ARAFURA RESOURCES LTD.
NOLANS PROJECT



SURFACE WATER MANAGEMENT DEFINITIVE FEASIBILITY STUDY – DESIGN REPORT

PREPARED FOR:

Arafura Resources Ltd.
Level 3, 263 Adelaide Terrace,
Perth WA 6000 Australia

PREPARED BY:

Knight Piésold Pty Limited
Level 1, 184 Adelaide Terrace
East Perth, WA 6004, AUSTRALIA
p. +61 8 9223 6300 • f. +61 8 9223 6399

PE801-00140/13
Rev 0
March, 2019

DOCUMENT CONTROL PAGE

ARAFURA RESOURCES LTD.

NOLANS PROJECT

SURFACE WATER MANAGEMENT

DEFINITIVE FEASIBILITY STUDY

DESIGN REPORT

KP Job No. PE801-00140/07

KP Report No. PE801-00140/13

CONTRACT

DOCUMENT INFORMATION

REV	DESCRIPTION	PREPARED	REVIEW	KNIGHT PIESOLD APPROVAL	DATE
A	Issued for Review	AM AM	- BAS	BAS BAS	30/11/2018
0	Issued as Final	AM	BAS	BAS	20/03/2019

DOCUMENT DISTRIBUTION

REV	DESTINATION	HARD COPY	ELECTRONIC COPY
A	ARAFURA RESOURCES LTD.	0	1
0	ARAFURA RESOURCES LTD.	0	1

CONTENTS **PAGE**

CONTENTS PAGE

CONTENTS **PAGE**

EXECUTIVE SUMMARY

Introduction

Knight Piésold Pty Ltd (KP) was commissioned by Arafura Resources Ltd. (Arafura) to undertake a Definitive Feasibility Study (DFS) for the Surface Water Management aspects at the Nolans Rare Earths Project, approximately 140 km north of Alice Springs within the Northern Territory, Australia.

General

The project will comprise of access and haul roads, an accommodation camp, an open pit mining operation, mine waste landforms, a processing plant and residue storage facilities. The current mine life is expected to be 23 years.

The surface water management system will provide sediment and flood control for areas disturbed by mining activities from the pre-commissioning construction phase until a stable landform is re-established as part of the closure process.

The major surface water management system structures include a river diversion system for the open pit and sediment control structures downstream of the mining area.

Site Conditions

The climate at site is characterised by a very dry winter and rain during summer months.

The surface water management structures are generally located on gentle sloping terrain at the base of rocky outcrops along the Reynolds Range.

No environmental, historical or cultural heritage exclusion zones or limited work areas were recorded during previous site surveillance work by others within areas where construction is planned.

Site Investigation

A geotechnical investigation of the Nolans Project area was undertaken 2010 followed by a supplementary borrow investigation in 2011. A site specific geotechnical investigation for the critical structures and infrastructure (based on the 2018 DFS site layout) was completed in August 2018. The investigation comprised of a series of diamond core drill holes, test pits, situ testing and laboratory classification.

The investigations undertaken indicated variable conditions but typically encountered:

- The boreholes indicate rock is present from between 1 to 2 m within the mining area and 2 m and 7 m depth within the process plant and RSF area. This is overlain by cemented clayey sand with some areas of calcrete.

- Investigation confirmed clayey sands prevalent near surface within the flatter areas.
- The material excavated during channel excavations will be suitable as embankment fill (soils) and erosion protection material (rock).

Pit Diversion System

As the pit is located across Kerosene Creek, an existing creek alignment with a significant upstream catchment, a diversion channel is required to divert runoff around the mining area. In order to reduce upfront capital expenditure and be able to collect site specific monitoring data prior to the construction of the final diversion system, a staged diversion channel development sequence has been developed.

The initial channel will bypass the mining infrastructure to the west. In Year 8 it is planned that the pit will expand west and a new diversion channel through the western ridge into an existing river course will be excavated. The diverted water will re-join the original natural flow path just to the north of the mining lease.

The diversion system will remain in place post closure to minimise the inflow into the pit void.

Mining Infrastructure Area Flood Protection

In addition to the pit diversion, a flood protection bund will be constructed along the eastern extent of the mining area to reduce the risk of Nolans Creek impacting the waste dumps and stockpiles located at the edge of the Nolans Creek flood plain.

Sediment Management

In addition to source control of sediments, sediment control structures will be built downstream of any disturbed mining or infrastructure area. The main structures will be located downstream of the mining areas to capture all runoff from the haul roads, waste dumps, stockpiles and other infrastructure areas. The dams are expected to contain soil particles down to a coarse silt.

Monitoring and Maintenance

A dedicated Operations and Monitoring Manual will be compiled prior to commissioning of the structures. Recording of all operational inputs / outputs as well as monitoring and inspection requirements, including monitoring instrumentation (standpipe and vibrating wire piezometers, survey pins and monitoring bores), water quality and flow rates will be undertaken. Regular geotechnical audits of the structures will be completed by a suitable qualified engineer on an annual basis.

Closure

Apart from the pit diversion system the surface water management structures will be cleaned of sediments, the embankments breached and any materials removed process hauled to be used in the waste dump closure. The disturbed areas will be rehabilitated. The flood protection bund along the waste dump toes will be integrated into the waste dump capping.

1. INTRODUCTION

1.1 GENERAL

The Nolans Project is located approximately 140 km north of Alice Springs in the Northern Territory, Australia. The mining project will include the construction of access and haul roads, an accommodation camp, an open pit mining operation, Residue Storage Facilities, waste landforms and a process plant. The current mine life is expected to be 23 years.

The surface water management for the project will include sediment and flood management structures for all disturbed areas from the pre-commissioning construction phase until a stable landform is re-established as part of the closure process. The major structures will be a diversion system for the pit, constructed in stages, and sediment control structures downstream of the mining area.

The main surface water management structures include:

- Pit Diversion.
- Mining Area Flood Management.
- Sediment Management Structures

As the starter pit is located across an existing creek course (Kerosene Creek) with a significant upstream catchment, a diversion channel is required to divert rainfall runoff around the mining area. In order to reduce upfront capital expenditure, a staged diversion channel construction sequence has been developed.

Stage 1 will have an initial diversion around the western extent of the starter pit, and will be utilised until Year 8, at which time the final diversion channel alignment around the future Western Waste Dump will be excavated. This channel will be maintained post closure to maintain a controlled and limited inflow into the pit void.

Both diversion channels have been designed to control and discharge the upstream runoff of a 0.1% Average Exceedance Probability (AEP) rainfall event.

As a contingency, if mining were to cease prior to the Stage 2 diversions excavation, the Stage 1 channel has been designed to enable the system to remain operational and meet closure requirements.

In addition to the diversion system, a flood protection bund towards Nolans Creek to the east of the mining infrastructure areas will be required to reduce the risk of flooding encroaching into stockpile and waste dump footprint areas.

In addition to sediment source control and minimising exposed areas, sediment control structures will be built downstream of the mining area which are expected to minimise sediments escaping from the project area.

As part of the surface water management the peak flows at potential culvert crossing points along the mine access road as well as the main haul road between the mining and the processing area were assessed.

The surface water management for the Residue Storage Facility (RSF) is considered separately in a stand-alone report (Ref. 1).

1.2 DESIGN PARAMETERS

The key design parameters are summarised in Table 1.1 below.

Table 1.1: Key Design Parameters

SURFACE WATER MANAGEMENT KEY DESIGN CRITERIA		
Design Climatic Conditions	Annual Rainfall: • Average: 291 mm • 1% AEP Dry: 30 mm • 1% AEP Wet: 847 mm Design Storm Depth: • 1% AEP 24 hour storm: 196 mm • 1% AEP 72 hour storm: 298 mm • PMP 24 hour storm: 670 mm • PMP 72 hour storm: 1,090 mm Annual Penmen Lake Evaporation: 1,982 mm Dominant Wind Direction: SEE to NWW	KP Climate Assessment
Catchment	Area Upstream Pit: 2,265 ha Peak Upstream Runoff: • 10% AEP: 64 m^3/sec • 1% AEP: 164 m^3/sec • 0.1% AEP: 324 m^3/sec	KP Design
Diversion Channel Hydraulic design	Channel / erosion protection sized to accommodate: - Stage 1 diversion – 0.1% AEP storm event - Stage 2 diversion – 0.1% AEP storm event	 Arafura Arafura
Embankment Freeboard	The critical elevation out of: • Minimum of 1.0 m to maximum design pond. • Minimum of 0.1 m for maximum spillway flow (1% AEP). • Dedicated embankment overflow sections to manage up to PMP flow.	KP Design
Sediment Management Structures	Sized to remove particles up to the medium to coarse silt fraction for flows up to 1 % AEP Storms.	KP Design
Sediment Management Structures - Spillway capacity	Sized to safely discharge: • 1% AEP Storms. • Embankment designed to manage overtopping for flows up to PMF.	KP Design
Design earthquake loading	OBE 1 in 1,000 year: 0.024g MDE 1 in 10,000 year: 0.045g Post Closure MCE: 0.053g	KP Design and Seismic Assessment
Stability minimum factor of safety	Long term drained 1.5 Short term undrained • Potential loss of containment 1.5 • No potential loss of containment 1.3 • Post seismic: 1.0 to 1.2	KP Design

2. SITE CHARACTERISTICS

2.1 LOCATION

The Nolans Project, a rare earth mining project, will be located at Nolans Bore, some 140 km north of Alice Springs in the Northern Territory, Australia. The site is accessible via the Stuart Highway (Highway 87) and a ~ 15 km long access road to site.

The mining infrastructure will be located in two distinct areas with the pit, waste dumps and other mining infrastructure located to the north in the Woodford River Catchment, at the southern extent of the Ti-Tree Basin. The process plant, residue storage facility and the accommodation camp will be located a further 7 km south, in the Southern Basin catchment. A haul road will be constructed between these two areas.

The general arrangement of the site is shown in Drg. No. 801-140-A5001-050.

2.2 TOPOGRAPHY

The project is located on flat areas north and south Reynolds Range, a small mountain range which extends in an west-east direction. A haul road crosses this range through a saddle and a gentle sloping valley.

In the southern area, the proposed processing plant and Residue Storage Facility area has generally flat slopes of 2.5% to 0.5% with the steeper areas towards the range to the north-east. The area slopes very gently to the south with elevations ranging from approximately RL650 m to RL675 m.

The area is generally not well defined by water courses in the southern project areas.

The mining area is located to the north of the catchment divide within Kerosene Creek, Nolans Creek is located to the east. Both creeks report to the Woodford River to the north of the lease boundary. The sediment management structures, mining infrastructure, stockpiles and the eastern waste dumps are located on a gently sloping area (slopes of 1.5% to 0.5%) between Kerosene and Nolans Creek. The actual construction area is surrounded by rock outcrops up to 100 m in height and slopes up to 25%.

2.3 SITE CONSTRAINTS

No exclusion areas or restricted work areas were identified within the proposed mining and processing areas. One area is along the mine access road and one close to the proposed haul road alignment. Further several exclusion zones are located near / at the lease boundary.

The existing Amadeus Gas Pipeline is located immediately to the east of the proposed processing plant and Residue Storage Facility area. The mine access road to the process plant will cross over this pipeline.

The exclusion zones as well as the gas pipeline are shown in the site general arrangement in Drg. No. 801-140-A5001-050.

2.4 CLIMATE ASSESSMENT

2.4.1 General

The climatology assessment was conducted using the latest Bureau of Meteorology (BOM) databases for the region and Australian Rainfall and Runoff (AR&R) 2016 methodologies to determine design short term storm events for surface water runoff. The project lies in the hot grassland climate region of the Northern Territory. The baseline design climatology assessment is attached as Appendix A.

2.4.2 Climate Summary

Rainfall records, sourced from the SILO climate database operated by the Queensland Government (Ref. 2), were assessed to derive the average as well as the extreme long term rainfall patterns on site. The average, extreme wet and extreme dry rainfall patterns are summarised in Table 2.1 below.

Table 2.1: Annual Rainfall Patterns

Month	Precipitation (mm)		
	100-Year ARI, 1-Year Wet Cycle	Average	100-Year ARI, 1-Year Dry Cycle
Jan	368.8	123.3	1.5
Feb	160.5	26.5	7.1
Mar	24.7	1.9	0.0
Apr	86.1	0.0	0.0
May	28.0	0.1	0.0
Jun	0.0	0.0	2.5
Jul	0.0	0.9	0.0
Aug	12.1	0.1	0.0
Sep	12.1	0.5	0.0
Oct	21.0	15.9	2.5
Nov	99.3	2.2	3.1
Dec	33.9	119.4	13.2
Total	846.5	290.8	29.9

Evaporation data was also derived from the SILO database. A curve developed by Stanhill (1976 - Ref. 3) was used to estimate monthly pan factors.

Table 2.2: Evaporation

Month	Ave. Pan Evap. (mm)	Ave. Penman Lake Evap. (mm)	Pan Factor
Jan	357.0	216.0	0.6
Feb	299.0	187.0	0.6
Mar	297.0	194.0	0.7
Apr	224.0	158.0	0.7
May	160.0	116.0	0.7
Jun	122.0	90.0	0.7
Jul	136.0	100.0	0.7
Aug	185.0	134.0	0.7
Sep	245.0	169.0	0.7
Oct	313.0	201.0	0.6
Nov	329.0	203.0	0.6
Dec	350.0	214.0	0.6
Total	3017.0	1982.0	

Short duration storm depths for a range of Average Reoccurrence Interval (ARI) storms were estimated using the Australian Government Bureau of Meteorology IFD Tool (Ref. 4) in accordance with the methods presented in the Australia Rainfall and Runoff Guidelines (Ref. 5).

Short duration storm depths estimated are summarised below in Table 2.3.

Table 2.3: Short Duration Storm – Rainfall Depth

Storm Duration			Precipitation Depth (mm) for AEP Storm Frequency (%)							
(min)	(h)	(day)	50%	20%	10%	5%	2%	1%	0.5%	0.1%
5			7	11	13	16	19	22	25	33
10			11	17	20	24	30	34	38	51
15			14	21	26	30	37	42	48	64
30	0.5		19	29	35	42	52	59	67	89
60	1		24	37	46	55	68	78	89	118
180	3		34	51	63	76	93	108	123	163
	6		41	61	75	90	111	129	147	195
	12	0.5	50	74	92	109	135	156	178	236
	24	1	62	93	114	135	169	196	230	313
	48	2	76	116	144	172	218	255	300	413
	72	3	84	131	164	198	252	298	347	481
	168	7	95	153	196	242	308	362	427	592

Probable Maximum Precipitation (PMP) was estimated using two different methods published by the BOM for different storm durations. For storm durations of up to 6 hours, the Generalise Short Duration Method (GSDM) procedures (Ref. 6) are employed. The BOM uses the Generalised Tropical Storm Method, Revised (GTSMR) zone procedures (Ref. 7) for storm durations from 24 hours to 120 hours. Composite curve results for the site are summarised in Table 2.4.

Table 2.4: Composite depth-duration relationship for PMP

Estimation Procedure	Duration (h)	Depth (mm)
GSDM	0.25	200
	0.5	280
	0.75	360
	1.0	410
	2.0	530
	3.0	610
	6.0	620
Interpolated Between GSDM and GTSMR Summer	9	620
	12	630
	18	650
GTSMR Summer	24	670
	30	720
	36	790
	48	900
	60	950
	72	1,090
	96	1,230
	120	1,370

Based on the Australian Government Bureau of Meteorology web resources the regional wind direction is east - west to southeast-northwest throughout the year (Ref. 8).

2.5 REGIONAL GEOLOGY AND HYDROGEOLOGY

2.5.1 General

The geology for the proposed site has been interpreted by others and was provided in the Environmental Impact statement for Nolans Project (Ref. 9). The information below is transferred from this document.

2.5.2 Basins

The basins (Southern Basins and Ti-Tree Basin) in the study area are hydrogeologically similar (although not identical) to each other and to adjacent basins across central Australia. Unlike the Ti-Tree Basin, which has been studied in detail and used extensively as a groundwater source, the Southern Basins in the study area have not previously been investigated in detail nor have they been used extensively as a groundwater source.

The Southern Basins encompass Cenozoic sedimentary basins previously referred to as the Whitcherry Basin, the Mount Wedge Basin, the Burt Basin and Lake Lewis Basin. In addition, the Whitcherry Basin overlies the eastern extent of the Palaeozoic Ngalia Basin. The study area encompasses only a small proportion of both the Whitcherry Basin and Mount Wedge Basin. These two basins extend westward beyond the study area boundary for a further 130 km and 220 km respectively. Even beyond this, there is believed to be connection through to the Mackay Basin, and the ultimate discharge point in the endorheic Lake Mackay, approximately 350 km away in the Western Australia border area. All of these basins are considered interconnected in this study and thus the collective term Southern Basins is applied.

Although previously treated as separate systems, the Southern Basins are now considered to be connected to the Ti-Tree Basin in an area referred to as The Margins. Despite the connection, The Margins are primarily a subtle groundwater divide with water flowing north of the divide to the Ti-Tree Basin and south of the divide to the Southern Basins. To the east, the Ti-Tree Basin is connected to the Waite Basin (and then Bundey Basin) and to the north it is believed to be connected to the Hanson Palaeovalley.

2.5.3 Basement Geology and Hydrogeology

The basement geology of the study area (Shaw, 1975, D'Addario and Chan, 1982) is complex but for the purposes of this hydrogeological assessment is simplified to the following:

- Proterozoic Arunta Block granites and gneiss outcrop forming the bulk of the hills and ranges adjacent to the mine area (including Reynolds Range and Yalyirimbi Range) and basement rocks beneath the basins.
- Proterozoic Vaughan Springs Quartzite and Treuer Member (basal units of the Ngalia Basin), outcropping as the Hann Range and Reaphook Hills as a distinct, almost linear feature across the southern plain, as isolated hills outcropping from

the plain at the southern fringe of the Yalyirimbi Range and as basement rocks beneath part of the Southern Basins.

- Other Neoproterozoic to Devonian sedimentary units of the Ngalia Basin are present in drill core in the western parts of the study area but they do not outcrop in the study area. These units also form basement to part of the Witcherry Basin.

It is recognised that the Arunta Block also contains multiple units other than granites and gneiss (i.e. schist, quartzite etc.) which may contain higher fracture permeability, but all Arunta Block rocks are collectively grouped as the hydrogeological unit „basement‟ for the purpose of this assessment. Only the mineralised areas of the ore deposit that contain primary porosity are considered in isolation as distinct aquifer. The rocks of the Vaughan Springs Quartzite and Treuer Member, as well as the other units of the Ngalia Basin are, like the units of the Arunta Block, collectively included in the hydrogeological unit „basement‟.

2.5.4 Basin Geology and Hydrogeology

Before the Cenozoic, deformation (folding and faulting) of the basement rocks (Shaw, 1975, D‟Addario and Chan, 1982) resulted in significantly deeper basins than can be readily observed today. At present, the basins are almost completely filled with sediment, with only subtle ranges and hills (relative to their former heights) protruding above the plains. During the Cenozoic, these basins filled during periods of erosion from the source rocks above and deposition in these deep palaeovalleys.

Hydrogeological units within the basin mimic previously applied geological differentiation and nomenclature. Of the Cenozoic deposits, only minor (usually less than 2-5 m) Quaternary deposits are present. These Quaternary deposits include, but are not limited to, wind blow (aeolian) sand, calcrete, locally derived soils and coarse river bed sands. The major hydrogeological unit differentiation for the basin materials are informally known, as per nomenclature in Higgins and Rafferty (2009) and Hussey (2014), as:

- Napperby Formation to the upper unit.
- Waite Formation to the middle unit.
- Hale Formation for the lower unit.

Wischusen et al. (2012) apply a different nomenclature and acknowledge the gaps and challenges in inter- or intra-basinal correlation. Whilst the Wischusen et al‟s. (2012) works provide significant detail, the Higgins and Rafferty (2009) nomenclature and logging provide a more applicable and widespread dataset for this assessment.

Ride‟s (2016) interpretation of the units within the Southern Basins concluded that despite the similarities between the basins the notable differences included:

- “The main source of the sediments in the NE Southern Basin deep palaeochannel (Reaphook Palaeochannel) appears to be different from the other regional Cainozoic basins though there are similarities with the overlying alluvial, fluvial and lacustrine sediments”.
- “The deep sediments in the Ti Tree Basin, Hale Basin, Burt Basin (NE and south eastern Southern Basins) have paludal sequences which have not been sighted in the NE Southern Basins possibly as we have targeted the deep locations where massive fluvial deposits are present and any pre-existing paludal deposits were likely to be removed by major runoff events”.

3. SITE INVESTIGATION

3.1 GENERAL

Site investigations were undertaken in mid-2010 (Ref. 10), followed by a supplementary borrow investigation in 2011 (Ref. 11). This work comprised of 9 No. diamond core drill holes, 80 No. test pits together with in situ and laboratory testing.

After a redesign of the project layout (2018), further geotechnical and investigation of the proposed RSF, Plant Site, surface water diversions at the pits, haul road, mine access road and accommodation camp was carried out in August 2018. This work is detailed in a stand-alone Geotechnical Interpretative Report (Ref. 12).

A summary of the key findings is provided in the sections below.

3.2 SITE INVESTIGATION FINDINGS

3.2.1 Alluvium

There are a number of creeks that cross the site, including one crossing the Plant Site, a number that cross the mine access and haul roads and a number in the areas of the pits. Alluvium and other unsuitable materials will be present and, if structures are to be located in these areas, the alluvium and other unsuitable materials will be removed and replaced with compacted engineered fill.

3.2.2 Residue Storage Facility

3.2.2.1 General

The RSF is located at the southwest toe of the Reynolds Range on surface deposits identified by geological maps to comprise Quaternary alluvium becoming red soil sedimentary deposits moving southward. The RSF occupies an area of approximately 1 km by 1.7 km and the embankments will be approximately 10 m high at Stage 1 and 20 m at final stage. The ground falls in a southward direction at an incline of approximately 1V:160H with steeper contours at the northern end at the foot of the hills.

A gas pipeline runs parallel to the south-eastern end of the RSF and is located approximately 200 m distant. The RSF is planned to be constructed in stages from the south-eastern end moving north-westward.

Three boreholes were undertaken at the RSF and are summarised in Table 3.1.

Table 3.1: Summary of boreholes

	Borehole		
Borehole	BH-18007	BH-18005	BH-18006
Location	Stage 1	Stage 1	Later stage
SPT	0 m = 13 1.5 m = Ref.	0 m = 14 1.5 m = Ref.	0 m = 9 1.5 m = Ref.
Topsoil	0 – 0.3	0 – 0.3	0 – 0.3
Cemented clayey sand, typically very dense and dense	0.3 – 5.4	0.3 – 4.5	0.3 – 7.0
Sandstone	HW to 19.5 m	HW to 18.5 m	HW to 13.8 m
Gneiss	HW to 21.0 m MW to 25.5 m	-	HW to 19.6 m

Notes:
1. Abbreviation: Ref. is refusal.

The rock was moderately fractured with infilling in many of the joints. The joints were typically horizontal to sub-vertical. Falling head tests undertaken in the boreholes (see Table 3.2) indicated an in situ permeability average between 1 and 2 x 10^{-8} m/s.

Twenty-six test pits (TP-18020 to 32 and 34 to 46) were undertaken across the footprint of the proposed RSF. Though variable, the majority of the test pits encountered relatively similar ground that typically comprised:

- Clayey Sand topsoil to an average depth of 300 mm.
- Clayey Sand (typically very dense to dense with some medium dense close to the surface) which is cemented and becomes progressively more cemented with depth. The majority of test pits refused (23 of 26) with an average depth to refusal of approximately 2 m.

Three test pits encountered shallow highly weathered rock or calcrete. These were all located at the northern end of the facility at the foot of the Reynolds Range hills.

3.2.2.2 Typical Ground Profile

Based on the findings from the site investigation, the following ground profile at the RSF is proposed:

- 0 – 0.3 m: topsoil.
- 0.3 – 7.0 m: medium dense clayey Sand becoming very dense from 1.5 m (where all SPT's refused).
- 7.0 – 20.0 m: highly weathered, very low to low strength rock.
- 20.0+ m: moderately weathered, medium strength rock.

A creek crosses the area which was not investigated. If structures are to be founded within the creek area, the alluvial and other unsuitable material will be removed and replaced with compacted structural fill.

Design should include sensitivity analysis to accommodate variability in material parameters and strata thicknesses.

3.2.3 Plant Site

3.2.3.1 General

The Plant Site is planned to be located immediately to the north-east of the RSF and close to the foot of the Reynolds Range hills. Geological maps indicate surface soils to comprise Quaternary alluvium becoming red soil sedimentary deposits moving south-eastward. The Plant Site occupies an area of approximately 1.4 km by 1.4 km. The ground falls in a south-eastward direction at a slope of approximately 1V:110H with steeper contours at the northern end at the foot of the hills.

The general area of the Plant Site area has been investigated but the specific location of Plant Site structures within this area has not been confirmed.

Three boreholes were undertaken at the Plant Site and are summarised in Table 3.2.

Table 3.2: Summary of boreholes

	Borehole		
Borehole	BH-18002	BH-18003	BH-18004
Location	North centre	North-east	South
SPT	0 m = 21 1.5 m = Ref.	0 m = 37 1.5 m = Ref.	0 m = 17 1.5 m = Ref.
Topsoil	0 – 0.3	0 – 0.3	0 – 0.3
Cemented clayey sand, typically very dense and dense	0.3 – 5.0	0.3 – 3.0	0.3 – 4.5
Schist	-	-	HW to 6.0 m DW to 12.0 m
Gneiss	HW to 5.8 m MW to 8.3 m MW/SW to 10.7 m	MW to 3.5 m MW/SW to 8.1 m	-

Notes:
1. Abbreviation: Ref. is refusal.

Six test pits (TP-18016 to 19 and 47 to 48) were undertaken across the footprint of the proposed Plant Site. Though variable, the majority of the test pits encountered relatively similar ground that typically comprised:

- Clayey Sand topsoil to an average depth of 300 mm.

- Clayey Sand (very dense to dense with some medium dense close to the surface) which is cemented and becomes progressively more cemented with depth. The majority of test pits reached their planned depth (5 of 6) of between 3 m and 4 m indicating that the hardpan was less cemented.

One test pit encountered rock (extremely and highly weathered gneiss) at 2.9 m depth.

3.2.3.2 Typical Ground Profile

Based on the findings from the site investigation, the following generalised ground profile at the Plant Site is proposed:

- 0 – 0.3 m: topsoil.
- 0.3 – 6.0 m: medium dense clayey Sand becoming very dense from 1.5 m (where all SPT's refused).
- 6.0 – 12.0 m: highly weathered, very low to low strength rock.
- 12.0 – 15.0 m: distinctly weathered, medium strength rock.
- 15.0+ m: slightly weathered, high strength rock.

This ground model is developed for the purposes of foundation assessment. When considering excavation, harder ground may be encountered closer to the surface.

3.2.4 ROM Pad

The ROM Pad will be located on the southern side of the pits.

Nine boreholes (KPBH01 to 08) were undertaken in 2010 in the area of the currently planned waste dump to the south-east of the pits. All boreholes encountered rock (schist and gneiss) very close to the surface. The boreholes are summarised in Table 3.3.

The following ground profile is estimated:

- 0 – 2.0 m: medium dense granular soil.
- 2.0 – 10.0 m: distinctly weathered medium strength rock.
- 10.0+ m: slightly weathered to fresh high strength rock.

This ground model is developed for the purposes of foundation assessment. When considering excavation, harder ground may be encountered closer to the surface.

Table 3.3: Summary of boreholes

Borehole	Borehole Depth (m)	Depth to Bedrock (m)	Summary
KPBH01-1	10	0.8	• DW, MS to 6.1 m • DW/SW, HS to EOH
KPBH02-1	18	0.4	• DW/SW, HS to 9.7 m • SW/FR, HS to EOH
KPBH03-1	15	1.4	• Variable throughout hole
KPBH04-1	10	0.7	• Typically SW, HS to EOH
KPBH05-1	15	0.3	• DW, MS to 6.0 m • SW/FR, HS to EOH
KPBH06	15	0.5	• Predominantly SW/FR, HS
KPBH07-1	10	2.6	• Variable throughout hole
KPBH08	10	1.2	• DW, MS to 5.0 m • FR, HS to EOH
KPBH09-1	10	0.7	• DW, HS to 5.2 m • SW/FR, HS to EOH

Notes:
1. Abbreviations: DW – distinctly weathered, SW – slightly weathered, FR – fresh, HS – high strength, VHS – very high strength.
2. Ten UCS tests were undertaken on core samples with values between

3.2.5 Pit Area Surface Water Diversion Structures

For the initial few years of operations, it is planned that the creek running through the area of the pits will be diverted around both sides of the pits using a series of channels and bunds. In later years, a single large channel will be constructed to permanently divert water north-westward and further away from the pits.

Preliminary design indicates that the initial surface water diversion channels require up to 3.5 m of excavation and the later constructed permanent surface water diversion channel requires up to 7 to 8 m of excavation.

Nineteen test pits (TP-18057 to 69 and 70 to 75) were undertaken along the proposed line of the surface water diversions. Test pits TP-18057 to 69 are located close to the pits and associated with initial surface water diversions. Test pits TP-18070 to 75 follow the line of the later and larger permanent surface water diversion.

The test pits were variable but typically encountered:

- Clayey Sand topsoil to an average depth of 300 mm.
- Clayey Sand (very dense to dense) which is cemented and becomes progressively more cemented with depth.
- All but one test pit refused at an average depth of 1.5 m. Most refusals occurred on weak rock.

Rock is likely to be encountered during the excavation of some of these channels, particularly those located close to rock outcrops or requiring deeper excavation, see Section 6.1.

3.2.6 Haul Road

The geological maps indicate the alignment of the haul road follows a gap in the Reynolds Range hills and traverses surface ground comprising Quaternary alluvium, red soil and granitic rock.

Eight test pits (TP-18049 to 56) were undertaken along the route, listed in sequence from the Plant Site to the pits. Though variable, the majority of the test pits encountered relatively similar ground that typically comprised:

- Clayey Sand topsoil to an average depth of 300 mm.
- Clayey Sand (very dense to dense) which is cemented and becomes progressively more cemented with depth.
- All but one test pit refused. Approximately half of these refused on cemented hardpan and the remainder on weathered granitic rock.

Four DCP tests were undertaken (DCP01 to 04) along the route which all refused at less than 700 mm depth.

The DCP test comprises hammering a rod of 20 mm tip diameter using a 9 kg drop hammer falling from a height of 510 mm. Refusal is taken as more than 25 blows for 50 mm penetration.

3.2.7 Mine Access Road

The proposed mine access road follows an approximately west-north-west alignment from the Stuart Highway towards the Plant Site and is approximately 15 km long and follows the foot of the Reynolds Range hills. Geological maps indicate that the surface material along to route to comprise Quaternary alluvium, red soil and calcrete with some area of granitic rock outcrop.

Ten test pits (TP-18015 to 13 and 07 to 01) were undertaken along the route, listed in sequence from the Plant Site to the Stuart Highway.

Though variable, the majority of the test pits encountered relatively similar ground that typically comprised:

- Clayey Sand topsoil to an average depth of 300 mm.
- Clayey Sand (very dense to dense) which is cemented and becomes progressively more cemented with depth. All test pits refused at an average depth of 1.4 m.
- No test pits encountered calcrete or penetrated the underlying rock.

Five DCP tests were undertaken (DCP05 to 09) along the route which all refused at less than 450 mm depth.

3.2.8 Accommodation Camp

The accommodation camp occupies and area of approximately 850 m by 850 m and is located on the north side of the proposed mine access road. The site has a fall of approximately 10 m (1V:85H) and is located at the foot of the Reynolds Range hills.

Four test pits were undertaken (TP18009-12). All four test pits refused at a depth of between 1 m and 2 m, averaging 1.7 m. The ground conditions encountered comprised a 300 mm thick layer of red brown clayey Sand topsoil underlain by cemented red brown clayey Sand hardpan which became progressively cemented with depth.

4. HYDROLOGIC ASSESSMENT

4.1 GENERAL

The hydrologic assessment, or routing model to determine catchment response and peak flows, was conducted using the rainfall runoff and stream routing software package RORB (Ref. 13). Peak flows were determined by simulating the flood response of the catchments when subject to design rainfall events. The rainfall runoff and stream routing software package RORB was used as shown schematically in figures 4.1 to 4.7 to represent the catchments.

The “ensemble model” option in RORB was used (average of numerous temporal patterns) to calculate the peak flow for AEP rainfall events ranging from 20% to 0.1% AEP rainfall events for varying event durations.

The catchment runoff properties determined during a previous study by others Surface Water Report (Ref. 14) were assessed and deemed adequate and very likely conservative for the site catchments. At this stage, these values have been maintained but monitoring of actual runoff flows and volumes will be undertaken during operations to confirm the design values.

The following design parameters were used in the RORB modelling:

- All Catchments were assigned an Initial Loss of 43.5 mm and a Constant Loss of 1 mm/hour (Ref. 14).
- All catchments were assigned a natural surface fraction impervious of 0.05 (5 percent) (Ref. 14).
- All reaches were designated as natural channels (F_i=1.0).
- As is common practice for areas within Australia with unknown routing parameters, the parameter “m” was set to 0.8.
- The value of k_c was set by adopting Pearcey’s relationship for the ratio of k_c to d_{av} ($C_{0\ 8}$) as 0.59 (Ref. 15).

4.2 PROJECT TOPOGRAPHY MAP

Topography data and aerial imagery was provided by Arafura Resources in the form of a point cloud in August 2018.

As the topography provided did not fully cover the major regional catchments in the area, the publicly available Digital Elevation Model (DEM-S) was used where required.

This topographic surface was derived from data from the Shuttle Radar Topography Mission (SRTM) (Ref. 16). Geoscience Australia provides the National Surface Hydrology Database consisting of surface water hydrology lines in the region.

The Nolans lease is spread over two distinct north and south regional catchments with the major catchment divide (east to west) running through the project site. The northern catchment eventually reports to Arden Soak (Woodford River), which is located to the north of the project. The southern catchment, through aerial imagery observation, does not appear to have sufficient flow to form a regular flow path. Studies concluded the overland and groundwater flow ultimately terminates in Lake Mackay to the south-west.

4.3 ROAD SURFACE WATER PEAK FLOW RATES

4.3.1 Catchment Delineation

The project area was divided by the alignment of the proposed Mine Access Road (MAR) and Haul Road (HR). Catchments report to their respective culverts/floodway crossings at the low point along the proposed road alignment that bounds the catchment. Any crossing is designed by others.

Figures 4.1–4.3 show the sub catchments, reaches and junction points of interest (for peak flow outputs) of the assessment. Table 4.1 below outlines the catchment modelling parameters, average flow distance (d_{av}) and k_c. The approximate locations these flow paths cross the proposed roads are summarised in tables 4.3 and 4.4.

Table 4.1: Catchment parameters

Catchment	Area (m^2)	D_{av} (km)	k_c
MAR-CH-001	2,938,000	1.69	0.99
MAR-CH-002	11,789,000	3.03	1.79
MAR-CH-003	4.584,000	1.43	0.84
MAR-CH-004	5,111,000	1.46	0.86
MAR-CH-005	12,457,000	2.60	1.53
MAR-CH-006	107,000	0.26	0.15
MAR-CH-007	49,000	0.29	0.17
MAR-CH-008	379,000	0.55	0.32
HR-CH-001	1,135,000	2.60	1.53
HR-CH-002	267,000	0.41	0.24
HR-CH-003	2,829,000	1.13	0.67
HR-CH-004	1,675,000	0.73	0.43

Table 4.2: Mine Access Road – Culvert Location

Culvert I.D.	Easting	Northing
MAR-CU-001	330878.7	7489660.1
MAR-CU-002	327000.7	7490402.1
MAR-CU-003	323640.0	7491743.2
MAR-CU-004	321560.5	7492746.1
MAR-CU-005	319171.4	7494083.8

Table 4.3: Haul Road – Culvert Location

Culvert I.D.	Easting	Northing
HR-CU-001	319317.3	7495593.1
HR-CU-002	318133.0	749551.7
HR-CU-003	318665.8	7498891.7
HR-CU-004	319119.4	7499219.5

4.3.2 Peak Flow Estimation

The peak flow was estimated at potential culvert locations that corresponded to the approximate runoff path of the individual upstream catchment. Three catchments were identified to the south of the MAR where peak flows were estimated to size the drainage channels along the road. Catchment peak flows are summarised in tables 4.4 and 4.5 below for a range of annual exceedance probability (AEP) storms.

Table 4.4: Mine Access Road – Peak Catchment Flows

Catchment	Culvert I.D.	Average Peak Flow (m^3/s) for a given AEP and Duration (h)							
		20%	Critical Duration	10%	Critical Duration	5%	Critical Duration	1%	Critical Duration
MAR-CH-001	MAR-CU-001	9.9	6	13.1	6	19.3	2	36.1	2
MAR-CH-002	MAR-CU-002	31.9	6	44.7	6	57.2	6	109.2	2
MAR-CH-003	MAR-CU-003	16.8	6	21.9	6	33.9	2	61.1	2
MAR-CH-004	MAR-CU-004	18.7	6	24.3	6	37.3	2	67.5	2
MAR-CH-005	MAR-CU-005	40.2	6	55.1	6	70.1	6	137.1	2
MAR-CH-006	NA	0.6	6	0.9	2	1.4	2	2.7	1
MAR-CH-007	NA	0.3	6	0.4	2	0.6	2	1.1	1
MAR-CH-008	NA	1.8	6	2.6	2	3.9	2	7.4	1

Table 4.5: Haul Road – Peak Catchment Flows

Catchment	Culvert I.D.	Average Peak Flow (m^3/s) for a given AEP and Duration (h)							
		20%	Critical Duration	10%	Critical Duration	5%	Critical Duration	1%	Critical Duration
HR-CH-001	HR-CU-001	5.1	6	6.6	2	10.3	2	18.9	1
HR-CH-002	HR-CU-002	1.3	6	2.1	2	3.1	2	5.8	1
HR-CH-003	HR-CU-003	11.1	6	14.9	2	23.4	2	42.6	1
HR-CH-004	HR-CU-004	7.6	6	11.1	2	17.0	2	31.8	1

4.4 PIT DIVERSION CHANNEL

4.4.1 General

The pit diversion channel is intended to divert the natural flow of Kerosene Creek around the open pit and waste dumps. To defer capital as well as to provide time to complete site specific runoff monitoring, the diversion system will be built in two stages. The initial stage will be operation during the first 8 years of mining. During this time a final diversion channel will be built to permanently divert the upstream runoff past the pit development.

The general arrangement of the diversion channels for Stage 1 and Stage 2 are shown in Drg. No. 801-140-A5001-101 and -102 respectively.

4.4.2 Catchment Delineation

The project area to the south of the pit was divided into sub catchments for the purpose of a hydrologic assessment. The combined catchment area that reports to the pit diversion is 20.2 Ha. Figure 4.4 shows the sub catchments, reaches and junction points of interest (for peak flow outputs) of the assessment. Table 4.6 below outlines the catchment modelling parameters. The Pit Diversion Channel RORB model uses a d_{av} of 3.25 km and a k_c of 1.92.

Table 4.6: Catchment parameters

Catchment	Area (m^2)
B01	4,427,000
B02	7,185,000
B03	2,909,000
B04	5,710,000

4.4.3 Peak Flow Estimation

The peak flow was estimated for the input of the pit diversion channel and used to size the pit diversion channel. Diversion channel peak flows are summarised in Table 4.7 for a range of AEP.

Table 4.7: Pit Diversion Channel Estimate Peak Flow Results

Pit Diversion I.D.	Average Peak Outflow (m3/s) for a Given AEP and Duration (h)							
	0.1%	Critical Duration	1%	Critical Duration	2%	Critical Duration	5%	Critical Duration
Inflow	323.4	1	163.9	3	123.8	3	85.6	6
Outflow	301.2	2	160.0	2	120.8	3	84.6	6

4.4.4 Stage 1 Design

The diversion channel will be located adjacent the western edge of the starter pit. Using the 0.1% AEP rainfall event the channel will be 35 m wide and have a maximum flow depth of 4 m. In rock the channel will be excavated with 0.5H:1V side slopes which will be flattened to 3H:1V in soil batters (nominally average 2H:1V). Material sourced from the channel excavation will be used to construct bunds towards the pit in areas where the storm flow depth in the channel exceeds the natural ground elevation.

The base of the channel is expected to be located in rock. Along with the small design grade and the relatively slow flow velocity it is not expected that erosion protection will be required. It is possible that some erosion protection material needs to be added in areas with softer underlying soils.

At this stage it is not expected that any waste haulage across the channel is required as the mining fleet will focus on material movements to the east.

The diversion channel will be crossing an area of the future pit excavation. It is possible that some mineralisation is encountered within channel excavation. These areas will be assessed by the mine geologist and if required over-excavated and backfilled / sealed with a thin concrete layer to prevent water flowing through the channel from pick up any contaminants.

The general arrangement of the Stage 1 diversion channel is shown on Drg. No. 801-140-A5001-101 and typical details of the diversion channel are shown on Drg. No. 801-140-A5001-303.

A small bund will be built upstream of the pit to divert flow from the current river bed of Kerosene Creek into the diversion channel. The pit inflow control bund will have a crest RL of 662.3 m and the pit outflow control bund will have a crest RL of 658.5 m. The bunds will have a crest 6 m wide, batter slopes at 3H:1V. A cut-off trench will be excavated to an in-situ low permeable soil strata and backfilled with low permeable fill where required to limit seepage through the foundation area.

The bund will be built from low permeable Zone A material and have a 500 mm wide layer of Zone E erosion protection on the upstream batter.

The typical details of the pit inflow control bund and pit outflow control bund are shown on Drg. No. 801-140-A5001-301 and -302 respectively.

4.4.5 Stage 2 Design

The Stage 2 pit diversion channel will permanently redirect the flow of Kerosene Creek to the north-west around the proposed pit development as well as the western waste dump. The diverted flow will join its natural river course approximately 1 km downstream of the mine.

Due to the topography, the diversion channel will be excavated considerably deeper into rock. This will provide a long-term stable river course. Currently it is expected that the channel will be in operation for approximately 15 years prior to closure to demonstrate it to be stable.

To minimise the excavation required the channel width will be reduced and the flow depth increased to maintain the required flood flow capacity. During mining the channel was sized to pass 0.1% AEP storm events safely, at closure this will be upgraded to pass the PMP runoff.

Using the 0.1% AEP rainfall event the channel will be 20 m wide and have a maximum flow depth of 6.6 m. The side slopes of the excavated channel will be 0.5H:1V where in rock. A 2 m wide bench will be left in place on top of the rock and the upper section of the channel in soils will be excavated at a slope of 3H:1V. Material sourced from the channel excavation will be used in the raising of the inflow control bund as well as in the rehabilitation work of the mine waste dumps.

Prior to construction of this channel, recorded actual Kerosene Creek flows will be utilised to calibrate the runoff model with site specific monitoring data, allowing for design adjustments (if required) to be made at that time.

The general arrangement of the Stage 2 diversion channel is shown on Drg. No. 801-140-A5001-102 and typical details of the diversion channel are shown on Drg. No. 801-140-A5001-303.

To increase the flow depth within the diversion channel the pit inflow bund will be raised as part of the construction works. The stage 2 pit inflow control bund will have a crest RL of 667 m. The bund will have a crest 10 m wide, batter slopes at 3H:1V.

The bund will be constructed as a zoned downstream filled embankment with a low permeability fill (Zone A) face, a transition fill (Zone B) and a downstream structural fill zone (Zone B). Erosion protection material (Zone E) will be placed on the upstream face of the bund.

The bund will remain in place as part of the mine closure to permanently divert Kerosene Creek. At the time of closure the bund will have been in operation for approximately 15 years, by which time, operation of the system will have been witnessed and allow any required adjustments made to be made well before decommissioning. As part of the closure works the bund will be upgraded to divert flows up to the PMP storm event runoff. Further additional erosion protection material will be added along the upstream face as required.

The typical section and details of the pit inflow control bund are shown on Drg. No. 801-140-A5001-301.

4.5 SEDIMENT DAMS AND WASTE DUMP RUNOFF CHANNELS

4.5.1 General

Local sediment source control will be used at all structures to minimise sediment laden runoff. In addition large Sediment Control Dams (SCDs) will be built downstream of the mining area to allow for settling out of remaining sediments. These dams will also form surface water sampling points to confirm the water quality is acceptable for release.

During the initial project development the mining infrastructure and waste dumps will only be located to the east of the pit, towards Nolans Creek. Two SCDs will be built downstream to capture all runoff from these areas. The SCDs will overtop into a polishing pond which then will discharge off-site. Further a SCD will be built near the mining maintenance area to the south of the pit which will capture the runoff from the nearby infrastructure there as well as from the ROM pad.

In Year 8 the Kerosene Creek diversion channel will be relocated to its final location and the pit as well as the waste dump development will expand towards the west. At this stage an additional SCD will be built to the west of the polishing pond to capture the run-off from the new waste dump.

Minor diversion channels will be excavated along waste dump and stockpile toes to divert any runoff into the sediment control dams.

The general arrangement of the Stage 1 and Stage 2 sediment management structures are shown in Drg. No. 801-140-A5001-101 and -102 respectively.

4.5.2 Catchment Delineation

The project area included the site structures and waste dumps and was bound by the hilly terrain to the south and sediment dams to the north. The catchments report either to the sediment dams or are diverted by the diversion channel and a natural drainage course to the confluence north of the sediment dams. Figures 4.5-4.6 show the sub catchments, reaches and junction points of interest (for peak flow outputs) of the assessment. Tables 4.8 and 4.9 outline the sub catchment modelling parameters for Stages 1 and 2. The sediment dam and waste dump runoff diversion channel RORB model uses a d_{av} of 5.12 km and a k_c of 3.02 for Stage 1 and a d_{av} of 2.45 km and a k_c of 1.45 for Stage 2.

Table 4.8: Stage 1 Catchment parameters

Catchment	Area (m^2)	Impervious Fraction
B01	5,576,000	0.05
B02	6,954,000	0.05
B03	2,950,000	0.05
B04	4,304,000	0.05
B05	24,000	0.808
B06	514,000	0.497
B07	2,471,000	0.693
B08	655,000	0.05
B09	123,000	0.05
B10	2,629,000	0.05
P01	30,000	1
P02	224,000	1
P03	65,000	1
P04	118,000	1

Table 4.9: Stage 2 Catchment parameters

Catchment	Area (m^2)	Impervious Fraction
B01	513,000	0.499
B02	2,471,000	0.694
B03	123,000	0.05
B04	1,712,000	0.327
B05	70,000	0.05
B06	291,000	0.434
B07	114,000	0.05
P02	224,000	1
P03	65,000	1
P04	117,000	1
P05	81,000	1

4.5.3 Peak Flow Estimation

The peak flow was estimated for the output of each sediment dam and along waste dump diversion channel flow paths. The peak flows were used to size the sediment dam spillways and diversion channels. Estimate peak flow are summarised in tables 4.10 - 4.12 for a range of AEP.

Table 4.10: Stage 1 - Sediment Dam Spillway Estimate Peak Flow Results

Sediment Dam I.D.	Average Peak Outflow (m3/s) for a Given AEP and Duration (h)					
	1%	Critical Duration	2%	Critical Duration	5%	Critical Duration
Southern Sediment Dam	1.3	2	1.1	2	0.9	2
North-Eastern Sediment Dam 1	17.6	3	15.2	3	11.8	3
North-Eastern Sediment Dam 2	16.8	6	14.6	6	11.6	6
Polishing Pond	163.2	6	136.8	6	99.4	6

Table 4.11: Stage 2 – Sediment Dam Spillway Estimate Peak Flow Results

Sediment Dam I.D.	Average Peak Outflow (m3/s) for a Given AEP and Duration (h)					
	1%	Critical Duration	2%	Critical Duration	5%	Critical Duration
North-Eastern Sediment Dam 1	19.6	3	16.4	3	12.7	3
North-Eastern Sediment Dam 2	18.5	3	15.6	3	12.2	3
Polishing Pond	31.4	3	26.5	3	20.8	6
Western Sediment Dam	16.0	3	13.4	3	9.4	3

Table 4.12: Waste Dump Runoff Diversion Channel Flow Estimation Results

Channel I.D.	Average Peak Outflow (m3/s) for a Given AEP and Duration (h)	
	1%	Critical Duration
Eastern WD Western Channel	5.4	2
Eastern WD Eastern Channel	37.2	1
Western WD Northern Channel	5.2	1
Western WD Southern Channel	17.9	2

4.5.4 Sediment Dam and Spillway Design

The SCDs will be built as zoned earth and rockfill dams with a central low permeable core and structural fill zones upstream and downstream. Where required to prevent excessive flow through the foundation of the embankment a cut-off trench will be excavated beneath the central core, extending into an in-situ low permeable strata and backfilled with low permeable material. Rock fill will be placed against the downstream face of the embankment to minimise any erosion in the unlikely event of overtopping of any of the embankments.

Each dam will have a spillway, sized to discharge flows of up to a 1% AEP storm event. Larger storms will result in flow over the embankments. A 300 mm deep Zone E erosion protection layer along the base and sides of the spillways as well as sill walls near the inlets will be installed to minimise erosion damage.

Monitoring instrumentations will be installed within all embankments to ensure the performance is in accordance with the design.

Sediments will be regularly removed from each sediment dam to ensure sufficient storage capacity is available. The geochemistry of the sediments will be assessed as part of the work.

The typical layout of the sediment dams is shown on Drg. Nos. 801-140-A5001-101 and -102 for Stage 1 and Stage 2 respectively. Typical sections and details are shown on Drg. Nos. 801-140-A5001-301 and -302.

4.5.4.1 Southern Sediment Dam

The Southern Sediment Dam will be built at the mining maintenance area, near the inlet of the Kerosene Creek diversion channel. This dam will capture runoff from the maintenance area as well as the ROM pad and stockpiling areas.

Under the adopted design conditions, this dam is not expected to overflow. Water captured in this pond will be used by mining as well as the haul road maintenance team. If the dam were to fill and overflow under extreme adverse conditions it is expected to remove and result in discharge of particles down to a medium silt size (at the design inflow estimated from a 1% AEP rainfall event). The dam crest RL will be 667.0 m and will have a capacity of approximately 100,000 m^3 to spillway invert at RL666.5 m. The spillway will be 25 m wide, 0.5 m deep with side slopes of 3H:1V and safely discharges a 1% AEP rainfall event.

4.5.4.2 North-Eastern Sediment Dams

Two SCDs will be built to north east of the mining area between Kerosene Creek and Nolans Creek. To maximise the retention time, while ensure the backwater does not encroach onto the pit excavation a larger dam will be built which cascades into a smaller, slightly lower dam. This SCD will then overflow into the Polishing Pond which is the discharge point for flow off-site towards the north.

It is expected that the SCDs will remove particles down to a medium to coarse silt size at the design inflow of a 1% AEP rainfall event. Storms of a lesser intensity may be contained which will result in better performance in terms of settled out particles.

The North-Eastern Sediment Dam 1 crest will be RL657.0 m and will have a capacity of approximately 217,000 m^3 to spillway invert at RL656.5 m. The spillway will be 30 m wide, 0.5 m deep with side slopes of 3H:1V and pass flows up to a 1% AEP rainfall event. This dam is only expected to overflow during wetter than average rainfall years or extreme storm events. Under regular operation conditions no overflow is expected.

The North-Eastern Sediment Dam 2 crest will be RL656.0 m and will have a capacity of approximately 54,000 m^3 to spillway invert at RL655.5 m. The spillway will be 30 m wide, 0.5 m deep with side slopes of 3H:1V and pass flows up to a 1% AEP rainfall event.

4.5.4.3 Polishing Pond

The Polishing Pond will be built within Kerosene Creek and will form the discharge point off site.

The Polishing Pond crest will be RL655.5 m and will have a capacity of approximately 78,000 m^3 to spillway invert at RL654.0 m.

The primary spillway at the eastern abutment will be 50 m wide, 1.5 m deep with side slopes of 3H:1V and safely discharge flows due to a 5% AEP rainfall event. An emergency spillway at the western abutment with an invert level of RL655.0 will increase the discharge capacity to manage flows up to a 1% AEP rainfall event. The western emergency spillway will be 50 m wide, 0.5 m deep with side slopes of 3H:1V.

4.5.4.4 North-Western Sediment Dam

The Western Sediment Dam will be built in Stage 2 (approximately Year 8 of mining) to the east of the Polishing Pond to capture runoff from the Western Waste Dump. Any SCD overflow will also pass through the Polishing Pond.

The Western Sediment Dam crest will be RL656.5 m and will have a capacity of approximately 71,000 m^3 to the spillway invert at RL656.0 m. The spillway will be

35 m wide, 0.5 m deep with side slopes of 3H:1V and safely discharge runoff due to a 1% AEP rainfall event. Similar to the eastern SCDs this pond is only expected to overflow during wetter than average rainfall years or extreme storm events. Under regular operation conditions no overflow is expected.

4.5.5 Waste Dump Runoff Diversion Channel Design Parameters

Waste dump runoff diversion channels will be built at the toe of the waste dumps to divert runoff to the sediment dams. The channels were sized to pass flows up to a 1% AEP rainfall event using conservative assumptions in regards to the waste dump development. It is expected that the construction of the channels can be staged in accordance with the actual waste dump construction.

The Eastern Waste Dump Channel will be built during the Stage 1 works. It will ensure any runoff from the eastern waste dumps, stockpiles and mining infrastructure areas report to the SCDs instead of Nolans Creek. The channel will have a width of 14 m and a depth of 1 m with sides slopes of 3H:1V.

The Western Waste Dump Channel will be constructed as part of the Stage 2 works to divert runoff from the Western Waste Dump into the SCD instead of reporting into the pit. The channel will be 8 m wide and 1 m deep with sides slopes of 3H:1V.

The excavated material from the channels will be used as toe bunds for the waste dumps or within flood protection bunds.

4.6 MINOR SEDIMENT MANAGEMENT STRUCTURES

Even that the haul trucks will pass through a wash bay before entering the haul road from the mining area to the process plant, small sediment management dams will be built along the road at regular intervals to capture the runoff from the road surface which potentially could contain ore particles.

Each sediment dam will be approximately 40 by 40 m and 2 m deep, providing approximately 2,000 m^3 of storage capacity. The exact dimensions will be adjusted to suite the individual dam locations. Placed at 500 m intervals along the haul road this will be sufficient to store the runoff due to a 1% AEP 24 hour storm if empty at the beginning of a storm. Emergency spillways will be installed to safely discharge any water in excess of the storage capacity.

The sediment dams will be regularly cleaned out of captured and settled out particles to re-establish the storage capacity. Any captured sediments will be tested to determine the geochemical composition.

4.7 FLOOD PROTECTION BUND

4.7.1 General

A Flood Protection Bund will be built during the Stage 1 development to ensure Nolans Creek does not encroach into the nominated mining infrastructure area, which will be built within the flood plain extents of the river. The bund was sized for flood levels up to 0.1% AEP rainfall events.

The typical layout of the bund is shown on Drg. No. 801-140-A5001-101 and 102 and the typical sections and details are shown on Drg. No. 801-140-A5001-303.

4.7.2 Catchment Delineation

The Nolans River catchment to the east of the pit and eastern dump area is defined by the hilly terrain to the west, south and east. The catchments eventually report to Arden Soak (Woodford River), north of the project. Figure 4.7 shows the sub catchments, reaches and junction points of interest (for peak flow outputs) of the assessment. Table 4.13 below outlines the catchment modelling parameters. The Flood Protection Bund RORB model uses a d_{av} of 6.85 km and a k_c of 4.04.

Table 4.13: Catchment Parameters

Catchment	Area (m^2)
PS-CH-001	14,922,000
PS-CH-002	16,297,000

4.7.3 Peak Flow Estimation

The peak flow was estimated in the Nolans Creek flow path at the beginning and end of the plant site lease to estimate a critical flow rate. Catchment peak flows are summarised in Table 4.14 below for a 0.1% AEP.

Table 4.14: Nolans Creek Peak Flow Estimation Results

Sediment Dam I.D.	Average Peak Outflow (m^3/s) for a Given AEP and Duration (h)	
	0.1%	Critical Duration
Start of Lease	437.0	1
End of Lease	334.3	2

4.7.4 Flood Level Estimate

A hydraulic assessment was conducted along Nolans Creek using the RORB peak flows determined above. Three cross sections were extracted from the topography and the channel slope at each determined. The flow depth and flow velocity was determined from Normal Depth calculations and an inundation extent overlayed on the topography. All channels were assigned a Mannings number of 0.040 representing natural mountain streams with little to no vegetation.

The adopted simplified cross sections are shown on figures 4.8 and 4.9 with the 0.1% AEP flood level shown. Table 4.15 presents the 0.1% AEP Normal Depth results along with the associated inundation extents shown in Figure 4.10.

Table 4.15: Normal depth calculation results

Cross Section	Channel Slope (m/m)	Flow Depth (Centre River) (m)	Flow Velocity (m/s)	Flow Elevation (m)
Nolans Creek – Section A	0.003	2.14	1.16	661.13
Nolans Creek – Section B	0.003	2.37	1.32	662.33
Nolans Creek – Section C	0.003	1.99	1.20	661.79
Nolans Creek – Section D	0.003	2.09	1.24	657.62

In addition to the peak flood depth, the results indicated that the flood water extents are not expected to inundate the Eastern Waste Dump area for AEPs greater than 10%.

The flood protection bund was sized to protect the Eastern Waste Dump from inundation from a 0.1% AEP storm event.

4.7.5 Flood Protection Bund Design

The Flood Protection Bund will have a 4 m wide crest, a height of 2 m and have 3H:1V batter slopes. A 6 m wide service and maintenance road will be built on the “dry” side of the bund to provide easy access to the bund for inspections and to complete maintenance. The Flood Protection Bund will be constructed out of Zone C structural fill won directly from the excavation of the waste dump runoff diversion channel adjacent to it.

Especially during the first notable flooding event it is recommended that the bunds be continuously inspected, and any maintenance work required completed immediately. If required, Zone E erosion protection material can be placed in areas where erosion was encountered.

The flood protection bund will be integrated in the final waste dump capping and subsequently will form the toe of the rehabilitated dump.

The typical layout of the Flood Protection Bund and Runoff Protection Bund are shown on Drg. No. 801-140-A5001-101 and -102 and the typical sections and details are shown on Drg. No. 801-140-A5001-303.

5. CONSTRUCTION MATERIALS

5.1 GENERAL

The construction of the water and sediment management structures will require a number of different material types. The main materials required are as follows:

- Zone A low permeability material.
- Zone B transition fill material
- Zone C embankment structural fill.
- Zone D general fill.
- Zone G clean rock materials.
- Erosion protection material.
- Drainage / filter materials.

Currently it is not expected that large waste rock quantities will be available for surface water management structure construction outside the mining area and the design was generated on the basis that benign construction fill material will be sourced from local excavations of structures where possible and supplemented by borrow development as required.

5.2 MATERIAL REQUIREMENTS

The requirements for the different construction materials are detailed below.

Zone A

Zone A material shall comprise low permeable fill material with a minimum plasticity index of 8.

The material will be moisture conditioned (if required) to be in the range of 0% < OMC < +3%. The layer will then be compacted to a minimum dry density of 98% SMDD. The material will be placed and compacted in successive horizontal layers of loose material so that the maximum compacted layer depth is not greater than 300 mm.

Compaction of Zone A material will be completed using vibratory pad foot compactors and sealed off using a smooth drum compactor in case of wet weather. Smooth surfaces will be scarified prior to the next layer being placed. During the compaction process the embankment foundation / previous layer will be lightly watered or allowed to dry as required to maintain the specified moisture content.

Zone B

Zone B is the filter zone between Zone A and Zone C. The material shall be sourced from stockpiles provided by the Company or from borrow areas as directed by the Engineer. The material shall be verified by the Engineer prior to use by the Contractor.

The material will be placed in layers not exceeding 500 mm, moisture conditioned (if required) to be in the range of -3% < OMC < +3% and compacted to a minimum dry density of 95% SMDD.

Zone C

Zone C is the structural fill zone. The material shall be sourced from borrow areas as directed by the Engineer. The material shall be verified by the Engineer prior to use by the Contractor.

Similar to Zone B, the material will be placed in layers not exceeding 500 mm, moisture conditioned (if required) to be in the range of -3% < OMC < +3% and compacted to a minimum dry density of 95% SMDD.

Zone D

Zone D will be general fill materials sourced from mine waste stockpiles or various locations around the site. Proposed materials may be sourced from borrow areas, excavations associated with the works, or other areas as directed by the Engineer.

Zone E

Zone E is a designated erosion protection zone to be made from competent rock materials sourced from benign mine waste stockpiles or from borrow areas. Crushing and screening is likely required.

Zone F

Zone F1 and F2 are filter sand and filter gravel respectively to be primarily used in the underdrainage system within the basin. It is expected that some of the required materials can be selectively borrowed within the creeks in the mining area. Alternatively the material needs to be produced by crushing and screening of mine waste and/or borrow material. Alternatively this material also can be imported from off-site sources.

Zone G

Zone G is the selected clean rock fill for use in the decant tower surrounds. This material will be selectively sourced from mine waste stockpiles or borrow areas and if required screened.

Zone G material will comprise sound, durable, clean, sub-angular to angular rock fragments, free of wood, steel, organics and other deleterious material. The material will generally be between 50 mm and 300 mm with no more than 5% of the material passing the 0.075 mm sieve.

5.3 FILL PLACEMENT

The embankment material shall be placed as uniform layers without abrupt changes in material type, quality or size for each zone.

5.4 CONSTRUCTION QUALITY ASSURANCE AND CONTROL

A dedicated construction management team, technical supervision and quality assurance/quality control (QA/QC) is required for each stage of construction to ensure the facility is constructed in accordance with the design intent. At the completion of each construction stage, an “as-built” drawing set and construction report will be prepared. The report will collate the QA/QC records and document changes to the design. The details of the design changes and the parameters of the construction material used will be detailed in this final construction report. An updated seepage and stability model shall be undertaken if required.

All quality control and acceptance testing associated with earthworks will be carried out as the work progresses to ensure that construction conforms to the technical minimum requirements. All tests will be carried out in accordance with AS1289 (Method of Testing Soils for Engineering Purposes) unless stated otherwise.

Testing frequencies for quality control will be as advised by the Engineer. Table 5.1 is the minimum amount of testing envisaged.

Table 5.1: Quality Control and Record Testing

Type of Test	Frequency (At least)
Cut-Off Trench (Construction complete)	
Atterberg Limits	2,500 m^3
Particle Size Distribution (PSD)	2,500 m^3
Moisture Content – Laboratory	2,500 m^3
Moisture – Density Relationship	1 per material type or 2,500 m^3 or as required.
Field density and moisture content	1 per layer or per 100 linear m.
Permeability*	10,000 m^3
Zone A	
Atterberg Limits	2,500 m^3
Particle Size Distribution (PSD)	2,500 m^3
Moisture – Density Relationship	1 per material type or 2,500 m^3 as required.
Field density and moisture content	500 m^3
Permeability*	40,000 m^3
Shear Strength**	40,000 m^3
Zone B & C	
Atterberg Limits	5,000 m^3
Particle Size Distribution (PSD)	5,000 m^3
Moisture – Density Relationship	1 per material type or 5,000 m^3 or as required.
Field density and moisture content	1,000 m^3
Zone E & G	
Particle Size Distribution (PSD)	2,500 m^3
Zone F1 & F2	
Particle Size Distribution (PSD)	500 m^3
Moisture – Density Relationship	1 per material type or 500 m^3

*As determined by falling head permeability test in accordance with AS 1289.6.7.2

**As determined by Triaxial and shear box test in accordance with AS 1289.6.2.2

6. MONITORING

6.1 GENERAL

A monitoring programme for the site will be developed to monitor for any potential problems which may arise during operations and provided in a standalone document prior to commissioning of the project.

Due to the elevated level of radioactivity of the ore and potential of the sediments, the monitoring requirement will also need to take into consideration any specific requirements of the Australian Radiation Protection and Nuclear Safety Agency. This will be detailed in a site specific radiation management plan.

The monitoring instrumentation for the sediment dams will include:

- Monitoring bores downstream of the sediment dams.
- Vibrating Wire Piezometers (VWP's) in the embankment to monitor the phreatic surface.
- Pond levels.
- Settlement pins to check embankment movement.

The piezometers and monitoring bores will be checked monthly for water levels. Further the monitoring bores will be checked quarterly for water quality.

Further monitoring stations for surface water peak flows in Kerosene Creek and in Nolans Creek will be installed to collect site specific runoff data of the upstream catchments. Surface water sampling locations will be defined to determine the water quality of any water entering the site as well as leaving the site.

If the monitoring programme indicates that potential problems are developing, an increase in monitoring frequency will be implemented and a response plan developed.

The proposed locations and typical details of the instrumentation of the initial construction stage are shown on Drg. No. 801-140-A5001-900. Typical details of the instrumentation are shown in Drg. Nos. 801-140-A5001-910.

In addition to the specific monitoring of the surface water management structures it is expected that other instrumentation such as dust and radiation monitoring stations will be installed in the area by others.

6.2 SEDIMENT CONTROL DAM MONITORING

6.2.1 General

As water retaining structures the performance of the SCDs will be monitored in detail to confirm it complies with the design assumptions.

6.2.2 Seepage Monitoring

The sediment dam designs incorporate a number of measures to reduce the amount of seepage that will occur from the sediment dams, in order to mitigate the extent of any effects on the downstream environment. Monitoring bores installed downstream of the sediment dams will facilitate early detection of changes in groundwater level and/or quality, both during operation and following decommissioning. The locations of the proposed monitoring stations are shown on Drg. No. 801-140-A5001-900.

The monitoring bore station consists of one shallow bore, extending to a depth of approximately 10 m in the surface horizon, and one deep bore terminating at approximately 60 m depth, in fresh rock. The shallow bore is intended to detect any seepage from the Sediment Dams flowing within the surface soils, whilst the deep bore will monitor the chemical composition of the existing groundwater. Each borehole will be cased and screened over an interval set in the field during installation and sealed back to surface with low permeability grout. The PVC tube for the monitoring bores will be 100 mm diameter. It is recommended that the boreholes are constructed before commissioning of the sediment dams in order to accumulate baseline data. Typical details of a monitoring bore are shown in Drg. No. 801-140-A5001-910.

6.2.3 Stability Monitoring

Porewater pressures will be monitored at several locations within the embankments to ensure that stability is not compromised. Vibrating wire piezometers will be installed at key locations within the dams as shown on Drg. No. 801-140-A5001-900.

The embankment vibrating wire piezometer cables run within a trench to the downstream perimeter of the embankments. If required by future construction work these cables can be extended. The ends of the cables will be connected to a data logger. Typical details of a vibrating wire piezometer are shown on Drg. No. 801-140-A5001-910.

In addition to the vibrating wire piezometers standpipe piezometers will be installed to allow for direct measurement of the phreatic surface within the embankments as well as allowing to sample any water picked up. If an embankment needs to be modified, the piezometers will be backfilled and new piezometers installed from the newly constructed crest. Typical details of a standpipe piezometer are shown on Drg. No. 801-140-A5001-910.

The piezometers will be monitored at regular intervals as outlined in the operating manual (to be issued prior to commissioning of the project) and if any unexpected rises in water level is noted. Increases of greater than 10% of the embankment height between readings should be referred to Knight Piésold for further investigation. The piezometer levels should be monitored to ensure that the phreatic surface does not reduce the overall stability of the embankments below acceptable levels. Remedial action will be undertaken if increases in pore water pressure are unacceptably high.

6.2.4 Survey Pins

Survey pins will be installed at regular intervals along the sediment dam embankments and pit control bund crests, at the end of each construction stage, in order to monitor embankment movements and assess effects of any such movement on the embankment integrity. The as-installed details of each pin (date of installation, settlement pin ID, Northing, Easting and RL) will be recorded during installation.

Each pin will be monitored for movement at regular intervals. Any displacement of the embankment that is considered excessive or ongoing, may indicate embankment stability problems and will require investigation by Knight Piésold. Remedial action will be undertaken if required based on the conclusions drawn from such an investigation.

The proposed locations as well as typical details of the settlement pins are shown on Drg. No. 801-140-A5001-900.

6.2.5 Captured Sediments

In each dry season the captured sediments will be removed from the basins to ensure the full storage capacity is available during the next wet season. During the removal the amount of captured sediments as well as the particle sizes and the geochemical composition should be recorded.

6.3 RAINFALL RUNOFF MONITORING

It is proposed that an automatic flow monitoring station is installed at the inlet to the pit diversion channel as well as a rainfall monitoring station within the mining area. This will allow the back-calculation of the rainfall runoff specifics for the actual catchment and calibrate the computer model better, which will subsequently be used in the design of the permanent diversion channel to the west.

It is proposed that the monitoring station consists of an automatic depth monitoring sensor and a data logger to generate a continuous record of any flow through the channel. The sensor will be installed in a well defined monitoring section within the channel with a known rating curve. In combination this will allow the channel peak flow as well as the runoff volume to be estimated.

6.4 SURFACE WATER QUALITY / SEDIMENT LOAD MONITORING

The surface water quality will be monitored upstream and downstream of the mining area as well as along other major flow path along the roads and the process infrastructure to demonstrate all discharge off-site is within permit requirements. Pump-back systems can be installed in the sediment control structures downstream of the pits to recycle water if exceeding permit requirements or to reduce make-up water requirements from the borefield.

Monitoring frequency and constituents will need to be in accordance to the permit requirements, but should at least include sampling of TDS and pH on a weekly basis when rivers/drains flow. A full geochemical sampling program should be completed at least once a month while rivers/drains are flowing.

6.5 MONITORING AND MAINTENANCE PROGRAMME

6.5.1 Monitoring Programme

As part of the operation of the sediment dams, diversion channels and pit control bunds, extensive monitoring of all aspects of the operation should be undertaken. This monitoring falls into three basic categories:

- Short-term operation monitoring – this includes items such as monitoring sediment loads, whether pumps are operational and pipe joints are leaking, erosion of water management structures etc., which are part of ensuring that the facilities are operating smoothly.
- Compliance monitoring – this includes items such as checking survey pins for movement and monitoring bores for contamination, etc., which are used to ensure that the project is meeting all of its commitments in regard to a safe, secure operation.
- Long-term performance monitoring – this includes such items as sediment build-up surveys and water flow measurements (using flow meters and surface water flow monitoring stations installed at designated locations), etc.,

which are used to monitor the long term performance of the facilities and refine future design work.

In addition, the sediment dams and pit diversion infrastructure will undergo annual audits by a suitably qualified geotechnical engineer to ensure that the facilities are operating in a safe and efficient manner.

A full monitoring and programme will be compiled prior to commissioning of the project and issued for implementation.

6.5.2 Maintenance Programme

Inspection and maintenance of the sediment dams and the pit diversion system is largely aimed at mitigating potential problems by dealing with them before they can develop into major problems as well as maintaining the performance of the structures.

A full maintenance programme for the sediment dams and pit diversion system will be incorporated into the operating manual (to be issued prior to commissioning of the sediment dams and pit diversion system). Modifications to the maintenance programme as a result of emergency situations or annual reviews should be made as required.

7. CLOSURE AND REHABILITATION

7.1 GENERAL

The main focus of the rehabilitation programme will be to provide a long-term stable landform, re-vegetation, erosion control and stormwater management. Establishing a surface cover of verdant vegetation will reduce the potential for adverse environmental impact such as dust generation and rainfall erosion, as well as improving aesthetics.

During the 23 years of operation of the project runoff data will have been collected from the main catchments to allow for a detailed assessment of the runoff properties and the requirements for the long-term management.

7.2 PIT SURFACE WATER MANAGEMENT SYSTEM

The main focus of the closure of the surface water management structures for the mining area is to minimise the inflow into the pit, as the pit closure plan requires it to become a groundwater sink to minimise the risk of any contaminants escaping.

At closure the diversion channel as well as the bunds will have been in place for approximately 15 years and will have demonstrated they are long term stable. It is expected that minor addition of erosion protection material at the inflow bund will be sufficient as part of the closure works.

The channel base will be located in rock. It is not expected that any additional work will be required.

7.3 MINOR DIVERSION CHANNELS AND FLOOD BUNDS

The minor diversion channels along the toes of the waste dumps will be infilled after the final waste dump slope is established and the surface area of the dump rehabilitation is completed.

The flood protection bund towards Nolans Creek will be integrated into the final waste dump encapsulation and will form the permanent toe of the dump.

7.4 SEDIMENT DAMS

At the end of the rehabilitation process of the mining area, in particular after the waste dumps are rehabilitated and the sediment generation is limited, the sediment dams will be drained and all remaining sediments removed from the basin and hauled to dedicated encapsulation areas within the waste dump. The embankments will then be removed and the basin as well as the embankment footprint rehabilitated and revegetated.

8. QUANTITY AND CAPITAL COST ESTIMATE

On the basis of the design presented and the parameters presented in Section 1, construction quantities have been determined. The detailed Bill of Quantities is attached as Appendix B and a summary is presented in Table 8.1 below. The quantities given are to an overall accuracy of ±25%.

The following exclusions are noted from the quantities and costs:

- Security measures at the construction areas.
- Surveying during the construction.
- Construction management during the construction.
- Power supply and electrical infrastructure.
- Land acquisition costs.
- Permitting costs and associated fees.
- Site access road earthworks.
- Pumps and associated infrastructure.
- Water return pipelines and associated infrastructure.
- Operating costs.

Quantities for major items were determined based on the following assumptions:

- Topsoil depth of 100 mm.
- All Zone A, B and C fill for the bunds and embankments will be sourced from close by borrow areas.
- Drainage sand material (Zone F) will require importing from a local commercial supplier or processed on site. The material will be delivered to stockpile by the supplier.
- Erosion protection rockfill (Zone E) will require importing from a local commercial supplier or processed on site from benign mine waste materials. The material will be delivered to stockpile by the supplier.
- Benign coarse rockfill material (Zone G) will be supplied from the mining operation or processed on site. The material will be delivered to stockpile by the supplier.

Table 8.1: Capital Cost Estimate Summary

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

9. RISKS AND OPPORTUNITIES

9.1 INTRODUCTION

An evaluation of risks and opportunities for the Surface Water Management structures discussed in this report was conducted as part of the design. The risks generally cover technical aspects of the work.

9.2 CONSTRUCTION MATERIALS

Currently it is assumed all construction materials are sourced from excavations or from borrow areas. If construction materials are available as direct haul of benign mine waste cost savings could be realised.

If it is found that materials from excavations are not acceptable as construction material, in particular is geochemically not benign, other material sources need to be found, likely increasing construction costs.

The construction of the dams and bunds will require materials which can be compacted to form low permeable layers. If insufficient suitable material can be sourced from the immediate area additional borrows need to be developed more remote or geosynthetics used to provide the required water retention layer.

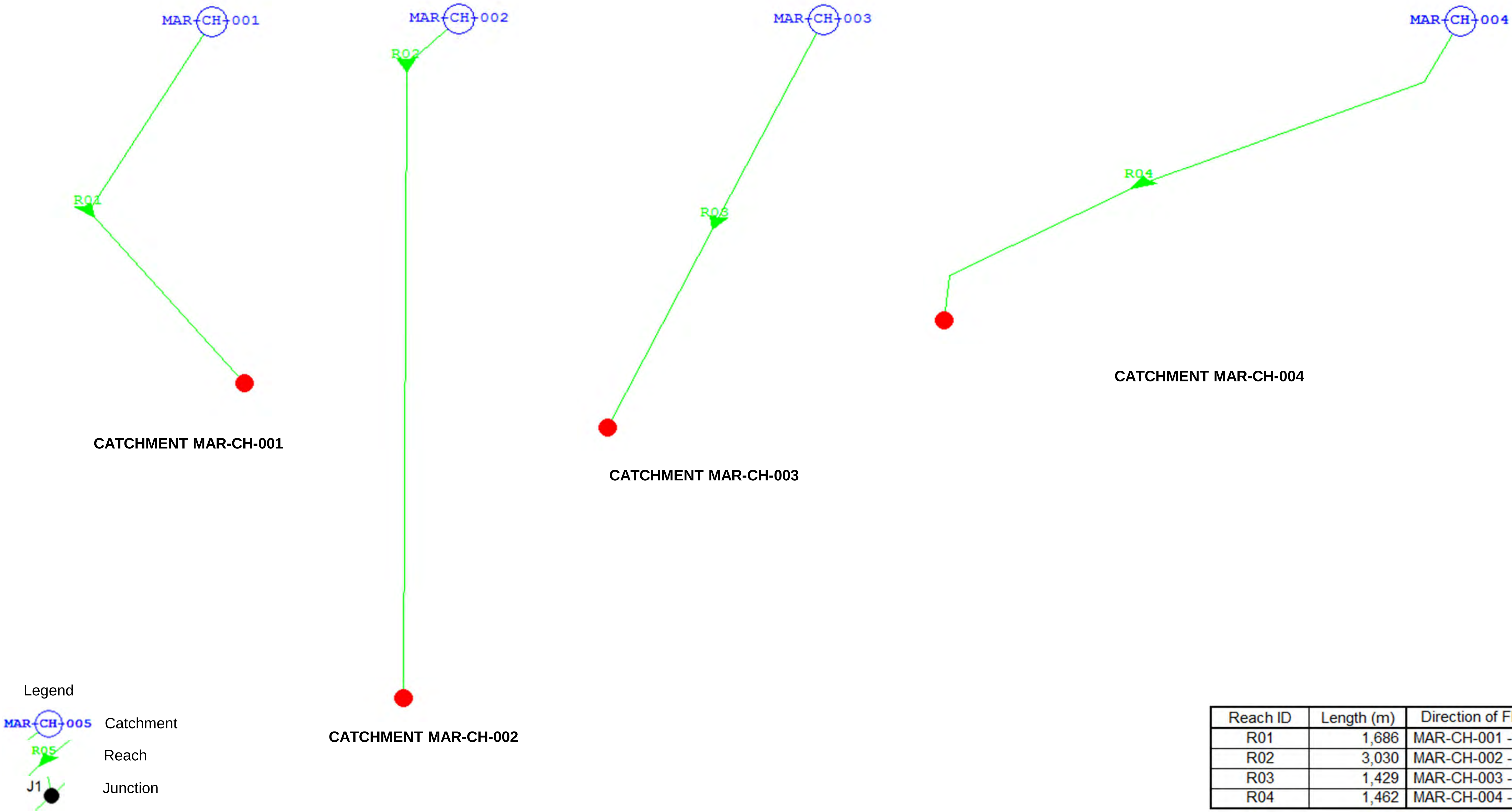
9.3 SCHEDULING OF FINAL DIVERSION WORKS

If the mining plan is modified it is possible that the construction of the final diversion channel can either be deferred or, if the pit encroaches on the diversion channel alignment earlier or the western waste dump is required earlier, needs to be brought forward.

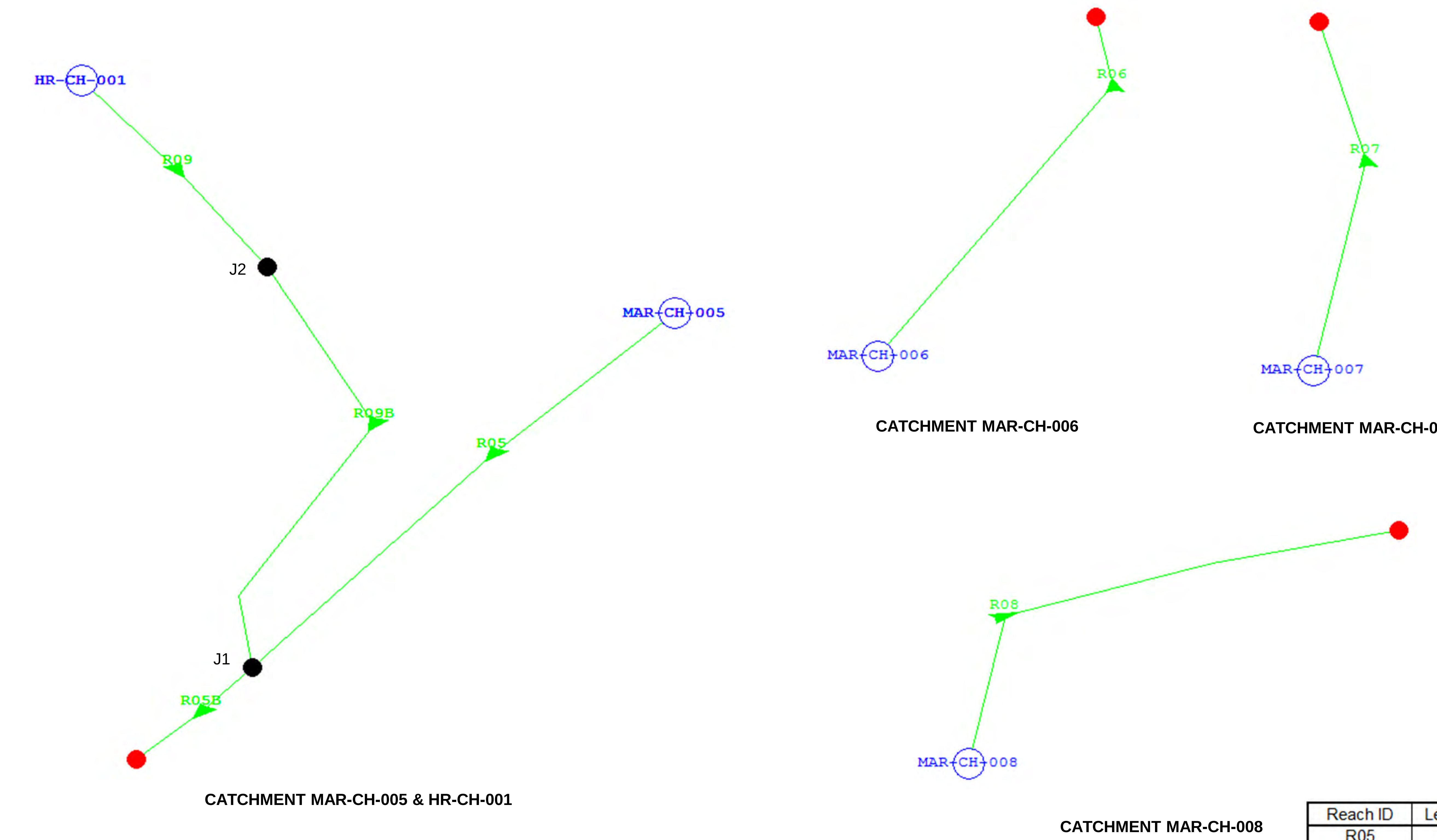
10. REFERENCES

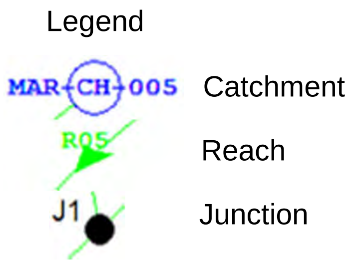
1. Knight Piésold, report PE801-00140/12, "*Nolans Project, Residue Storage Facility, Definitive Feasibility Study – Design Report*", Rev. A, November 2018.
2. Queensland Government Website, https://silo.longpaddock.qld.gov.au/ Data sourced 20th June 2018.
3. Stanhill, G. *"The CIMO International Evaporimeter Comparisons".* Publication 449, World Meteorological Organisation, Geneva; 1976.
4. Australian Government Bureau of Meteorology, 2016 Rainfall IFD Data System, http://www.bom.gov.au/water/designRainfalls/revised-ifd/? Data sourced 20th June 2018.
5. 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.
6. Bureau of Meteorology "*The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method*" (GSDM), June 2003.
7. Bureau of Meteorology "Revision of the *Generalised Tropical Storm Method for Estimating Probable Maximum Precipitation*" (GTSMR), August 2003.
8. Australian Government Bureau of Meteorology, Web Resource, http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/windrose_selector.cgi?period=Annual&type=9&location=15590 Data sourced 22nd June 2018.
9. Arafura Resources Limited, Nolans Environmental Impact Statement, Volume 2, Appendix K *"Groundwater Report"*, May 2016.
10. Knight Piésold, report PE801-00140/02, "*Nolans Project, Plant Site and Haul Road, Geotechnical Report*", Rev. A, October 2010.
11. Knight Piésold, report PE801-00140/06, "*Nolans Project, Geotechnical Site Investigation Report*", Rev. B, October 2011.
12. Knight Piésold, report PE801-00140/14, "*Nolans Project, Geotechnical Interpretative Report*", Rev. A, November 2018
13. HARC RORBwin Version 6.31. http://www.harconsulting.com.au/software/rorb/.
14. GHD (May 2016) Nolans Project Environmental Statement – Appendix I: Surface Water Report.
15. Pearcey, Mark; Pettett, Sam; Cheng, Sheena and Knoesen, Darryn. *Estimation of RORB Kc parameter for ungauged catchments in the Pilbara region of Western Australia* [online]. In: Hydrology and Water Resources Symposium 2014. Barton, ACT: Engineers Australia, 2014: 206-214.
16. Geoscience Australia. "*1 Second SRTM Level 2 Derived Digital Elevation Model V1.04*", (software), 2011. Canberra, ACT. Australia.

FIGURES

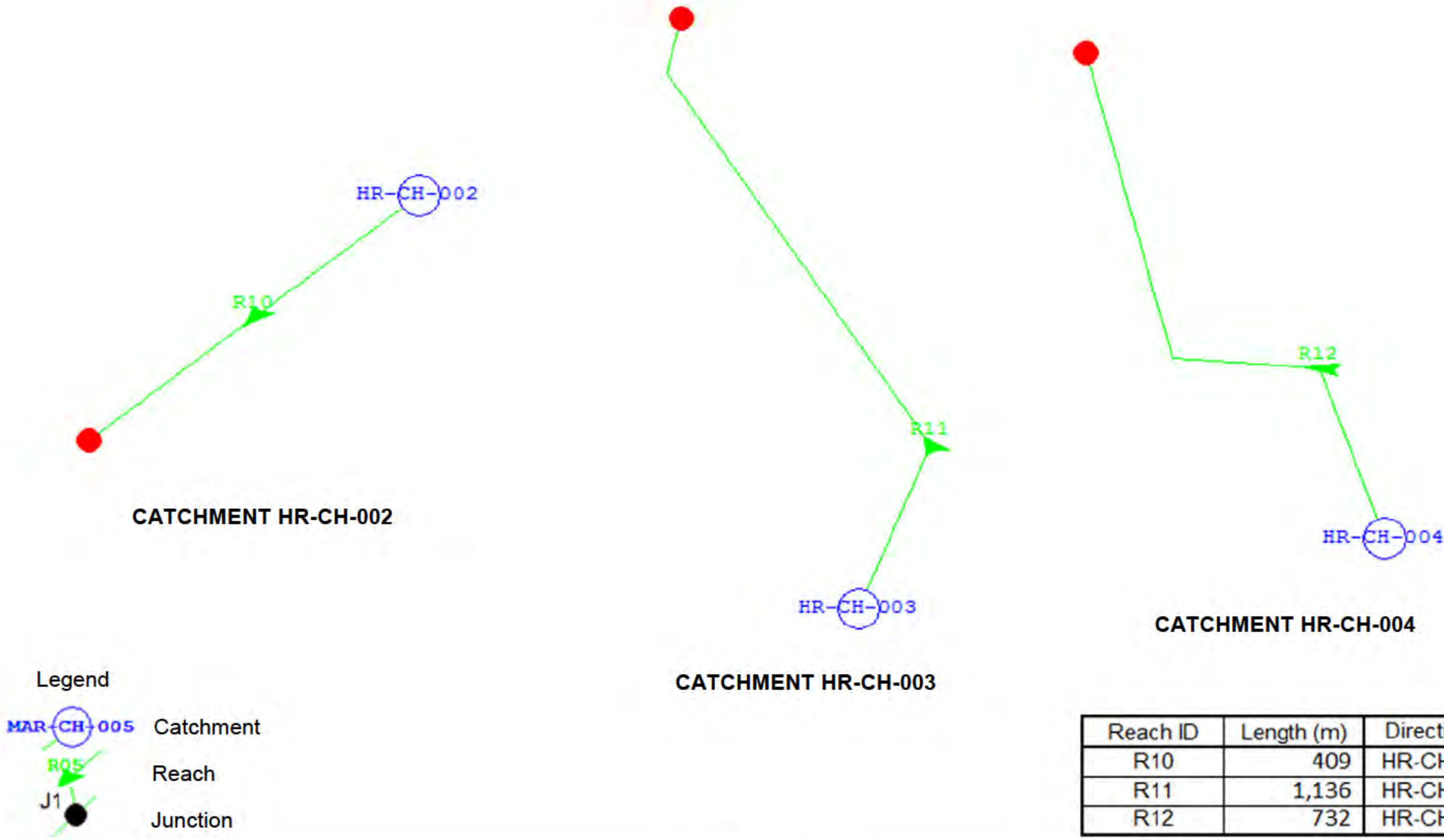


Reach ID	Length (m)	Direction of Flow
R01	1,686	MAR-CH-001 - End
R02	3,030	MAR-CH-002 - End
R03	1,429	MAR-CH-003 - End
R04	1,462	MAR-CH-004 - End

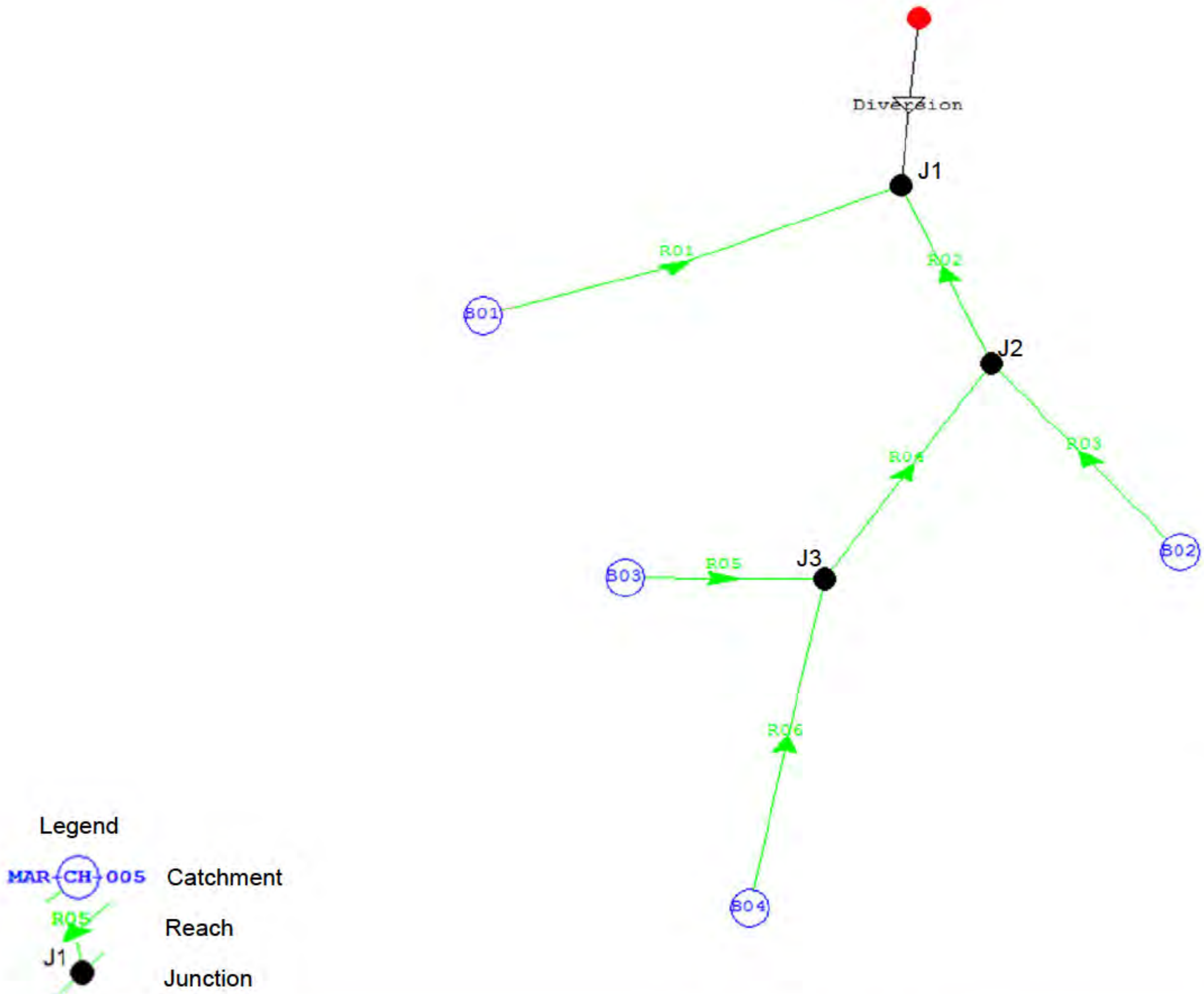




Reach ID	Length (m)	Direction of Flow
R05	2,454	MAR-CH-005 - J1
R05B	141	J1 - End
R06	258	MAR-CH-006 - End
R07	294	MAR-CH-007 - End
R08	548	MAR-CH-008 - End
R09	573	HR-CH-001 - J2
R09B	1,918	J2 - J1



Reach ID	Length (m)	Direction of Flow
R10	409	HR-CH-002 - End
R11	1,136	HR-CH-003 - End
R12	732	HR-CH-004 - End

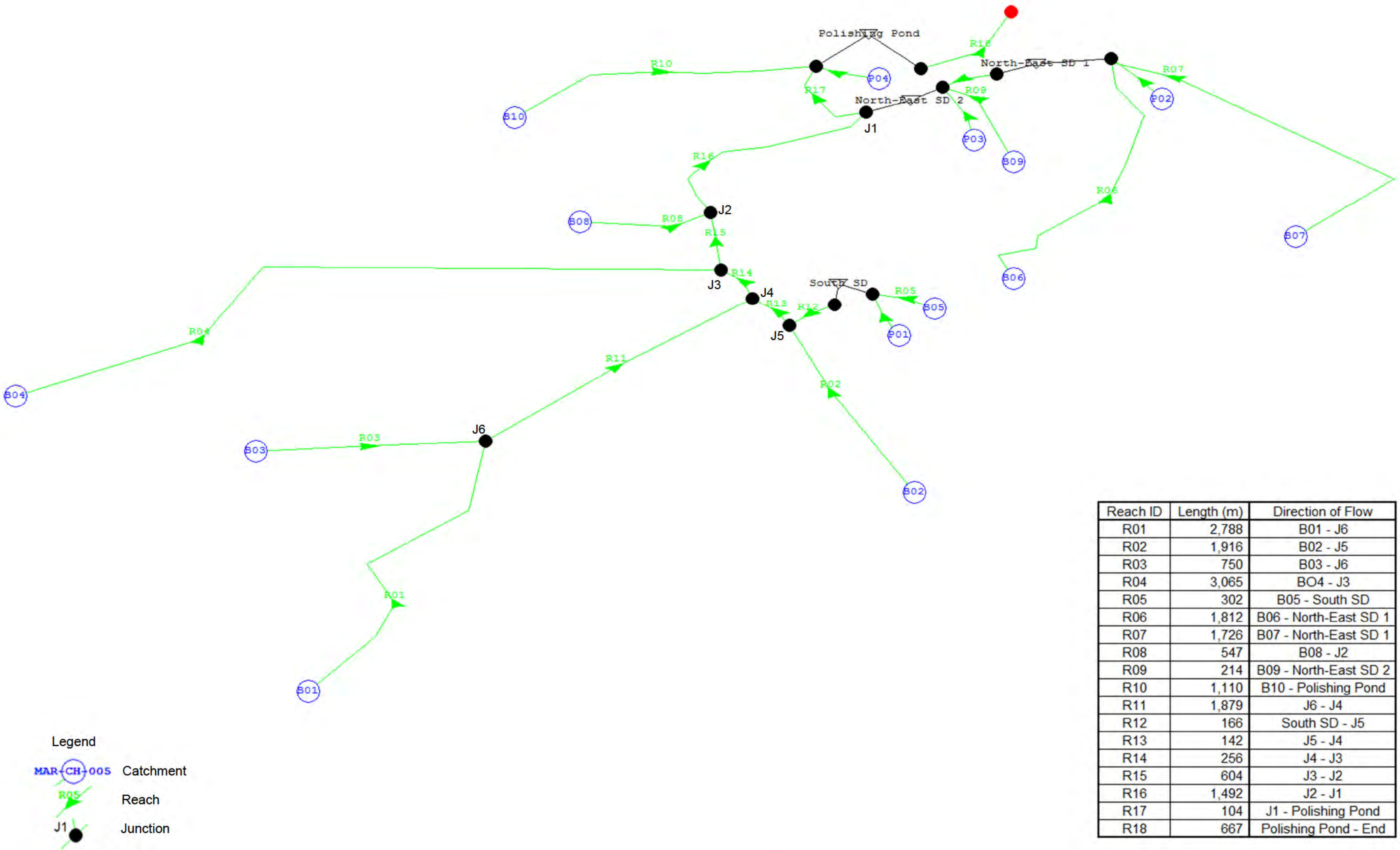


Reach ID	Length (m)	Direction of Flow
R01	2,900	B01 - J1
R02	333	J2 - J1
R03	1,900	B02 - J2
R04	1,921	J3 - J2
R05	707	B03 - J3
R06	2,677	B04 - J3

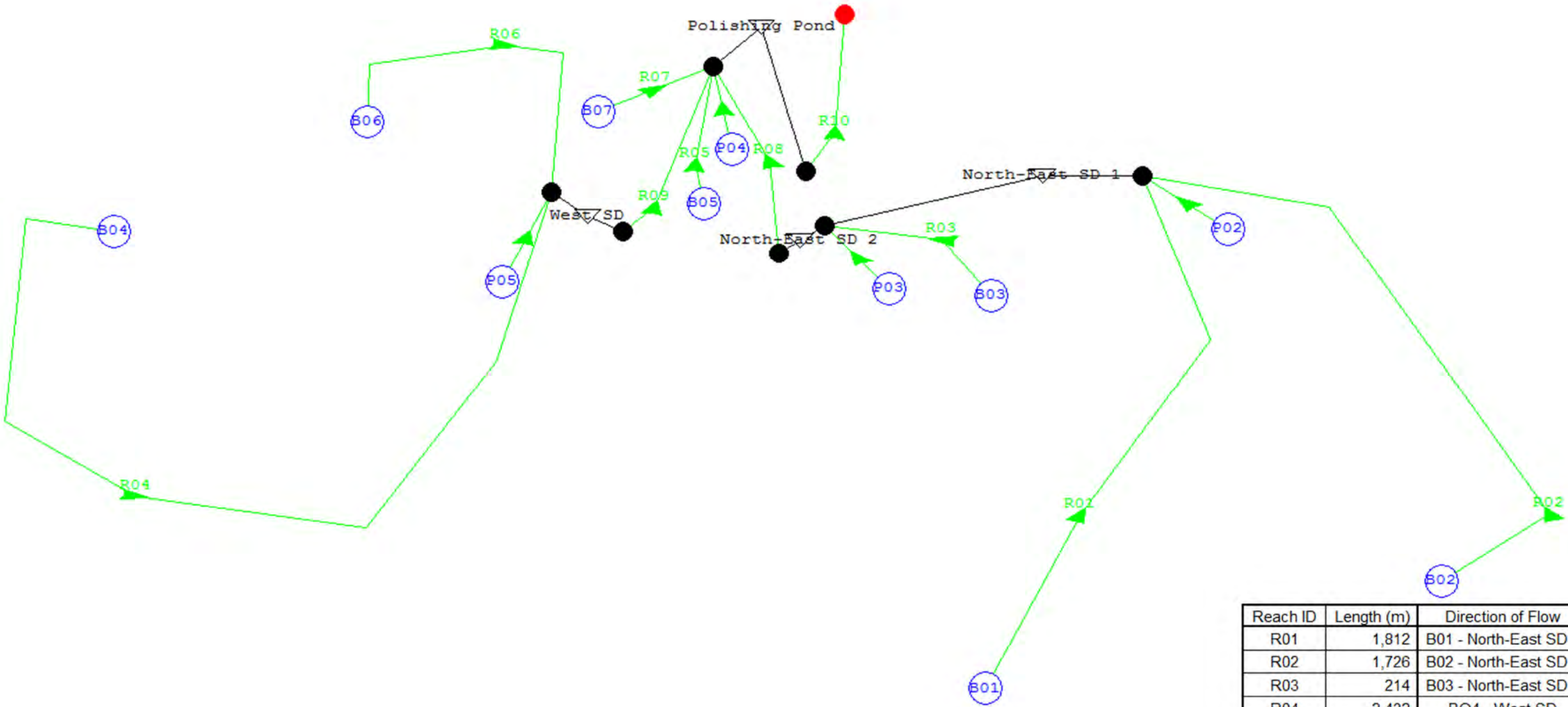
Knight Piésold CONSULTING

NOLANS PROJECT
SURFACE WATER MANAGEMENT
PIT DIVERSION RORB MODEL

PE801-00140/13
Figure 4.4



Reach ID	Length (m)	Direction of Flow
R01	2,788	B01 - J6
R02	1,916	B02 - J5
R03	750	B03 - J6
R04	3,065	BO4 - J3
R05	302	B05 - South SD
R06	1,812	B06 - North-East SD 1
R07	1,726	B07 - North-East SD 1
R08	547	B08 - J2
R09	214	B09 - North-East SD 2
R10	1,110	B10 - Polishing Pond
R11	1,879	J6 - J4
R12	166	South SD - J5
R13	142	J5 - J4
R14	256	J4 - J3
R15	604	J3 - J2
R16	1,492	J2 - J1
R17	104	J1 - Polishing Pond
R18	667	Polishing Pond - End



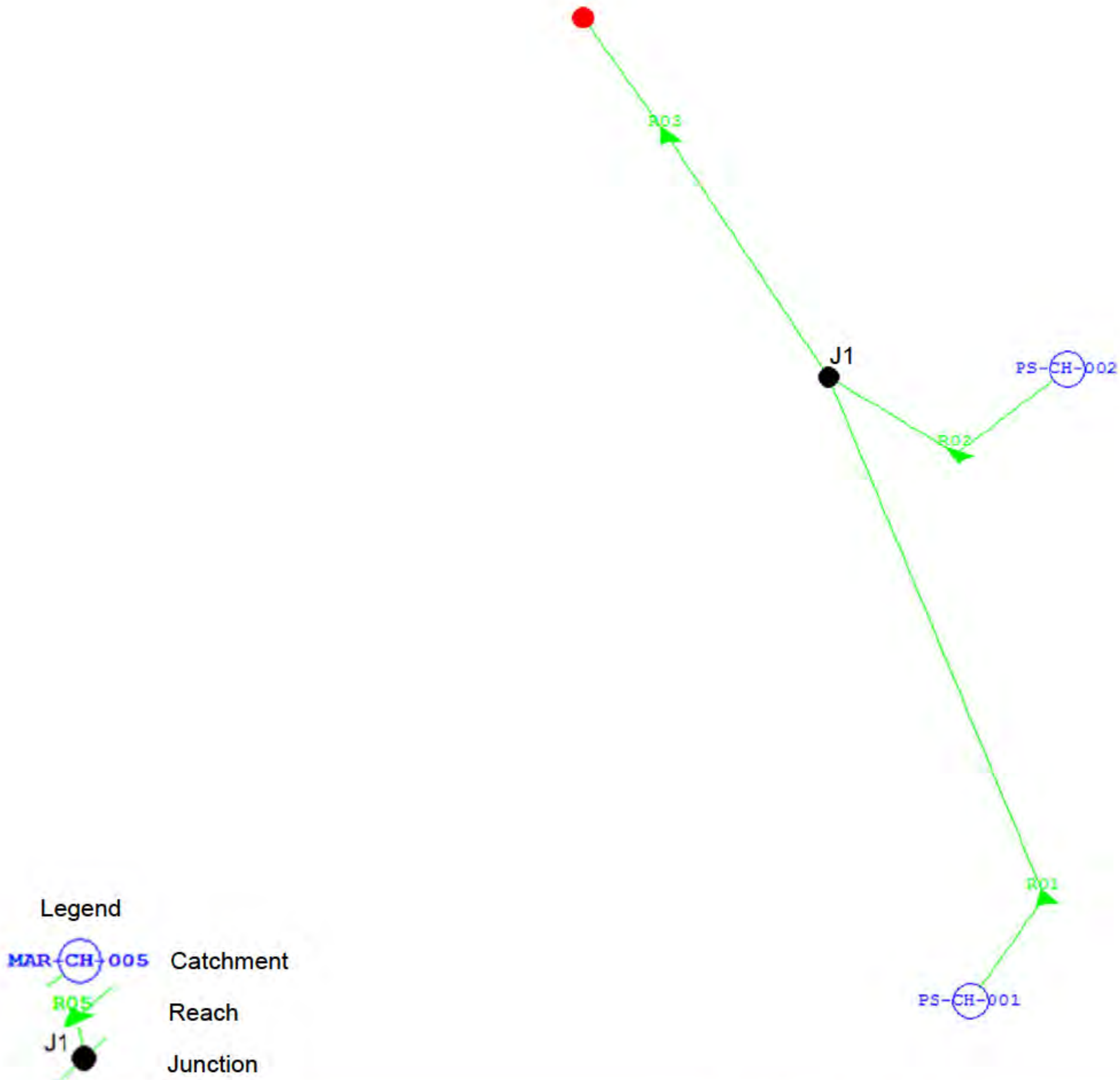
Reach ID	Length (m)	Direction of Flow
R01	1,812	B01 - North-East SD 1
R02	1,726	B02 - North-East SD 1
R03	214	B03 - North-East SD 2
R04	2,432	BO4 - West SD
R05	140	B05 - Polishing Pond
R06	777	B06 - West SD
R07	220	B07 - Polishing Pond
R08	104	North-East SD 2 - Polishing Pond
R09	153	West SD - Polishing Pond
R10	667	Polishing Pond - End

Legend

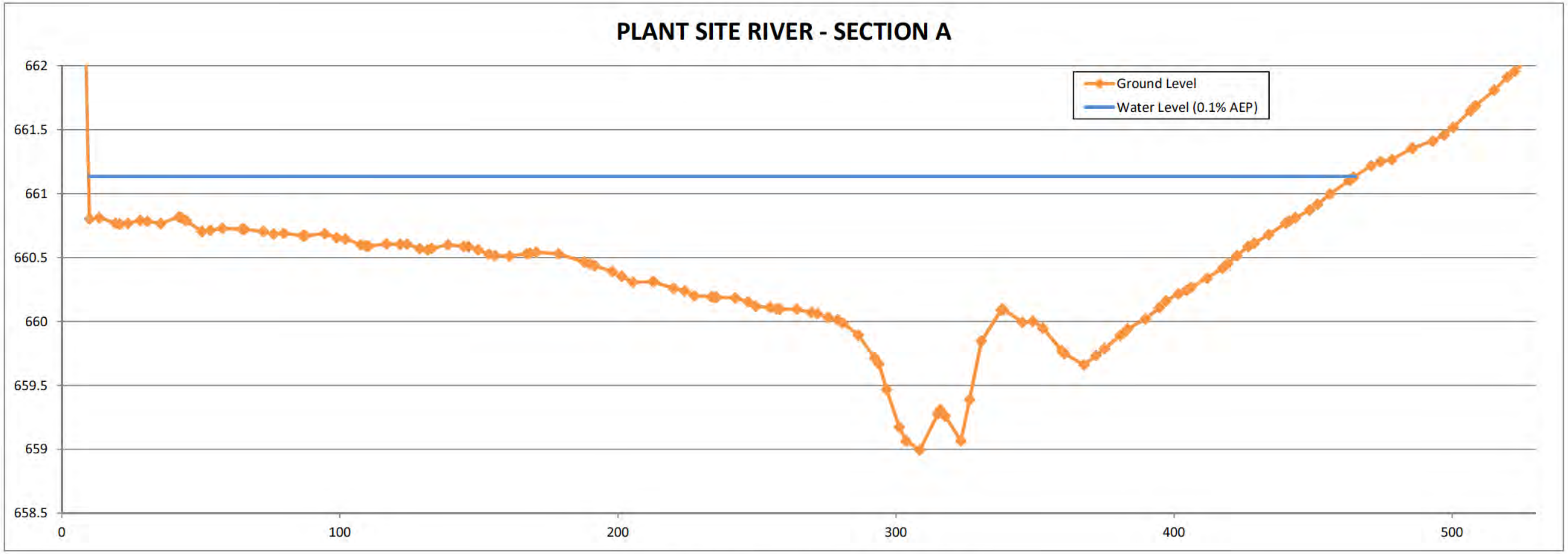
MAR-CH-005 Catchment

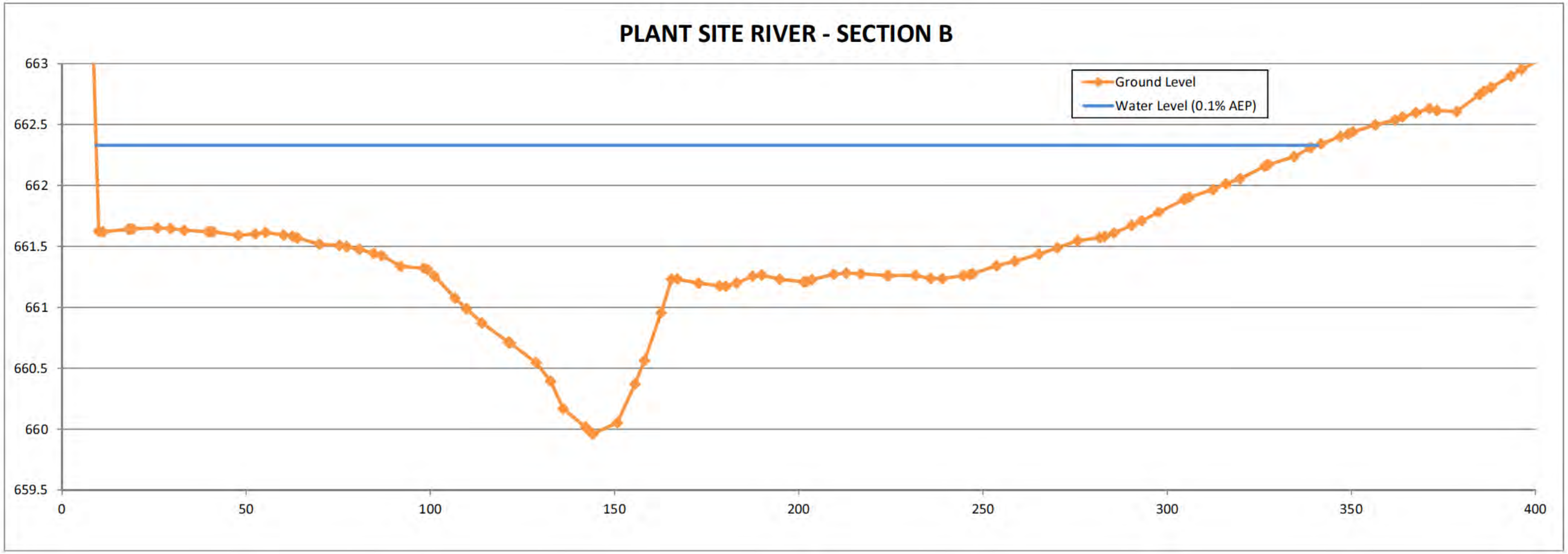
R05 Reach

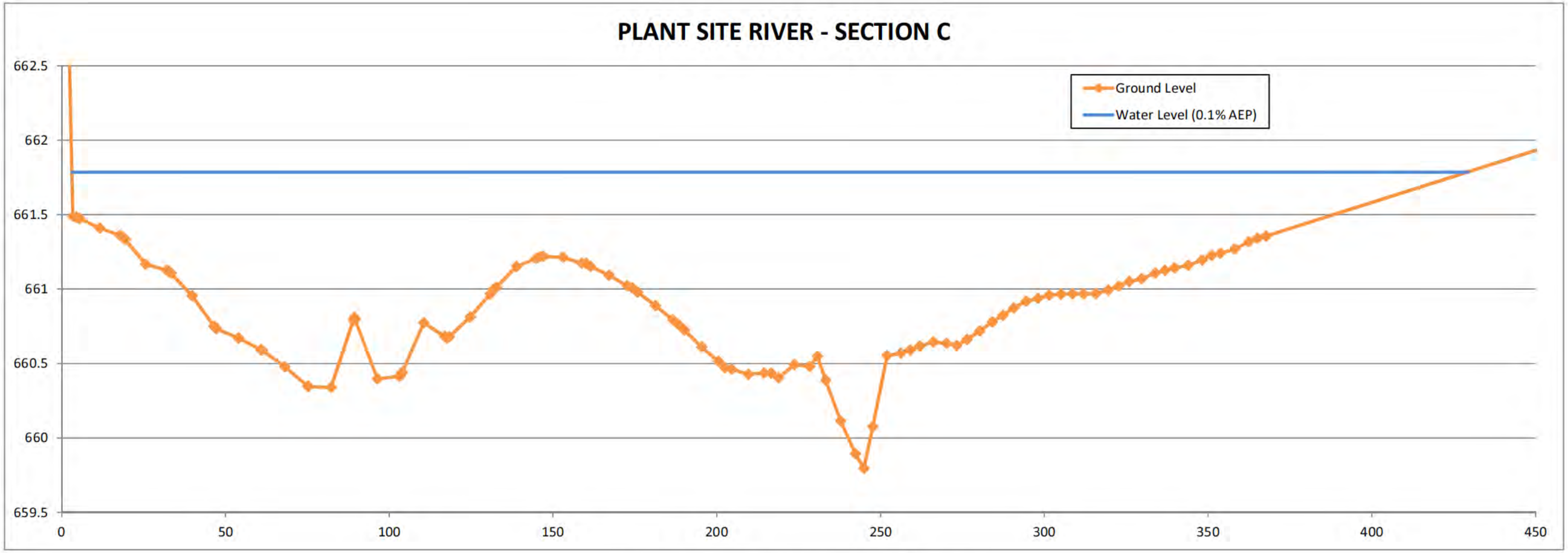
J1 Junction

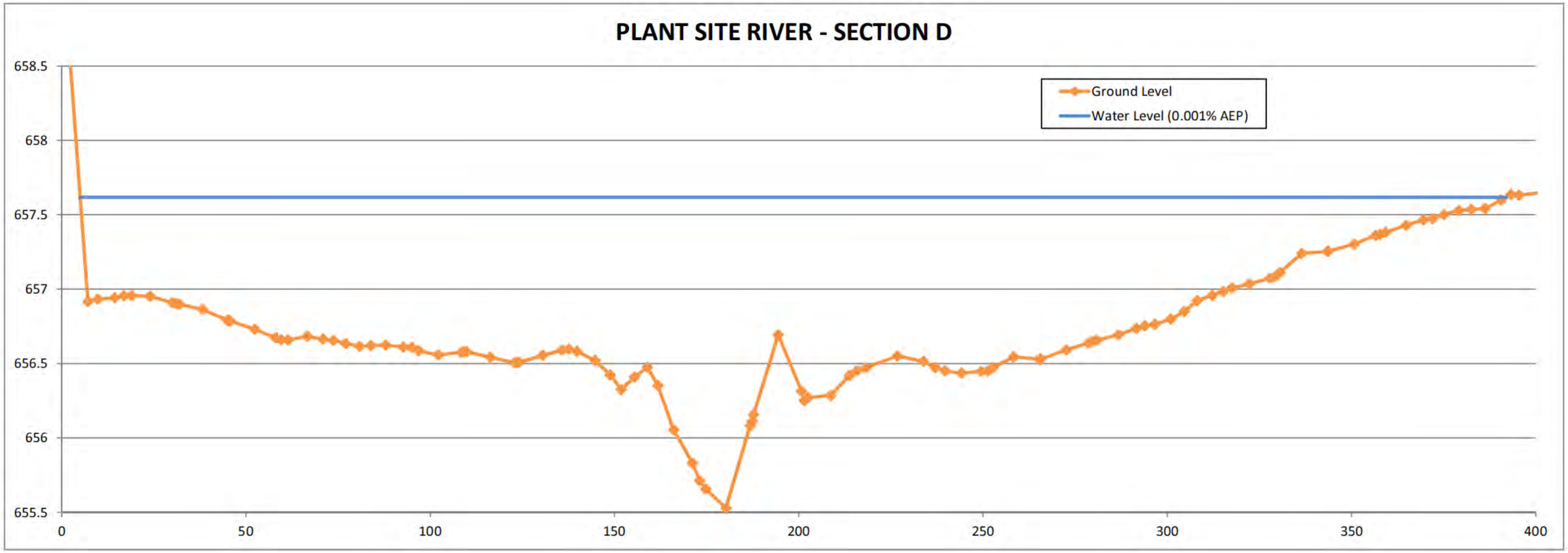


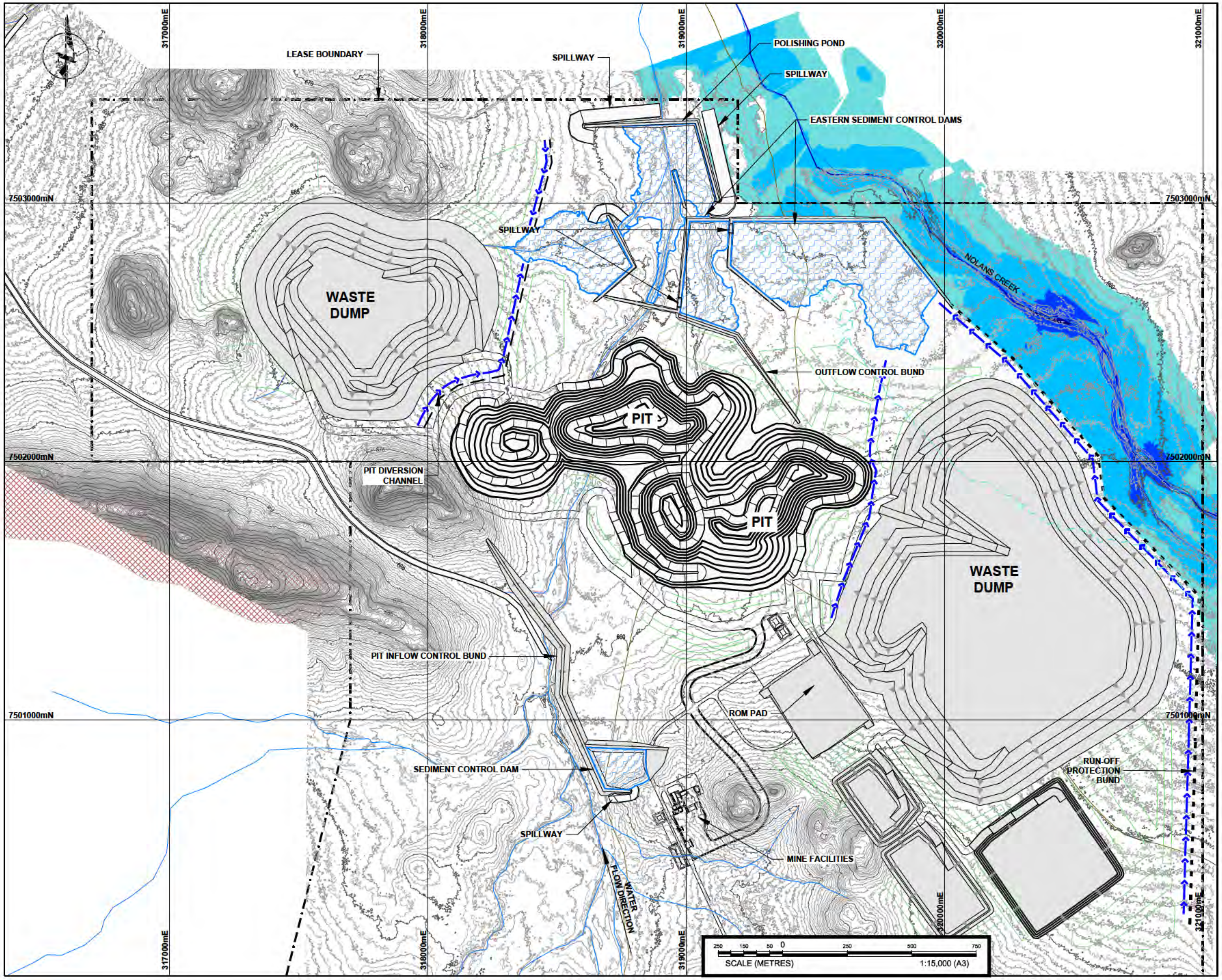
Reach ID	Length (m)	Direction of Flow
R01	5,686	PS-CH-001 - J1
R02	2,013	PS-CH-002 - J1
R03	2,998	J1 - End


PLANT SITE RIVER - SECTION A
Ground Level
Water Level (0.1% AEP)
662
661.5
661
660.5
660
659.5
659
658.5
0
100
200
300
400
500


PLANT SITE RIVER - SECTION B
Ground Level
Water Level (0.1% AEP)
663
662.5
662
661.5
661
660.5
660
659.5
0
50
100
150
200
250
300
350
400


PLANT SITE RIVER - SECTION C
Ground Level
Water Level (0.1% AEP)
662.5
662
661.5
661
660.5
660
659.5
0
50
100
150
200
250
300
350
400
450


PLANT SITE RIVER - SECTION D
Ground Level
Water Level (0.001% AEP)
658.5
658
657.5
657
656.5
656
655.5
0
50
100
150
200
250
300
350
400



NOTES:

1. 1m CONTOUR NTERVALS SHOWN. TOPOGRAPHY PROVIDED BY ARAFURA, JUNE 2018.
2. YEAR 8 PIT LAYOUT SHOWN.

LEGEND:

- EXISTING WATER COURSE
- EXCLUSION ZONE - LIMITED WORK
- POND EXTENTS
- LEASE BOUNDARY
- FLOOD PROTECTION BUND
- DIVERSION DRAIN
- RUN-OFF PROTECTION BUND
- 0m -1m INUNDATION
- 1m -2m NUNDATION
- 2m -3m INUNDATION
- 3m -4m INUNDATION
- INUNDATION EXTENTS

Knight Piésold CONSULTING

NOLANS PROJECT
SURFACE WATER MANAGEMENT
SITE GENERAL ARRANGEMENT

Ref: PE801-00140/13
Figure 4.10

DRAWINGS

NOLANS PROJECT

MINE AREA
SURFACE WATER MANAGEMENT

ISSUED FOR REVIEW
NOVEMBER, 2018

Prepared for:

ARAFURA RESOURCES LIMITED

ARAFURA
RESOURCES LIMITED

Prepared by:

Knight Piésold CONSULTING

A.B.N. 67 001 040 419
A.C.N. 001 040 419

Knight Piésold Pty. Ltd.
Level 1, 184 Adelaide Terrace
EAST PERTH, WA 6004
AUSTRALIA

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

DRAWING No.	DRAWING TITLE

SHEET SIZE A3 — REFERENCES — REVISIONS

ORIGINAL STAMPED IN RED

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

Knight Piésold CONSULTING — CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES LIMITED
NOLANS PROJECT
MINE AREA SURFACE WATER MANAGEMENT
TITLE PAGE

SCALE N.T.S.
STATUS: IFR
DRAWING NUMBER: **801-140-A5001-001**
REV: **A**

287 410

ABBREVIATIONS

C.M.	CONSTRUCTION MANAGER
N.T.S.	NOT TO SCALE
APPROX. ≈	APPROXIMATELY
BOP	BOTTOM OF P PE
℄	CENTRELINE
CPT	CORRUGATED POLYETHYLENE TUBING
DIA. Ø	DIAMETER
ELEV	ELEVATION
HDPE	HIGH DENSITY POLYETHYLENE
D	NSIDE DIAMETER
L	NVERT LEVEL
LLDPE	LINEAR LOW DENSITY POLYETHYLENE
MH	MANHOLE
MAX	MAX MUM
M N	M N MUM
MMDD	MAX MUM MODIFIED DRY DENSITY
NOM	NOMINAL
OD	OUTSIDE DIAMETER
OMC	OPTIMUM MOISTURE CONTENT
PC	POINT OF CURVATURE
PI	POINT OF INTERSECTION
PT	POINT OF TANGENT
PVC	POLYV NYL CHLORIDE
RC	REINFORCED CONCRETE
RCP	REINFORCED CONCRETE P PE
REQ'D	REQUIRED
R.L.	REDUCED LEVEL
SDR	STANDARD D MENSIONAL RATIO
SCH	SCHEDULE
SMDD	STANDARD MAXIMUM DRY DENSITY
SOL	SETTING OUT L NE
SOP	SETTING OUT POINT
IWL	NTEGRATED WASTE LANDFORM
TYP	TYPICAL

INDEX OF DRAWINGS

COMMON LEGEND

EXIST NG GROUND SURFACE OR BOTTOM OF EXCAVATION

260 EXIST NG GROUND CONTOUR AND ELEVATION (IN METRES)

SLOPE INDICATOR

H:V SLOPE INDICATOR (HORIZONTAL TO VERTICAL)

SECTION OR DETA L NUMBER

1/100 A/100

DRAW NG NO. WHERE SECTION IS SHOWN OR CALLED OUT (INTERNAL SHEET REFERENCE ONLY)

SECTION OR DETAIL NUMBER

801-140-A5001- 1/100 A/100

FULL DRAW NG NO. REFERENCE FOR EXTERNAL SHEETS

GENERAL NOTES

1. ALL DIMENSIONS IN M LLIMETRES UNLESS OTHERWISE NOTED.
2. ALL COORDINATES STATED N GRID PROJECTION: MGA94 ZONE 53
3. ALL ELEVATIONS IN METRES, RELATIVE TO MEAN SEA LEVEL.
4. DRAWINGS ARE NOT TO BE SCALED.
5. DRAWINGS TO BE READ IN CONJUNCTION WITH THE TECHNICAL SPECIFICATIONS.

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

REFERENCES: DRAWING No. | DRAWING TITLE

SHEET SIZE A3

REVISIONS

ORIGINAL STAMPED IN RED

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

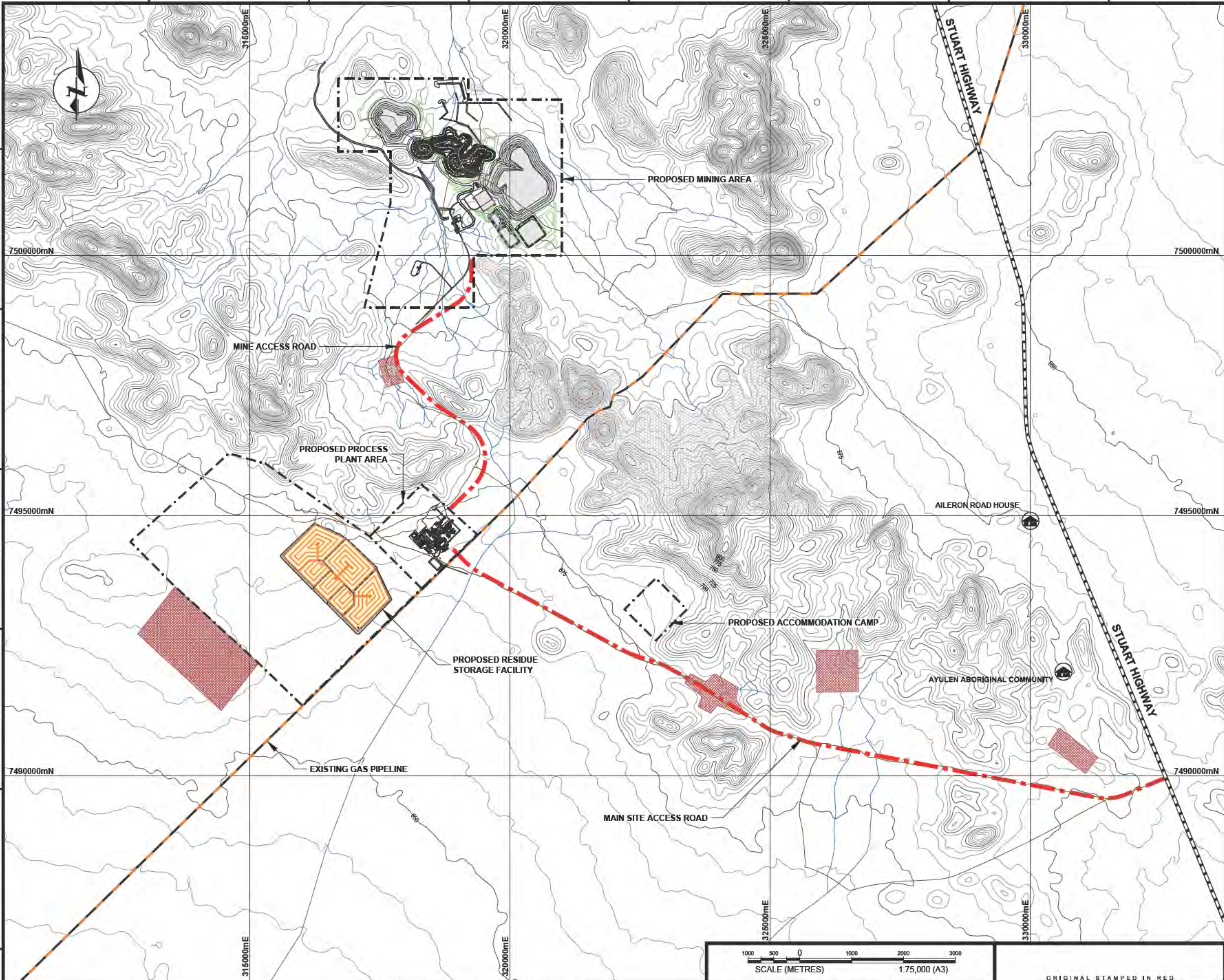
Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
INDEX, COMMON LEGEND AND ABBREVIATIONS

SCALE N.T.S.
STATUS: IFR
DRAWING NUMBER 801-140-A5001-002
REV A

287 410



LEGEND:

- L MITED WORK EXCLUSION ZONE
- OFF LIMITS EXCLUSION ZONE
- TOPSO L STOCKP LE
- EXIST NG DRAINAGE COURSE
- EXIST NG GAS PIPEL NE
- EXIST NG HIGHWAY
- EXIST NG ROAD (SEALED)
- EXIST NG ROAD (UNSEALED)
- LEASE BOUNDARY
- SITE ROAD ALIGNMENT

NOTES:

1. 5m CONTOUR INTERVALS SHOWN.TOPOGRAPHIC NFORMATION DERIVED FROM 1 SECOND SRTM DATA, OBTAINED FROM GEOSC ENCE AUSTRALIA, (2011).
2. YEAR 24 PIT LAYOUT SHOWN.
3. STAGE 2 SURFACE WATER MANAGEMENT STRUCTURES SHOWN.

SCALE (METRES) 1:75,000 (A3)

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

REFERENCES

DRAWING No.	DRAWING TITLE

SHEET SIZE A3

ORIGINAL STAMPED IN RED

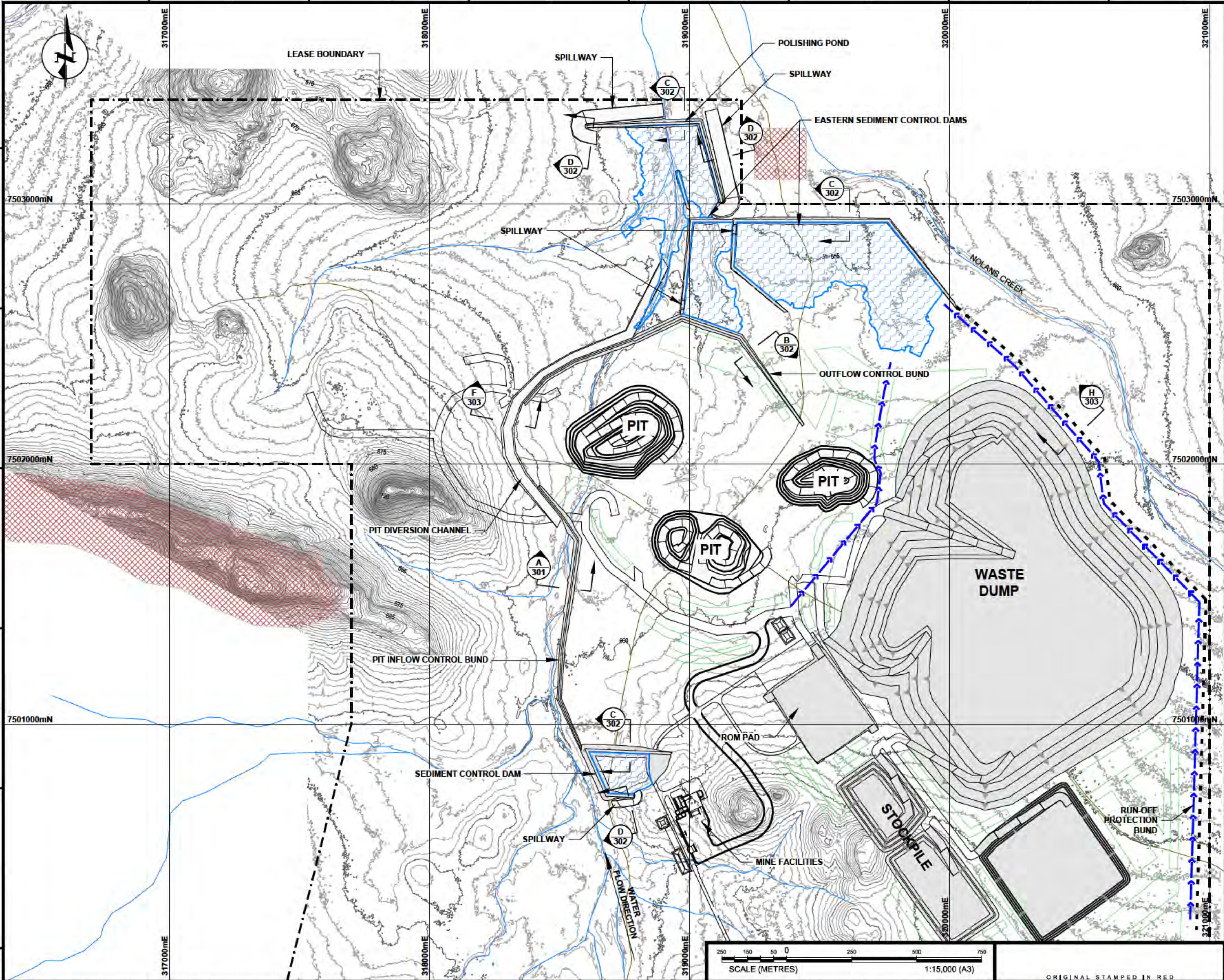
DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
SITE GENERAL ARRANGEMENT

SCALE 1:75,000
STATUS: IFR
DRAWING NUMBER: 801-140-A5001-050
REV: A



LEGEND:

- EXISTING WATER COURSE
- EXCLUSION ZONE - LIMITED WORK
- POND EXTENTS
- TOPSOIL STOCKPILE
- LEASE BOUNDARY
- FLOOD PROTECTION BUND
- DIVERSION DRAIN
- RUN-OFF PROTECTION BUND

NOTES:

1. 1m CONTOUR NTERVALS SHOWN. TOPOGRAPHY PROVIDED BY ARAFURA, JUNE 2018.
2. YEAR 8 PIT LAYOUT SHOWN.

REFERENCES

DRAWING No.	DRAWING TITLE
801-140-A5001-301	TYPICAL SECTIONS AND DETAILS - SHEET 1
801-140-A5001-302	TYPICAL SECTIONS AND DETAILS - SHEET 2
801-140-A5001-303	TYPICAL SECTIONS AND DETAILS - SHEET 3

REVISIONS

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

SHEET SIZE A3

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

ORIGINAL STAMPED IN RED

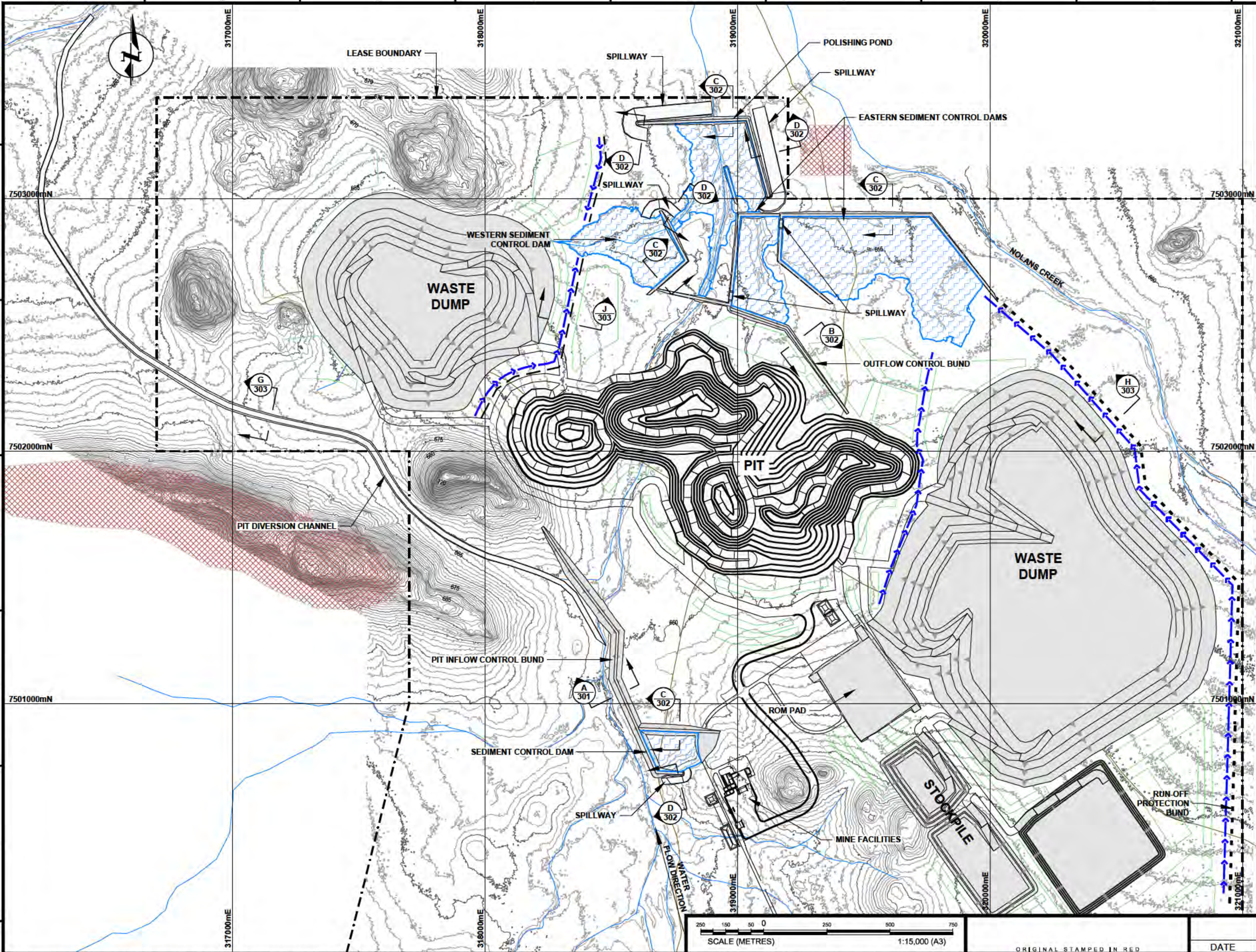
Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
GENERAL ARRANGEMENT - STAGE 1

SCALE 1:15,000
STATUS: IFR

DRAWING NUMBER	REV
801-140-A5001-101	A



LEGEND:

- EXISTING WATER COURSE
- EXCLUSION ZONE - LIMITED WORK
- POND EXTENTS
- TOPSOIL STOCKPILE
- LEASE BOUNDARY
- FLOOD PROTECTION BUND
- DIVERSION DRAIN
- RUN-OFF PROTECTION BUND

NOTES:

1. 1m CONTOUR NTERVALS SHOWN. TOPOGRAPHY PROVIDED BY ARAFURA, JUNE 2018.
2. YEAR 24 PIT LAYOUT SHOWN.

REFERENCES

DRAWING No.	DRAWING TITLE
801-140-A5001-301	TYPICAL SECTIONS AND DETAILS - SHEET 1
801-140-A5001-302	TYPICAL SECTIONS AND DETAILS - SHEET 2
801-140-A5001-303	TYPICAL SECTIONS AND DETAILS - SHEET 3

REVISIONS

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

SHEET SIZE A3

ORIGINAL STAMPED IN RED

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
GENERAL ARRANGEMENT - STAGE 2

SCALE 1:15,000
STATUS: IFR
DRAWING NUMBER: 801-140-A5001-102
REV: A

TABLE 1:
ZONE SPECIFICATIONS SUMMARY

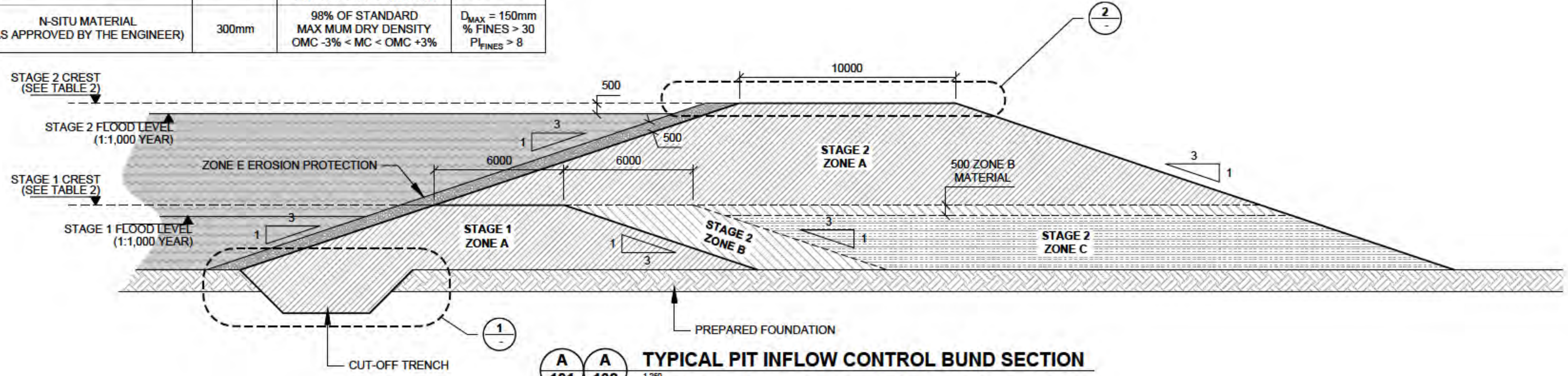
ZONE KEY	ZONE TYPE	DESCRIPTION	MAXIMUM LAYER THICKNESS	COMPACTION SPECIFICATION	GRADING
	ZONE A	LOW PERMEABILITY FILL	300mm	98% OF STANDARD MAX MUM DRY DENSITY OMC -2% < MC < OMC +3%	D_{MAX} = 150mm % FINES > 30 PI_{FINES} > 8
	ZONE B	TRANSITION MATERIAL	300mm	98% OF STANDARD MAX MUM DRY DENSITY OMC -3% < MC < OMC +3%	D_{MAX} = 300mm
	ZONE C	STRUCTURAL F LL	500mm	TRAFFIC COMPACTED 95% OF STANDARD MAX MUM DRY DENSITY OMC -2% < MC < OMC +3%	D_{MAX} = 300mm
	ZONE C1	STRUCTURAL F LL (NAF MINE WASTE)	1000-2000mm	TRAFFIC COMPACTED 95% OF STANDARD MAX MUM DRY DENSITY OMC -2% < MC < OMC +3%	D_{MAX} = 600mm
	ZONE C2	STRUCTURAL F LL (NAF MINE WASTE)	1000-2000mm	TAMPED WITH EXCAVATOR BUCKET	D_{MAX} = 300mm % F NES < 5
	ZONE D	APPROVED GENERAL FILL	700mm	92% OF STANDARD MAX MUM DRY DENSITY OMC -3% < MC < OMC +3%	N/A
	ZONE E	EROSION PROTECTION (CLEAN ROCKFILL)	300mm	TAMPED WITH EXCAVATOR BUCKET	D_{MAX} = 300mm % F NES < 5
	WEARING COURSE	LATERITE GRAVEL	150mm	98% OF STANDARD MAX MUM DRY DENSITY OMC -0% < MC < OMC +3%	D_{MAX} = 37.5mm % FINES < 5-15
	EMBANKMENT FOUNDATION	N-SITU MATERIAL (AS APPROVED BY THE ENGINEER)	300mm	98% OF STANDARD MAX MUM DRY DENSITY OMC -3% < MC < OMC +3%	D_{MAX} = 150mm % FINES > 30 PI_{FINES} > 8

TABLE 2:
EMBANKMENT AND SPILLWAY DETAILS

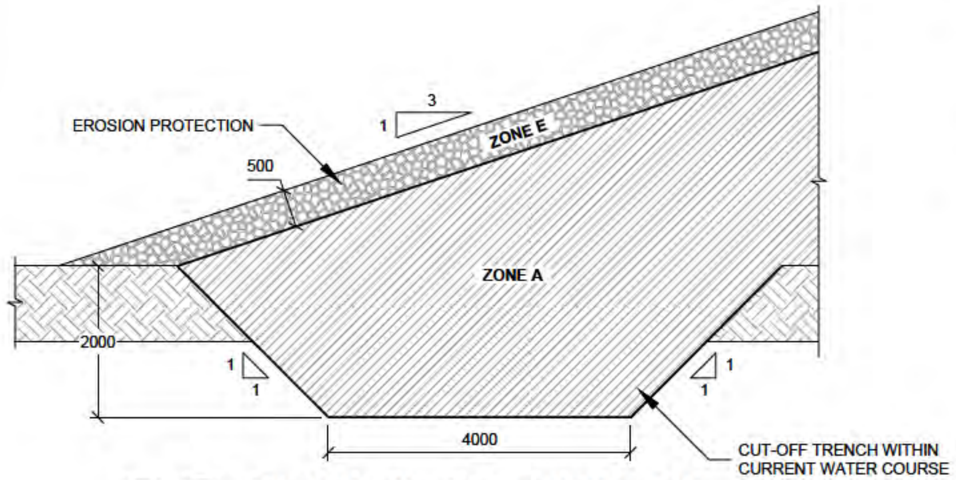
ITEM	STAGE	EMBANKMENT CREST LEVEL (m R.L.)	SPILLWAY INLET LEVEL (m R.L.)	SPILLWAY DEPTH (m) 'D'	SPILLWAY WIDTH (m) 'W'
NORTH-EASTERN SEDIMENT DAM No.1	1	657.0	656 5	0.5	30
NORTH-EASTERN SEDIMENT DAM No 2		656.0	655 5	0.5	30
SOUTHERN SEDIMENT DAM		667.0	666 5	0.5	25
POLISH NG POND		655 5	654 0	1.5	50
			655 0	0.5	50
OUTFLOW CONTROL BUND		658 5	-	-	-
PIT NFLOW CONTROL BUND		662.3	-	-	-
	2	667.0	-	-	-
WESTERN SED MENT POND		656 5	656 0	0.5	35

NOTES:

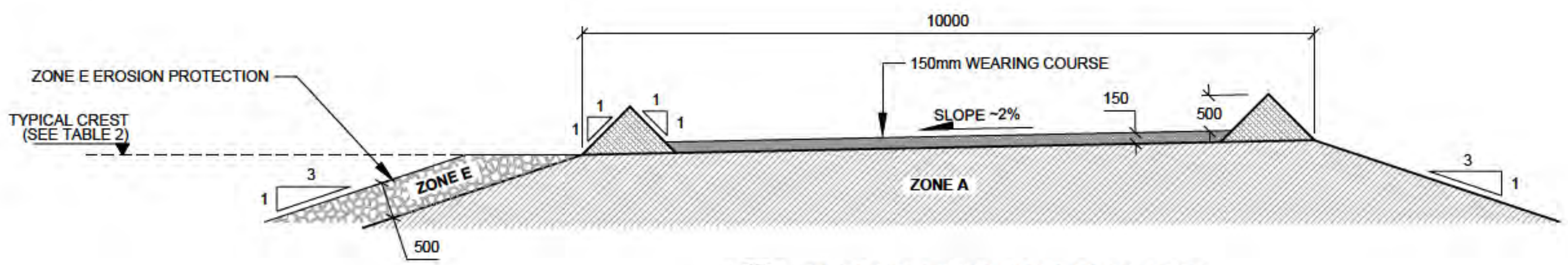
1. CUT-OFF TRENCH TO BE EXCAVATED TO 1 0m (MIN.) DEPTH INTO COMPETENT LOW PERMEAB LITY FOUNDATION MATERIAL.
2. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
3. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
4. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
5. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
6. SAFETY BUND MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. SAFETY BUNDS ARE TO BE INSTALLED (500mm HIGH M N.) WITH BREAKS IN UPSTREAM SAFETY BUNDS AT 50m INTERVALS TO ALLOW FOR DRA NAGE OF RAINFALL RUNOFF.



A 101 A 102 **TYPICAL PIT INFLOW CONTROL BUND SECTION** 1 250



1 - 1 302 **TYPICAL CUT-OFF TRENCH DETAIL** 1 100



2 - **TYPICAL EMBANKMENT CREST** 1 100

REFERENCES DRAWING No.	DRAWING TITLE
801-140-A5001-101	STAGE 1 GENERAL ARRANGEMENT
801-140-A5001-102	STAGE 2 GENERAL ARRANGEMENT
801-140-A5001-302	TYPICAL SECTIONS AND DETAILS - SHEET 2

REVISIONS

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

SHEET SIZE A3

ORIGINAL STAMPED IN RED

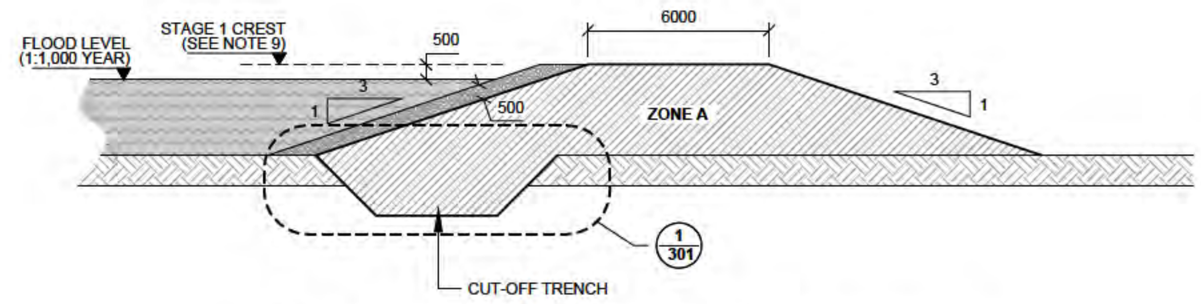
DATE | DESIGNED | CHECKED | APPROVED | CLIENT APP'D

Knight Piésold CONSULTING

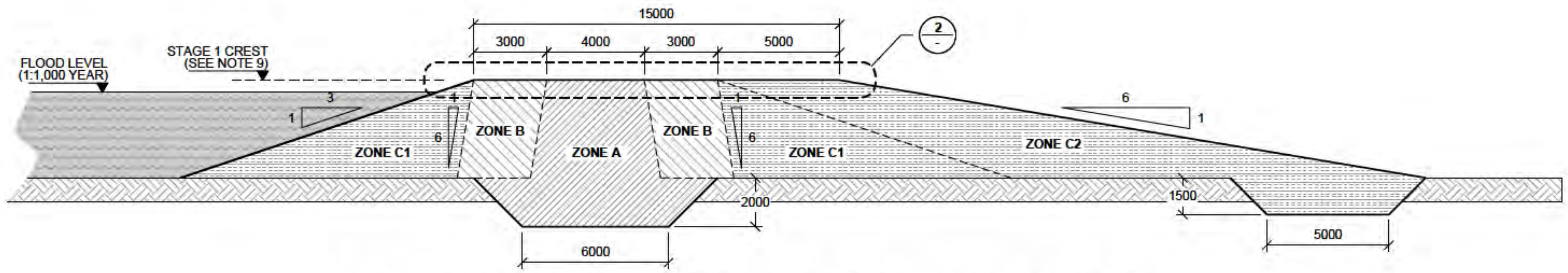
CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
TYPICAL SECTIONS AND DETAILS - SHEET 1

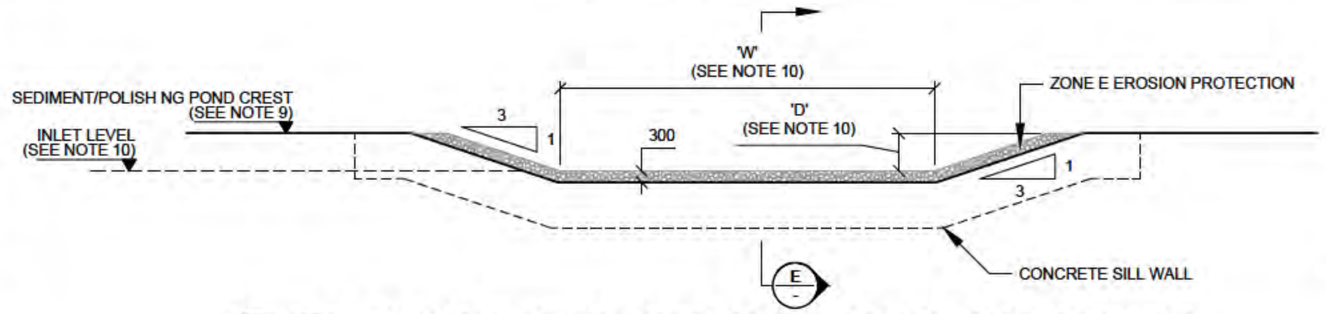
SCALE AS SHOWN
STATUS: IFR
DRAWING NUMBER 801-140-A5001-301
REV A



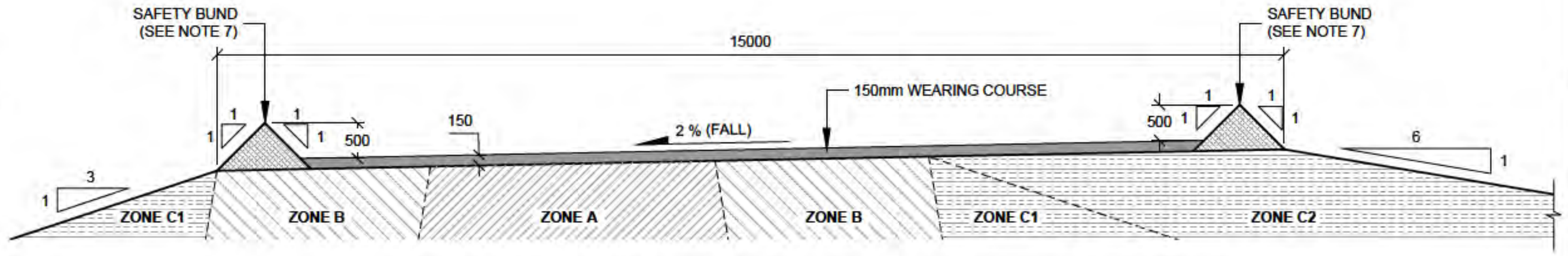
B 101 B 102 **TYPICAL OUTFLOW CONTROL BUND SECTION**
1:250



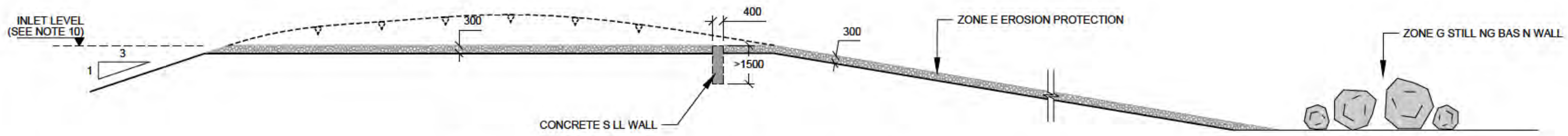
C 101 C 102 **TYPICAL SEDIMENT AND POLISHING POND EMBANKMENT SECTION**
1:250



D 101 D 102 **TYPICAL SEDIMENT AND POLISHING POND SPILLWAY SECTION**
1:200



2 - **TYPICAL SEDIMENT AND POLISHING POND EMBANKMENT CREST DETAIL**
1:100



E - **TYPICAL SEDIMENT AND POLISHING POND SPILLWAY SECTION**
1:200

NOTES:

1. CUT-OFF TRENCH TO BE EXCAVATED TO 1.0m (MIN.) DEPTH INTO COMPETENT LOW PERMEABILITY FOUNDATION MATERIAL.
2. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
3. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
4. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
5. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
6. SAFETY BUND MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. SAFETY BUNDS ARE TO BE INSTALLED (500mm HIGH MIN.) WITH BREAKS IN UPSTREAM SAFETY BUNDS AT 50m INTERVALS TO ALLOW FOR DRAINAGE OF RAINFALL RUNOFF.
8. FOR EMBANKMENT ZONE SPECIFICATIONS REFER TABLE 1 ON DRAWING 801-140-A5001-301.
9. FOR EMBANKMENT CREST LEVELS REFER TABLE 2 ON DRAWING 801-140-A5001-301.
10. FOR SPILLWAY DETAILS REFER TABLE 2 ON DRAWING 801-140-A5001-301.

REFERENCES

DRAWING No.	DRAWING TITLE
801-140-A5001-101	STAGE 1 GENERAL ARRANGEMENT
801-140-A5001-102	STAGE 2 GENERAL ARRANGEMENT
801-140-A5001-301	TYPICAL SECTIONS AND DETAILS - SHEET 1

REVISIONS

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

SHEET SIZE A3

ORIGINAL STAMPED IN RED

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

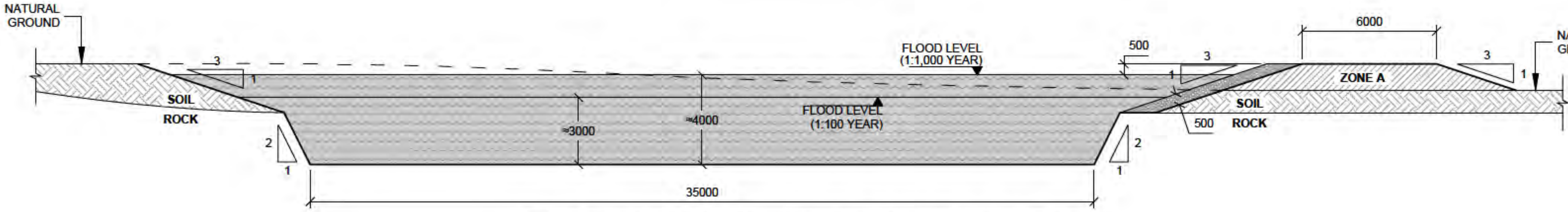
Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

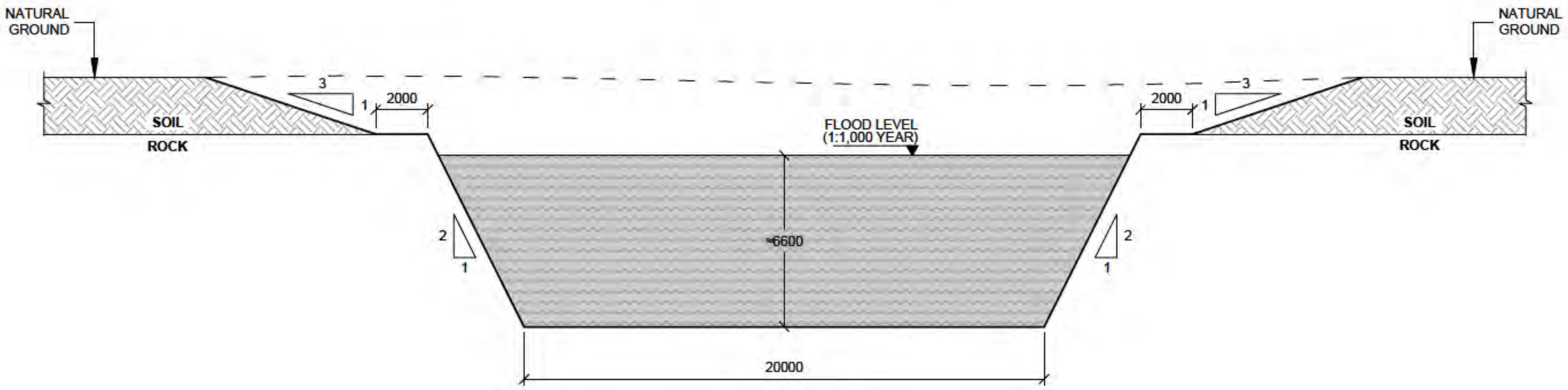
ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
TYPICAL SECTIONS AND DETAILS - SHEET 2

SCALE AS SHOWN
STATUS: IFR
DRAWING NUMBER 801-140-A5001-302
REV A

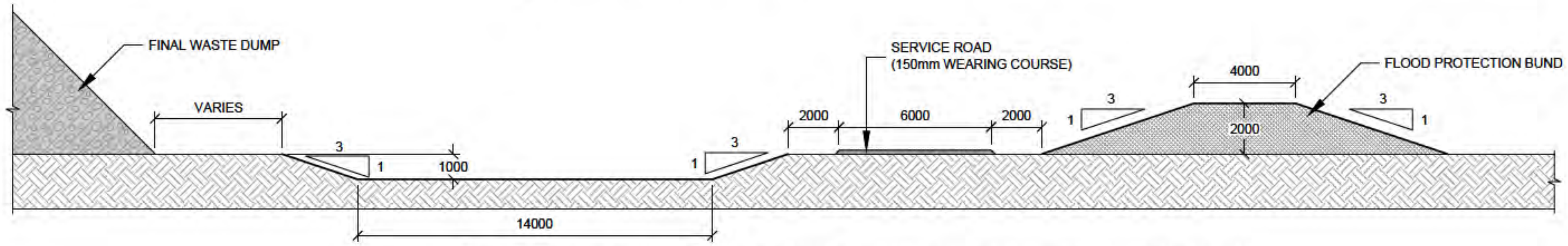
287 410



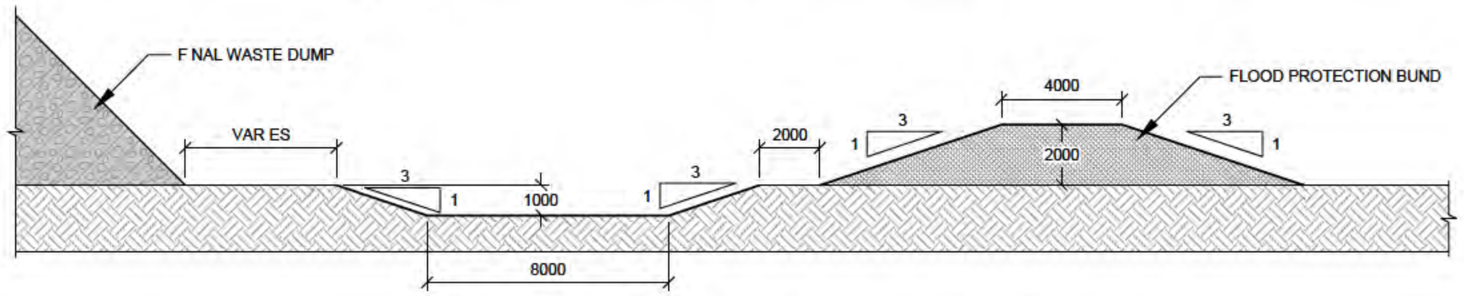
F/101 TYPICAL STAGE 1 DIVERSION CHANNEL SECTION
1:250



G/102 TYPICAL STAGE 2 DIVERSION CHANNEL SECTION
1:250



H/101 H/102 TYPICAL STAGE 1 WASTE DUMP RUN-OFF DIVERSION SECTION
1:250



J/102 TYPICAL STAGE 2 WASTE DUMP RUN-OFF DIVERSION SECTION
1:250

NOTES:

1. CUT-OFF TRENCH TO BE EXCAVATED TO 1.0m (MIN.) DEPTH INTO COMPETENT LOW PERMEAB LITY FOUNDATION MATERIAL.
2. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
3. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
4. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
5. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
6. SAFETY BUND MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. SAFETY BUNDS ARE TO BE INSTALLED (500mm HIGH M N.) WITH BREAKS IN UPSTREAM SAFETY BUNDS AT 50m INTERVALS TO ALLOW FOR DRA NAGE OF RAINFALL RUNOFF.
8. FOR EMBANKMENT ZONE SPECIFICATIONS REFER TABLE 1 ON DRAWING 801-140-A5001-301.

REFERENCES

DRAWING No.	DRAWING TITLE
801-140-A5001-101	STAGE 1 GENERAL ARRANGEMENT
801-140-A5001-102	STAGE 2 GENERAL ARRANGEMENT
801-140-A5001-301	TYPICAL SECTIONS AND DETAILS - SHEET 1

REVISIONS

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

SHEET SIZE A3

ORIGINAL STAMPED IN RED

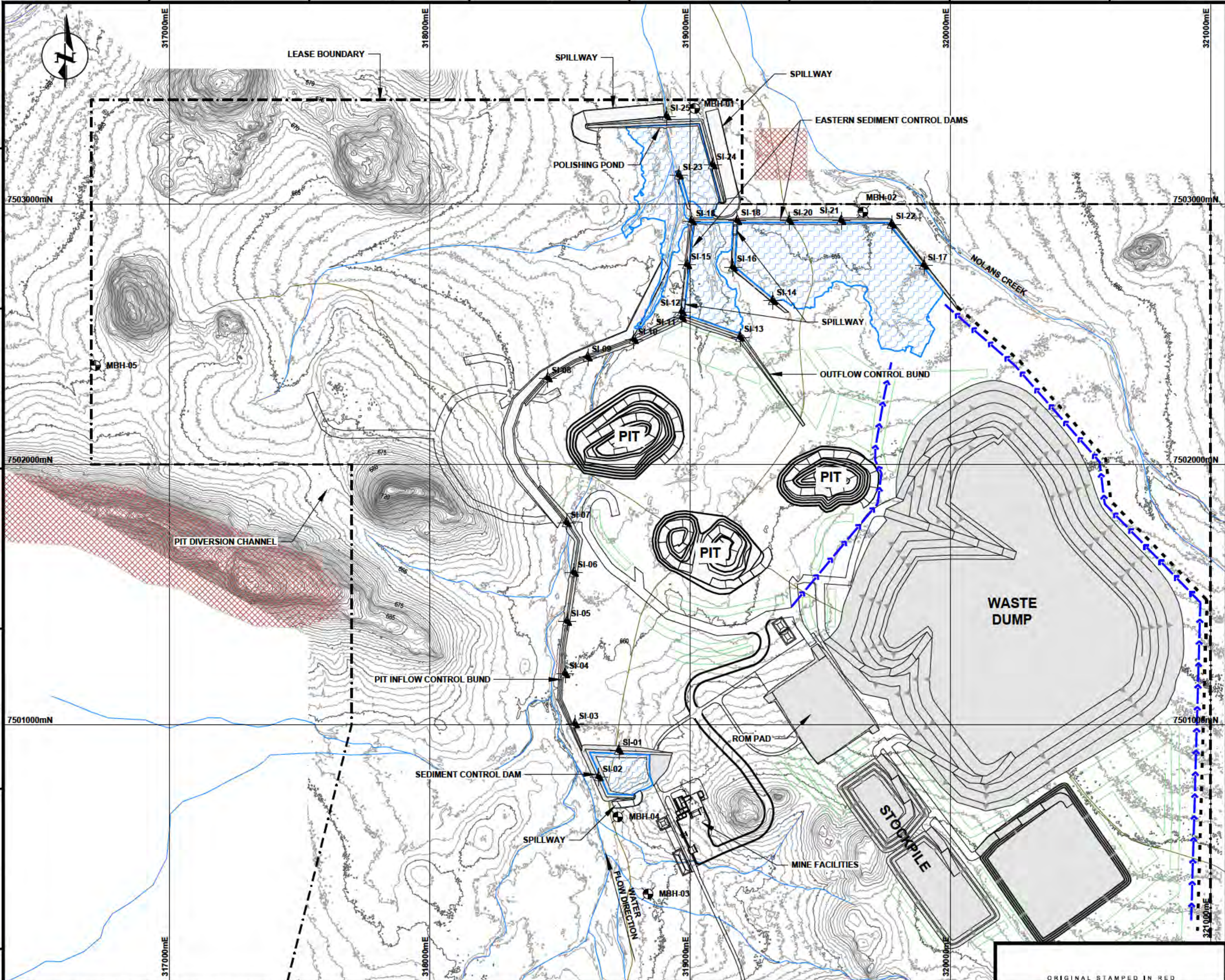
DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
TYPICAL SECTIONS AND DETAILS - SHEET 3

SCALE AS SHOWN
STATUS: IFR
DRAWING NUMBER: 801-140-A5001-303
REV: A



LEGEND:

- EXISTING WATER COURSE
- EXCLUSION ZONE - LIMITED WORK
- POND EXTENTS
- TOPSOIL STOCKPILE
- LEASE BOUNDARY
- FLOOD PROTECTION BUND
- DIVERSION DRAIN
- MONITORING BORE LOCATION
- PIEZOMETER AND SETTLEMENT PIN LOCATION

NOTES:

1. 1m CONTOUR NTERVALS SHOWN. TOPOGRAPHY PROVIDED BY ARAFURA, JUNE 2018.
2. YEAR 24 PIT LAYOUT SHOWN.

[redacted]

[redacted]

250 150 50 0 250 500 750

SCALE (METRES) 1:15,000 (A3)

DRAWING No.	DRAWING TITLE
801-140-A5001-910	MONITORING INSTRUMENTATION DETAILS

REFERENCES

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

REVISIONS

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

ORIGINAL STAMPED IN RED

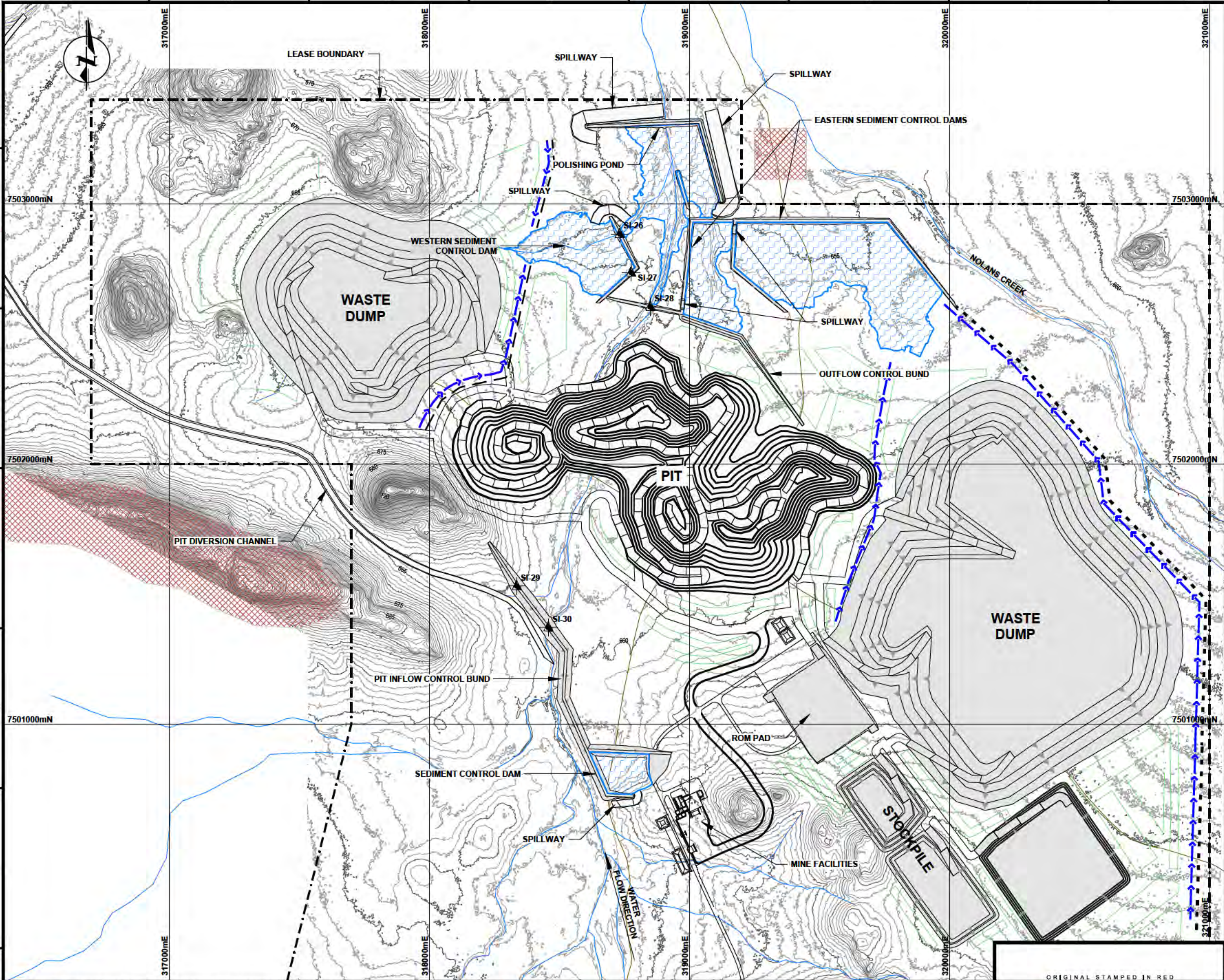
Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
MONITORING INSTRUMENTATION LAYOUT - STAGE 1

SCALE 1:15,000
STATUS: IFR
DRAWING NUMBER 801-140-A5001-900
REV A

SHEET SIZE A3



LEGEND:

- EXISTING WATER COURSE
- EXCLUSION ZONE - LIMITED WORK
- POND EXTENTS
- TOPSOIL STOCKPILE
- LEASE BOUNDARY
- FLOOD PROTECTION BUND
- DIVERSION DRAIN
- PIEZOMETER AND SETTLEMENT PIN LOCATION

NOTES:

1. 1m CONTOUR NTERVALS SHOWN. TOPOGRAPHY PROVIDED BY ARAFURA, JUNE 2018.
2. YEAR 24 PIT LAYOUT SHOWN.

SETTLEMENT PIN AND PIEZOMETER [redacted]

POINT	[redacted]	[redacted]
SI-26	[redacted]	[redacted]
SI-27	[redacted]	[redacted]
SI-28	[redacted]	[redacted]
SI-29	[redacted]	[redacted]
SI-30	[redacted]	[redacted]

250 150 50 0 250 500 750
SCALE (METRES) 1:15,000 (A3)

DRAWING No.	DRAWING TITLE
801-140-A5001-910	MONITORING INSTRUMENTATION DETAILS

SHEET SIZE A3 — REFERENCES

REVISIONS

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

ORIGINAL STAMPED IN RED

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

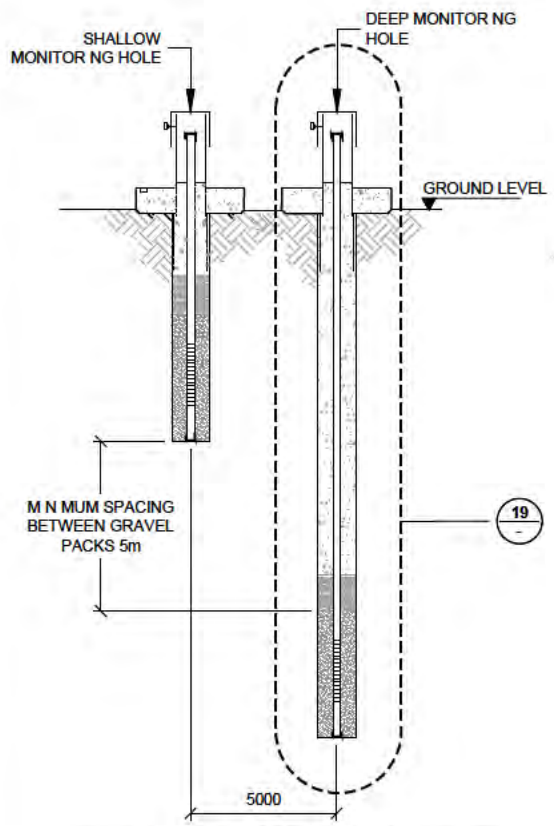
ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
MONITORING INSTRUMENTATION LAYOUT - STAGE 2

SCALE 1:15,000
STATUS: IFR
DRAWING NUMBER **801-140-A5001-902** REV **A**

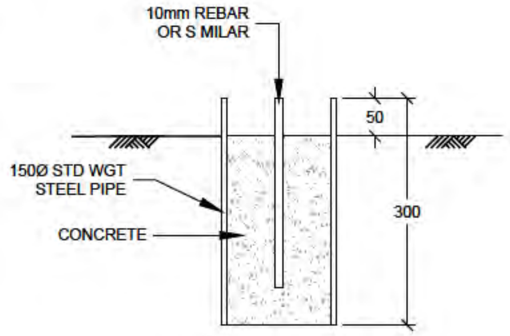
287 410

NOTES:

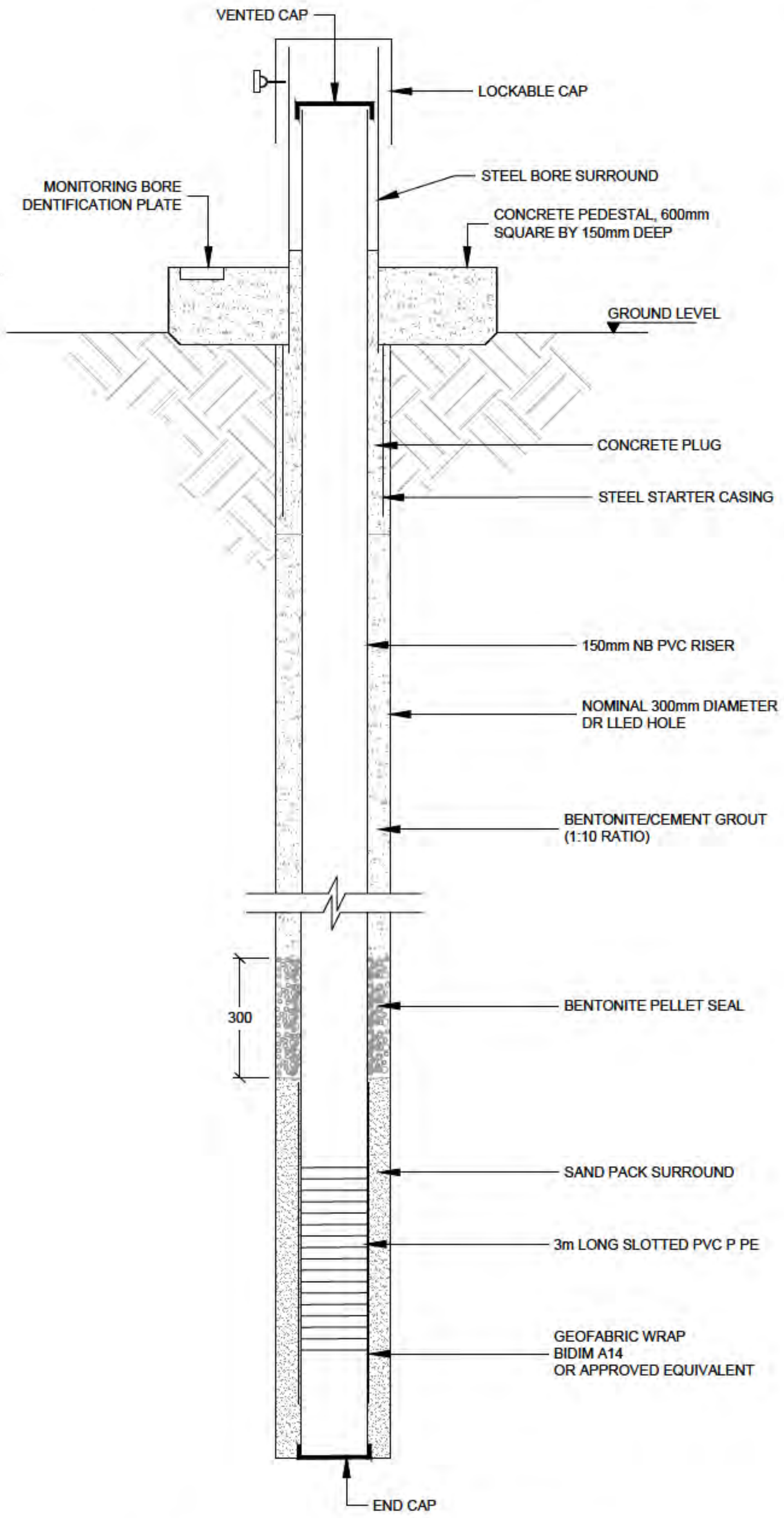
1. DEPTH OF MONITOR NG BORES TO BE DETERM NED ON SITE. (APPROXIMATELY 10m AND 20m)
2. BOREHOLE DRILLING TO BE SUPERVISED BY ENGINEER FOR GEOLOGICAL LOGG NG.
3. NSTRUMENTATION LOCATIONS TO BE DETERMINED BY THE ENG NEER ON SITE.



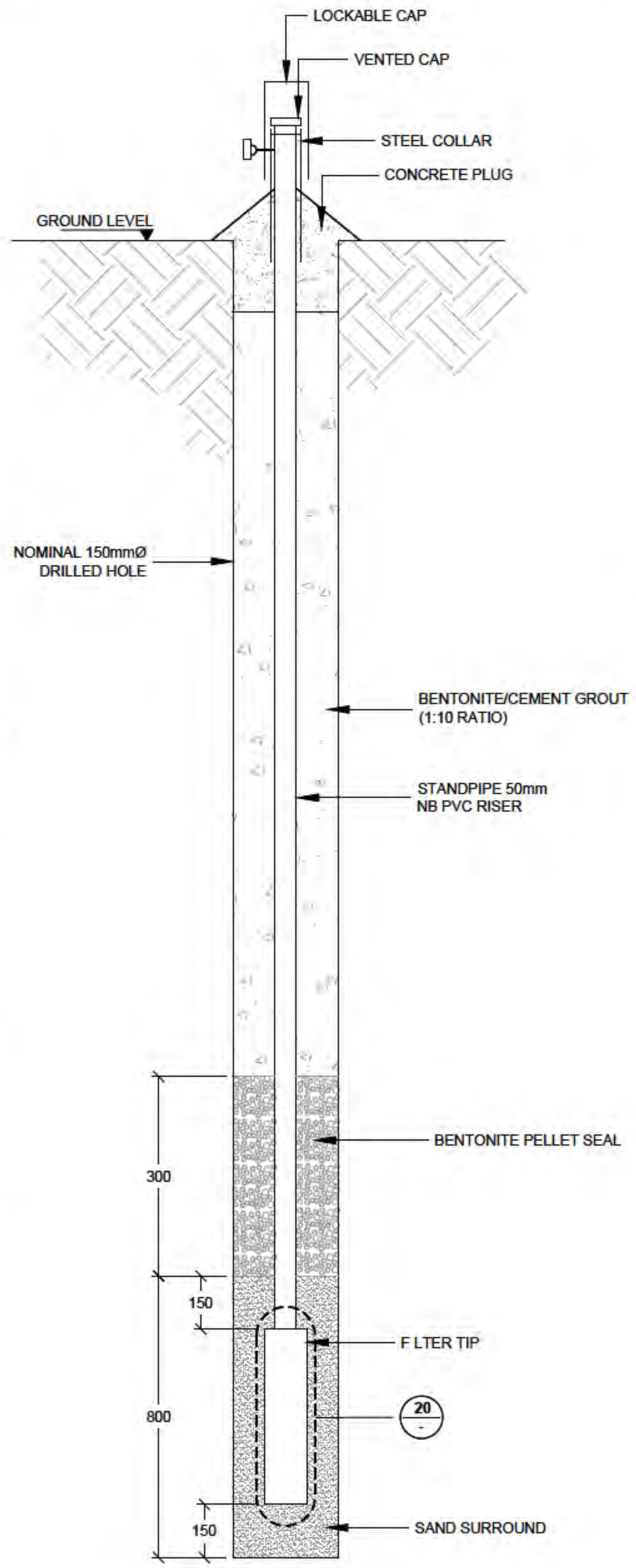
TYPICAL MONITORING BORE STATION ARRANGEMENT
N.T.S.



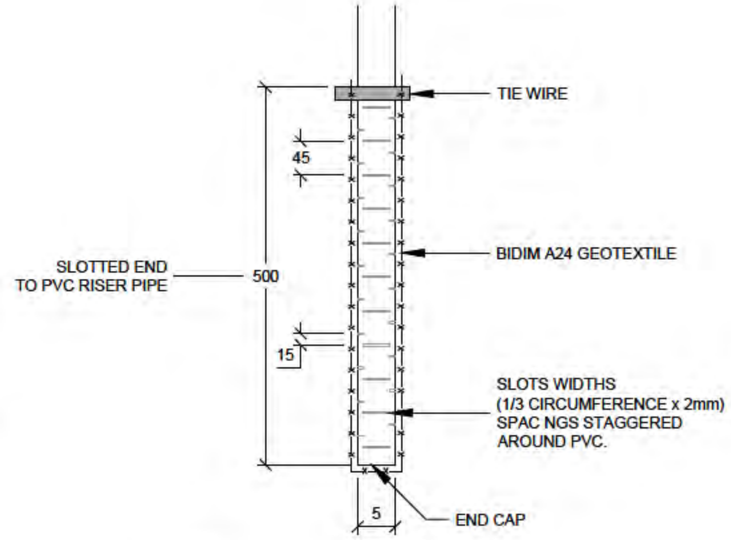
TYPICAL SURVEY STATION PIN SECTION
1:10



19 - TYPICAL MONITORING BORE INSTALLATION DETAIL
N.T.S.



TYPICAL STANDPIPE PIEZOMETER SECTION
N.T.S.



20 - TYPICAL FILTER TIP DETAIL
1:10

REV	DATE	DESCRIPTION	DRN	DESIGN	CKD	APP	CLIENT APP
A	30/11/2018	ISSUED FOR REVIEW	PRK	AM	AM	BAS	

REVISIONS

DRAWING No.	DRAWING TITLE

REFERENCES
SHEET SIZE A3

ORIGINAL STAMPED IN RED

DATE	DESIGNED	CHECKED	APPROVED	CLIENT APP'D

Knight Piésold CONSULTING

CONSULT AUSTRALIA Member Firm

ARAFURA RESOURCES
NOLANS PROJECT
MINING AREA SURFACE WATER MANAGEMENT
MONITORING INSTRUMENTATION DETAILS

SCALE AS SHOWN
STATUS: IFR
DRAWING NUMBER: 801-140-A5001-910
REV: A

287 410

APPENDIX A

Baseline Design Climatology Memo

MEMORANDUM

To:	**Arafura Resources Limited**	**Date:**	27 November 2018
Attn:	Stewart Watkins	**Our Ref:**	PE18-01183
		KP File Ref.:	PE801-00140/07-A acsb M18001
cc:		**From:**	Brett Stevenson

RE: NOLANS PROJECT – BASELINE DESIGN CLIMATOLOGY

Please find herein an assessment of baseline design climatology (rainfall and evaporation only) for the Nolans Project in the Northern Territory, Australia. This assessment will provide the hydrological basis for the Definitive Feasibility Design.

It is noted that the site is located in a region with a Köppen climate classification of Grassland, hot (persistently dry).

1. DATA SOURCE / SUMMARY

KP Normal Indent: text that follows numbered headings:
Daily historic climate data were obtained from the Scientific Information for Land Owners (SILO) database for use in deriving the basic climatology. The SILO data is based on all available climatic records in the area of the site. There are 18 weather stations with daily precipitation data within 100 km of the site. Table 1.1 lists the five closest stations to the Project site which have recorded daily precipitation data.

Table 1.1: Weather stations in project area with daily precipitation data

Station Name	First Reading	Last Reading	Years of Data	Distance from Site (km)
Aileron	Jan 1949	Jan 2017	57.6	11
Pine Hill	Jan 1967	Jan 2017	28.7	31
Territory Grape Farm	Jan 1987	Jun 2018	31.1	43
Napperby	Jan 1955	Dec 2014	59.8	52
Ti Tree Station	Jan 1966	Sep 1989	12.2	52

There are seven weather stations with daily pan evaporation data within 250 km of the site as listed in Table 1.2.

Table 1.2: Weather stations in project area with daily pan evaporation data

Station Name	First Reading	Last Reading	Years of Data	Distance from Site (km)
Territory Grape Farm	May 1987	Aug 2003	7.7	43
Barrow Creek	Jan 1967	Apr 1988	20.8	136
Alice Springs Post Office	Feb 1890	Dec 1953	54.1	138
Alice Springs Airport	Jun 1959	Jun 2017	52.4	148
Papunya	Oct 2001	Nov 2012	11.0	152
Arltunga	Nov 2000	May 2018	17.6	174
Ali Curung	Jun 1988	Dec 2013	21.3	213

The stations listed in tables 1.1 and 1.2 are shown on Figure 1.1.

The SILO data integrates the available records to produce a daily climate data set. The data from SILO (extracted as a data drill down) spanning the period January 1889 – June 2018 were analysed to obtain required design inputs for water balance modelling, namely:

- Typical variability of annual precipitation and evaporation;
- Typical variability of monthly precipitation and evaporation; and
- Synthetic monthly precipitation sequences for three climate scenarios:
  - 100 year Average Recurrence Interval (ARI) Wet precipitation, 1 year duration;
  - Average precipitation, 1 year duration; and
  - 100 year ARI Dry precipitation, 1 year duration.

Design storms were developed using the Bureau of Meteorology (BOM) 2016 IFD generating tool. Probable Maximum Precipitation (PMP) was estimated using the methods developed by the BOM (Refs. 1 & 2).

2. WATER BALANCE PRECIPITATION ANALYSES

Precipitation data from the SILO dataset were reduced into a standardised format and then analysed on annual and monthly timescales to develop inputs for water balance modelling. The following sections detail the various analyses conducted and the results achieved. It is noted that as the wetter period of the year runs from December through to April, the annual data were analysed as Water Years, spanning September through to August.

2.1 ANNUAL ANALYSES

Daily precipitation records from the SILO dataset were summed to produce annual totals for the 129 years of records. Water years were excluded from the analysis if greater than 15% of the daily data were missing so as to prevent missing records from introducing bias into computed climate statistics. On this basis, of the 130 water years of data 2 years were excluded from the annual analysis. Sampling statistics were computed from the annual sums to provide a broad overview of the variability of annual climate at the Project site, as given in Table 2.1. The stationarity of the data was assessed as outlined in Section 2.2 and as a result two sets of climatic data were generated, one for the full record and one for the last 30 years of the record.

Table 2.1: Annual precipitation statistics

Selected statistic	Precipitation Value Full Record (mm)	Precipitation Value 30 Year Record (mm)
Average	291	333
Median	265	303
Std. Deviation	149	152
Minimum	6	89
Maximum	909	724
25th Percentile	195	241
75th Percentile	355	406

2.2 NON-STATIONARY CLIMATE ASSESSMENT

The annual precipitation totals for the Nolans Project for the period 1889 to 2018 were assessed looking for any long term trends. The complete annual rainfall dataset is shown in Figure 2.1. Also shown in Figure 2.1 is a linear trend line and a 10 year moving average. The trend lines indicate that the recent time period is slightly wetter than previous time periods. It is consistent with the Intergovernmental Panel on Climate Change (IPCC) assessment which identifies the region around the Nolan Project as having an increasing trend in annual rainfall (Ref. 3).

For the Nolans Project the long term mean rainfall (1889 to 2017) is 291 mm. The mean for the last 30 years of record (1987-1988 to 2016-2017) is 333 mm. As the difference is not significant the full dataset was assessed to develop the design values.

2.3 MONTHLY ANALYSES

Daily precipitation data from the SILO dataset were summed in a manner similar to that described in Section 2.1 to produce monthly totals. To avoid bias in a manner similar to that outlined in Section 2.1, monthly totals were excluded from the analyses if greater than 25% of the daily data from that month (approximately 1 week) were missing. The monthly data were assessed using the full length of the record. Sampling statistics were computed on the monthly sums to provide a broad overview of the variability of monthly climate data at the Project site, as given in Table 2.2.

Table 2.2: Monthly precipitation statistics (mm)

Month	Average	Median	Std. Dev.	Min.	Max.	25th Pct.	75th Pct.
Sep	7	0	15	0	84	0	6
Oct	18	9	21	0	99	1	26
Nov	28	22	28	0	156	7	39
Dec	45	30	50	0	254	11	59
Jan	50	26	62	0	396	7	72
Feb	49	30	62	0	360	4	70
Mar	34	9	53	0	248	0	38
Apr	15	1	30	0	224	0	18
May	18	1	30	0	159	0	25
Jun	12	2	19	0	108	0	18
Jul	10	0	24	0	141	0	7
Aug	6	0	14	0	81	0	4

The sample statistics for monthly precipitation were also depicted as “box and whisker” plots to illustrate the variability of monthly values at the Project site, as shown in Figure 2.2. For each month shown the “box and whisker” plots are read as follows:

- Top of each “box” indicates the 75th percentile of the monthly values;
- Central line within each “box” indicates the median (or 50th percentile) of the monthly values;
- Bottom of each “box” indicates the 25th percentile of the monthly values;
- Red diamond inside each “box” indicates the average of the monthly values;
- The “whiskers”, each of length 1.5 times the inter-quartile range (which is the 75th minus the 25th percentile values) indicate the range of expected readings above and below each “box”. Values above and below the “whiskers” are considered to be outliers; and
- Individual monthly outlier values are indicated as blue crosses with monthly readings adjacent.

As indicated in Figure 2.2 the monthly precipitation is quite variable, with January and February typically being the wettest months of the year at the Project site but with measurable precipitation occurring throughout the year.

2.4 SYNTHETIC WATER BALANCE SCENARIOS

KP performed frequency analysis on annual duration values (from the SILO climate dataset) to estimate the statistical likelihood of experiencing extremely “Wet” or “Dry” periods of weather at the project site. Exceedance and non-exceedance probabilities were assigned to various duration totals of daily precipitation values, by sorting the values in descending (for the “Wet” series) and ascending (for the “Dry” series) order.

A number (64) of different probability distributions, e.g.: Log-Pearson 3, Generalised Extreme Value, Wakeby, Inverse Gaussian, etc. were fitted to the various sums of daily precipitation data using EasyFit 5.4 Professional software. Three of the best fits were selected for comparison in each case, as shown in the following figures:

- Wet precipitation series 1 year duration – Figure 2.3; and

- Dry precipitation series, 1 year duration – Figure 2.4.

Ideally, the distributions having the best weighted Kolmogorov-Smirnov and Anderson-Darling goodness-of-fit test ranking results will match across all scenarios, thereby providing consistent results. In this case, the goodness-of-fit test results indicated the Burr (4P) distribution was statistically the best fit.

However, upon examination of Figure 2.3 it was concluded that the Burr (4P) distribution may underestimate extreme wet years. The Log-Pearson 3 distribution was fitted to the data for the Wet precipitation series for the data points with ARI’s ≥5 years using least-squares regression analysis. This was done as this distribution provides a more reasonable fit to the larger wet events than the other distributions. This distribution was then selected for estimating the extreme wet precipitation series depths. For the Dry precipitation series, Burr (4P) Value distribution was selected as it was the best statistical fit (as fit by EasyFit 5.4). The resulting estimated extreme wet and dry annual precipitation depths are shown in Table 2.3.

Table 2.3: Design annual precipitation - Wet and Dry scenarios

ARI (yr)	1 Year Precipitation Totals (mm)	
	Wet	Dry
100	847	30
50	735	60
20	594	103
10	491	137
5	390	178

In order to apportion the statistically-computed climate series precipitation totals to monthly time series for use in water balance modelling, the following observed rainfall patterns were used:

- 1 year duration Wet scenarios: September 1973 – August 1974, the wettest observed water year of record;
- 1 year duration Average scenario: September 1929 – August 1930, a year closest to the median observed water year of record with no total months of rainfall that are statistical outliers; and
- 1 year duration Dry scenarios: September 1986 – August 1987, the driest observed water year of record.

Ratios of observed monthly to observed total precipitation were computed for each scenario. These ratios were then multiplied by the computed statistical totals (at the selected design frequency, 100 years ARI) to form the desired synthetic climate scenarios for water balance modelling. The resulting climate scenarios are summarised (in monthly format) in Table 2.4.

Table 2.4: Annual synthetic climate scenarios

Month	Annual Climate Scenarios (mm)		
	100 year Dry	Average	100 year Wet
Sep	0.0	0.5	12.1
Oct	2.5	15.9	21.0
Nov	3.1	2.2	99.3
Dec	13.2	119.4	33.9
Jan	1.5	123.3	368.8
Feb	7.1	26.5	160.5
Mar	0.0	1.9	24.7
Apr	0.0	0.0	86.1
May	0.0	0.1	28.0
Jun	2.5	0.0	0.0
Jul	0.0	0.9	0.0
Aug	0.0	0.1	12.1

It is noted that the 100 year Wet year may have months where the precipitation is less than the average or the 100 year dry year. Similarly the 100 year Dry year may have months where the precipitation is greater than the average or the 100 year wet year. This is not an error and is due to the rainfall pattern within the specific year selected to develop the rainfall patterns.

3. DESIGN STORMS

Aside from climate scenarios for water balance modelling, design storms were derived for surface water management design.

3.5 PROBABLE MAXIMUM PRECIPITATION (PMP)

PMP was estimated using two different methods published by BOM. For storm durations of up to 3 hours, the Generalised Short Duration Method (GSDM) procedures (Ref. 1) were employed.

The Project site lies in the GTSMR Inland Zone. As such the Generalised Tropical Storm Method, Revised (GTSMR) procedures (Ref. 2) were used to determine the governing method for deriving PMP for storm durations from 24 hours to 96 hours.

Composite curve results for the Project site are summarised in Table 3.1. It is noted that for both the GSDM and GTSMR the catchment area was assumed to be 1 km^2.

Table 3.1: Composite depth-duration relationship for PMP

Estimation Procedure	Duration (hr)	Depth (mm)
GSDM	0.25	200
	0.50	280
	0.75	360
	1.0	410
	1.5	480
	2.0	540
	2.5	590
	3.0	620
GTSMR Summer	24	670
	30	730
	36	790
	48	900
	60	1,000
	72	1,090
	96	1,230

3.6 INTENSITY / FREQUENCY / DURATION

Intensity / Frequency / Duration (IFD) and corresponding Depth / Frequency / Duration (DFD) relationships for design storms (10% ≤ ARI ≤ 0.05%) were sourced from the BOM 2016 IFD tool (Ref. 4) for the grid cell (22.6°S, 133.25°E). It is noted that at the time the data was extracted from the tool for storms greater than the 1% AEP, only the 24 hour to 168 hour durations are available. The design storm information is summarised as storm depths in Table 3.2.

Table 3.2: Design storm depths

Duration (h)	Precipitation Depth (mm) for a given AEP							
	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
0.017	3.61	4.31	5.25	6				
0.033	6.52	7.87	9.73	11.2				
0.050	8.99	10.8	13.3	15.3				
0.067	11.2	13.4	16.4	18.8				
0.083	13.1	15.6	19.1	21.9				
0.167	20.4	24.3	29.5	33.7				
0.25	25.6	30.4	37	42.2				
0.5	35.4	42.2	51.6	59.1				
1	45.7	54.9	67.5	77.7				
2	56.4	67.9	83.8	96.6				
3	62.9	75.7	93.4	108				
6	75.4	90.4	111	129				
12	91.6	109	135	156				
24	114	135	169	196	230	276	313	354
48	144	172	218	255	300	361	413	469
72	164	198	252	298	347	420	481	547
96	178	216	277	328	380	460	527	600
120	187	228	293	347	403	487	558	636
144	193	237	303	358	417	505	579	660
168	196	242	308	362	427	516	592	674

A more extensive summary of storm events for the site area are provided in Appendix A.

4. EVAPORATION

Daily evaporation data from the SILO dataset were summed in a manner similar to that described in Section 2.1 to produce annual and monthly totals.

Annual totals were excluded from the analyses if greater than 15% of the daily data from that year were missing (approximately 2 months) and monthly totals were excluded from the analyses if greater than 25% of the daily data from that month (approximately 1 week) were missing, for the same reason given in Section 2.1. Average annual and monthly pan evaporation values for the site were calculated from the SILO dataset for 1970 onwards and are summarised in tables 4.1 and 4.2 respectively.

Table 4.1: Average annual pan evaporation

Selected Statistic	Evaporation Value (mm)
Average	3,012
Median	3,070
Std. Deviation	297
Minimum	2,233
Maximum	3,463
25th Percentile	2,817
75th Percentile	3,258

The expected evaporation from the ponds at the site were estimated based on a relationship between Penman estimate of lake evaporation rate and pan evaporation described by Stanhill 1976 (Ref. 5). The resulting lake evaporation and assumed pan factor are summarised in Table 4.2.

Table 4.2: Average monthly pan evaporation

Month	Pan Evaporation (mm)	Ave. Penman Lake Evap. (mm)	Pan Factor
Sep	245	216	0.60
Oct	313	187	0.63
Nov	329	194	0.66
Dec	350	158	0.70
Jan	357	116	0.73
Feb	299	90	0.74
Mar	297	100	0.74
Apr	224	134	0.72
May	160	169	0.69
Jun	122	201	0.64
Jul	136	203	0.62
Aug	185	214	0.61

We trust that this memorandum is sufficient for your current needs. Please contact us if you have any queries.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

ANDREW BROWN
Engineer

Pete Veld
PETER VELD
Technical Consultant

REFERENCES

1. Australian Bureau of Meteorology. *"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*", 2003. Melbourne, VIC. Australia.

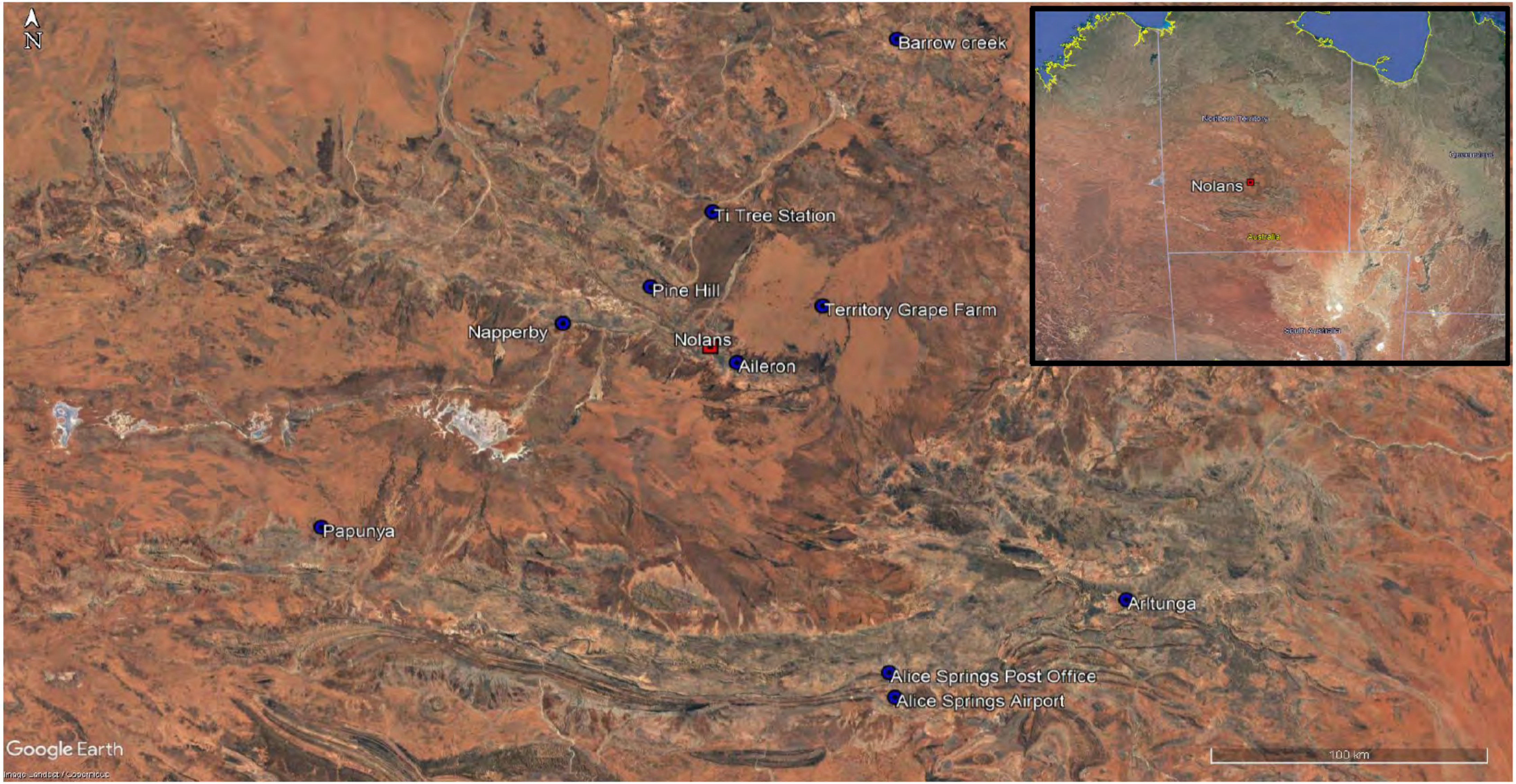
2. Australian Bureau of Meteorology. "*Revision of the Generalised Tropical Storm Method for Estimation Probable Maximum Precipitation, HRS Report No. 8*", 2003. Melbourne, VIC. Australia.

3. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. "*IPCC Fourth Assessment Report: Climate Change 2007: Working Group I: The Physical Science Basis*", Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

4. Bureau of Meteorology, "*Design Rainfall Data System (2016)*", http://www.bom.gov.au/water/designRainfalls/revised-ifd/?

5. Stanhill, G. 1976. "*The CMO International Evaporimeter Comparisons.*" Publication 449 (World Meteorological Organisation, Geneva) 38pp.

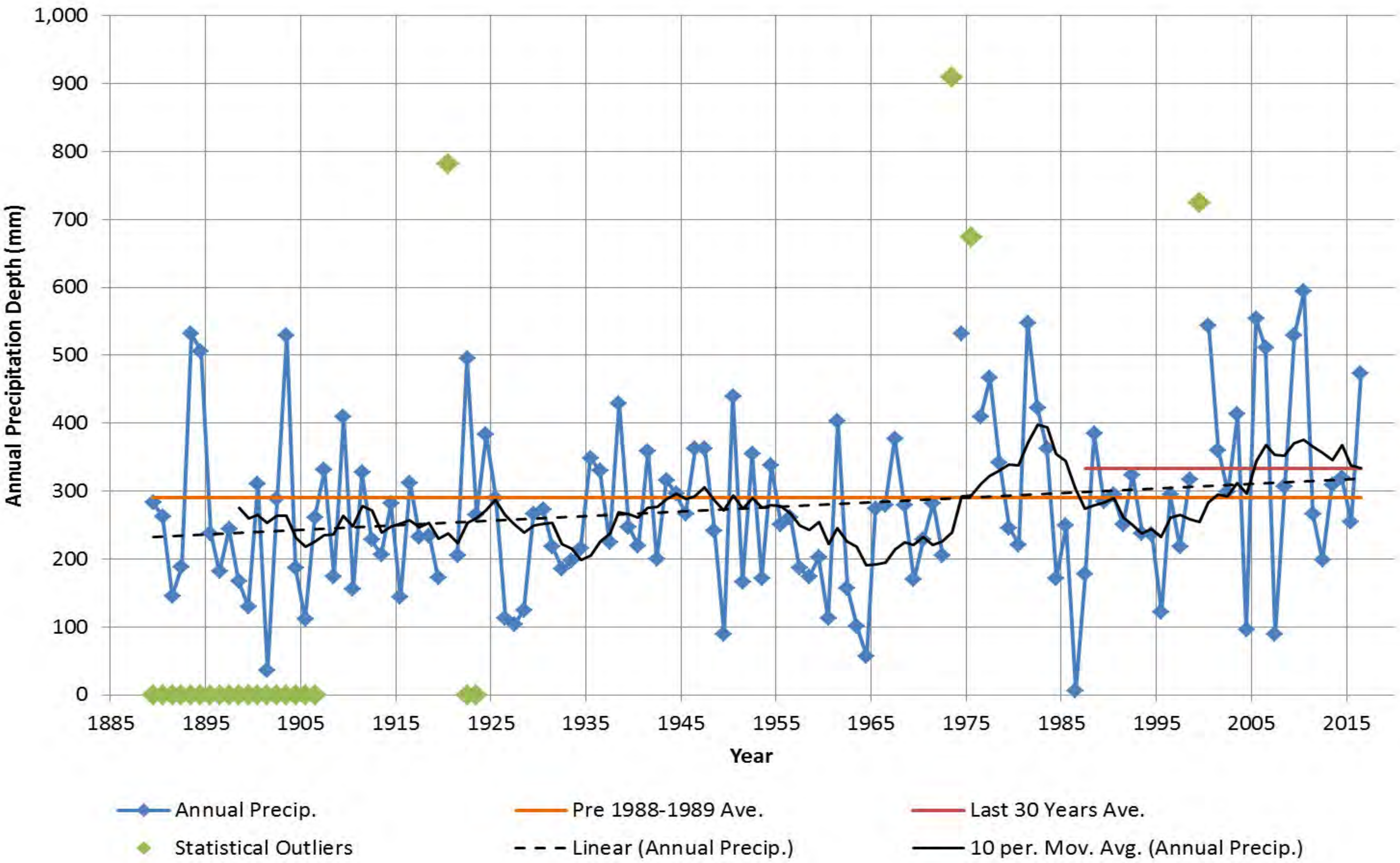
FIGURES



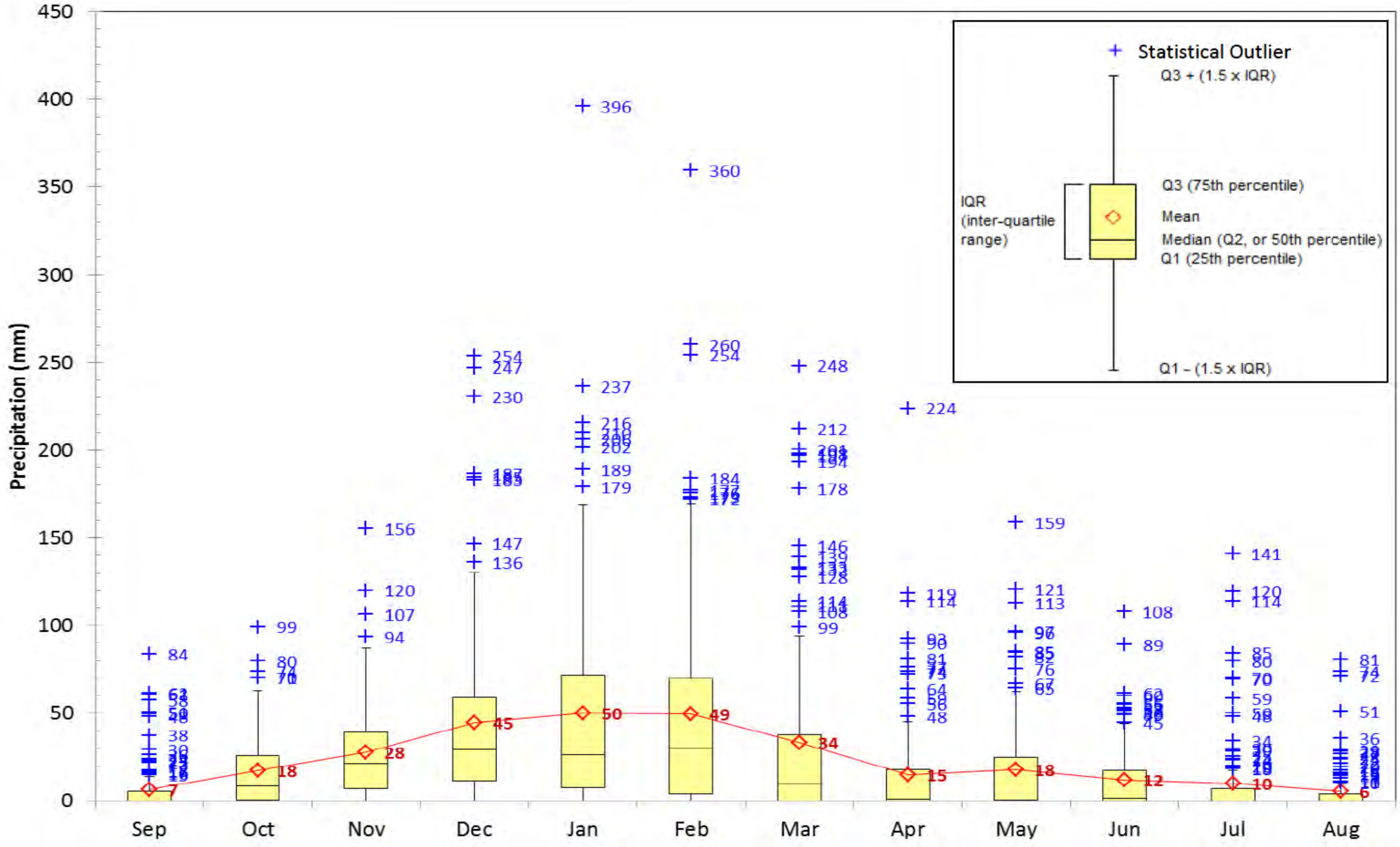
Knight Piésold CONSULTING

NOLANS PROJECT
BASELINE DESIGN CLIMATOLOGY
NEARBY STATIONS

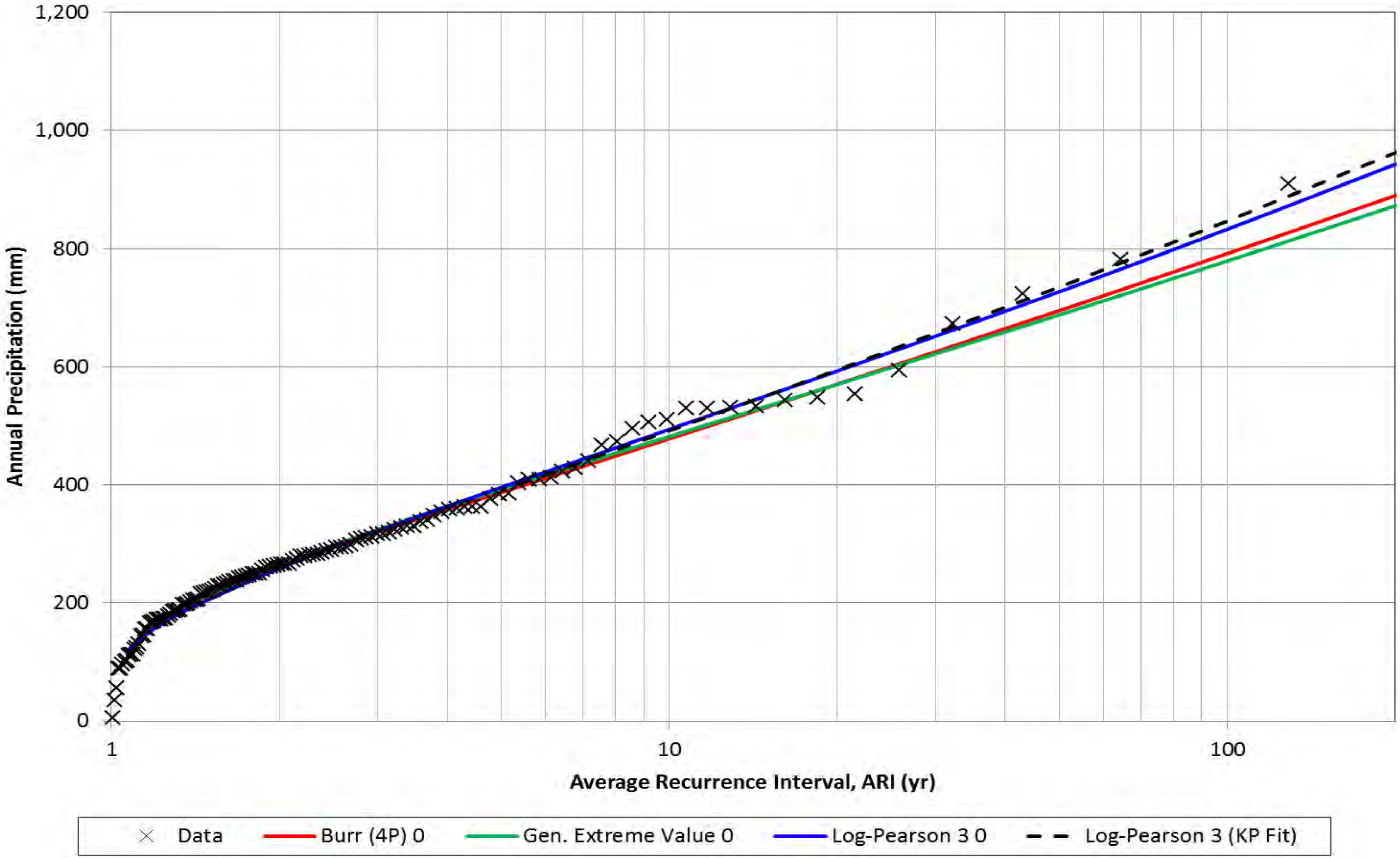
PE801-00140 M18001
Figure 1.1



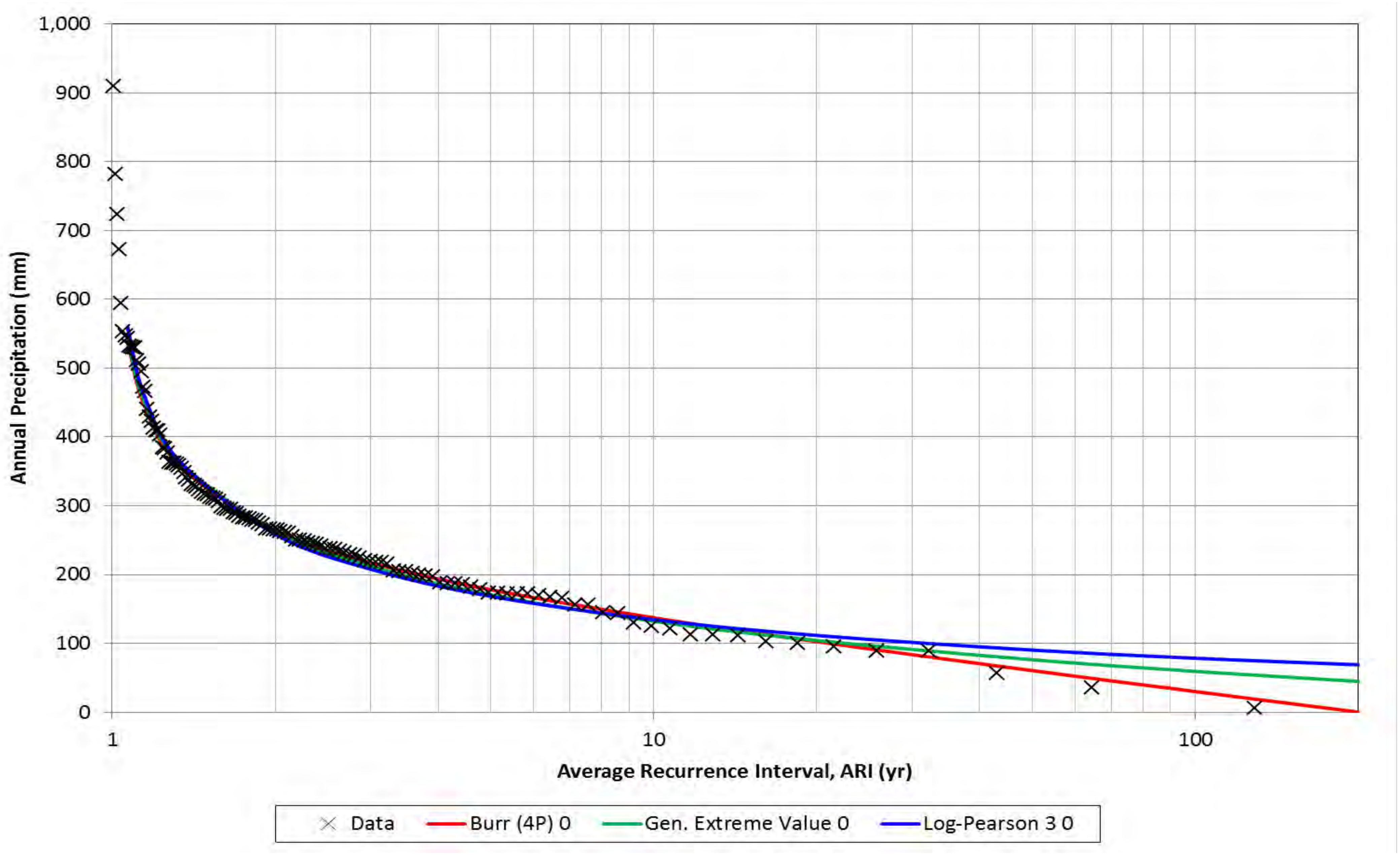
1,000
900
800
700
600
500
400
300
200
100
0
1885
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Annual Precipitation Depth (mm)
Year
Annual Precip.
Pre 1988-1989 Ave.
Last 30 Years Ave.
Statistical Outliers
Linear (Annual Precip.)
10 per. Mov. Avg. (Annual Precip.)



Precipitation (mm)
450
400
350
300
250
200
150
100
50
0
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
7
18
28
45
50
49
34
15
18
12
10
6
396
360
254
247
230
237
189
179
260
254
248
212
178
224
156
120
107
94
147
136
159
121
113
108
89
141
84
99
38
51
Statistical Outlier
Q3 + (1.5 x IQR)
IQR
(inter-quartile
range)
Q3 (75th percentile)
Mean
Median (Q2, or 50th percentile)
Q1 (25th percentile)
Q1 - (1.5 x IQR)



1,200
1,000
800
600
400
200
0
Annual Precipitation (mm)
1
10
100
Average Recurrence Interval, ARI (yr)
Data
Burr (4P) 0
Gen. Extreme Value 0
Log-Pearson 3 0
Log-Pearson 3 (KP Fit)



1,000
900
800
700
600
500
400
300
200
100
0
Annual Precipitation (mm)
1
10
100
Average Recurrence Interval, ARI (yr)
Data
Burr (4P) 0
Gen. Extreme Value 0
Log-Pearson 3 0

APPENDIX B

Quantity and Cost Estimate

Knight Piésold
CONSULTING