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Memo

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Surplus water discharge extent assessment: Mesa H

Overview

The Mesa H deposit is located approximately 11 km southwest of Pannawonica and adjacent to the Robe JV Mesa J mine, downstream of the confluence of the Robe River and Jimmawurrada Creek (Figure 1). Approximately 40% of the resource is below the current water table (which has been lowered by dewatering at Mesa J). Consequently, approval will be sought to commence mining below water table, which will require dewatering.

Management of water on Rio Tinto sites follows strict environmental and water use standards (refer to Rio Tinto Environmental Standards). These standards align with the "Pilbara Water in Mining Guideline" (DoW, 2009) which identifies options for use and/or release of dewatering discharge:

- Efficient on-site use, including mitigation of any impacts.
- Used for fit for purpose activities (such as processing and dust suppression). The proponent needs to demonstrate that the water is of suitable quality for the end use.
- Transferred to meet other demand including other proponents in the area and public water supply, as approved by the Department. Where it is proposed to use the water for public supply, a drinking water source protection plan should be developed and approved by the Department of Water and the Department of Health.
- Injection back into the aquifer at designated sites determined by the proponent and agreed by the Department.
- Controlled release to the environment where the dewater release is allowed to flow (either through a pipe or overland) into a designated water course or wetland and determined by the proponent and agreed by the Department.

Management of surplus water at Mesa H may include the controlled discharge of surplus water at existing discharge locations at Mesa J, namely Discharge point 5 (Jimmawurrada Creek) or Discharge Point B (Robe River tributary immediately west of Mesa J). Therefore, the objective of this study was to estimate the extent of impact of surplus water discharge along the respective watercourses. The methodology to achieve this objective is outlined below:

- Develop a 2D hydraulic model of the river system downstream of the proposed discharge location.
- Determine the hydraulic characteristics that are not inherently accounted for by the 2D hydraulic model, i.e. saturated hydraulic conductivity of the soils.
- Estimate the maximum possible extent that surplus water discharge will flow under steady-state conditions.
- Investigate multiple steady-state scenarios, namely a continuous discharge rate of 5, 10, 15, 20, 25 and 30 ML/day.

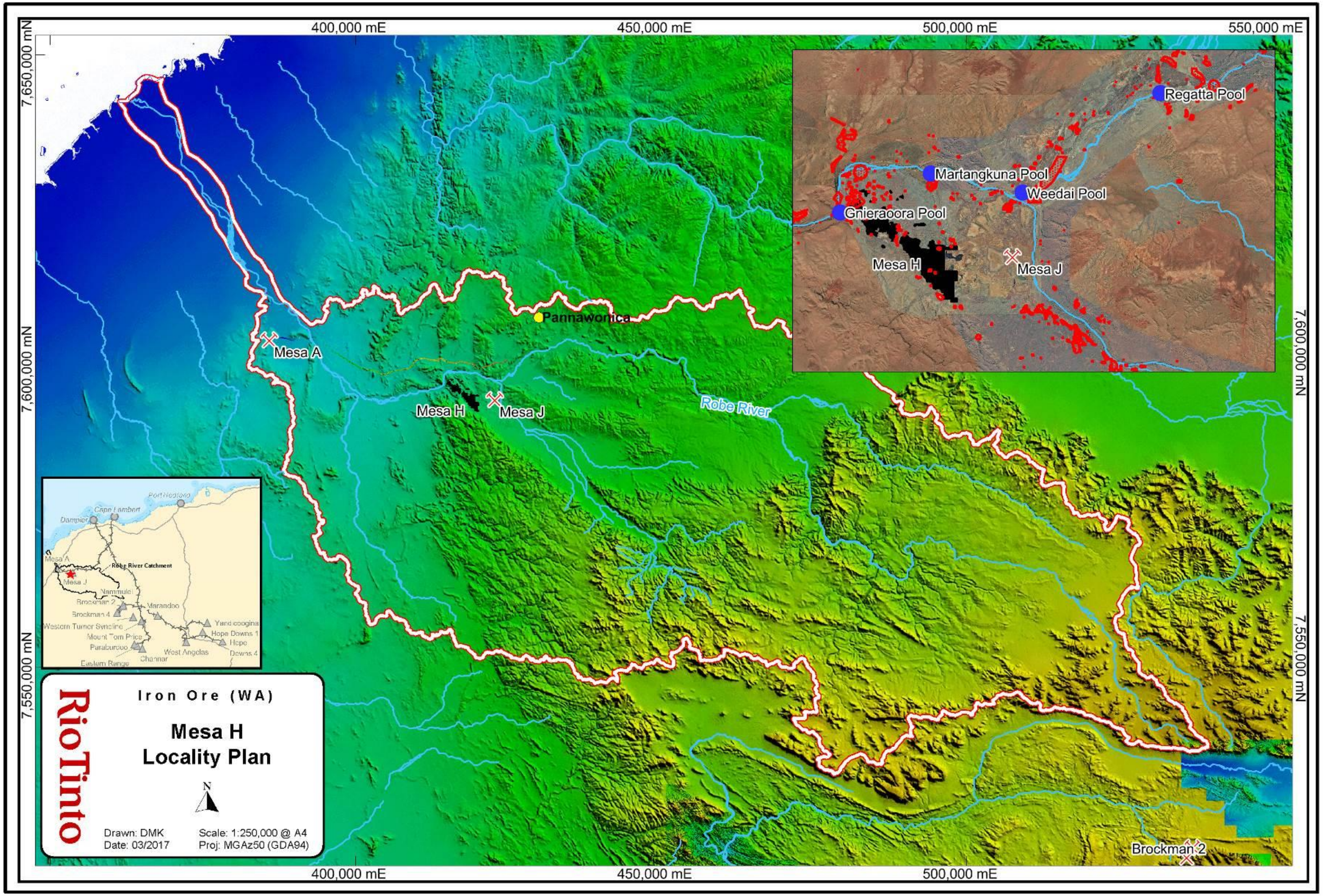

Figure 1: **Mesa H surplus water discharge study location plan**

Modelling Approach

Water flowing in a watercourse is removed from the surface via two mechanisms, namely: evaporation and infiltration. However, these hydrologic processes are inextricably intertwined with the flow characteristics, and hence the hydraulics, of the river system. The braided nature of typical Pilbara watercourses creates a complex hydrodynamic environment where the flow behaviour is essentially 2D in nature, which may be poorly represented using a 1D model.

Recent developments to the **T**wo-dimensional **U**nsteady **Flow** (TUFLOW) model have effectively transformed TUFLOW into a 2D coupled hydrologic-hydraulic modelling system, with the ability to model soil infiltration in both unsaturated and saturated conditions. This makes the TUFLOW model a useful tool for the estimation of surplus water discharge extent.

This section documents the process and assumptions made in developing the 2D hydraulic model for the Mesa H surplus water discharge.

TUFLOW hydraulic model

For this study, TUFLOW's GPU Module was adopted. This is a powerful new solver built into the TUFLOW software, which utilises the substantial parallel computing ability of modern Graphics Processor Units, or GPUs (TUFLOW, 2014). TUFLOW GPU is an explicit solver for the full 2D Shallow Water Equations, including a sub-grid scale eddy viscosity model. The scheme is both volume and momentum conserving. Owing to the power of modern GPUs very large models (>100 million cells) with fine grids can now be run within a sensible timeframe (TUFLOW, 2014). This allowed for a high resolution 1 m DEM, derived from LiDAR, to be used to describe the topography of the river system. This represents a major advantage of this approach. The model configurations are shown in Figure 2.

Manning's roughness coefficient *n*

Surface roughness is defined using the Manning's *n* roughness coefficient. The roughness coefficients adopted for this study were determined according to Chow (1959), which takes into consideration channel irregularities, variation in cross section, obstructions, vegetation density and meandering of the reach. These factors were assessed using aerial photography and confirmed during a site visit. The adopted Manning's *n* roughness coefficient for the Robe River and Jimmawurrada Creek was 0.045, while the Robe River tributary immediately west of Mesa J was assigned a Manning's *n* roughness coefficient of 0.035. These values were applied to all applicable active cells in the model, which was limited to the river/creek channels, as can been seen in Figure 2.

Model inflows

Multiple steady-state scenarios were assessed, namely a continuous discharge of 5, 10, 15, 20, 25 and 30 ML/day.

Model outflows

The maximum discharge extent is achieved when equilibrium is reached between the inflows to and the outflows from the system. Water flowing in a watercourse is removed from the surface through evaporation and/or infiltration.

Evaporation

Annual and monthly potential evaporation rates (A-pan) are available from the Bureau of Meteorology (BoM) website. However, evaporation from open water bodies can be significantly less than A-pan estimates owing to a variety of climatic factors. As such, correction factors are often required to relate A-pan evaporation to evaporation from open water bodies. From Figure 3 it can be seen that evaporation from open water bodies for most of the Pilbara region of Western Australia is between 60-70% of the A-pan evaporation rates.

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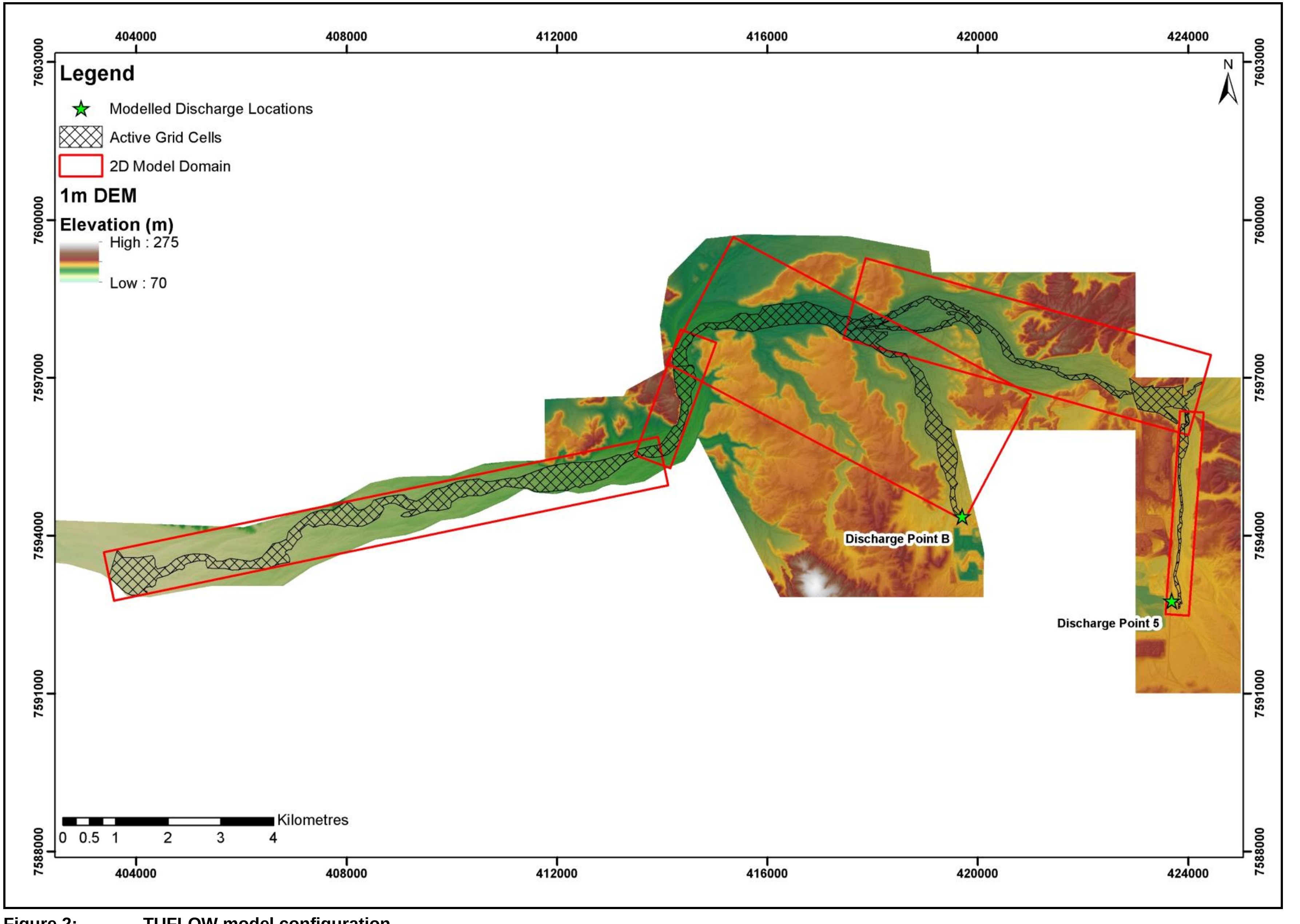

Figure 2: **TUFLOW model configuration**

From Figure 3, the A-pan evaporation rate for Mesa H was determined to be 3400 mm per year. However, the lowest monthly A-pan evaporation occurs in June (157 mm). This was multiplied by 0.65 (Luke et al., 1987) to relate A-pan to open water body evaporation. Consequently the adopted evaporation rate was 102 mm per month, which translates to an average rate of 0.14 mm/h.

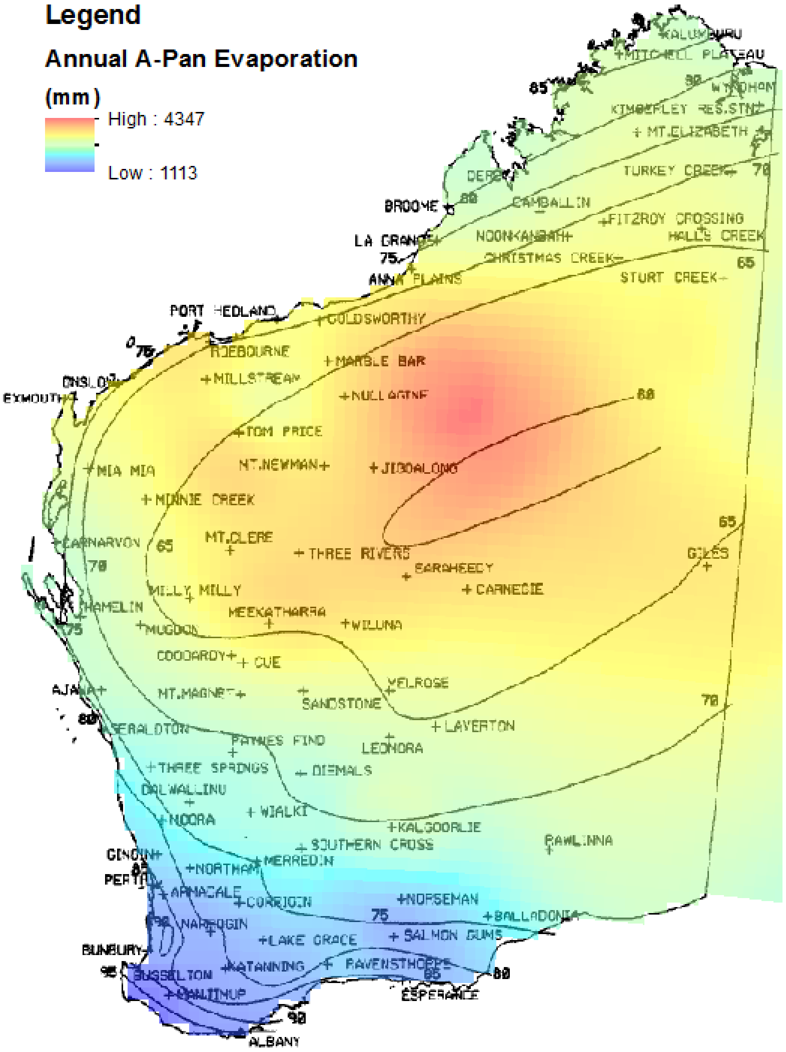

Figure 3: **Gridded annual A-pan evaporation and A-pan correction factors (contours) for Western Australia (from BoM and Luke et al., 1987)**

Infiltration

The maximum discharge extent is achieved when equilibrium is reached between the inflows to and the outflows from the system. As the soil moisture content increases so the infiltration rate of the soil decreases until the saturated hydraulic conductivity (K_{sat}) of the soil is reached. Consequently, equilibrium between the inflows and outflows, and hence the maximum discharge extent, can only be achieved once the soils have reached saturation. As such, when the aim of the discharge extent modelling is to determine the maximum discharge extent for long-term discharge there is no need to simulate losses in unsaturated conditions, and a continuing loss equal to K_{sat} may be adopted.

Although the Soil Hydrological Properties for Australia (Western and McKenzie, 2006) provides K_{sat} values for the whole of Australia, experience has shown that these values can be up to three orders of magnitude too high, thereby overestimating losses from the system and drastically under estimating the maximum discharge extent. As a result, a texture based approach to estimate K_{sat} in the absence of measured data has been applied. This approach derives a weighted clay content for each Map Unit in the Atlas of Australian Soils (Northcote et al., 1960-1968), which places the Map Unit into one of six Texture Groups documented by McKenzie et al. (2000), shown in Table 1.

Table 1: Texture groups according to clay content - adapted from McKenzie et al. (2000)

Weighted Clay Content (%)	Texture Group	Texture Grade
0 – 8	Sands	Sand Clayey Sand Loamy Sand
8 – 17.5	Sandy Loams	Sandy Loam Fine Sandy Loam Light Sandy Loam
17.5 – 25	Loams	Loam Loam, Fine Sandy Silt Loam Sandy Clay Loam
25 – 35	Clay Loams	Clay Loam Silty Clay Loam Fine Sandy Clay Loam
35 – 47.5	Light Clays	Sandy Clay Silty Clay Light Clay Light Medium Clay
47.5 – 100	Clays	Medium Clay Heavy Clay

The least permeable texture grade is adopted as the representative texture for each Texture Group, and is therefore considered to be a conservative estimate. The adopted K_{sat} values for each Texture Group are presented in Table 2.

Table 2: Saturated hydraulic conductivities for different texture groups – adapted from Clapp and Hornberger (1978), Cosby et al. (1984) and van Gool et al., (2005)

Texture Group	Adopted K_{sat} (mm/h)
Sands	50.6
Sandy Loams	18.8
Loams	10.1
Clay Loams	6.1
Light Clays	3.7
Clays	3.0

Figure 4 shows that the creeks and rivers downstream of the discharge locations cross four different soil Map Units, namely, B27, Fa13, My1 and Oc66. Using the approach outlined above the Texture Group and K_{sat} for each Map Unit was derived, and is presented in Table 3.

Table 3: Soil Map Units in study area and adopted saturated hydraulic conductivities

Soil Map Unit	Weighted Clay Content of Limiting Soil Horizon (%)	Texture Group	Adopted K_{sat} (mm/h)
B27	30.0	Clay Loams	6.1
Fa13	27.5	Clay Loams	6.1
My1	36.5	Light Clays	3.7
Oc66	44.0	Light Clays	3.7

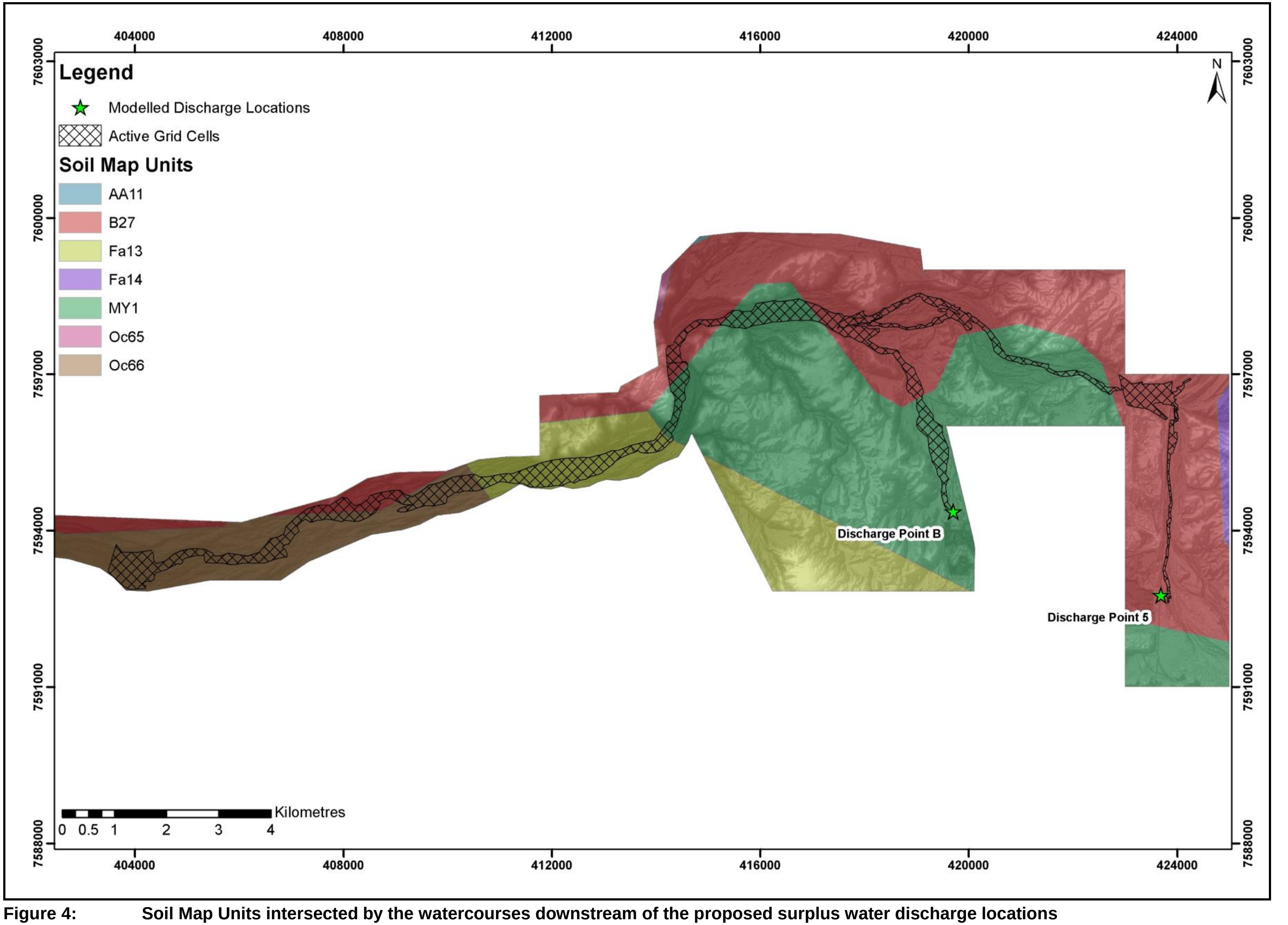

Figure 4: **Soil Map Units intersected by the watercourses downstream of the proposed surplus water discharge locations**

Results

Results for the various discharge modelling scenarios are presented in Table 4 and Figure 5. It is estimated that the surplus water discharge extent will range from 3.5 km to 20 km down gradient of the assumed discharge point depending on the discharge rate and discharge location, before completely infiltrating/evaporating.

Table 4: Estimated discharge extent from discharge location for various discharge rates

Scenario	Distance Travelled (km)	
	Discharge Point 5	Discharge Point B
5 ML/d	3.5	4.7
10 ML/d	5.2	8.8
15 ML/d	5.2	11.8
20 ML/d	5.9	14.4
25 ML/d	9.3	17.2
30 ML/d	11.8	19.9

The braided nature of typical Pilbara watercourses creates a complex hydrodynamic environment where the flow behaviour is essentially 2D in nature. Often braided flows are thought of as a consequence of flooding where flows break out onto poorly defined floodplains. Figure 6 clearly demonstrates that complex bifurcations can also be a characteristic of the low flow regime, and was found in this assessment to be typical in the Robe River, thereby justifying the selection of a 2D hydraulic model.

The surplus water discharge volume would be significantly smaller than the volume generated by the catchment during flood events. Based on model results, discharged water would be contained within the low flow channel/s, hence overtopping of the creek banks in dry conditions is not anticipated.

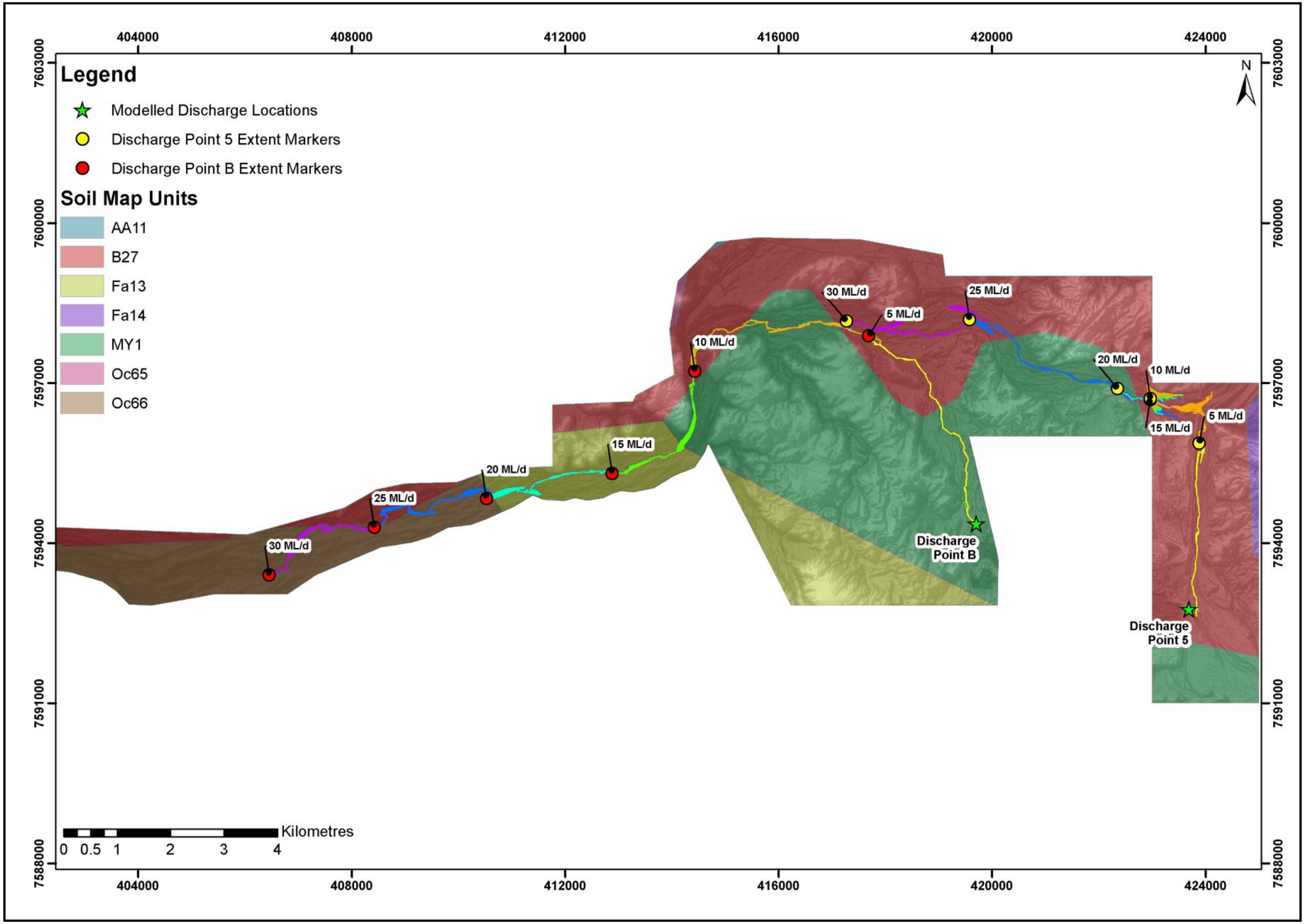

Figure 5: **Modelled maximum discharge extents for various discharge rates**

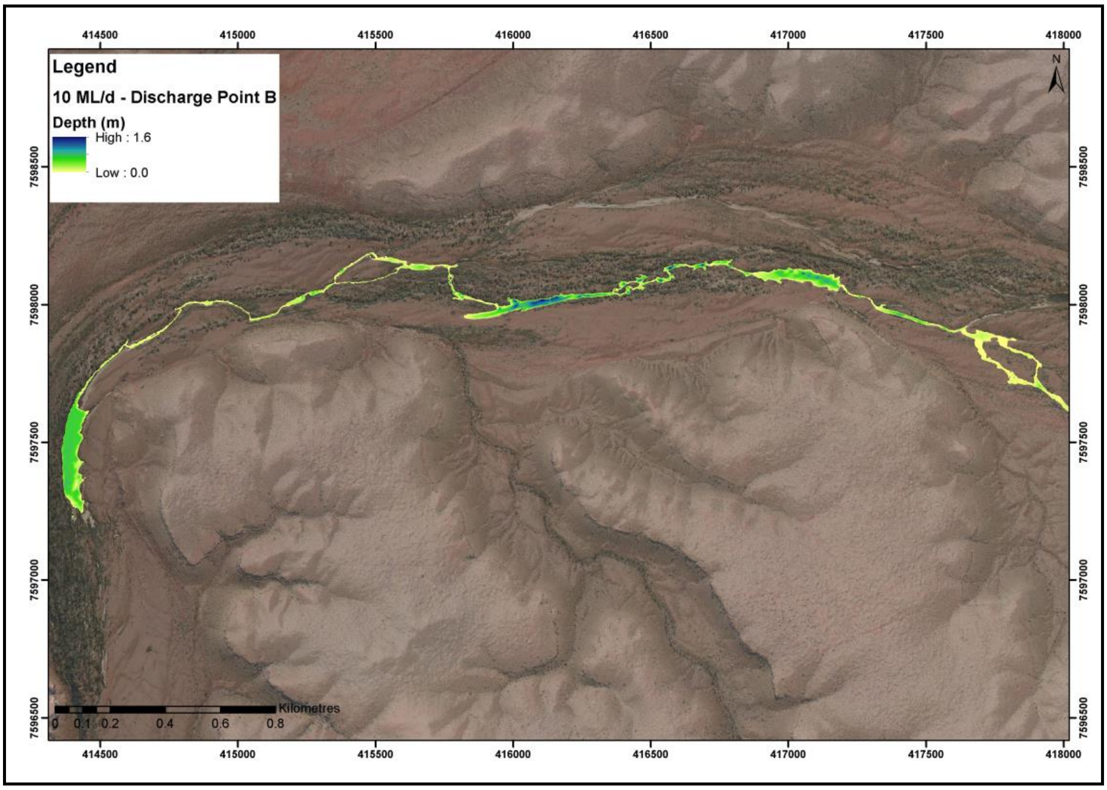

Figure 6: Complex flow regime of the Robe River modelled in TUFLOW

Conclusion

A 2D hydraulic model of the Robe River and relevant tributaries has been developed to estimate the extent of future potential surplus water discharge from the proposed Mesa H operations. The key advantage of the approach was the ability to hydraulically simulate the complex hydrodynamic environment while simultaneously accounting for hydrologic processes such as infiltration and evaporation.

The maximum surface water extents from five discharge scenarios were modelled: namely a continuous rate of 5, 10, 15, 20, 25 and 30 ML/day. It is estimated that the surplus water discharge extent will range from 3.5 km to 20 km down gradient of the assumed discharge point depending on the discharge rate and discharge location, before completely infiltrating/evaporating.

The surplus water discharge volume would be significantly smaller than the volume generated by the catchment during flood events. Based on model results, discharged water would be contained within the low flow channel/s, hence overtopping of the creek banks in dry conditions is not anticipated.

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