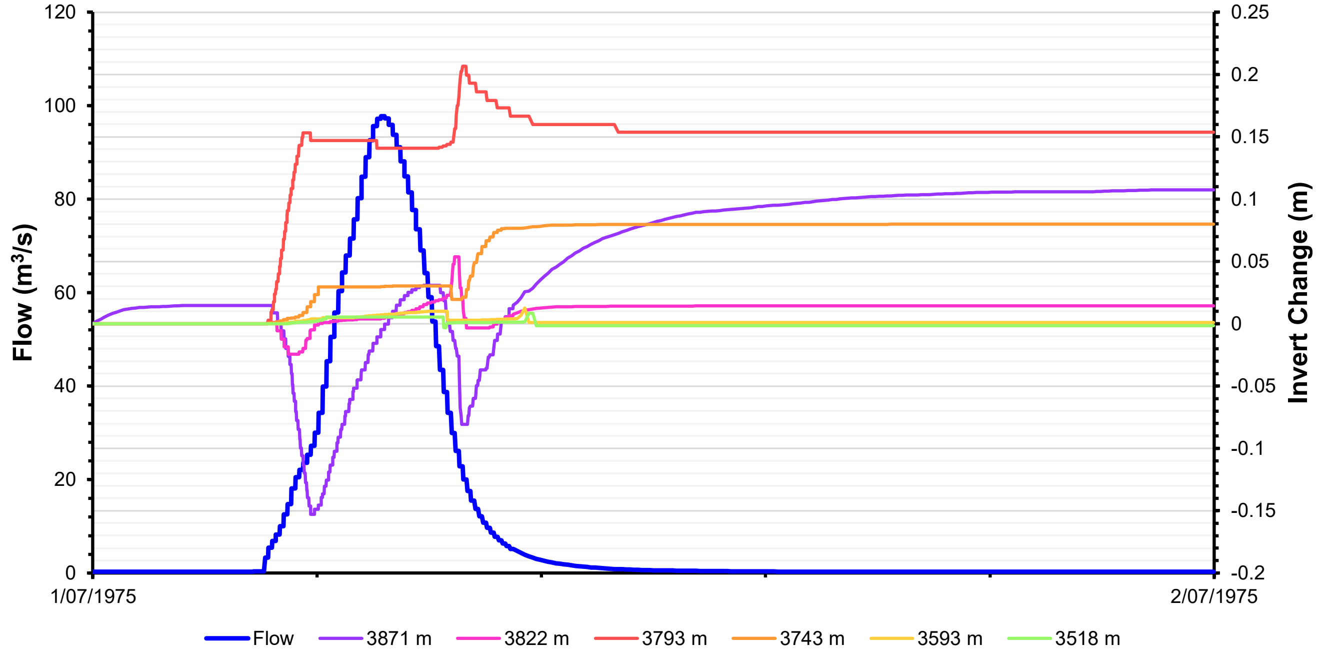
Stage 2 Soil Excavation Sensitivity
1 in 50 AEP Design Event

PSM

Invert Change

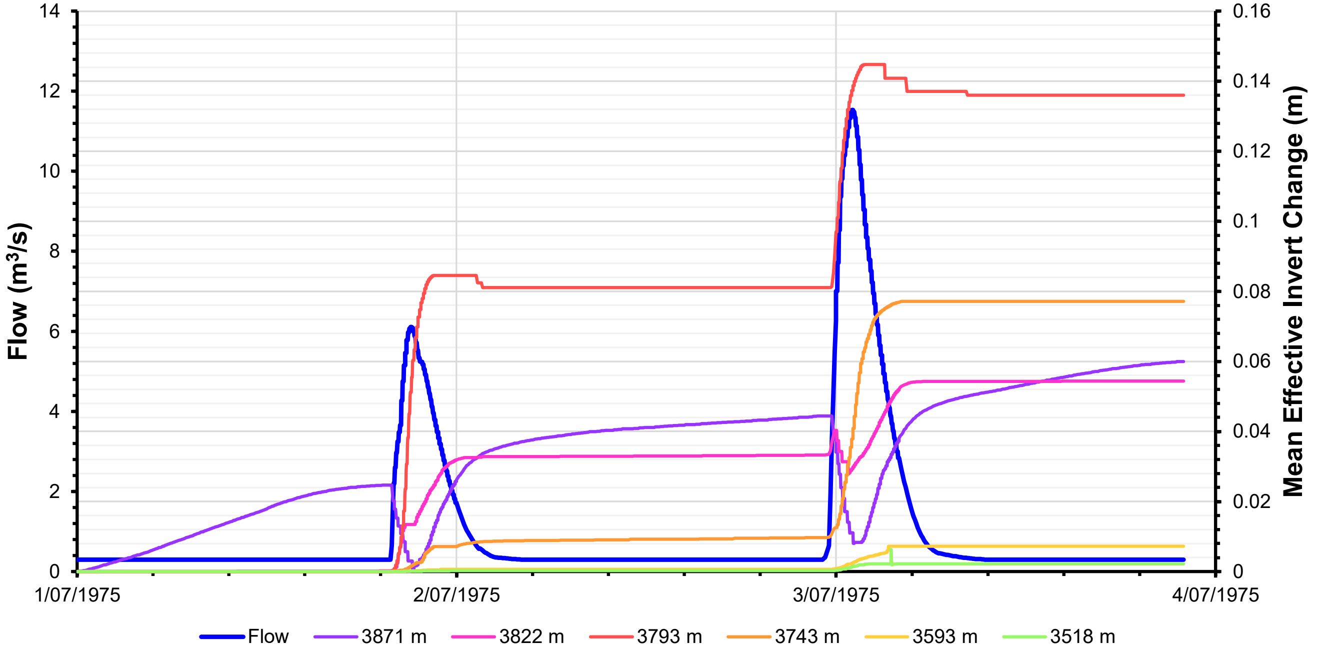


Stage 2 Soil Excavation Sensitivity 1 in 2 AEP Design Event

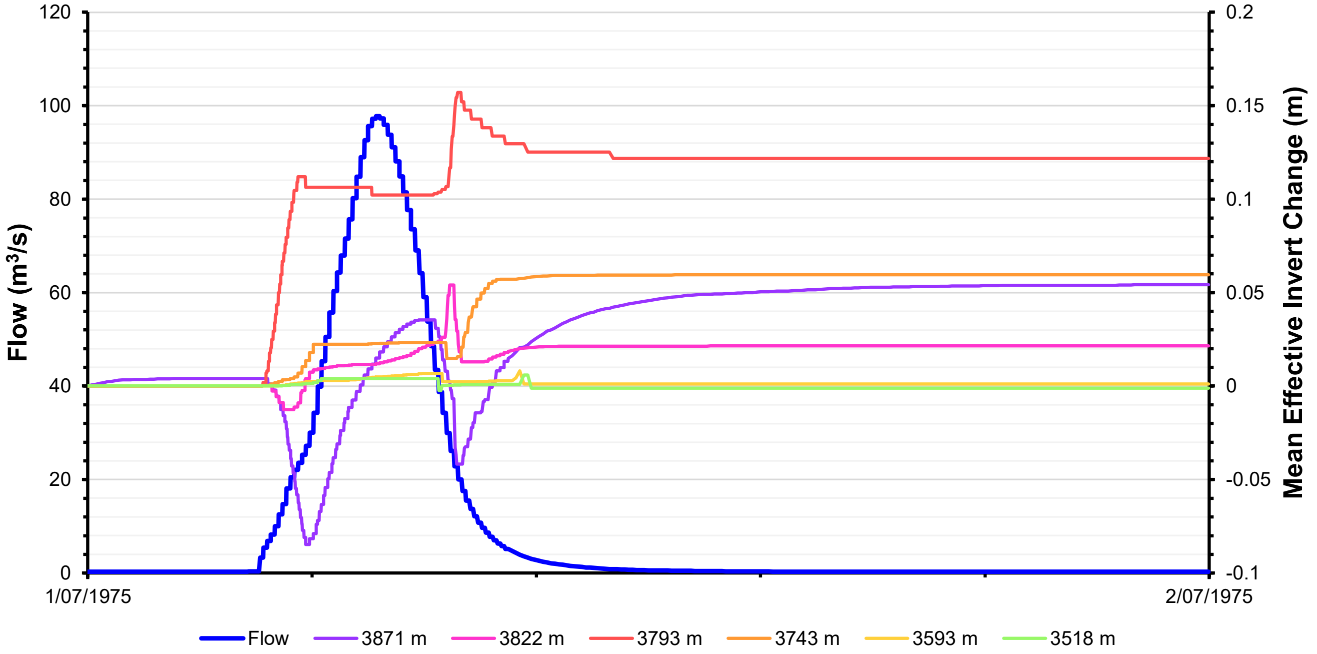


Stage 2 Soil Excavation Sensitivity 1 in 50 AEP Design Event

Mean Effective Invert Change

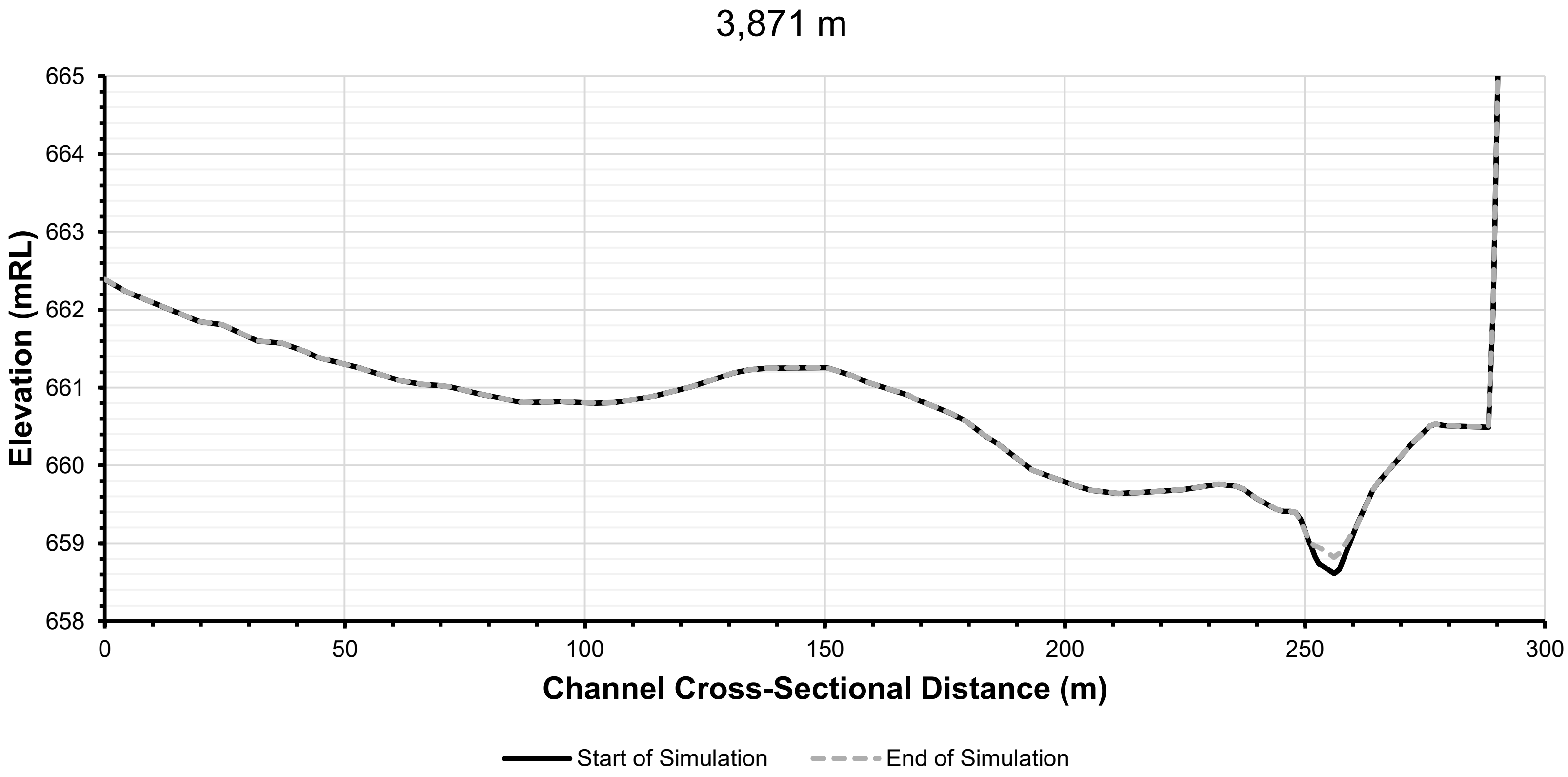


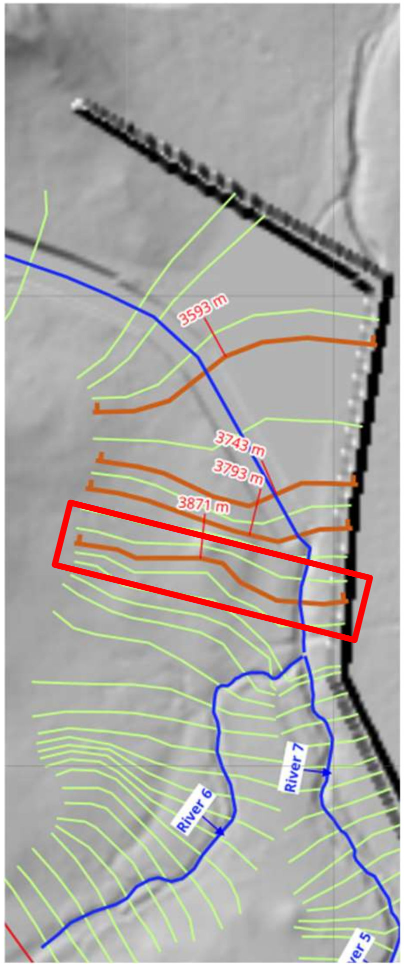
Stage 2 Soil Excavation Sensitivity
1 in 2 AEP Design Event



Stage 2 Soil Excavation Sensitivity
1 in 50 AEP Design Event

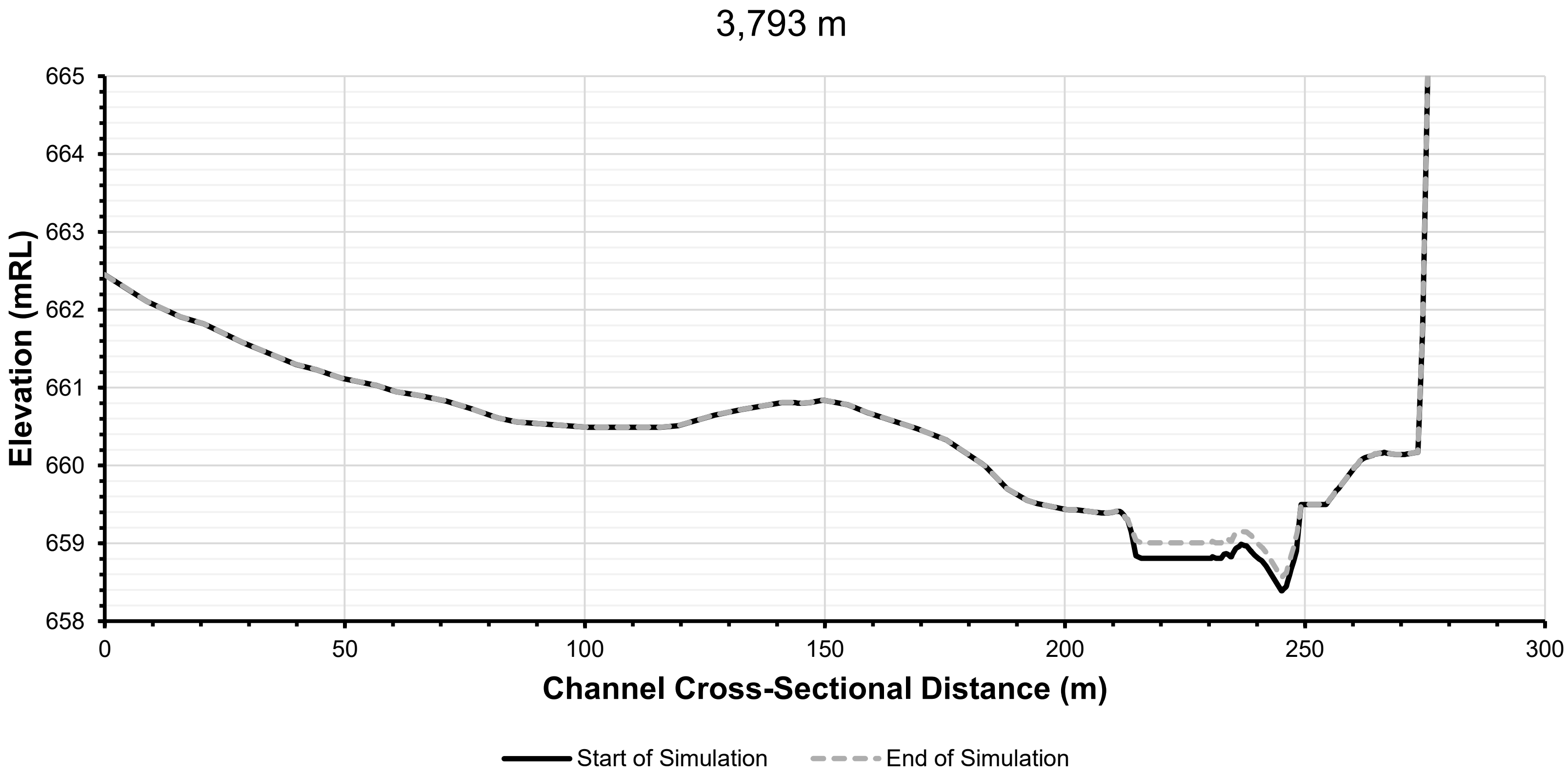
Cross-Section Profile Chainage 3,871 m

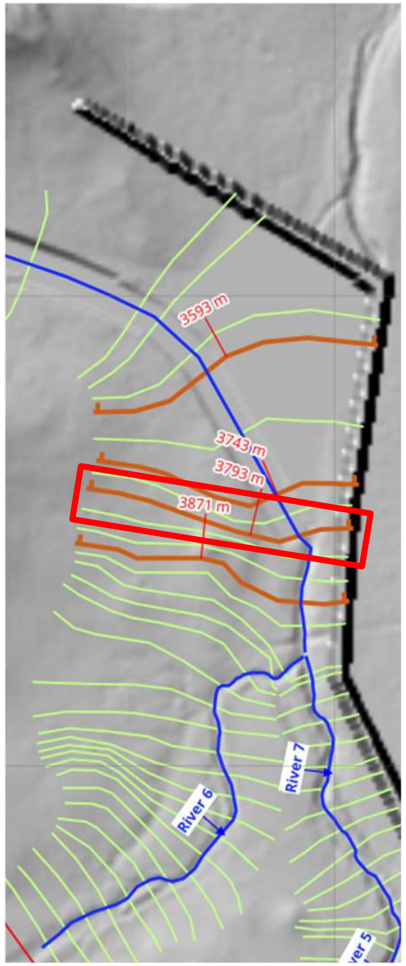




Stage 2 Soil Excavation Sensitivity
1 in 2 AEP Design Event

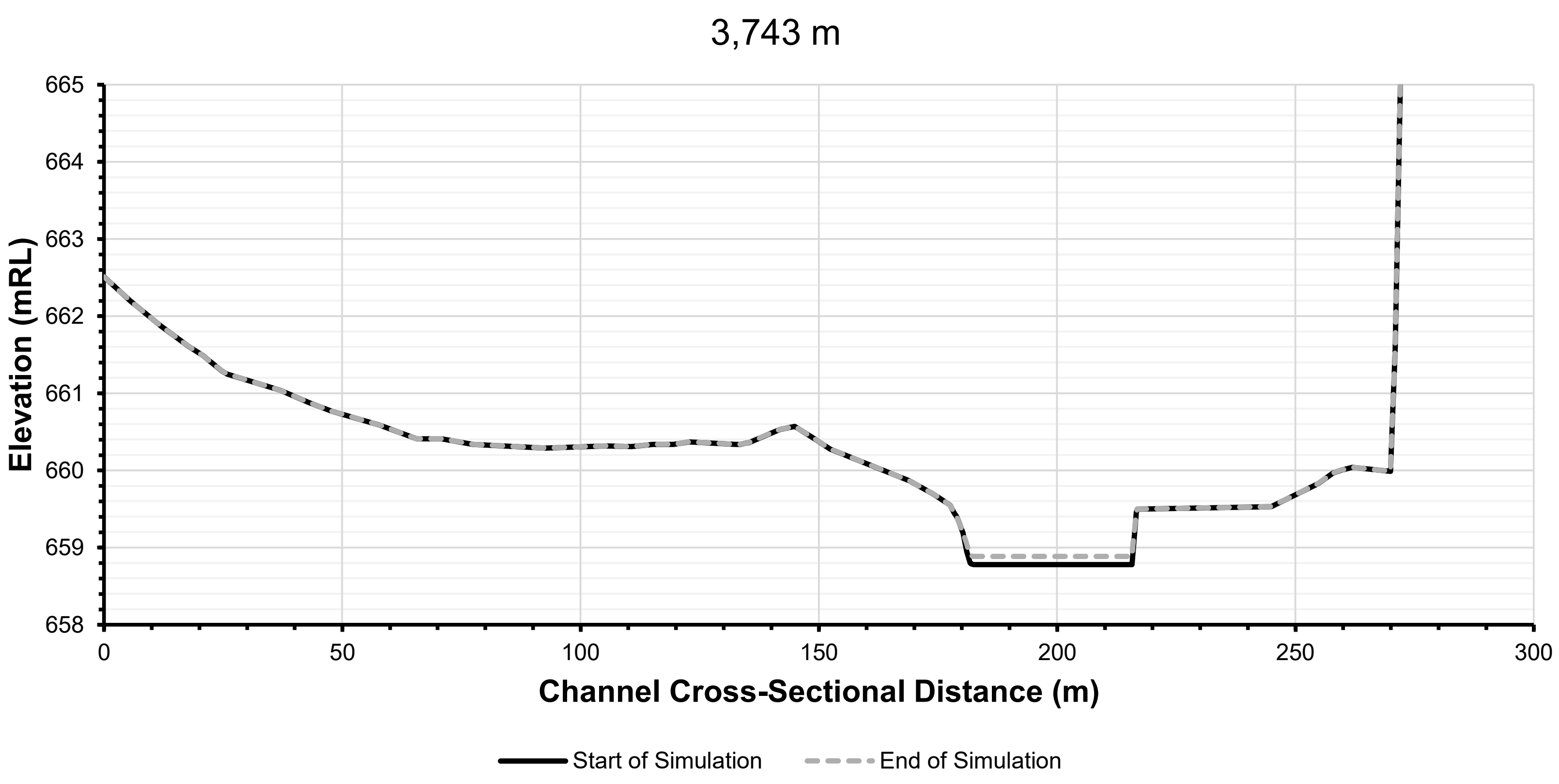
Cross-Section Profile Chainage 3,793 m

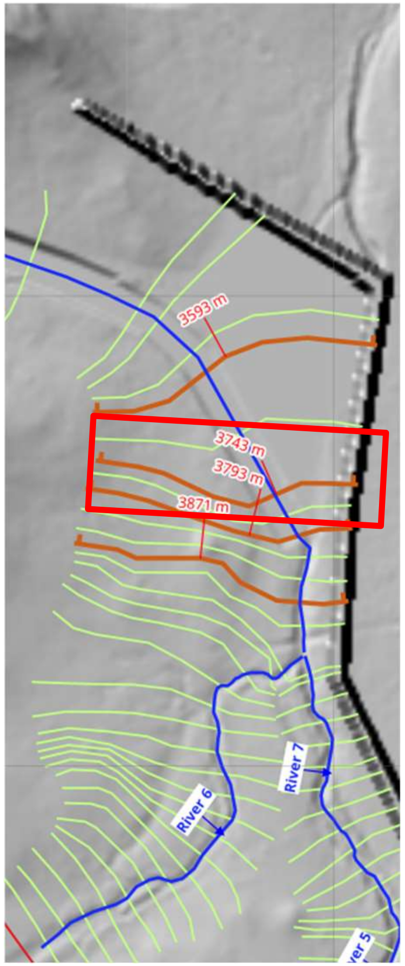




Stage 2 Soil Excavation Sensitivity
1 in 2 AEP Design Event

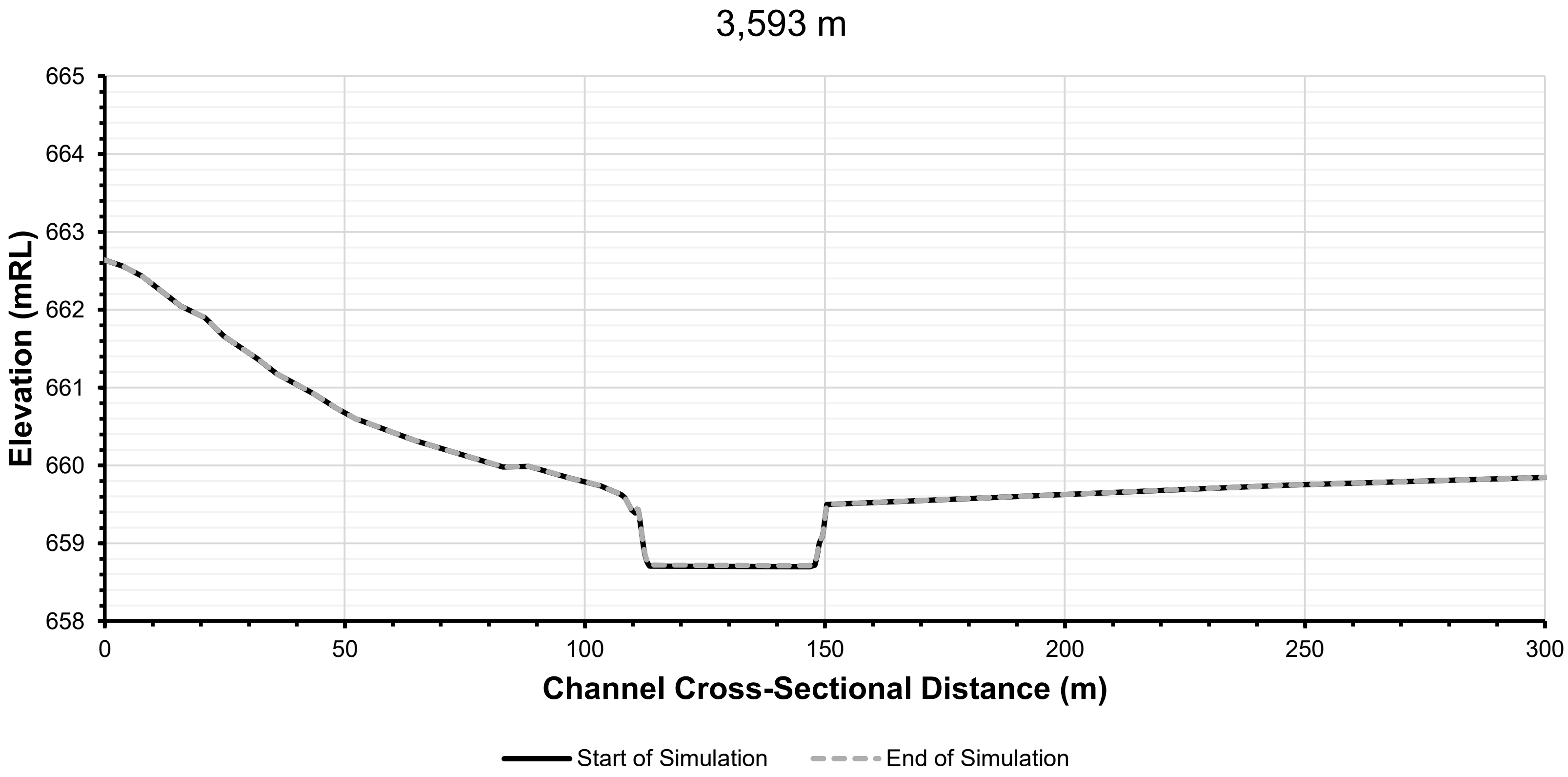
Cross-Section Profile Chainage 3,743 m

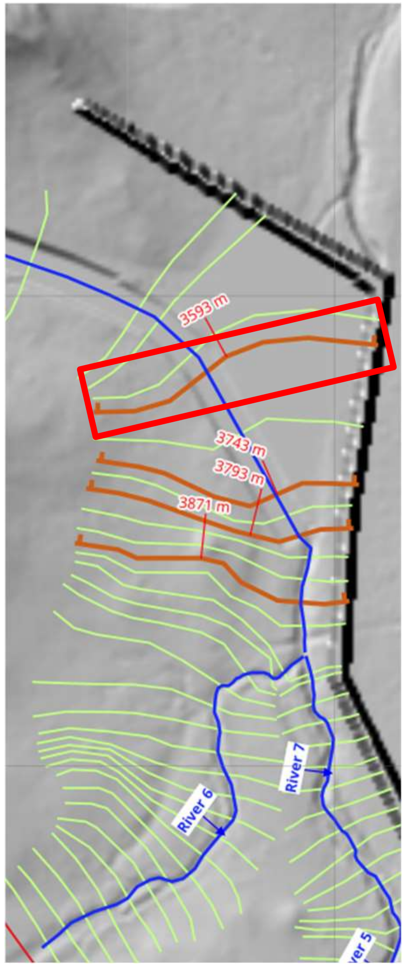




Stage 2 Soil Excavation Sensitivity
1 in 2 AEP Design Event

Cross-Section Profile Chainage 3,593 m





Stage 2 Soil Excavation Sensitivity
1 in 2 AEP Design Event

Appendix C
Erosion Analysis Results

PSM

Transport Function Sensitivities

Model 1 – Ackers-White and fines defined along diversion drain

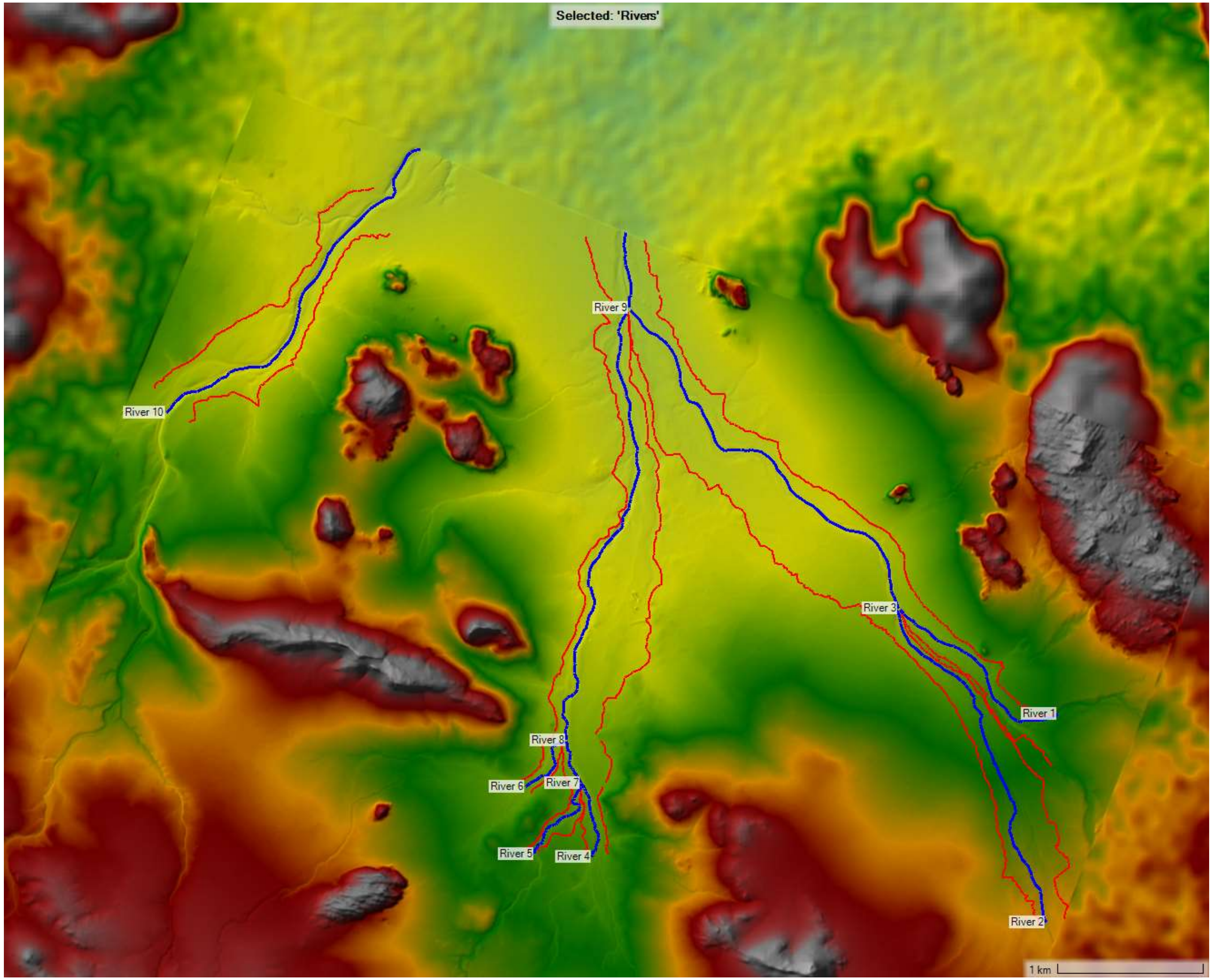
Model 2 – Toffaleti and fines defined along diversion drain

Model 3 – Ackers-White and no erosion defined along diversion drain

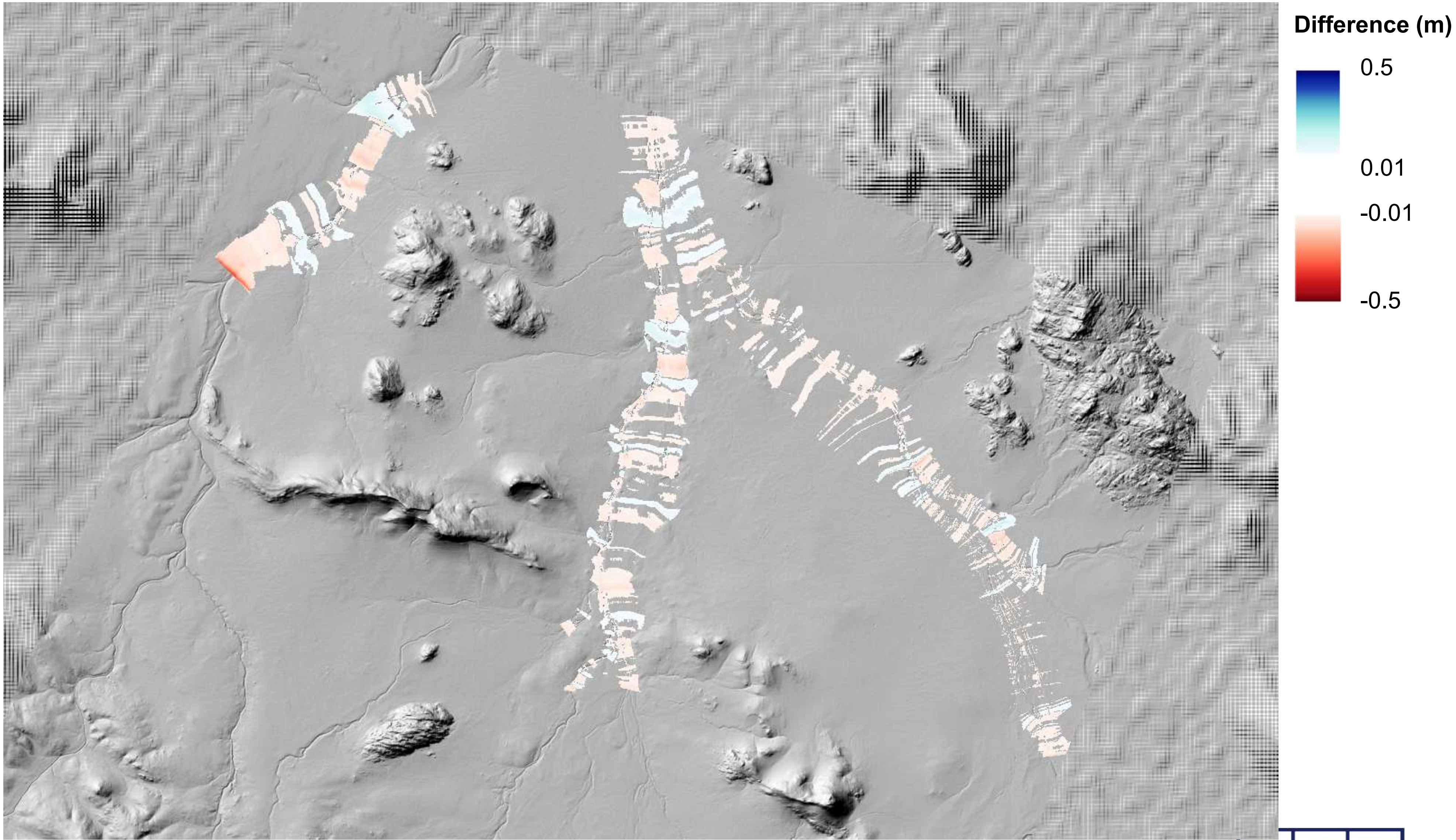
Model 4 – Yang and no erosion defined along diversion drain

CASE – EXISTING

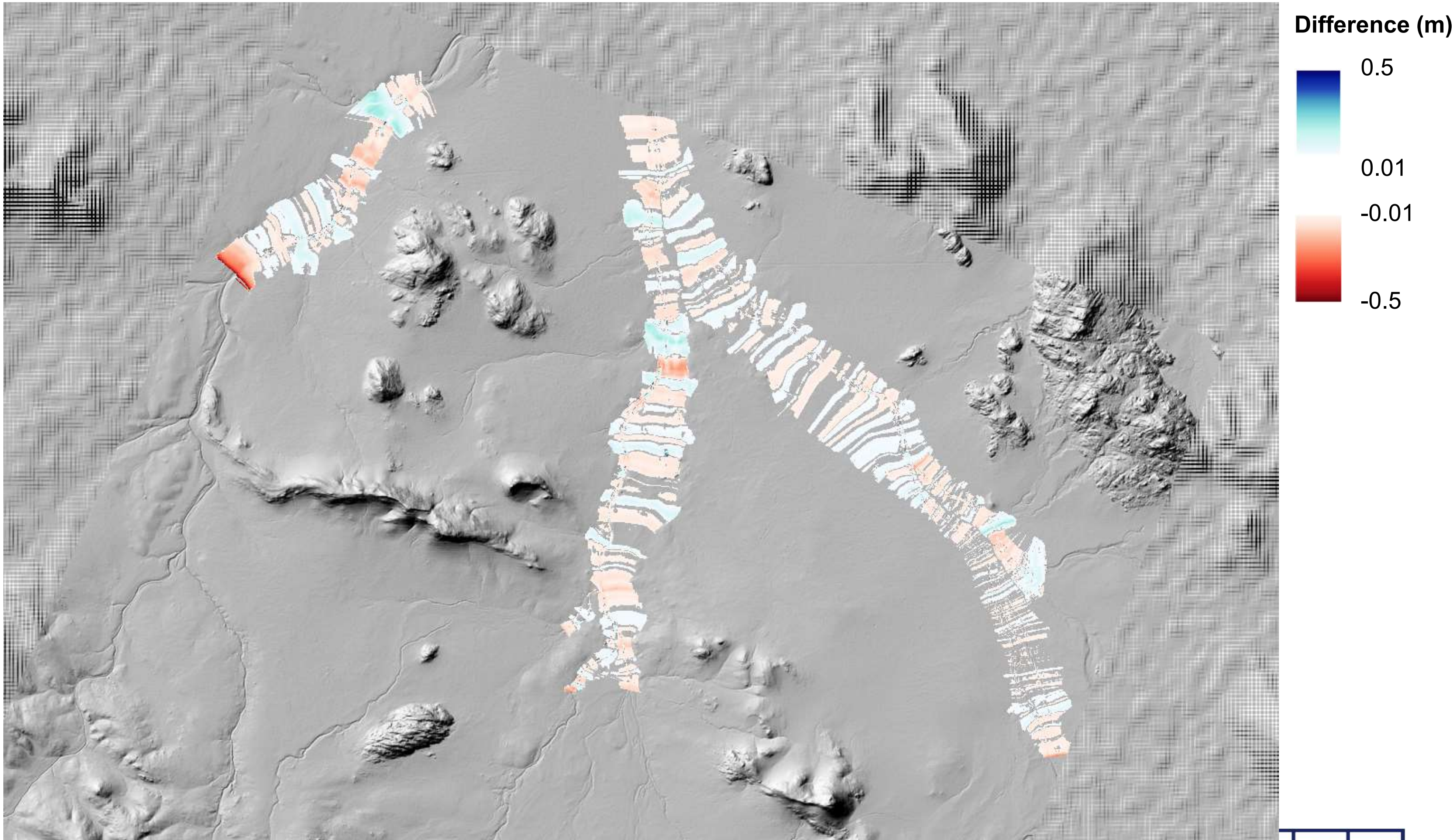
Plan


Selected: 'Rivers'
River 10
River 9
River 3
River 1
River 8
River 6
River 7
River 5
River 4
River 2
1 km

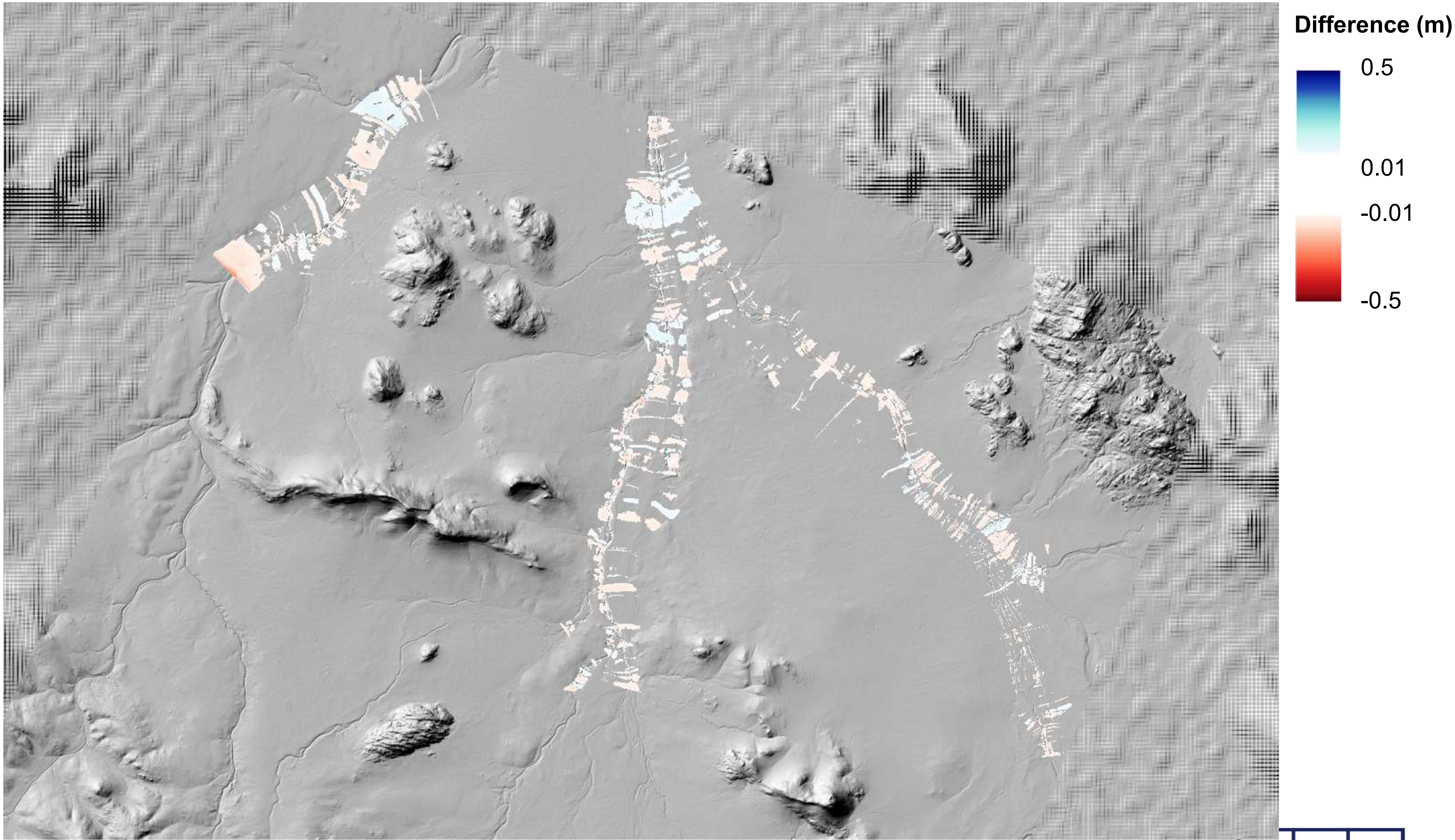
Scour – 1 in 1,000 AEP (Model 1 – Baseline)



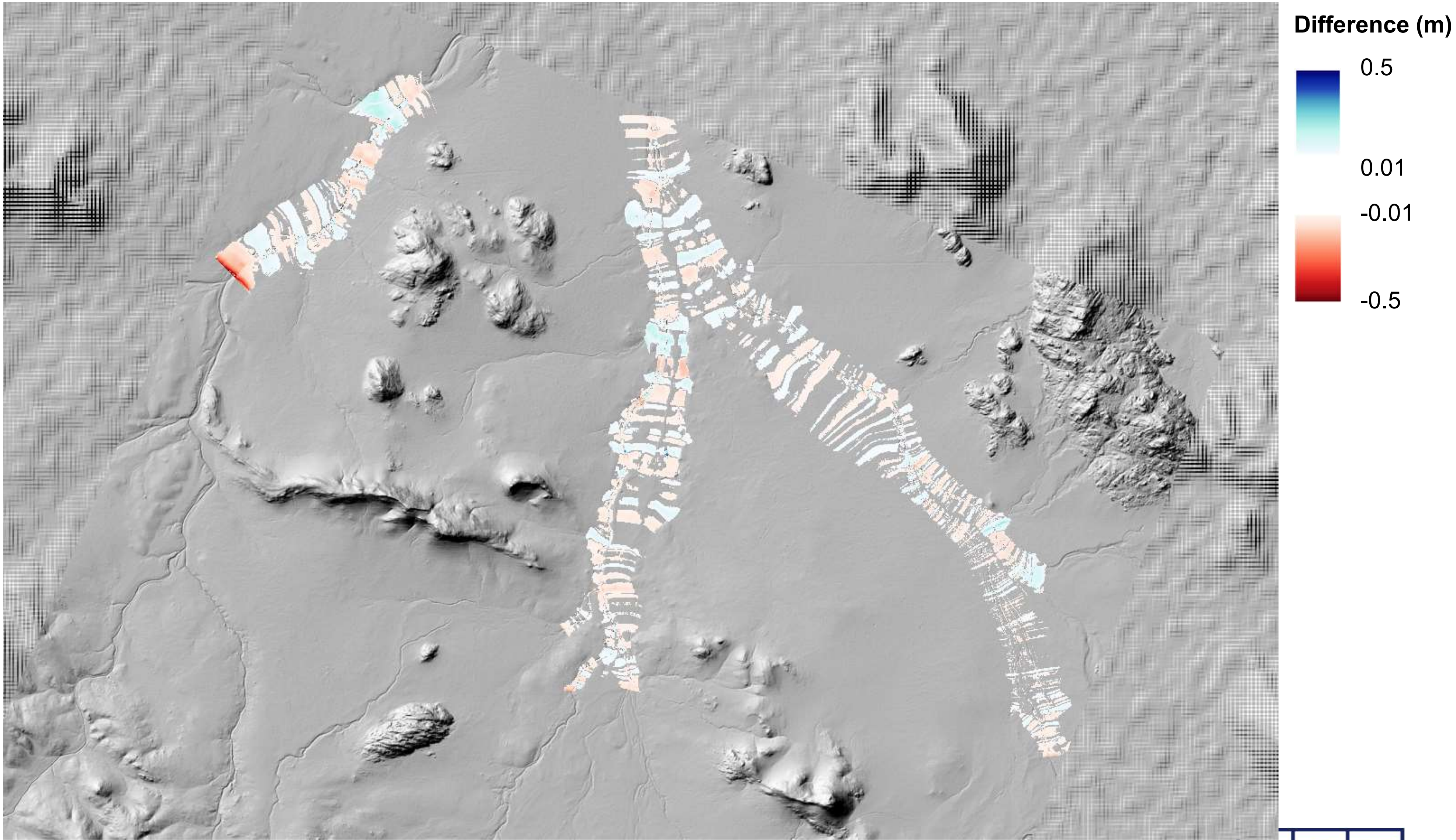
Scour – 1 in 1,000 AEP (Model 4 – Baseline)



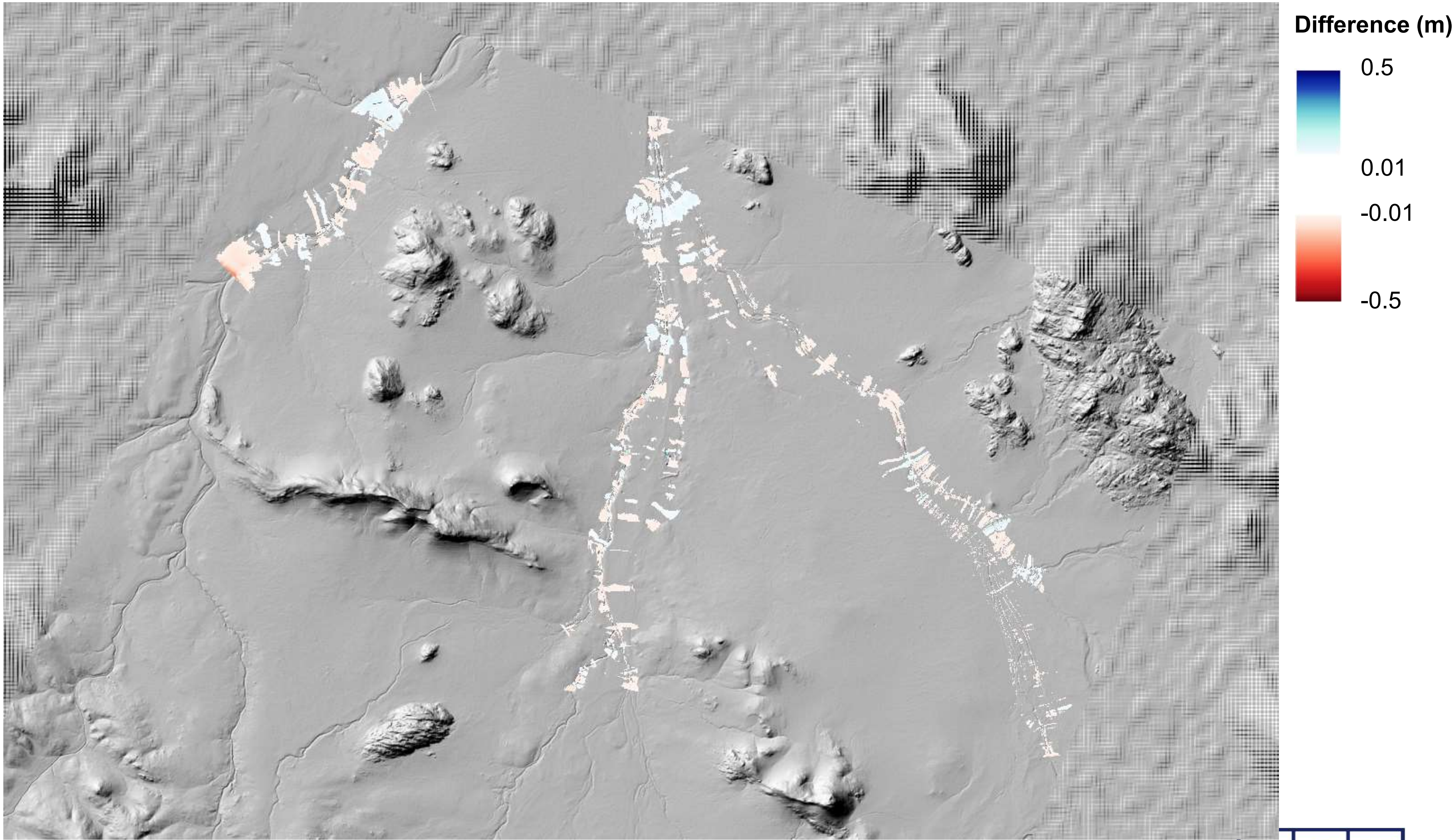
Scour – 1 in 100 AEP (Model 1 – Baseline)



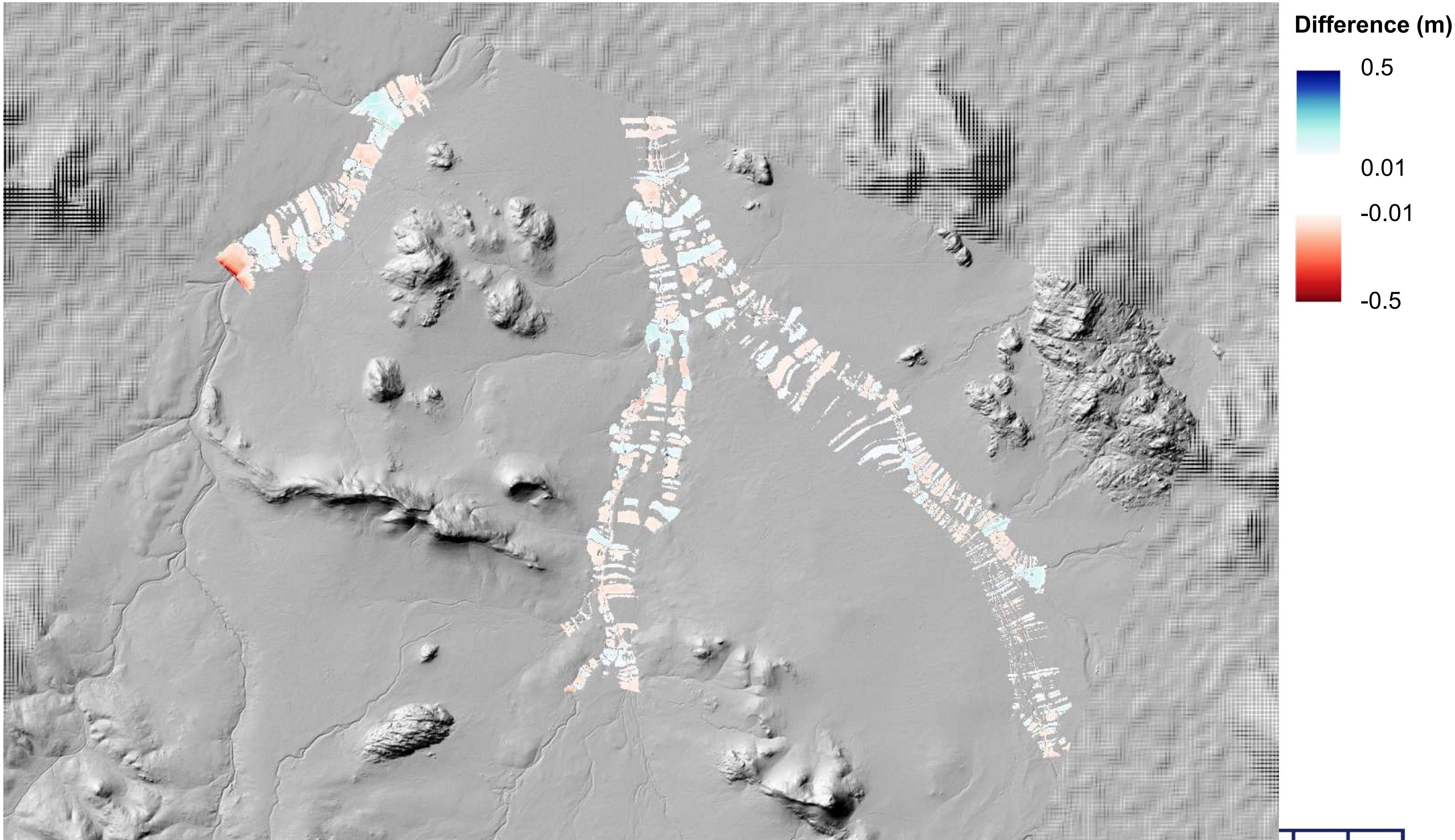
Scour – 1 in 100 AEP (Model 4 – Baseline)



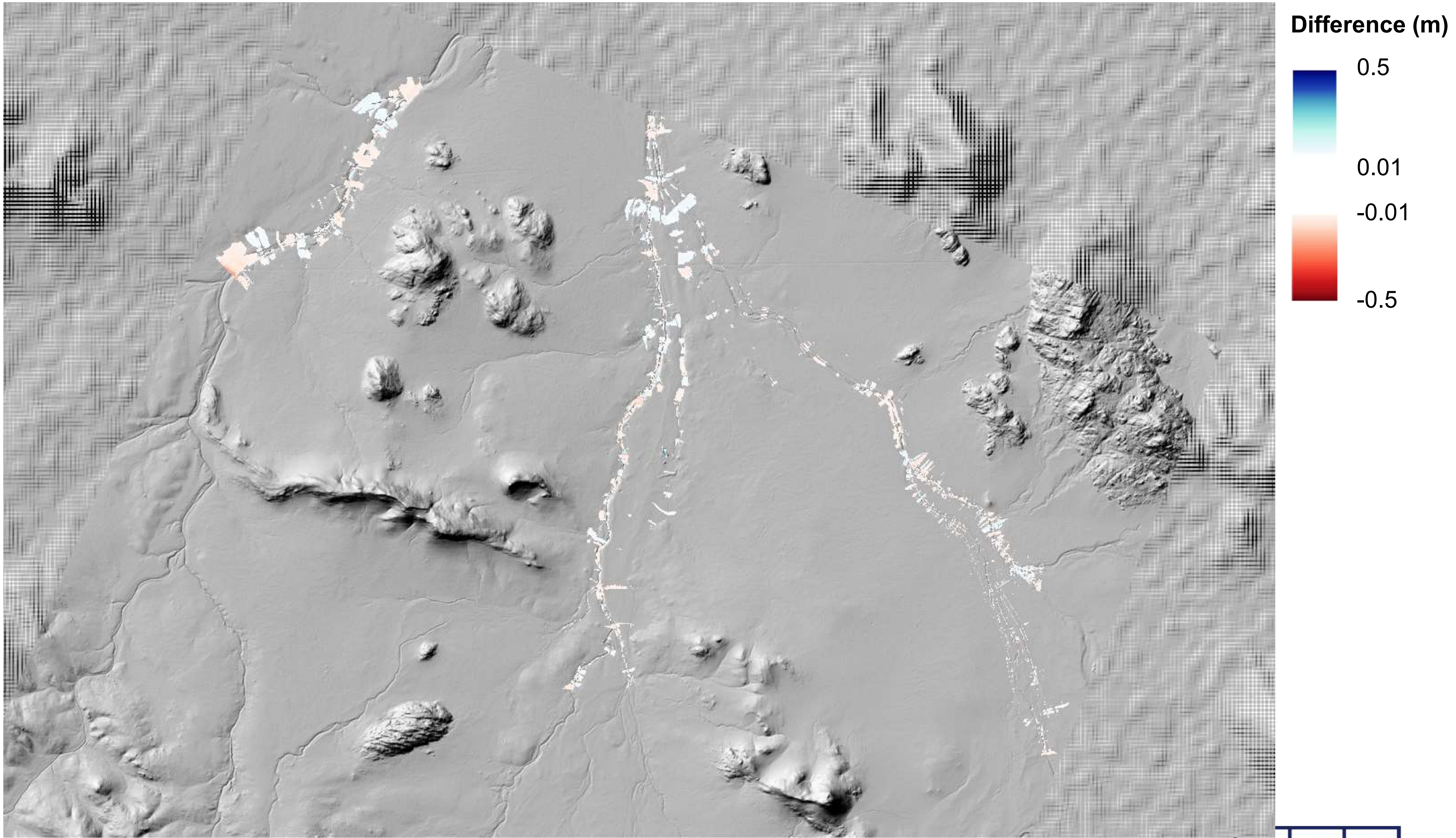
Scour – 1 in 50 AEP (Model 1 – Baseline)



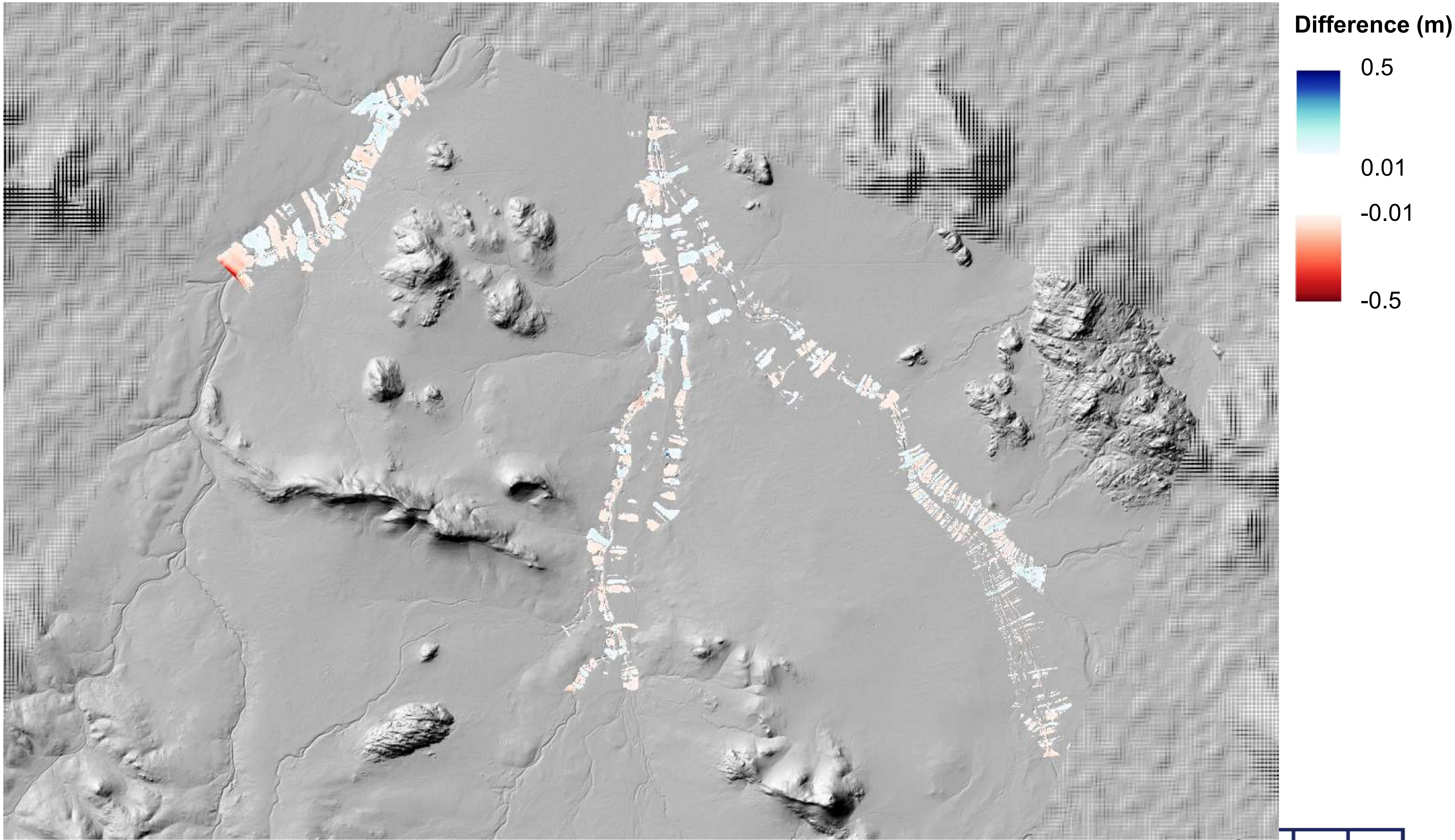
Scour – 1 in 50 AEP (Model 4 – Baseline)



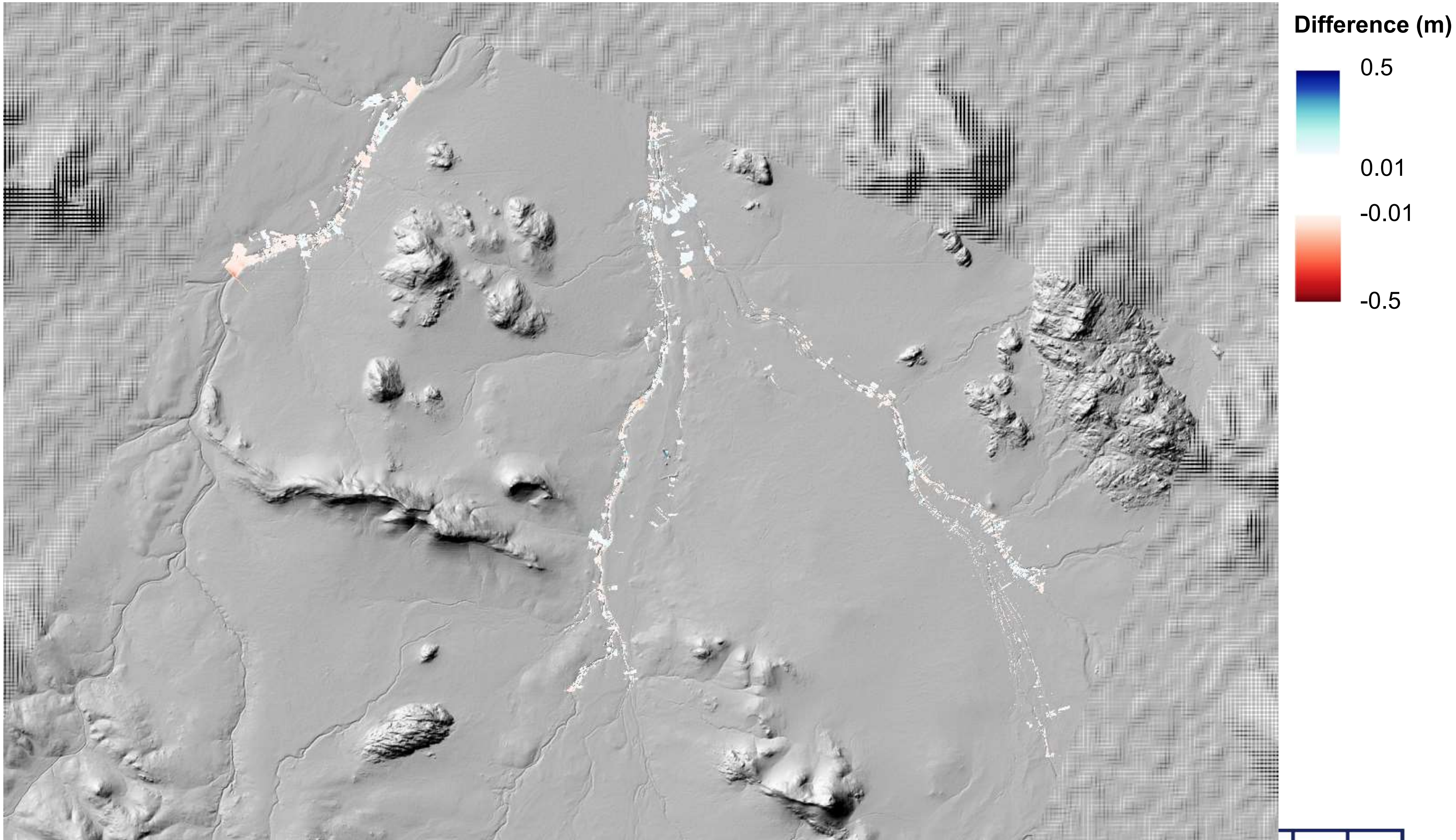
Scour – 1 in 20 AEP (Model 1 – Baseline)



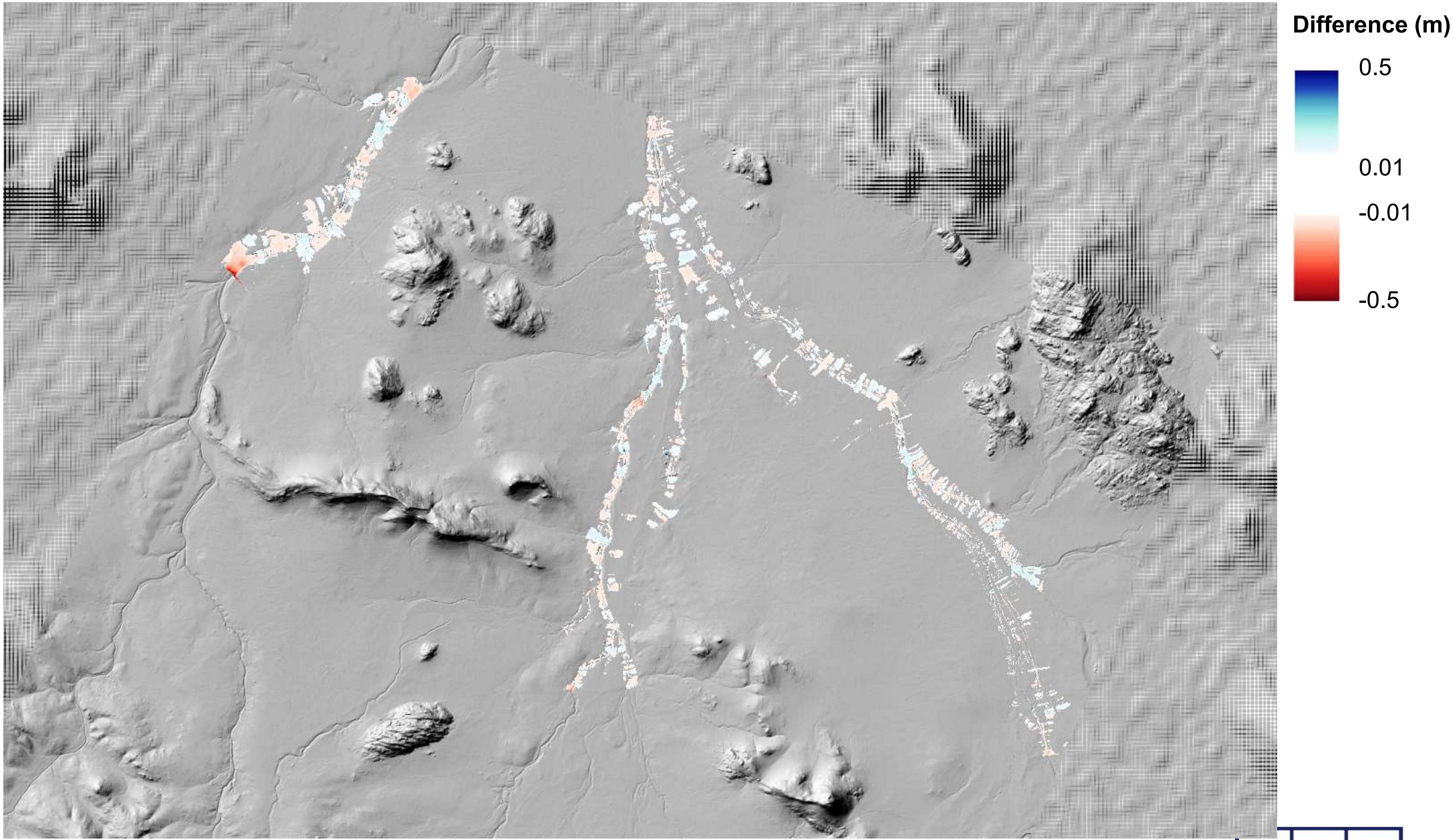
Scour – 1 in 20 AEP (Model 4 – Baseline)



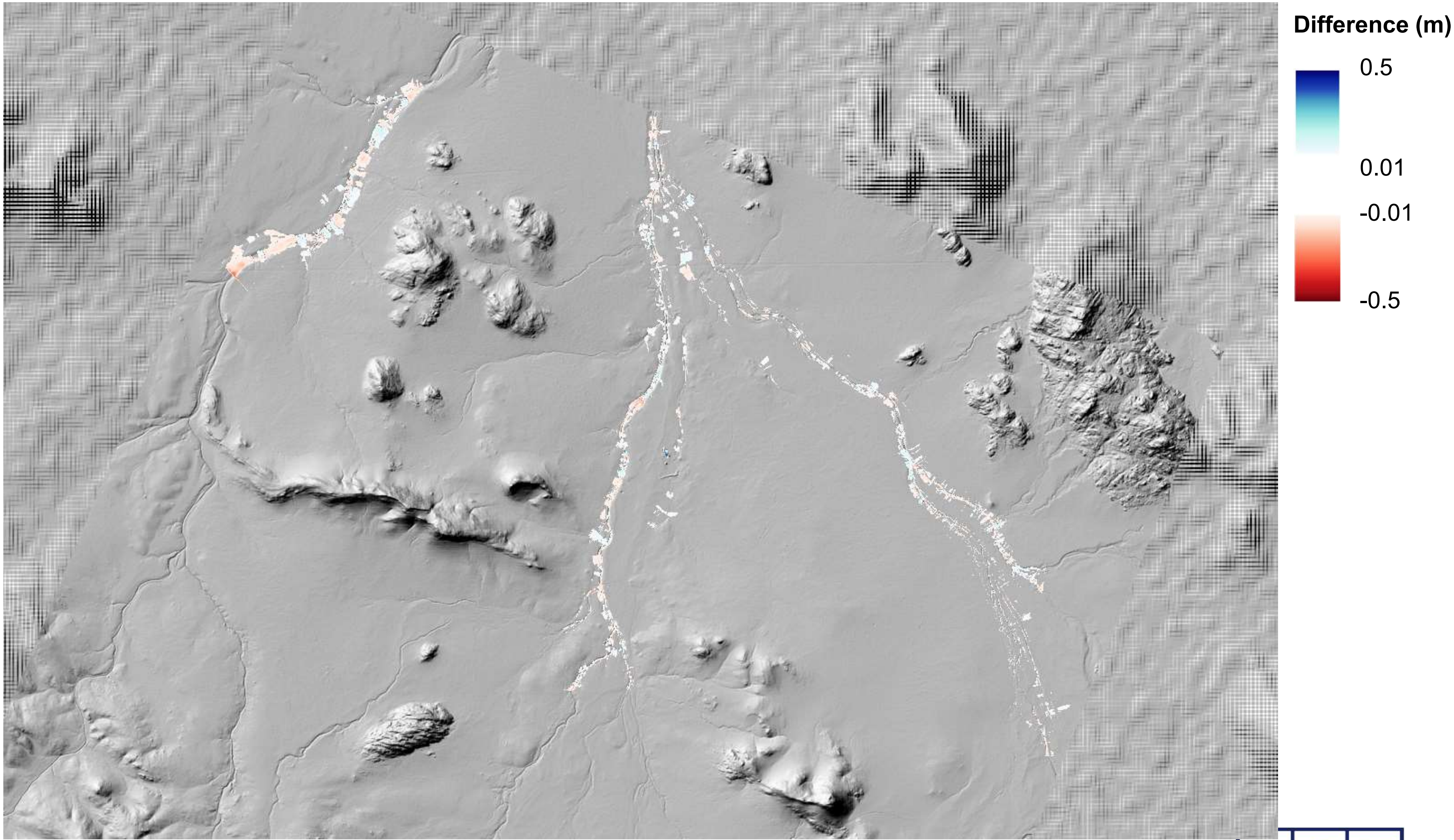
Scour – 1 in 10 AEP (Model 1 – Baseline)



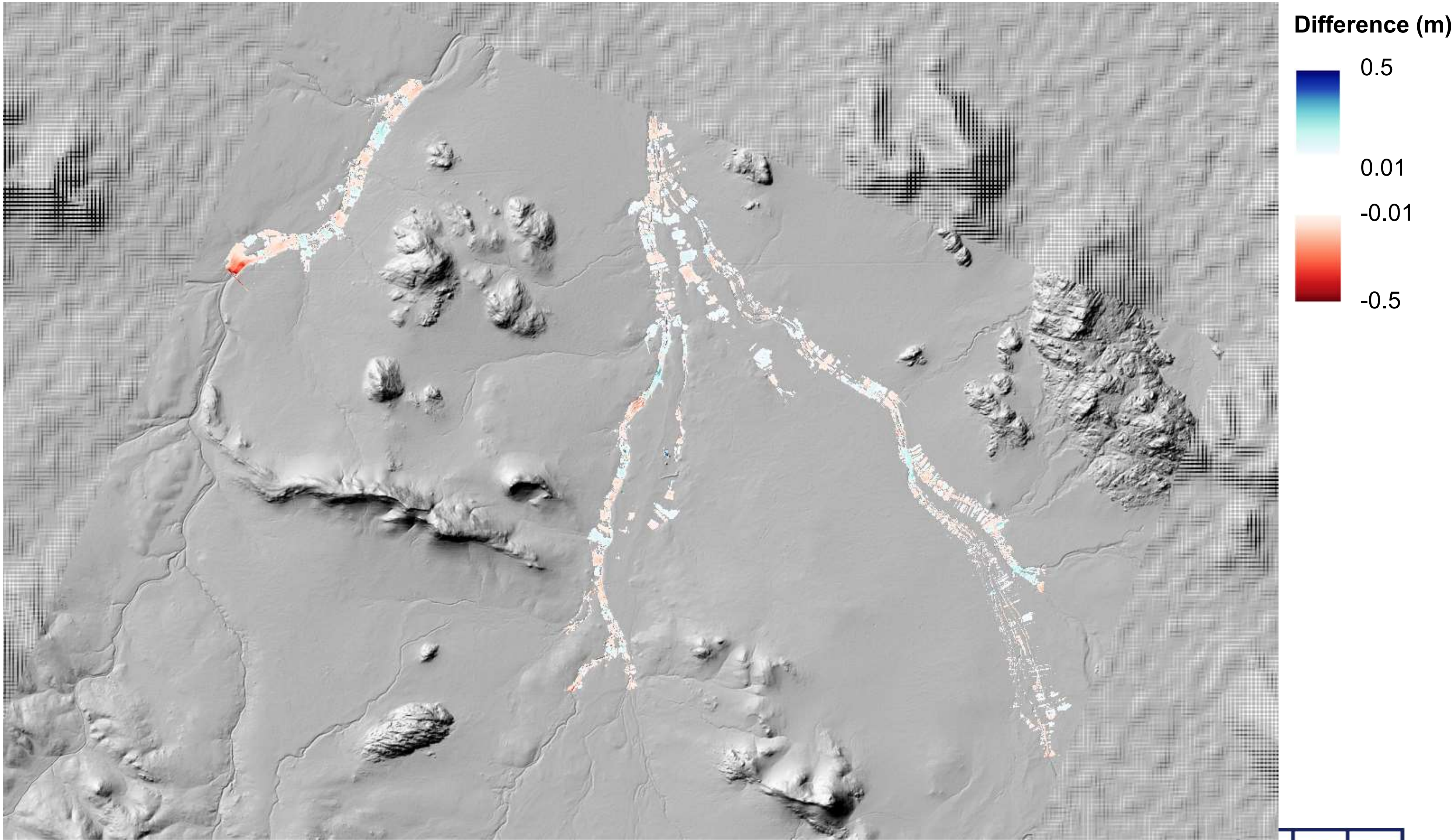
Scour – 1 in 10 AEP (Model 4 – Baseline)



Scour – 1 in 5 AEP (Model 1 – Baseline)

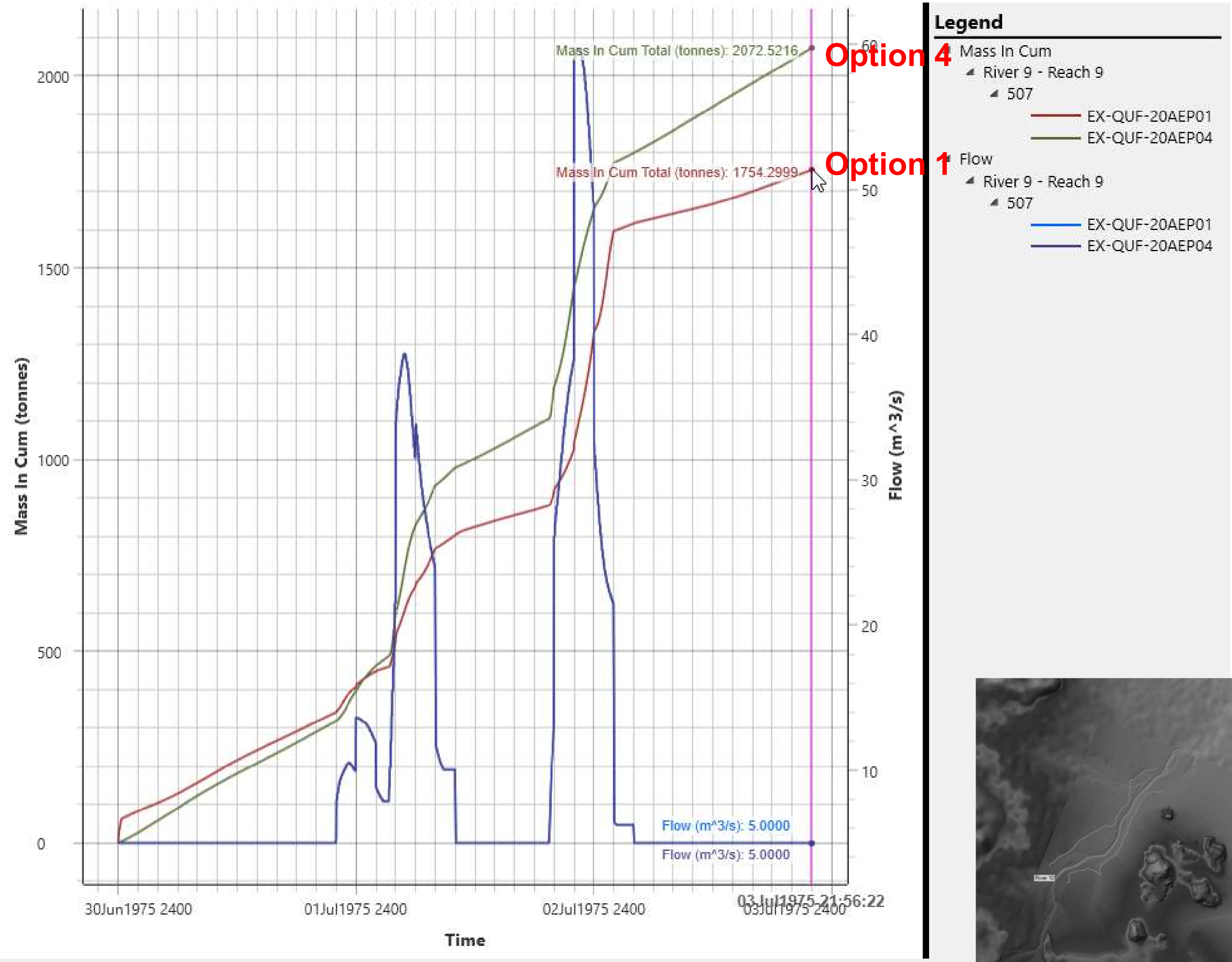


Scour – 1 in 5 AEP (Model 4 – Baseline)

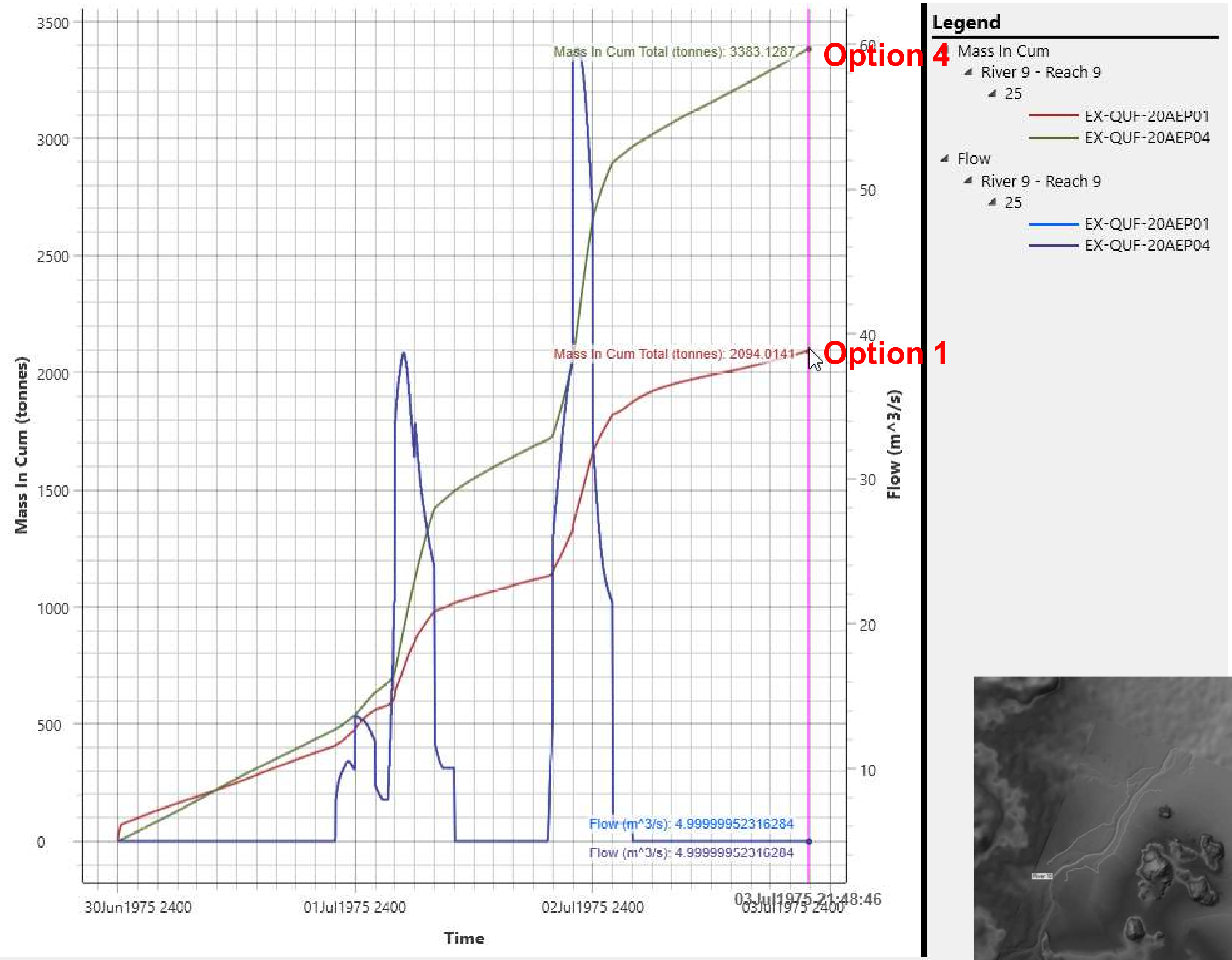


Mass In (1 in 5 AEP)

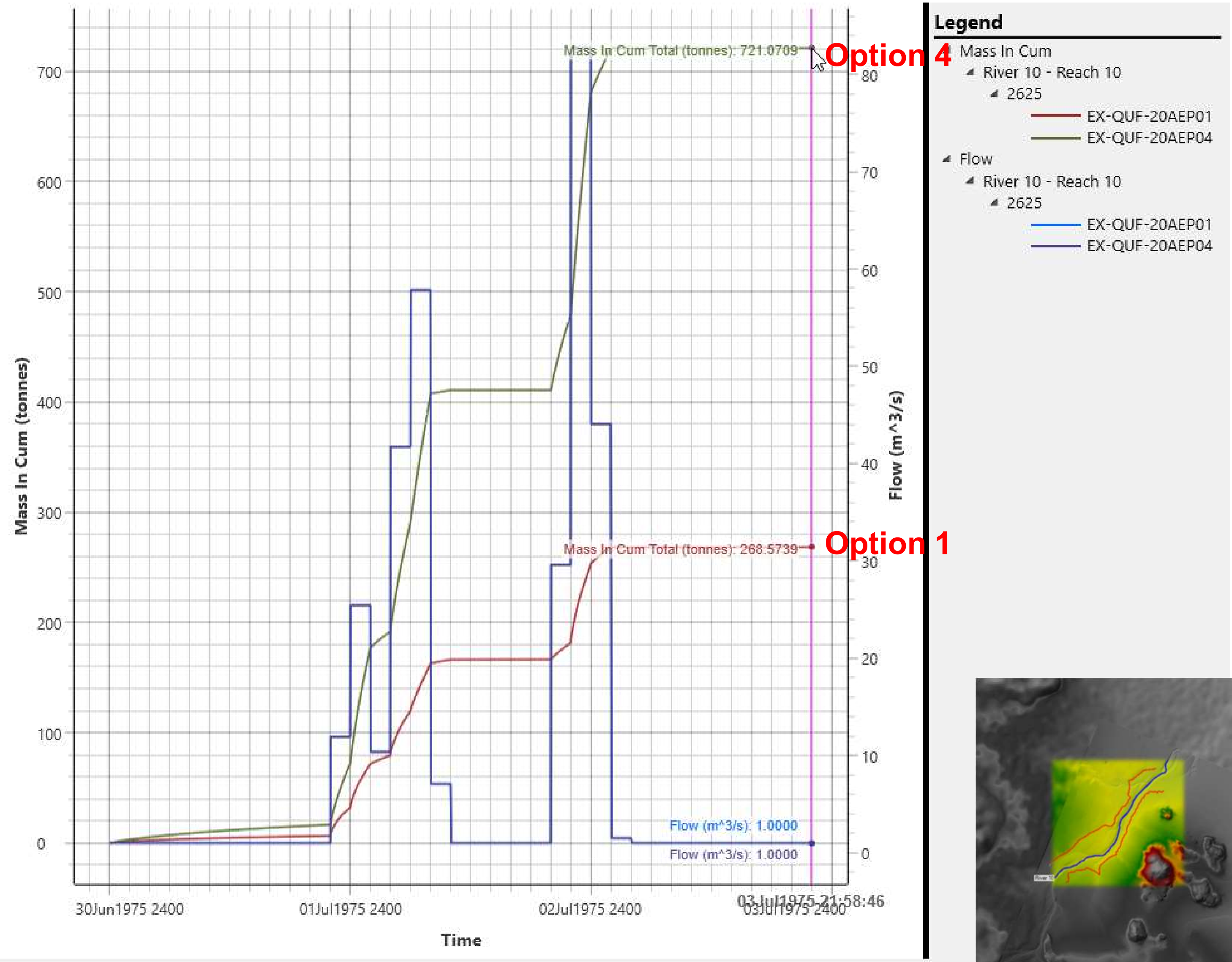
River 9 – Station 507 (U/S)

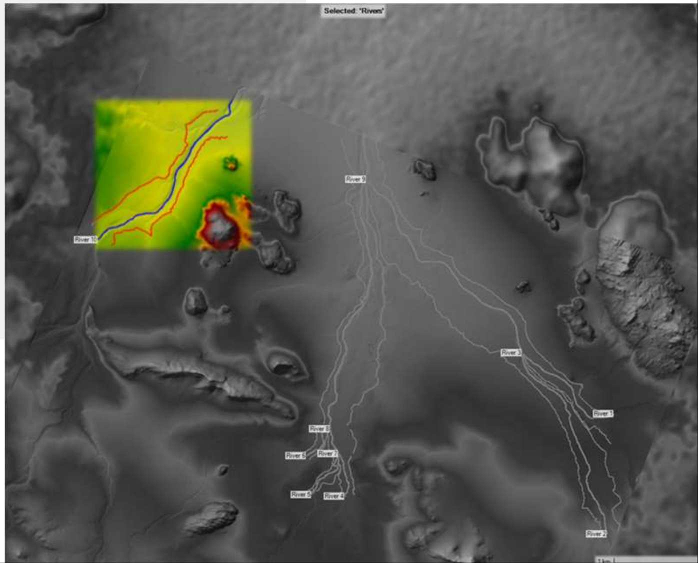


River 9 – Station 25 (D/S)

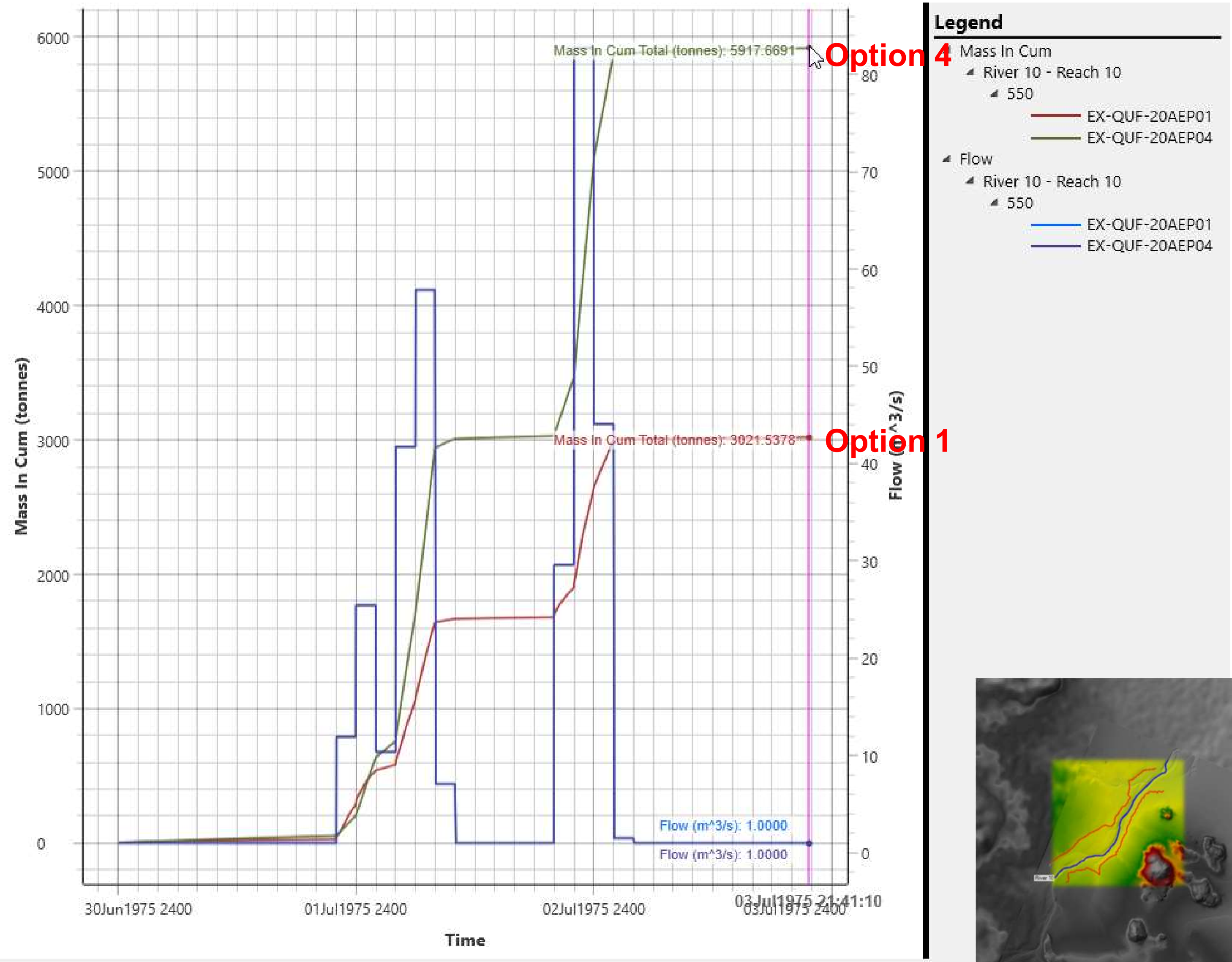


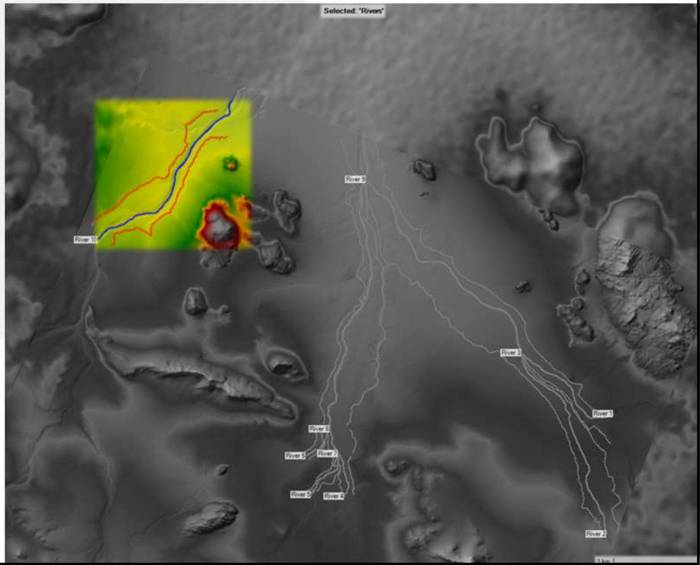
River 10 – Station 2625 (U/S)





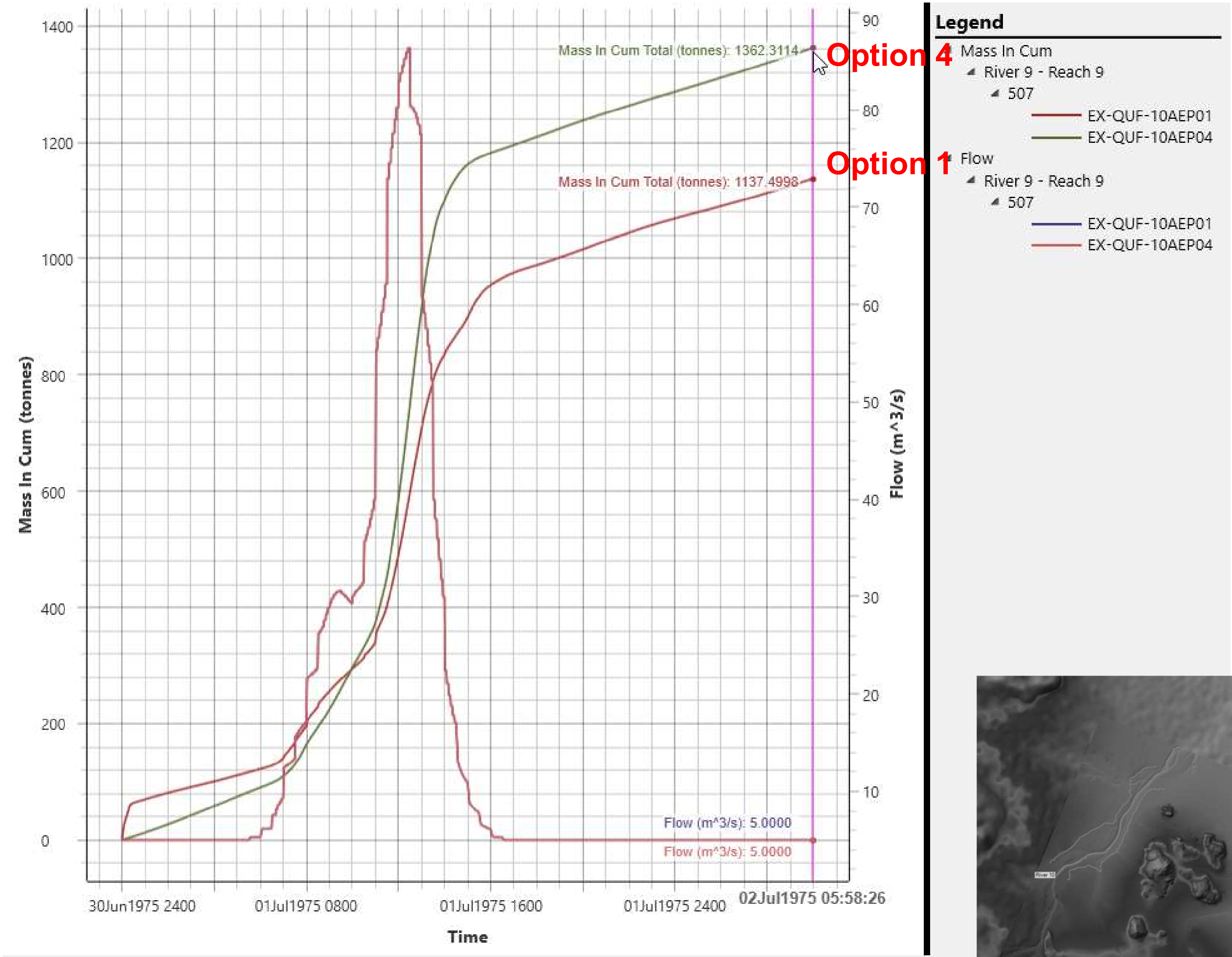
River 10 – Station 550 (D/S)



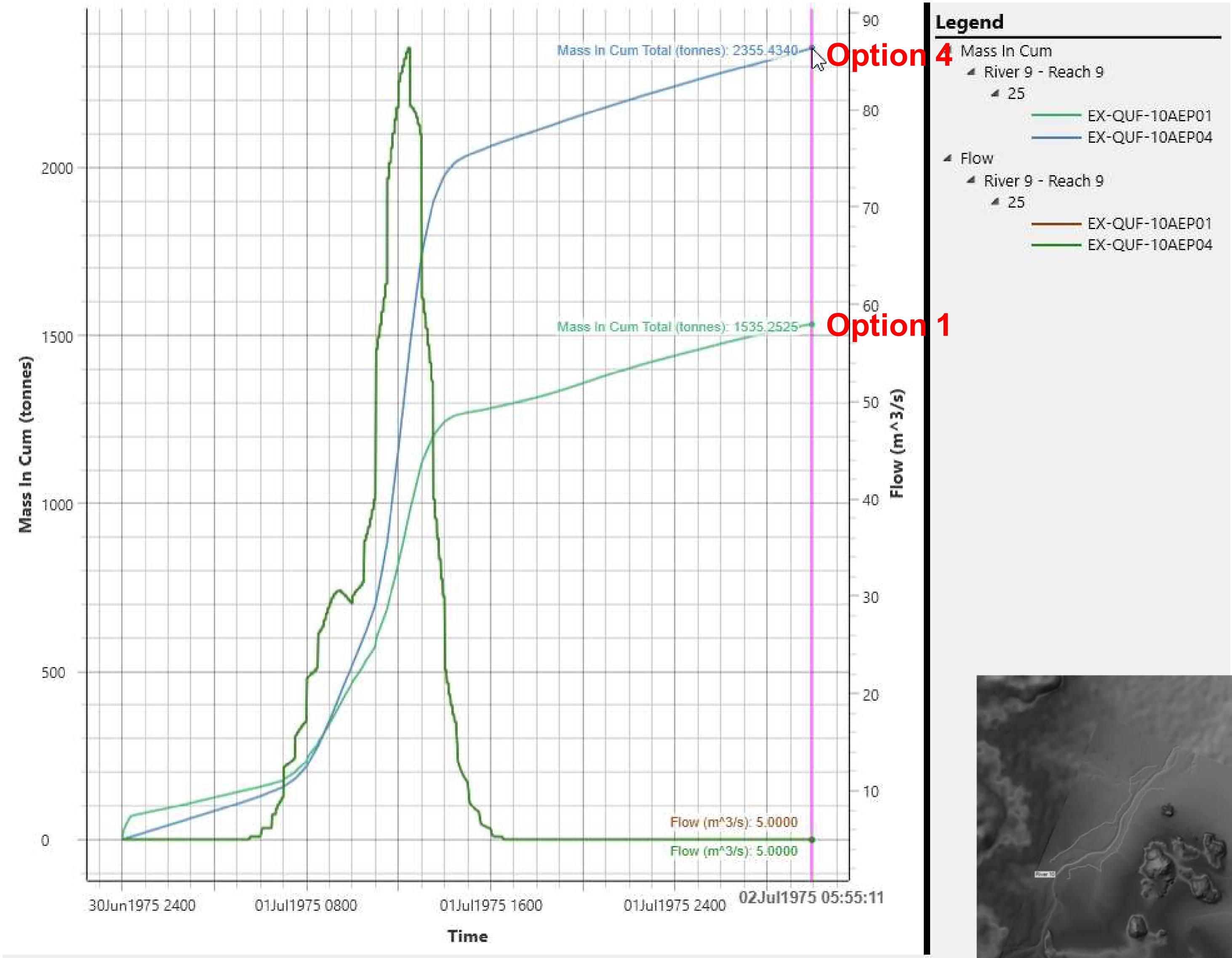


Mass In (1 in 10 AEP)

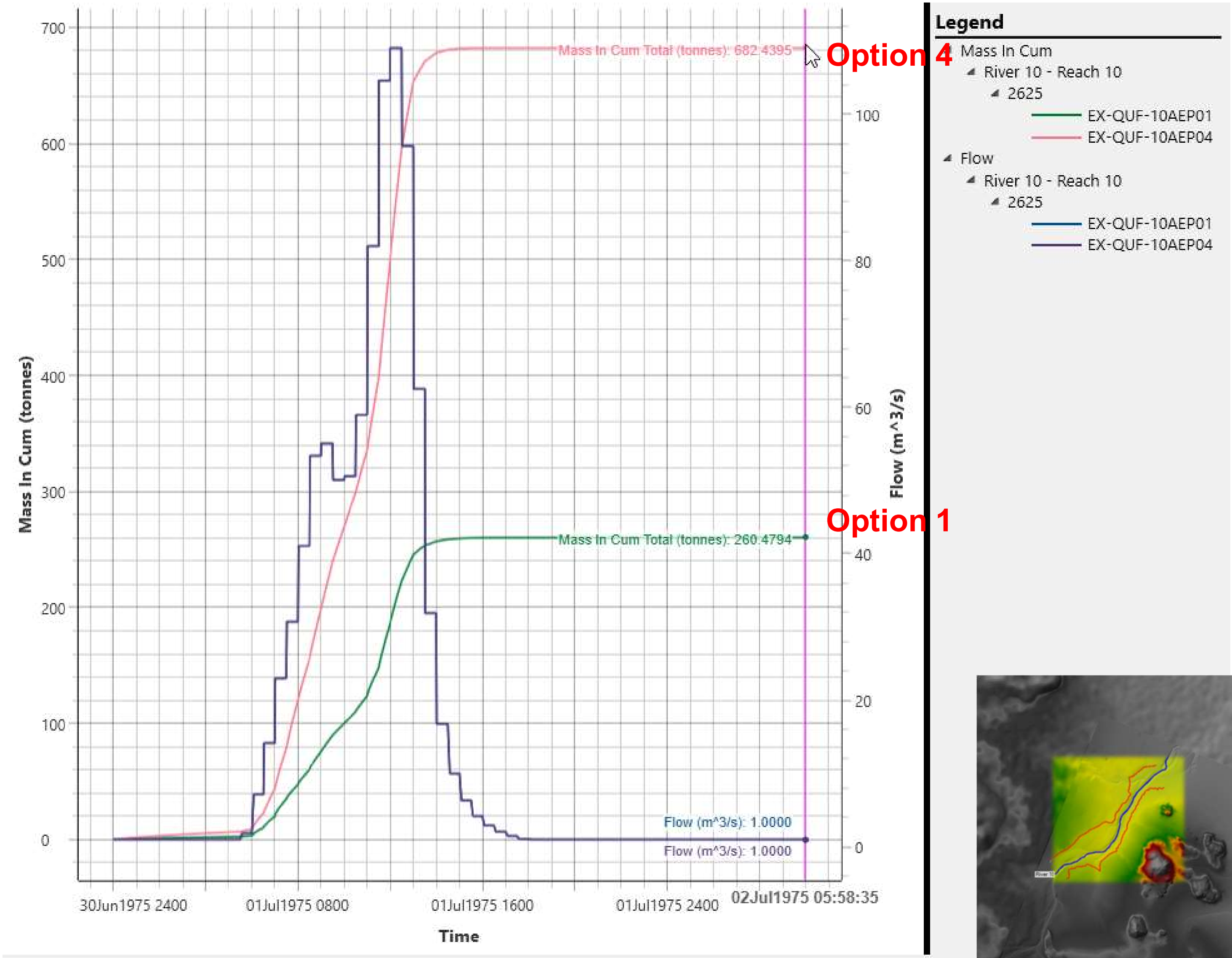
River 9 – Station 507 (U/S)

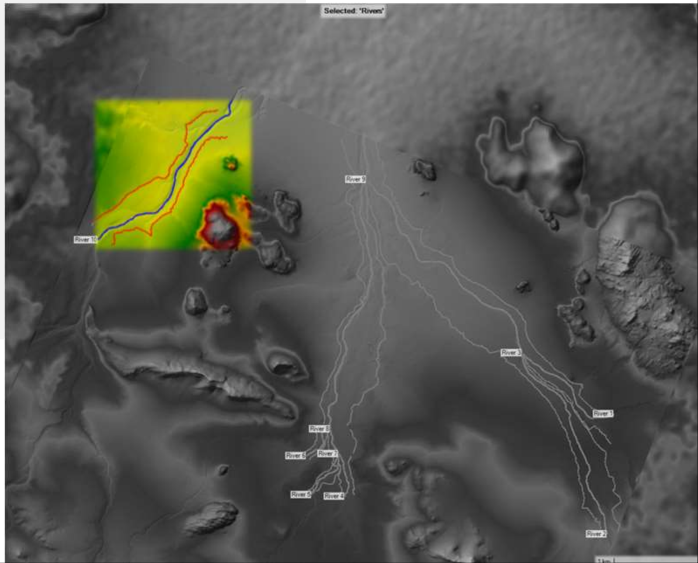


River 9 – Station 25 (D/S)

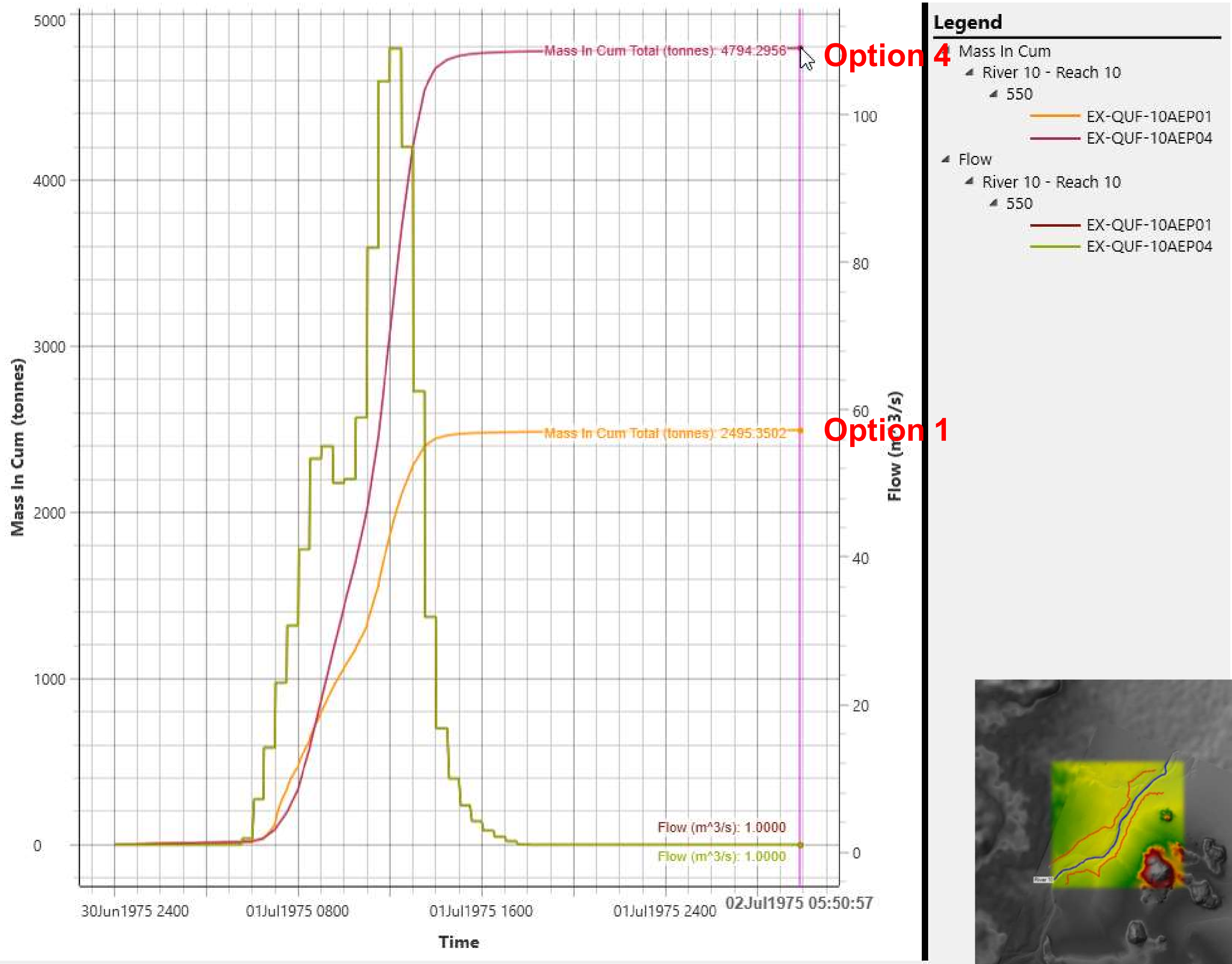


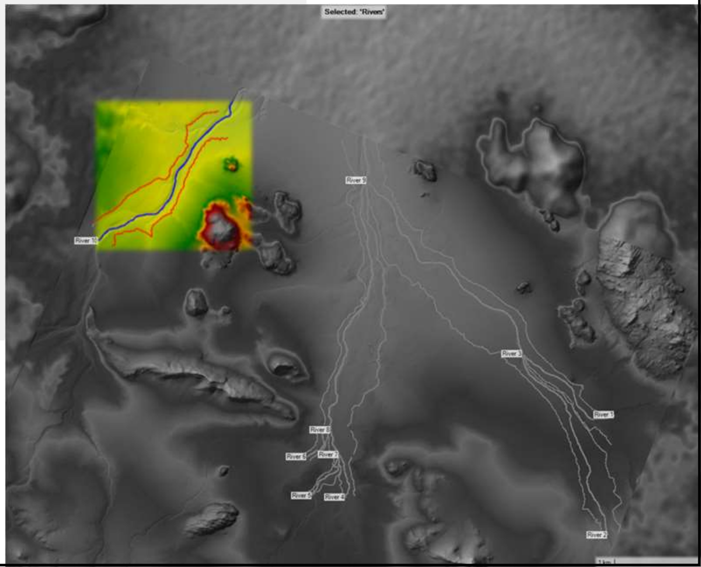
River 10 – Station 2625 (U/S)





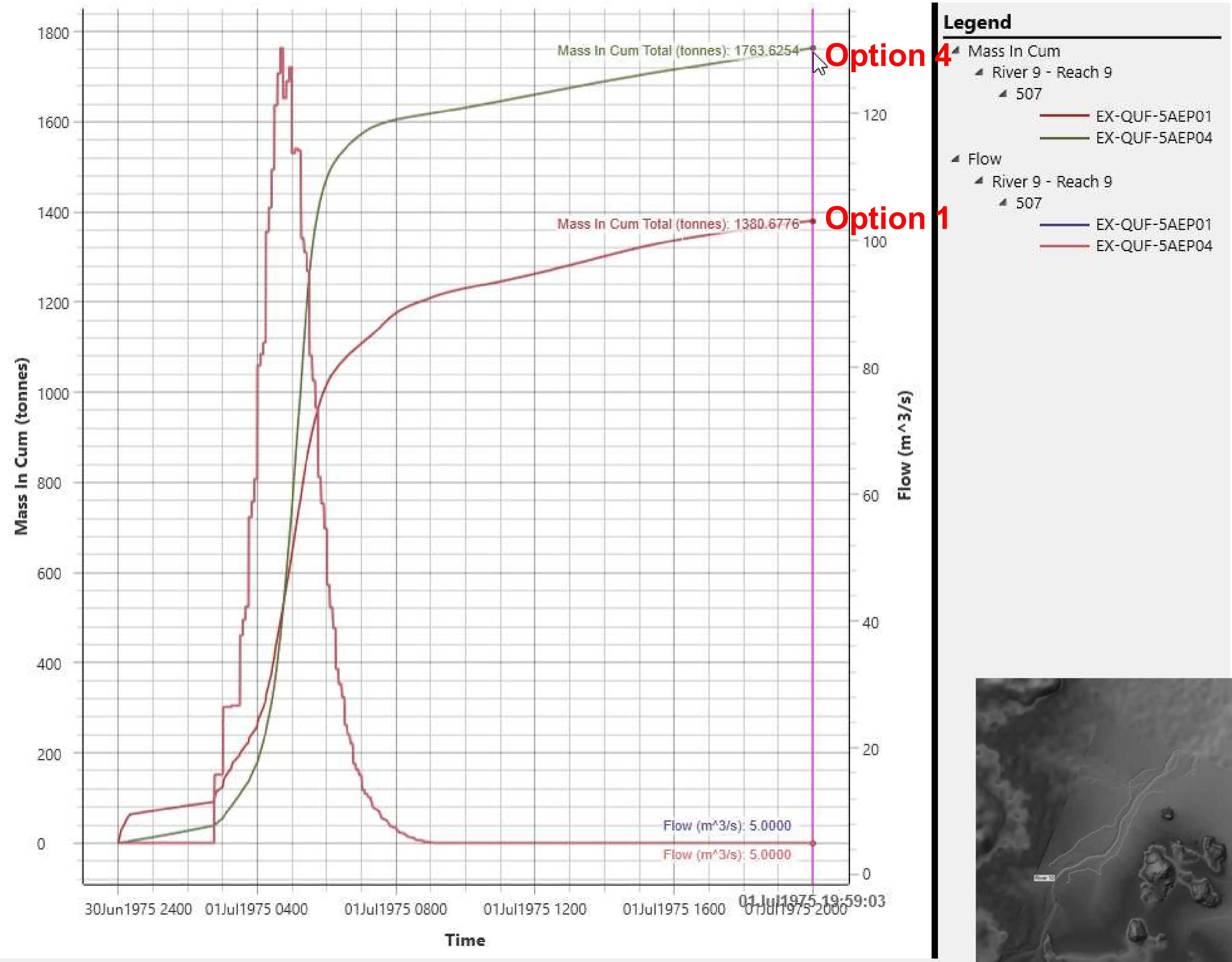
River 10 – Station 550 (D/S)



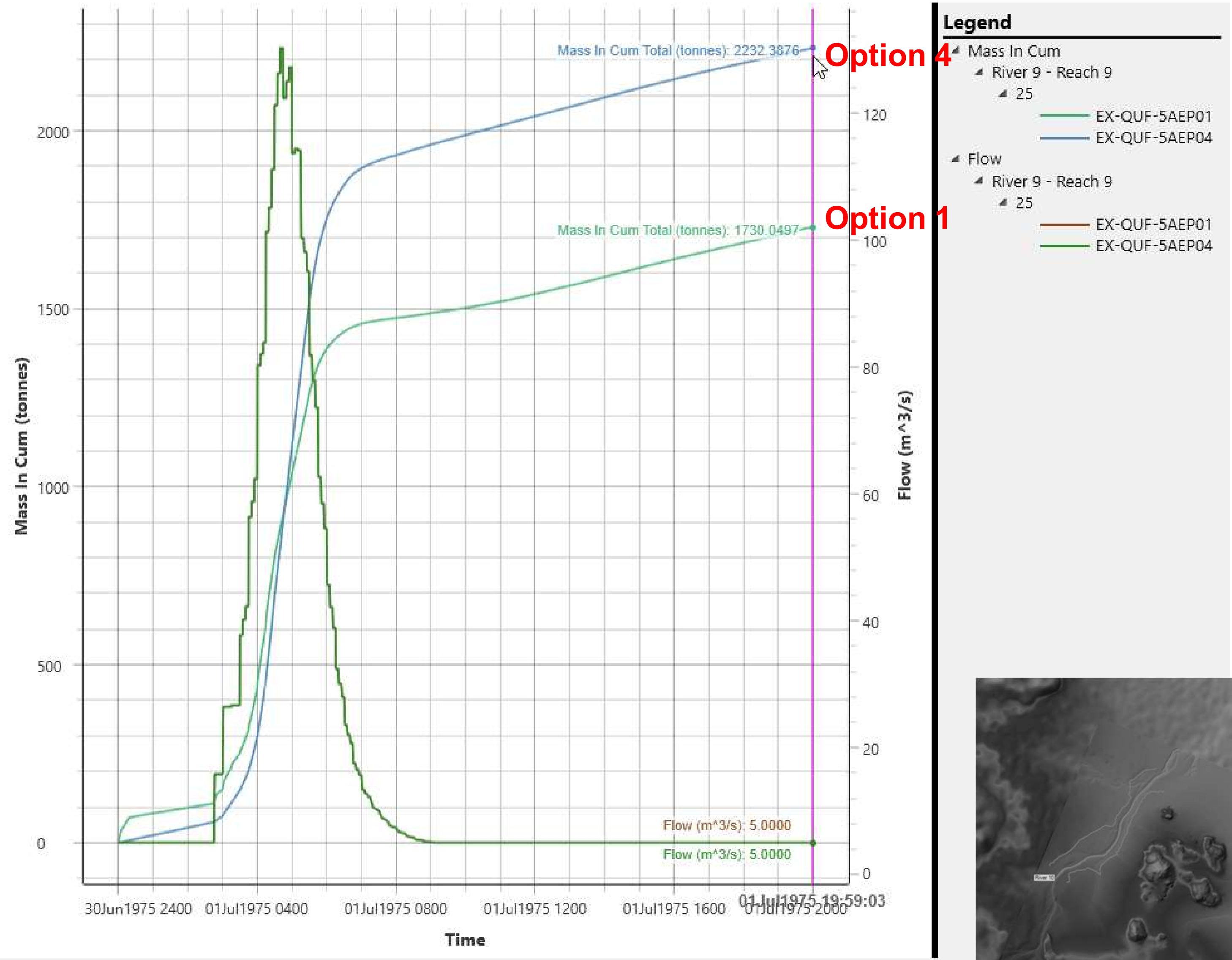


Mass In (1 in 20 AEP)

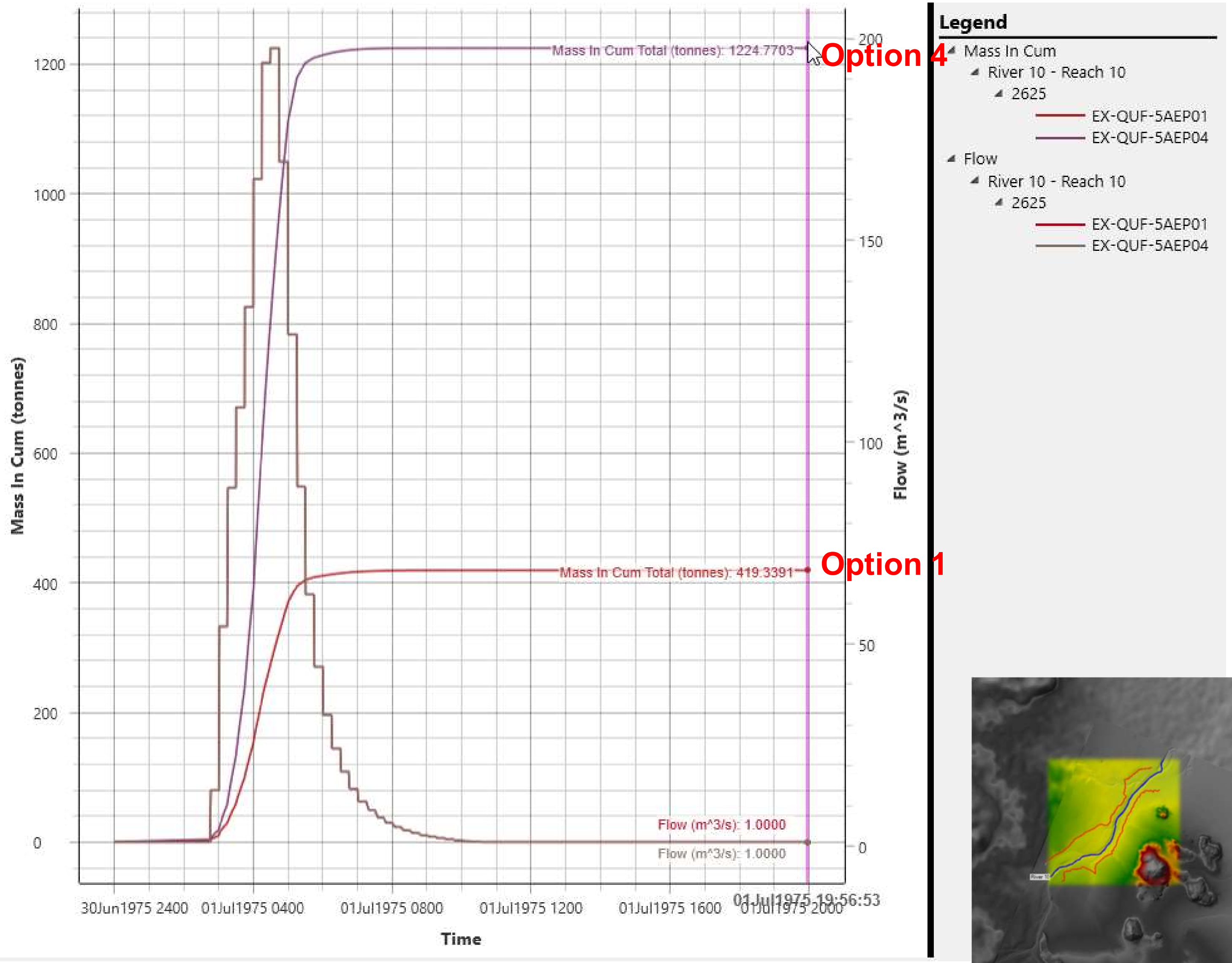
River 9 – Station 507 (U/S)

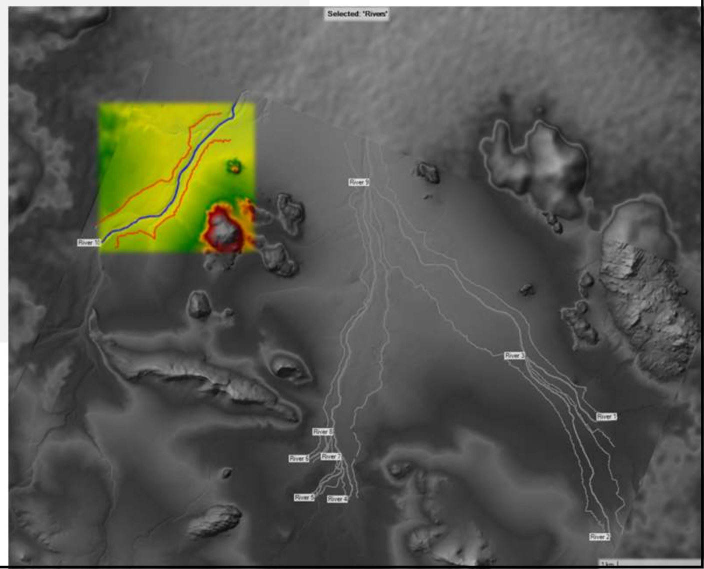


River 9 – Station 25 (D/S)

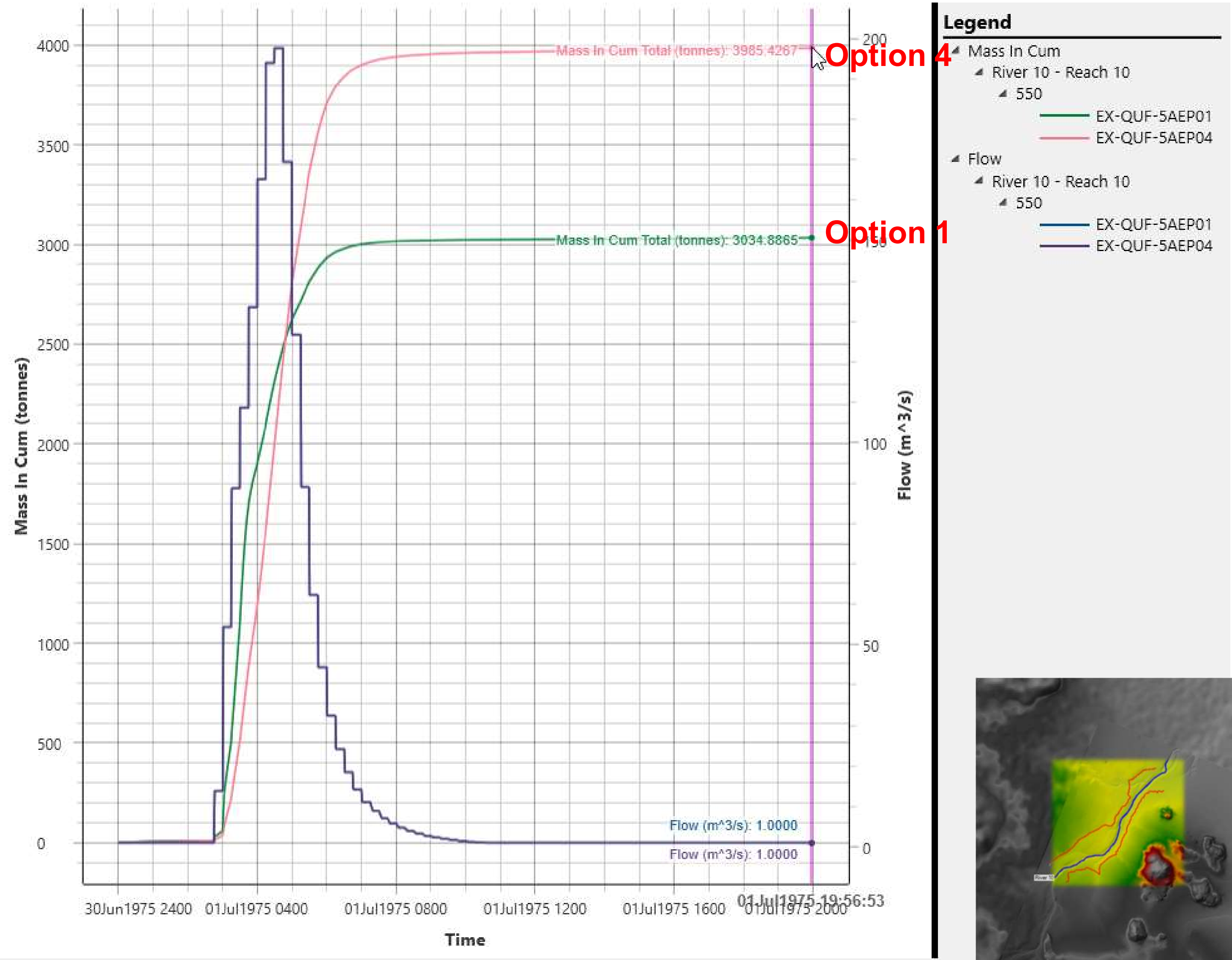


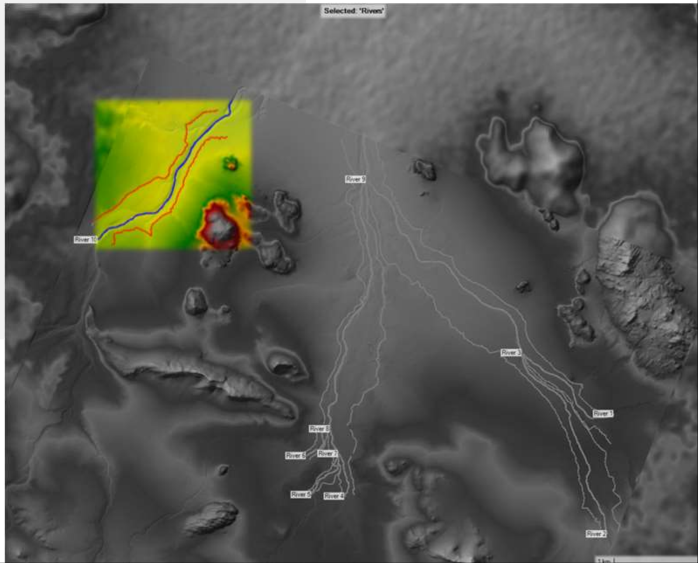
River 10 – Station 2625 (U/S)





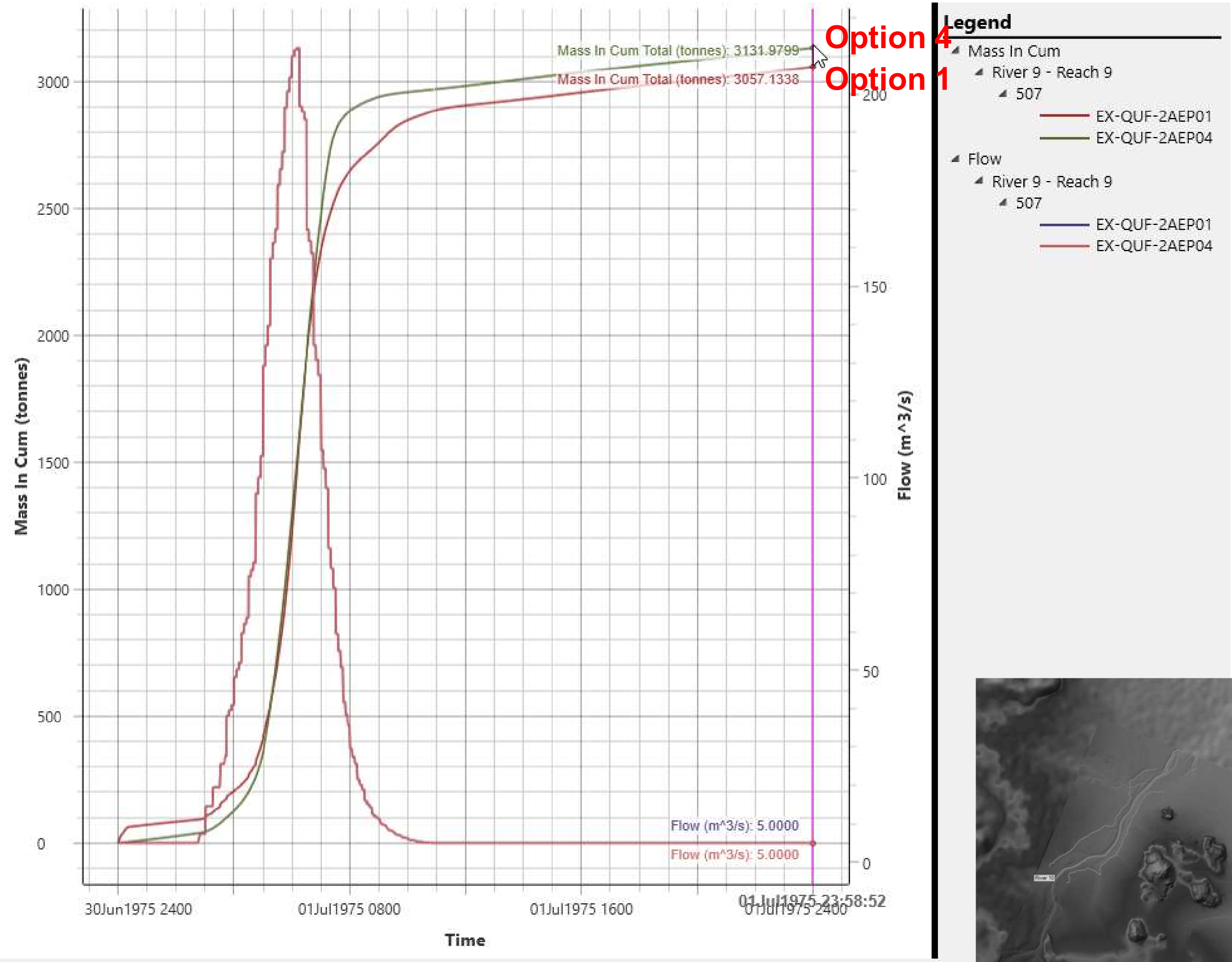
River 10 – Station 550 (D/S)



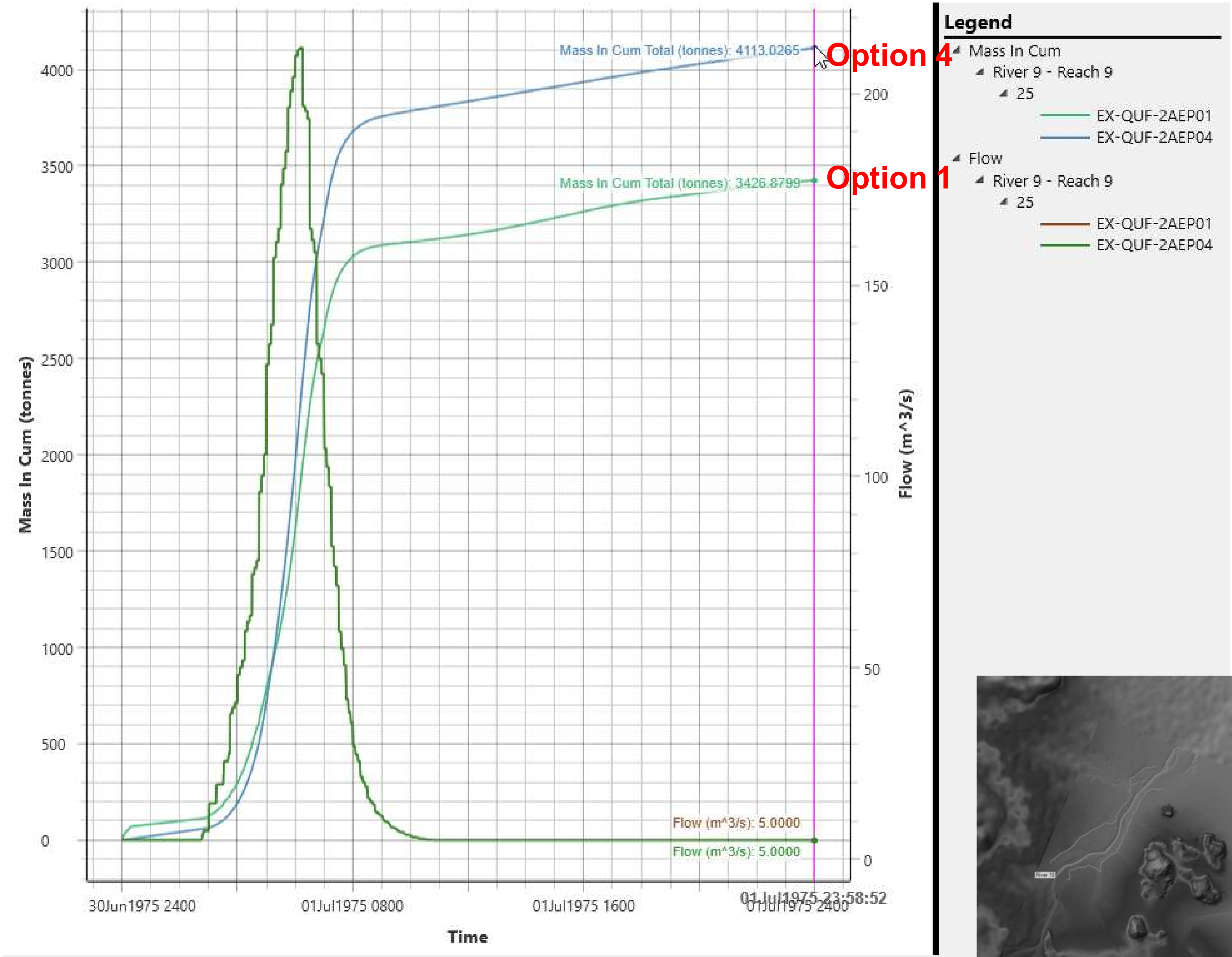


Mass In (1 in 50 AEP)

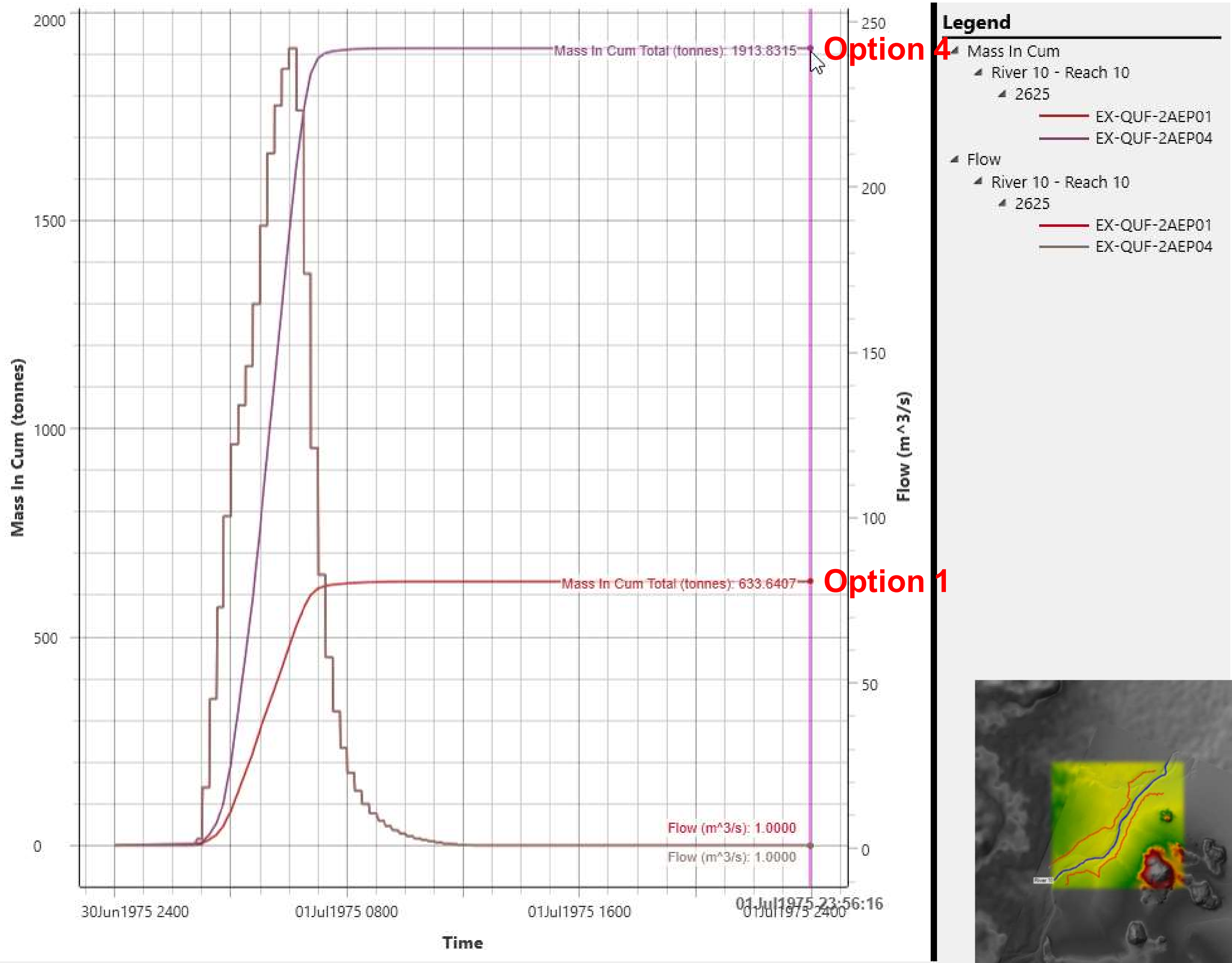
River 9 – Station 507 (U/S)

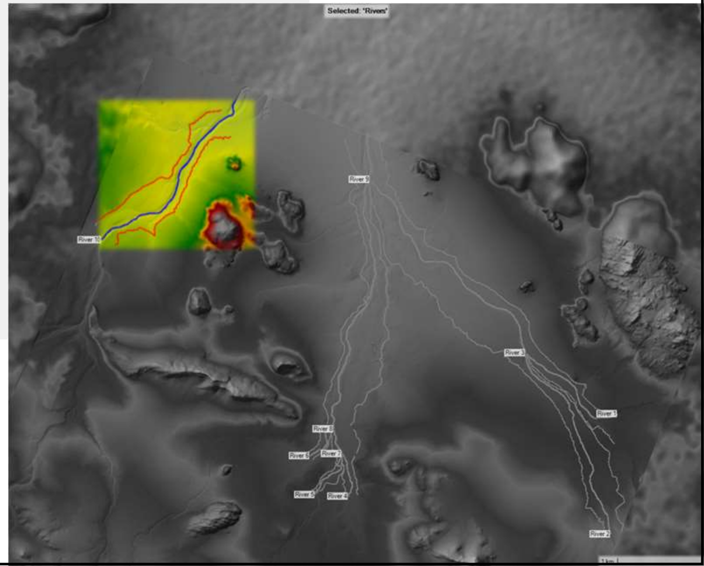


River 9 – Station 25 (D/S)

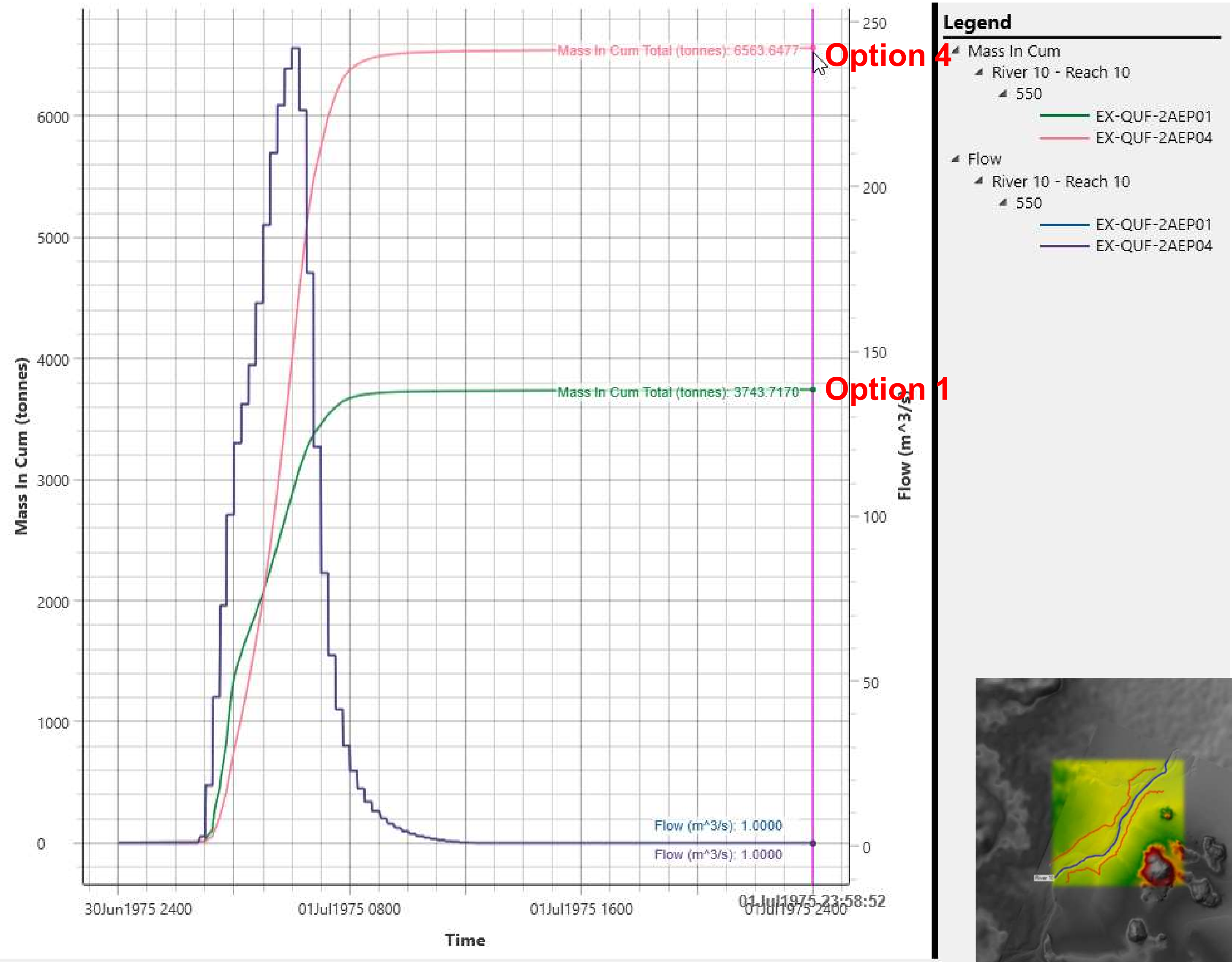


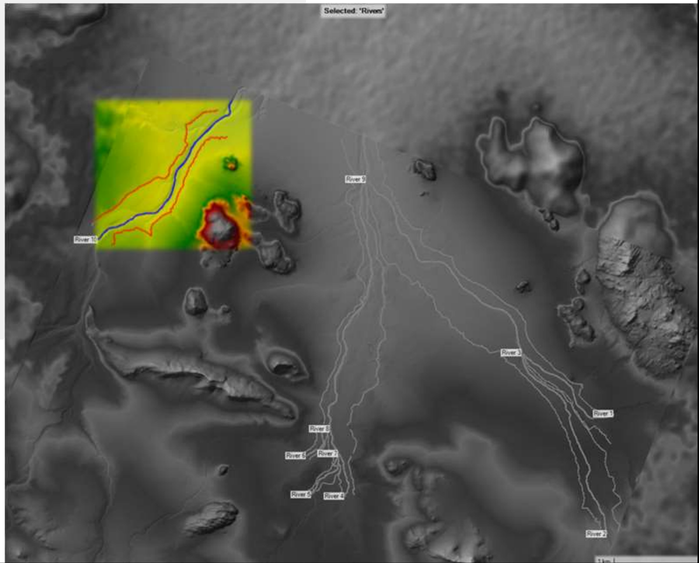
River 10 – Station 2625 (U/S)





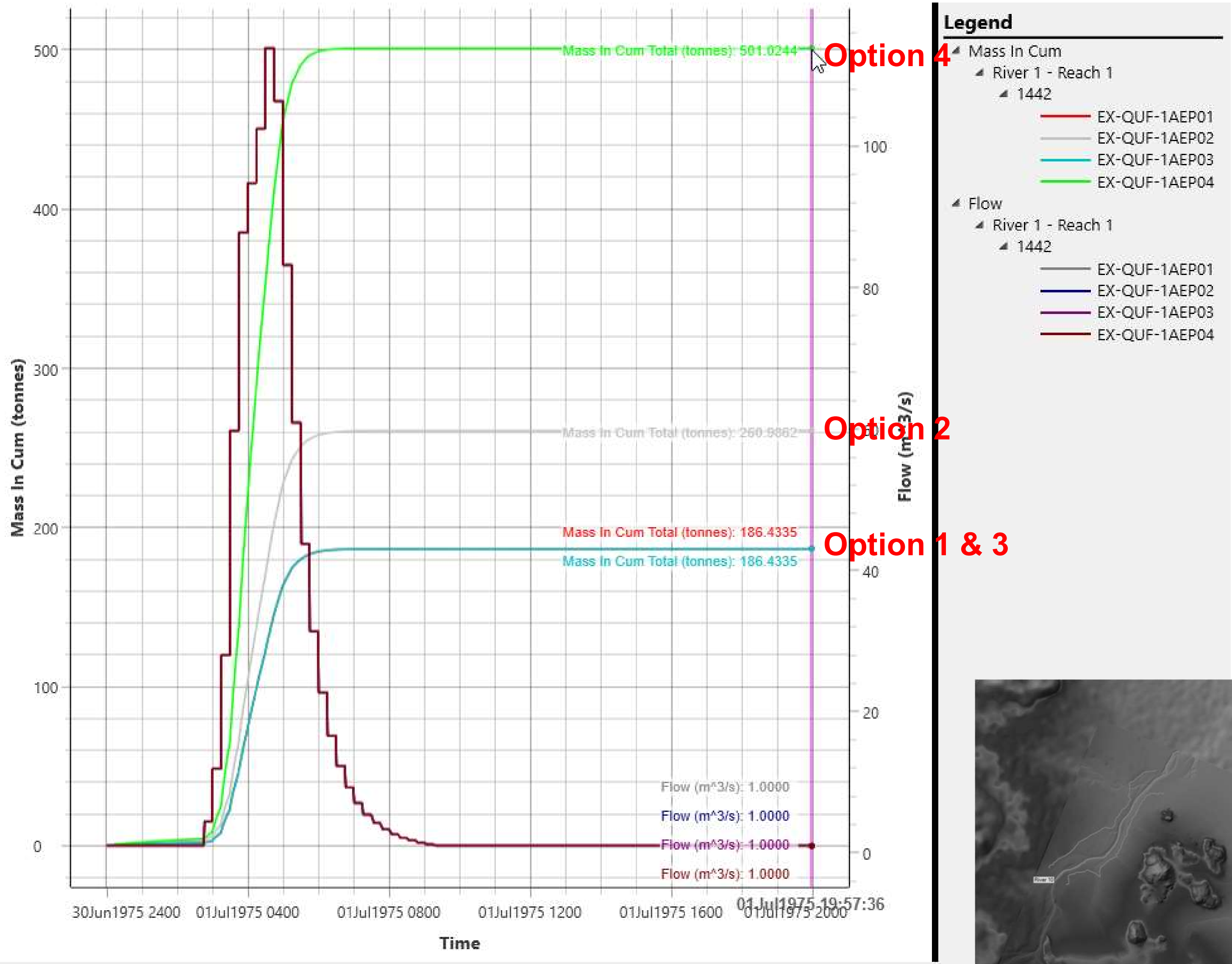
River 10 – Station 550 (D/S)

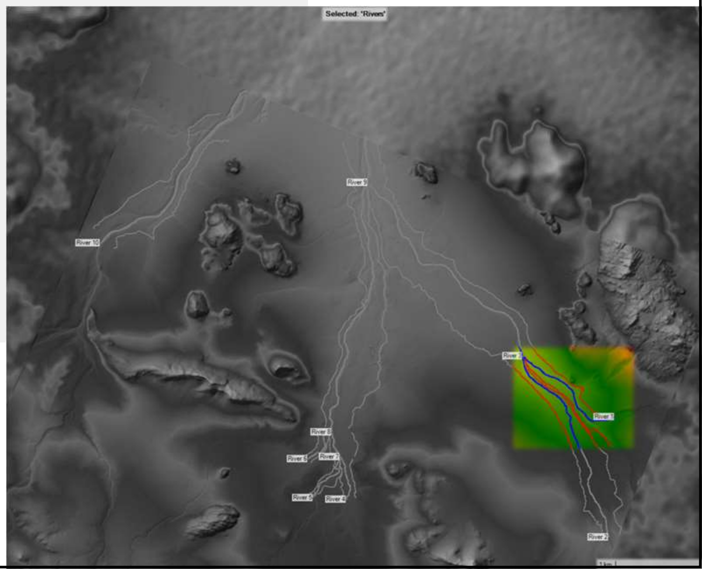




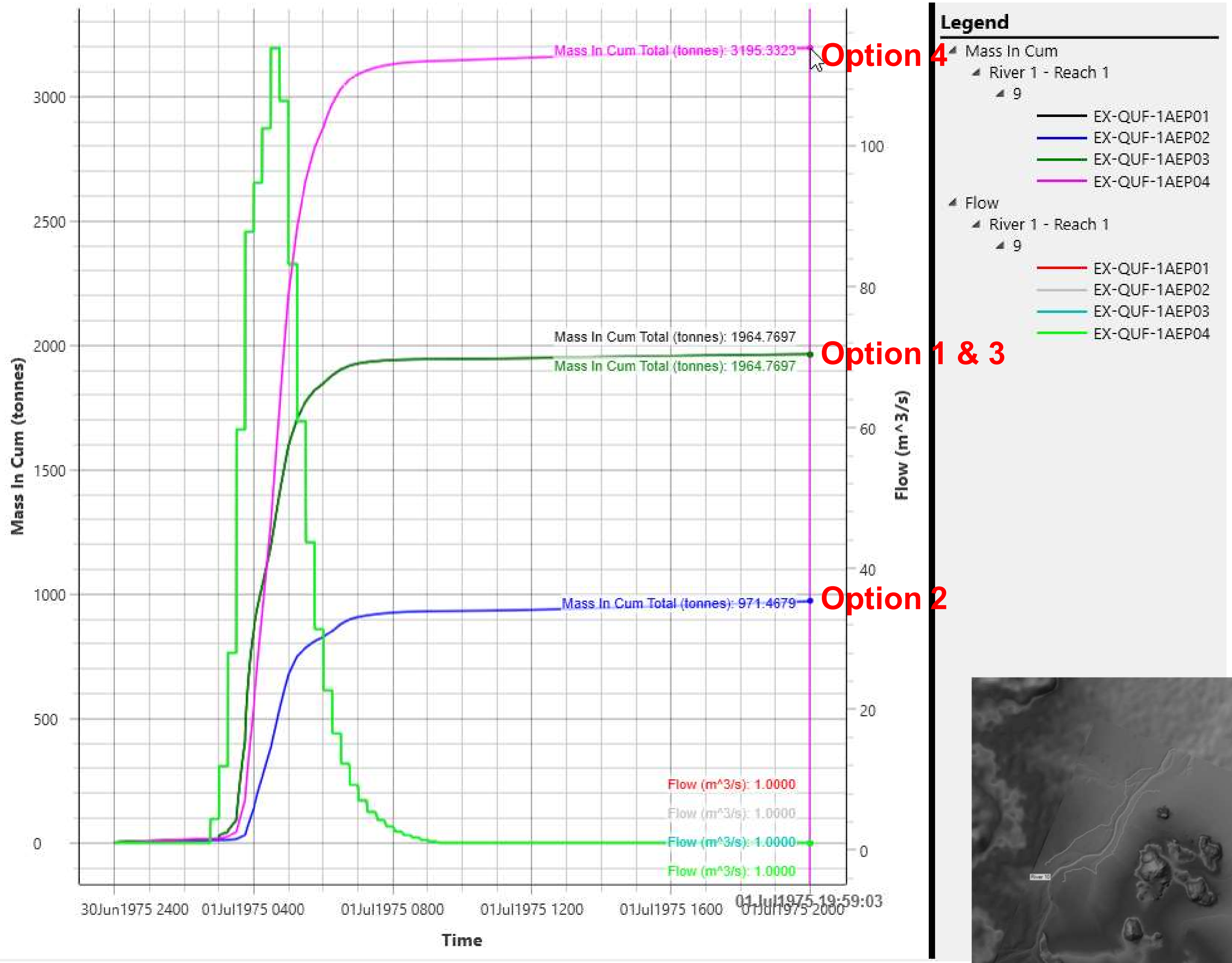
Mass In (1 in 100 AEP)

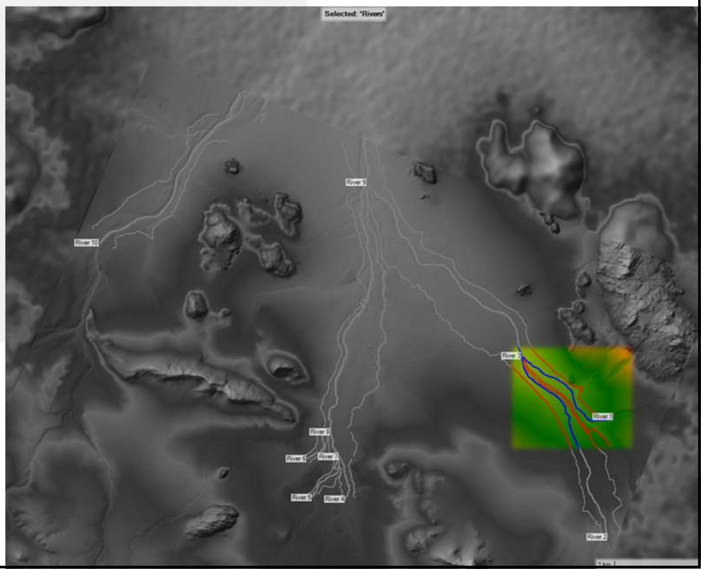
River 1 – Station 1442 (U/S)



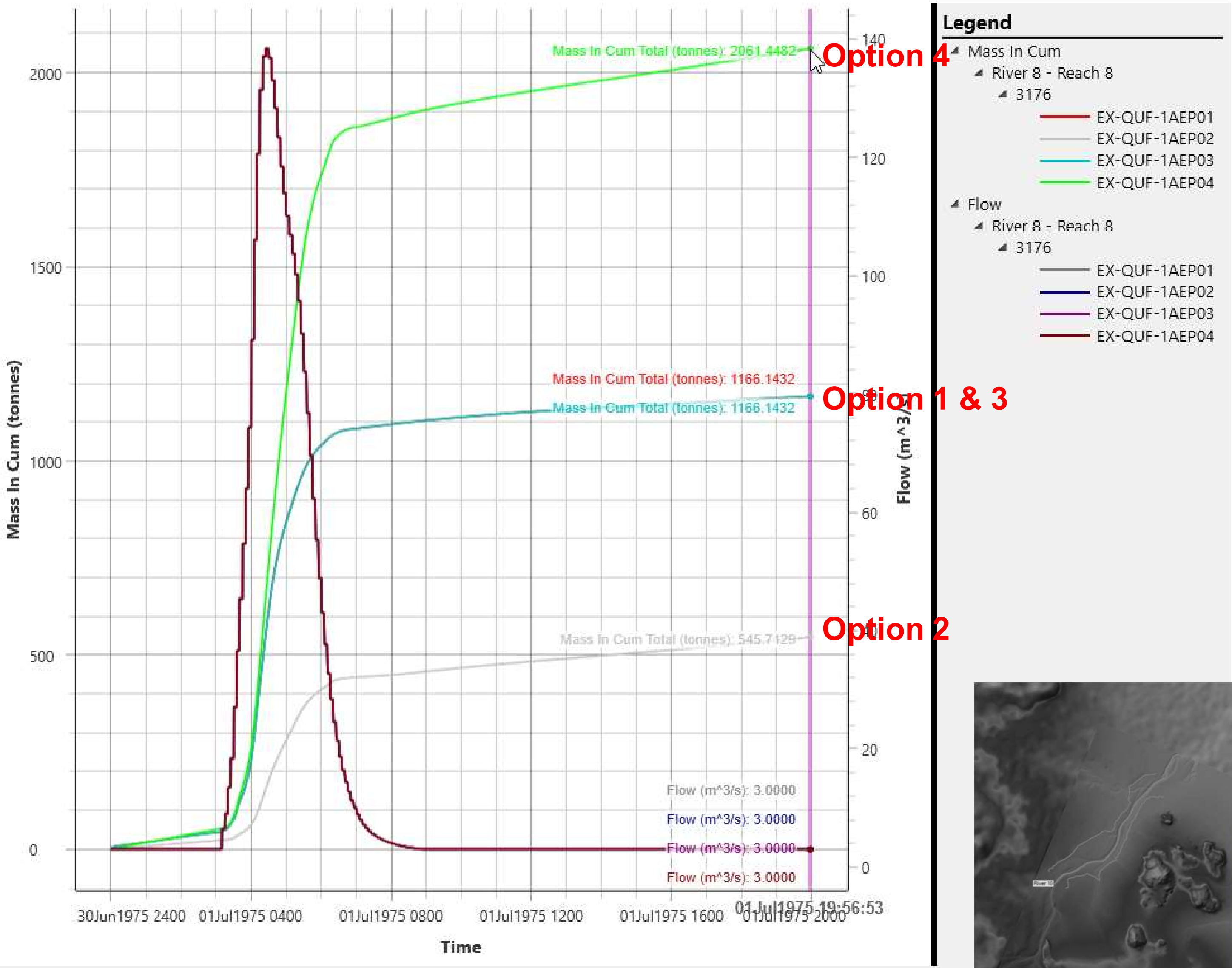


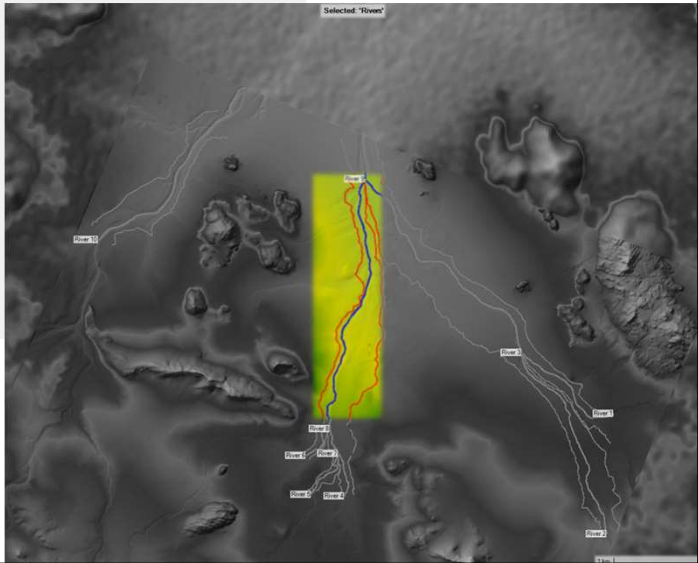
River 1 – Station 9 (D/S)



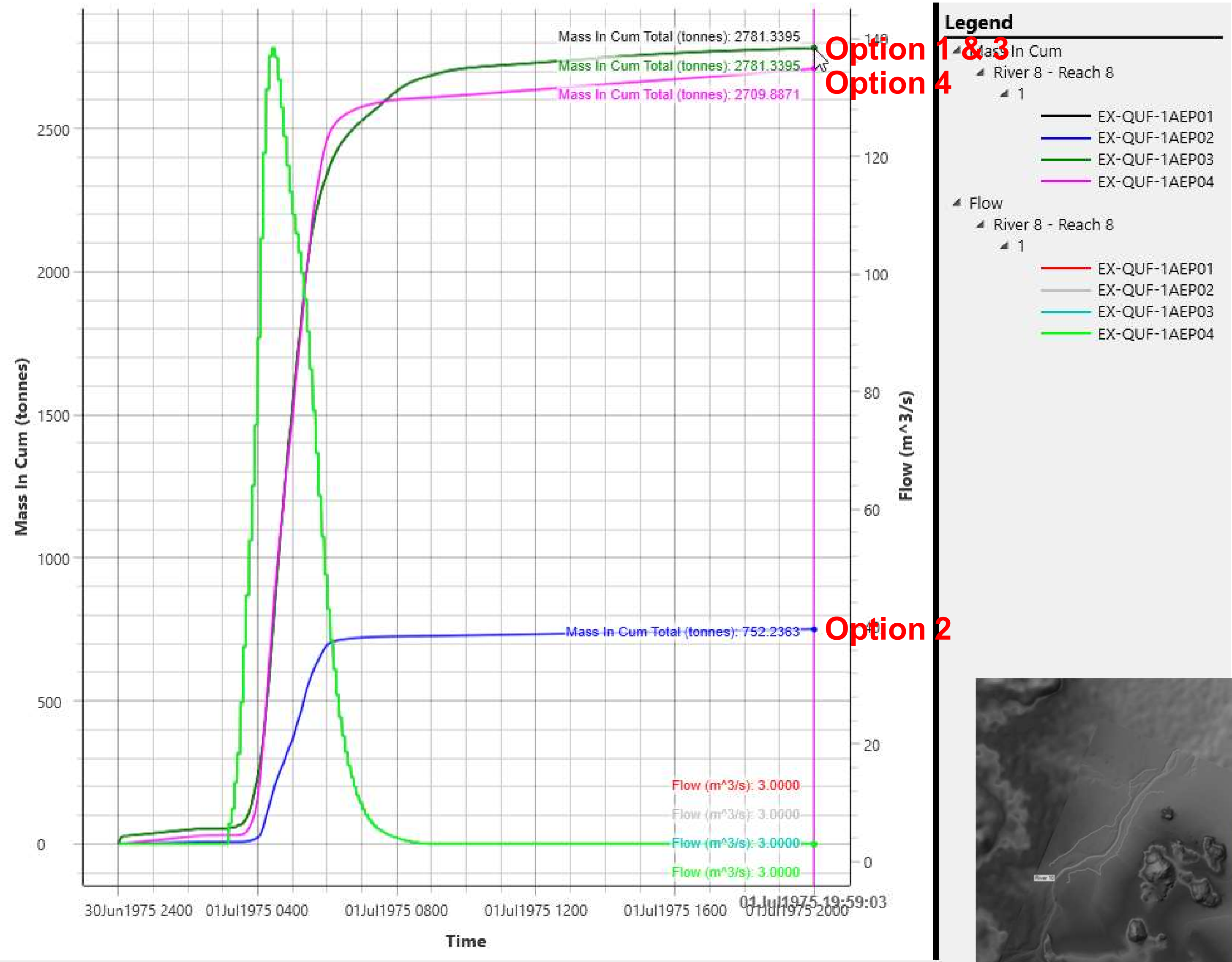


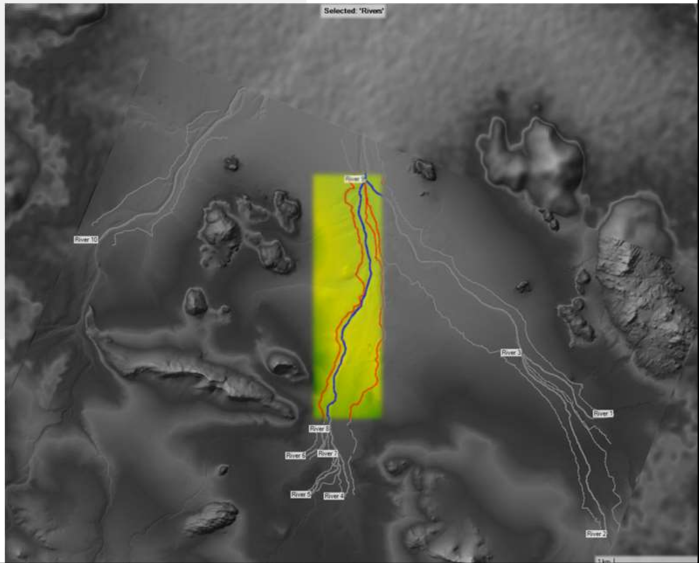
River 8 – Station 3176 (U/S)



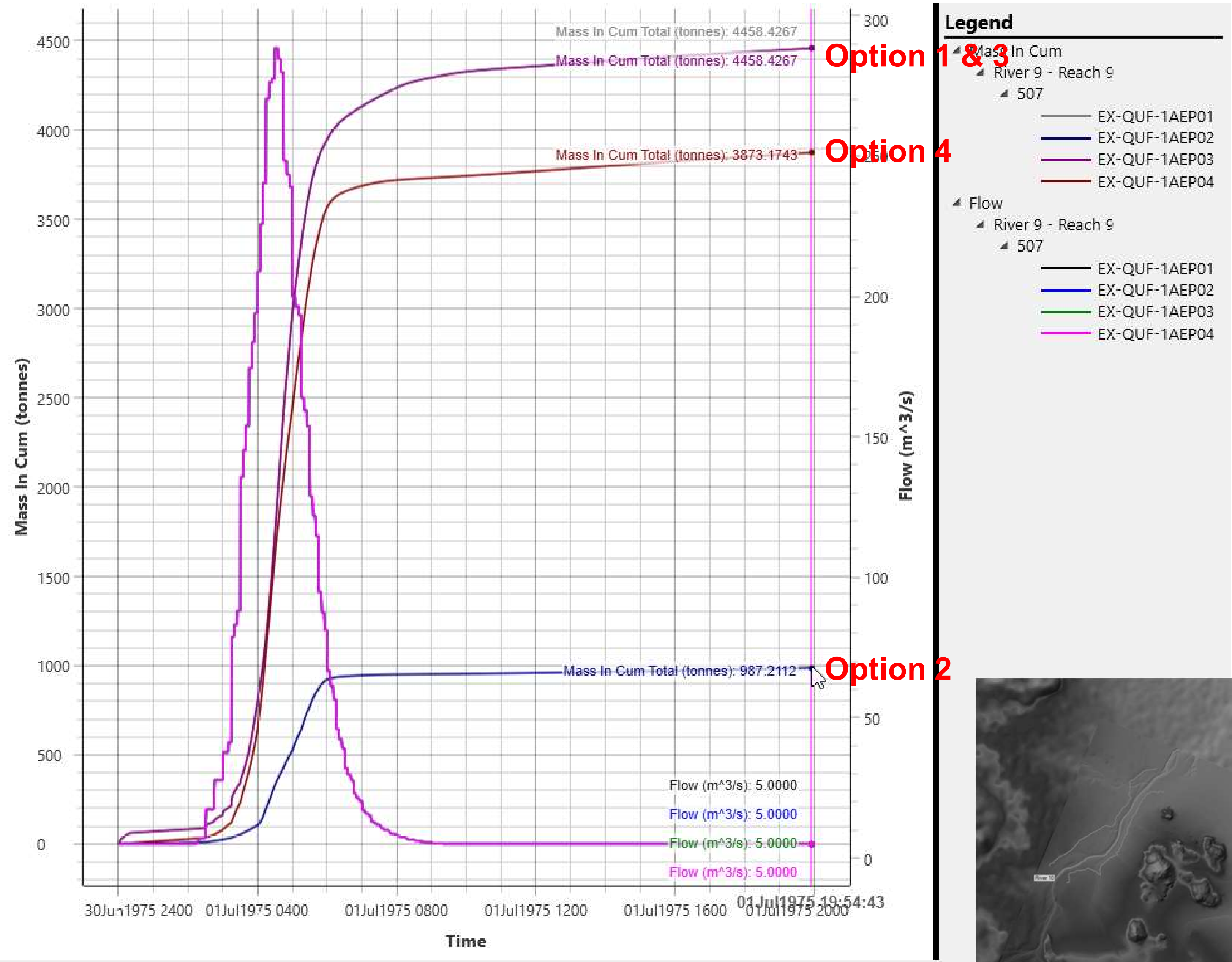


River 8 – Station 1 (D/S)

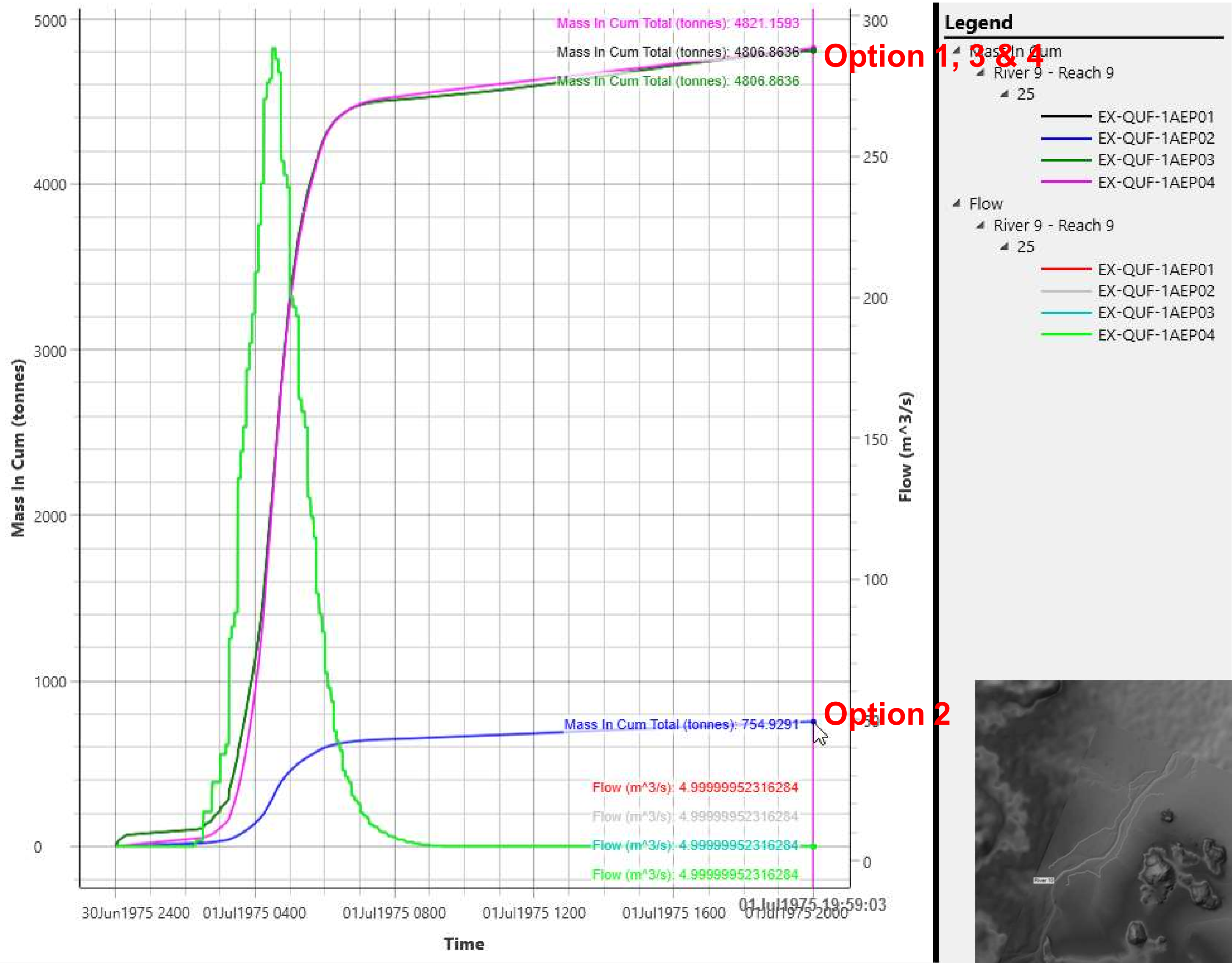




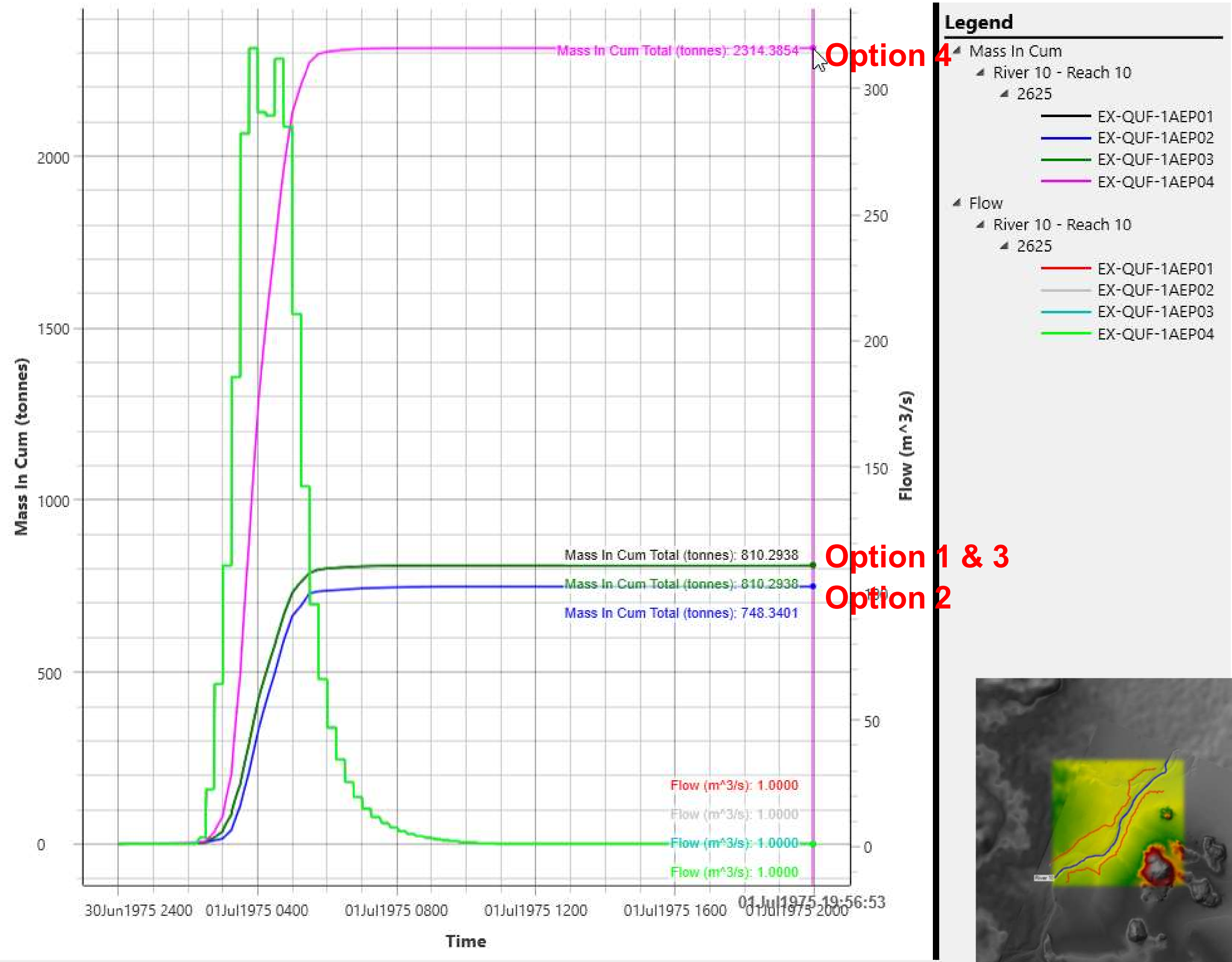
River 9 – Station 507 (U/S)

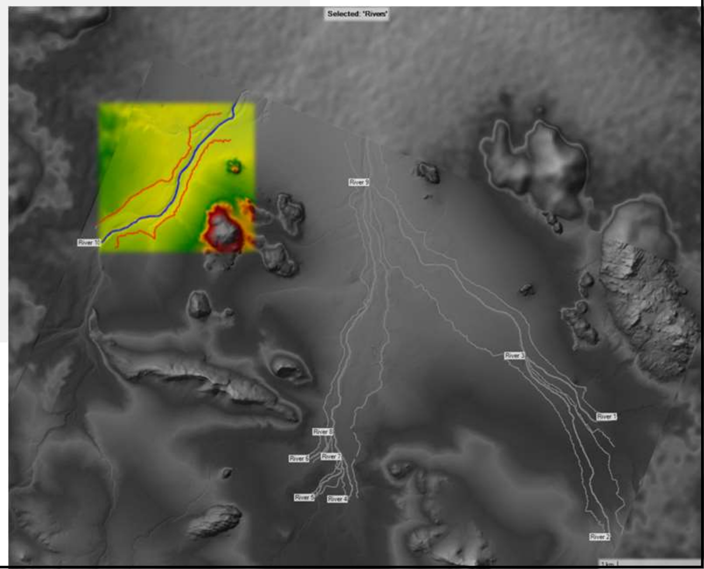


River 9 – Station 25 (D/S)

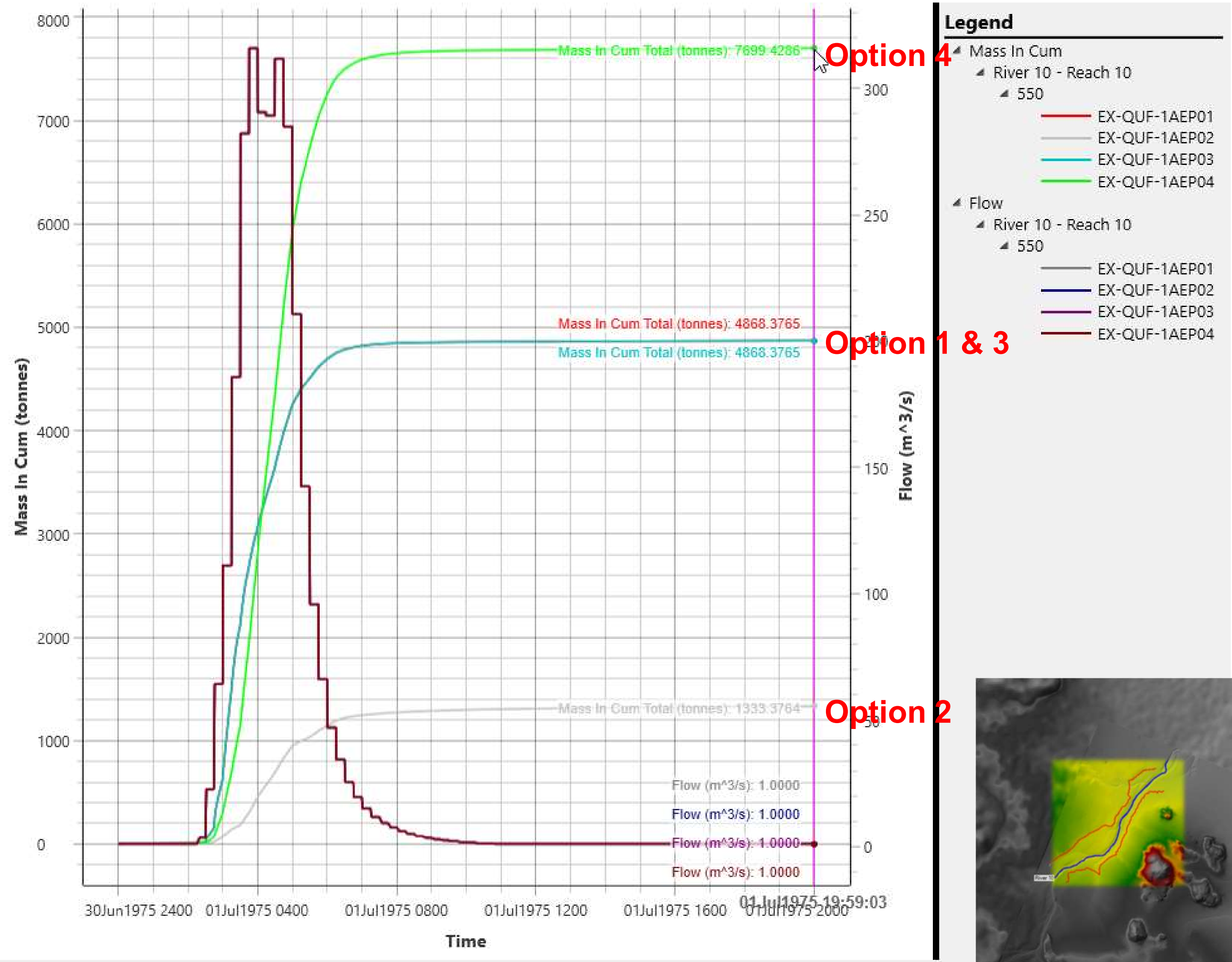


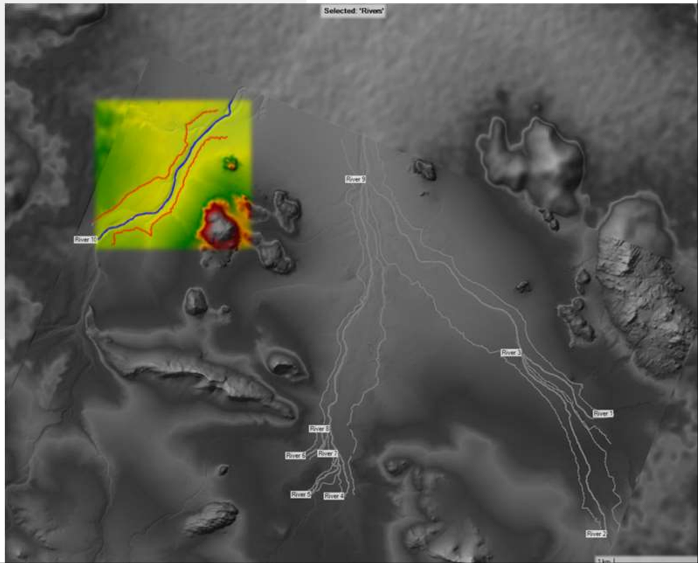
River 10 – Station 2625 (U/S)





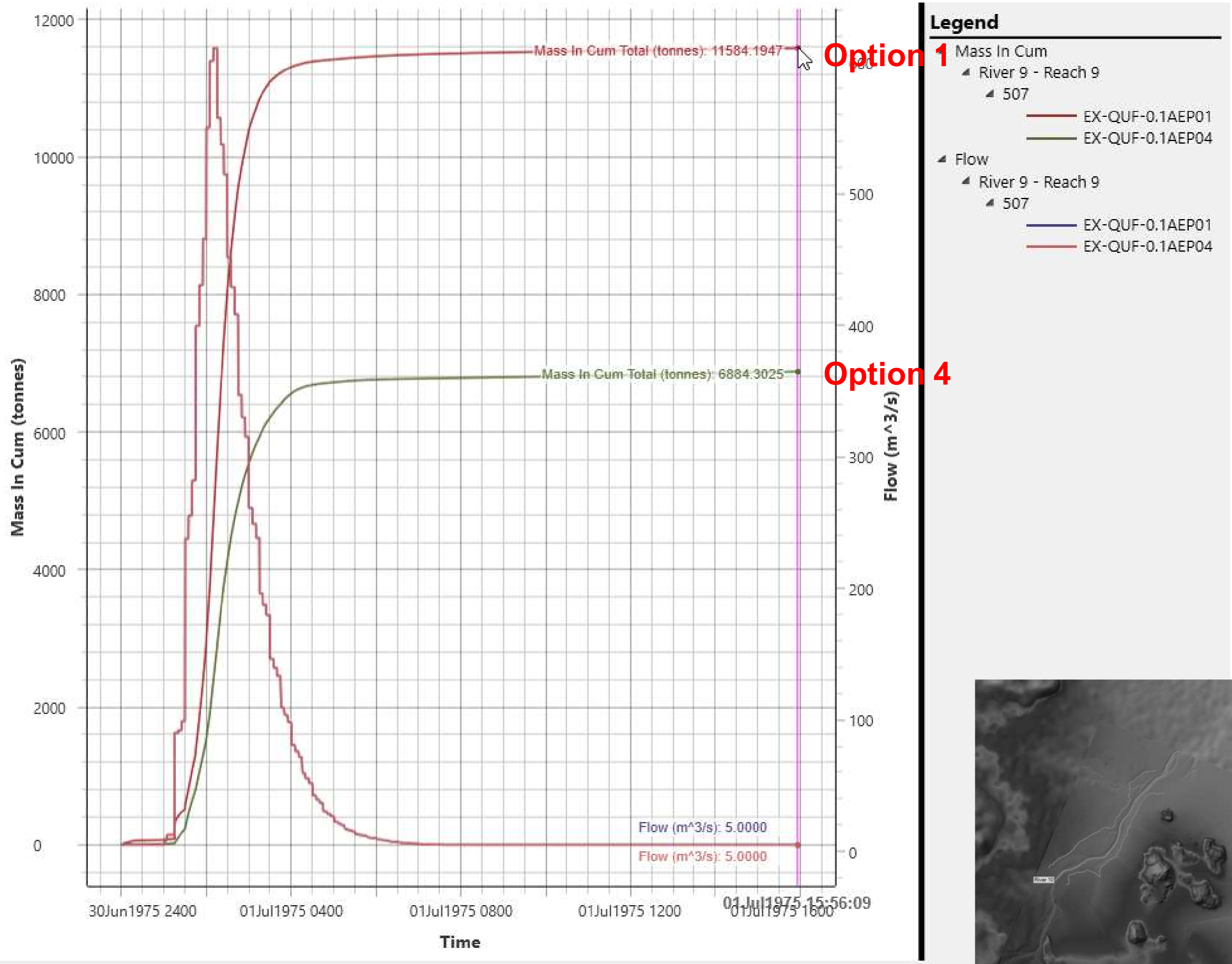
River 10 – Station 550 (D/S)



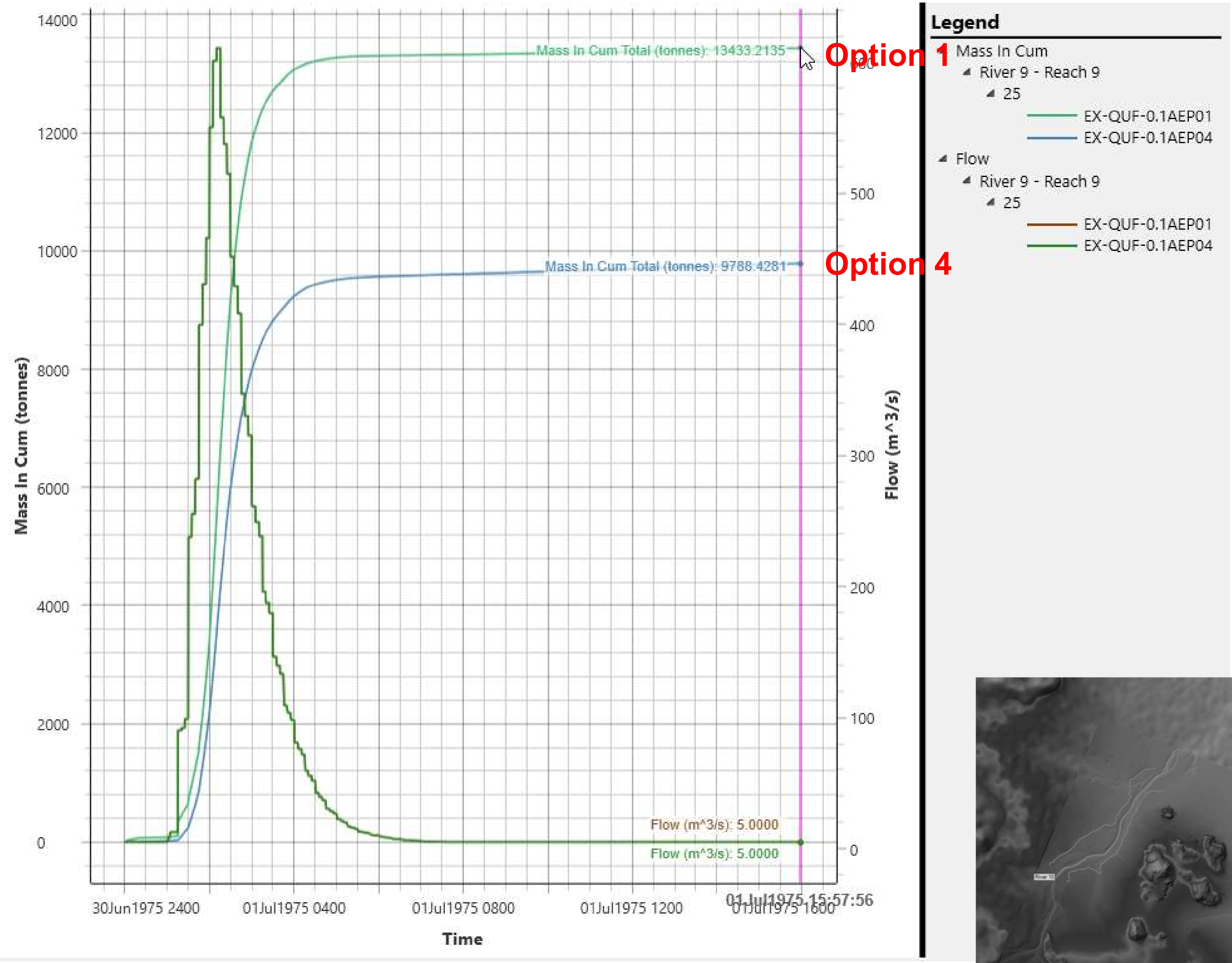


Mass In (1 in 1,000 AEP)

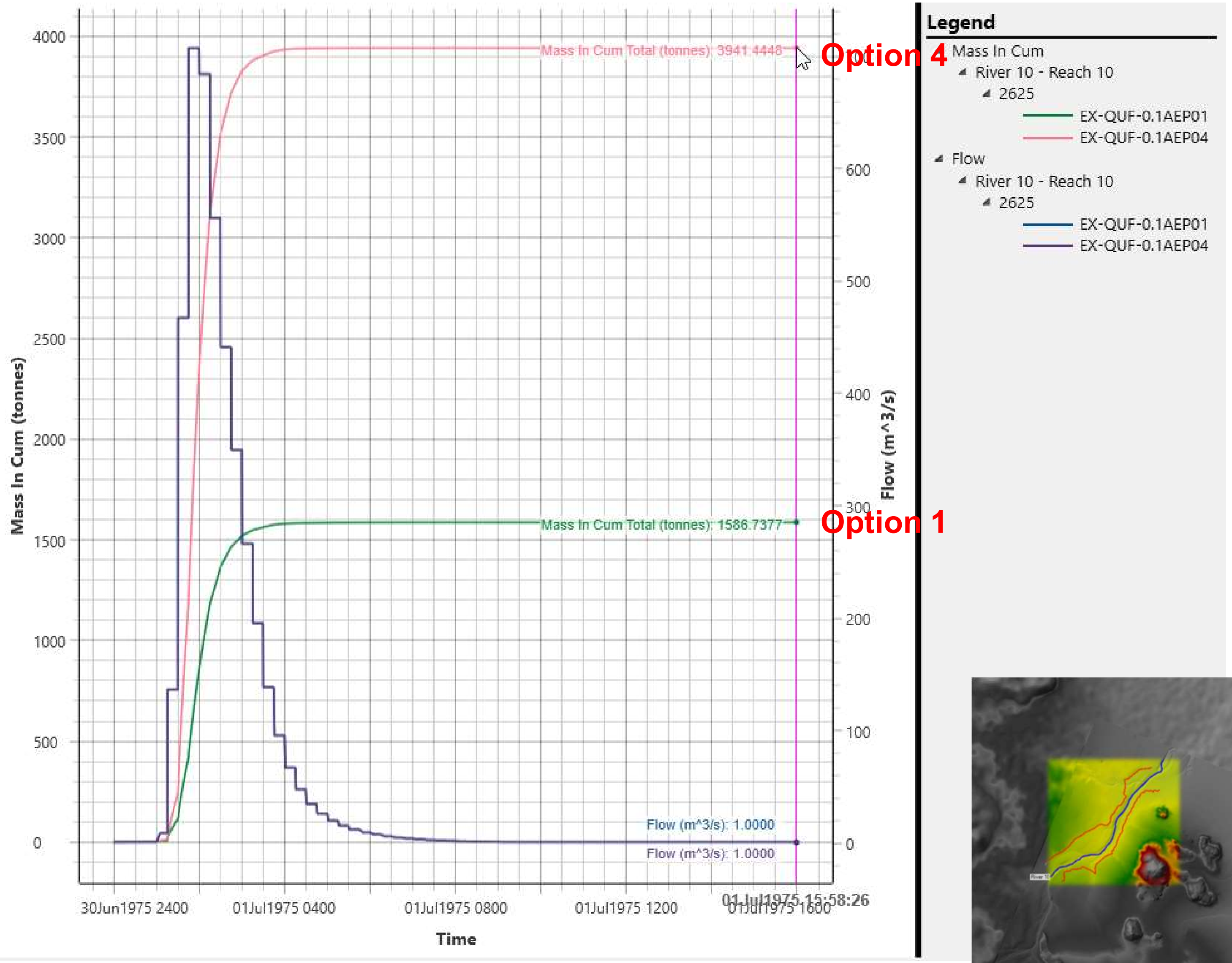
River 9 – Station 507 (U/S)

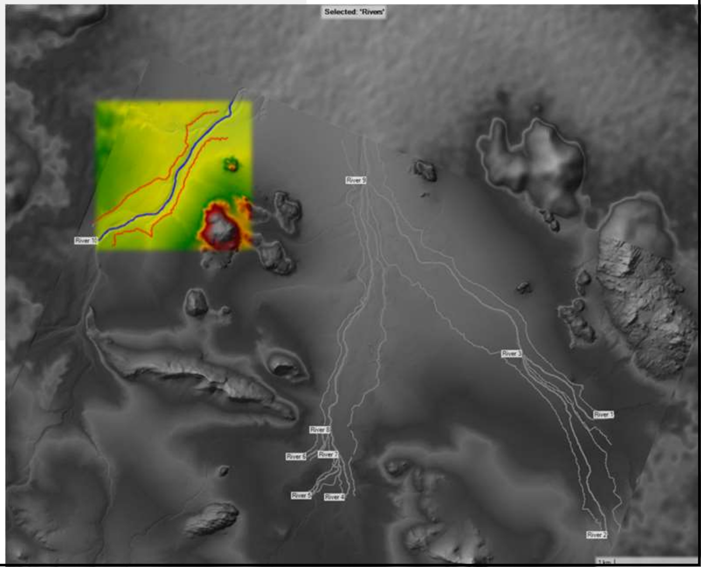


River 9 – Station 25 (D/S)

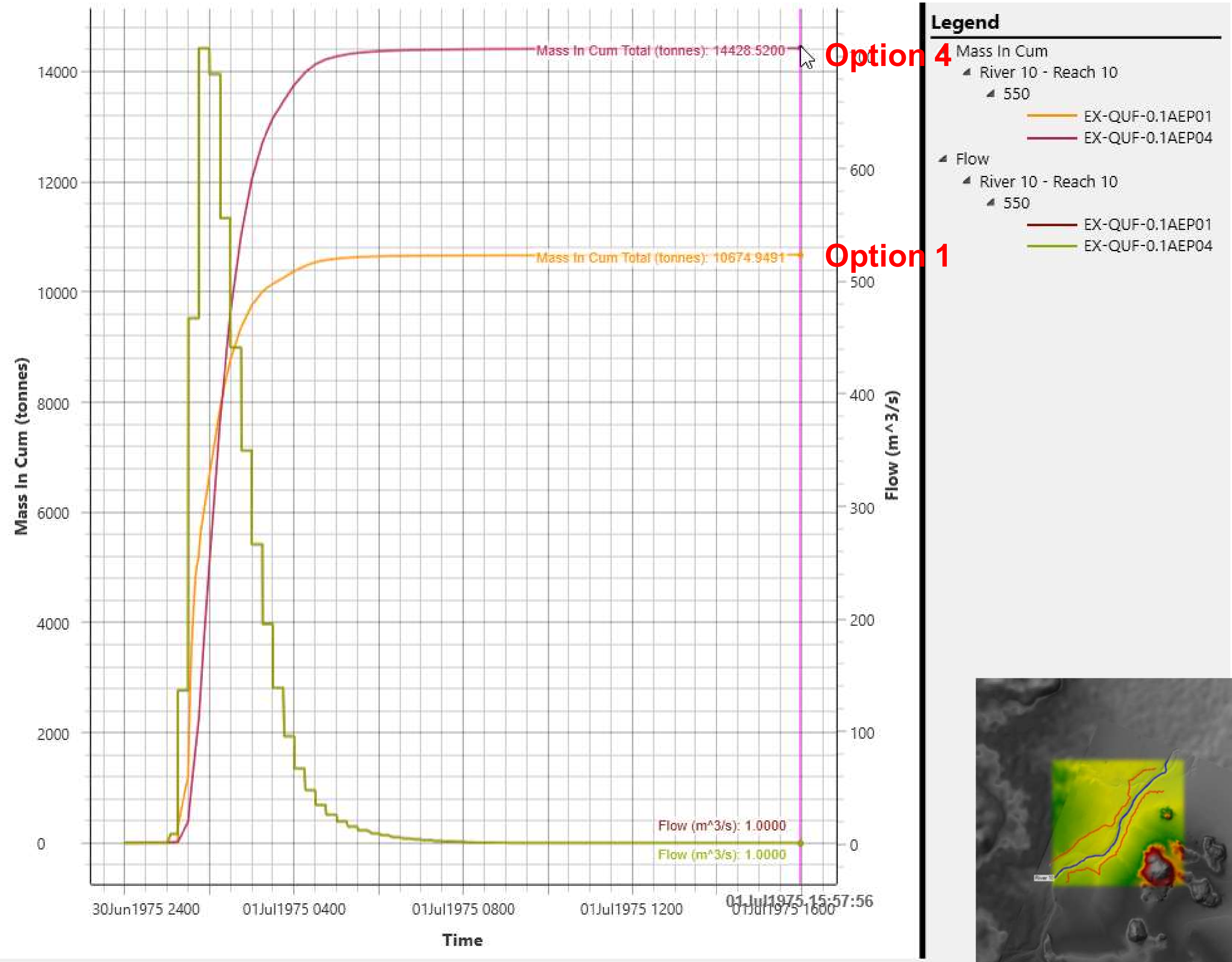


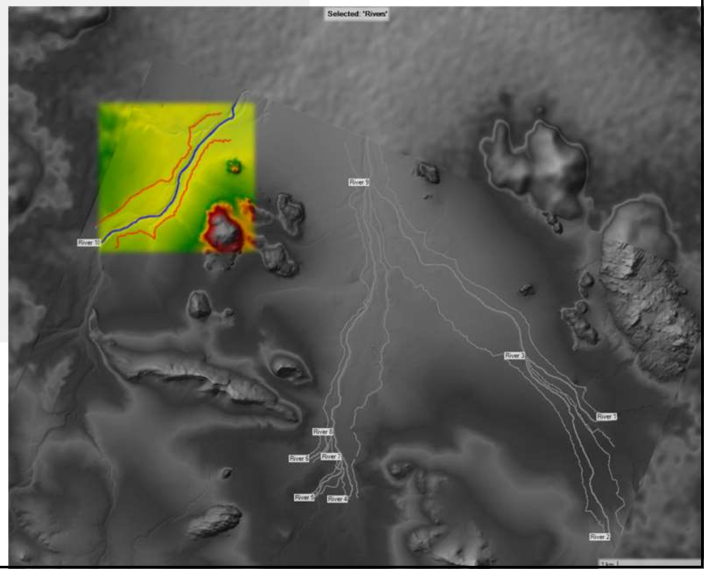
River 10 – Station 2625 (U/S)





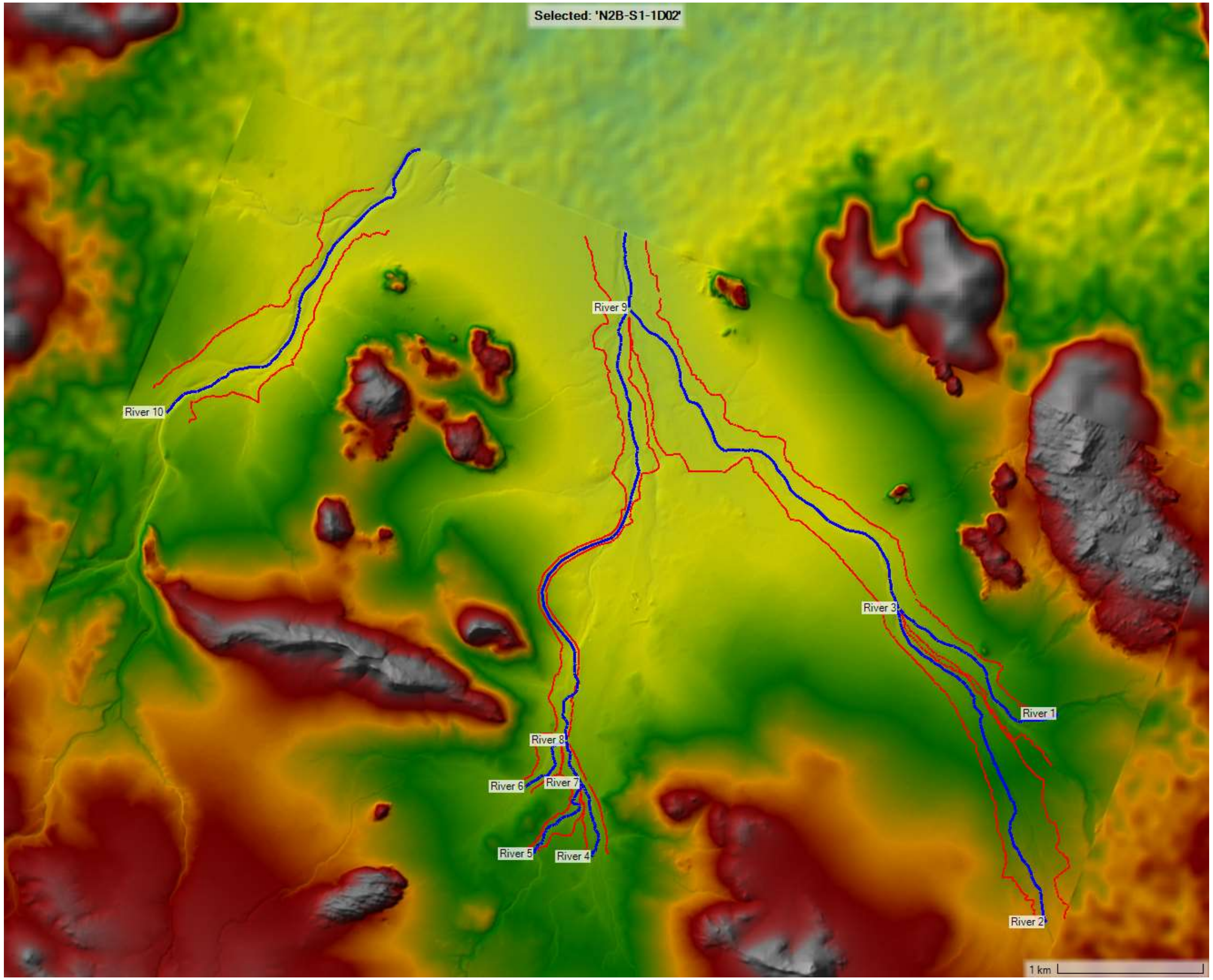
River 10 – Station 550 (D/S)





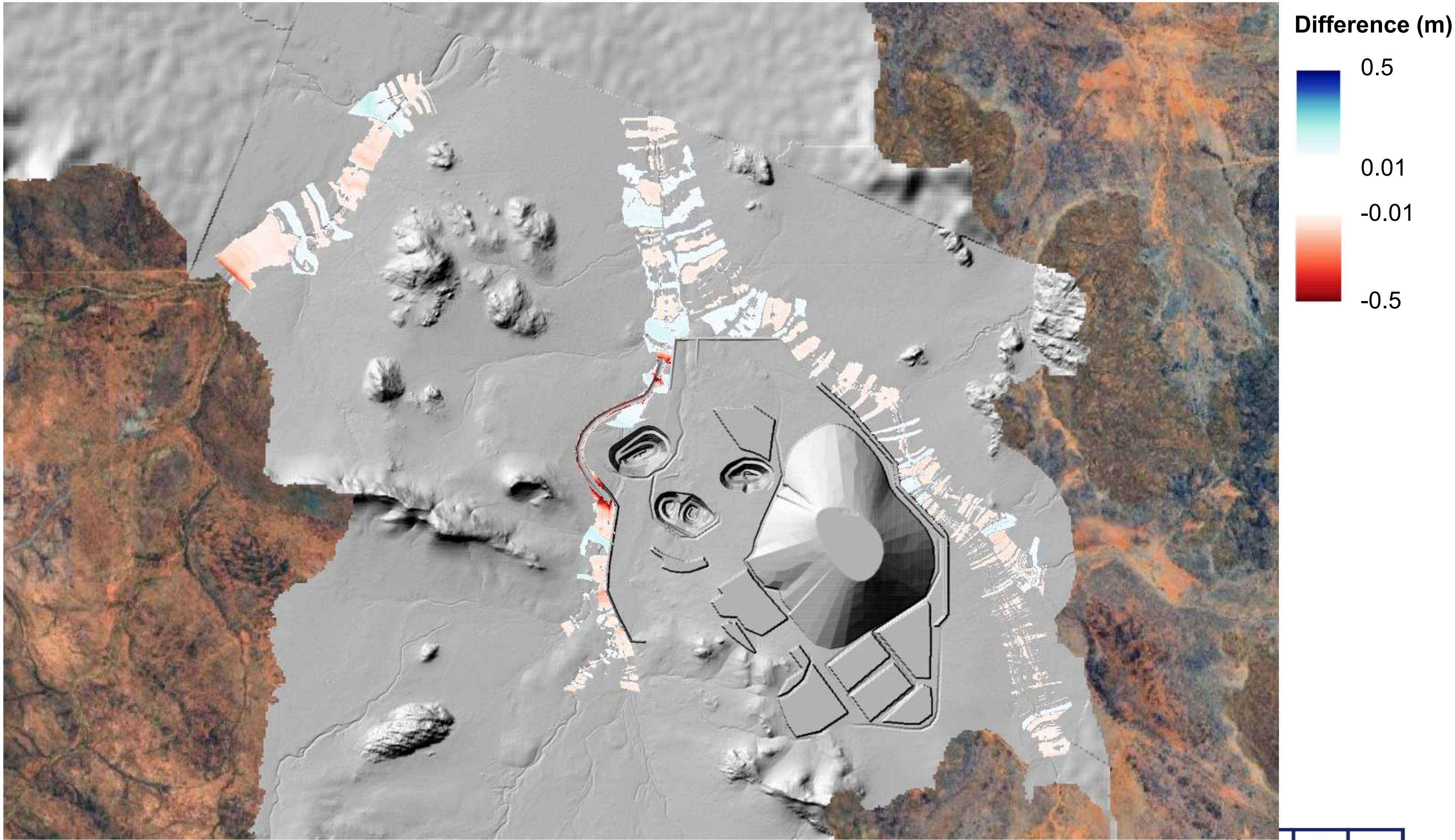
CASE – STAGE 1

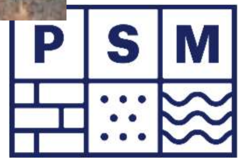
Plan



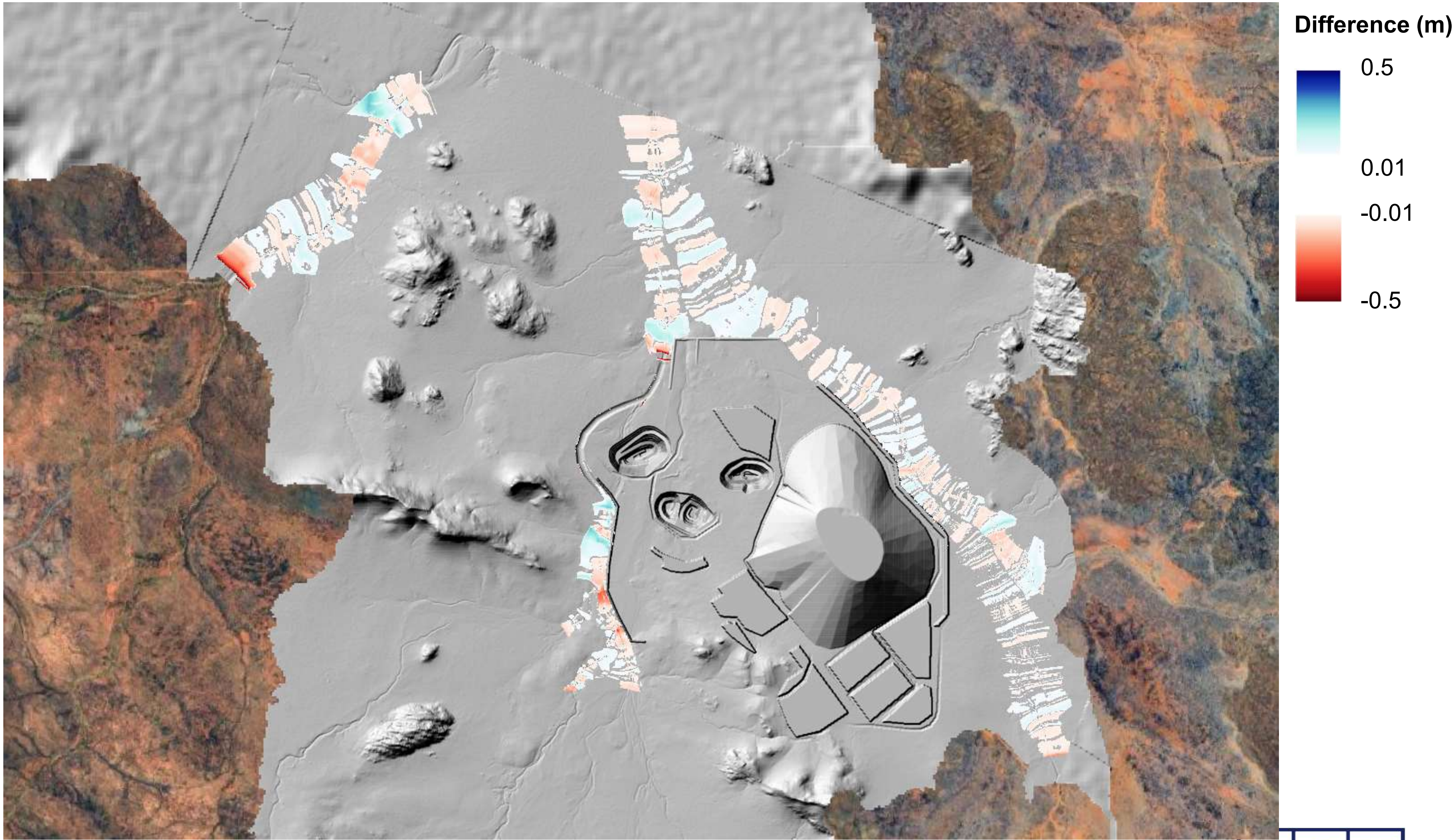
Selected: 'N2B-S1-1D02'
River 10
River 9
River 3
River 1
River 8
River 6
River 7
River 5
River 4
River 2
1 km

Scour – 1 in 1,000 AEP (Model 1 – Baseline)

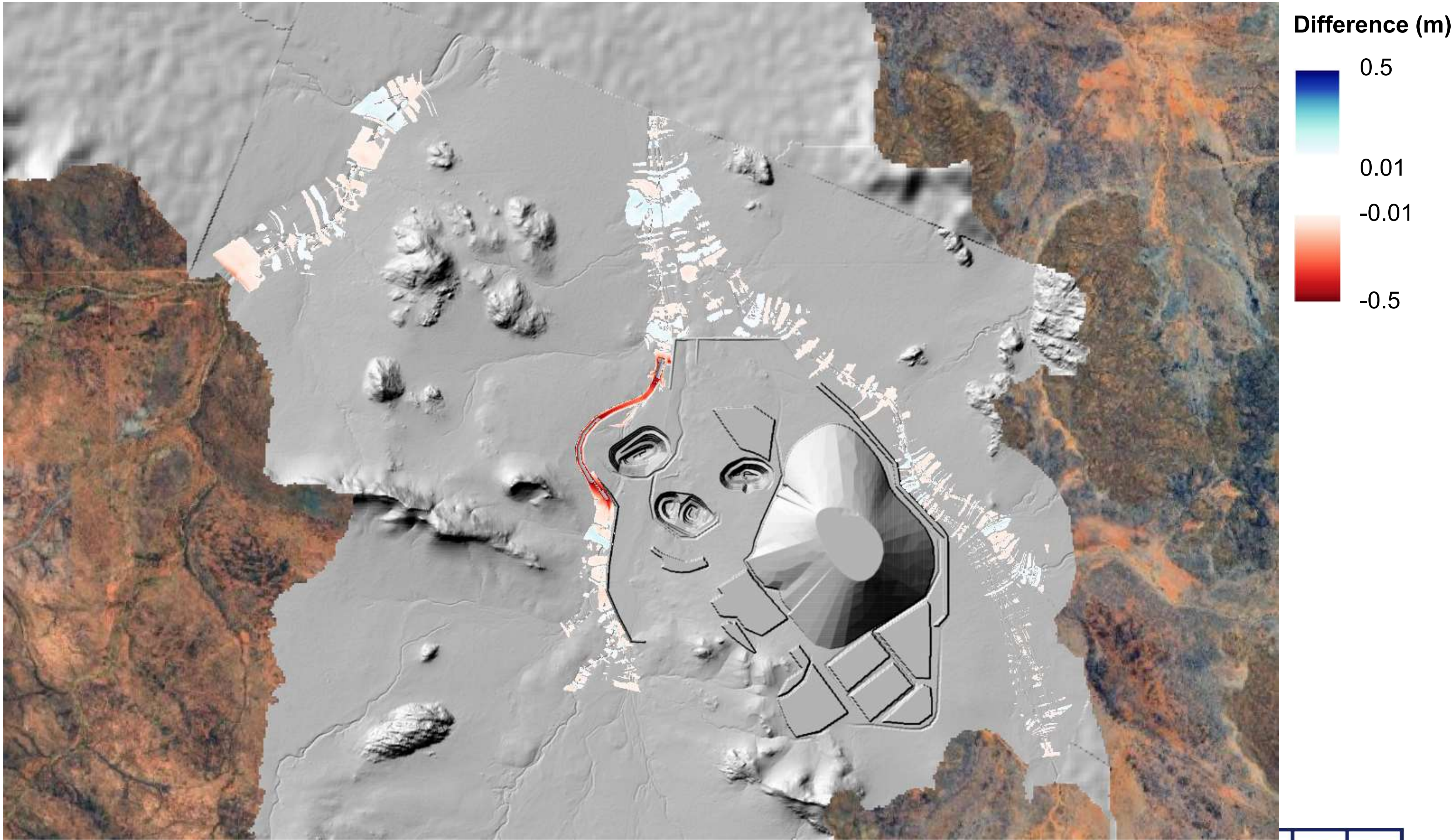




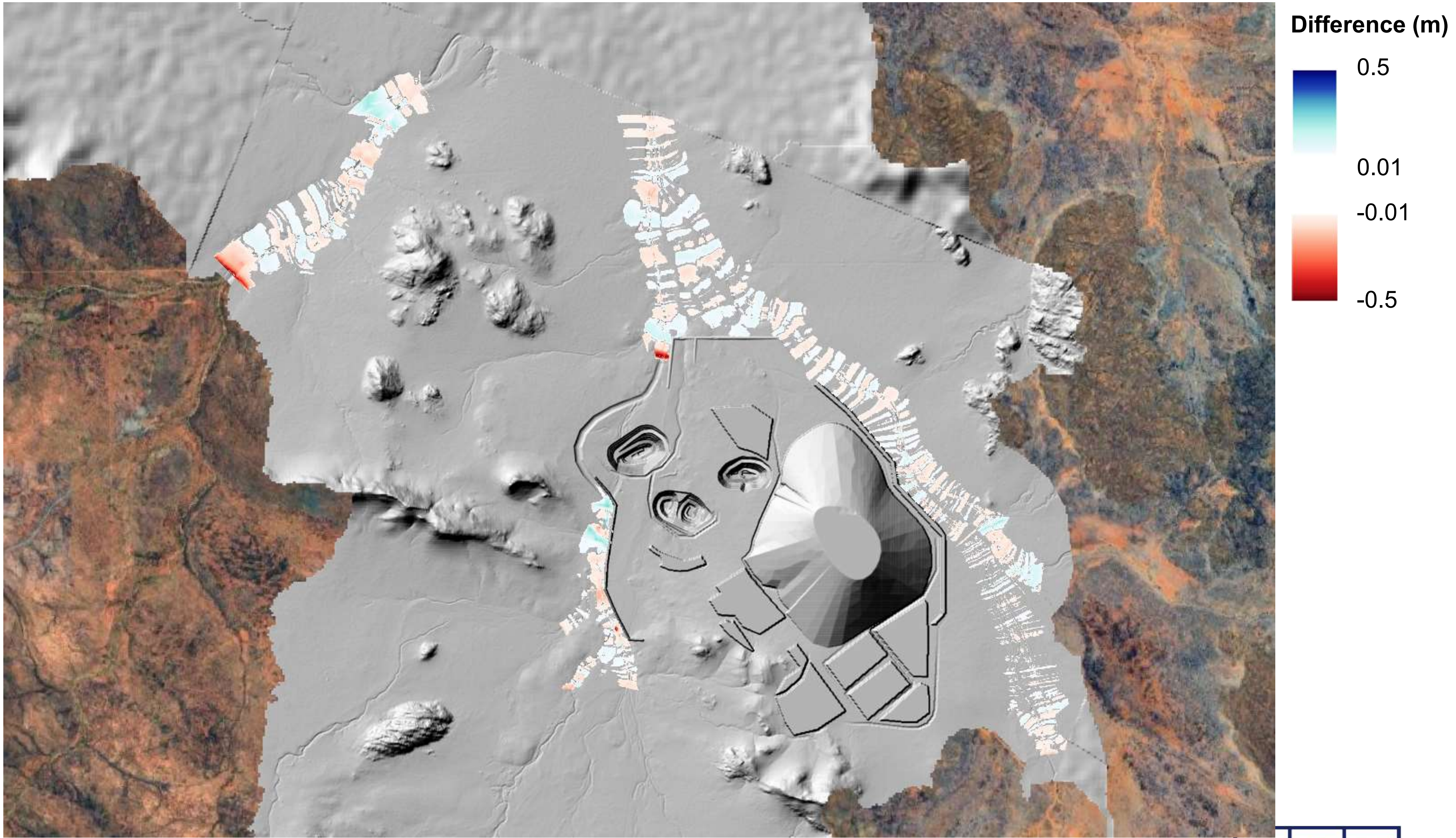
Scour – 1 in 1,000 AEP (Model 4 – Baseline)



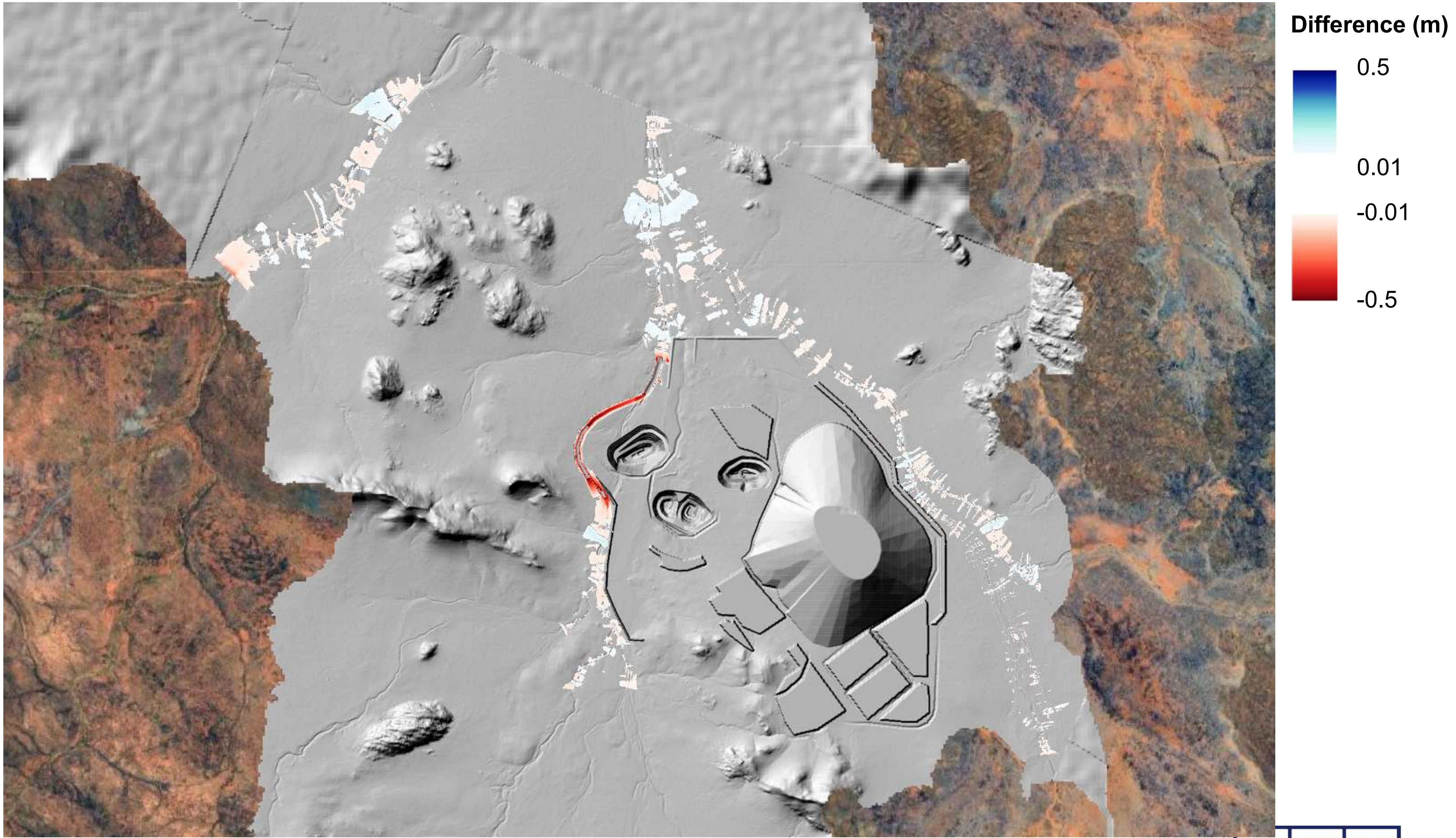
Scour – 1 in 100 AEP (Model 1 – Baseline)



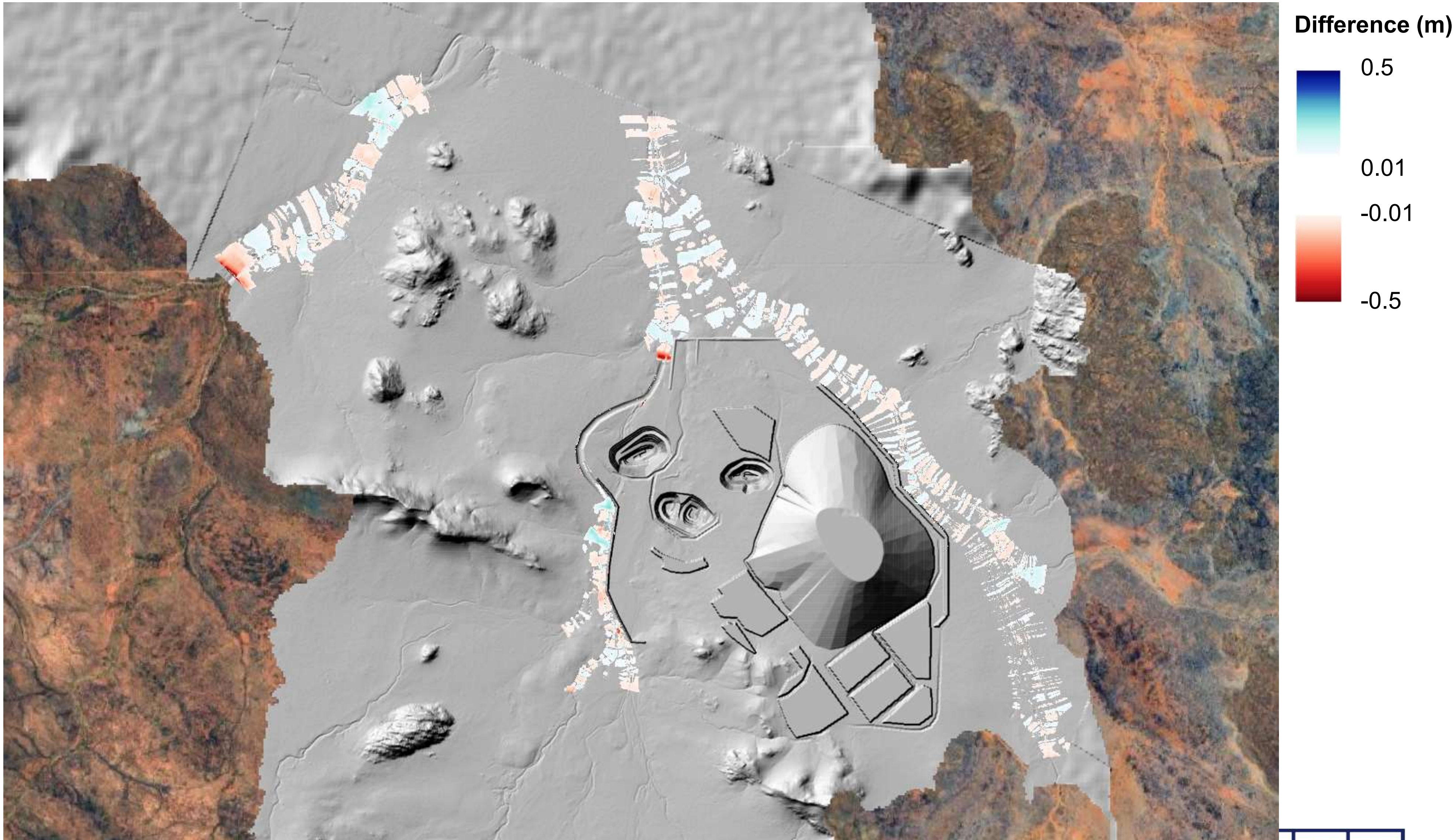
Scour – 1 in 100 AEP (Model 4 – Baseline)



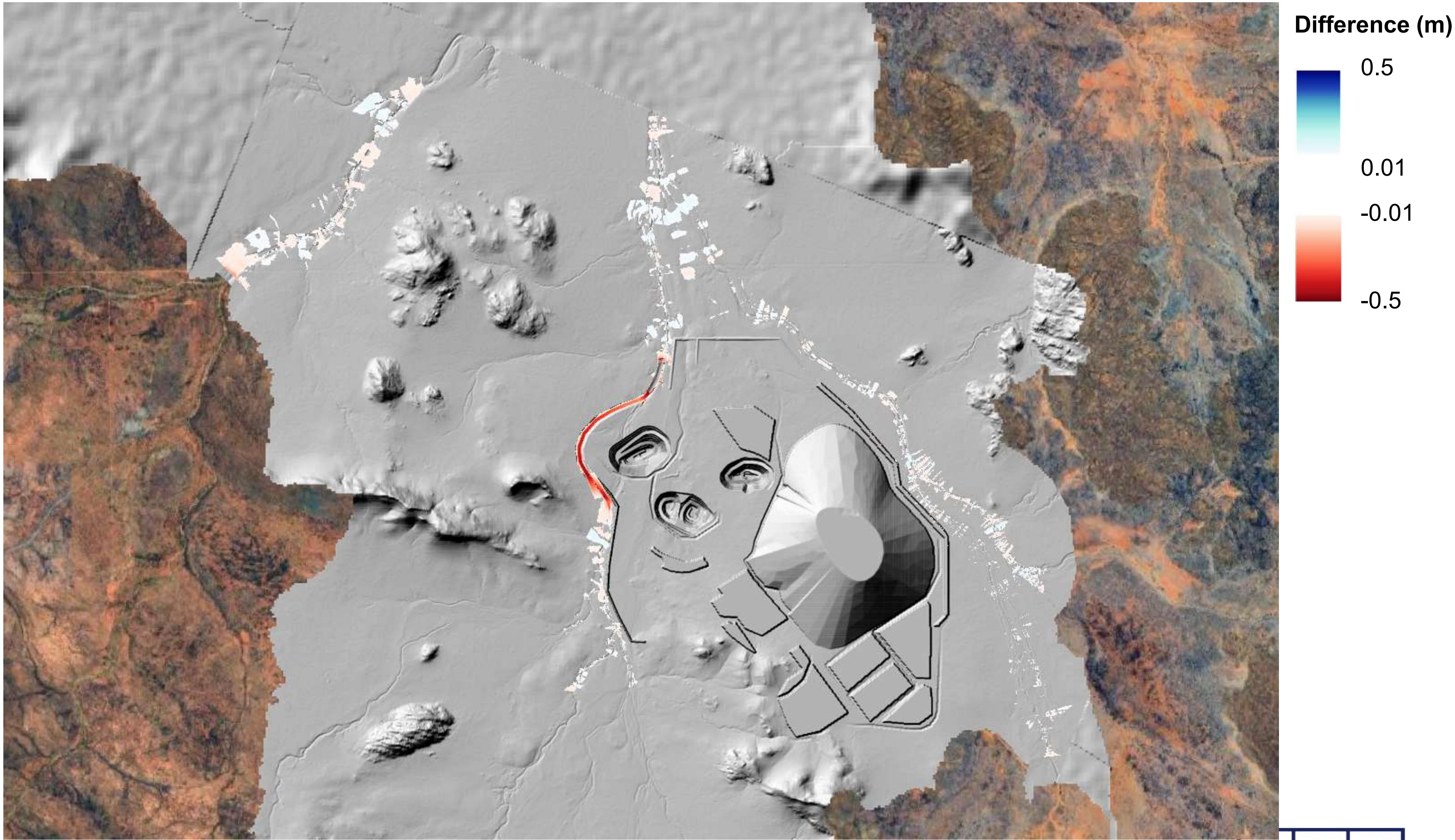
Scour – 1 in 50 AEP (Model 1 – Baseline)



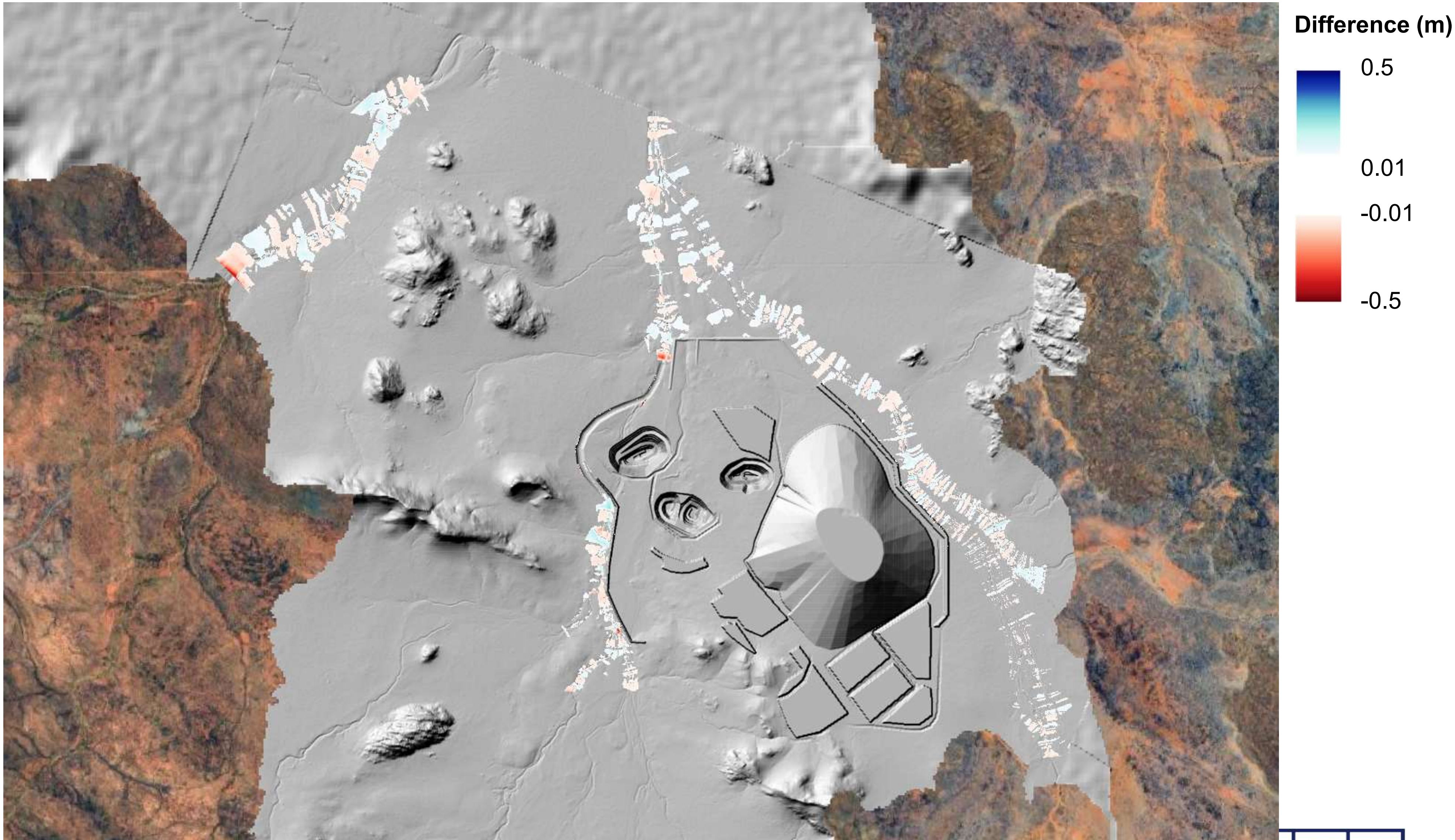
Scour – 1 in 50 AEP (Model 4 – Baseline)



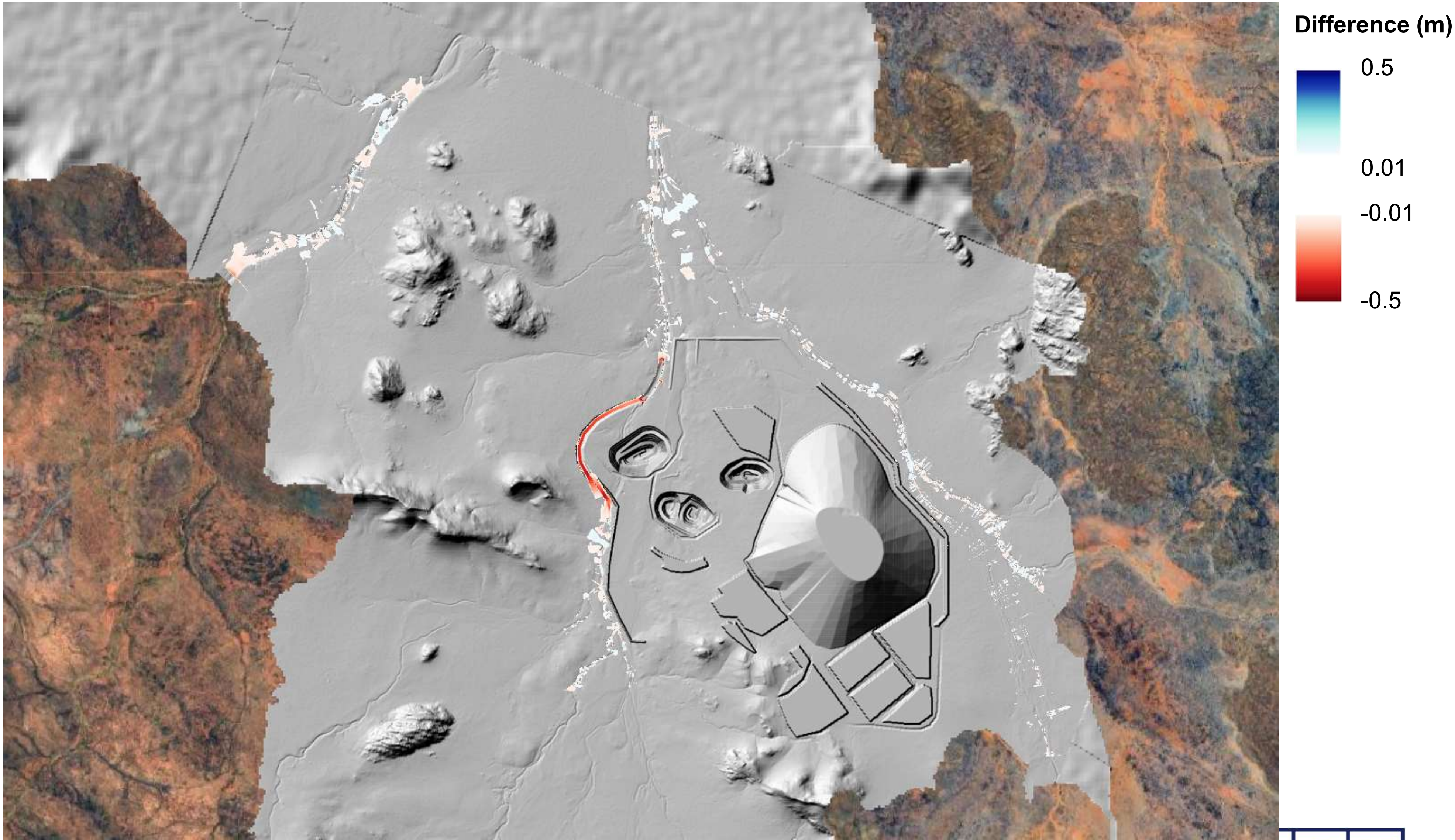
Scour – 1 in 20 AEP (Model 1 – Baseline)



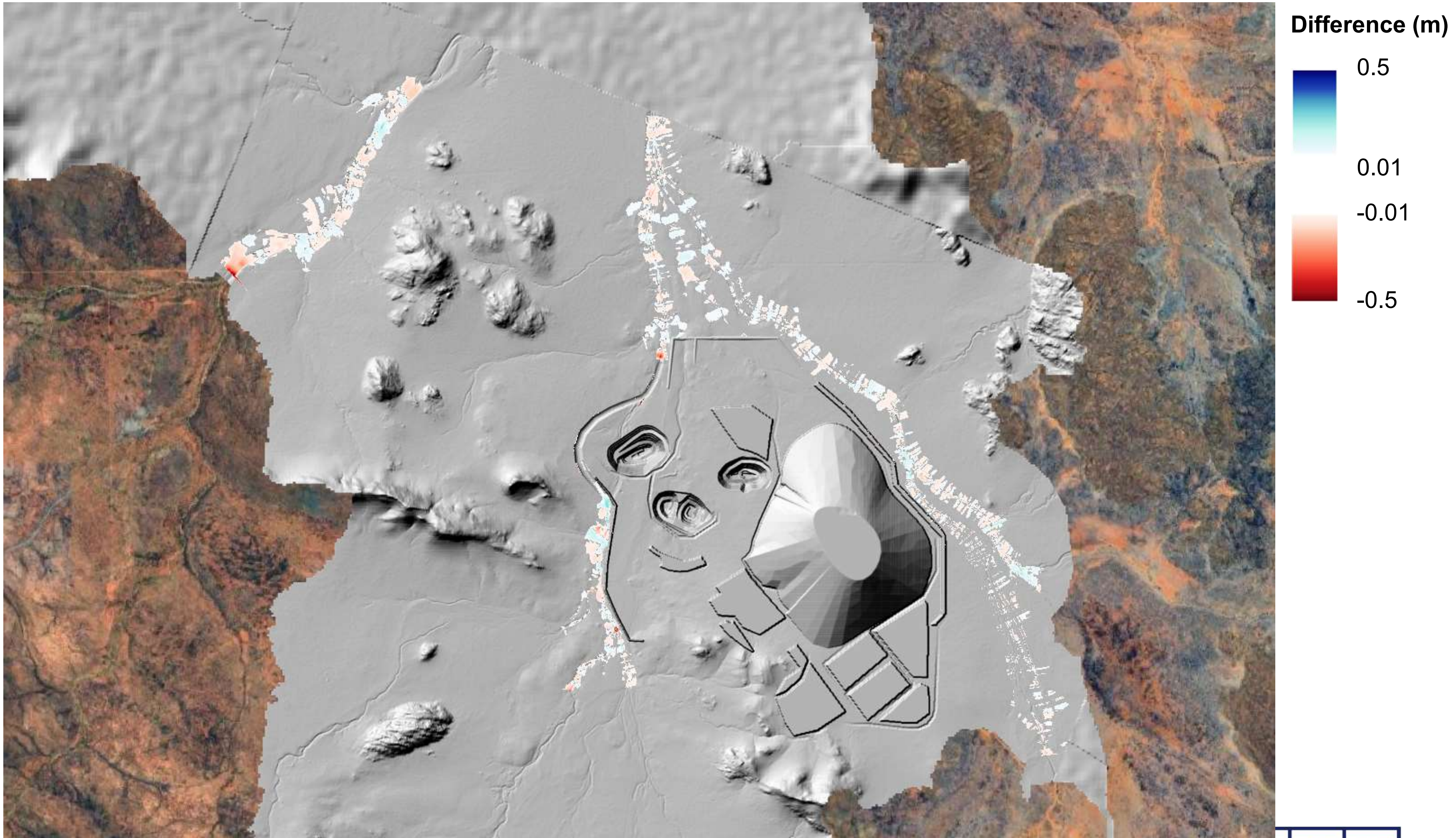
Scour – 1 in 20 AEP (Model 4 – Baseline)



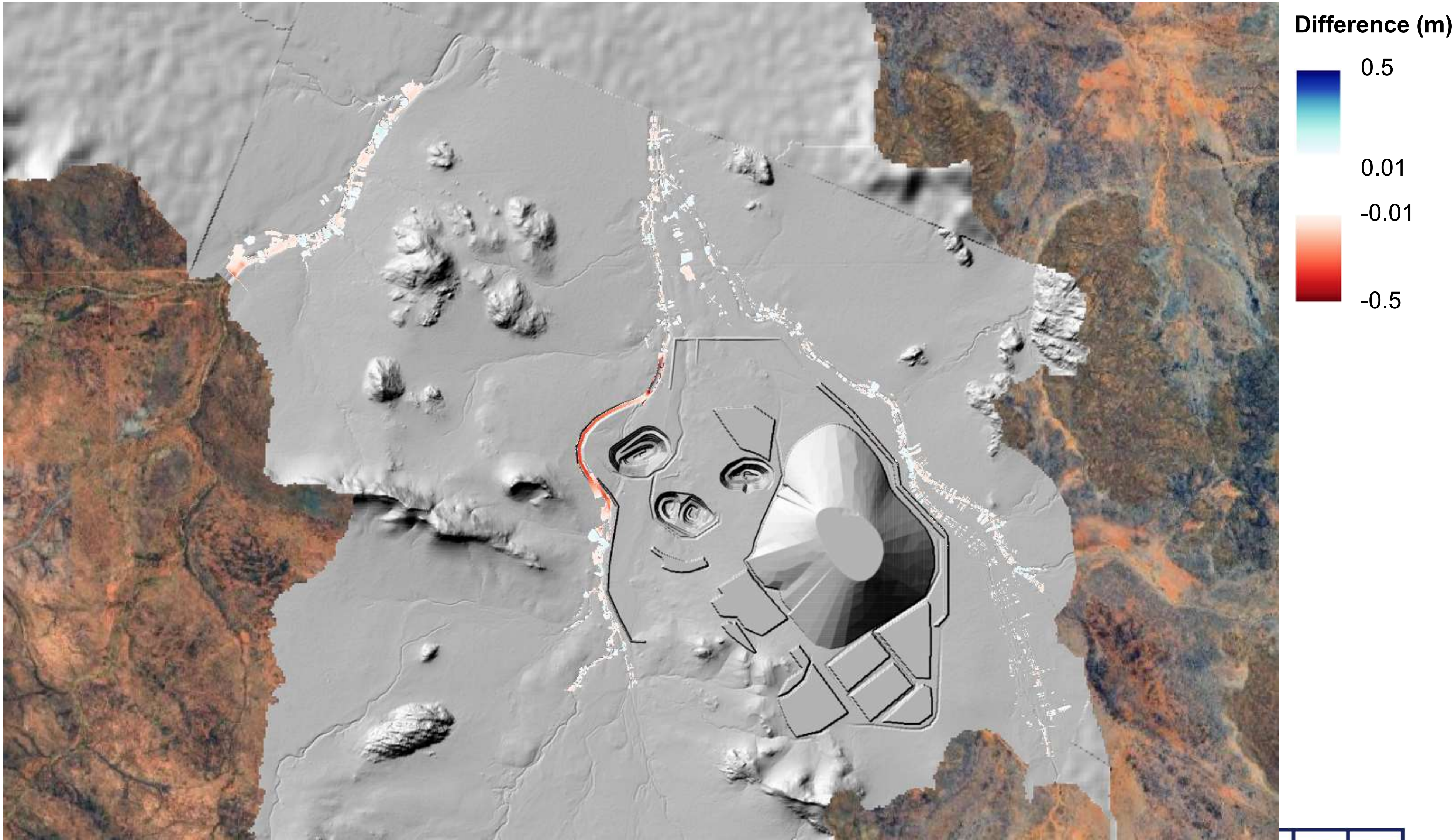
Scour – 1 in 10 AEP (Model 1 – Baseline)



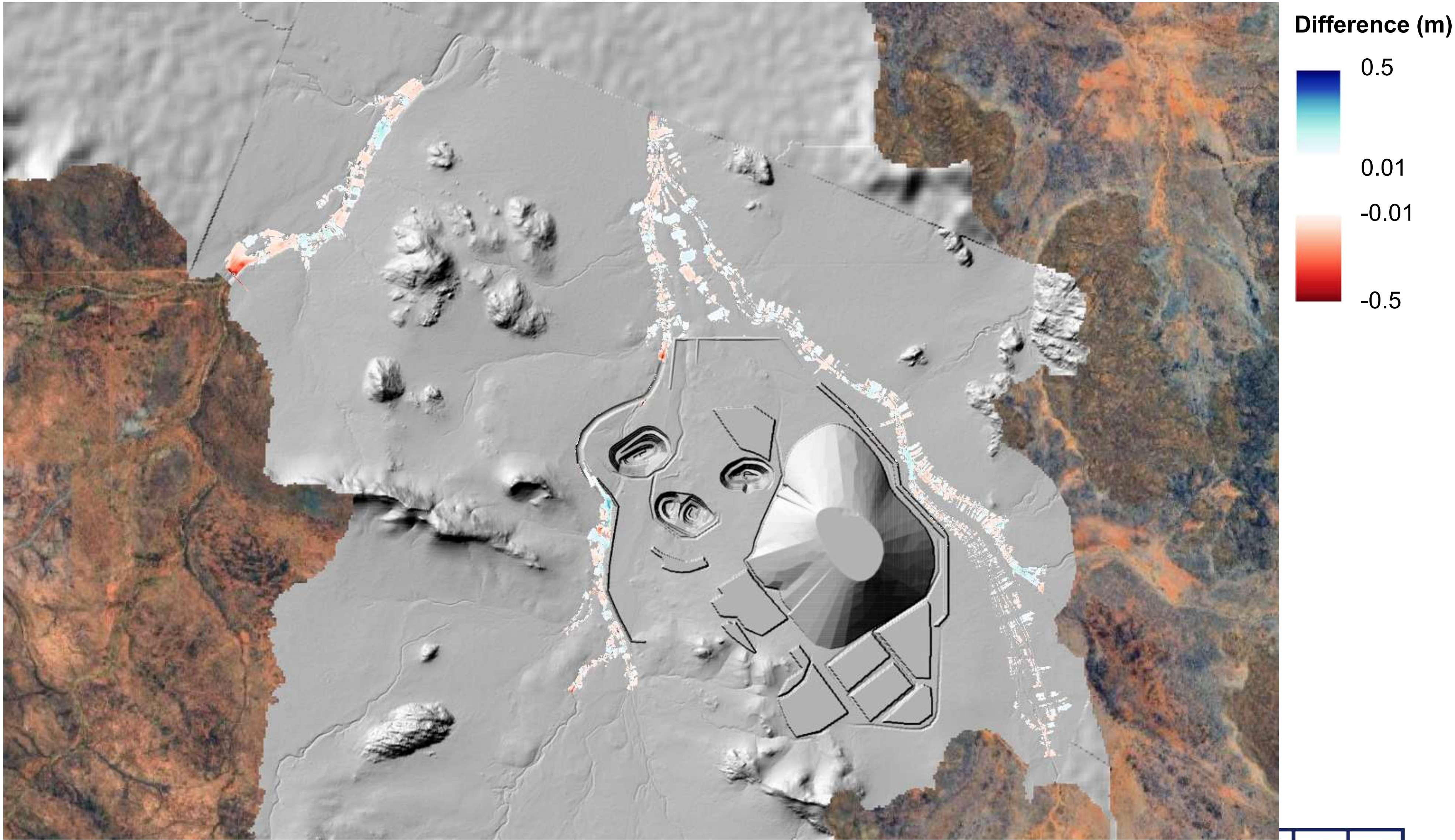
Scour – 1 in 10 AEP (Model 4 – Baseline)



Scour – 1 in 5 AEP (Model 1 – Baseline)

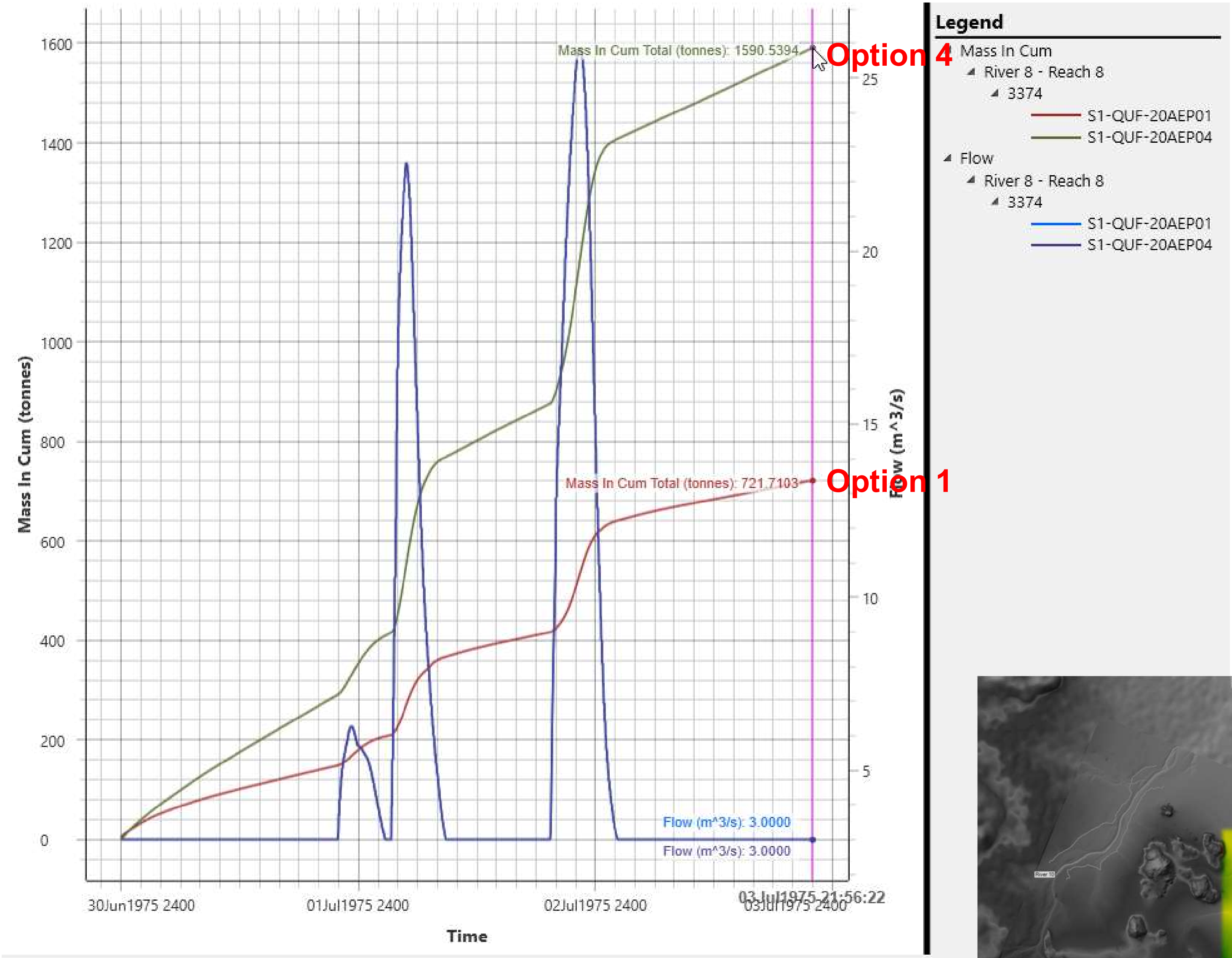


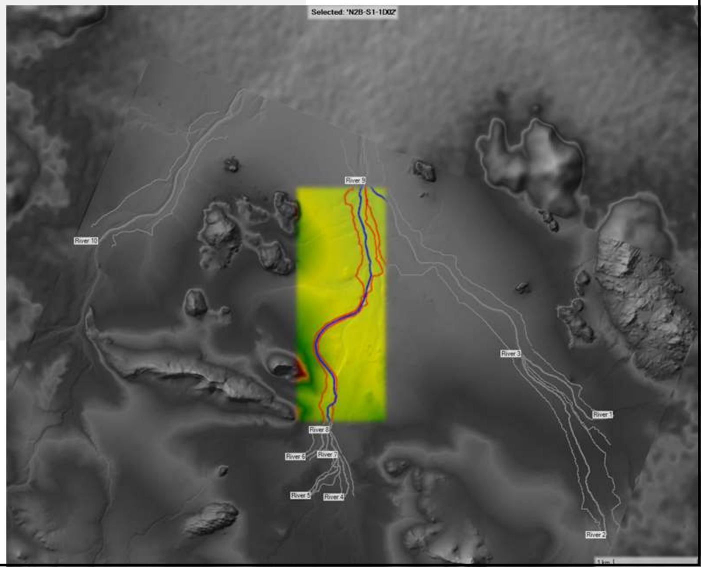
Scour – 1 in 5 AEP (Model 4 – Baseline)



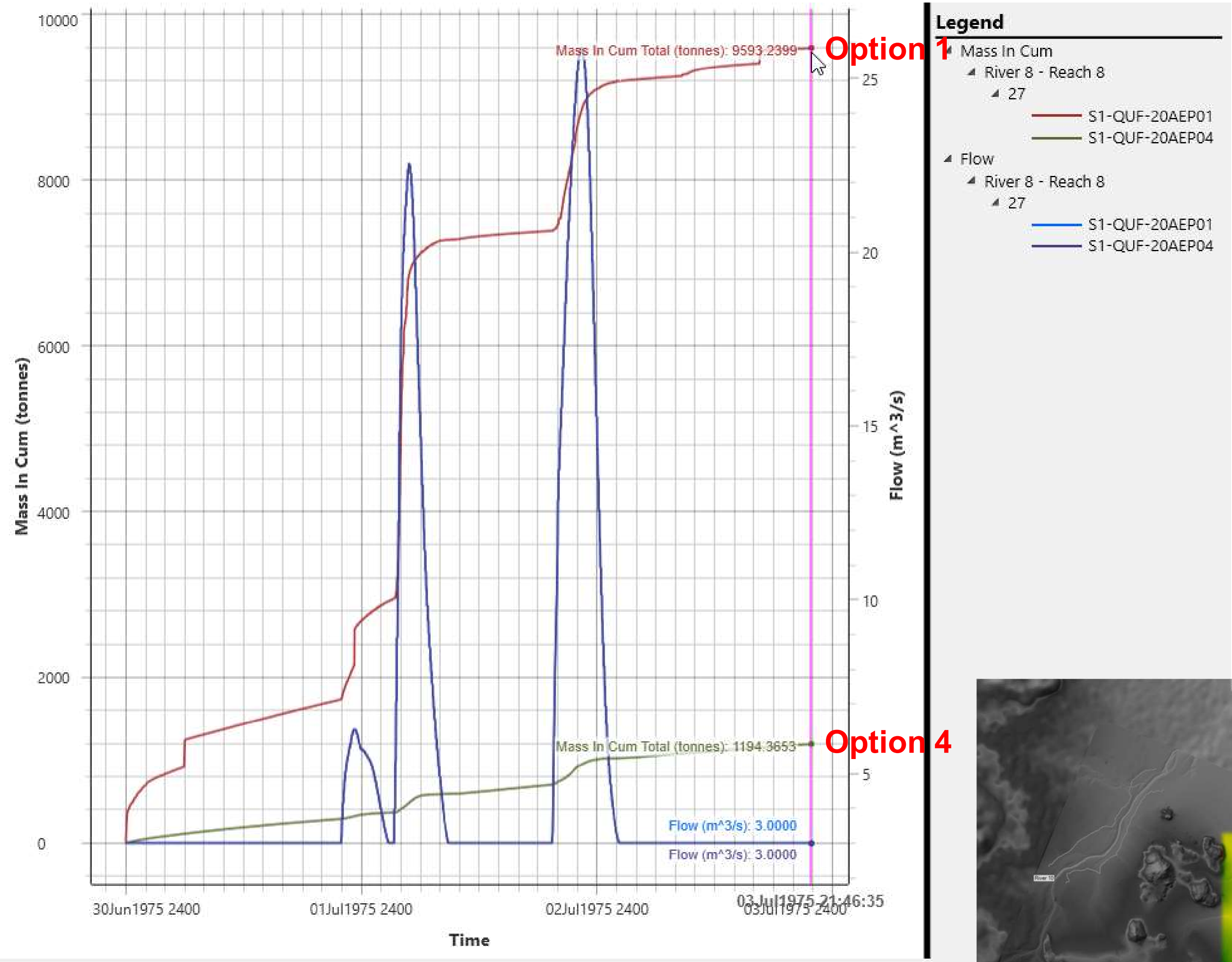
Mass In (1 in 5 AEP)

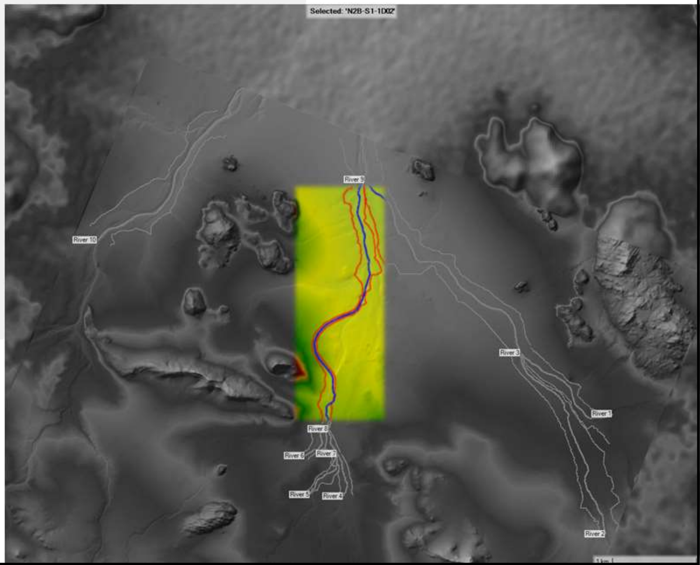
River 8 – Station 3374 (U/S)



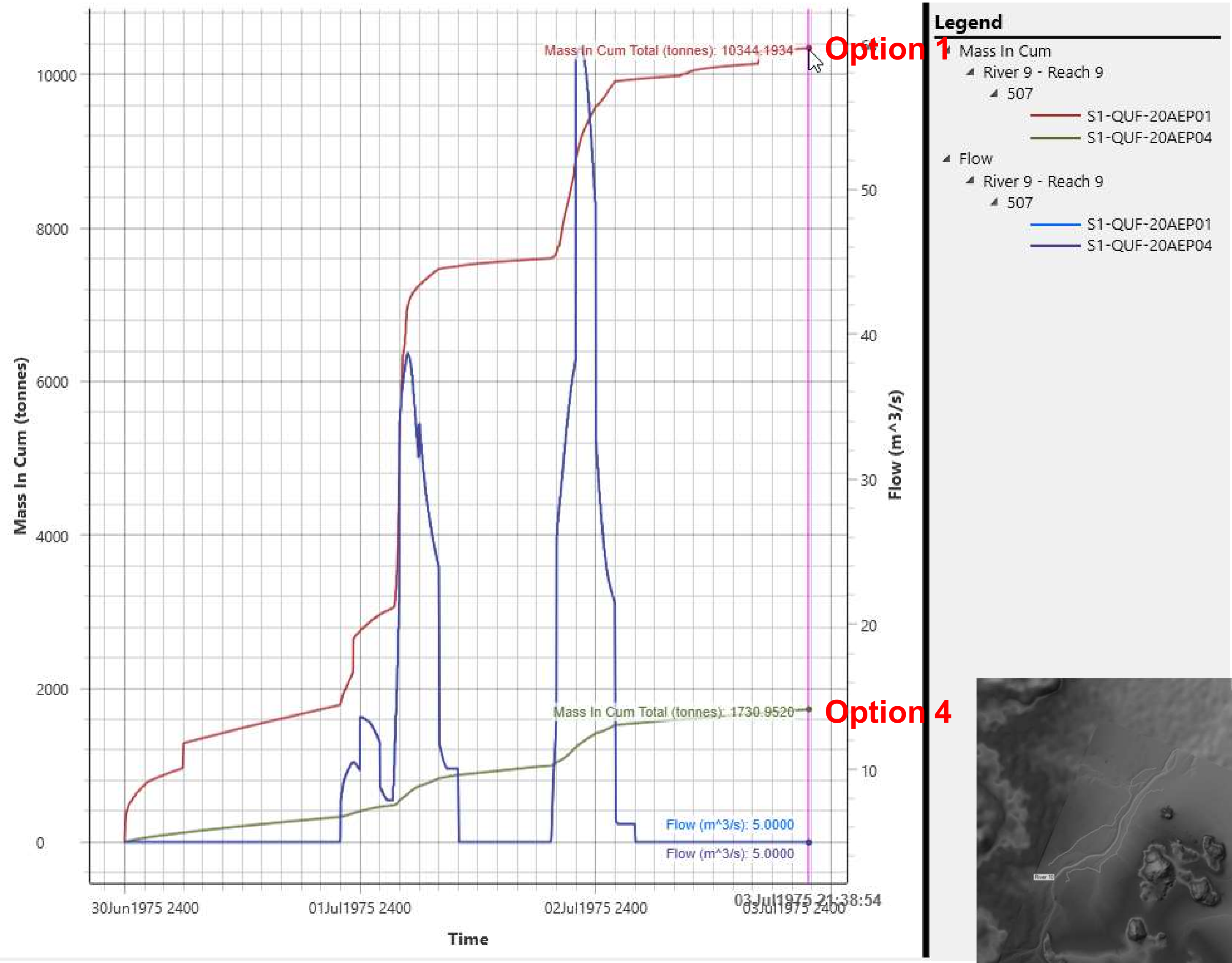


River 8 – Station 27 (D/S)

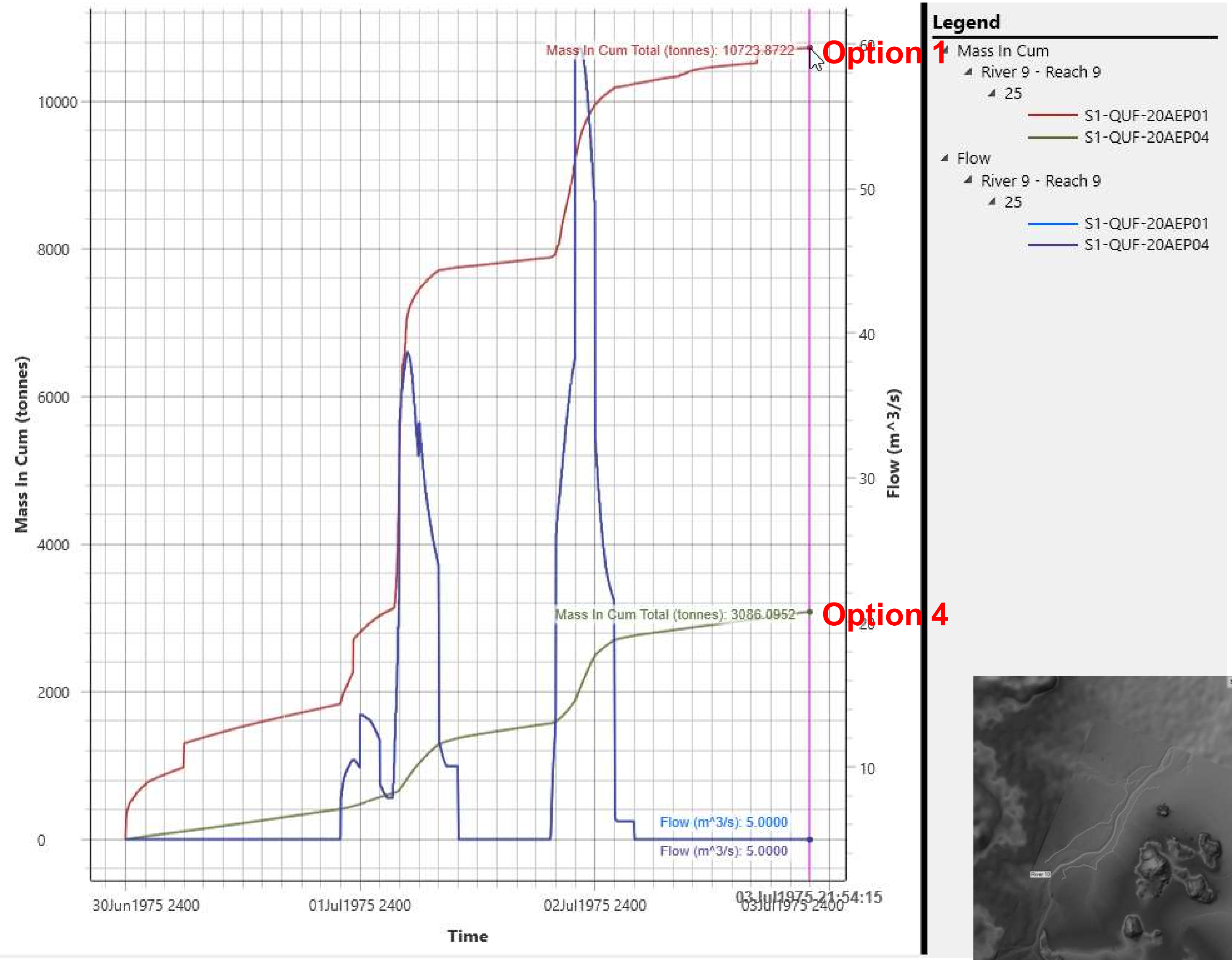




River 9 – Station 507 (U/S)

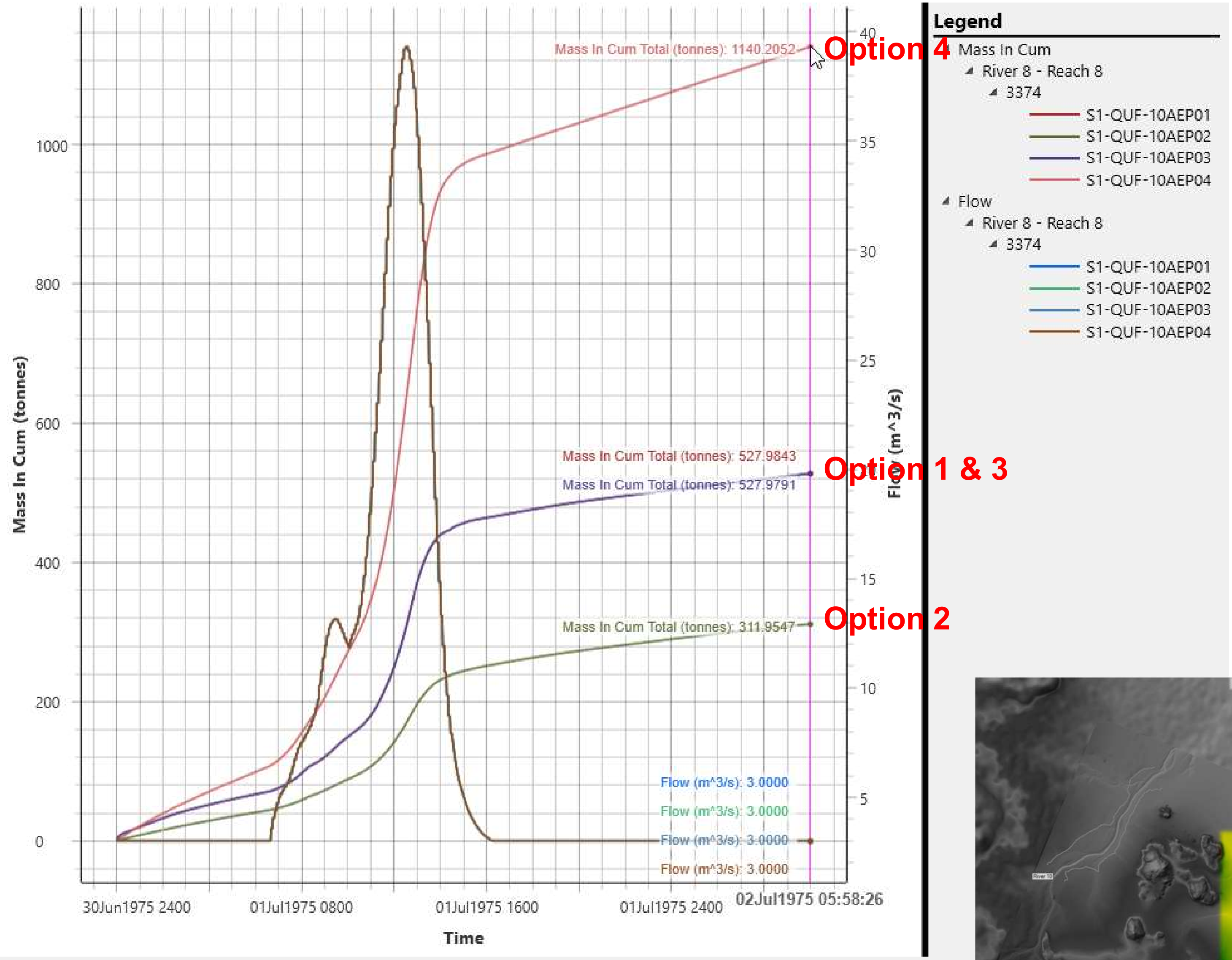


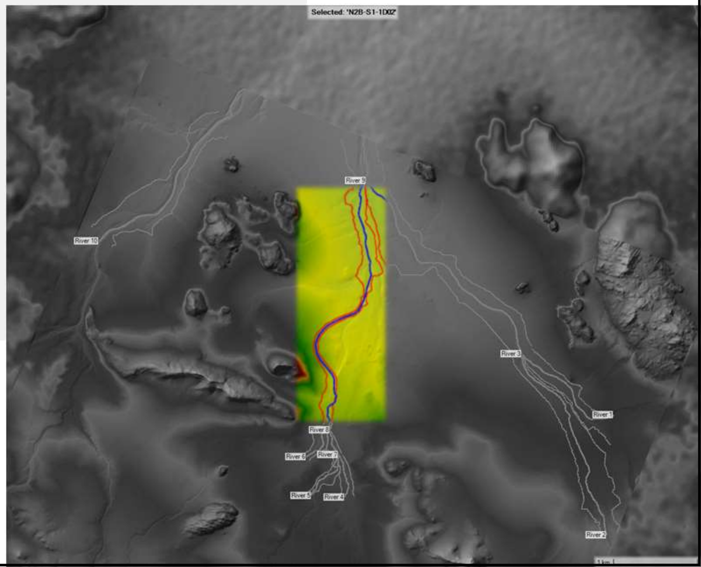
River 9 – Station 25 (D/S)



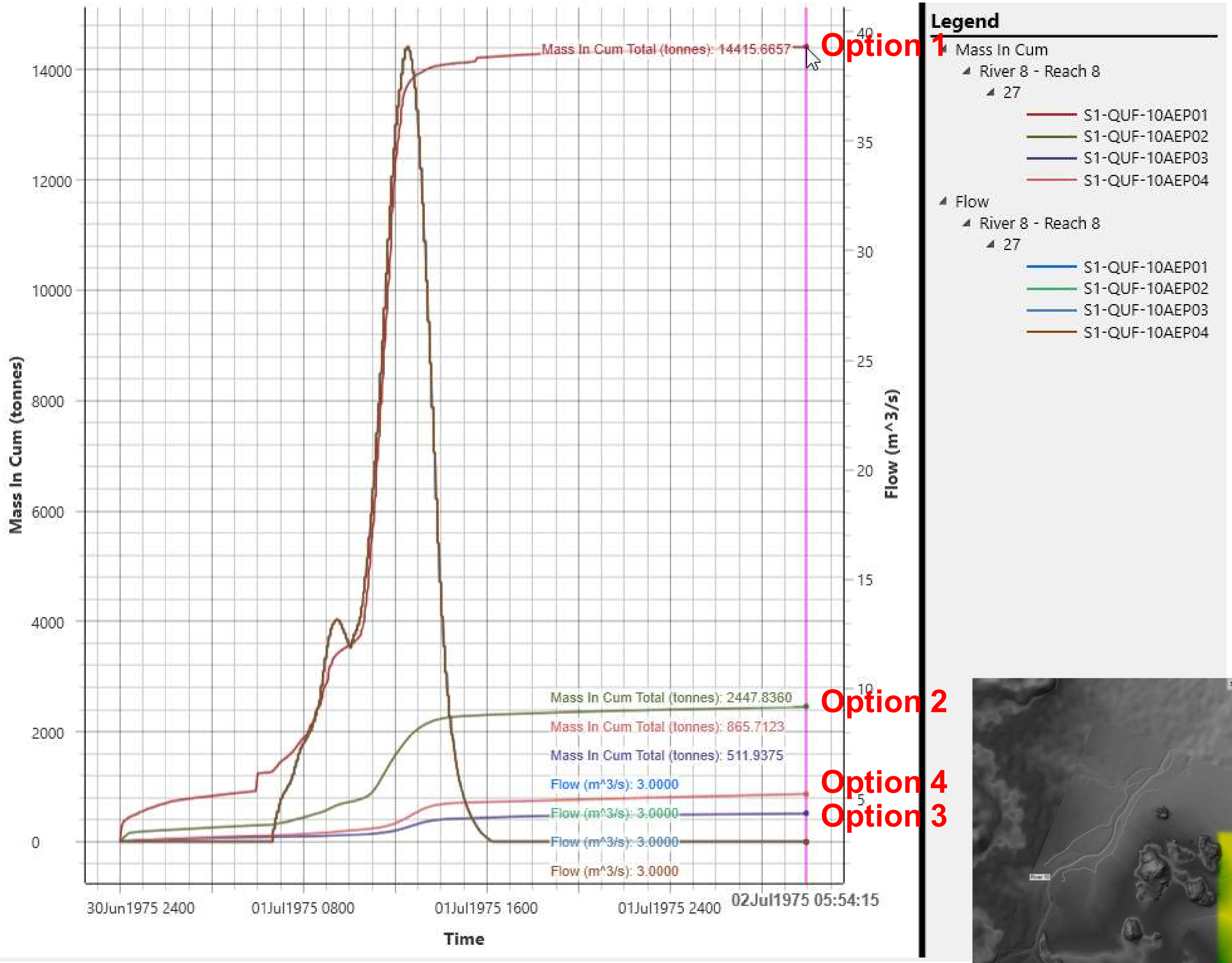
Mass In (1 in 10 AEP)

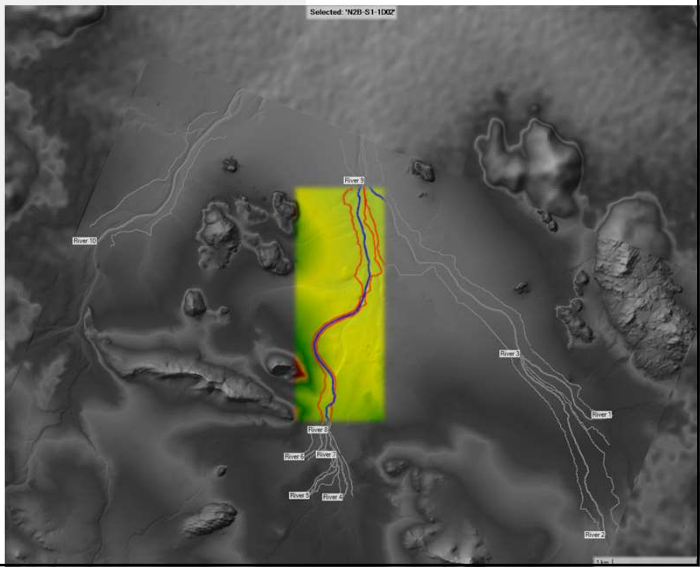
River 8 – Station 3374 (U/S)



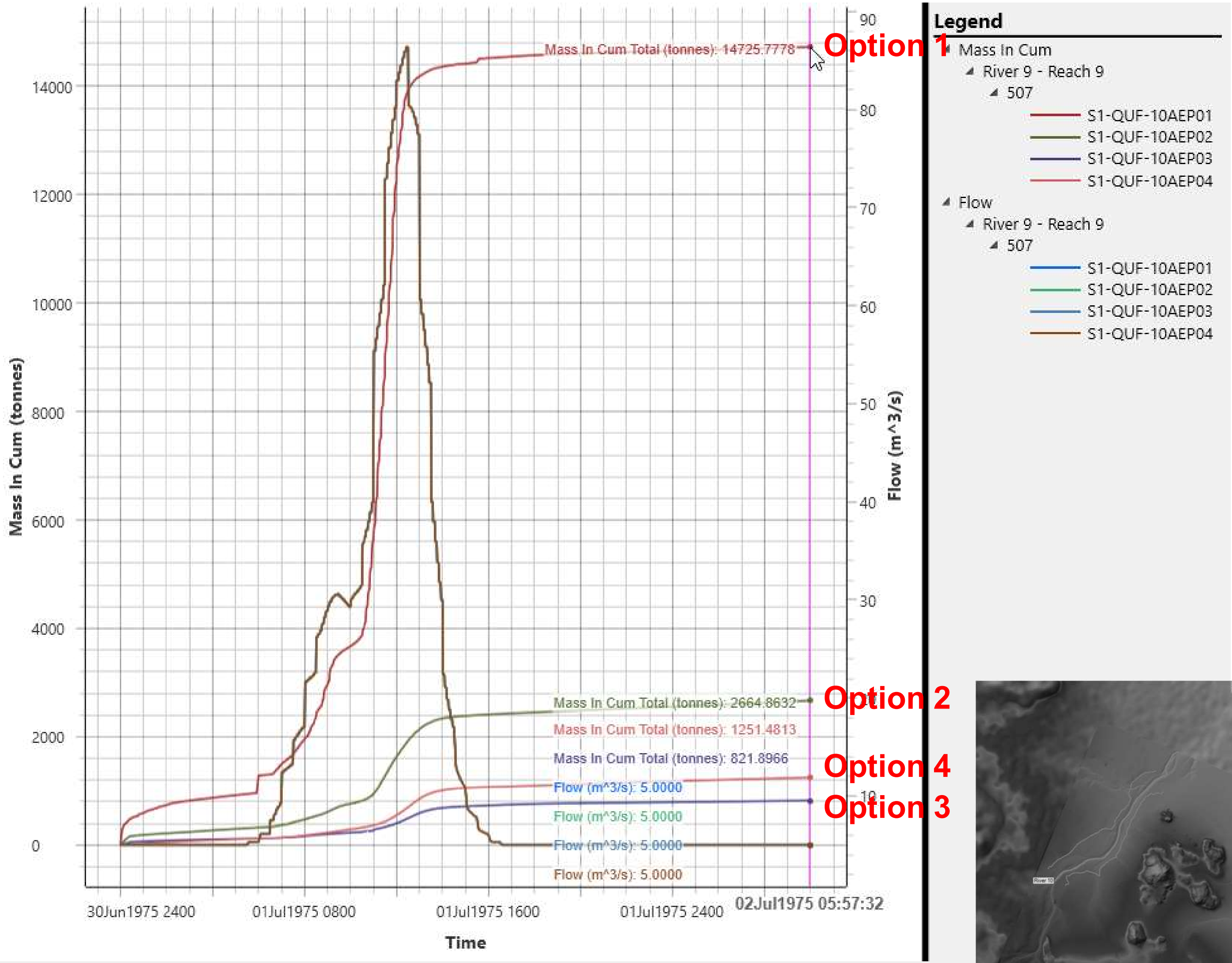


River 8 – Station 27 (D/S)

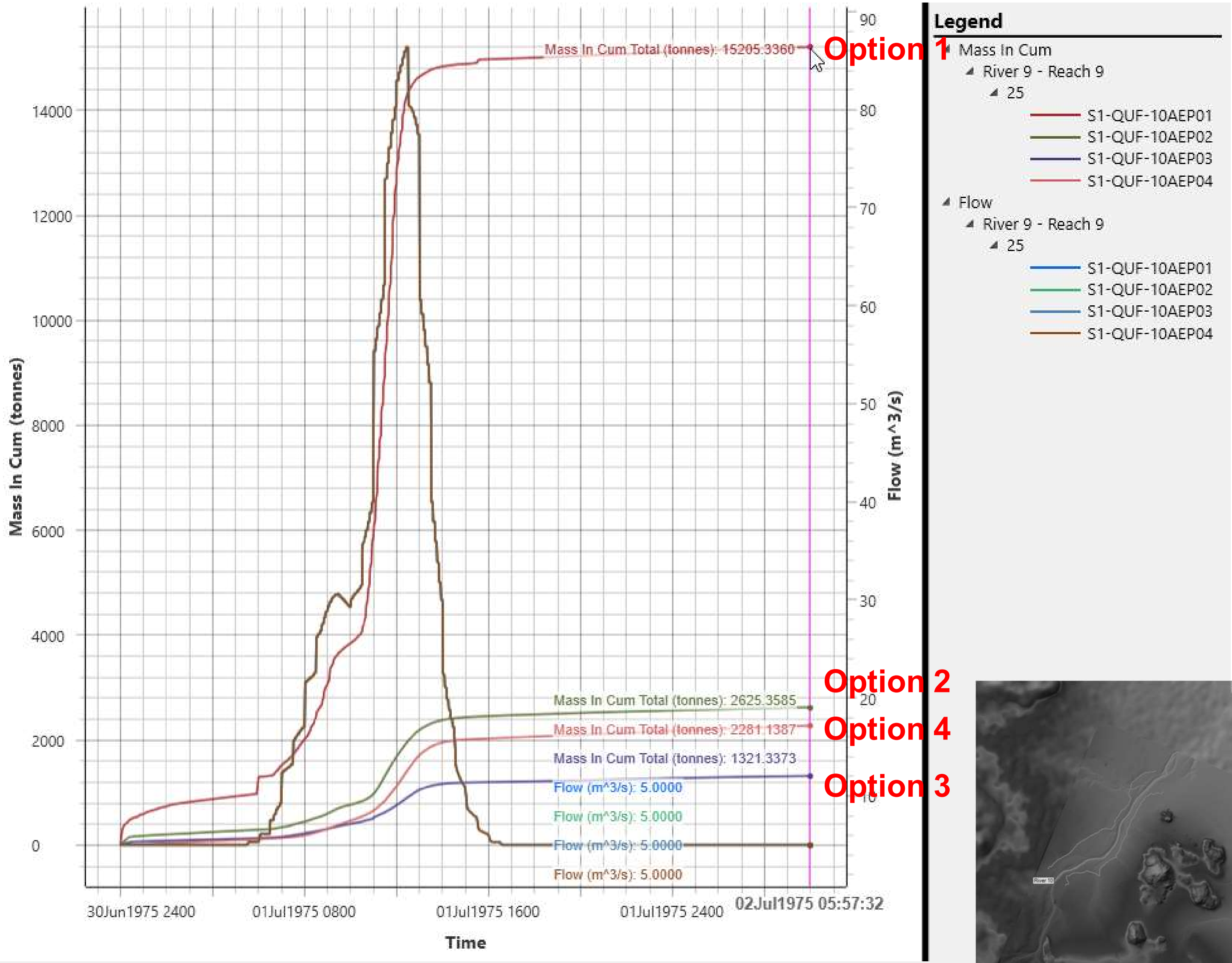




River 9 – Station 507 (U/S)

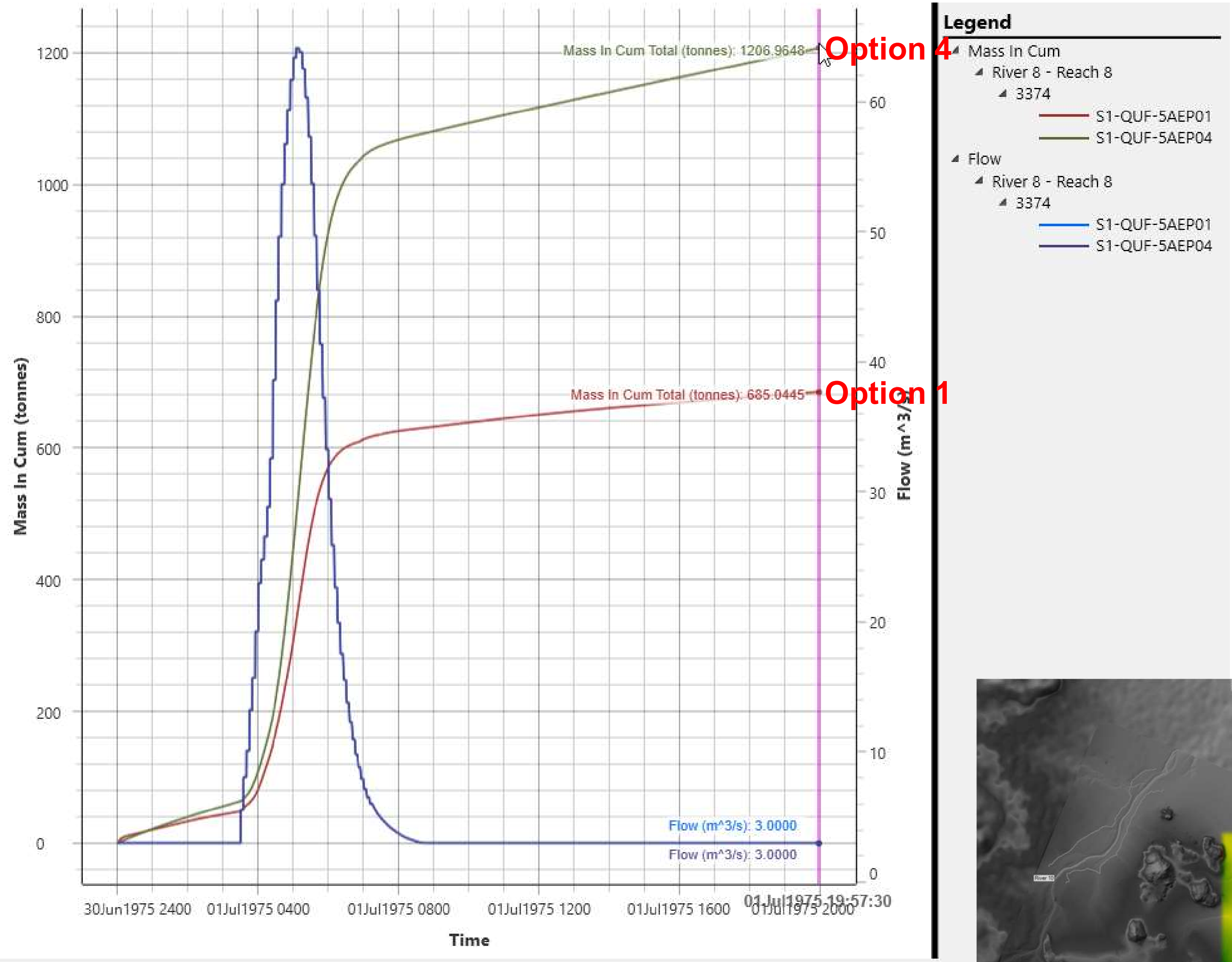


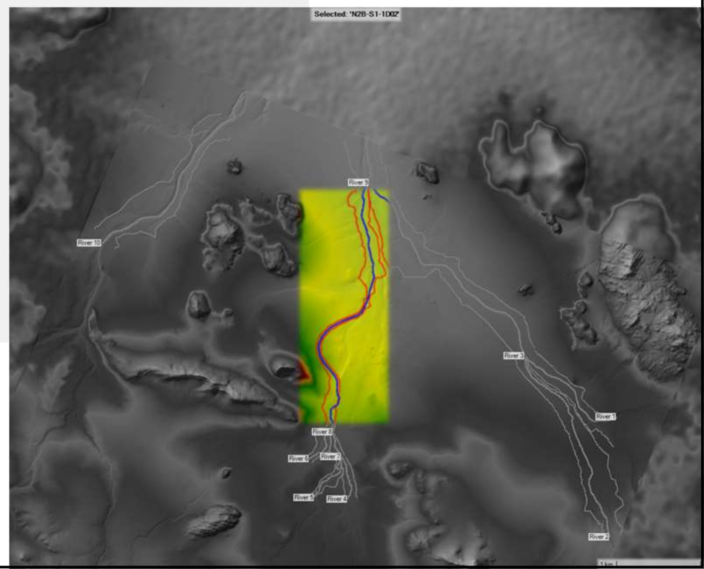
River 9 – Station 25 (D/S)



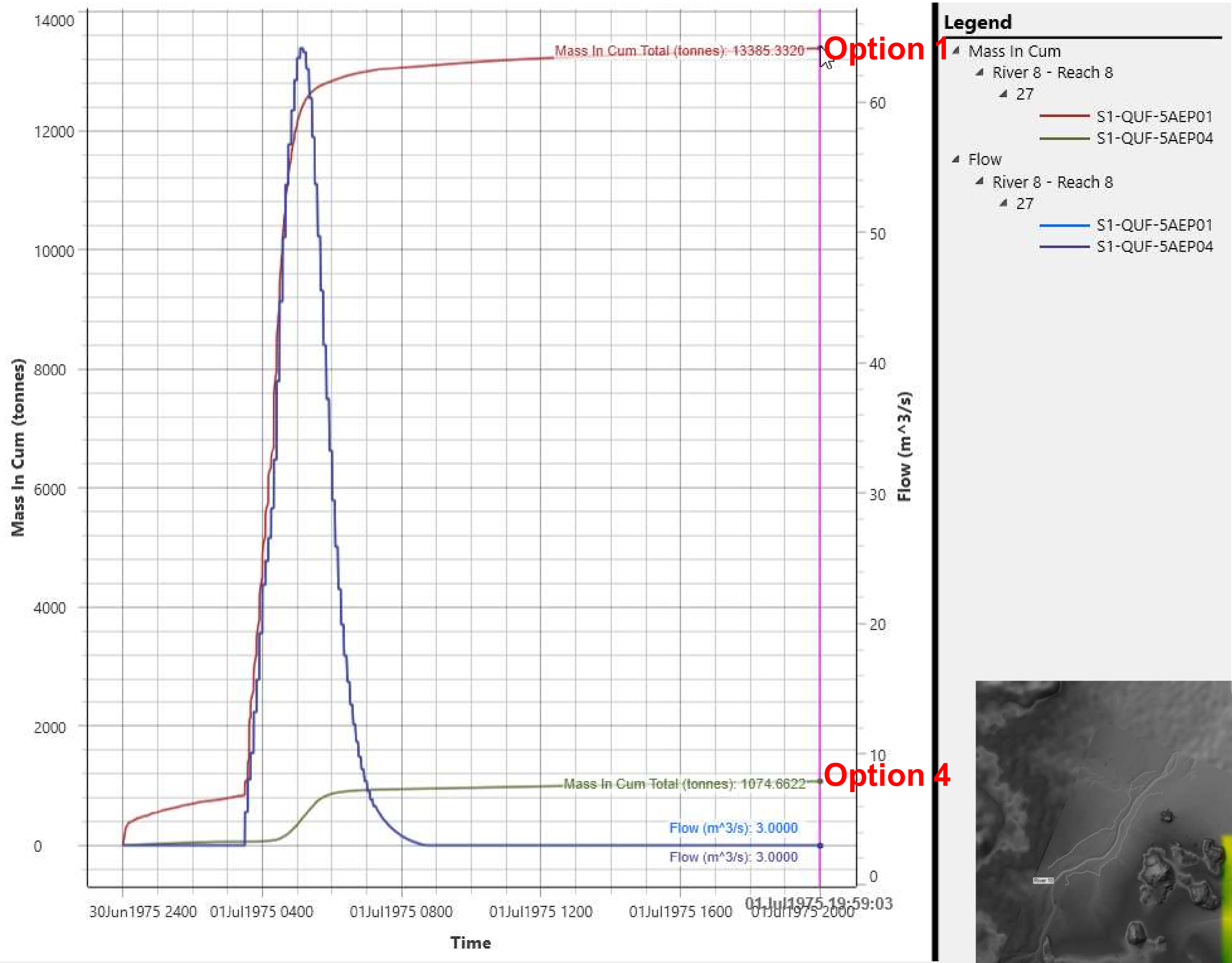
Mass In (1 in 20 AEP)

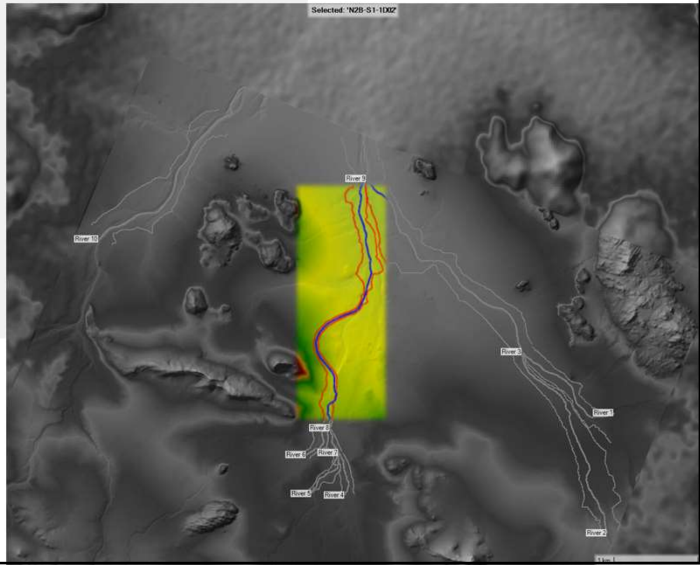
River 8 – Station 3374 (U/S)



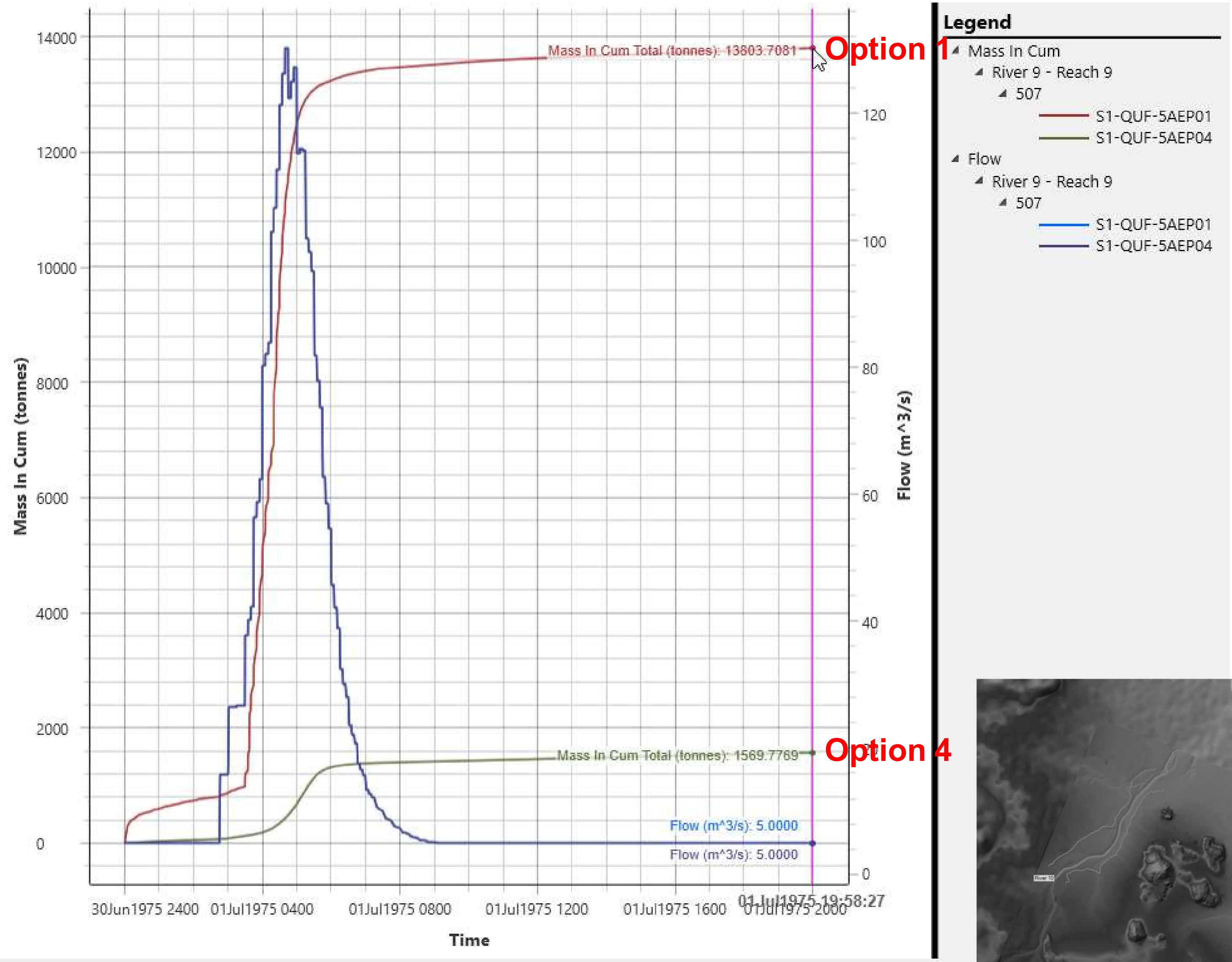


River 8 – Station 27 (D/S)

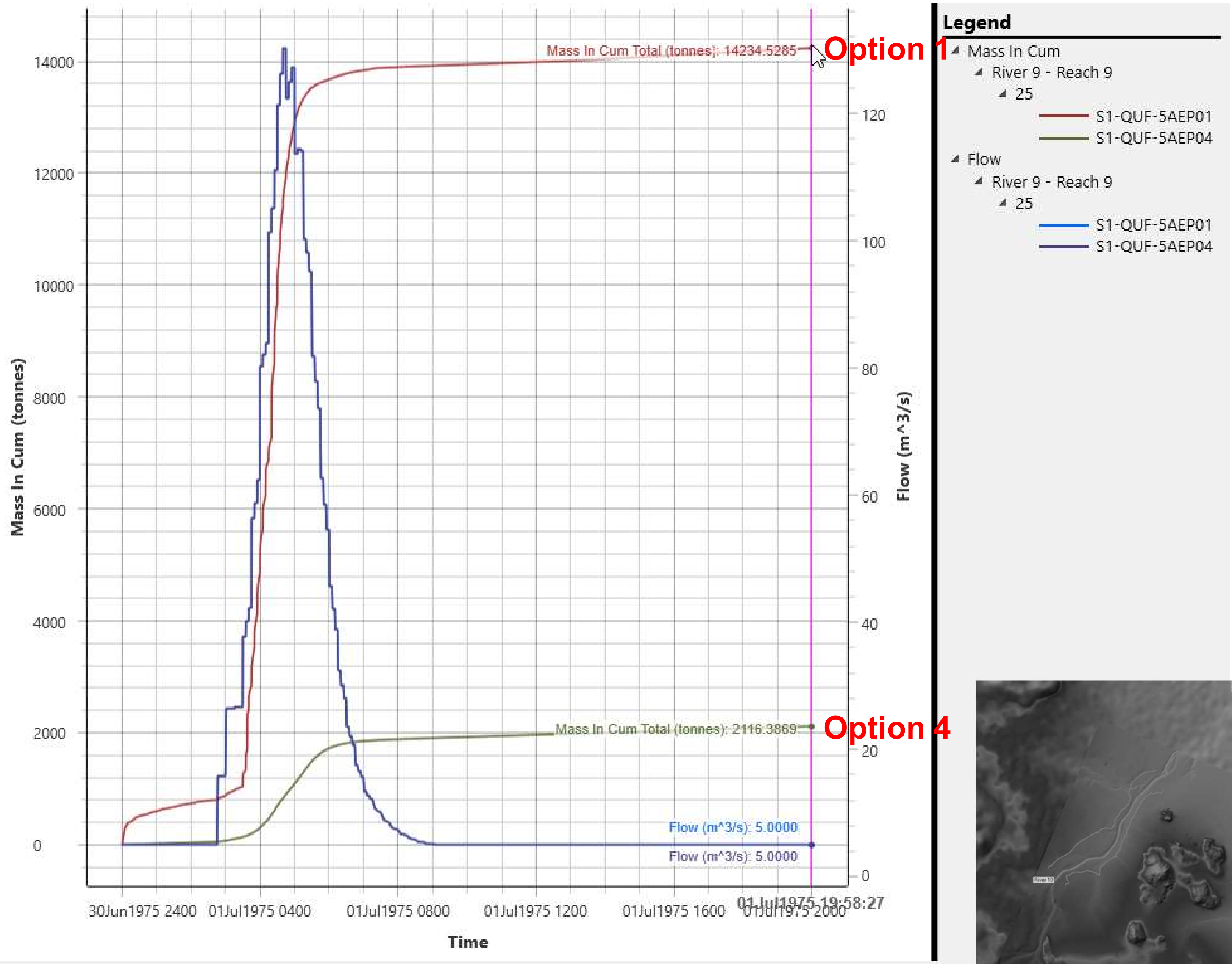




River 9 – Station 507 (U/S)

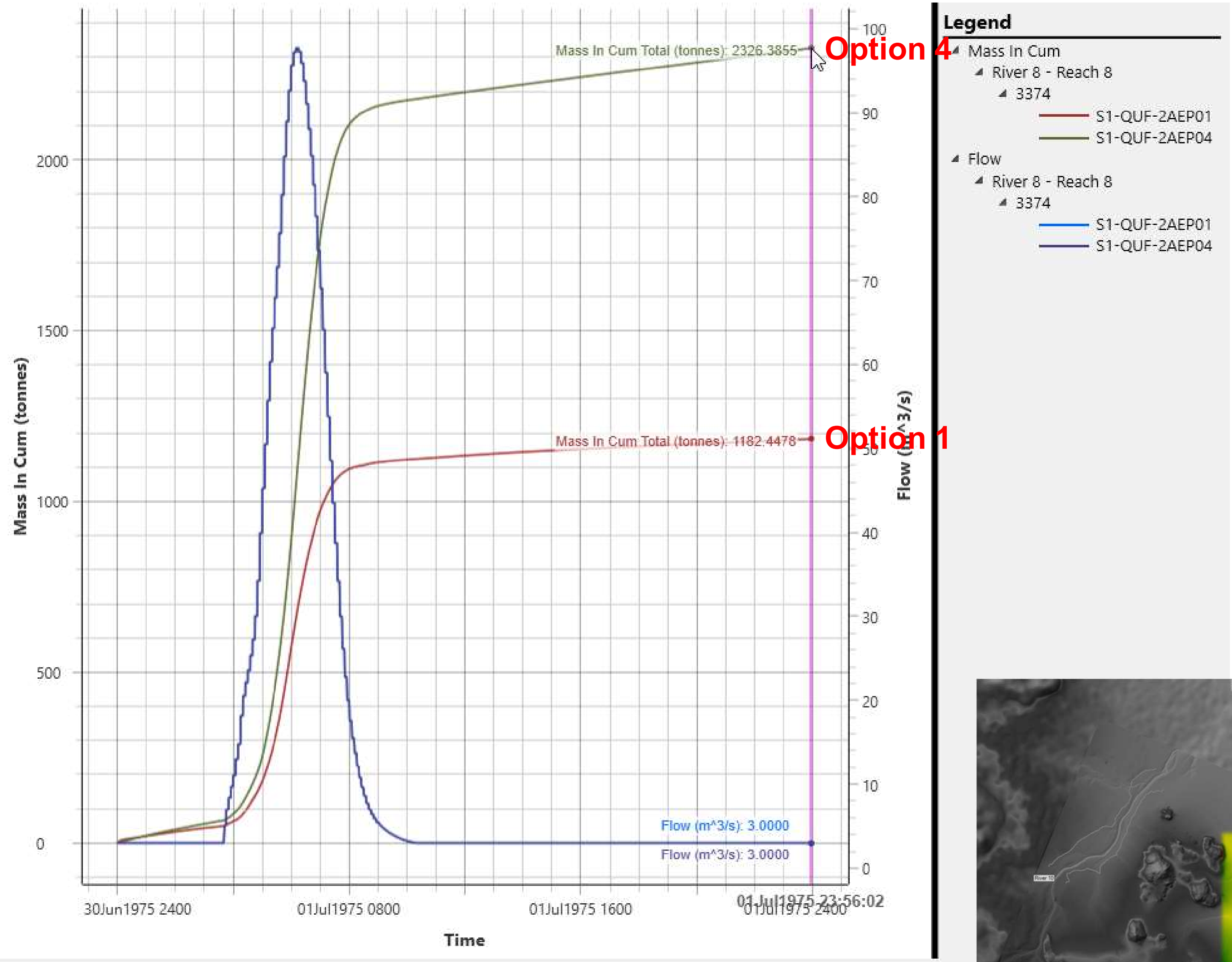


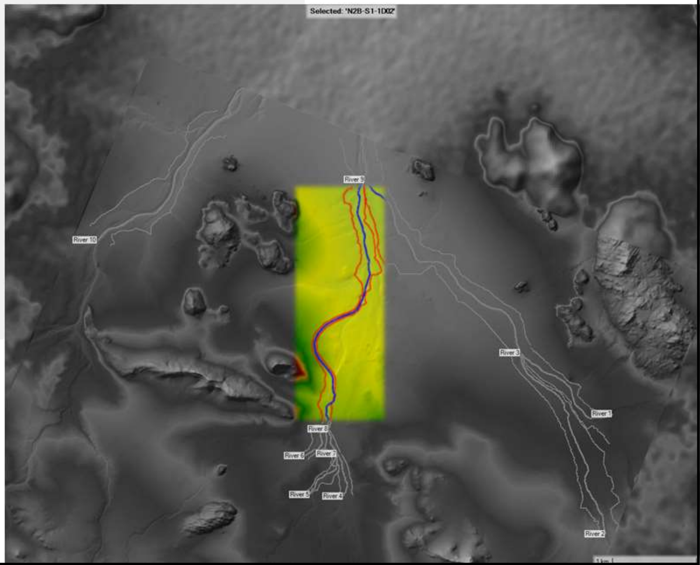
River 9 – Station 25 (D/S)



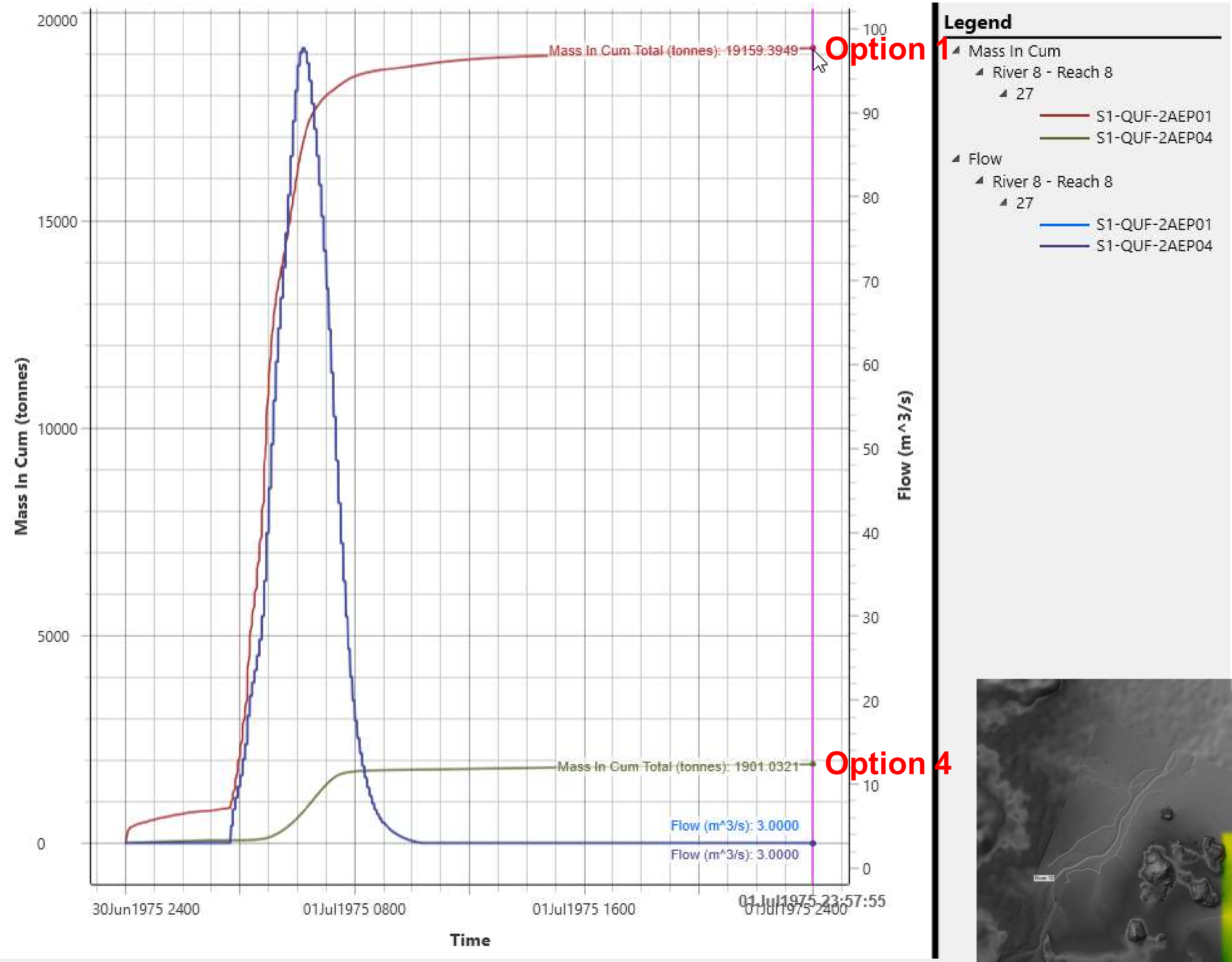
Mass In (1 in 50 AEP)

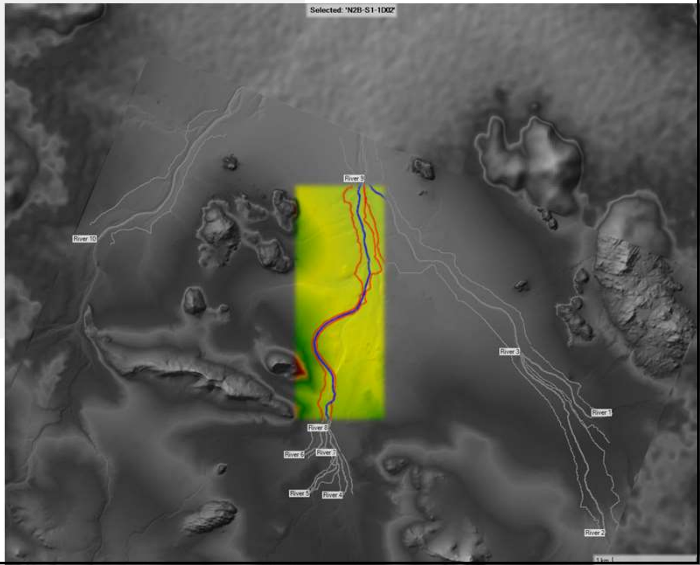
River 8 – Station 3374 (U/S)



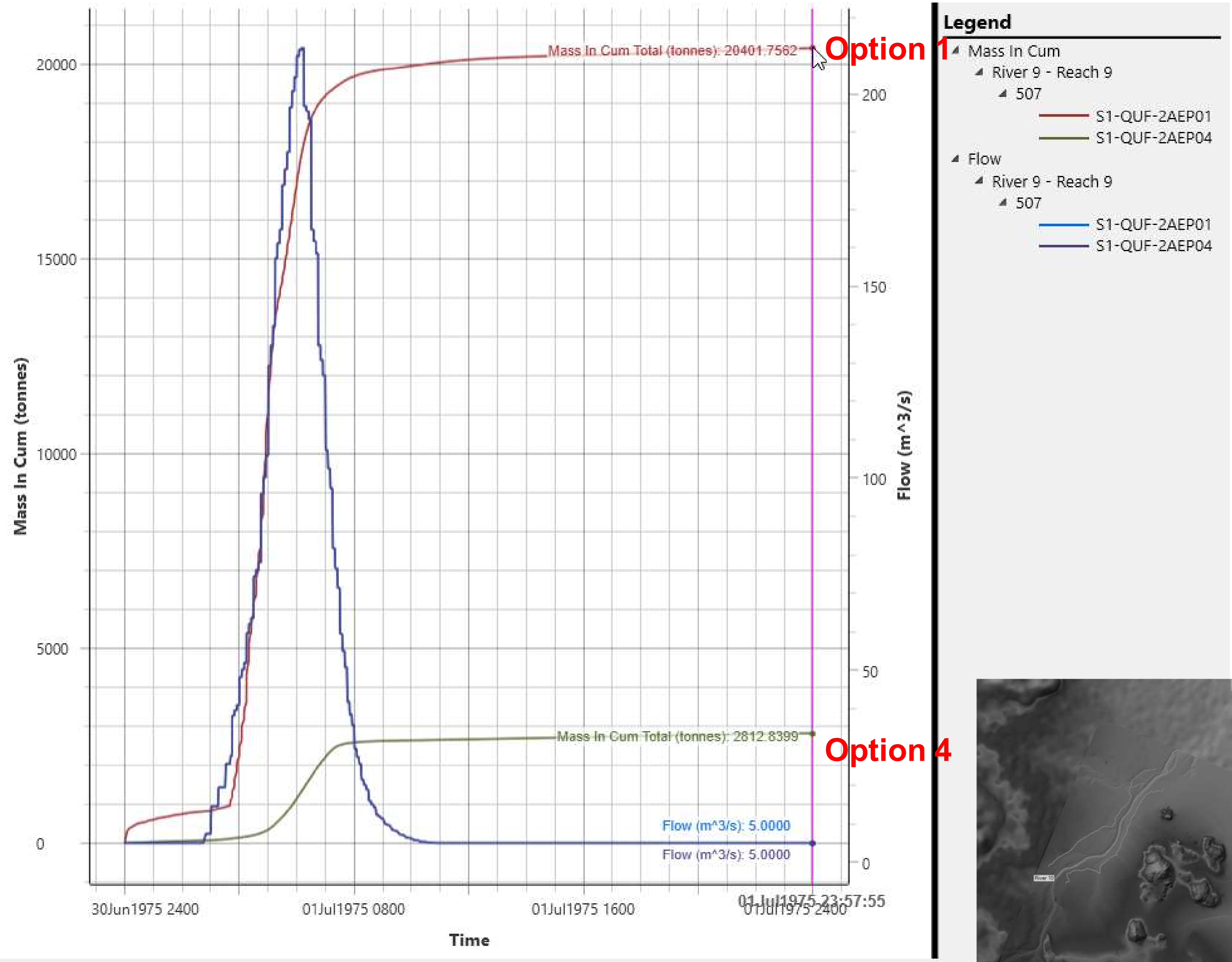


River 8 – Station 27 (D/S)

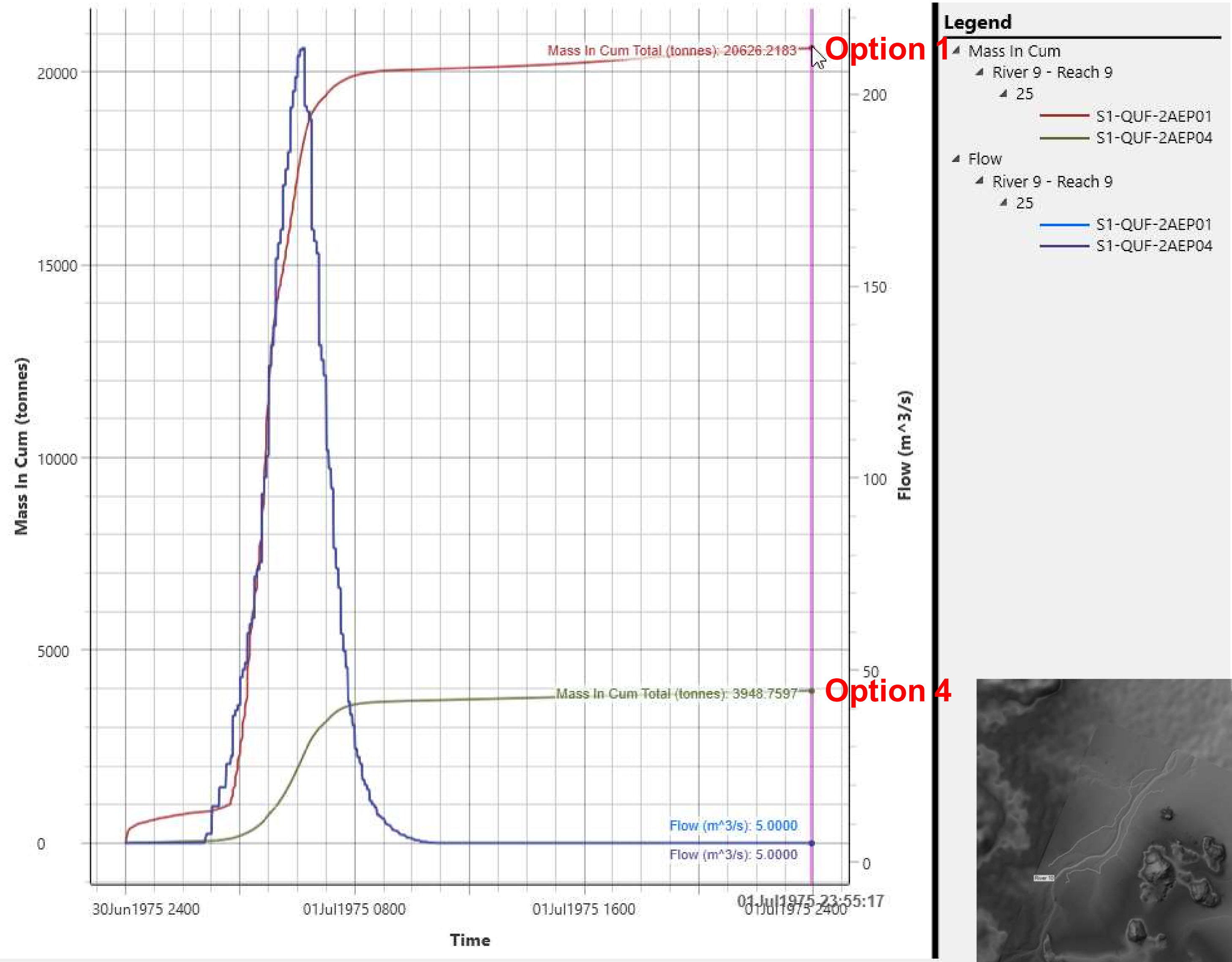




River 9 – Station 507 (U/S)

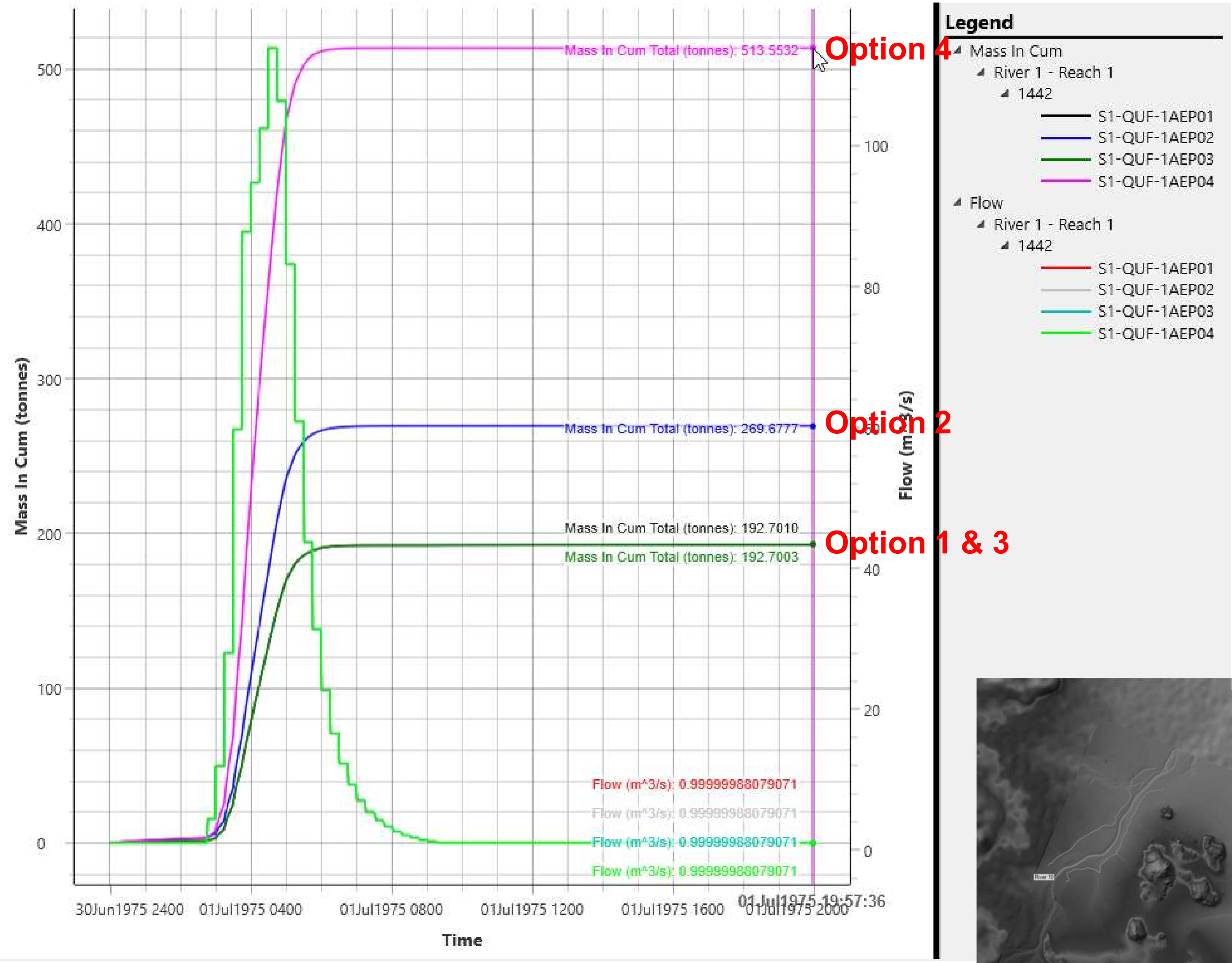


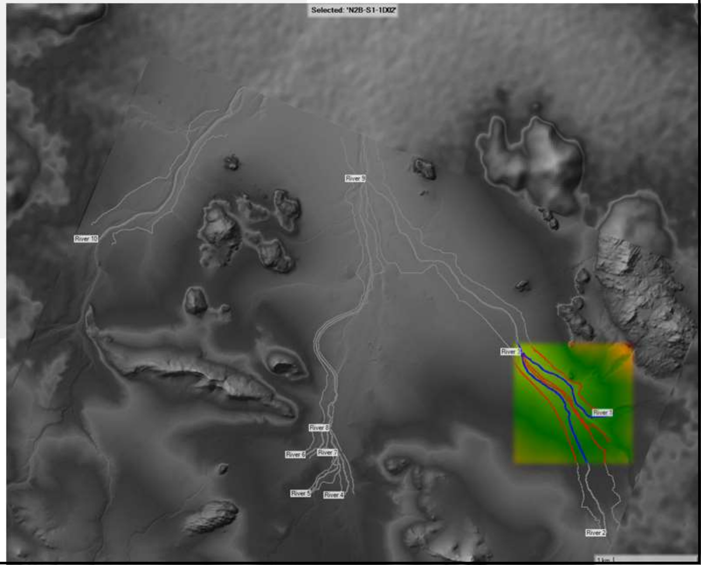
River 9 – Station 25 (D/S)



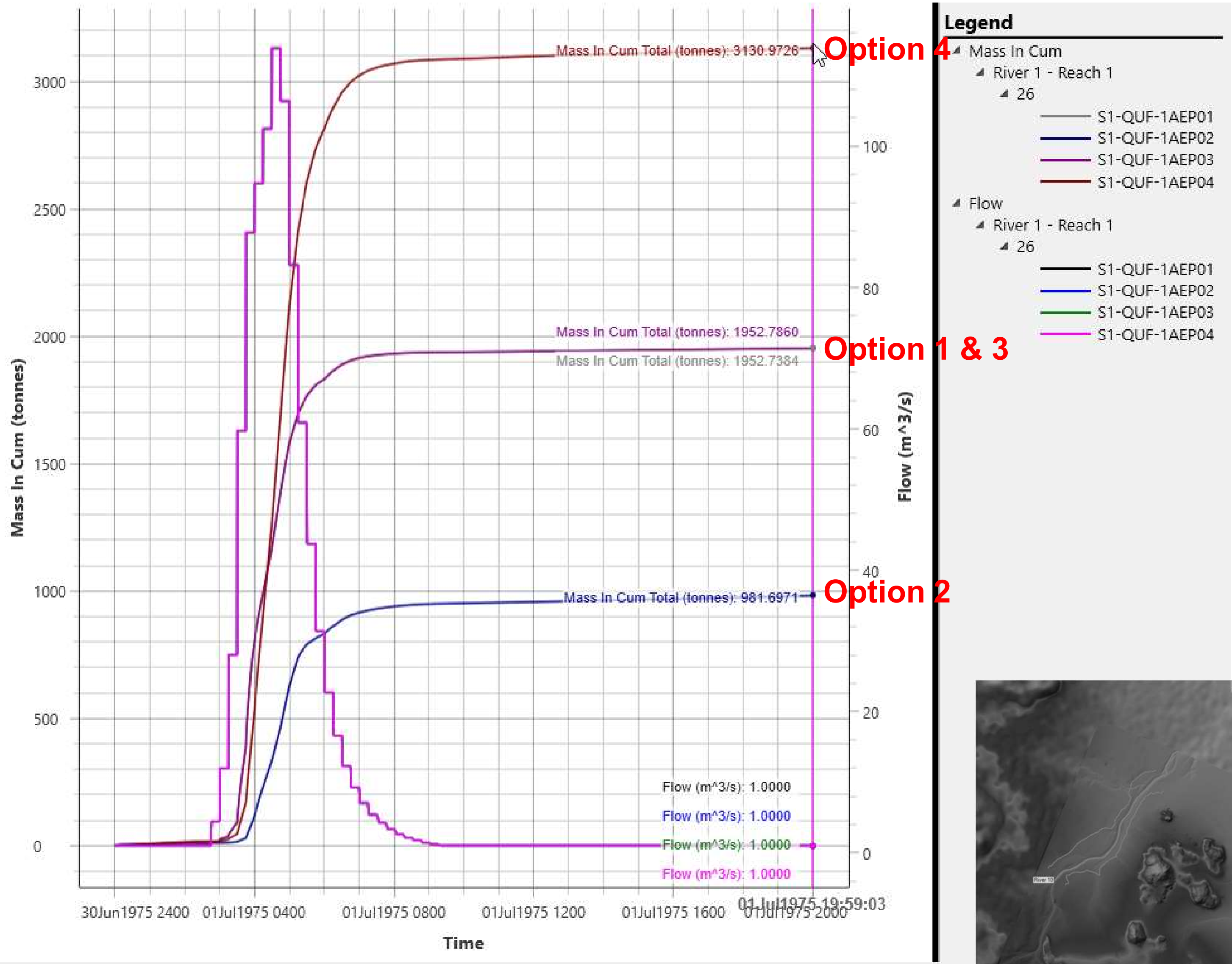
Mass In (1 in 100 AEP)

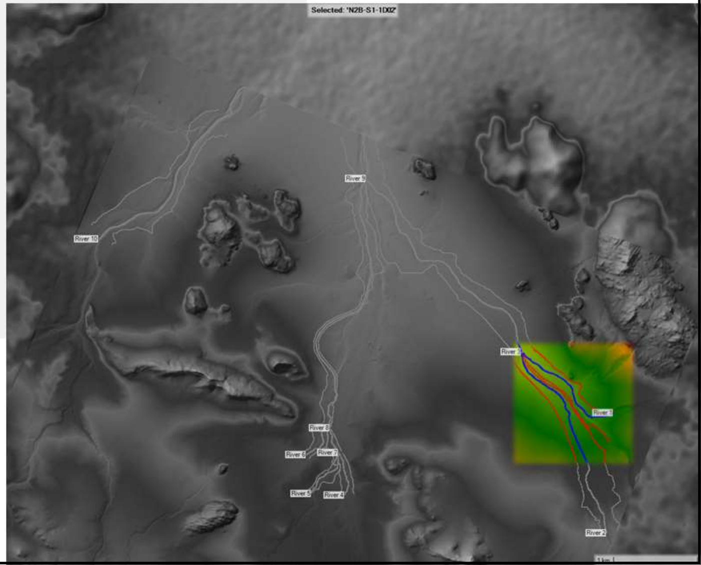
River 1 – Station 1442 (U/S)



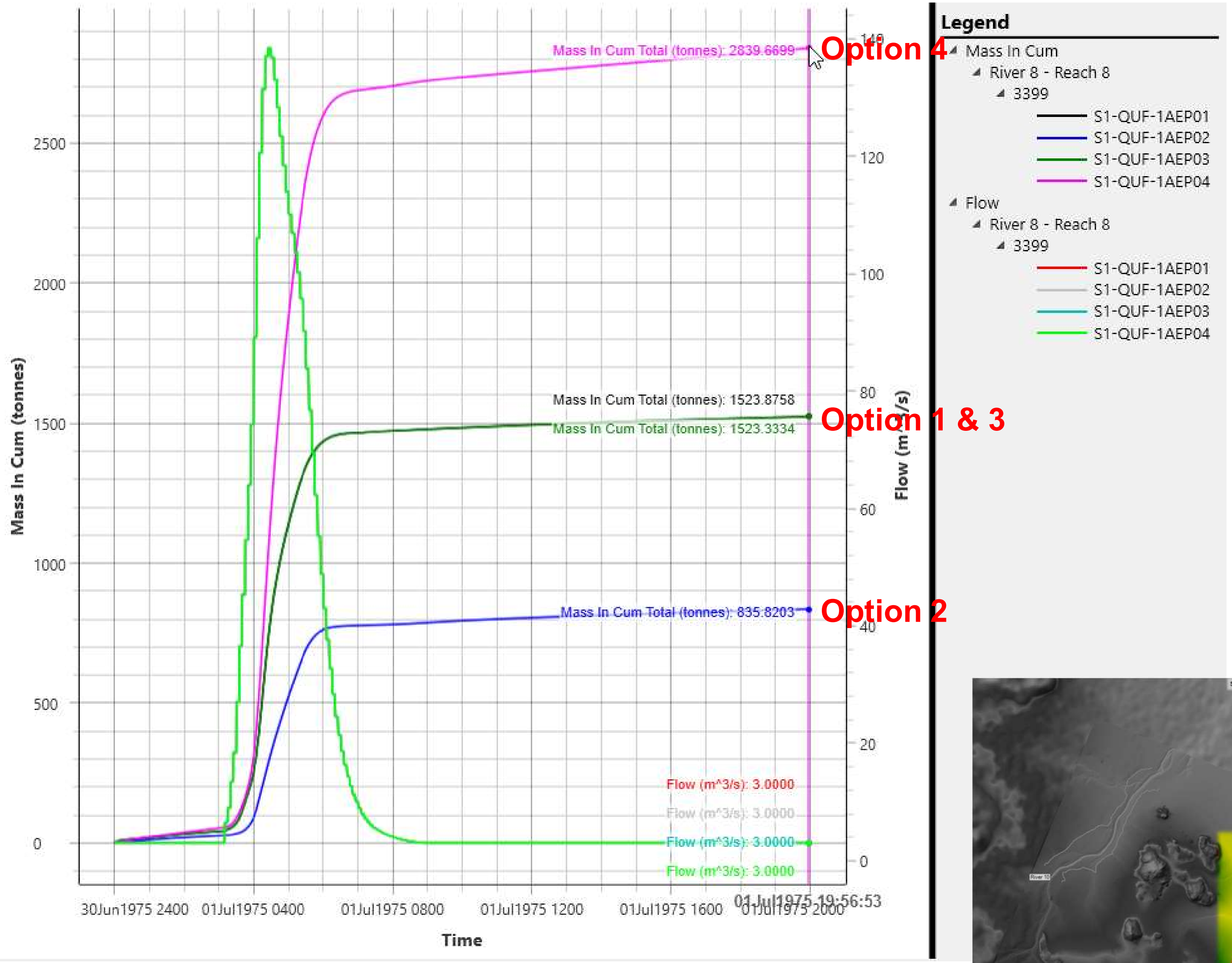


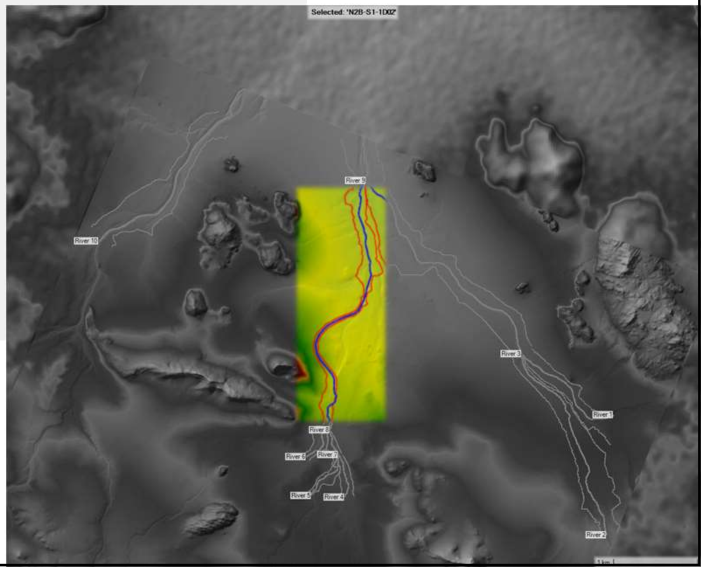
River 1 – Station 26 (D/S)



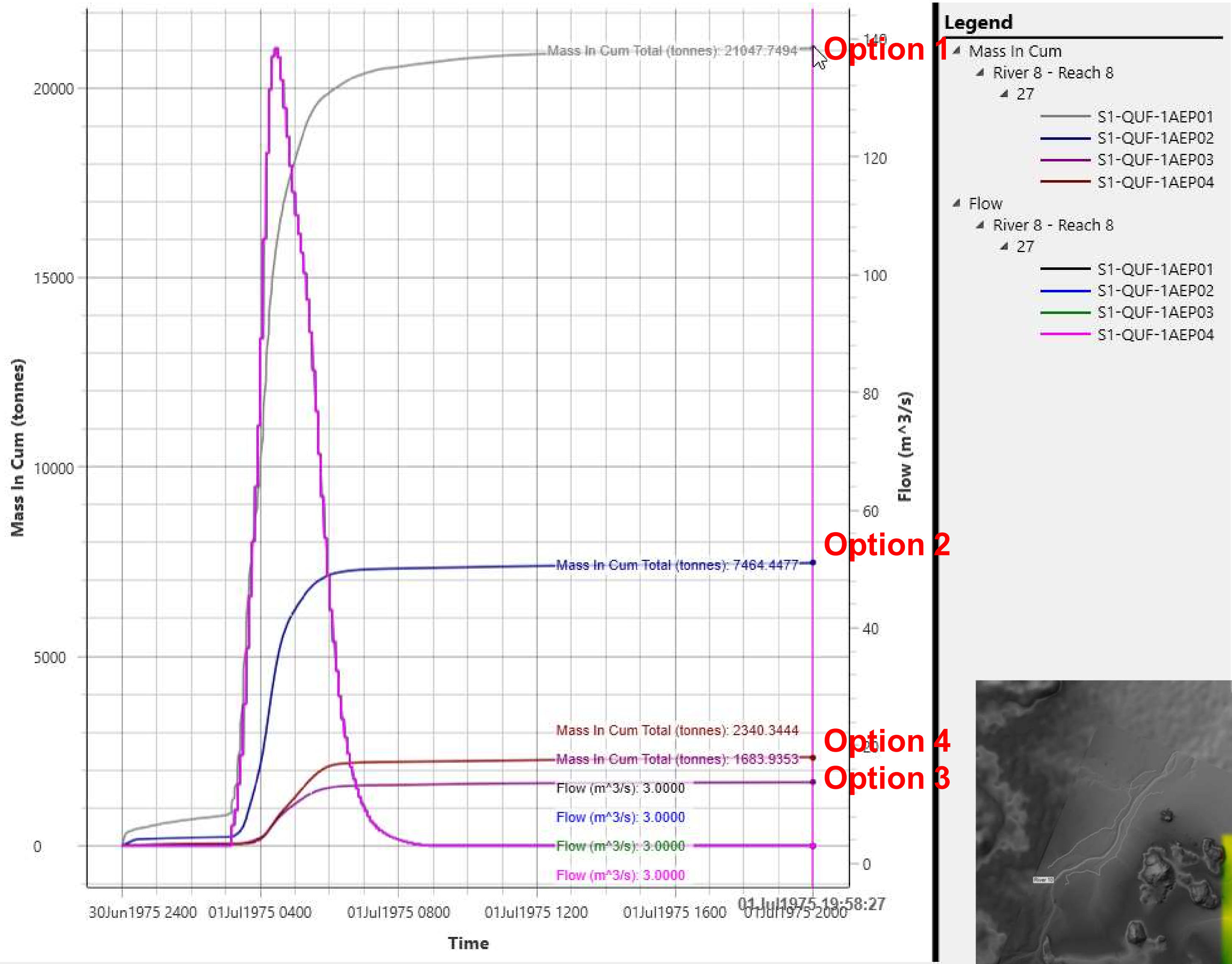


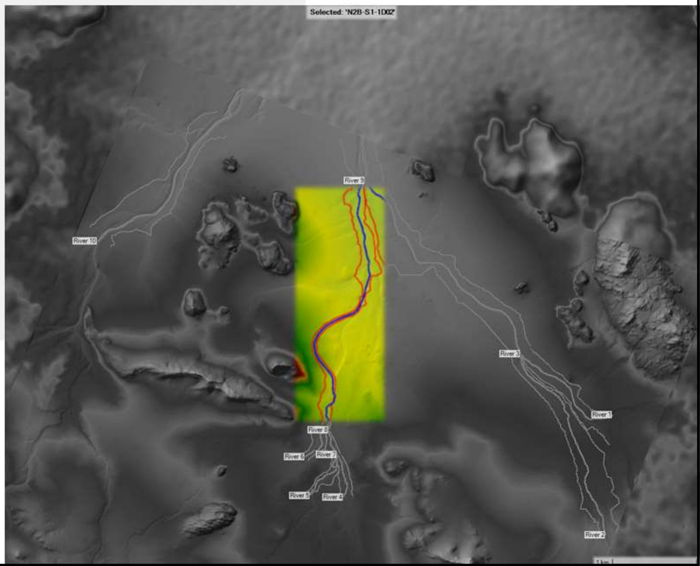
River 8 – Station 3374 (U/S)



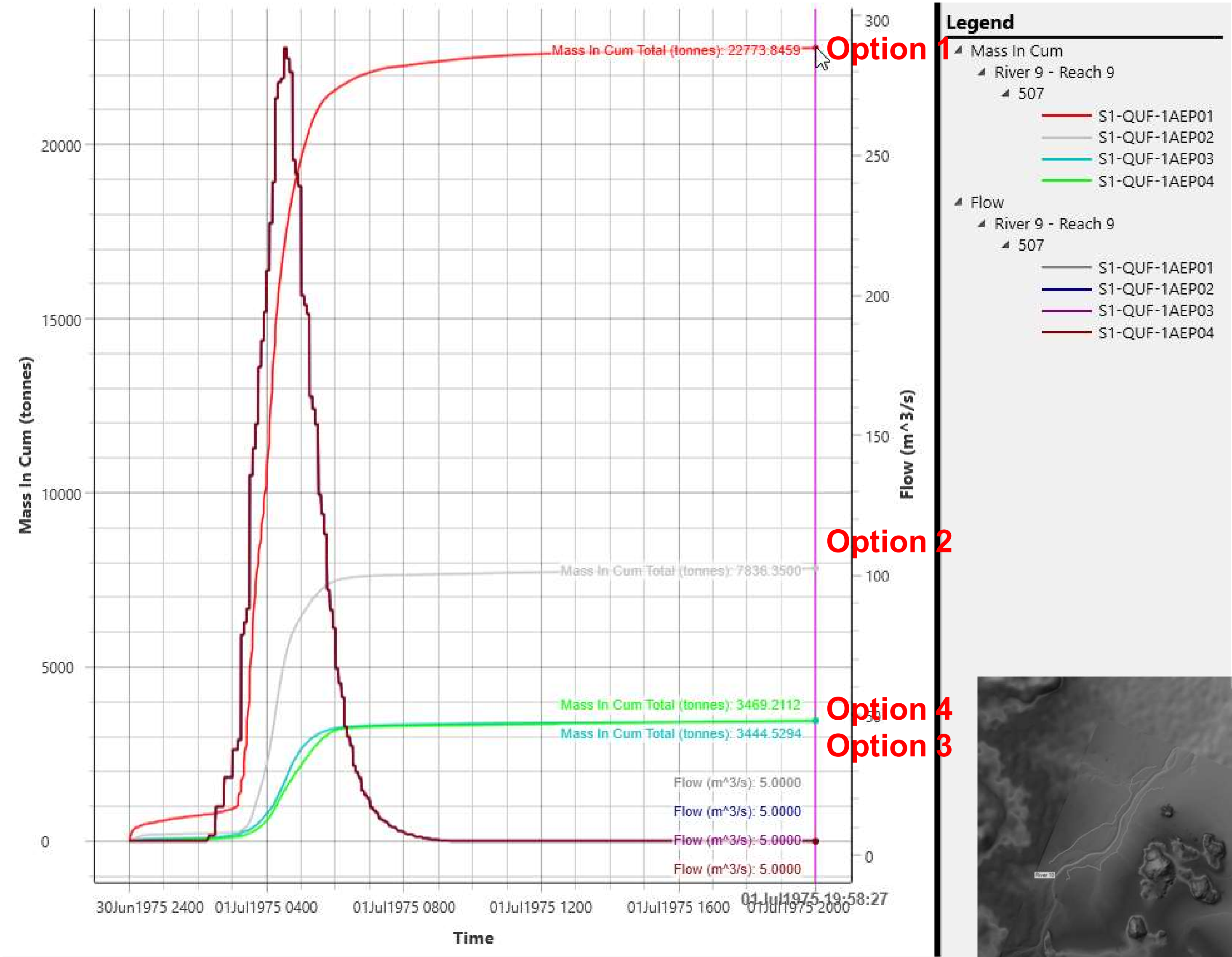


River 8 – Station 27 (D/S)

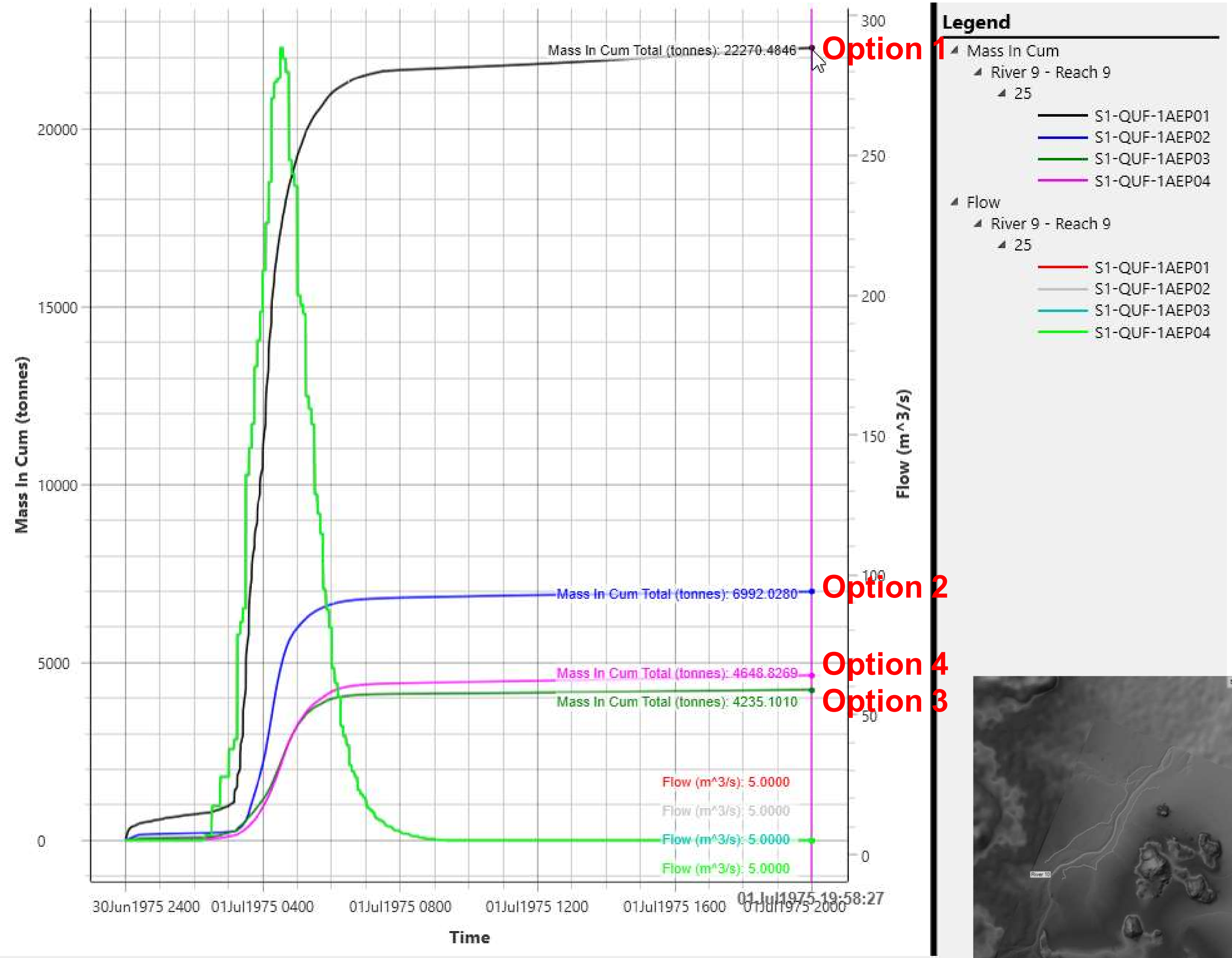




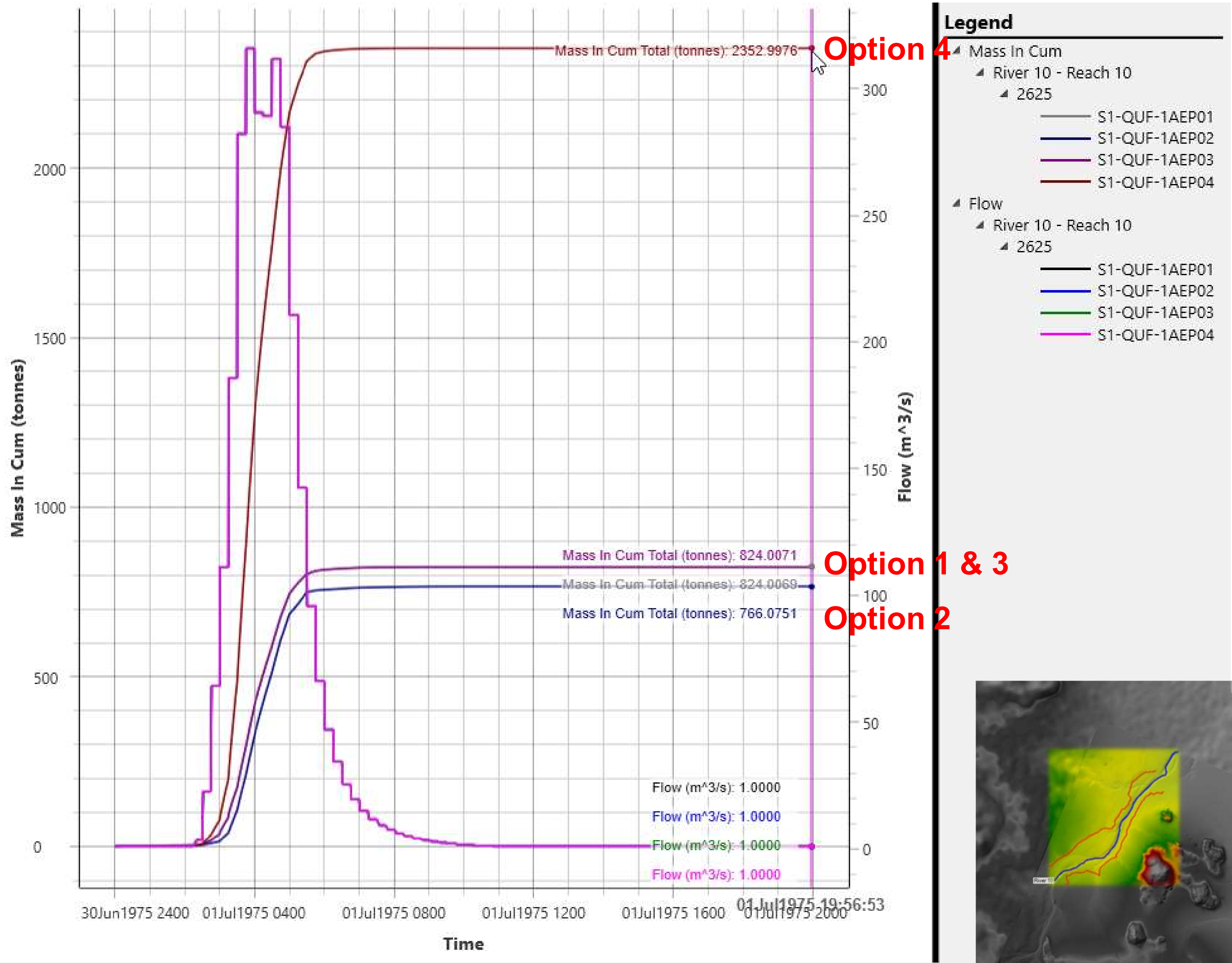
River 9 – Station 507 (U/S)

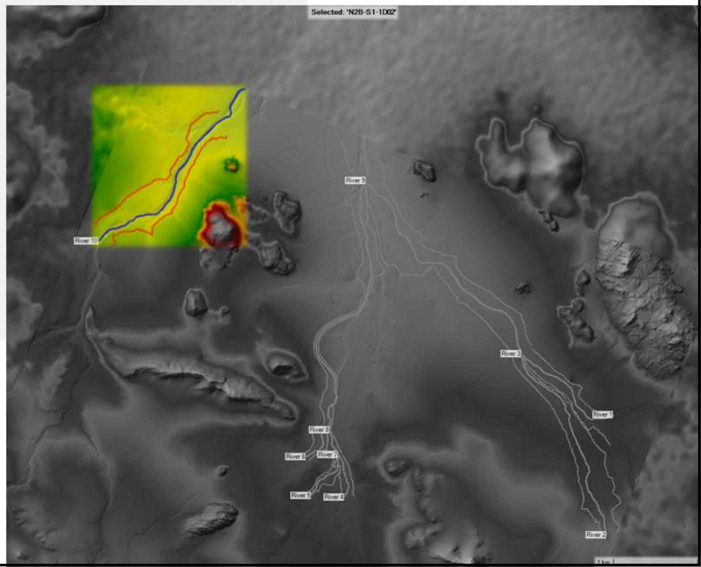


River 9 – Station 25 (D/S)

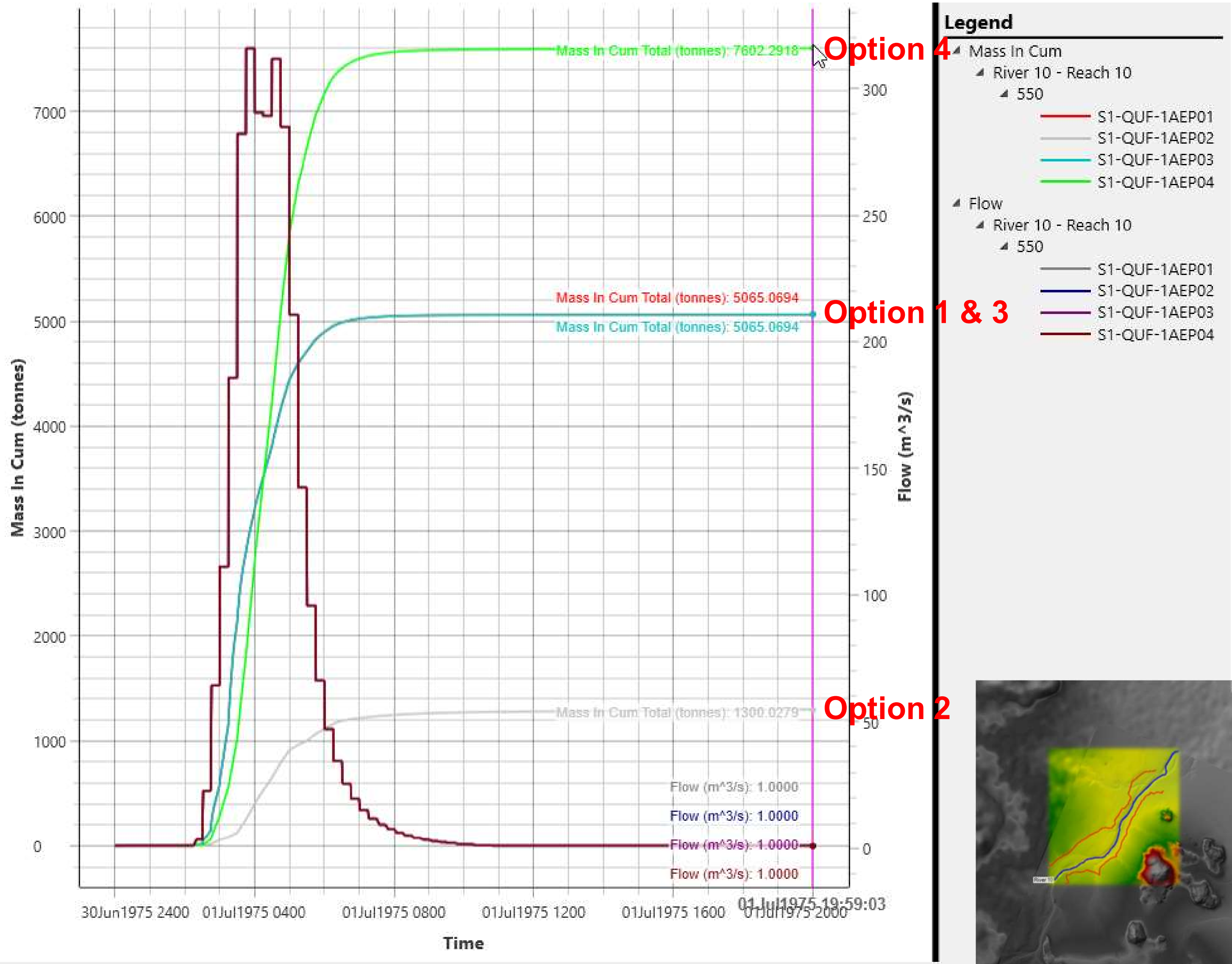


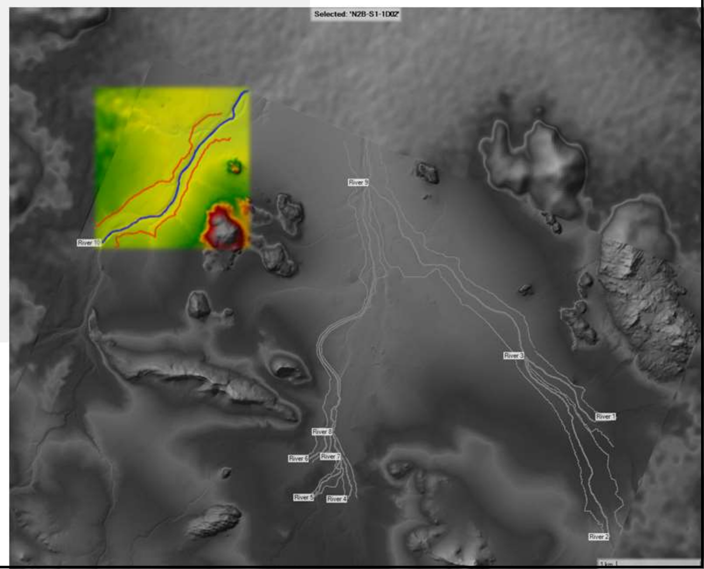
River 10 – Station 2625 (U/S)





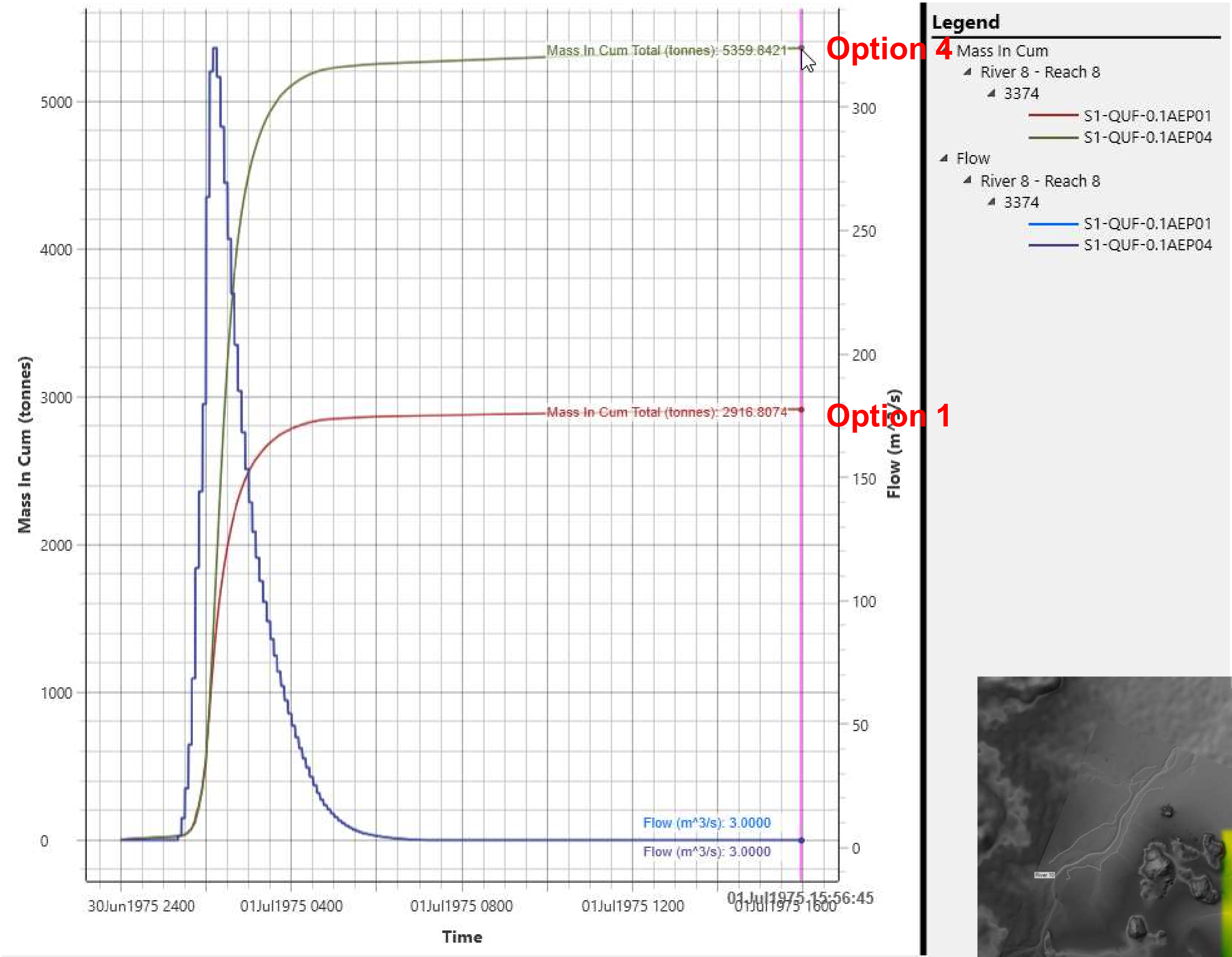
River 10 – Station 550 (D/S)



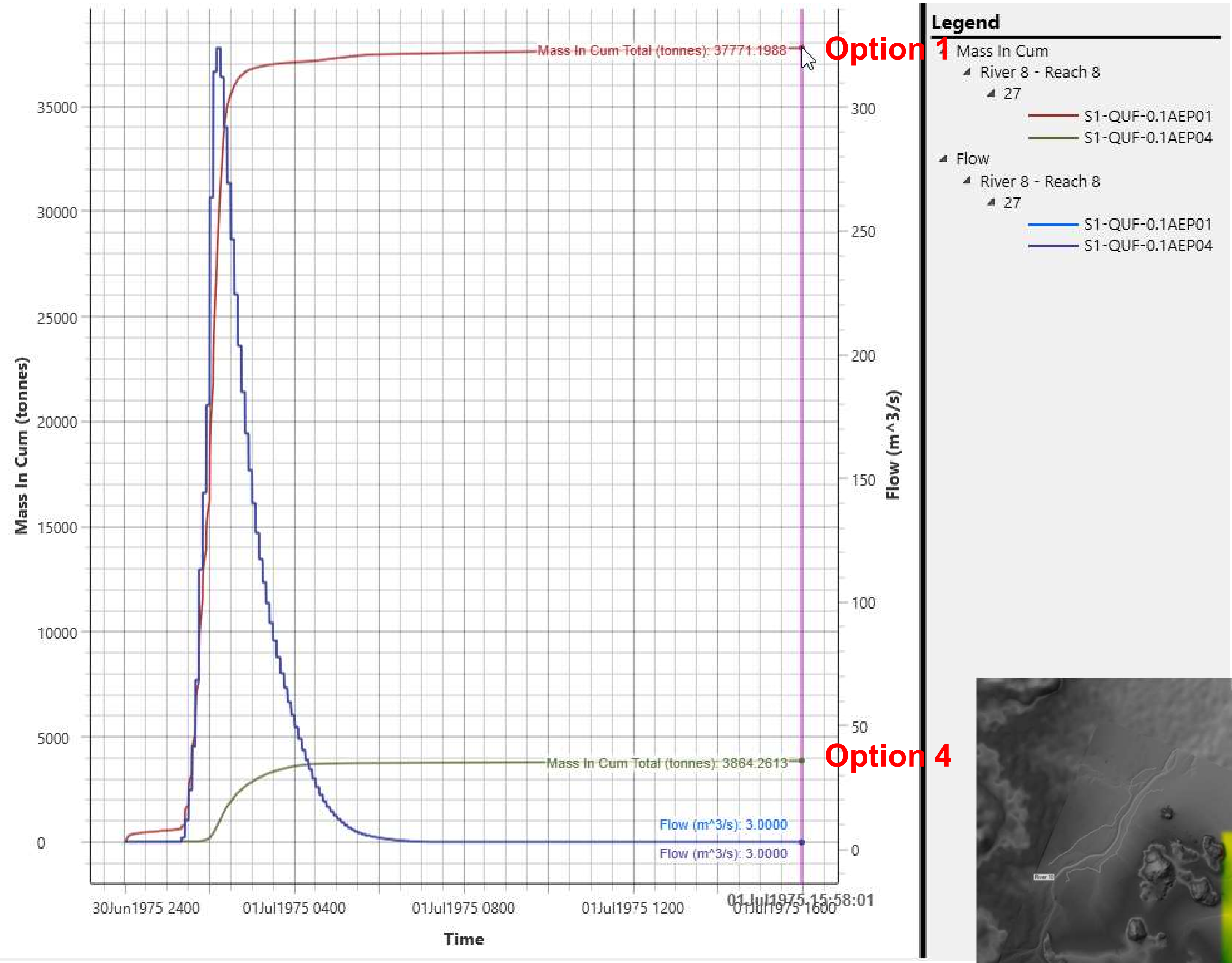


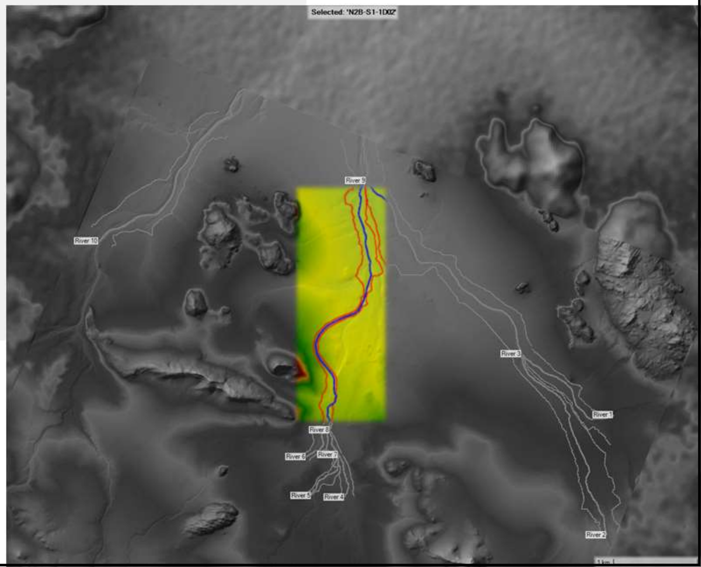
Mass In (1 in 1,000 AEP)

River 8 – Station 3374 (U/S)

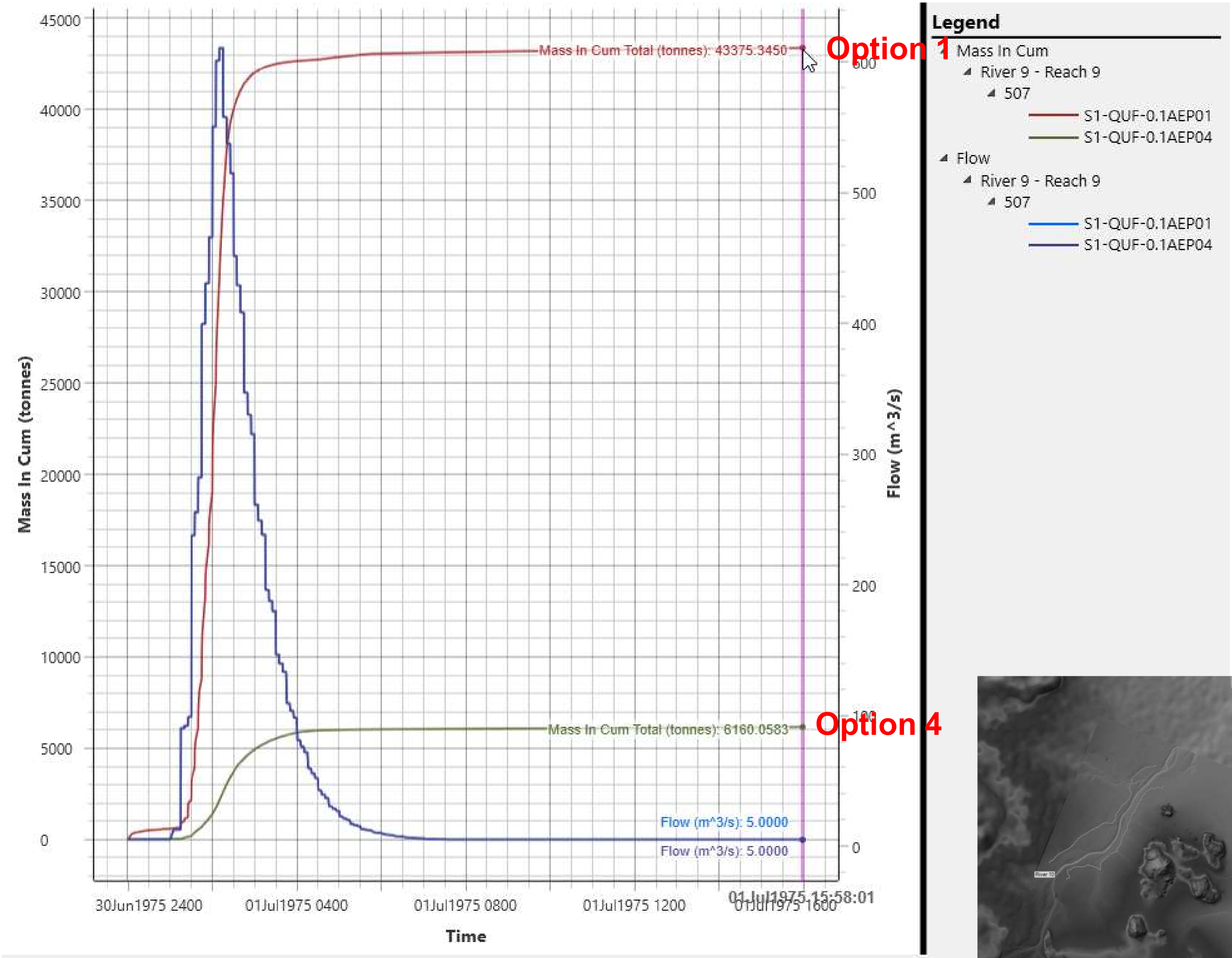


River 8 – Station 27 (D/S)

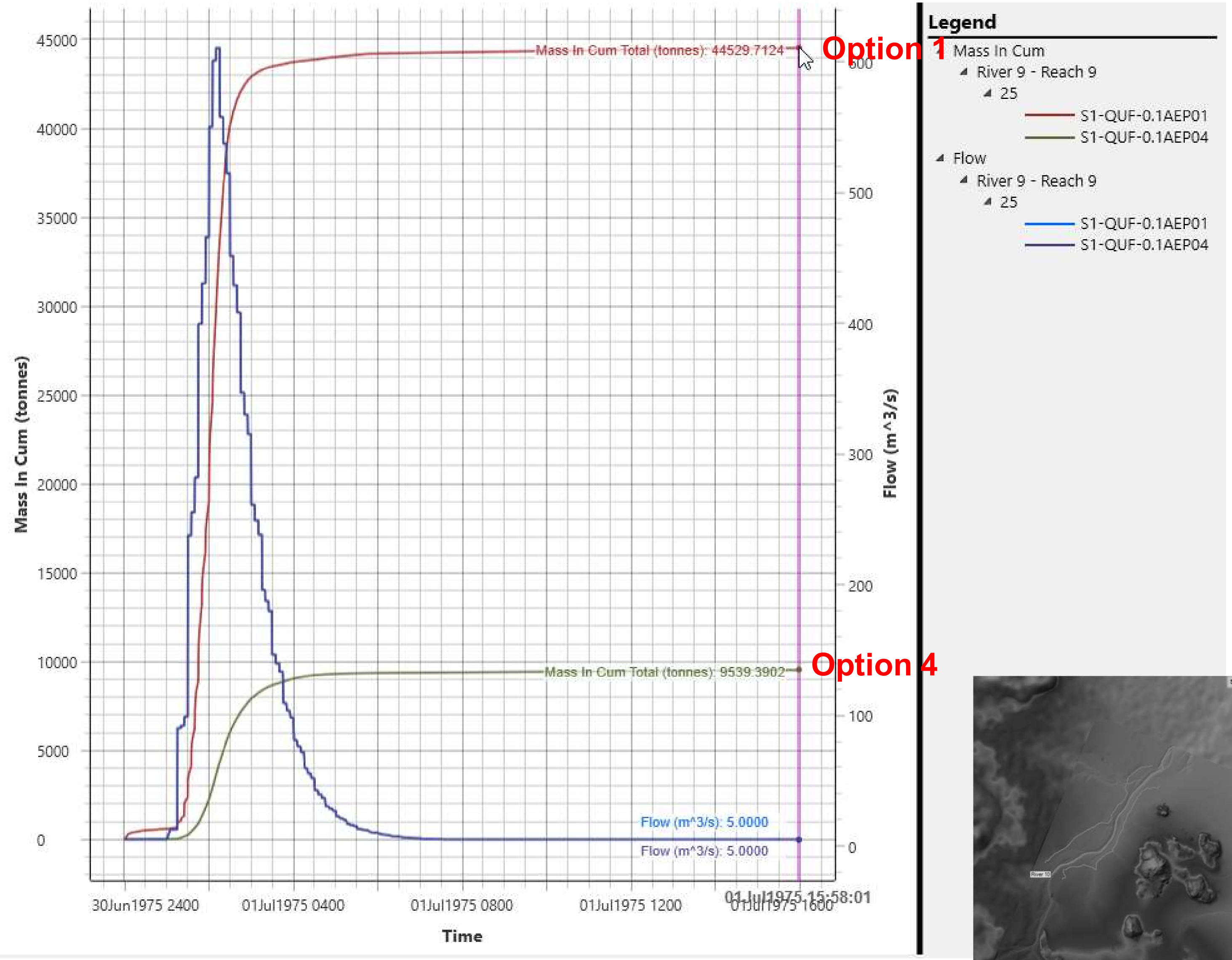




River 9 – Station 507 (U/S)

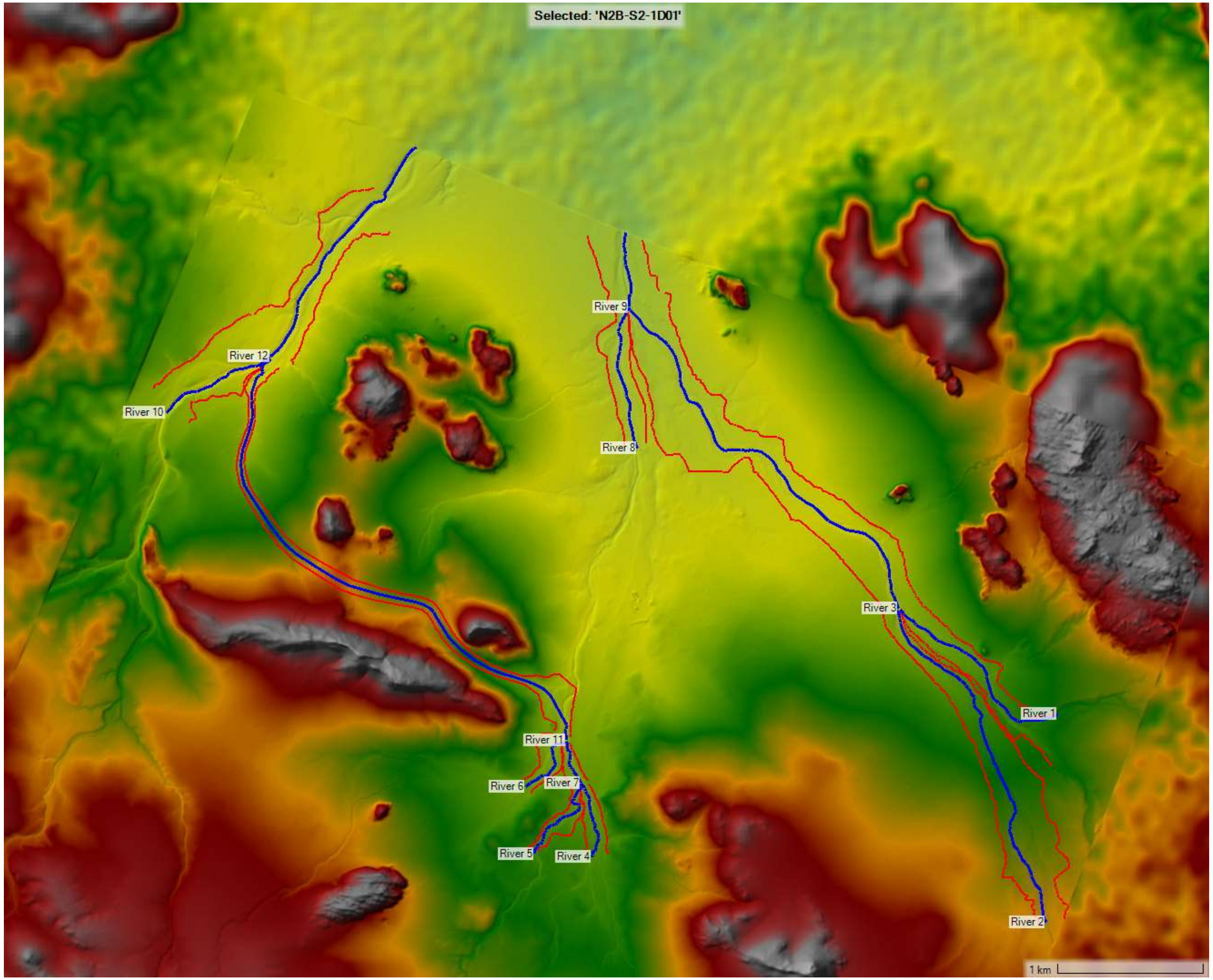


River 9 – Station 25 (D/S)

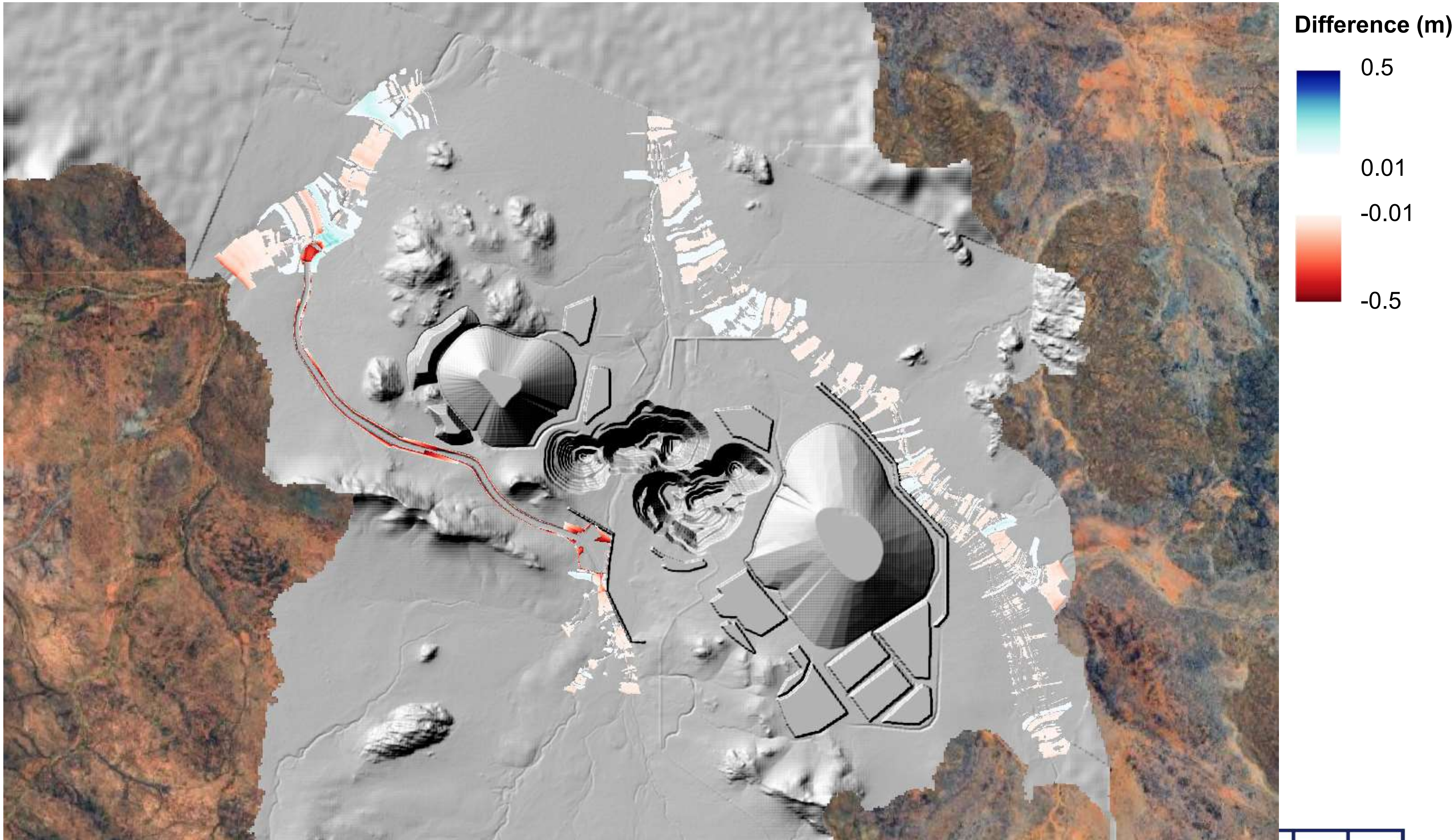


CASE – STAGE 2

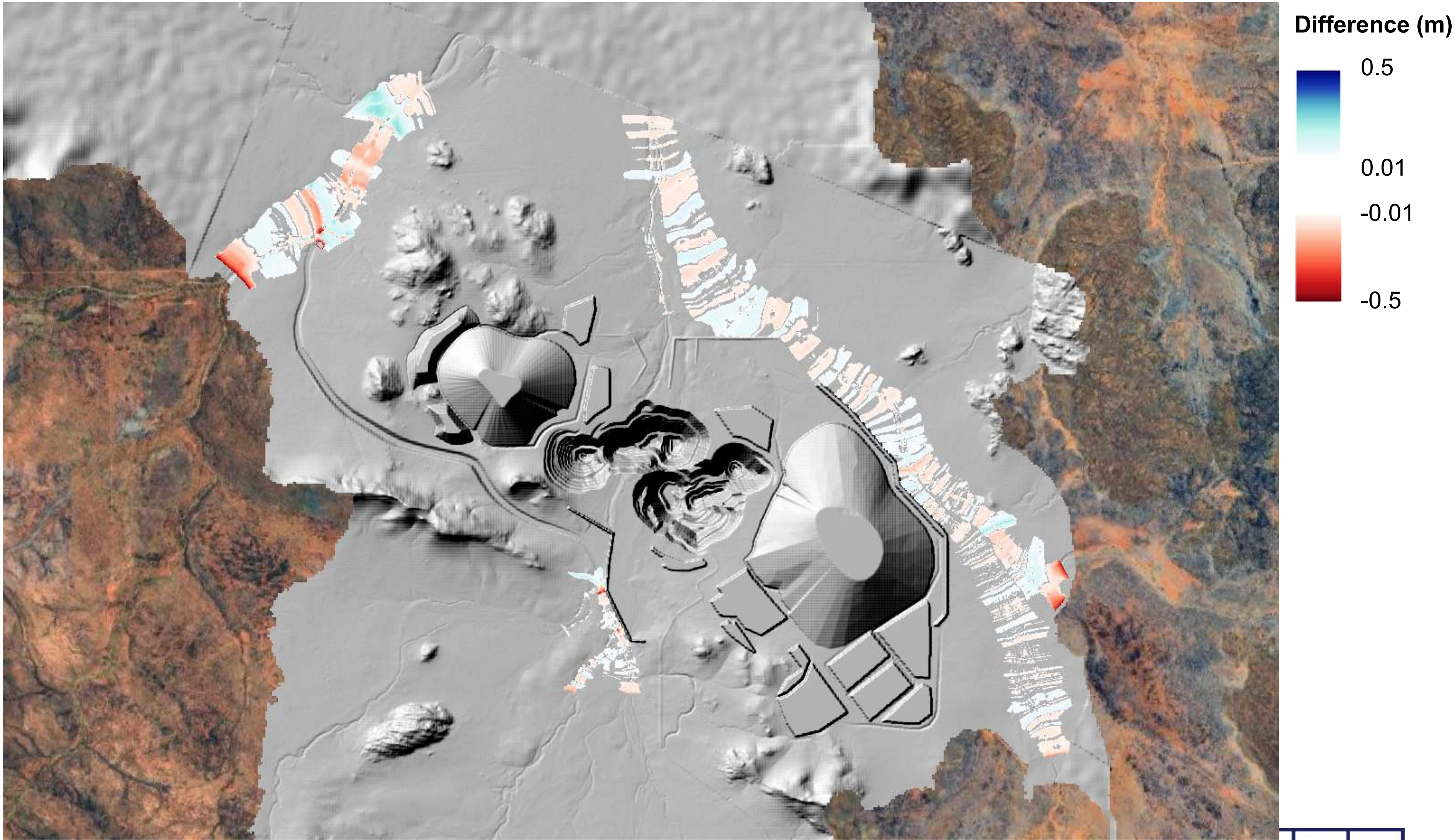
Plan


Selected: 'N2B-S2-1D01'
River 12
River 10
River 9
River 8
River 3
River 1
River 11
River 6
River 7
River 5
River 4
River 2
1 km

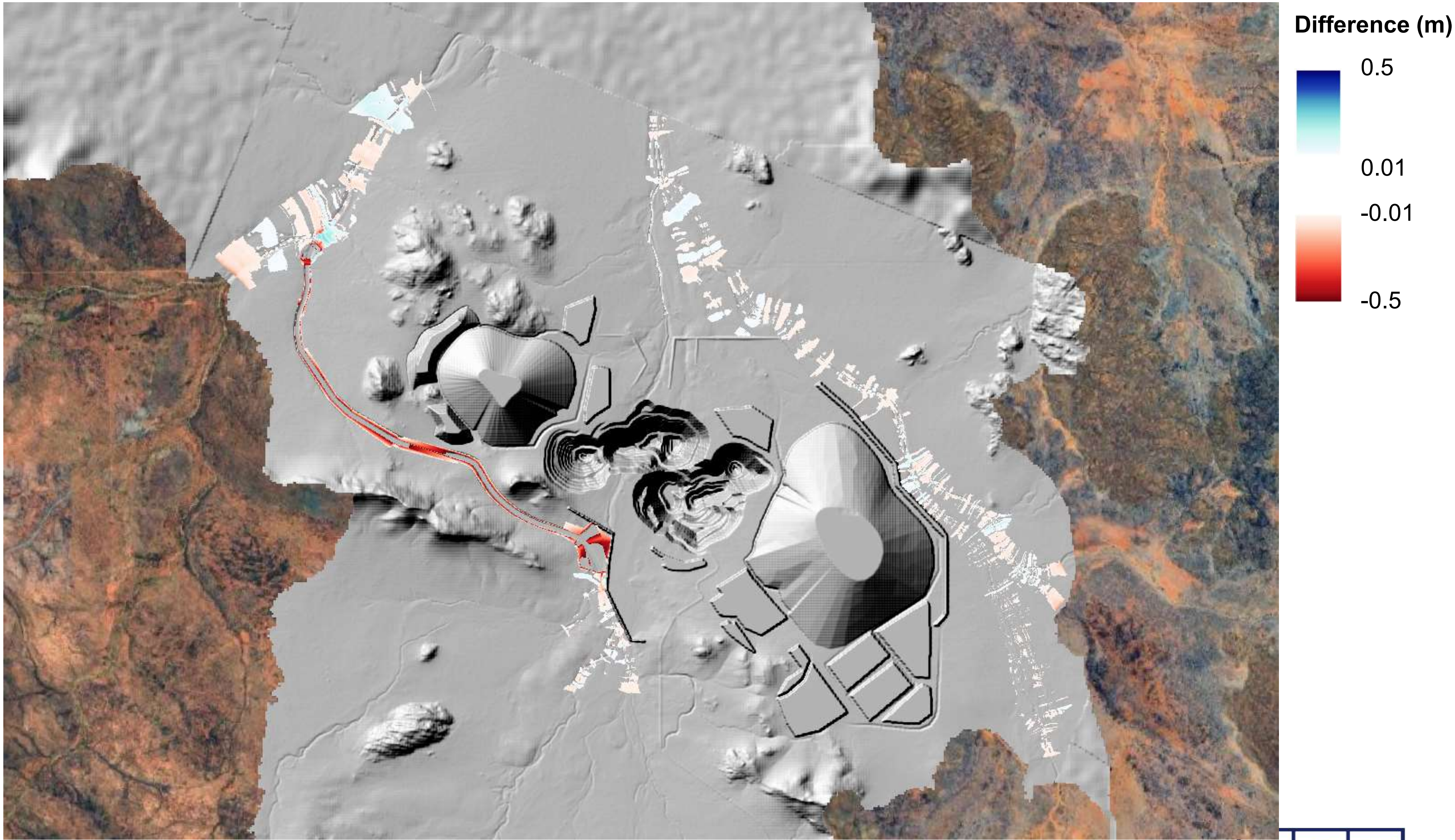
Scour – 1 in 1,000 AEP (Model 1 – Baseline)



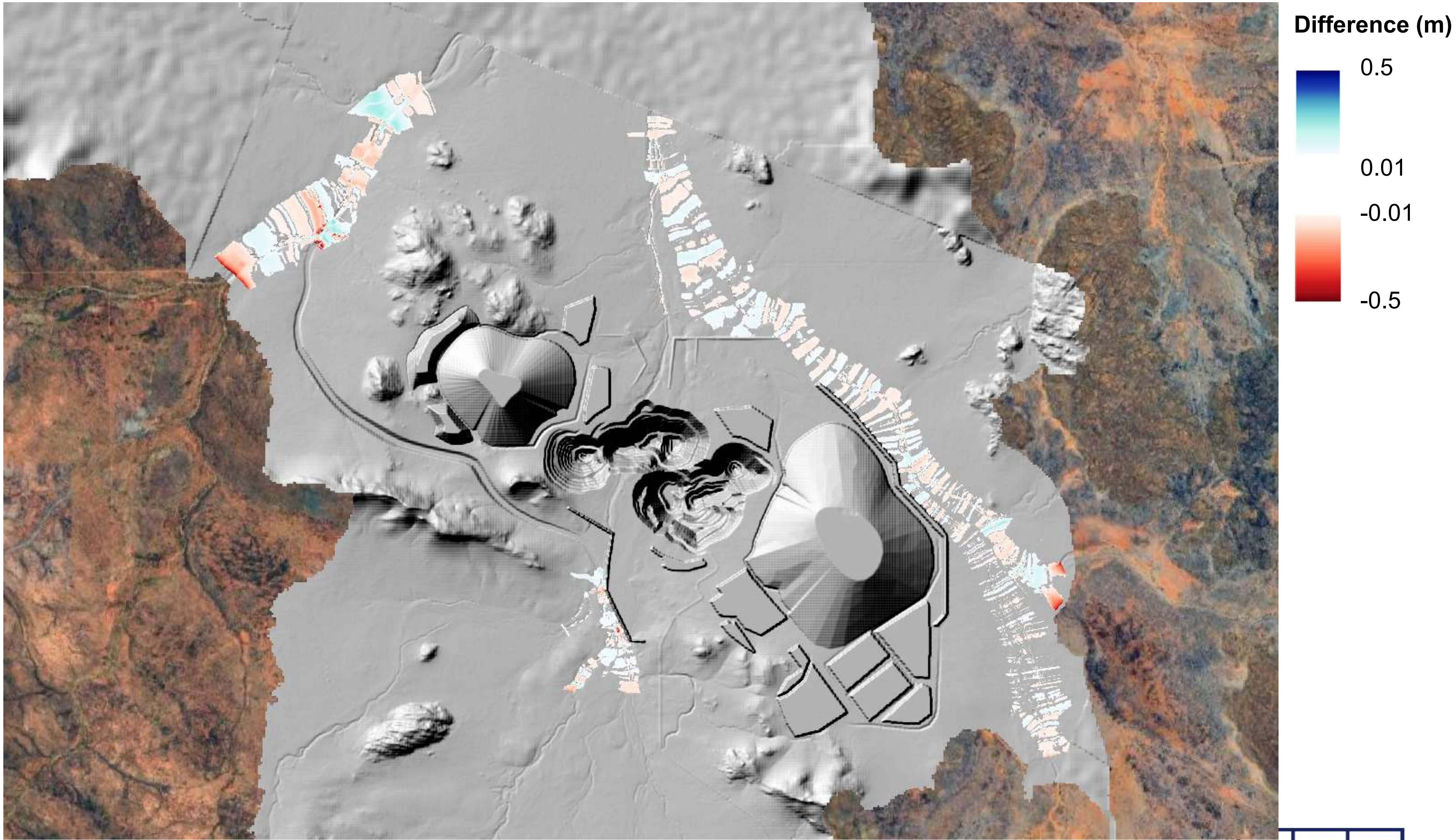
Scour – 1 in 1,000 AEP (Model 4 – Baseline)



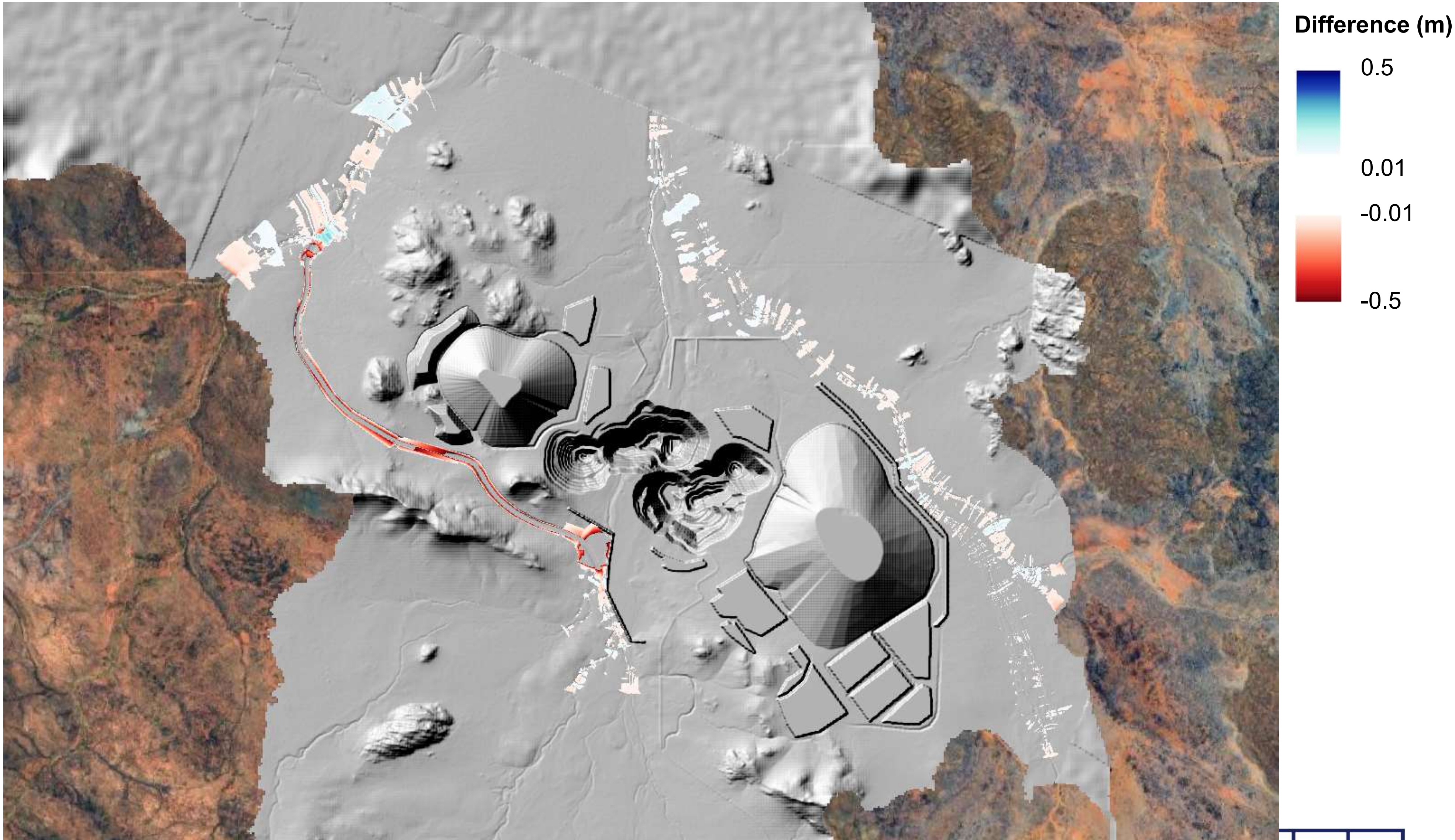
Scour – 1 in 100 AEP (Model 1 – Baseline)



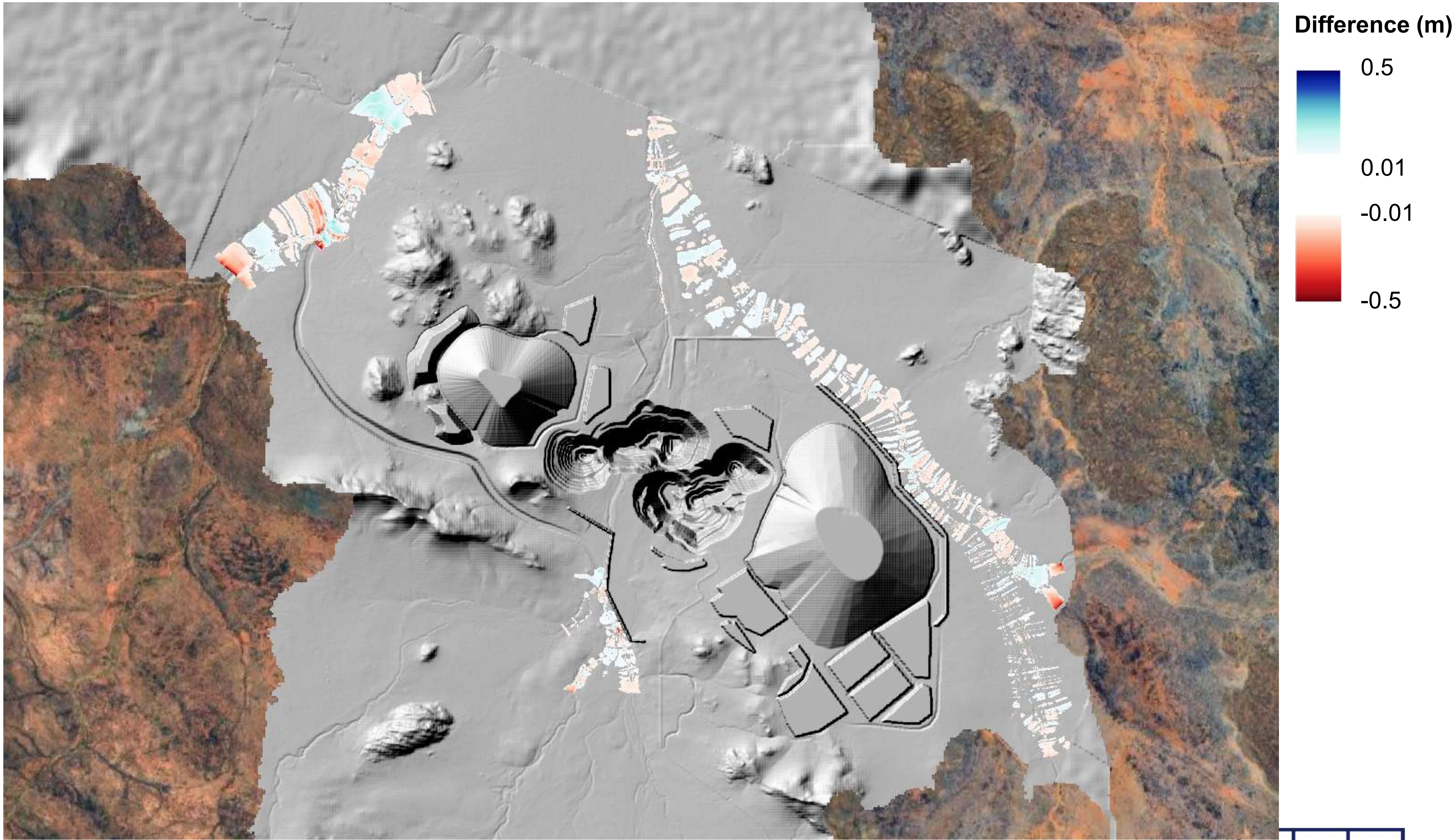
Scour – 1 in 100 AEP (Model 4 – Baseline)



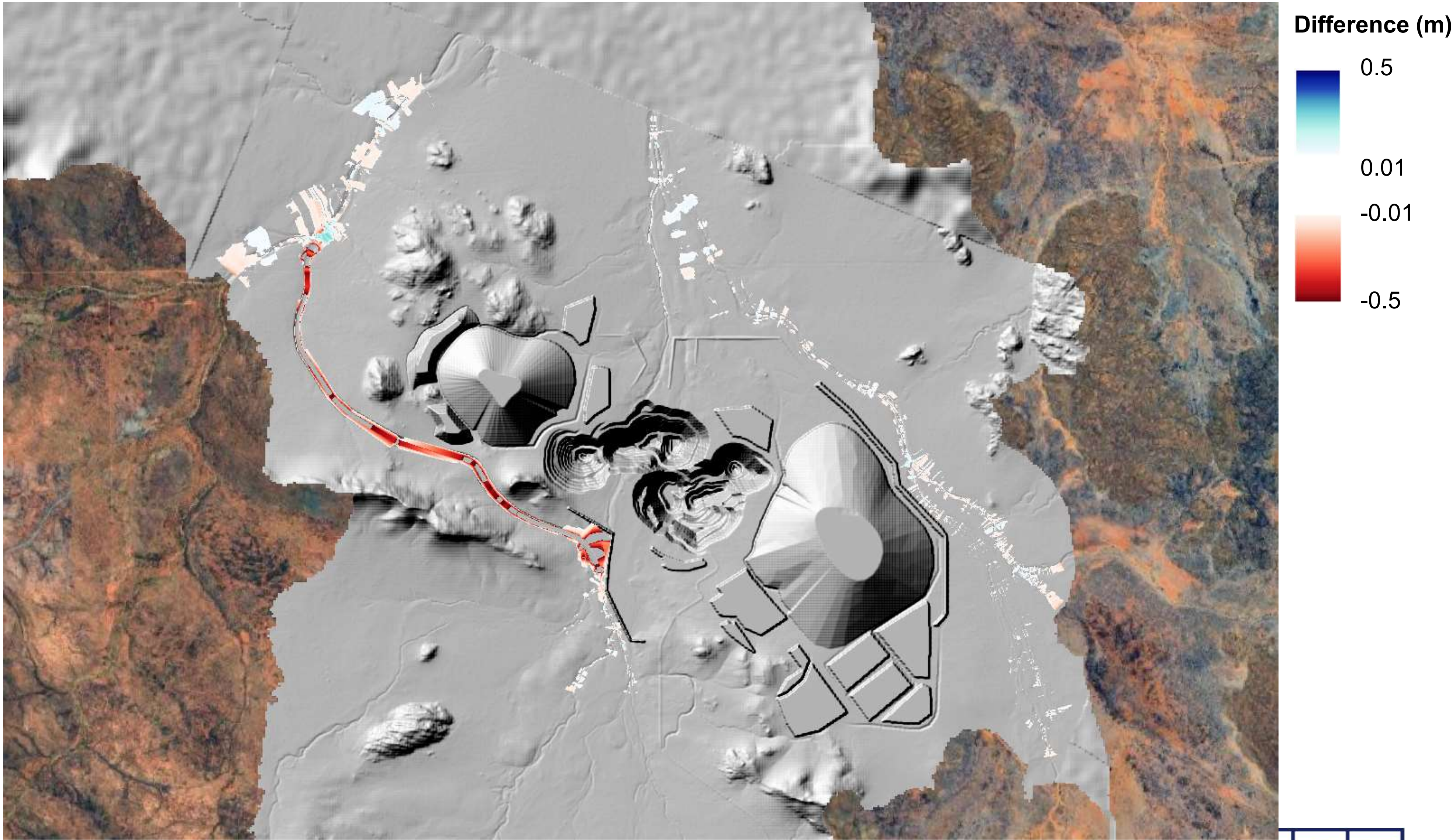
Scour – 1 in 50 AEP (Model 1 – Baseline)



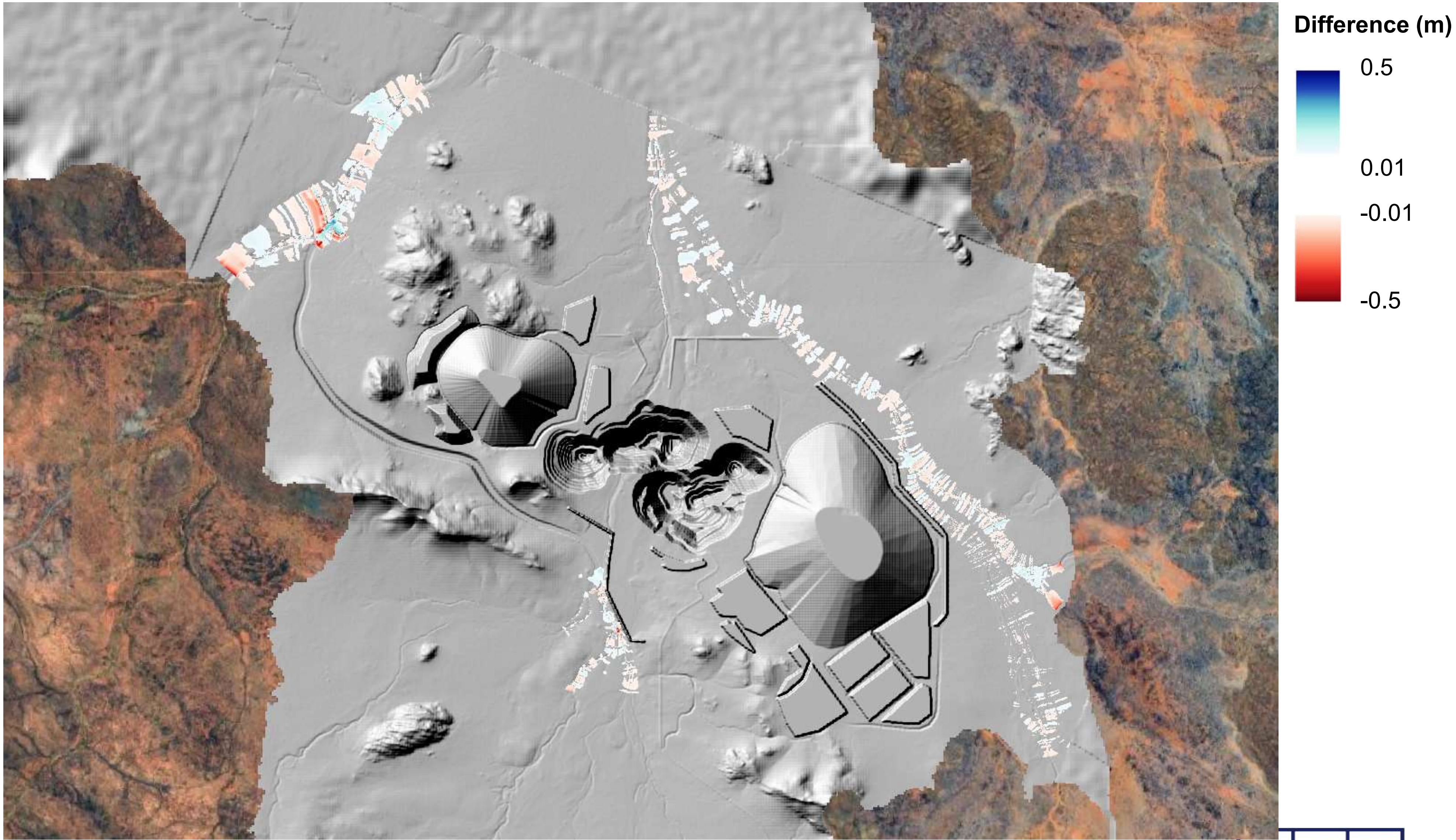
Scour – 1 in 50 AEP (Model 4 – Baseline)



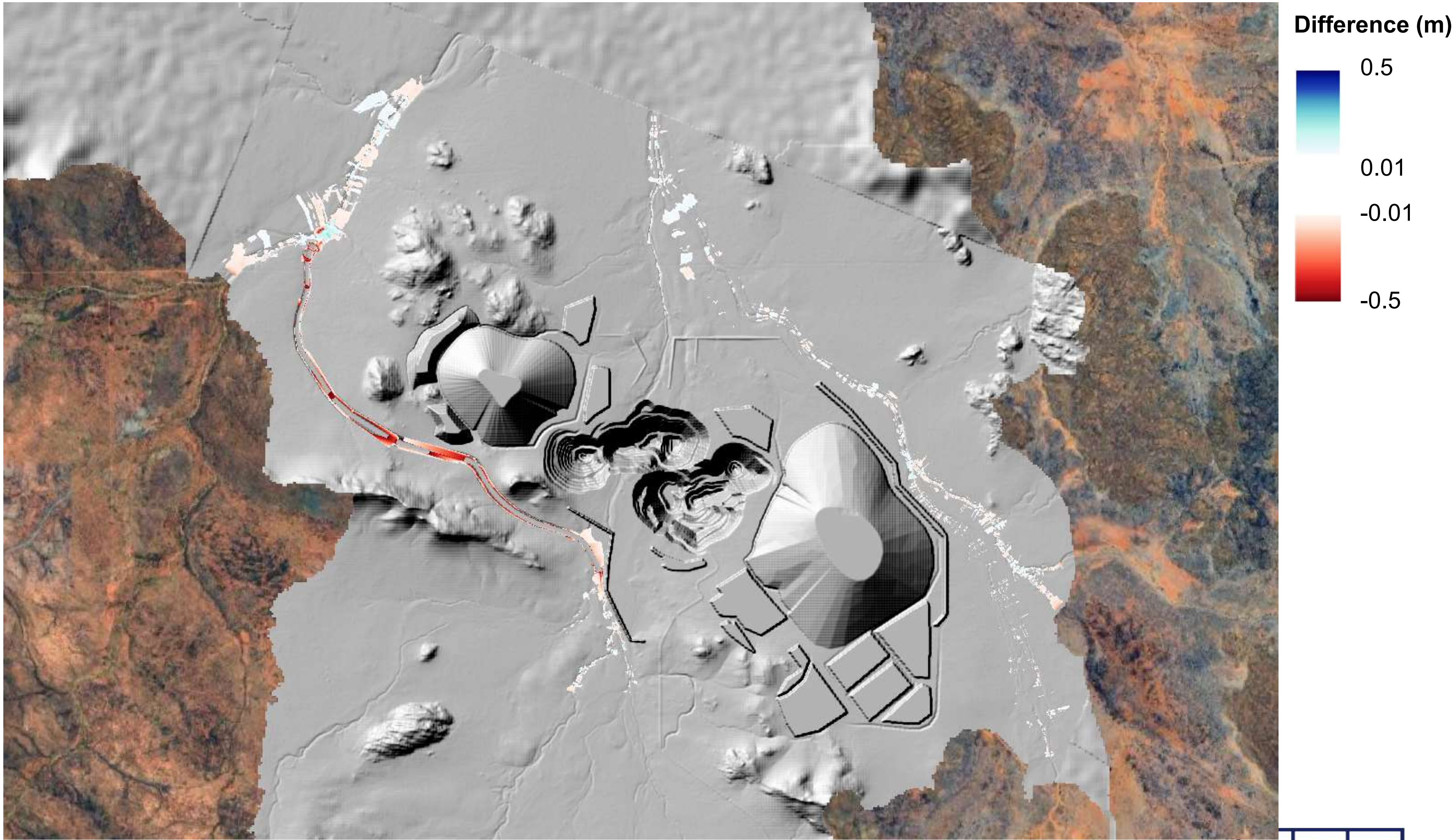
Scour – 1 in 20 AEP (Model 1 – Baseline)



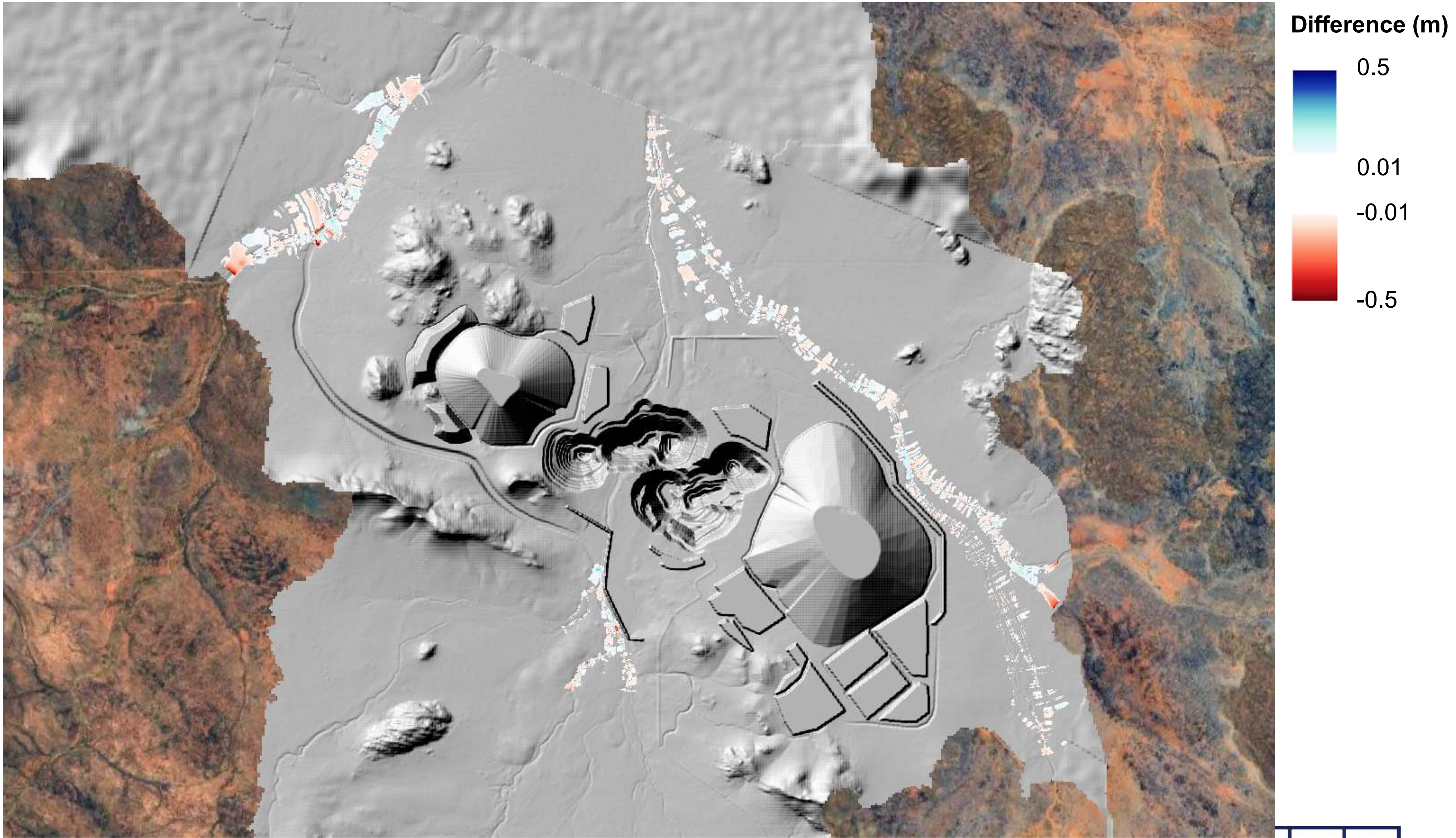
Scour – 1 in 20 AEP (Model 4 – Baseline)



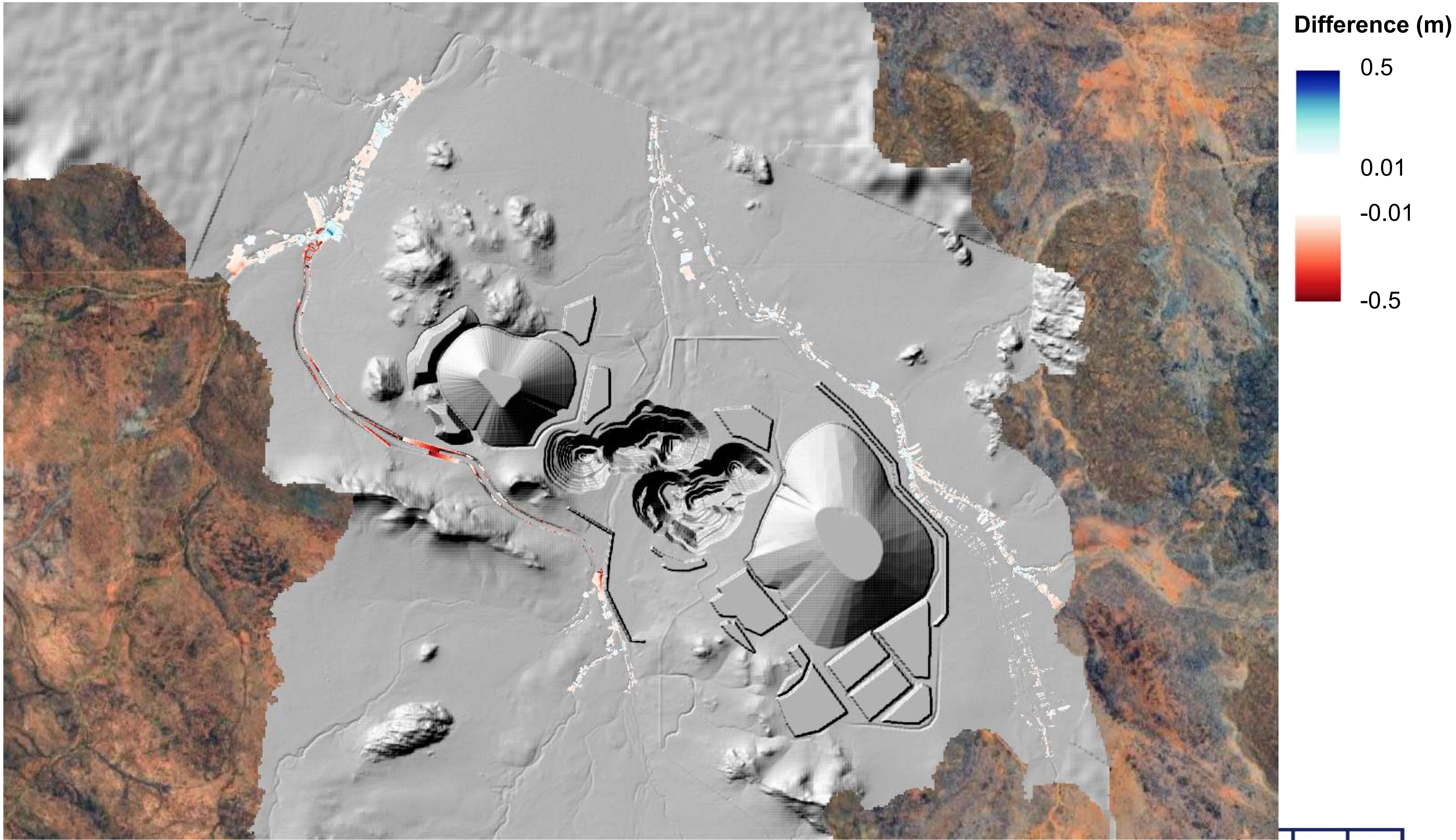
Scour – 1 in 10 AEP (Model 1 – Baseline)



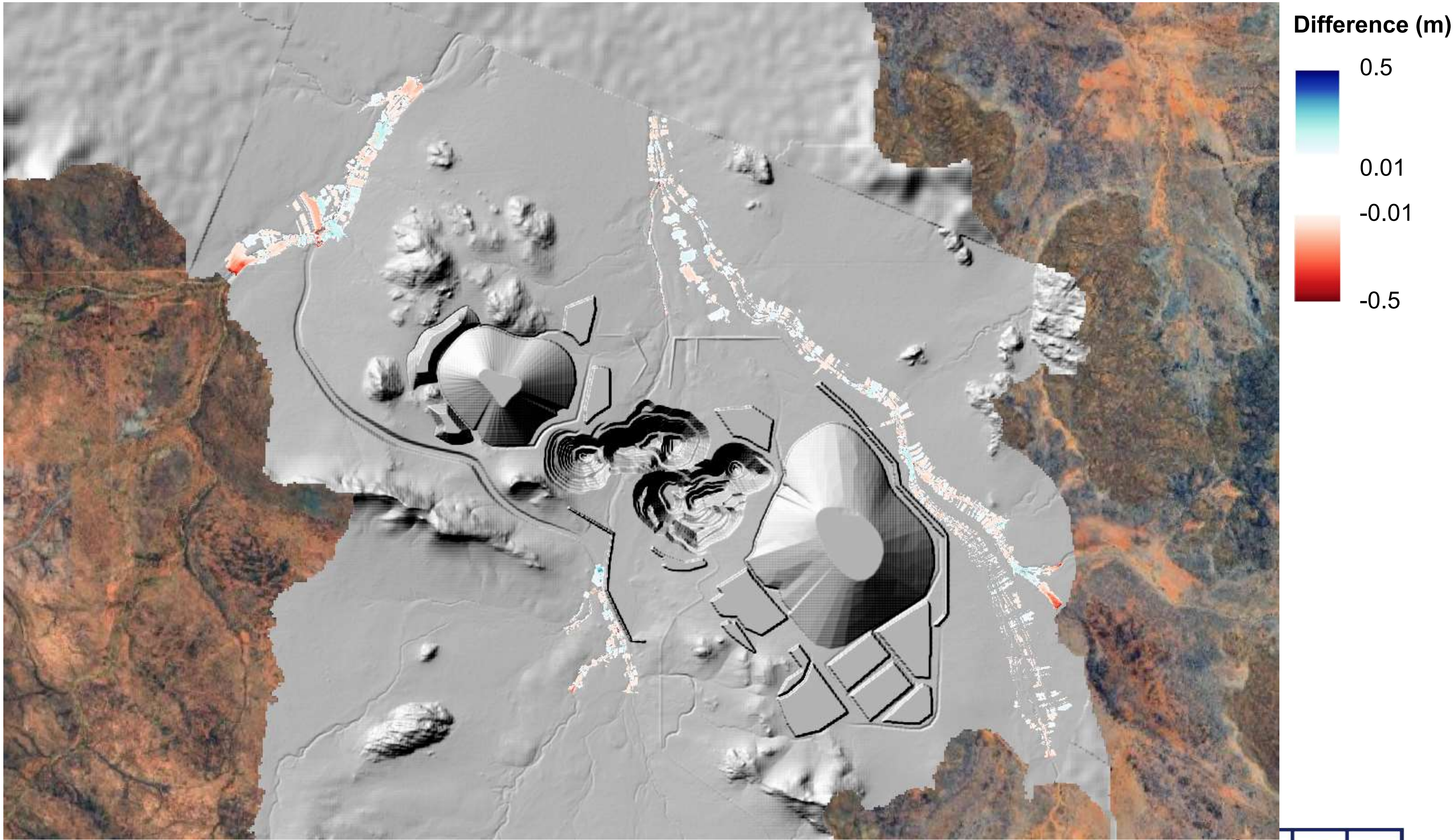
Scour – 1 in 10 AEP (Model 4 – Baseline)



Scour – 1 in 5 AEP (Model 1 – Baseline)

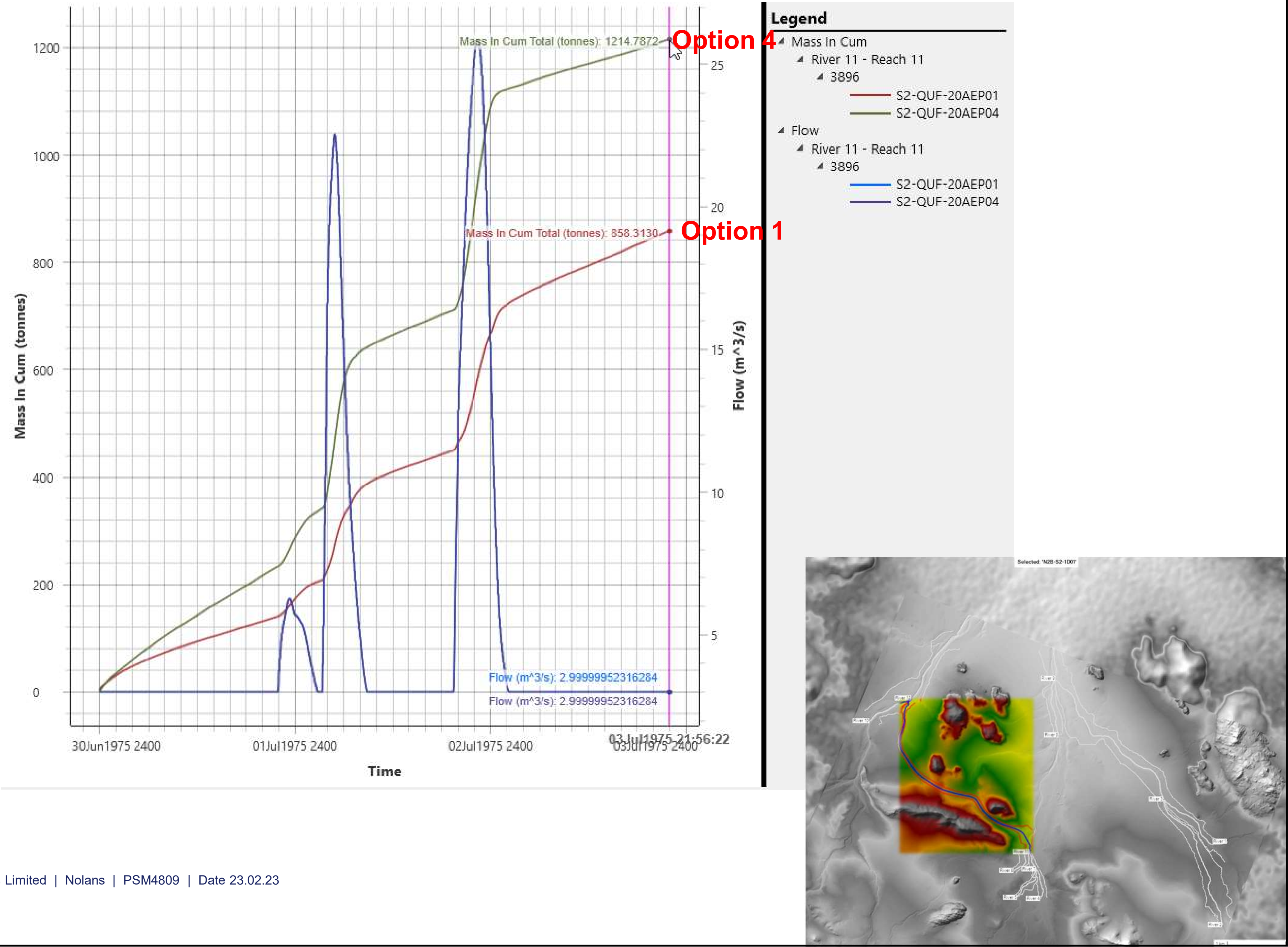


Scour – 1 in 5 AEP (Model 4 – Baseline)

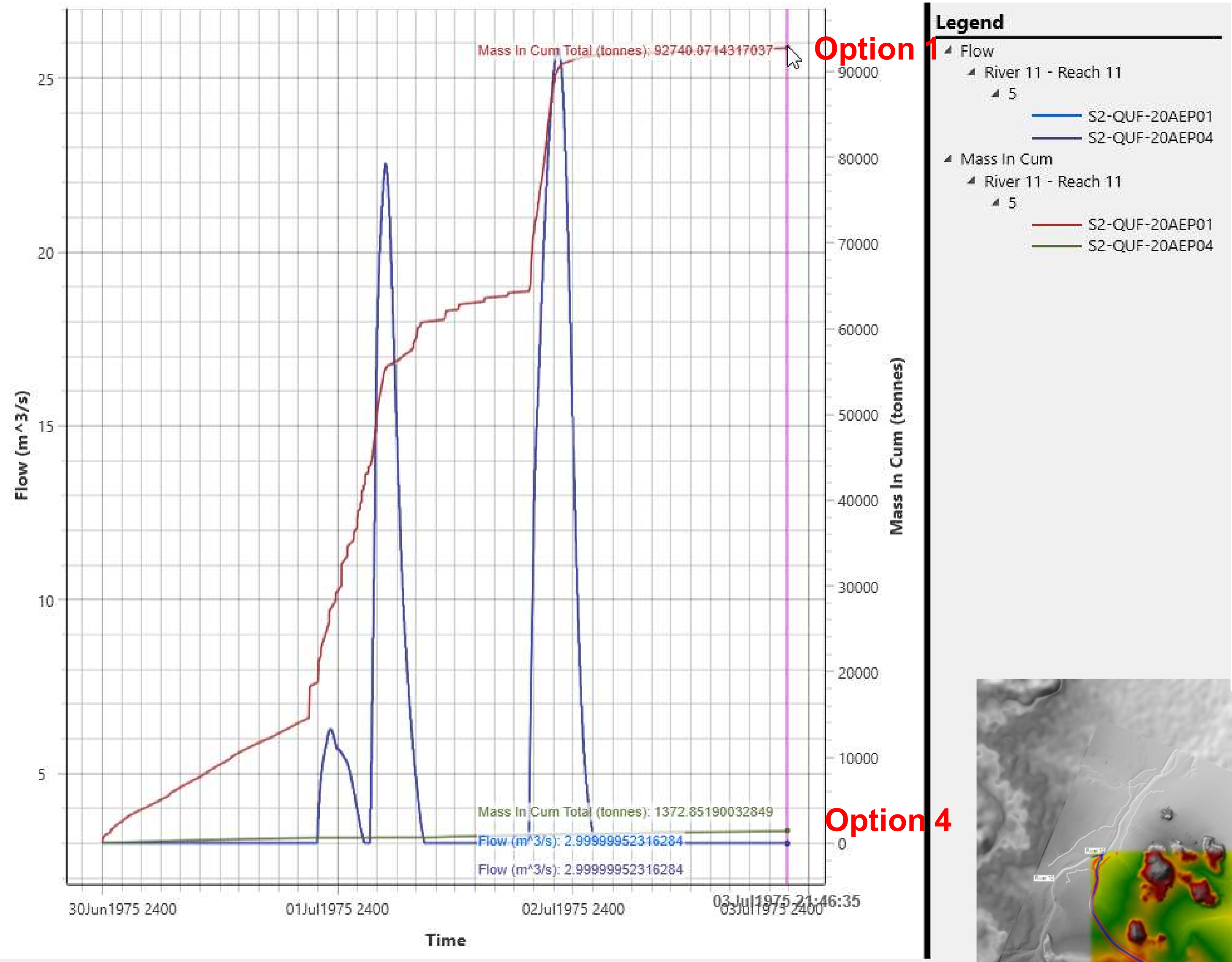


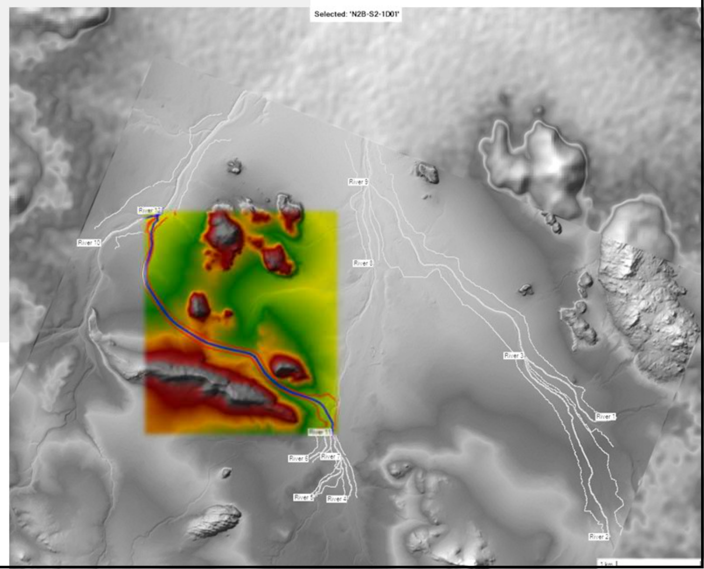
Mass In (1 in 5 AEP)

River 11 – Station 3896 (U/S)

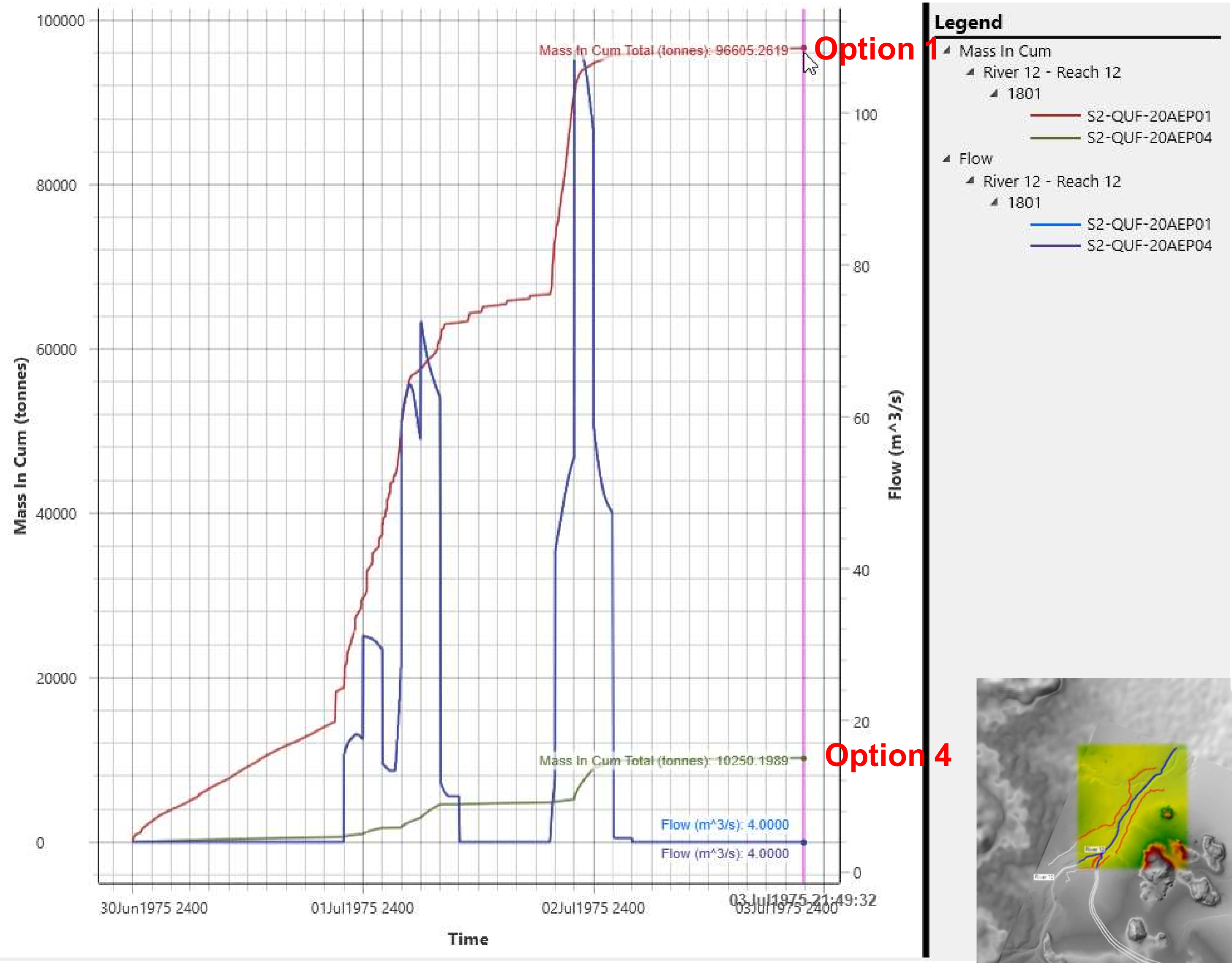


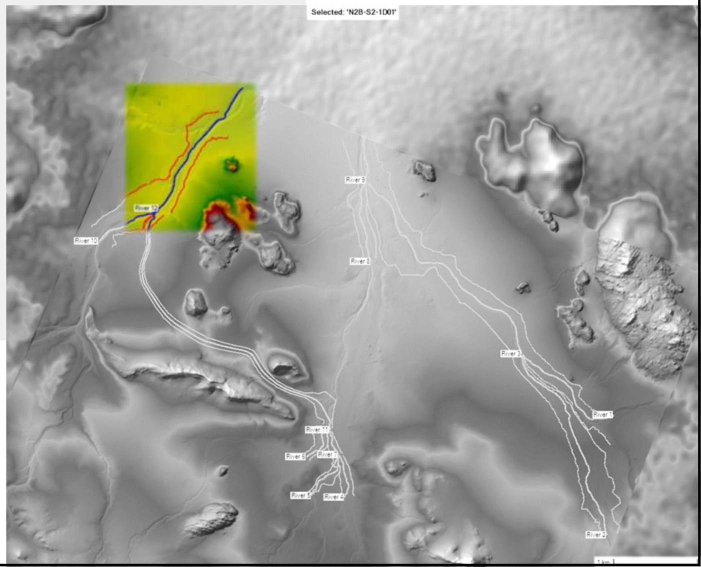
River 11 – Station 5 (D/S)



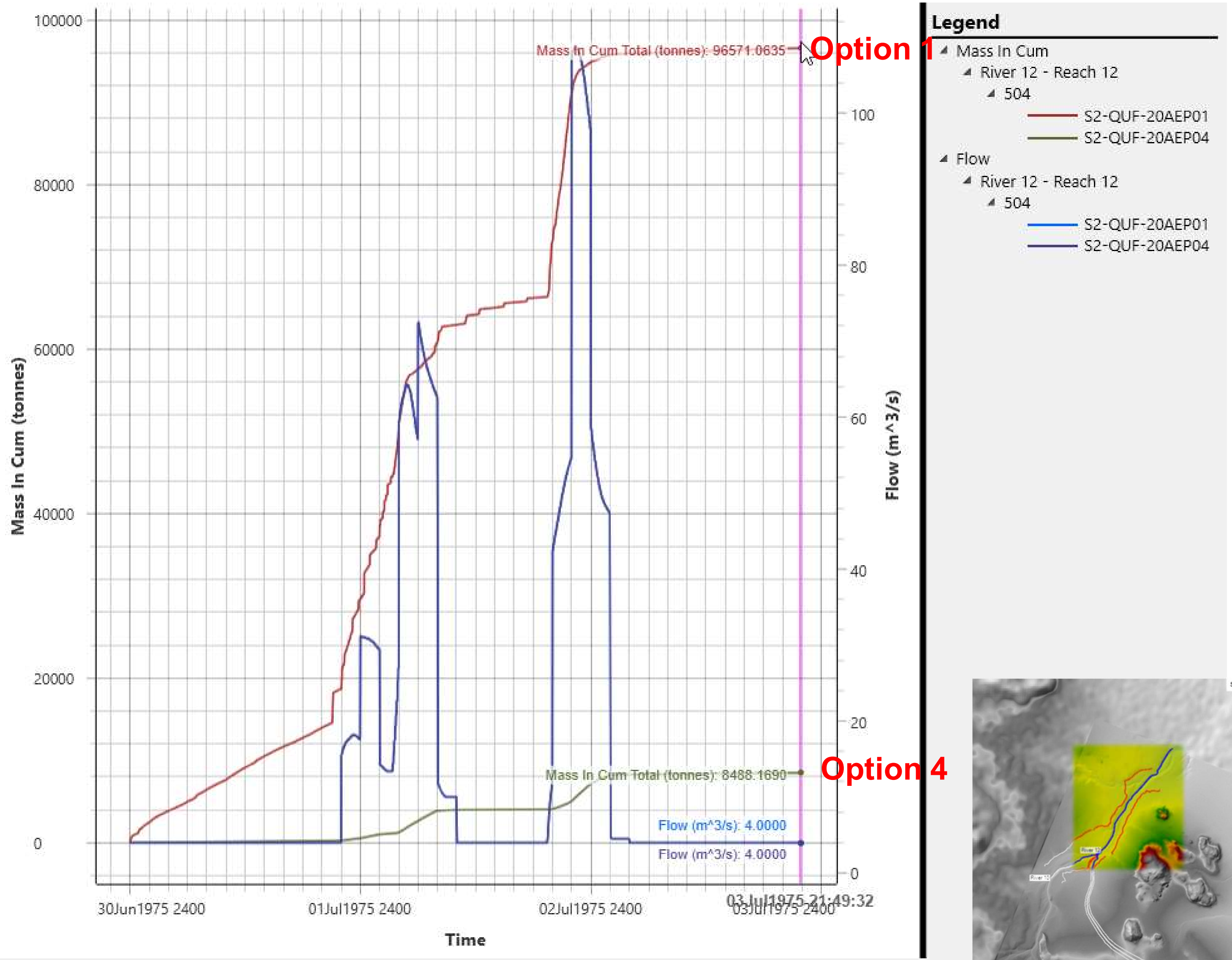


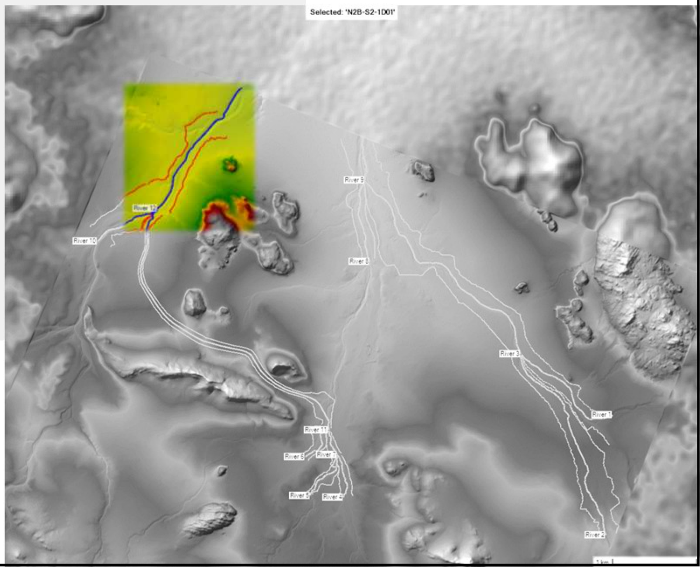
River 12 – Station 1801 (U/S)





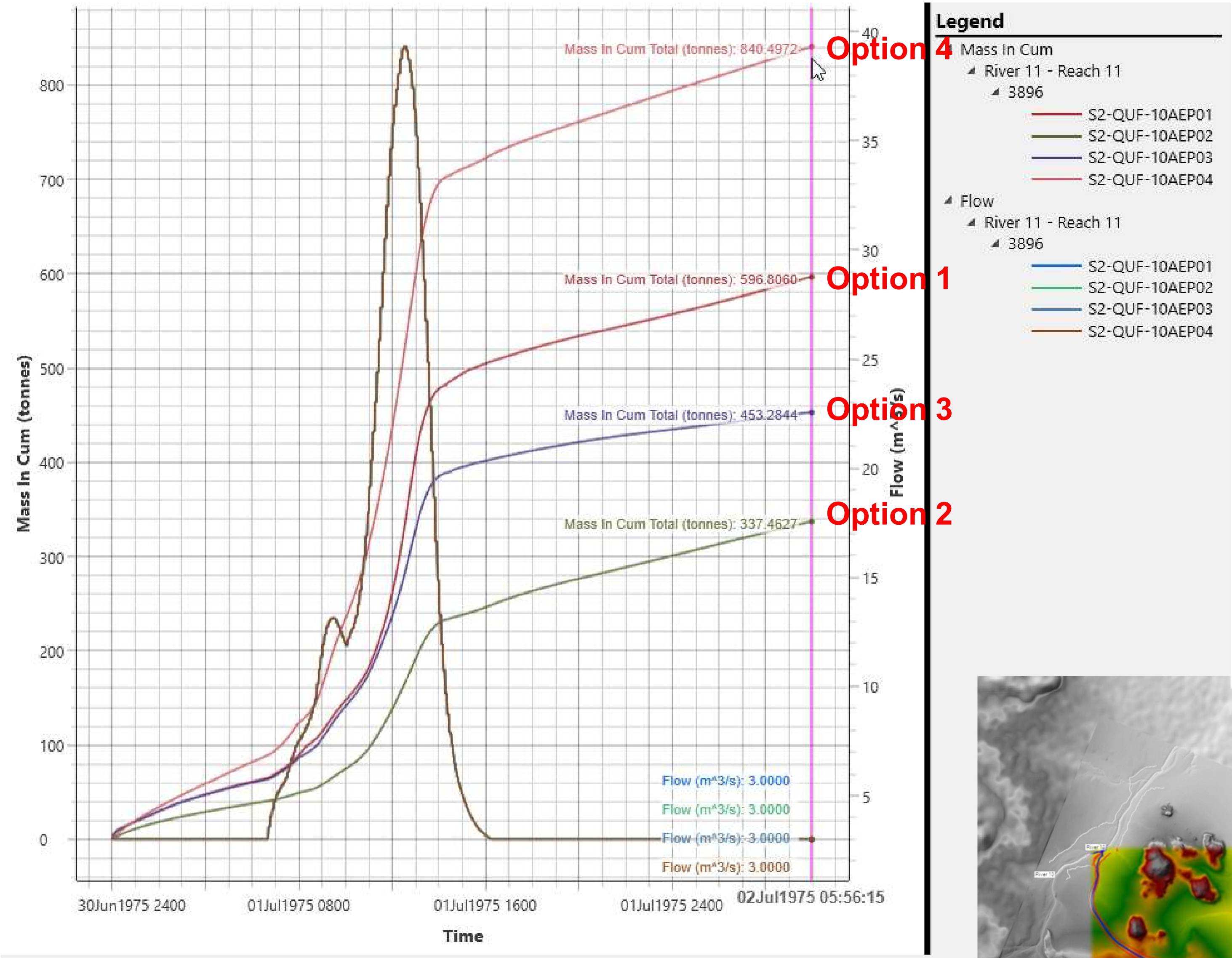
River 12 – Station 504 (D/S)

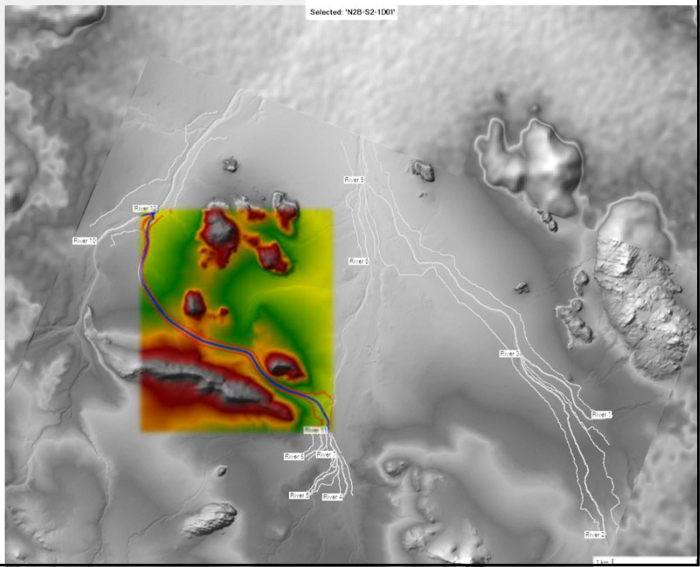




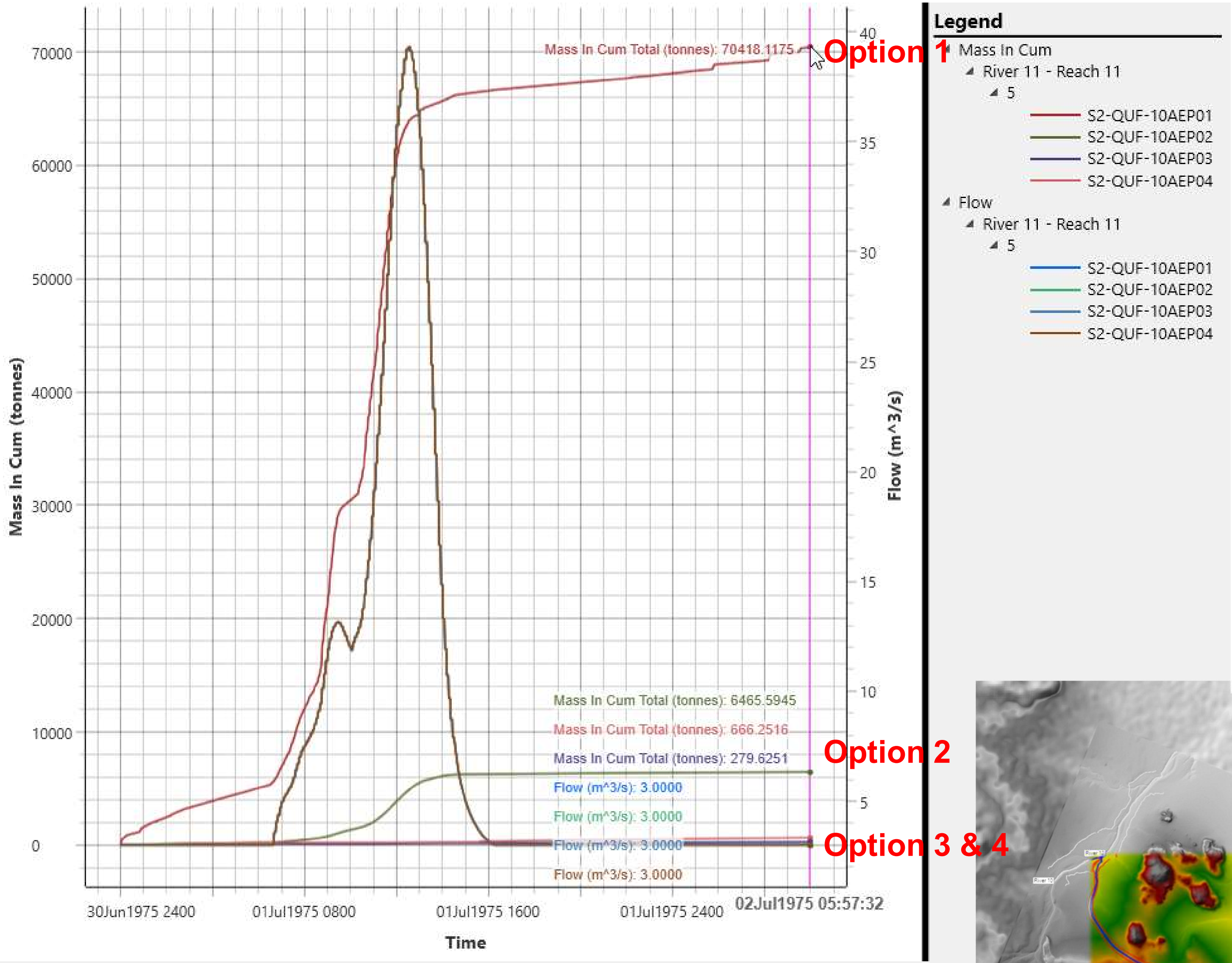
Mass In (1 in 10 AEP)

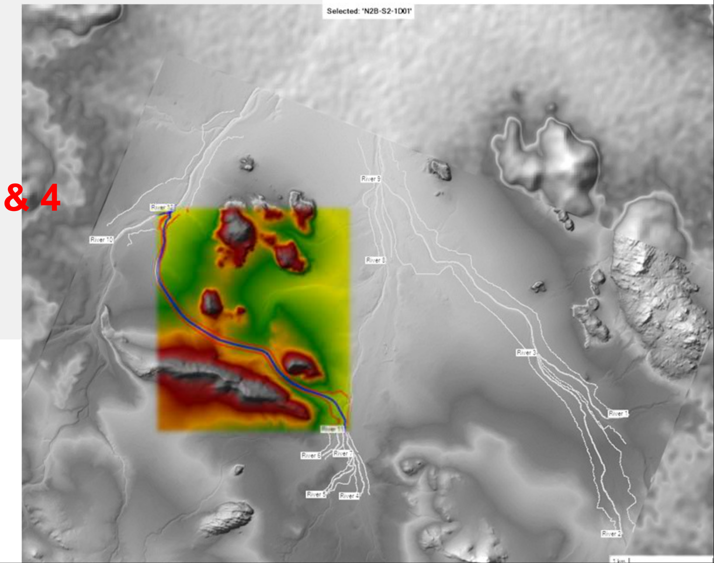
River 11 – Station 3896 (U/S)



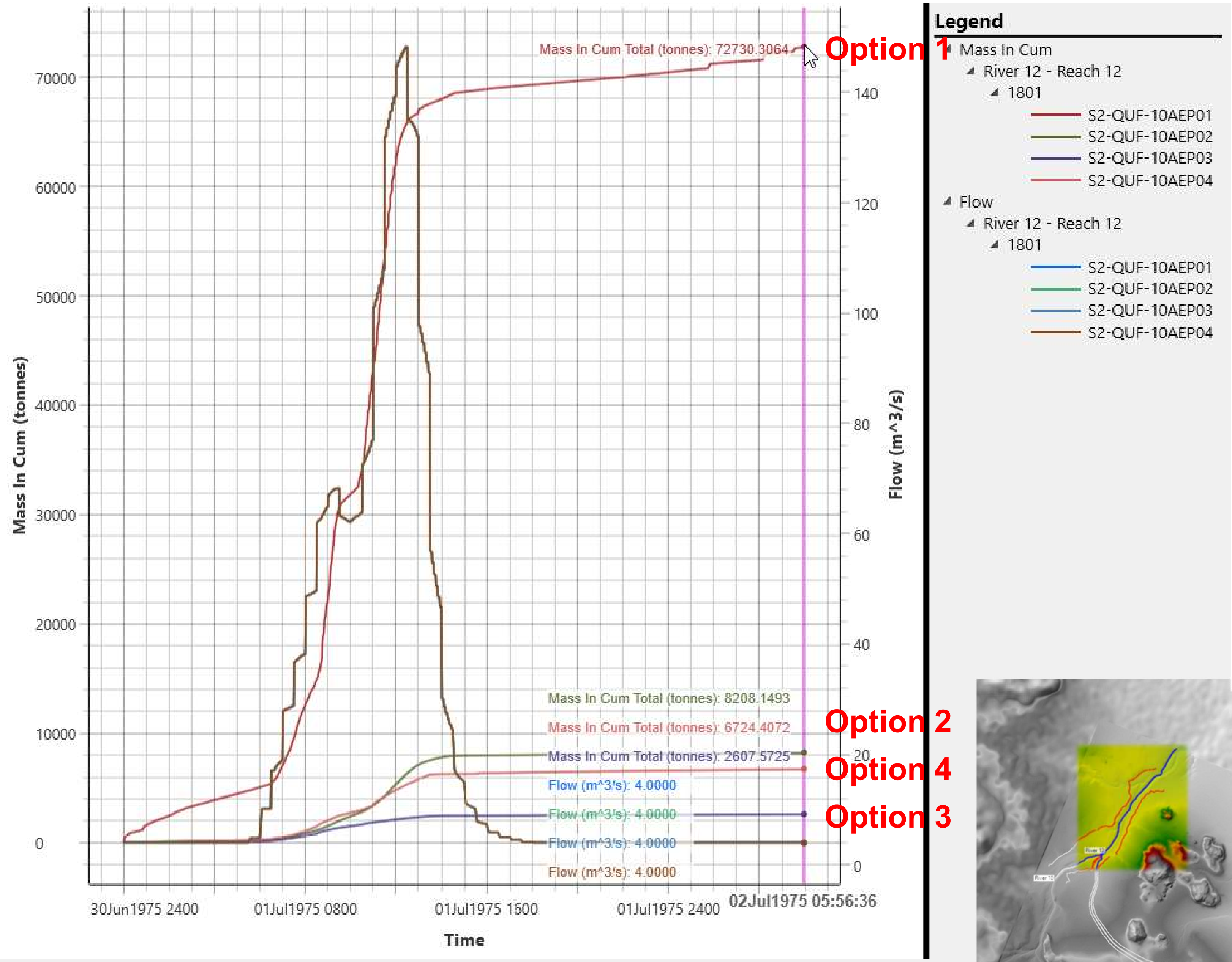


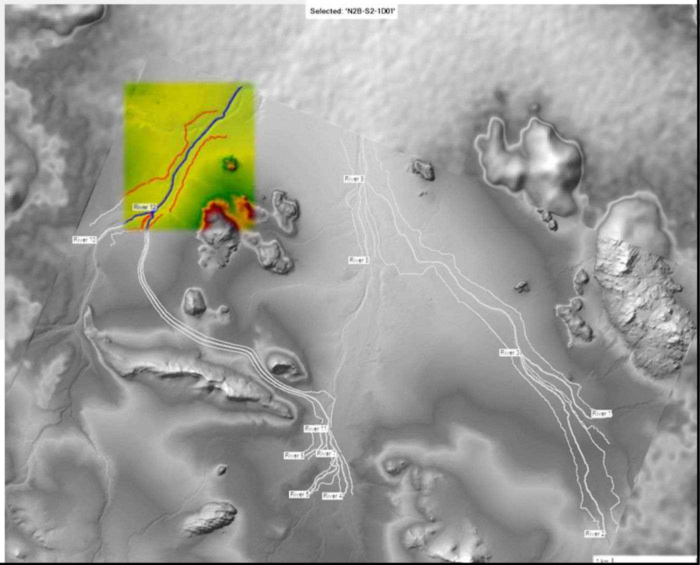
River 11 – Station 5 (D/S)



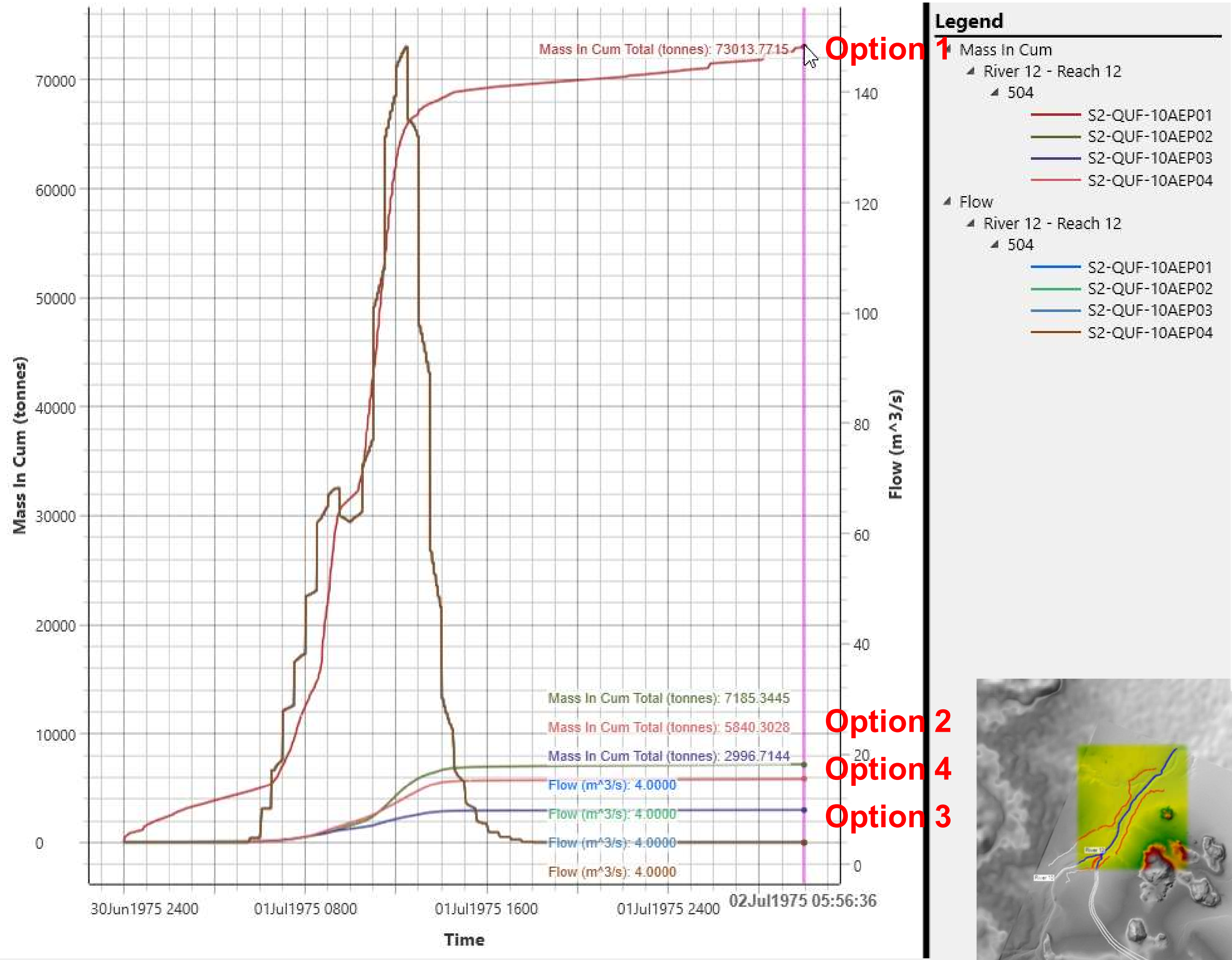


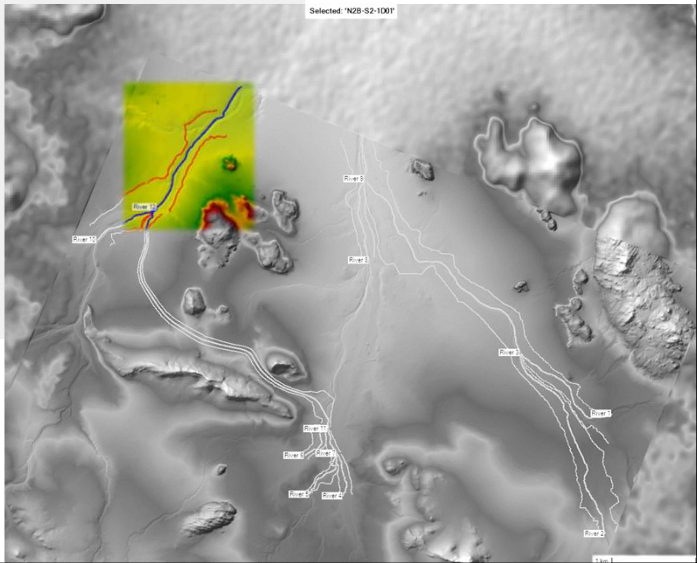
River 12 – Station 1801 (U/S)





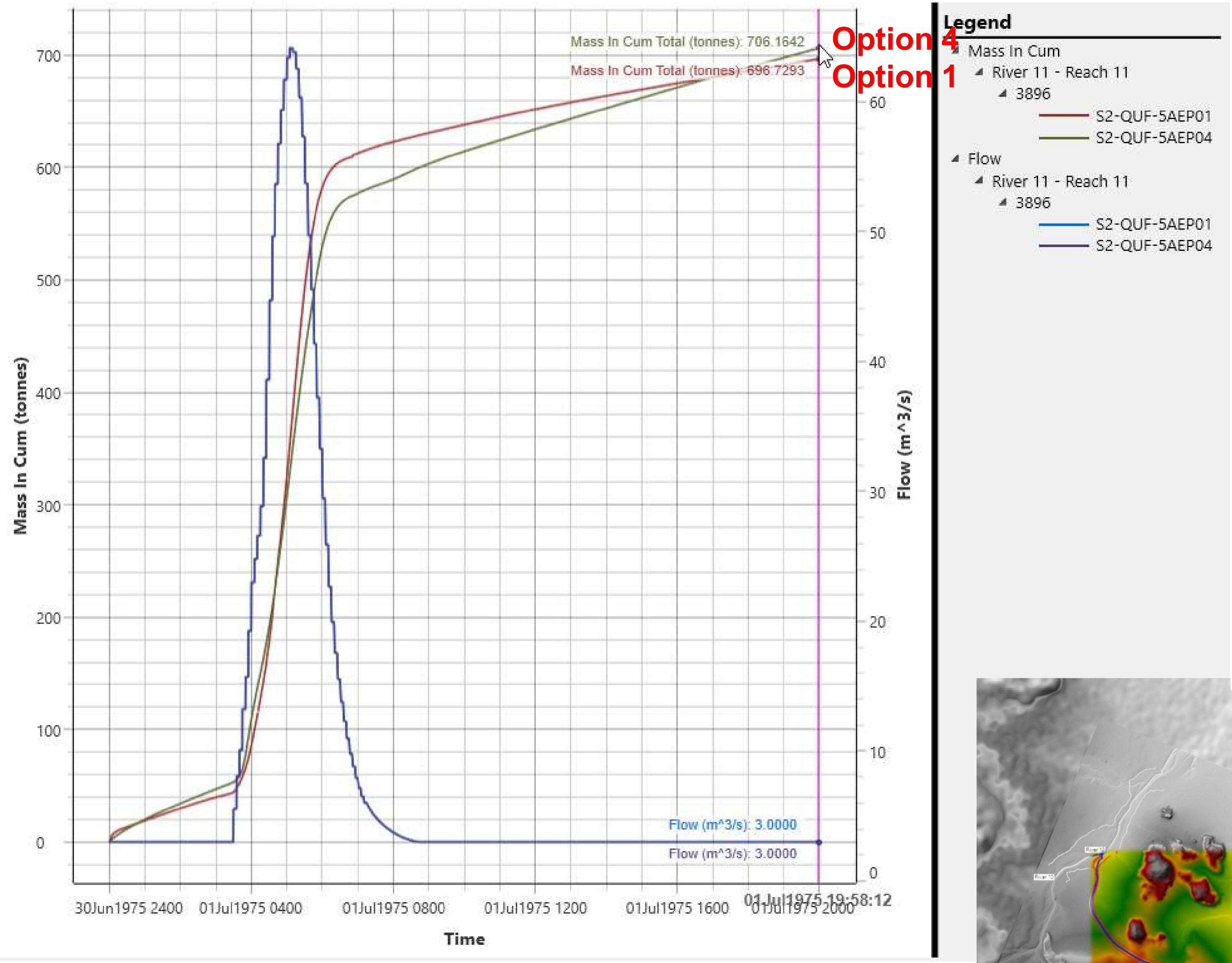
River 12 – Station 504 (D/S)

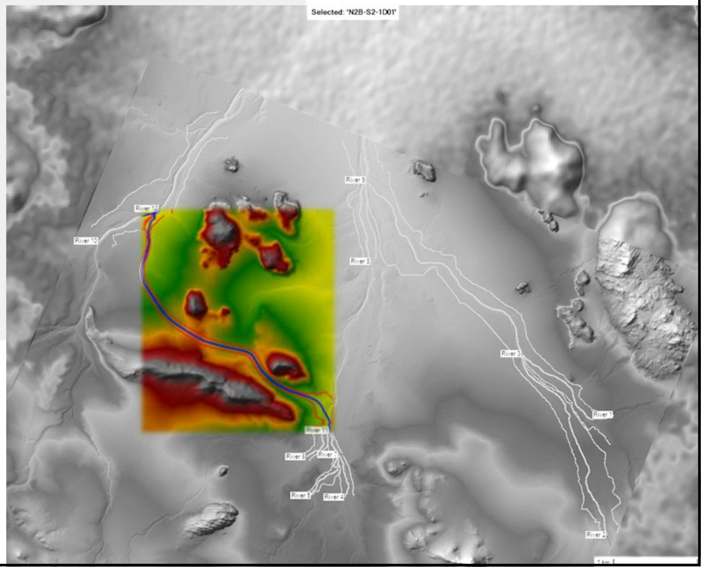




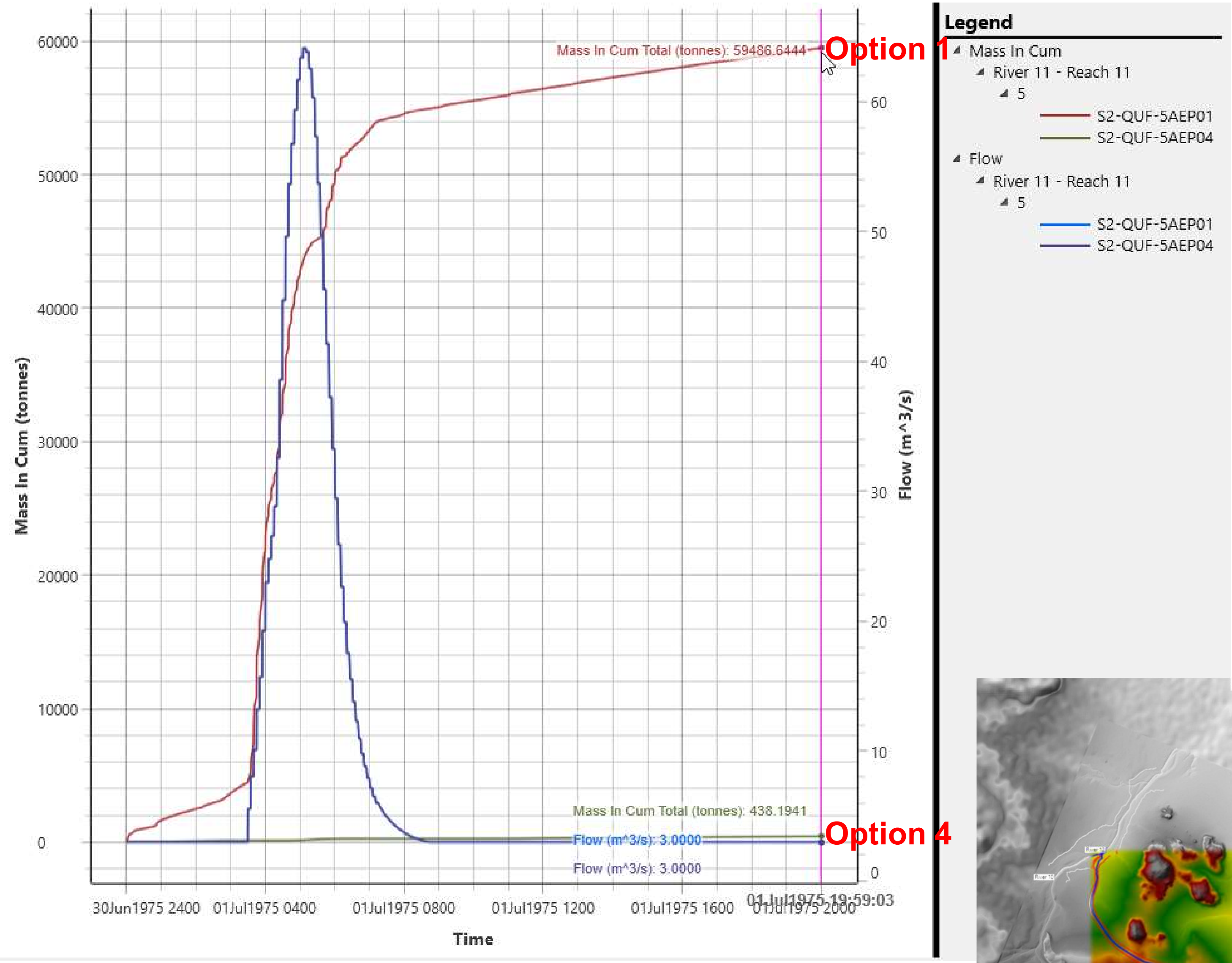
Mass In (1 in 20 AEP)

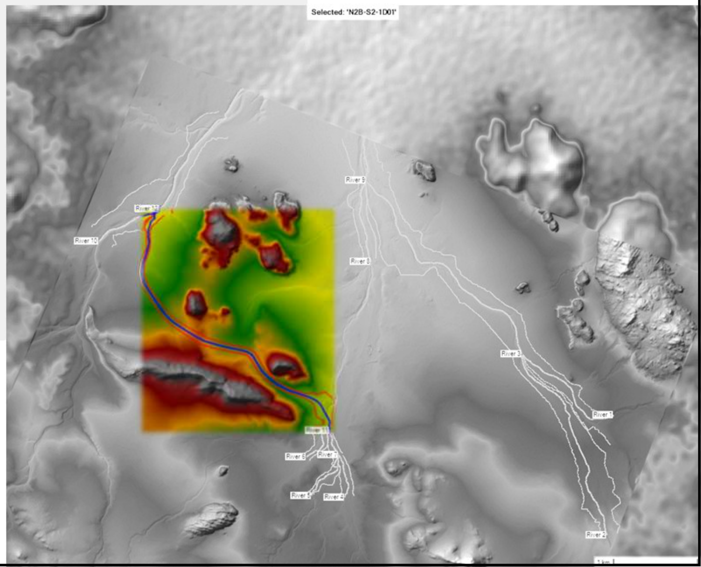
River 11 – Station 3896 (U/S)



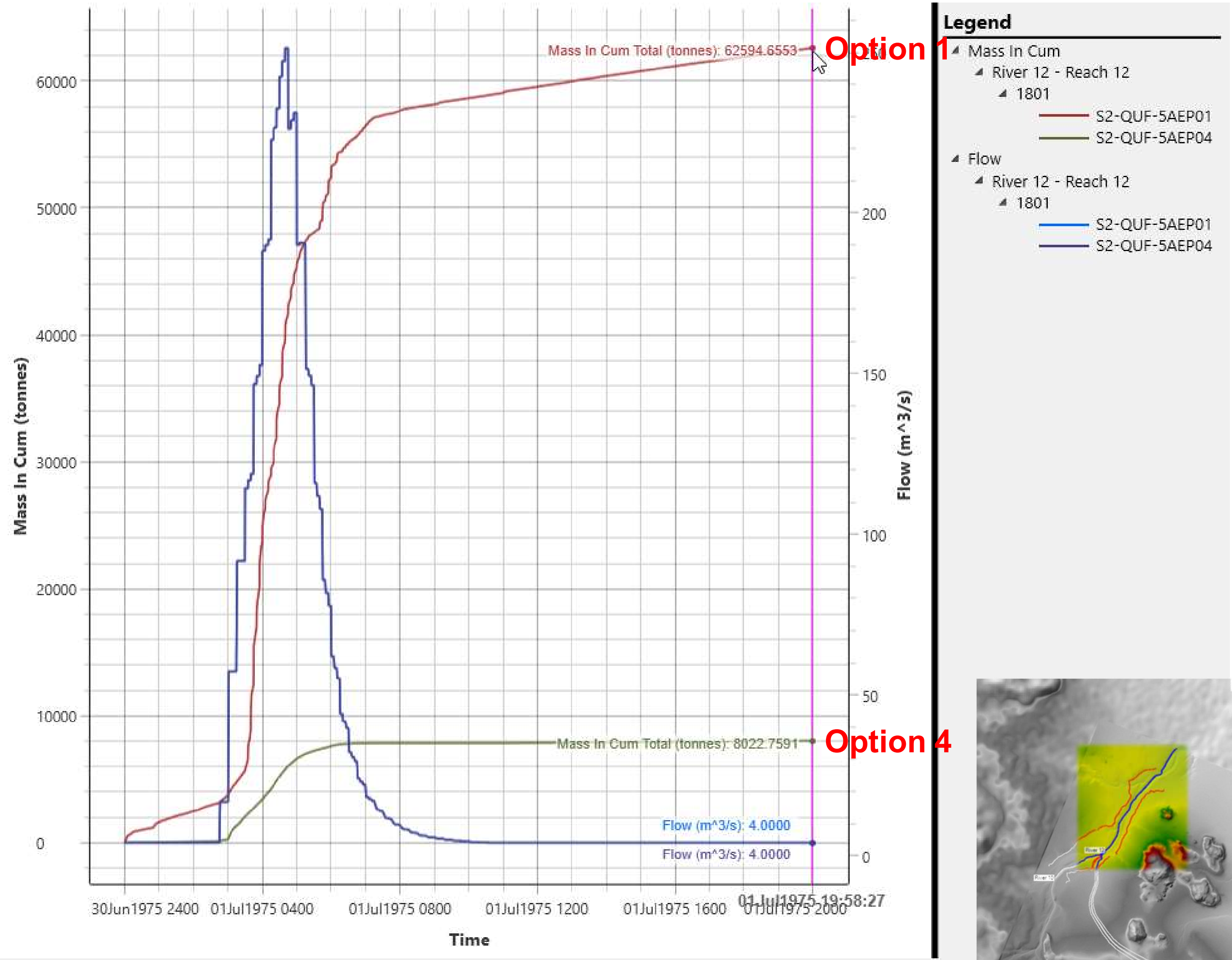


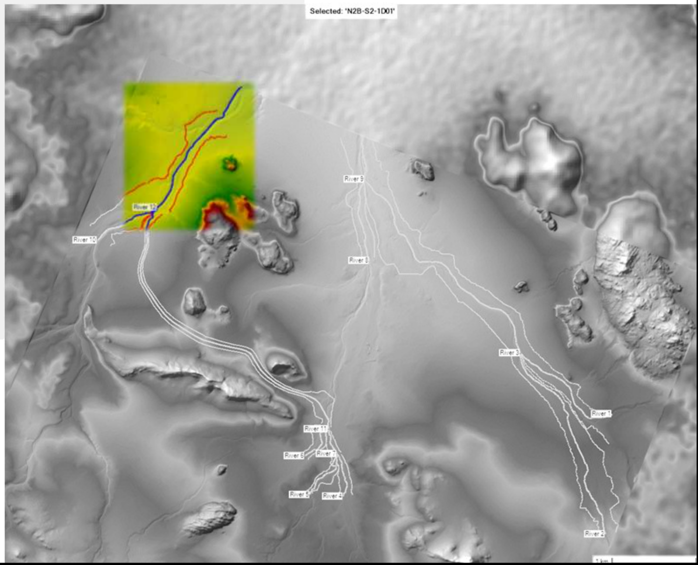
River 11 – Station 5 (D/S)



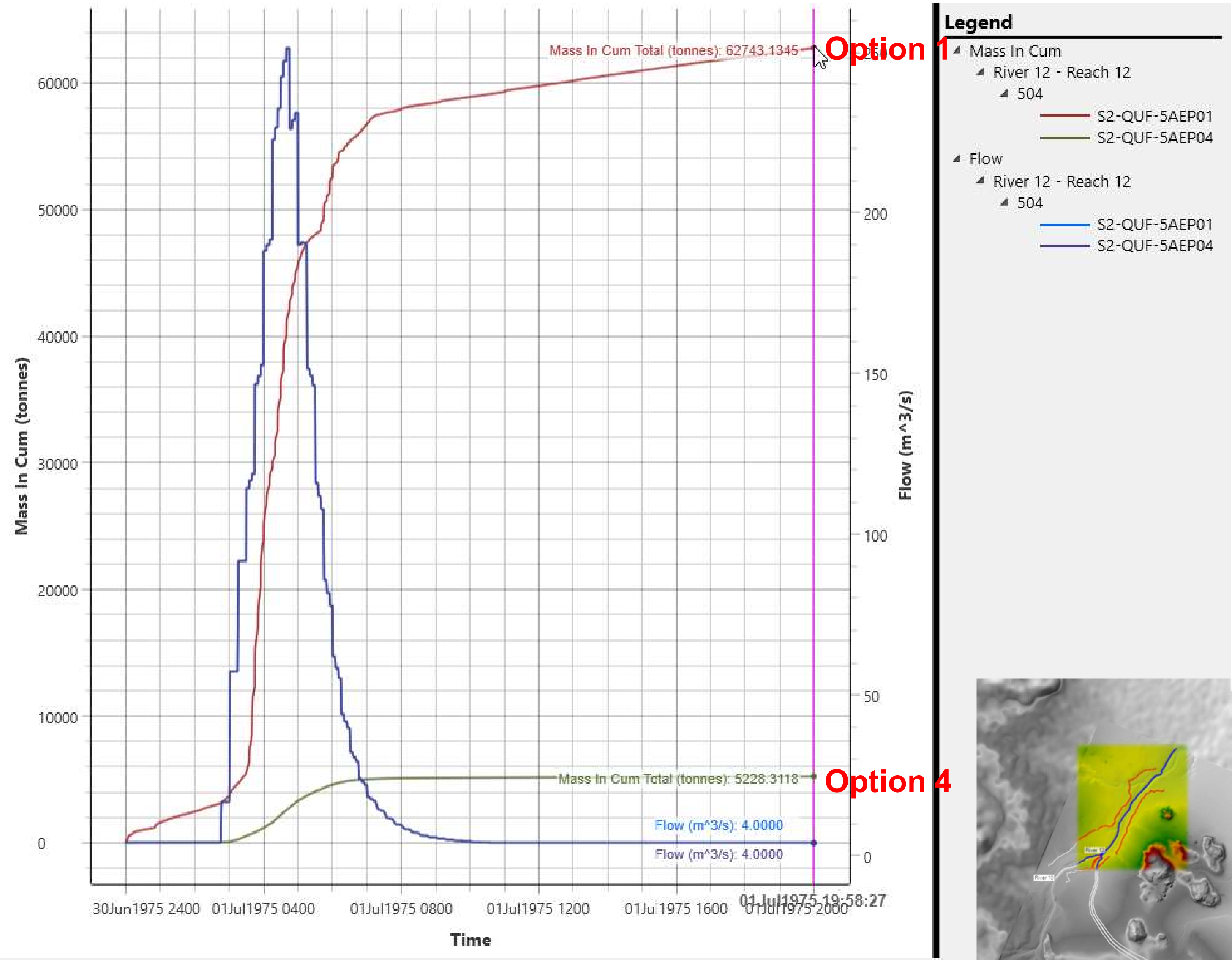


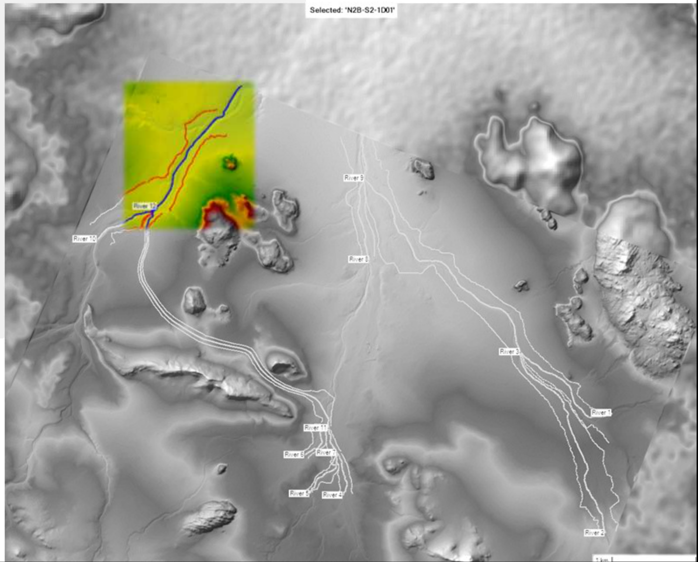
River 12 – Station 1801 (U/S)





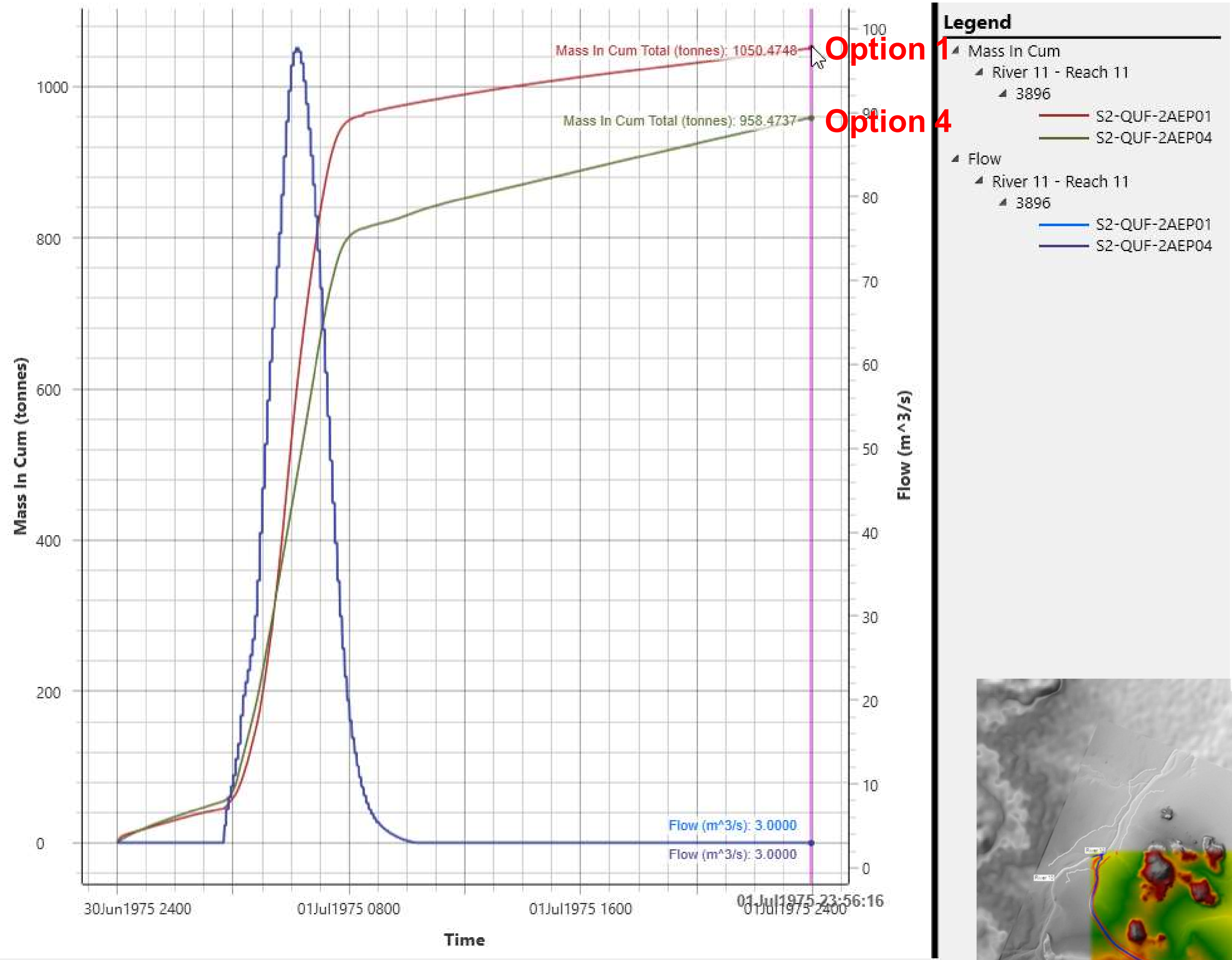
River 12 – Station 504 (D/S)

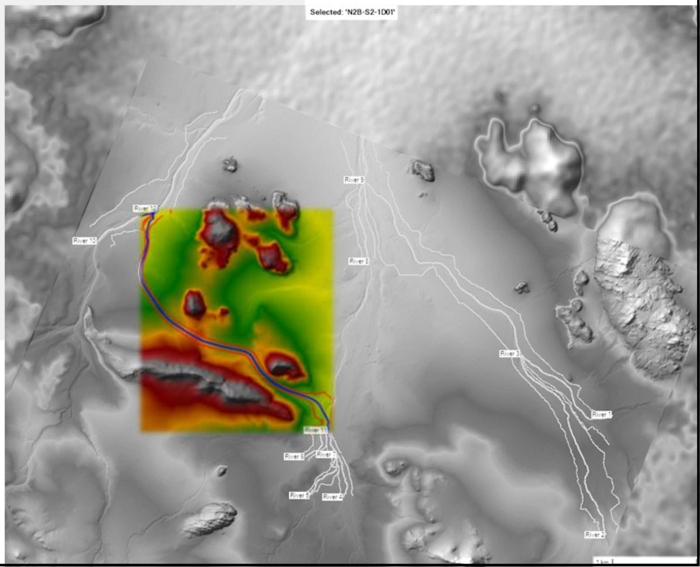




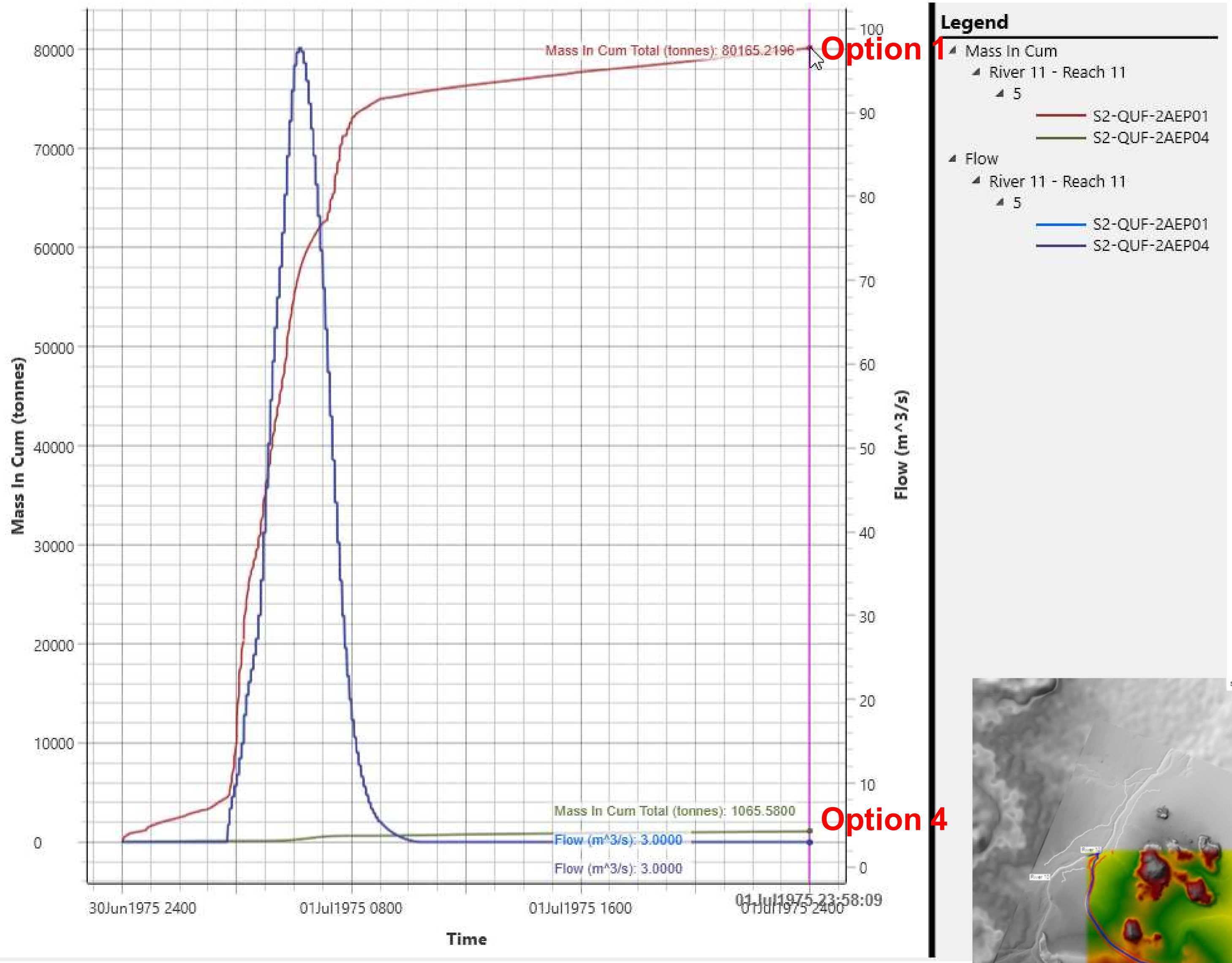
Mass In (1 in 20 AEP)

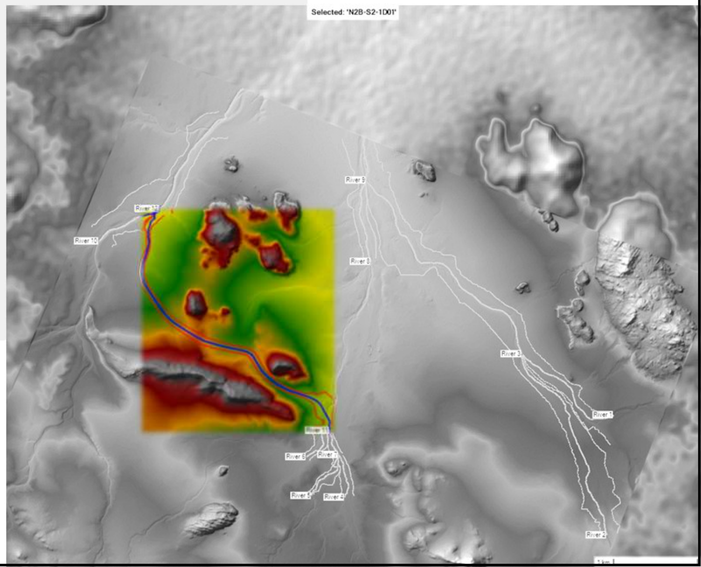
River 11 – Station 3896 (U/S)



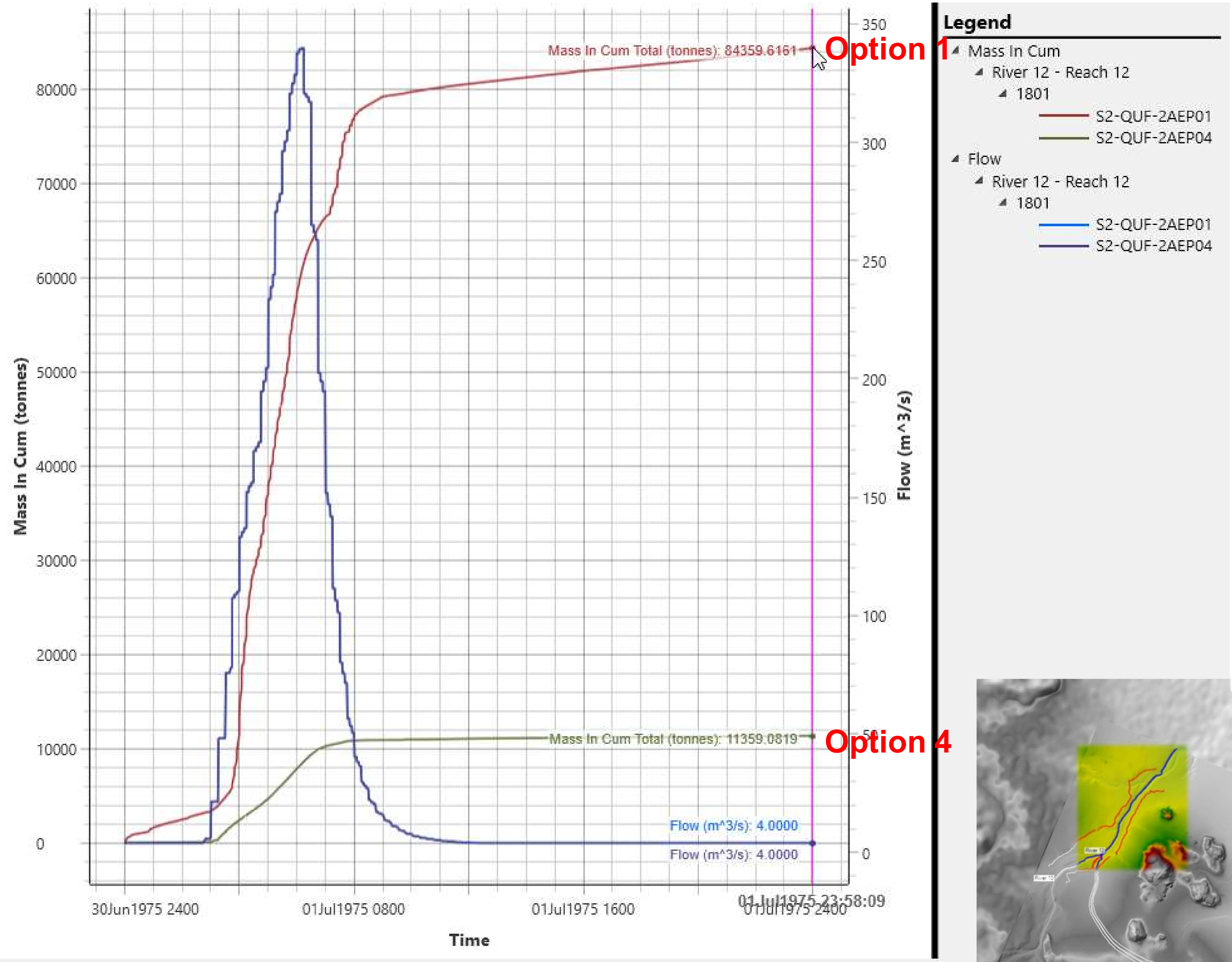


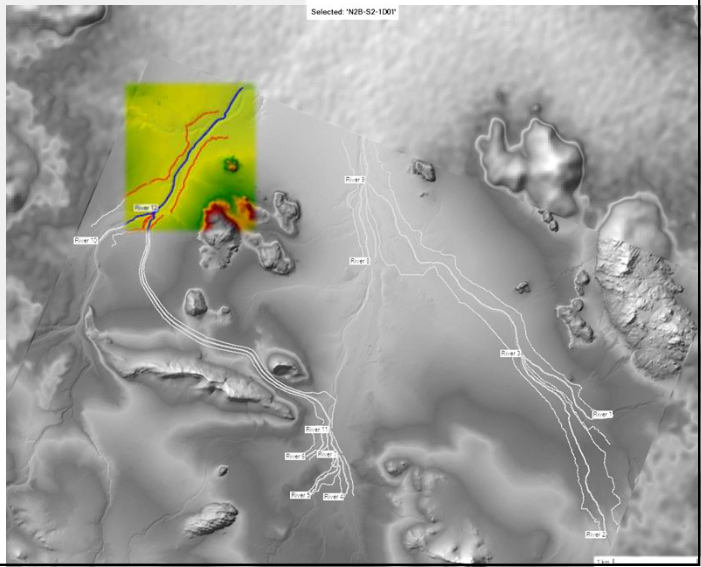
River 11 – Station 5 (D/S)



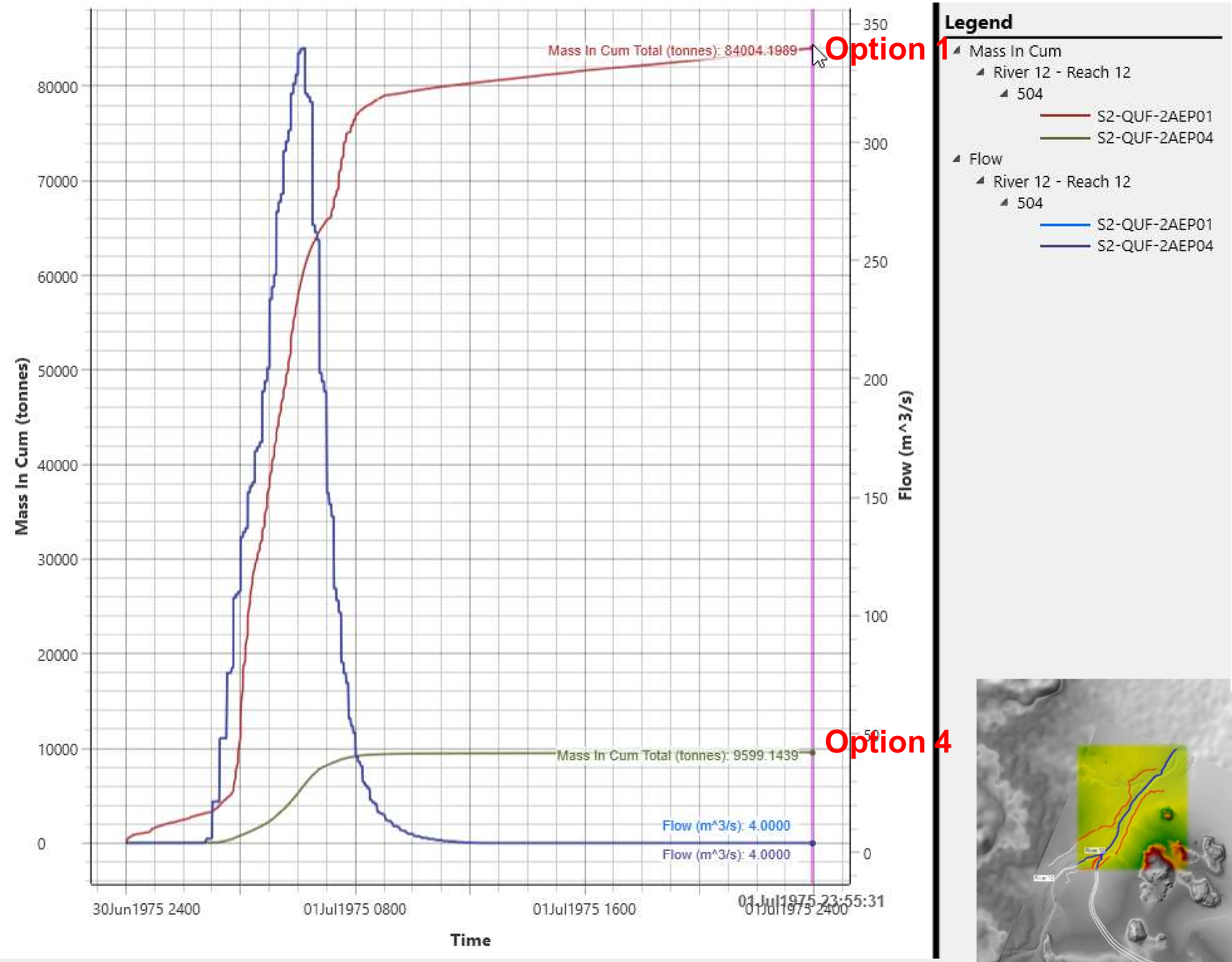


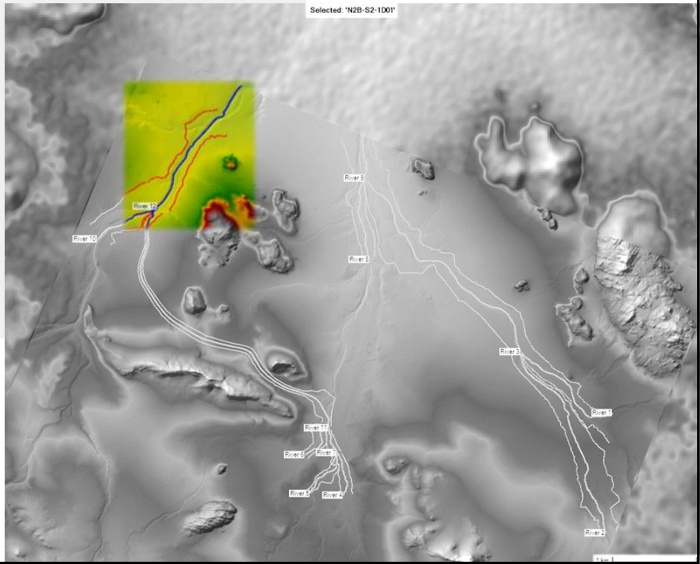
River 12 – Station 1801 (U/S)





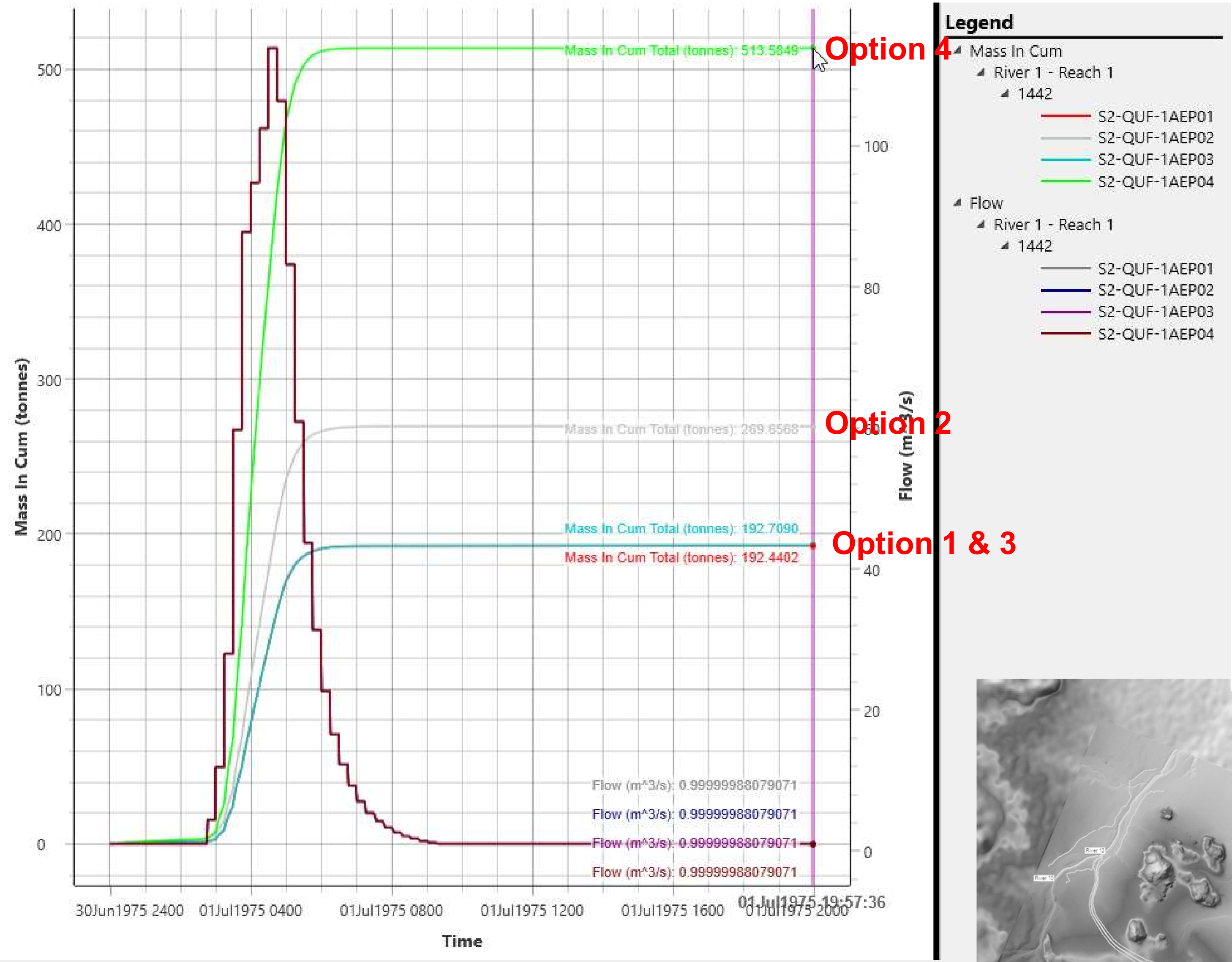
River 12 – Station 504 (D/S)

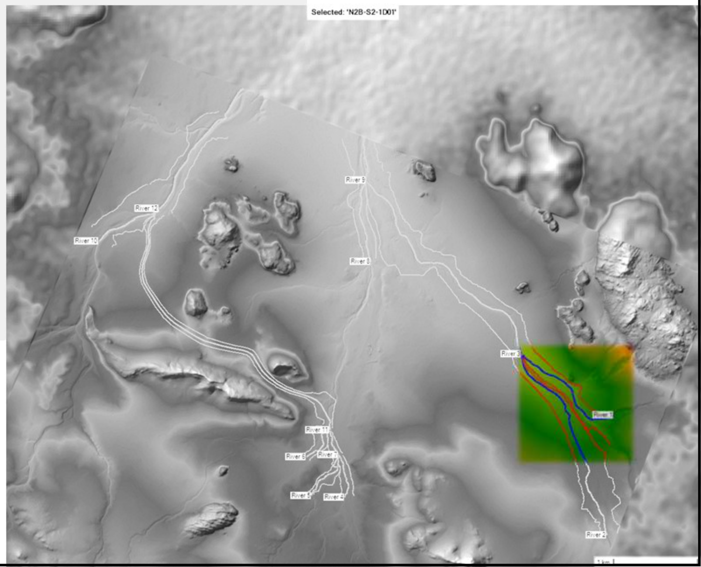




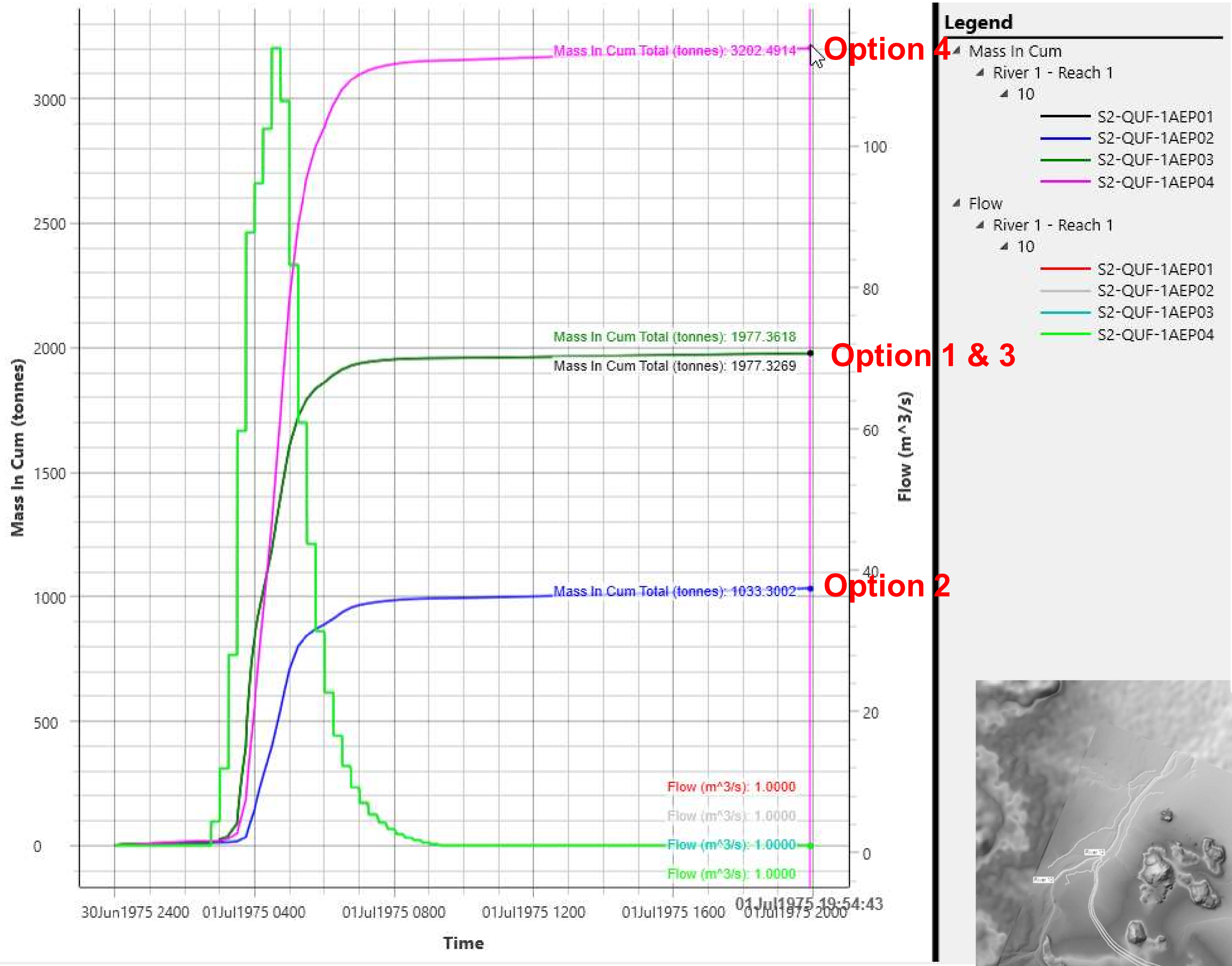
Mass In (1 in 100 AEP)

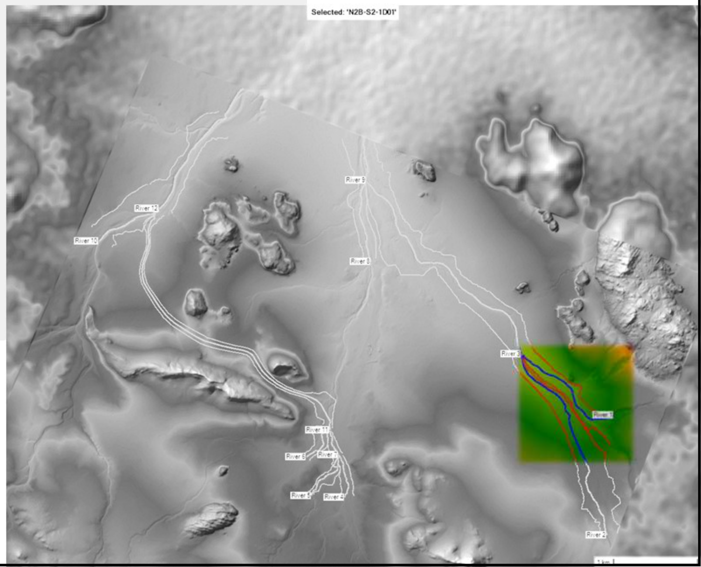
River 1 – Station 1442 (U/S)



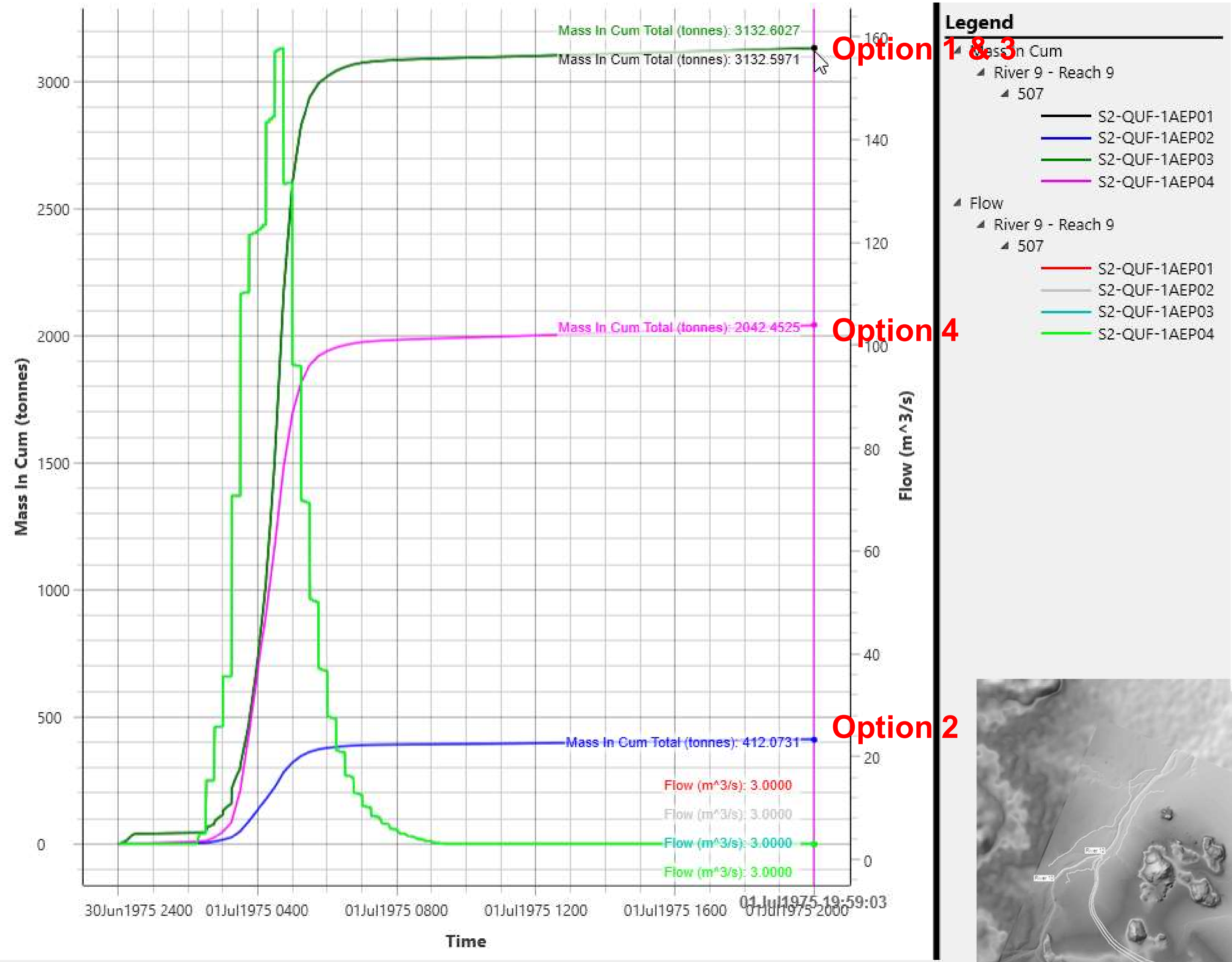


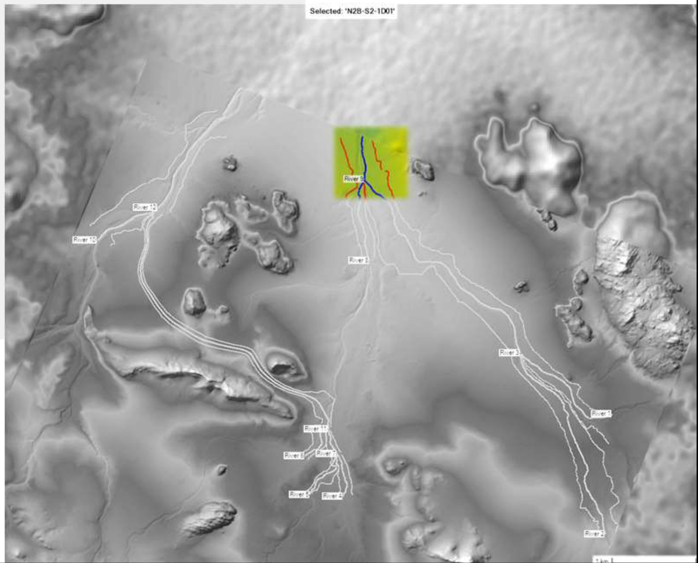
River 1 – Station 10 (D/S)



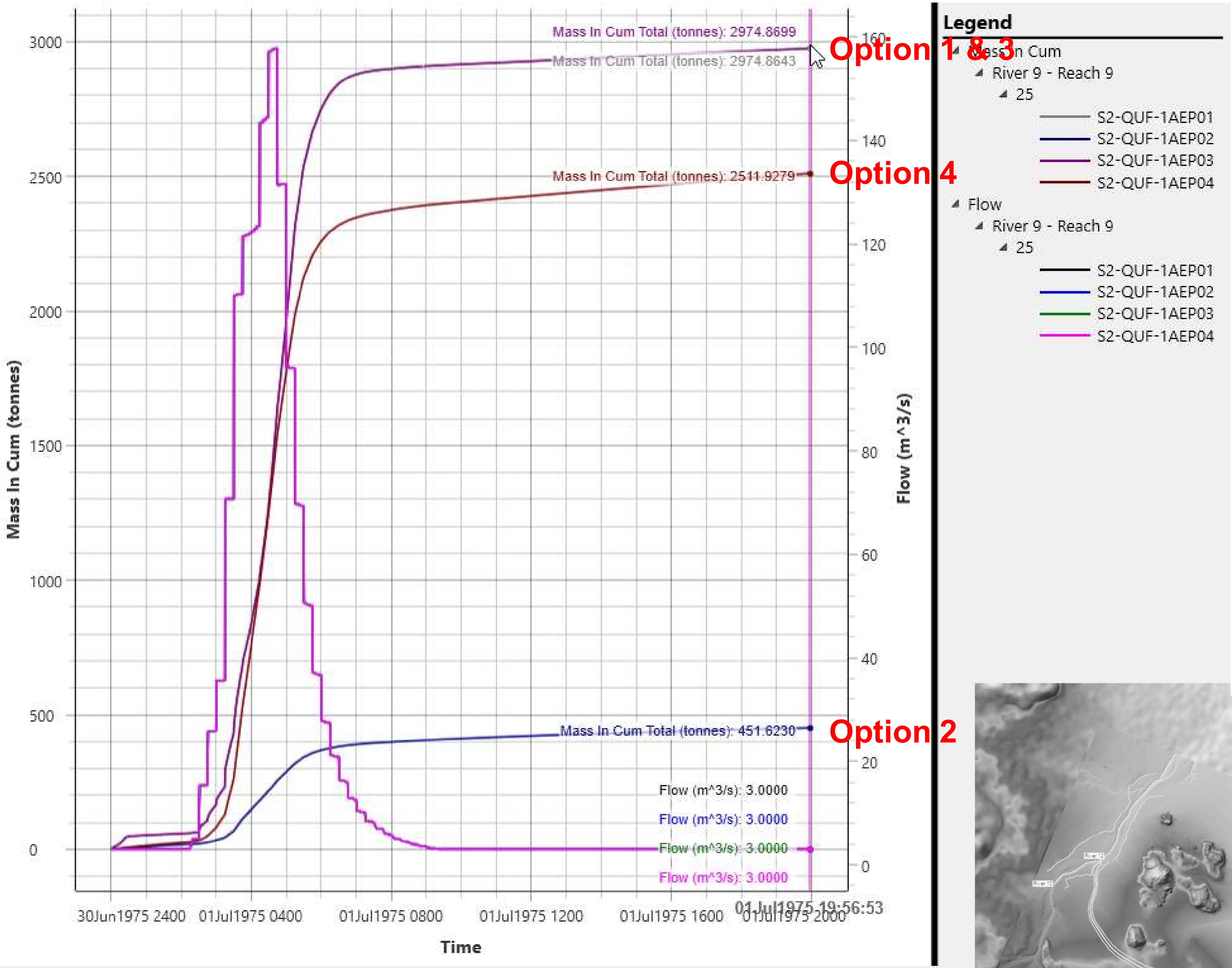


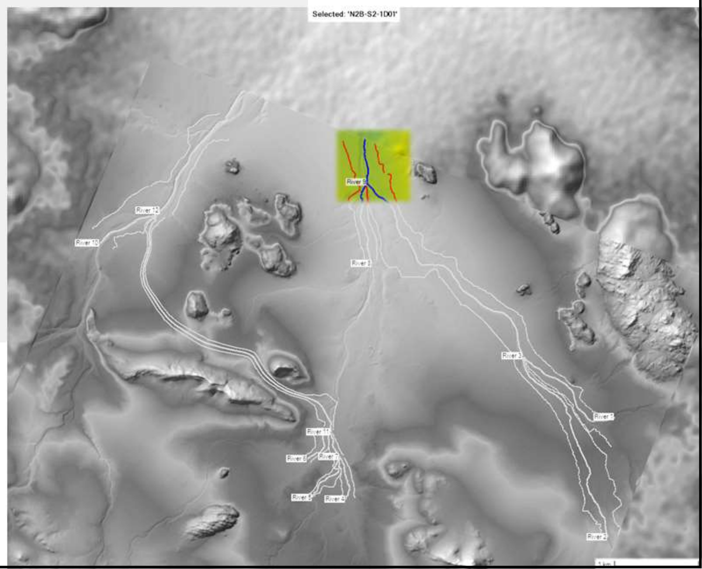
River 9 – Station 507 (U/S)



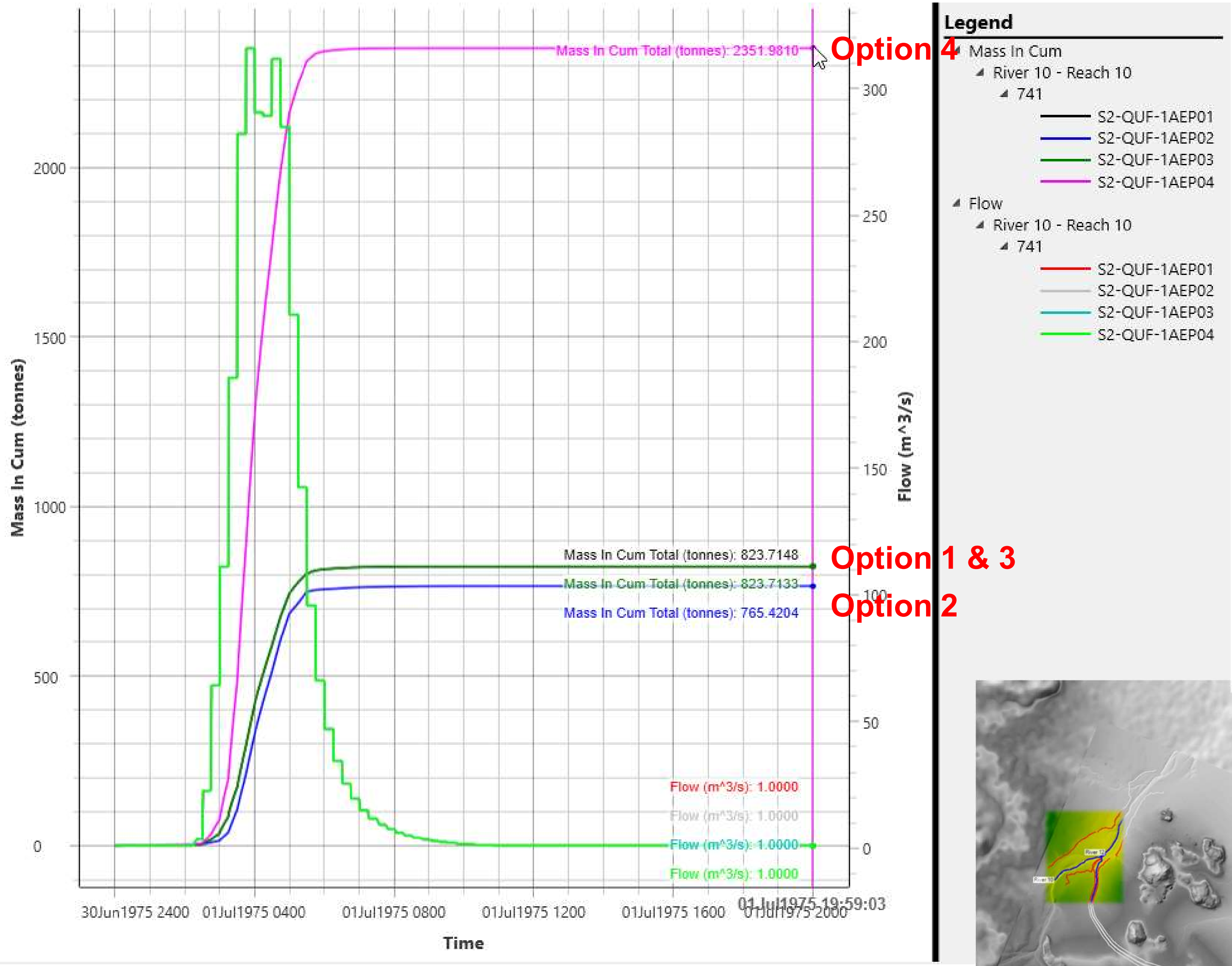


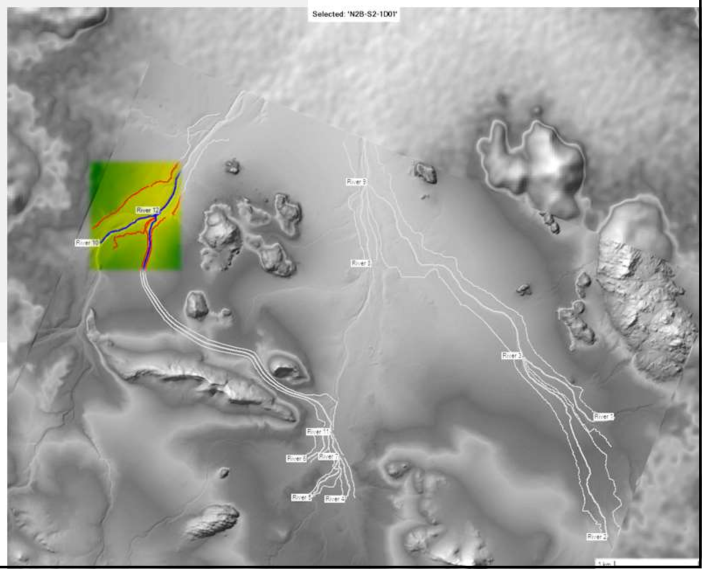
River 9 – Station 25 (D/S)



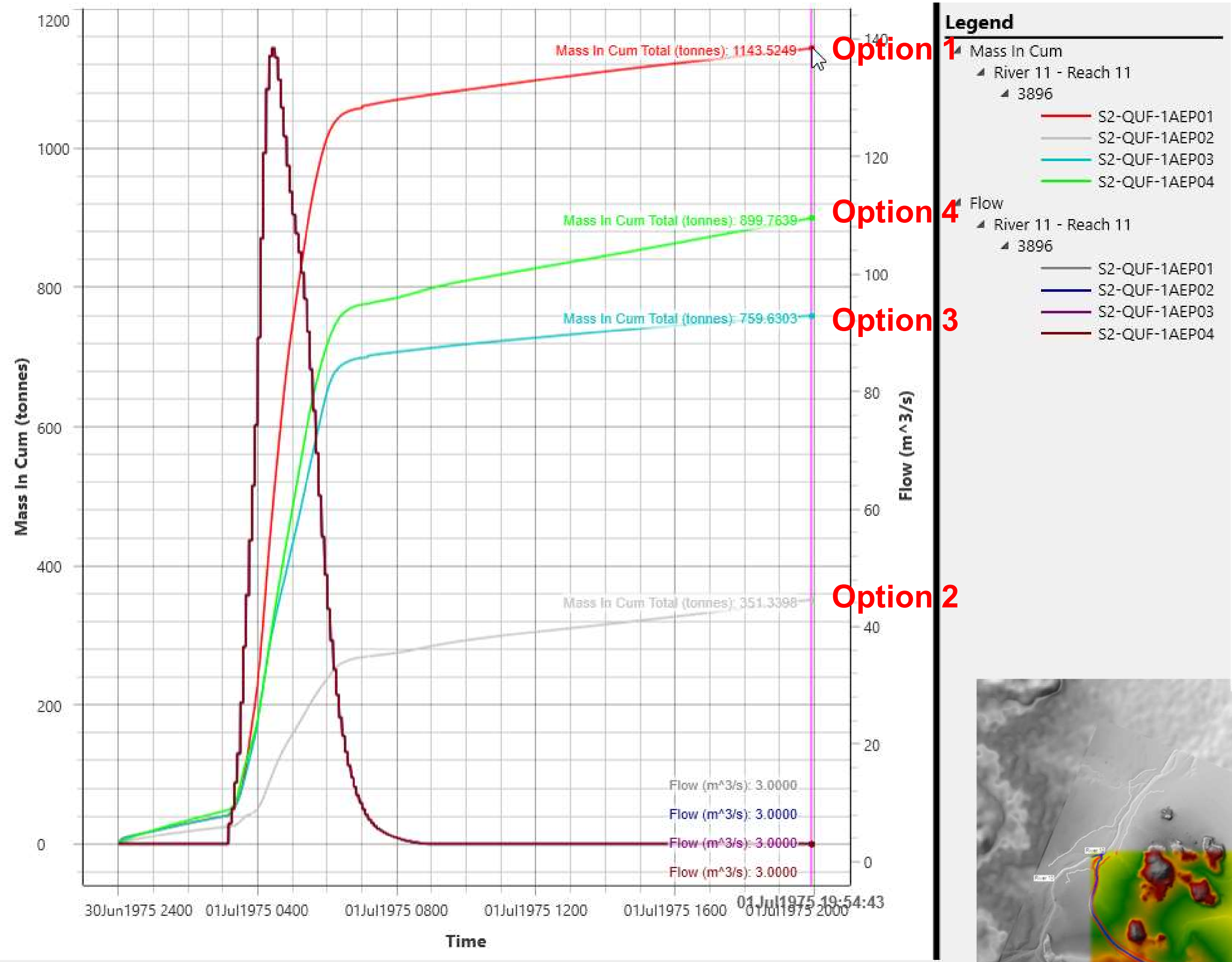


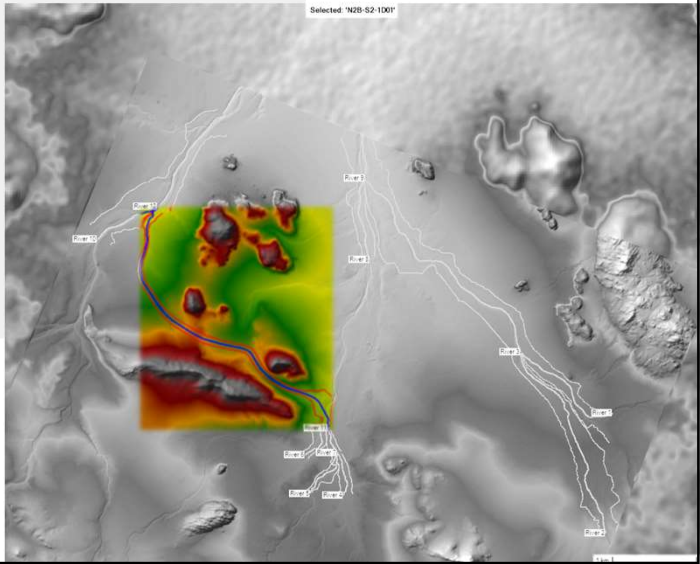
River 10 – Station 741 (U/S)



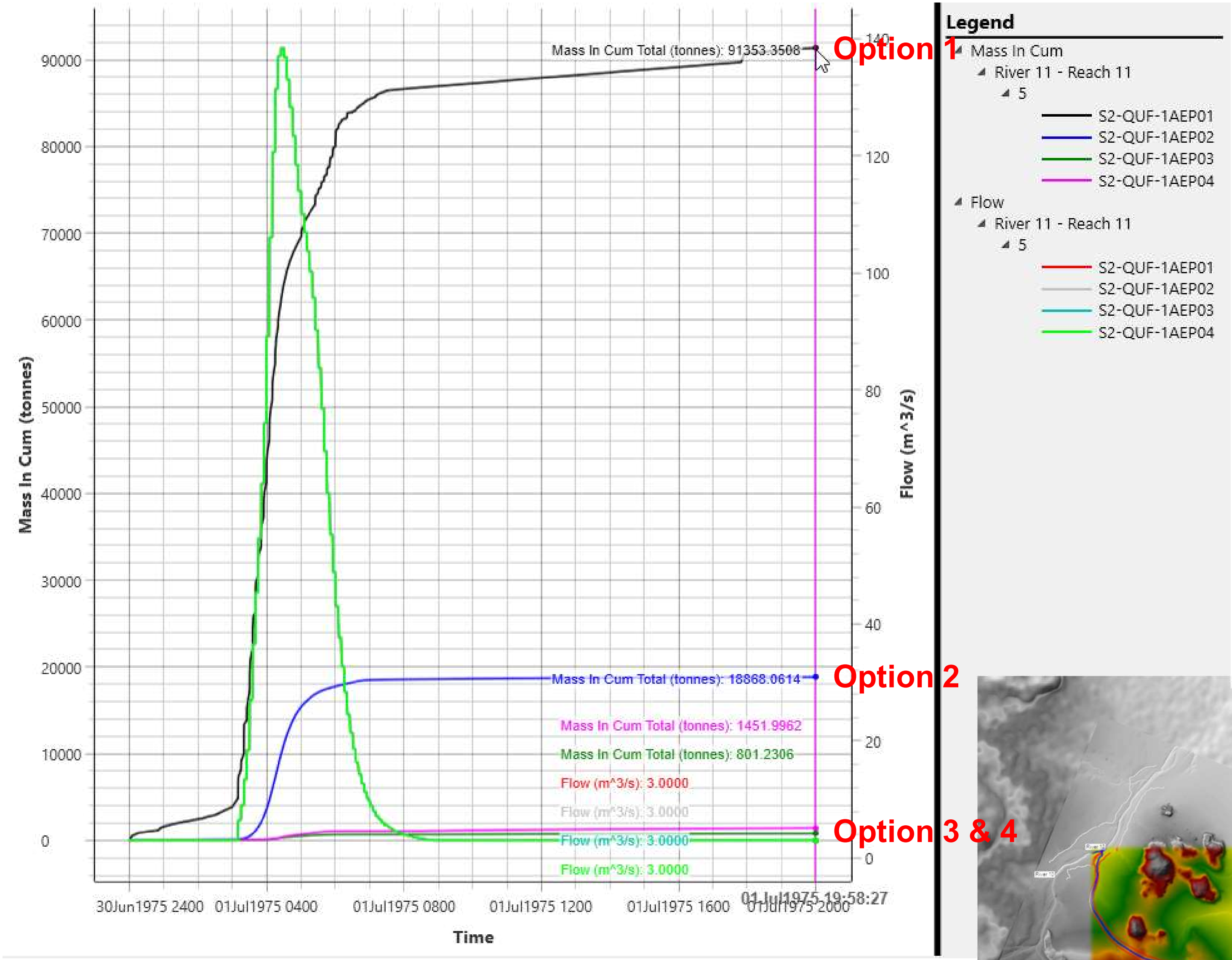


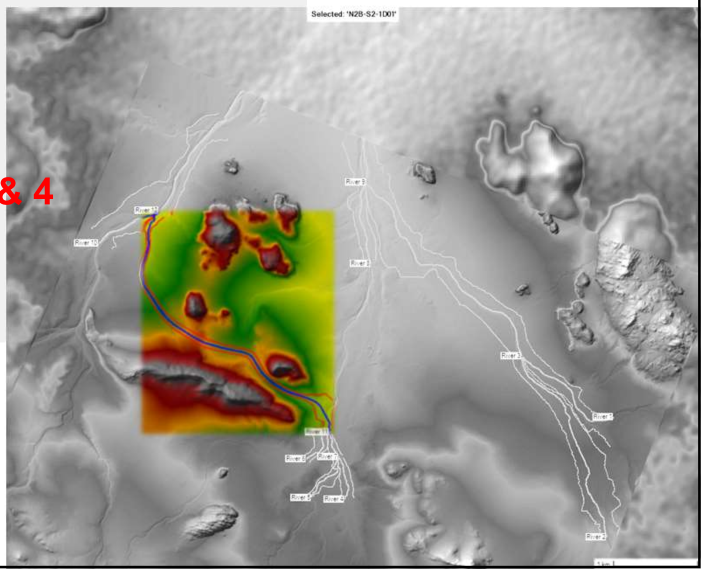
River 11 – Station 3896 (U/S)



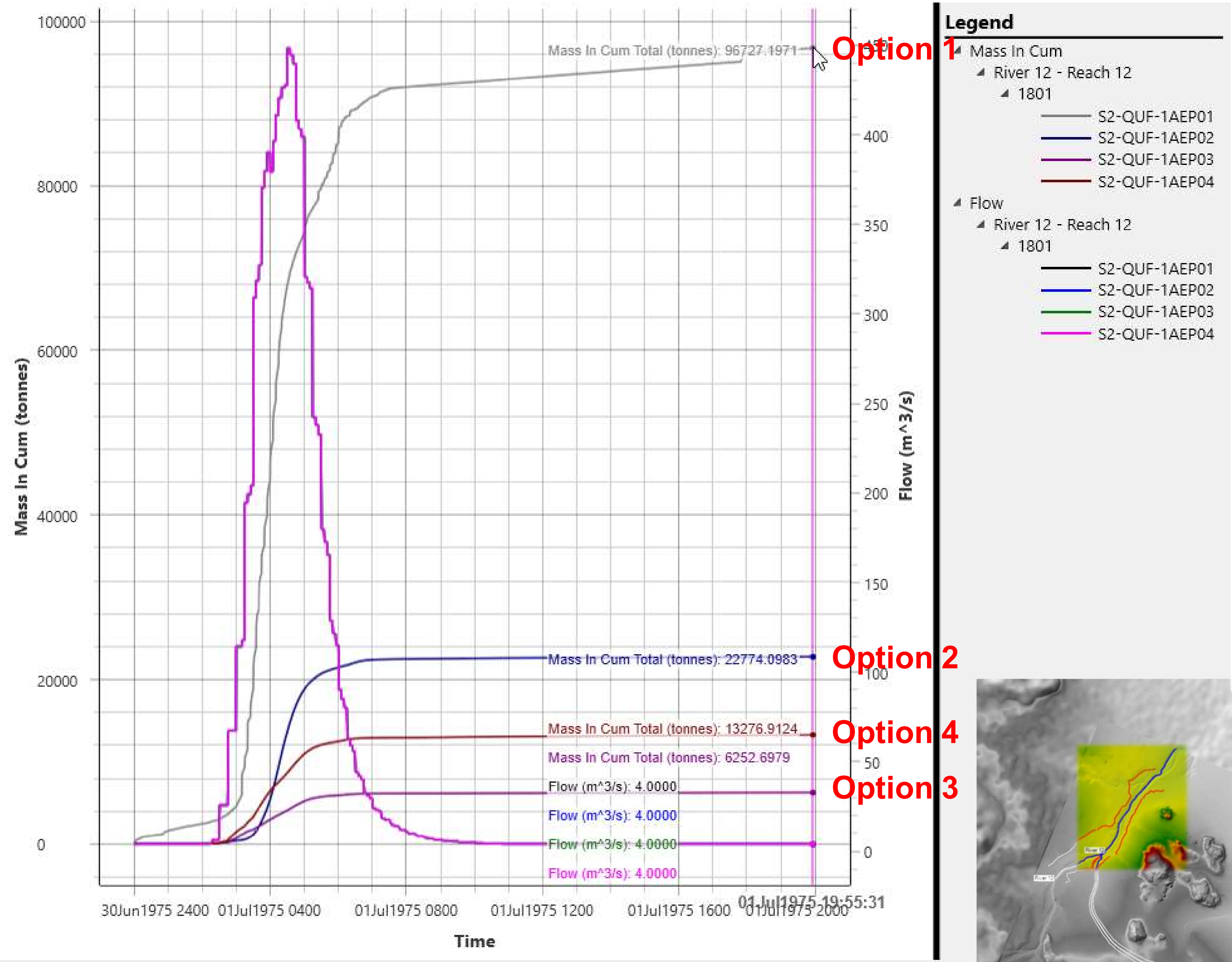


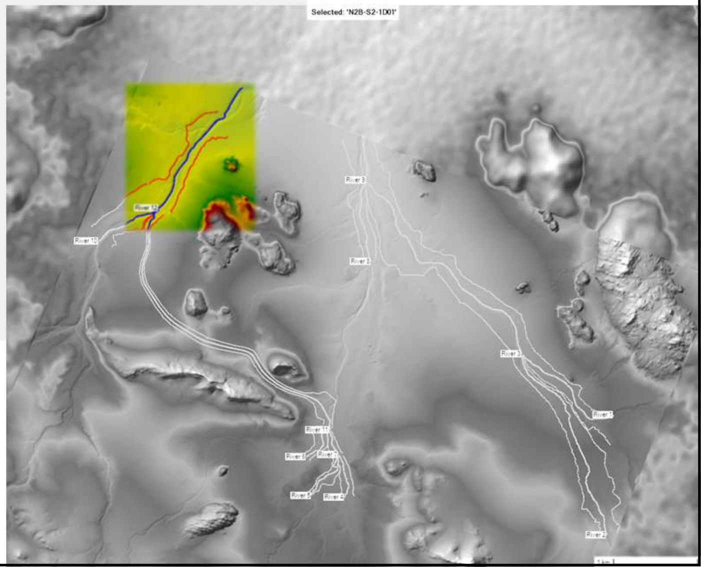
River 11 – Station 5 (D/S)



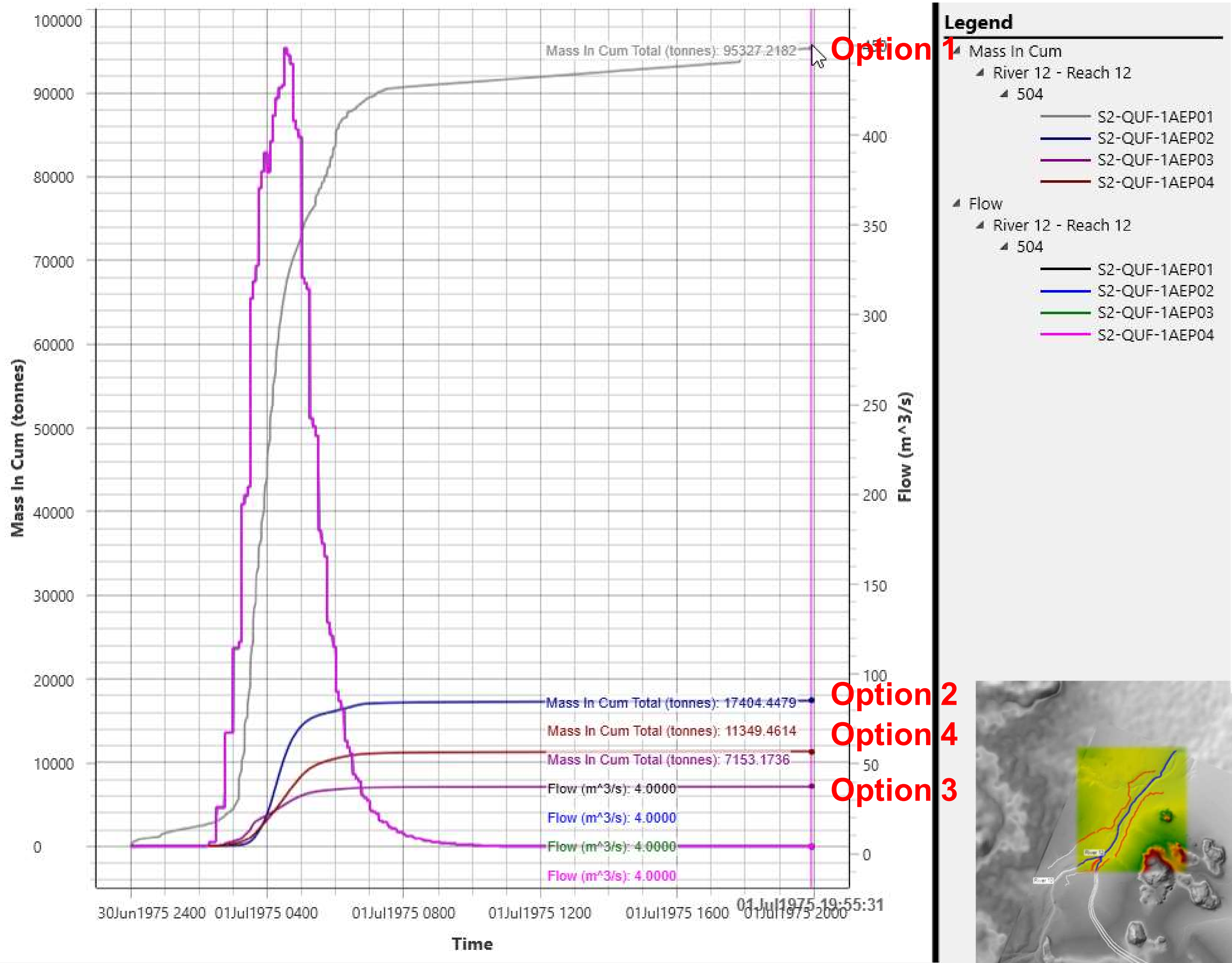


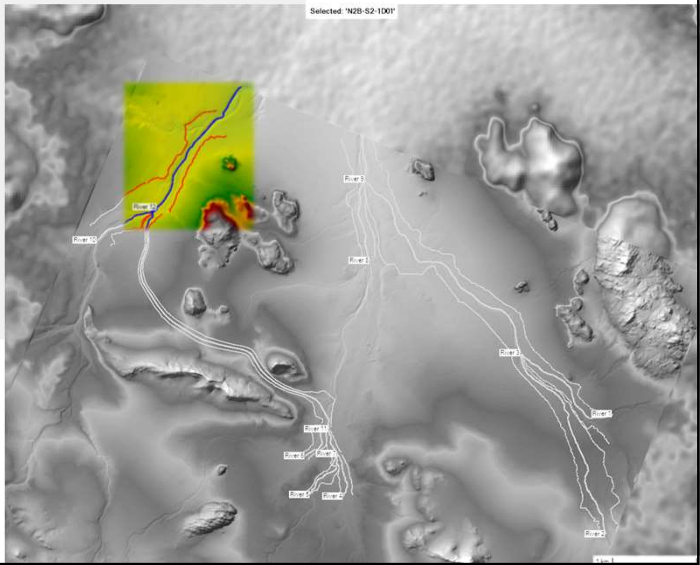
River 12 – Station 1801 (U/S)





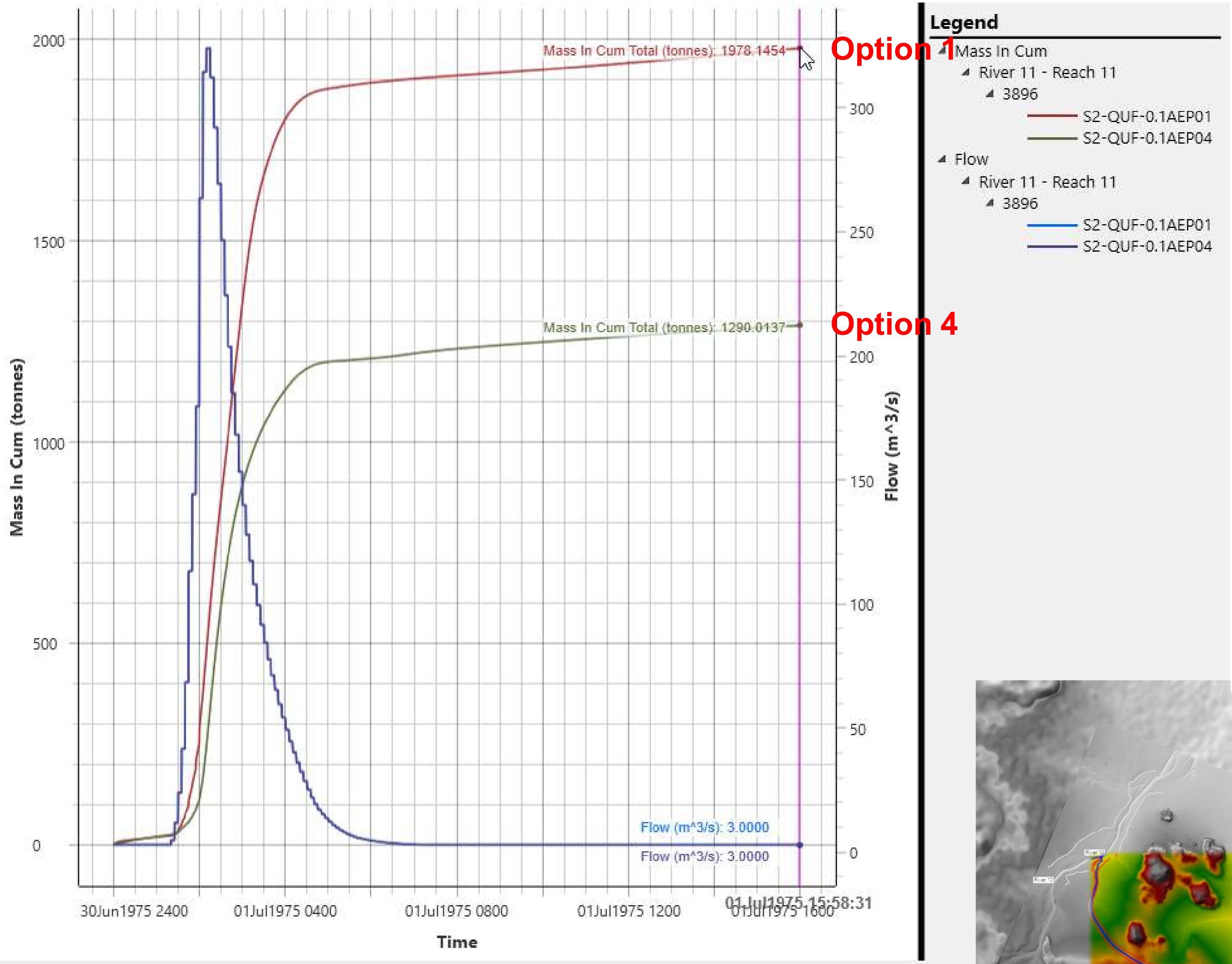
River 12 – Station 504 (D/S)

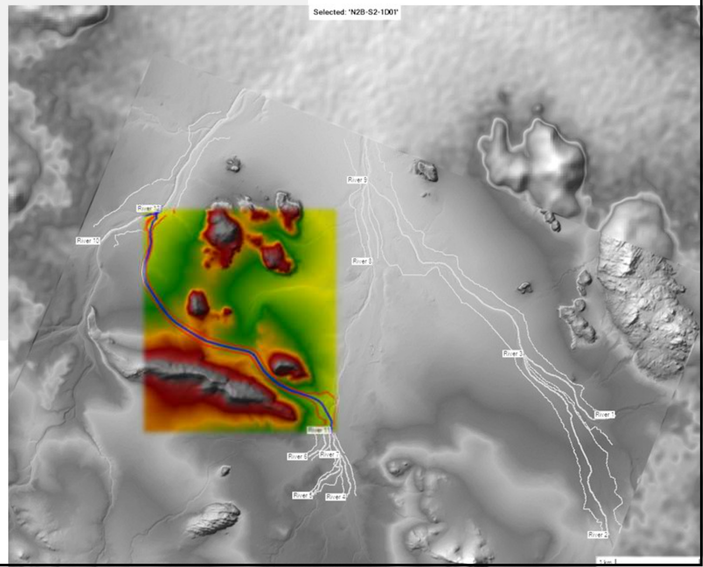




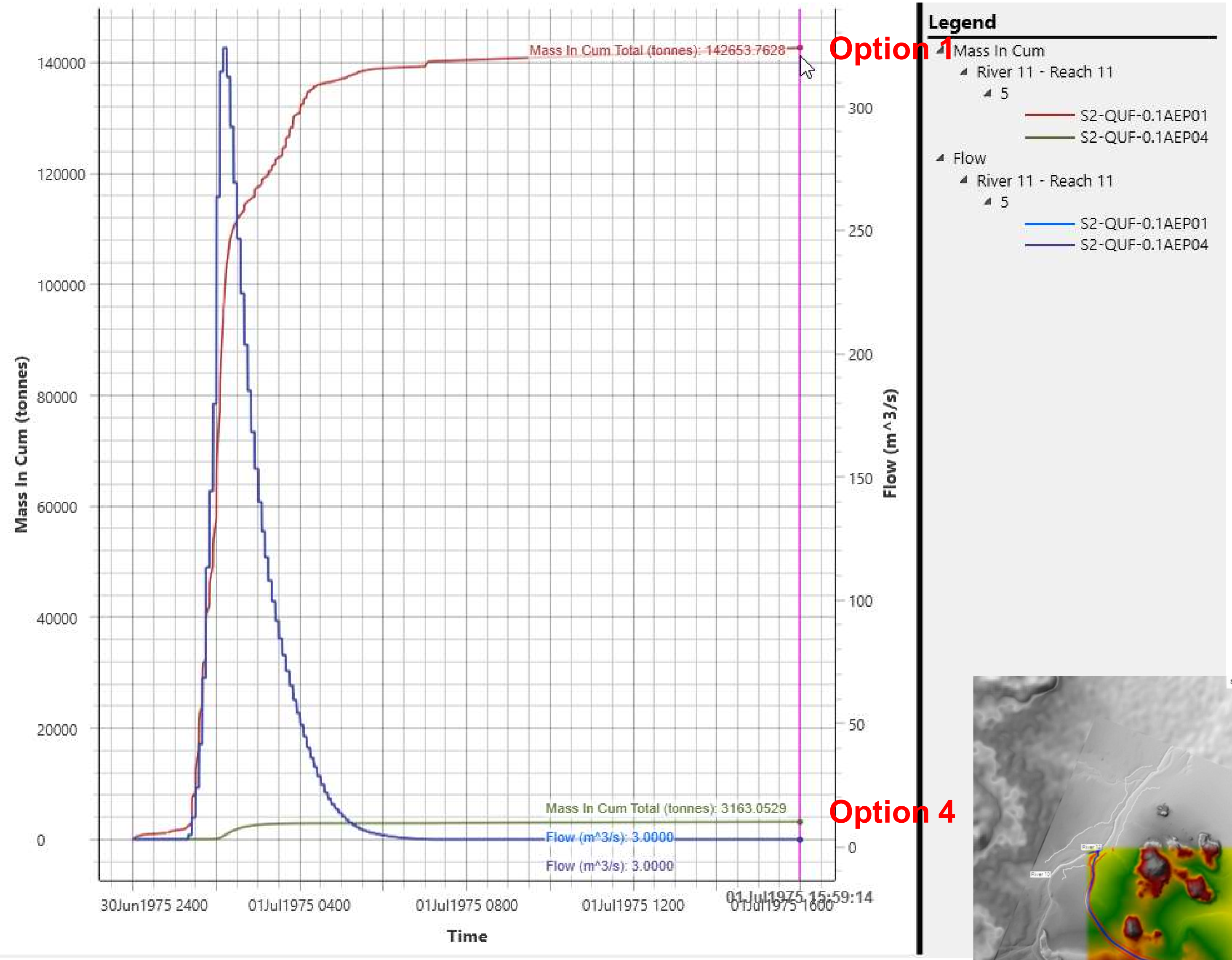
Mass In (1 in 1,000 AEP)

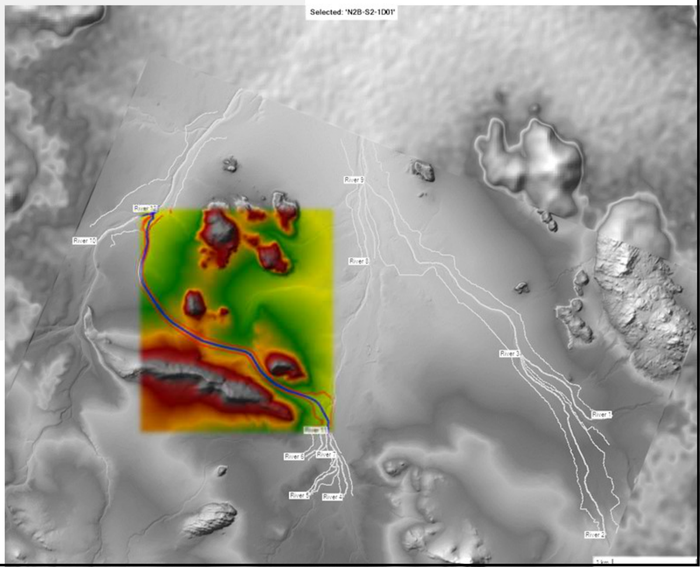
River 11 – Station 3896 (U/S)



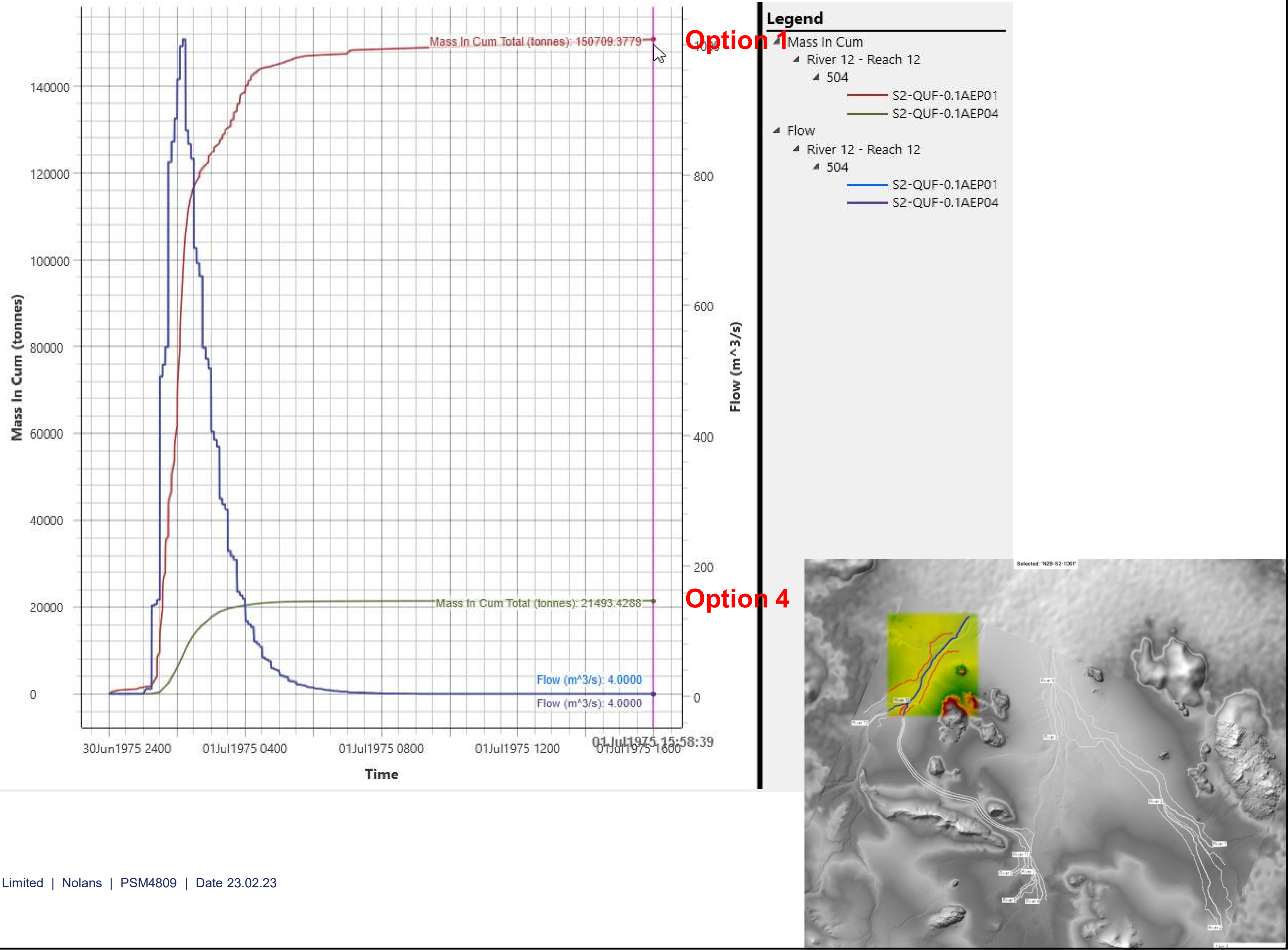


River 11 – Station 5 (D/S)





River 12 – Station 1801 (U/S)



River 12 – Station 504 (D/S)