APPENDIX A

JACOBS

Appendix A. Geotechnical Investigation

A.1 Background

A.1.1 Purpose

The purpose of this geotechnical report is to provide a summary of the key background information available, and coupled with additional fieldwork (when it is available), to provide key points for the project covering both ground condition assessments and associated risk and design considerations. At the time of writing of this version of the report site specific geotechnical investigations were being undertaken. The results of these additional investigations will be incorporated into subsequent updated versions of this report, and may result in necessary amendments to the interpretations of the ground conditions and the related engineering designs and construction considerations as set out in the following subsequent sections.

A.1.2 Methodology

The general approach/method to the ground engineering aspects of this project, in chronological sequence, are set out as follows:

1) Desk Study, Walkover Survey and Geological Mapping Exercise
2) Define and undertake/supervise a site-specific Geotechnical Investigation for the proposed pipeline alignment and associated infrastructure
3) Carry out Factual Reporting of the Geotechnical Investigation, define a Ground Model and representative design parameters for the proposed infrastructure
4) Undertake excavatability and reuse of materials assessment, as well as identification of areas of poor ground and/or problematic soils that will require measures to deal with during construction and the operational phase
5) Define high level temporary works required for trench installations; identify specific treatments required for backfilling, precautions during construction and measures for long term maintenance control of problematic soils; define control measures if required for potential scour or buoyancy locations; define the most appropriate method of pipeline installation over/under creek lines, roads and railways; define foundations and earthworks for pumping and pigging stations and ancillary structures; and
6) Provide inputs into project risks assessments and cost estimates, as well as any community or potential water customer forums/meetings

Based on Jacobs previous experience of Detailed Business Cases (DBC) of this type, this project is being carried out over very short timescales, therefore as can be seen at present ground condition interpretations and related engineering and construction considerations for the optimum defined and proposed scheme of the Stage 2 development, rely on mainly Desk Study, previous experience and a limited project specific geotechnical investigation.

A.1.3 Assumptions

The presumed assumptions that have been used for the present geotechnical interpretations for the DBC include the following:

- At present this report is focused on providing technical inputs to only the Stage 2 pipeline and associated ancillary works proposed development, however, many of the findings could be applied to other alternative development options for this project;
- The location of the proposed solar array has not been identified as yet and therefore has not been considered in this report at present; it can be assumed that the solar array foundations may incorporate either a screw pile or peg arrangement;
- No significant earthquake effect will impact on the proposed development within the design life of the project;
- The proposed pipeline is composed of steel rather than the Stage 1 GRP material being employed;

- The pipeline trench will employ the use of excavators rather than trenching machines (following a similar approach to most of the Stage 1 pipeline constructions);
- The present interpretation of ground conditions is based on primarily Desk Study, site observations from a Jacobs Walkover Survey, an assessment of the previous Haughton Main Channel (HMC) geotechnical investigations, limited additional project specific geotechnical investigations, and experience with similar ground conditions and projects; actual ground conditions that could be encountered in Stage 2 construction works (if they were to be undertaken) may differ from those presently defined in this report;
- Only a small percentage of excavated materials for the proposed Stage 2 works are considered Acid Sulphate Soils, which will require lime treatment;
- No contaminated land or contaminated groundwater will be encountered during any of the construction works;
- No specific precautions are presently envisaged to deal with potential reactive or sodic soil nature and behaviour;
- No specific precautions are presently envisaged to deal with potential aggressive soil or groundwater conditions;
- The vast majority of the excavated material from the proposed project excavations will be spoiled to an appropriate location without the need for any specific treatment (to be identified and transported to by the construction contractor);
- General backfill for the proposed pipeline installation trench will be sand material sourced from local quarries; and
- Similar pumping station arrangements are currently envisaged for both Burdekin and Haughton River locations.

A.2 Topography, Geomorphological, Geological and Soil Characteristics

A.2.1 Topography

The proposed pipeline alignment traverses through generally a wide essentially flat lying floodplain formed by both the Burdekin and Haughton River systems. The floodplain varies for the most part only between approximately 30 and 35 mAHD. The only two significant topographical rises are seen near Millaroo close to the Burdekin River (Mount Dalrymple) where the existing Sunwater Main Channel cuts through low granitic hills (at approximately 50mAHD), as well as another granitic hill where the Main Channel cuts through at approximately a maximum height of 40 mAHD, within the vicinity of Woodhouse between Ch17,000-20,000m (see Figure 1).

The proposed sediment dam and pumping station close to the Burdekin River lies within Sunwater leased land, owned by S & J Sheahan. From here the proposed pipeline alignment runs in parallel with existing HMC for the majority of its length being approximately 40m offset to the west of the western HMC fence line.

The pipeline alignment generally crosses grazing land (see Plate 1) of only 4 landholders (see Figure 2), being in order between the Burdekin and Haughton Rivers, S & J Sheahan (between approximate pipeline Ch0-12,200m at Scotts Creek), Rapisarda Investments Pty Ltd (between approximate pipeline CH12,200-24,850m), D Cox (between approximate pipeline Ch25,000-31,390m) and Sunwater (between approximate pipeline Ch31,390-35,174 at the proposed Haughton Pumping Station).

In terms of existing surface infrastructure the proposed pipeline alignment traverses the following main components:

- The sealed Dalberg & Ayr-Ravenswood Roads (at approximate pipeline Ch-050 and 14,100m respectively);
- The named unsealed Keith Venables Road within close proximity to the Haughton River;
- Defined Road Reserves at approximate pipeline Ch12,300 and between Ch24,820 and 26,446m;
- High Voltage Ergon Power Cables on significant pylons/towers at approximate pipeline Ch750 (see Plate 2), two power lines at approximate pipeline Ch25,200m, and a low voltage overhead line within the vicinity of Keith Venables Road at approximate Ch33,500m; and
- Narrow gauge cane railway lines running in parallel with Dalberg Road (see Plate 3).

Figure 1: Topography, Utilities and Main Road and Railways Associated with Stage 2

Figure 2: Property Extents Over Proposed Pipeline Alignment

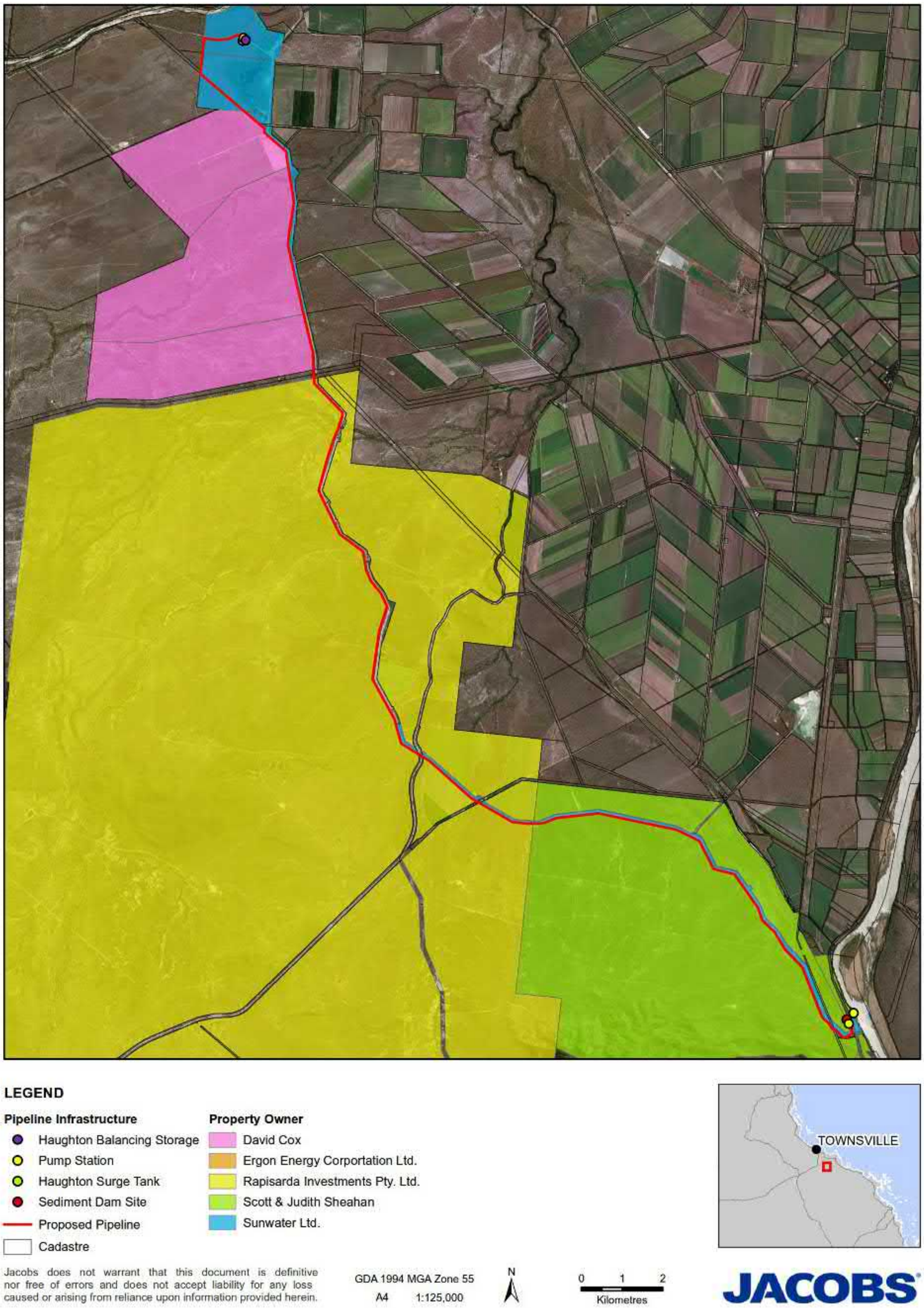


Plate 1 General Landscape Character of Proposed Pipeline Alignment

Plate 2 Close to the Commencement of the Existing HMC at Clare Cross Cutting HV Power Lines

Plate 3 Typical Cane Railway Formation Within the Region

A.2.2 Geomorphology

As previously indicated the proposed pipeline alignments traverse through a wide floodplain formed by both the Burdekin and Haughton River systems, and encompasses the Deep, Scott, Woodhouse, Horse Camp, Barratta, Lagoon and Oaky creeks (see Figure 3, and Plates 4 and 5).

The proposed pipeline (adjacent to the existing Sunwater Main Channel) skirts the edge floodplain and the foothills of the aforementioned low granitic/granodiroite hills close to the commencement of the existing HMC, at around approximate pipeline Ch0 – 6,400m.

It is likely due to the wide floodplain morphology that both the Burdekin and Haughton Rivers and the associated creeks have meandered across this floodplain and therefore a number of previous channels and levees may have been reworked. Potential numerous abandoned channels may be seen in the 1969 aerial photograph composite, presented in Figure 4.

Site observations of the main creeks required to be traversed indicate that as a result of the recent extreme weather event and associated significant flooding in the Townsville area, little scour may have occurred with the accumulation of sediments in the bed and banks (see Plate 5).

The main water features which the proposed works may influence or impact are set out in Figure 3. Of particular note is the present recognised significant wetland of the Haughton Balancing Storage.

Figure 3: Water Features Within the Vicinity of the Proposed Pipeline Alignment

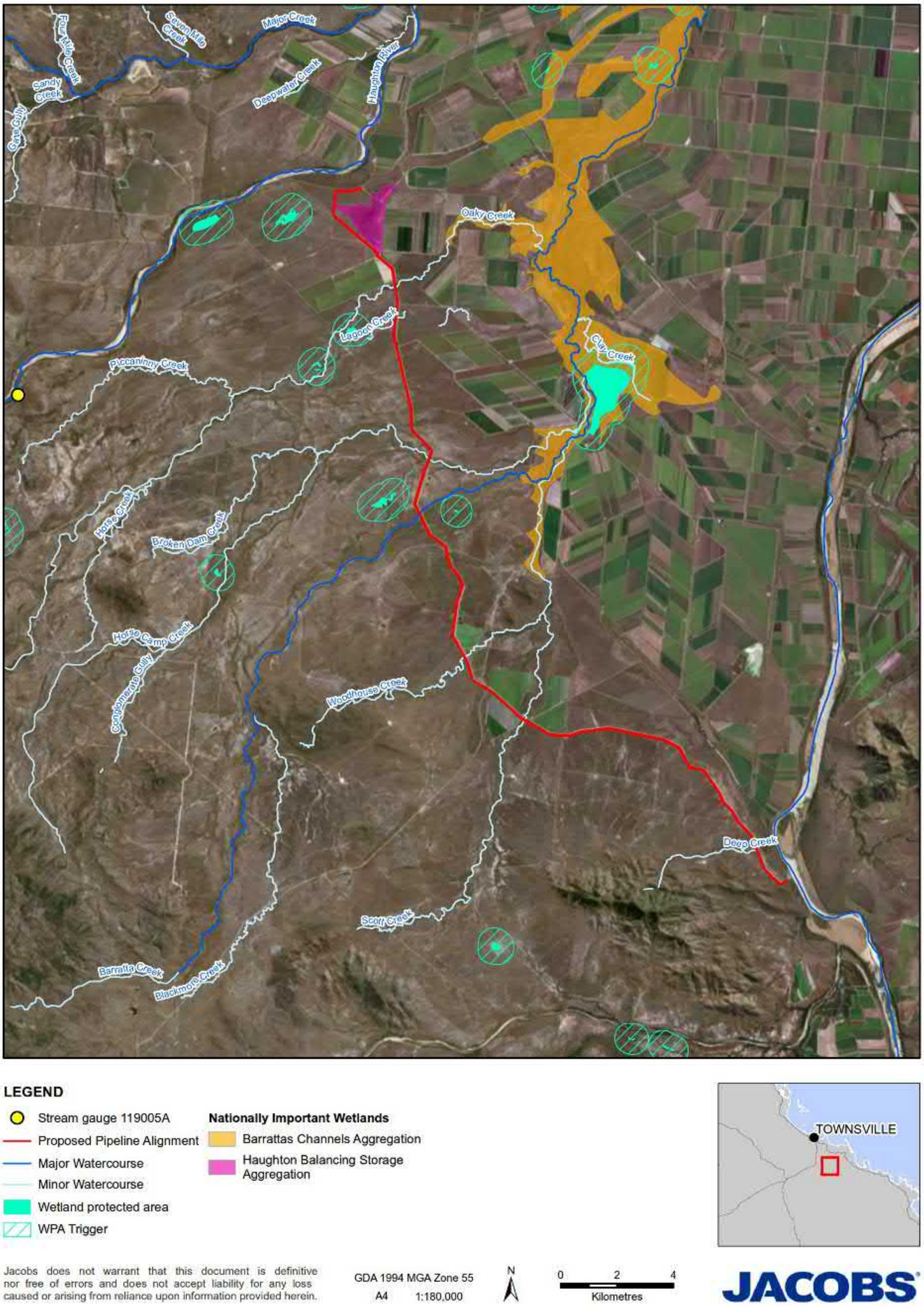
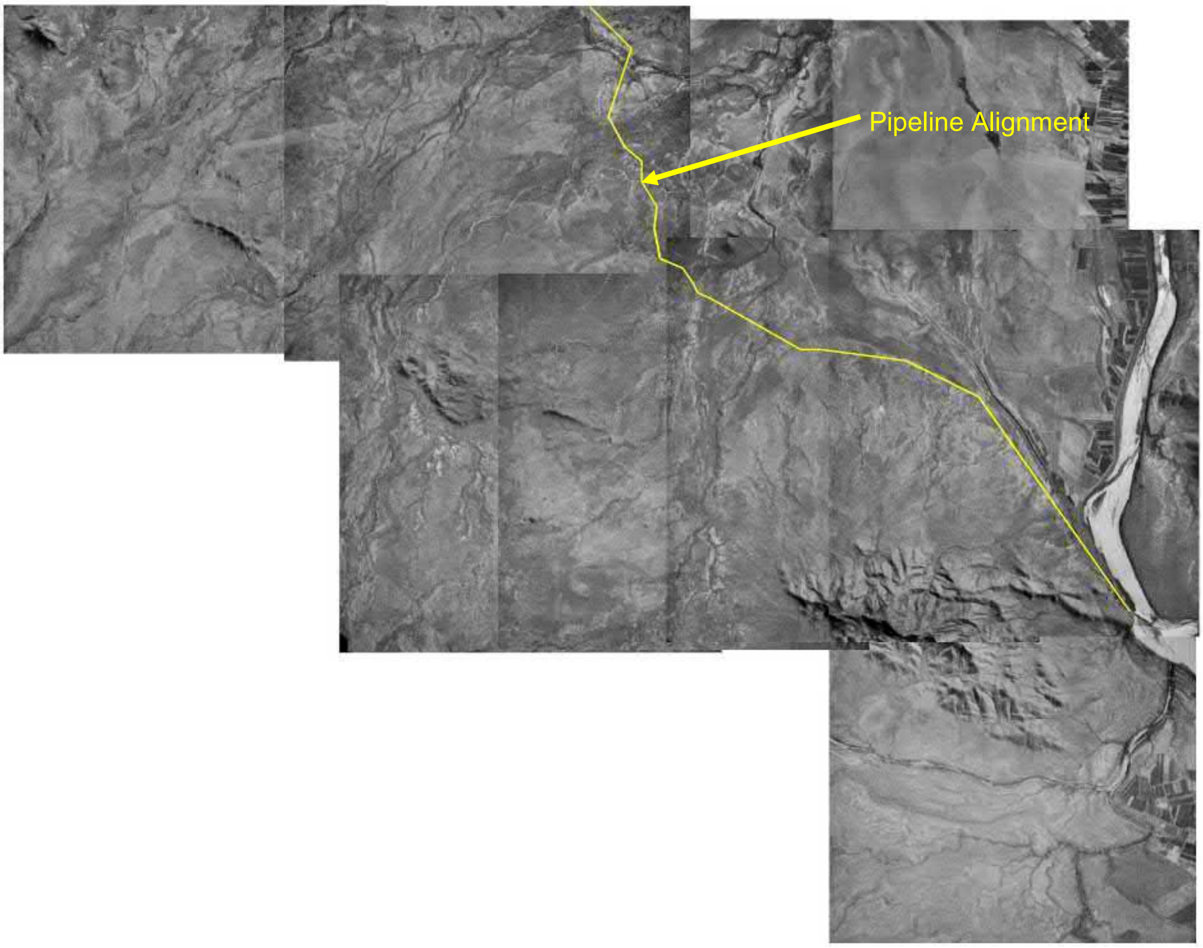


Plate 4 Existing Small Creeks that will Require Traversing

Plate 5 Existing Major Creeks that will Require Traversing

Figure 4: 1969 Aerial Photography Montagne Showing Dynamic Floodplain Character



A.2.3 Geology

The published geology of the proposed alignment (see Figure 5) indicates that the vast majority of the proposed works are likely to encounter surface Quaternary Alluvium. From the Jacobs Walkover Survey and the previous HMC geotechnical investigations the alluvium deposits vary in thickness and composition with areas of both cohesive and sand granular dominated strata, which are probably not stratigraphical concurrent, due to the aforementioned reworking floodplain character. It is also evident that the alluvium may directly overly both residual soil and/or extremely weathered bedrock horizons, as well as directly above competent rock (defined as medium strength and moderately weathered or better). Within the more weathered rock sequences corestones of competent rock (perhaps up to 5m in dimension) may be apparent, which is typical of granitic based rock types in terms of their weathering sequence.

The bedrock in the area is interpreted to be granitic in origin varying between granites and granodiorites as observed in the existing HMC cutting (see Plate 6).

From the published information only potentially one general NW-SE trending concealed fault may cross the proposed pipeline alignment at approximate Ch11,500m.

Figure 5: Proposed Stage 2 Development Structural and Surface Geology

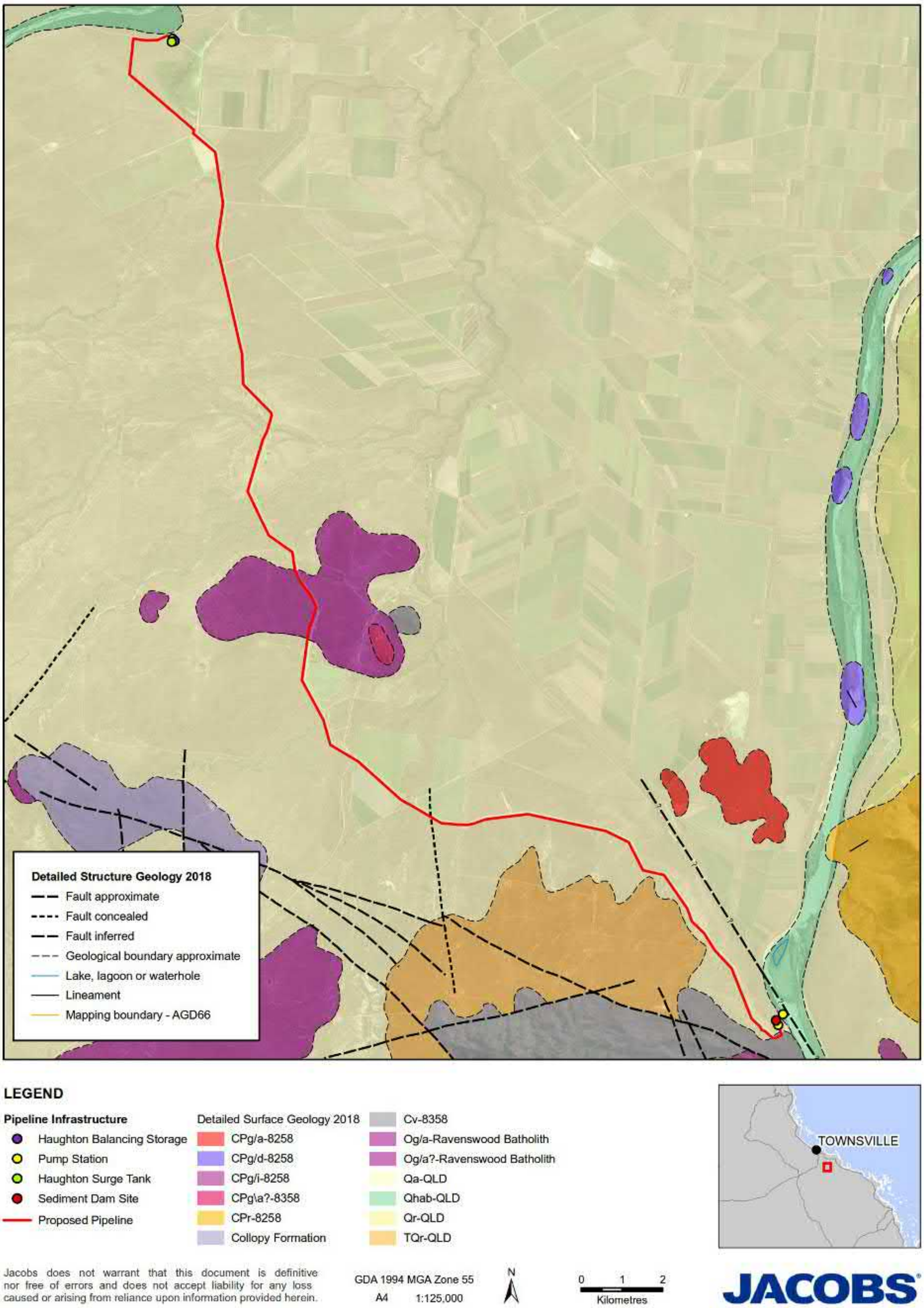


Plate 6 Existing Haughton Main Channel Cutting through Granodiorite Hillock

A.2.4 Soils

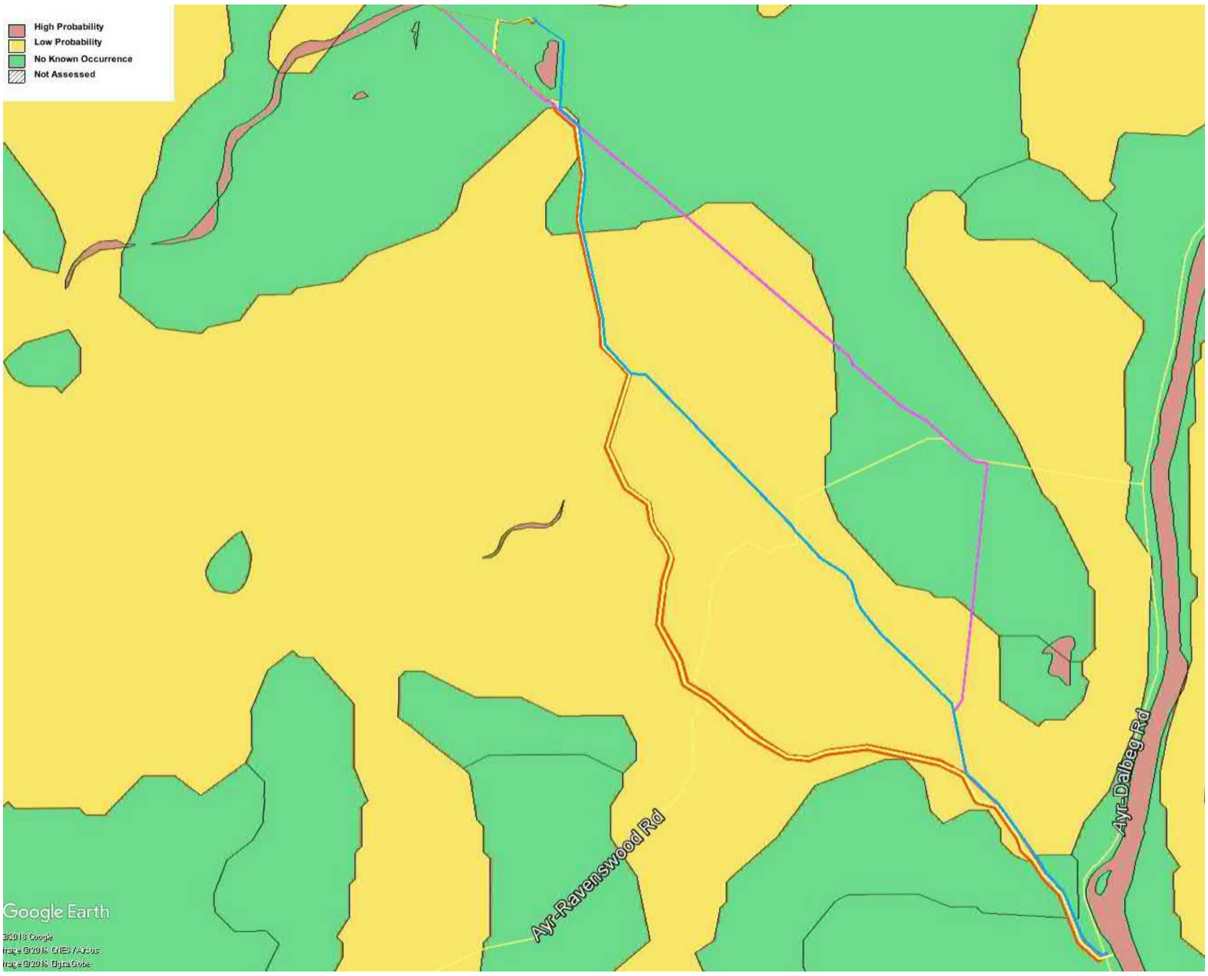
The published soils along the proposed pipeline alignments are presented in Figure 6. These soils can be subdivided into sand rich soils (colluvial/residual) derived from the low hills close to the Burdekin River and the Granitic hillocks around Chainage 17,000-20,000m of the proposed alignment; potentially reactive clays (defined as vertosols) occurring over significant portions of the northern area, including the Haughton River floodplain; but generally over much of pipeline consist of variable composed Alluvial soils (as indicated by the previous HMC geotechnical investigations, see Appendix B) with a potential to be sodic in nature and saline in character (defined as sodosols). This dispersive character, resulting in tunnel erosion and/or piping failures, is driven by the high concentrations of sodium within the upper horizons, which clogs soil pores. This clogging results in erosion/dispersion of the upper soil surfaces when overlandflow occurs. This potential dispersive nature was observed during a Jacobs drive through of the existing Sunwater HMC alignment, which indicated that in some areas erosive/dispersive soils may be apparent by the tunnelling and piping erosion seen in the channel banks and associated bunds. Potential practical methods of dealing with sodic soils are dealt with in Section 5.1.8 Because of its potential importance the project specific geotechnical investigations will include appropriate laboratory testing for sodic soils.

Figure 7 indicates that the presence of Acid Sulphate Soils over the pipeline alignments is unlikely, which is supported by the elevation being at least 10m above the 20 mAHD upper threshold levels for these types of soils. However, based on recent Jacobs experience in Queensland, the Potential Acid Sulphate Soil (PASS) may exist in similar floodplains at similar elevations. In this respect the project specific on-going geotechnical investigations are carrying out a screening process to confirm the existence or otherwise of PASS. If PASS is found occurring within potential excavated volumes then it may require treatment by the addition of lime before being allowed to be reused within the project (which is currently unlikely) or spoiled. This may have significant cost and time implications.

From the Jacobs walkover survey it is believed the extent of the reactive/black soils may be greater than indicated by the published soil maps, however the overall impression is that the clay reactivity may be at a low level due to the character of the surface soils, ie., the significant lack of surface expression of self-mulching, polygoidal cracking and the occurrence of gilgais.

Figure 6: Proposed Stage 2 Development Soils

Figure 7: Proposed Stage 2 Development Potential Acid Sulphate Soils



A.2.5 Groundwater

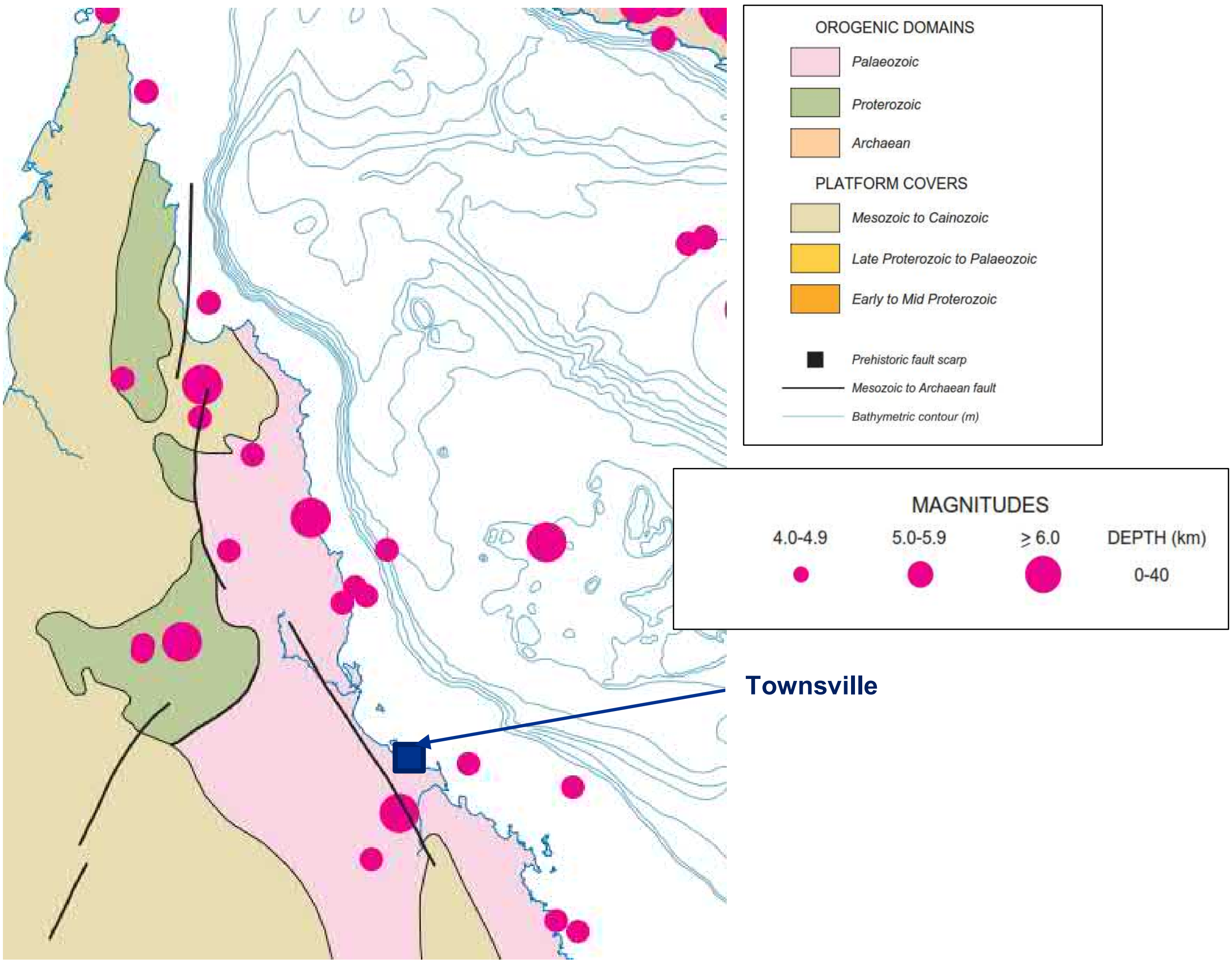
Groundwater for much of all the alignments is interpreted to be high even during the dry season, ie., approximately 1-2 m below present ground levels (see Plate 8). For the unlined existing Sunwater Main Channel, in many areas this has been constructed above the original ground level, and seepages for the channel base and sides could be occurring as evidenced by the encountering of “boggy” ground and water lying on the surface immediately at the western toe for significant sections (see Plate 1).

A.2.6 Seismology

Figure 8 indicates that in historic time an earthquake >6M may have occurred in relatively close proximity to the project area. However, the National Earthquake Hazard Map of Australia (2012) indicates the project area to lie approximately in the <0.01 g peak ground acceleration of a 1:500 chance of annual exceedance, ie., a low risk of a significant ground acceleration event occurring within the design life of the project. This is supported by the fact that the majority of Eastern Australia is categorised as being within an intraplate boundary. With this in mind, and the fact that only one potential minor fault may cross cut the proposed pipeline alignment, it is presently considered unlikely that a strong enough seismic event would occur within the design life of the project to impact significantly detrimentally on the proposed Stage 2 developments. With this premise no other consideration of ground acceleration on design elements for this project has been undertaken.

In later phases of the project it may be prudent to undertake a project site specific seismic assessment for the project to confirm this assumption.

Figure 8: Extract from Earthquake Epicentres in Australia 1841-2000 and Recent Fault Scarps (Geoscience Australia, 2004)



A.2.7 Potential Contaminated Land

Jacobs have undertaken EMR/CLR searches of the lots which the proposed pipeline will traverse (see Table 1). Two of the parcels are listed on the EMR register with the notifiable activities or hazardous contaminant listed as operating a livestock dip or spray race facility. However, for the majority of rural properties only a small area may be affected by the chemicals used in livestock dips and spray races. The Department of Environment and Science may hold further information relating to the location of the dip site within this property. Land parcel 22/GS1042 is 4,231 hectares in area. The proposed pipeline in this land parcel extends approximately 10km in length, and the proposed construction corridor is 40m wide. Therefore, the total area of the construction corridor in land parcel 22/GS1042 is about 4 hectares, which is less than 1% of the land area of this land parcel. Based on aerial photography interpretation of the proposed pipeline in this land parcel, there is no obvious evidence that indicates the existence of the livestock dip and/or spray race facilities adjacent to the proposed pipeline.

Table 1: EMR/CLR search results for land parcels within the proposed pipeline alignment

	Lot Plan	If on EMR/CLR register	Notifiable activities
1	22/GS1042	EMR	Livestock dip or spray race
2	1/AP3570	No	N/A
3	308/GS1041	EMR	Livestock dip or spray race
4	71/SP289517	No	N/A
5	3/SP302825	No	N/A
6	101/SP111327	No	N/A

	Lot Plan	If on EMR/CLR register	Notifiable activities
7	301/SP107466	No	N/A
8	1/SP302825	No	N/A
9	2/SP302825	No	N/A
10	3/SP302825	No	N/A
11	500/CP903751	No	N/A
12	41/CP903751	No	N/A
13	12/GS815	No	N/A

Based on the results of the historical images analysis, there is no other notifiable activities in this area with the exception of farming activities. Therefore, there is potential for contamination from chemicals such as organochlorine pesticides (OCPs) / organophosphate pesticides (OPPs), herbicides, nitrates, metals, nutrients, and carbamates to be present. This poses a potential risk to human health and the environment and should be assessed prior to construction. Given that the proposed pipeline alignment encounters limited cropping lands, the associated risks are considered low.

Based on Jacobs assessments the current assumption is that there is a low probability of contaminated lots within the proposed Stage 2 development areas. However, there could be the possibility that some isolated zones of contamination could exist.

A.2.8 Stage 1 Pipeline Geotechnical Observations and Findings

Under the escort of Townsville City Council and their Premise Construction Manager, Jacobs undertook a drive through of contracts 4 and 3 of the present construction of Stage 1 of this project. The observations of the present Stage 1 construction has provided some important insights into the ground conditions and their behaviour, practical construction methodologies (what may work and what may not work) and progress rates, possible environmental and Cultural Heritage considerations, and potential contractual issues. These findings have been used in the Stage 2 assessments.

The main summary points coming from Jacobs Stage 1 inspection, were as follows:

- The Stage 1 Pipeline Alignment has been subdivided into 4 x 9km packages – this was apparently done to allow local contractors to bid for the works;
- Package 4, the northern most is being constructed by NQ Excavations using both excavators and a trenching machine;
- Package 3 is being constructed by CivilPlus by excavators and includes a potentially significant volume of rock excavation;
- Package 1 and 2, will be installed by the use of large excavators;
- The 1.8m ID (1.9m OD) GRP pipe has been free issued for all packages of the 36kms of the Stage 1 pipeline; this was undertaken due to lead in times for pipe production and the likely significant disparity between tender prices; the pipe has been supplied from a company in Adelaide;
- Pipe fittings (rubber joints) have been supplied by local companies;
- The GRP pipe in water crossings has been further laminated presumably due to the issues of possible scour;
- The pipeline has a minimum of 900mm cover and 300mm of bedding material so the minimum construction trench depth is 3.10m, but this varies depending on ground level to achieve the required gradients;
- Backfill material is in the Stage 1 contract as per the relevant Australian Standard Table 2.0 with the bedding and backfill homogeneous; generally a single size aggregate (perhaps 5-10mm) for the pipe bedding and backfill material is being utilised, but increases size to fine to medium gravel for areas of potential scour where a geofabric is also laid over the pipe and the excavation;
- Generally all pipe trench excavated materials are being spoiled (to be removed as part of the contract by the construction contractor);
- Each water crossing is by trenching, but requires at each location 3 thrust blocks formed by 900mm diameter 4 x bored piles installed between 10-14mbgl (see Plate 7 and 9); this is presumed to be because of the use of GRP pipe and its buoyancy characteristics;
- For the piling of the thrust blocks each piling pad had to have a tri-geogrid installed for stability;
- Many areas of the thrust blocks have issues with high groundwater tables that seemingly have difficulty in being controlled by sump pumping (see Plate 8);
- The ground conditions seen in the thrust blocks and pipeline excavations were generally thin alluvial/colluvial deposits overlying thick volcanic Residual Soils/Extremely Weathered horizons that have good temporary stability (see Plate 7);
- The Stage 1 Pipeline contract was based on a 50m/day installation rate, it was reported that none of the contractors have reached this target and are were highly unlikely to meet this target;
- In general the pipeline corridor is approximately 40m wide including an allowance for a construction access road, which will be the permanent access road;
- The Haughton Pumping Station has a submersible pump with piled penstocks;
- The traverse under the existing QR line is by underbore with a considerable excavation and associated thrust wall and block arrangement required (see Plate 9); a 2.5m distance is between the crown of the pipe and the bottom of the ballast of the rail formation; the contract has stated maximum differential and total settlement targets; survey targets are set on probably the rail sleepers and read continuously with also provision in the construction contract for a certain amount of tamping of the ballast;

- Significant environmental issues include the endangered Black Throated Finch, which the Stage 1 Pipeline has spent over $2M on studies for the birds; noxious weeds is a significant issue as well; environmental approvals took 12 months to get for Stage 1 and included the provision that the original ground surface be maintained; and
- In terms of Cultural Heritage no Management Plan was produced but a formal agreement was made with the local Traditional Owners who had representatives on site during vegetation clearing and then in specific areas where the pipe was excavated.

Plate 7 Stage 1 Pipeline Thrust Block Excavation in Weathered Rock Sequences

Plate 8 Stage 1 Pipeline Thrust Block Excavation Water Filled

Plate 9 Stage 1 Thrust Excavation for QR Railway Underbore (Package 4)

A.3 Geotechnical Investigations

A.3.1 Previous Investigations

Through Jacobs external contacts, the Company has been able to secure a copy of the HMC geotechnical long sections between the original channel chainages of 4,000 to 33,700m, terminating within the vicinity of the existing Haughton Balancing Storage. These sections are based on a site specific geotechnical investigation carried for the design of the HMC and include a large number of test pits and shallow boreholes, undertaken at short intervals along the alignment. Jacobs have tried exhaustively to gain a copy of the original geotechnical factual and interpretive reports for this investigation, but have been unsuccessful in securing these documents.

The geotechnical long sections were produced by a local engineering consultant, McIntyre & Associated Pty Ltd in 1983, working for the Queensland Water Resources Commission (QWRC). McIntyre & Associated Pty Ltd were subsequently bought by AECOM, but unfortunately again Jacobs enquiries to AECOM's Townsville Office has not been successful in procuring the aforementioned geotechnical reports. In addition the QWRC is believed now to form part of Sunwater, who have also been contacted to secure these reports.

Securing the original geotechnical reports would be extremely useful in terms of the interpretation of potential ground conditions, definition of geotechnical design parameters and associated temporary and permanent works design and construction considerations. It is recommended that in later stages of this project that continued efforts to secure these documents should be made.

The present geotechnical long sections do provide the following useful information that has been considered in the geotechnical interpretation:

- Based on the long sections plan the investigations have been estimated to lie offset from the actual HMC being to the west of the existing channel and proposed pipeline (see Appendix A & B); it is likely that these investigations are further east from their present Jacobs interpreted location, but no additional information is presently available to confirm this;
- The historic test pits and boreholes were generally terminated at depths which either incorporate some, the majority or all of the final excavation levels for the proposed Stage 2 pipeline alignment (see Appendix B);
- The long sections provide a general stratigraphy of the Stage 2 pipeline alignment in terms of the origin of the soils, definition of alluvial cohesive and granular dominated soils, the occurrence of potential corestones within the more weathered rock sequences, and the definition of potential competent rock levels; what the sections do not provide are more detailed descriptions of soil and rock types encountered including their actual composition, consistency, secondary constituents, moisture content, plasticity and rock strength and rockmass discontinuity character and nature, as well as groundwater level data; it is believed that the vast majority of this more detailed information would be provided in the outstanding and previously mentioned geotechnical reports; this information would be extremely useful in providing more certainty/accuracy in defining ground conditions, geotechnical design parameters, temporary and permanent works, as well as related constructability aspects; and
- The sections provide useful information on the material suitability of potential excavated volumes for the HMC lining and embankment quality, as well as defining unsuitable materials; however the material definitions used at the time do not currently fit with the vast majority of the proposed Stage 2 requirements.

A.3.2 Project Specific Site Investigations

With reference to the assessment and related use of the previous HMC geotechnical investigations, Jacobs have designed and undertaken (in May 2019) an additional project specific geotechnical investigation. The scope of this additional investigation was designed taking into consideration the following factors:

1) The aforemention worth of the original HMC investigations; this can be further subdivided into:
    a) Filling the gaps between approximate Chainage 0 to 4,000m which was not covered by the original investigations;
    b) Undertaking investigations as a correlation tool against the HMC scope to provide more detailed descriptions of soil and rock types, composition, consistency, secondary constituents, moisture

content, plasticity and rock strength and rockmass discontinuity character and nature, as well as groundwater level data;

2) To investigate the proposed pumping stations and water storage facilities within the vicinity of the Burdekin and Haughton Rivers;
3) The need to investigate deeper subsurface levels at major road and creek crossings to evaluate potential pipeline traverse options;
4) The level of investigation required for a DBC, ie., for a reference design level;
5) The short time available between the definition of the optimum alignment and the required delivery time frames for DBC reporting;
6) The need to locate proposed investigations at sites which could be relatively easily accessed, ie., on or near existing tracks as far as possible;
7) The time available to liaise and secure access and permissions from landholders (Sunwater approval is still currently outstanding) and cultural heritage groups;
8) Availability of geotechnical drilling contractors; and
9) The weather and associated trafficking conditions for heavy plant and machinery.

The additional site specific geotechnical investigation completed is presented in Appendix C, while Appendix A and Table 2 set out the locations and reasons for each borehole and test pit undertaken.

Table 2: Project Specific Geotechnical Investigations

Investigation ID	Type	Easting (m)	Northing (m)	Depth (mbgl)	Purpose
JTP1	Test Pit	522781	7796526	3.4	Stage 2 Sedimentation Dam
JTP2	Test Pit	522816	7796168	2.4	For Gap Analysis
JTP3	Test Pit	522235	7796529	2.8	For Gap Analysis
JTP4	Test Pit	521965	7797058	3.5	For Gap Analysis
JTP5	Test Pit	521834	7797366	3.6	For Gap Analysis
JTP6	Test Pit	521250	7798266	2	For Gap Analysis
JTP7	Test Pit	520973	7798703	3.5	For Gap Analysis
JTP8	Test Pit	520582	7799239	3.5	For Gap Analysis
JTP9	Test Pit	520277	7799718	1.1	For Gap Analysis
JTP10	Test Pit	519470	7800260	1.4	Correlation with HMC investigations
JTP11	Test Pit	518841	7801109	3.2	Correlation with HMC investigations
JTP12	Test Pit	518115	7801316	1.3	Correlation with HMC investigations
JTP13	Test Pit	517621	7801412	0.95	Correlation with HMC investigations
JTP14	Test Pit	515032	7801363	1.3	Correlation with HMC investigations
JTP15	Test Pit	514577	7801397	1.75	Correlation with HMC investigations
JTP16	Test Pit	513823	7801830	1.4	Correlation with HMC investigations

Investigation ID	Type	Easting (m)	Northing (m)	Depth (mbgl)	Purpose
JTP17	Test Pit	512551	7802854	3.4	Correlation with HMC investigations
JTP18	Test Pit	511286	7804595	1.4	Correlation with HMC investigations
JTP19	Test Pit	511112	7805040	1	Correlation with HMC investigations
JTP20	Test Pit	511390	7806475	1.6	Correlation with HMC investigations
JTP21	Test Pit	510282	7808472	2.2	Correlation with HMC investigations
JTP22	Test Pit	510062	7810514	2.2	Correlation with HMC investigations
JTP23	Test Pit	509646	7812609	3.4	Correlation with HMC investigations
JTP24	Test Pit	509339	7814165	3.1	Correlation with HMC investigations
JTP25	Test Pit	509087	7815882	3.5	Correlation with HMC investigations
JTP26	Test Pit	508429	7818500	3.4	Keith Venables Road Crossing
JTP27	Test Pit	507947	7818884	3-5	For Gap Analysis
JTP28	Test Pit	507189	7819544	3-5	For Gap Analysis
JTP29	Test Pit	506925	7820088	3-5	For Gap Analysis
JTP30	Test Pit	506981	7820626	3-5	For Gap Analysis
JTP31	Test Pit	507607	7820629	3-5	For Gap Analysis
JTP32	Test Pit	507923	7820578	3-5	Possible Stage 2 Haughton Surge Tank
JTP33	Test Pit	508010	7820608	3-5	Stage 2 Haughton Balancing Storage
JBH1	Borehole	522734	7796602	19.58	Stage 2 Sedimentation Dam
JBH2	Borehole	522765	7796545	9.75	Stage 2 Sedimentation Dam
JBH3	Borehole	522814	7796451	18.44	Stage 2 Transfer Pumping Station
JBH4	Borehole	512265	7803040	9.95	Traverse of Ayr-Ravenswood Road
JBH5	Borehole	511518	7804152	9.76	Traverse of Creek
JBH6	Borehole	510896	7807858	9.6	Traverse of Creek and Main Track
JBH7	Borehole	509906	7809257	9.75	Major Creek Crossing
JBH8	Borehole	510259	7811103	10.95	Major Creek Crossing
JBH9	Borehole	509031	7817337	9.95	Major Creek Crossing
JBH10	Borehole	507946	7820654	20	Stage 2 Haughton Pumping Station
JBH11	Borehole	508017	7820577	10	Stage 2 Haughton Balancing Storage

Note – locations shown with yellow shading were in Sunwater property, within the vicinity of the Haughton River. Jacobs made exhaustive efforts to gain approval to access these locations but were unsuccessful.

No groundwater monitoring wells (piezometers) were installed in the drilled boreholes, because of the lack of time required to reach steady state groundwater levels.

Because of time restraints the generally associated laboratory testing from recovered samples from the investigations were restricted to the following areas:

- Assessment of general index properties;
- Assessment of ground aggressivity;
- Assessment of PASS; and
- Assessment of the sodic nature/potential of soils encountered.

A summary of the index soil tests results is provided in Table 3.

The factual results of the fieldworks and associated laboratory testing are presented in Appendix A & C, and the findings of this project specific investigation are also considered in the current geotechnical interpretation.

Table 3: Project Specific Geotechnical Investigations - Soil Index Laboratory Test Results

Investigation (ID)	Depth (mbgl)	Soil Type	Origin	MC (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class No.	PSD Soil
JTP1	0.8 to 1.0	CLAY	Alluvium	10	25	16	9	6	5	Silty CLAY
	3.1 to 3.2	Sandy CLAY	Alluvium	8	27	17	10	7	5	CLAY
JTP2	0.6 to 0.7	CLAY	XW	14	54	23	31	18	5	CLAY
JTP3	0.5 to 0.7	Sandy CLAY	RS						2	
	2.3 to 2.4	Sandy CLAY	RS	10	50	17	33	16	2	CLAY
JTP4	2.8 to 2.9	CLAY	RS	13	37	15	22	8	2	CLAY
JTP5	0.5 to 0.6	CLAY	RS	12	27	20	7	4	5	
JTP6	0.5 to 0.6	CLAY	RS	8					2	CLAY
JTP7	1.9 to 2.0	CLAY	RS	17	88	19	69	17	2	CLAY
JTP8	2.5 to 2.6	Sandy CLAY	XW	8	47	30	17	10.5	3	Silty SAND
JTP9	0.4 to 0.5	CLAY	RS	6	18	15	3	2	3	
JTP11	0.6 to 0.8	Sandy CLAY	RS	14	26	13	13	9	5	CLAY
JTP14	0.9 to 1.0	Sandy CLAY	RS	11	28	13	15	11.5	3	Sandy CLAY
JTP16	0.4 to 0.5	Sandy CLAY	Alluvium	14	21	13	8	7	5	Sandy CLAY
JTP17	0.6 to 0.7	CLAY	Alluvium	22					5	CLAY
	2.6 to 2.7	Clayey SAND	RS	10	30	16	14	10.5	6	Clayey SAND
JTP18	0.4 to 0.5	Silty SAND	Alluvium	2					3	Clayey SAND
	0.8 to 0.9	Clayey GRAVEL	Alluvium	8						Clayey sandy GRAVEL
JTP19	0.8 to 0.9	Clayey SAND	Alluvium	8	23	11	12	8	2	Silty CLAY
JTP20	1.3 to 1.4	Clayey GRAVEL	RS	8						Clayey SAND
JTP21	0.3 to 0.4	Sandy CLAY	Alluvium	15	22	17	5	3.5	5	CLAY

Investigation (ID)	Depth (mbgl)	Soil Type	Origin	MC (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class No.	PSD Soil
	2.1 to 2.2	Sandy CLAY	Alluvium	10	20	12	8	6	2	Clayey SAND
JTP23	0.5 to 0.6	Sandy CLAY	Alluvium	10	34	16	18	12.5	2	CLAY
	2.8 to 2.9	SAND	Alluvium	2					2	SAND
JTP24	2.6 to 2.7	Sandy CLAY	Alluvium	15	49	16	33	16	2	CLAY
JTP25	1.2 to 1.3	Sandy CLAY	Alluvium	13	42	21	21	15	2	CLAY
	2.7 to 2.8	Sandy CLAY	RS	14	41	18	23	14.5	2	CLAY
JTP26	0.3 to 0.4	CLAY	Alluvium	18	24	12	12	8	3	CLAY
JBH1	0.5 to 0.95	Silty CLAY	Alluvium						2	
	1.5 to 1.95	Silty CLAY	Alluvium	13	33	15	18	9	2	CLAY
JBH2	1.5 to 1.95	Silty CLAY	Alluvium	7					2	CLAY
JBH3	1.5 to 1.95	Silty CLAY	Alluvium	12					2	CLAY
	3.5 to 3.95	Silty CLAY	Alluvium	11						CLAY
	6.5 to 6.95	Silty CLAY	Alluvium	10						CLAY
JBH4	1.5 to 1.95	Silty CLAY	Alluvium	12					2	Silty CLAY
	5.5 to 5.95	CLAY	RS	17					2	Silty CLAY
JBH5	7.5 to 7.95	Clayey SAND	RS/XW	14					2	Clayey SAND
JBH6	1.5 to 1.95	Silty CLAY	RS	12	36	15	21	9		Silty CLAY
JBH7	1.5 to 1.92	Sandy CLAY	Alluvium	13					2	Sandy CLAY
	4.5 to 4.95	Clayey SAND	Alluvium	14					2	Clayey SAND
JBH8	1.55 to 1.92	Clayey SAND	RS							Sandy CLAY
	3.5 to 3.56	Sandy CLAY	RS						2	Clayey SAND
JBH9	0.5 to 0.95	CLAY	Alluvium	10					2	CLAY
	3.5 to 3.95	Sandy CLAY	Alluvium	18					2	CLAY

Notes :- RS = Residual Soil; XW = Extremely Weathered Material; orange denotes soils in excess of LS >7% threshold value & indicative of high shrinkage potential; red indicates soils with a dispersion potential.

A.4 Geotechnical Engineering Design and Related Construction Considerations

A.4.1 Ground Model

Based on the Desk Study and limited site specific geotechnical investigation, the following summary comments are made in relation to the published geology and soils information, and the related project specific ground model :-

- Colluvial or Residual Soils extend further to the north and west than the published soil maps indicate; apart from the proposed Clare Sedimentation Dam, Pumping & Pigging Station and Intake Structure (which have been found to be located within thick superficial deposits), alluvial deposits are not particularly prevalent over the proposed pipeline until beyond approximately Ch6,400m;

- Both alluvial and soils derived as part of the bedrock weathering sequence compose the vast majority of the pipeline trench excavations;

- High level (within the proposed pipeline excavations) potential competent rock was encountered in only 5 test pits excavated; these were generally believed to be of igneous origin;

- The thickness and composition of alluvial soils varies, but there is generally a lack of gravels, subordinate sand layers, with cohesively dominated soils making up these deposits;

- Generally all soils encountered within the recent geotechnical investigations have consistencies of very stiff to hard, however this could be a reflection of seasonal climatic and associated lower groundwater tables; these shear strengths also resulted in the termination of many test pits (excavated by use of a backhoe) above the intended investigation depths, such that the base levels of these investigations were above the intended final dig level of the proposed pipeline trench;

- No significant physical evidence of black or vertosol soils, was encountered over the indicated published northern sections of the proposed Stage 2 pipeline alignment; this was enforced by the generally low to medium plasticity of the soils encountered;

- The weathered and competent granodiorite sequence in and around the vicinity of the existing major Woodhouse rock cutting in which the HMC passes, was confirmed;

- There is only one isolated location (surface sample at JBH4) from the multiple tested samples, which indicate the presence of PASS encountered during the site specific geotechnical investigations;

- No significant physical evidence of sodic soils was encountered during the site specific geotechnical investigations (the exception being in areas of more trafficked unsealed tracks, creek banks and a farmer’s dam on the Sheahan Property); however, specific sodic laboratory testing undertaken (including high Exchangeable Sodium Percentages, low Exchangeable Calcium/Magnesium ratios and low Cation Exchange Capacity values) on recovered soil samples of Alluvium, Residual Soils and Extremely Weathered rock sequences indicate a sodic nature in approximately 40% of the samples tested; in addition, the Emerson Class testing completed (from subsurface profiles) suggests that more than 60% of the soils (all origins) may have a dispersive nature;

- No indication of any ground contamination was encountered during the site specific geotechnical investigation;

- No aggressive ground conditions for buried concrete and reinforcement, as well as the intended steel pipeline has been interpreted from the laboratory testing currently completed; and

- Only one of the project specific investigations encountered a groundwater strike (JTP20); this may again be a reflection of the lower groundwater table within the dry season; borehole drilling advance rates often are to quick to pick up groundwater levels, especially if casing is used to support the borehole sidewalls; for the purposes of this project specific ground model the worst case scenario of a high groundwater table is still believed to be valid in a wet season situation.

Appendix B provides a geological long section of the proposed pipeline alignment incorporating both original and project specific geotechnical investigations.

A.4.2 Major Crossing Potential Ground Conditions

As indicated in Section 4.2 additional site investigations have been undertaken for the proposed major crossings of the Stage 2 pipeline. Table 4 below provides a summary of the possible ground conditions that could be encountered at these crossings (note groundwater considered to be within 2m of the existing ground surface)

Table 4: Proposed Major Crossing Potential Ground Conditions

Proposed Major Pipeline Crossing	Type of Crossing	Approximate Chainage	Geotechnical Investigation Reference	Potential Ground Conditions
Ayr-Dalbeg Road & Cane Railway Crossing	Sealed Road and Narrow Gauge Railway	-230m	JBH1	Approximately an upper 9m of Alluvial stiff to very stiff silty CLAY with minor medium dense to dense clayey SAND interbeds, overlying at least 11m of Residual Soil to Extremely Weathered hard CLAY and dense to very dense clayey SAND
Deep Creek	Creek	1,900m	JTP5	>3.50m of Residual Soil very stiff to hard CLAY
Scotts Creek	Creek	12,400m	TP162	3.00m of Alluvial stiff to very stiff CLAY, overlying potentially competent bedrock
Ayr-Ravenshoe Road	Sealed Road	14,200m	JBH4	2.50m of Alluvial stiff to very stiff CLAY overlying at least 7.50m of Residual Soil to Extremely Weathered hard CLAY and very dense clayey SAND
Woodhouse Creek	Creek	15,600m	JBH5	1.80m of Alluvial very stiff CLAY overlying at least 8.00m of Residual Soil to Extremely Weathered hard CLAY and very dense clayey SAND
Unnamed Creek Crossing	Creek	19,600m	JBH6	1.50m of Alluvial loose to medium dense clayey SAND overlying at least 8.00m of Residual Soil to Extremely Weathered hard CLAY and very dense clayey SAND
Barratta Creek	Creek	21,400m	JBH7	5.00m of Alluvial soft to firm CLAY and loose to medium clayey SAND overlying at least 4.75m of Alluvial hard CLAY and very dense clayey SAND
Horse Camp Creek	Creek	23,400m	JBH8	0.65m of Alluvial stiff to very stiff CLAY overlying at least 10.0m of Residual Soil to Extremely Weathered hard CLAY and dense to very dense clayey SAND

Proposed Major Pipeline Crossing	Type of Crossing	Approximate Chainage	Geotechnical Investigation Reference	Potential Ground Conditions
Lagoon Creek	Creek	29,900m	JBH9	>10.00m of Alluvial very stiff to hard CLAY with minor interbeds of very dense SAND
Keith Venables Road	Unsealed Road	31,500m	JTP26	>3.40m of Alluvial very stiff to hard CLAY

A.4.3 Pipeline

Jacobs have had considerable experience in investigating, designing and supervising the construction of multiple pipeline projects. Based on this pool of knowledge Figure 9 sets out the main geotechnical risks that may be associated with projects of this type.

In relation to the proposed Stage 2 pipeline, Figure 10 provides an outline of the potential geotechnical considerations related to this project.

The following sections provide geotechnical considerations for the proposed pipeline, and are based on the following overall assumptions:

- The pipeline will be steel;
- The pipeline excavation depth will be generally 3.68mbgl (pipeline gradient is end-to-end 0.02%, but the minimum design grade applied in any one location is 0.1%; isolated short sections are approximately 7%); and
- The pipeline will be installed on a 0.50m sand or rockfill bedding material.

A.4.4 Excavatability

Pipeline excavatability is often a subjective view point, with either different interpretations of similar criteria used and/or differing approaches employed.

As previously indicated, the assumption at this stage of the project is that trench excavation will be undertaken by use of excavators rather than the application of trenching plant (an example is presented in Plate 10).

- Based on an assessment of historic geotechnical investigations carried out for the HMC and the recent project specific investigations, Free Digging then Hard Digging required for Alluvial deposits overlying Residual Soils/Extremely Weathered Rock (with or without corestones) – 10,621m or approximately 31% of the proposed pipeline alignment; and
- Free Digging and then Ripping required for Alluvial deposits overlying competent bedrock – 2,891m or approximately 9% of the proposed pipeline alignment.

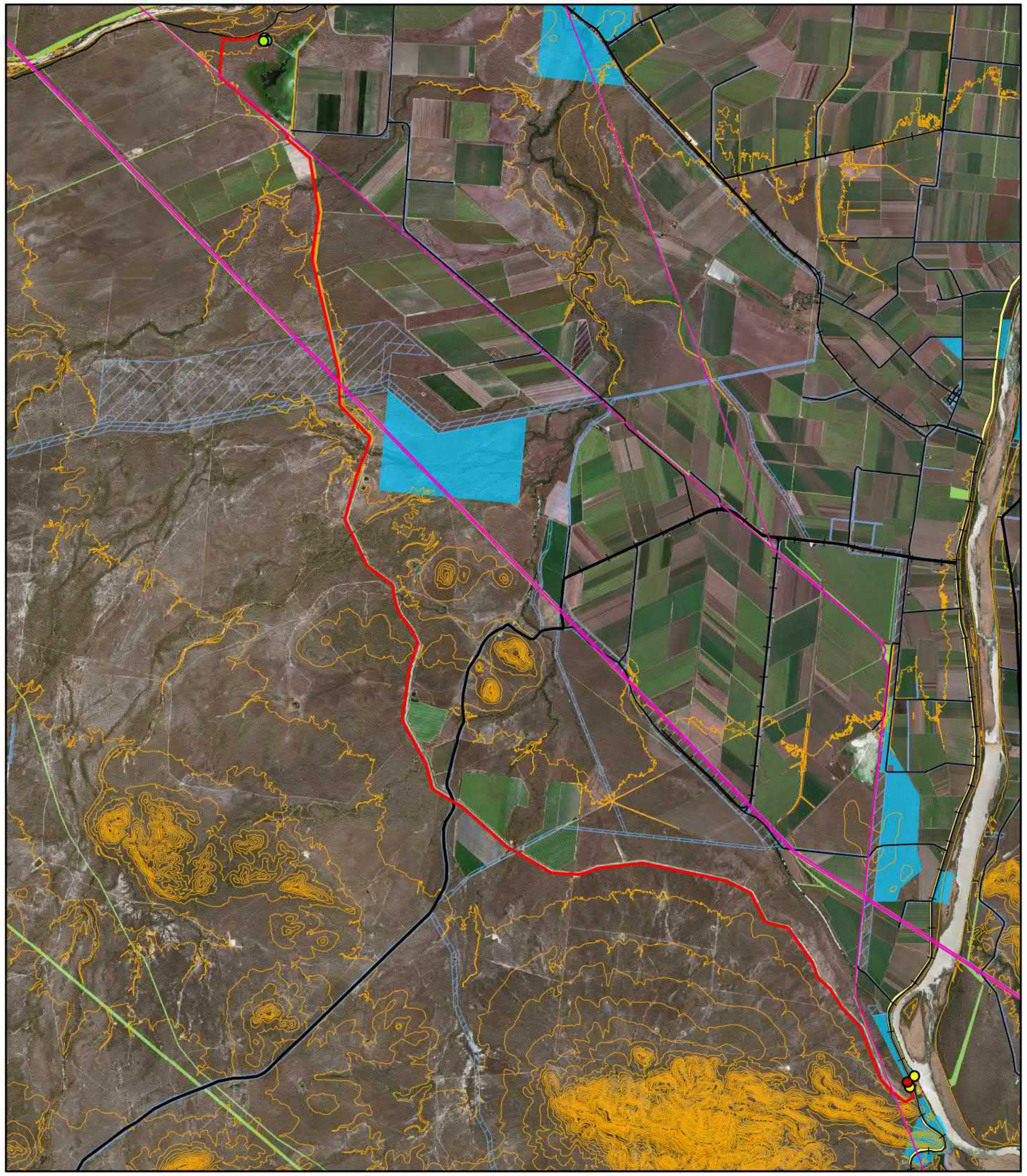
Table 5 below provides a preliminary assessment of the ground conditions relative to possible construction methodology for the proposed Stage 2 pipeline alignment. It should be noted that for the recent investigations a backhoe with a 600mm wide tooth bucket was used to excavate the test pits.

Based on the above assessments, provisional summary totals in terms of excavation are:

- Free Digging totally within Alluvium – 17,927m or approximately 51% of the proposed pipeline alignment;
- Hard Digging then Ripping required within Residual Soils/Extremely Weathered Rock overlying competent bedrock – 2,669m or approximately 9% of the proposed pipeline alignment;

Figure 9: General Geotechnical Considerations for Pipeline Installations

Figure 10: Main Geotechnical Aspects of Proposed Pipeline



Main Geotechnical Aspects of Proposed Pipeline that could affect cost and program:

- Ease of excavation (free dig, ripping, blasting ?) – especially around Woodhouse and Mount Dalrymple
- Necessary temporary works for trench stability (dewatering, trenching boxes, sheet piling, laying back cut slopes)
- The reuse of excavated material within other project works, or spoiling and backfilling with imported materials
- The availability of large volumes of appropriate imported backfilling material
- The potential sodic and Acid Sulphate nature of insitu soils that may be encountered by project works, and the associated necessary remedial measures required to deal with these characteristics
- The potential impacts of pipeline installation in relation to the existing Sunwater HMC
- The methodology of pipeline installation for existing sealed and unsealed roads, cane railways and major creek crossings (trenchless or in trenches) to minimise environmental and stakeholder/community disturbance
- The potential need to deal with pipeline buoyancy and/or scour across wide alluvial floodplains
- The availability and/or required processing of excavated materials for lining of the proposed sedimentation and storage dams
- The foundations for the proposed pumping (include the Burdekin intake structure) and pigging stations
- Aggressivity of subsurface conditions to steel and concrete

- Free Digging then Hard Digging required for Alluvial deposits overlying Residual Soils/Extremely Weathered Rock (with or without corestones) – 10,621m or approximately 31% of the proposed pipeline alignment; and

- Free Digging and then Ripping required for Alluvial deposits overlying competent bedrock – 2,891m or approximately 9% of the proposed pipeline alignment.

Table 5: Provisional Assessment of Pipeline Excavatability

Chainage Start(m)	Chainage Finish (m)	Total Linear Length (m)	Potential Ground Conditions	Potential Excavation Method*
0	80	80	Thick Residual Soils/Extremely Weathered Rock overlying competent bedrock	Digging and Ripping required at depth
80	164	84	Thin Residual Soils/Extremely Weathered Rock overlying thick competent bedrock	Digging and Ripping required for most of the excavation
164	6,400	6,316	Thin colluvium or alluvium overlying thick Residual Soils/Extremely Weathered Rock with corestones	Digging with production rates decreasing with depth & possible Ripping required in places (especially between Ch4,600 & 6,000m)
6,400	7,620	1,220	Alluvium	Free Digging
7,620	9,090	1,470	Thin Alluvium overlying thick Residual Soils/Extremely Weathered Rock with corestones	Digging with production rates decreasing with depth
9,090	9,370	280	Thin Alluvium overlying thick competent rock	Digging and Ripping required for most of the excavation
9,370	9,665	295	Thin Alluvium overlying thick Residual Soils/Extremely Weathered Rock	Digging with production rates decreasing with depth
9,665	9,810	135	Thin Alluvium overlying thick competent rock	Digging and Ripping required for most of the excavation
9,810	9,992	182	Thin Alluvium overlying thick Residual Soils/Extremely Weathered Rock	Digging with production rates decreasing with depth
9,992	10,267	275	Alluvium	Free Digging
10,267	10,937	670	Thin Alluvium overlying thick Residual Soils/Extremely Weathered Rock with corestones	Digging with production rates decreasing with depth
10,937	11,250	317	Alluvium	Free Digging
11,250	12,070	820	Alluvium overlying Residual Soils/Extremely Weathered Rock & then competent bedrock	Digging and Ripping required for 50% of the excavation
12,070	12,396	226	SCOTTS CREEK - Alluvium	Free Digging
12,396	12,406	10	Thin Alluvium overlying thick competent rock	Digging and Ripping required for most of the excavation

Chainage Start(m)	Chainage Finish (m)	Total Linear Length (m)	Potential Ground Conditions	Potential Excavation Method*
12,406	12,800	394	Alluvium	Free Digging
12,800	13,105	305	Thin Alluvium overlying thick Residual Soils/Extremely Weathered Rock with corestones	Digging with production rates decreasing with depth
13,105	13,937	832	Alluvium	Free Digging
13,937	14,205	68	AYR-RAVENSWOOD ROAD – Thick Alluvium overlying thin Residual/Extremely Weathered Rock	Digging with production rates decreasing with depth
14,205	14,400	195	Alluvium	Free Digging
14,400	14,600	200	Thick Alluvium overlying thin Residual/Extremely Weathered Rock and corestones	Digging with production rates decreasing with depth
14,600	15,440	840	Alluvium	Free Digging
15,440	15,825	385	WOODHOUSE CREEK - Alluvium overlying Residual/Extremely Weathered Rock	Digging with production rates decreasing with depth
15,825	16,271	446	Thin Alluvium overlying thick competent rock	Digging and Ripping required for most of the excavation
16,271	17,140	869	Alluvium overlying competent rock	Digging and Ripping required for most of the excavation
17,140	19,645	2,505	GRANODIORITE CUTTING – Thick Residual Soils/Extremely Weathered Rock overlying bedrock	Hard Digging from surface and then ripping at depth required
19,645	20,760	1,115	Thin Alluvium overlying thick Residual/Extremely Weathered Rock with corestones	Digging with production rates decreasing with depth
20,760	21,400	640	BARRATTA CREEK - Alluvium	Free Digging
21,400	22,060	660	Alluvium overlying competent bedrock	Digging and Ripping required for 10% of the excavation
22,060	26,400	4,340	Alluvium overlying Residual/Extremely Weathered Rock	Digging with production rates decreasing with depth
26,400	26,555	155	Alluvium overlying competent bedrock	Digging and Ripping required for 50% of the excavation
26,555	35,174	8,619	Including LAGOON CREEK – Alluvium	Free Digging

Notes :* Assessment based on acceptable productive rates using at least a 20 tonne excavator with a toothed bucket

Of special note is that based on the ground interpretation no blasting is considered required for any section of the proposed excavations, and although competent bedrock corestones of up to 5m in dimension could be encountered within the excavated profile, it is presently interpreted that these could be effectively ripped at acceptable production rates.

Plate 10 Typical Trenching Machinery Used in Large Diameter Pipeline Installation

A.4.5 Reuse of Excavated Material and Pipeline Backfill Materials

At present it is interpreted that the vast majority of excavated materials will not be used as pipeline backfill materials for the following reasons:

a) Most of the pipeline will be in alluvial deposits that will be variable in composition and consistency with cohesive materials interbedded with granular materials and therefore difficult to segregate;

b) Much of the excavated soils may have a sodic nature, which would require significant costs to render usable (lime or gypsum dosing or additional significant drainage controls);

c) Table 4 suggests that many of the proposed excavated volumes may have a high shrinkage potential;

d) With a high water table, probably within 2m of the existing ground surface, the excavated materials will have a high moisture content and require drying out before being potentially used in backfilling, within generally only a 40m wide corridor (and perhaps 20m at creek crossings) very little room is available to construct the works, and no room is interpreted to be available to stockpile spoil material and/or to spread it out for reprocessing/drying out, before being potentially used as backfill material;

e) It's unlikely that it is going to be practical to keep large lengths of excavated trench dewatered throughout the construction and pipeline installation process, therefore it is likely that during backfilling of the trench a highwater table would be re-established; in this event trying to place cohesive material at the right moisture content and related required compaction density is considered to be impractical.

With the above considered, spoiling of the excavated trench materials is deemed the most practical approach with the use imported granular backfill (a similar approach is being used for Stage 1). ASS related testing indicates a low PASS possibility for potential excavated material, therefore no specific associated lime dosing treatment has been considered. The granular backfill underwater will self-compact.

A considerable amount of imported granular backfill material (perhaps in the region of 800,000m^3) will be required. Enquiries at the local Clare BQC quarry to produce pea gravel (5mm gravel) as a uniform backfill material have indicated a significant and uneconomic cost. In Jacobs experience this is not atypical for the cost of producing anything <10mm aggregate from a commercial quarry.

A feasible alternative to using pea gravel could be the use of sand from commercial quarries/extraction licenses on the Burdekin River and/or Don River, with both rivers being self-replenishing (which is environmentally sustainable). Based on the potential required volumes multiple sources may need to be used.

Another alternative to sand could be the use of crusher dust, which is a by-product of general quarrying processing. The use of these materials would require careful control of the fines content (ie., <10% passing the 475 micron sieve and a PI <5%) but this could be done by appropriate screening by quarries to potentially produce a sand based product for backfilling pipeline trench purposes at a potentially relatively cheap cost with the added benefit of reducing waste at the quarries. With this in mind, apart from the BQC Quarry at Clare the below list of quarries, within the vicinity of the project and Townsville area, have been previously dealt with by Jacobs personnel, and could be potential sources of crusher dust:

- Roseneath (Holcim);
- Black River;
- Pinnacles; and
- Manton.

In terms of materials for the proposed Sedimentation and Balancing Storage Dams (clay lining) and general levee banks or low embankment fills, sufficient materials may be available from the required project excavations, but again would require careful segregation of pipeline trench spoil and drying out.

Roadbase for the access road and/or drainage/scour rock materials could again be sourced from the ripped rock horizons within the pipeline trench excavations, but again it could be more cost effective in obtaining these materials from the QGC Clare Quarry.

A.4.6 Design of Pipeline Open Trench Excavation

As previously indicated the general final dig level of the proposed pipeline trench will be 3.68mbgl. Taking into consideration the assessed ground conditions (and excluding creek/road and rail crossings), and the general 40m wide corridor, Figure 11 sets outs the general approach of the open excavated trench. This design incorporates three single batter sections (laid back on 1:1) with intermediate benches. The stability of this design will involve effective dewatering of the excavation.

It is envisaged that the pipeline excavations would be over a number of fronts with a limited open trench length to reduce overbreak and a feasible effective dewatering strategy.

A.4.7 Proposed Creek, Road and Rail Crossing Approach

With the use of a steel pipe, this has negated the requirement for significant thrust blocks to be used for creek/road crossings, which are being used for the GRP pipeline for Stage 1 (see Plates 7 and 9).

A variety of trenchless techniques have been assessed for these pipeline crossing types, taking into consideration environmental, community, technical practicality and construction costs and program.

The diameter of the pipe coupled with traverse/crossing lengths does not lend itself to horizontal directional drilling techniques (HDD). The drive length and the probable need for ground treatment is not advantageous for both pipe jacking and/or mini-TBM construction methodologies.

The optimum crossing solution has been deemed to be open trenching, as per the Stage 1 approach. However, to reduce potential adverse environmental impacts, it is proposed that the working corridor be reduced to a 20m width, and the excavation will be supported by sheet piling (see Figure 12).

To minimise both potential environmental and community impacts, these types of crossing could be undertaken during the winter dry season, outside of cane harvesting, and potentially at night for the sealed road traverses.

Figure 11: Proposed General Pipeline Excavation Design

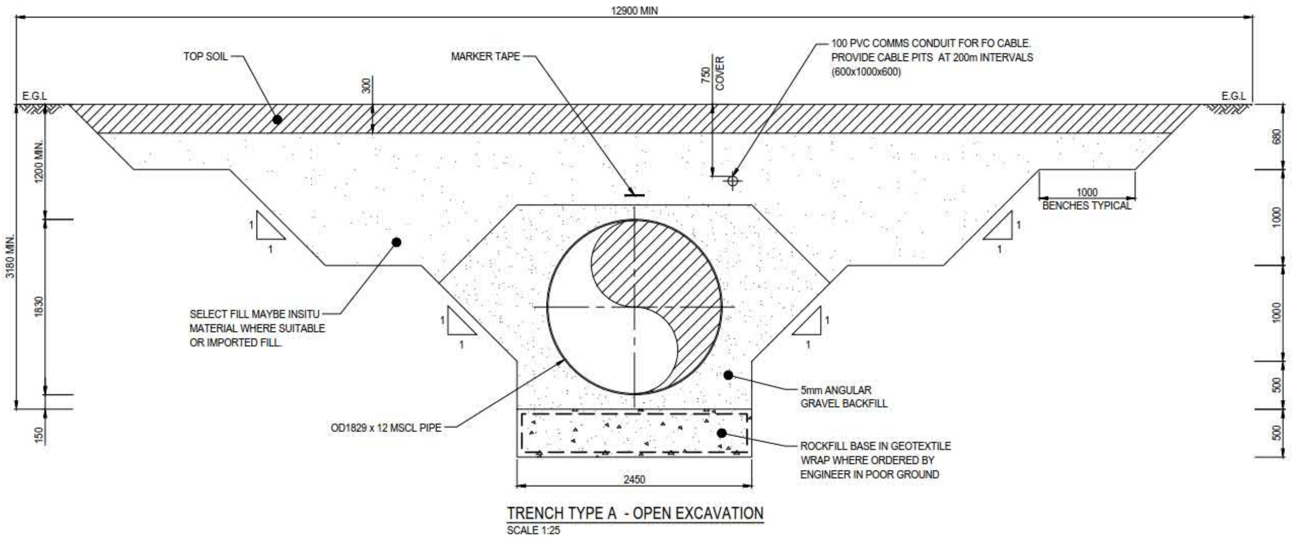
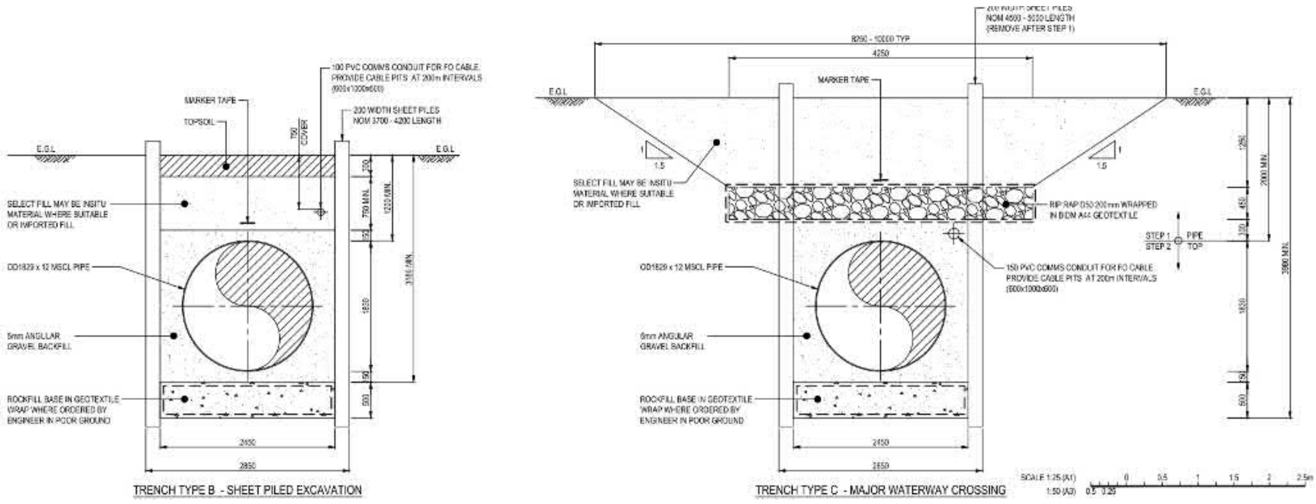


Figure 12: Proposed Soft Ground, Road, Rail and Creek Crossing Pipeline Excavation Design



A.4.8 Potential Pipeline Trench Temporary Works

Effective dewatering of both the general open trench and specific crossing excavations will be critical in both achieving acceptable temporary stability, and the overall construction progress. Effective dewatering may be an issue for Stage 1 (see Plate 8).

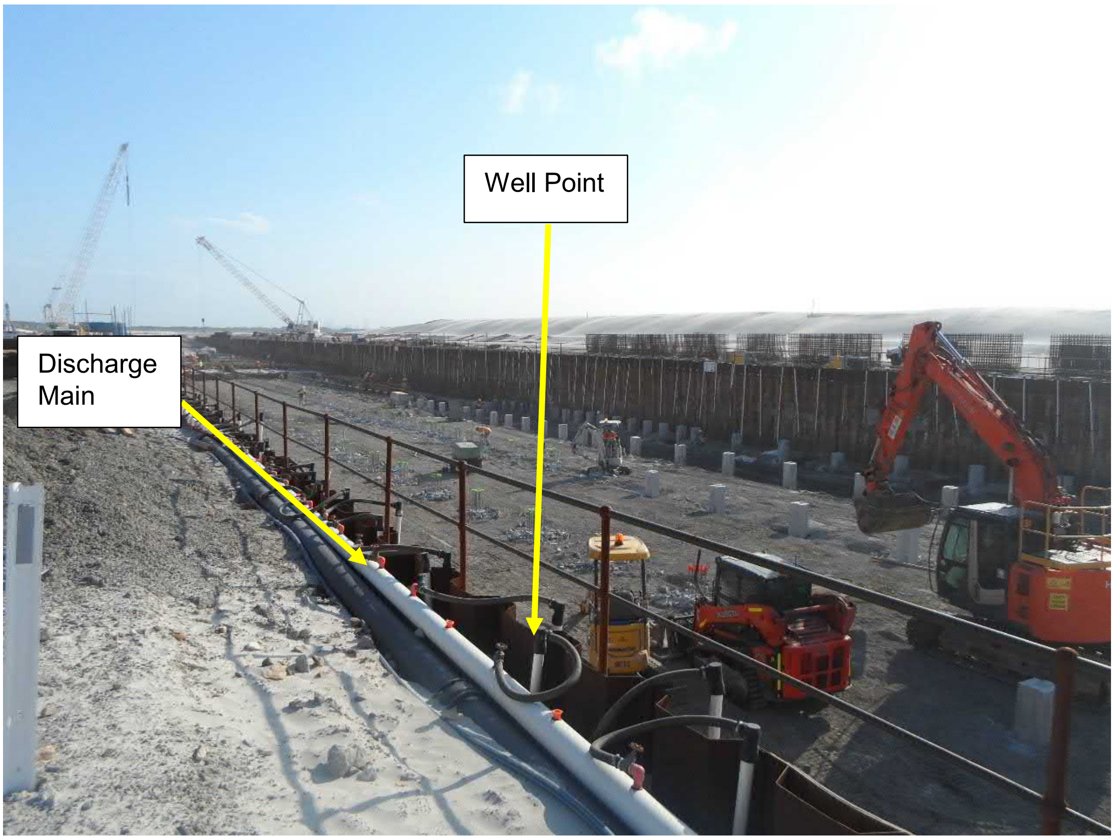
As previously indicated it is envisaged that a number of working fronts would be used for pipeline excavation. These excavations would probably require a well point system (see Plate 11), potentially coupled with local sump pumping, to efficiently draw down the groundwater table. The derivation of an effective well point dewatering system will rely on trials due to the variability of the soils within the proposed pipeline excavations.

It is assumed that the pump groundwater is not contaminated, its quality is not affected by ASS and it can be discharged into the existing surface courses through a v-notch weir system to remove the required sediment load.

It could be the case that on installation of the bedding material the dewatering could be backed off to allow the groundwater table to recharge and rise within the excavation. This would provide the potential advantages of:

- Providing a self-densification of hydraulically placed granular backfill material; and
- Potentially allowing the easier installation of welded and stringed pipe sections by towing within the trench.

Plate 11 Example of Well Point Dewatering System with Sheet Piling Retained Excavation



A.4.9 Potential Pipeline Buoyancy

Buoyancy of pipelines within the alluvial floodplains with high groundwater tables can be a significant issue, but is dependent on also the depth of pipe below ground level, backfilling material type and specification and the actual pipe material type. The use of Stage 1 GRP requires the aforementioned significant thrust blocks for restraining this pipeline.

For the Stage 2 pipeline the use of steel pipes negates the need for such restraints. However, there could be a requirement to restrain the pipeline at section valves. Here the alternatives that could be used include:

a) Concrete linings (see Plate 12);

b) The use of sand bagging; or

c) The use of geotextile wrapping (see Figure 13).

A.4.10 Potential Scour Considerations

Within the main creek crossings, an upper protection layer of rip-rap rock over the pipeline crown has been designed to minimise any detrimental effects of scour from flood events (see Figure 13).

This is seen as the most cost effective and environmentally sensitive approach to potential scour issues. The other alternative considered was that of concrete lining (see Plate 12), but this was dismissed generally based on cost impacts.

A.4.11 Dealing with Reactive and Sodic Soil Potential Issues

Although the limited site specific geotechnical investigations undertaken in the northern sector of the proposed pipeline alignment do not suggest it, there remains the possibility that reactive cracking clays could be encountered in this area (see Figure 6), which may have a high potential for shrink-swell, as well as being extremely difficult for plant to traffic over when wet. Again, moisture control of these soils will be extremely important for successful backfilling with possibly the need for the addition of lime. The high swelling pressures that could generate on wetting of these soils beneath the pipeline invert (see Plate 13), could require either a deeper dig out and replacement with inert soils or the use of sandbags, concrete linings or geotextile/fabric wrapping/the use of soil pillows (see Figure 13).

As indicated, based on Jacobs current interpretation of the character of the encountered northern sector soils, there is a low probability for excessive shrink-swell to occur. In this respect, it is interpreted that there is no current need to employ specific measures to deal with potential uplift pressures on the proposed pipeline.

Plate 12 Typical Concrete Lined Steel Pipes for Scour Protection Purposes

Plate 13 Example of Reactive Soils at Pipeline Inverts

Figure 13: Potential use of Geotextile Wrapping/Soil Pillows to Restrain Pipeline Uplift

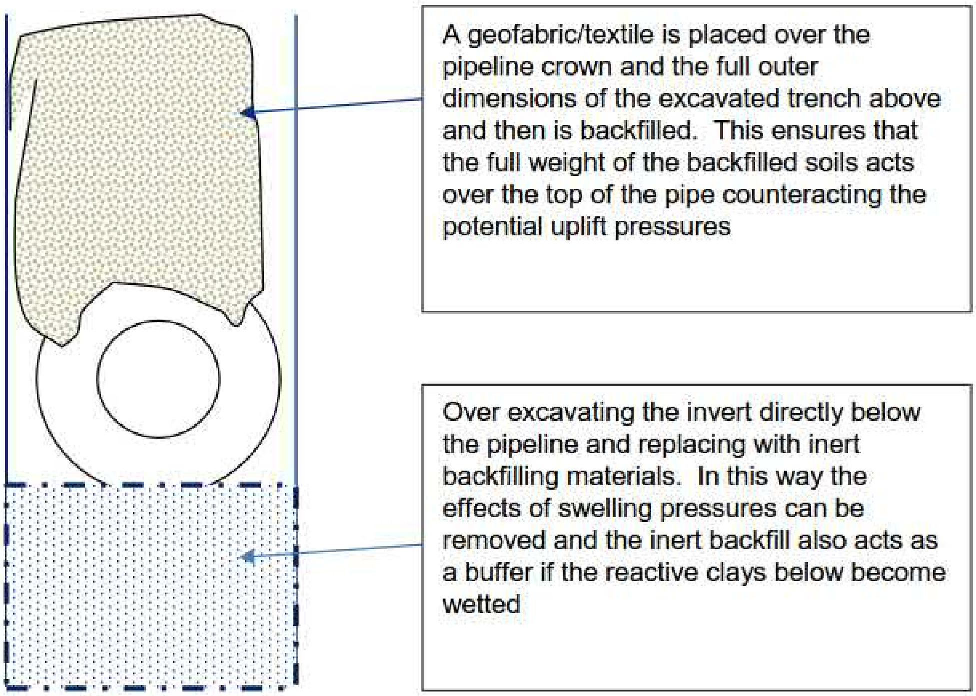


Figure 6 and Section 2.4 indicate the potential high possibility of encountering sodic soils over the proposed Stage 2 pipeline alignment. The effects of such sodic dispersive potential on pipeline temporary and permanent works, as well as the possible measures required to reuse these type of soils for fill materials are significant considerations (see Plates 14 and 15).

Current indications from Jacobs observations, along and within the vicinity, of the proposed pipeline alignment, as well as limited laboratory test results from the site specific investigation, suggest that exposed soils may have a mild dispersive characteristic.

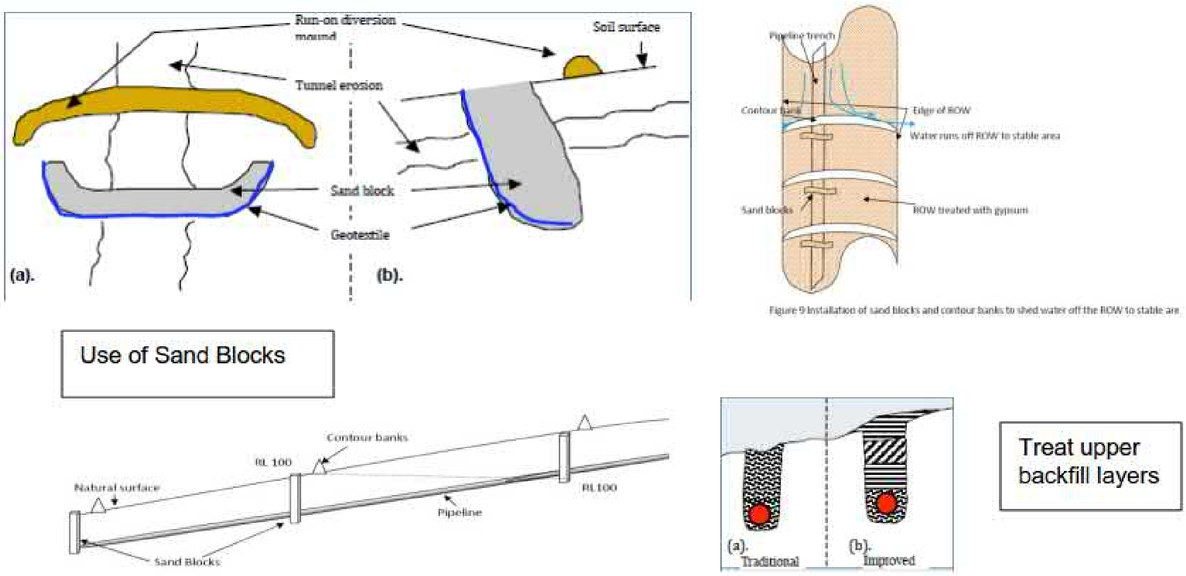
If the type soils were considered as reuse within project works a variety of approaches may be required for this to be enabled, including:

- Additional drainage control measures;
- Using a non-reactive covering over the surface of the pipeline;
- For cohesive dominated backfill soils treat the upper 300-500mm by mixing with potentially between 2 to 5% by weight of gypsum (see Figure 14) - the calcium will replace the sodium minerals and improve soil permeability and allow water to pass through this layer without erosion occurring – in addition the mixed zone needs to be carefully compacted;
- For granular dominated backfill soils install a geotextile 300-500mm below ground surface and then replace with the excavated soil – the geotextile will act as a barrier in this case; and
- Installing sand blocks or barriers across/around proven tunnel prone areas (see Figure 14).

Plate 14 Piping Erosion of Sodic Soils Within Open Pipeline Excavations

Plate 15 Typical Tunnel Erosion of Over Pipeline Backfilled Alignments

Figure 14: Potential Control Measures for Pipeline in Sodic Soils



As it is intended to backfill the pipeline trench with imported inert granular materials (which will not have a sodic nature) the issues of tunnel erosion should be negated. To minimise the potential effects of piping erosion within the exposed pipeline trench it is recommended that backfilling to ground level should occur as soon as practically possible. This approach should fit in with the proposed multiple fronts and short lengths of trench excavation, allied with dewatering, and backfilling strategy previously indicated.

A.4.12 Ground Aggressivity

Aggressive (acidic) soil and groundwater conditions in terms of fabric attack to buried concrete, reinforcement or steel pipes may have a significant impact on cost and durability overtime. If such conditions exist then concrete cover to reinforcement may be required to be increased and or specific concrete mixes may be required. In addition, sacrificial thicknesses for the steel pipeline or cathodic protection could be warranted.

Soil pH, sulphate and chloride testing undertaken on various soil samples from differing depths and origins, from the site specific geotechnical investigations, as well as the low PASS possibility, suggest non-aggressive conditions for the steel pipe and buried concrete & reinforcement. Indications of infrastructure durability within the vicinity of the project do not suggest that corrosion, and therefore the presence of aggressive subsurface conditions, are a significant risk. Therefore, at present no additional measures for dealing with aggressive ground have been considered.

A.4.13 Proposed Pipeline Excavation Effects on Existing HMC

From the Jacobs walkover survey undertaken of the existing HMC, the following impressions of the stability of the Main Channel were concluded:

- The channel sides have been cut in places at 1:1 not at the design of 1v:2h;
- The channel width varies along with the flow velocities;
- When the vegetation dies out the Main Channel banks and the levee banks slopes do experience both piping and rill erosion; in some places (around the middle of the alignment) the Main Channel banks are rock armoured;
- There is little room either side of the channel and at the toe of the levee bank with seepage/leakage from the Main Channel and drainage shedding resulting in very wet conditions (see Plate 1); these wet conditions were a significant determining factor in not considering installing the proposed Stage 2 pipeline at this location (in terms of time and cost, and for potential adverse effects on the existing stability of the Main Channel side slopes);

- No major global or even relatively shallow slope stability issues were identified in relation to the channel and levee banks;
- The rock cutting (within the vicinity of Woodhouse) in which the current Main Channel passes through is not a great distance and rocks are weathered Granodiorites which seemed to have been effectively ripped; here the channel is concrete lined for a significant distance and is narrower; and
- Seemingly where the gradient of the Main Channel is at its lowest and the channel width is at or closest to its greatest weed development and sedimentation have occurred.

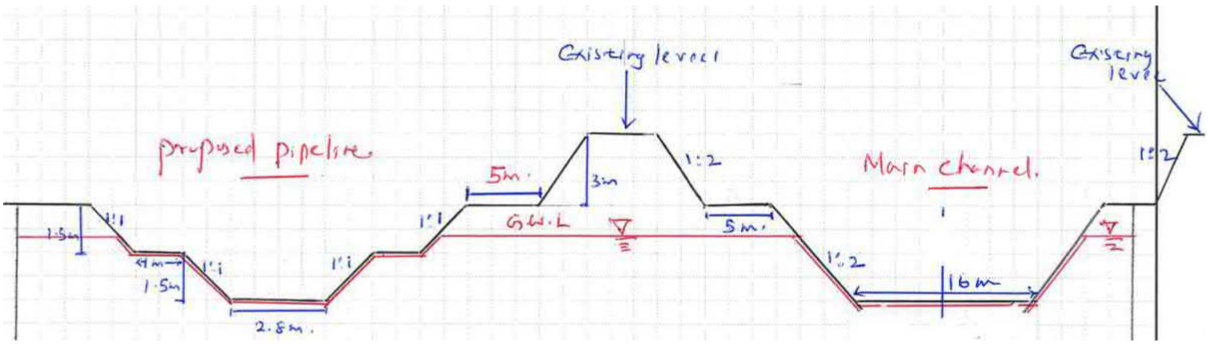
As part of the geotechnical assessment for this project Jacobs have undertaken a series of stability analysis to try and ascertain the potential impact of constructing the proposed Stage 2 pipeline on the existing HMC. This analysis was primarily to determine what was the critical distance west of the toe of the existing HMC which would not adversely affect its present stability.

Appendix D sets out the design parameters (drained and undrained) used in the analysis based on a variety of ground conditions (8 differing ground models have been used) and groundwater levels that may be present (with due consideration of the historic HMC geotechnical investigations). The analysis was also based on a 3.0m deep benched proposed pipeline trench excavation, a general width of the HMC, the water table being drawn down by dewatering to the base of the proposed excavation, and a distance of 5m between the toe of the HMC and top of the proposed pipeline trench excavation (see Figure 15). In addition, the following worst case defined scenarios were also employed in the analysis:

- The Main Channel was considered empty during the two week yearly shut down, ie., the confined pressure of water on the channel slopes did not exist; and
- A 15kPa surcharge was applied between the edge of pipeline excavation and the bottom of the Main Channel levee toe to mirror heavy plant being used during construction.

A summary table of the stability analysis and plots for the SLOPEW runs are also provided in Appendix C.

Figure 15: Worst Case Scenario of Proposed Pipeline Installation Relative to the HMC



Using the worst case conditions the stability analysis indicates low Factors of Safety (FoS) for the Main Channel existing slopes, and unacceptable for permanent works (FoS ≥1.5, and some cases well below unity (FoS=1)), where the upper soil horizons (top 2m) are composed of loose to medium dense/dense sands. Jacobs have discounted these based on the fact that there are no shallow or deep seated failures have been seen of the Main Channel slopes. In addition, for 50 weeks of the year the worst case of an empty HMC does not apply.

If it is considered that the actual proposed pipeline is now planned to be excavated approximately >40m away from the toe of the HMC then the likelihood of adverse impact on the HMC is considerably reduced to negligible.

A.5 Structural Foundations

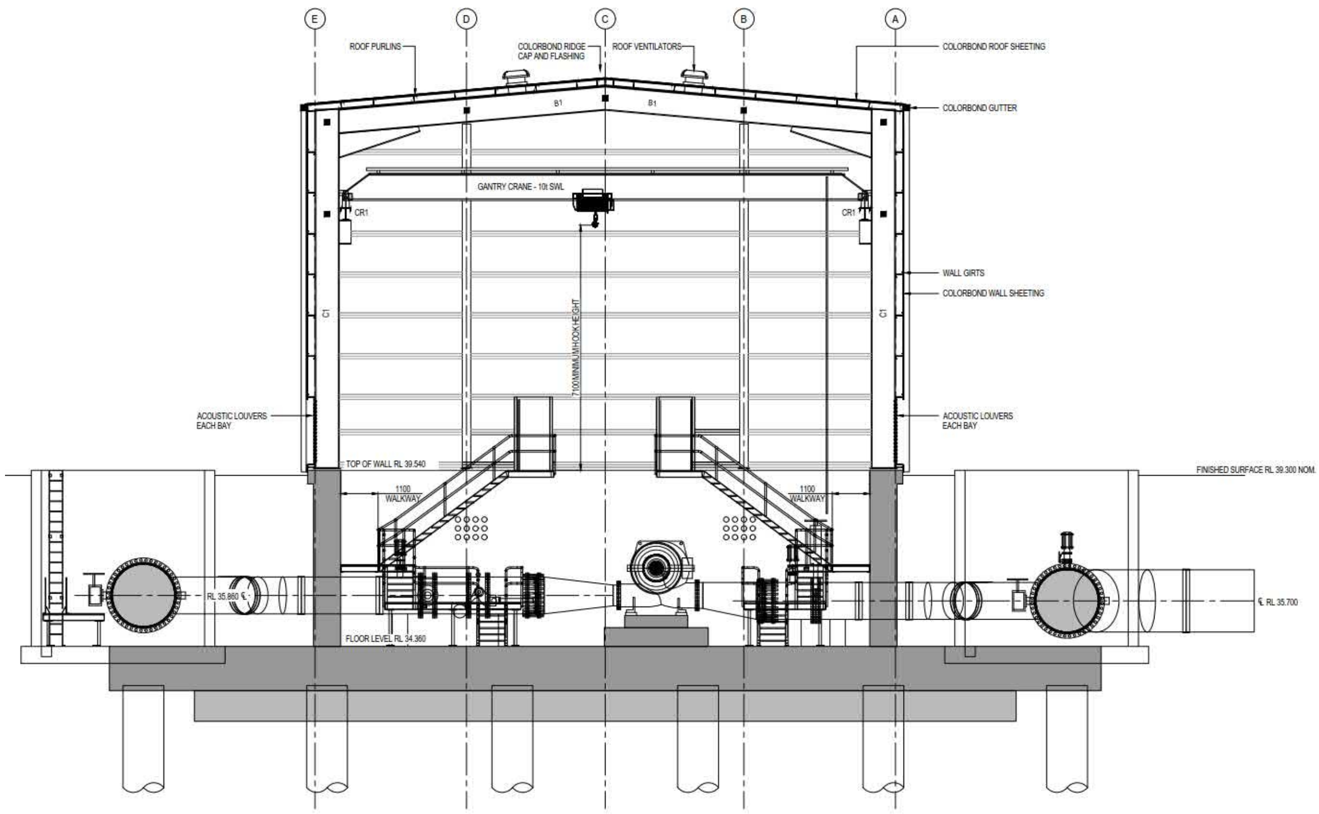
A.5.1 Pumping Stations

Similar pumping stations layouts and loads are currently envisaged for both the Burdekin and Haughton River locations. A general layout of these facilities is provided in Figure 16 and Figure 17, while Plate 16 presents the current Haughton Pumping Station, which may provide an impression of what these structures may look like.

Due to the probability of encountering deep rockhead at both of the proposed pumping station locations (noting that the recent site specific investigations (borehole JBH3 at the prosed Clare Pumping Station site, drilled to 18.41mbgl) did not encountered competent rock, and the likelihood of improving density/shear strength of both alluvial and weathered rock sequences with depth (as indicated by the recent investigations), driven 1.2m diameter concrete piles driven provisional to 15mbgl, have been considered as appropriate for both acceptable load and associated settlement criteria.

At the proposed Burdekin pumping station an intake along the similar lines of the existing Sunwater Tom Fenwick elevated intake structure (see Plate 17) is required. This is proposed to encompass a 20m high intake shaft structure, supported nominally by 1.20m diameter vertical concrete or steel driven piles driven to 25m below current river bed level, which have been considered as appropriate for both acceptable load and associated settlement criteria. This intake shaft will be connected by a series of pipes carried on an access bridge deck (also used for pedestrian and vehicle access) supported by 1.2m diameter steel or concrete driven vertical and raking piles driven to a nominal termination depth of 20m below river bank level. Figure 18 and Figure 19 provide provisional layout, geotechnical design parameters and foundation details for this intake structure and associated bridge deck.

Figure 16: General Layout, Elevation & Foundation Details of Proposed Pumping Stations



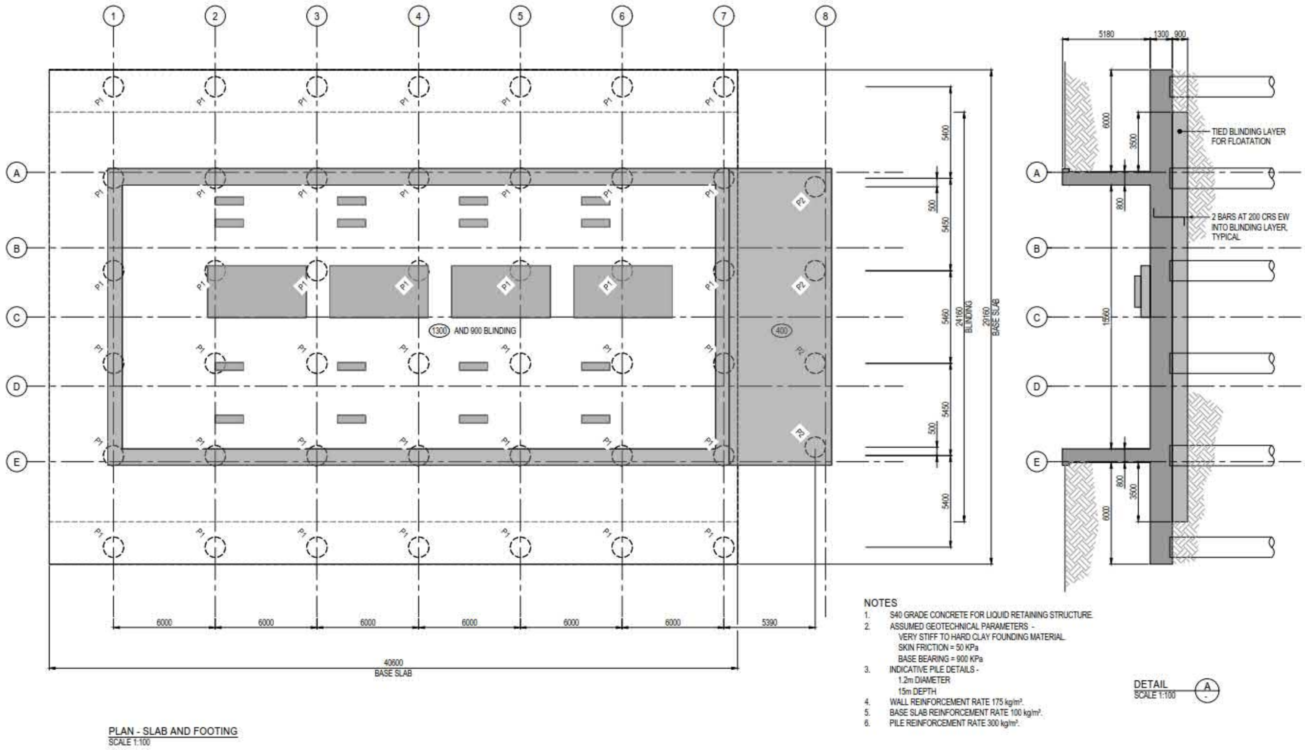


Plate 16 Existing Haughton River Pumping Station

Figure 17: Proposed Pumping Station Floor Plan

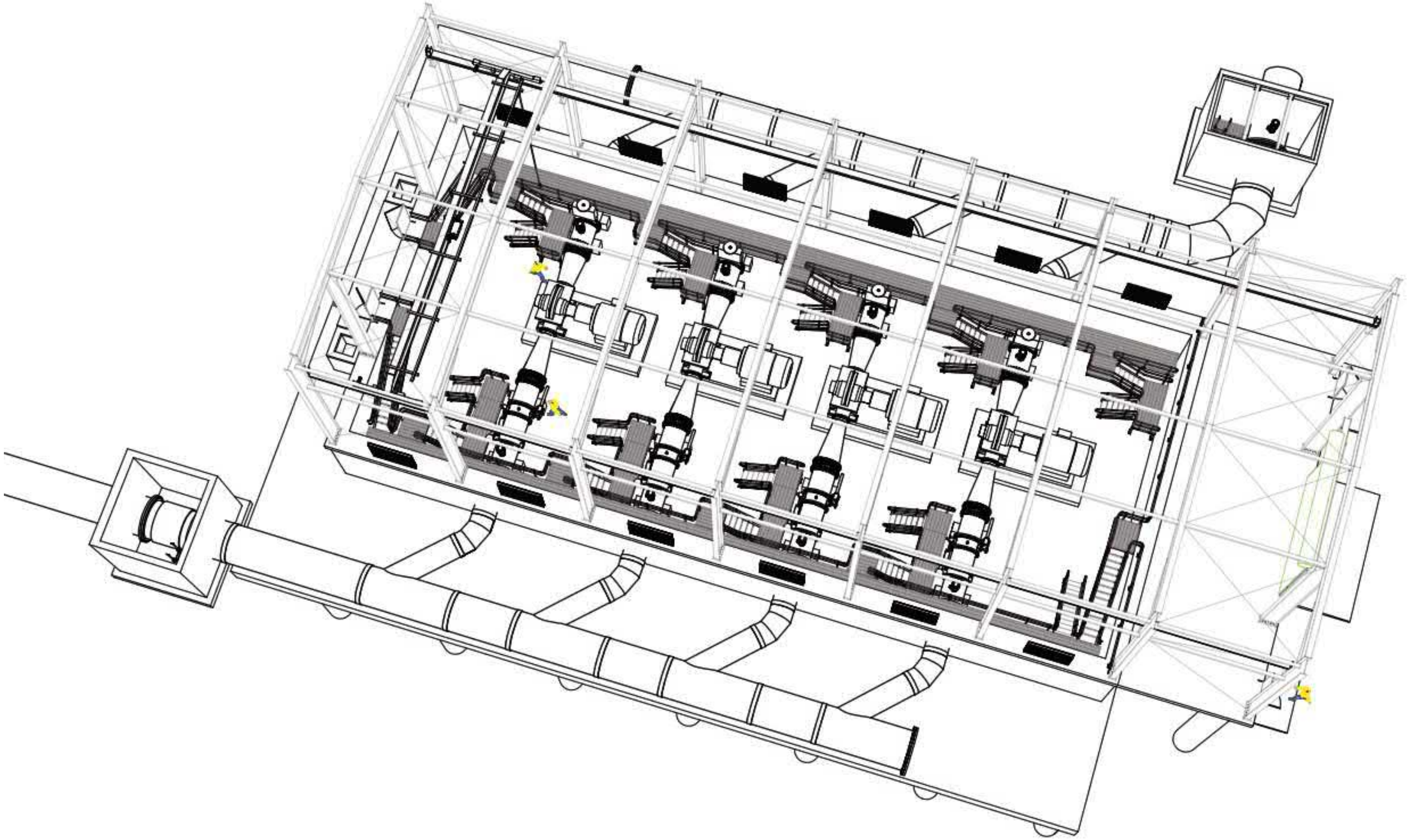


Figure 18: Proposed Burdekin River Intake Structure Layout

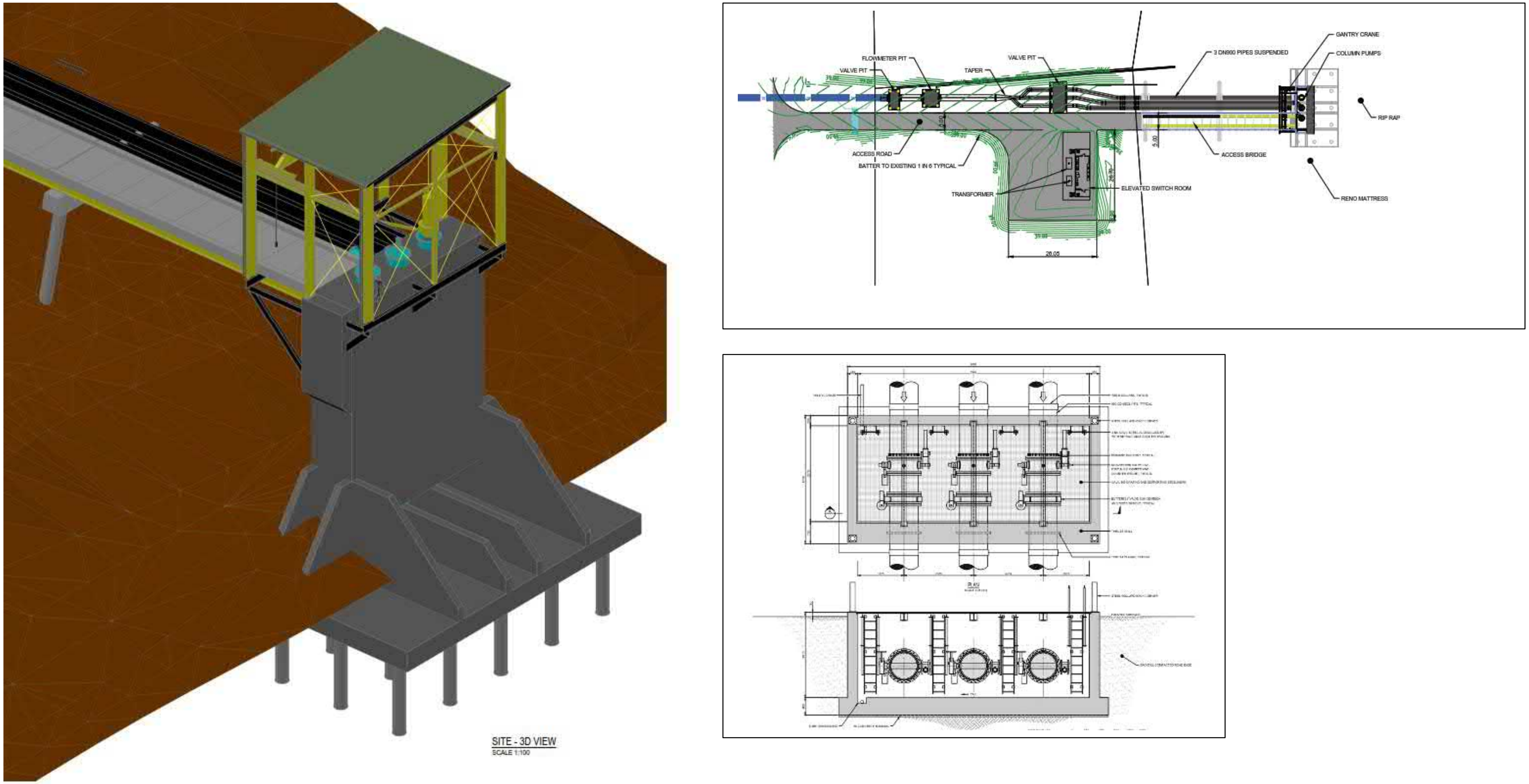


Figure 19: Proposed Burdekin River Intake Structure, Bridge Deck Layout and Foundations

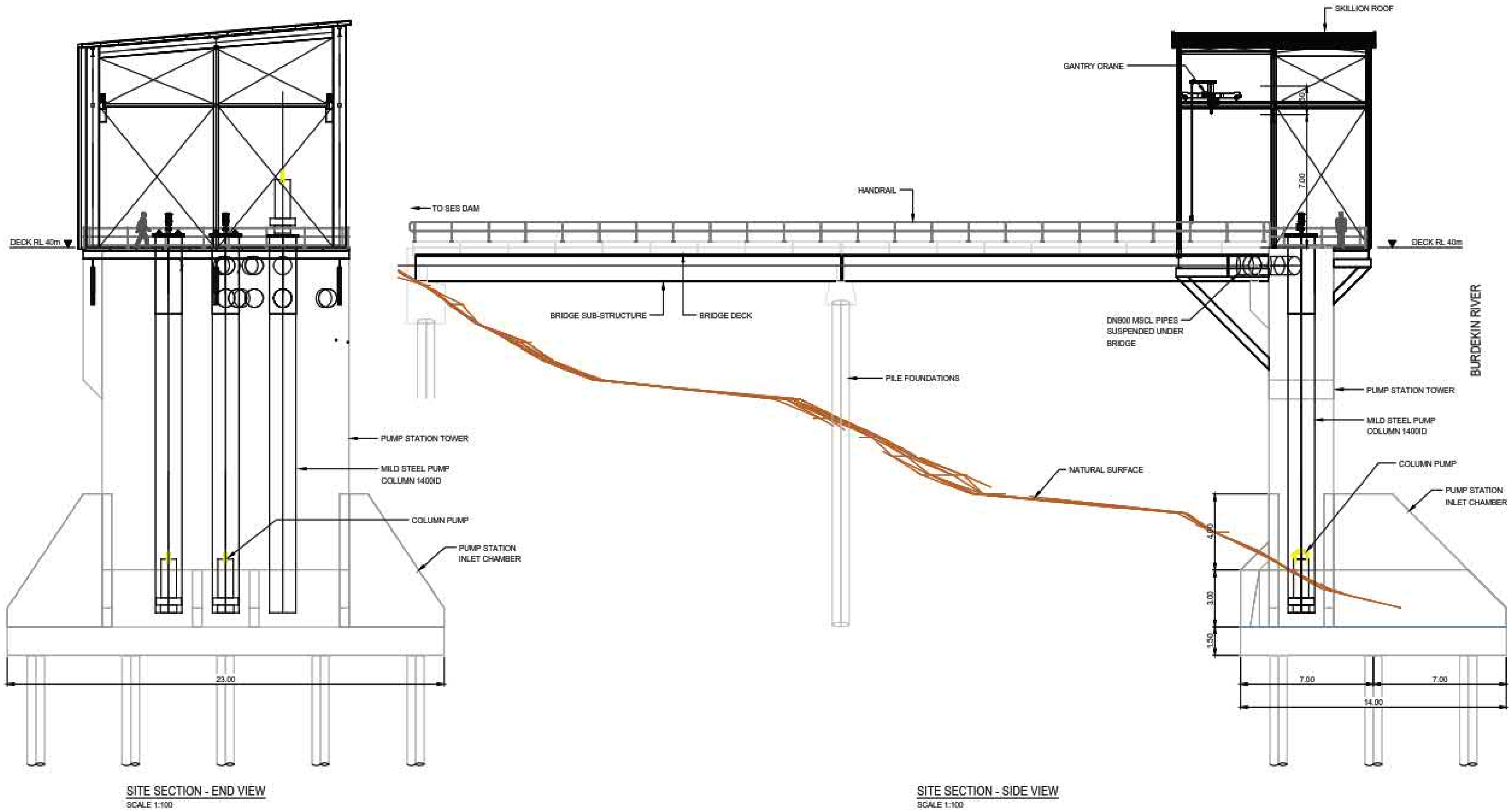


Plate 17 Existing Sunwater Tom Fenwick Intake and Pumping Station

A.5.2 Pigging Stations

Pigging stations will be required for the proposed Stage 2 pipeline. The general details of the layout of these stations is provided in Figure 20.

Based on the recent site specific geotechnical investigations (namely boreholes JBH1 & 2 and test pit JPT1, which revealed very stiff to hard clay) proposed foundations for these structures include a ground bearing slab supported by 400mm diameter 6m deep mini-piles, which have been considered as appropriate for both acceptable load and associated settlement criteria.

A.6 Proposed Storage Facilities

A.6.1 Burdekin Sedimentation Dam

The Burdekin Sedimentation Dam will be required to settle out sediment arising from the intake of the river water, to minimise potential clogging of the Stage 2 pipeline. An idea of the possible makeup of the dam is provided in Plate 18 which is of the existing Tom Fenwick Dam.

Figure 21 provides some general details of the proposed dam, with the significant components being:

- 5 to 6m high homogeneous earth embankment constructed at 1v:2.5h, with a 3m wide crest, and a shear key – this is at present planned to be composed of either suitable clay materials from the pipeline or dam excavations, but will not include potential sodic or high shrink-swell clays, and in addition will require reprocessing of suitable won materials; on the basis that the embankment will be constructed in no greater than 300mm lift heights with suitably compacted low permeability clays, no global stability issues are envisaged for the proposed dam embankments; and
- A 3.5 to 4.5m deep dam is required; based on the recent site specific geotechnical investigations (namely boreholes JBH1 & 2 and test pit JPT1) a significant thickness of between 9 to 12m of very stiff to hard low plasticity clay was encountered over the footprint of the dam; based on these ground conditions it is suggested that material from the dam excavations can be used to form the dam retaining embankment, and that the dam base is of appropriate character to not require a PE liner to be installed.

Figure 20: Proposed Generalised Pigging Station & Sedimentation Dam Layout Details

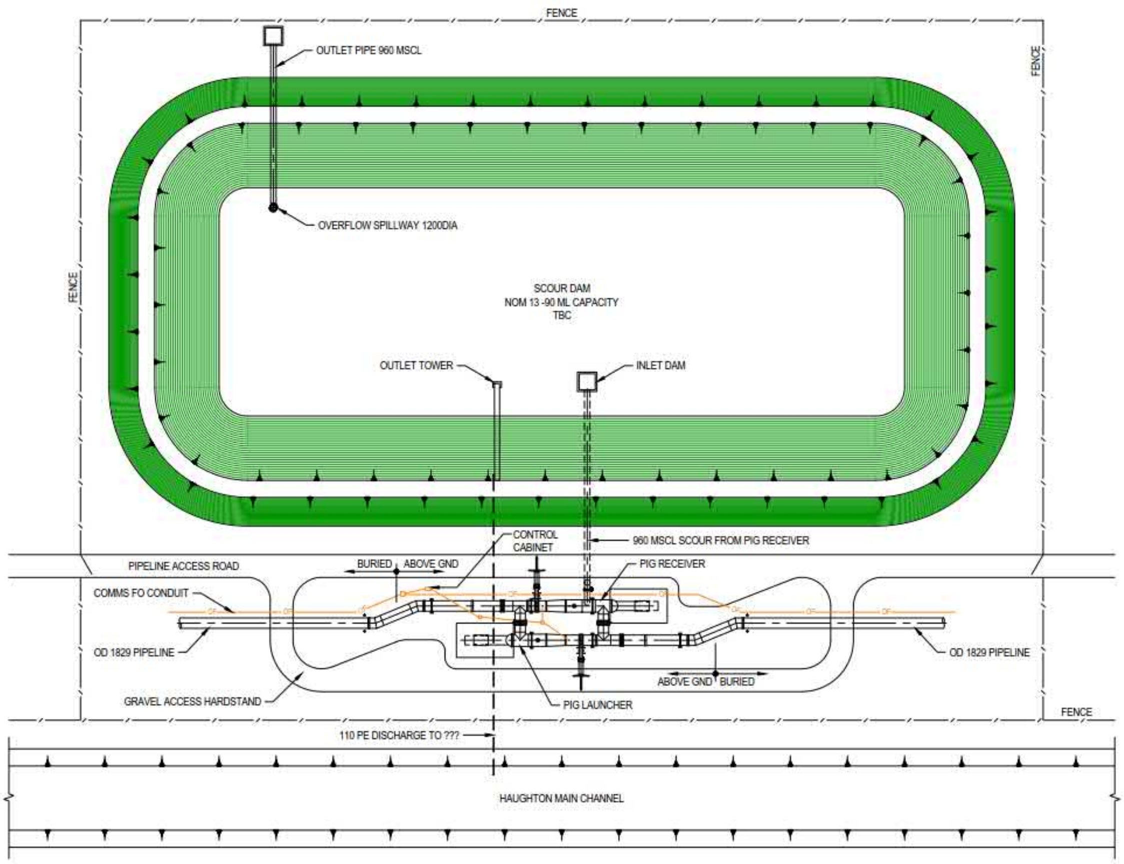
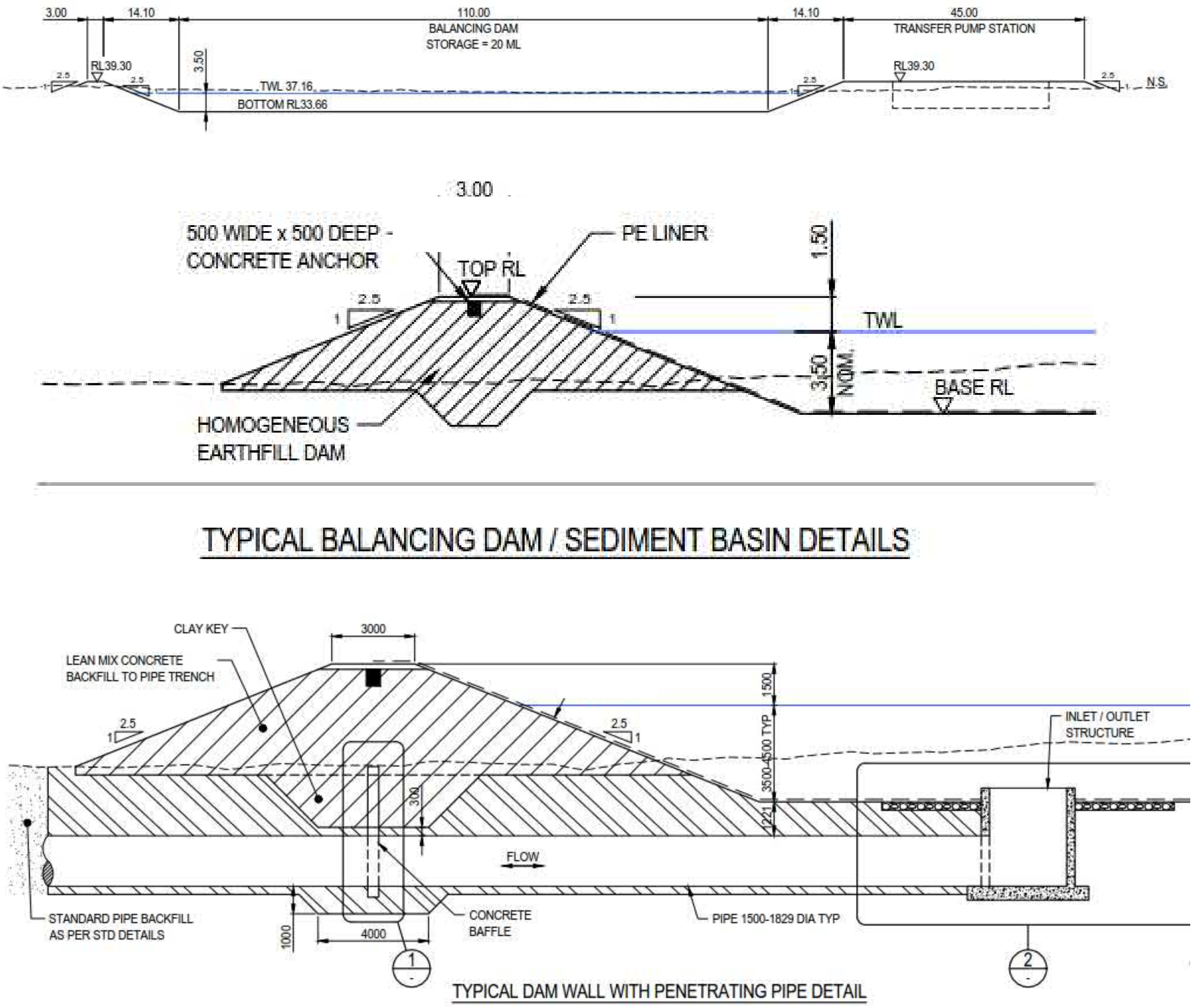


Plate 18 Existing Sunwater Tom Fenwick Surge/Balancing/Sedimentation Dam

Figure 21: Proposed Burdekin Sedimentation Dam General Details

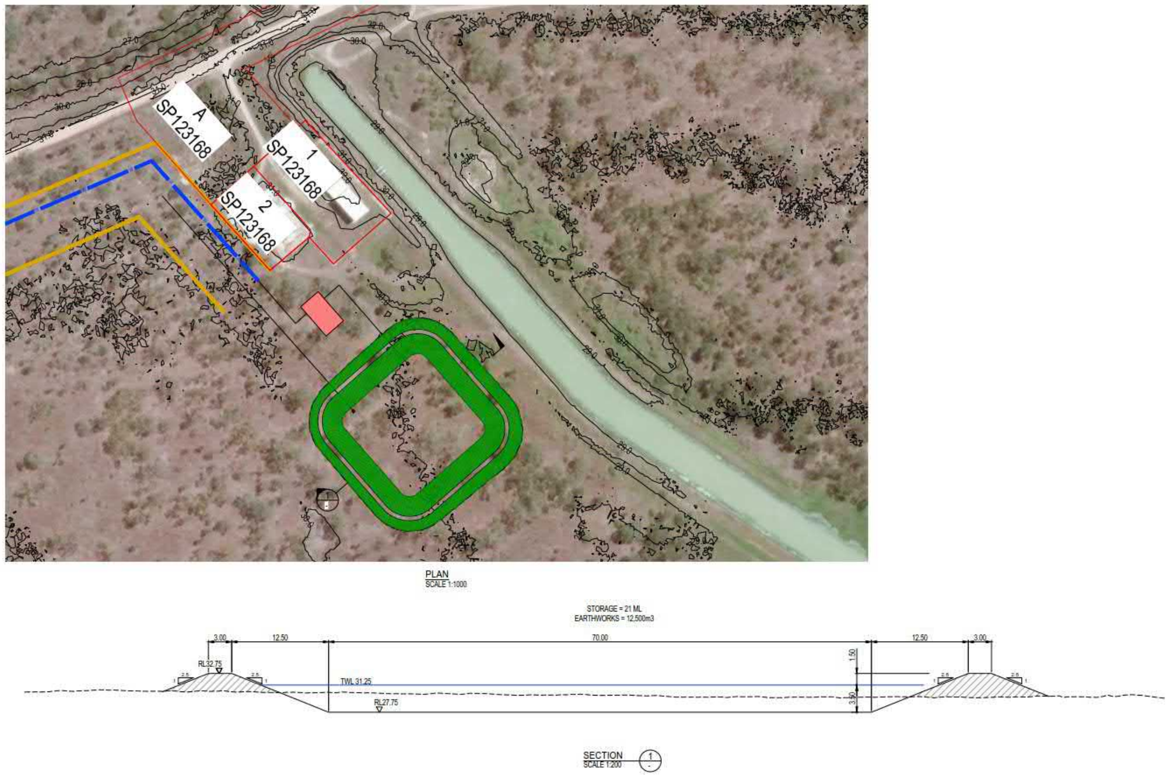


A.6.2 Haughton Balancing Storage

The Haughton Balancing Storage will have the following characteristics (see Figure 22):

- Approximately 2.0m in height with 1v:2.5h slopes composed of an earth embankment;
- 3.0m wide crest and approximately 95m wide containment structure; and
- Required approximately 12,500m^3 of earthworks to construct, be approximately 3.50m deep and have a capacity of 21ML.

Figure 22: General Layout of Proposed Haughton Balancing Storage



This dam walls for this balancing storage are again at present planned to be composed of either suitable clay materials from the pipeline or dam excavations, but will not include potential sodic or high shrink-swell clays, and in addition will require reprocessing of suitable won materials. Again if the dam walls are constructed in lift heights of 300mm of well compacted suitable materials no global stability issues are envisaged, especially as these dam walls are perhaps 3 times less in height than the Burdekin Sedimentation Dam. At present without any site specific ground condition information it is suggested that a PE liner be installed for this structure.

A.7 Summary and Key Conclusions

Based on the available information to date the following key geotechnical aspects of the proposed Stage 2 development have been concluded:

1) Present geotechnical ground models, design parameters and associated ground engineering and related construction considerations are presently based on Desk Study, Walkover Survey, a limited site specific geotechnical investigation campaign and previous experience;
2) Related to the present interpretation of ground conditions, the following geotechnical key aspects are considered for the proposed Stage 2 development:
    a) The potential existence of sodic, reactive, ASS and contaminated soils and the definition of related appropriate design and construction considerations to effectively deal with these strata; based on present information available and the assumed construction methodologies to be employed, no specific treatment for these soils is presently deemed to be necessary, however for the case of sodic soils construction sequencing will need to address possible issues associated with physical erosion from rainfall on construction exposed surfaces
    b) The excavatability assessment of the ground to install the pipeline at present indicates that >50% can be free dug and <10% may require ripping of competent bedrock; no blasting is currently thought necessary
    c) The proposed pipeline will be for the most part be installed by an open trench excavation method, by the use of large excavation plant; significant creek, rail and road crossing will also be installed by trenching, but with the use of sheet piling
    d) The stability of the pipeline trenches, along with constructability aspects, will probably require dewatering by use of probable well point systems; discharge of pumped water is presently considered to be back into surface water courses via settlement tanks
    e) Reuse of excavated materials may be limited due to its variable nature both vertically and horizontally, its inherent characteristics, high moisture contents, lack of space for stockpiling and reprocessing and high groundwater tables; in this respect significant volumes of imported granular backfill materials sourced from offsite commercial quarries or licensed sand extraction locations will be required; the spoiled material will be required to be removed offsite to a suitable receiving location
    f) Scour and buoyancy issues associated with the extensive floodplains can be suitability dealt with (in part due to the use of steel pipe), with appropriate designs and options provided
    g) At present no significant issues are associated with aggressive ground conditions for buried concrete, reinforcement or the steel pipeline; however design solutions have been provided if these are to be encountered
    h) The construction of the pipeline alignment is considered to have no detrimental effect on the existing HMC
    i) Due to the probable existence of deep soil profiles, driven pile foundations have been defined for the proposed pumping station foundations, as well as the associated Intake Structure for the Burdekin Transfer Pumping Station
    j) A concrete raft support by shallow driven pile foundations have been designed for the pigging stations
    k) Dam storage facilities earthworks could be composed of won materials from project excavations, but will require careful control of composition, compaction and moisture contents; at present for the Haughton Storage dam a PE liner is recommended, but will not be required for the Clare Sedimentation Dam.