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P.O. Box 6837,
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PROJECT: LD Project - Surface Water Assessment

NUMBER: PE801-00326/03-A

TO: Rewards Minerals Ltd
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Nedlands WA 6009

ATTENTION: Daniel Tenardi

FROM: Peter Veld

Please find enclosed the following documents:

Quantity	Document Ref.	Revision No.	Particulars
1	PE801-00326/2	0	Lake Disappointment – Hydrological Study

These have been sent for: ☐Approval ☐Construction ☒Comment ☐Other ☐Preliminary

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REWARD MINERALS LTD
LD SOP PROJECT

LAKE DISAPPOINTMENT - HYDROLOGICAL STUDY

PREPARED FOR:

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159 Stirling Highway
NEDLANDS WA 6009

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REWARD MINERALS LTD

LD SOP PROJECT

LAKE DISAPPOINTMENT HYDROLOGY STUDY

KP Job No. PE801-00326_03

KP Report No. PE801-00326_02

CONTRACT
PROJECT CONTRACT #

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1. INTRODUCTION

1.1 GENERAL

Reward Minerals Ltd (RML) is in the process of developing the LD SOP Project on Lake Disappointment in Western Australia. Lake Disappointment is a large salt Lake (~38,000 ha) in Western Australia approximately 300 km east of Newman.

RML appointed Knight Piésold Pty Limited (KP) to undertake a Concept Study (CS) for the design of the hydrological aspects of the project.

1.2 SCOPE OF WORK

The scope of work of the Hydrology study includes the following activities:

- Demarcation of surrounding catchment areas.
- Estimate of storm flood levels.
- River and streamflow estimates into Lake Disappointment.
- Surface water management design around proposed infrastructure and ponds.

1.3 OBJECTIVES

Based on the scope of work this study had the following objectives:

- Develop an understanding of the surface water environment around Lake Disappointment and use this understanding to estimate frequency, magnitude and duration of flooding events.
- Evaluate the impact of the flooding events on the project infrastructure (both flooding depths and flow regimes) and conversely the impact of the infrastructure on the flood patterns of the lake.
- Provide design advice on flood mitigation effects and if necessary modifications to the design concepts for the infrastructure.

1.4 DESIGN PARAMETERS

Design parameters for the site infrastructure are summarised in Table 1.3 of the “Brine Collection, Evaporation Ponds and Residue Disposal Concept Study” (Ref. 1). The critical factors relating to storm volumes and flood conditions are as follows:

- Characterisation of the hydrological environment to include all surface water and groundwater effects.
- Storm storage capacities of a 1% AEP event (1 in 100 year nominal return period).

- Diversion channel capacities of a 10% AEP event for temporary works and 1% AEP event for long term diversion works. This includes management of external flood events and flood bypass design.

Intensity-Frequency-Duration (IFD) information for design storms was sourced from the Bureau of Meteorology 2013 IFD (Ref. **Error! Reference source not found.**). Additional climatic and hydrologic parameters were assumed as per the Australian Rainfall and Runoff (ARR) guidelines (Ref. 3).

Hydraulic structures were either sized to convey the 1% AEP storm for the critical duration (the storm duration that results in the largest peak flow) or were sized to attenuate and then convey the 1% AEP 72 hour event. For the design of the bunds for the Infiltration Trenches and Plant Site Feed Channel, no freeboard allowance was provided.

1.5 AVAILABLE DATA

The topography used for the hydrologic study for the lake surroundings is based on '1 arc-second' DEM-S data from Geoscience Australia (Ref. 4). The vertical accuracy of the data is 0.5 m or greater. The spot height values provided by RML were used to generate contours for the lake surface itself. The two topography datasets are shown on Figure 1.1. The two topographic datasets were combined for the assessment.

Water Observations from Space (WOfS) data was also available for the area (Ref. 5). WOfS data consists of satellite observations from 1987 onwards which have been assessed as to whether or not surface water was present.

2. HYDROLOGICAL ASSESSMENT

2.1 CLIMATE DATA

The climate is defined as Arid (Bureau of Meteorology Classification AZ (SS)) with an annual rainfall of about 367 mm and an annual average evaporation rate of 4,630 mm (Class A Pan – Lake Evaporation = 2,777 mm).

Daily precipitation data and pan evaporation data was available from the Bureau of Meteorology climate station at Telfer Aero, approximately 180 km North of the site. Pan evaporation data was available for 1974 through to 1995 and daily rainfall data was available from 1974 through to 2016.

Parnngurr climate station is located approximately 50 km to the North of the site. However, it only had a limited amount of daily precipitation data: February 2004, March 2004, November 2004, March 2006 and January to August 2013. Daily rainfall for this station was only used for the Cyclone Rusty rainfall pattern.

Cyclone Rusty generally resulted in three days of appreciable rainfall at the gauges that were impacted. The daily rainfall recorded from February 24th to March 2nd 2013 for both Telfer Aero and Parnngurr are summarised in Table 2.1.

Table 2.1: Daily rainfall due to Cyclone Rusty

Date	Daily Precipitation (mm)	
	Parnngurr	Telfer Aero
24/02/2013	0	0
25/02/2013	2.5	2.4
26/02/2013	55.2	28.8
27/02/2013	35.4	68.8
28/02/2013	165	177
01/03/2016	0	4.6
02/03/2016	0	0.2

Hyetographs from Australian Rainfall and Runoff (1999) were used for storms with ARIs up to and including the 100 year event. For the 500 year event, the hyetograph used was as per the Revised Generalised Tropical Storm Method (GTSMR).

2.2 WATER OBSERVATIONS FROM SPACE

Water Observations from Space (WOfS) was available for Lake Disappointment. Figure 2.1 shows the WOfS data with the site infrastructure overlayed. It is noted that the WOfS data is a measurement of the percentage of all observations of a given location that detected surface water. As such, the probability of flooding occurring at a given point cannot be directly inferred from this data. However the WOfS data does provide some indication as to the topography of the lake as lower points would be more likely to be inundated by surface water.

2.3 CATCHMENT AREA

The total catchment area of Lake Disappointment has been estimated previously as 50,654 km^2 (Ref. 1). This consists of two sub-catchments, the western catchment with an area of 26,160 km^2 that drains into the lake via Savory Creek and the southern catchment with an area of 24,494 km^2 that drains into the lake via the Disappointment Paleoriver (Ref. 6).

2.4 CALIBRATION OF LAKE AND CATCHMENT DATA

2.4.1 Topographic Adjustment

The available topographic data (Section 1.5), was combined to make one working surface. In order to do this, the provided spot elevations were triangulated into a surface. This triangulated surface did not cover the full area required. The surface was extended to cover the full area by projecting it outwards. The extended spot elevation topography was then patched into the SRTM topography, where it replaced the lake surface. This was required as in the SRTM topography the lake surface had been set as a flat surface at RL325 m. All of the ongoing modelling was based on this integrated topographic surface.

2.4.2 Cyclone Rusty Modelling

Cyclone Rusty resulted in a pond nominally at 327.7 m. At RL327.7 m, the pond volume post Cyclone Rusty was estimated at approximately 139 Mm^3. Figure 2.2 shows satellite imagery sourced from NASA’s Earth Observatory of Lake Disappointment (Ref. 7) taken on the 4th of March 2013. This imagery formed the basis of the Cyclone Rusty flood level estimate.

As shown in Table 2.1, the majority of the precipitation resulting from Cyclone Rusty occurred over three days. Therefore, for modelling purposes, Cyclone Rusty has been assumed to be effectively a 72 hour duration storm event. As Parnngurr is closer to Lake Disappointment the precipitation depth for the three day Cyclone Rusty event has been taken as 255.6 mm.

2.4.3 Nominal Runoff Parameters

Flavell and Belstead (Ref. 8) recommend an Initial Loss value between 40 to 50 mm and Constant Loss values of 5 mm/h for the Pilbara. As such, for the modelling of runoff into lake disappointment, an Initial loss of 45 mm and a constant loss of 5 mm/h were assumed. It is noted that for the 0.2% AEP event (500 year ARI), the loss parameters were reduced to an IL of 37.1 mm and a constant loss of 4.3 mm/h.

These nominal runoff parameters were applied to Cyclone Rusty as it was recorded at the Parnngurr station. This assessment estimated the overall runoff coefficient as being 17.6%.

2.4.4 Catchment Zone of Influence

The catchment area around the lake that actually contributes runoff that reaches the lake is called the Zone of Influence. Using the calculated runoff coefficient of 17.6% and the estimated runoff volume of 139 Mm^3, the Zone of Influence was estimated as 3,090 km^2.

2.5 RUNOFF COEFFICIENT VS STORM RETURN PERIOD

Utilising the selected Initial Loss, Constant Loss and estimated Zone of Influence, the runoff from a range of 72 hour storms was estimated. The results of the assessment for 72 hour storms from an AEP of 10% down to an AEP of 0.2% as summarised in Table 2.2.

Table 2.2: Runoff coefficient versus AEP for 72 hour storms

Annual Exceedance Probability (AEP)	Average Return Interval (ARI)	Runoff Coefficient	Flood Volume (Mm^3)
0.2%	500 years	21.1%	193.1
Cyclone Rusty (Parnngurr)	212 years	17.6%	139.1
1%	100 years	10.2%	72.5
2%	50 years	6.7%	40.1
5%	20 years	7.5%	35.6
10%	10 years	0.0%	0.0

It is noted that the 5% AEP 72 hour storm resulted in a slightly higher runoff coefficient than the 2% AEP 72 hour storm. This is due to the use of a different hyetograph for the two events and is not an error.

Cyclone Rusty was estimated to have a 212 year return interval (AEP = 0.47%).

2.6 POND / FLOODING DURATION

KP performed basic water balance modelling on a daily time step to assess how long it would take for the storm flood at Lake Disappointment to dry out. KP assumed a start date of the first of March for each of the model runs. Average daily lake evaporation was estimated for each month from the Telfer Aero dataset whilst seepage was assumed to be a nominal 1.5 mm per day.

As shown on Figure 2.3, for the higher frequency events, the surface water was gone in under two months, with water possibly lasting up to 5 months for longer return period events. A summary of the number of days it takes to reach a pond depth of approximately 0.1 m is summarised in Table 2.3.

Table 2.3: Pond / Flooding Duration

Annual Exceedance Probability (AEP)	Average Return Interval (ARI)	No. Days Pond Depth >0.1 m
0.2%	500 years	129
Cyclone Rusty (Parnngurr)	212 years	106
1%	100 years	73
2%	50 years	55
5%	20 years	53

These durations are consistent with data on flood durations from other sources.

3. FLOOD IMPACT

3.1 PRE DEVELOPMENT

The pre-development flood extents and flood depths were modelled for the design storms outlined in Section 2 and for Cyclone Rusty. The flood extents and depths are shown on figures 3.1 to 3.5. The flood WSE (water surface elevation) levels are summarised in Table 3.1.

Table 3.1: Increase in Flood Level Post Development

Annual Exceedance Probability (AEP)	Average Return Interval (ARI)	WSE (m)
0.2%	500 years	327.83
Cyclone Rusty (Parnngurr)	212 years	327.70
1%	100 years	327.50
2%	50 years	327.38
5%	20 years	327.36

3.2 DEVELOPMENT IMPACT

3.2.1 Development Impact on Flood Levels

The development of the LD project includes the construction of a number of ponds and other infrastructure on Lake Disappointment. As such, the lake will lose some capacity, which could increase the flood levels resulting from storm events.

The impact was assessed by developing a stage storage of the lake with the lake with the footprint areas of the ponds and waste dumps removed. This stage storage was then used to estimate the new flood level for 72 hour storms with a range of ARIs. As shown in Table 3.2, the increase in the flood level is negligible.

Table 3.2: Increase in Flood Level Post Development

Annual Exceedance Probability (AEP)	Average Return Interval (ARI)	Increase in Flood Level (m)
Cyclone Rusty (Parnngurr)	212 years	0.004
0.2%	500 years	0.010
1%	100 years	0.000
2%	50 years	0.000
5%	20 years	0.000

3.2.2 Depth in Trench Areas

As the change in flood level was found to be generally negligible, the flood inundation and depths provided in Section 3.1 were not remodelled. The pond resulting from the

72 hour 1% AEP storm event in the Infiltration Trench area is shown on Figure 3.6. The only channel where the flood depth exceeds the planned flood bund height of 0.55 m is Channel A. Therefore, if constructed as planned, this channel would be inundated during the 1% AEP event as the max flood level along Channel A is approximately 0.6 to 0.7 m. This issue can be rectified by raising the road and protection bund around Trench A to 0.8 m or alternatively Channel A's length can be reduced by approximately 2.3 km and this infiltration trench level provided elsewhere.

3.2.3 Depth in Pond Areas

Flooding in the Pond Areas is not expected to be a significant issue. This is due to the fact all of the ponds are fully enclosed with no external catchment. The embankments will have a minimum height of 1.5 m at any point around the perimeter and are located in a higher section of the lake. Figure 3.7 shows the 72 hour 1% AEP flood depth in the pond areas, with the only ponds in the area of flooding being the Back Mix Ponds (flood depth < 0.1 m). The south-eastern tip of the waste dumps may also have minimal inundation around it but as the waste dumps will include a 0.8 m high perimeter bund the impact of this flooding is expected to be negligible.

4. INFLOW MODELLING

4.1 BREAKDOWN OF ZONE OF INFLUENCE INTO INDIVIDUAL CATCHMENTS

Inflow into Lake Disappointment, in regards to flood inflows, was broken down between two primary external catchments and the area of the lake itself. The total combined catchment area of Lake Disappointment has previously been estimated as 50,654 km^2, whilst the Zone of Influence, the area that provides runoff to the lake was estimated as 3,090 km^2.

The Zone of Influence was distributed around the lake as follows:

- There are two primary sub-catchments that contribute runoff into Lake Disappointment; Savory Creek to the West and the Disappointment Paleoriver to the South.
- Savory Creek is well defined with its morphology indicating that surface water flows down its entire length. The Disappointment Paleoriver channel is much less well defined. As such Savory Creek is more significant to peak inflow modelling.
- The Disappointment Paleoriver catchment is located to the south, further away from the coast than the Savory Creek catchment and therefore is expected to receive less rainfall on average as well as from major storm events.

On this basis the division of the Zone of Influence was estimated as 75% Savory Creek : 25% Disappointment Paleoriver. The total catchment area of Savory Creek contributing to the lake inflow is thus 2,318 km^2. The remainder of the Zone of influence is attributed to the Disappointment Paleo River catchment and the lake area itself.

4.2 INFLOW MODELLING FOR SAVORY CREEK

The inflow into Lake Disappointment from Savory Creek is expected to be the largest inflow and therefore the most critical inflow. In order to estimate the hydrograph for Savory Creek, a hydrologic model was developed using RORB. Due to the complex nature of the surface water and the lack of data, a simplistic model was developed to provide an indicative estimate of the hydrograph resulting from various design storms.

The Savory Creek RORB model consists of 20 identical sub catchments and 20 identical reaches that cover the entire 350 km length of Savory Creek. Each of the 20 sub catchments were assumed to be 115.9 km^2 in area and each reach was assumed to be 17.4 km long. The loss parameters used were also consistent with values discussed in Section 2.4.3. The RORB model was run with a range of storm durations for the 5%, 2% and 1% AEP events. The resulting critical duration and the peak flow are summarised in Table 4.1.

Table 4.1: RORB Results Summary

Storm AEP (%)	Storm ARI (years)	Critical Duration (h)	Peak Flow (m^3/s)
5%	20	30	126
2%	50	30	209
1%	100	24	386

4.3 CULVERT DESIGN TO PASS SAVORY CREEK INFLOW

The infrastructure (in particular the infiltration trenches) will impact the flow patterns on the lake surface. The adjusted flow patterns are indicated on Figure 4.1.

The adjusted flow patterns mean that culverts or flood crossings will be needed at a number of locations to allow incoming flood waters to pass through the infrastructure area without impacting the operation or causing damage.

The critical peak flow would be from Savory Creek onto the lake surface. Due to the high inflow rates from Savory Creek, bridging the infiltration trenches using culverts is not expected to be viable. An alternative option is a sump at the end of the infiltration trenches pumping through a pipeline to the plant feed channel. A buried pipeline would result in a configuration that would provide a gap between the infiltration trenches and the start of the feed channel to allow the peak flow from Savory Creek to pass through the system. In addition, a number of infiltration trenches on the east side of the current infiltration layout would need to be adjusted to allow the inflows from Savory Creek to flow to the deepest area of the lake.

The width of the gap was estimated by calculating normal depth of a trapezoidal channel. Flow attenuation was assumed to be negligible; as such the peak flows listed in Table 4.1 were used. It is noted that no freeboard was assumed, with the gaps sized such that the flow depth would be equal to 0.55 m. The required gap width depending on design event is summarised in Table 4.2.

Table 4.2: Infiltration trench gap sizing results

Storm AEP (%)	Storm ARI (years)	Required Gap Length (m)
5%	20	700
2%	50	1,200
1%	100	2,100

In order to maintain hydraulic performance of the lake, a site layout such as that shown on Figure 4.2 is required. Figure 4.2 shows the addition of the pipeline section from the sump to the start of the feed channel and the removal of L10. Additionally Infiltration Trenches A through E have had their lengths reduced and Infiltration Trench F has been completely removed. The reduction in the length of Trench A is discussed in Section 3.2.2. The reduction of Trenches B to E and removal of Trench F will allow suitable space for the flow from storms to make its way through the lake. The addition of Trenches L, M, N and O ensures that the total length of infiltration trench is maintained at 116 km.

4.4 CULVERT DESIGN

Culverts will still be required to bridge from the western areas of Lake Disappointment that will become hydraulically isolated due to the infiltration trenches. Culvert crossings over the segments of Infiltration Trench L will be required at the low points between Trenches H, I J and K to convey runoff to the deeper sections of the lake.

Hydrologic models were developed for each of the three areas that will generate runoff that needs to be conveyed over Infiltration Trench L. The catchment area for each area was assumed to be the lake area contained up to the border of the lake as shown on Figure 4.3.

The hydrologic models were run to estimate the number of 300 mm diameter plastic pipe culverts would be required to convey the 1% AEP flood whilst maintaining the maximum bund height of 0.55 m. The results of which are summarised in Table 4.3.

Table 4.3: No. culverts required to convey 1% AEP Flow

Catchment ID	Critical Duration	Required No. Culverts
SC01	30	610
SC02	18	910
SC03	30	140

As shown in Table 4.3, the number of culverts required to convey the 1% AEP flood is considerable. An alternative option was therefore assessed, with the number of culverts set to 5 for each catchment outlet. The required bund height to contain and eventually discharge the 72 hour 1% AEP storm was then estimated. The results of this assessment are summarised in Table 4.4.

Table 4.4: No. culverts required to convey 1% AEP Flow

Catchment ID	Max. Bund Height (m)	Min. Bund Elevation (m)
SC01	0.9	328.2
SC02	0.9	328.2
SC03	0.7	328.1

It is noted that the heights quoted in Table 4.4 are the maximum heights required at the topographic low points. Overall, for the bunds that form the boundaries of the three catchments, the bund height will increase to an average of 0.65 m.

More detailed modelling will be required to determine flood bund heights in different areas to match the flood ponding during a given storm event.

4.5 CONCLUSIONS / COMMENTS

If the flood bund is overtopped during a storm event, all the material from the flood bund is expected to be washed into the Infiltration Trenches or the Plant Feed Channel. This material would require removal at a later date to re-establish the brine collection system. Additionally any inflows would result in dilution of the brine, which would also result in delays whilst the brine re-concentrates.

The nominal design as shown on Figure 4.2 (or an equivalent approach) should allow the first 20 years of operation to be undertaken without having interruptions due to flooding for any event up to the 1% AEP(100 year ARI) event.

Our recommendation is for modifications to the infiltration trenches to be made for the initial 20 year design period. During this initial operating period the hydrologic behaviour of Savory Creek can be assessed and alternative ways of harvesting brine from the high risk area can be investigated.

It should be noted that although we have suggested modifications to the infiltration trench layout, alternative layouts are just as viable provided the trenches don't encroach on the floodway zone. The client's hydrogeologist is developing and undertaking modelling to specifically design the infiltration trench system and that design will supersede the modifications suggested by KP.

5. CLOSURE

At closure, it is proposed that the pond walls be breached and smoothed out. The Infiltration Trenches and the Plant Site Feed Channel will need to be backfilled. It is expected that the trenches will be backfilled by the bunds and roads that were constructed adjacent them. The backfilling of the trenches and feed channel is required to ensure that no fauna can find become trapped.

The waste dumps will consist primarily of halite and will be left in place and allowed to reintegrate into the lake surface via rainfall infiltration. This is consistent with current industry practice for closure of salt stacks (halite waste dumps).

The long term impacts of the project are expected to be minimal as disturbed areas will be reshaped to levels that approach natural conditions. Additionally, as all structures are to be constructed out of material borrowed from the lake and the waste products are concentrated salt no long term contamination is expected. Any erosion of the fill or mobilisation of the salts post closure will only result in material and salts returning to their original source area.

6. CONCLUSIONS

Based on the findings of this assessment, it can be concluded that:

- The initial concept design of the infiltration trenches will be impacted by major flood events (as discussed in Section 4.3 to 4.5). The trench alignment is being assessed by the Project Hydrogeologist and this assessment will need to incorporate the potential hydrological impacts as outlined in this report.
- Construction of the infrastructure for the LD Project will not impact the hydrological behaviour of the lake if adjustments to the design are made.
- The flood levels within the lake will not increase with the addition of the proposed infrastructure. The impact to the local and regional environment as a consequence of the operations will not be significant.
- The north-western portion of the lake where the majority of the proposed ponds and other infrastructure will be located is a higher area of the lake. With the WOfS data and flood modelling showing it is infrequently flooded.

7. RECOMMENDATIONS

KP recommends that a range of work be undertaken in order to increase the level of confidence in the modelling.

It is recommended that a high quality topographic survey be undertaken, with vertical accuracies within ±0.1 m over the relevant areas of the lake. This would significantly improve the level of accuracy in the design as it progresses from current concept design to the next more detailed design phase. KP notes that the best time to complete such a topographic survey would be when the lake is dry, as the survey would yield no data for areas inundated with water.

The installation of a climate station, at the very least precipitation gauges, should be considered for the proposed camp site or adjacent to the proposed pond area. An additional precipitation gauge would be useful approximately 150 km west of the site, which is approximately the centroid of the Savory Creek catchment. These two precipitation gauges, along with the existing BOM gauge at Newman (Newman Aero) should provide satisfactory coverage.

It is recommended that instrumentation be installed at Savory Creek in order to monitor inflows into Lake Disappointment. This information, as well as the aforementioned precipitation monitoring, could be used to calibrate a rainfall/runoff model for Savory Creek.

In order to monitor the water level of Lake Disappointment, it is recommended that a flow depth gauge be installed at one of the deeper parts of the lake. This gauge would not only assist in understanding of how the lake fills but also how it empties over time.

8. REFERENCES

1. Knight Piésold Pty Ltd, "*Brine Collection, Evaporation Ponds and Residue Disposal Concept Study*", Report PE801-00326/01, Rev B, November 2016.

2. http://www.bom.gov.au/water/designRainfalls/revised-ifd/.

3. http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/.

4. http://www.ga.gov.au/elvis/
   (Elvis = Elevation Information System)

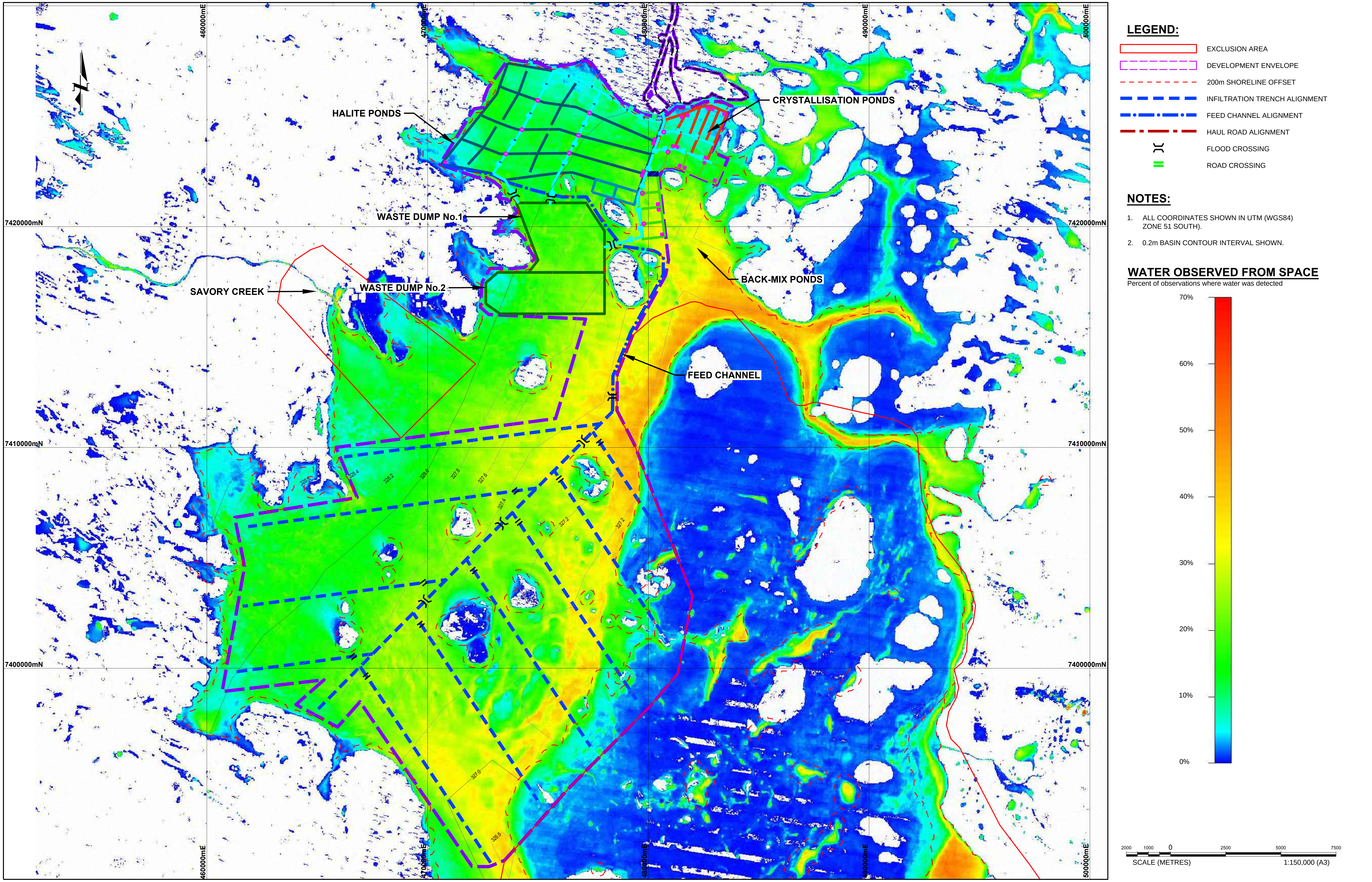
5. http://www.ga.gov.au/scientific-topics/hazards/flood/wofs.

6. Beard, J. S. "Palaeogeography and drainage evolution in the Gibson and Great Victoria deserts, Western Australia." *Journal of the Royal Society of Western Australia* 85 (2002): 17-29.

7. http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=80569.

8. Flavell, DJ and Belstead, BS. "*Losses for Design Flood Estimation in Western Australia*". In: Hydrology and Water Resources Symposium (17th : 1986 : Brisbane, Qld.).

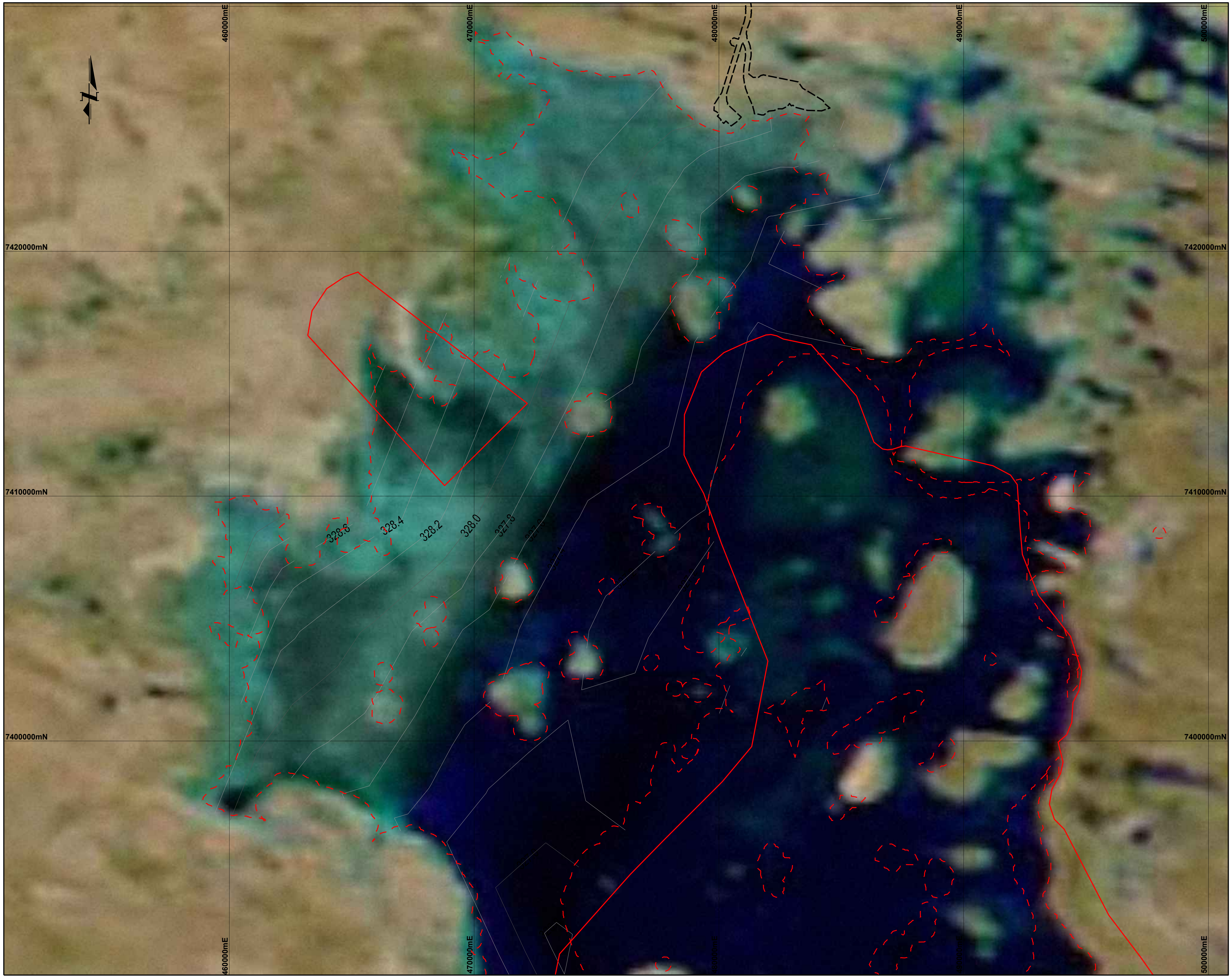
FIGURES



Knight Piésold CONSULTING

LD PROJECT
HYDROLOGICAL STUDY
WATER OBSERVATIONS FROM SPACE

Ref: PE801-00326/02
Figure 2.1



LEGEND:

EXCLUSION AREA

200m SHORELINE OFFSET

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

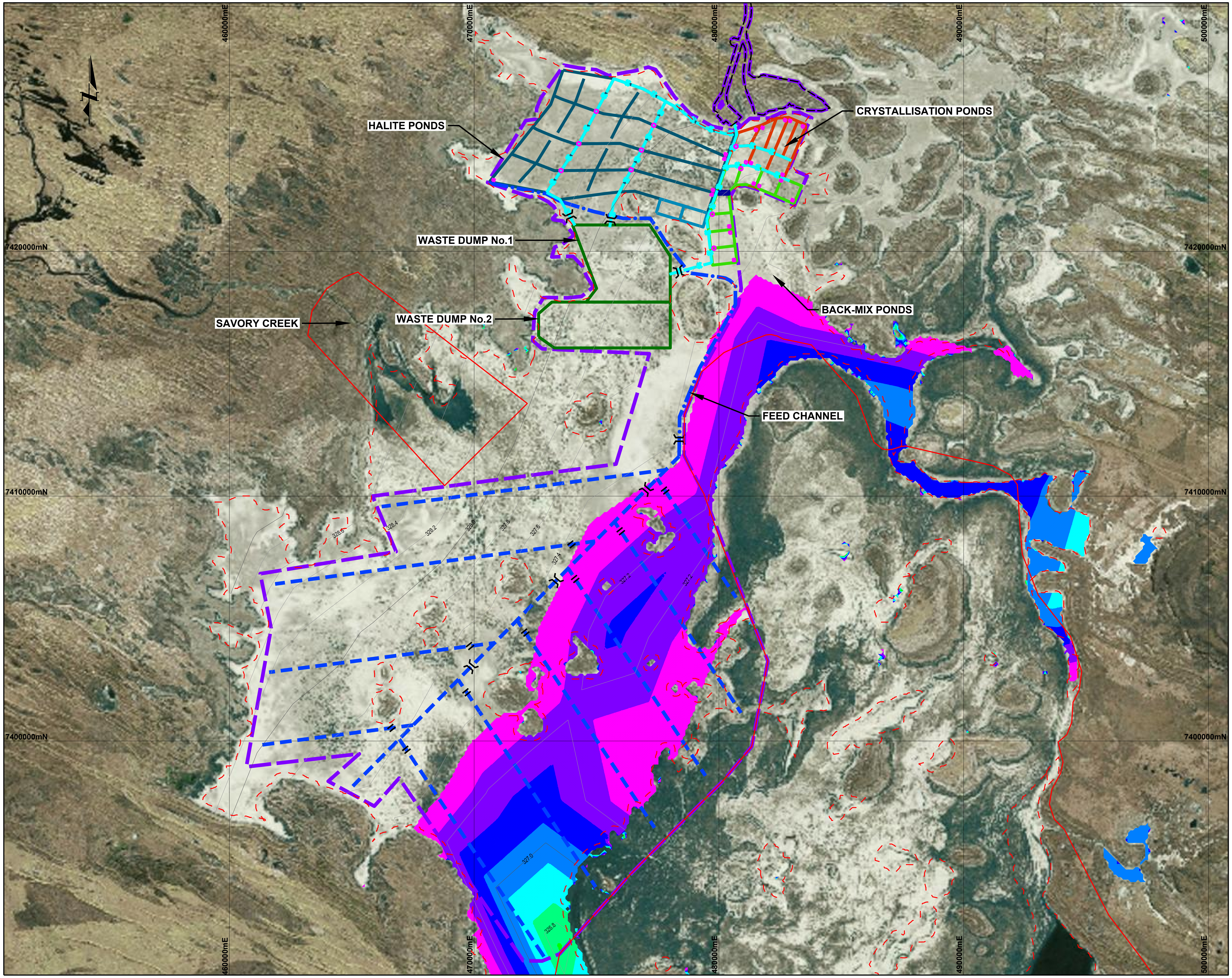
2000 1000 0 2500 5000 7500

SCALE (METRES) 1:150,000 (A3)

Knight Piésold CONSULTING

LD PROJECT
HYDROLOGICAL STUDY
SATELLITE IMAGERY POST CYCLONE RUSTY (NASA EARTH OBSERVATORY)

Ref: PE801-00326/02
Figure 2.2



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- INFILTRATION TRENCH ALIGNMENT
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- ROAD CROSSING

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

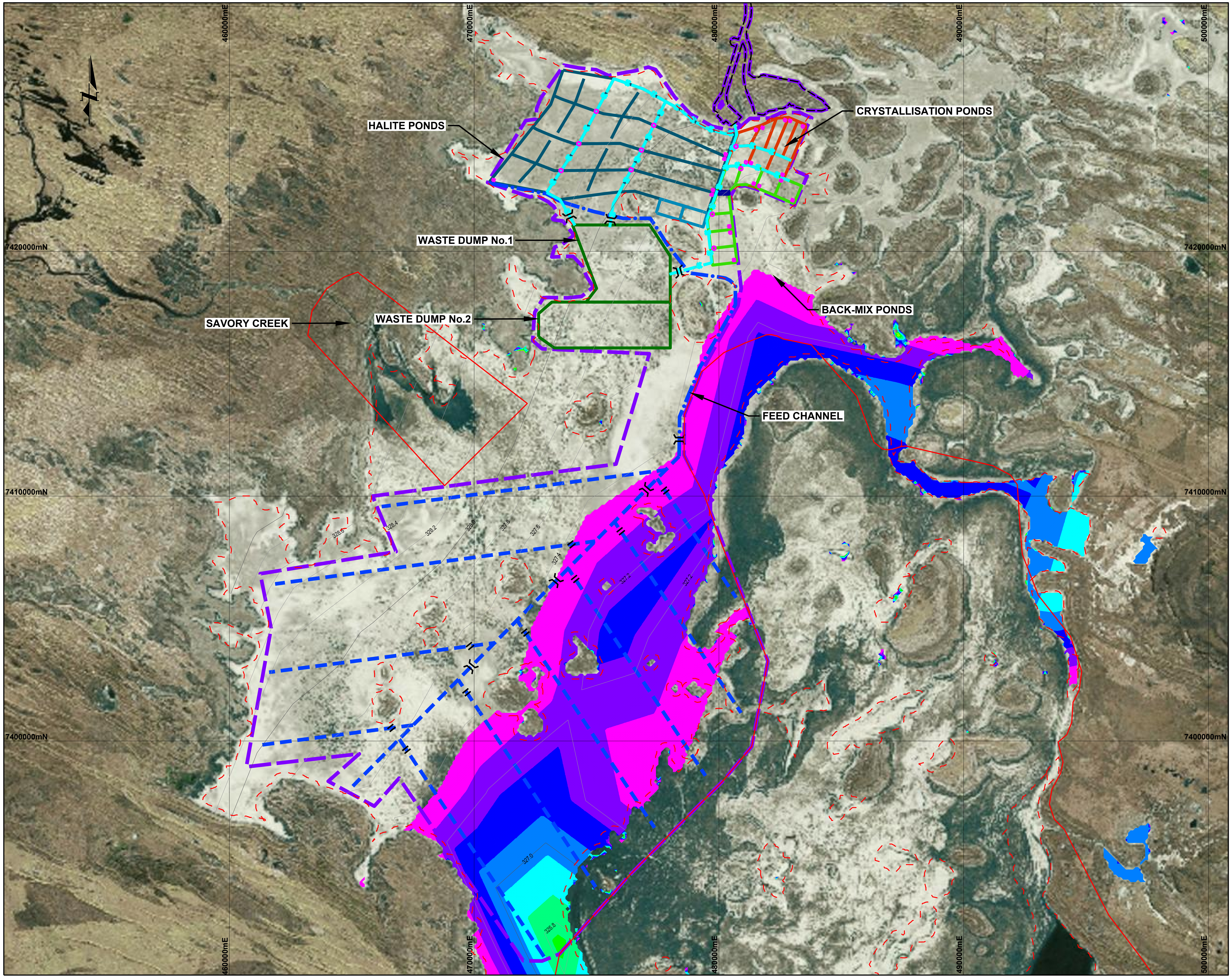
Flood Depth (m)		
Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

SCALE (METRES) 1:150,000 (A3)

Knight Piésold CONSULTING

LD PROJECT
HYDROLOGICAL STUDY
72 HOUR 5% AEP FLOOD DEPTHS (1 IN 20 YEAR ARI)

Ref: PE801-00326/02
Figure 3.1



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- INFILTRATION TRENCH ALIGNMENT
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- ROAD CROSSING

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)		
Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

2000 1000 0 2500 5000 7500
SCALE (METRES) 1:150,000 (A3)

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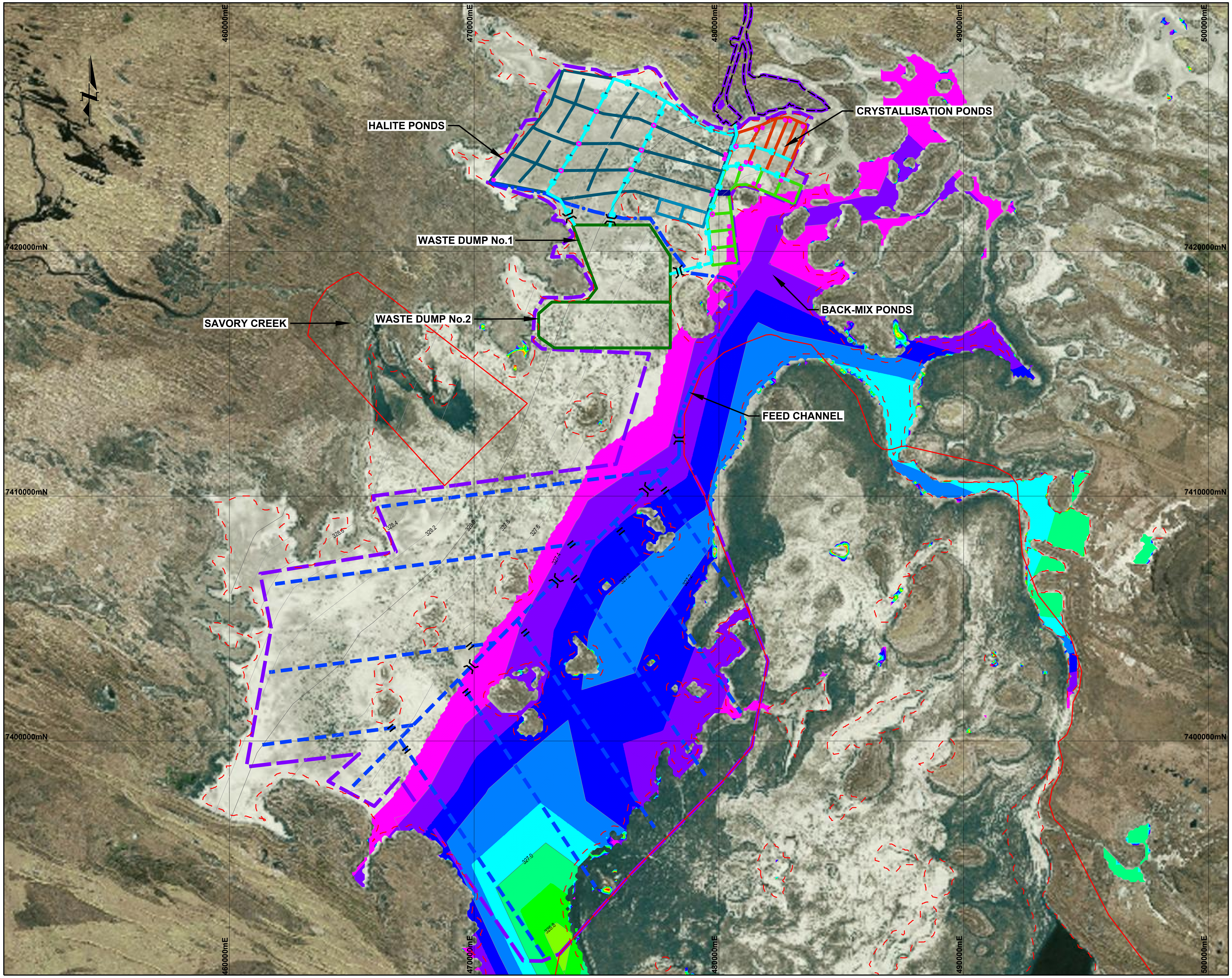
LD PROJECT
HYDROLOGICAL STUDY
72 HOUR 2% AEP FLOOD DEPTHS (1 IN 50 YEAR ARI)

Ref: PE801-00326/02
Figure 3.2



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- INFILTRATION TRENCH ALIGNMENT
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- ROAD CROSSING

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)

Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

2000 1000 0 2500 5000 7500

SCALE (METRES) 1:150,000 (A3)

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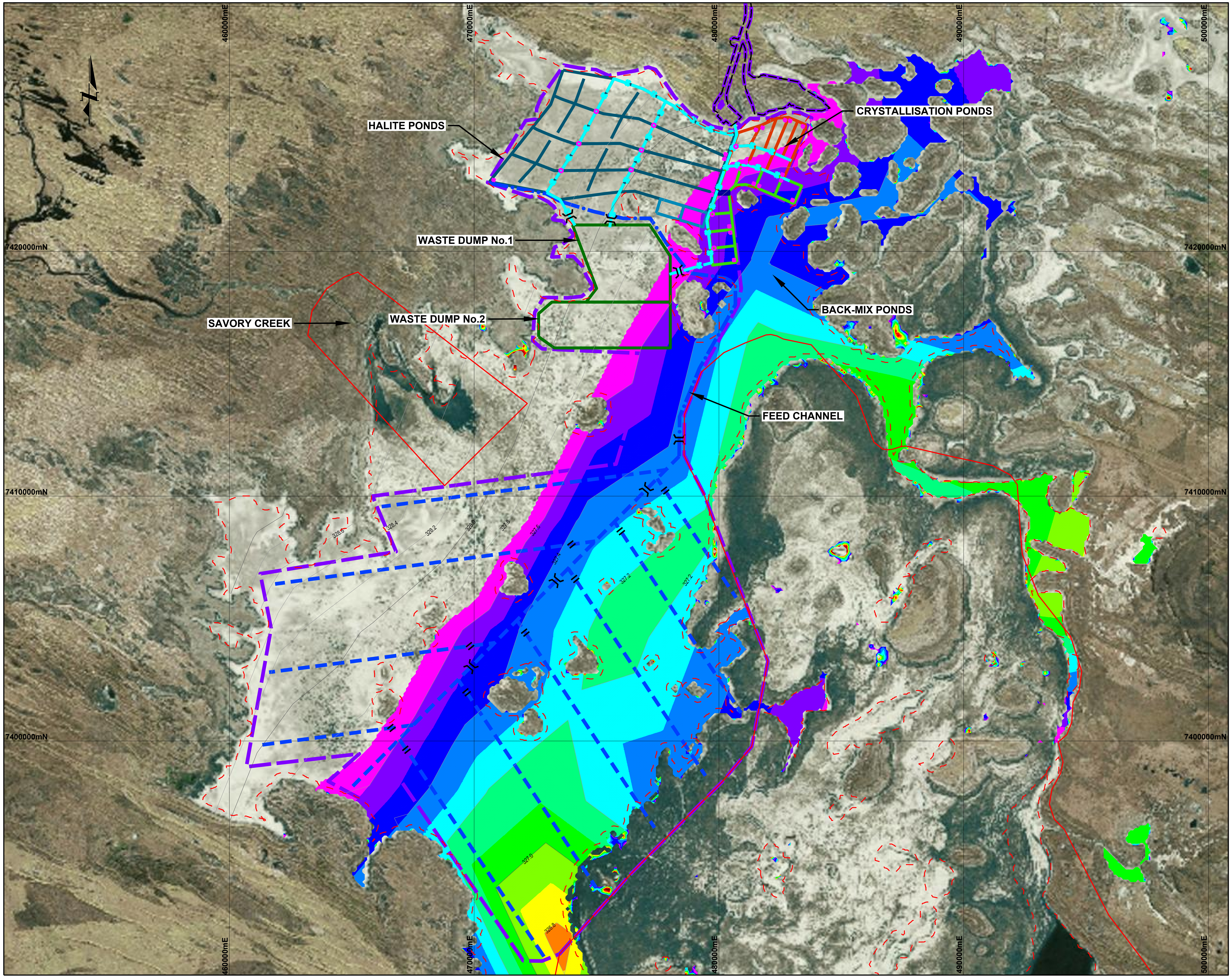
LD PROJECT
HYDROLOGICAL STUDY
72 HOUR 1% AEP FLOOD DEPTH (1 IN 100 YEAR ARI)

Ref: PE801-00326/02
Figure 3.3



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- INFILTRATION TRENCH ALIGNMENT
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- ROAD CROSSING

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)		
Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

2000 1000 0 2500 5000 7500

SCALE (METRES) 1:150,000 (A3)

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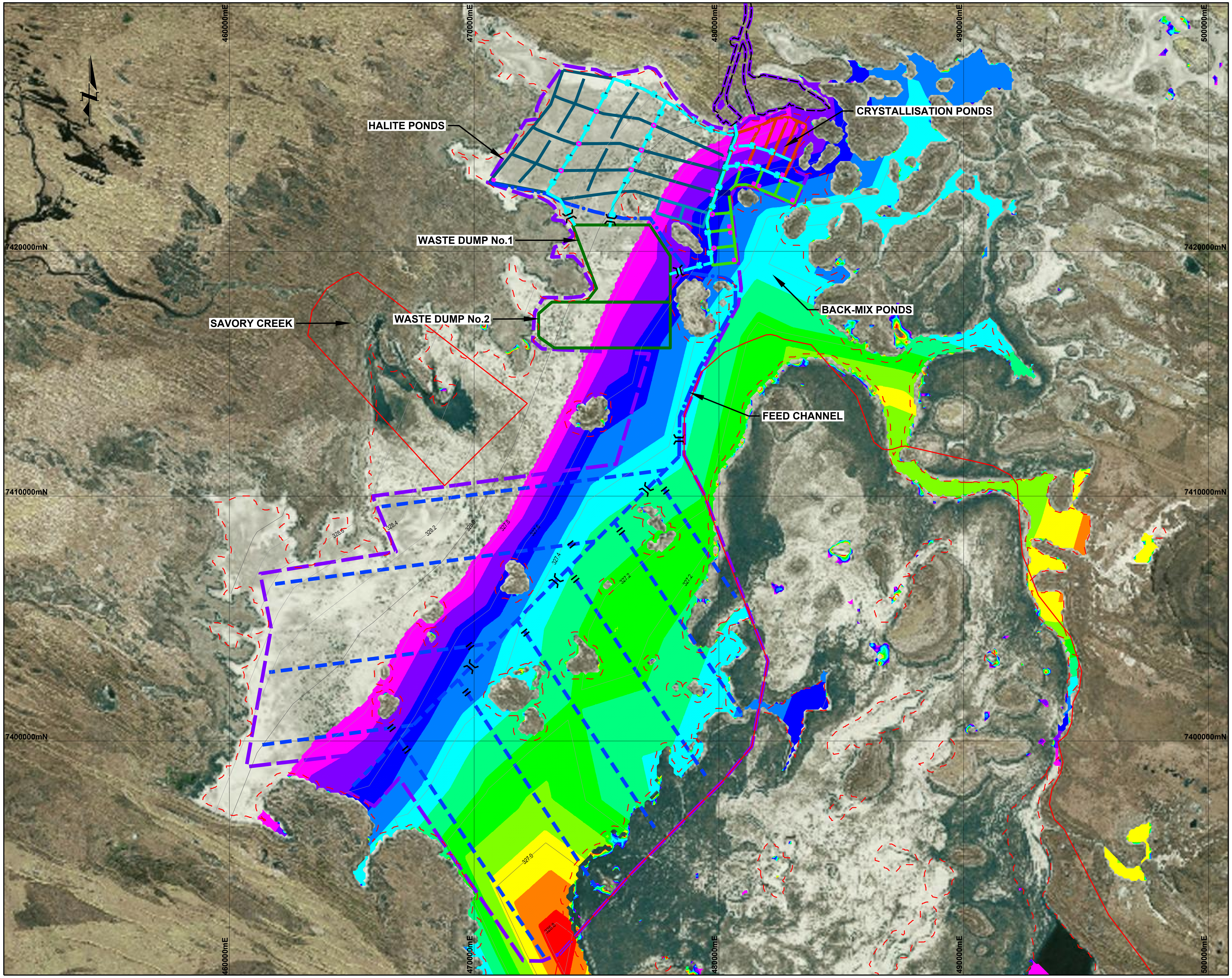
LD PROJECT
HYDROLOGICAL STUDY
CYCLONE RUSTY FLOOD DEPTH (APPROX. 1 IN 212 YEAR ARI)

Ref: PE801-00326/02
Figure 3.4



Flood Depth (m)

Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

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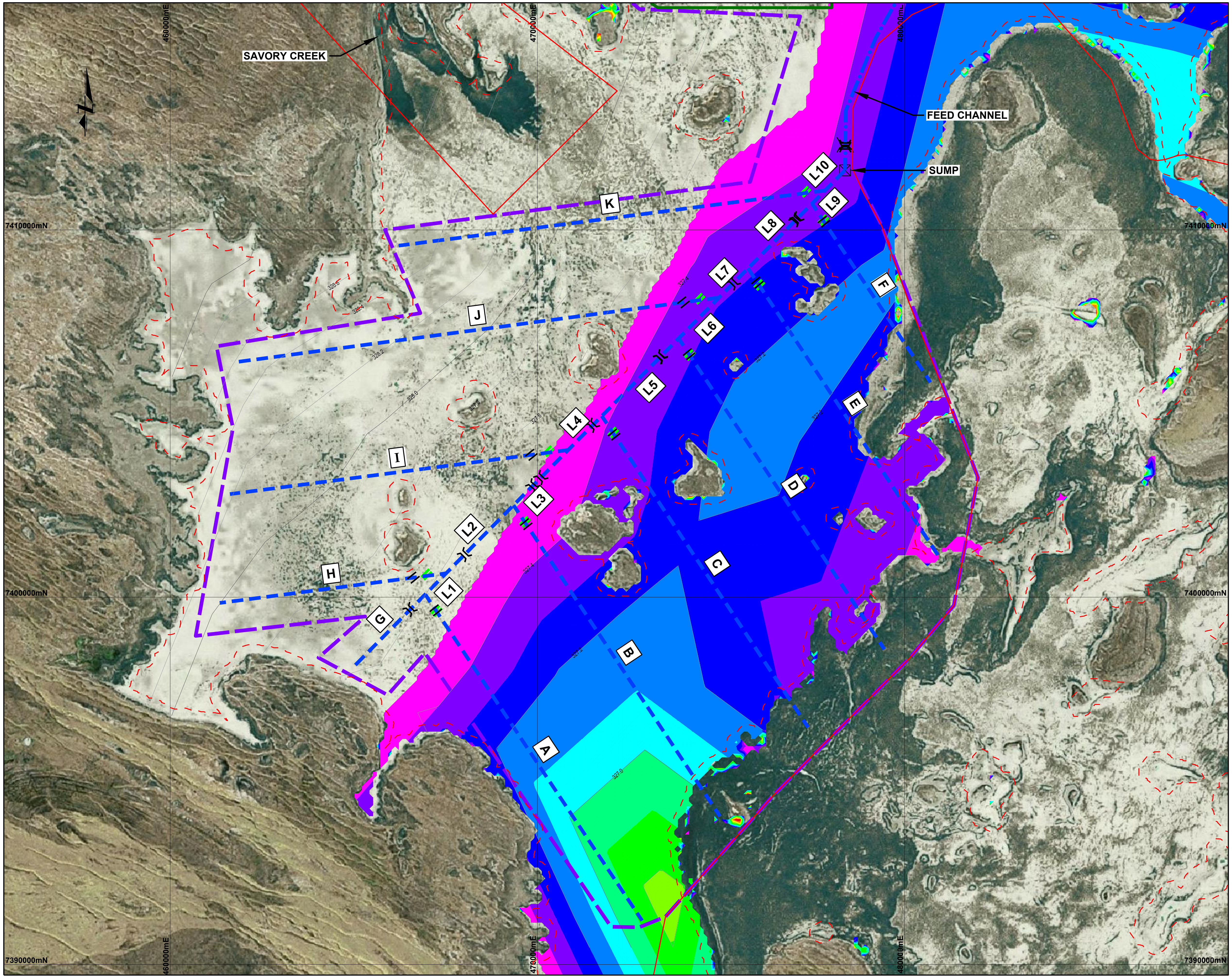
LD PROJECT
HYDROLOGICAL STUDY
72 HOUR 0.2% AEP FLOOD DEPTH (1 IN 500 YEAR AR1)

Ref: PE801-00326/02
Figure 3.5



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- INFILTRATION TRENCH ALIGNMENT
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- ROAD CROSSING

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)

Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

2000 1000 0 2000 4000
SCALE (METRES) 1:100,000 (A3)

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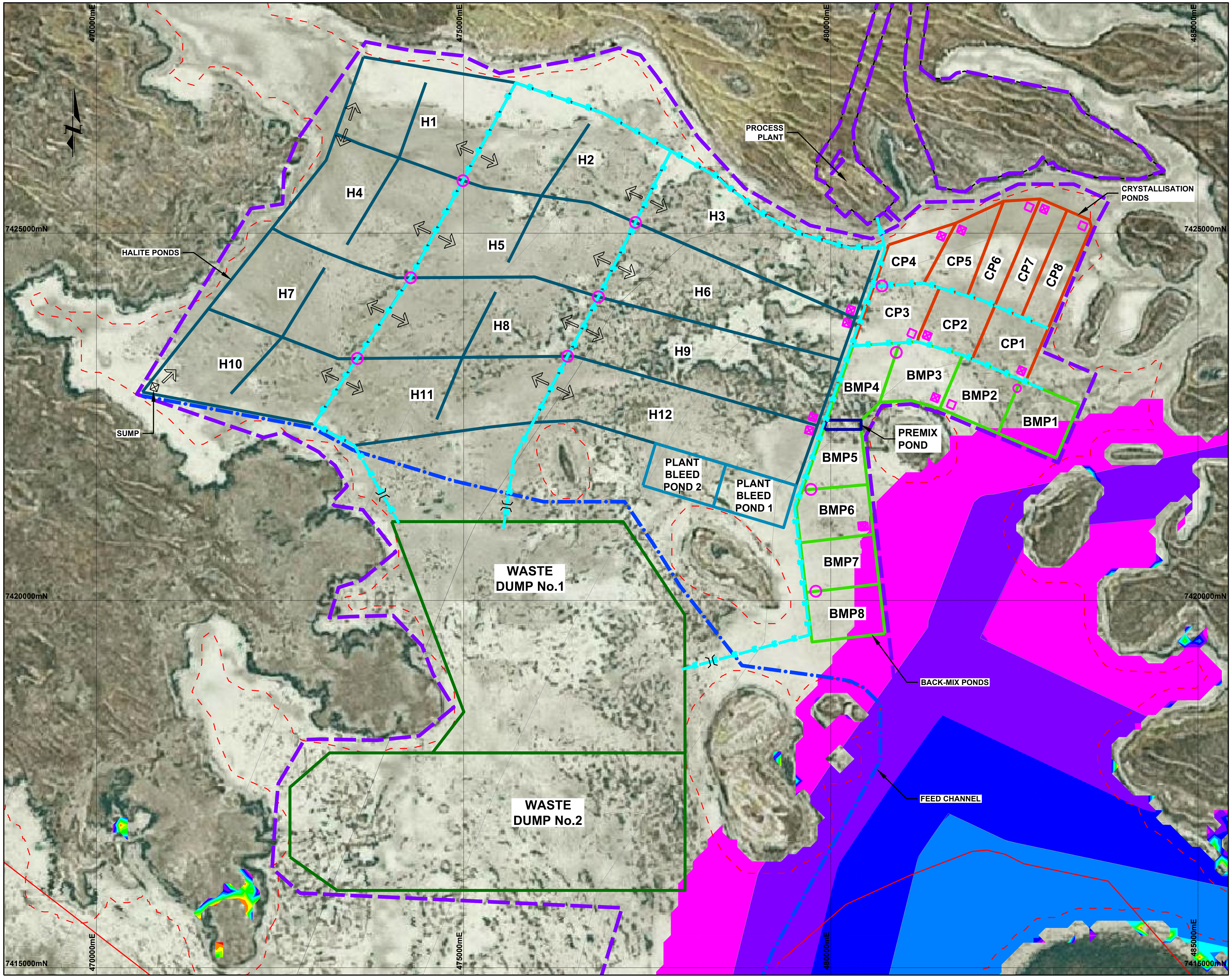
LD PROJECT
HYDROLOGICAL STUDY
INFILTRATION TRENCH AREA WITH 1% AEP FLOOD DEPTHS

Ref: PE801-00326/02
Figure 3.6



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- TRANSFER SUMP - OUTLET
- TRANSFER SUMP - INLET
- FLUME-POND DISCHARGE
- RAMP

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)		
Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

1000 600 200 0 500 1000 1500 2000
SCALE (METRES) 1:50,000 (A3)

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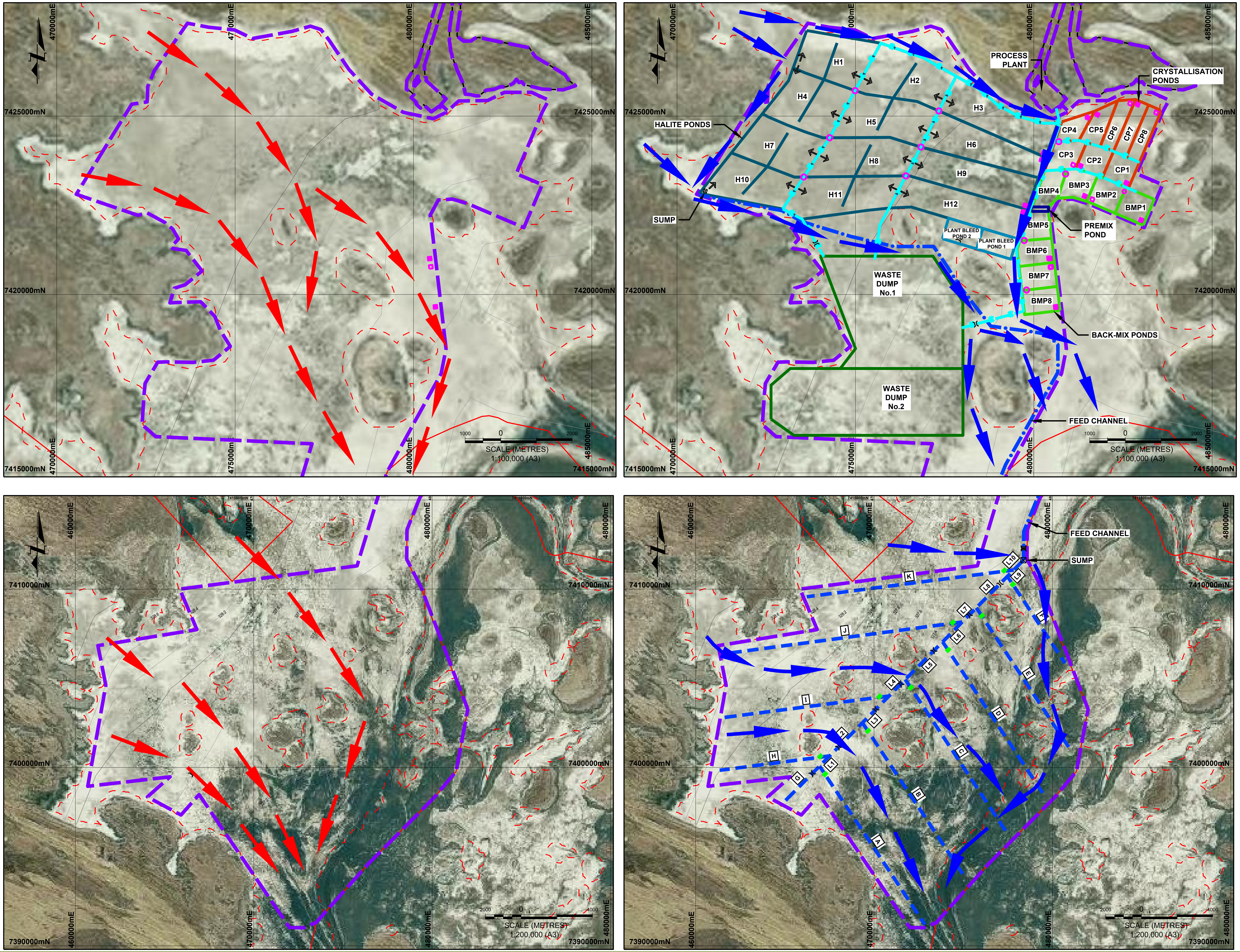
LD PROJECT
HYDROLOGICAL STUDY
SCHEMATIC PONDS LAYOUT AND 72 HOUR 1% AEP FLOOD DEPTH (1 IN 100 YEAR ARI)

Ref: PE801-00326/02
Figure 3.7



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- FLOOD CROSSING
- TRANSFER SUMP - OUTLET
- TRANSFER SUMP - INLET
- FLUME-POND DISCHARGE

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)		
Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

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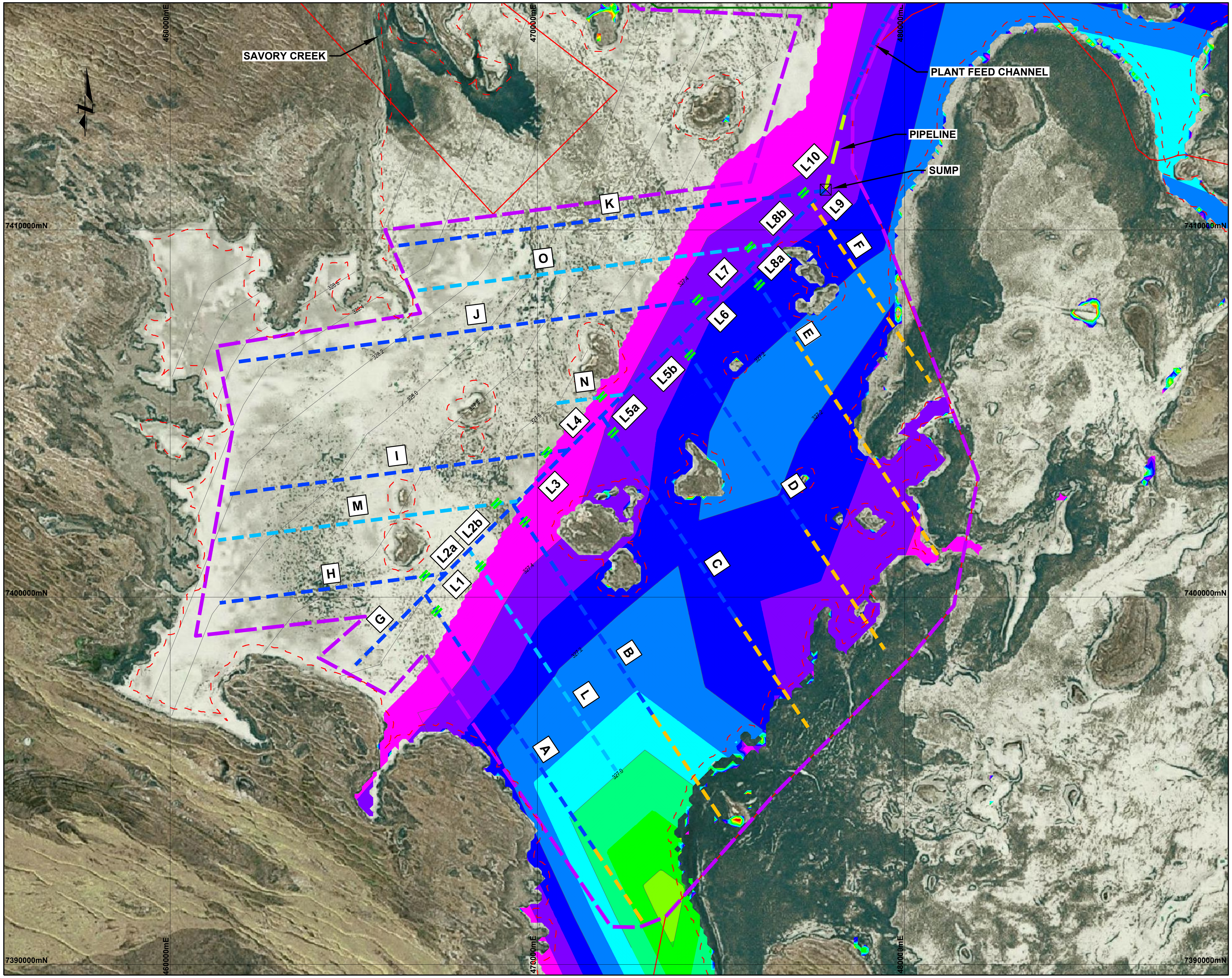
LD PROJECT
STORM FLOW
INFRASTRUCTURE MODIFICATION

Ref: PE801-00326/02
Figure 4.1



LEGEND:

- EXCLUSION AREA
- DEVELOPMENT ENVELOPE
- 200m SHORELINE OFFSET
- INFILTRATION TRENCH ALIGNMENT
- INFILTRATION TRENCH ALIGNMENT - ADDITIONAL
- INFILTRATION TRENCH ALIGNMENT - REMOVED
- FEED CHANNEL ALIGNMENT
- HAUL ROAD ALIGNMENT
- PIPELINE
- ROAD CROSSING
- 'n' CHANNEL I.D.

NOTES:

1. ALL COORDINATES SHOWN IN UTM (WGS84) ZONE 51 SOUTH).
2. 0.2m BASIN CONTOUR INTERVAL SHOWN.

Flood Depth (m)

Minimum Elevation	Maximum Elevation	Color
0.0	0.1	
0.1	0.2	
0.2	0.3	
0.3	0.4	
0.4	0.5	
0.5	0.6	
0.6	0.7	
0.7	0.8	
0.8	0.9	
0.9	1.0	
1.0	1.1	
1.1	1.2	
1.2	1.3	

2000 1000 0 2000 4000
SCALE (METRES) 1:100,000 (A3)

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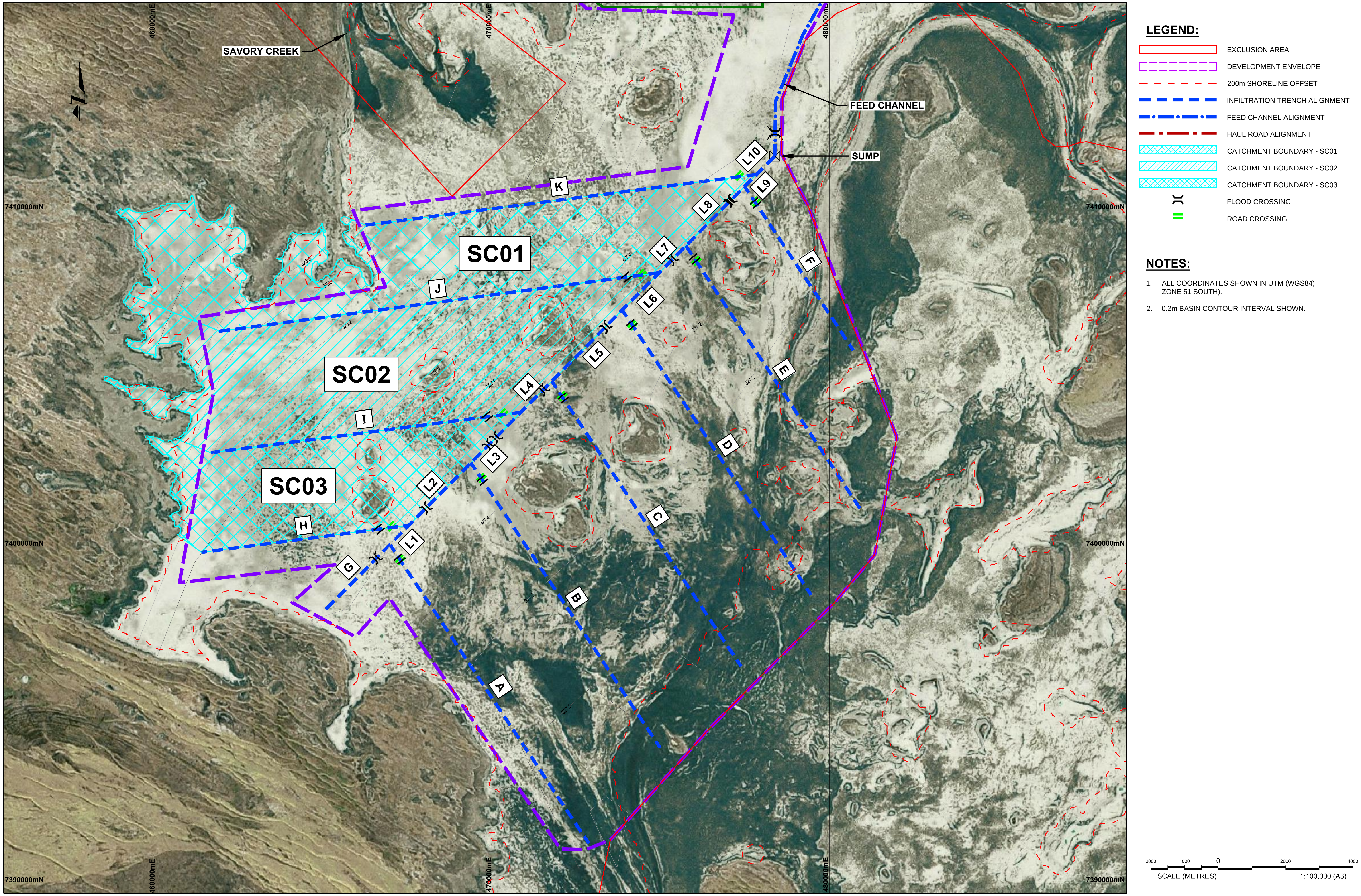
LD PROJECT
HYDROLOGICAL STUDY
MODIFIED INFILTRATION TRENCH LAYOUT WITH 1% AEP FLOOD DEPTHS (1 IN 100 YEAR ARI)

Ref: PE801-00326/02
Figure 4.2



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HYDROLOGICAL STUDY
INFILTRATION TRENCH CULVERT OVERPASS CATCHMENTS

Ref: PE801-00326/02
Figure 4.3