Rio Tinto Iron Ore

Appendix 4 – Hydrological Modelled Scenario for Discharge to Boolgeeda Creek

Brockman Syncline 4

January 2014

1 MODELLING SCENARIOS

The total maximum predicted discharge to Boolgeeda Creek may approach 17.5 ML/day, although the expected average discharge into the natural watercourse will be in the region of 10-12.5ML/day.

Surplus water discharge will be released from an outlet to Boolgeeda Creek and an extra 1.4 km discharge pipe will be required to be extended from the existing B4 discharge pipe network to the proposed outlet.

The response of the creek system through a continual discharge for a range of discharge options varying from 2.5 ML/day to 20 ML/day was investigated. Discharge footprints were determined based on the assumption that steady state conditions were established.

2 MODELLING RESULTS

2.1 REACH CHARACTERISTICS

A 52 km long section of Boolgeeda Creek was modelled from the proposed discharge outlet. The creek was subdivided into three reaches with similar creek morphology, soil conditions and vegetation type and patterns. The reach locations are illustrated in Figure 2-1. Descriptions of the average reach characteristics (subsequently used in the water balance equations) and the predicted reaction of the creek to the selected discharge volumes (10 ML/day, 12.5 ML/day, 15 ML/day and 17.5 ML/day) are provided in Table 2-1, Table 2-2 and Table 2-3.

Results for all of the modelling scenarios are subsequently presented in the next section.

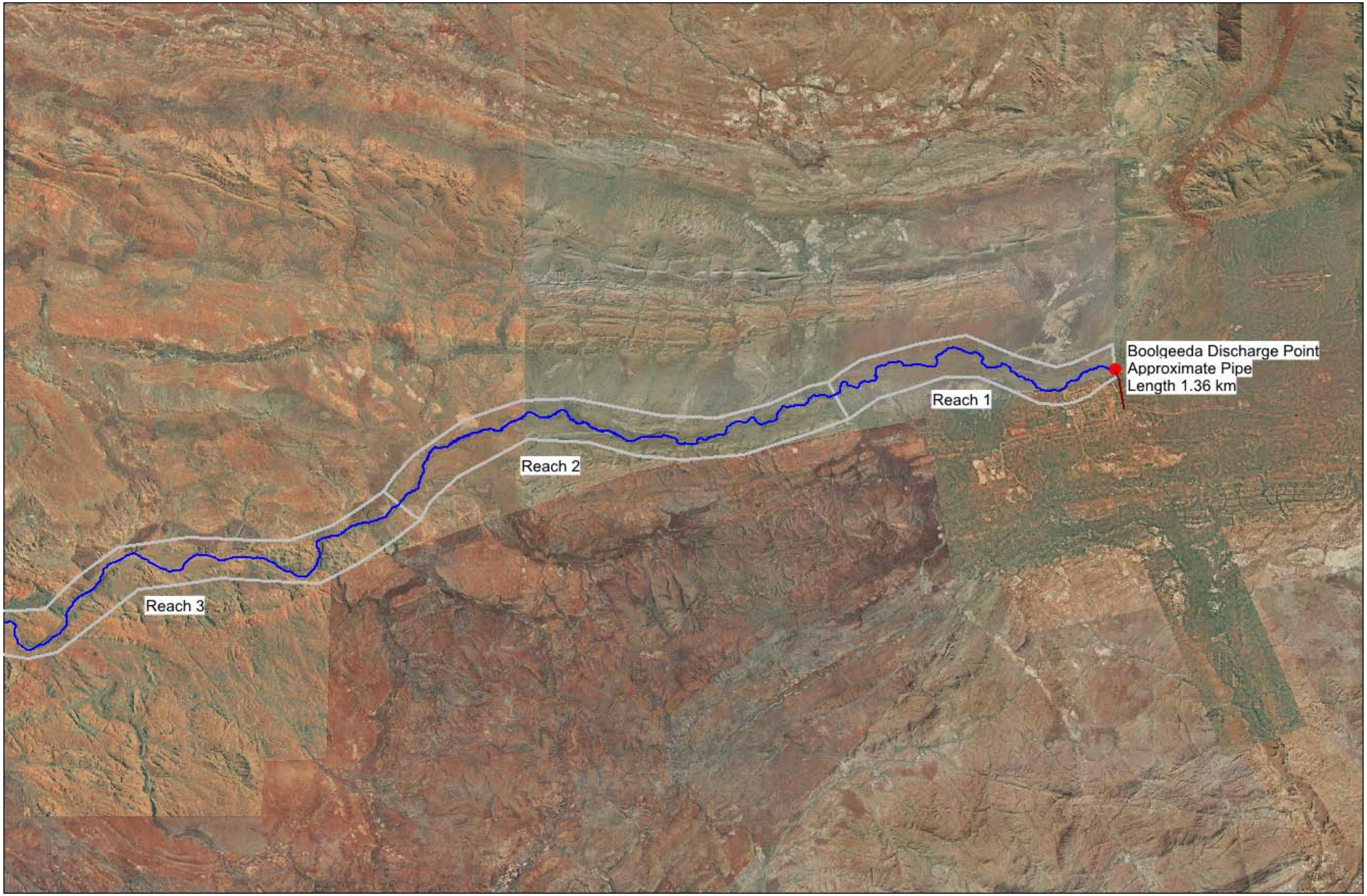


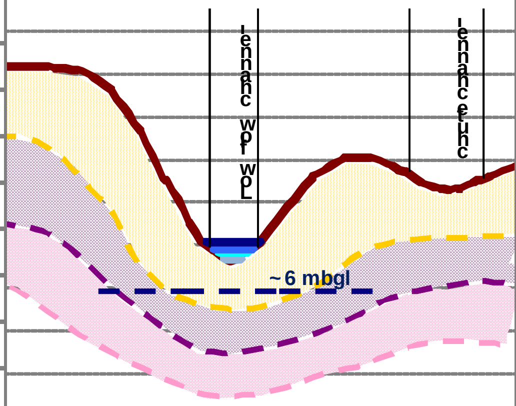
Figure 2-1: Reach locations along Boolgeeda Creek

Table 2-1: Reach 1 characteristics used for the water balance modelling and predicted response to scheduled modelled discharge to Boolgeeda Creek

Reach characteristics

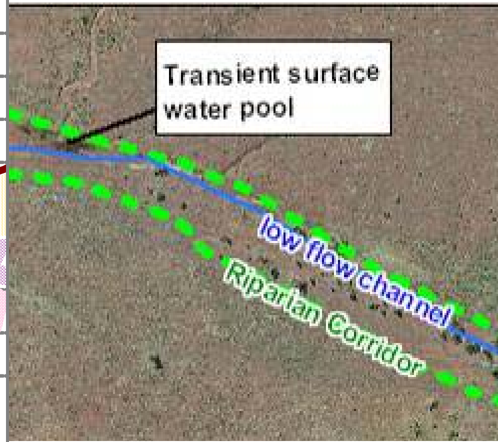
Reach length (m)	12,508
Low flow channel - base width (m)	13
Bed slope (m/m)	0.003
Manning's roughness	0.045
Riparian width (m)	42
Common riparian veg types	Ev; H
ET (mm/year)	530
Alluvial/colluvial depth (m)	~ 20
SW&GW interactions	Losing
Recharge rate (m/s)	1.16 x 10^{-9}
Limiting factor to water loss	Subsurface geology

Typical cross section



Not to scale

Riparian vegetation corridor



Flow conditions

Peak discharge	Water depth (m)	Flow width (m)	Velocity (m/s)
10ML/d 0.12 m^3/s	0.05	20	0.14
12.5 ML/d 0.14 m^3/s	0.06	21	0.15
15 ML/d 0.17 m^3/s	0.065	22	0.16
17.5 ML/d 0.20 m^3/s	0.07	23	0.17

Key

Alluvium/Colluvium

Woongara Volcanics

Boolgeeda Iron Formation

Estimated groundwater level

Modelled discharge rates:

10 ML/d

12.5 ML/d

15 ML/d

17.5 ML/d

Riparian vegetation types

Ev - *Eucalyptus victrix* (Coolibah)

H - Open herbland

Summary

Reach 1 defines the first reach of the Boolgeeda Creek, immediately downstream from the Brockman 4 discharge outlet. It is located within a wide, flat floodplain that stretches several hundred metres across and is defined by a braided, meandering creek system that is capable of changing course during a large flood event. Water will be distributed across a wide area during floods in this reach, hence reduces the average flood water levels and velocities. It potentially allows deposition of sediments along this reach. Riparian vegetation commonly found in Reach 1 includes *Eucalyptus victrix* (Coolibah) and some herb species.

The average groundwater elevation along Reach 1 was estimated to be approximately 6 m below ground level. Surface water pools can be observed from aerial photograph but they are likely to depend on rainfall, creek runoff and shallow alluvial interflow rather than groundwater. These pools are likely to be transient and accumulated water is expected to dissipate via infiltration and evaporation during dry periods.

Reach 1 is recognised as a losing system and subsurface geological constraints are identified as the likely limiting factor for the volume of water lost from the system. It was determined that the bedrock units underlying Reach 1 are generally of low permeability, hence recharge into the regional groundwater system is likely to be limited, which may lead to build up of water within the alluvials and/or valley fill materials following prolong surplus water discharge.

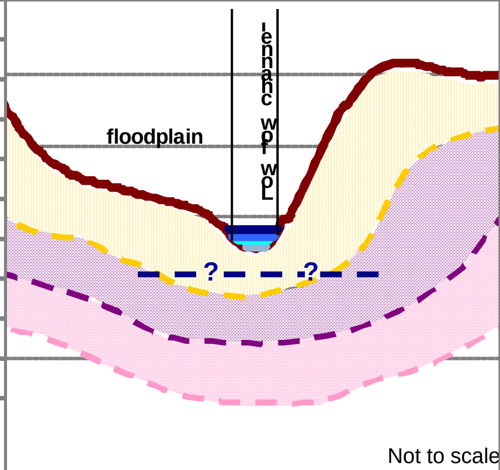
Water released into the creek is likely to be contained within the channel.

Table 2-2: Reach 2 characteristics used for the water balance modelling and predicted response to scheduled modelled discharge to Boolgeeda Creek

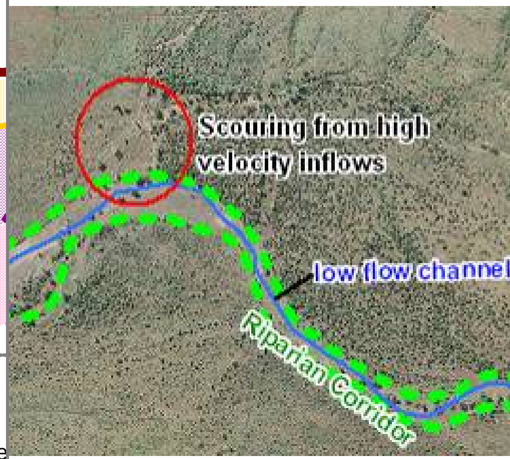
Reach characteristics

Reach characteristics	
Reach length (m)	**18,780**
Low flow channel - base width (m)	13
Bed slope (m/m)	0.006
Manning's roughness	0.05
Riparian width (m)	61
Common riparian veg types	Ev; Ac; Tu
ET (mm/year)	600
Alluvial/colluvial depth (m)	~ 20
SW&GW interactions	Losing
Recharge rate (m/s)	1.16×10^{-9}
Limiting factor to water loss	Subsurface geology

Typical cross section



Riparian vegetation corridor



Flow conditions

Peak discharge	Water depth (m)	Flow width (m)	Velocity (m/s)
10ML/d 0.08 m^3/s	0.04	19	0.15
12.5 ML/d 0.11 m^3/s	0.04	20	0.16
15 ML/d 0.14 m^3/s	0.05	21	0.17
17.5 ML/d 0.17 m^3/s	0.05	22	0.18

Key

- Alluvium/Colluvium
- Woongara Volcanics
- Boolgeeda Iron Formation
- Estimated groundwater level

Modelled discharge rates:

- 10 ML/d
- 12.5ML/d
- 15 ML/d
- 17.5 ML/d

Riparian vegetation types

Ev - *Eucalyptus victrix* (Coolibah)
H - Open herbland

Summary

Reach 2 is characterised by a meandering creek with an active floodplain that varies in width. Reach 2 is differentiated from Reach 1 by a slightly more incised channel with more defined banks and a floodplain that supports denser riparian vegetation. Common plant species found in Reach 2 includes *Eucalyptus. victrix* (Coolibah), *Acacia citrinovirdis* (Black Mulga) and some tussock grasses. Scouring observed at tributary outlets along Reach 2 (an example is highlighted in the aerial imagery above) indicates high velocity runoffs can be generated from the northern and southern valley slopes.

Groundwater elevations along this reach are unknown but increase in vegetation density may indicate increased water availability. There is a distinctive water source contributing to Reach 2, originating from the southern valley, which results in the sudden increase in vegetation density within the floodplain (adjacent figure).

Reach 2 is recognised as a losing system and subsurface geological constraints are identified as the likely limiting factor for the volume of water lost from the system. Similar to Reach 1, the bedrock units underlying this reach are generally of low permeability thus limits recharge into the regional groundwater table and may lead to build up of water within the alluvials and/or valley fill materials following prolong surplus water discharge.

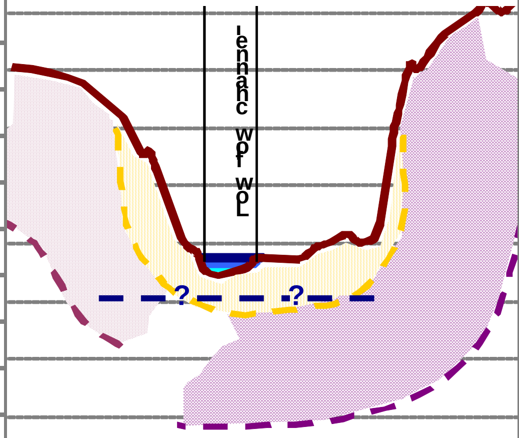
Water discharged into the creek is likely to be contained within the channel, hence overtopping of the creek banks is not anticipated.

Table 2-3: Reach 3 characteristics used for the water balance modelling and predicted response to scheduled modelled discharge to Boolgeeda Creek

Reach characteristics

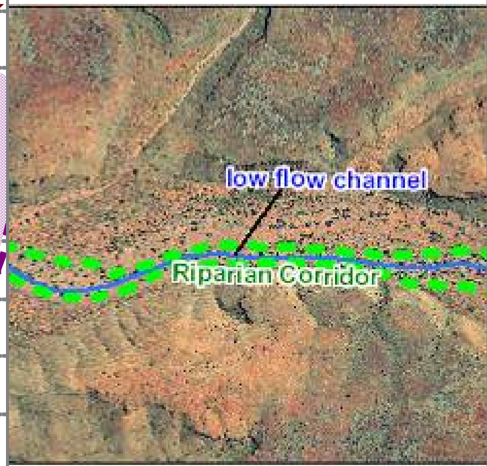
Reach length (m)	20,765
Low flow channel - base width (m)	13
Bed slope (m/m)	0.003
Manning's roughness	0.045
Riparian width (m)	81
Common riparian veg types	Ev; A; Tu
ET (mm/year)	600
Alluvial/colluviall depth (m)	~ 10
SW&GW interactions	Losing
Recharge rate (m/s)	2 x 10^{-7}
Limiting factor to water loss	Subsurface geology

Typical cross section



Not to scale

Riparian vegetation corridor



Flow conditions

Peak discharge	Water depth (m)	Flow width (m)	Velocity (m/s)
10ML/d 0.02 m^3/s	0.02	16	0.08
12.5 ML/d 0.05 m^3/s	0.03	17	0.11
15 ML/d 0.08 m^3/s	0.04	18	0.13
17.5 ML/d 0.10 m^3/s	0.05	19	0.14

Key

Alluvium/Colluvium

Woongara Volcanics

Boolgeeda Iron Formation

Estimated groundwater level

Modelled discharge rates:

10 ML/d

12.5ML/d

15 ML/d

17.5 ML/d

Riparian vegetation types

Ev - *Eucalyptus victrix* (Coolibah)

H - Open herbland

Summary

Reach 3 illustrates the section of Boolgeeda Creek that drains the gorge system. The creek is flanked north and south by outcropping Boolgeeda Iron Formation and Robe Pisolite mesas, which constricts flows, thus increases the average water levels and velocities and may cause water to back up during large flood events. Similar to Reach 2, Reach 3 is likely to receive high velocity runoff generated from local sub-catchments that may scour the creek bed.

Riparian vegetation commonly found in Reach 3 may include *Eucalyptus. victrix* (Coolibah), some *Acacia* (Mulga) species and tussock grasses.

Groundwater elevations are unknown along this reach but are expected to be deep, possibly > 5 m below ground level; riparian vegetation maintained within this reach is unlikely to be groundwater dependent but sustained by water available within the soil layer, recharged by surface flows and rainfall infiltration.

Reach 3 is recognised as a losing system and subsurface geological constraints are identified as the likely limiting factor for the volume of water lost from the system. Although the outcropping rock units are believed to be of low permeability, faults/fracture zones (generally found in this reach) will significantly increase the permeability of the rocks thus increase the recharge potential of this reach.

Water released into the creek is likely to be contained within the channel, hence overtopping of the creek banks is not anticipated. The footprint is terminated within this reach.

3 RESULTS

Results for the modelled discharge options are summarised in Table 3-1 and wetting fronts, measured from the proposed discharge outlet, for selected volumes 10, 12.5 and 17.5 ML/day are presented in Figure 3-1.

Table 3-1: Estimated wetting fronts, for modelled volumes 2.5 to 20 ML/day, along Boolgeeda Creek

Discharge volume (ML/day)	Surface water expression (km)	Steady state distance (km)	Maximum wetting front (km)
2.5	1.0	12.0	12.0
5	13.0	22.0	22.0
7.5	14.0	31.0	31.0
10	32.0	33.0	33.0
12.5	33.0	34.0	34.0
15	34.0	35.0	35.0
17.5	34.0	37.0	37.0
20	35.0	38.0	38.0

For all modelled discharge rates, the surface water expression footprint was less than the steady state distance. This suggests water released into the creek is likely to move in and out of the creek bed, creating transient pools in topographical depressions and associated saturated bank conditions within the reach. Modelling indicated that the maximum wetting front would extend from approximately 12 km to 38 km down gradient from the proposed discharge outlet for modelled volumes 2.5 ML/day to 20 ML/day.

The peak flow volume of water discharged into Boolgeeda Creek is significantly smaller than the peak flow volume generated by the catchment during any flood events (a 2 year ARI flood event would deliver 148 m^3/s at the proposed discharge outlet, compared with peak modelled discharge rates of 17.5 ML/day which is equivalent to 0.2m^3/s). However the duration of flow events, days to weeks for flood events and months for discharge events, pose a change to the current hydrological regime.

All potential water movement is likely to be confined within the channel, hence overtopping of the creek banks is not anticipated. While the creek bed will remain saturated, the creek banks are likely to become saturated such that riparian vegetation should be largely unaffected by the flows. However, the continuous flow will increase water availability close to the creek. Thus the content of water in unsaturated zones moving away from the saturated creek bed may increase vegetation vigour and/or encourage sapping growth.

It was determined that the bedrock units underlying the Boolgeeda Creek valley are of low permeability. Hence water loss to the environment via recharge will be minimal.

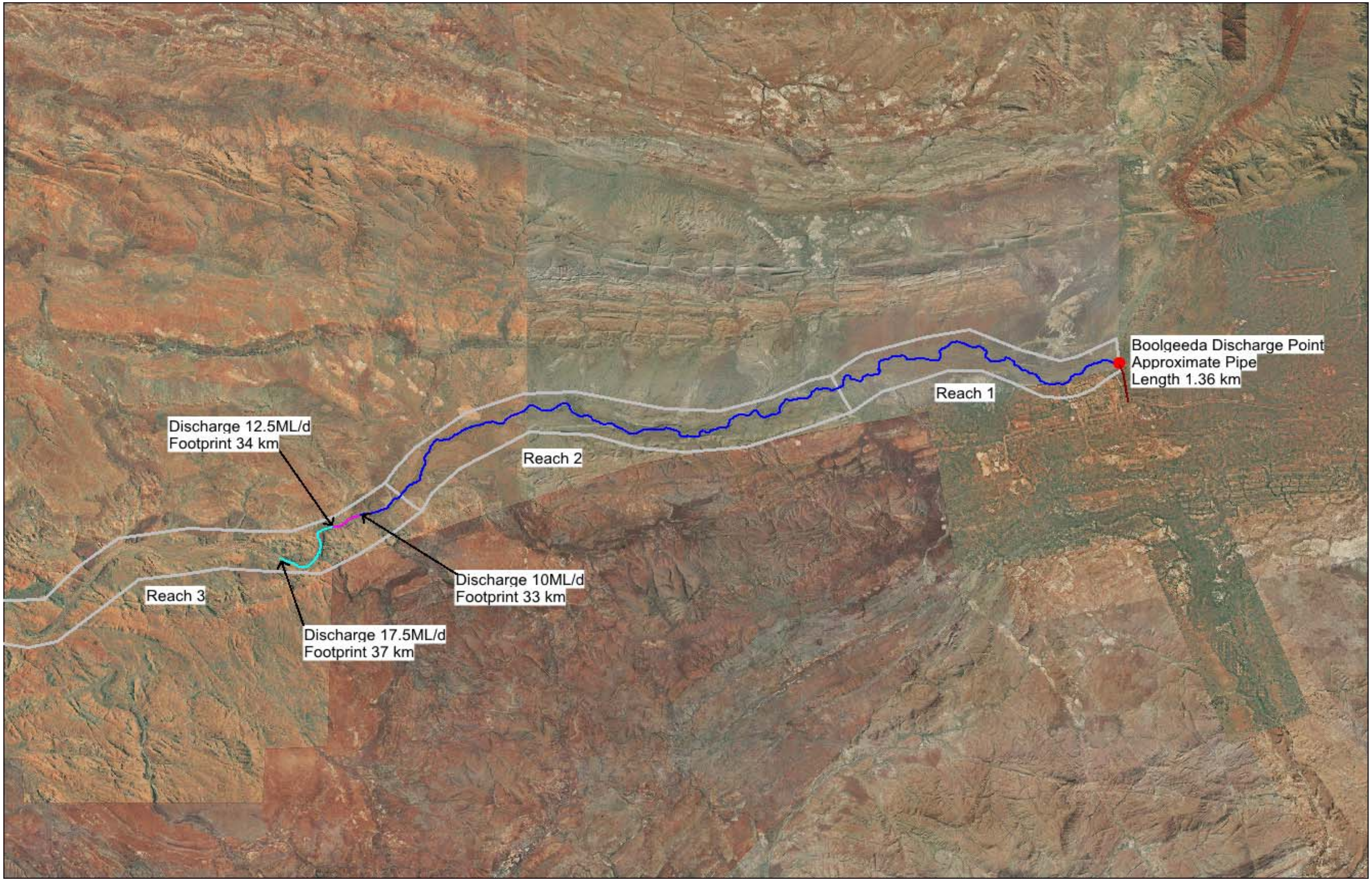


Figure 3-1: Estimated wetting front for Boolgeeda Creek for selected volumes 10, 12 and 17.5ML/day