

# Final Report

## Eliwana Mine Project Discharge Assessment

Fortescue Metals Group

January 2018





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# 1 INTRODUCTION

Development of the Eliwana Mine Project has the potential to encounter periods of surplus dewatering and as such, surface discharge to local ephemeral creek systems is a water management strategy that is being investigated Fortescue Metals Group (Fortescue). Water Technology (WT) has been commissioned by Fortescue to complete an assessment of potential discharge scenarios to determine the possible extent of discharge. This report outlines the methodology, assumptions, results and recommendations derived from Water Technology's analysis.

## 2 METHODOLOGY

The primary objective of this project was to determine the respective discharge extents for different controlled discharge scenarios. The process applied in completing this is described below:

1. Data collection
  - a. Adoption of Fortescue discharge rates
  - b. Collection of topographic data
2. Hydrologic Assessment
  - a. Assessment of conceptual water balance
  - b. Review of local geology to determine infiltration rates based on current literature
3. Development of a hydraulic model using TUFLOW HPC (BUILD: 2017-09-AA)
4. Results Analysis/Mapping

To accurately assess the footprint of controlled discharge locations, key inputs needed to be assessed, which are presented in Figure 2-1.

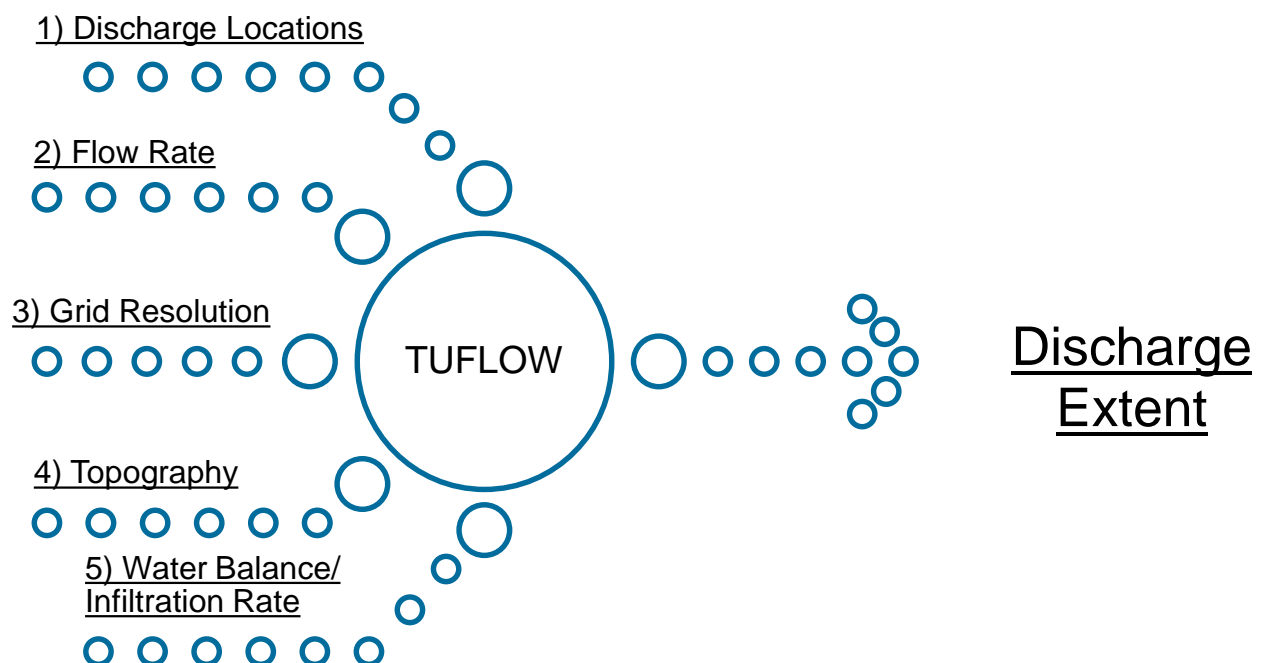


FIGURE 2-1 TUFLOW INPUTS



## 3 DISCHARGE LOCATIONS

Two controlled discharge locations were selected for the purposes of hydraulic modelling. These locations have been based on suitable sites close to below water table mining areas. These two locations have been presented in Figure 3-1.

### 3.1 Flow Rate

The peak rate of discharge to be modelled was supplied by Fortescue as 350 L/s, which translates to 30.24 ML/day. Fortescue have advised that based on current water balance modelling, this rate is a conservative estimate of the upper limit of potential discharge rate, although it is unlikely that such a rate would be sustained over an extended period, for modelling this peak rate has been held constant in attempt to quantify the maximum possible dry weather extent.

### 3.2 Grid Size

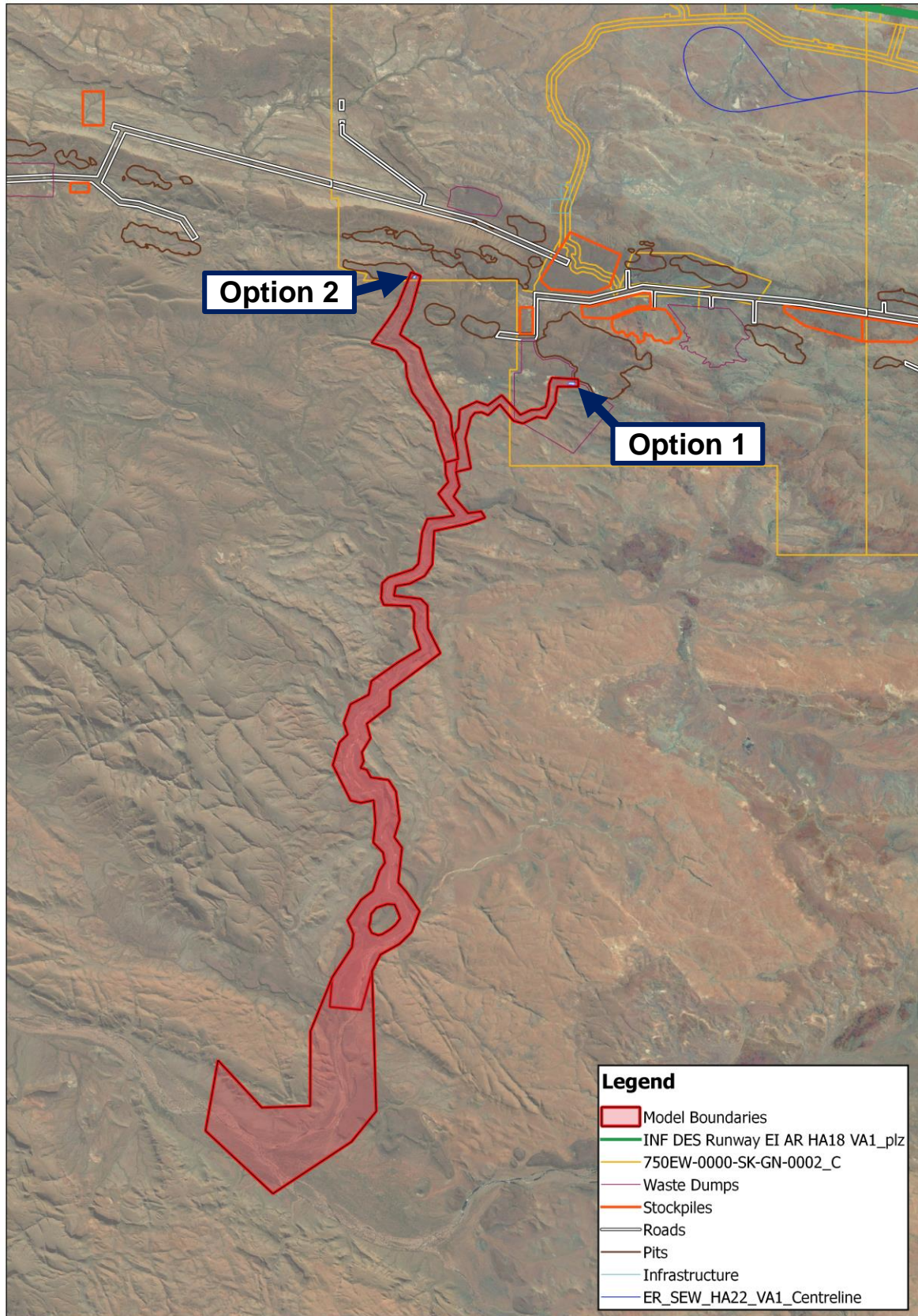
A 2m resolution was used in the TUFLOW hydraulic model. This resolution was selected as it resulted in a scale fine enough to capture key topographic changes within the creek systems while still enabling practical model run times.

### 3.3 Topography

Photogrammetry was the primary form of data provided by FMG, captured in June 2014. A small amount of LiDAR was available for the Northern sections of the option 1 and option 2 model extents. The date of capture of the option 1 LiDAR was April 2012 while the option 2 LiDAR was captured in June 2017. The extent of each topographic dataset is shown in Figure 3-2.

Furthermore, an assessment of LiDAR vs Photogrammetry was completed for option 1 to determine both the sensitivity and differences associated with photogrammetry and LiDAR in overlapping areas. Figure 3-3 highlights a sample long section comparison.

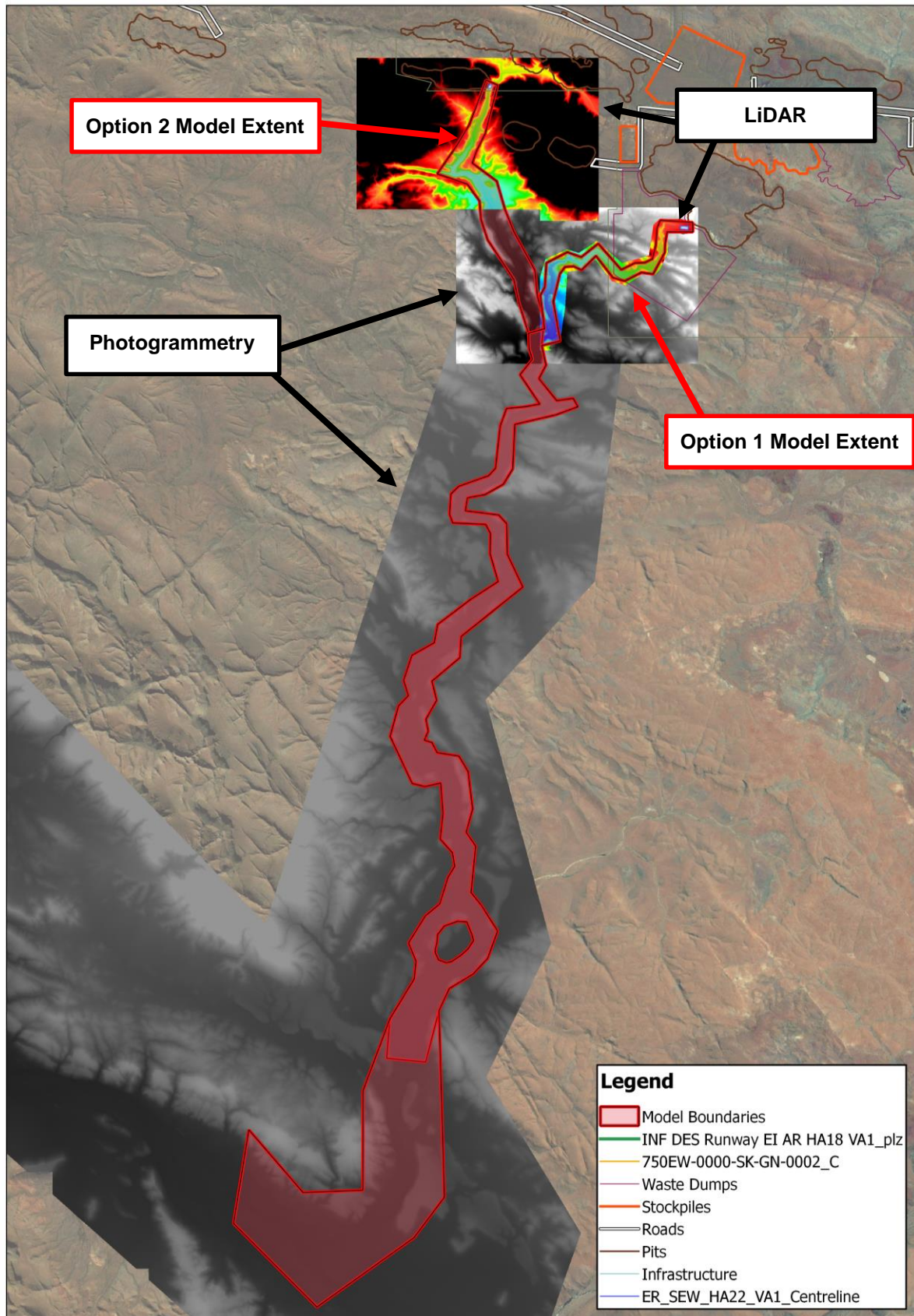




**FIGURE 3-1 DISCHARGE OPTIONS**

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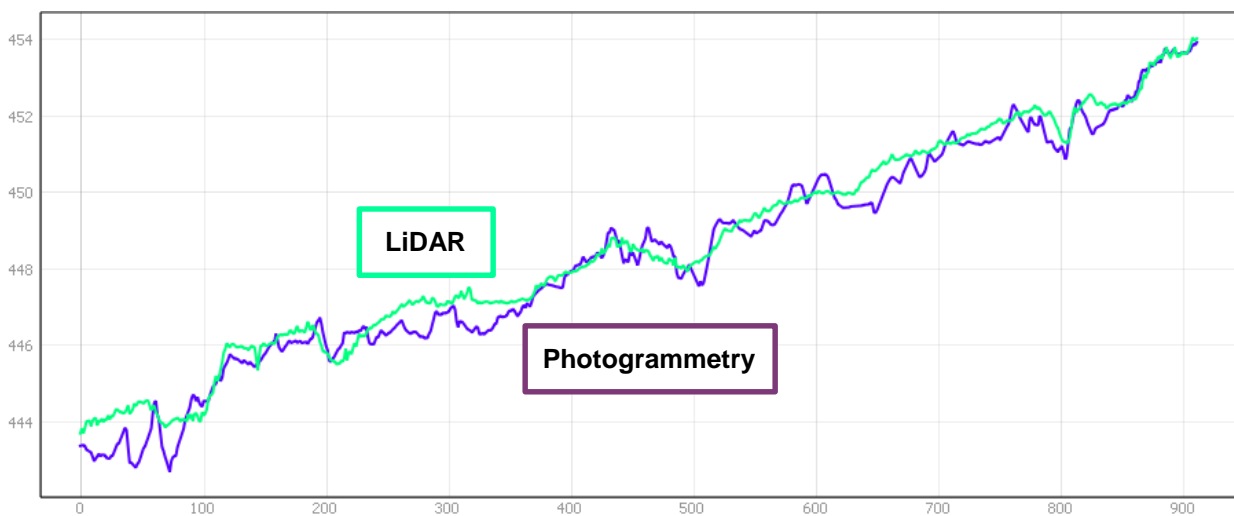
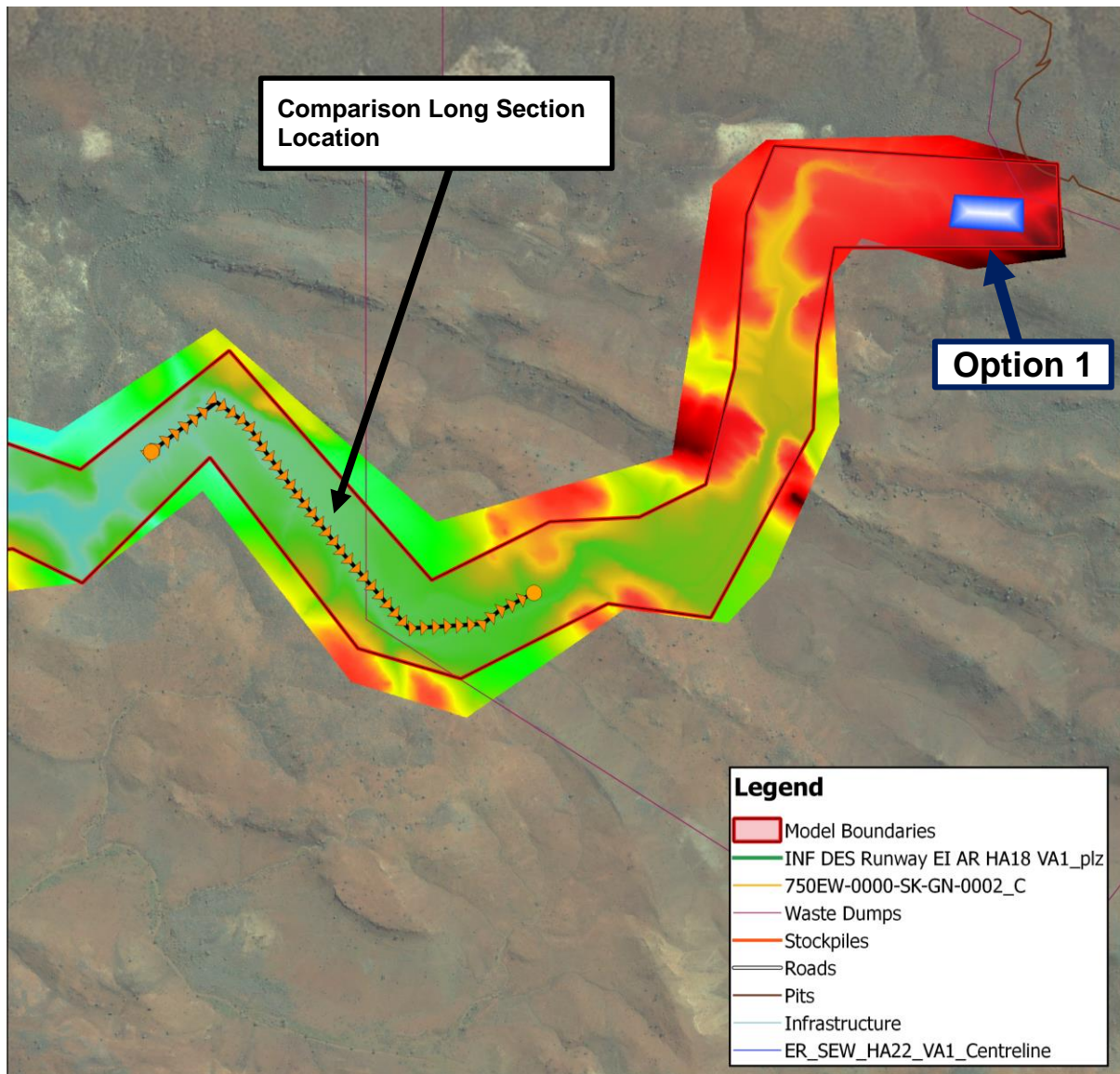




**FIGURE 3-2 LIDAR VS PHOTOGRAMMETRY EXTENTS**

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**FIGURE 3-3 LIDAR VS PHOTOGRAMMETRY COMPARISON LONG SECTION**

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Figure 3-3 demonstrates that moderate differences are present in the LiDAR vs Photogrammetry. The LiDAR has captured a greater level of detail compared to the Photogrammetry. As described in the metadata reports provided by AAM (2017), the accuracy of the LiDAR and Photogrammetry is summarised in Table 3-1.

**TABLE 3-1 LIDAR VS PHOTOGRAMTRY SUMMARY**

Topographic Data	Vertical Error	Horizontal Error
LiDAR	+/- 0.1m	+/- 0.2m
Photogrammetry	+/-0.3m	N/A

Given that the absolute error between the LiDAR and Photogrammetry is 0.4m, based on 1 standard deviation, this generally correlates with the differences observed in Figure 3-3. This indicates that the LiDAR is generally more accurate than the Photogrammetry. In areas of dense vegetation, the accuracy of the Photogrammetry is limited as it does not penetrate vegetation well to pick up the ground elevation. Whilst LiDAR can penetrate vegetation more effectively, both types of capture methods are ineffective through standing water bodies. In these areas, the ground elevations are simply interpolated across. Given the minor discrepancies, the datasets are generally comparable and able to be used in series as inputs within the TUFLOW modelling, however it is important to note the inherent limitations of the data.

A sensitivity assessment has been completed for Option 1, whereby LiDAR was available for the Northern section of the model extent. In the sensitivity analysis, LiDAR was removed and only Photogrammetry was utilised. The results of the TUFLOW sensitivity simulations are highlighted in Table 3-2.

**TABLE 3-2 PHOTOGRAMETY VS LIDAR COMPARISON**

Scenario	Stream Length (km)
Option 1 – 10mm/hr (Photogrammetry)	7.55
Option 1 – 10mm/hr (LiDAR)	8.20
Difference	0.65 (7.3%)

Table 3-2 indicates that the stream length has decreased when photogrammetry was applied. This is primarily due to the LiDAR providing finer detail, with better definition in the vegetated creek channels. This can result in a smaller channel width and/or a reduction in artificial depression storage within the reach. Hence, there is a slightly smaller surface area for water to infiltrate within each reach of the LiDAR model, resulting in a greater stream length.

While neither dataset provides a perfect representation of the true elevation, they both provide a reasonable level of confidence of ground level (based on horizontal and vertical accuracy) for conceptual characterisation of discharge extent.



## 4 CONCEPTUAL WATER BALANCE

To evaluate discharge extent, a conceptual water balance has been considered for the discharge environment, which includes components of evaporation, evapotranspiration, infiltration (including recharge), and rainfall which are described below.

### 4.1 Development of Steady State

This assessment involves simulation of steady state conditions to a point in which equilibrium occurs. The analysis considers dry weather conditions and simulates inflows and losses for a period until which time the volume in (provided via dewatering) equals volume out (provided by infiltration losses). The subsequent discharge footprint that is required to achieve this equilibrium is considered the maximum possible footprint given the conservative approach which has been adopted in this analysis.

### 4.2 Infiltration Rate

The infiltration rate determines the rate of outflow from the model for each grid cell. With no other mechanism for water to exit the model, the rate of infiltration dictates the number of wet cells the model requires to reach a state of equilibrium. As such, the adopted infiltration rate needs to be conservative and reference appropriate scientific sources.

McKenzie et al, (2000) provides estimation of soil properties using the Atlas of Australian Soils. This found that for the area encapsulating the discharge locations, an infiltration rate ranging from 3-300 mm/hr could be expected. Given that the Atlas of Australian soils does not feature definition of channels, and given the broad range of expected values, this source does not provide suitable definition or accuracy which will enable adoption of an infiltration rate in the case of this assessment.

To provide guidance on the likely soil classification present within the local creeks, the 250K scale Government Geology layer from the Geological Survey of Western Australia was utilised. This spatial file classified the soil type within the main creek channels, which are subject to dewatering, as:

*“Alluvium unconsolidated silt, sand, and gravel; in drainage channels and on adjacent floodplains”*

The United States Department of Agriculture (USDA) National Engineering Handbook provides guidance on varying hydrologic soil groups. Table 4-1 below highlights the USDA recommended infiltration rates based on general soil types which have been converted to mm/hr.

**TABLE 4-1 USDA SOIL CLASSIFICATIONS**

Soil Category		
A	<i>“Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.”</i>	>36mm/hr



Soil Category		
B	<i>“Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.”</i>	36mm/hr – 14.4mm/hr
C	<i>“Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.”</i>	14.4mm/hr – 1.4mm/hr

Based on the USDA soil classifications, it is evident that material characterised by high clay content features low infiltration rates, while material featuring high proportions of sand feature significantly greater infiltration rates. It is important to note that observations from creek bed inspections completed by Fortescue have not indicated the presence of high clay content to date. This indicates that the material likely aligns with categories A and B as opposed to category C.

Furthermore, it is important to note that these losses are for saturated conditions, which are significantly less than what would occur in unsaturated scenarios. ARR (2016) provides guidance on loss rates which could be expected for the local region which feature losses of:

- Initial Loss: 60 mm
- Continuous Loss 10 mm/hr

The unsaturated losses are significantly greater to the saturated losses based on the USDA guidance. It is likely that unsaturated condition will often occur as dewatering will not be carried out indefinitely but will likely be completed in stages via dewatering campaigns.

For the purposes of this assessment, and without the availability of more detailed soil information, infiltration rates of 2.5 mm/hr, 5 mm/hr and 10 mm/hr have been selected for analysis. These values have been selected as they form conservative estimates that align with saturated infiltration rates based on values provided by USDA, the 250K scale Government Geology layer and discussions with Fortescue regarding observations made on the local creek bed soil characteristics to date.

## 4.3 Evaporation & Evapotranspiration

An analysis on the effects of evaporation and evapotranspiration was completed, which found that the evaporation was not significant in influencing the losses present within the system. Given that conservative loss rates of 5 mm/hr have been assumed within the catchment, this equates to 120 mm/day.

Given that the average daily evaporation is 8.48 mm/day (Silo, Department of Science, Information Technology and Innovation), the losses due to evaporation are relatively insignificant when compared to infiltration, and lie well within the infiltration rate uncertainty range. Therefore, the losses caused by evaporation have been assumed to be incorporated into the overall losses to simplify the analysis, and to ensure that a conservative estimate of the maximum footprint was achieved.

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## 4.4 Rainfall

Rainfall has not been considered in the water balance analysis as the modelling is based on dry weather conditions only. This assumption was necessary due to the variable nature of rainfall events, and because the discharge footprint would be highly diluted and would simply form rainfall runoff as per the existing hydrologic regime. As such, this analysis is only relevant for dry weather periods outside of rainfall events.

## 4.5 Groundwater

Creeks have been assumed to be losing streams as illustrated in Figure 4-1 below. Based on discussions with Fortescue, there were no identified groundwater to surface feeds creating permanent to semi-permanent pools or baseflow. Hence, the impacts of groundwater did not need to be included in the modelling.

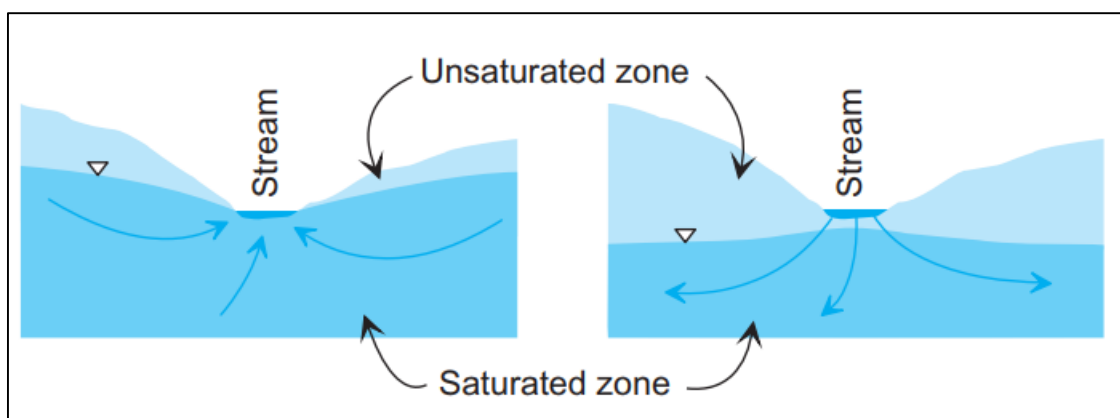
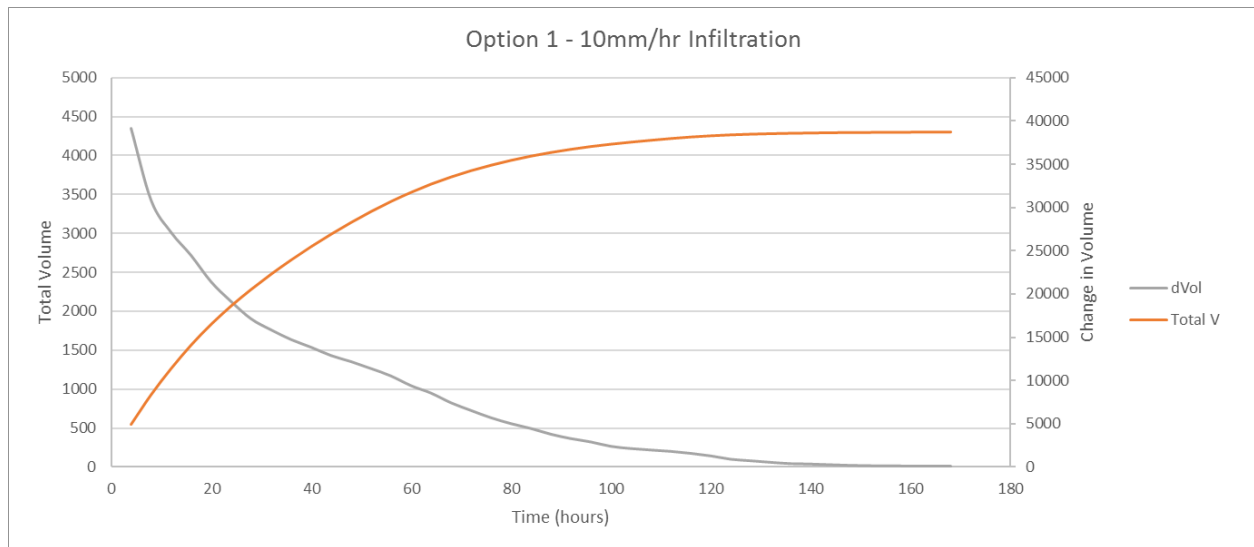


FIGURE 4-1 GAINING STREAM (LEFT) VS LOSING STREAM (RIGHT), SOURCE: FITTS, 2013

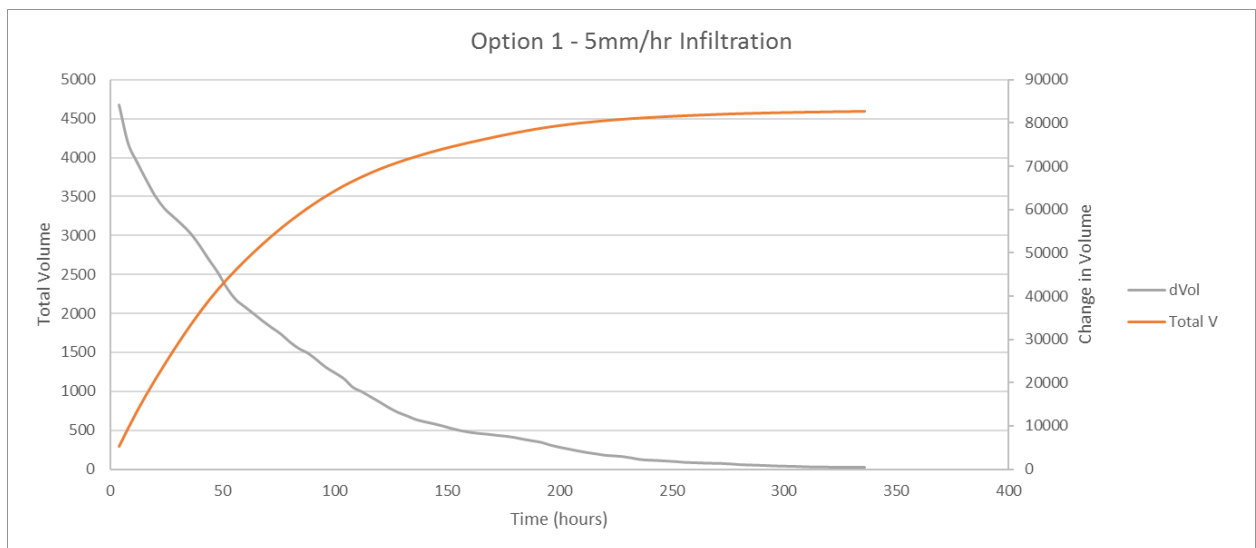
## 4.6 Adopted Methodology & Assumptions/Limitations

The key assumptions that were adopted include:

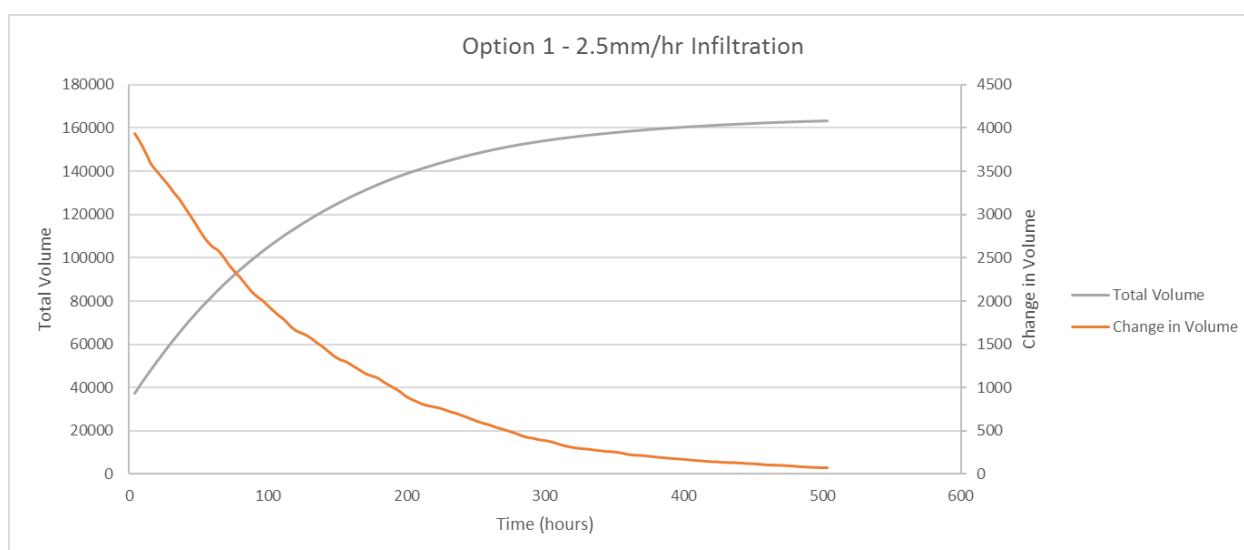
1. No evaporation was considered as part of the analysis as described in section 4.3.
2. Rainfall has not been considered as potential for impact from discharge occurs outside of periods of rainfall and streamflow as described in section 4.4
3. No gaining reaches have been considered as part of the analysis as described in section 4.5.
4. Given the variations in infiltration scenarios, the time taken to reach equilibrium varied substantially, and as a result the runtimes of the models were:
  - a. 168 hours (1 week) for 10mm/hr Scenarios
  - b. 336 hours (2 weeks) for 5mm/hr Scenarios
5. Simulations were run until equilibrium was reached (i.e. Rate of change to the extent of the flooding =0). See Figure 4-2, Figure 4-3 and Figure 4-4 below for change in volume vs time series plots.
6. This method has not been calibrated or validated to real world results.



**FIGURE 4-2 OPTION 1 – 10MM/HR INFILTRATION**



**FIGURE 4-3 OPTION 1 – 5MM/HR INFILTRATION**



**FIGURE 4-4 OPTION 1 – 2.5MM/HR INFILTRATION**

## 5 RESULTS

### 5.1 Overview

The results of the discharge assessment have been provided in appendix A in the form of GIS mapping. The resulting discharge extents have been determined and are presented in Table 5-1.

**TABLE 5-1 FOOTPRINT LENGTH (KM)**

Loss Rate	Discharge Point	
	Option 1	Option 2
<b>2.5 mm/hr (Sensitivity Check)</b>	22.5	N/A
<b>5 mm/hr</b>	13.0	12.1
<b>10 mm/hr</b>	8.2	7.6

### 5.2 Comparison to Previous Studies

Rio Tinto Iron Ore (RTIO) previously completed a similar assessment for their Nammuldi Silvergrass Expansion Project, which is documented in their Baseline Hydrology Assessment for Duck Creek Discharge (Rio Tinto, 2011). The approach used by RTIO involved application of a conceptual water balance which divided the creek into sections and completed a water balance using inputs such as evaporation, evapotranspiration, infiltration/seepage and discharge inflow. This method was completed in 2010, a time when 2-dimensional modelling of the catchment was not practical. Because of the significant advances in modelling technology through the development of GPU and HPC TUFLOW modelling, more detailed assessments of stream discharge using a grid based method, which takes into account real life topography, can be completed.

The results of the assessment are summarised in Table 5-2, with additional comparisons to Fortescue's flow rates. The upper reaches of RTIO's assessment including gaining sections, hence discharge footprints were large compared to flow rates. Where reaches aren't gaining, and assuming a homogenous system, the flow rate to discharge footprint relationship is linear. Hence, the relative impact on the discharge footprint due to



additional flow can be used for comparison Fortescue's flow rates. The last column in Table 5-2 is the relative footprint increase scaled according to the relative flow rate increase compared to Fortescue's flow rate of 350 L/s. Beyond a 100-km discharge extent, RTIO's reaches were no longer gaining, which provides a good comparison to the reaches in this analysis. The highlighted cells show these reaches, which have discharge footprints that correlate well with Table 5-1.

**TABLE 5-2 COMPARISON TO RTIO DISCHARGE ASSESSMENT**

Flow Rate (ML/d)	Relative Flow Rate Increase (ML/d)	Relative Flow Rate Increase (L/s)	Maximum Discharge Footprint (km)	Relative Footprint Increase (km)	Comparative Footprint Increase for Flow Rate of 350 L/s (30.2 ML/d)
15	15	174	30	30	60.3
20	5	58	83	53	320.5
50	30	347	109	26	26.2
100	50	579	124	15	9.1
150	50	579	140	16	9.7
200	50	579	157	17	10.3

Given that the water balance completed by RTIO correlates well with the method adopted in this analysis for the same region, further confidence can be placed in the results generated in this assessment.

## 6 RECOMMENDATIONS

A conservative assumption of 5 mm/hr for the infiltration rate was adopted for this analysis. It is likely that the actual infiltration rate will be higher, however the uncertainties in other model inputs, particularly the topography, mean that adopting a conservative infiltration rate is recommended. This approach has been validated through the comparison to RTIO's alternative methodology, which found that produce slightly larger comparable discharge areas were produced in this study. Water Technology believes that the impact area extents presented in this report are an appropriate conceptual extent of the maximum discharge case scenarios under steady state conditions.

Furthermore, a sensitivity analysis was completed using a 2.5mm/hr infiltration rate for Option 1, which resulted in a 73% increase in the discharge extent. As such, Water Technology recommends adoption of the 5 mm/hr discharge extent as this represents a conservative estimate of what can be considered the maximum discharge footprint, which correlates well with previous assessments.

If Fortescue wish to further optimise the TUFLOW model prior to construction of the mine site and reduce the level of uncertainty and conservatism the following actions may be undertaken:

1. Preform onsite ground truthing to determine a refined infiltration rate (this will likely result in higher infiltration rates given the conservative value applied); and
2. Use of LiDAR over photogrammetry in places where LiDAR was not available at the time of this study.
3. Complete a more detailed water balance to contrast the impacts of short term temporally varying discharge plans vs long term steady state footprints.

This level of assessment would require more information, including a more detailed site water balance. As this information won't be available until closer to construction, the level of analysis in this report is suitable for the current purposes.





## 7 REFERENCES

AAM 2017, Eliwana Rail Project LiDAR Survey June 2017 – Final Delivery Complete.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia).

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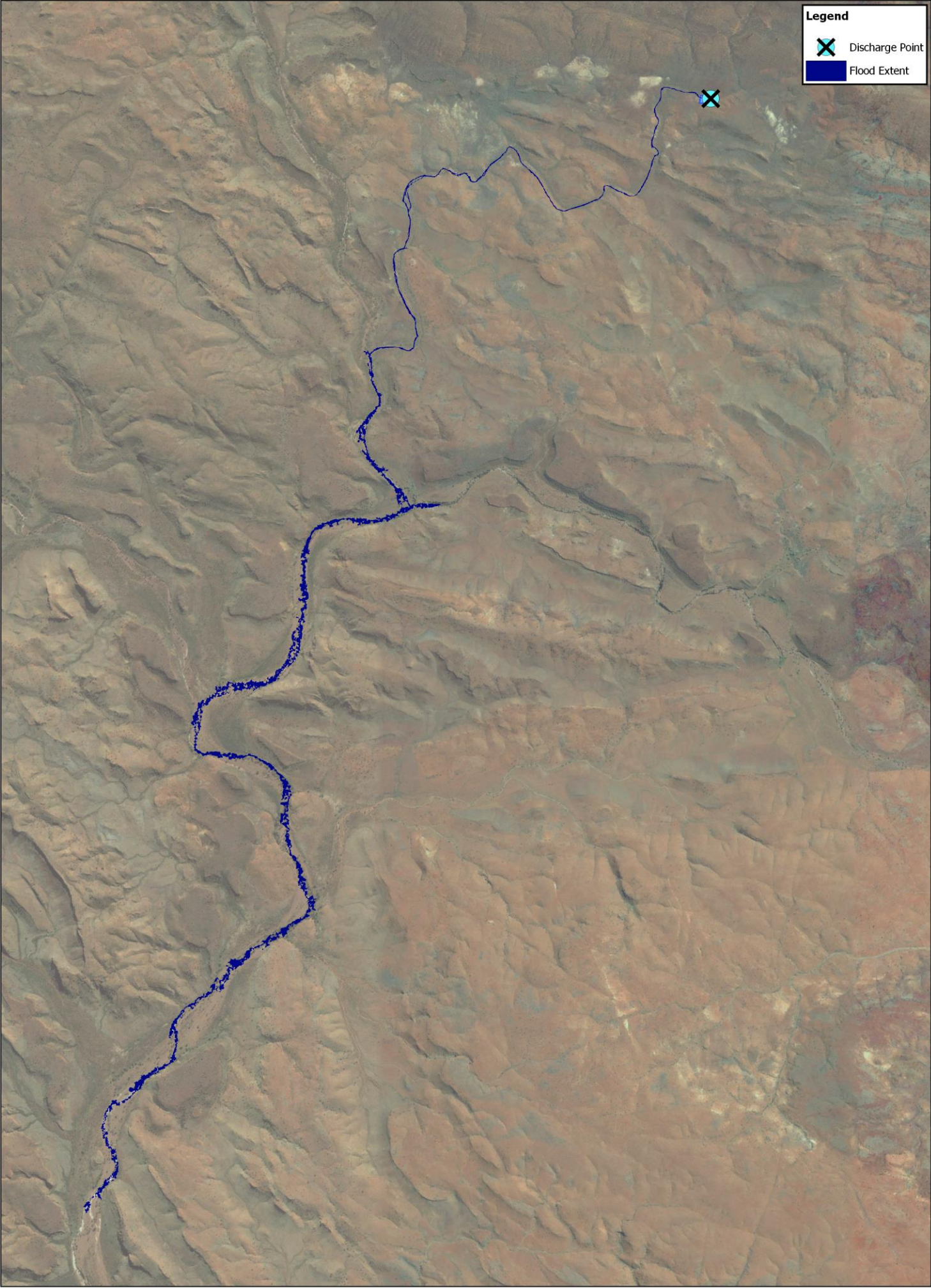
Rio Tinto, Baseline hydrology assessment for Duck Creek discharge, 2011.

United States Department of Agriculture, Part 630 Hydrology National Engineering Handbook, Chapter 7. Hydrologic Soil Groups. <https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba>



## APPENDIX A FLOOD EXTENT MAPPING



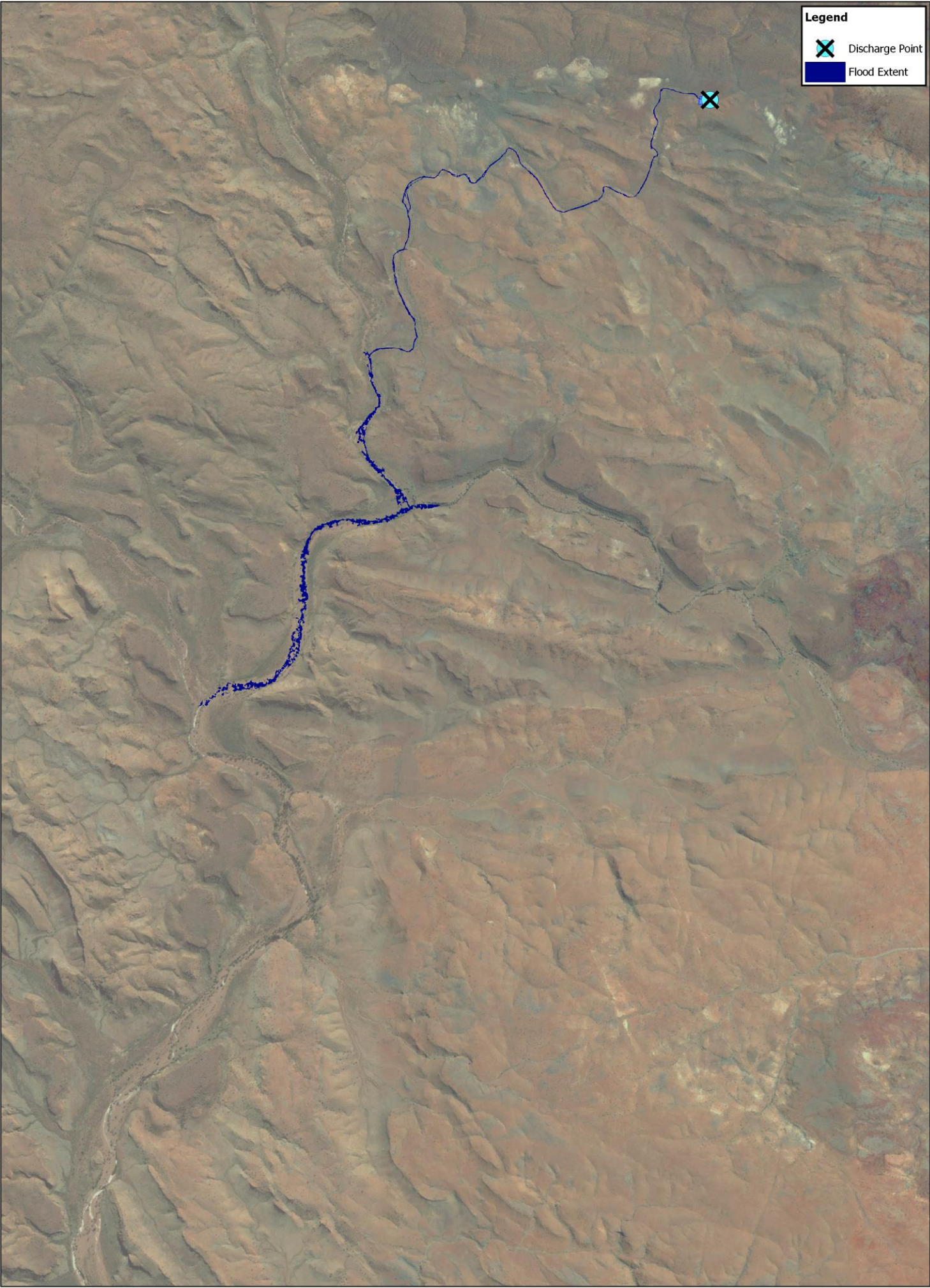


**Legend**

 Discharge Point

 Flood Extent



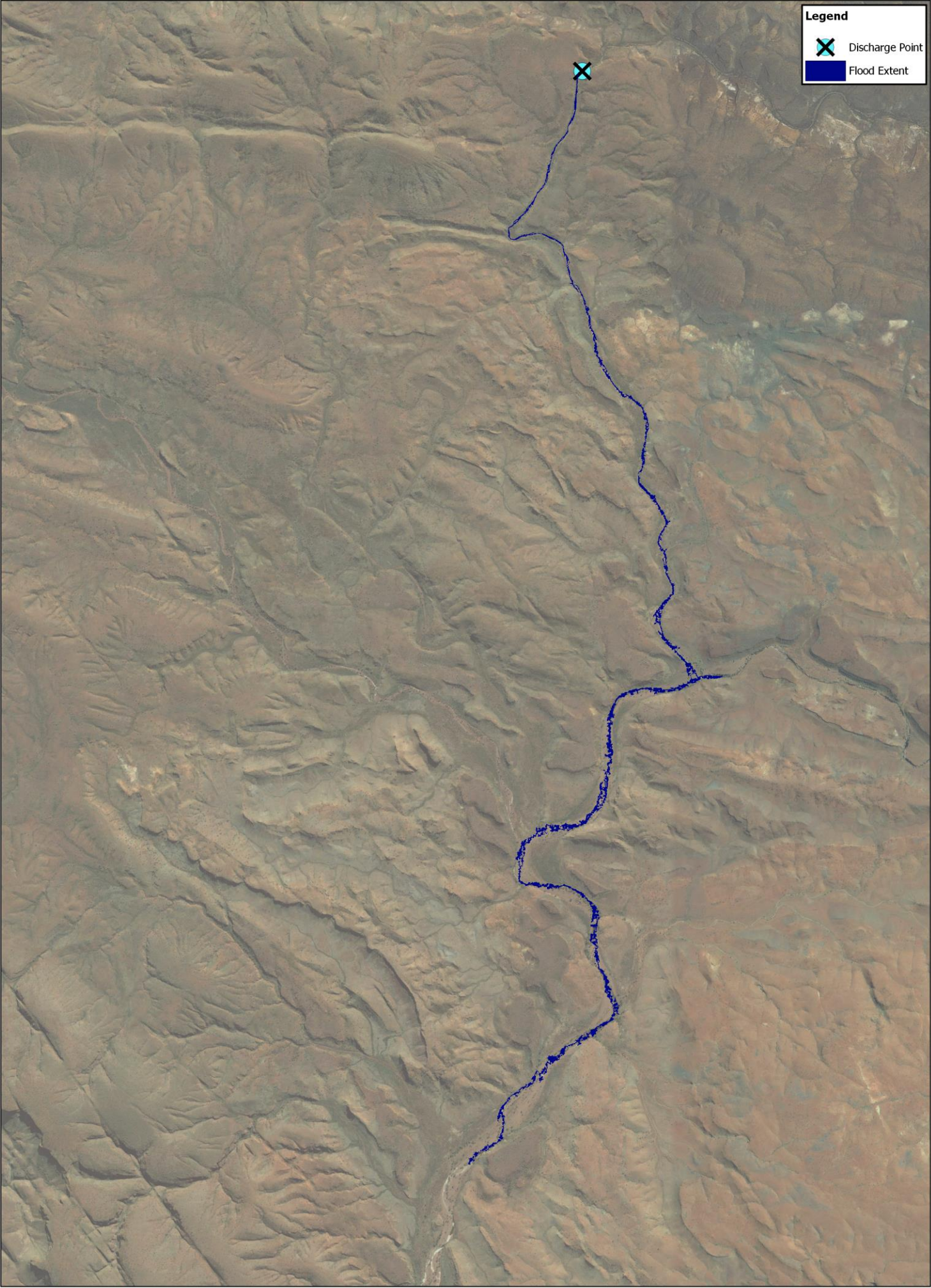


**Legend**

 Discharge Point

 Flood Extent



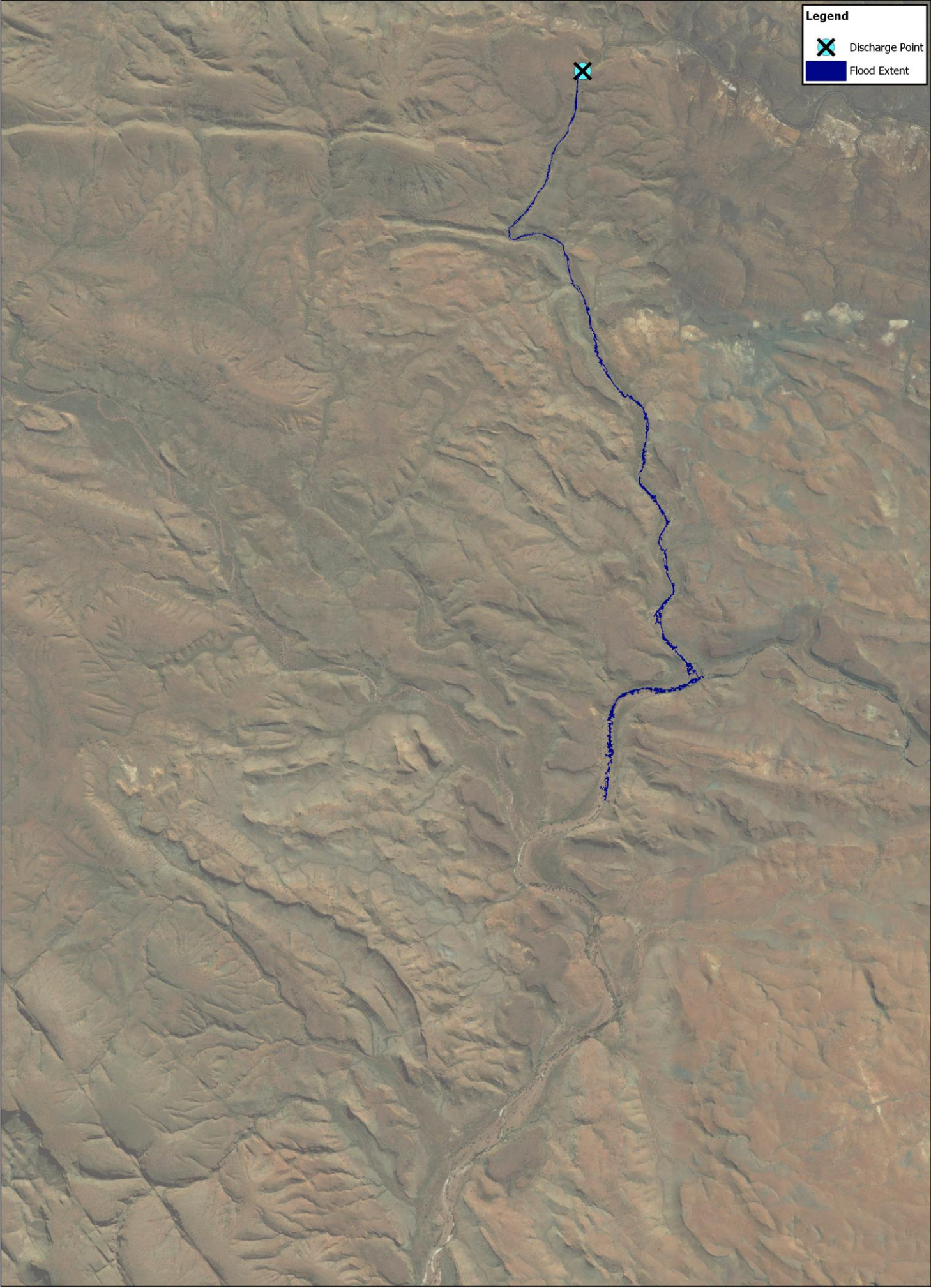


**Legend**

 Discharge Point

 Flood Extent





**Legend**

 Discharge Point

 Flood Extent

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15 Business Park Drive  
Notting Hill VIC 3168  
Telephone (03) 8526 0800  
Fax (03) 9558 9365

## Wangaratta

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