WorleyParsons
resources & energy

EcoNomics

FLINDERS MINES LIMITED

Ajax, Blackjack and Badger Groundwater Impact Assessment Report

201012-00322-5000-WW-REP-0001

21-Sep-12

Infrastructure & Environment
Level 7, QV1 Building
250 St Georges Terrace
Perth WA 6000 Australia
Tel: +61 8 9278 8111
Fax: +61 8 9278 8110
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

WorleyParsons
resources & energy

EcoNomics

FLINDERS MINES LIMITED
AJAX, BLACKJACK AND BADGER GROUNDWATER IMPACT ASSESSMENT REPORT

SYNOPSIS

This report provides a preliminary assessment of the potential groundwater impacts associated with the Pilbara Iron Ore Project at the Ajax, Blackjack and Badger deposits, with particular reference to identified Groundwater Dependent Ecosystems (GDEs) – August 2012.

PROJECT 201012-00322-5000-WW-REP-0001 - AJAX, BLACKJACK AND BADGER GROUNDWATER IMPACT ASSESSMENT REPORT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Client Review	D. Linehan	S. Atkinson	N/A	27 Aug 2012	N/A	
0	Issued for Use	D. Linehan	S. Atkinson	P. Knudsen	29 Aug 2012		
1	Re-Issued for Use	D. Linehan	S. Atkinson	P. Knudsen	30 Aug 2012		
2	Re-Issued for Use	D. Linehan	S. Atkinson	P. Knudsen	21 Sept 2012		

i:\projects\201012-00322 fms vip\10.0 engineering\hydrogeology\phase 3 dfs investigations\reporting\ajax blackjack badger eia report\rev2\201012-00322-5000-ww-rep-001 ajax_blackjack_badger gw_impact assessment report_rev2.docx

CONTENTS

Appendix List

1. INTRODUCTION

1.1 Background

WorleyParsons was commissioned to undertake a preliminary assessment of the potential groundwater impacts associated with the Pilbara Iron Ore Project at the Ajax, Blackjack and Badger deposits, with particular reference to identified Groundwater Dependent Ecosystems (GDEs). The work has been carried out in response to the Environmental Protection Authority's request for clarifications in response to the Flinders Mines submission to the EPA in March 2012 (WorleyParsons, 2012a). The impacts have been evaluated in terms of permanent vegetation loss due to clearing within the pit boundaries and reversible impacts due to groundwater drawdown associated with pit dewatering.

1.2 Scope of Work

The scope of work for this study includes:

- Review of existing exploration data associated with Ajax, Blackjack and Badger;
- Development of GIS baseline relative to pit layout, GDE database and exploration information;
- Determination of hydrogeological characteristics of each deposit to use in quantitative analysis;
- Application of quantitative analysis technique to estimate drawdowns associated with dewatering;
- Preparation of maps showing permanent loss and reversible loss associated with GDE's; and
- Presentation of recommended management measures to minimise adverse environmental impacts.

2. HYDROGEOLOGY

The Ajax, Blackjack and Badger deposits are situated within valleys containing Quaternary and Cainozoic sediments overlying Banded Iron Formation (BIF) bedrock from the Brockman Iron Formation, a part of the Hamersley group. The Brockman Iron Formation, with an estimated maximum thickness of about 550m, is the main iron-bearing formation within the Hamersley Group and has been described in detail in previous WorleyParsons reports (WorleyParsons, 2012a&b).

Exploration drilling has been performed along a number of traverses at Ajax, Blackjack and Badger. The geological logs were used to develop a series of conceptualised cross sections for each of the deposits, presented in Appendix A. The general sequence of deposits is very similar for each deposit and comprises recent alluvial and colluvial material (RCT), overlying Detrital Iron Deposits (DID), Bedded Iron Deposits (BID) and Banded Iron Formation (BIF). The geometry and extent of each unit however varies significantly between catchments. Each deposit is discussed in more detail below.

2.1 Ajax Deposit

The hydrogeology of Ajax has been described previously in the “Ajax Site Characterisation Report” (WorleyParsons 2012b) so is only briefly summarised in this report. The cross sections presented in Appendix A for Ajax suggest that the conceptual geology at Ajax differs from the Champion, Delta and Eagle deposits in that there is a much shallower soil profile overlying the BIF bedrock. The average depth to basement is 15m but varies between 0m to 36m in the drilled area. The BID and CID deposits, which are known to be the most transmissive units and most likely to contain groundwater, are thin and not extensive throughout the catchment at Ajax. Therefore the storage capacity of the CID and BID units at Ajax are likely to be significantly smaller than at Champion, Delta and Eagle.

Groundwater levels shown in the cross sections in Appendix A are based on a one-off set of water level measurements recorded in November 2011. Therefore the magnitude of likely seasonal groundwater level fluctuations is currently unknown. The data does suggest that the extent of the permanent aquifer is limited, particularly during the dry season, but this may increase in response to recharge during significant rainfall events. Groundwater monitoring data collected at Champion, Delta and Eagle deposits show groundwater response to rainfall recharge. The groundwater response to recharge at Ajax is expected to be similar to those recorded at Champion, Delta and Eagle.

Analysis of the geological cross sections and water levels recorded in exploration holes and pools suggests there are two distinctive occurrences of groundwater at Ajax:

1. An extensive groundwater aquifer located within the BID, CID and DID deposits, just above the existing BIF bedrock; and
2. Pockets of perched groundwater associated with less extensive porous zones of alluvial sediments underlain by surface clays and located within or adjacent to creeks.

The deeper aquifer tends to follow the surface of the highly-resistant and impermeable Brockman formation (BIF). Local perched aquifers are restricted to saturated zones of a porous material above clay layers resulting from depositional changes during flooding events. These zones naturally follow creek beds and channels within the top several meters of colluvium. Further investigation is needed to confirm the degree of connectivity between the shallow perched groundwater and the deep aquifer however connectivity is expected to be limited.

Some permanent pools are present at locations where groundwater discharges out of the alluvial deposits and out over exposed bedrock. These pools are fed by groundwater stored in aquifers up gradient.

2.2 Blackjack Deposit

The geology at Blackjack is characterised by recent alluvial and colluvial material overlying an extensive layer of DID, which is in turn underlain by either BID or BIF basement. The average depth to basement is 25m but varies between 2m and 60m in the drilled area. The BIF also forms the lateral extent of the aquifer and can be seen outcropping along the flanks of valleys. This is similar to the geology encountered in the upper reaches of Champion, Delta and Eagle deposits. Two conceptual cross sections for Blackjack are presented in Appendix A.

Groundwater was encountered in the upstream part of the valley at Blackjack, within the basement or as a very shallow layer of water above the basement in BID or DID as shown in the upper valley cross section in Appendix A. The saturated thickness is expected to increase in the downstream direction and is approximately 13m at the lower portion of the Blackjack catchment. These water levels are based on a one-off set of water level measurements recorded in August 2012. Therefore the magnitude of likely seasonal groundwater level fluctuations is currently unknown. The data does suggest that the extent of the permanent aquifer is limited during the dry season, but this may increase in response to recharge during significant rainfall events. Groundwater monitoring data collected at Champion, Delta and Eagle deposits show groundwater response to rainfall recharge. The groundwater response to recharge at Blackjack is expected to be similar to those recorded at Champion, Delta and Eagle.

2.3 Badger Deposit

The general stratigraphy at Badger consists of BIF, BID, DID and RCT as shown in Appendix A. The BID is expected to extend laterally into the main CID aquifer at Serenity. CID was intercepted in only one of the exploration holes and probably represents the lateral extent of the CID aquifer.

The deposits at Badger sit relatively high in the topography. The average depth to basement is 17m but varies between 2 and 40m within the drilled area. Standing groundwater was encountered in only one of the exploration holes in August 2012 and was located at depth within the BIF. Therefore the majority of the BID/CID deposits are expected to be dry and unlikely to contain significant volumes of stored groundwater for most of the year. The BID/CID deposits may contain groundwater during significant rainfall events, as recharge flows through the permeable deposits and down into the CID aquifer at Serenity. However the period of inundation is likely to be of short duration.

3. PIT LAYOUTS AND GDES

Ajax has been identified as an area containing significant GDEs including two permanent pools. The nature of the GDEs is discussed in the Groundwater Dependent Ecosystem Mapping report (Ecoscape 2012) and the Ajax Site Characterisation report (WorleyParsons, 2012b). The survey data provided suggests that there are no GDEs within or immediately down gradient of the Blackjack deposit. The survey data indicates that no GDEs are present within the Badger deposit however there are GDEs approximately 800m down gradient off-tenement within the Serenity area. The relative layout of all the pits and GDEs are shown in Figure 7 in Appendix A.

The relative position of GDEs and pit footprints at Ajax is shown in more detail Figure 8. The pit footprints presented in the impact assessment do not overlap with any of the known / mapped GDEs. As such there are not expected to be any permanent losses of vegetation associated with clearing within the pit shells for mining.

4. DEWATERING REQUIREMENTS AND DRAWDOWN

4.1 Dewatering requirements

The recorded water levels at Ajax, Badger and Blackjack were compared to the design elevation of the proposed pits provided by Flinders, to determine where mining would proceed below the water table. These results are based on once off water level measurements only so will need to be confirmed using additional groundwater monitoring data. The results are shown in Table 1.

The aquifers within the upper catchment areas supply groundwater flow which supports and maintains the permanent pools and GDEs downstream. The mining of these aquifers is likely to reduce the supply of water so mitigation measures are needed to maintain the groundwater flow and quality of water reaching the permanent pools and GDEs.

The GDEs and permanent pools also rely on seasonal flooding to recharge aquifers, which increases storage and maintains groundwater flows throughout the year. Mining has the potential to starve downstream areas of surface water flow unless managed carefully using diversions and mine planning.

The results presented in Table 1 suggest that groundwater dewatering is likely to only be required at one pit each at Ajax and Blackjack. All of the other pits sit above the recorded groundwater levels, however as the recorded levels represent the dry season only, it is possible that the other pits may still have potential to intercept groundwater recharge and through flow generated during significant rainfall events. The expected duration of recharge and through flow at these pits is small and the majority of groundwater could be collected in sumps at the bottom of the pits and pumped out of the pits to sedimentation ponds prior to discharge back to the aquifer downstream.

Table 1: Comparison of pit design levels and groundwater levels to determine dewatering requirements

Pit	Hole ID	Ground Level (mAHD)	Pit Base Level (mAHD)	Basement Level (mAHD)	Groundwater Level (mAHD)	Dewatering required
Ajax 1	HPRC0891	585.68	582.00	577.68	Dry	No
Ajax 1	HPRC0892	592.69	582.00	578.69	570.43	No
Ajax 2	HPRC0883	581.39	570.00	565.39	564.59	No
Ajax 3	HPRC0801	572.98	570.00	564.98	568.62	No
Ajax 3	HPRC0882	575.34	570.00	563.34	569.34	No
Ajax 4	HPRC0802	629.45	603.10	601.45	Dry	No
Ajax 5	HPRC0810	591.80	588.00	571.80	578.30	Yes
Ajax 5	HPRC0844	593.59	576.00	571.59	580.75	Yes
Ajax 6	HPRC0819	615.09	588.00	591.09	Dry	No
Ajax 6	HPRC0820	612.22	594.00	582.22	580.72	No
Ajax 6	HPRC0854	633.51	630.51	627.51	Dry	No
Ajax 6	HPRC0855	624.18	588.00	588.18	Dry	No
Ajax 6	HPRC0856	619.61	630.51	603.61	585.51	No
Blackjack 1	HPRC0418	577.42	546.00	543.42	544.48	No
Blackjack 1	HPRC0431	569.05	522.00	519.05	520.14	No
Blackjack 1	HPRC0432	568.97	516.00	518.96	520.25	Yes
Blackjack 1	HPRC0441	561.05	504.00	501.05	514.50	Yes
Blackjack 2	HPRC0423	588.72	564.00	564.72	Dry	No
Blackjack 3	HPRC0412A	585.81	546.00	547.81	541.14	No
Blackjack 3	HPRC0413	599.97	582.00	585.97	Dry	No
Blackjack 3	HPRC0426	589.13	546.00	549.13	543.46	No
Blackjack 3	HPRC0438	581.70	546.00	545.70	540.29	No
Badger 1	HPRC3802	578.06	540.00	538.06	Dry	No
Badger 2	HPRC3807	576.62	546.00	548.62	535.10	No

4.2 Drawdown

The drawdown associated with the dewatering requirements for each pit was evaluated using a simple and conservative analytical approach. The analysis was based on the late-time drawdown component of the Theis equation which is applicable for unconfined flow. The analysis is based on a number of assumptions which are significant in terms of the hydrogeological setting at Ajax and Blackjack. The assumptions include:

- The aquifer is laterally extensive;
- The thickness is uniform throughout;
- The aquifer is homogeneous and isotropic; and
- Water is instantaneously released from storage when the head is reduced.

All but the last of these assumptions is known not to be fully valid for the site hydrogeological setting. Nevertheless they provide a good starting point for evaluating the order of magnitude of impacts prior to adopting more complex numerical methods.

Hydraulic parameters used in the analysis are shown in Table 2.

Results from the analysis are presented as drawdown contours in Figures 9 and 10 in Appendix A. The drawdown contours at Ajax extend across the known GDE locations, so management measures will be required to minimise potential impacts. The predicted drawdown at Blackjack does not impact on surveyed GDE locations.

The total area of GDEs on-tenement at Ajax and the potential area of GDEs impacted by mine dewatering at Ajax are shown in Table 3. The potential area of GDEs impacted by mine dewatering must be defined with respect to a nominated minimum drawdown level; for reference, Table 3 presents the area of GDE vegetation within the 2m and 0.25m drawdown contours.

Table 2: Hydraulic parameters used for the drawdown calculations.

Parameter	Symbol	Unit	Blackjack 1a	Blackjack 1b	Ajax 5
Horizontal Hydraulic Conductivity	Kh	m / day	40 (10 - 100)	40 (10 - 100)	40 (10 - 100)
Saturated Thickness	b	m	13.45	1.28	9.16
Specific yield	Sy	-	0.2 (0.1 - 0.25)	0.2 (0.1 - 0.25)	0.2 (0.1 - 0.25)
Required Drawdown	s	m	12.00	5.74	6.25

Table 3: Area of GDEs potentially impacted by mine dewatering and the total area of GDEs on-tenement at Ajax

Vegetation Code[1.]	On-tenement area (ha)	Area within 2m contour (ha)	Area within 0.25m contour (ha)
EvAmTt	6.39	0	6.39
EvTrg	29.85	14.73	29.85
EvFbTt	9.16	0	9.16
EvApSg	6.59	0	6.59
EcEvSg	65.22	2.24	65.22
EvSg	1.54	0	1.53
Total	94.36	16.97	118.74

1. Vegetation codes are described in detail by Ecoscape (2012)

5. CONCLUSIONS

Ajax has been identified as an area containing significant GDEs including two permanent pools. No GDEs have been identified within the Blackjack and Badger deposits.

Comparison of the current mine plan and surveyed GDE areas shows that there are no GDEs located with the pit areas. Therefore clearing to allow for mining at Ajax, Blackjack and Badger is not expected to cause permanent loss of GDEs.

The GDEs and permanent pools rely on seasonal flooding to recharge aquifers and maintain groundwater flows throughout the year. Groundwater and surface water runoff may be intercepted by pits at Ajax, Blackjack and Badger during significant rainfall-recharge events. Therefore mining has the potential to starve downstream areas of surface water flows unless managed carefully using diversions and mine planning.

The groundwater monitoring data collected shows the base of pits extending below the water table at one pit in Ajax and one pit in Blackjack, while no significant groundwater was encountered at Badger. Therefore groundwater dewatering may be required at one pit in Ajax and Blackjack to maintain groundwater levels below the base of the pit while mining, while groundwater dewatering is not expected to be required at Badger.

The results of the preliminary analytical drawdown assessment have been presented as drawdown contours for Ajax and Blackjack in Figures 9 and 10 (Appendix A). The drawdown contours at Ajax extend across the known GDE locations, so management measures are likely to be required to minimise potential impacts. Mine dewatering at Blackjack is not expected to impact on GDEs, because there are no GDEs on-tenement or immediately down gradient in off-tenement areas.

It is recommended that appropriate management measures are developed and incorporated into mine planning to ensure that surface and groundwater flows, volumes and qualities are maintained at pre development conditions where possible, at the GDE's and permanent pools to minimise adverse environmental impacts.

Management measures may include the following:

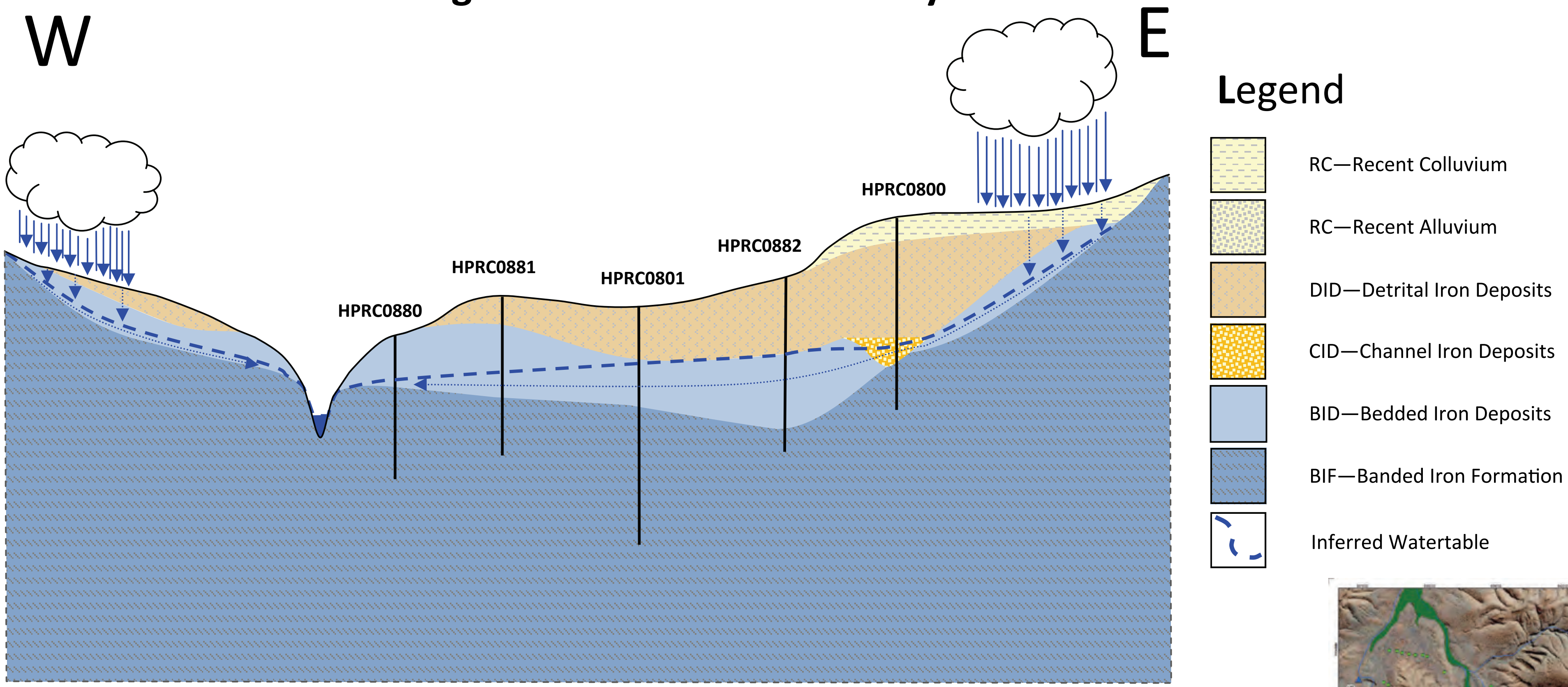
- Mine dewater and groundwater intercepted in sumps while mining should be pumped to sedimentation ponds before being returned to the aquifer via reinjection or direct discharge to maintain groundwater/water levels at GDE locations;
- Mine dewater may also need to be pumped directly to the pools to maintain water levels in the pools and flows from the pool/s to downstream GDEs;

- Surface water flow through mine areas will need to be managed using diversions, sedimentation ponds and appropriate mine planning to ensure that pre and post development flows and quality at the GDEs and permanent pools are similar; and
- Appropriate methods for backfilling mine pits should be adopted for mine closure to ensure that sufficient water storage is retained is the upper reaches of the catchment to maintain flow to the permanent pools and GDEs located downstream.

The analytical drawdown assessment undertaken as part of this study is considered conservative, indicative only and based on a preliminary mine plan. Additional investigative work is needed to better characterise the site hydrogeology, understand the GDE dependence on groundwater and quantify the potential impacts associated with mine dewatering more accurately. The results can then be used to develop appropriate management measures in more detail.

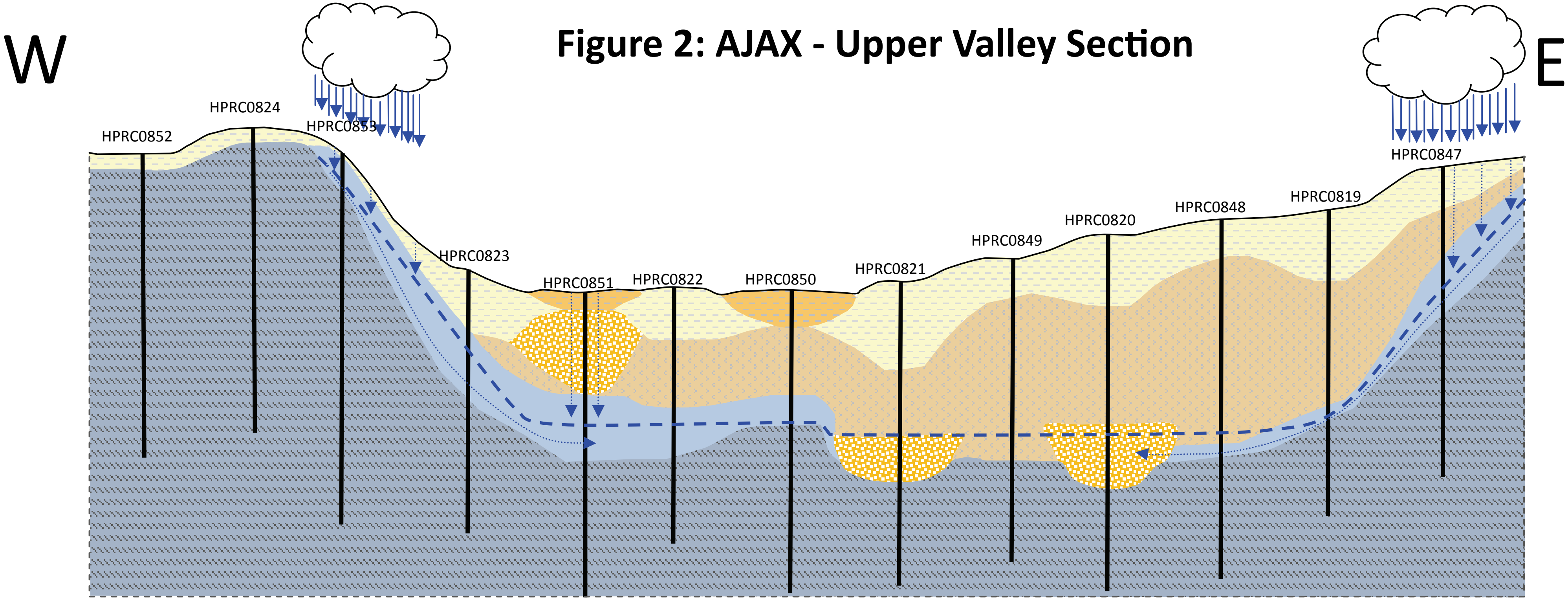
Appendix A - Figures

Figure 1: AJAX - Lower Valley Section



Approximately 10x Vertical exaggeration

Figure 2: AJAX - Upper Valley Section



Approximately 9x Vertical exaggeration

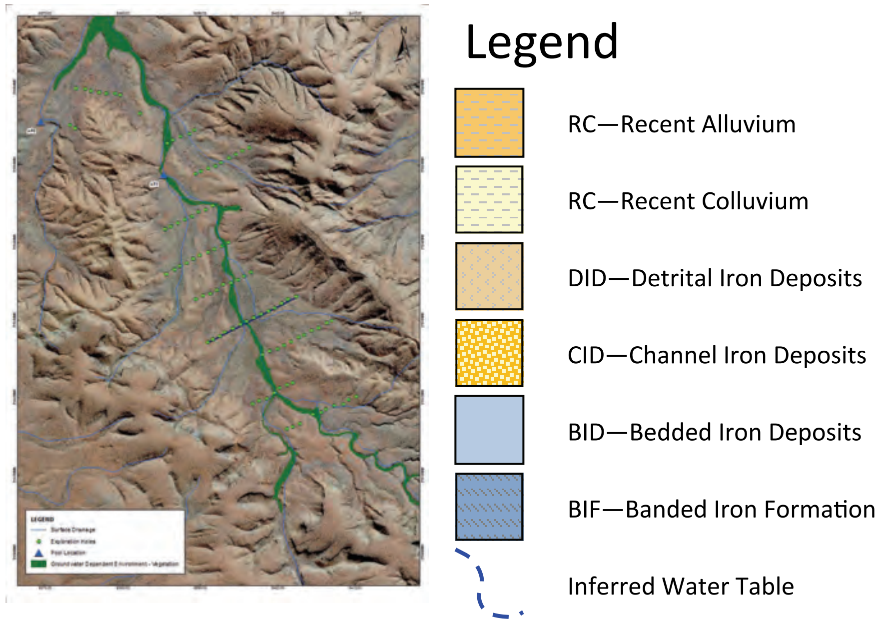
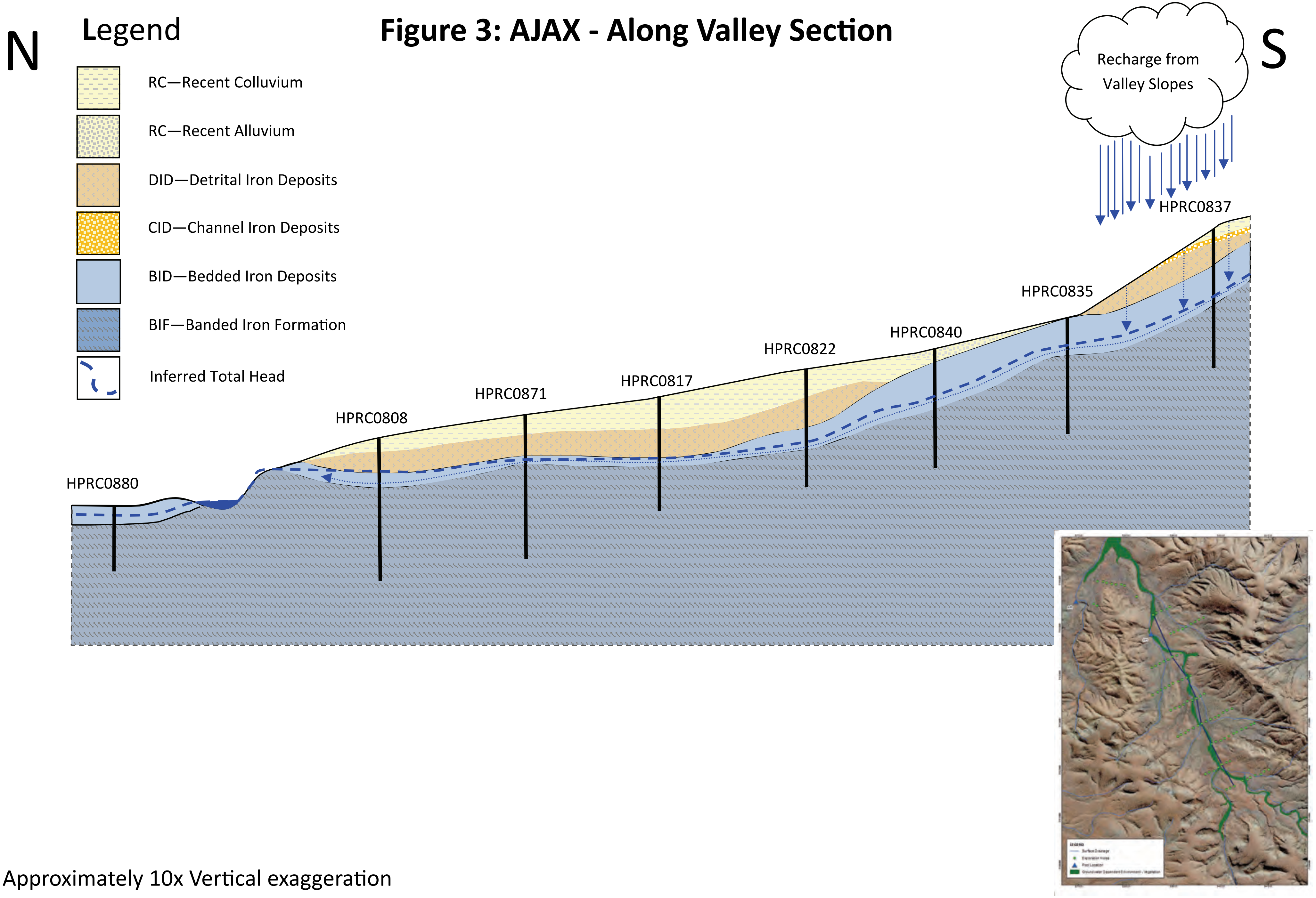
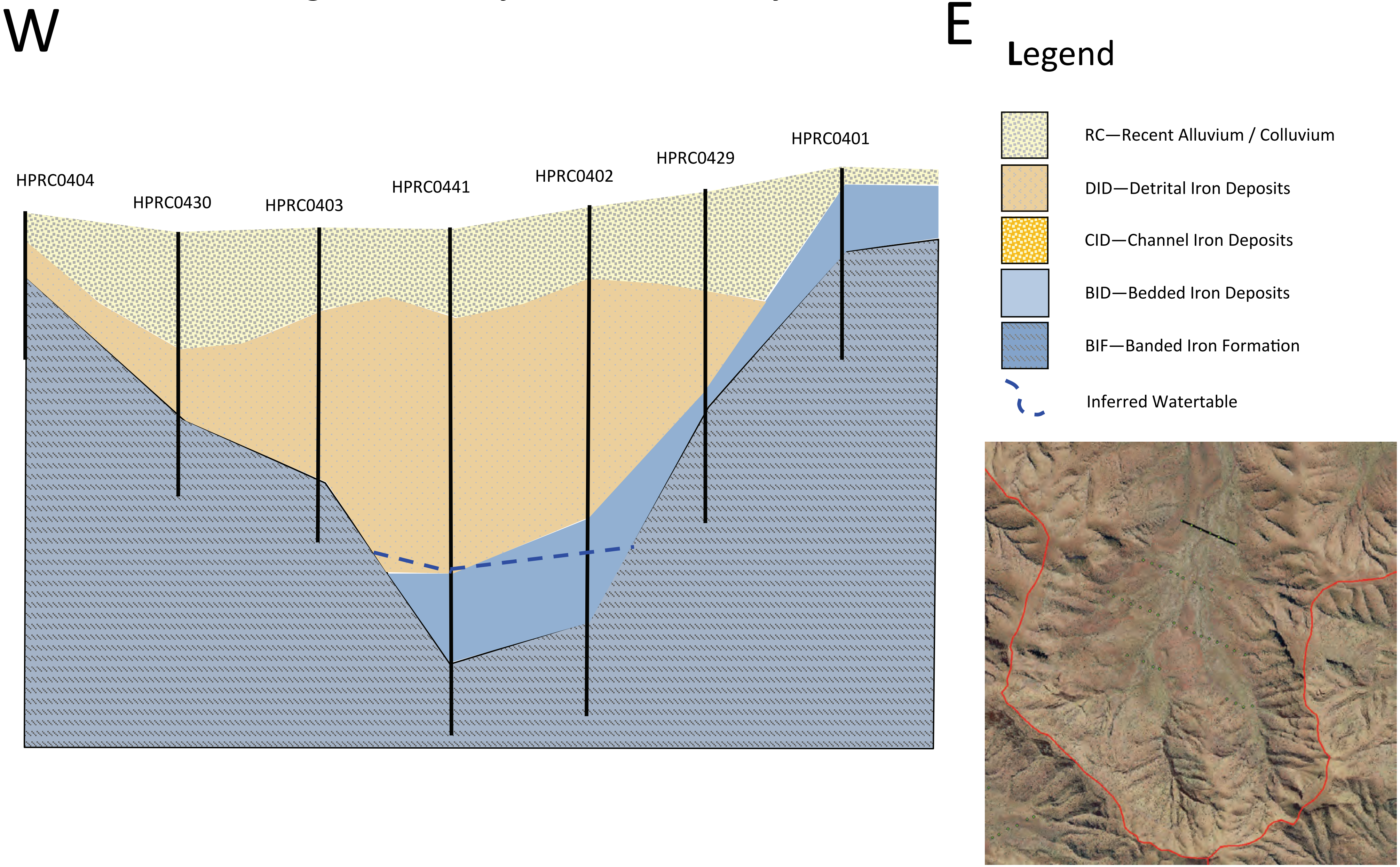


Figure 3: AJAX - Along Valley Section



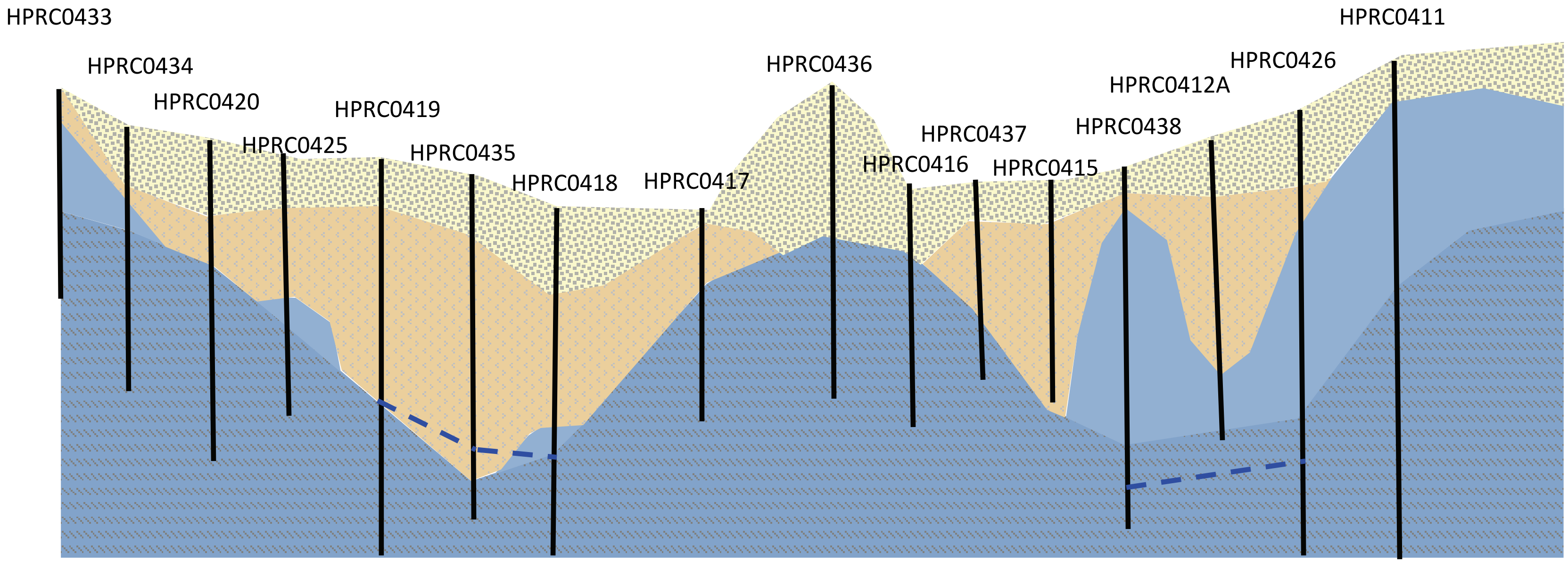
Approximately 10x Vertical exaggeration

Figure 4: Blackjack - Lower Valley Section

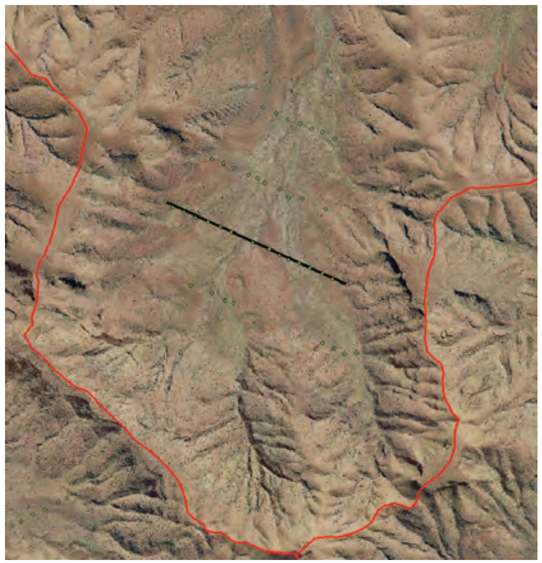


Approximately 8x Vertical exaggeration

Figure 5: Blackjack - Upper Valley Section



Approximately 10x Vertical exaggeration



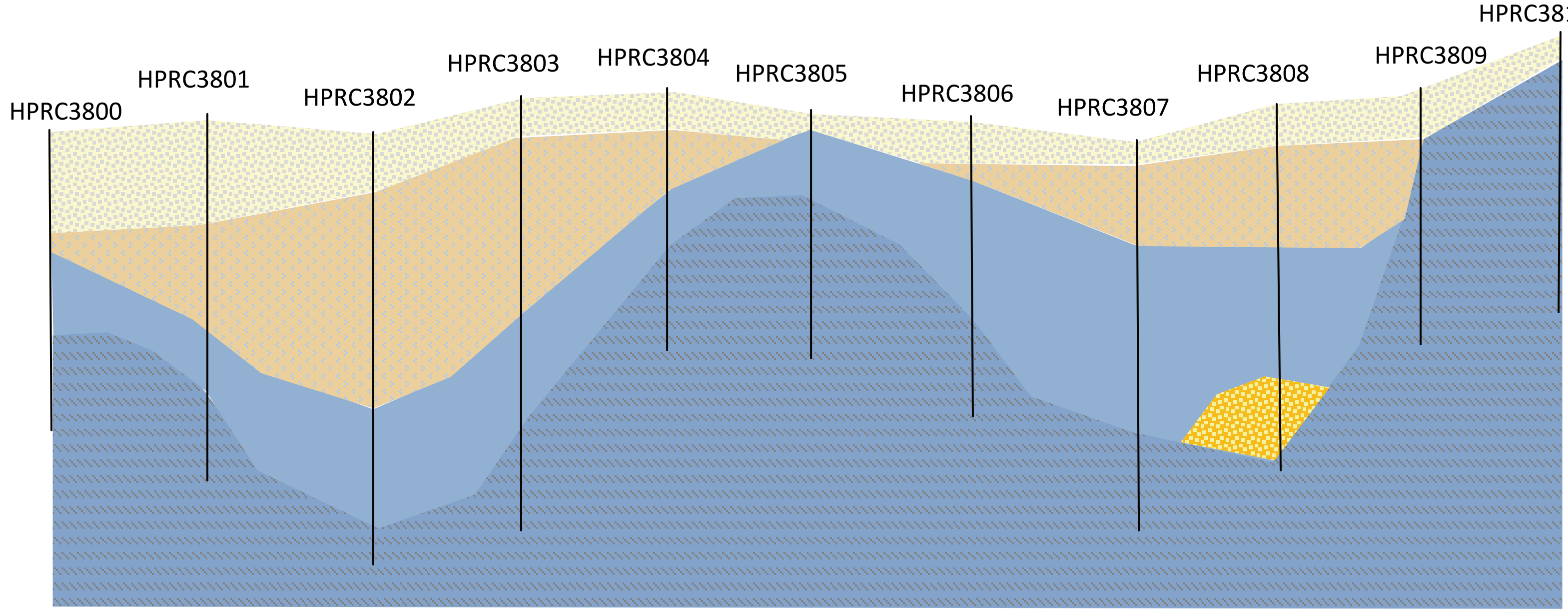
Legend

- RC—Recent Alluvium / Colluvium
- DID—Detrital Iron Deposits
- CID—Channel Iron Deposits
- BID—Bedded Iron Deposits
- BIF—Banded Iron Formation
- Inferred Water Table

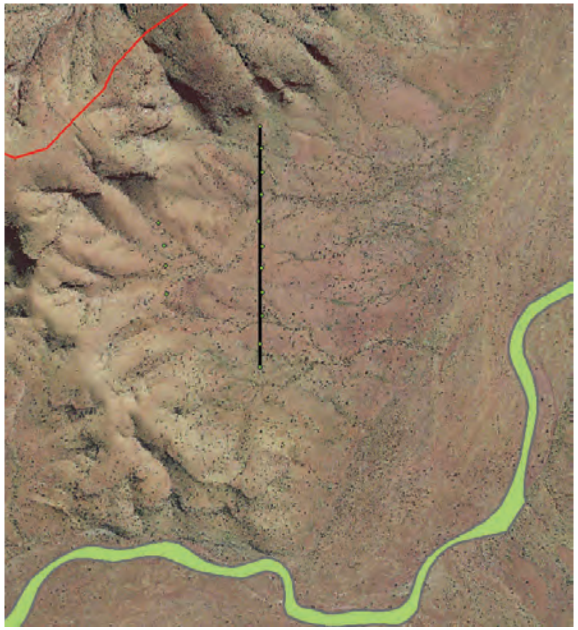
S

Figure 6: Badger Section

N

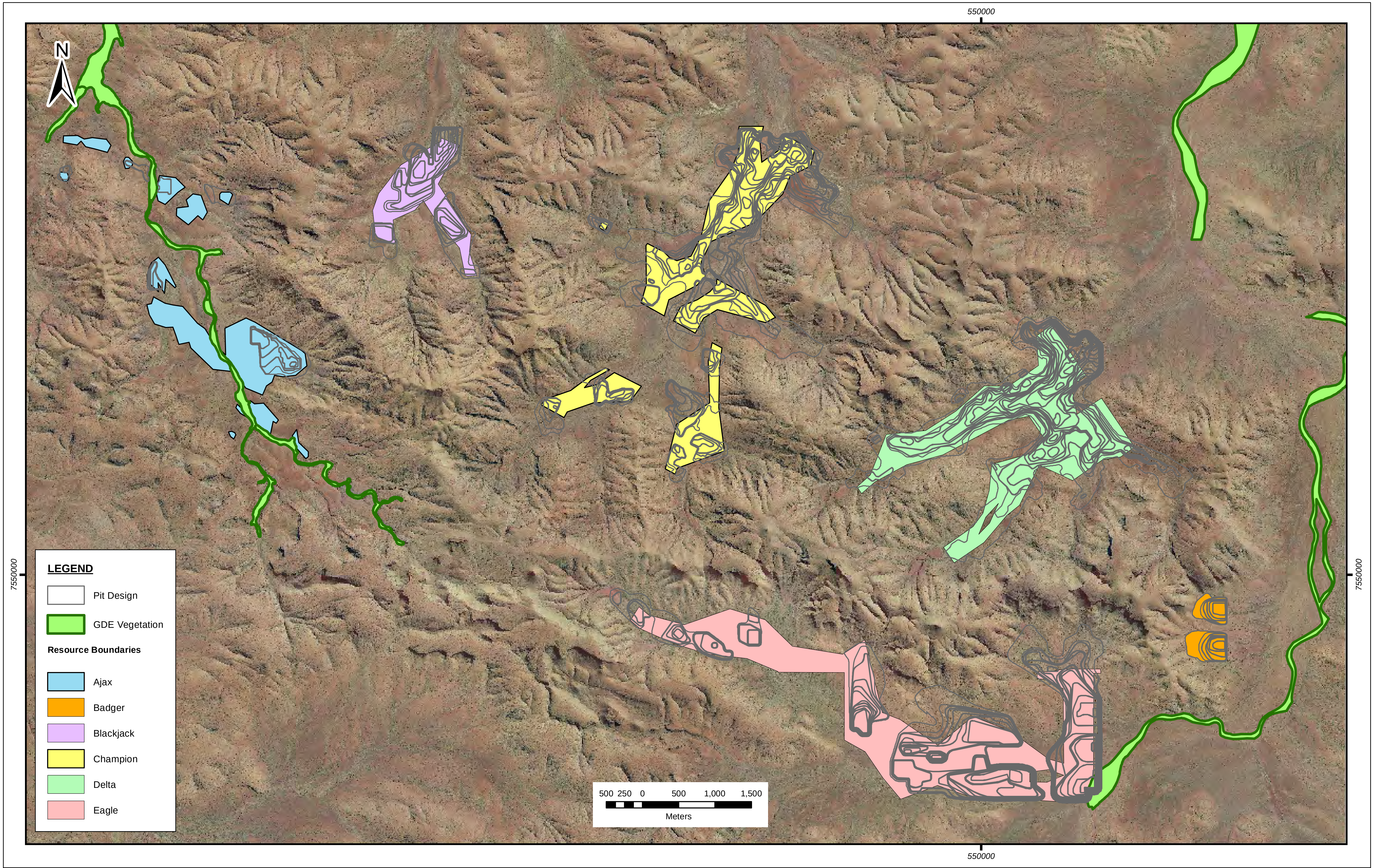


Approximately 10x Vertical exaggeration



Legend

- RC—Recent Alluvium / Colluvium
- DID—Detrital Iron Deposits
- CID—Channel Iron Deposits
- BID—Bedded Iron Deposits
- BIF—Banded Iron Formation
- Inferred Water Table



WorleyParsons
resources & energy

LOCALITY MAP: BROOME, PORT HEDLAND, KARRATHA, PANNAWONICA, TOM PRICE, PARABURDOO

A	FOR INFORMATION ONLY	DL	LS	22-08-2012
REV	REVISION DESCRIPTION	DRN	CHK	DATE

NOTES

CLIENT: Flinders Mines

TITLE: FLINDERS MINES

FIGURE 7 - Pit layouts, GDE's and resource boundaries for Flinder's mining tenement

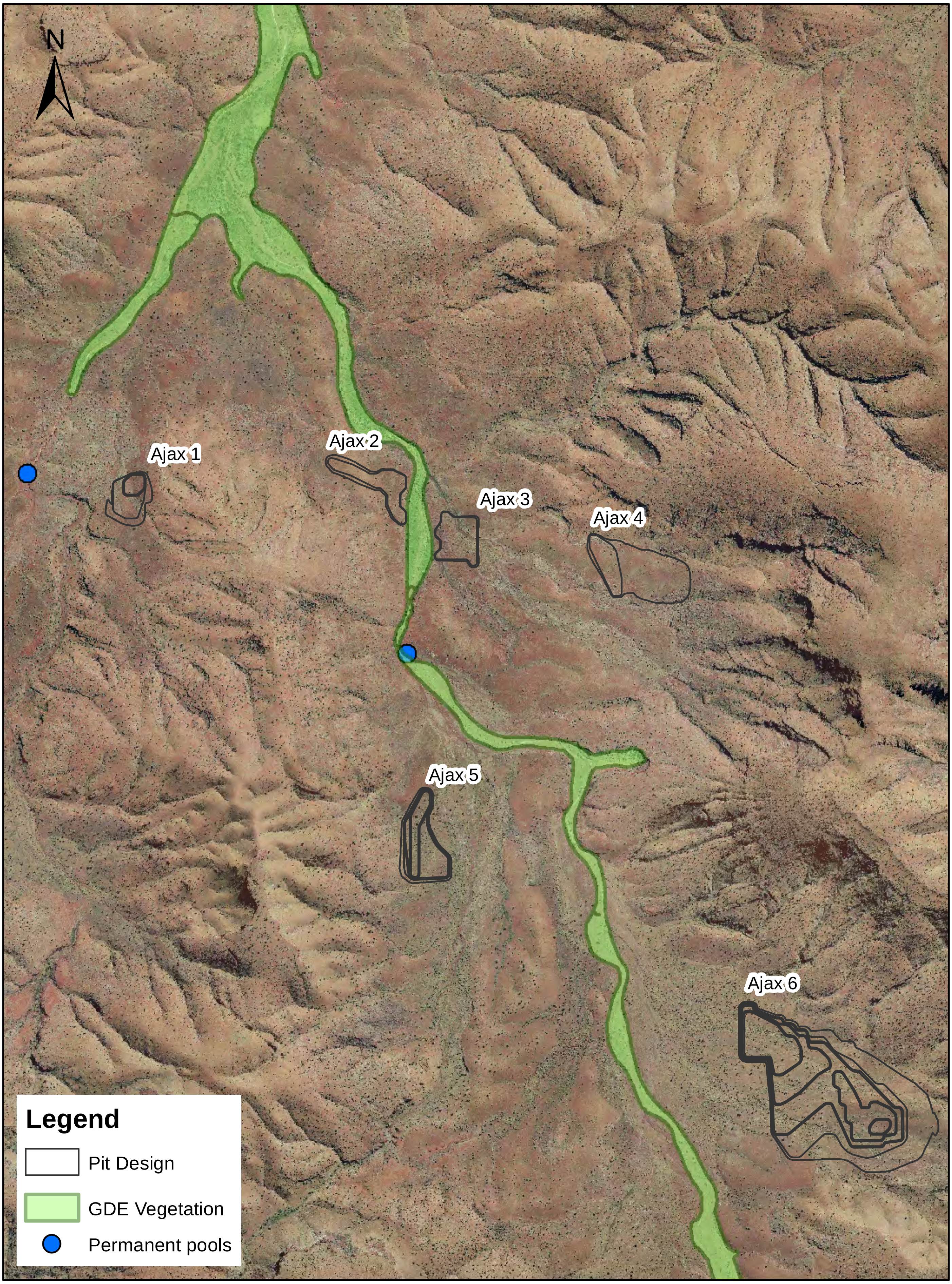
WORLEYPARSONS PROJECT: 201012-00322

DATUM: GDA 1994 MGA Z50S

DRG NO: Groundwater Impact Assessment Figure 7

REV: A

I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Phase 3 DFS Investigations\Ajax Blackjack Badger EIA\Figures\Groundwater Impact Assessment Figure 7.mxd



WorleyParsons
resources & energy
OneWay to zero harm

CLIENT
Flinders Mines

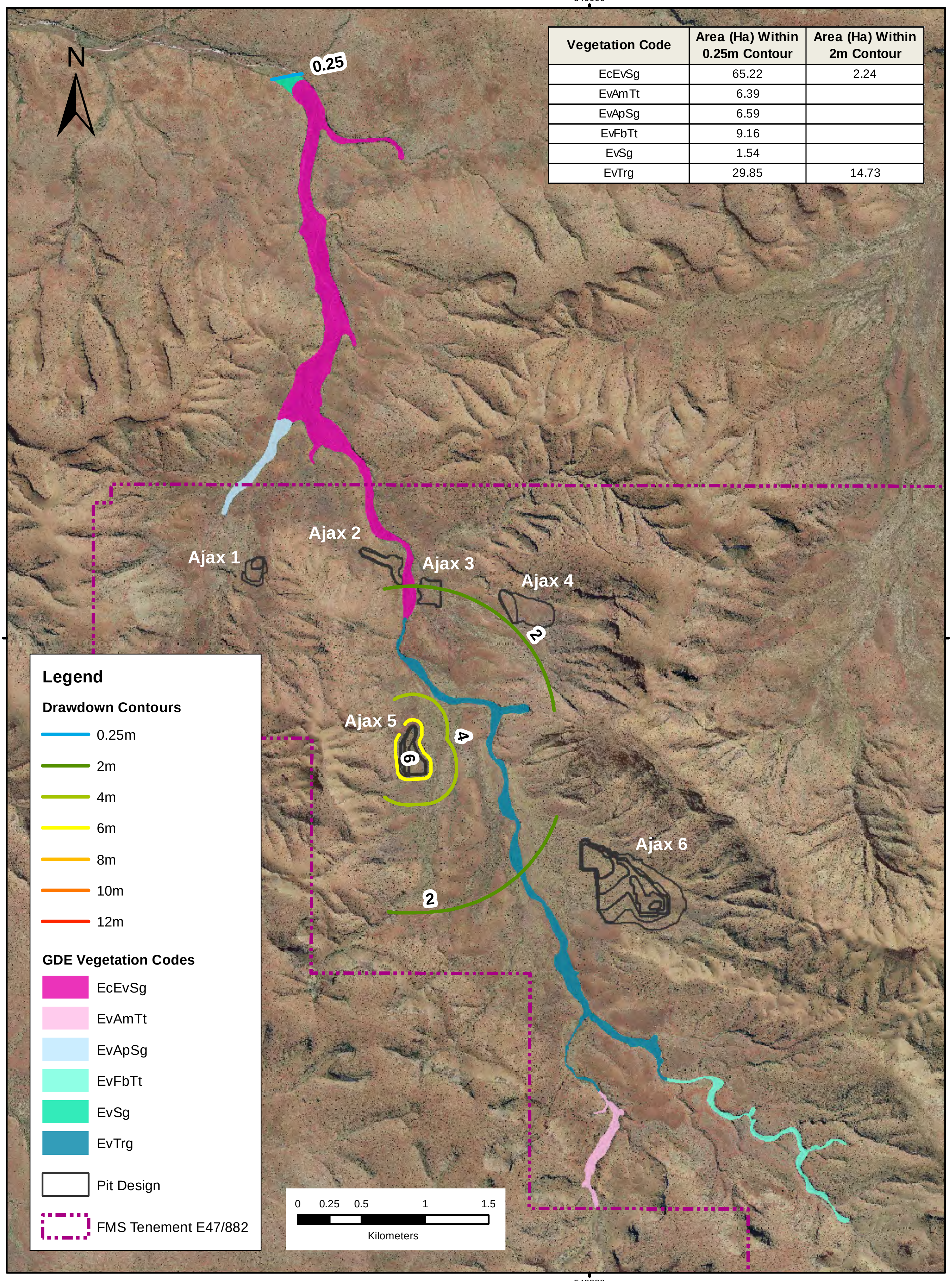
FIGURE 8 - Ajax pit layouts, GDE's and permanent pools

WORLEYPARSONS PROJECT 201012-00322	DATUM GDA 1994 MGA Z50S

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	FOR INFORMATION ONLY	DL	LS	22-08-2012

DWG No.
Groundwater Impact Assessment Figure 8

I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Phase 3 DFS Investigations\Ajax Blackjack Badger EIA\Figures\Groundwater Impact Assessment Figure 8.mxd



Vegetation Code	Area (Ha) Within 0.25m Contour	Area (Ha) Within 2m Contour
EcEvSg	65.22	2.24
EvAmTt	6.39	
EvApSg	6.59	
EvFbTt	9.16	
EvSg	1.54	
EvTrg	29.85	14.73

WorleyParsons
resources & energy
OneWay to zero harm

CLIENT
Flinders MINES

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	FOR INFORMATION ONLY	MR	LS	12-09-2012

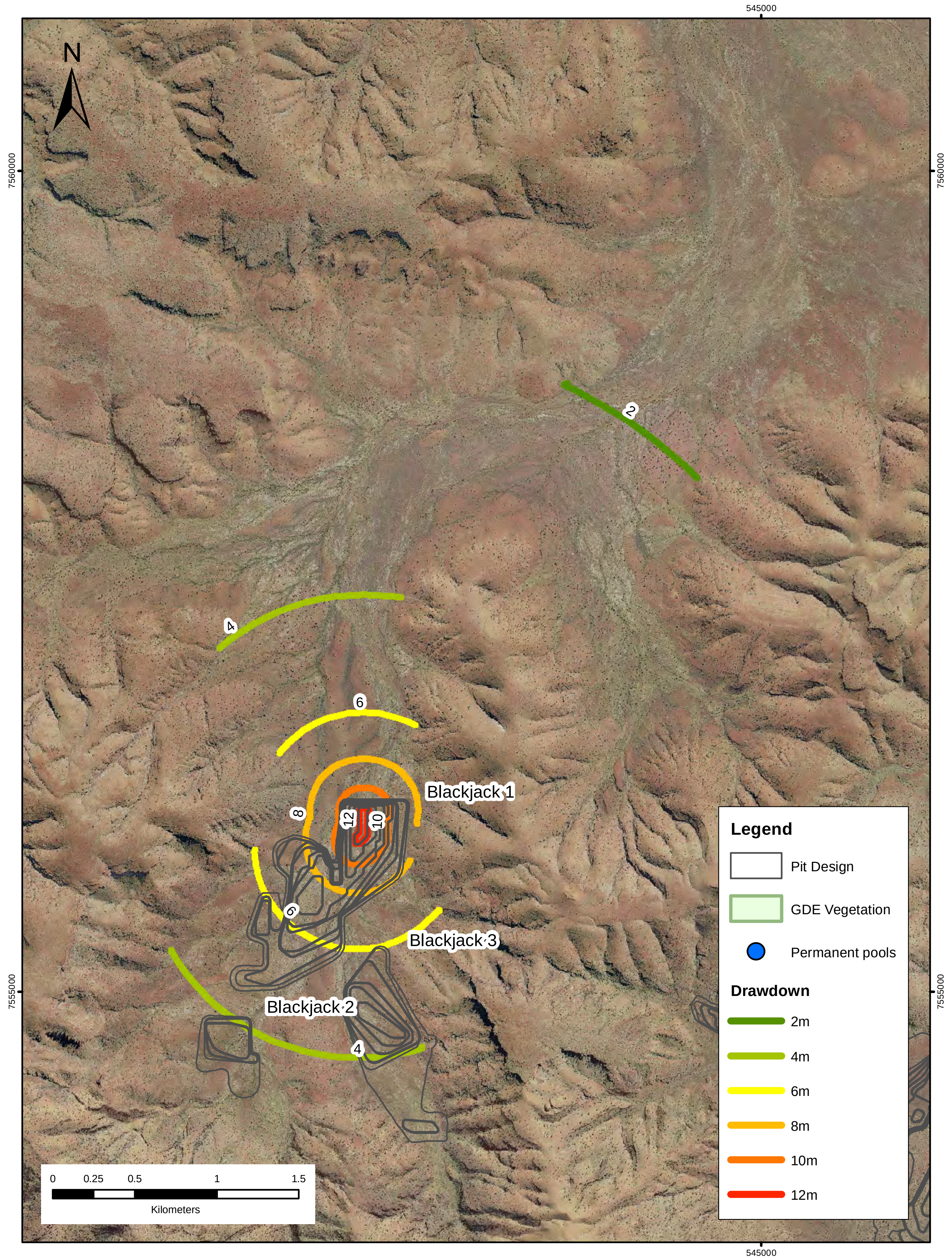
FIGURE 9 - AJAX DRAWDOWN CONTOURS

WORLEYPARSONS PROJECT
201012-00322

SCALE 1:40,000 @ A4
DATUM GDA 1994 MGA Z50S

DWG No.
Groundwater Impact Assessment Figure 9

I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Phase 3 DFS Investigations\Ajax Blackjack Badger EIA\Figures\Groundwater Impact Assessment Figure 9.mxd



WorleyParsons
resources & energy
OneWay to zero harm

CLIENT
Flinders Mines

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	FOR INFORMATION ONLY	DL	LS	22-08-2012

WORLEYPARSONS PROJECT
201012-00322

SCALE 1:30,000 @ A4
DATUM GDA 1994 MGA Z50S

FIGURE 10 - Blackjack drawdown contours

DWG No. Groundwater Impact Assessment Figure 10

I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Phase 3 DFS Investigations\Ajax Blackjack Badger EIA\Figures\Groundwater Impact Assessment Figure 10.mxd