Department of Local Government Racing and Multicultural Affairs

Bundaberg East Levee – Concept Engineering Report

28 March 2019

listen. think. deliver.

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March 28, 2019
Project Number: BEN170175.02

David Murray
Department of Local Government Racing and Multicultural Affairs
1 William Street
Brisbane City
Queensland 4000

Dear David,

RE: Bundaberg East Levee – Concept Engineering Report

Please find attached the concept engineering report for your review.

Sincerely

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Executive Summary

The Queensland Government is progressing the Bundaberg 10-year Action Plan to determine how best to reduce flood risk in the Bundaberg region and improve the safety of the Bundaberg community. Funding has been allocated to progress flood mitigation initiatives and develop the 10-year Action Plan which will build on projects previously undertaken by the Bundaberg Regional Council.

CDM Smith was engaged by the Department of Local Government, Racing and Multicultural Affairs (DLGRMA) (formerly the Department of Infrastructure, Local Government and Planning (DILGP)) to undertake the investigation and conceptual design of the Bundaberg East Levee. This included the assessment of river flow conditions during flood and alternatives for levee configuration and alignment. The conceptual design applies knowledge of other levee and flood mitigation measures from other areas in Queensland and around the world specifically the USA.

The proposed Bundaberg East Levee site is located in an urban, residential, and mixed-use area adjacent to the southern bank of the Burnett River in Bundaberg, Queensland. The project site is bounded by Walla Street to the west, Bourbong and Cran Streets to the South, the Bundaberg Sugar Mill to the east, and the Burnett River to the north. The ground surface elevation generally ranges from between approximately 2 m Australia Height Datum (AHD) to 11 m AHD across the project site with the low-lying areas located near Saltwater Creek and Distillery Creek.

The Bundaberg East Levee is proposed to run parallel to the southern bank of the Burnett River and across Saltwater Creek and Distillery Creek. The levee is proposed to consist of a concrete floodwall with an indicative top of wall elevation of 9.5 m AHD. The top of floodwall elevation is approximately 300 mm above the 100-year ARI design flood elevation at this location. The floodwall will be founded approximately 1.5 m below ground surface (BGS) on a stepped foundation system consisting of both shallow and deep foundations.

Various alignments were evaluated and assessed with factors including ground suitability to construct a levee, and property and existing land use. As a result, the selected floodwall alignment will consist of two main segments, the City Alignment and the Sugar Mill Alignment.

> The City Alignment is approximately 1045 m long and generally extends along the northern edge of Quay Street from the intersection of Toonburra Street across Saltwater Creek to the intersection of Scotland Street. The alignment then follows Scotland Street to the intersection of Cran Street.
>
> The Sugar Mill Alignment is approximately 680 m long and crosses Distillery Creek. The Sugar Mill Alignment extends from the intersection of Cran Street and Scotland Street and runs east along Cran Street, and parallels the river bank until it terminates north of the sugar mill.

Pump station and flood gate structures will be constructed at the Saltwater Creek crossing with a flood gate at the Distillery Creek crossing. The pump station and flood gate structures will be significantly larger at Bundaberg Creek due to the larger creek width and larger contributing upstream catchment. In addition, an equipment building will be constructed adjacent to the Bundaberg Creek pump station and flood gate structure.

The flood control levee at Saltwater Creek and Distillery Creek will require flood closure structures, which will allow passage of normal flows in each creek, and provide closure during flood events. The recommended flood closure structures for both facilities are vertical lift gates. These are the most-common gates used in flood control projects in conjunction with pumping facilities.

One permanent pump station is planned for the Project at Saltwater Creek, and a temporary skid / trailer mounted mobile engine-driven pump is planned for service at Distillery Creek. These pumps will operate to pump water from Saltwater Creek and Distillery Creek into the Burnett River during flood conditions. The Saltwater Creek Pump station will house two electric-motor-driven pumps for flood control. The pump station will include an empty pump bay configuration for a contingency pump. The pump station will use submersible axial pumps to provide as low-profile a pump station as possible to limit obstructions of the view of the Burnett River enjoyed by residents.

CDM Smith prepared an Environmental Advice Statement for the Project which is attached. An indicative preparation and assessment timeframe matrix is provided to guide the requirements for environmental permits and approvals. It identifies material that will be required to support each application.

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Section 1 Introduction

1.1 Project Background

This report presents a conceptual-level engineering design for flood management facilities consisting of proposed floodwalls, pump station and flood gate structures and associated support facilities located in Bundaberg, Queensland. These flood management facilities are recommended to increase the flood protection, mitigate damage, and protect the Bundaberg East area from the 100-year average recurrence interval (ARI) design flood event from the Burnett River.

Refer to **Figure 1-1** for the project site plan.

1.2 Selection of Recommended Floodwall Alignment

Originally, the proposed levee consisted of two main segments, the City Alignment and the Distillery Alignment, each with multiple alternatives, that are shown on **Figure 1-1** of **Appendix A** (Factual Geotechnical Report). The proposed levee / floodwall included three (3) proposed City Alignment alternatives (City Alignment 1 through 3) and two (2) proposed Sugar Mill Alignment alternatives (Sugar Mill Alignments 1 and 2).

An earthen levee, flood wall alternative and combination of the two were also considered along these two main alignment segments, both of which have different footprint requirements based upon geotechnical and height requirements. As result of the geotechnical testing and the under-seepage modelling performed within the 'Interpretive Geotechnical Report (2 March 2018)', a flood prevention wall was identified as the most viable and effective solution for flood protection of East Bundaberg.

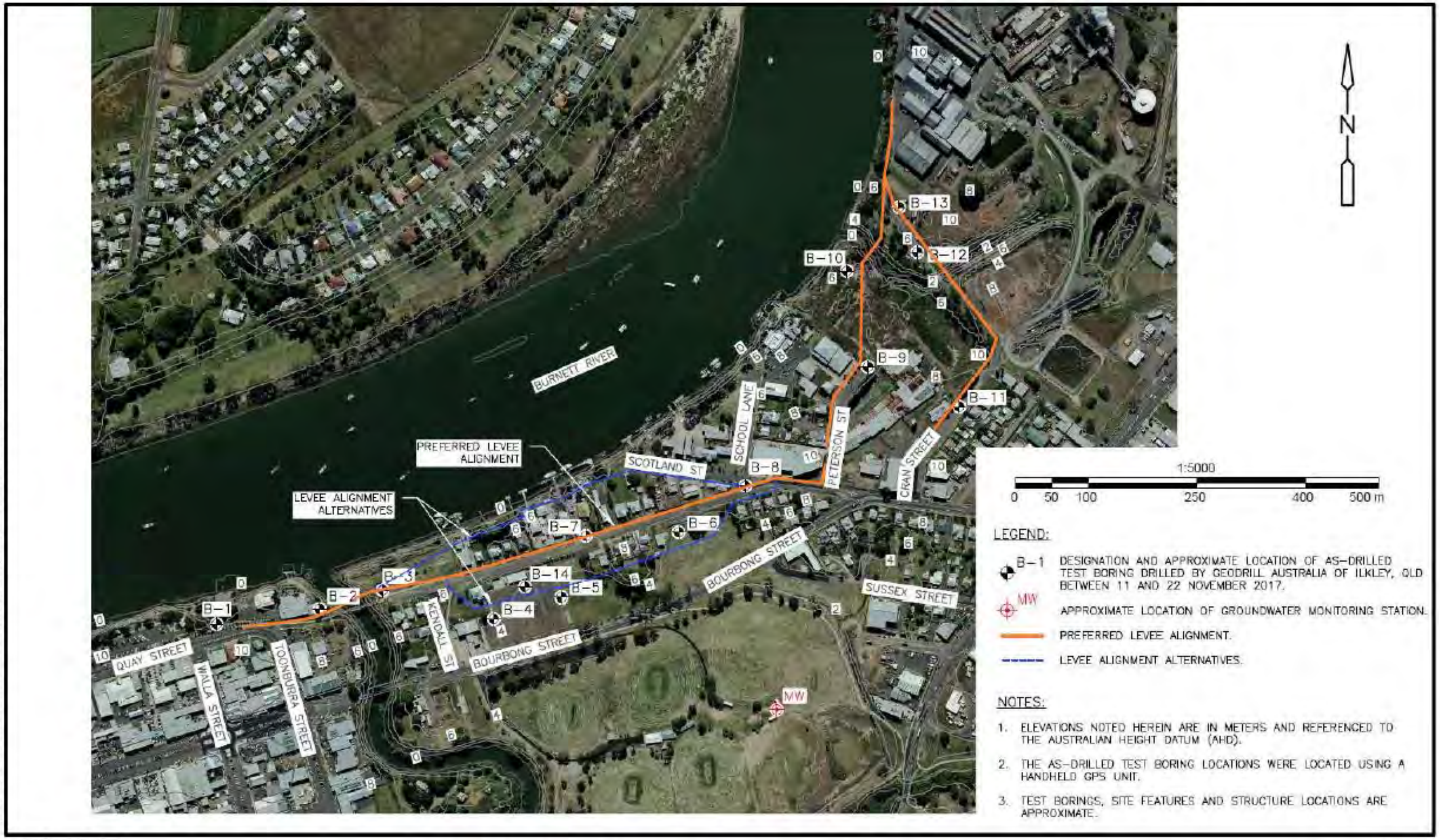
The City Alignments were between approximately 850m and 900m in total length. The City Alignment alternatives generally extended along Quay Street from the intersection of Toonburra Street across Saltwater Creek to the intersection of Scotland Street. The alignments then followed Scotland Street to Peterson Street where the alignment terminated shortly after the intersection. The routes of the various City Alignment alternatives only varied in location between Saltwater Creek and Scotland Street. City Alignment 1 extended south of Quay Street through the park and behind many of the residences along the roadway. City Alignment 2 was located along the northern edge of Quay Street within the public right-of-way. City Alignment 3 extended to the north of Quay street near the southern bank of the Burnett River north of the residences and businesses and then extended along Scotland Street to the intersection with Quay Street.

Based on the CDM Smith's evaluation, City **Alignment 2** was the preferred alignment due the following disadvantages associated with the other alignments:

- **Disadvantages of City Alignment 1:**
  - The proximity to Burnett River may result in thicker soft alluvial soil deposits increasing deep foundation lengths and extra construction costs due to geotechnical conditions;

- This alignment may necessitate acquisition of right-of-way through private land and limit the access to jetties along the Burnett River;
- The type of flood protection measure along this alignment would be limited to a flood wall due to the footprint requirements, and
- This alignment will result in longest floodwall alignment thereby increasing construction costs.

The various alignment options considered in the selection process were presented at a series of community consultation events held in Bundaberg in during the first week of June, 2018. Information on alignment choices was described, including the extent to which the findings of the geotechnical campaign (refer Section 3)



CDM Smith

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND LOCAL GOVERNMENT
BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

FIGURE NO. 1-1
SITE AND TEST BORING LOCATION PLAN
FEBRUARY 2018

- **Disadvantages of City Alignment 3**
  - Portions of this alignment may require excavation in a former construction and demolition (C&D) debris landfill located south of Quay Street near the public netball courts. This would result in increased construction costs due to potential environmental testing and disposal of waste materials along with potential subsurface under-seepage issues;
  - At first pass there seemed to be enough physical space for an earthen levee in the park, however following geotechnical investigations it was identified that an earth levee batter angle of *at least* 4H:1V as a minimum is required for an adequate factor of safety as well as potential levee settlement issues, which subsequently resulted in an excessive earth levee footprint; and
  - This alignment will extend through public ball courts and multiple parks including a dog park, Daphne Geddess Park, and East Bundaberg Rotary Park, which may result in public relations issues for the project.

The two Sugar Mill Alignment alternatives (Alignments 1 and 2) were approximately 530 m and 500 m in total length, respectively. Both alignments were proposed to cross Distillery Creek. The Sugar Mill Alignment 1 extended along the majority of Cran Street and then paralleled the river bank until it terminated north of the distillery. Alignment 2 extended along the majority of Peterson Street then paralleled the river bank until it terminated north of the sugar mill.

Alignment 1 was the preferred alignment due the following disadvantages associated with the other alignment:

- **Disadvantages of Distillery Alignment 2**
  - The proximity to the river will likely result in thicker soft alluvial soil deposits increasing deep foundation lengths and construction costs; and
  - This alignment will require additional installation through wetland areas.

1.3 Project Coordinate System

Horizontal coordinates noted herein are in meters and are referenced to the Geocentric Datum of Australia 1994 (GDA94) Map Grid of Australia (MGA) Zone 56.

Elevations herein are in meters and referenced to the Australian Height Datum (AHD). The ground surface elevations discussed herein were approximated using publicly available LiDAR data for the City of Bundaberg.

1.4 Creek Naming

For the purposes of this report:

- The names “Bundaberg Creek” and “Saltwater Creek” refer to the creek system to the east of and behind the CBD, which includes the floodplain area of Kendall Flats. Bundaberg creek rises in the farmlands around Ashfield, and travels in a westerly direction towards Kendall Flats. Saltwater Creek originates near Bundaberg Airport, and drains generally in a north-easterly direction through the southern extremity of the CBD. The two creeks have a confluence in the parklands near the low (South) end of Toonburra Street, after which the combined system drains to a confluence with the Burnett river, some 700m to the north. The short section of watercourse between the confluence and the Burnett River is named as Saltwater Creek.

- The unnamed creek adjacent the Bundaberg Sugar property is referred to as Distillery Creek herein.

1.5 Existing Conditions

The proposed Bundaberg East Levee site is located within an urban, residential, and mixed-use area adjacent to the southern bank of the Burnett River in Bundaberg, Queensland. The project site is bounded by Walla Street to the west, Bourbong and Cran Streets to the South, the Bundaberg Sugar Mill to the east, and the Burnett River to the north. The ground surface elevation (excluding creek channels) generally ranges from between approximately 2 m Australia Height Datum (AHD) to 11 m AHD across the project site with the low-lying areas located near Bundaberg Creek and Distillery Creek.

1.6 Proposed Construction

The Bundaberg East Levee is proposed to run parallel to the southern bank of the Burnett River and across Saltwater Creek and Distillery Creek. The levee is proposed to consist of a concrete floodwall with an indicative top of wall elevation of 9.5 m AHD. The top of floodwall elevation is approximately 300 mm above the 100-year ARI design flood elevation at this location. The floodwall will be founded approximately 1.5 m below ground surface (BGS) on a stepped foundation system consisting of both shallow and deep foundations. The floodwall will consist of two main segments, the City Alignment and the Distillery Alignment as shown on Figure 1-1.

The City Alignment is approximately 1045 m long and generally extends along the northern edge of Quay Street from the intersection of Toonburra Street across Bundaberg Creek to the intersection of Scotland Street. The alignment then follows Scotland Street to the intersection of Cran Street.

The Distillery Alignment is approximately 680 m long and crosses Distillery Creek. It extends from the intersection of Cran Street and Scotland Street and runs east along Cran Street parallel with the river bank until it terminates to the north of the sugar mill.

Pump station and flood gate structures will be constructed at the Saltwater Creek crossing, and a penstock culvert with stand-alone demountable pump at the Distillery Creek crossing. The pump station and flood gate structures will be significantly larger at Saltwater Creek due to the larger creek width and larger contributing upstream catchment. In addition, an equipment building will be constructed adjacent to and on the eastern side of Saltwater Creek.

1.7 Purpose and Scope

The purpose of this report is to present the results of CDM Smith's study and provide a recommended conceptual-level alternative for the proposed Bundaberg East Levee project. Specifically, the scope of work included the following:

- Conduct a hydrologic and hydraulic (H/H) analysis to refine pumping capacity and flood gate sizing, and to identify anticipated pump operational frequency to reduce backwater flooding during the design flood event;
- Develop a proposed layout of the floodwall, pump station and flood gate structures, equipment building, and associated support facilities;
- Develop design criteria for the flood management facility components;
- Determine land acquisition requirements associated with the proposed flood management facilities and the ancillary support facilities;
- Develop a description of the environmental considerations for the project, and
- Develop an opinion of probable construction costs (OPCC) for the recommended conceptual-level design this currently being completed by an estimation company for inclusion in the final report.

1.8 Report Organisation

The conceptual engineering report (CER) provides information to support the Bundaberg East Levee project. The following sections are included in the report.

Section 1 provides a brief description of project background, existing and proposed conditions, and purpose and scope for the overall project.

Section 2 includes an H/H analysis to determine pumping capacity and gate sizing, and to identify anticipated pump and gate operating frequency.

Sections 3 and **4** summarise the geotechnical investigation and geotechnical design recommendations.

Section 5 provides a description of the proposed design criteria for process and mechanical equipment associated with the pump station facility, including pumps, piping, associated support systems, and miscellaneous features of the pump station facility.

Section 6 provides a description of the proposed design criteria for the flood gate structures, including types, sizes, and layout.

Section 7 provides a description of design criteria and requirements for the structural design of the proposed facilities.

Section 8 provides a description of design criteria and requirements for civil site work.

Section 9 provides a description of the environmental considerations for the project site.

Section 10 summarizes the conceptual-level OPCC (to be included).

This document also includes appendices that contain the detailed technical work and reports (eg. geotechnical campaign, hydrology and hydraulics studies) that form the basis of this over-arching concept engineering report.

1.9 Conceptual-Level Drawings

This report includes conceptual-level engineering drawings produced at a half-size scale, which can be found in **Appendix B**.

Section 2 Hydrologic and Hydraulic Analysis

2.1 Scope of Works

2.1.1 Purpose and Scope

Section 2 is an abbreviated version of the detailed Surface Water Technical Report. The purpose of this section is to concentrate solely on hydrologic and hydraulic tasks affecting design of the Bundaberg East Levee.

Specifically, our scope included the following:

- Determine, using calibrated models, suitable design crest elevations and freeboard values for the levee;
- Assess the previous recommendations for pump sizes, and test other sizes and operating strategies;
- Estimate the likely hydraulic impacts of placing a gate structure across Saltwater Ceek; and
- Make recommendations for further work to occur in the detailed design phase.

2.1.2 Previous Studies

Numerous studies associated with Burnett River flooding have been produced over the past two decades, the most recent and comprehensive of which was GHD's 2013 report entitled "Burnett River Flood Study – Final Report (October 2013)", referred to herein as "GHD (2013)". Readers are encouraged to familiarise themselves with the 2013 report, as it partly forms the basis for the CDM Smith's Surface Water Technical Report, as well as the work documented in the following sections of this report.

2.2 Hydrologic Modelling

2.2.1 Catchment Description

The Burnett River catchment spans an area of some 32,000 km^2 in the Wide Bay-Burnett region of Central Queensland. Spanning approximately 300 km from north to south, and about 200 km from east to west at its widest points, the catchment is generally considered to be comprised of five major sub-catchment areas, namely:

- **Upper Burnett.** The most-northerly portion of the basin, which includes the Nogo River, Three Moon Creek, and the headwaters of the Burnett River;
- **Auburn.** To the west of Mundubbera, incorporating the Auburn River, Johnson Creek, and Cadarga Creek;
- **Boyne.** Rising in the Bunya Mountains to the south of Kingaroy, the Boyne and Stuart Rivers flow in a northerly direction to a confluence with the Burnett River near Mundubbera;
- **Barker and Barambah Creeks**. To the east of the Boyne sub-catchment, also flowing in a generally northerly direction to a confluence with the Burnett River near Gayndah; and

- **Lower Burnett.** For the purposes of this study, defined as the Burnett River downstream from the town of Mundubbera, to the ocean outfall near Burnett Heads.

Annual rainfall totals exhibit some variability across the catchment. The majority of the catchment inland from the coastal range receives around 800 mm annually, whilst the coastal east is significantly wetter at around 1200 mm annually. Orographic effects in the Upper Burnett (around the Burnett, Dawes, and Hogback ranges) can be pronounced, leading to high daily rainfall totals and a corresponding increase in annual averages.

The catchment shape means that heavy rainfall in any one of the major sub-catchment areas can be sufficient to cause a flood event in the lower Burnett. Flooding is relatively infrequent and typically requires sustained rainfall normally caused by tropical low-pressure systems. For a thorough description and thematic maps of the rainfall patterns leading to the major floods on record, readers should refer to Figures 6-1 through 6-5 of GHD's 2013 report.

2.2.2 URBS Rainfall Runoff Model

The conceptual runoff routing model URBS (Carroll 2009) was used to model the behaviour of the catchment. URBS is a computer-based, hydrologic modelling program that enables the simulation of catchment storage and runoff response by a network of conceptual storages representing the stream network and reservoirs.

2.2.2.1 Model Calibration

For the purpose of calibration, the catchment was modelled as five separate sub-catchment models (corresponding to the major areas listed in Section 2.2.1), enabling a better representation in spatial variability of model parameters. The URBS model was built with the intention of determining a set of model parameters that reproduce observed flooding conditions at a gauged location. Four model parameters are used to fit the modelled hydrographs to observed values, namely:

- **Rainfall Loss Parameters:** Initial loss (IL) in mm, Continuing loss (CL) in mm/h; and
- **Runoff Routing Parameters:** channel lag parameter alpha (α), catchment lag parameter beta (β), and catchment non-linearity parameter (m).

The 2013 rainfall event, which produced the flood of record at Bundaberg, was selected as the calibration event. In terms of selecting model parameters, the initial loss was selected to match the start of the rise of the calculated hydrograph to the recorded hydrograph. The continuing loss rate was selected as the value that gave the closest agreement between modelled and observed flood volume.

Alpha, beta, and m were adjusted to match the rising limb, magnitude, and timing of the recorded peak, and the shape of the hydrographs. Calibration was focused on preserving the catchment response at the gauging locations. Particular effort was taken to obtain a good match at Paradise Dam and at Walla; these being the two gauging locations with the most-accurate rating curves at high flows. Through a process of test and review, calibration parameters were adopted as shown in Table 2-1.

Table 2-1 2013 Flood Event – URBS Calibration Parameters

Sub-catchment	Initial Loss (mm)	Continuing Loss (mm/h)	α	β	m
Upper Burnett	180	1.5	0.18	3	0.7
Auburn	160	1.5	0.25	3	0.7
Boyne	180	1.5	0.15	2.5	0.7
Barker & Barambah	170	1.5	0.16	3	0.7
Lower	110	1.5	0.15	2.6	0.7

Applying these parameters to the model yielded the hydrographs shown below in Figure 2-1 (stream/spillway discharges) and Figure 2-2 (stream/spillway heights). Observed values are plotted in blue; modelled values in orange.

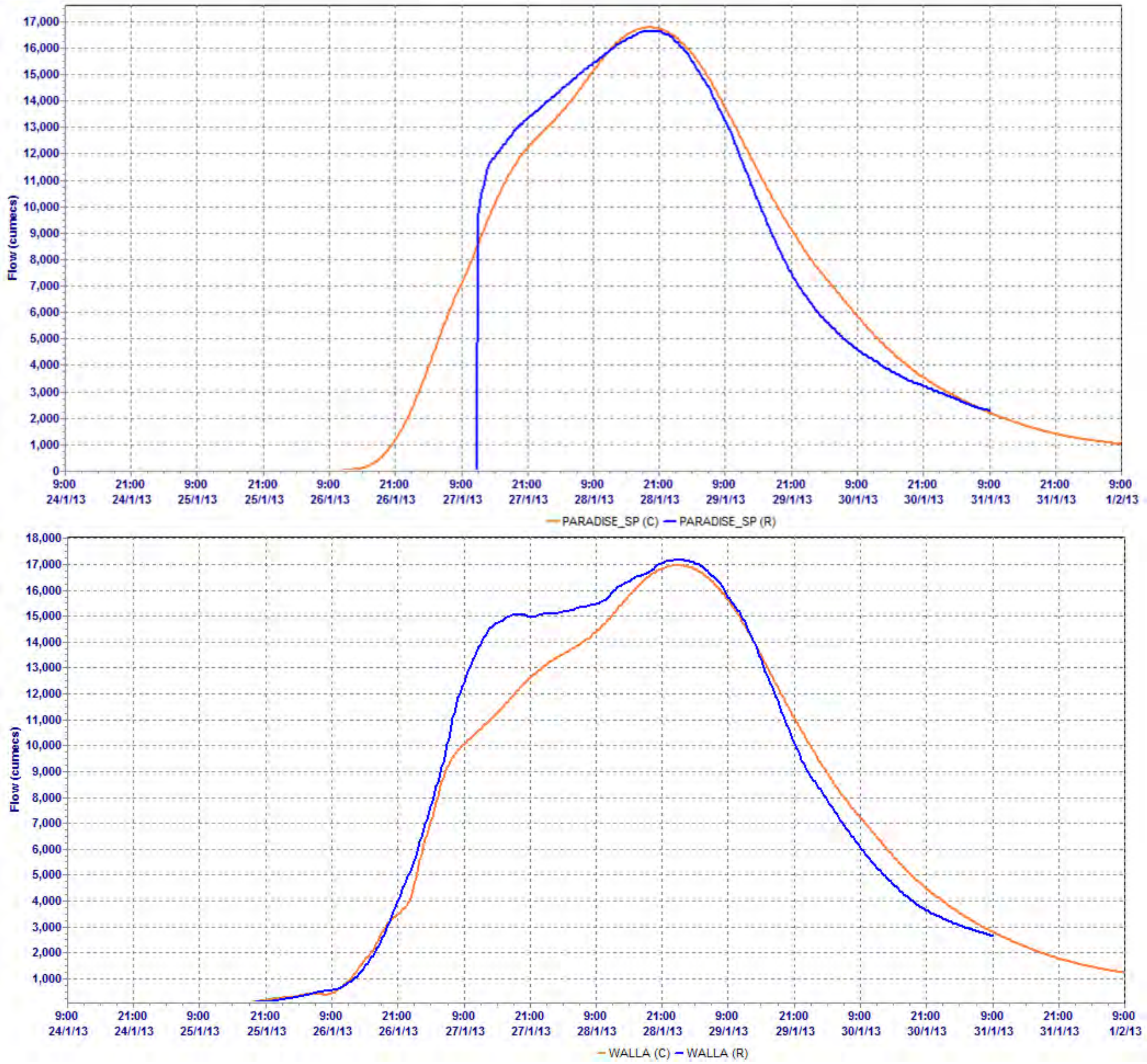


Figure 2-1 2013 Flood Event – Discharge at Paradise Dam and Walla

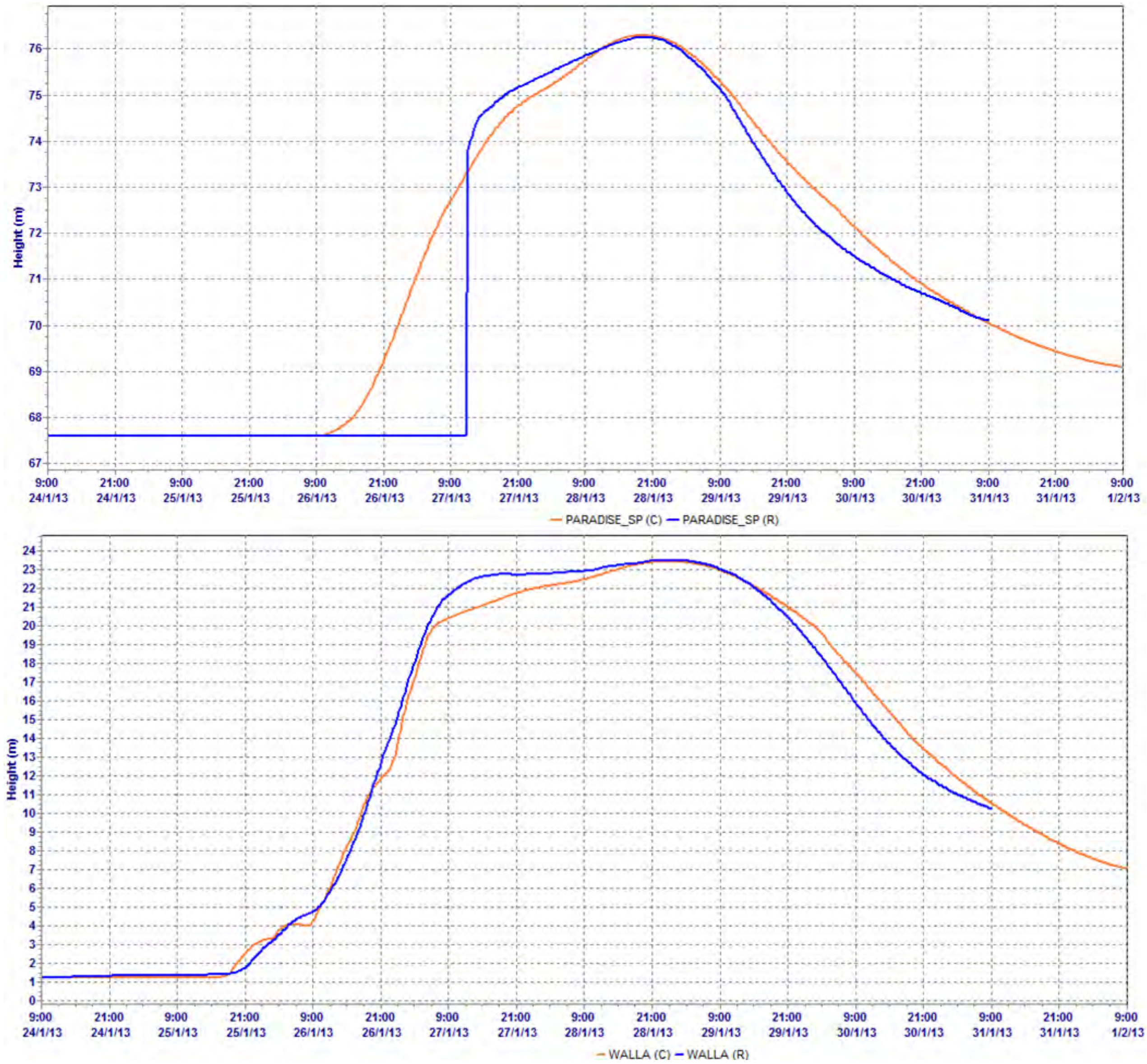


Figure 2-2 2013 Flood Event – Stream Heights at Paradise Dam and Walla.

The results presented in above indicate that the model can accurately recreate the conditions observed in the catchment during the 2013 flood event. Thus, the model parameters from Table 2-2 were adopted for use in developing probabilistic flood discharge estimates, discussed below.

Table 2-2 2013 Flood Event – Peak Result Values

Location	Variable	Peak Value		Difference
		Observed	Modelled	
Paradise Dam	Height (m)	76.25	76.30	+ 0.05 m
	Flow (m^3/s)	16,630	16,770	+ 0.8 %
Walla	Height (m)	23.50	23.42	- 0.07 m
	Flow (m^3/s)	17,200	16,970	- 1.3 %

2.2.2.2 Design Event Hydrology

The URBS model was used to develop design flood hydrographs, following the guidance provided in "Australian Rainfall and Runoff 2016: A Guide to Flood Estimation" (AR&R 2016). The AR&R2016 guidelines provide methodologies for estimating design flood characteristics in Australia. Of relevance to this study, advice is given for the estimation of key design parameters, including:

- Rainfall depths;
- Rainfall areal reduction factors;
- Rainfall temporal patterns; and
- Rainfall initial loss values.

Rainfall depths were calculated from Intensity-Frequency-Duration (IFD) tables, developed from the online tool hosted at the Bureau of Meteorology website.

The Burnett catchment sits within the "East Coast North" zone, as defined by AR&R. Temporal patterns and areal reduction factors for this zone were downloaded from the AR&R "Data Hub" website.

An "ensemble" of ten temporal patterns is provided for each rainfall duration and exceedance probability. The patterns are varied - some are heavily front-end loaded, some distributed quite evenly, others back-end loaded – and designed to capture the underlying natural variability in observed rainfall patterns. For the purposes of this study, the temporal pattern that produced the hydrograph with the median discharge value (technically, rank 6 of 10) at the Walla gauge was selected as the representative hydrograph for the particular flood event under consideration.

It is assumed that initial loss values are event-specific, depending heavily on antecedent catchment conditions, whereas continuing loss values are generally regarded to be an inherent property of the catchment, related to soil type and vegetation cover. For this reason, an initial loss value of 38 mm was adopted in accordance with AR&R, whilst the continuing loss value (i.e., 1.5 mm/h) was adopted from the calibrated hydrologic model.

Design hydrology results at Walla are presented in Table 2-3**,** below.

Table 2-3 Design Hydrology – Peak Discharge at Walla

Probability Classification in		Critical Storm Duration (h)	Peak Discharge (m^3/s)
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)		
50 %	1.44 year	48	2,077
20 %	4.48 year	48	4,673
10 %	9.5 year	48	7,150
5 %	20 year	36	10,677
2 %	50 year	36	14,768
1 %	100 year	36	18,001
0.5 %	200 year	36	21,387
0.2 %	500 year	36	25,426

To determine the level of confidence in these results, the design hydrology peak discharges are compared to the results of a flood frequency analysis in the following section.

2.2.3 Flood Frequency Analysis

A flood frequency analysis was carried out using the FLIKE software. FLIKE is an extreme-value analysis package that calculates the probability of flood events based on historical records. It incorporates a range of probability models and uses a Bayesian inference model that allows the user to censor data and test for outliers.

In order to perform a flood frequency analysis based on discharge estimates, the following data are needed at the gauged location:

- A reliable rating curve that can accurately transform gauged heights into flood discharges; and
- A series of annual height maxima, transformed into discharges via the rating curve.

2.2.3.1 Rating Curve

For the purposes of this study, CDM Smith has adopted the revised Walla rating curve, as described by GHD in Section 4.4 of their 2013 report. Based on a previous rating curve developed by DNRM, the revised rating curve was developed by analysing the 2013 spillway discharges at Paradise Dam, routing these through a hydrologic model, and checking against results produced by a hydraulic model simulation of the same event.

In checking to ensure that the revised rating curve was appropriate for use in this study, CDM Smith contacted Ray Maynard, a DNRM hydrographer from Bundaberg, for his opinion. Mr. Maynard has 30 years' experience in gauging flood flows and developing rating curves, with a focus on the Burnett catchment. He confirmed that the rating curve should generally be considered as reliable, and that it should be used in preference to previous DNRM curves. The adopted rating curve from the GHD 2013 report (dashed black line) is reproduced below in Figure 2-3.

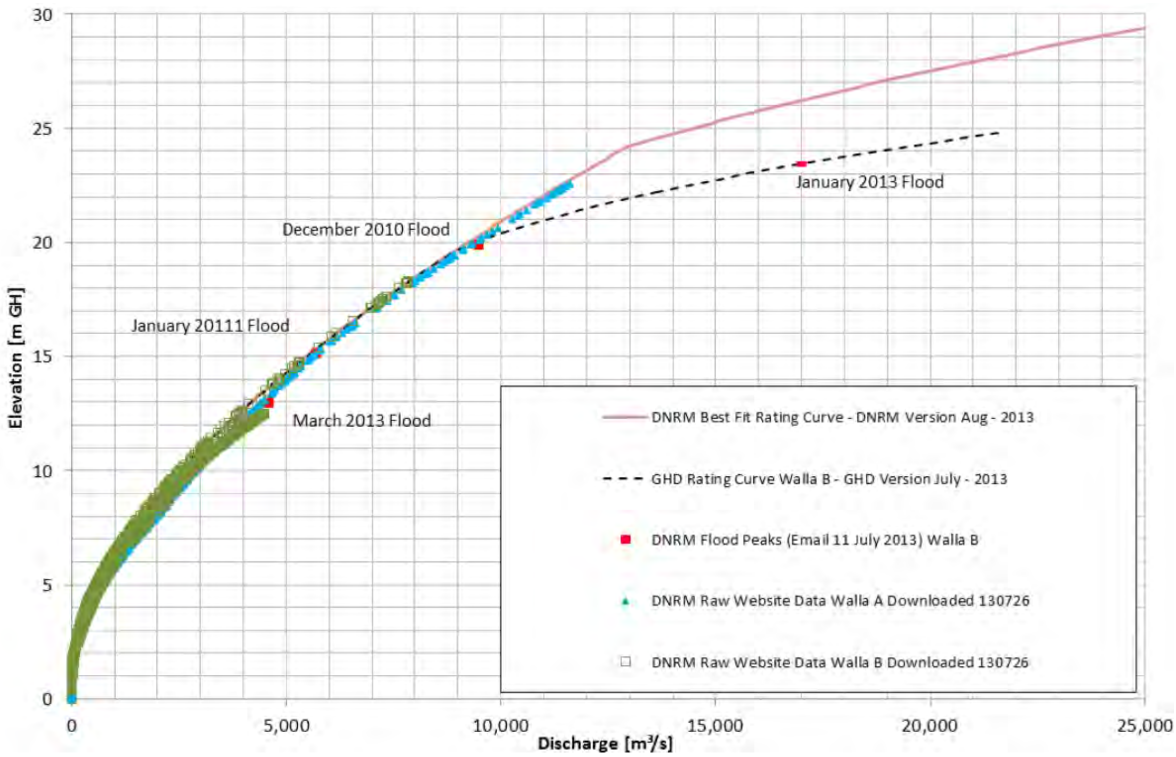


Figure 2-3 Rating Curve at Walla

The following assumptions apply to the use of the rating curve in this study:

- That the discharge information used in developing the rating curve (Paradise Dam rating curve and spillway discharges, physical gauging during flood events) is correct;
- That the physical characteristics of the river channel (bed elevation, channel cross-section, vegetation cover) at the Walla gauge do not exhibit significant temporal variations; and
- That the construction of the new Bruce Highway embankments and bridge (approximately 1km downstream of the gauge) has not significantly altered the longitudinal flood profile.

2.2.3.2 Flow Maxima

Annual flow Maxima at Walla were obtained from the DNRM's Water Monitoring Information Portal website. The site contains near-real-time streamflow and rainfall information for 27 active locations in the Burnett catchment, as well as historic records for a further 55 closed monitoring sites. Two locations were used to reconstruct the streamflow record at Walla:

- 136001A Burnett River at Walla. From 30/09/1910 to 29/11/1965; and
- 136001B Burnett River at Walla. From 01/10/1965 to current day.

The time series of annual flow maxima (as transformed via the rating curve) is presented below in Figure 2-4.

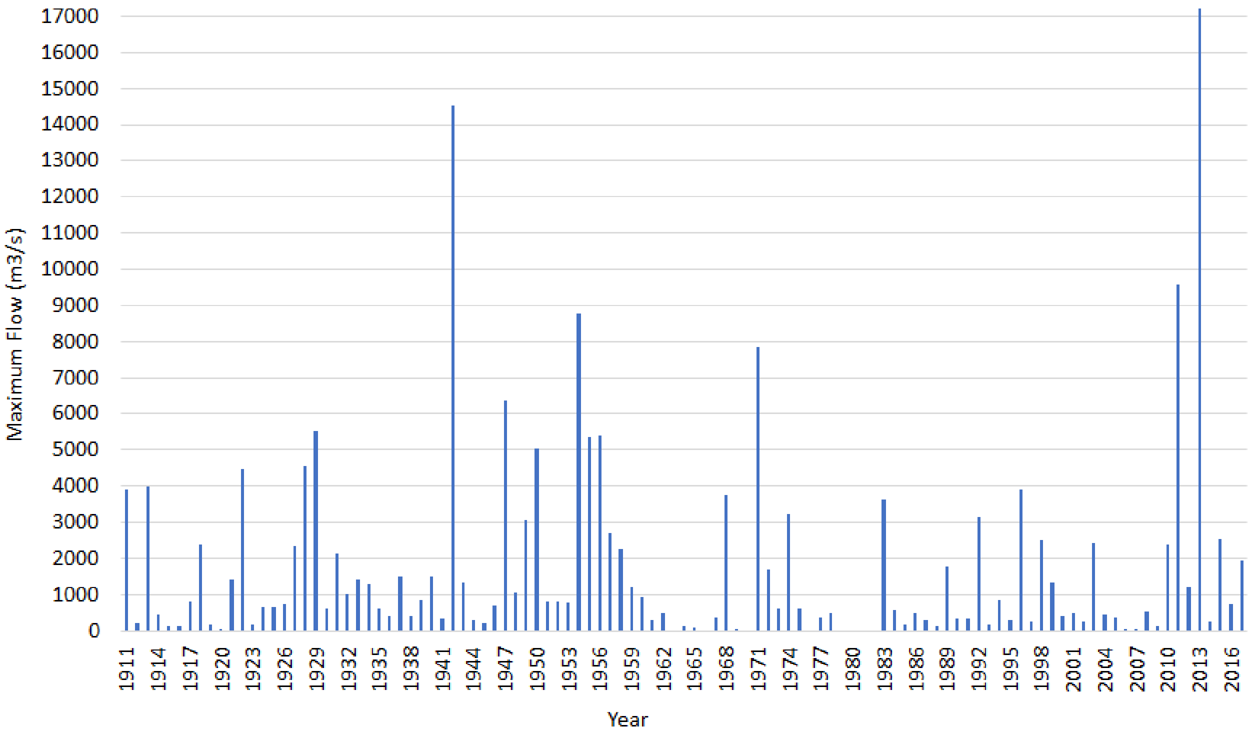


Figure 2-4 Annual Flow Maxima at Walla

2.2.3.3 Results

Several fitting models were tested in the FLIKE software. A Log-Pearson Type 3 distribution, with the exclusion of annual maximum flows of less than 400 m^3/s, was found to provide the best fit. The resultant curve is plotted against the URBS runoff model results in Figure 2-5, and tabulated below in Table 2-4**.**

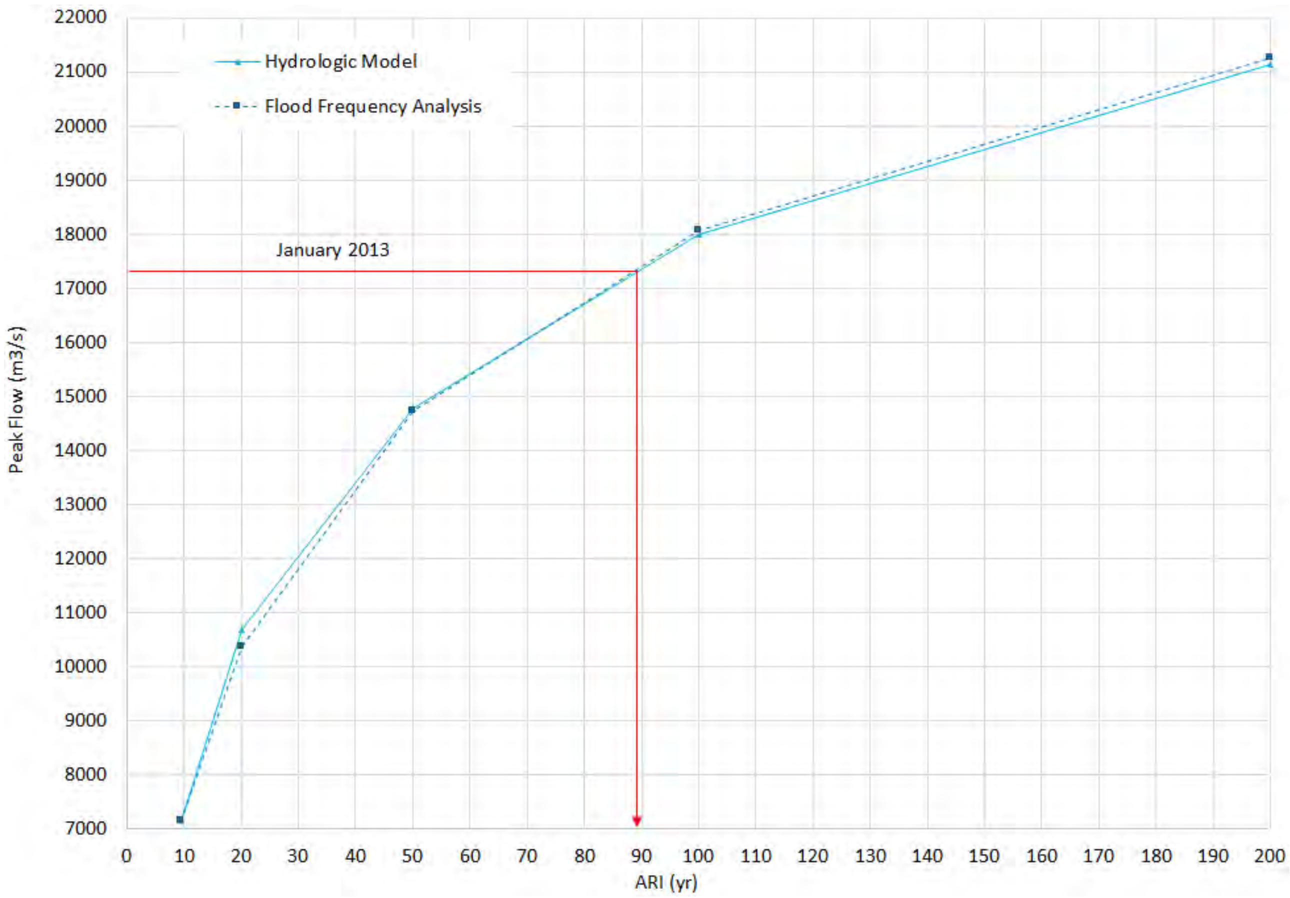


Figure 2-5 Comparison between Runoff Model and Flood Frequency Analysis

Table 2-4 Comparison between Runoff Model and Flood Frequency Analysis

Probability Classification		Peak Discharge (m^3/s)		Difference (%)
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	URBS Runoff Model	FLIKE Flood Frequency Analysis	
10 %	9.5 year	7,150	7,146	- 0.1
5 %	20 year	10,677	10,356	- 3.0
2 %	50 year	14,768	14,736	- 0.2
January 2013		17,200 (gauged)		n/a
1 %	100 year	18,001	18,071	+ 0.4
0.5 %	200 year	21,387	21,267	- 0.6
0.2 %	500 year	25,426	25,235	- 0.8

Overall, the flood frequency analysis agrees very closely with the results obtained from the calibrated runoff model, giving confidence that the design hydrographs are suitable for use as inputs to the hydraulic model. Note also that based on these results, the 2013 flood event would be classified as having approximately a 90-year ARI at Walla.

2.3 Hydraulic Modelling

2.3.1 Purpose

The hydrologic model was used to develop historic and design discharge hydrographs. In the case of the Burnett River, the most-downstream gauging station for which an accurate rating curve exists is that of Walla (DNRM 136001B), located approximately 1 km north of the Bruce Highway crossing of the Burnett River. Downstream of this point, river heights are recorded at Bundaberg but due to the complex nature of the floodplain, no reliable rating curve is known to exist.

Thus, to determine flood behaviour downstream of Walla (i.e., for the Bundaberg reach of the Burnett River), hydrologic model hydrographs are required to be routed through a hydrodynamic model. The goal is to produce a model that can accurately reproduce the system dynamics (travel time, attenuation, peak heights) for a known flood event, with the ultimate purpose of calculating design flood elevations in Bundaberg, from which levee design-crest elevations can be selected.

2.3.2 HEC-RAS Hydraulic Model

The hydrodynamic model HEC-RAS 5.0.5 (US Army Corps of Engineers, 2017) was used to model the hydraulic characteristics of the Burnett River along a reach extending from the Walla streamflow gauge to the river mouth at Burnett Heads, a stream centreline distance of approximately 100 km.

The model was setup as a 2D semi-structured mesh with a default cell size of 90 m. This resolution would typically be considered too coarse for river channel modelling in a traditional gridded model. However, HEC-RAS utilises a sub-grid sampling routine (in which the characteristics of the underlying 1 m LiDAR grid are incorporated into the cell and face hydraulic properties) that allows for detailed hydraulic characteristics to be captured on a relatively large grid. Further detail on this methodology is provided in the HEC-RAS user's manual, which is freely available from the US Army Corps of Engineers website.

Key hydraulic controls (such as tops of banks, embankments, bridge abutments, channel constrictions) were captured by the addition of breaklines, which serve to align cell faces along the control, ensuring that the hydraulic effects are adequately represented in the model. Additionally, so-called "refinement regions" were used to set finer cell sizes, giving greater resolution in areas where additional model detail was desired, such as at hydraulic controls (50 m), or at narrow sections of the river channel (50 m).

2.3.2.1 Calibration Modelling

The January 2013 flood was simulated in the HEC-RAS hydrodynamic model. The URBS discharge hydrograph, as observed at the Walla gauge, was applied as the upstream boundary condition. Historic tidal data from the Bundaberg Port gauge was reduced to the Australian Height Datum and applied as a time-variant level boundary at the river mouth.

Two key parameters were available with which to affect the calibration, namely:

- Manning's 'n', a representation of surface roughness; and
- Selection of channel bathymetric data from several available historic surveys.

A thorough discourse on the calibration process is beyond the scope of this report and can be found in the Surface Water Technical Report. The general process was one of parameter testing and review, after which incremental changes were applied to the model for the subsequent iteration. At the conclusion of calibration, the HEC-RAS model gave a fair reproduction of the 2013 flood event, as evidenced in the two figures below – first, the river height time series at the Targo Street gauge, and second, the peak river height profile with respect to levels surveyed at (or near) the time of the peak seen below in Figure 2-6, Figure 2-7Figure , and Table 2-5.

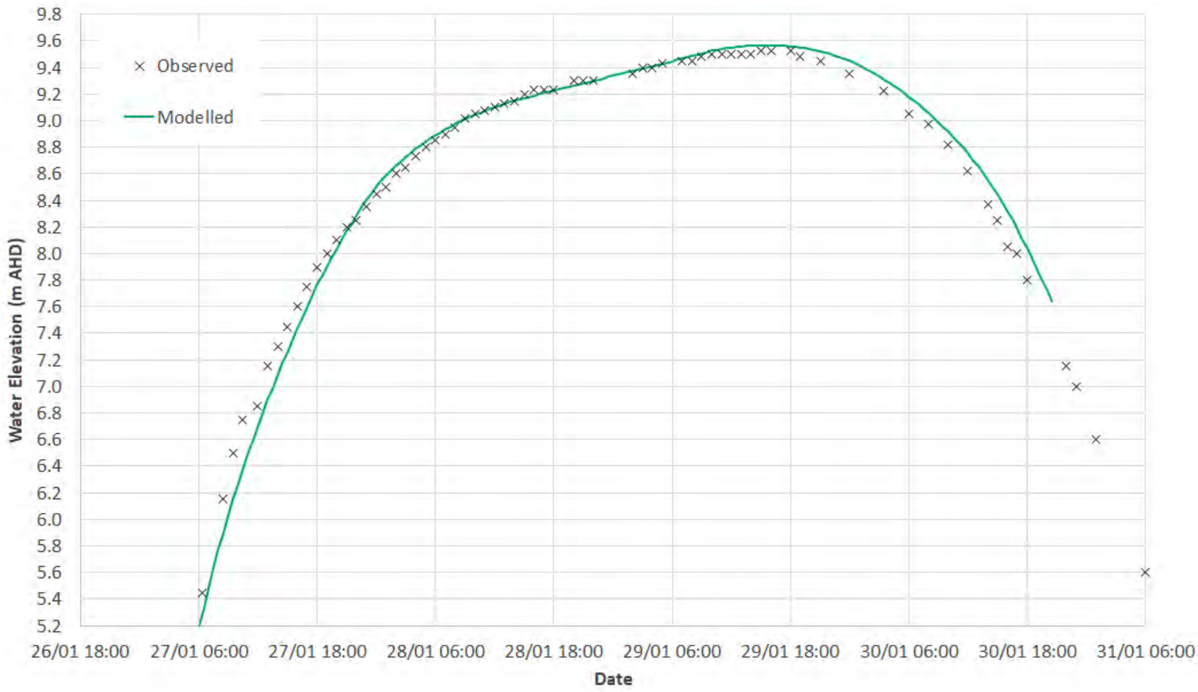


Figure 2-6 HEC-RAS Calibration at Targo Street Gauge

Table 2-5 HEC-RAS Calibration at Targo Street Gauge

Location	Peak River Height		Difference (2 – 1)
	Observed (1)	Modelled (2)	
Targo Street Gauge	9.53 m AHD	9.57 m AHD	+ 0.04 m

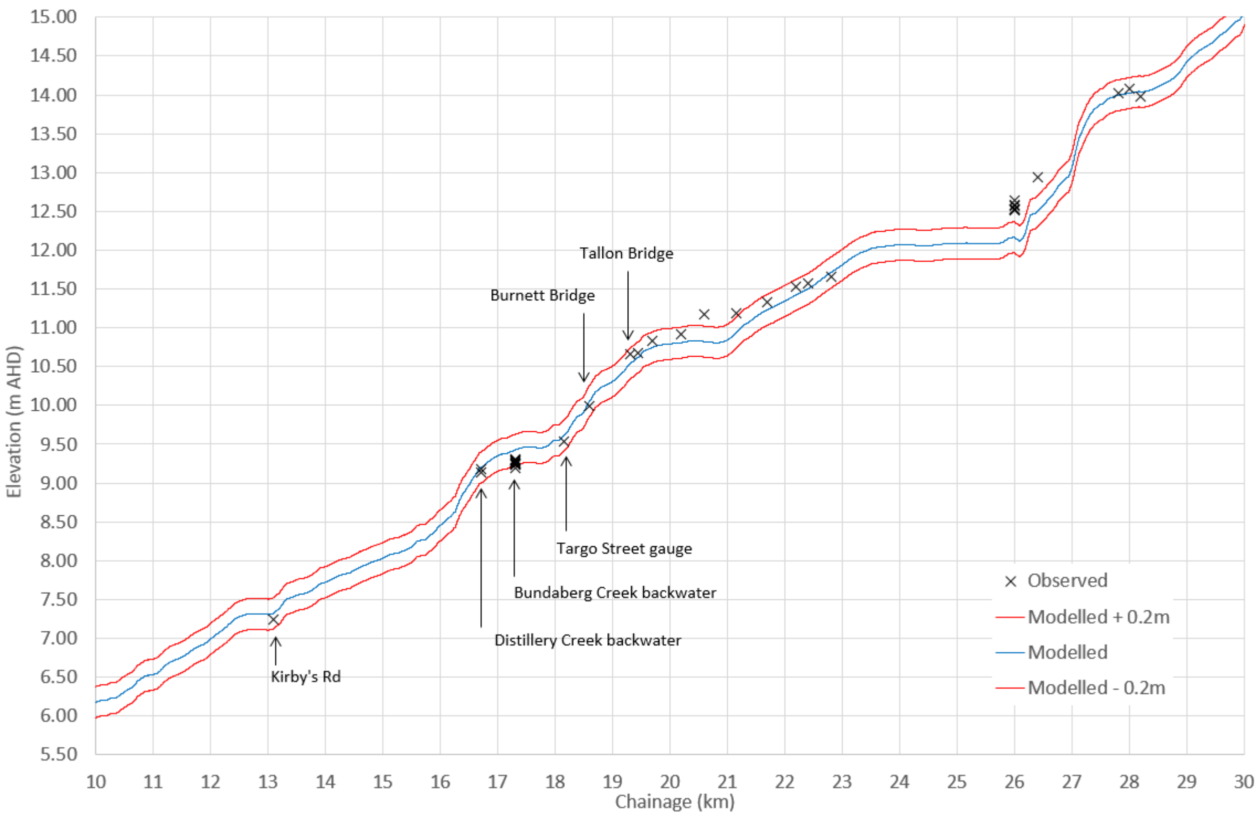


Figure 2-7 HEC-RAS Calibration, Burnett River Longitudinal Profile

This result provides confidence that the runoff hydrographs are being routed through the hydrodynamic model in a way that reflects the characteristics of the Burnett River, and that therefore the model can be used to calculate probabilistic flood levels at Bundaberg.

2.3.2.2 Design Event Modelling

Runoff hydrographs for the range of probabilistic flood events (as discussed in **Section 2.2.2**) were routed through the HEC-RAS model. A uniform tailwater level of Mean High Water Springs (MHWS); 1.17 m AHD; was applied as the downstream model boundary. The resultant peak flood levels at the Targo Street gauge location are presented in Table 2-6 below.

Table 2-6 Design Hydraulics, Peak Flood Levels

Probability Classification in		Peak Flood Level (m AHD)	
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	Targo Street Gauge	Saltwater Creek/Burnett River Confluence
50 %	1.44 year	3.80	3.71
20 %	4.48 year	5.46	5.35
10 %	9.5 year	6.63	6.46
5 %	20 year	8.02	7.76
2 %	50 year	9.00	8.65
1 %	100 year	9.50	9.20
January 2013 (modelled)		9.57	9.30
0.5%	200 year	9.79	9.49

Probability Classification in		Peak Flood Level (m AHD)	
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	Targo Street Gauge	Saltwater Creek/Burnett River Confluence
0.2 %	500 year	10.46	10.18

Of note is the fact that the 100-year ARI design flood level at Bundaberg is lower than the 2013 observed flood level, despite the opposite being true upstream at Walla. This is due to the extreme volume and extended duration of the 2013 flood, which had the effect of utilising most of the available floodplain storage. As a result, only minor attenuation of the flood peak occurred between Walla and Bundaberg. In contrast, the 100-year ARI design flood has a higher peak runoff value but a smaller total volume; consequently, the flood wave undergoes a greater degree of attenuation, leading to a predicted lower peak flood level at Bundaberg. This is a complex topic, further discussion on which is provided in the Surface Water Technical Report.

2.3.2.3 Levee Crest Elevation

The levee alignment encloses two flood-prone areas (i.e., Saltwater and Bundaberg Creeks, and Distillery Creek) which act predominately as backwater storages during river flood events. As a result of this topography, peak flood levels do not vary greatly along (i.e., in the direction of flow) the proposed alignment.

Therefore, for the purposes of the Concept Engineering Design Report, the following design crest level has been adopted:

- Design crest level (without freeboard) = 9.3 m AHD
- Design crest level (with freeboard) = 9.5 m AHD

The design crest level with freeboard places the top of the levee above both the 2013 historic flood and 1% AEP design flood events. During the detailed design phase, consideration could be given to refining the crest elevation towards the distillery, which would likely lead to a slight reduction in elevation and necessitate one or more “steps” in the levee top profile.

2.4 Pump Sizing Verification

2.4.1 Background

The Bundaberg East Levee project had its genesis in a report from December 2016 prepared by Jacobs, titled “Bundaberg Flood Protection Study – Flood Mitigation Options Assessment Report”. This report identified an early concept for a levee alignment, acknowledging also that some type of pumping arrangement would likely be required to convey local runoff over the levee in the case where the Burnett River was in flood, thus limiting inundation behind the levee.

At that time and for the purpose of a high-level cost assessment, an installed pump capacity of 40 m^3/s was designated. This figure was derived based on the instantaneous average pump rate that would be required in the scenario where a 100 mm daily rainfall total fell uniformly over the catchment in space and time. Whilst suitable for the objective of that report, the calculation considered neither the runoff characteristics of the catchment, nor the possibility of utilising floodplain storage to attenuate flood flows and reduce the required pump size. This conceptual design report considers these aspects in more detail, the analysis and results of which are presented below.

2.4.2 Basis of Design

The Saltwater/Bundaberg Creek system has a significant low-lying floodplain area that is currently given over to playing fields, parkland, and wetland reserves. The same is true of Distillery Creek, albeit to a lesser extent. When enclosed by a levee, these low-lying areas will function like dam storages, attenuating any inflows in accordance with their respective storage curves, which are presented on Figure 2-8, below.

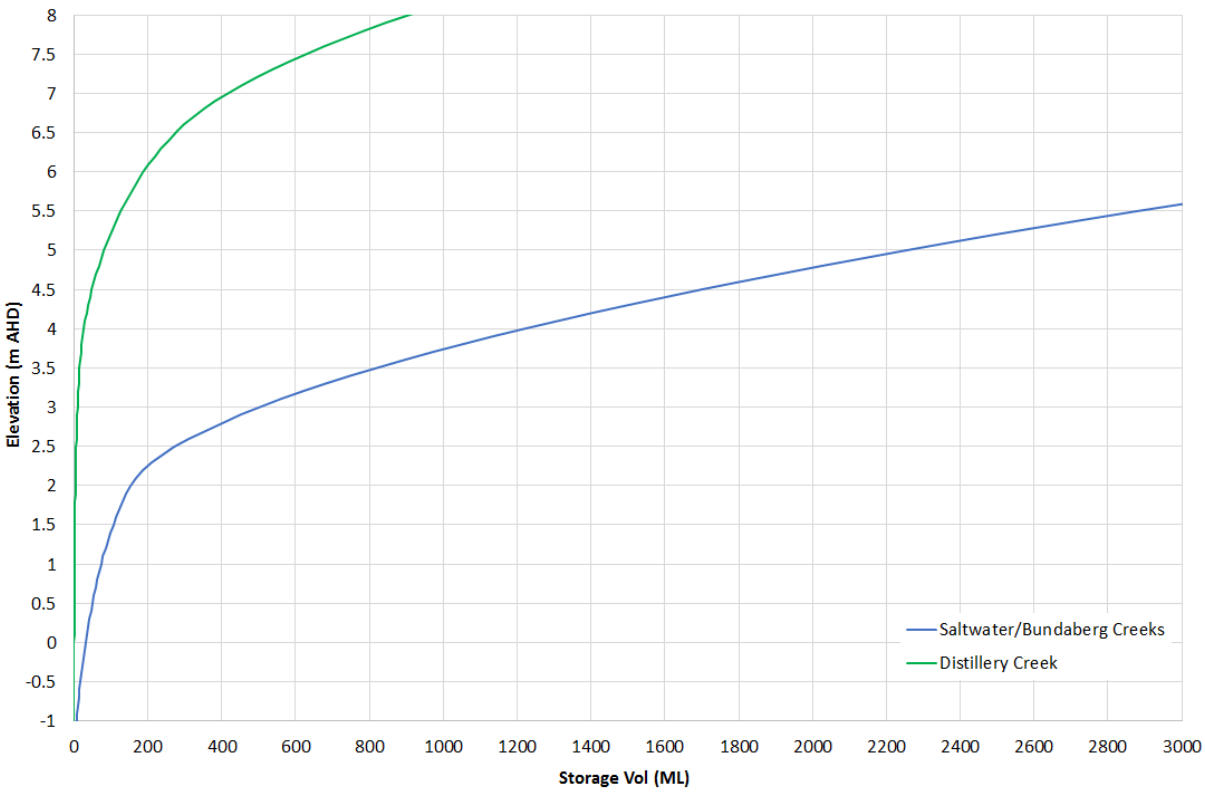


Figure 2-8 Local Creek Storage Curves

For Saltwater Creek, analysis of the contours with respect to the built environment suggests that water could be impounded to a level of around 5 m AHD without causing major impacts, allowing for up to 2200 ML of storage. At Distillery Creek, it is likely that local runoff could be stored up to a level of about 6 m AHD, giving some 200 ML of storage. Analysis of structures in and around the floodplain suggest that to temporarily store water up to these elevations it is likely that some minor mitigation works (e.g., local bunding, etc.) may need to be carried out. The scope of such local mitigation works is a matter for detailed design and is not considered further herein.

The extent to which the floodplain storages can be utilised to reduce the required pump size is investigated in the following section.

2.4.3 Local Runoff Models

The delay between the onset of rain and the start of runoff at a given location (in this case, the storage area behind the levee) is known as the catchment response time. It is affected by such things as: catchment size, catchment shape, land-use patterns, and rainfall losses. To represent these phenomena together with the catchment storage in order to test various pump rates, XP-RAFTS runoff models were built for each of the creek catchments as summarised in Table 2-7. The models are uncalibrated.

Table 2-7 XP-RAFTS Model Details

Item	Model	
	Saltwater/Bundaberg Creek	Distillery Creek
Total Catchment Area	3456 ha	192 ha
No. of model sub-catchments	15	5
Initial Rainfall Loss	10 mm	
Continuing Rainfall Loss Rate	4.1 mm/h	
Floodplain Storage represented as	Retarding Basin node	
Pump rate represented as	Defined spillway level-discharge relationship	
Design Storm Durations	10 minutes to 1440 minutes	
Design Storm Magnitudes	5, 10, 20, 50, 100 year ARIs	

2.4.4 Results

A thorough analysis and discussion of the results is presented in the Surface Water Technical Report. For brevity, a small sample of the outputs is presented below. Figure 2-9 shows the predicted peak water level behind the city section of levee, for the 20-year ARI design rainfall event, with standard durations ranging from 10 minutes (41 mm total rainfall depth) to 2160 minutes (317 mm total rainfall depth). Six curves are plotted, for pump rates ranging between 0 m^3/s (i.e., no pump) and 35 m^3/s, in increments of 7 m^3/s.

Following this, the differences in peak water level are plotted in Figure 2-10, with respect to the no-pump case.

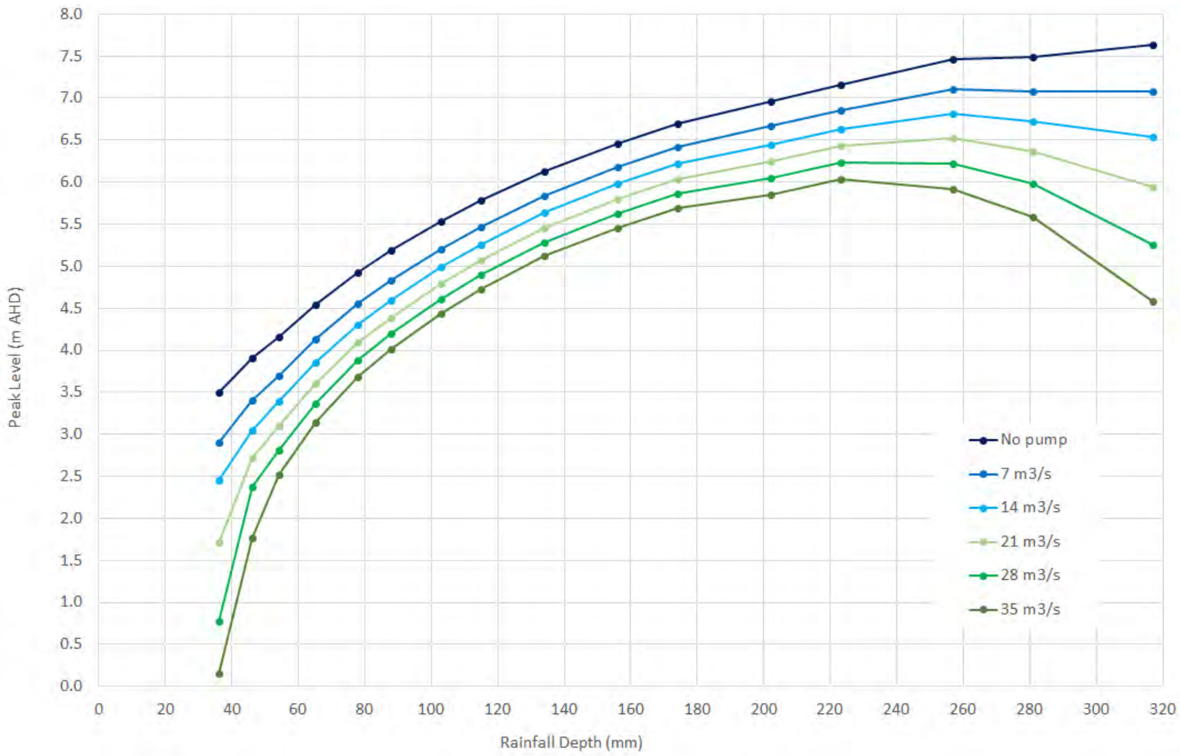


Figure 2-9 Peak Levels Behind Levee, Saltwater/Bundaberg Creek, 20-Year ARI Standard Rainfall Durations

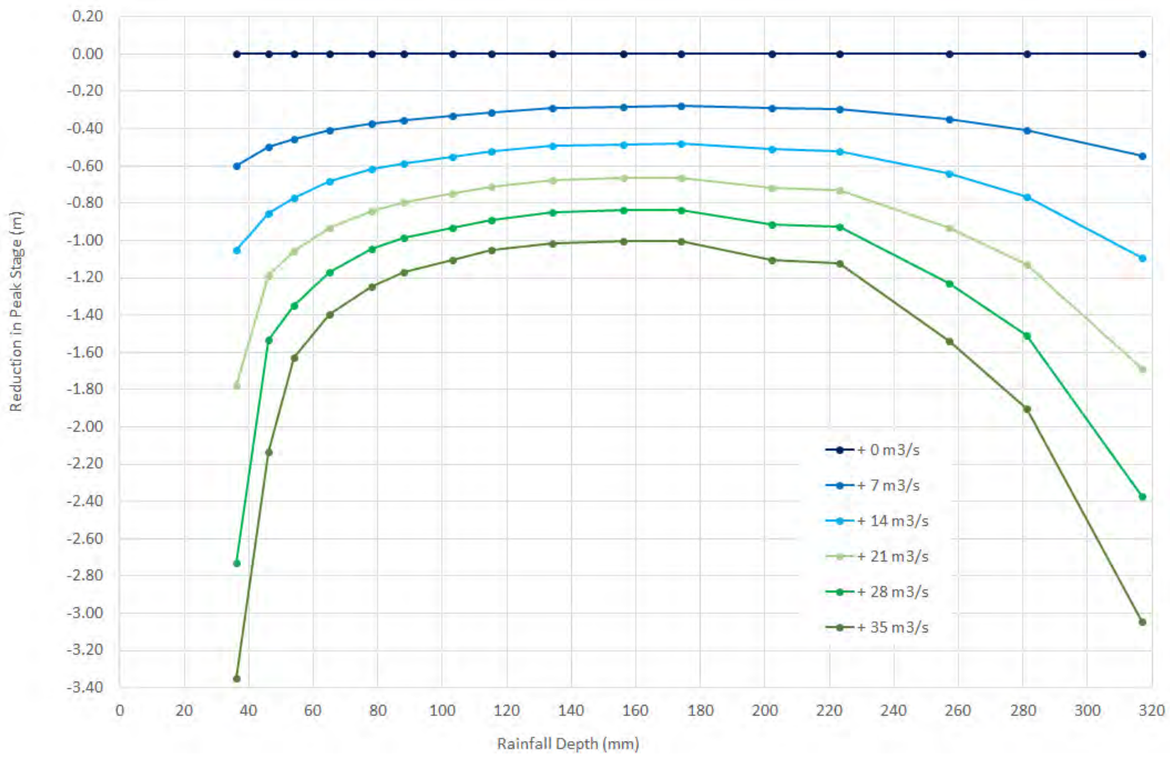


Figure 2-10 Peak Level Differences, Saltwater/Bundaberg Creek, 20-Year ARI Standard Rainfall Durations

The results indicated that pump rate had only a weak influence upon peak level throughout much of the curve, although effects were more pronounced for very small rainfall depths (small total volume, easily pumped away) and very large rainfall depths (corresponding to long storm durations, and thus distributed over a longer time frame, giving smaller peak inflows). Generally, however, it appears that the cost of larger pumps is not justified by the reduction in peak level.

For example, when comparing the 7 m^3/s case to the 35 m^3/s case, it can be seen that for storms ranging in duration between 30 minutes (65 mm total rainfall depth) and 12 hours (223 mm total rainfall depth), the incremental reduction in peak level is less than one metre – unlikely to be significant enough to justify a 5-fold increase in capital expenditure.

From this analysis, it can be concluded that it is the available floodplain storage and total rainfall depths that are the main drivers of peak flood levels behind the levee. Based on this result, the following design pump rates (duty capacity) have been adopted:

- **Saltwater/Bundaberg Creek:** 7 m^3/s
- **Distillery Creek:** 1 m^3/s

In both cases, the design pump rate in tandem with available floodplain storage is sufficient to accommodate a storm with a total rainfall depth of approximately 100 mm, without causing undue impacts to the built environment behind the levee.

In reality, the decision to open or close the gates in the face of an impending flood is a complex one, driven by multiple factors including the size of flood, likelihood of future local rainfall, and the current conditions of both river levels and creek runoff. A detailed operating strategy taking these considerations into account should be developed as part of the detailed design phase.

2.5 Flood Gate Hydraulics

2.5.1 Basis of Design

The design of pump station and flood gate structures is considered in **Sections 5** and **6** of this report. Consideration of the ground conditions, required pump sizes, and topography has led to the following configurations:

- **Saltwater Creek:** 4 gates, each 4.5 m wide by 4.5 m high, invert level -1.0 m AHD.
- **Distillery Creek:** 2 gates, each 2 m wide by 3 m high, invert level 0.5 m AHD

2.5.2 Gate Hydraulic Models

A steady-state HEC-RAS model was constructed to evaluate the possible hydraulic impacts arising from installation of the gate structure with the respective creek channels. The systems were first evaluated in its current state, followed by implementation of the gates as a 1D inline structure. Simulations were carried out for a range of ARI's, using peak discharge values taken from the local runoff model (as discussed in Section 2.4).

Results are presented in Table 2-8 and Table 2-9. Flood levels and comparisons are evaluated on the immediate upstream side of the gates, where any impacts are likely to be the most pronounced.

Table 2-8 Results of Gate Hydraulic Model – Saltwater Creek

Probability Classification in		Peak Flowrate (m^3/s)	Peak Flood Level (m AHD)		Difference (m)
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)		Existing Case (no gates)	Future Case (with gates)	
50 %	1.44 year	76	2.02	2.05	0.03
20 %	4.48 year	131	2.05	2.15	0.09
10 %	9.5 year	173	2.1	2.23	0.13
5 %	20 year	213	2.16	2.44	0.28
2 %	50 year	261	2.25	2.87	0.62
1 %	100 year	304	2.37	3.31	0.94

With respect to Saltwater Creek, water level increases are generally predicted to be minor for events smaller than the 20-year ARI. Head losses increase with increasing flood magnitude, however even under the 100-year ARI case the gate opening does not become pressurised – that is, the predicted peak flood level (3.31 m) is less than the top-of-gate level (3.4 m AHD). It should also be noted that these impacts are likely to be conservatively high. In reality, peak discharge occurs only momentarily, and a dynamic simulation would likely predict lower levels and smaller impacts. Based on these results the proposed gate dimensions are found to be suitable with respect to conveyance of local creek runoff.

Table 2-9 Results of Gate Hydraulic Model – Distillery Creek

Probability Classification in		Peak Flowrate (m^3/s)	Distance from Burnett River (m)	Peak Flood Level (m AHD)		
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)			Existing Case (no gates)	Future Case (with gates)	Difference (m)
20 %	4.48 year	21	140 (u/s gate)	1.17	2.6	+ 1.43
10 %	9.5 year	25	140 (u/s gate)	1.22	2.86	+ 1.64
5 %	20 year	28	140 (u/s gate)	1.26	3.05	+ 1.79
2 %	50 year	32	140 (u/s gate)	1.31	3.29	+ 1.98
1 %	100 year	36	140 (u/s gate)	1.36	3.46	+ 2.10
20 %	4.48 year	21	185	2.96	2.96	+ 0.00
10 %	9.5 year	25	185	3.09	3.09	+ 0.00
5 %	20 year	28	185	3.18	3.18	+ 0.00
2 %	50 year	32	185	3.29	3.29	+ 0.00
1 %	100 year	36	185	3.4	3.4	+ 0.00

At Distillery Creek the hydraulic picture is slightly more complex, owing to the relatively steep longitudinal grade where the floodwall crosses the creek. In the existing case, the HEC-RAS model predicted supercritical flow at this location (fast velocities, low water levels) and a resulting hydraulic jump downstream where the bed grade flattens. In contrast, the future case implementation of a gated structure would disrupt this hydraulic jump, forcing the flow to remain sub-critical and leading to comparatively higher water levels, and lower velocities.

Analysis of the results suggests that a break in grade at around Ch 180 m would serve as the hydraulic control in both the existing and future cases. That is, downstream of this point construction of the gates is likely to cause increases in peak water levels, whereas upstream of this point, there is essentially no change. This is illustrated below in Figure 2-11.

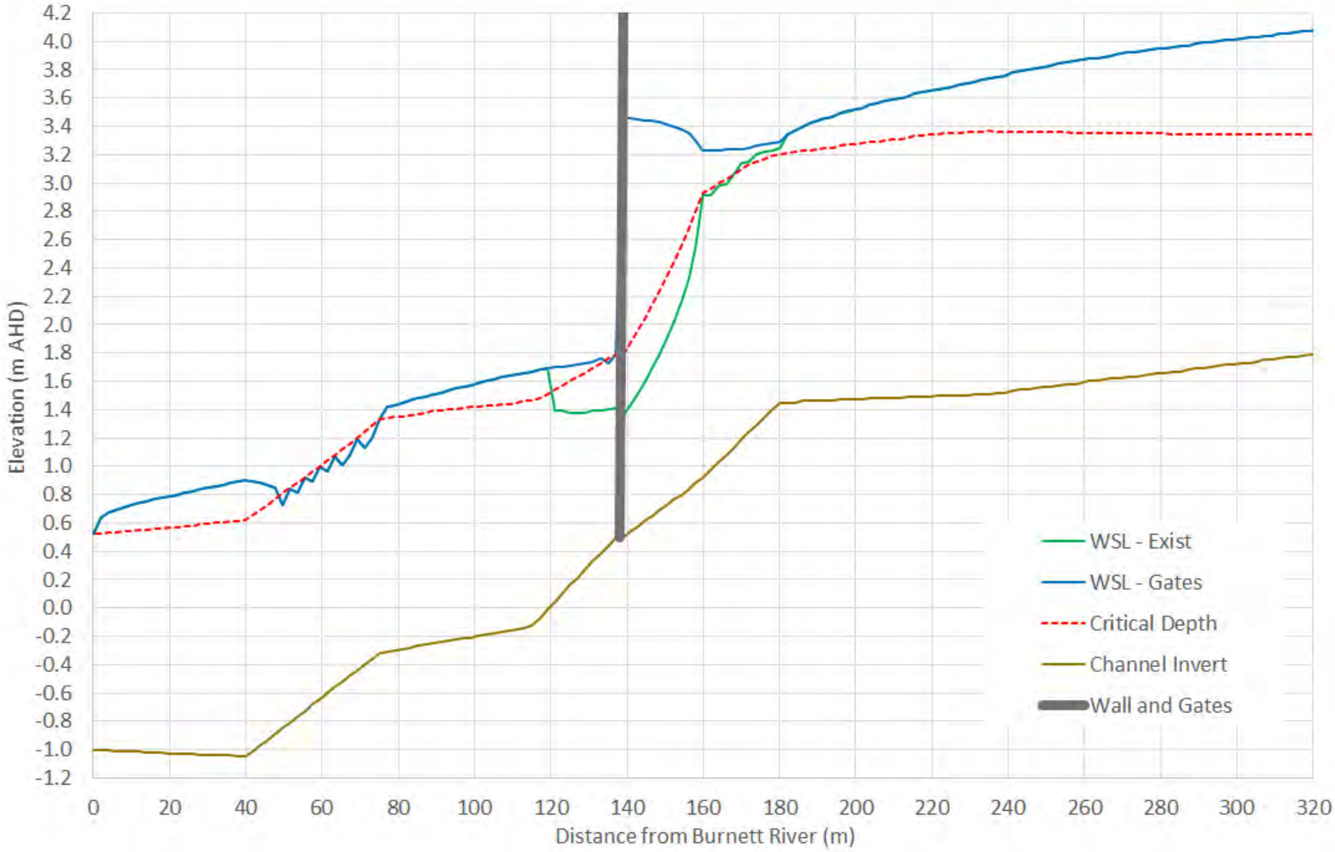


Figure 2-11 Longitudinal Water Surface Profile – Distillery Creek 100-year ARI.

For all flood events under consideration, peak water levels in Distillery Creek are predicted to remain both contained within the channel, and below the top-of-gate level. Based on these results the proposed gate dimensions are found to be suitable with respect to conveyance of local creek runoff.

2.6 Local Drainage Considerations

The construction of flood mitigation levees often causes natural flow paths to be cut, requiring the provision of cross-drainage infrastructure so that local overland flow can be conveyed under/across the levee without causing undue impacts on the upstream side. Given the prevailing topography – the wall is proposed to be constructed largely along the high ground of Quay Street – and the requirement to maintain dry-weather road and lot access, it should be possible to construct the levee with few or no penetrating cross-drainage elements.

It is noted that Council's existing piped stormwater drainage network would be required to pass through the wall foundation, although only if left in its current configuration, an unlikely assumption considering the broad changes (footing excavation etc) required during construction.

Such cross-drainage structures as are necessitated by the design will require treatment to prevent backflow from river flooding. Broadly speaking, a wide range of products exist that serve to isolate stormwater networks and culverts from flooding backflow. These include such things as outlet flap valves, inflatable down-hole plugs, and down-hole penstocks. Similar treatments can be applied to the sewer network.

Further consideration to these matters will be given during the detail design phase.

2.7 Conclusions and Recommendations

Conclusions from the preceding sections are summarised below:

- **Confidence in Design Runoff Estimates.** Peak discharge values from the calibrated URBS model were found to match closely to those derived from the Flood Frequency Analysis, giving a good level of confidence that the estimates are indicative of the underlying probabilities, and are thus suitable for use in the design process.

- **Hydraulic Model Representative of Flood Behaviour.** A HEC-RAS 2D hydrodynamic model was constructed to route flood hydrographs from the Walla stream gauge to the river mouth. The calibration process resulted in a model that gave good agreement to the 2013 flood event in peak water levels and hydrograph timing, from which it is concluded that the model represents the hydraulic regime of the Burnett River, and is suitable for use in the design process.

- **Refined Pump Sizes.** Previous work had indicated that a pump size with a capacity in the order of 40 m^3/s would be required to protect against interior flooding at Saltwater/Bundaberg Creeks. This estimate was refined by accounting for the floodplain storage that naturally becomes available as local runoff ponds on the inside of the levee, and building XP-RAFTS models to test various combinations of pump sizes and storm events. It was found that pump rates were relatively insensitive to peak interior water levels, and that pump rates of 7 m^3/s and 1 m^3/s (for Saltwater Creek and Distillery Creek, respectively) would provide a good balance of flood protection and capital cost

- **Flood Gate Hydraulics.** Steady-state HEC-RAS models were constructed to analyse the impacts that the flood gates might have on water levels, with respect to local creek runoff (ie. in the case when the gates are open and Burnett River levels are not elevated). It was found that the gate sizes as proposed cause some level of afflux, but that increases were not major, and in the case of Distillery Creek, confined to only a short section of the stream.

Based on the work documented in the preceding sections of this report, the following recommendations are made:

- **Levee Crest Elevation.** Although a significant longitudinal flood gradient does not exist along the levee alignment (owing to the backwater effect), there is a slight decrease towards the eastern end of the distillery section. Consideration should be given to refining the crest elevation in this area during the detailed design phase.

- **Flood-gate/Pump Operating Strategy.** As part of the detailed design phase, a thorough investigation should be carried out to develop a robust operating strategy and decision support tool that can be implanted by local stakeholders during a flood event.

Section 3 Geotechnical Investigation

3.1 Regional Geology

CDM Smith's review of available subsurface data indicates that multiple geologic formations are present within the vicinity of the project site including Flood-Plain Alluvium (Alluvial Soils) surrounding the two creeks along with the Elliott Formation along the entire length of the proposed flood wall alignment (Department of Mines and Energy, 2008).

Flood-Plain Alluvium is characterized by clay, silt, sand, and gravel associated with alluvial deposition in the Quaternary age. The Elliott Formation is characterized by sandstone, conglomerate, siltstone, mudstone, and shale up to 34 m thick, that were deposited on the river plain in the Early Miocene age. The formation was typically deeply weathered during the Cenozoic Era, which resulted in a reddish-brown layer of iron-oxide-rich material over a white-red mottled layer. The surface layer is hardened (ferricrete) due to wetting and drying over repeated seasonal cycles. The Elliott Formation generally consists of a few meters of moderately plastic clay above a weakly cemented sandstone cap that overlies approximately 20 m to 30 m of gravelly and clayey sands. Top of bedrock is typically encountered approximately 60 m below existing grade, based on discussions with the local drilling contractor C.M. Testing Service (CM Testing).

3.2 Subsurface Exploration Programme

The subsurface exploration program completed by CDM Smith was conducted to investigate subsurface conditions at the proposed Bundaberg East Levee site. The program consisted of fourteen (14) test borings (B-1 through B-14) drilled by GeoDrill Australia under contract to CM Testing. All test borings were conducted from 14 to 22 November 2017.

The as-drilled test boring locations were recorded using a handheld global positioning system (GPS) unit and are shown on **Error! Reference source not found.**. CDM Smith's Factual Geotechnical Report of F ebruary 2018, included in Appendix A, provides a detailed discussion of this subsurface exploration programme.

3.3 Geotechnical Laboratory Testing

Geotechnical laboratory tests were performed on select split spoon and Shelby tube soil samples obtained from the subsurface exploration program. Geotechnical laboratory index tests on split spoon samples were performed at CM Testing in Bundaberg, Queensland. Organic content tests on split spoon samples were performed at ALS Environmental in Brisbane, Queensland. Geotechnical laboratory index, triaxial, and consolidation tests on split spoon and Shelby tube samples were performed at Trilab Pty. Ltd. (Trilab) in Geebung, Queensland.

The tests were performed in accordance with Australian Standards. The purpose of these tests was to assist with soil classification and to estimate soil parameters to be used in engineering analyses.

The Factual Geotechnical Reports included in Appendix A provide a detailed discussion of the geotechnical laboratory testing program.

3.4 Subsurface Conditions

Subsurface soil conditions at the Bundaberg East Levee project site were interpreted from the test borings conducted as part of this study. The test borings typically encountered fill over alluvial soils over the Elliott Formation. The Factual Geotechnical Reports included in Appendix A provide a detailed discussion of the subsurface conditions.

Subsurface cross-sections for the proposed levee alignment alternatives have been developed at the approximate locations shown on Figure 1-1. The levee alignment subsurface cross-sections summarizing the available data from the test borings including split spoon sampler blow counts, Unified Soil Classification System (USCS) classification symbols, and approximate layering are shown on Figure 3-1 and Figure 3-2.

3.4.1 Fill

The fill layer was encountered at the ground surface in eleven of the fourteen test borings at the site, the exceptions being B-1, B-9, and B-11. The thickness of the fill layer ranged from 1.3 m to 5.5 m. The layer typically consisted of low plasticity clay (CL) and clayey sands (SC). Miscellaneous debris from a possible C&D debris landfill was encountered in test borings B-5 and B-14 and included wood, waste material, glass, ceramics, fabric, and wire. In addition, test boring B-2 encountered gravel and cobble fill to 3 m BGS, and test borings B-12 and B-13 encountered metal scraps, boiler ash, and charcoal to 2.5 m BGS.

3.4.2 Alluvial Soils

The alluvial soils layer was encountered in ten of the fourteen test borings, being absent from B-1, B-8, B-11, and B-14. The alluvial soils layer was typically encountered below the fill layer except at test boring B-9 where it was encountered at the ground surface. The thickness of the alluvial soils layer ranged from 2.0 m to 17.5 m where the layer was fully penetrated. The layer typically consisted of very soft to soft high-plasticity clays (CH), low-plasticity clays (CL), and organic high-plasticity clays (OH).

3.4.3 Elliott Formation

The Elliott Formation layer was encountered in twelve of the fourteen test borings except for test borings B-5 and B-14. The Elliott Formation layer was typically encountered below the alluvial soils layer except at test borings B-1 and B-11 where it was encountered at the ground surface and at test boring B-8 where it was encountered below the fill layer. The Elliott Formation layer was not fully penetrated at any of the test boring locations and was penetrated up to 16.95 m. The layer typically consisted of high-plasticity clay (CH), low-plasticity clay (CL), clayey sand (SC), clayey gravel (GC), and poorly graded sand (SP). In test boring B-8, a 3.2-m-thick layer of mudstone was encountered at the top of the Elliott Formation. In the vicinity of Saltwater Creek, the Elliott Formation typically consisted of clayey soils (CH and CL). In the vicinity of Distillery Creek, the Elliott formation typically consisted of coarse-grained soils (SC, GC and SP).

Figure 3-1 Levee Subsurface Cross-Sections (C1)

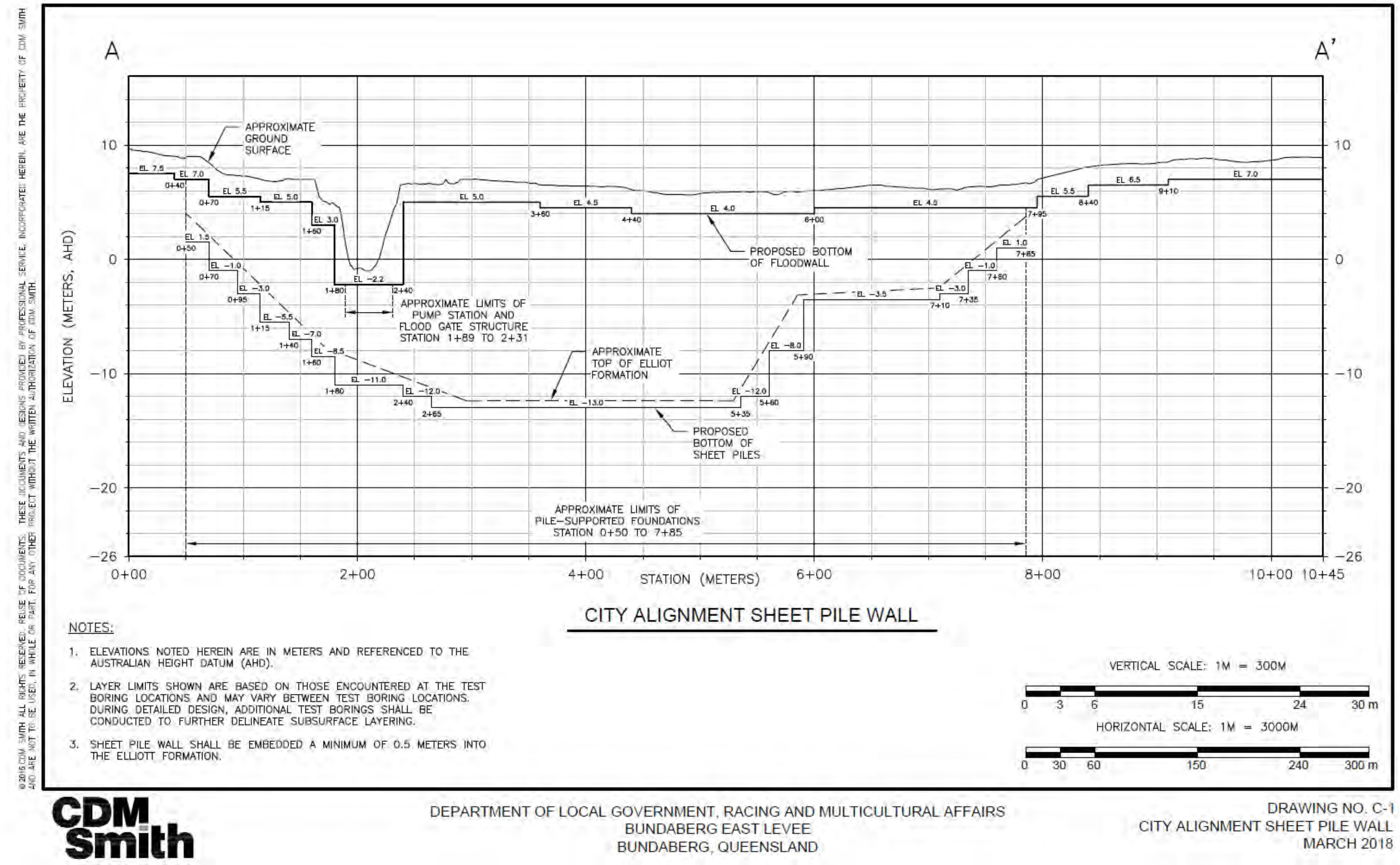
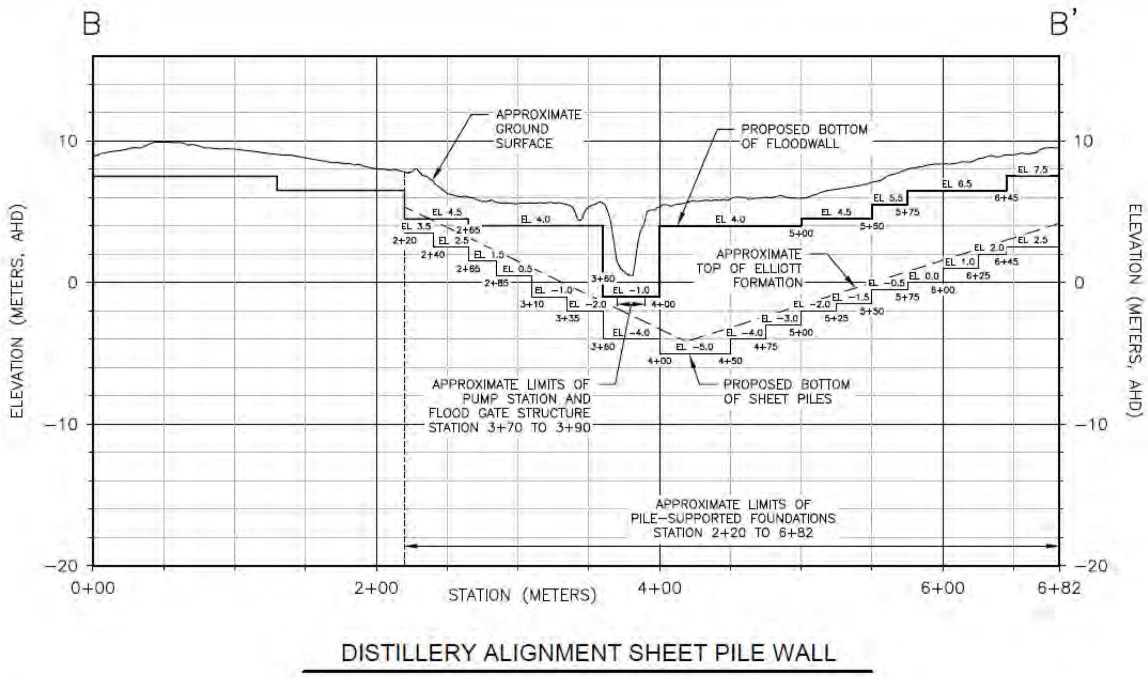


Figure 3-2 Levee Subsurface Cross-Sections (C2)



NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. LAYER LIMITS SHOWN ARE BASED ON THOSE ENCOUNTERED AT THE TEST BORING LOCATIONS AND MAY VARY BETWEEN TEST BORING LOCATIONS. DURING DETAILED DESIGN, ADDITIONAL TEST BORINGS SHALL BE CONDUCTED TO FURTHER DELINEATE SUBSURFACE LAYERING.
3. SHEET PILE WALL SHALL BE EMBEDDED A MINIMUM OF 0.5 METERS INTO THE ELLIOTT FORMATION.

VERTICAL SCALE: 1M = 300M

0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M

0 30 60 150 240 300 m

CDM Smith

DEPARTMENT OF LOCAL GOVERNMENT, RACING AND MULTICULTURAL AFFAIRS
BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

DRAWING NO. C-2
DISTILLERY ALIGNMENT SHEET PILE WALL
MARCH 2018

3.5 Groundwater Conditions

The depth to groundwater was recorded prior to backfilling at test boring B-6 and was measured at approximately 1 m bgs (2.5 m AHD). The groundwater measurement was taken within the steel casing at the test boring location and may not represent static groundwater conditions. No groundwater monitoring wells were installed as part of the test boring program.

A real-time groundwater monitoring station (DNRM Station RN13600207A) exists at Kendall Flats, approximately 200 m south of the proposed flood wall alignment. The average daily groundwater elevation at this station for 2017 was measured to be 1.5 m AHD with the average daily minimum measured at 0.9 m AHD, and the average daily maximum measured at 2.3 m AHD. The approximate location of the groundwater monitoring station is shown on **Error! Reference source not found.**.

3.6 Expected Variations in Subsurface Conditions

Subsurface conditions presented herein are based on soil and groundwater conditions observed at the test boring locations. However, subsurface conditions may vary at other locations within the site.

Groundwater levels may change with river and creek levels, time, season, temperature, and construction activities in the area, as well as with other factors. In addition, stabilized groundwater levels can be difficult to obtain in test borings drilled using mud rotary due to the presence of drilling fluid in the borehole. Therefore, groundwater conditions at the time of construction may be different from those observed at the time of the test borings.

3.7 Supplemental Investigation

The initial geotechnical investigation was required to cover a broad area, reflecting the possible alignments that were under consideration at the time. During the concept design process, a preferred alignment was selected, and it was determined that a targeted supplemental investigation was required to provide more detail in portions of the preferred alignment that were not covered under the initial drilling. Nine (9) boreholes (BH-101 through BH-109) were drilled between 12 and 15 November 2018. Core Consultant’s Factual Geotechnical Report of February 2019, included in Appendix A, provides a detailed discussion of this subsurface exploration programme.

Section 4 Geotechnical Design Recommendations

4.1 Geotechnical Engineering Evaluations

Geotechnical engineering evaluations have been made as they relate to the proposed floodwall, pump station and flood gate structure and equipment building design in Bundaberg, Queensland. In general, these evaluations have been based on the results of the geotechnical investigation, laboratory test results, published correlations with soil properties, and the requirements of the relevant Australian Standards. In addition, recommended design criteria are based on performance tolerances, such as allowable settlement, as understood to relate to similar structures.

The Interpretive Geotechnical Reports (IGR) included in **Appendix C** provide a detailed discussion of the geotechnical analyses performed related to the geotechnical design recommendations. The IGR also provides construction considerations related to the geotechnical design. The documents in Appendix C, and the summary of them provided below takes into account the information contained in both the initial and supplementary factual geotechnical reports of Appendix A.

4.2 Foundation Design Recommendations

4.2.1 General

Based on the proposed alignment, anticipated dimensions, depths, and loadings of the proposed structures and subsurface conditions present at the site, the majority of the proposed floodwall, the pump station and flood gate structures, and the equipment building should be supported on deep foundations bearing in the Elliott Formation. At select locations discussed below, portions of the floodwall may be supported on shallow foundations bearing in the Elliott Formation or on structural fill placed over the Elliott Formation after removal of unsuitable soils.

4.2.2 Recommendations for Design of Pile-Supported Foundations

Based on the available subsurface information, project requirements, and anticipated foundation loading conditions, we recommend that the floodwall along the City Alignment between Ch. 50 m and Ch. 785 m and the floodwall along the Distillery Alignment between Ch. 150 m and Ch. 682 m be supported on deep foundations. In addition, the pump station and flood gate structures and equipment building should be supported on deep foundations. Refer to Figures 3-1 and 3-2 for the subsurface conditions along the City and Distillery Alignments and approximate extents of the floodwalls to be supported on pile foundations.

4.2.3 Pile Types

500-mm-diameter driven steel cast in place piles, 400-mm-square driven concrete preformed piles (CPP), and 1-m-diameter bored cast in place piles (BCIPP) are considered suitable for the range of anticipated loads (i.e., 250 kN to 6,000 kN) for the proposed structures. Allowable capacities for the different pile types and minimum embedment depths into the Elliott Formation soil layer are provided below in **Table 4-1**. The allowable compression pile capacity is estimated based on skin friction and tip resistance developed in accordance with procedures outlined in the Federal Highway Administration “Design and Construction of Driven Pile Foundations” and “Drilled Shafts: Construction Procedures and LRFD Design Methods”, using

SPT N-values from test borings and other test results. A factor of safety of 1.39 is applied based on AS 2159-2009 Section 4.3.1 to the allowable compression and uplift capacities.

Table 4-1 Summary of Pile Capacities

		Total Allowable Compression Pile Capacity (kN)	Total Allowable Uplift Capacity (kN)	Minimum Embedment in Elliott Formation (m)
Saltwater Creek Pump Station and Flood Gate	500mm-diameter Driven Steel Cast in Place Pile	250	200	-
		500	325	-
		750	475	-
		1000	725	-
	400mm-square Driven Concrete Preformed Pile	250	200	3
		500	325	5
		750	525	9
		1000	725	12
	1m-diameter Bored Cast in Place Pile	250	400	1
		500	400	1
		750	400	1
		1000	450	3
		2000	650	9
		4000	1050	25
		6000	1400	40
City Alignment Ch. 100 m to Ch. 350 m	500mm-diameter Driven Steel Cast in Place Pile	250	200	1
		500	325	2
		750	475	5
		1000	725	8
	400mm-square Driven Concrete Preformed Pile	250	200	1
		500	325	2
		750	525	5
		1000	725	8
	1m-diameter Bored Cast in Place Pile	250	400	1
		500	400	1
		750	400	1
		1000	450	2
		2000	650	8
		4000	1050	25
		6000	1400	40
City Alignment Ch. 350 m to Ch. 750 m	500mm-diameter Driven Steel Cast in Place Pile	250	150	2
		500	375	8
		750	525	12
		1000	750	17
	400mm-square Driven Concrete Preformed Pile	250	150	2
		500	375	8
		750	525	12
		1000	750	17
	1m-diameter Bored Cast in Place Pile	250	200	1
		500	250	3
		750	350	7
		1000	450	11
Distillery Creek Flood Gate, and Distillery	500mm-diameter Driven Steel Cast in Place Pile	250	75	1
		500	175	4
		750	325	8

		Total Allowable Compression Pile Capacity (kN)	Total Allowable Uplift Capacity (kN)	Minimum Embedment in Elliott Formation (m)
Alignment Ch. 250 m to Ch. 700 m		1000	475	11
	400mm-square Driven Concrete Preformed Pile	250	75	1
		500	200	5
		750	375	9
		1000	525	12
	1m-diameter Bored Case in Place Pile	250	250	2
		500	300	3
		750	375	5
		1000	400	6

Based on the available subsurface information, project requirements, anticipated foundation loading conditions, and our understanding of current market conditions, we recommend that the floodwalls and Distillery Creek flood gate structure be supported on 400-mm-square CPP bearing in the Elliott Formation, and the Saltwater Creek pump station and flood gate structure be supported on 400-mm-square CPP and/or 1m diameter BCIPP bearing in the Elliott Formation. These recommendations are made for the following reasons:

- Based on conversations with a local piling contractor (Wagstaff Piling Pty Ltd.), steel pipe piles are approximately 150 to 200 percent more expensive than CPP piles due to the cost of steel in the Australian market; and
- The pile lengths may vary along the length of the floodwall alignment due to the highly variable density and material types within the Elliott Formation (i.e., the bearing layer). This variation would result in difficulties correlating compression and uplift capacity using drilled pile methods. However, driven piles are considered a more-appropriate solution for highly variable soils because the compression and uplift capacity can be correlated to a driving criteria (resistance) recorded during pile driving.
- CDM Smith has considered a combination of 400 mm square CPP and/or 1m diameter BCIPP at the Saltwater Creek pump station and flood gate structure, allowing for the construction cost estimator the flexibility to determine the most cost effective piling solution for this heavily loaded structure.

4.2.3.1 CPP Installation Criteria

Pile Tip Embedment and Blow Count Criteria

Piles should be installed to a specified final driving resistance (criteria) and into the underlying Elliott Formation or to practical refusal, whichever is encountered first. Practical refusal is defined as a penetration of 25 mm or less for the final 10 blows with a properly functioning pile hammer operated at the maximum energy setting. Piles should not be driven harder than practical refusal. Piles may occasionally encounter refusal in the Elliott Formation prior to reaching the specified minimum embedment in the Elliott Formation. All piles must be driven to at least 1 m into the Elliott Formation. Piles with less than the minimum embedment into the Elliott Formation may be subject to allowable capacity reductions following evaluation by the geotechnical engineer.

The final driving resistance criteria should be determined based on a wave equation analysis conducted using the Contractor's proposed pile driving equipment and subsequently confirmed with the dynamic load tests. Regardless of the results of the wave equation analysis, the final driving resistance should not be less than an average of 3 hammer blows per 25 mm of penetration for the last 300 mm of pile driving.

Pile Details
CPP should be fabricated with steel plate tips to protect the pile during driving. Piles should be spaced no closer than three pile widths on center. Piles should be embedded into the pile caps no less than 76 mm. Pile connections into the pile caps should be designed in accordance with the relevant Australian Standards.

Estimated Driven Pile Lengths
Final pile lengths will vary due to the variation in the elevation of the bottom of structure and variations of subsurface conditions along the floodwall alignments. Assuming that piles are driven from the approximate bottom of the proposed foundations, we estimate that pile lengths will range between 5 m and 20 m for the flood walls, between 8 m and 10 m for the Distillery Creek flood gate structure, and between 20 m and 30 m for the Saltwater Creek equipment building. Pile splices are not anticipated to be required. All piles should be installed as one piece, and no splices should be allowed. The use of followers for the installation of piles should not be permitted.

Indicator Piles and Pile Load Test
We recommend that indicator piles be driven at five percent of the production pile locations within the footprints of the pump station and flood gate structure and equipment building and five percent of the production piles along the length of the floodwall to assist the Contractor in determining production pile lengths and confirming hammer performance, stresses in the pile during driving, and pile capacity. Dynamic pile testing (PDA testing) should be conducted on each of the indicator piles. The locations of the indicator piles selected by the Contractor should be approved prior to installation. Indicator piles may be installed at production pile locations.

Dynamic pile testing using a Pile Driving Analyzer™ (PDA) should be conducted on all indicator piles in accordance with Australian Standard 2159-2009 Piling - Design and Installation (AS 2159) during initial driving and for restrikes. Restrikes should be conducted on all indicator piles a minimum of 7 days following the end of initial driving to evaluate "setup" or "pile freeze" effects in the Elliott Formation. A Case Pile Wave Analysis Program (CAPWAP®) should be performed to predict ultimate pile capacity in accordance with the AS 2159. A CAPWAP® analysis should be performed for each indicator pile for the end of initial driving and beginning of restrike.

4.2.3.2 BCIPP Installation Criteria

The BCIPP will be considered pending the results of the OPCC for the Bundaberg Creek pump station and flood gate structure. Therefore, this section is included in the report to provide context should BCIPP be selected as the final conceptual alternative to CPP for the Saltwater Creek pump station and flood gate structure.

Pile Tip Embedment
All piles must be drilled to at least 1 m into the Elliott Formation.

Pile Details
Piles should be spaced no closer than three pile diameters on centre. Piles should be embedded into the pile caps no less than 76 mm. Pile connections into the pile caps should be designed in accordance with the relevant Australian Standards.

Estimated Drilled Pile Lengths

Final pile lengths will vary due to the variation in the elevation of the bottom of structure and variations of subsurface conditions within the footprint of the structure. The estimated drilled pile lengths will be determined pending the results of the OPCC for the CPP.

Indicator Piles and Pile Load Tests

We recommend that indicator piles be drilled at five percent of the production pile locations within the footprint of the pump station and flood gate structure to assist the Contractor in determining production pile lengths and pile capacity. The locations of the indicator piles selected by the Contractor should be approved prior to installation. Indicator piles may be installed at production pile locations.

Dynamic pile testing should be conducted on all indicator piles in accordance with AS 2159.

4.2.3.3 Pile Cap and Grade Beam Depth

Pile caps and grade beams should extend at least 1.5 m below any adjacent ground surface and interior pile caps and grade beams should extend at least 1.5 m below the top of the slab.

4.2.3.4 Foundation Settlement

Settlement of the pile-supported structures, under the anticipated loads and designed as recommended above, are expected to be less than 26 mm of total settlement and 13 mm of differential settlement.

4.2.3.5 Underseepage Considerations

Due to high seepage gradients through the alluvial soils layer, all floodwalls supported on pile foundations shall include a sheet pile wall below the pile cap that extends a minimum of 0.5 m into the Elliott Formation.

4.2.4 Recommendations for Design of Shallow Foundations

Based on the proposed project site layout, anticipated dimensions, depths, and loadings of the proposed floodwall, and other design requirements, we recommend that the proposed floodwalls along the City Alignment between Ch. 0 m and Ch. 50 m and between Ch. 785 m and Ch. 1045 m and along the Distillery Alignment between Sta. 0+00 and Sta. 2+20 be supported on shallow foundations bearing on suitable foundation bearing soils. Suitable bearing soils consist of the Elliott Formation or structural fill over the Elliott Formation placed after removal of unsuitable soils. Unsuitable soils include existing fill, alluvial soils, organic soils, or any other soft, loose, or disturbed soil present at the foundation subgrade level. Foundations for the proposed floodwalls may be designed for a maximum allowable bearing pressure of 150 kPa provided they bear on suitable bearing soils.

Where the structure is founded on structural fill, the fill should extend two feet from the edge of the foundation, then outward and downward at a slope of 1 horizontal to 1 vertical (1H:1V) to suitable bearing soils.

4.2.4.1 Foundation Depth

All foundations supported on soil should bear at least 1.5 m below any adjacent ground surface exposed to freezing.

4.2.4.2 Foundation Settlement

Settlement of the shallow foundations, with maximum allowable footing bearing pressures and assumed loading indicated herein, is anticipated to be less than 26 mm of total settlement and 13 mm of differential settlement.

4.3 Design Groundwater Elevation

A real-time groundwater monitoring station exists at Kendall Flats, approximately 200 m south of the proposed flood wall alignment. The average daily groundwater elevation at this station for 2017 was measured to be 1.5 m AHD with the average daily minimum measured at 0.9 m AHD, and the average daily maximum measured at 2.3 m AHD.

The 100-year flood level for the site is RL 9.3 m AHD based on the hydrologic and hydraulic (H/H) analyses.

For the purpose of design, we recommend a design groundwater level at RL 9.3 m AHD on the river side of the flood wall and at the ground surface on the land side of the flood wall.

4.4 Seismic Considerations

Based on "The 2012 National Earthquake Hazard Map of Australia", the project lies within a region with a peak ground acceleration of 0.05 g for the 500-year return period ground peak acceleration (PGA) hazard map. Based on the subsurface soil conditions, the soils at the site are not considered susceptible to liquefaction.

4.5 Lateral Pressure on Below-Grade Walls and Floodwalls

Below-grade walls that are backfilled with engineered fill on one side and restrained against rotation at the top, should be designed for lateral pressures from soil and groundwater based on an equivalent fluid unit weight of 9.4 kN/m^3 above the design groundwater level and 14.1 kN/m^3 below the design groundwater level.

In addition, a pressure equal to 0.5 times surface surcharge loads from vehicular loads, building foundations, or other loads should be applied over the full height of all walls. Earthquake induced pressures should be included as applicable per the applicable Australian Standards.

Below-grade walls that are backfilled with engineered fill on one side and free to rotate at the top should be designed for lateral pressures from soil and groundwater based on an equivalent fluid unit weight of 6.3 kN/m^3 above the design groundwater level and 12.6 kN/m^3 below the design groundwater level.

Surface surcharges and other loads should be applied in the same manner as the restrained walls described above.

4.6 Resistance to Unbalanced Lateral Loads

Unbalanced lateral loads should be designed to be resisted by friction on the bottom of the shallow foundation bearing on the Elliott Formation or on structural fill placed directly over the Elliott Formation. For purposes of design, a coefficient of friction of 0.4 should be used. It is expected that the available friction will be sufficient to resist the unbalanced lateral loads. However, should lateral loads exceed the friction available, the additional loads may be resisted by passive pressures on the foundations, provided the walls are appropriately design for the pressures.

A passive lateral earth pressure resistance of up to a maximum equivalent fluid pressure of 31.5 kN/m^3 may be assumed provided the foundations are backfilled with structural fill compacted to a density of at least 98 percent of the maximum dry density as determined by laboratory test AS 1289.5.1.1. The resistance from the upper 0.6 m of soil should be neglected due to surface effects and potential for disturbance from frost action and other factors. Frictional resistance should be assumed to be mobilized first and to its full capacity before any passive pressure is developed.

For pile-supported foundations, lateral load resistance of 25 percent of the compression pile capacity summarized in Table 4-1 can be developed from piles battered at 1H:4V. The effects of passive soil resistance should not be considered. No frictional resistance may be assumed on the bottom of pile-supported foundations.

4.7 Resistance to Buoyancy

The proposed structures should be designed to resist flotation due to buoyancy under the design groundwater condition. Dead weight of the structure, the weight of soil vertically above the structure, and any extension of the foundation beyond the structure wall may be assumed to resist flotation. The unit weight of the backfill soil used to calculate resistance to flotation should be assumed to be 18.1 kN/m^3. In addition, for pile-supported foundations, uplift capacities as summarized in Table 4-1 may be used for design against uplift.

A minimum factor of safety against flotation of 1.25 should be used to evaluate uplift resistance under normal groundwater and 100-year flood conditions. A minimum factor of safety of 1.1 should be used to evaluate uplift resistance under 500-year flood conditions.

4.8 References

- Australian Building and Construction Commission, *National Construction Code: Volumes One and Two*, 1 May 2016.
- American Petroleum Institute, *API Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*, 21st Edition, December 2000.
- Federal Highway Administration, *Drilled Shafts: Construction Procedures and LRFD Design Methods*, Publication No. FHWA-NHI-10-016, May 2010.
- Standards Australia, *AS 2159-2009, Australian Standard - Piling -Design and Installation*, Amendment No. 1, 4 November 2009.

Section 5 Pump Station Design

5.1 Introduction

5.1.1 Description of Works

One permanent pump station (PS) is planned for the Project at Saltwater Creek, and a temporary skid / trailer mounted mobile engine-driven pump is planned for service at Distillery Creek.

The Saltwater Creek PS described in this Section will house electric-motor-driven pumps for flood control. A project goal is to limit obstruction of the view of the Burnett River enjoyed by residents with consideration given regarding the visual amenity aspect, so submersible pumps have been selected. Use of these pumps will result in a low-profile pump station. Conceptual drawings of the pump stations are included in Appendix B.

The Saltwater Creek PS will consist of a pump floor slab with appropriate concrete openings for access to the pumps/piping. Discharge from the pumps will be located underneath the slab to the river via a flood flap. A separate Control Building will be constructed to house the electrical room, control room, break room with refrigerator and restroom. This pump station is for flood control and, as a result, is considered to be a staffed station during flood events. For this reason, provisions have been considered for full-time occupancy during these events. The finished floor elevation of the Control Building at BCPS will be above the 500-year flood elevation to keep controls and personnel safe should an event exceed the design flood.

5.1.2 Project Location

The proposed PS at Saltwater Creek will consist of a flood control dam and water control facility, with pump bays integrated into the civil works structures. The flood control dam is proposed to be located on Saltwater Creek, downstream of the pedestrian bridge (ie. old rail bridge), and near the confluence at the Burnett River. An undeveloped 1200 m^2 at 1E Quay Street East to the east of the Creek turnout is proposed as a location for the Control Building.

The proposed Distillery Creek operations platform is located adjacent to the floodwall on Distillery Creek, where Cran Street enters the Bundaberg Sugar property, approximately 150m upstream from the Burnett River confluence. The waters flowing in the creek are a combination of industrial wastewater effluent and local rainfall run-off.

5.2 Hydraulic Requirements

5.2.1 Intake Forebay and Suction Bay Sump Design – Saltwater Creek Pump Station

A layout of the Saltwater Creek PS is shown on Drawing M-1. The transition from the forebay into each pump bay sump must provide a smooth path that limits the development of undesirable flow phenomena, which can include the following:

- Non-uniform flow at the pump intake, which can cause pulsating loads on the propeller blades, noise, and damaging vibration. This phenomenon can also decrease efficiency, increase power, and cause nuisance motor tripping.

- Unsteady flow, which is often caused by debris in the intake, can also lead to noise and damaging vibration.
- Swirl in the intake, which can change the head, flow, efficiency, and power in undesirable ways. This phenomenon can exacerbate others, such as vortices.
- Vortices with a steady and coherent core, which can cause discontinuities in the flow and can lead to noise, damaging vibration, and local cavitation. When vortices emanate from the free surface of the intake water, they can draw air and floating debris into the pump.
- Entrained air can reduce flow and efficiency, and cause noise and damaging vibration.

A bathymetric survey of the Saltwater Creek and Distillery Creek must be performed as part of the detail design phase to determine the range of bottom elevation in each waterway. Approach velocities within the pump inlet forebay will be limited to a maximum of 0.3 m/s.

There are two commonly used intake configurations, which are typically used at United States Army Corps of Engineer (USACE) flood control pump stations, and each were considered alternatives for the PS. Alternative No. 1 is the Rectangular Intake (RI) design in accordance with ANSI/HI 9.8-1998. Alternative No. 2 is the Formed Suction Intake (FSI) design. The RI design consists of a rectangular pump well (ANSI/HI 9.8-1998) open on one side to the influent flow and with the pump supported from the structural slab over the well. The RI design, in accordance with ANSI/HI 9.8-1998, is generally more economical to design and construct. However for the ease of installation and reduction in inlet pump vortices the Preferred Alternative selected for the PS is a FSI design, as shown on Drawing M-2.

The FSI intake is the Preferred Alternative, based on our experience at facilities of similar capacity and configuration, and input from pump manufacturers. Typically, FSI design is used in medium- and large-capacity pump stations. An FSI requires less excavation depth to establish the intake floor elevations than an equivalent RI. Since the intake floor is the lowest point in the pump station, this design may have a significant cost impact. The FSI also provides radial support to the lower end of the pump as opposed to an unsupported pump in an RI. This configuration reduces pump stresses and vibration, particularly for starting, stopping, and transients.

The negative side of an FSI is the additional cost of concrete and concrete forming. However, the concrete forming costs can be offset by the benefit of less excavation depth. Intake and pump model testing is required for the pump station. The model tests will be used to confirm the configuration of the proposed intake channel, hydraulic losses to the pump, pump position in the intake bay, and selection of the pump. However, for the purposes of design, calculations will be performed based on preliminary pump manufacturer requirements and ANSI/HI 9.8-1998.

As part of the specifications, the selected pump manufacturer will be responsible for performing a physical model of the intake structure prior to the start of construction and providing the design of the formed suction intake. The FSI configuration is dependent on each manufacturer. Any modifications to the intake channels required by the results of the physical model will be incorporated into the design by change order to both the engineer and the contractor.

Table 5-1 Estimated Pumping Head for Minimum and Maximum Conditions

Description	Estimated Pumping Head (m)	
	Minimum	Maximum
Screen Losses	0.15	0.30
Screen Channel Floor Elevation	-1.0	-1.0
Forebay Water Elevation	0.15	0.30
Pump Operating Floor Elevation	9.9 AHD	9.9 AHD
Discharge Water Elevation	5.0 AHD	9.3 AHD
Static Head	1.1	4.2
Friction Loss	1.3	1.5
Total Dynamic Head	1.4	5.7

5.3 Pump Station Layout and Design Criteria

5.3.1 Trash Rack Design Requirements

The PS has a forebay with a trifurcation directing flow to each pump bay sump. In each bay, the pumps must be protected from large debris that could restrict the hydraulic capacity of the pumps or damage components within the pumps. Size and quantity of debris will vary widely. Typically, seasonal variations should be expected, and some of the largest debris volume and size would be expected after a significant storm event. Trash racks will be installed on the entrance to each pump intake sump. The design criteria for the trash racks are included in Table 5-2.

Table 5-2 Trash Rack Design Criteria

Description	Design Parameter/Sizing
Aperture Between Bars	75 mm
Maximum Allowable Velocity	0.3 m/s
Maximum Allowable Head Differential	1.3 m
Inclination Angle (from vertical)	30 degrees
Screen Channel Widths	3.0 m
Channel Floor Elevation	-1.0 m AHD
Operating Floor Elevation	9.5 m AHD
Water Elevation (downstream of screen)	5.0 m AHD

Due to large vertical distances, the structural support of the trash racks will be considered during detailed design. The maximum width available for each trash rack is 3 m.

5.3.2 Trash Rack Selection

Front-cleaned trash racks were selected due to their low cost, simplicity, and relatively low level of anticipated maintenance. Removal of trash is automatic with maintenance access provided on the service bridge. A mobile crane will be necessary for removal and the servicing of the trash racks.

The trash racks rake machinery consists of horizontal scraping bars attached at each end to chain loops supported on rotating sprockets driven by electric motors. The scraper extends into the spaces between the bar rakes, pulling the debris to the top of the screen on the ascending travel of the loop, and returning the scrapper bar to the bottom of the rake on the descending travel of the chain loop. Screened materials will be discharged directly onto a horizontal conveyor that will transport the material to a container for temporary storage prior to removal and transport to an off-site disposal location.

5.3.3 Number of Pumps and Capacity

The PS will require isolation from the Burnett River and Saltwater Creek by flood closure structures (stop logs), discussed in **Section 6**, and pumping machinery to maintain the design pool elevation of 5.0 m AHD in Saltwater Creek during flood events. Based on the results of the hydrologic and hydraulic analysis included in **Section 2**, the PS design flow and total head are BCPS is 7 m^3/s and of 5.7 m, respectively. Three pumps have been selected for the PS, two duty pumps and one standby pump. Each pump will have a capacity of 3.5 m^3/s at a total head of 5.7 m.

The Distillery Creek will be serviced during times of flooding with a movable engine pump to be temporally installed with the suction line to be placed in a sump area on the side of the floodgate penstock area and discharge over the flood wall.

A summary of the pump station pumps and capacity is provided in Table 5-3.

Table 5-3 Summary of Pumps and Capacities

Facility	Design Capacity	Quantity and Type	Total Connected Electrical Load
Saltwater Creek Pump Station	7.0 m^3/s	- 3 units (2 Duty ,1 Standby) at 3.5 m^3/s each. - Submersible, axial flow pumps, vertical arrangement. - Electric motor driven, constant speed.	500 kW

5.3.4 Pumping Discharge Configuration

The recommended discharge configuration for the flood control pumps includes flap gates installed at the end of the discharge pipe, mounted to embedded frames in the walls on the flood side of the PS. Flap gates designed for pump discharge service must meet very severe operating conditions. They must be capable of withstanding forward and reversing surges of flow as the pump is turned on and off; and they must absorb the shock of rapid closure.

Flap gates can be furnished in cast iron or fabricated stainless steel. In rivers, the robustness of cast iron is preferred, but extra heavy-duty stainless steel gates can be specified that will meet the design life of the project. The flap gates come in a variety of configurations. The general approach is to position the hinge arms such that the lower pivot allows for a controlled cover rotation, which allows the leaf and frame seats to be aligned in the same plane.

Most flap gates have a head loss of 60 mm or less. The exit losses in the hydraulic calculations must be taken into account, but the losses due to the cover are not significant.

5.3.5 Electrical

The pump station control building will be built on Parcel RP2476715, located at 1E Quay Street East. Adjacent to the new flood control structure at Saltwater Creek. The power company serving this area is Ergon Energy. A new 480-V, 50Hz three-phase service will be required for the pump station location. Underground service to a pad-mounted utility transformer will be brought to the site to feed the pump station service entrance equipment. Coordination with the utility company will need to be arranged for details and requirements of transformer locations, pads, metering, etc.

The electrical power distribution design for Saltwater Creek PS will follow applicable design codes and standards and applicable guidelines. Continuous and reliable power will be provided to equipment. The design will include considerations for reliability, maintainability, and safety. The electrical distribution design criteria should include considerations for reliability, maintainability and safety. To provide for a reliable distribution the system should be designed with two independent sources of power and protection from common mode failures. These sources are generally a utility service and standby generators.

Common mode failures occur when a single fault or loss of power causes a disruption to the power distribution (i.e. more than one switchgear bus, motor control center or complete pumping units). To provide for an electrical distribution system for the station, that is reliable and maintainable, will require the ability to take portions of the distribution system out of service for routine maintenance (i.e. cable meggering, bus meggering, circuit breaker inspection/testing, etc.).

Provisions for safety are directly related to maintainability. A radial distribution has several limitations even when two sources of power are provided. The best distribution for the Saltwater Creek PS is a dual-ended secondary selective type design., where the distribution is divided into two parallel systems that have interconnecting tie breakers.

Under normal conditions main breakers will be closed and the tie breaker will be opened. Upon a failure of one of the main circuit breakers, or a utility feeder, the affected main breaker will open and the tie breaker will close, connecting all loads thru the other main circuit breaker. Electrical distribution equipment will be located in the climate controlled electrical room. The motor control center will be used to distribute small smaller loads such as lighting panels, etc. The motor control center will be dual-ended as well, and circuit breakers from each bus will feed the process loads. A lightning protection system for the pump station will be provided. Grounding systems will be designed for new building and structures in accordance with the Queensland Electrical Codes of Practice.

5.3.6 Standby Power

Standby power will be required at Saltwater Creek pump stations. The portable skid -mounted pumps will be engine driven so no standby power is needed. Due to concerns about reliability, security and vandalism, a portable trailer-mounted generator is recommended.

5.3.7 Instrumentation and Controls

The Saltwater Creek Pump Station will utilize a single non-redundant programmable logic controller (PLC) to control and monitor devices. The pump station PLC will receive a continuous level signal from an absolute shaft encoder, manufactured by located on the protected side of the pump station, which will be used to control the pumps. The pumps will operate in a lead-lag standby pumping sequence via PLC level set points; these set points within the PLC will be pre-determined and adjustable locally on the panel mounted operator interface terminal (OIT). The pump station control system and field equipment will be provided with local manual controls such that pump and equipment control operation can be accomplished locally, without going through the PLC. The pump controls will be located at each pump MCC. Controls for field equipment will be adjacent to the equipment. These local controls will manually override the PLC and/or control function commands from the remote locations (SFWMD SCADA).

The pump station will be equipped with a stand-alone control system, housed in a control panel which will include a PLC, an uninterruptible power supply, network switches, and I/O. Reduced voltage soft starters will be used to control the three pumps in the pump station. The pump operation will be controlled by the PLC. The pumping station will be equipped with level instrumentation installed on the flood and protected side of the pumping station. The stilling wells on the protected side of each pump channel will use a level encoder along with a mechanical float switch to indicate low level conditions. Stilling wells on the protected side of the pumps will be wall mounted in the respective channels for accessibility.

All pump station control panels and instrument enclosures for indoor use will be rated NEMA 12 (Australia equivalent). Any instrument enclosures used outdoors will be 316 stainless steel, NEMA 4X (Australian equivalent). Mounting hardware will be galvanized for indoor enclosures and stainless steel outdoor enclosures. It is anticipated that all control panel enclosures will reside inside the new control building.

A security panel will be installed in the Control Building to monitor entry points in the building. In addition to the security panel, Internet Protocol (IP) cameras will be installed at two locations outside the building to monitor activity on the property. Both systems will be connected to the S-191A Pump Station network through industrial network switches.

The control panel terminals and relays will be rated 300-V minimum for use on a 120- V system. Digital instruments which are not looped powered will require 120-V alternating current (AC) power source with contracts rated for 5 amps. Analog type instruments, installed outside of the main structure, will be loop powered where possible and will require lightning surge protection at both ends of the signal, as close to the field instrument being protected as possible.

5.3.8 HVAC System and Plumbing

HVAC systems for the Saltwater Creek Pump Station Control Building will include ventilation systems configured to “pull” outside air into and through the building and around the Electrical equipment. A separate room will be constructed for the control equipment, and have a separate cooling system to maintain the proper temperature and humidity required.

Louvered openings on both the intake and discharge sides of the building will be designed and sized to minimize water intrusion and meet minimum protection requirements per code. When not in use, the space will generally use natural means to realize venting to the outside with forced assistance available from the motorized forced ventilation fan system when necessary under thermostat control. The control and electrical equipment rooms located within the Control Building will be provided with dedicated air conditioning systems. The following summarizes the cooling system design:

Supply and return air shall re-circulate within the space via a ceiling mounted ductless supply air unit. To meet indoor air quality requirements, outside air is introduced to the room through a wall mounted intake duct directly connected to the AHU. A ceiling mounted exhaust fan will be provided in the restroom. The fan exhaust discharges through a wall-mounted louver. For the electrical room, three wall-mounted ductless air handling units are sized to maintain a cool dry space to protect associated equipment. As this is an unoccupied equipment only space, no outside air or heating is provided in the design.

A restroom with a water closet, sink and shower will be provided. The potable water system and building sewer will be connected to the City water and sewer system. A backflow preventer will be installed for non-potable water use, including hose bibs and yard hydrants. A grinder pump capable of operating under flooded conditions should be installed to pump through a small force main to the collection system.

5.4 References

- USACE EM 1110-2-3102 General Principles of Pumping Station Design and Layout, 28 February 1995
- USACE 1110-2-3105 Mechanical and Electrical Design of Pumping Stations, 30 November 1999
- ANSI/HI 9.8-1998 Standard for Pump Intake Design
- Pumping Station Design 3rd Edition, Garr M. Jones & Robert L. Sanks, 2014
- Handbook of Applied Hydraulics 3rd Edition, K. E. Davis & C. V. Sorensen, 1969
- National Electrical Manufacturers Association (NEMA).
- ISA S5.3 Graphic Symbols for Distributed Control/Shared Display
- ISA S5.4 Instrument Loop Diagrams.
- ISA RP60.3, Human Engineering for Control Centers.

Section 6 Flood Gate Design

6.1 Definitions

Definitions for the following key terms used in the narrative text are as follows:

Flood Closure Structure (FCS) – Refers to the entire flood control facility which houses the flood control gates, operating machinery, and controls.

Gate – refers to the entire gate system within each bay of the *FCS*. There may be several bays required to meet the hydraulic, structural and other criteria specific to this application.

Gate Leaf – refers to the movable part of the *Gate* that provides the backwater protection, and must withstand the hydraulic loading from the river during the design flood stages

Gate Frame – refers to the fabricated frame assembly embedded in the concrete at the opening in the FCS, which works with the sealing system on the *Gate Leaf* to limit leakage.

Gate Guides – refers to the guide system embedded in the concrete flood control structure. The *Gate Leaf* is raised, lowered, and stored in the guide system.

Gate Hoist – refers to the operating machinery, power system, and controls.

USACE – United States Army Corps of Engineers

DIN – Deutsches Institut Für Normung (German Institute of Standardization)

6.2 Introduction and Design Criteria

The flood control levee at Saltwater Creek and Distillery Creek will require flood closure structures, which will allow passage of normal flows in each creek, and provide closure during flood events. The recommended flood closure structures for both facilities are vertical lift gates. These are the most-common gates used in flood control projects in conjunction with pumping facilities. Two vertical lift gate designs were selected for the project, and they're classified by their mounting: slide mounted (slide gates) and wheel-mounted (roller) gates. The reasons for their frequent use of these gate designs include the following:

- The gates can close under their own weight when power is not available,
- The gates can be dogged in the raised position out of the waterway allowing ease of inspection and maintenance; and
- The gates can be operated using gate hoists installed above the design flood stage.

The recommended design life for permanently installed components and gate leaves is 100 years. The recommended design life for operating machinery should be 50 years. Reliability requires predictable results over the design life of the project. In gate design, this evaluation starts with material selection. It is vital that a corrosion survey, including a review of published water quality data and measurement of resistivity of the in the Burnett River must be performed during final design. Galvanic and other modes of corrosion typically found in riverine environments, such as microbiologically influenced corrosion, and the proper countermeasures must be considered in every aspect of the design.

The recommended material for all gates is carbon steel, unless the water quality analysis of Distillery Creek and Saltwater Creek waters indicate the need for more-corrosion-resistant materials. Protective coating systems recommended for gate leaves include a zinc-rich primer, with intermediate and top coats of a coal tar epoxy. Coal tar epoxy combines coal tar converted to a powder and mixed with an epoxy binder. This is the toughest coating for submerge service in hydraulic steel structures, and it is still widely used by the USACE and Tennessee Valley Authority.

Large fabricated gates will be designed in accordance with the criteria included in USACE EM 1110-2-2105 "Design of Hydraulic Steel Structures." These guidelines include criteria for both allowable stress design (ASD), and load resistance factor design (LRFD). This manual provides minimum requirements and recommended load combinations for analysis. More stringent requirements may be added for site specific, or unique loading conditions, as they may arise during final design.

- Material selection, design details and considerations for operating machinery will follow guidelines included in USACE EM 1110-2-2701 "Vertical Lift Gates". Weldments will be designed and fabricated in accordance with AWS D1.1 "Structural Welding Code – Steel" and AWS D1.6 Structural Welding Code – Stainless Steel.".

6.3 Flood Gate Alternatives and Design Details – Saltwater Creek

6.3.1 Gate Selection

Hydraulic gate sizing was discussed in detail in Section 2. Saltwater Creek will require four 4.5 m x 4.5 m gates. The Saltwater Creek gate size is suitable for roller gates, which are custom designed for each application. Roller gates use rolling friction, which can be a fraction of the load due to sliding friction. These gates are fabricated and can be constructed of corrosion-resistant materials. The gate layout for Saltwater Creek can be seen on Drawing M-3.

6.3.2 Embedded Guide Components

Gate guides for the Saltwater Creek roller gates will be embedded in the concrete civil works structures. The guides serve two functions: provide a structural mount for the gate leaf, and provide a sealing surface for the gate leaf seals. The guides include a rail system for the gate leaf load wheels to operate on. Although carbon steel gate leaves have been recommended for the roller gates, stainless steel guides are often furnished with them in corrosive environments. The guides will remain in the creek throughout its service life. A stainless steel seal plate is welded inside of the guide for use with the gate leaf seals. Modern elastomer seals need finer surface finishes to function properly. The seal plate must be delivered with a 1.6 µm Ra (Roughness) surface finish or better.

The most common method of construction follows a two-stage approach. The first stage is to create a block-out in the primary concrete. The embedded components are attached, aligned, and braced within the block-out until the secondary concrete is placed within forms installed after alignment. The project specifications should have stringent requirements for alignment during gate guide installation. This is the most common cause of defective work.

For this project we recommended installation of cast iron slide gates as an alternative for Distillery Creek. They're robust and have been used successfully on similar applications. The gate frames for the Distillery Creek gates will be concrete encased in the wall and the guides will be supported from the wall and the frame.

Gate guides at Bundaberg and Distillery Creek can be affected by siltation at the bottom and require periodic cleaning. This can be designed into the guide permitting remote cleaning, but may require work below the water line occasionally.

6.3.3 Load Wheels

For the Bundaberg Creek gates, load wheels must be specified to meet the project requirements. It is common today to specify the gate wheels in hardened and abrasion resistant stainless steel. This is what we recommend for the Bundaberg gates. Trolley wheels for bridge cranes are often used for this purpose. These wheels must be hard enough to take the Hertzian stresses applied during operation under load, which can cause deformation or permanent flattening of the rolling surface. The wheels for the Bundaberg Creek gates will forged stainless steel fitted with permanently lubricated PTFE-impregnated graphite, trepanned, sleeve bearings installed on 17-4 precipitation hardened stainless steel shafts.

6.3.4 Elastomer Gate Seals and Bumpers

Elastomers used for the seal material will generally be selected based on frequency of operation and the exposure to sunlight. The following design criteria will be applied:

Significant research has been conducted on gates seals with the goal of adjusting the formulations of elastomers as necessary to meet the performance requirements in hydraulic structures. This has been accomplished by adding carbon black, zinc oxide, accelerators, and plasticizers in the process. For Bundaberg, if fixed-wheel gates are used, a natural rubber/polyisoprene would be suitable because the gate leaf would spend most of its time in the raised position within the structure.

The Bundaberg and Distillery Creek gate elastomer seals will be the bulb or "music note" type. Single-stem bulb seals will be used on the gate-frame-side sealing surfaces, if they're constructed of fabricated carbon steel. On the gate frame lintel, double-stem bulb seals will be used. There are several configurations used to seal at the gate frame sill usually depending on application. The gate will require molded corners specifically designed for the geometric combination in a specific corner configuration. The design must allow the corners to be joined to the seal strips at square and flat surfaces by vulcanized bonds. This requires special dies developed by the seal manufacturer.

Both project gate designs will utilize elastomer seals and ultrahigh molecular weight polyethylene bumpers. The elastomer seals add approximately 400 N/m of seal friction at pull out. This can be decreased by fitting the seal face with fluoropolymer facing material which decreases the load due to friction to approximately 150 N/m of seal. Along with deadweight, this load is common to all fabricated vertical lift gates.

6.3.5 Gate Controls and Operating Machinery

Roller gates can be operated using fluid-powered hoists, base-mounted drum hoists, or crane. The selection of a hoist should be based on reliability, life-cycle cost, ambient conditions, and owner preference, which sometimes overrules the other criteria. Three alternatives were considered and they're described in the following paragraphs:

6.3.5.1 Hydraulic Gate Hoists

Hydraulic gate hoists can be very attractive in some applications. Fluid power systems are complex and can be very expensive to design and maintain. For vertical lift gates, fluid power systems are often used at pumping station installations and other applications requiring redundancy and operation during a utility power outage. Electric gate hoists tend have a problem of stripping out the operating nuts on large gate installations, so hydraulic hoists are the preferred approach especially for frequently operated installations. That is not the case here and these systems are too complex for the application. These gate hoists are not the preferred alternative.

6.3.5.2 Mass-Produced Electric Gate Hoists

The "mass-produced gate hoist" refers to valve actuators furnished in standard sizes by a variety of manufacturer's in many different configurations. There are a significant number of documented incidents of these devices having catastrophic failures when used with large gates. The gates strip the threads out of the nuts and fall into their guides. It is advisable to avoid the use of these actuators for gates larger than 1.5 m x 1.5 m, nominal. These gate hoists are not the preferred alternative.

6.3.5.3 Base-Mounted Electric Wire Rope Gate Hoist

Base-mounted electric wire rope gate hoists are the most-common type used for roller gates in North America. They are extremely reliable and can be custom designed to suit each application. Wire rope selection would follow guidelines included in USACE EM 1110-2-3200 "Wire Rope Selection Criteria for Gate Operating Devices." The drum hoist is typically designed around a parallel shaft gear box. Its motor driven and usually has an electric brake and brake wheel with powered release, or manual release when power is not available.

Digital encoders can be included in the drive systems to allow gate position indication remotely if required. The gate operation stops at the end of its travel using rotary cam-type limit switches in the drive. A manual hand crank can be added allowing the gate to be operated during a power outage by manually releasing the brake and removing the dogs to allow the gate leaf to lower (drop) under its own weight. This is accomplished by installing an eddy current brake in the drive.

The eddy current brake is a device that allows the gate to drop at a controlled rate without the electric brake engaged. The engineer specifies the break providing the mass of the gate and the desired speed of descent. Permanent magnets use the force of their magnetic fields to apply resistance. This is a feature that makes the base-mounted drum hoists very reliable for FCS applications. Drum hoists can combine commercially available electric gate hoists with the gear box in some cases but the preferred approach is use of a continuous duty squirrel cage induction motor. Like hydraulic hoists, these gate hoists are too complex and expensive for this facility and not the preferred alternative.

6.3.5.4 Mobile Crane

It is possible to use a mobile crane at Saltwater Creek. These gates can be dogged in their guides when not in use, but can be hoisted by mobile crane in advance of a flood event. This could be a viable option that would simplify the installed system.

Mobile crane operation is the preferred alternative, and recommended for Saltwater Creek. It will save significant capital cost and reduce the visual impact of the structure since no operating machinery will be installed on the deck of the dam.

6.3.6 Gate Selection

The Distillery Creek installation requires two 3.0 m x 2.0 m vertical lift gates. The pump platform and gate structure for Distillery Creek will be built within a future easement on Parcel RP432642 located at 16 Cross Street. The flood wall will require flood closure structures, which will allow passage of normal flows to the creek and provide closure during flood events. We have selected slide gates or penstocks for this application.

Penstocks are readily available in standard sizes in Australia. As mentioned in paragraph 6.2 the preferred material is high-performance liquid epoxy coated carbon steel. but cast iron can also be used at Distillery Creek. The layout of the distillery creek facility is shown on Drawing M-5. The examples shown are cast iron slide gates.

6.3.7 Gate Controls and Operating Machinery

Slide gates at Distillery Creek can be operated using permanently installed electric gate hoists. Design and selection of this equipment will follow guidelines included in USACE EM 1110-2-2610 “Mechanical and Electrical Design for Lock and Dam Operating Equipment.” Electric gate hoists will likely be fitted with intermediate reduction gear that will increase the operating time to lift the gate to more than 15 minutes, which is their typical duty cycle. To resolve this, continuous duty motors will be specified for the hoists.

The power company serving this area is Ergon Energy. A new 480-V, 50Hz three-phase service will be run to a pedestal cabinet installed above the 500 yr stage. The gate hoist will be powered and controlled from this cabinet. Underground service to a pad-mounted utility transformer will be brought to the site to feed the electric gate hoists. Coordination with the utility company will need to be arranged for details and requirements of transformer locations, pads, metering, etc.

6.4 References

- AWS D1.1 Structural Welding Code – Steel
- AWS D1.6 Structural Welding Code – Stainless Steel
- USACE EM 1110-2-2105 Design of Hydraulic Steel Structures, 31 March 1993
- USACE EM 1110-2-2701 Vertical Lift Gates, 30 November 1997
- USACE EM 1110-2-2705 Structural Design of Closure Structures for Local Flood Protection Projects, 31 March 1994
- USACE EM 1110-2-2610 Mechanical and Electrical Design for Lock and Dam Operating Equipment, 30 June 2013
- USACE EM 1110-2-3200 Wire Rope Selection Criteria for Gate Operating Devices, 30 November 2016
- DIN 19704 -1: Hydraulic Steel Structures - Part 1: Criteria for Design and Calculation, 1 May 1998
- Hydraulic Gates and Valves 7th Edition, Jack Lewin, Thomas Telford, 2001
- Design of Hydraulic Gates 2nd Edition, Paulo C.F. Erbisti, CRC Press, 2014

- Handbook of Applied Hydraulics 3rd Edition, C. V Sorensen, K. E. Davis, 1969

Section 7 Structural Design

7.1 Structural Descriptions

7.1.1 Flood Walls

7.1.1.1 Evaluation of Floodwall Types

The conceptual-level design of the Bundaberg East Levee project included an initial screening evaluation of levee system alternatives and a final levee alternatives evaluation. The evaluation highlighted important factors that differentiate the alternatives from each other and are based on the evaluation criteria presented herein. The initial screening evaluation consisted of the following levee alternatives:

- Earthen Levee Embankment;
- Earthen Levee Embankment with Concrete Wall;
- Earthen Levee Embankment with Sheet Pile Wal;
- Soldier Pile and Lagging Embankment, and
- Concrete Floodwall.

Based on the soft alluvial soils encountered on site (as discussed in Section 2), it was concluded that the earthen levee embankment alternatives were not recommended. The main concern regarding the earthen embankments was the soft, compressible alluvial soils along the levee alignment. The soft, compressible soils would result in a large levee footprint due to the need for side slopes of 4H:1V to account for potential embankment settlement plus the additional width for the crest to permit reconstruction of the roadways. In addition, the sheet pile embankment and the soldier pile and lagging embankment would be subject to high lateral loads that would be difficult to resist in the soft alluvial soils. Therefore, CDM Smith recommended the construction of a concrete floodwall for the proposed levee system for the final levee alternatives evaluation.

As summarized in US Army Corps of Engineers *Engineering Manual 1110-2-2502 for Retaining and Flood Walls* (EM 1110-2-2502), typical concrete flood walls include the following types:

- Inverted T-Type Cantilever Walls (Inverted T-Walls);
- Cantilever I-Type Sheet Pile Walls (Sheet Pile Walls), and
- Braced Sheet Pile Coastal Flood Walls (Braced Sheet Pile Walls).

As discussed in EM 1110-2-2502, sheet pile walls are not recommended for height exceeding 2.4 to 3.1 m, which eliminated their consideration due to walls heights up to 3.5 m. In addition, the braced sheet pile wall was eliminated from consideration due to the cost compared to a typical concrete wall. Therefore, inverted T-walls are recommended for the proposed floodwall system.

7.1.1.2 Floodwalls

The evaluation of the floodwall types, based on the soil conditions discovered during the geotechnical investigations, concluded that conventional cast-in-place concrete inverted-T walls would be the best choice. The conventional inverted T- wall consists of a concrete footer slab supporting a concrete cantilever wall.

The soil conditions encountered along each of the two floodwall alignments vary from very soft and compressible soils (i.e., alluvial soils) not capable of supporting much load, to stiff to hard soils (i.e., Elliott Formation) capable of supporting bearing loads. Where the floodwalls may encounter soils deemed to be soft and compressible, the inverted T-walls have been designed to be supported by piles. However, where reasonably stiff to hard soils are expected to be encountered, the floodwalls have been designed to be supported on shallow foundations. (refer to Drawing No. S-3 in Appendix B).

The tops of the floodwalls are to be located above the anticipated flood elevation (i.e., 9.3 m AHD plus 200 mm freeboard) and have been set at the constant elevation of 9.5 m AHD. The bottoms of the base slabs have been set at about 1.5 m below existing grade. Because the existing grade varies along the alignments, the bottoms of the footings have been stepped to reduce the amount of excavation needed and to reduce the wall heights. The changes in footing elevations are shown Drawing Nos. S-1 and S-2 in Appendix B.

Along the alignment where soft and compressible soils are anticipated, the walls have been designed to be supported on piles. Based on the range of wall heights resulting from the "stepping" patterns, two wall heights were selected to represent the range of wall heights, and two pile-supported wall designs have been developed (refer to Drawing No. S-3 in Appendix B). Where soil-supported walls were deemed possible, only one wall design is developed (refer to Drawing No. S-3 in Appendix B). Under floodwalls supported on pile foundations, a steel sheet pile cut-off wall is to be provided to reduce the reduce underseepage and exit gradients on the land side of the floodwall.

For this conceptual-level study, the floodwalls were designed according to the guidelines listed in the EM-1110-2-2502. The predominant load case for the conceptual design of the floodwalls considers water at flood elevation RL 9.3 m AHD on the river side and water at the ground surface on the land side. Also, included is the upward water pressure applied to the underside of the base slab from the heel (the river side) to the cut-off wall. This upward pressure was developed from the seepage analysis discussed in the IGR included in Appendix C. Any resistance from passive soil pressure on the toe side (land side) of the wall was ignored.

For the pile-supported floodwalls, two rows of piles along the length of the walls were provided. The spacings of the piles perpendicular to the wall lengths were established so that resultant levels of compression and net tension loads on the piles due to overturning effects were limited to reasonable values. Lateral loads on the walls were resisted solely by the lateral load resistance offered by battered piles. Due to the poor soil conditions, lateral load resistance offered by the bending resistance of a pile was considered to be low and was ignored. The maximum batter considered practical and achievable in this area is 1H:4V.

The piles selected are 400-mm-square driven concrete preformed piles (CPP), achieving their capacity through a combination of side "skin friction" and end bearing. All piles must be driven into the Elliott Formation. Based on the range of estimated pile loads and the varying soils conditions encountered, a 1000 kN CPP pile was selected and the pile tip elevations varied along the floodwall lengths. The conceptual spacing of the piles and the estimated pile tip elevations are shown on Drawing Nos. S- 1, S-2, and S-3 in Appendix B.

Where the floodwalls were supported by shallow foundations, lateral loads on the floodwalls are resisted by sliding friction between the base of the footing slab and the soil sub-base material. The assumed coefficient of friction for sliding is 0.4.

7.1.1.3 Flood Doors

At several locations along the floodwall alignments, openings will be required either for vehicle or pedestrian access. These openings will remain open at all times except when flood conditions are occurring. Thus, some means of closing these access openings must be provided.

There are a variety of methods that can achieve a watertight closure ranging from stop logs manually installed and removed just before and after a flooding event to swinging, sliding, or overhead roll-up flood doors, that can be manually or remotely activated.

Stop logs would likely be made of light-weight aluminum planks made with custom vendor design tube shapes. Vertical stainless steel or aluminum channel slots are provided at either side of the wall opening and sometimes at the base slab. The planks are dropped into the vertical slots and stacked one upon another to build a temporary wall. Then, the planks bear against the vertical edges of these slots when water pressure builds up on one side of wall. Typically, the stop logs provide some type of continuous compressible waterstops along all edges in order to provide for watertight joints. **Figure 7-1** shows two examples of typical stop logs.

Figure 7-1 Typical Floodwall Stop Log Examples

The diagrams shown on Drawing No. S-4 in Appendix B conceptually indicate how the stop log system would be installed in the floodwalls. It is to be noted that the stop logs would require a manual installation and removal before and after a flood. Because these walls are tall, installation methods must be evaluated. The tall walls and heavier plank (based on the width of the openings) may require the use of a small crane or manlift truck to install and remove the stop logs. Also, consideration must be given to where and how the stop logs are stored and transported to the location of the wall opening. Theft or other unwarranted damage could occur if these stop logs are left beside the openings unattended or unprotected.

Another approach for closing off the wall openings before a flood considers the use of a swinging, sliding, or overhead roll-up flood doors. These doors remain in place at the opening and in the open position.

When a flood is approaching, these doors can be designed to be manually or remotely closed. The doors can be crafted to meet a wide variety of architectural appearances. See the **Figures 7-2** through **7-4** below for examples of some flood doors.

Figure 7-2 Typical Examples of Swinging Flood Doors

Figure 7-3 Typical Examples of Sliding (left) and Overhead Roll-Up (right) Flood Doors

The use of swinging doors for large openings may create a bulky industrial appearance. Sliding flood doors can more easily hidden with ornamental grillage, plants or other means. Drawing No. S-5 in Appendix B shows a concept where a decorative precast or metal panel is provided to the side of a wall opening and is located in front of the "as-stored" door position. This panel masks the door and could also be made from metal grills or even with landscaping

These types of flood doors are typically custom designed and built for each unique situation. However, flood door fabricators do have more standard designs that can be adapted. One clear advantage to this type of door is that it can be more quickly and easily closed, even by residents located nearby.

7.1.1.4 Wall Aesthetics

The floodwalls will be traversing through residential and commercial areas and thus, the finished appearances of the concrete walls may need to be sensitive to the aesthetic desires of the community. Plan gray/buff colored walls with surface imperfections due to formwork may be an undesirable appearance. There are many ways to enhance the exposed surface appearance of the concrete floodwalls. Suggestions are provided below and may be used alone or in combination:

1. After removing the formwork, all concrete protrusions should be ground off, air pockets filled, and the entire wall rubbed to a smooth finish. The use of steel surfaced metal forms or highly smooth coated wood forms can reduce the amount of surface voids.

2. Surface sealers such as acrylics and urethanes can be applied to the cured concrete. Several of these products may impart a darker glossy sheen to the surfaces.

3. Stains can be applied to select wall sections along the alignments. However, a high level of color uniformity is it is difficult to achieve when applying the stains to large surface areas.

4. Color tints can be added to the concrete placed in the walls. However, it is difficult to control color variations over large concrete areas since each batch of concrete may produce slightly different shades.

5. Exposed aggregate finishes can easily be achieved on wall surfaces. The depths of the exposures can be typically range from 3 mm up to 20 mm. A nice feature of the exposed aggregate option is that various patterns of smooth plain concrete and zones of exposed aggregates can be architecturally designed in any specific section of wall area.

6. Colored acrylic coatings can be applied to the finished concrete surfaces. These come in a variety of colors and offer good durability. Color variations over large areas are easy to control.

7. A wide variety of geometric patterns can be cast into the wall surfaces during the initial placing of the concrete wall. This is achieved by using reusable form liners that are attached to the inside of the wall forms before the fresh concrete is placed. There is a very wide variety of form liner patterns available. Many are standard models and are stocked by many manufacturers. And, it is common to have custom made form liners to match a unique required surface design. Patterns can reflect brick, block, and stone patterns. Wood grained and fluted patterns can be provided, and chamfered or radial reveal grooves can be provided. The following figures provide a small sample of what types of cast patterns are available.

Figure 7-4 Typical Examples of Floodwall Cast Patterns

With cast-in-place concrete floodwalls, the items listed above can provide for an endless number of possibilities of aesthetically pleasing wall surfaces. The options of casting geometric patterns into the wall surfaces and then coating them with a colored acrylic coating can make for a very attractive appearance for a relatively small cost. Finally, some type of ornamental railing can be added to the tops of the walls in select locations.

7.1.2 Bundaberg Creek Pump Station and Flood Gate Structure

The Saltwater Creek Pump Station and Flood Gate structure has been conceptually developed as a combined structure consisting of three overall elements; flood gates, a pump station, and wingwalls at the creek banks (refer to Drawing Nos. S-6 and S-7 in Appendix B).

Due to the water-exposed nature of this overall structure, it is critical to consider the use of durable materials. Thus, a majority of the structures will be constructed of cast-in-place concrete, and, where metals are required, stainless steel or aluminum will be favored over painted steel.

The flood gate area will be comprised of four channels defined by concrete dividing walls and retaining walls. Inside each channel will be flood gates, which are described in greater detail in **Section 6** of this report. The walls on each side of each channels will have stainless steel vertical slots for the placement of stop logs. These stop logs will allow a channel to be isolated from water flow and drained when maintenance work must be performed on a gate. A flat floor slab will be placed over top of portions of the channels. This roof type slab will provide access to the gates and for crane access to be used as needed for installing stop logs and for doing future maintenance. The base floor of the channels will be constructed with structural concrete. Refer to Drawing Nos. S-6 and S-7 in Appendix B for additional details. The entire channel structure will be supported by CPP or bored cast in place piles (BCIPP).

The flood gate structure will be connected to and share common walls and floors with the pump station structure. The pump station will consist of an inlet forebay channel feeding into three stainless steel bar screens that in turn will allow water to enter three concrete suction inlet chambers. From there the water feeds vertically into two submersible axial pumps which discharge into the river side of the pump station (there is one spare pump bay for future use).

An elevated floor near the top of the pump station will be provided to allow access to the flood gates, access to the bar screens, and access to the stop log locations. Vertical stainless steel slots will be provided in the walls of the pump inlet chambers for the installation of stop logs. CAccess will be provided to allow entry to the top levels of the combined structure and to access the stop log locations.

The base floor of the forebay and other pump station areas will be constructed with structural concrete supported by CPP or BCIPP. The remaining portions of the pumps station walls and slabs will be constructed with concrete. The concrete structure housing the pumps will be designed to be tuned to the dynamic loadings of any rotating pumps such that the potential for equipment damaging resonance is reduced.

The wing walls straddling either side of the flood gates and pump station will be designed as concrete cantilevered retaining walls consisting of a wall bearing on a footer slab which in turn is supported by CPP or BCIPP.

The entire flood gate and pump station facility will be supported by 400-mm-square driven CPP driven to a load capacity of 1000 kN. Pile spacings and tip elevations for the CPP are indicated on Drawing No. S-7 in Appendix B. For this conceptual design, the piles supporting this facility are not anticipated to be driven or drilled on a batter since the diaphragm action of the connected base slab will allow most lateral loads to cancel each other.

The exterior floodwalls along the alignment will connect into the exterior walls of the flood wall/ pump station structure. Where the concrete walls and footers of the floodwall butt into these walls, a flexible PVC type waterstop will be provided to maintain a watertight joint that allows for differential settlements (horizontal and vertical) between the floodwalls and the adjacent structure. The sheet pile cut-off wall attached to the underside of the floodwalls will also connect into the walls of the floodwall/ pump station structure. At this joint location, waterstops will also be provided. Finally, the sheet pile cut-off wall will step down and extend under the base slabs of the floodwall/ pump station and flood gate structure and will cross beneath the structure to the opposite side.

The normal elevations on either side of the combined structure under normal conditions will vary with the tidal range. Mean High Water Springs (MWHS), a fairly high tide, is of the order of 1.2 m AHD at this location. However, when there is a flood, the water elevation on the land side, in the flood gate and forebay area, is desired to be kept below 5.0 m AHD, while the flood elevation at the river side rises. At times of maintenance of gates, screens and/ or pumps, stop logs can be installed to create a dry chamber in any one of the flood gate channels, or pump inlet chambers.

7.1.3 Saltwater Creek Equipment Building

For this conceptual-level design, the Saltwater Creek Equipment Building will consist of a pre-engineered steel-framed building anticipated to house electrical equipment (refer to Drawing Nos. S-8 and S-9).

The roof will be gabled in profile and will consist of a light gauge metal roof supported on purlins. The exterior façade walls may be constructed of various materials that will be discussed later in this section.

The base level of the equipment building will be raised above the flood level to elevation 10.5 m so that all equipment is located above the flood water and can remain operational during the design flood event. Thus, the base level of the building will be constructed as an elevated structural floor consisting of a concrete floor slab and beams that are supported by concrete columns. The concrete columns will extend down to the ground level and will be supported by concrete pile caps supported by concrete piles and grade beams. The piles are anticipated to be 400-mm-square driven CPP driven to a load capacity of 800 kN and to a tip elevation of -18.0 m AHD.

Two sets of concrete stairs will extend from the grade level up to landings at the elevated floor levels. Roll up doors or roof hatches will be provided so that equipment can be removed and replaced as needed.

The exterior façade walls of the elevated building can be constructed of a variety of materials selected to suit the desired aesthetics of the surrounding areas. At a minimum, metal-insulated panels may be used. However, the use of these panels may provide a rather commercial or industrial appearance. So, concrete masonry block with exterior brick may be considered to provide a more-aesthetic appearance, or decorative precast concrete façade panels with decorative finishes may be used.

7.1.4 Distillery Creek Pump Station and Flood Gate Structure

The Distillery Creek Pump Station and Flood Gate structure has been conceptually developed as a combined structure consisting of a tall floodwall with two penstock gates. A side service platform will be included to provide a space for equipment to be placed (refer to Drawing Nos. S-10 to S-13). Due to the water-exposed nature of this overall structure, it is critical to consider the use of durable materials. Thus, a majority of the structures will be constructed of concrete, and, where metals are required, stainless steel or aluminum will be favored over painted steel.

The floodwall houses the slide gates and becomes part of the pump station structure. Divider walls act to channel water to each of the three gates. The divider walls rest on the footer slab of the floodwall. The slide gates will remain in the open position a majority of the time to allow water to freely pass through the front floodwall. During a flood, the slide gates will be closed to protect against the rising flood waters. An aluminum grating access platform with structural support framing will be provided at the top of the floodwall to allow access to the slide-gate actuators. The support framing can be made with wither aluminum or galvanized steel. Stainless steel vertical slots will be provided in each of the divider walls to allow stop logs to be installed at each gate chamber. This will create a dry working space for when a gate needs maintenance.

Adjacent to the slide gates, there will be a combined structure consisting of a forebay and wet well where water can be pumped from the land side to the river side. The walls of this facility are concrete and connect into the floodwall. These walls also rest on the footer slab of the floodwall. One of the walls will act as a water channeling wall and the other wall will act as a soil retaining wall. An aluminum grating access platform with either aluminum or galvanized steel support framing will be provided over the wet well area to provide access to the pumps and slide gates beyond. Adjacent to the pumping area of this structure is a structural concrete pad, located at the top of the wet well walls. This concrete pad will be used to house any equipment required for this facility.

The top of the floodwalls and the walls at the pumping area are set at 9.5 m AHD with the base of the wall at 0.5 m AHD. Thus, these tall walls, if designed as vertical cantilever walls, would need to be excessively thick as would the base footing slab. So, the divider walls at the screens along with the walls at the wet well are to be designed as "stiffening" counterfort walls. Additional cross walls are added where needed to reduce wall and footer thicknesses.

The walls and base slabs of this overall structure will be supported by 400-mm-square driven CPP driven to a load capacity of 1000 kN and to a tip elevation of -15.0 m AHD.

Under the entire length of the floodwall supported on pile foundations, a steel sheet pile cut-off wall will be provided to reduce underseepage and exit gradients.

7.2 Design Codes, References and Criteria

The structural design of the floodwalls will be in accordance with the codes, references and other structural design criteria listed herein

7.2.1 Codes and References

The Australian Building codes do not appear to address the design of flood control structures. Therefore, for the design approaches concerning items such as loading scenarios, factors of safety, durability and serviceability and other items, the design guidelines from the US Army Corps of Engineers will be used. These guidelines will be supplemented by Australian design standards where possible and applicable for items such as material properties, material design such as the design of reinforced concrete and appropriate gravity and environmental loads.

- US Army Corps of Engineers (USACE):
  - EM 1110-2-2502 Retaining and Flood Walls
  - EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures
- Australian Standards:
  - National Construction Code 2016, Volume 1 and Volume 2
  - AS 1170 - Structural Design Actions
  - AS 1154 - Structural Steel Welding
  - AS 3600 - Concrete Structures
  - AS 4100 - Steel Structures
- American Waterworks Association:
  - AWWA C561-14 Fabricated Stainless-Steel Slide Gates

AWWA C560-07 Cast Iron Slide Gates

7.2.2 Materials

- Reinforced Concrete: 28-day strengths based on 6" diameter x 12" long cylinders
  - Concrete for Hydraulic Structures: 30 Mpa (minimum)

- Concrete for Enclosed Buildings: 28 Mpa (minimum)
- Concrete for Profiling Fill: 28 Mpa

- Reinforcing Bars: 420 Mpa

7.2.3 Loads and Approaches

7.2.3.1 Floodwalls

The flood elevation on the river side was set at RL 9.5 m AHD (with 0.2m freeboard). The predominant load case for the conceptual design of the floodwalls considers flood water on the river side and no water on the land side. Also, an upward pressure applied must be applied to the underside of the base slab from the heel (river side) to the cut-off wall or to the end of the toe on the dry side. This upward pressure is to be developed from the seepage analysis discussed in the draft interpretive geotechnical report in Appendix C. Also, lateral load resistance from passive soil pressure on the toe side (land side) of the wall is to be ignored.

For the pile-supported floodwalls, lateral loads are to be resisted solely by the lateral load resistance offered by battered piles. Due to the poor soil conditions, lateral load resistance offered by the bending resistance of a pile is considered to be low and should be ignored. The maximum batter considered practical and achievable in this area is 1H:4V.

For floodwalls supported by soil bearing, lateral loads on the floodwalls are resisted by sliding friction between the base of the footing slab and the soil sub-base material. The assumed coefficient of friction for sliding is 0.4.

7.2.3.2 Pump Station and Flood Gate Structures

At times of maintenance of flood gates, slide gates, screens, and/ or pumps, stop logs can be installed in channel walls to create a dry chamber in any one of the chambers. When this occurs, lateral forces will occur on divider walls from a different water levels on either side of the walls. For design, the minimum differential water elevation on either side of a divider wall is to be 300 mm.

Also, buoyant and seepage uplift forces will occur at the bottom of floor slabs. Uplift forces are to be resisted by the self-weight of the slab and structure above, by tension in the piles or a combination of each.

Floor slabs should be designed for a minimum live load of 9.6 kN/m^2 or the wheel loads of a specific crane which may be driven on the floors.

Bar screens are to be designed to resist the full hydrostatic lateral pressures considering the screens to be 100% plugged.

At the slide gates, the supports for the operators and gate frames are to be designed for the stem loads created when the operators stall. The code required stem loads, per AWWA guidelines will vary based on the specific gate manufacturer. However, the stem loads can be large and the anchorages attaching into the supporting structure require some additional localized structural design considerations. Localized design of these stem loads was not considered at this conceptual level stage and will need to be considered during the detailed design stages.

The soil retaining wing walls have been designed for the lateral loads of soils plus the difference in water levels on either side of the walls. A rapid drawdown condition could occur when the flood waters recede. In this case, the water levels behind the wing walls could remain at the flood levels while the water in front of the wall returns to normal pool elevations. This would create additional lateral pressures on the walls. However, it is anticipated that a fabric wrapped granular backfill zone will be placed behind the wing walls, and this layer will allow water levels behind the wing walls to rapidly return to the same water levels as the water in front of the walls. For this conceptual level study, a rapid drawdown condition was not considered.

7.2.3.3 Equipment Building

The Equipment Building is to be designed as a normal industrial type building per the National Construction Code 2016, Volume 2, of the Australian Standards. This structure is not to be considered as hydraulic/ flood control structure. Site specific environmental loads such as wind, rain, and seismic loads are to be developed based on the Australian Standards during the detailed design stage. The live loads required to be applied to the elevated floor of this building will depend on the specific type of equipment located inside of it. Live loads ranging from 4.8 kN/m^2 to 14.4 kN/m^2 are commonly used for the live load when designing buildings of this nature. For this conceptual level design, a live load of 12.0 kN/m^2 was used.

At the pump stations, the structures supporting and housing the pumps must designed to be tuned to the dynamic loadings of any rotating pumps such that the potential for equipment damaging resonance is reduced. Typically, the natural frequencies of the supporting structure should be 30%-50% greater or less than the operating frequencies of the rotating equipment. Also, considerations should be given to equipment vibrations travelling into other lighter platforms and stairs such that potential for vibrations undesirable to human occupants is reduced.

7.2.3.4 Crack Control and Joints

The water tightness and long-term durability of hydraulic and flood control structure depends on reducing the potential for cracking of concrete. Also, leaking cracks can produce leaching calcium carbonate that makes for an unsightly appearance on the wall surfaces. From the design side, cracking of concrete is controlled from the design side by specifying proper concrete mixes, requiring proper placement and curing methods during construction, specifying proper amounts of temperature and shrinkage reinforcing steel bars in the concrete, and specifying the locations of construction, contraction, and expansion joints.

Joints must be strategically located and the intervals between installing adjacent concrete placements must be adequate to allow reasonable amounts of shrinkage to occur. Partial contraction joints should be constructed as construction joints with only 50% of the horizontal reinforcing bars extending through the joints. All joints must contain waterstops. The types and locations of all construction, partial contraction, and expansion joints must be specified by the design engineer and must be indicated in the design documents, preferably on the design drawings.

For the floodwalls, partial contraction joints and construction joints should be placed in the walls and footings at a horizontal spacing no greater than 15 m and expansion joints placed at a spacing no greater 30 m.

Section 8 Civil Site Design

8.1 Site Preparation

Site preparation will consist of clearing and grubbing of the job site in the vicinity of the Distillery Creek alignment. The Contractor will also be responsible for stockpiling of native soils that are determined to be suitable for use in the construction and disposing of excavated debris deemed unsuitable for future use. Detailed descriptions and limits of the Contractor's work will be included in the project specifications.

8.2 Clearing and Grubbing

The Contractor will cut and remove all timber, trees, stumps, brush, shrubs, roots, grass, weeds, rubbish, and any other material resting on or protruding through the surface of the ground. During this operation, the Contractor will be responsible to preserve and protect trees and other vegetation designated to remain. Limiting the clearing to the designated project site will be of the utmost importance so as not to disturb areas located outside of the permitted footprint of the project.

Once clearing operations are complete, grubbing operations shall begin. The Contractor will grub and remove all stumps, roots in excess of 4 cm in diameter, matted roots, brush, timber, logs, concrete rubble, and other debris encountered to a depth of 0.5 m below original grade.

The Contractor will be responsible to refill all grubbing holes and depressions excavated below the proposed ground surface elevation with suitable materials and compact to a density as specified by the IGR. Grubbed material should be stockpiled in designated areas and disposed of off-site.

8.3 Disposal

The Owner will determine whether they want to keep harvested timber from the cleared areas prior to construction. Any materials that are deemed debris will be disposed of by the Contractor. The Contractor should cut tree trunks and limbs exceeding 10 cm in diameter into one-meter lengths and stockpiled on site in the area designated.

The material and debris from site preparation operations will be disposed of by hauling such materials and debris to an approved offsite disposal area. No rubbish or debris of any kind shall be buried on the site. Burning of cleared and grubbed materials or other fires for any reason will not be permitted unless express permission is given by the Owner. Burning of material on site may marginally reduce site preparation costs. If allowed, burning operations and ash disposal shall be conducted in strict accordance with local and state requirements, subject to applicable permit requirements.

8.4 Earthwork

All excavation, trenching, sheeting, bracing, etc. will comply with the requirements of Safe Work Australia and all local, state, and commonwealth requirements. Where conflicts exist between Safe Work Australia, local, state, and commonwealth regulations, the most stringent requirements will apply.

Earthwork includes all labor materials, equipment and incidentals required to perform all excavation work and grading; place and compact backfill and fill; and disposal of unsuitable, waste and surplus materials. All excavation deemed suitable for use as embankment material will be stockpiled in designated areas for future use.

It will be required that the Contractor secure the services of a Registered Professional Engineer of Queensland (RPEQ) to prepare temporary excavation support system designs and submittals. The Contractor will furnish and install temporary excavation support systems, including sheeting, shoring, and bracing, to insure the safety of personnel and protect adjacent structures in accordance with local and state laws, regulations and requirements.

8.5 Erosion Control

The Contractor will take all necessary precautions to prevent erosion of all site facilities during construction. The Contractor will develop an erosion and sedimentation control plan and implement it during construction. This plan includes installation of temporary access ways and staging areas, silt fences, sediment removal and disposal, device maintenance, removal of temporary devices, temporary mulching, and final cleanup. All necessary permits required for construction will be obtained by the Contractor.

Section 9 Environmental Approvals and Strategy

9.1 Introduction and Purpose

CDM Smith prepared an Environmental Advice Statement for the Project. The purpose of the report was to:

- Present a summary of environmental matters potentially impacting the proposed levee alignment. The review context relates the levee alignment and ancillary facilitating activities;
- Give consideration to Commonwealth, State and Local Environmental Matters of Significance (MNES, MSES and MLES);
- Review the proposed development to identify the environmental permits and statutory planning approvals required to be attained so as to lawfully construct the levee;
- Identify development application drafting requirements and the associated timeframes for achieving the permit and application approvals; and
- Make recommendations relating to an effective approval strategy.

The full report is presented as Appendix E to this design report. Presented in the following sections are the key findings, including a snapshot of the required approvals, and a pathway and timeline to achieve them.

9.2 Approvals Identified

The Environmental Advice Statement considered a number of environmental permits and approvals and has provided a summary of these in Table 9-1. This includes an indicative preparation and assessment timeframe matrix and identifies material that will be required to support each application.

The major approval for the Project will be for a Category 3 Levee as identified in Schedule 10, Part 19, Division 4, Subdivision 1 (32) of the *Planning Regulation 2017.* The Guidelines for the Construction or Modification of Category 2 and 3 Levees is a document that provides information to help proponents meet requirements for the construction of levees. The Project will be assessed against 'State Code 10: Category 3 Levees' as well as the local planning scheme requirements and state interests will be coordinated by the State Assessment and Referral Agency. Both the Guideline and State Code 10 identify additional studies and requirements for constructing a Category 3 levee and include:

- A vulnerability and tolerability assessment report;
- Hydrological/hydraulic assessment;
- Levee categorisation and impact acceptability;
- Design specification and operations and maintenance manual; and
- Emergency action plan in the local governments local disaster management plan.

For category 3 levees, the applicant may provide an appraisal report, signed off by a suitably qualified person. This appraisal report should describe the alternative options that have been considered and compared these to the levee option. This process should address the potential social, economic and environmental impacts as well as the technical aspects of the proposed levee.

Other approvals under the various acts and the *Bundaberg Planning Scheme 2015* will also be required, these are further identified in Table 9-1.

9.3 Recommendations

Prior to the start of the detailed design phase it is recommended that a project coordination meeting be held to understand the Department's preferred approach to attaining approvals for the proposed project. The meeting would identify the projects delivery timeframes and match these with the appropriate approvals strategy along with the overall schedule for the detailed design phase.

On initial review of the proposed options with the available information, the infrastructure designation path would provide the Department with a greater level of certainty to manage the application assessment process the associated timeframes and the public notification and consultation process.

Table 9-1 Approval Timeframes and Supporting Material

Approval	Justification	Status	Time Frame	Supporting Material
Commonwealth				
Referral under the EPBC Act	The Project is unlikely to have a significant impact on MNES therefore not requiring an EPBC Referral, however this needs to be confirmed during the detailed design phase.	**Unlikely – Requiring Confirmation**	**N/A**	**N/A**
Queensland				
Environmental Authority (EA) application for Environmentally Relevant Activity	A preliminary review of Environmentally Relevant Activities (ERAs) has been undertaken, with ERA 16 Extractive and Screening Activities identified as a potential ERA. Should construction be confirmed, a review of ERA's as identified in the *Environmental Protection Regulation 2008* should be undertaken.	**Likely – Requiring Confirmation**	**Preparation of Application – 2-3 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Method of operation; ▪ Construction methods; ▪ Vegetation assessment; ▪ Environmental controls; and ▪ Owners consent.
Operational works for vegetation clearing	A search of regional ecosystems has been undertaken. These areas in proximity to the site are identified in Appendix E. Both alignments are located in Category X vegetation under the *Vegetation Management Act 1999*. There is however a portion of mapped Category B Remnant Vegetation located immediately to the south of the alignment. It is recommended a vegetation survey be undertaken to confirm the location and presence of vegetation located in the vicinity of the pipeline. This will confirm whether an application to clear vegetation is required.	**Likely – Requiring Confirmation**	**Preparation of Application – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Method of operation; ▪ Construction methods; ▪ Vegetation assessment; and ▪ Owners consent.
Clearing permit (protected plants)	The Protected Plants Flora Survey Trigger Map shows areas which are applicable to provisions of the *Nature Conservation Act 1992*. A search of flora survey trigger areas has identified that the site is not within a flora survey trigger area Under Section 256 of the *Nature Conservation (Wildlife Management) Regulation 2006*, a flora survey is required before any clearing is undertaken in a high risk area. It is recommended a pre-clearance survey be undertaken prior to work. This may identify protected plants at which point a clearing permit may still be required.	**Unlikely – Requiring Confirmation based on Pre-Clearance Survey**	**Preclearance Survey – 1 Week**	▪ Protected Plants Assessment Guidelines

Approval	Justification	Status	Time Frame	Supporting Material
Operational works for construction of a levee	The Project involves the construction of a Category 3 Levee. This is assessable development and will require approval prior to construction commencing.	**Required**	**Preparation of Application and Supporting Information – 2-3 Months** **Assessment Timeframe – 5-6 Months**	▪ A vulnerability and tolerability assessment report; ▪ Hydrological/hydraulic assessment; ▪ Levee categorisation and impact acceptability; ▪ Design specification and operations and maintenance manual; ▪ Emergency action plan in the local governments local disaster management plan; and ▪ Owners consent.
Riverine Protection Permit	There are two watercourses that are intersected by the Project. A Riverine Protection Permit for interfering or diverting a watercourse is expected.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout; ▪ Method of operation; ▪ Construction methods; and ▪ Owners consent.
Cultural Heritage Clearance	A review of this register identified there are no aboriginal cultural heritage sites within close proximity to the Project; however, a cultural heritage management plan may be required for	**Unlikely – Requiring Confirmation**	**N/A**	**N/A**
Material change of use for development on a Queensland Heritage Place	There are two Queensland Heritage places in close proximity to the Project. As the Levee is a project carried out by the state, the development is not considered assessable development. Under the QH Act, a person is required to report to the Department of Environment and Heritage Protection (EHP) the discovery of any archaeological artefact or underwater cultural heritage artefact that is an important source of information about an aspect of Queensland history.	**Unlikely – Requiring Confirmation**	**N/A**	**N/A**

Approval	Justification	Status	Time Frame	Supporting Material
Operational works for tidal works and works in a CMD	The site is within a within a CMD and is located between two mapped tidal waterways. It is expected that the section between the two tidal polygons is indeed tidal water. It is also assumed that the Project is likely to involve some placing of spoil or other solid material in tidal water. As such, an application for Tidal Works or Works in a CMD is expected.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout ▪ Clearing method ▪ Owners consent
Operational Works for removal, destruction or damage of a marine plants	The mapped RE (12.1.3) includes Least Concern mangrove shrubland to low closed forest on marine clay plains and estuaries. This is a marine plant, as such damage or disturbance to these plants will require an operational works development permit.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout ▪ Clearing method ▪ Owners consent
Operational works for waterway barrier works	There is mapped Major (Level 4) waterway for waterway barrier works that the City Alignment crosses. It is expected that the construction and operation of the levee will impede fish passage in this waterway, as such an operational works development permit for Waterway Barrier Works is expected	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Details of construction materials ▪ Details of proposed barrier ▪ Details of construction method ▪ Owners consent
Local				
Material change of use for Utility Installation.	As the Project does not have a clear use definition a request would need to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with.	**Likely – Requiring Confirmation**	**Preparation of Application and Supporting Information – 1-2 Months** **Assessment Timeframe – 3-4 Months**	▪ Design details and layout ▪ Details of construction materials ▪ Acid sulphate soil investigation; ▪ Site-specific geotechnical assessment

Approval	Justification	Status	Time Frame	Supporting Material
Operational work - engineering work or landscaping work	As the Project does not have a clear use definition and is not understood to be exempt development or not, a request would need to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with.	**Likely – Requiring Confirmation**	**Preparation of Application and Supporting Information – 1-2 Months** **Assessment Timeframe – 3-4 Months**	▪ Design details and layout ▪ Details of construction materials ▪ Acid sulphate soil investigation; ▪ Drawings showing fill and excavation proposed; ▪ Fill and excavation amount; and ▪ Owners' consent.
Operational work – excavating or filling	As the Project involves significant excavation and filling, this is expected.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout ▪ Details of construction materials ▪ Acid sulphate soil investigation; ▪ Drawings showing fill and excavation proposed; ▪ Fill and excavation amount; and ▪ Owners consent.

Section 10 Cost Estimates

10.1 Probable Construction Costs

The Probable Cost Estimate (PCC) summary identifies the estimated construction costs associated with the flood control works for the Bundaberg East Levee. Initial cost estimates were completed by Estimating and Construction Support (ECS) in consultation with CDM Smith project engineers and associated vender quotations. P50 and VE costs were developed for the construction of the Bundaberg East Flood Levee, flood gates and pump stations. Initial 'base case' estimates were completed on the initial engineering concept design, followed by a further estimate with adjusted value engineering (VE) inputs along with basic architectural cost workups to improve the public amenity of the scheme.

The following table identifies the anticipated costs for construction of the flood levee and flood prevention works for Bundaberg East. This followed completion of the value engineering (VE) of the scheme in conjunction with DLGRMA, US CDM Smith and Australian engineering teams along with the project estimator (ECS).

Table 10-1 Estimate of Construction Costs

Total for all items	Cost ($)	Notes
CAPEX cost	$ 55,079,548	Updated – further piling quote
Client costs – Concept (excluded)	n/a	Excluded as complete, per DLGRMA
Client costs – Development	$ 4,710,000	Now includes $3.5m for property acquisition, resumption and disruption
Client costs – Implementation	$ 4,819,389	Updated for PUPs VE reduction
Client costs – Principal's materials	$ 4,286,212	Per base estimate (incl. architectural)
Client costs – Finalisation	$ 550,796	Per base estimate
Escalation costs (excluded)	n/a	Excluded, as instructed DLGRMA
Contingency VE	$14,574,220	Applied to construction value and architectural elements
TOTAL	**$ 84,020,165**	With adjustments (VE)

The detailed report of this costing exercise is included as Appendix F to this report. It includes the fine-grained details concerning estimation assumptions, vendor quote data and Bill of Quantity (BoQ) workups.

Appendix A Factual Geotechnical Report

FACTUAL GEOTECHNICAL REPORT

Bundaberg East Levee

Bundaberg, Queensland

Department of Infrastructure, Local Government and Planning

2 February 2018

CDM Smith

Bundaberg East Levee

Bundaberg, Queensland

Factual Geotechnical Report

2 February 2018

Prepared By:
CDM Smith

John Briand
Geotechnical Engineer

Reviewed By:
CDM Smith

Stephen Whiteside
Vice President
Senior Geotechnical Engineer

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Section 1

Introduction

1.1 Project Description

This report summarizes CDM Smith's geotechnical field exploration and laboratory test programs for the Bundaberg East Levee project located in Bundaberg, Queensland. This work was completed for the Department of Infrastructure, Local Government and Planning (DILGP), Brisbane.

The Bundaberg East Levee project will include the construction of levees and/or floodwalls to increase the flood protection, mitigate damage, and protect the Bundaberg East area from the 100-year design flood event from the Burnett River. In addition, the project will include flood gates and pump stations to mitigate interior flooding due to coincident rainfall in the protected area inboard of the levee and/or floodwall.

This factual geotechnical report (FGR) presents the results of geotechnical field exploration and laboratory test programs conducted to obtain subsurface data for the proposed levee and floodwall alignment alternatives and for the pump stations and flood gates. The geotechnical engineering evaluation and foundation design recommendations and construction considerations for this project will be included as part of the Interpretive Geotechnical Report (IGR) to be developed at a later date.

The project site and as-drilled test boring location plan are presented on **Figure 1-1**.

1.2 Project Datum

Unless otherwise indicated, elevations (El.) herein are in meters and referenced to the Australian Height Datum (AHD). The ground surface elevations discussed herein were approximated using publicly available LiDAR data for the City of Bundaberg unless otherwise noted.

Horizontal coordinates noted herein are in meters and referenced to the Geocentric Datum of Australia 1994 (GDA94) Map Grid of Australia (MGA) Zone 56.

1.3 Purpose and Scope

The purpose of the subsurface exploration and laboratory testing program was to provide the design team with subsurface information at the Bundaberg East Levee project site including test boring logs, groundwater levels, and laboratory testing of soil samples for geotechnical analysis.

Specifically, CDM Smith's scope of work included:

- Review existing subsurface information including geologic maps and LiDAR topographic surveys of the site and surrounding area;
- Conduct a subsurface exploration program consisting of fourteen (14) test borings to evaluate subsurface conditions and obtain soil samples for geotechnical laboratory testing;

1:5000

0 50 100 250 400 500 m

LEGEND:

B-1 DESIGNATION AND APPROXIMATE LOCATION OF AS-DRILLED TEST BORING DRILLED BY GEODRILL AUSTRALIA OF ILKLEY, QLD BETWEEN 11 AND 22 NOVEMBER 2017.

MW APPROXIMATE LOCATION OF GROUNDWATER MONITORING STATION.

PREFERRED LEVEE ALIGNMENT.

LEVEE ALIGNMENT ALTERNATIVES.

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. THE AS-DRILLED TEST BORING LOCATIONS WERE LOCATED USING A HANDHELD GPS UNIT.
3. TEST BORINGS, SITE FEATURES AND STRUCTURE LOCATIONS ARE APPROXIMATE.

CDM Smith

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND LOCAL GOVERNMENT
BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

FIGURE NO. 1-1
SITE AND TEST BORING LOCATION PLAN
FEBRUARY 2018

- Perform geotechnical laboratory tests on select soil samples to assist with the classification of soils encountered and to estimate the engineering properties of the soil;
- Prepare test boring logs;
- Support design and development of conceptual levee, flood gate, and pump station design alternatives for mitigation of flood events; and
- Prepare this Factual Geotechnical Report summarizing the geotechnical data collected in of the subsurface exploration program.

1.4 Report Limitations

This report has been prepared for the Bundaberg East Levee project, located in Bundaberg, Queensland and is based upon information available at the time of this report and presented herein. This report has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made. In the event that changes in the design or location of the structures occur or a variation in the subsurface or hydrologic/hydraulic conditions is encountered, the conclusions and recommendations contained herein should not be considered valid unless verified in writing by CDM Smith.

Section 2

Site and Subsurface Conditions

2.1 Existing and Proposed Conditions

2.1.1 Existing Conditions

The proposed Bundaberg East Levee site is located in an urban, residential, and mixed-use area adjacent to the southern bank of the Burnett River in Bundaberg, Queensland. The project site is bounded by Walla Street to the west, Bourbong and Cran Streets to the South, the Bundaberg Distillery to the east, and the Burnett River to the north. The ground surface elevation generally ranges from approximate El. 2 to El. 11 across the project site with the low-lying areas near the Saltwater Creek and the unnamed creek near the distillery (Distillery Creek).

2.1.2 Proposed Construction

The Bundaberg East Levee is proposed to run parallel to the southern bank of the Burnett River and across Saltwater Creek and Distillery Creek. The levee is proposed to consist of a flood wall for the length of the alignment with an approximate top of wall elevation at El. 9.5, which is 300mm above the 100-year design flood elevation. The flood wall will be founded approximately 1.5m below ground surface (bgs) on a stepped foundation system consisting of both shallow and deep foundations. The flood wall will consist of two main segments, the City Alignment and the Distillery Alignment, each with multiple alternatives, which are shown on Figure 1-1.

There are three (3) proposed City Alignment alternatives (City Alignment 1 through 3), which are between approximately 850m and 900m in total length. The City Alignment alternatives generally extend along Quay Street from the intersection of Toonburra Street across Saltwater Creek to the intersection of Scotland Street. The alignments then follow Scotland Street to Peterson Street where the alignment terminates shortly after the intersection. The routes of the various City Alignment alternatives only vary in location between Saltwater Creek and Scotland Street. City Alignment 1 extends south of Quay Street through the park and behind many of the residences along the roadway. City Alignment 2 is located along the northern edge of Quay Street within the public right-of-way. City Alignment 3 extends to the north of Quay street near the southern bank of the Burnett River north of the residences and businesses and then extends along Scotland Street to the intersection with Quay Street.

City Alignment 2 is the preferred alignment due the following disadvantages associated with the other alignments:

- City Alignment 1
    - The proximity to Burnett River may result in thicker soft alluvial soil deposits increasing deep foundation lengths and construction costs;
    - This alignment may necessitate acquisition of right-of-way through private land; and
    - This alignment will result in longest flood wall alignment increasing construction costs.

- City Alignment 3
  - Portions of this alignment require excavation of a possible construction and demolition (C&D) debris landfill in the upper few meters of the overburden. This would result in increased construction costs due to potential environmental testing and disposal of contaminated materials; and
  - This alignment will extend through public courts and multiple parks including a dog park, Daphne Geddess Park and East Bundaberg Rotary Park, which may result in public relations issues for the project.

There are two (2) proposed Distillery Alignment alternatives (Distillery Alignment 1 and 2), which are approximately 530m and 500m in total length, respectively. Both alignments cross Distillery Creek. The Distillery Alignment 1 extends along the majority of Cran Street and then parallels the river bank until it terminates north of the distillery. Distillery Alignment 2 extends along the majority of Peterson Street then parallels the river bank until it terminates north of the distillery.

Distillery Alignment 1 is the preferred alignment due the following disadvantages associated with the other alignments:

- Distillery Alignment 2
  - The proximity to the river will likely result in thicker soft alluvial soil deposits increasing deep foundation lengths and construction costs; and
  - This alignment will require additional installation through wetland areas.

There are two locations where flood gate and pump station structures will be constructed, which include the Saltwater Creek crossing and the Distillery Creek crossing. It is anticipated that the flood gate and pump station structures will be significantly larger at Saltwater Creek due to the size of the creek.

2.2 Regional Geology

CDM Smith's review of available subsurface data indicates that multiple geologic formations are encountered in the vicinity of the project site including the Flood-Plain Alluvium (Alluvial Soils) in the vicinity of the two creeks and the Elliott Formation along the entirety of the proposed flood wall alignment (Department of Mines and Energy, 2008).

The Flood-Plain Alluvium is characterised by clay, silt, sand, and gravel associated with alluvial deposition in the Quaternary age. While, the Elliot Formation is characterised by sandstone, conglomerate, siltstone, mudstone and shale up to 34 m thick, which were deposited on the river plain in the Early Miocene age. The formation was typically deeply weathered during the Cenozoic Era, which results in a reddish-brown layer of iron-oxide rich material over a soft, white-red mottled layer. The surface layer is hardened (ferricrete) due to wetting and drying over repeated seasonal cycles. The Elliott Formation generally consist of a few meters of moderately plastic clay above a weakly cemented sandstone cap that overlies approximately 20 to 30m of gravelly and clayey sands. Top of bedrock is typically encountered approximately 60m below existing grade based on discussions with the local drilling contractor C.M. Testing Service (CM Testing).

2.3 Subsurface Exploration Program

The subsurface exploration program completed by CDM Smith was conducted to investigate subsurface conditions at the proposed Bundaberg East Levee site. The program consisted of fourteen (14) test borings (B-1 through B-14) drilled by GeoDrill Australia under contract to CM Testing. All test borings were conducted from 14 to 22 November 2017.

All test borings, except for test boring B-14, were conducted using mud rotary drilling techniques with bentonite clay. The drilling was completed using a 7.6-cm-diameter drill bit with a GD04 Hydrapower Scout rubber tire, track-mounted drill rig. Test borings were drilled to approximate depths between 2.5 and 30.45m bgs. Ground surface elevations at the test boring locations ranged between El. 3.5 and El. 8.8.

Split spoon sampling was typically conducted in soils at intervals of 1m in the upper 3m and at 1.5m intervals thereafter in accordance with ASTM D1586 (using a 38.1mm inside-diameter (ID) sampler, driven 0.45m by blows from a 63.5 kg hammer falling freely for 0.76m). The number of blows required to drive the sampler each 0.15m increment was recorded, and the Standard Penetration Resistance (N-value) was determined as the sum of the blows over the middle 0.3m of penetration. Refusal is defined as less than 0.15m of penetration for 100 blows from a 63.5 kg hammer. When a refusal condition was encountered, the number of blows with the corresponding depth of penetration was recorded. A CDM Smith representative visually classified the soil samples recovered in the field in general accordance with the Burmister soil classification system and assigned a Unified Soil Classification System (USCS) symbol for each sample. Representative soil samples from each split spoon were collected and stored in bags for subsequent review and geotechnical laboratory testing.

7.6-cm-diameter undisturbed (Shelby tube) samples were collected in cohesive soils in general accordance with ASTM D1587 in test borings B-3, B-4, and B-10. The Shelby tube samples were trimmed back from both ends of the tube to ensure that only relatively undisturbed material was retained in the tube. Both ends of the tube samples were then sealed with plastic caps and wrapped in tape. The tubes were labeled and stored upright for transportation.

All soil samples were transported to CM Testing in Bundaberg, Queensland for storage and geotechnical laboratory testing.

All test borings were backfilled with cuttings to the ground surface upon completion.

The as-drilled test boring locations were recorded using a handheld global positioning system (GPS) unit and are shown on Figure 1-1. The test boring logs, prepared by CDM Smith, are included in **Appendix A**.

2.4 Geotechnical Laboratory Testing

Geotechnical laboratory tests were performed on select split spoon and Shelby tube soil samples obtained from the subsurface exploration program. Geotechnical laboratory index tests on split spoon samples were performed at CM Testing in Bundaberg, Queensland. Organic content tests on split spoon samples were performed at ALS Environmental in Brisbane, Queensland. Geotechnical laboratory index, triaxial, and consolidation tests on split spoon and Shelby tube samples were performed at Trilab Pty. Ltd. (Trilab) in Geebund, Queensland. Laboratory testing included the following tests:

- CM Testing Geotechnical Laboratory
  - Ten (10) moisture content tests were performed in accordance with Australian Standard (AS) 1289.2.1.1;
  - Ten (10) grain size analyses with wash of the 0.075 mm sieve were performed in accordance with AS 1289.3.6.1;
  - Ten (10) Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1;
  - Ten (10) linear shrinkage tests were performed in accordance with AS 1289.3.4.1; and
  - Three (3) Emerson classification tests were performed in accordance with AS 1289.3.8.1.
- ALS Environmental Laboratory
  - Three (3) organic content tests were performed in accordance with EP003.
- Trilab Geotechnical Laboratory
  - Seventeen (17) moisture content tests were performed in accordance with Australian Standard (AS) 1289.2.1.1;
  - Seven (7) grain size analyses with wash of the 0.075 mm sieve were performed in accordance with AS 1289.3.6.1;
  - Nine (9) grain size analyses with hydrometer were performed in accordance with AS 1289.3.6.1;
  - Eleven (11) Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1;
  - Eleven (11) linear shrinkage tests were performed in accordance with AS 1289.3.4.1;
  - Three (3) Emerson classification tests were performed in accordance with AS 1289.3.8.1;

- Three (3) three-point consolidated, isotropically undrained (CIU) triaxial tests were performed in accordance with AS1289.6.4.2; and
- Two (2) eight-stage one-dimensional consolidation tests were performed in accordance with AS1289.6.6.1 and AS 1289.3.5.1.

The tests were performed in accordance with the indicated Australian Standards. The purpose of these tests was to assist with soil classification and to estimate soil parameters to be used in engineering analyses.

A summary of the geotechnical laboratory index test results is presented in **Table 2-1**. A summary of the CIU triaxial compression test results is presented in **Table 2-2**. A summary of the consolidation test results is included in **Table 2-3**. The geotechnical laboratory test results are included in **Appendix B**.

2.5 Subsurface Conditions

Subsurface soil conditions at the Bundaberg East Levee project site were interpreted from the test borings conducted as part of this study. The test borings typically encountered Fill over Alluvial Soils over the Elliott Formation.

A summary of the soil and groundwater conditions encountered in the test borings is included in **Table 2-4**.

Subsurface cross-sections for the proposed levee alignment alternatives have been developed at the approximate locations shown on **Figure 2-1**. The levee alignment subsurface cross-sections summarizing the available data from the test borings including sampler blow counts, USCS classification symbols and approximate layering are shown on **Figures 2-2** through **2-4**.

2.5.1 Fill

The fill layer was encountered at the ground surface in eleven of the fourteen test borings at the site except for test borings B-1, B-9, and B-11. The thickness of the fill layer ranged from 1.3m to 5.5m. The layer typically consisted of lean clays (CL) and clayey sands (SC). Miscellaneous debris from a possible C&D debris landfill was encountered in test borings B-5 and B-14 and included wood, waste material, glass, ceramics, fabric and wire. In addition, test boring B-2 encountered gravel and cobble fill to 3m bgs, and test borings B-12 and B-13 encountered metal scraps, boiler ash and charcoal to 2.5m bgs. SPT N-values in the fill layer ranged from 3 blows per 0.3 m (b/0.3m) to 8 b/0.3m with an average of about 6 b/0.3m at the test boring locations.

The detailed Burmister soil classification for this layer was moist to wet, soft to medium stiff, brown, reddish brown and dark brown, CLAY & SILT to CLAY, little to trace fine to coarse sand and fine gravel or moist, very loose to loose, brown, fine to medium SAND, some silty clay.

2.5.2 Alluvial Soils

The alluvial soils layer was encountered in ten of the fourteen test borings except for test borings B-1, B-8, B-11, and B-14. The alluvial soils layer was typically encountered below the fill layer except at test boring B-9 where it was encountered at the ground surface. The thickness of the

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Table 2-1
Summary of Geotechnical Laboratory Index Test Results

<table>
<tr><th rowspan="3">Test Boring Number</th><th rowspan="3">Sample Number</th><th rowspan="3">Sample Depth (m)</th><th rowspan="3">Layer</th><th rowspan="3">USCS Classification [1]</th><th colspan="4">Grain Size Analysis [2]</th><th colspan="3">Atterberg Limits [3]</th><th rowspan="3">Linear Shrinkage [4] (%)</th><th rowspan="3">Moisture Content [5] (%)</th><th rowspan="3">Organic Content [6] (%)</th><th rowspan="3">Emerson Class [7]</th></tr>
<tr><th rowspan="2">Gravel (%)</th><th rowspan="2">Sand (%)</th><th colspan="2">Fines (%)</th><th rowspan="2">LL (%)</th><th rowspan="2">PL (%)</th><th rowspan="2">PI (%)</th></tr>
<tr><th>Silt</th><th>Clay</th></tr>
<tr><td>B-1</td><td>S-4</td><td>4.0 - 4.45</td><td>Elliott Formation</td><td>CH</td><td>0</td><td>17</td><td colspan="2">83</td><td>51</td><td>12</td><td>39</td><td>15.5</td><td>20.0</td><td>0.1</td><td>6</td></tr>
<tr><td>B-2</td><td>S-3</td><td>5.5 - 5.95</td><td>Alluvial Soils</td><td>CH</td><td>0</td><td>2</td><td colspan="2">98</td><td>71</td><td>21</td><td>50</td><td>17.0</td><td>49.3</td><td>1.8</td><td>--</td></tr>
<tr><td>B-2</td><td>S-9</td><td>14.5 - 14.95</td><td>Elliott Formation</td><td>SP</td><td>40</td><td>46</td><td>8</td><td>6</td><td>--</td><td>--</td><td>--</td><td>--</td><td>10.4</td><td>--</td><td>--</td></tr>
<tr><td>B-2</td><td>S-12</td><td>20.5 - 20.95</td><td>Elliott Formation</td><td>CH</td><td>0</td><td>5</td><td colspan="2">95</td><td>81</td><td>24</td><td>57</td><td>13.0</td><td>22.1</td><td>--</td><td>--</td></tr>
<tr><td>B-3</td><td>U-1</td><td>2.5 - 3.0</td><td>Alluvial Soils</td><td>CH</td><td>0</td><td>1</td><td colspan="2">99</td><td>60</td><td>16</td><td>44</td><td>16.0</td><td>23.0</td><td>--</td><td>--</td></tr>
<tr><td>B-3</td><td>U-2</td><td>7.5 - 8.0</td><td>Alluvial Soils</td><td>CH</td><td>0</td><td>1</td><td colspan="2">99</td><td>82</td><td>23</td><td>59</td><td>21.5</td><td>49.8</td><td>--</td><td>2</td></tr>
<tr><td>B-3</td><td>U-3</td><td>15.0-15.5</td><td>Alluvial Soils</td><td>CH</td><td>0</td><td>1</td><td colspan="2">99</td><td>79</td><td>29</td><td>50</td><td>18.0</td><td>74.8</td><td>--</td><td>2</td></tr>
<tr><td>B-3</td><td>S-11</td><td>19.5 - 19.95</td><td>Elliott Formation</td><td>CL</td><td>0</td><td>22</td><td>44</td><td>34</td><td>--</td><td>--</td><td>--</td><td>--</td><td>27.9</td><td>--</td><td>--</td></tr>
<tr><td>B-3</td><td>S-14</td><td>24.0 - 24.45</td><td>Elliott Formation</td><td>CL</td><td>0</td><td>26</td><td colspan="2">74</td><td>49</td><td>15</td><td>34</td><td>9.5</td><td>13.4</td><td>--</td><td>--</td></tr>
<tr><td>B-4</td><td>U-1</td><td>2.0 - 2.5</td><td>Alluvial Soils</td><td>CL</td><td>0</td><td>3</td><td colspan="2">97</td><td>44</td><td>20</td><td>24</td><td>11.0</td><td>29.8</td><td>--</td><td>3</td></tr>
<tr><td>B-4</td><td>U-2</td><td>7.5 -8.0</td><td>Alluvial Soils</td><td>CH</td><td>0</td><td>8</td><td colspan="2">92</td><td>86</td><td>24</td><td>62</td><td>17.5</td><td>63.2</td><td>--</td><td>2</td></tr>
<tr><td>B-5</td><td>S-4</td><td>4.5 - 4.95</td><td>Alluvial Soils</td><td>CH</td><td>0</td><td>6</td><td colspan="2">94</td><td>51</td><td>20</td><td>31</td><td>13.0</td><td>62.0</td><td>--</td><td>--</td></tr>
<tr><td>B-5</td><td>S-8</td><td>10.0 - 10.45</td><td>Alluvial Soils</td><td>OH</td><td>0</td><td>16</td><td colspan="2">84</td><td>112</td><td>37</td><td>75</td><td>20.5</td><td>97.1</td><td>8.8</td><td>--</td></tr>
<tr><td>B-6</td><td>S-7</td><td>9.0 - 9.45</td><td>Elliott Formation</td><td>CH</td><td>0</td><td>9</td><td colspan="2">91</td><td>63</td><td>21</td><td>42</td><td>17.5</td><td>30.2</td><td>--</td><td>--</td></tr>
<tr><td>B-7</td><td>S-4</td><td>4.5 - 4.95</td><td>Marine Clay</td><td>CL</td><td>2</td><td>8</td><td colspan="2">90</td><td>46</td><td>18</td><td>28</td><td>13.0</td><td>32.6</td><td>--</td><td>--</td></tr>
<tr><td>B-8</td><td>S-1</td><td>1.0 - 1.45</td><td>Fill</td><td>CL</td><td>1</td><td>17</td><td>52</td><td>30</td><td>46</td><td>17</td><td>29</td><td>13.0</td><td>14.1</td><td>--</td><td>--</td></tr>
<tr><td>B-8</td><td>S-6</td><td>7.5 - 7.95</td><td>Elliott Formation</td><td>CH</td><td>4</td><td>24</td><td>36</td><td>36</td><td>63</td><td>23</td><td>40</td><td>7.5</td><td>22.4</td><td>--</td><td>--</td></tr>
<tr><td>B-9</td><td>S-3</td><td>3.0 - 3.45</td><td>Elliott Formation</td><td>CL</td><td>0</td><td>25</td><td colspan="2">75</td><td>45</td><td>22</td><td>23</td><td>9.0</td><td>21.0</td><td>--</td><td>--</td></tr>
<tr><td>B-10</td><td>U-1</td><td>3.0 - 3.5</td><td>Alluvial Soils</td><td>CL</td><td>0</td><td>9</td><td colspan="2">91</td><td>44</td><td>17</td><td>27</td><td>14.0</td><td>28.7</td><td></td><td>--</td></tr>
<tr><td>B-10</td><td>S-6</td><td>9.0 - 9.45</td><td>Elliott Formation</td><td>SC</td><td>0</td><td>64</td><td>14</td><td>22</td><td>27</td><td>14</td><td>13</td><td>7.0</td><td>22.0</td><td>--</td><td>2</td></tr>
</table>

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Table 2-1
Summary of Geotechnical Laboratory Index Test Results

Test Boring Number	Sample Number	Sample Depth (m)	Layer	USCS Classification (1)	Grain Size Analysis (2) Gravel (%)	Sand (%)	Fines (%) Silt	Fines (%) Clay	Atterberg Limits (3) LL (%)	PL (%)	PI (%)	Linear Shrinkage (4) (%)	Moisture Content (5) (%)	Organic Content (6) (%)	Emerson Class (7)
B-10	S-11	16.5 - 16.95	Elliott Formation	SC	16	58	11	15	--	--	--	--	14.9	--	--
B-11	S-3	3.0 - 3.45	Elliott Formation	SC	9	53	15	23	--	--	--	--	15.0	--	--
B-12	S-6	7.0 - 7.45	Alluvial Soils	CH	0	3	97		59	21	38	15.0	57.0	--	6
B-12	S-9	11.5 - 11.95	Elliott Formation	SC	23	48	29		41	17	24	9.0	18.8	--	--
B-12	S-13	17.5 - 17.95	Elliott Formation	SC	9	69	7	15	--	--	--	--	18.9	--	--
B-13	S-4	5.5 - 5.95	Alluvial Soils	CH	0	2	98		60	22	38	14.0	41.6	--	5
B-13	S-7	10.0 - 10.45	Elliott Formation	SC	4	71	9	16	--	--	--	--	19.6	--	--

Notes:
1. USCS classifications were performed in accordance with ASTM D2488.
2. Grain size tests were performed in accordance with AS 1289.3.6.1.
3. Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1.
4. Linear shrinkage tests were performed in accordance with AS 1289.3.4.1.
5. Moisture content tests were performed in accordance with AS 1289.2.1.1.
6. Organic content tests were performed in accordance with EP003.
7. Emerson classification tests were performed in accordance with AS 1289.3.8.1.

Abbreviations:

--	Test Not Performed
AS	Australian Standard
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
USCS	Unified Soil Classification System

Legend:

CL	Lean Clay
CH	Fat Clay
OH	Organic Fat Clay
SC	Clayey Sand

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Table 2-2
Summary of Triaxial Compression Test Results

Test Boring Number	Sample Number	Sample Depth (m)	Layer	USCS Classification[1]	Atterberg Limits[2]			Initial Conditions		Effective Confining Stress, σ_c' (kPa)	Failure at Peak Principal Stress Ratio [4&5]			Effective Strength Parameters		Total Strength Parameters	
					LL (%)	PL (%)	PI (%)	Initial Moisture Content (%)[3]	Initial Dry Unit Weight (t/m^3)		Failure Strain (%)	p' (kPa)	q (kPa)	Friction Angle, ϕ' (Degrees)	Cohesion, c' (kPa)	Friction Angle, ϕ (Degrees)	Cohesion, c (kPa)
B-3	U-2	7.5-8.0	Alluvial Soils	CH	82	23	59	42.6	1.24	54 95 151	1.9 3.0 4.8	72.0 109.5 160.5	50.0 66.5 89.5	26.5	20.0	16.5	22.0
B-3	U-3	15.0-15.5	Alluvial Soils	CH	79	29	50	63.6	0.97	98 171 252	2.1 3.6 6.0	111.0 164.5 207.0	62.0 79.5 126.0	19.4	26.4	10.0	35.0
B-10	U-1	3.0-3.5	Alluvial Soils	CL	44	17	27	25.4	1.60	40 61 92	0.8 1.7 2.6	81.0 101.0 139.5	49.0 60.0 81.5	33.9	4.6	20.7	18.0

Notes:
1. USCS classifications were performed in accordance with ASTM D2488.
2. Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1.
3. Moisture content tests were performed in accordance with AS 1289.2.1.1.
4. Consolidated Isotropically Undrained (CIU) Triaxial Compression tests were performed in accordance with AS128
5. Failure criterion: Peak Principal Stress Ratio

Abbreviations:
CL Lean Clay
CH Fat Clay
LL Liquid Limit
PL Plastic Limit
PI Plasticity Index
USCS Unified Soil Classification System

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Table 2-3
Summary of One-Dimensional Consolidation Test Results

Test Boring Number	Sample Number	Sample Depth (m)	Layer	USCS Classification(2)	Atterberg Limits(3)			Initial Moisture Content(4) (%)	Void Ratio		Pre-consolidation Pressure, σ'_p (kPa)	Estimated Existing Effective Vertical Stress, σ'_{vo} (kPa)	OCR	Compression Ratio/Index		Recompression Ratio/Index		Coefficient of Consolidation, Cv (m^2/yr)
					LL (%)	PL (%)	PI (%)		Initial, e_o	Final, e_f				CR	Cc	RR	Cr	At σ'_{vo}
B-3	U-1	2.5-3.0	Marine Clay	CH	60	16	44	22.1	0.62	0.53	80	40	2.0	0.350	0.567	0.016	0.026	0.55
B-4	U-2	7.5-8.0	Marine Clay	CH	86	24	62	70.1	1.69	1.18	101	80	1.3	0.298	0.802	0.050	0.085	0.48

Notes:
1. Consolidation testing was performed in accordance with AS1289.6.6.1 and AS1289.3.5.1
2. USCS classifications were performed in accordance with ASTM D2488.
3. Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1.
4. Moisture contest tests were performed in accordance with AS1289.2.1.1.

Abbreviations:

CH	Fat Clay	Cc	Compression Index
LL	Liquid Limit	CR	Compression Ratio
PI	Plasticity Index	Cr	Recompression Index
PL	Plastic Limit	RR	Recompression Ratio

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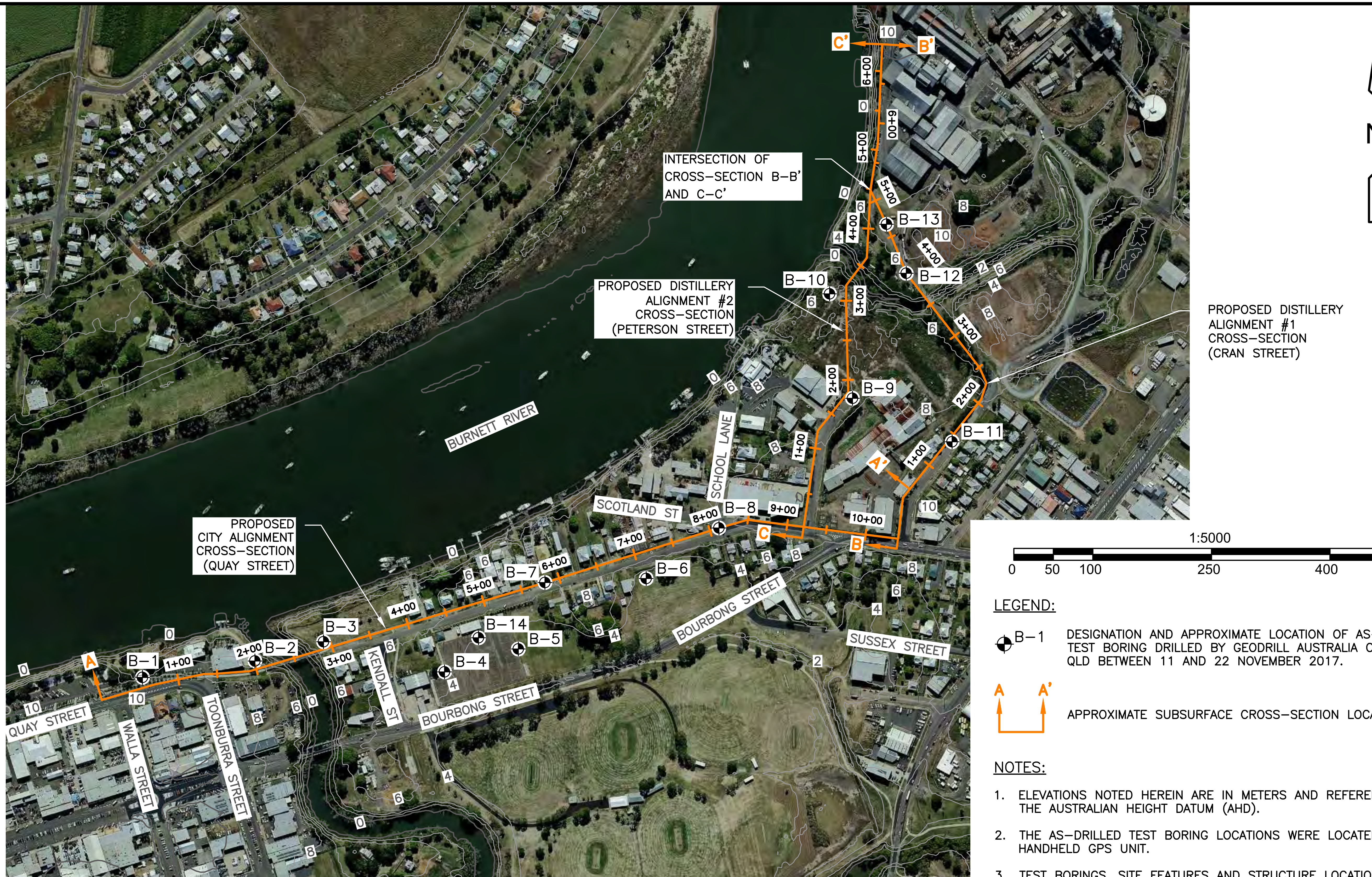
Table 2-4
Summary of Subsurface Exploration Program

Test Boring Number	Ground Surface Elevation (1) (m)	Boring Location(2)		Exploration Depth (3) (m)	Layer Thickness (m)			Groundwater Elevation(1&4) (m)
		Northing	Easting		Fill	Marine Clay	Elliott Formation	
B-1	7.8	7250079	434874	10.45	NE	NE	>10.45	NR
B-2	5.3	7250099	434874	29.95	3.0	10.0	>16.95	NR
B-3	7.1	7250124	435103	30.45	2.0	17.5	>10.95	NR
B-4	4.2	7250086	435256	10.45	2.0	7.0	>1.45	NR
B-5	3.8	7250114	435349	14.45	2.0	>12.45	NE	NR
B-6	3.5	7250204	435511	10.45	2.0	4.0	>4.45	2.5
B-7	5.9	7250199	435383	10.45	4.5	4.5	>1.45	NR
B-8	7.5	7250268	435603	9.45	1.27	NE	>8.18	NR
B-9	5.9	7250432	435772	9.45	NE	2.0	>7.45	NR
B-10	6.0	7250564	435743	19.95	3.0	4.5	>12.45	NR
B-11	8.8	7250377	435898	9.05	NE	NE	>9.05	NR
B-12	5.8	7250590	435840	20.45	5.5	4.5	>10.45	NR
B-13	6.3	7250652	435815	10.45	5.5	3.0	>1.95	NR
B-14	4.0	7250129	435299	2.5	1.75	NE	>0.75	NR

Notes:
1. Elevations are in meters and referenced to the Australian Height Datum (AHD).
2. Boring location coordinates are in meters and referenced to the Geocentric Datum of Australia 1994 (GDA94) Map Grid of Australia (MGA) Zone 56.
3. Indicated depths are depths below ground surface at the time of drilling.
4. Groundwater levels were measured at the time of drilling and may not represent actual groundwater level.

Abbreviations:

NE Not Encountered
NR Not Recorded
> Indicates Layer Not Fully Penetrated



LEGEND:

B–1 DESIGNATION AND APPROXIMATE LOCATION OF AS–DRILLED TEST BORING DRILLED BY GEODRILL AUSTRALIA OF ILKLEY, QLD BETWEEN 11 AND 22 NOVEMBER 2017.

A A' APPROXIMATE SUBSURFACE CROSS–SECTION LOCATION.

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. THE AS–DRILLED TEST BORING LOCATIONS WERE LOCATED WITH A HANDHELD GPS UNIT.
3. TEST BORINGS, SITE FEATURES AND STRUCTURE LOCATIONS ARE APPROXIMATE.

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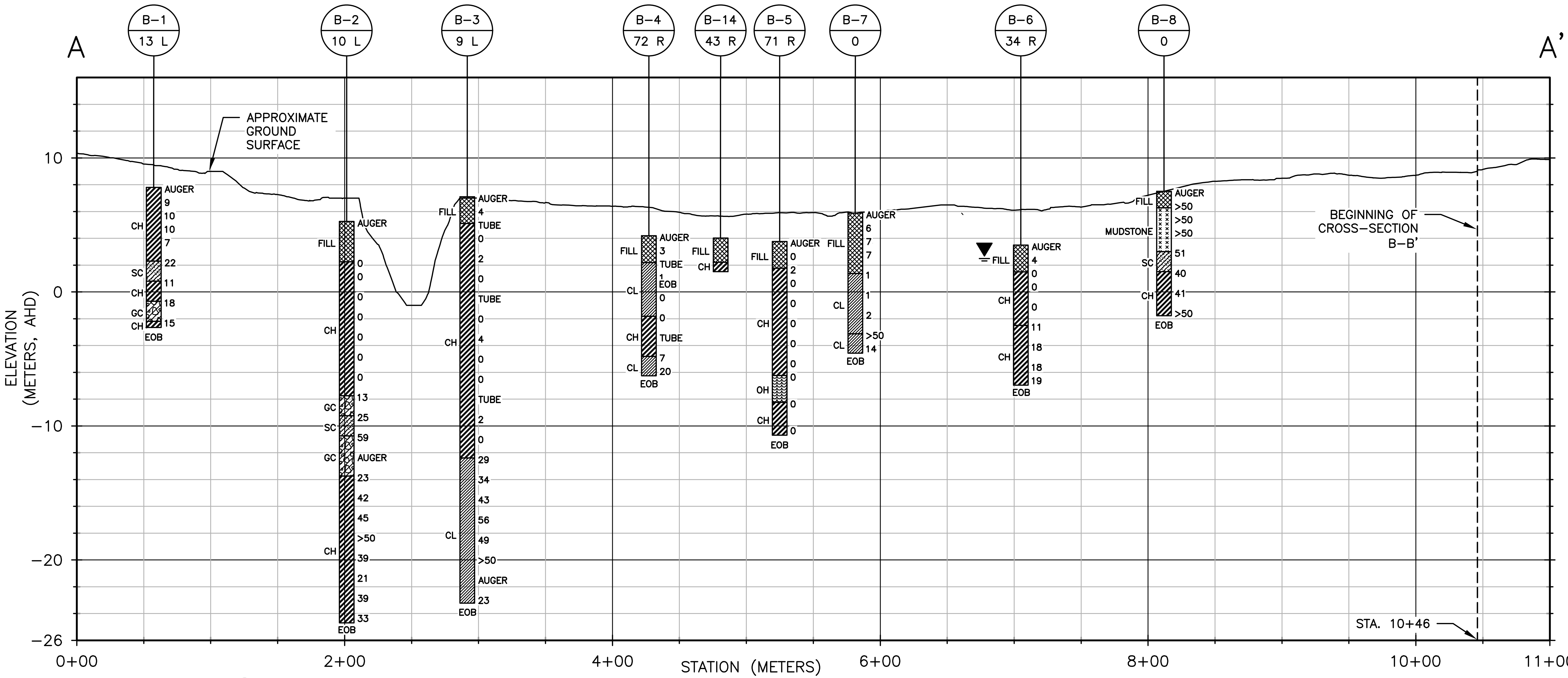
BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

FIGURE NO. 2-1
SUBSURFACE CROSS-SECTION PLAN
FEBRUARY 2018



LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY-GRADED GRAVEL
- FAT CLAY
- ORGANIC FAT CLAY
- LEAN CLAY
- MUDSTONE

B-1	TEST BORING NUMBER
1 L/R	OFFSET DISTANCE, LEFT OR RIGHT (METERS)
13	STANDARD PENETRATION RESISTANCE N-VALUE (BL/0.3M)
▼	OBSERVED GROUNDWATER LEVEL
—	USCS CLASSIFICATION CHANGE
CL	USCS CLASSIFICATION
EOB	END OF BORING

CITY ALIGNMENT CROSS-SECTION A-A'

NOTES:

1. REFER TO FIGURE 2-1 FOR NOTES.

VERTICAL SCALE: 1M = 300M

0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M

0 30 60 150 240 300 m

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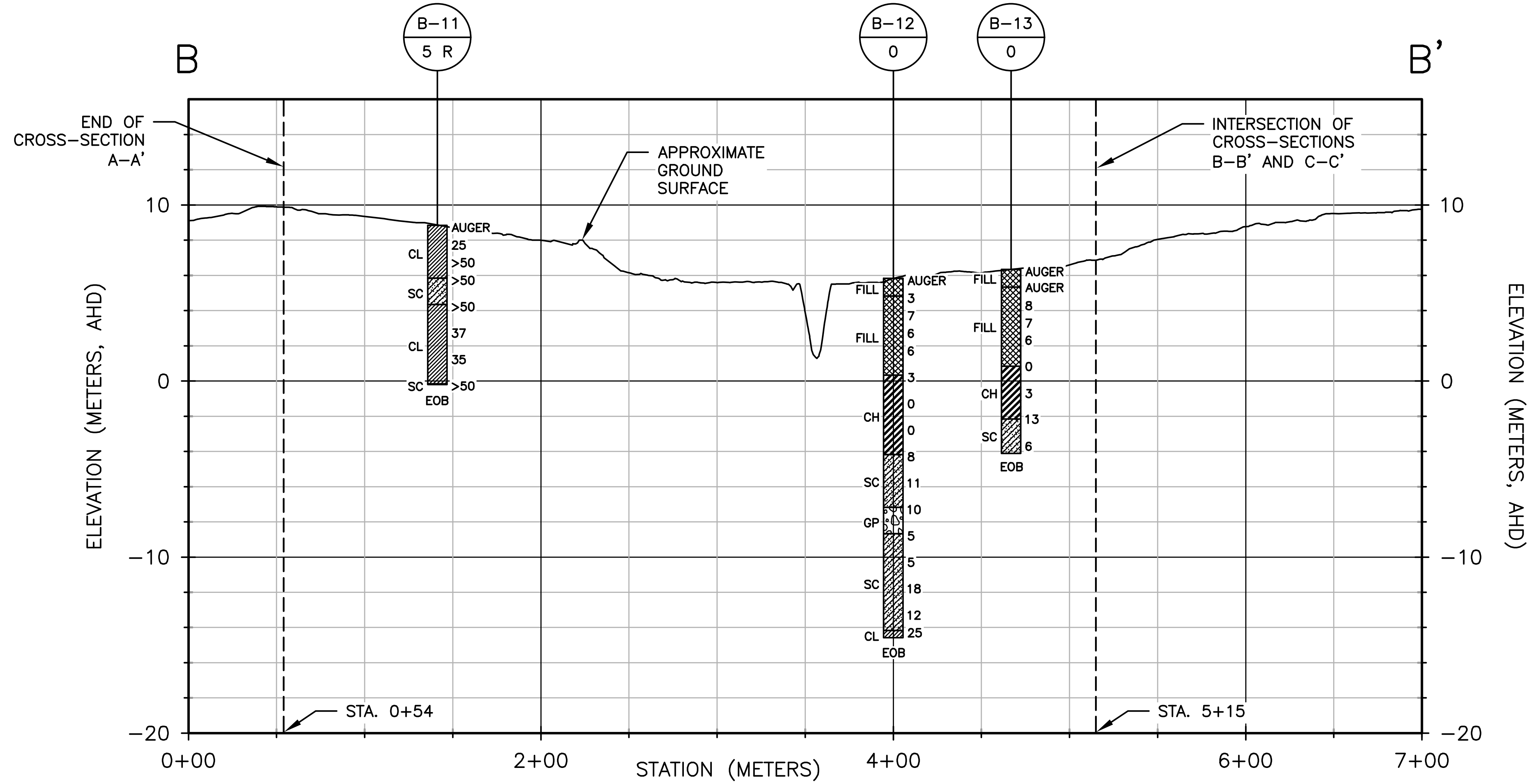
BUNDABERG, QUEENSLAND

FIGURE NO. 2-2
GENERAL CITY ALIGNMENT CROSS-SECTION A-A'
FEBRUARY 2018



DISTILLERY ALIGNMENT 1 CROSS-SECTION B-B'

LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY-GRADED GRAVEL
- FAT CLAY
- ORGANIC FAT CLAY
- LEAN CLAY
- MUDSTONE

B-1 — TEST BORING NUMBER
1 L/R — OFFSET DISTANCE, LEFT OR RIGHT (METERS)
13 — STANDARD PENETRATION RESISTANCE N-VALUE (BL/0.3M)
OBSERVED GROUNDWATER LEVEL
USCS CLASSIFICATION CHANGE
CL — USCS CLASSIFICATION
EOB — END OF BORING

NOTES:

1. REFER TO FIGURE 2-1 FOR NOTES.

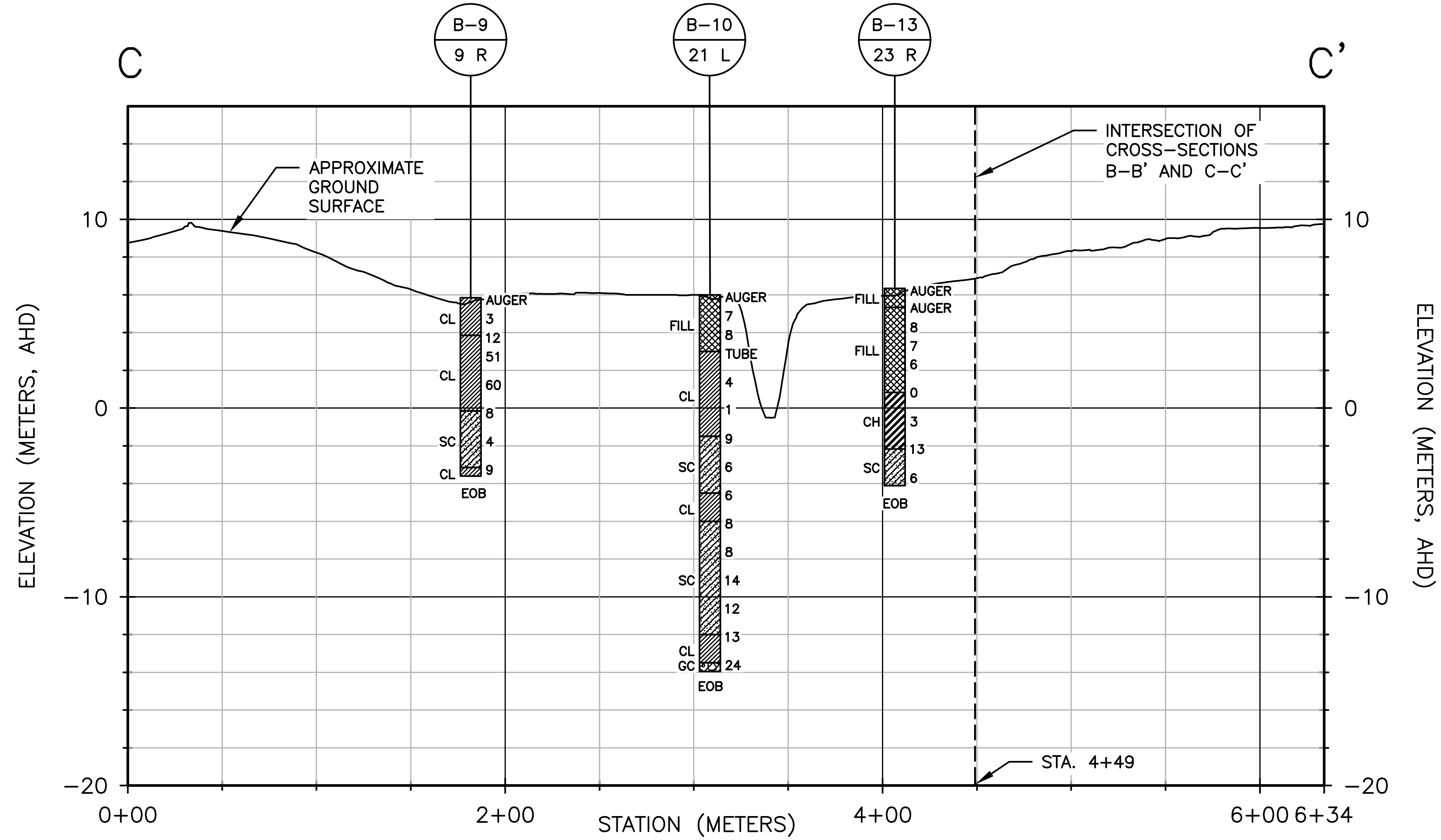
VERTICAL SCALE: 1M = 300M
0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M
0 30 60 150 240 300 m

CDM Smith

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND LOCAL GOVERNMENT
BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

FIGURE NO. 2-3
DISTILLERY ALIGNMENT 1 CROSS-SECTION B-B'
FEBRUARY 2018



DISTILLERY ALIGNMENT 2 CROSS-SECTION C-C'

LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY-GRADED GRAVEL
- FAT CLAY
- ORGANIC FAT CLAY
- LEAN CLAY
- MUDSTONE

B-1 — TEST BORING NUMBER

1 L/R — OFFSET DISTANCE, LEFT OR RIGHT (METERS)

13 — STANDARD PENETRATION RESISTANCE N-VALUE (BL/0.3M)

OBSERVED GROUNDWATER LEVEL

USCS CLASSIFICATION CHANGE

CL — USCS CLASSIFICATION

EOB — END OF BORING

NOTES:

1. REFER TO FIGURE 2-1 FOR NOTES.

VERTICAL SCALE: 1M = 300M

0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M

0 30 60 150 240 300 m

CDM Smith

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BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

FIGURE NO. 2-4
DISTILLERY ALIGNMENT 2 CROSS-SECTION C-C'
FEBRUARY 2018

alluvial soils layer ranged from 2.0m to 17.5m where the layer was fully penetrated. The layer typically consisted of fat clays (CH), lean clays (CL), and organic fat clays (OH). SPT N-values in the alluvial soils layer ranged from weight of hammer (WOH) to 4 b/0.3m with an average value of about 1 b/0.3m at the test boring locations.

The detailed Burmister soil classification for this layer was wet, very soft to soft, gray and brown, Silty CLAY to CLAY, little to trace fine to coarse sand, trace to no fine gravel. Note that little to trace organics and wood were encountered during the subsurface investigation within this layer.

2.5.3 Elliott Formation

The Elliott Formation layer was encountered in twelve of the fourteen test borings except for test borings B-5 and B-14. The Elliott Formation layer was typically encountered below alluvial soils layer except at test borings B-1 and B-11 where it was encountered at the ground surface and at test boring B-8 where it was encountered below the fill layer. The Elliott Formation layer was not fully penetrated at any of the test boring locations and was drilled and sampled between 0.75m and 16.95m. The layer typically consisted of fat clay (CH), lean clay (CL), clayey sand (SC), clayey gravel (GC), and poorly-graded sand (SP). SPT N-values in the Elliot Formation layer ranged from 4 b/0.3m to greater than 50 b/0.3m with an average of about 34 b/0.3m at the test boring locations.

The detailed Burmister soil classification for this layer was stiff to hard, red, gray and brown, Silty CLAY to CLAY, some to little fine sand; loose to medium dense, gray, fine to coarse SAND and to little Silty CLAY to CLAY, trace to no fine gravel; or medium dense, fine to coarse GRAVEL, some to little clay and silt, some to little fine to coarse sand.

2.6 Groundwater Conditions

The depth to groundwater was recorded prior to backfilling at test boring B-6 and was measured at approximately 1m bgs (El. 2.5). The groundwater measurement was taken within the steel casing at the test boring location and may not represent static groundwater conditions. No groundwater monitoring wells were installed as part of this test boring program.

A real-time groundwater monitoring station exists at Kendall Flats, approximately 200m south of the proposed flood wall alignment. The average daily groundwater elevation at this station for 2017 was measured to be El. 1.5 with the average daily minimum measured at El 0.9 and the average daily maximum measured at El. 2.3. The approximate location of the groundwater monitoring station is shown on Figure 1-1.

2.7 Expected Variations in Subsurface Conditions

Subsurface conditions presented herein are based on soil and groundwater conditions observed at the test boring locations. However, subsurface conditions may vary at other locations within the site.

Groundwater levels may change with river and creek levels, time, season, temperature, and construction activities in the area, as well as with other factors. In addition, stabilized groundwater levels can be difficult to obtain in test borings drilled using mud rotary due to the presence of drilling fluid in the borehole. Therefore, groundwater conditions at the time of construction may be different from those observed at the time of the test boring.

Appendix A

Test Boring Logs

BOREHOLE LOG
B-1

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 7.8
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 10.45
Drillers: Anthony/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: Start: 21-11-17 **End:** 21-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates: See Boring Location Plan
Field Screening Instrument: PP
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			7.8 / 0					
AS	AS-1	1/0		AUGER	N/A		CH	
SS	S-1	0.45/0.26		9	1 3 6		CH	Moist, stiff, dark reddish gray, CLAY and SILT, trace fine to coarse sand. **-ELLIOTT FORMATION-**
SS	S-2	0.45/0.45	2	10	2 4 6		CH	Moist, stiff, light brownish gray, CLAY, trace fine to medium sand.
SS	S-3	0.45/0.45		10	3 3 7		CH	Moist, stiff, grayish brown, CLAY, trace fine sand. (PP = 311 kPa)
SS	S-4	0.45/0.45	4	7	3 4 3		CH	Moist, medium stiff, gray, slightly Organic Silty CLAY, little fine to medium sand -Trace roots (PP = 72 kPa)
			2.8					
SS	S-5	0.45/0.45		22	6 11 11		SC	Wet, medium dense, light gray, fine to medium SAND and CLAY.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
- HSA - Hollow Stem Auger
- SSA - Solid Stem Auger
- HA - Hand Auger
- AR - Air Rotary
- DTR - Dual Tube Rotary
- FR - Foam Rotary
- MR - Mud Rotary
- RC - Reverse Circulation
- CT - Cable Tool
- JET - Jetting
- D - Driving
- DTC - Drill Through Casing

SAMPLING TYPES:
- AS - Auger/Grab Sample
- CS - California Sampler
- BX - 1.5" Rock Core
- NX - 2.1" Rock Core
- GP - Geoprobe
- HP - Hydro Punch
- SS - Split Spoon
- ST - Shelby Tube
- WS - Wash Sample

OTHER:
- AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm, Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

CDM Smith

BOREHOLE LOG
B-1

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			6				SC	
SS	S-6	0.45/0.45		11	4 4 7		CH	Wet, stiff, light gray, CLAY, trace fine sand. (PP = 287 kPa)
			8					
SS	S-7	0.45/0.19		18	7 8 10		GC	Wet, medium dense, light gray, fine to medium GRAVEL, some clay and silt, little fine to coarse sand.
			-2.2					
SS	S-8	0.45/0.45	10	15	5 7 8		CH	Wet, stiff to very stiff, light gray, CLAY and fine to coarse SAND, trace fine gravel.
								Boring terminated at 10.45 m-bgs.
			12					
			14					
			-7.2					

BOREHOLE LOG
B-2

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 5.3
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 29.95
Drillers: Anthony/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: **Start:** 21-11-17 **End:** 21-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
See Boring Location Plan
Field Screening Instrument: PP/TV
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			5.3 0					Augered through coarse gravel and cobble fill. **-FILL-**
AS	AS-1	3/0	2	AUGER	N/A		Fill	
SS	S-1	0.45/0.45		0	WOH WOH WOH		CH	Wet, very soft, grayish brown, CLAY, some fine to medium sand, trace fine gravel. **-ALLUVIAL SOILS-** (PP = 38 kPa)
SS	S-2	0.45/0.45	4	0	WOH WOH WOH			Wet, very soft, grayish brown, Silty CLAY, little fine sand. (PP = 57 kPa)
			0.3					
SS	S-3	0.45/0.45		0	WOH WOH WOH			Wet, very soft, dark gray, slightly Organic CLAY, trace fine to medium sand. -Little wood

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
- HSA - Hollow Stem Auger
- SSA - Solid Stem Auger
- HA - Hand Auger
- AR - Air Rotary
- DTR - Dual Tube Rotary
- FR - Foam Rotary
- MR - Mud Rotary
- RC - Reverse Circulation
- CT - Cable Tool
- JET - Jetting
- D - Driving
- DTC - Drill Through Casing

SAMPLING TYPES:
- AS - Auger/Grab Sample
- CS - California Sampler
- BX - 1.5" Rock Core
- NX - 2.1" Rock Core
- GP - Geoprobe
- HP - Hydro Punch
- SS - Split Spoon
- ST - Shelby Tube
- WS - Wash Sample

OTHER:
- AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

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BOREHOLE LOG
B-2

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			6					(TV = 8 kPa)
SS	S-4	0.45/0.45		0	WOR WOR WOH			Wet, very soft, dark gray, Silty CLAY, trace fine sand. (PP < 24 kPa)
			8					
SS	S-5	0.45/0.15		0	WOH WOH WOH			Wet, very soft, dark gray, CLAY, little fine to coarse sand. (PP < 24 kPa)
							CH	
SS	S-6	0.45/0.45	-4.7 10	0	WOH WOH WOH			Wet, very soft, dark gray, slightly Organic CLAY, trace fine sand. -Trace peat (PP = 19 kPa)
SS	S-7	0.45/0.45		0	WOR WOR WOH			Wet, dark gray, very soft, CLAY, trace fine sand. (PP = 19 kPa)
			12					
SS	S-8	0.45/0.14		13	5 3 10		GC	Wet, medium dense, dark gray, fine to coarse GRAVEL, little clay and silt, little fine to coarse sand. **-ELLIOTT FORMATION-**
			14					
SS	S-9	0.45/0.2	-9.7	25	16 12 13		SC	Wet, medium dense, light gray, fine to coarse Sand and fine Gravel, trace clay and silt

BOREHOLE LOG
B-2

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. / Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
							SC	
SS	S-10	0.45/0.22	16	59	14 30 29		GC	Wet, very dense, grayish brown, fine to coarse GRAVEL, some fine to coarse sand, little clay and silt.
AS	AS-2	1.5/0	18	AUGER	N/A			Gravel collapsed into borehole. Augered through gravel from 17.5-19 m-bgs.
SS	S-11	0.45/0.29		23	7 11 12		CH	Wet, very stiff, light reddish brown, CLAY, trace fine gravel, trace fine to coarse sand.
			-14.7 20					
SS	S-12	0.45/0.25		42	11 17 25			Moist, hard, reddish gray, CLAY, trace fine to medium sand.
SS	S-13	0.45/0.3	22	45	9 19 26			Moist, hard, light gray, CLAY, trace fine sand.
SS	S-14	0.3/0.16		>50	21 50/15			Moist, hard, light brownish gray, Silty CLAY, trace fine sand.
			24 -19.7					
SS	S-15	0.45/0.28		39				Moist, hard, light gray, CLAY, trace fine sand.

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BOREHOLE LOG
B-2

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. / Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-15	0.45/0.28		39	11 15 24			
			26					
SS	S-16	0.45/0.26		21	20 13 8			Moist, very stiff, light gray, CLAY, trace fine sand.
							CH	
SS	S-17	0.45/0.4	28	39	10 18 21			Moist, hard, light gray, CLAY, trace fine sand.
								Moist, hard, light gray, CLAY, little fine sand.
SS	S-18	0.45/0.35		33	9 14 19			
			-24.7 / 30					Boring terminated at 29.95 m-bgs.
			32					
			34					

CDM Smith

BOREHOLE LOG
B-3

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 7.1
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 30.45
Drillers: Jonathan/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: Start: 14-11-17 **End:** 15-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
Field Screening Instrument: PP/TV
See Boring Location Plan
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			7.1 0					
AS	AS-1	1/0		AUGER	N/A			
SS	S-1	0.45/0.3		4	2 2 2		Fill	Moist, very loose to loose, brown, fine to medium SAND, some silty clay. **-FILL-**
ST	U-1	0.5/0.43	2	TUBE	PUSH		CH	Moist, dark brown, CLAY, trace fine sand. **-ALLUVIAL SOILS-**
SS	S-2	0.45/0.45		0	WOH WOH WOH			Wet, very soft, brown, CLAY, little fine sand. (PP = 48 kPa)
			4					
SS	S-3	0.45/0.45	2.1	2	WOH WOH 2			Wet, very soft, gray brown, CLAY, little fine to coarse sand. (PP = 96 kPa)

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
- HSA - Hollow Stem Auger
- SSA - Solid Stem Auger
- HA - Hand Auger
- AR - Air Rotary
- DTR - Dual Tube Rotary
- FR - Foam Rotary
- MR - Mud Rotary
- RC - Reverse Circulation
- CT - Cable Tool
- JET - Jetting
- D - Driving
- DTC - Drill Through Casing

SAMPLING TYPES:
- AS - Auger/Grab Sample
- CS - California Sampler
- BX - 1.5" Rock Core
- NX - 2.1" Rock Core
- GP - Geoprobe
- HP - Hydro Punch
- SS - Split Spoon
- ST - Shelby Tube
- WS - Wash Sample

OTHER:
- AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

BOREHOLE LOG
B-3

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-4	0.45/0.45	6	0	WOH WOH WOH			Wet, very soft, dark gray, CLAY, little fine to coarse sand. -Increasing sand with depth (TV = 17 kPa)
ST	U-2	0.5/0.45		TUBE	PUSH			Wet, dark gray, CLAY trace fine sand.
			8					
SS	S-5	0.45/0.45		0	WOH WOH WOH			Wet, very soft, dark gray, CLAY, trace fine sand. (PP = 24 kPa)
			-2.9 10					
SS	S-6	0.45/0.45		4	1 1 3		CH	Wet, soft to medium stiff, dark gray, slightly Organic CLAY, trace fine to coarse sand. -Trace peat (PP = 24 kPa)
SS	S-7	0.45/0.45	12	0	WOH WOH WOH			Wet, very soft, gray, CLAY, trace fine sand. (TV = 14 kPa)
SS	S-8	0.45/0.45		0	WOR WOR WOH			Wet, very soft, dark gray, CLAY, trace fine to coarse sand.
			14 -7.9					
ST	U-3	0.5/0.45		TUBE	PUSH			Wet, gray, CLAY, trace fine sand.

BOREHOLE LOG
B-3

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			16					
SS	S-9	0.45/0.45		2	WOR WOH 2		CH	Wet, very soft to soft, dark gray, CLAY, little fine to coarse sand.
SS	S-10	0.45/0.45	18	0	WOR WOR WOR			Wet, very soft, gray, CLAY and fine to medium Sand.
SS	S-11	0.45/0.4	-12.9	29	11 15 14			Wet, medium dense, grayish brown, Silty Clay, some fine sand. **-ELLIOTT FORMATION-**
			20					
SS	S-12	0.45/0.32		34	8 15 19			Moist, hard, pale red, Silty CLAY, trace fine sand. (PP = 431+ kPa)
			22					
SS	S-13	0.45/0.38		43	11 18 25		CL	Moist, hard, pale red, Silty CLAY, trace fine sand.
SS	S-14	0.45/0.45	24	56	16 26 30			Moist, hard, light gray, Silty CLAY, some fine to coarse sand.
			-17.9					

BOREHOLE LOG
B-3

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-15	0.45/0.25		49	14 20 29		CL	Moist, hard, light reddish gray, CLAY, trace fine sand.
			26					
SS	S-16	0.25/0.25		>50	13 50/10			Moist, hard, light gray, Silty CLAY, trace fine sand.
			28					
AS	AS-2	1.5/0.0		AUGER	N/A			
			-22.9 30					
SS	S-17	0.45/0.33		23	6 10 13			Moist, hard, light gray with dark red seams, Silty CLAY, trace fine sand.
								Boring terminated at 30.45 m-bgs.
			32					
			34					

CDM Smith

BOREHOLE LOG
B-4

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 4.2
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 10.45
Drillers: Jonathan/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: Start: 15-11-17 **End:** 15-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
See Boring Location Plan
Field Screening Instrument: PP/TV
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			4.2 0					
AS	AS-1	1/0		AUGER	N/A			
SS	S-1	0.45/0.15		3	1 1 2		FILL	Moist, soft, brown to reddish brown, Silty CLAY, little fine gravel, trace fine to coarse sand. **-FILL-**
ST	U-1	0.5/0.24	2	TUBE	PUSH			Wet, dark gray, Silty CLAY, trace fine to coarse sand. **-ALLUVIAL SOILS-**
SS	S-2	0.45/0.45		1	WOR WOH 1			Wet, very soft, dark brown, CLAY, little fine to coarse sand.
			4				CL	
SS	S-3	0.45/0.45	-0.8	0	WOH WOH WOH			Wet, very soft, dark gray, slightly Organic CLAY, trace fine sand. -Trace peat. (PP = 24 kPa, TV = 7 kPa)

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
- HSA - Hollow Stem Auger
- SSA - Solid Stem Auger
- HA - Hand Auger
- AR - Air Rotary
- DTR - Dual Tube Rotary
- FR - Foam Rotary
- MR - Mud Rotary
- RC - Reverse Circulation
- CT - Cable Tool
- JET - Jetting
- D - Driving
- DTC - Drill Through Casing

SAMPLING TYPES:
- AS - Auger/Grab Sample
- CS - California Sampler
- BX - 1.5" Rock Core
- NX - 2.1" Rock Core
- GP - Geoprobe
- HP - Hydro Punch
- SS - Split Spoon
- ST - Shelby Tube
- WS - Wash Sample

OTHER:
- AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm, Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

CDM Smith

BOREHOLE LOG
B-4

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-4	0.45/0.45	6	0	WOR WOR WOR		CH	Wet, very soft, dark gray, Silty CLAY, trace fine sand. (PP = > 24 kPa)
ST	U-2	0.5/0.5		TUBE	PUSH			Wet, dark gray, CLAY, trace fine to medium sand.
			8					
SS	S-5	0.45/0.45		7	2 3 4		CL	Wet, medium stiff, dark gray, CLAY, some fine to coarse sand. (PP = 120 kPa) **-ELLIOTT FORMATION-**
			-5.8					
SS	S-6	0.45/0.45	10	20	6 8 12			Wet, very stiff, gray, CLAY and fine to coarse SAND. (PP = 311 kPa)
			12					Boring terminated at 10.45 m-bgs.
			14					
			-10.8					

BOREHOLE LOG
B-5

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Drillers: Jonathan/Alex
Drilling Date: Start: 15-11-17 **End:** 15-11-17
Borehole Coordinates:
See Boring Location Plan
Surface Elevation (m): 3.8
Total Depth (m): 14.45
Depth to Initial Water Level (m-bgs): NR
Abandonment Method: Backfilled with cuttings
Field Screening Instrument: PP/TV
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			3.8 / 0					
AS	AS-1	1/0		AUGER	N/A		FILL	
SS	S-1	0.45/0.15		0	WOH WOH WOH			Wet, very soft, brown, Organic CLAY, little fine to coarse sand. -Little wood **-FILL-**
SS	S-2	0.45/0.23	2	2	1 1 1		CH	Wet, very soft to soft, dark gray, CLAY, trace fine sand. **-ALLUVIAL SOILS-**
SS	S-3	0.45/0.45		0	WOR WOR WOR			Wet, very soft, grayish brown, CLAY, trace fine sand.
			4					
SS	S-4	0.45/0.45	-1.2	0	WOH WOH WOH			Wet, very soft, dark gray, slightly Organic Silty CLAY, trace fine to coarse sand. -Trace wood chips (PP = < 24 kPa)

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm, Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

CDM Smith

BOREHOLE LOG
B-5

Client: DILGP | **Project Name:** Bundaberg East Levee

Project Location: Bundaberg, QLD | **Project Number:** 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-5	0.45/0.45	6	0	WOR WOR WOR		CH	Wet, very soft, dark gray, slightly Organic CLAY, little fine to coarse sand. -Trace wood (PP = < 24 kPa)
SS	S-6	0.45/0.45		0	WOR WOR WOR			Wet, very soft, dark gray, CLAY, trace fine to medium sand. (PP = 19 kPa)
			8					
SS	S-7	0.45/0.45		0	WOH WOH WOH			Wet, very soft, dark gray, slightly Organic CLAY, some fine to medium sand. -Trace wood chips (PP = 24 kPa, TV = 7 kPa)
			-6.2					
SS	S-8	0.45/0.45	10	0	WOH WOH WOH		OH	Wet, very soft, dark gray, Organic CLAY, little fine to medium sand.
SS	S-9	0.45/0.45	12	0	WOH WOH WOH		CH	Wet, very soft, dark gray, CLAY, trace fine sand.
SS	S-10	0.45/0.45	14	0	WOH WOH WOH			Wet, very soft, dark gray, CLAY, trace fine to coarse sand. -Seams of fine to coarse sand
			-11.2					Boring terminated at 14.45 m-bgs.

CDM Smith

BOREHOLE LOG
B-6

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 3.5
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 10.45
Drillers: Jonathan/Alex
Depth to Initial Water Level (m-bgs): 1
Drilling Date: Start: 16-11-17 **End:** 16-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
Field Screening Instrument: PP
See Boring Location Plan
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			3.5 0					
AS	AS-1	1/0		AUGER	N/A		FILL	
SS	S-1	0.45/0.1		4	WOH 1 3			Wet, soft to medium stiff, dark brown, Silty CLAY and fine to medium SAND. -Little waste material **-FILL-**
SS	S-2	0.45/0.19	2	0	WOH WOH WOH		CH	Wet, very soft, dark gray, CLAY, trace fine to coarse sand. **-ALLUVIAL SOILS-**
SS	S-3	0.45/0.45		0	WOR WOR WOR			Wet, very soft, dark gray, CLAY, trace fine sand. (PP = 72 kPa)
			4					
SS	S-4	0.45/0.45	-1.5	0	WOR WOR WOR			Wet, very soft, dark gray, CLAY, trace fine sand. (PP = < 24 kPa)

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand
Date: 1-2-18

BOREHOLE LOG
B-6

Client: DILGP **Project Name:** Bundaberg East Levee

Project Location: Bundaberg, QLD **Project Number:** 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-5	0.45/0.45	6	11	3 5 6		CH	Wet, stiff, dark grayish brown, CLAY, some fine to coarse sand. (PP = 96 kPa) **-ELLIOTT FORMATION-**
SS	S-6	0.45/0.45		18	4 8 10			Moist, very stiff, dark grayish brown and red, CLAY, trace fine to coarse sand. (PP = > 431 kPa)
			8					
SS	S-7	0.45/0.45		18	5 8 10			Wet, very stiff, light gray, CLAY, trace fine to coarse sand.
			-6.5					
SS	S-8	0.45/0.45	10	19	5 11 8			Moist, very stiff, grayish brown, Silty CLAY, trace fine sand.
			12 14 -11.5					Boring terminated at 10.45 m-bgs.

CDM Smith

BOREHOLE LOG
B-7

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 5.9
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 10.45
Drillers: Jonathan/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: Start: 16-11-17 **End:** 16-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
See Boring Location Plan
Field Screening Instrument: PP/TV
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			5.9 0					
AS	AS-1	1/0		AUGER	N/A		FILL	
SS	S-1	0.45/0.37		6	WOH 3 3			Moist, medium stiff, dark brown, CLAY, trace fine sand. (PP = 120 kPa) **-FILL-**
SS	S-2	0.45/0.45	2	7	3 3 4			Moist, medium stiff, dark brown, CLAY, trace fine to medium sand. (PP = 120 kPa)
SS	S-3	0.45/0.45		7	1 3 4			Moist, medium stiff, dark grayish brown, Silty CLAY, trace fine to coarse sand, trace fine gravel. (TV = 24 kPa)
			4					
SS	S-4	0.45/0.45	0.9	1	WOH WOH 1		CL	Wet, very soft, grayish brown, Silty CLAY, trace fine to coarse sand, trace fine gravel. (PP = 72 kPa) **-ALLUVIAL SOILS-**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm, Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

CDM Smith

BOREHOLE LOG
B-7

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-5	0.45/0.45	6	1	WOH WOH 1			Wet, very soft, dark gray, CLAY, trace fine sand. (PP = 120 kPa)
							CL	
SS	S-6	0.45/0.45		2	WOH WOH 2			Wet, very soft to soft, dark gray, CLAY, trace fine sand. (PP = 24 kPa)
			8					
SS	S-7	0.27/0.27		>50	6 50/12			Wet, hard, gray, CLAY, little fine to coarse sand. **-ELLIOTT FORMATION-**
			-4.1				CL	
SS	S-8	0.45/0.45	10	14	3 6 8			Wet, stiff, gray, CLAY, trace fine sand.
			12 14 -9.1					Boring was terminated at 10.45 m-bgs.

CDM Smith

BOREHOLE LOG
B-8

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 7.5
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 9.45
Drillers: Tom/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: **Start:** 16-11-17 **End:** 17-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
See Boring Location Plan
Field Screening Instrument: PP
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			7.5 0					
AS	AS-1	1/0		AUGER	N/A		FILL	
SS	S-1	0.27/0.22		>50	4 50/12			Moist, hard, light brownish gray, Silty CLAY, little fine to medium sand, trace fine gravel. -3 cm piece of mudstone in spoon tip. (PP = 263 kPa) **-FILL-**
SS	S-2	0.4/0.39	2	>50	2 4 50/10			Dry, very dense, pinkish gray, MUDSTONE, some silt, trace fine sand. -Highly weathered **-ELLIOTT FORMATION-**
							Mudstone	
SS	S-3	0.14/0.12		>50	50/14			Moist, very dense, light gray, MUDSTONE, some silt, trace fine sand. - Highly weathered
			4					
SS	S-4	0.45/0.45	2.5	51	10 21 30		SC	Moist, very dense, reddish gray, fine to medium SAND and CLAY.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand
Date: 1-2-18

BOREHOLE LOG
B-8

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. / Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-5	0.45/0.38	6	40	11 21 19		CH	Moist, hard, reddish gray, Silty CLAY, little fine to coarse sand.
SS	S-6	0.45/0.3		41	15 11 30			Moist, dense, dark reddish gray, Silty CLAY, some fine to medium sand, trace fine gravel.
			8					
SS	S-7	0.29/0.27		>50	14 50/14			Moist, hard, gray, Silty CLAY, some fine to medium sand.
								Boring was terminated at 9.29 m-bgs.
			-2.5 / 10					
			12					
			14					
			-7.5					

BOREHOLE LOG
B-9

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Drillers: Tom/Alex
Drilling Date: Start: 17-11-17 **End:** 17-11-17
Borehole Coordinates:
See Boring Location Plan
Surface Elevation (m): 5.9
Total Depth (m): 9.45
Depth to Initial Water Level (m-bgs): NR
Abandonment Method: Backfilled with cuttings
Field Screening Instrument: PP
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			5.9 / 0					
AS	AS-1	1/0		AUGER	N/A			
SS	S-1	0.45/0		3	WOH 1 2		CL	Moist, soft, black, Silty CLAY, little fine to coarse sand, trace fine gravel. **-ALLUVIAL SOILS-**
SS	S-2	0.45/0.24	2	12	2 3 9			Moist, stiff, brown, CLAY and SILT, little fine to coarse sand. (PP = 96 kPa) **-ELLIOTT FORMATION-**
SS	S-3	0.45/0.39		51	17 21 30			Moist, hard, light gray, Silty CLAY, some fine to coarse sand. (PP = 431 kPa)
			4				CL	
SS	S-4	0.45/0.34	0.9	60	10 30 30			Moist, hard, reddish brown, Silty CLAY, trace fine to coarse sand.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

BOREHOLE LOG
B-9

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-5	0.45/0.45	6	8	4 4 4		SC	Wet, loose, light brown, fine to coarse SAND, some clay and silt.
SS	S-6	0.45/0.45		4	2 2 2		SC	Wet, very loose to loose, light yellowish brown, fine to medium SAND and CLAY.
			8					
SS	S-7	0.45/0.45		9	2 3 6		CL	Wet, stiff, dark reddish gray, CLAY and fine SAND. (PP = 96 kPa)
			-4.1 / 10					Boring terminated at 9.45 m-bgs.
			12					
			14					
			-9.1					

CDM Smith

BOREHOLE LOG
B-10

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 6.0
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 19.95
Drillers: Tom/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: Start: 17-11-17 **End:** 17-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
Field Screening Instrument: PP
See Boring Location Plan
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			6.0 0					
AS	AS-1	1/0		AUGER	N/A		FILL	
SS	S-1	0.45/0.1		7	2 3 4		FILL	Moist, medium stiff, brown, CLAY and SILT, little fine to medium sand. **-FILL-**
SS	S-2	0.45/0.3	2	8	2 3 5		FILL	Moist, medium stiff to stiff, dark grayish brown, CLAY, trace fine sand. (PP = 168 kPa)
ST	U-1	0.5/0.35		TUBE	PUSH		CL	Moist, dark gray, Silty CLAY, trace fine sand. **-ALLUVIAL SOILS-**
			4				CL	
SS	S-3	0.45/0.45	1.0	4	WOH 1 3		CL	Moist, very soft to soft, light gray, Organic CLAY, trace fine to coarse sand. -Little peat (PP = 86 kPa)

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
- HSA - Hollow Stem Auger
- SSA - Solid Stem Auger
- HA - Hand Auger
- AR - Air Rotary
- DTR - Dual Tube Rotary
- FR - Foam Rotary
- MR - Mud Rotary
- RC - Reverse Circulation
- CT - Cable Tool
- JET - Jetting
- D - Driving
- DTC - Drill Through Casing

SAMPLING TYPES:
- AS - Auger/Grab Sample
- CS - California Sampler
- BX - 1.5" Rock Core
- NX - 2.1" Rock Core
- GP - Geoprobe
- HP - Hydro Punch
- SS - Split Spoon
- ST - Shelby Tube
- WS - Wash Sample

OTHER:
- AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

BOREHOLE LOG
B-10

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-4	0.45/0.45	6	1	WOR WOH 1		CL	Wet, very soft, dark gray, Organic CLAY, trace fine to coarse sand. -Little peat (PP = 24 kPa)
SS	S-5	0.45/0.34		9	4 3 6		SC	Wet, loose, gray, fine to coarse SAND, some clay and silt, some fine gravel. **-ELLIOTT FORMATION-**
			8					
SS	S-6	0.45/0.45		6	2 3 3			Wet, loose, light gray, fine to medium SAND, some clay and silt.
			-4.0 10					
SS	S-7	0.45/0.45		6	1 2 4		CL	Wet, medium stiff, light gray, CLAY and fine to medium SAND.
SS	S-8	0.45/0.14	12	8	2 4 4		SC	Wet, loose, light gray, fine to coarse SAND, some fine to coarse gravel, little clay and silt.
SS	S-9	0.45/0.45		8	4 5 3			Wet, loose, light gray, fine to coarse SAND, some clay and silt, little fine to coarse gravel.
			14 -9.0					
SS	S-10	0.45/0.16		14	2 5 9			Wet, medium dense, light gray, fine to coarse SAND, some fine to coarse gravel, little clay and silt.

CDM Smith

BOREHOLE LOG
B-10

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			16					
SS	S-11	0.45/0.4		12	4 7 5		SC	Wet, medium dense, light gray, fine to coarse SAND, some clay and silt, little fine gravel.
SS	S-12	0.45/0.1	18	13	4 6 7		CL	Wet, stiff, light gray, CLAY and fine to coarse SAND, trace fine gravel.
SS	S-13	0.45/0.06	-14.0 / 20	24	2 7 17		GC	Wet, medium dense, brown, fine GRAVEL, some fine to coarse sand, some clay and silt.
								Boring terminated at 19.95 m-bgs.
			22					
			24					
			-19.0					

CDM Smith

BOREHOLE LOG
B-11

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Drillers: Anthony/Alex
Drilling Date: Start: 20-11-17 **End:** 20-11-17
Borehole Coordinates:
See Boring Location Plan

Surface Elevation (m): 8.8
Total Depth (m): 9.45
Depth to Initial Water Level (m-bgs): NR
Abandonment Method: Backfilled with cuttings
Field Screening Instrument: N/A
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			8.8 0					
AS	AS-1	1/0		AUGER	N/A		CL	
SS	S-1	0.45/0.35		25	10 13 12		CL	Dry, very stiff, brown, CLAY and SILT, little fine to coarse sand. **-ELLIOTT FORMATION-**
SS	S-2	0.14/0.14	2	>50	50/14		CL	Dry, hard, light reddish gray, CLAY and SILT, little fine to coarse sand.
SS	S-3	0.05/0.02		>50	50/5		SC	Moist, very dense, grayish brown, fine SAND and Silty CLAY, trace fine gravel.
			4				SC	
SS	S-4	0.15/0.15		>50	50/15		CL	Moist, hard, light grayish brown, CLAY and fine to medium coarse SAND.
			3.8				CL	

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

CDM Smith

BOREHOLE LOG
B-11

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-5	0.45/0.45	6	37	18 19 18		CL	Moist, hard, dark reddish gray, CLAY, some fine to medium sand.
SS	S-6	0.45/0.45		35	12 14 21		CL	Dry, hard, light grayish brown, CLAY, little fine to medium sand.
			8					
SS	S-7	0.05/0.05		>50	50/5		SC	Wet, very dense, gray, fine to coarse SAND, little fine gravel, little clay and silt.
								Boring terminated at 9.05 m-bgs.
			-1.2 / 10					
			12					
			14					
			-6.2					

BOREHOLE LOG
B-12

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 5.8
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 20.45
Drillers: Anthony/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: **Start:** 20-11-17 **End:** 20-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates: See Boring Location Plan
Field Screening Instrument: PP/TV
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			5.8 0					
AS	AS-1	1/0		AUGER	N/A		FILL	No Recovery.
SS	S-1	0.45/0.15		3	2 2 1		FILL	Boiler Ash and Charcoal. **-FILL-**
SS	S-2	0.45/0.21	2	7	2 3 4			Moist, medium stiff, dark brown, CLAY, trace fine sand.
SS	S-3	0.45/0.45		6	1 3 3			Wet, medium stiff, dark brown, CLAY, trace fine sand. (TV = 43 kPa)
SS	S-4	0.45/0.45	4	6	2 2 4			Wet, medium stiff, dark reddish brown, CLAY, trace fine to coarse sand. (PP = 144 kPa)
			0.8					
SS	S-5	0.45/0.45		3	WOH 1 2		CH	Wet, soft, grayish brown, CLAY, trace fine sand. (PP = 96 kPa) **-ALLUVIAL SOILS-**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm,
Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

CDM Smith

BOREHOLE LOG
B-12

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. / Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			6				CH	
SS	S-6	0.45/0.45		0	WOH WOH WOH			Wet, very soft, gray, Silty CLAY, trace fine to coarse sand. (PP = 57 kPa)
			8					
SS	S-7	0.45/0.45		0	WOH WOH WOH			Wet, very soft, dark gray, Organic CLAY, little fine to coarse sand. -Little peat (PP = 48 kPa)
			-4.2 / 10				SC	
SS	S-8	0.45/0.4		8	3 4 4			Wet, loose, gray, fine to coarse SAND, some clay and silt. **-ELLIOTT FORMATION-**
SS	S-9	0.45/0.35		11	5 4 7			Wet, medium dense, light grayish brown, fine to coarse Sand, some silty clay, some fine gravel.
			12					
SS	S-10	0.45/0.19		10	4 6 4		GP	Wet, loose to medium dense, light brown, fine GRAVEL and fine to coarse SAND, trace silt.
			14					
SS	S-11	0.45/0.2		5	2 2 3		SC	Wet, loose, light gray, fine to coarse SAND and CLAY, trace fine gravel.
			-9.2					

CDM Smith

BOREHOLE LOG
B-12

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. / Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
SS	S-12	0.45/0.45	16	5	2 2 3		SC	Wet, loose, light grayish brown, fine to coarse SAND, some clay and silt, trace fine gravel.
SS	S-13	0.45/0.4		18	3 9 9		SC	Wet, medium dense, reddish brown, medium to coarse SAND, some clay and silt, trace fine gravel.
			18					
SS	S-14	0.45/0.2		12	1 6 6		SC	Wet, medium dense, light brownish gray, fine to coarse SAND, little clay and silt, trace fine gravel.
			-14.2					
SS	S-15	0.45/0.4	20	25	4 9 16		CL	Wet, very stiff, light reddish gray, CLAY, trace medium to coarse sand.
								Boring terminated at 20.45 m-bgs.
			22					
			24					
			-19.2					

CDM Smith

BOREHOLE LOG
B-13

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Drillers: Anthony/Alex
Drilling Date: **Start:** 21-11-17 **End:** 21-11-17
Borehole Coordinates:
See Boring Location Plan

Surface Elevation (m): 6.3
Total Depth (m): 10.45
Depth to Initial Water Level (m-bgs): NR
Abandonment Method: Backfilled with sand
Field Screening Instrument: PP/TV
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			6.3 / 0					
AS	AS-1	1/0		AUGER	N/A		FILL	
AS	AS-2	1/0		AUGER	N/A		FILL	Metal scraps and boiler ash. **-FILL-**
SS	S-1	0.45/0.37	2	8	3 3 5			Wet, medium stiff to stiff, dark grayish brown, CLAY, trace fine to medium sand. (PP = 144 kPa)
SS	S-2	0.45/0.45		7	1 3 4			Wet, medium stiff, grayish brown, CLAY, trace fine sand. (TV = 38 kPa)
SS	S-3	0.45/0.45	4	6	3 3 3			Wet, medium stiff, grayish brown, CLAY, trace fine sand. (PP = 239 kPa)
			1.3					
SS	S-4	0.45/0.45		0	WOH WOH WOH		CH	Wet, very soft, brownish gray, Silty CLAY, trace fine to coarse sand. (PP = 38 kPa) **-ALLUVIAL SOILS-**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer Weight = 70 kg, Hammer Drop Height = 700 mm, Spoon Size = 50 mm OD and 450 mm Length.
WOH=Weight of Hammer, WOR=Weight of Rod
m-bgs = Meters Below Ground Surface
PP = Pocket Penetrometer
TV = Torvane
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand **Date:** 1-2-18

BOREHOLE LOG
B-13

Client: DILGP
Project Location: Bundaberg, QLD
Project Name: Bundaberg East Levee
Project Number: 121923-221532

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			6					
SS	S-5	0.45/0.45		3	WOH WOH 3		CH	Wet, soft, gray, Silty CLAY, trace fine sand. (PP = 96 kPa)
			8					
SS	S-6	0.45/0.45		13	11 8 5		SC	Wet, medium dense, grayish brown, fine to coarse SAND, some clay and silt. **-ELLIOTT FORMATION-**
			-3.7					
SS	S-7	0.45/0.05	10	6	2 2 4			Wet, loose, light brownish gray, medium to coarse SAND, some clay and silt, trace fine gravel.
			12					Boring terminated at 10.45 m-bgs.
			14					
			-8.7					

BOREHOLE BUNDABERG.GPJ CDM_CORP.GDT 2/1/18

CDM Smith

BOREHOLE LOG
B-14

Client: DILGP
Project Name: Bundaberg East Levee
Project Location: Bundaberg, QLD
Project Number: 121923-221532

Drilling Contractor: GeoDrill Australia
Surface Elevation (m): 4.0
Drilling Method/Rig: 7.6 cm Mud Rotary/Hydrapower
Total Depth (m): 2.5
Drillers: Tom/Alex
Depth to Initial Water Level (m-bgs): NR
Drilling Date: Start: 21-11-17 **End:** 21-11-17
Abandonment Method: Backfilled with cuttings
Borehole Coordinates:
Field Screening Instrument: N/A
See Boring Location Plan
Logged By: J. Connor

Sample Type	Sample Number	Sample Adv/Rec (m)	Elev. Depth (m)	N-Value	Blows per 15cm	Graphic Log	USCS Designation	Material Description
			4.0 0				FILL	Asphalt and base course **-FILL** Dry, brown, Silty CLAY, some fine to coarse gravel, little fine to coarse sand. Glass, ceramics, fabric and wire -Miscellaneous debris
			2				CH	Wet, dark gray, CLAY, trace fine to coarse sand. **-ALLUVIAL SOILS-**
			4 -1.0					Boring terminated at 2.5 m-bgs.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

m-bgs = Meters Below Ground Surface
NR = Not Recorded, N/A = Not Applicable

Reviewed by: J. Briand
Date: 1-2-18

Appendix B

Geotechnical Laboratory Test Results

Appendix B-1

CM Testing

Geotechnical Laboratory Test Results

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062

PO Box 5421 West Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405

2 Turner St Bundaberg Qld 4670
Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129977
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 21/11/17 BY CLIENT

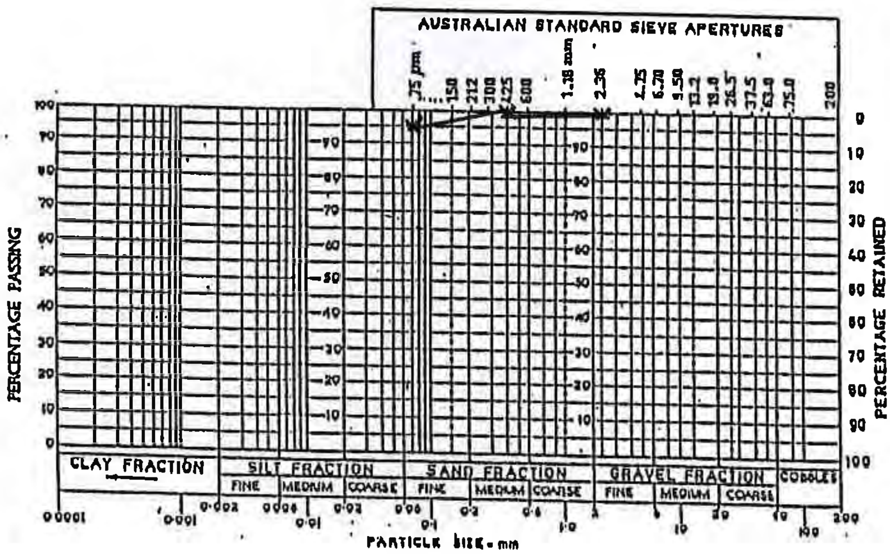
MATERIAL: LIGHT REDDISH BROWN CLAY (TRACE FINE/COARSE SAND) **SAMPLE NO.:** 31830

SOURCE: HOLE B-2 (S-12) - 20.5-20.95m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	100
0.300	
0.150	
0.075	95
0.0135	



OTHER TESTS:

LIQUID LIMIT	81%	AS1289.3.1.2
PLASTIC LIMIT	24%	AS1289.3.2.1
PLASTICITY INDEX	57%	AS1289.3.3.1
LINEAR SHRINKAGE	13.0%	AS1289.3.4.1
FIELD MOISTURE	22.1%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 150.0mm length.
Grading: entire sample washed over 75μm sieve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062
PO Box 5421 West Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405
2 Turner St Bundaberg Qld 4670
Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD

CERTIFICATE NUMBER: C129978

PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS

JOB NUMBER: BC13130

DATE ISSUED: 09/01/18

DATE SAMPLED: 14/11/17 BY CLIENT

MATERIAL: LIGHT GREY CLAY

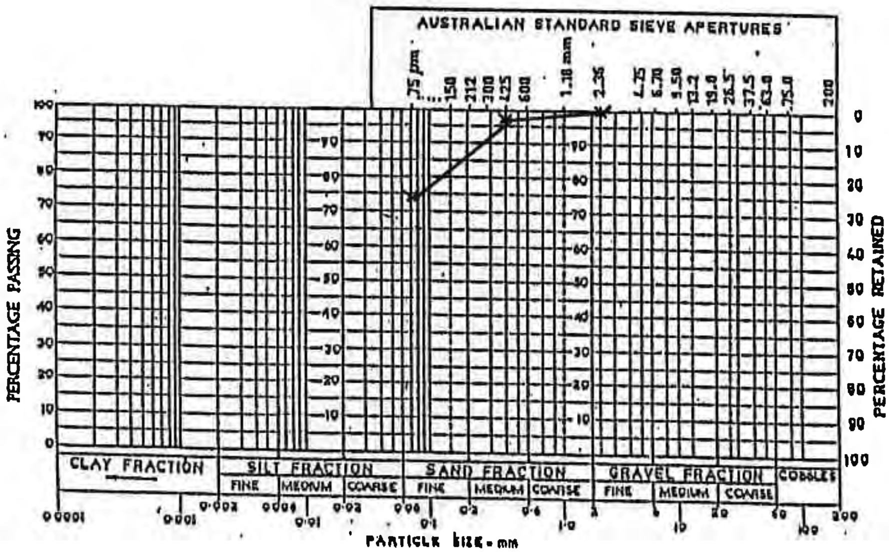
SAMPLE NO.: 31831

SOURCE: HOLE B-3 (S-14) - 24.0-24.45m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	98
0.300	
0.150	
0.075	74
0.0135	



OTHER TESTS:

LIQUID LIMIT	49%	AS1289.3.1.2
PLASTIC LIMIT	15%	AS1289.3.2.1
PLASTICITY INDEX	34%	AS1289.3.3.1
LINEAR SHRINKAGE	9.5%	AS1289.3.4.1
FIELD MOISTURE	13.4%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 150.0mm length.
Grading: entire sample washed over 75µm sieve.
Moisture content determined using AS 1289 2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062

PO Box 5421 West Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405

2 Turner St Bundaberg Qld 4670
Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD

CERTIFICATE NUMBER: C129979

PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS

JOB NUMBER: BC13130

DATE ISSUED: 09/01/18

DATE SAMPLED: 15/11/17 BY CLIENT

MATERIAL: DARK GREY CLAY

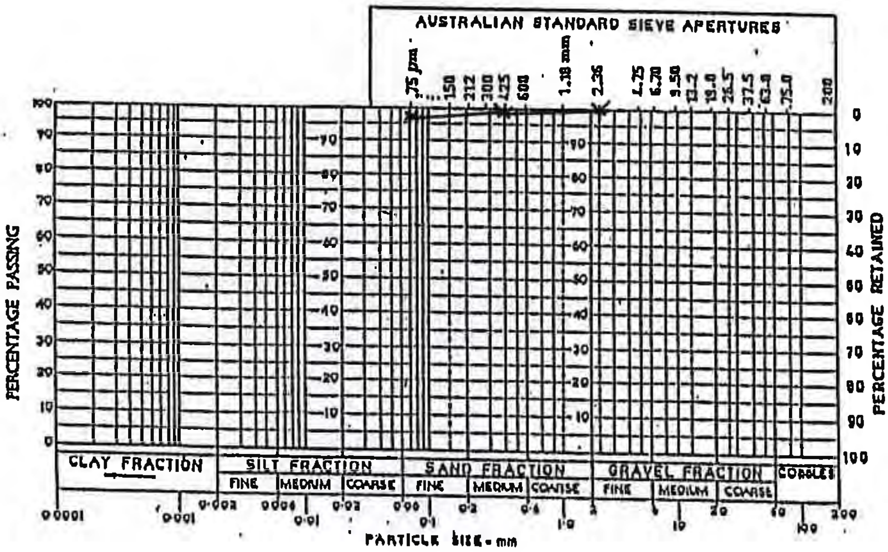
SAMPLE NO.: 31832

SOURCE: HOLE B-4 (U-1) - 2.0-2.5m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	99
0.300	
0.150	
0.075	97
0.0135	



OTHER TESTS:

LIQUID LIMIT	44%	AS1289.3.1.2
PLASTIC LIMIT	20%	AS1289.3.2.1
PLASTICITY INDEX	24%	AS1289.3.3.1
LINEAR SHRINKAGE	11.0%	AS1289.3.4.1
FIELD MOISTURE	29.8%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 125.0mm length.
Grading: entire sample washed over 75µm sieve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

AD13-01/05

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062

PO Box 5421 West Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405

2 Turner St Bundaberg Qld 4670
Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129980
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 15/11/17 BY CLIENT

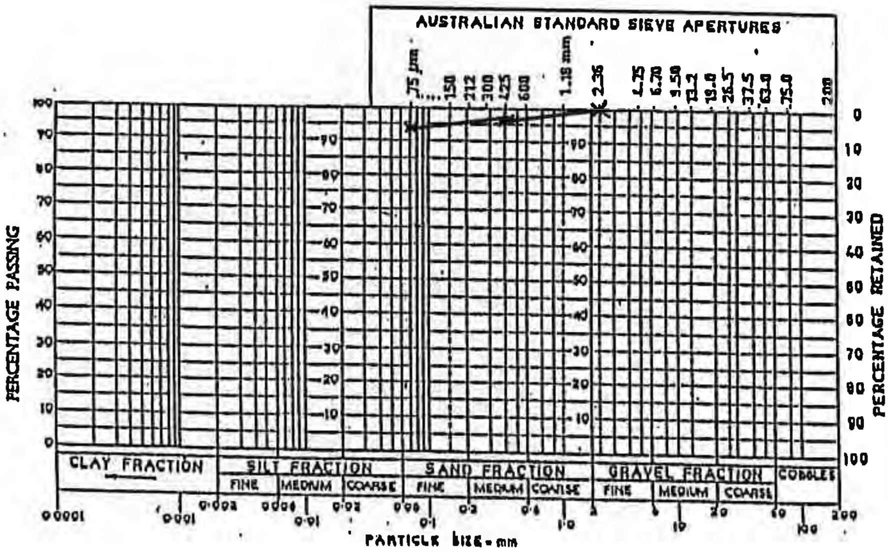
MATERIAL: DARK GREY CLAY (ORGANICS) **SAMPLE NO.:** 31833

SOURCE: HOLE B-5 (S-4) - 4.5-4.95m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	96
0.300	
0.150	
0.075	94
0.0135	



OTHER TESTS:

LIQUID LIMIT	51%	AS1289.3.1.2
PLASTIC LIMIT	20%	AS1289.3.2.1
PLASTICITY INDEX	31%	AS1289.3.3.1
LINEAR SHRINKAGE	13.0%	AS1289.3.4.1
FIELD MOISTURE	62.0%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 125.0mm length.
Grading: entire sample washed over 75μm sieve.
Moisture content determined using AS 1289 2.1.1
If Sampled by CMTS it is in accordance with AS1289 1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062

PO Box 5421 West Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405

2 Turner St Bundaberg Qld 4670
Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

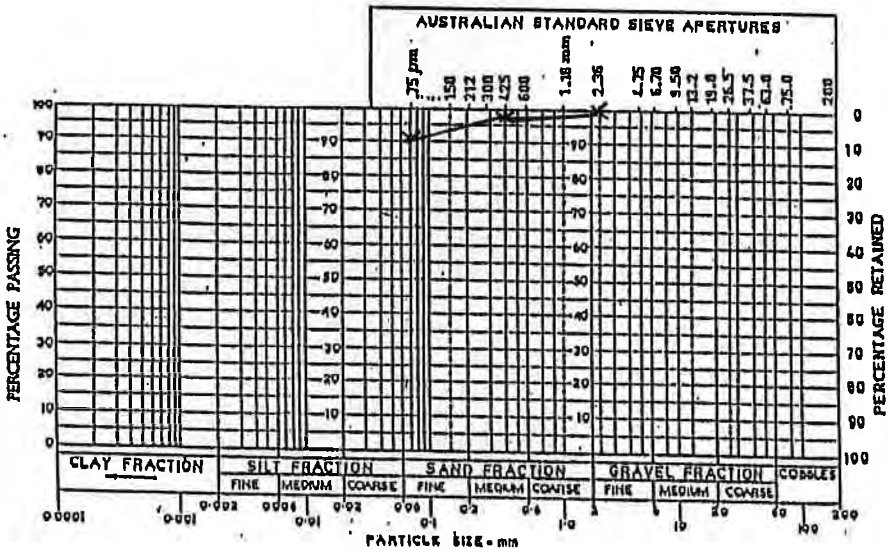
CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129981
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 16/11/17 BY CLIENT

MATERIAL: DARK GREYISH BROWN CLAY **SAMPLE NO.:** 31834

SOURCE: HOLE B-6 (S-7) - 9.0-9.45m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	98
0.300	
0.150	
0.075	91
0.0135	



OTHER TESTS:

LIQUID LIMIT	63%	AS1289.3.1.2
PLASTIC LIMIT	21%	AS1289.3.2.1
PLASTICITY INDEX	42%	AS1289.3.3.1
LINEAR SHRINKAGE	17.5%	AS1289.3.4.1
FIELD MOISTURE	30.2%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 125.0mm length.
Grading: entire sample washed over 75µm sieve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

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Authorised Signatory: Mark Rohdmann

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Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

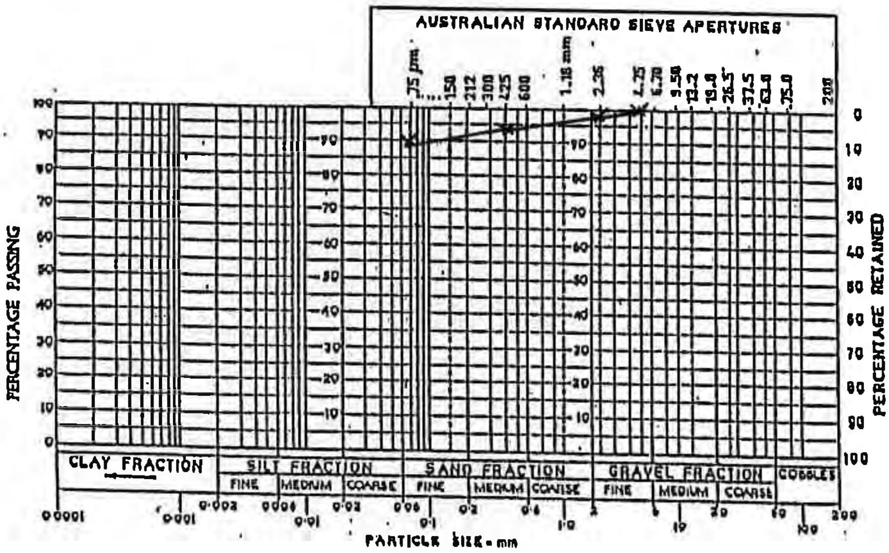
CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129982
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 16/11/17 BY CLIENT

MATERIAL: GREYISH BROWN CLAY **SAMPLE NO.:** 31835

SOURCE: HOLE B-7 (S-4) - 4.5-4.95m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	100
2.36	98
1.18	
0.600	
0.425	94
0.300	
0.150	
0.075	90
0.0135	



OTHER TESTS:

LIQUID LIMIT	46%	AS1289.3.1.2
PLASTIC LIMIT	18%	AS1289.3.2.1
PLASTICITY INDEX	28%	AS1289.3.3.1
LINEAR SHRINKAGE	13.0%	AS1289.3.4.1
FIELD MOISTURE	32.6%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 127.0mm length.
Grading: entire sample washed over 75μm sieve.
Moisture content determined using AS 1289 2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129983
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 17/11/17 BY CLIENT

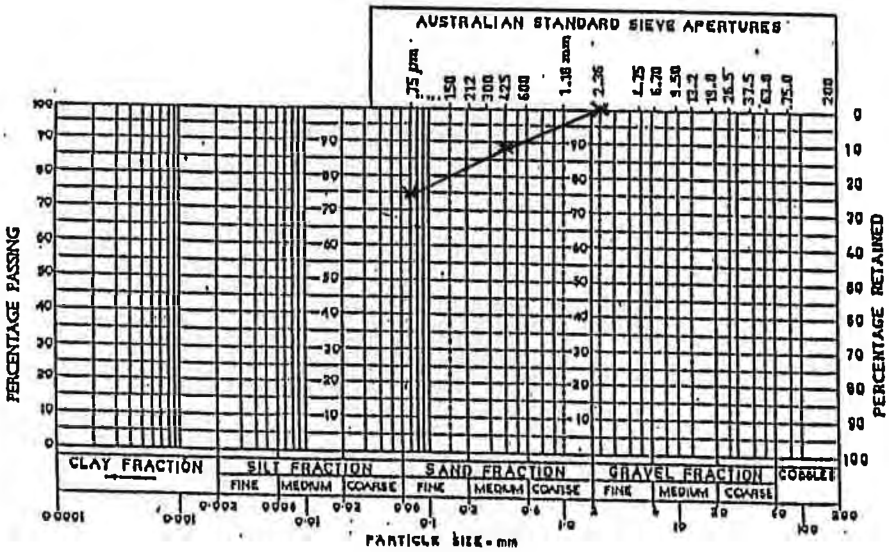
MATERIAL: LIGHT GREY SILTY CLAY **SAMPLE NO.:** 31836

SOURCE: HOLE B-9 (S-3) - 3.0-3.45m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	88
0.300	
0.150	
0.075	75
0.0135	



OTHER TESTS:

LIQUID LIMIT	45%	AS1289.3.1.2
PLASTIC LIMIT	22%	AS1289.3.2.1
PLASTICITY INDEX	23%	AS1289.3.3.1
LINEAR SHRINKAGE	9.0%	AS1289.3.4.1
FIELD MOISTURE	21.0%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 127.0mm length.
Grading: entire sample washed over 75µm sleve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS It Is In accordance with AS1289.1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062 Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

AD13-01/05

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129984
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 20/11/17 BY CLIENT

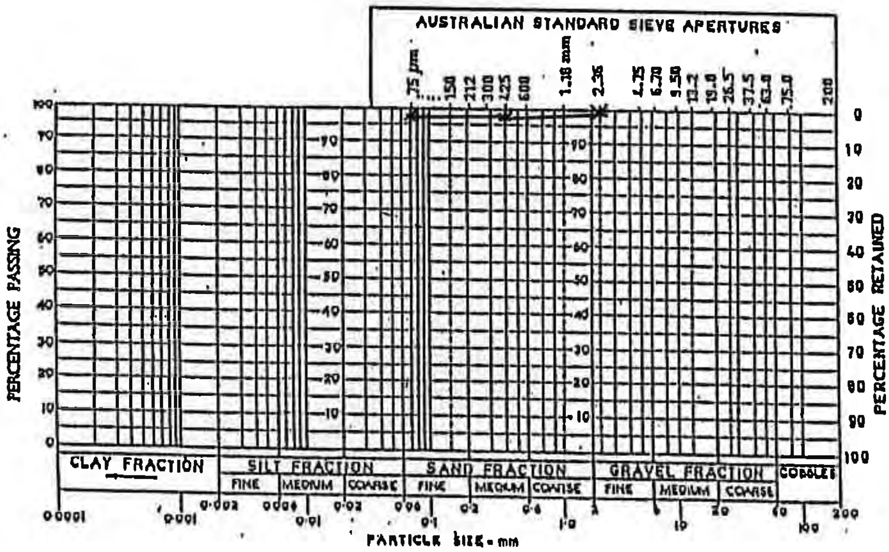
MATERIAL: GREY CLAY **SAMPLE NO.:** 31837

SOURCE: HOLE B-12 (S-6) - 7.0-7.45m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	98
0.300	
0.150	
0.075	97
0.0135	



OTHER TESTS:

LIQUID LIMIT	59%	AS1289.3.1.2
PLASTIC LIMIT	21%	AS1289.3.2.1
PLASTICITY INDEX	38%	AS1289.3.3.1
LINEAR SHRINKAGE	15.0%	AS1289.3.4.1
FIELD MOISTURE	57.0%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 150.0mm length.
Grading: entire sample washed over 75μm sieve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

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Authorised Signatory: Mark Rohdmann

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD

CERTIFICATE NUMBER: C129985

PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS

JOB NUMBER: BC13130

DATE ISSUED: 09/01/18

DATE SAMPLED: 20/11/17 BY CLIENT

MATERIAL: LIGHT GREYISH BROWN CLAY

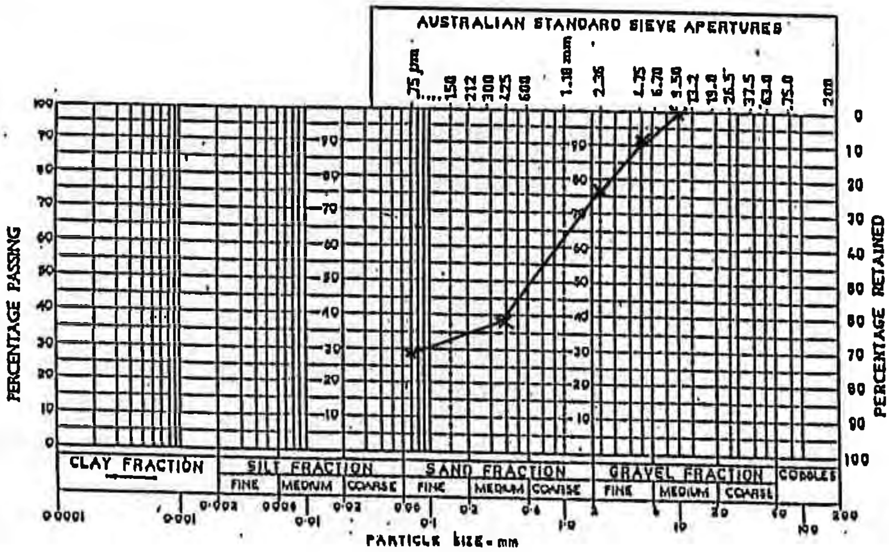
SAMPLE NO.: 31838

SOURCE: HOLE B-12 (S-9) - 11.5-11.95m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	100
6.7	
4.75	92
2.36	77
1.18	
0.600	
0.425	37
0.300	
0.150	
0.075	29
0.0135	



OTHER TESTS:

LIQUID LIMIT	41%	AS1289.3.1.2
PLASTIC LIMIT	17%	AS1289.3.2.1
PLASTICITY INDEX	24%	AS1289.3.3.1
LINEAR SHRINKAGE	9.0%	AS1289.3.4.1
FIELD MOISTURE	18.8%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 150.0mm length.
Grading: entire sample washed over 75µm sieve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

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Authorised Signatory: Mark Rohdmann

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MATERIAL PROPERTIES CERTIFICATE

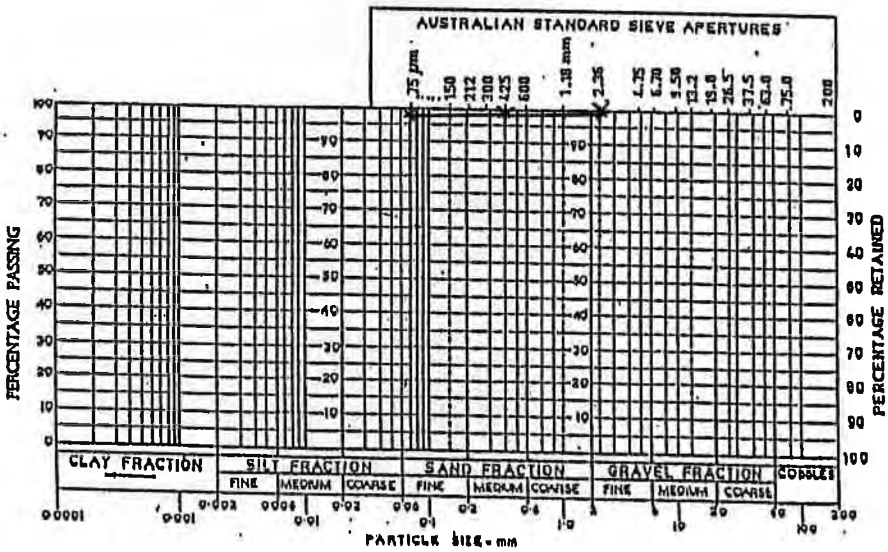
CLIENT: CDM SMITH AUSTRALIA PTY LTD	**CERTIFICATE NUMBER:** C129986
PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS	**JOB NUMBER:** BC13130
DATE ISSUED: 09/01/18	**DATE SAMPLED:** 21/11/17 BY CLIENT

MATERIAL: BROWNISH GREY CLAY **SAMPLE NO.:** 31839

SOURCE: HOLE B-13 (S-4) - 5.5-5.95m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	99
0.300	
0.150	
0.075	98
0.0135	



OTHER TESTS:

LIQUID LIMIT	60%	AS1289.3.1.2
PLASTIC LIMIT	22%	AS1289.3.2.1
PLASTICITY INDEX	38%	AS1289.3.3.1
LINEAR SHRINKAGE	14.0%	AS1289.3.4.1
FIELD MOISTURE	41.6%	AS1289.2.1.1

Samples 50°C oven dried and prepared dry unless otherwise stated.
Shrinkage mould 150.0mm length.
Grading: entire sample washed over 75µm sieve.
Moisture content determined using AS 1289.2.1.1
If Sampled by CMTS it is in accordance with AS1289.1.2.1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062

PO Box 5421 West Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405

2 Turner St Bundaberg Qld 4670
Email: mark@cmtesting.com.au

EMERSON CLASS DISPERSION CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD

CERTIFICATE NUMBER: C129987

PROJECT: BUNDABERG EAST FLOOD LEVEE INVESTIGATIONS

JOB NUMBER: BC13130

DATE ISSUED: 09/01/18

DATE SAMPLED: 15/11/17,20/11/17,21/11/17

SAMPLED BY: CLIENT

TEST METHOD: AS1289.3.8.1

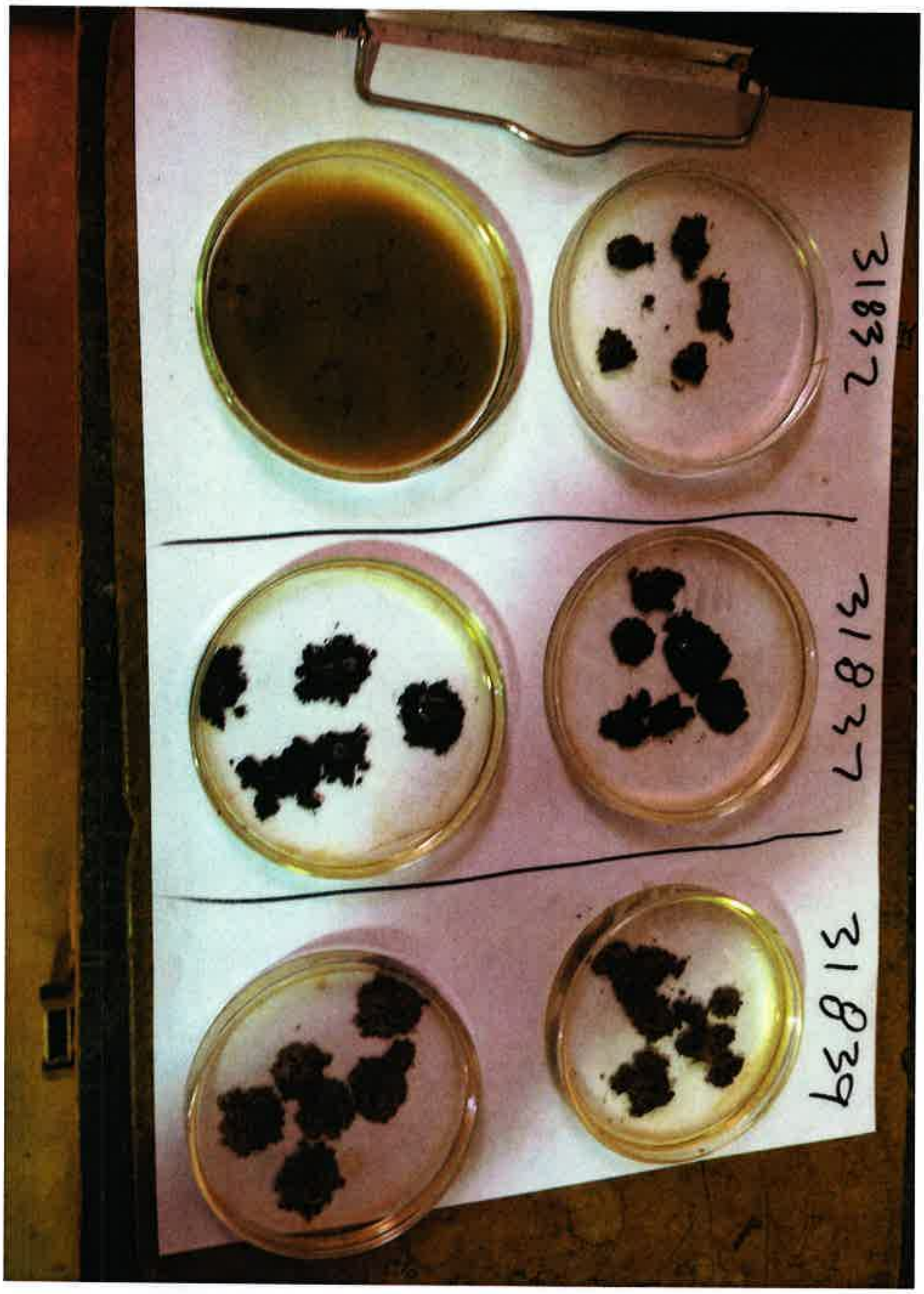
HOLE NO.	SAMPLE NO.	SOURCE	SOIL DESCRIPTION	EMERSON CLASS
Hole B-4 (U-1)	31832	2.0-2.5m	DARK GREY CLAY	3
Hole B-12 (S-6)	31837	7.0-7.45m	GREY CLAY	6
Hole B-13 (S-4)	31839	5.5-5.95m	BROWNISH GREY CLAY	5

DEMINERALISED WATER AT 24^{0}C USED IN TEST

Authorised Signatory: Mark Rohdmann

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing


31832
31827
31839

Appendix B-2

ALS Environmental

Geotechnical Laboratory Test Results

CERTIFICATE OF ANALYSIS

Work Order	: **EB1801660**	Page	: 1 of 2
Client	: **TRILAB PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR CHRIS CHANNON	Contact	: Customer Services EB
Address	: 346A BILSEN RD GEEBUNG QLD, AUSTRALIA 4031	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3265 5656	Telephone	: +61-7-3243 7222
Project	: BC-13130	Date Samples Received	: 10-Jan-2018 10:50
Order number	: BNE 1801007	Date Analysis Commenced	: 16-Jan-2018
C-O-C number	: ----	Issue Date	: 17-Jan-2018 13:42
Sampler	: ----		
Site	: ----		
Quote number	: EN/333/17		
No. of samples received	: 3		
No. of samples analysed	: 3		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	18010049 / S-8-B-5 / 10.00-10.45m	18010053 / S-4-B-1 / 4.00-4.45m	18010054 / S-3-B2 / 5.50-5.95m	----	----
			Client sampling date / time	[10-Jan-2018]	[10-Jan-2018]	[10-Jan-2018]	----	----
Compound	CAS Number	LOR	Unit	EB1801660-001	EB1801660-002	EB1801660-003	--------	--------
				Result	Result	Result	----	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**8.80**	**0.11**	**1.75**	----	----

Appendix B-3

Trilab

Geotechnical Laboratory Test Results

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010048-G
		Workorder No.	3654
Address	PO Box 5421 BUNDABERG QLD 4670	**Report Date**	19/01/2018
Project	BC-13130		

Sample No.	18010048	18010049	18010052	18010053	18010054	18010056	18010057
Test Date	15/01/2018	15/01/2018	15/01/2018	15/01/2018	15/01/2018	15/01/2018	15/01/2018
Client ID	U-2 - B-4	S-8 - B-5	U-1 - B-10	S-4 - B-1	S-3 - B-2	U-1 - B-3	U-2 - B-3
Depth (m)	7.50-8.00	10.00-10.45	3.00-3.50	4.00-4.45	5.50-5.95	2.50-3.00	7.50-8.00
Moisture (%)	63.2	97.1	28.7	20.0	49.3	23.0	49.8
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75							
2.36		100					
1.18	100	99		100			
0.600	99	96		99	100		
0.425	98	94	100	95	99		
0.300	98	91	99	91	99	100	100
0.150	96	84	91	83	98	99	99
0.075	92	79	86	78	95	90	98

NOTES/REMARKS:

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Park

NATA
TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

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346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010058-G
		Workorder No.	3654
Address	PO Box 5421 BUNDABERG QLD 4670	**Report Date**	19/01/2018
Project	BC-13130		

Sample No.	18010058						
Test Date	15/01/2018						
Client ID	U-3 - B-3						
Depth (m)	15.00-15.50						
Moisture (%)	74.8						
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75							
2.36							
1.18							
0.600							
0.425							
0.300	100						
0.150	99						
0.075	98						

NOTES/REMARKS:

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Park

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

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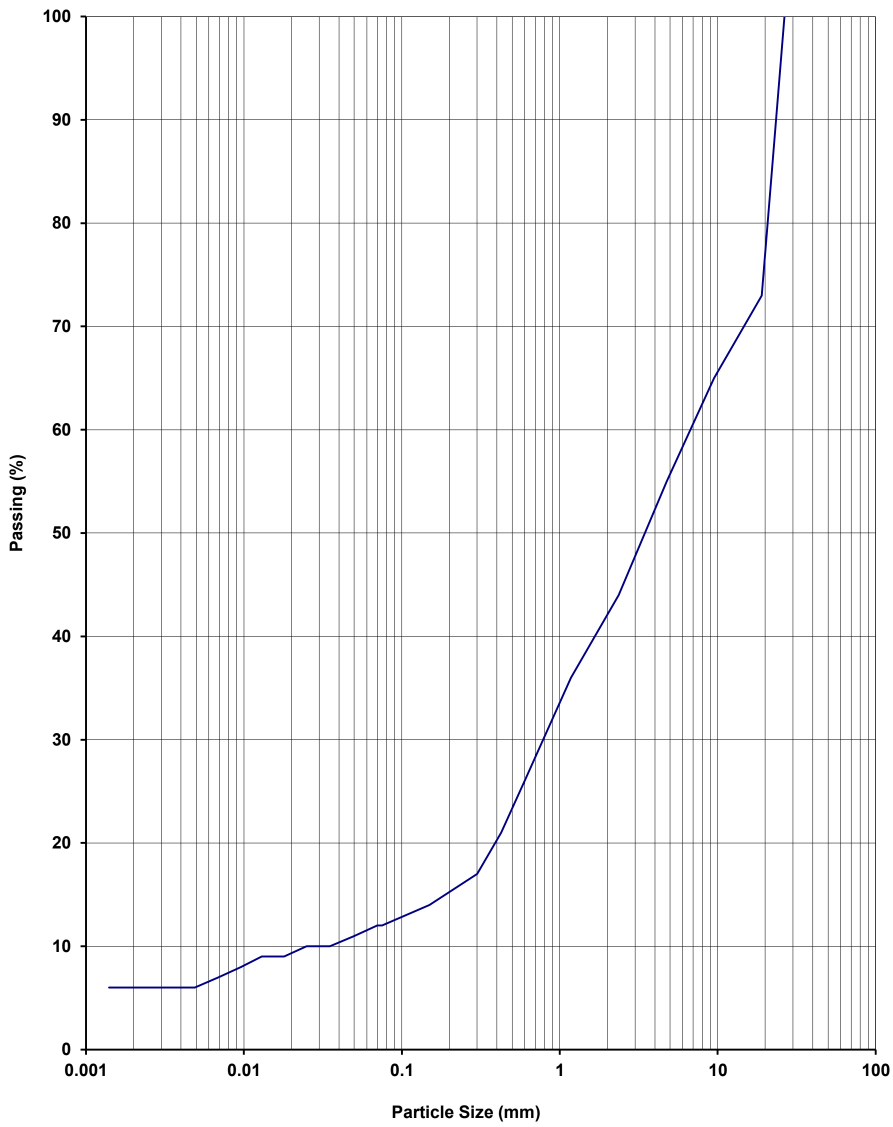
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010055-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-9 - B-2	**Depth (m)**	14.50-14.95

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	100
19.0	73
13.2	69
9.5	65
6.7	60
4.75	55
2.36	44
1.18	36
0.600	26
0.425	21
0.300	17
0.150	14
0.075	12
0.07	12
0.05	11
0.035	10
0.025	10
0.018	9
0.013	9
0.0096	8
0.0069	7
0.0049	6
0.004	6
0.0035	6
0.0028	6
0.0025	6
0.0014	6



NOTES/REMARKS: -

Moisture Content 10.4% -2.36mm Soil Particle Density(t/m^3) 2.62

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Park

NATA TECHNICAL COMPETENCE

Laboratory No. 9926

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Soil Rock Calibration

Brisbane
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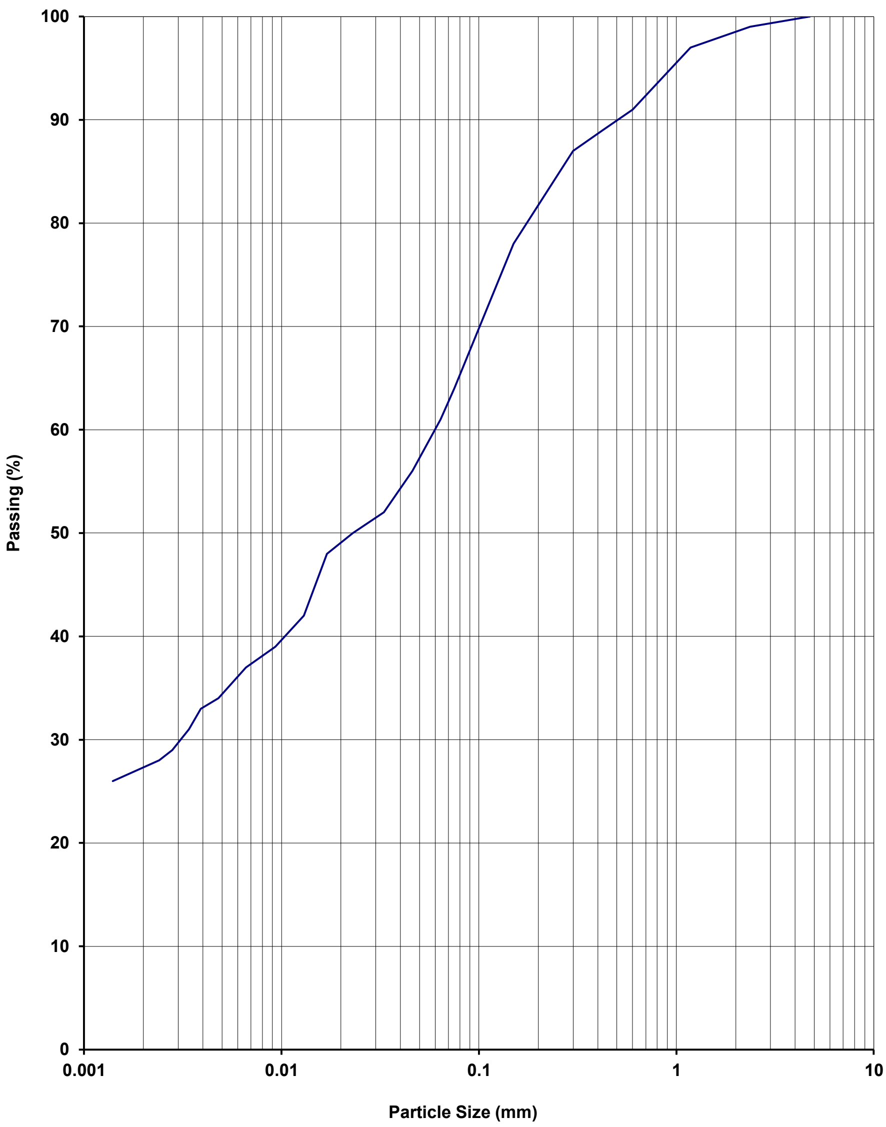
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010047-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-11 - B-3	**Depth (m)**	19.50-19.95

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	100
2.36	99
1.18	97
0.600	91
0.425	89
0.300	87
0.150	78
0.075	64
0.064	61
0.046	56
0.033	52
0.023	50
0.017	48
0.013	42
0.0093	39
0.0066	37
0.0048	34
0.0039	33
0.0034	31
0.0028	29
0.0024	28
0.0014	26



NOTES/REMARKS: -

Moisture Content 27.9% -2.36mm Soil Particle Density(t/m^3) 2.56

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Park

NATA
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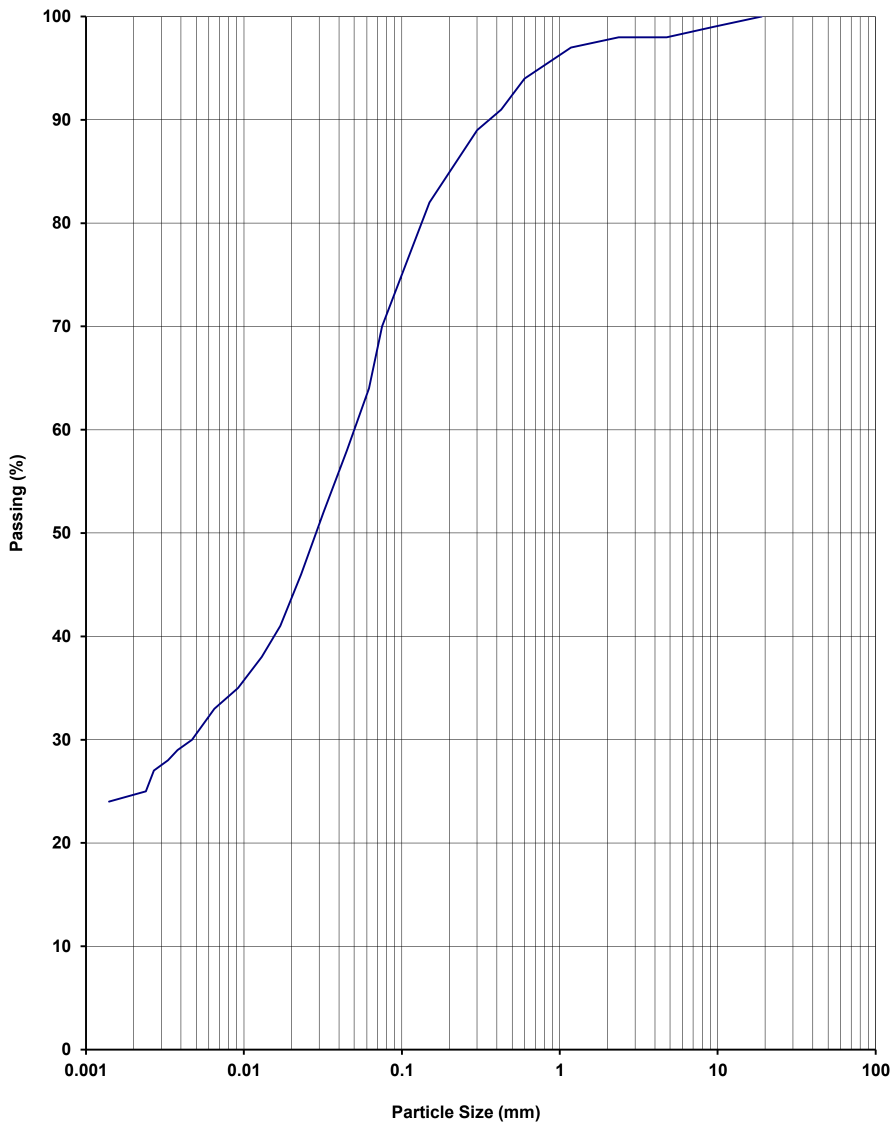
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010050-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	17/1/18-22/1/18
		Report Date	22/1/2018
Project	BC-13130		
Client ID	S-1 - B-8	**Depth (m)**	1.00-1.45

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	99
9.5	99
6.7	99
4.75	98
2.36	98
1.18	97
0.600	94
0.425	91
0.300	89
0.150	82
0.075	70
0.062	64
0.045	58
0.032	52
0.023	46
0.017	41
0.013	38
0.0092	35
0.0065	33
0.0047	30
0.0038	29
0.0033	28
0.0027	27
0.0024	25
0.0014	24



NOTES/REMARKS: -

Moisture Content 14.1% -2.36mm Soil Particle Density(t/m^3) 2.58

Sample/s supplied by the client

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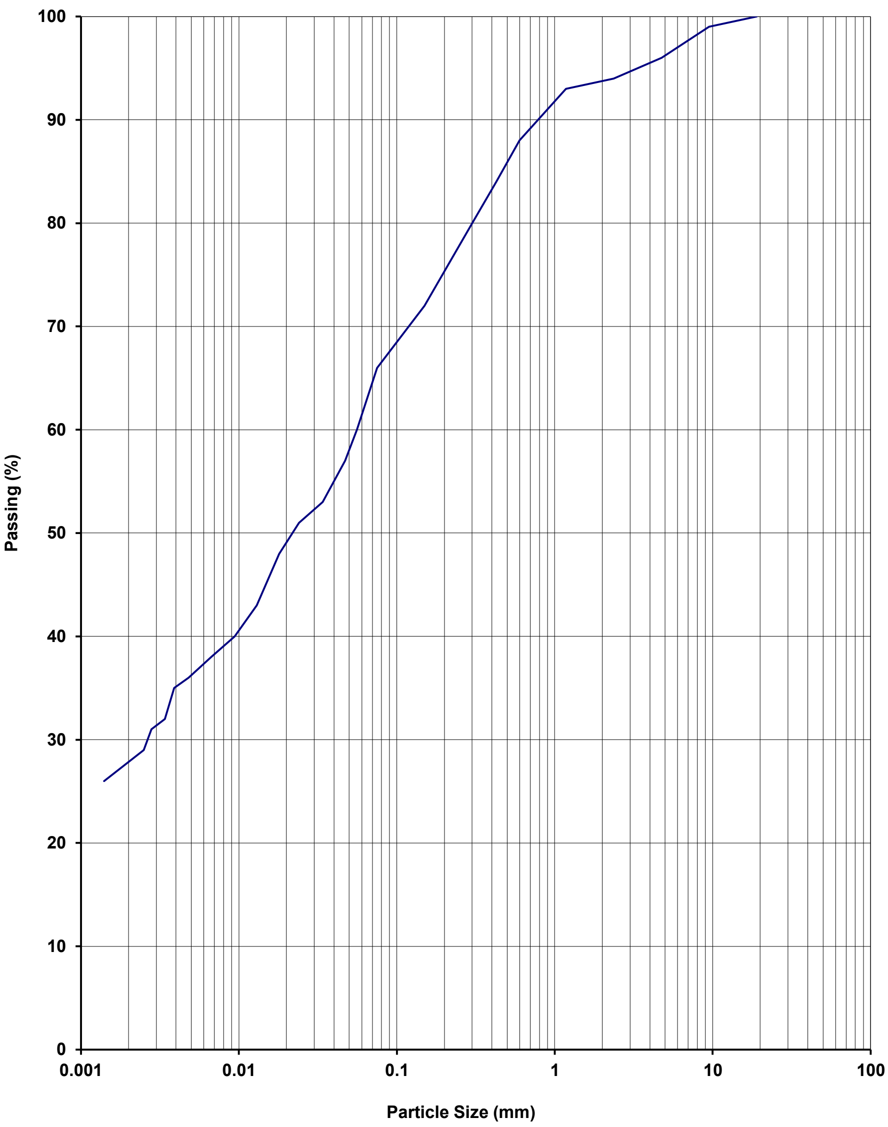
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010051-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-6 - B-8	**Depth (m)**	7.50-7.95

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	99
9.5	99
6.7	96
4.75	96
2.36	94
1.18	93
0.600	88
0.425	84
0.300	80
0.150	72
0.075	66
0.056	60
0.047	57
0.034	53
0.024	51
0.018	48
0.013	43
0.0094	40
0.0067	38
0.0048	36
0.0039	35
0.0034	32
0.0028	31
0.0025	29
0.0014	26



NOTES/REMARKS: -

Moisture Content 22.4% -2.36mm Soil Particle Density(t/m^3) 2.51

Sample/s supplied by the client

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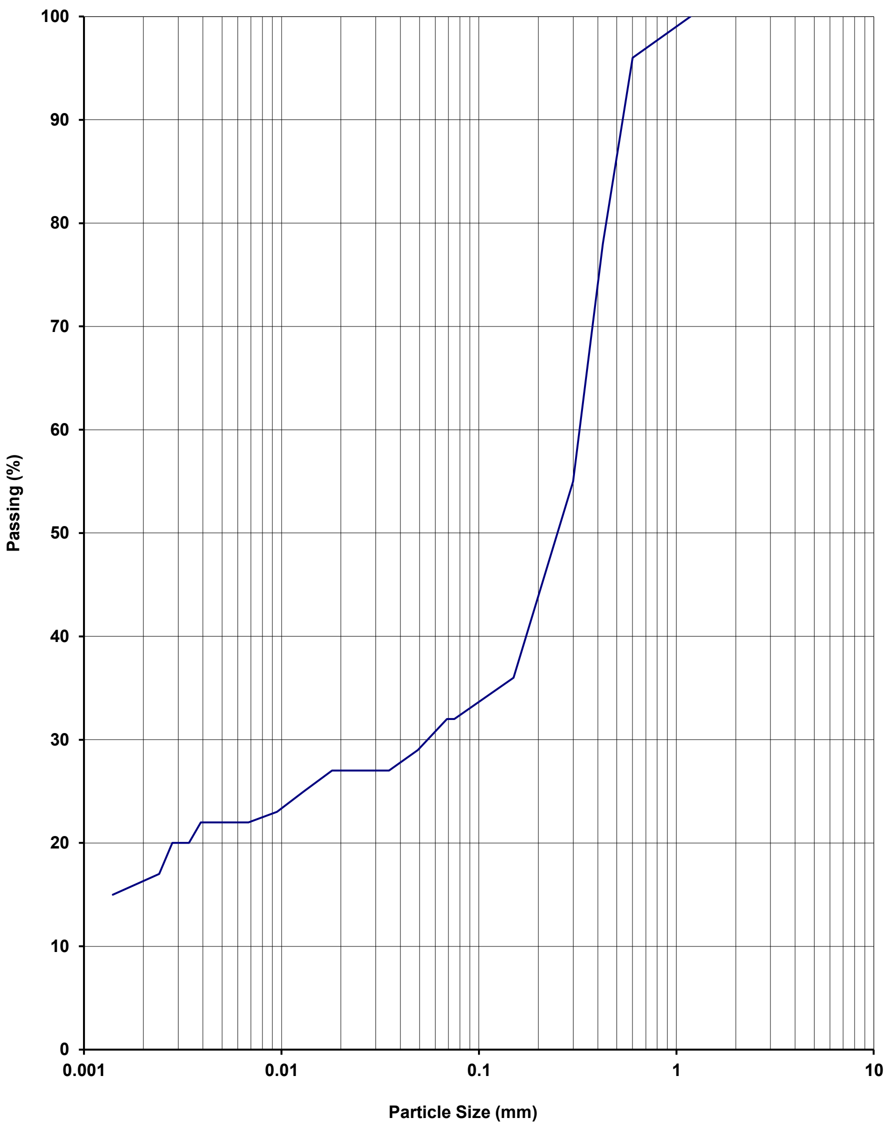
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010059-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-6 - B-10	**Depth (m)**	9.00-9.45

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	100
0.600	96
0.425	78
0.300	55
0.150	36
0.075	32
0.069	32
0.049	29
0.035	27
0.025	27
0.018	27
0.013	25
0.0095	23
0.0068	22
0.0048	22
0.0039	22
0.0034	20
0.0028	20
0.0024	17
0.0014	15



NOTES/REMARKS: -

Moisture Content 22% -2.36mm Soil Particle Density(t/m^3) 2.60

Sample/s supplied by the client

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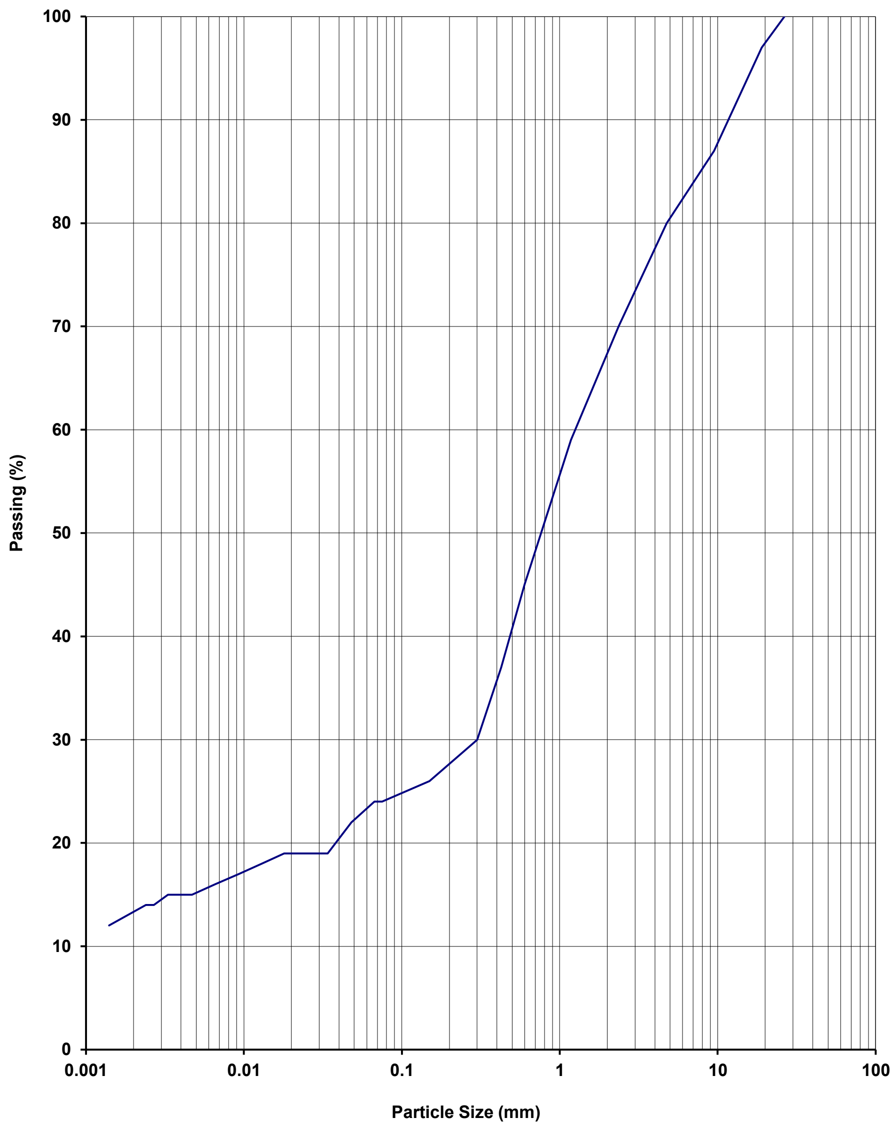
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010060-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-11 - B-10	**Depth (m)**	16.50-16.95

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	100
19.0	97
13.2	96
9.5	87
6.7	84
4.75	80
2.36	70
1.18	59
0.600	45
0.425	37
0.300	30
0.150	26
0.075	24
0.067	24
0.048	22
0.034	19
0.024	19
0.018	19
0.013	18
0.0093	17
0.0066	16
0.0047	15
0.0038	15
0.0033	15
0.0027	14
0.0024	14
0.0014	12



NOTES/REMARKS: -

Moisture Content 14.9% -2.36mm Soil Particle Density(t/m^3) 2.61

Sample/s supplied by the client

Page 1 of 1 REP03904

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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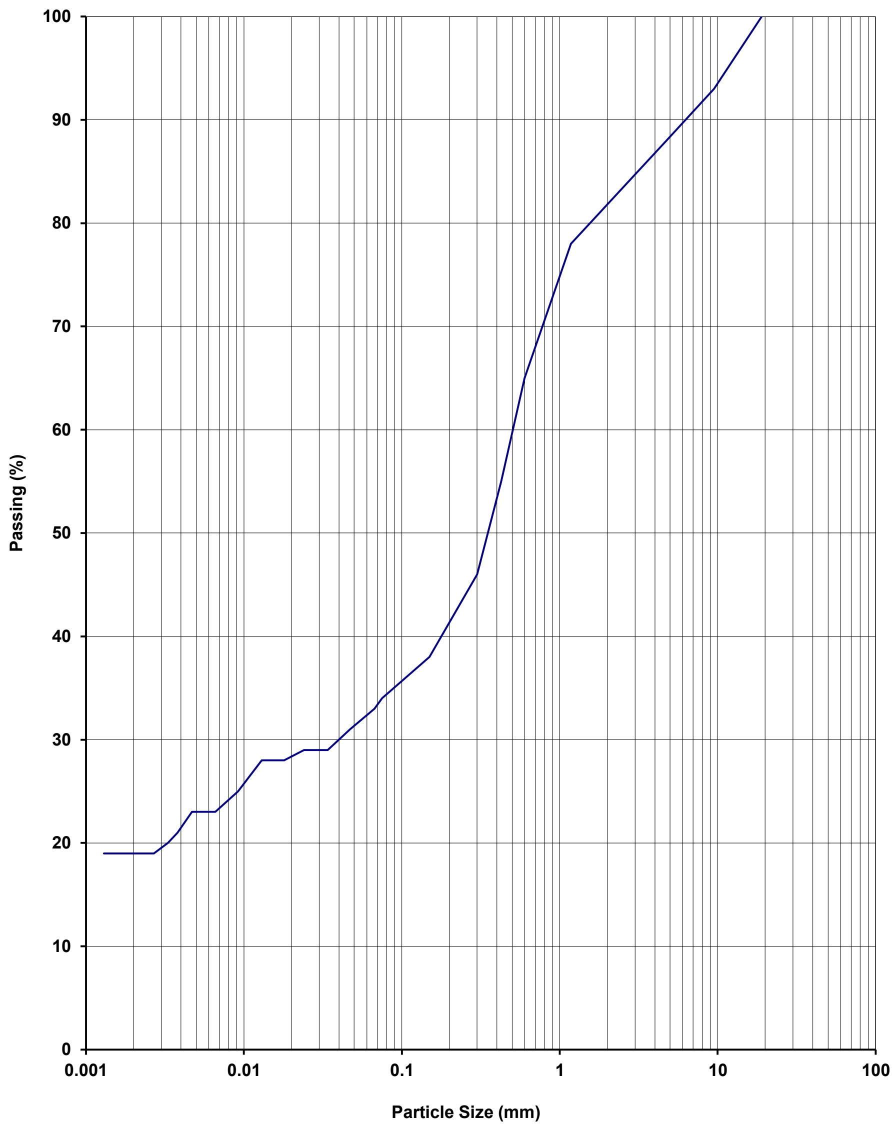
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010061-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-3 - B-11	**Depth (m)**	3.00-3.45

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	94
9.5	93
6.7	91
4.75	88
2.36	83
1.18	78
0.600	65
0.425	55
0.300	46
0.150	38
0.075	34
0.067	33
0.047	31
0.034	29
0.024	29
0.018	28
0.013	28
0.0092	25
0.0066	23
0.0047	23
0.0038	21
0.0033	20
0.0027	19
0.0024	19
0.0013	19



NOTES/REMARKS: -

Moisture Content 15%   -2.36mm Soil Particle Density(t/m^3) 2.67

Sample/s supplied by the client

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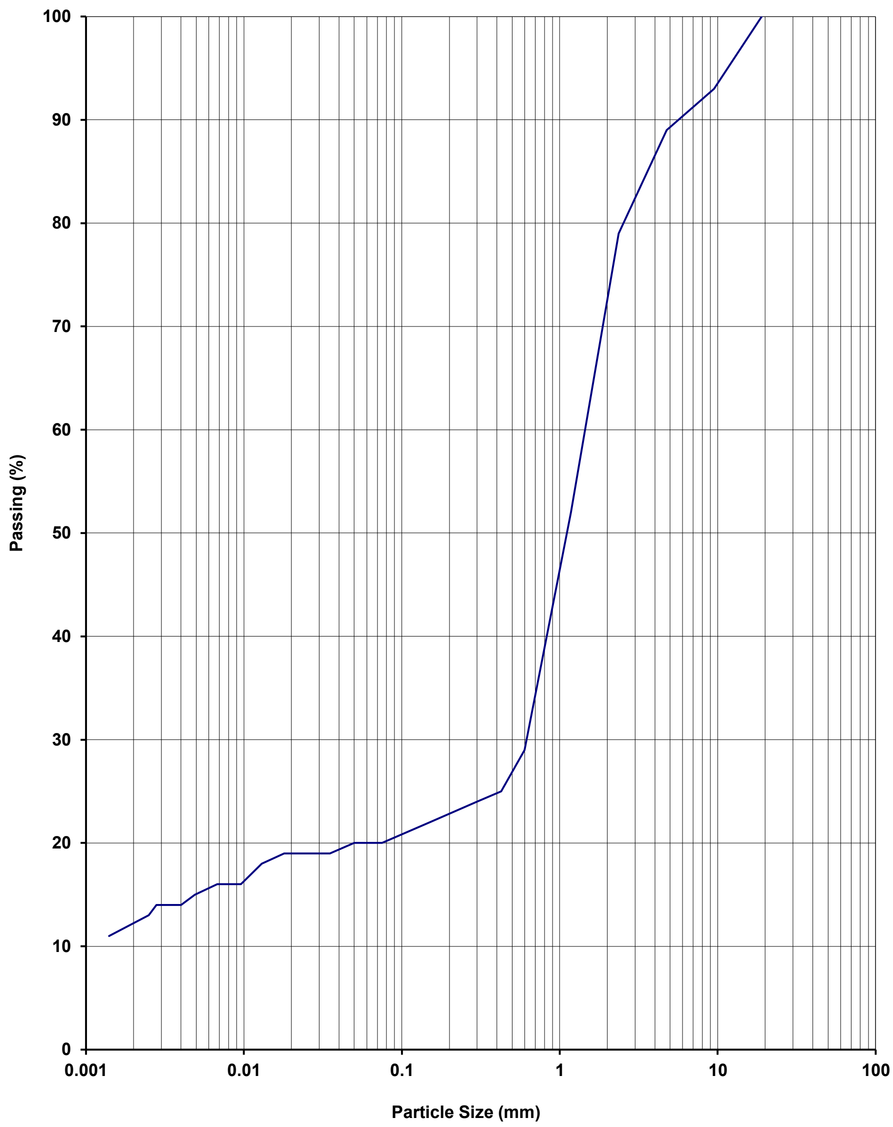
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010062-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-13 - B-12	**Depth (m)**	17.50-17.95

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	95
9.5	93
6.7	91
4.75	89
2.36	79
1.18	52
0.600	29
0.425	25
0.300	24
0.150	22
0.075	20
0.07	20
0.05	20
0.035	19
0.025	19
0.018	19
0.013	18
0.0096	16
0.0068	16
0.0049	15
0.004	14
0.0035	14
0.0028	14
0.0025	13
0.0014	11



NOTES/REMARKS: -

Moisture Content 18.9% -2.36mm Soil Particle Density(t/m^3) 2.59

Sample/s supplied by the client

Page 1 of 1 REP03904

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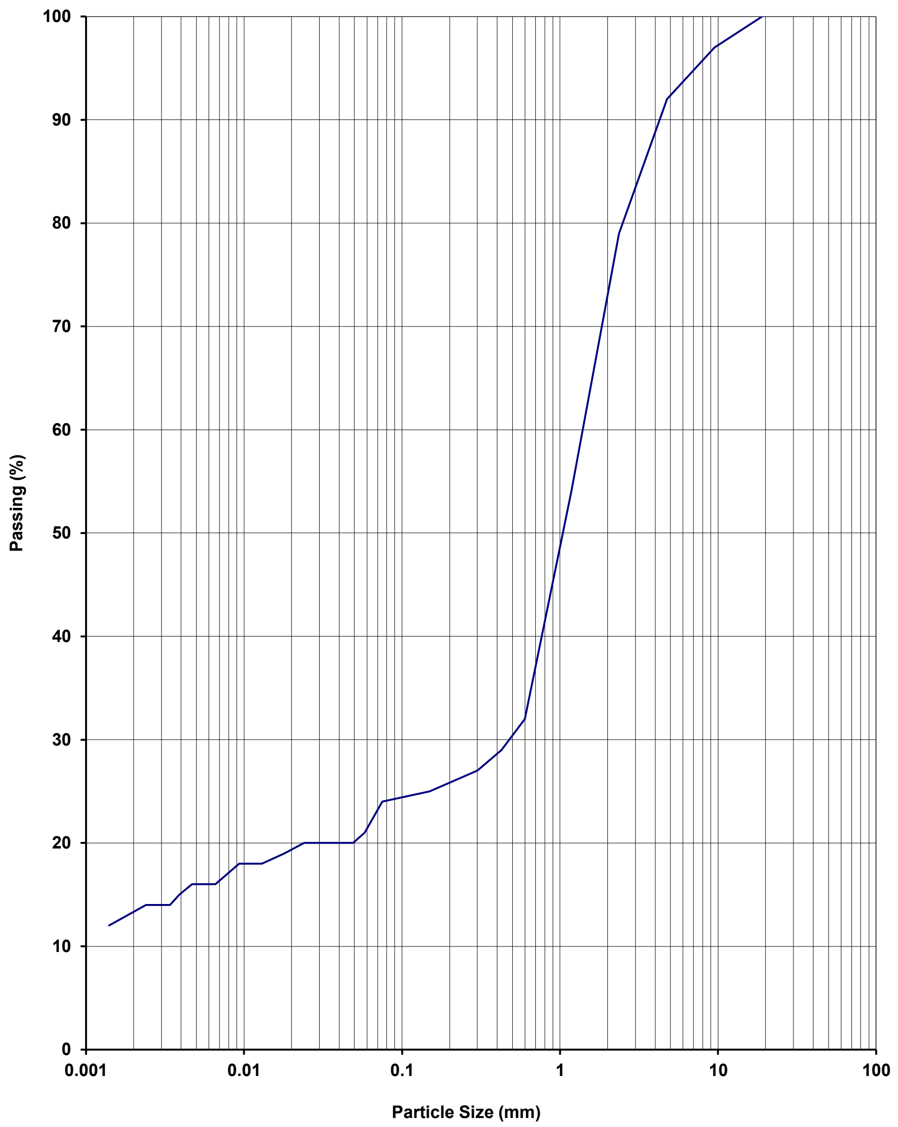
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010063-G
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	9/1/18-17/1/18
		Report Date	19/1/2018
Project	BC-13130		
Client ID	S-7 - B-13	**Depth (m)**	10.00-10.45

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	98
9.5	97
6.7	96
4.75	92
2.36	79
1.18	54
0.600	32
0.425	29
0.300	27
0.150	25
0.075	24
0.058	21
0.049	20
0.034	20
0.024	20
0.018	19
0.013	18
0.0093	18
0.0066	16
0.0047	16
0.0039	15
0.0034	14
0.0028	14
0.0024	14
0.0014	12



NOTES/REMARKS: -

Moisture Content 19.6% -2.36mm Soil Particle Density(t/m^3) 2.60

Sample/s supplied by the client

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010048-AL
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Report Date**	25/01/2018
Project	BC-13130		

Sample No.	18010048	18010049	18010050	18010051	18010052	18010053
Test Date	17/01/2018	17/01/2018	17/01/2018	23/01/2018	20/01/2018	17/01/2018
Client ID	U-2 - B-4	S-8 - B-5	S-1 - B-8	S-6 - B-8	U-1 - B-10	S-4 - B-1
Depth (m)	7.50-8.00	10.00-10.45	1.00-1.45	7.50-7.95	3.00-3.50	4.00-4.45
Liquid Limit (%)	86	112	46	63	44	51
Plastic Limit (%)	24	37	17	23	17	12
Plasticity Index (%)	62	75	29	40	27	39
Linear Shrinkage (%)	17.5 +	20.5 +	13.0	7.5 +	14.0 +	15.5
Moisture Content (%)	63.2	97.1	14.1	22.4	28.7	20.0

Sample No.	18010054	18010056	18010057	18010058	18010059	
Test Date	17/01/2018	20/01/2018	20/01/2018	23/01/2018	20/01/2018	
Client ID	S-3 - B-2	U-1 - B-3	U-2 - B-3	U-3 - B-3	S-6 - B-10	
Depth (m)	5.50-5.95	2.50-3.00	7.50-8.00	15.00-15.50	9.00-9.45	
Liquid Limit (%)	71	60	82	79	27	
Plastic Limit (%)	21	16	23	29	14	
Plasticity Index (%)	50	44	59	50	13	
Linear Shrinkage (%)	17.0	16.0 *	21.5 +	18.0 +	7.0 +	
Moisture Content (%)	49.3	23.0	49.8	74.8	22.0	

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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EMERSON CLASS NUMBER TEST REPORT

Test Method: AS 1289 3.8.1

Client	CM Testing Service Pty Ltd	**Report No.**	18010048-EM
		Workorder No.	3654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	17/1/18-22/1/18
		Report Date	22/01/2018
Project	BC-13130		

Sample No.	18010048	18010053	18010057	18010058	18010059	-	-
Client ID	U-2 - B-4	S-4 - B-1	U-2 - B-3	U-3 - B-3	S-6 - B-10	-	-
Depth (m)	7.50-8.00	4.00-4.45	7.50-8.00	15.00-15.50	9.00-9.45	-	-
Description	CLAY - grey	CLAY - grey	CLAY - grey	CLAY - grey	CLAYEY SAND - grey	-	-
Emerson Class Number	**2**	**6**	**2**	**2**	**2**	**-**	**-**

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	**-**	**-**	**-**	**-**	**-**	**-**	**-**

NOTES/REMARKS:

Sample/s supplied by the client Tested with Distilled water at 22°C

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010057 - CU
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	8/01/2018
		Report Date:	24/01/2018
Project:	BC-13130		
Client Id.:	U-2 - B-3	**Depth (m):**	7.50-8.00
Description:	CLAY- dark grey		

SAMPLE & TEST DETAILS

Initial Height:	99.4	mm	Initial Moisture Content:	42.6	%	Rate of Strain:	0.006	%/min
Initial Diameter:	47.1	mm	Final Moisture Content:	42.8	%	B Response:	97	%
L/D Ratio:	2.1 : 1		Wet Density:	1.76	t/m^3			
			Dry Density:	1.24	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
54 kPa	564 kPa	510 kPa	510 kPa	542 kPa	122 kPa	22 kPa	5.557	100 kPa	1.90 %
95 kPa	601 kPa	506 kPa	506 kPa	558 kPa	176 kPa	43 kPa	4.093	133 kPa	3.01 %
151 kPa	652 kPa	501 kPa	501 kPa	581 kPa	250 kPa	71 kPa	3.520	179 kPa	4.81 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**20.6**	**19.2**	**20.0**
Angle of Shear Resistance Φ' (Degrees) :	**26.0**	**26.8**	**26.5**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

REP03001

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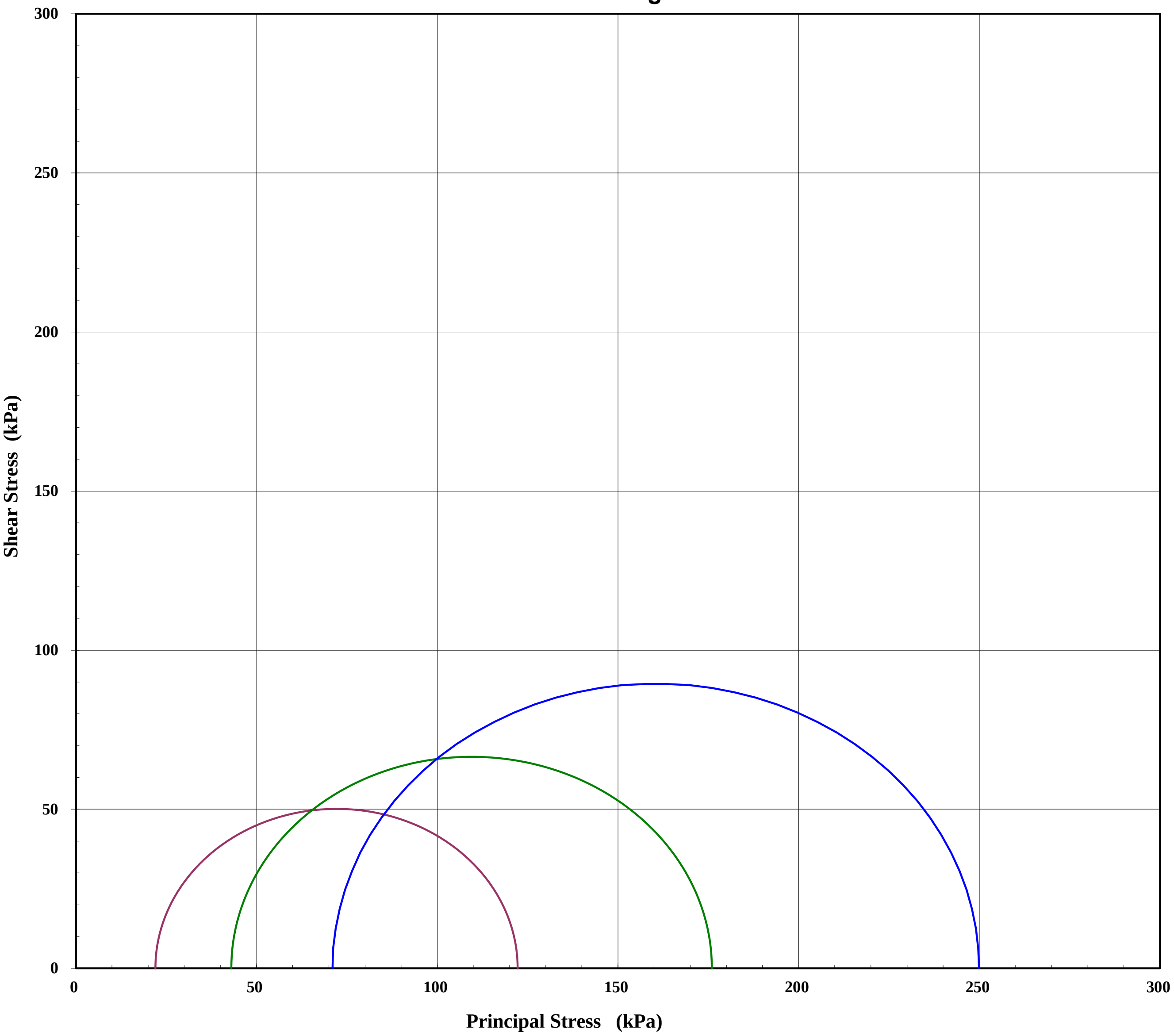
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010057 - CU

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	20.6	19.2	20.0
Angle of Shear Resistance Φ' (Degrees) :	26.0	26.8	26.5
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

REP03001

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

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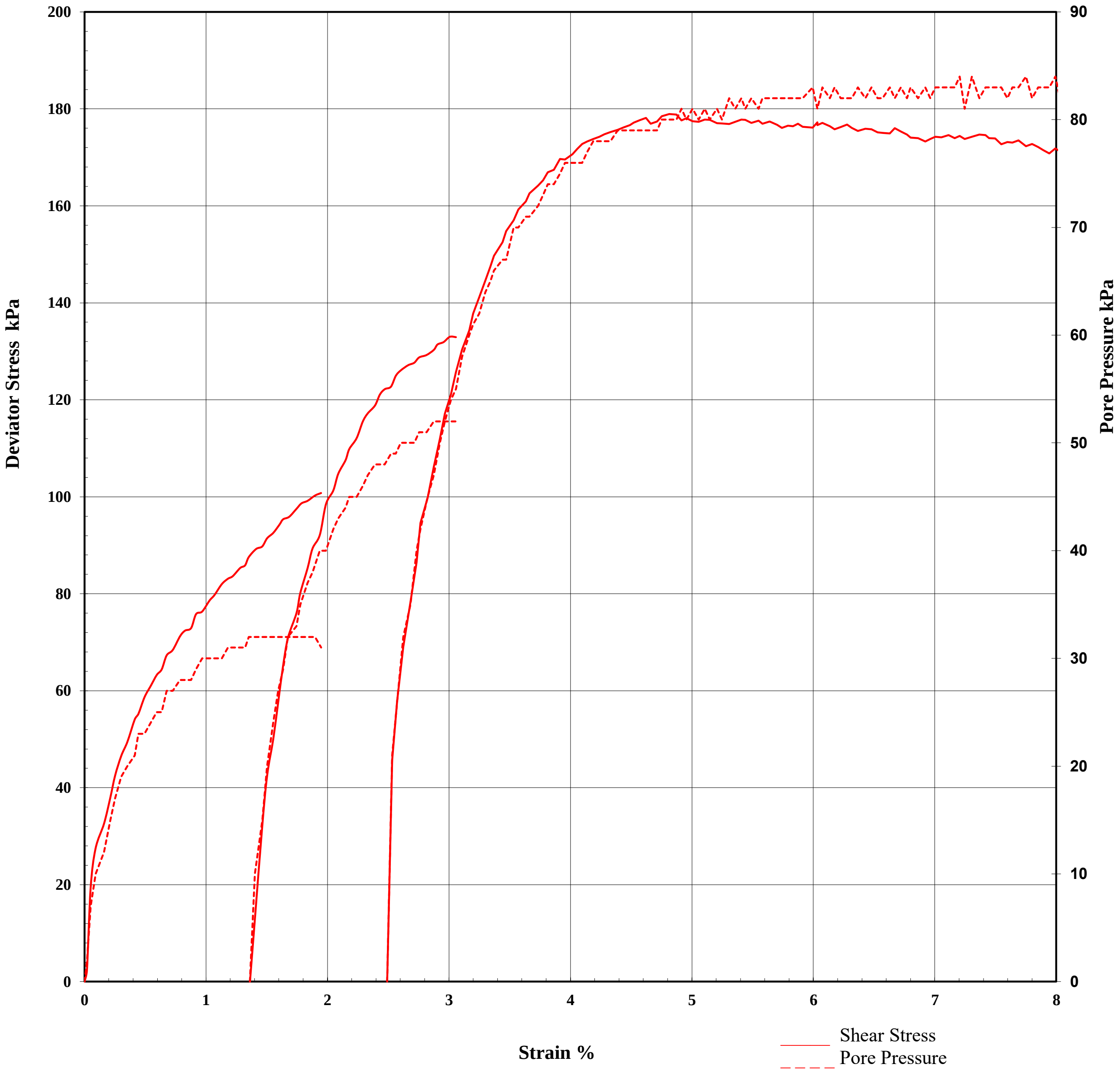
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010057 - CU

Stress/Strain & Pore Pressure/Strain Diagram



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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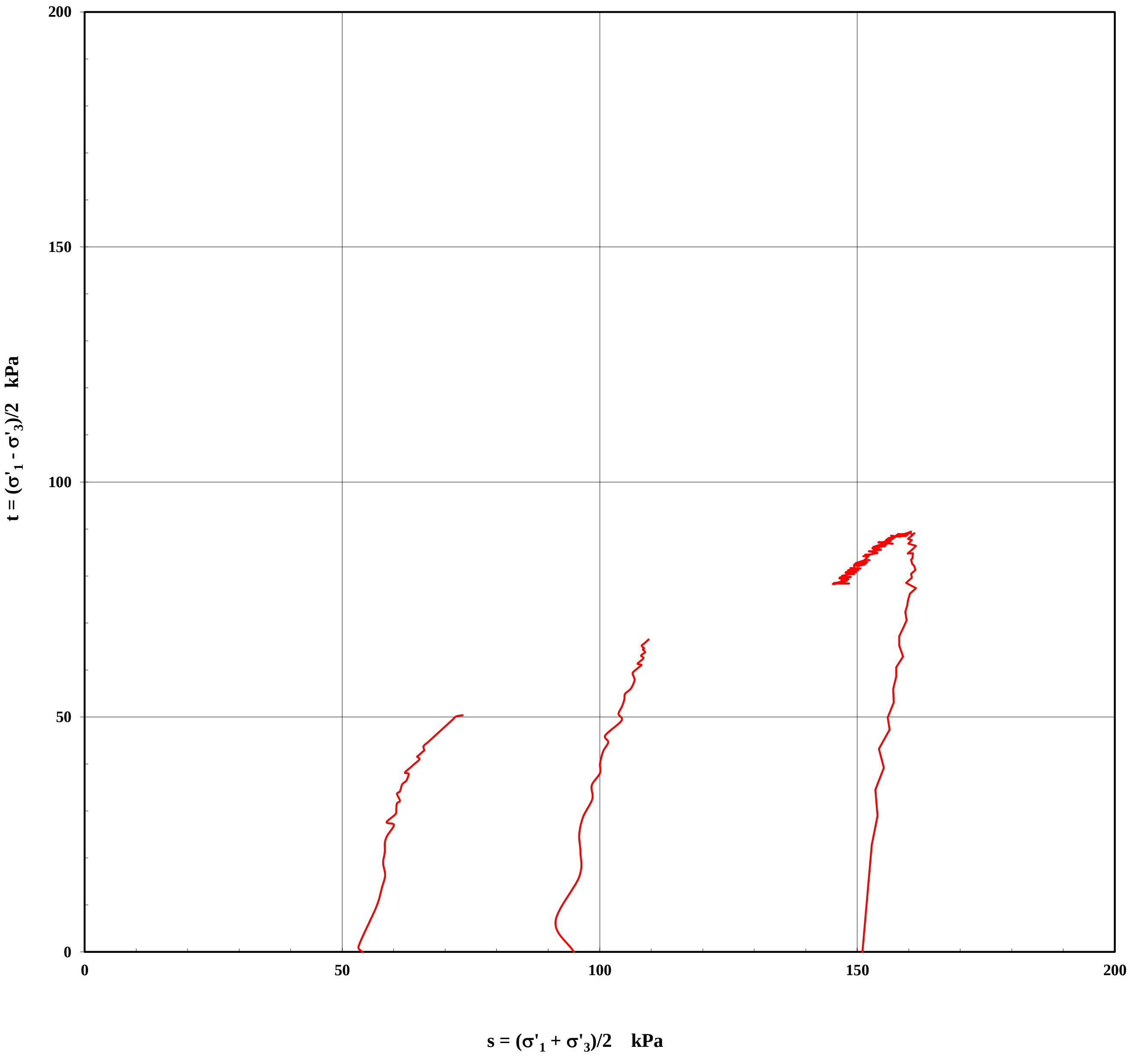
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd

Report No.: 18010057 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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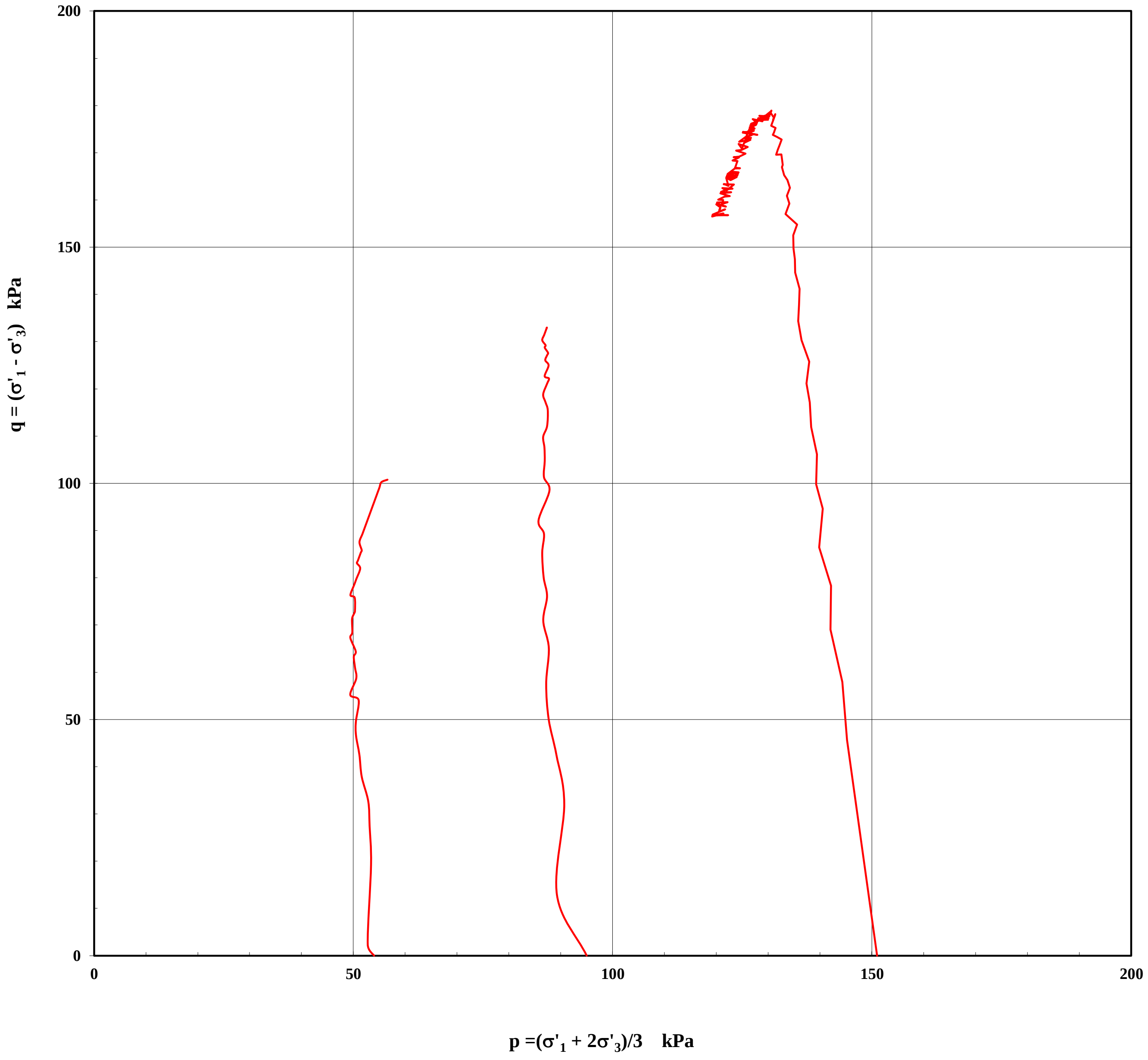
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010057 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010057 - CU

Remarks: Tested as Received

Sample/s supplied by the client

Note: Photo not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010058 - CU
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	8/01/2018
		Report Date:	24/01/2018
Project:	BC-13130		
Client Id.:	U-3 - B-3	**Depth (m):**	15.00-15.50
Description:	CLAY-dark grey		

SAMPLE & TEST DETAILS

Initial Height:	99.5	mm	Initial Moisture Content:	63.6	%	Rate of Strain:	0.006	%/min
Initial Diameter:	47.3	mm	Final Moisture Content:	58.7	%	B Response:	99	%
L/D Ratio:	2.1 : 1		Wet Density:	1.58	t/m^3			
			Dry Density:	0.97	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
98 kPa	597 kPa	499 kPa	499 kPa	548 kPa	173 kPa	49 kPa	3.525	124 kPa	2.10 %
171 kPa	672 kPa	501 kPa	501 kPa	587 kPa	244 kPa	85 kPa	2.868	159 kPa	3.58 %
252 kPa	750 kPa	498 kPa	498 kPa	637 kPa	301 kPa	113 kPa	2.660	188 kPa	6.00 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**27.1**	**25.1**	**26.4**
Angle of Shear Resistance Φ' (Degrees) :	**19.1**	**19.8**	**19.4**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

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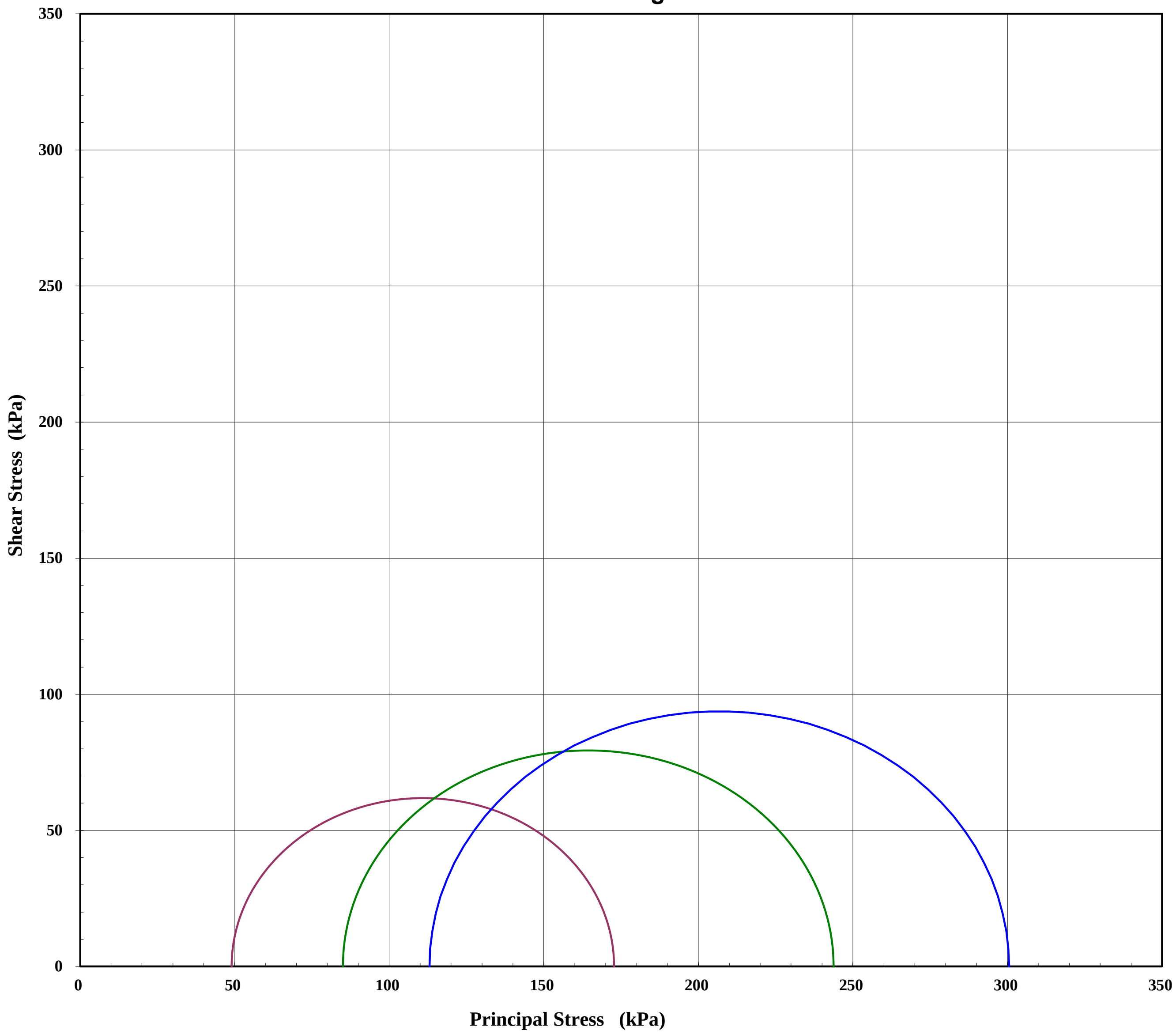
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010058 - CU

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	27.1	25.1	26.4
Angle of Shear Resistance Φ' (Degrees) :	19.1	19.8	19.4
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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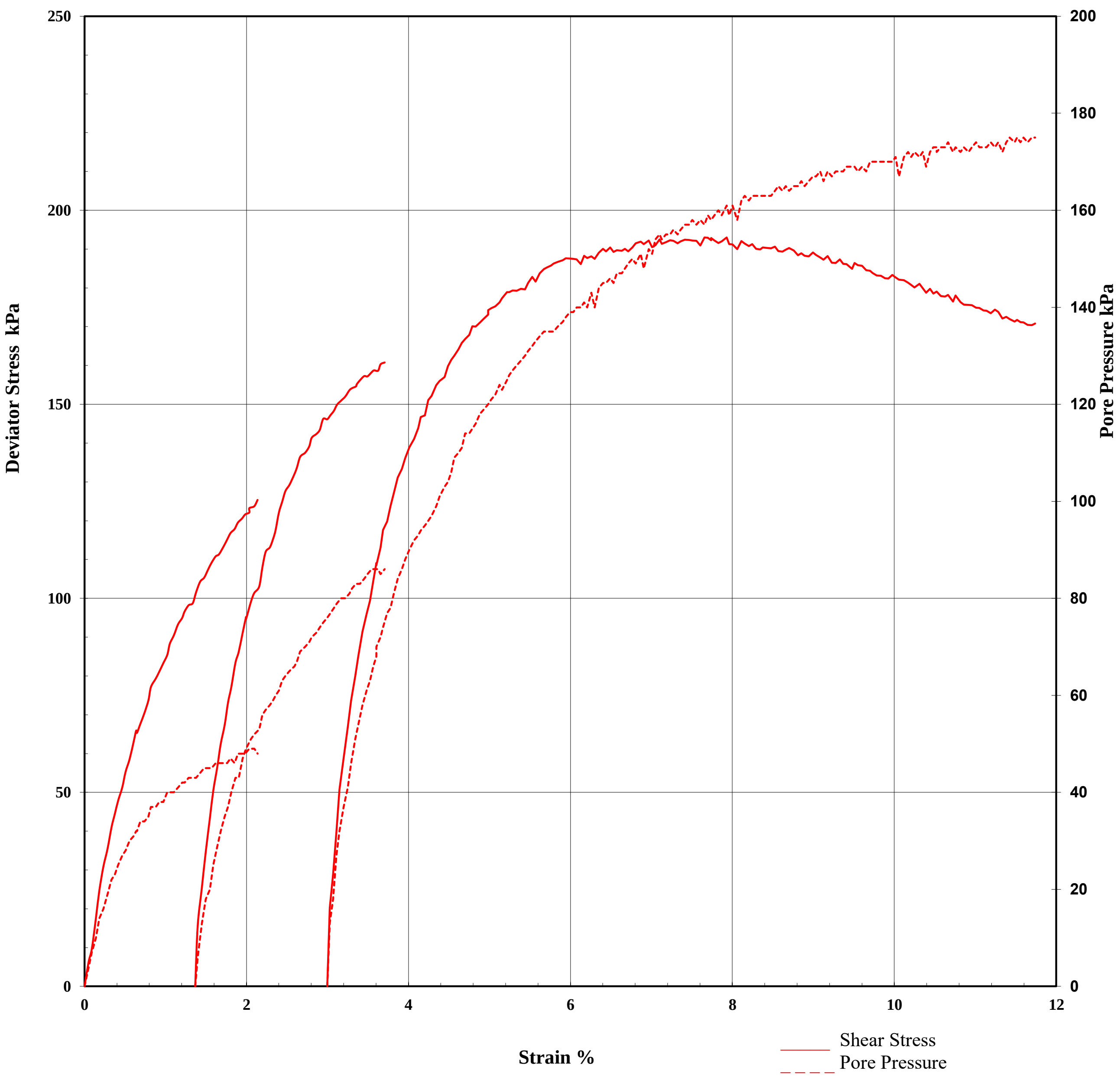
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010058 - CU

Stress/Strain & Pore Pressure/Strain Diagram



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Note: Graph not to scale

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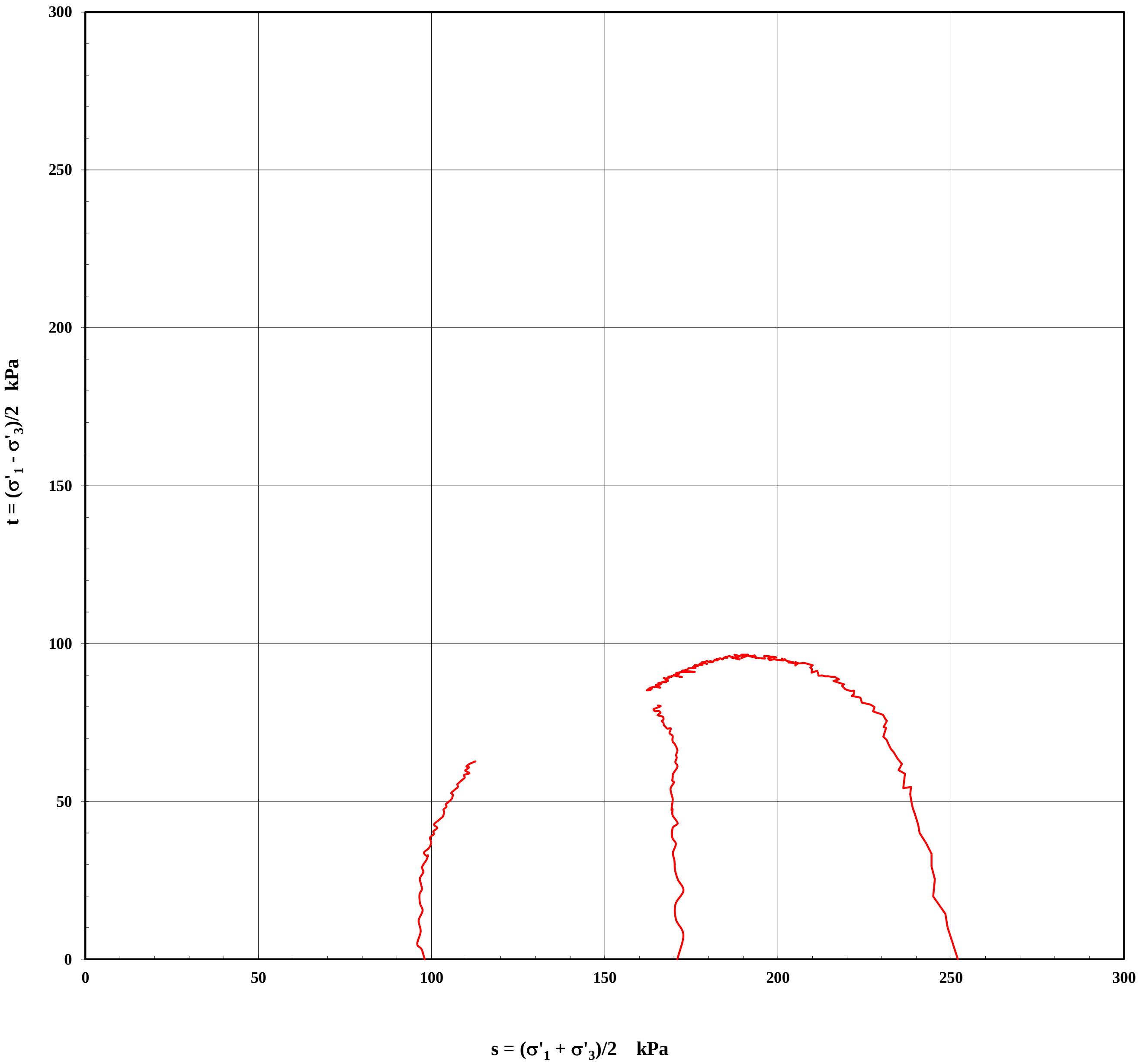
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010058 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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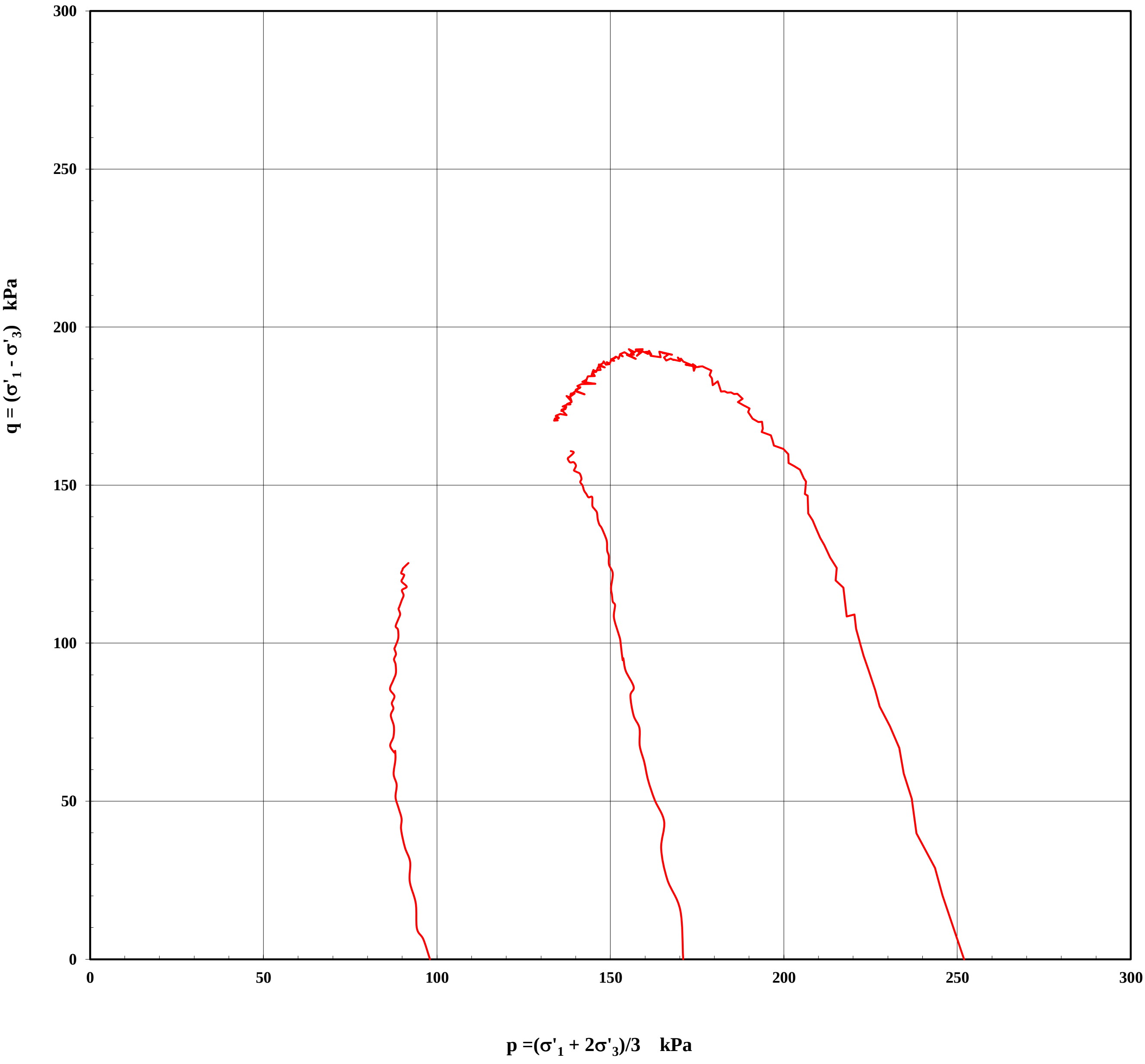
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010058 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010058 - CU

Remarks: Tested as Received

Sample/s supplied by the client

Note: Photo not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010052 - CU
		Workorder No.	0003654
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	9/01/2018
		Report Date:	24/01/2018
Project:	BC-13130		
Client Id.:	U-1 - B-10	**Depth (m):**	3.00-3.50
Description:	SANDY CLAY- dark grey brown		

SAMPLE & TEST DETAILS

Initial Height:	99.8	mm	Initial Moisture Content:	25.4	%	Rate of Strain:	0.006	%/min
Initial Diameter:	47.0	mm	Final Moisture Content:	25.1	%	B Response:	97	%
L/D Ratio:	2.1 : 1		Wet Density:	2.00	t/m^3			
			Dry Density:	1.60	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
40 kPa	540 kPa	500 kPa	500 kPa	508 kPa	130 kPa	32 kPa	4.057	98 kPa	0.75 %
61 kPa	560 kPa	499 kPa	499 kPa	519 kPa	161 kPa	41 kPa	3.930	120 kPa	1.70 %
92 kPa	590 kPa	498 kPa	498 kPa	532 kPa	221 kPa	58 kPa	3.814	163 kPa	2.59 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**4.9**	**4.3**	**4.6**
Angle of Shear Resistance Φ' (Degrees) :	**33.6**	**34.0**	**33.9**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

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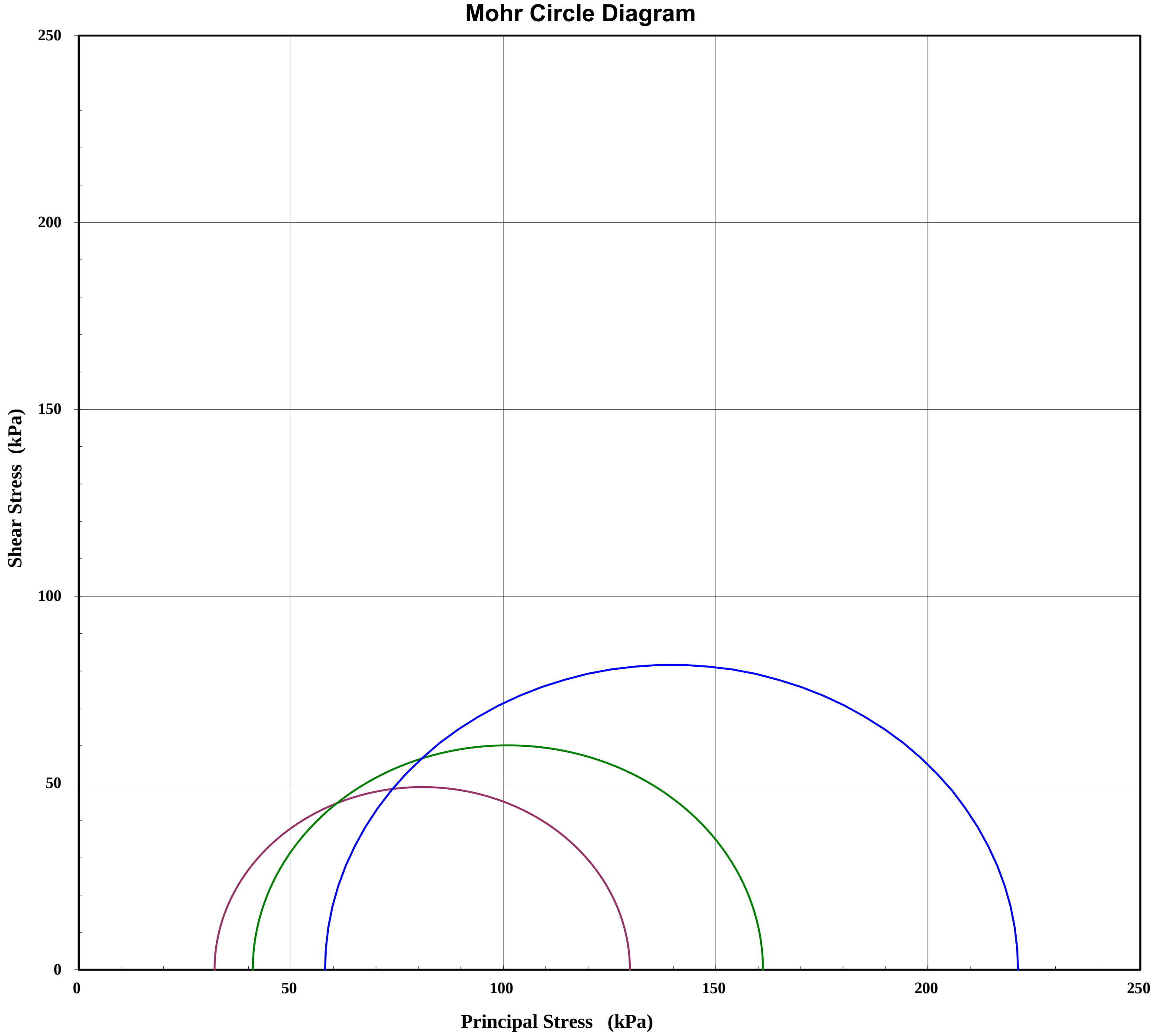
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd

Report No.: 18010052 - CU

Mohr Circle Diagram



Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	4.9	4.3	4.6
Angle of Shear Resistance Φ' (Degrees) :	33.6	34.0	33.9
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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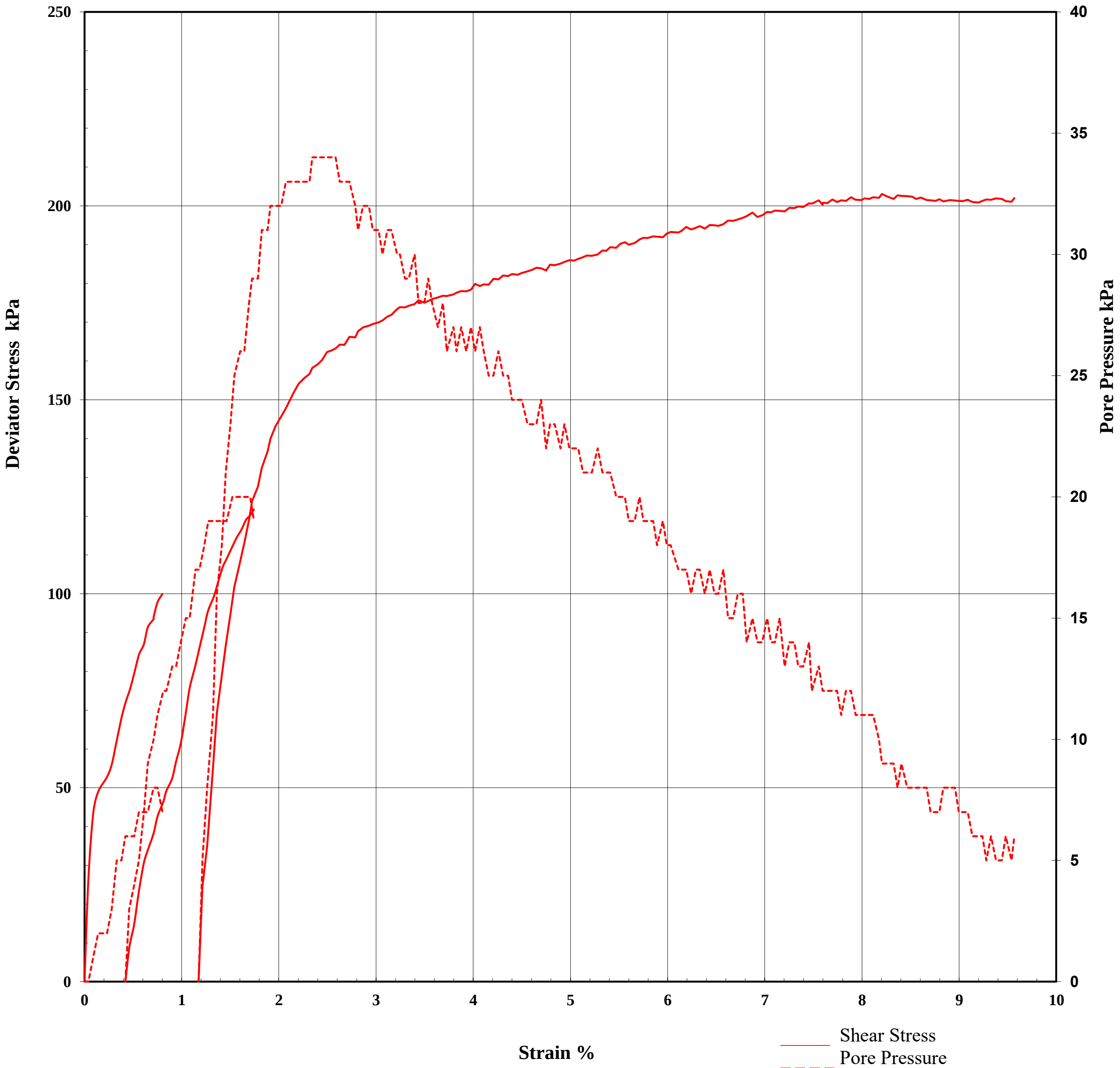
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010052 - CU

Stress/Strain & Pore Pressure/Strain Diagram



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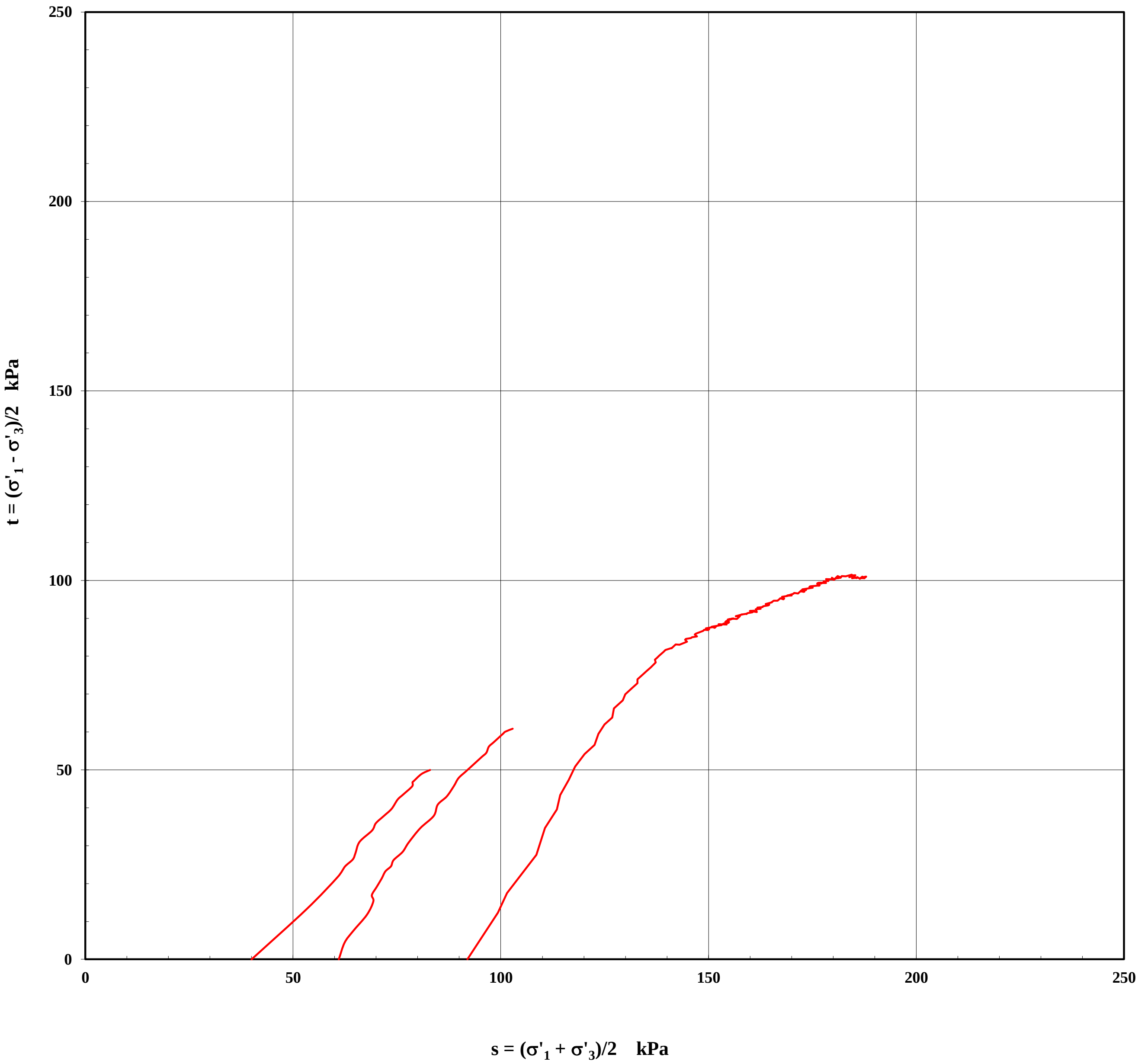
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010052 - CU

MIT Method - Effective Stress Path



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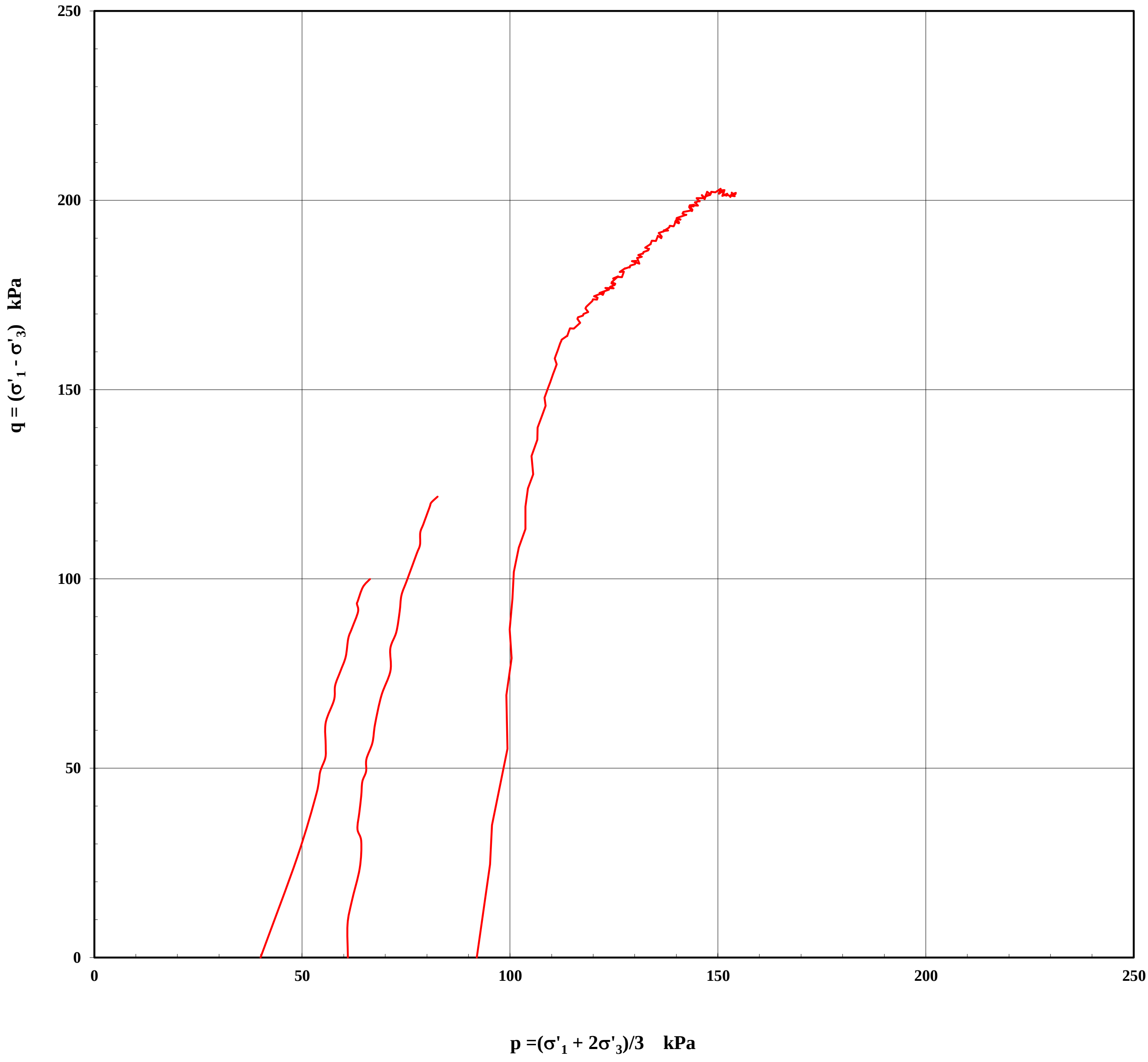
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010052 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18010052 - CU

Remarks: Tested as Received

Sample/s supplied by the client

Note: Photo not to scale

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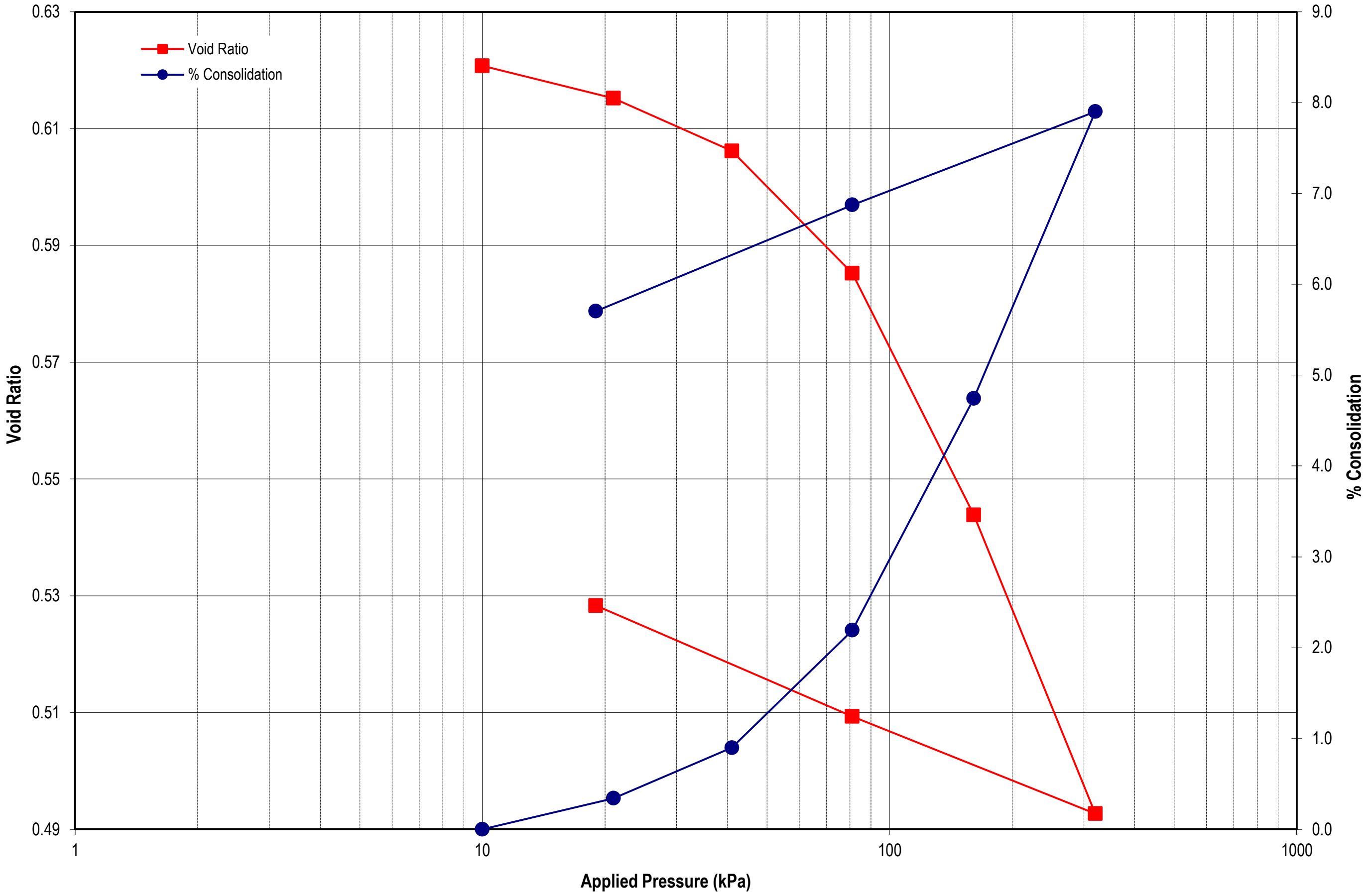
OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010056-OED
		Workorder No.	3654
Address:	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	10/01/2018
		Report Date:	22/01/2018
Project:	BC-13130		
Client Id.:	U-1 - B-3	**Depth (m):**	2.50-3.00
Description:	SILTY CLAY- brown		



Wet Density (t/m^3):	1.95	Initial Moisture (%):	22.1	Test Condition:	Inundated on load
Particle Density (t/m^3):	2.58	Initial Voids Ratio:	0.620	Initial Degree of Saturation (%):	92.6
Undisturbed sample supplied by the client		Remarks:	Tested as Received	Page 1 of 2	

REP03102

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010056-OED
		Workorder No.	3654
Address:	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	10/01/2018
		Report Date:	22/01/2018
Project:	BC-13130		
Client Id.:	U-1 - B-3	**Depth (m):**	2.50-3.00
Description:	SILTY CLAY- brown		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	10-21	0.017	7.4E-09	1.02	77.25	0.311	0.86	0.3
2	21-41	0.031	2.2E-09	0.53	25.71	0.279	1.29	0.9
3	41-81	0.071	2.9E-09	0.57	28.23	0.326	1.71	2.2
4	81-161	0.139	6.1E-09	1.27	60.50	0.326	2.48	4.7
5	161-320	0.172	3.2E-09	0.75	48.94	0.208	2.20	7.9
6	320-81	0.028	2.1E-10	1.04	14.46	0.047	0.55	6.9
7	81-19	0.030	1.2E-10	0.15	1.95	0.203	2.40	5.7

Remarks: Tested as Received

REP03102

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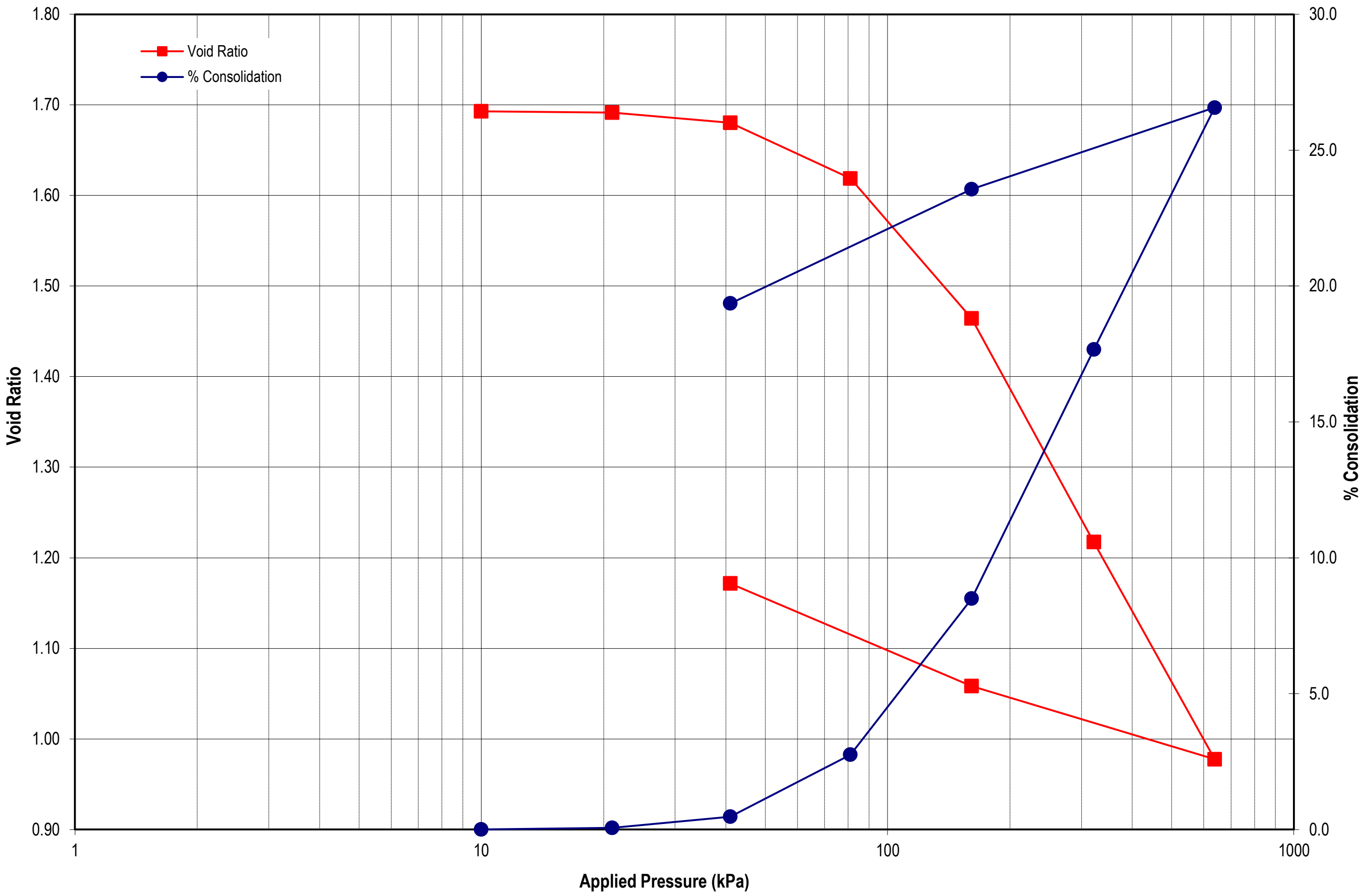
OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010048-OED
		Workorder No.	3654
Address:	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	10/01/2018
		Report Date:	25/01/2018
Project:	BC-13130		
Client Id.:	U-2 - B-4	**Depth (m):**	7.50-8.00
Description:	CLAY- dark grey		



Wet Density (t/m^3):	1.58	Initial Moisture (%):	70.1	Test Condition:	Inundated on load
Particle Density (t/m^3):	2.50	Initial Voids Ratio:	1.688	Initial Degree of Saturation (%):	100.0
Undisturbed sample supplied by the client		Remarks:	Tested as Received	Page 1 of 2	

REP03102

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

Trilab Soil Rock Calibration

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	CM Testing Service Pty Ltd	**Report No.:**	18010048-OED
		Workorder No.	3654
Address:	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	10/01/2018
		Report Date:	25/01/2018
Project:	BC-13130		
Client Id.:	U-2 - B-4	**Depth (m):**	7.50-8.00
Description:	CLAY- dark grey		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	10-21	0.005	1.7E-10	2.56	10.71	0.051	0.65	0.1
2	21-41	0.038	1.5E-10	0.67	2.41	0.207	1.46	0.5
3	41-81	0.208	2.1E-10	0.61	1.21	0.573	4.16	2.8
4	81-161	0.518	1.9E-10	0.34	0.82	0.738	11.80	8.5
5	161-322	0.820	5.4E-11	0.19	0.28	0.622	16.03	17.7
6	322-639	0.806	2.2E-11	0.15	0.21	0.341	11.85	26.6
7	639-161	0.135	3.5E-11	0.30	1.34	0.086	3.57	23.6
8	161-41	0.190	1.6E-11	0.09	0.11	0.458	10.79	19.4

Remarks: Tested as Received

REP03102

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

cdmsmith.com

core
consultants pty ltd

Geotechnical Investigation Factual Report

Proposed Bundaberg East Flood Levee

Quay St East, Scotland St and Cran St, Bundaberg East

Prepared for:
Mr Stuart Brown
CDM Smith
Level 4, 51 Alfred Street
Fortitude Valley QLD 4006

Email: brownsa@cdmsmith.com

Report Number: J000800-001-R-Rev0

February 2019

Table of Contents

Tables

Figures

Appendices

1.0 INTRODUCTION

CDM Smith (CDM) engaged Core Consultants Pty Ltd (Core) to carry out a geotechnical investigation for the proposed Bundaberg East flood levee project located in East Bundaberg.

The work is being carried out in accordance with Core proposal Q001793-002-L-Rev0.

This factual report presents the fieldwork methodology together with the results of the investigation.

2.0 PROPOSED LEVEE ALIGNMENT

The proposed levee alignment starts at the western end of Quay Street East. The levee will run east along Quay Street East to the intersection with Scotland Street, the levee then continues east along Scotland Street to its intersection with Cran Street. At Cran Street the levee will run north and north-east, before heading north-west to its termination at the Bundaberg sugar refinery (refer Figure 1).

3.0 REGIONAL MAPPING

Reference to the Geological Survey of Queensland's 1:1250,000 series "Bundaberg" Geological Map indicates that the area of the proposed levee is underlain by Quaternary aged flood plain alluvial deposits. The alluvial deposits are underlain by the Early Miocene aged Elliott Formation typically comprising heavily weathered *"conglomerate, siltstone, sandstone and shale"*.

The results of the field investigation indicate ground conditions are representative of the published geology.

4.0 FIELD INVESTIGATION

The investigation fieldwork was undertaken between 12 November and 15 November 2018 and comprised the drilling and sampling of nine (9) boreholes denoted BH101 to BH109.

The test locations were nominated by CDM and are shown on the test location plan (refer Figure 1).

The nominated borehole locations were assessed for underground services by a licensed service locator prior to drilling, using electromagnetic wand and/or ground penetrating radar (GPR) techniques.

Boreholes BH101 to BH103 and BH106 to BH109 were drilled using a truck-mounted Hydrapower Scout drilling rig. The boreholes were advanced from the ground surface using rotary auger drilling, followed by cased 'wash-boring' using a rotating blade bit to between 10.5 m and 24.1 m depth.

The boreholes denoted BH104 and BH105 were drilled using a trailer mounted GD-10 auger drill rig to 10.5 m and 10 m depth respectively. These boreholes were drilled under the supervision of an employee from CMT Testing. The borehole logs for these boreholes will be provided to CDM by CMT.

Standard penetration testing (SPT) was typically conducted at 1.5 m intervals from either 1 m or 1.5 m depth. SPT's were replaced with undisturbed tube sampling (U50) where suitable clay soils were encountered, and pocket penetrometer testing and shear vane testing was undertaken on the ends of the tube samples.

On completion of drilling standpipes were installed to the base of the boreholes BH101 and BH105 and are shown on the logs in Appendix A. The remaining boreholes were backfilled with the excavated spoil.

The supervision of boreholes BH101 to BH103 and BH106 to BH109 were undertaken by an engineering geologist from Core who logged the subsurface conditions in accordance with AS1726-2017. Groundwater observations were also made during drilling and the boreholes depths are summarised in Table 1.

Table 1: Geotechnical Borehole Summary.

Borehole No.	Target Depth (m)	Termination Depth (m)	Note
BH101	20	20	Standpipe Installed
BH102	20	24.1	Refusal
BH103	20	21.45	Standpipe
BH104	10	10.5	Target depth
BH105	10	10	Standpipe Installed
BH106	10	10.95	Target depth
BH107	20	19.5	Target depth
BH108	20	19.95	Target depth
BH109	10	10.5	Target depth

5.0 SUMMARY OF GROUND CONDITIONS

Details of subsurface conditions encountered in the boreholes are given on the borehole report sheets included in Appendix A. These should be read in conjunction with the explanatory notes which comment on the sampling methods, soil descriptions, and symbols and abbreviations used in their preparation, also included in Appendix A.

In summary, the ground conditions encountered in the boreholes comprised **fill** overlying **flood plain alluvial soils,** underlain by the **Elliott Formation**. In more detail, the boreholes encountered the following:

- **Fill:** silty sand, sand, silty clay and ash fill was encountered from the surface in all boreholes to between 0.2 m and 2.2 m depth
- **Alluvial Soils:** loose silty sand, generally firm silty clay and sandy clay were encountered below the fill in all boreholes to between 1.2 m and 19.3 m depth. Boreholes BH104 and BH105 were terminated within the alluvial soils at 10.5 m and 10 m depth respectively.
- **Elliott Formation:** stiff to hard sandy clay, silty clay, medium dense to dense silty sand, clayey sand or sand and gravel were encountered below the alluvial soils in all boreholes except for BH104 and BH105. Indurated very dense clayey sand or hard sandy clay was encountered between 1.6 m and 8.6 m depth in BH106 and between 5.2 m and 7.4 m depth in BH107. BH101 and BH103 to BH109 were drilled to target depths of between 10.5 m and 21.45 m. BH102 was terminated at a refusal depth of 24.1 m.

Groundwater seepage was noted at approximately 4 m and 5 m depth in BH104 and BH105 respectively. No groundwater or groundwater seepages were encountered in the remaining boreholes, prior to employing washboring drilling techniques.

6.0 LIMITATIONS

Your attention is drawn to the document, 'Limitations' which is attached in Appendix B.

Yours sincerely,

Core Consultants Pty Ltd

Andrew Short BSc (Hons)
Engineering Geologist

Geoff Hurley MSc DIC C.Geol RPEQ
Director

AS/GH/as A.B.N. 75 603 384 050

Drawing Adapted from CDM Smith, Levee Alignment Drawing

Legend

- Approximate Borehole Location

core consultants pty ltd www.coreconsultants.com.au	CLIENT CDM Smith		PROJECT Proposed Bundaberg East Levee	
	DRAWN AS	DATE 07/02/2019	TITLE TEST LOCATION PLAN	
	CHECKED GH	DATE 07/02/2019		
	SCALE As shown		PROJECT No J000800	FIGURE No 1 · REV No 0 · A4

Note: The * typed beside the initials indicates that the original drawing was signed or checked by that respective person

Appendix A:
Borehole Report Sheets

core consultants pty ltd

REPORT OF BOREHOLE: BH101

CLIENT:	CDM Smith	EAST:	435071.3 m	SHEET	1 OF 3
PROJECT:	Proposed Levee	NORTH:	7250126.7 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.75 m	LOGGED DATE:	12/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling — METHOD: ADT (0–3.00 m), WB (3.00–8.00 m); PENETRATION RESISTANCE: L; WATER: Not Encountered

DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
0.00	5.75	D 0.50-0.60 m D 1.00-1.10 m	SM	SAND (FILL): fine to medium grained, orange brown and brown, with trace angular to sub-rounded, fine to medium grained gravel	M	L
1.30	4.45	SPT 1.50-1.95 m 3/3/5 N = 8	CI	SILTY CLAY (ALLUVIAL): medium plasticity, dark grey, with trace fine grained sand	M	F
2.00	3.75	SPT 3.00-3.45 m 3/3/4 N = 7	SM	SILTY SAND (ALLUVIAL): fine to medium grained, orange and brown, with interbedded bands of firm silty clay	M	L
4.00	1.75	SPT 4.50-4.95 m 2/4/4 N = 8	CI	SANDY CLAY (ALLUVIAL): medium plasticity, orange brown and brown	M	F
5.50	0.25	U50 6.00-6.40 m PP 6.00 m =100 kPa	CH	SILTY CLAY (RESIDUAL SOIL): medium plasticity, red brown, yellow brown and grey	M	St
7.00	-1.25	SPT 7.50-7.95 m WOH N = 0 PP 7.50 m =60 kPa	CH	SILTY CLAY (MARINE CLAY): medium plasticity, becoming dark grey, with thinly bedded bands of fine sand	M	F

PIEZOMETER DETAILS: MW1 — Backfill

This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

core consultants pty ltd

REPORT OF BOREHOLE: BH101

CLIENT:	CDM Smith	EAST:	435071.3 m	SHEET	2 OF 3
PROJECT:	Proposed Levee	NORTH:	7250126.7 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.75 m	LOGGED DATE:	12/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	PIEZOMETER DETAILS
WB	L	Not Encountered	8					CH	SILTY CLAY (MARINE CLAY): medium plasticity, becoming dark grey, with thinly bedded bands of fine sand	M	F	
			9		SPT 9.00-9.45 m 0/0/1 N = 1							
			10									
					SPT 10.50-10.95 m 0/0/1 N = 1							
			11									
			12		U50 12.00-12.40 m PP 12.00 m =90 kPa FV 12.00 m Sv=30 kPa							
			13									
					SPT 13.50-13.95 m WOH N = 0 PP 13.50 m =80 kPa							
			14									
			15		SPT 15.00-15.45 m WOH N = 0 PP 15.00 m =900 kPa							
			16									Bentonite

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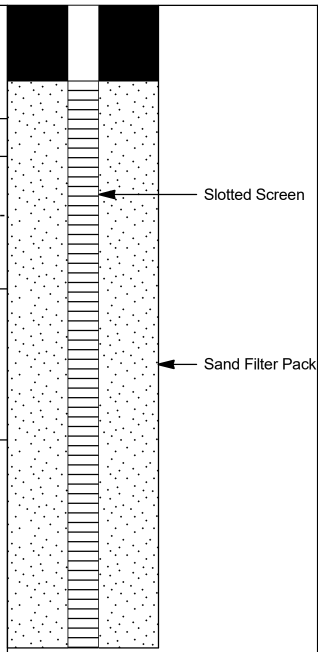
REPORT OF BOREHOLE: BH101

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435071.3 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250126.7 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.75 m	LOGGED DATE:	12/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description				
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
WB	L	Not Encountered	16					CH	SILTY CLAY (MARINE CLAY): medium plasticity, becoming dark grey, with thinly bedded bands of fine sand	M	F
				16.60 / -10.85	SPT 16.50-16.95 m 5/12/17 N = 29			CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, grey, medium grained sand		St
			17	16.80 / -11.05				SM	SILTY SAND (ELLIOT FORMATION): medium to coarse grained, grey, with trace rounded, medium quartz gravel		MD - D
			18	17.50 / -11.75	SPT 18.00-18.45 m 2/5/11 N = 16			CI	SILTY CLAY (ELLIOT FORMATION): medium plasticity, grey		St
			19	18.30 / -12.55	SPT 19.50-19.95 m 6/3/5 N = 8			SP	GRAVELLY SAND (ELLIOT FORMATION): medium grained, grey, fine to coarse and sub-angular to rounded gravel		MD
			20	19.85				CI	SILTY CLAY (ELLIOT FORMATION): medium plasticity, grey, red brown and yellow brown		St
				20.00					END OF BOREHOLE @ 20.00 m TARGET DEPTH STANDPIPE INSTALLED		
			21								
			22								
			23								
			24								

PIEZOMETER DETAILS



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REPORT OF BOREHOLE: BH102

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435141.5 m	SHEET	1 OF 4
PROJECT:	Proposed Levee	NORTH:	7250142.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.40 m	LOGGED DATE:	13/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling — METHOD: ADT (0.00–2.50 m), WB (2.50–8.00 m); PENETRATION RESISTANCE: L; WATER: Groundwater inflow encountered at 0.5 m depth (ADT section); Not Encountered (WB section)

DEPTH (m)	RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.00	7.40		SM	SAND (FILL): fine to medium grained, orange brown and brown, with trace fine to medium, angular to sub-angular gravel and metal fragments	M	MD	0.00: Variable drilling
0.60	6.80	SPT 1.50-1.95 m 6/8/10 N = 18	CI	SILTY CLAY (FILL): medium plasticity, dark brown, with trace fine sand and concrete fragments	M	VSt	1.50: Boulder encountered
2.00	5.40	2.50 m PP 2.50 m =180 kPa	CI	SILTY CLAY (ALLUVIUM): medium plasticity, brown and dark orange brown, with trace fine sand	M	St	
2.70	4.70	SPT 3.00-3.45 m 2/4/3 N = 7	SM	SILTY SAND (ALLUVIUM): fine to medium grained, orange brown, with some angular to sub-angular, fine to coarse sized gravel	M	L	
3.60	3.80	U50 4.50-4.90 m PP 4.50 m =130 kPa	CI	SILTY CLAY (ALLUVIUM): brown and dark orange brown, with trace fine sand	M	St	
5.60	1.80			Becoming grey and orange brown	M	St	
6.00	1.40	SPT 6.00-6.45 m 2/1/3 N = 4		Becoming firm	M	F	
7.20	0.20	SPT 7.50-7.95 m WOH N = 0 PP 7.50 m =80 kPa	CH	SILTY CLAY (MARINE CLAY): high plasticity, dark grey, with thinly bedded bands of fine sand	M	F	

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core consultants pty ltd

REPORT OF BOREHOLE: BH102

CLIENT:	CDM Smith	EAST:	435141.5 m		
PROJECT:	Proposed Levee	NORTH:	7250142.5 m	SHEET	2 OF 4
LOCATION:	East Bundaberg	SURFACE RL	7.40 m	LOGGED:	AS
JOB NO:	J000800	CONTRACTOR:	Geodrill	LOGGED DATE:	13/11/18
		DRILL RIG:	Hydra Power Scout	CHECKED:	AS
		INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8					CH	SILTY CLAY (MARINE CLAY): high plasticity, dark grey, with thinly bedded bands of fine sand	M	F	
			9		SPT 9.00-9.45 m WOH N = 0 PP 9.00 m =70 kPa							
			10		SPT 10.50-10.95 m 0/0/1 N = 1							
			11									
			12	12.00 -4.60	PP 12.00 m =60 kPa				With some organic matter and shell fragments			
			13		SPT 13.50-13.95 m WOH N = 0 PP 13.50 m =60 kPa							
			14									
			15	15.00 -7.60	U50 15.00-15.40 m PP 15.00 m =100 kPa FV 15.00 m Sv=42 kPa				Becoming firm/stiff			
			16									

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REPORT OF BOREHOLE: BH102

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435141.5 m		
PROJECT:	Proposed Levee	NORTH:	7250142.5 m	SHEET	3 OF 4
LOCATION:	East Bundaberg	SURFACE RL	7.40 m	LOGGED:	AS
JOB NO:	J000800	CONTRACTOR:	Geodrill	LOGGED DATE:	13/11/18
		DRILL RIG:	Hydra Power Scout	CHECKED:	AS
		INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

Drilling: METHOD WB; PENETRATION RESISTANCE L (16.00–22.50 m), H (22.50–24.00 m); WATER Not Encountered. MOISTURE CONDITION M (16.00–24.00 m).

DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
16.00–18.00		SPT 16.50-16.95 m 0/0/4 N = 4	CH	SILTY CLAY (MARINE CLAY): high plasticity, dark grey, with thinly bedded bands of fine sand	F	
18.00–18.75	18.00 / -10.60	SPT 18.00-18.45 m 4/3/0 N = 3	CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, orange brown and grey, medium to coarse grained sand	F	
18.75–19.30	18.75 / -11.35		CH	SILTY CLAY (ELLIOT FORMATION): high plasticity, dark grey, with thinly bedded bands of fine sand	F	
19.30–20.50	19.30 / -11.90	SPT 19.50-19.95 m 5/13/22 N = 35	CL	SANDY CLAY (ELLIOT FORMATION): low plasticity, pale grey and red brown, medium to coarse grained sand, with trace sub-angular to rounded gravel	H	
20.50–21.50	20.50 / -13.10	SPT 21.00-21.45 m 7/5/8 N = 13		With some gravel	St	
21.50–24.00	21.50 / -14.10	SPT 22.50-22.95 m 8/15/16 N = 31	CI	SANDY CLAY (ELLIOT FORMATION): orange brown, medium to coarse grained sand, with some sub-angular to rounded, medium to coarse grained gravel	H	
24.00	24.00					

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core consultants pty ltd

REPORT OF BOREHOLE: BH102

CLIENT:	CDM Smith	EAST:	435141.5 m	SHEET	4 OF 4
PROJECT:	Proposed Levee	NORTH:	7250142.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.40 m	LOGGED DATE:	13/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
	H	Not Encountered	24	24.10	SPT 24.00-24.07 m 30 for 70 mm				SANDY GRAVEL (POSSIBLE CONGLOMERATE): brown, medium to coarse grained sand, with angular to sub-angular, medium to coarse quartz	M	VD	
									END OF BOREHOLE @ 24.10 m REFUSAL BACKFILLED			
			25									
			26									
			27									
			28									
			29									
			30									
			31									
			32									

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REPORT OF BOREHOLE: BH103

core consultants pty ltd

CLIENT: CDM Smith	EAST: 435203.1 m		
PROJECT: Proposed Levee	NORTH: 7250150.9 m	SHEET	1 OF 3
LOCATION: East Bundaberg	SURFACE RL 6.40 m	LOGGED:	AS
JOB NO: J000800	CONTRACTOR: Geodrill	LOGGED DATE:	13/11/18
	DRILL RIG: Hydra Power Scout	CHECKED:	AS
	INCLINATION: -90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

METHOD (Drilling)	PENETRATION RESISTANCE (Drilling)	WATER (Drilling)	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST (Sampling)	RECOVERED (Sampling)	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION (Field Material Description)	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT (0–2.50)	L	Not Encountered	0	6.40			SM	SILTY SAND (FILL): fine grained, orange brown and grey	M	L	
				0.20 / 6.20			CI	SILTY CLAY (ALLUVIAL): medium plasticity, dark brown		VSt	
			1.50		SPT 1.50-1.95 m 6/8/10 N = 18						
WB (2.50–8.00)			3.00	*3.00* / 3.40	U50 3.00-3.40 m PP 3.00 m =110 kPa			Becoming stiff		St	
			4.50	*4.50* / 1.90	SPT 4.50-4.95 m 0/3/3 N = 6			Orange brown and grey, becoming firm		F	
			6.00		SPT 6.00-6.45 m WOH N = 0 PP 6.00 m =60 kPa						
			6.30	*6.30* / 0.10			CH	SILTY CLAY (MARINE CLAY): high plasticity, grey			
			7.50		SPT 7.50-7.95 m WOH N = 0 PP 7.50 m =50 kPa						

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REPORT OF BOREHOLE: BH103

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435203.1 m		
PROJECT:	Proposed Levee	NORTH:	7250150.9 m	SHEET	2 OF 3
LOCATION:	East Bundaberg	SURFACE RL	6.40 m	LOGGED:	AS
JOB NO:	J000800	CONTRACTOR:	Geodrill	LOGGED DATE:	13/11/18
		DRILL RIG:	Hydra Power Scout	CHECKED:	AS
		INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

Drilling: METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	Sampling: SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	Field Material Description: SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8					CH	SILTY CLAY (MARINE CLAY): high plasticity, grey	M	F	
			9		U50 9.00-9.40 m PP 9.00 m =90 kPa							
			10									
					SPT 10.50-10.95 m WOH N = 0 PP 10.50 m =70 kPa							
			11									
			12	12.00 -5.60	SPT 12.00-12.45 m WOH N = 0 PP 12.00 m =70 kPa				Some organics present			
			13									
					SPT 13.50-13.95 m WOH N = 0 PP 13.50 m =70 kPa FV 13.50 m Sv=30 kPa							
			14									
				14.80 -8.40				SC	CLAYEY SAND (ELLIOT FORMATION): medium to coarse grained, grey		L	
			15		SPT 15.00-15.45 m 0/1/1 N = 2							
			16									

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REPORT OF BOREHOLE: BH103

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435203.1 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250150.9 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	6.40 m	LOGGED DATE:	13/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

METHOD (Drilling)	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST (Sampling)	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION (Field Material Description)	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16					SC	CLAYEY SAND (ELLIOT FORMATION): medium to coarse grained, grey	M	L	
				16.50 / -10.10	SPT 16.50-16.95 m 2/4/4 N = 8				Fine to medium grained grained			
			17									
				17.80 / -11.40					Orange brown and grey, interbedded bands of fine grained sand			
			18		SPT 18.00-18.45 m 6/4/4 N = 8							
			19									
				19.40 / -13.00	SPT 19.50-19.95 m 3/4/7 N = 11			CL	SILTY CLAY (ELLIOT FORMATION): low plasticity, pale grey, red brown and orange brown, with trace fine sand		St	
			20									
			21	21.00 / -14.60	SPT 21.00-21.45 m 5/8/9 N = 17				No sand, very stiff		VSt	
				21.45					END OF BOREHOLE @ 21.45 m TARGET DEPTH BACKFILLED			
			22									
			23									
			24									

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REPORT OF BOREHOLE: BH106

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435925.8 m	SHEET	1 OF 2
PROJECT:	Proposed Levee	NORTH:	7250439.9 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.92 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling | **Sampling** | **Field Material Description**

DEPTH (metres)	RL	METHOD	PENETRATION RESISTANCE	WATER	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0	7.92	ADT	L	Not Encountered		CI-CH	SILTY CLAY (FILL): medium plasticity, dark brown, with some brick and concrete fragments	M	F	
0.60	7.32	ADT	L			CI	SILTY CLAY (ALLUVIUM): medium plasticity, grey and orange brown	M	F	
1.20	6.72	ADT	L		SPT 1.50-1.63 m 30 for 130 mm	CI	SILTY CLAY (ELLIOT FORMATION): medium plasticity, grey, brown and yellow brown, with some fine sand, trace fine to medium grained angular to sub-rounded gravel	M	F	
1.60	6.32	ADT	H		SPT 10 blows to 100 mm then bouncing		SANDSTONE (INDURATED/CEMENTED): grey and brown, highly weathered, fine to medium grained	M	VD	
1.80	6.12	ADT	L				Becomes very low strength, highly weathered	M	VD	
2.50	5.42	WB	L			CI	SILTY CLAY (INDURATED/CEMENTED): medium plasticity, red brown, yellow brown and brown grey, with some fine to medium grained	M	H	
3.00	4.92	WB	L (to 4.0), M		SPT 3.00-3.28 m 7/30 for 125 mm; SPT 4.50-4.79 m 30 for 140 mm; SPT 6.00-6.44 m 12/18/30 for 140 mm	SC	CLAYEY SAND (INDURATED/CEMENTED): fine to medium grained, pale grey, with red brown and yellow brown and brown bands	M	VD	
7.30	0.62	WB	H		SPT 7.50-7.53 m 30 for 30 mm		SILTSTONE (INDURATED/CEMENTED): pale grey, moderately weathered	M	H	
8										

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REPORT OF BOREHOLE: BH106

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435925.8 m	SHEET	2 OF 2
PROJECT:	Proposed Levee	NORTH:	7250439.9 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.92 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
RR	L	Not Encountered	8 – 8.60						SILTSTONE (INDURATED/CEMENTED): pale grey, moderately weathered	M	H	
			8.60 – 10.50	8.60 / -0.68	SPT 9.00-9.45 m 3/5/4 N = 9			CI-CH	SANDY CLAY (INDURATED/CEMENTED): pale grey, fine to coarse grained sand		St	
			10.50 – 10.95	10.50 / -2.58	SPT 10.50-10.95 m 6/8/15 N = 23				CLAY (INDURATED/CEMENTED): pale grey, becoming stiff		VSt	
			10.95	10.95					END OF BOREHOLE @ 10.95 m TARGET DEPTH BACKFILLED			

Depth scale: 8, 9, 10, 11, 12, 13, 14, 15, 16

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REPORT OF BOREHOLE: BH107

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435889.2 m	SHEET	1 OF 3
PROJECT:	Proposed Levee	NORTH:	7250543.0 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling				Sampling	Field Material Description				
METHOD	PENETRATION RESISTANCE	WATER	DEPTH RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L	Not Encountered	0.00 / 5.82		SM	SILTY SAND (FILL): fine grained, dark brown and yellow brown, with ash fragments and some angular to sub-angular, medium to course grained gravel and cobbles	M	L	
ADT	L	Not Encountered	0.60 / 5.22		CL	SILTY CLAY (FILL): low plasticity, dark brown, red brown, and yellow brown, with ash fragments and some angular to sub-angular, medium to course grained gravel and cobbles	M	F	
ADT	L	Not Encountered	1.00 / 4.82	SPT 1.50-1.95 m 2/2/1 N = 3		Dark brown, with ash fragments	D	L	
ADT / WB	L	Not Encountered	2.20 / 3.62	SPT 3.00-3.45 m 2/3/6 N = 9	CH	SILTY CLAY (ALLUVIUM): high plasticity, dark brown, orange and dark grey	M	St	
WB	L	Not Encountered	4.00 / 1.82	SPT 4.50-4.95 m WOH N = 0 PP 4.50 m =70 kPa	CH	SILTY CLAY (ELLIOT FORMATION): high plasticity, pale grey and yellow brown, with trace of fine grained sand	M	F	
WB / RR	H	Not Encountered	5.20 / 0.62	SPT 6.00-6.05 m 30 for 50 mm		SILTSTONE (INDURATED/CEMENTED): red brown, orange brown and grey, highly weathered, recovered as fine to coarse grained angular to sub-angular gravel (possibly indurated clay/sand)	M	H	
RR	H	Not Encountered	7.40 / -1.58	SPT 7.50-7.75 m 19/30 for 50 mm	CL	SILTY CLAY (INDURATED/CEMENTED): low plasticity, pale grey, with trace of fine sand	M	H	

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core consultants pty ltd

REPORT OF BOREHOLE: BH107

CLIENT:	CDM Smith	EAST:	435889.2 m
PROJECT:	Proposed Levee	NORTH:	7250543.0 m
LOCATION:	East Bundaberg	SURFACE RL	5.82 m
JOB NO:	J000800	CONTRACTOR:	Geodrill
		DRILL RIG:	Hydra Power Scout
		INCLINATION:	-90° HOLE DIA. 100 mm

SHEET	2 OF 3
LOGGED:	AS
LOGGED DATE:	14/11/18
CHECKED:	AS
CHECKED DATE:	26/11/18

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
RR	H	Not Encountered	8			CL	SILTY CLAY (INDURATED/CEMENTED): low plasticity, pale grey, with trace of fine sand	M	H	
WB	L		9	9.00 -3.18	SPT 9.00-9.45 m 6/5/5 N = 10	SC	CLAYEY SAND (INDURATED/CEMENTED): fine to coarse grained, pale grey		L / MD	
			10	10.20 -4.38	SPT 10.50-10.95 m 6/9/11 N = 18	CI	SANDY CLAY (INDURATED/CEMENTED): low plasticity, dark grey, fine to coarse grained sand, with some fine grained angular to sub angular gravel		VSt	
			11							
			12	12.00 -6.18	SPT 12.00-12.45 m 4/4/4 N = 8	SC	CLAYEY SAND (INDURATED/CEMENTED): fine to coarse grained, orange brown		L	
			13		SPT 13.50-13.95 m 3/2/2 N = 4					
			14							
			15	15.00 -9.18	SPT 15.00-15.45 m 2/3/4 N = 7		Becoming pale grey and orange brown			
			16							

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REPORT OF BOREHOLE: BH107

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435889.2 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250543.0 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling: METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	Sampling: SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	Field Material Description: SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16					SC	CLAYEY SAND (INDURATED/CEMENTED): fine to coarse grained, orange brown	M	L	
					SPT 16.50-16.95 m 3/4/5 N = 9 does not drill like a gravel deposit, drills like a rock							16.50: does not drill like a gravel deposit, drills like a rock
			17									
			18		SPT 18.00-18.45 m 5/6/8 N = 14							
				18.30 -12.48				GW-GC	GRAVEL (INDURATED/CEMENTED): fine to medium grained, pale grey, with band of sub-rounded to rounded gravel		MD	
			19									
					SPT 19.50-19.95 m 3/4/4 N = 8						L	
				19.95								
			20						END OF BOREHOLE @ 19.95 m TARGET DEPTH BACKFILLED			
			21									
			22									
			23									
			24									

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core consultants pty ltd

REPORT OF BOREHOLE: BH108

CLIENT: CDM Smith
PROJECT: Proposed Levee
LOCATION: East Bundaberg
JOB NO: J000800

EAST: 435868.9 m
NORTH: 7250568.2 m
SURFACE RL 5.82 m
CONTRACTOR: Geodrill
DRILL RIG: Hydra Power Scout
INCLINATION: -90° HOLE DIA. 100 mm

LOGGED: AS
LOGGED DATE: 15/11/18
CHECKED: AS
CHECKED DATE: 26/11/18

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT (0–2.5 m)	L	Not Encountered	0	5.82		SM	SILTY SAND (FILL): fine grained, brown	M	L	
				0.20 / 5.62	SPT 1.50-1.95 m 2/2/1 N = 3	SM	SAND (FILL): black, ash fill	D	VL	
				1.90 / 3.92		CH	SILTY CLAY (ALLUVIUM): high plasticity, brown orange brown, and dark grey	M	F	
WB (2.5–8 m)	L			3.00 / 2.82	U50 3.00-3.45 m PP 3.00 m =200 kPa; U50 4.50-4.95 m PP 4.50 m =120 kPa		Grey, orange brown and brown, with trace fine sand		VSt	
				4.95 / 0.87			Becoming dark grey and orange brown		St	
				5.80 / 0.02	SPT 6.00-6.45 m WOH N = 0 PP 6.00 m =80 kPa; U50 7.50-7.95 m PP 7.50 m =80 kPa (change of strata within U50 sample)	CH	SILTY CLAY (MARINE CLAY): high plasticity, grey, dark grey and orange brown, with strong hydrocarbon odour in marine clay		F	
			8							

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REPORT OF BOREHOLE: BH108

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435868.9 m		
PROJECT:	Proposed Levee	NORTH:	7250568.2 m	SHEET	2 OF 3
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED:	AS
JOB NO:	J000800	CONTRACTOR:	Geodrill	LOGGED DATE:	15/11/18
		DRILL RIG:	Hydra Power Scout	CHECKED:	AS
		INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8			CH	SILTY CLAY (MARINE CLAY): high plasticity, grey, dark grey and orange brown, with strong hydrocarbon odour in marine clay	M	F	
			9		SPT 9.00-9.45 m WOH N = 0 PP 9.00 m =60 kPa					
				9.80 / -3.98			Grey, dark grey and orange brown, with trace fine sand			
			10	10.30 / -4.48	SPT 10.50-10.95 m 1/2/2 N = 4	SC	CLAYEY SAND (ELLIOT FORMATION): fine to coarse grained, grey, with some silt		L	
			11	11.70 / -5.88		CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, blue green, dark brown, and brown, fine to coarse grained sand, with some medium to coarse grained gravel		F	
			12		SPT 12.00-12.45 m 4/4/4 N = 8					
			13	12.90 / -7.08			Becoming orange brown and brown, no gravel present			
					SPT 13.50-13.95 m 4/3/4 N = 7					
			14	14.70 / -8.88			Pale grey, with some fine to coarse grained angular gravel			
			15		SPT 15.00-15.45 m 5/4/4 N = 8					
			16							

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REPORT OF BOREHOLE: BH108

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435868.9 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250568.2 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16					CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, blue green, dark brown, and brown, fine to coarse grained sand, with some medium to coarse grained gravel	M	F	
				16.50 -10.68	SPT 16.50-16.95 m 5/5/10 N = 15				Becoming orange brown, pale grey and brown		St / VSt	
			17									
			18	18.00 -12.18	SPT 18.00-18.45 m 11/5/5 N = 10			GP	GRAVEL (ELLIOT FORMATION): fine to coarse subangular to rounded, pale grey and brown, becomes stiff		MD	
			19		SPT 19.50-19.95 m 17/21/16 N = 37						D	
				19.95					END OF BOREHOLE @ 19.95 m TARGET DEPTH BACKFILLED			
			20									
			21									
			22									
			23									
			24									

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core consultants pty ltd

REPORT OF BOREHOLE: BH109

CLIENT:	CDM Smith	EAST:	435788.5 m	SHEET	1 OF 2
PROJECT:	Proposed Levee	NORTH:	7250696.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.03 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling | **Sampling** | **Field Material Description**

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT (0–2.5 m)	L	Not Encountered	0	7.03		SM	SAND (FILL): brown	M	L	
				0.20 / 6.83		CI	SILTY CLAY (FILL): medium plasticity, brown and red brown, with ash fragments		L	
			1	1.20 / 5.83		SM	SILTY SAND (FILL): red brown, with some ash fragments		MD	
				1.40 / 5.63	SPT 1.50-1.95 m 3/5/6 N = 11		Becoming orange brown		MD	
			2	2.10 / 4.93		CI	SILTY CLAY (ALLUVIUM): high plasticity, red brown, orange brown and dark grey		St	
WB (2.5–8 m)			3		SPT 3.00-3.45 m 4/5/6 N = 11				St	
			4	4.20 / 2.83			Becoming dark grey and orange brown		St	
					SPT 4.50-4.95 m 12/13/15 N = 28				VSt	
			5–6		SPT 6.00-6.45 m 0/2/2 N = 4				VSt / F	
			7	7.00 / 0.03		CI	SILTY CLAY (ELLIOT FORMATION): high plasticity, pale grey and orange		H	
					U50 7.50-7.95 m PP 7.50 m =550 kPa				H	
			8							

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REPORT OF BOREHOLE: BH109

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435788.5 m		
PROJECT:	Proposed Levee	NORTH:	7250696.5 m	SHEET	2 OF 2
LOCATION:	East Bundaberg	SURFACE RL	7.03 m	LOGGED:	AS
JOB NO:	J000800	CONTRACTOR:	Geodrill	LOGGED DATE:	15/11/18
		DRILL RIG:	Hydra Power Scout	CHECKED:	AS
		INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8 – 10.50	10.50	SPT 9.00-9.45 m 10/12/18 N = 30			CI	SILTY CLAY (ELLIOT FORMATION): high plasticity, pale grey and orange	M	H	
			10.50 – 16						END OF BOREHOLE @ 10.50 m TARGET DEPTH BACKFILLED			

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EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT REPORTS

DRILLING/EXCAVATION METHOD

AS*	Auger Screwing	RD	Rotary blade or drag bit	NQ	Diamond Core - 47 mm
AD*	Auger Drilling	RT	Rotary Tricone bit	NMLC	Diamond Core - 52 mm
*V	V-Bit	RAB	Rotary Air Blast	HQ	Diamond Core - 63 mm
*T	TC-Bit, e.g. ADT	RC	Reverse Circulation	HMLC	Diamond Core – 63mm
HA	Hand Auger	PT	Push Tube	BH	Tractor Mounted Backhoe
ADH	Hollow Auger	CT	Cable Tool Rig	EX	Tracked Hydraulic Excavator
DTC	Diatube Coring	JET	Jetting	EE	Existing Excavation
WB	Washbore or Bailer	NDD	Non-destructive digging	HAND	Excavated by Hand Methods

PENETRATION/EXCAVATION RESISTANCE

L **Low resistance.** Rapid penetration possible with little effort from the equipment used.

M **Medium resistance.** Excavation/possible at an acceptable rate with moderate effort from the equipment used.

H **High resistance** to penetration/excavation. Further penetration is possible at a slow rate and requires significant effort from the equipment.

R **Refusal or Practical Refusal.** No further progress possible without the risk of damage or unacceptable wear to the digging implement or machine.

These assessments are subjective and are dependent on many factors including the equipment power, weight, condition of excavation or drilling tools, and the experience of the operator.

WATER

▽	Water level at date shown	◁	Partial water loss
▷	Water inflow	◀	Complete water loss

GROUNDWATER NOT OBSERVED — The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

GROUNDWATER NOT ENCOUNTERED — The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11 N=18	4,7,11 = Blows per 150mm. N = Blows per 300mm penetration following 150mm seating
30/80mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
DS	Disturbed sample
BDS	Bulk disturbed sample
G	Gas Sample
W	Water Sample
FP	Field permeability test over section noted
FV	Field vane shear test expressed as uncorrected shear strength (s_v = peak value, s_r = residual value)
PID	Photoionisation Detector reading in ppm
PM	Pressuremeter test over section noted
PP	Pocket penetrometer test expressed as instrument reading in kPa
U63	Thin walled tube sample - number indicates nominal sample diameter in millimetres
WPT	Water pressure tests
DCP	Dynamic cone penetration test
CPT	Static cone penetration test
CPTu	Static cone penetration test with pore pressure (u) measurement

Ranking of Visually Observable Contamination and Odour (for specific soil contamination assessment projects)

R = 0	No visible evidence of contamination	R = A	No non-natural odours identified
R = 1	Slight evidence of visible contamination	R = B	Slight non-natural odours identified
R = 2	Visible contamination	R = C	Moderate non-natural odours identified
R = 3	Significant visible contamination	R = D	Strong non-natural odours identified

ROCK CORE RECOVERY

TCR = Total Core Recovery (%)

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100$$

SCR = Solid Core Recovery (%)

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100$$

RQD = Rock Quality Designation (%)

$$= \frac{\sum \text{Axial lengths of core} > 100\text{ mm}}{\text{Length of core run}} \times 100$$

METHOD OF SOIL DESCRIPTION USED ON BOREHOLE AND TEST PIT REPORTS

FILL

GRAVEL (GP or GW)

SAND (SP or SW)

SILT (ML or MH)

CLAY (CL, CI or CH)

ORGANIC SOILS (OL or OH or Pt)

COBBLES or BOULDERS

Combinations of these basic symbols may be used to indicate mixed materials such as sandy clay.

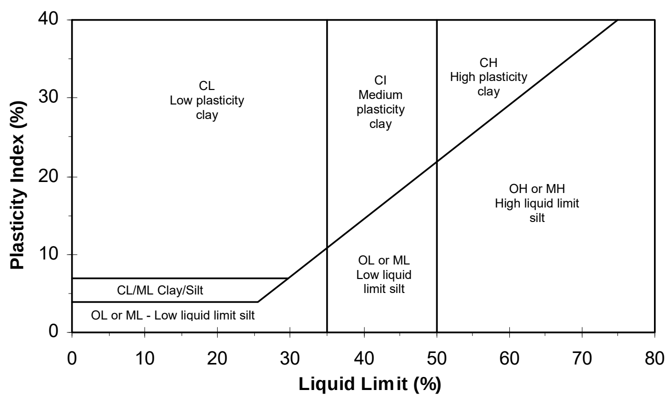
CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil and Rock is classified and described in Reports of Boreholes and Test Pits using the preferred method given in AS1726 – 1993, (Amdt1 – 1994 and Amdt2 – 1994), Appendix A. The material properties are assessed in the field by visual/tactile methods.

Particle Size

Major Division	Sub Division	Particle Size
BOULDERS		> 200 mm
COBBLES		63 to 200 mm
GRAVEL	Coarse	20 to 63 mm
	Medium	6.0 to 20 mm
	Fine	2.0 to 6.0 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties



MOISTURE CONDITION

AS1726 - 1993

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays & Silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition & may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

CONSISTENCY AND DENSITY

AS1726 - 1993

Symbol	Term	Undrained Shear Strength	Symbol	Term	Density Index %	SPT "N" #
VS	Very Soft	0 to 12 kPa	VL	Very Loose	Less than 15	0 to 4
S	Soft	12 to 25 kPa	L	Loose	15 to 35	4 to 10
F	Firm	25 to 50 kPa	MD	Medium Dense	35 to 65	10 to 30
St	Stiff	50 to 100 kPa	D	Dense	65 to 85	30 to 50
VSt	Very Stiff	100 to 200 kPa	VD	Very Dense	Above 85	Above 50
H	Hard	Above 200 kPa				

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.
SPT correlations are not stated in AS1726 – 1993, and may be subject to corrections for overburden pressure and equipment type.

core consultants pty ltd

TERMS FOR ROCK MATERIAL STRENGTH & WEATHERING AND ABBREVIATIONS FOR DEFECT DESCRIPTIONS

STRENGTH

Symbol	Term	Point Load Index, $Is_{(50)}$ (MPa)	Field Guide
EL	Extremely Low	< 0.03	Easily remoulded by hand to a material with soil properties.
VL	Very Low	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm can be broken by finger pressure.
L	Low	0.1 to 0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blows of pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
M	Medium	0.3 to 1	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
H	High	1 to 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken with pick with a single firm blow; rock rings under hammer.
VH	Very High	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
EH	Extremely High	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

ROCK STRENGTH TEST RESULTS

▼ Point Load Strength Index, $I_s(50)$, Axial test (MPa)

◀ Point Load Strength Index, $I_s(50)$, Diametral test (MPa)

Relationship between $I_s(50)$ and UCS (unconfined compressive strength) will vary with rock type and strength, and should be determined on a site-specific basis. UCS is typically 10 to 30 x $I_s(50)$, but can be as low as 5.

ROCK MATERIAL WEATHERING

Symbol		Term	Field Guide
RS		Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
EW		Extremely Weathered	Rock is weathered to such an extent that it has soil properties - i.e. it either disintegrates or can be remoulded, in water.
DW	HW	Distinctly Weathered	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores. In some environments it is convenient to subdivide into Highly Weathered and Moderately Weathered, with the degree of alteration typically less for MW.
	MW		
SW		Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength relative to fresh rock.
FR		Fresh	Rock shows no sign of decomposition or staining.

ABBREVIATIONS FOR DEFECT TYPES AND DESCRIPTIONS

Defect Type

B	Bedding parting
X	Foliation
C	Contact
L	Cleavage
J	Joint
SS/SZ	Sheared seam/zone (Fault)
CS/CZ	Crushed seam/zone (Fault)
DS/DZ	Decomposed seam/zone
IS/IZ	Infilled seam/zone
S	Schistocity
V	Vein

Coating or Infilling

Cn	Clean
Sn	Stain
Vr	Veneer
Ct	Coating or Infill

Planarity

Pl	Planar
Un	Undulating
St	Stepped

Roughness

Sl	Slickensided
Sm	Smooth
Ro	Rough

Vertical Boreholes – The dip (inclination from horizontal) of the defect is given.

Inclined Boreholes – The inclination is measured as the acute angle to the core axis.

Appendix B: Limitations

LIMITATIONS

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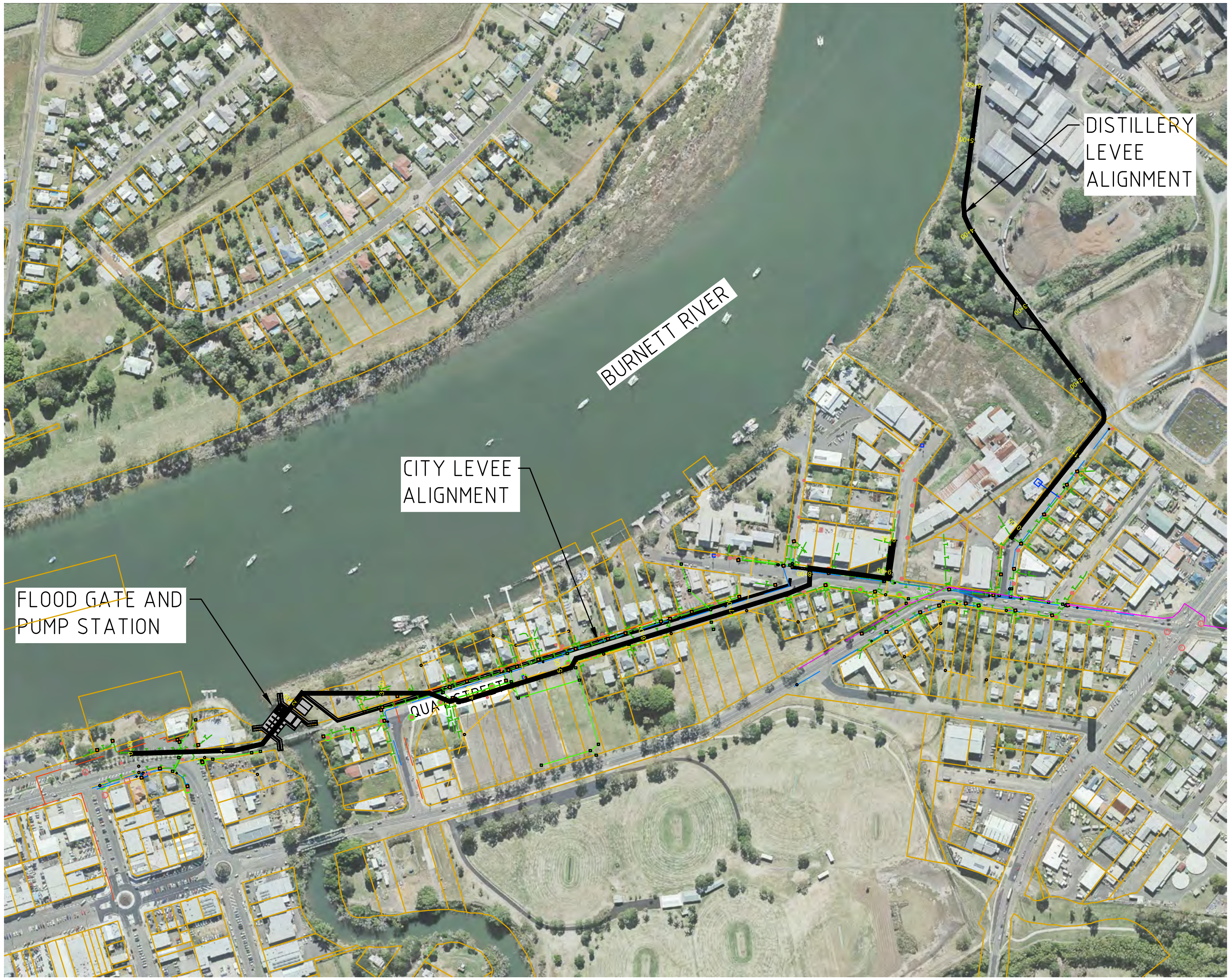
Appendix B Concept Design Drawings

BUNDABERG EAST LEVEE
CONCEPT DESIGN

N

LOCALITY PLAN
NTS



LOCATION PLAN
SCALE 1:2500

REVISIONS				
NO.	BY	DATE	DESCRIPTION	CHKD
			E08	
0	RR	9.08.18	BASE CASE	
A	APS	23.03.18	FOR INFORMATION	EOB

DESIGNED	SB	CHECKED	EOB
DRAWN	APS	CHECKED	EOB
APPROVED	SB	DATE	09.08.18
RPEQ NO. AND SIGNATURE		RPEQ 19034	

SCALE
0 100 200 300 400 500m
SCALE 1:5,000 AT A1 SHEET SIZE
A3 ORIGINAL SIZE

HORIZONTAL:
Map Grid of Australia Zone 56, using GDA94 datum

VERTICAL:
(m) AHD

DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

PROJECT NO. BEN170175.01
CLIENT DRG NO.

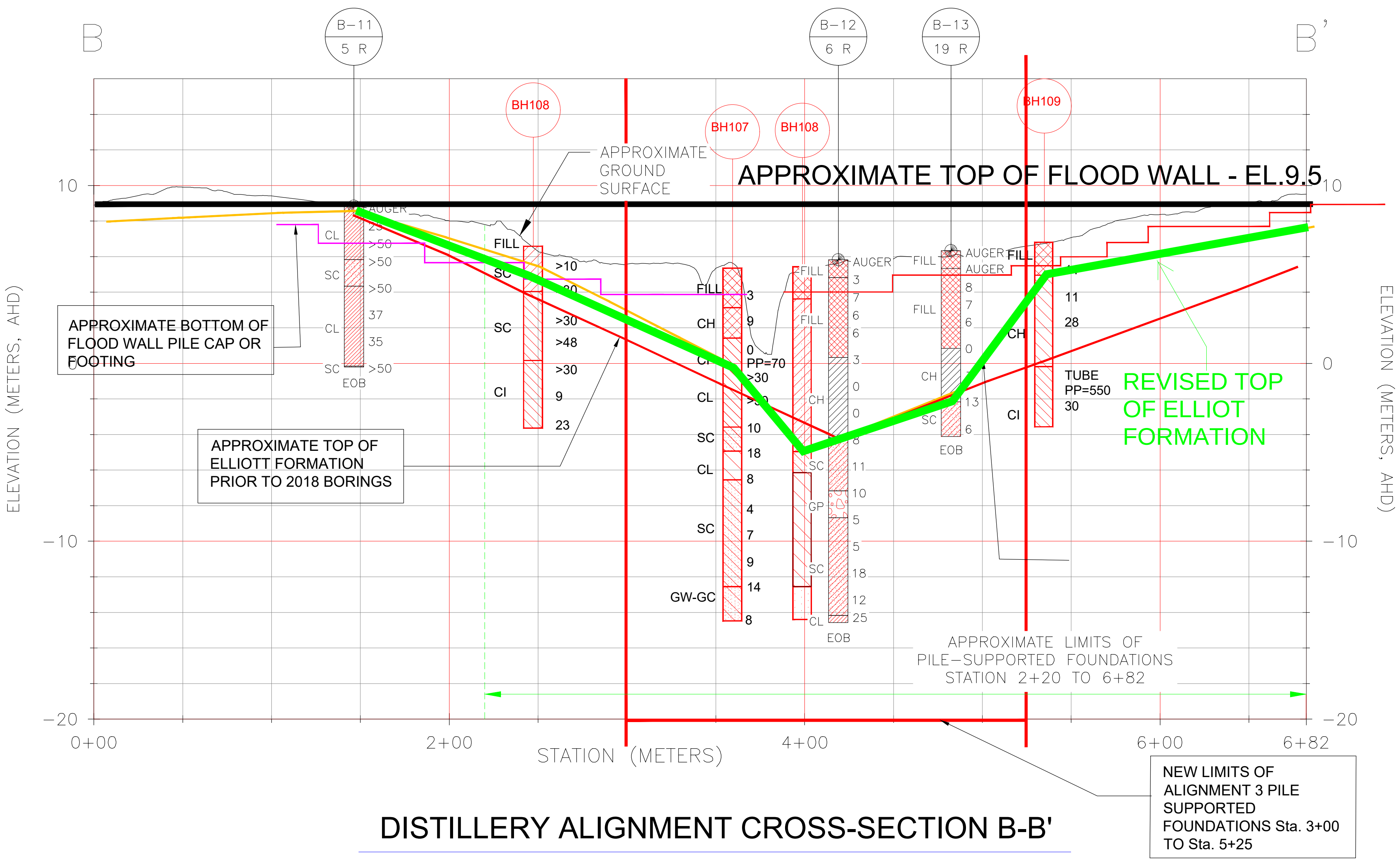
TITLE
BUNDABERG FLOOD LEVEE
COVERSHEET AND
MARCH 2019

STATUS
BASE CASE

CDM SMITH DRG NO.
BEN170175-01-GEN-1000

REV.
0

CAD FILE: \\bgafsvr1\DAS-Asia-Projects\Bundaberg East Levee\2019\working files\BEN170175.01-GEN-1000-Location Plan.dwg



DISTILLERY ALIGNMENT CROSS-SECTION B-B'

LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY–GRADED GRAVEL
- HIGH PLASTICITY CLAY
- ORGANIC HIGH PLASTICITY CLAY
- LOW PLASTICITY CLAY
- MUDSTONE

B–1	TEST BORING NUMBER
1 L/R	OFFSET DISTANCE, LEFT OR RIGHT (METERS)
13	STANDARD PENETRATION RESISTANCE N–VALUE (BL/0.3M)
▼	OBSERVED GROUNDWATER LEVEL
	USCS CLASSIFICATION CHANGE
CL	USCS CLASSIFICATION
EOB	END OF BORING

NOTES:

1. SUBSURFACE CONDITIONS SHOWN ARE BASED ON THOSE ENCOUNTERED AT THE TEST BORING LOCATIONS AND MAY VARY BETWEEN TEST BORING LOCATIONS. DURING DETAILED DESIGN, ADDITIONAL TEST BORINGS SHALL BE CONDUCTED TO FURTHER DELINEATE SUBSURFACE LAYERING.
2. REFER TO FIGURE 3–1 FOR ADDITIONAL NOTES.

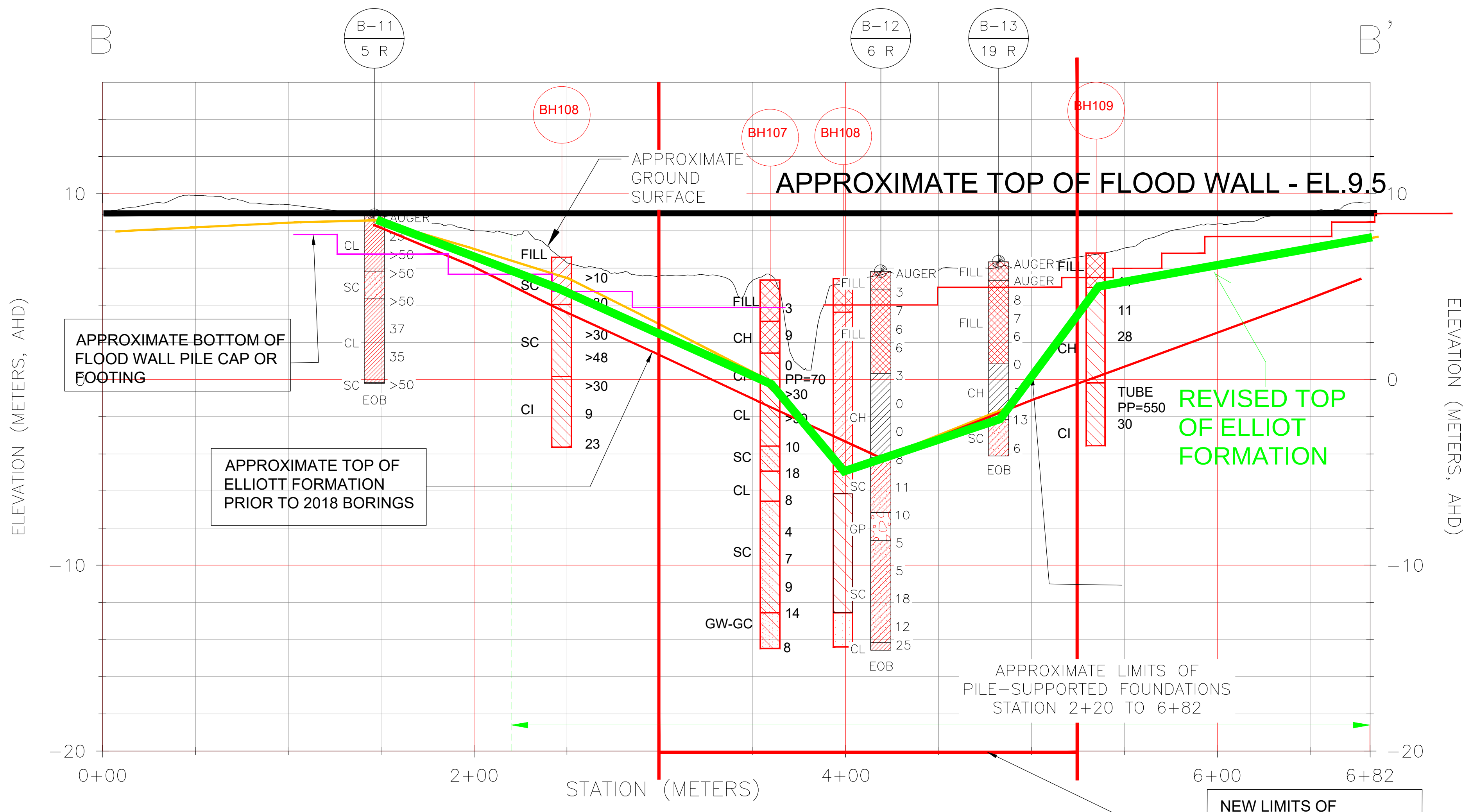
VERTICAL SCALE: 1M = 300M

0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M

0 30 60 150 240 300 m

FIGURE 3-3.
DISTILLERY ALIGNMENT CROSS-SECTION B-B'
MARCH 2018



DISTILLERY ALIGNMENT CROSS-SECTION B-B'

LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY-GRADED GRAVEL
- HIGH PLASTICITY CLAY
- ORGANIC HIGH PLASTICITY CLAY
- LOW PLASTICITY CLAY
- MUDSTONE

B-1 / 1 L/R — TEST BORING NUMBER / OFFSET DISTANCE, LEFT OR RIGHT (METERS)

13 — STANDARD PENETRATION RESISTANCE N-VALUE (BL/0.3M)

▼ — OBSERVED GROUNDWATER LEVEL

USCS CLASSIFICATION CHANGE

CL — USCS CLASSIFICATION

EOB — END OF BORING

NOTES:

1. SUBSURFACE CONDITIONS SHOWN ARE BASED ON THOSE ENCOUNTERED AT THE TEST BORING LOCATIONS AND MAY VARY BETWEEN TEST BORING LOCATIONS. DURING DETAILED DESIGN, ADDITIONAL TEST BORINGS SHALL BE CONDUCTED TO FURTHER DELINEATE SUBSURFACE LAYERING.
2. REFER TO FIGURE 3-1 FOR ADDITIONAL NOTES.

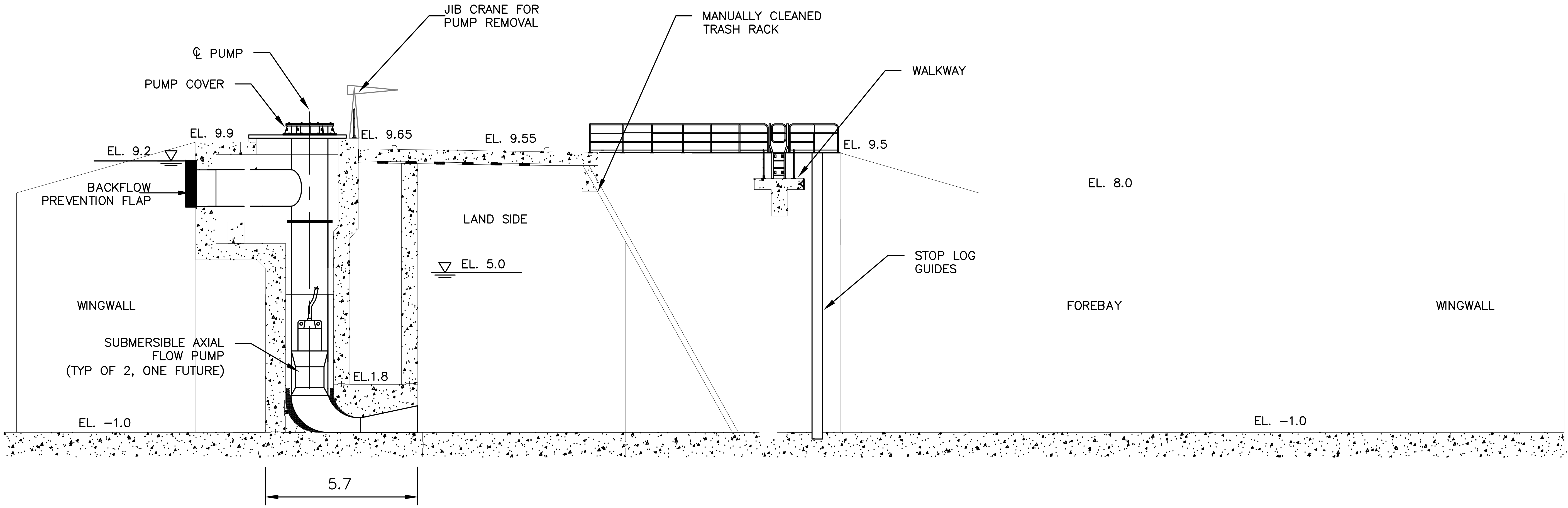
VERTICAL SCALE: 1M = 300M

0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M

0 30 60 150 240 300 m

FIGURE 3-3.
DISTILLERY ALIGNMENT CROSS-SECTION B-B'
MARCH 2018



SECTION 1 / M−1

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).

CAD FILE: \\bgalsvr1\DAS-Asia-Projects\Bundaberg East Levee\2018\working files\BEN170175.01-STR-6009-6015.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	NH	22.03.18	FOR INFORMATION	SB

DESIGNED	NH	CHECKED	SB
DRAWN	NH	CHECKED	EOB
APPROVED	SB	DATE	22.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:150
0 1 2 5
A3 ORIGINAL SIZE

DESIGNER: CDM Smith — cdmsmith.com

CLIENT: Queensland Government

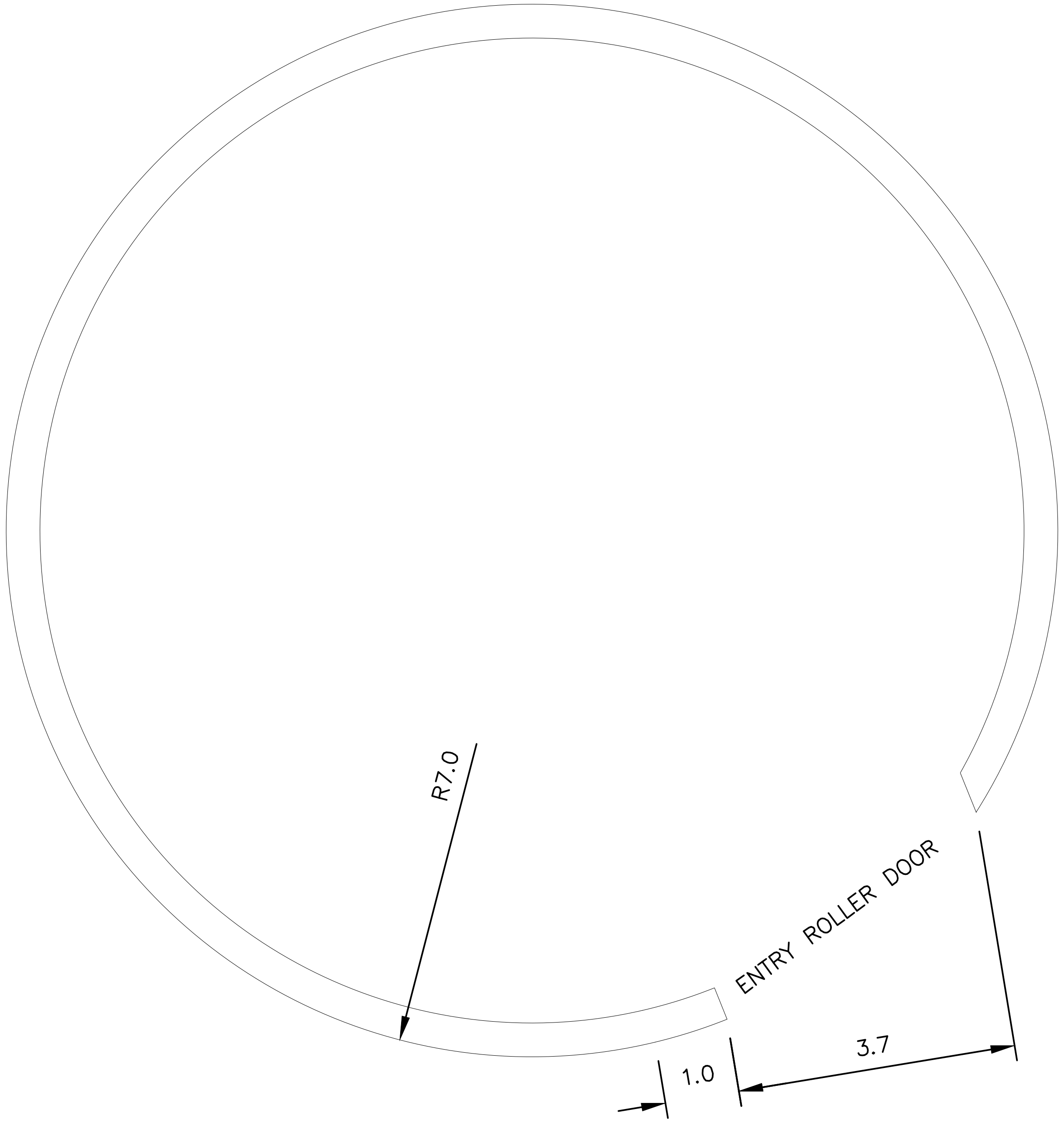
PROJECT NO. BEN170175-01

TITLE: BUNDABERG CREEK PUMPSTATION AND FLOOD GATE STRUCTURE SECTION 1

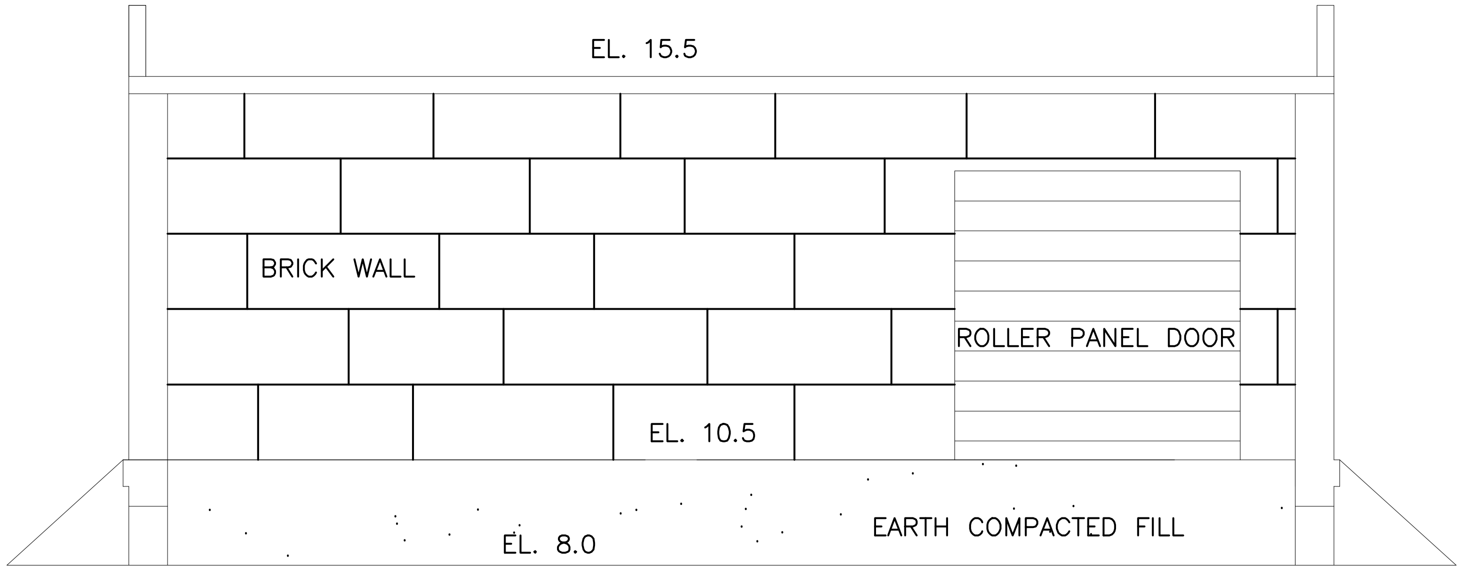
STATUS: BASE CASE

CDM SMITH DRG NO. BEN170175-01-DRG-STR-6010

REV. 0



PLAN



ELEVATION

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. DIMENSIONS OF BUILDING TO BE FURTHER DEVELOPED DURING DETAILED DESIGN BY ARCHITECT.

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	NH	22.03.18	FOR INFORMATION	SB

DESIGNED	NH	CHECKED	SB
DRAWN	NH	CHECKED	EOB
APPROVED	SB	DATE	22.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:100
0 1 2 5m
A3 ORIGINAL SIZE

DESIGNER: CDM Smith
cdmsmith.com

CLIENT: Queensland Government

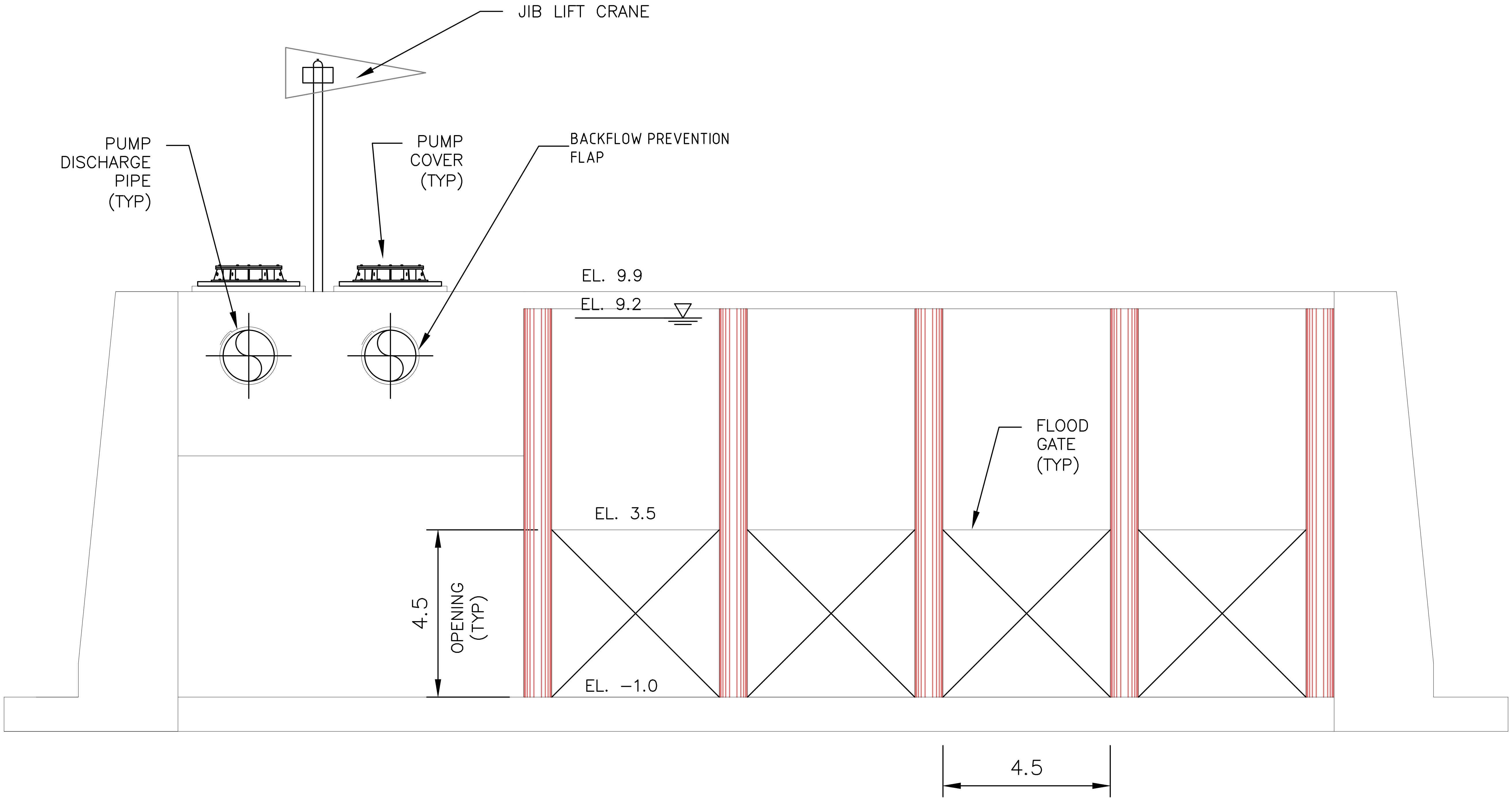
PROJECT NO. BEN170175-01

TITLE: BUNDABERG CREEK EQUIPMENT BUILDING PLAN AND ELEVATION

STATUS: BASE CASE

CDM SMITH DRG NO. BEN170175-01-DRG-STR-6012

REV. 0



SECTION 2 / M−1

NOTES:

1. FOOD FLAPS TO BE PROVIDED ON THE RIVER SIDE OF PUMP DISCHARGE PIPES.
2. DETAILS OF FLOOD GATES LITHERS(BASE MOUNTED ELECTRIC WIRE ROPE HOISTS).
3. GATE TYPES (VERTICAL LIFT GATES) PROVIDED WITHIN THE CONCEPT ENGINEERING REPORT.

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).

CAD FILE: \\bga1svr1\DAS-Asia-Projects\Bundaberg East Levee\2918\working files\BEN170175.01-STR-6499-6415.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	NH	22.03.18	FOR INFORMATION	SB

DESIGNED	NH	CHECKED	SB
DRAWN	NH	CHECKED	EOB
APPROVED	SB	DATE	22.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:50 (0 1 2 5m)
A3 ORIGINAL SIZE

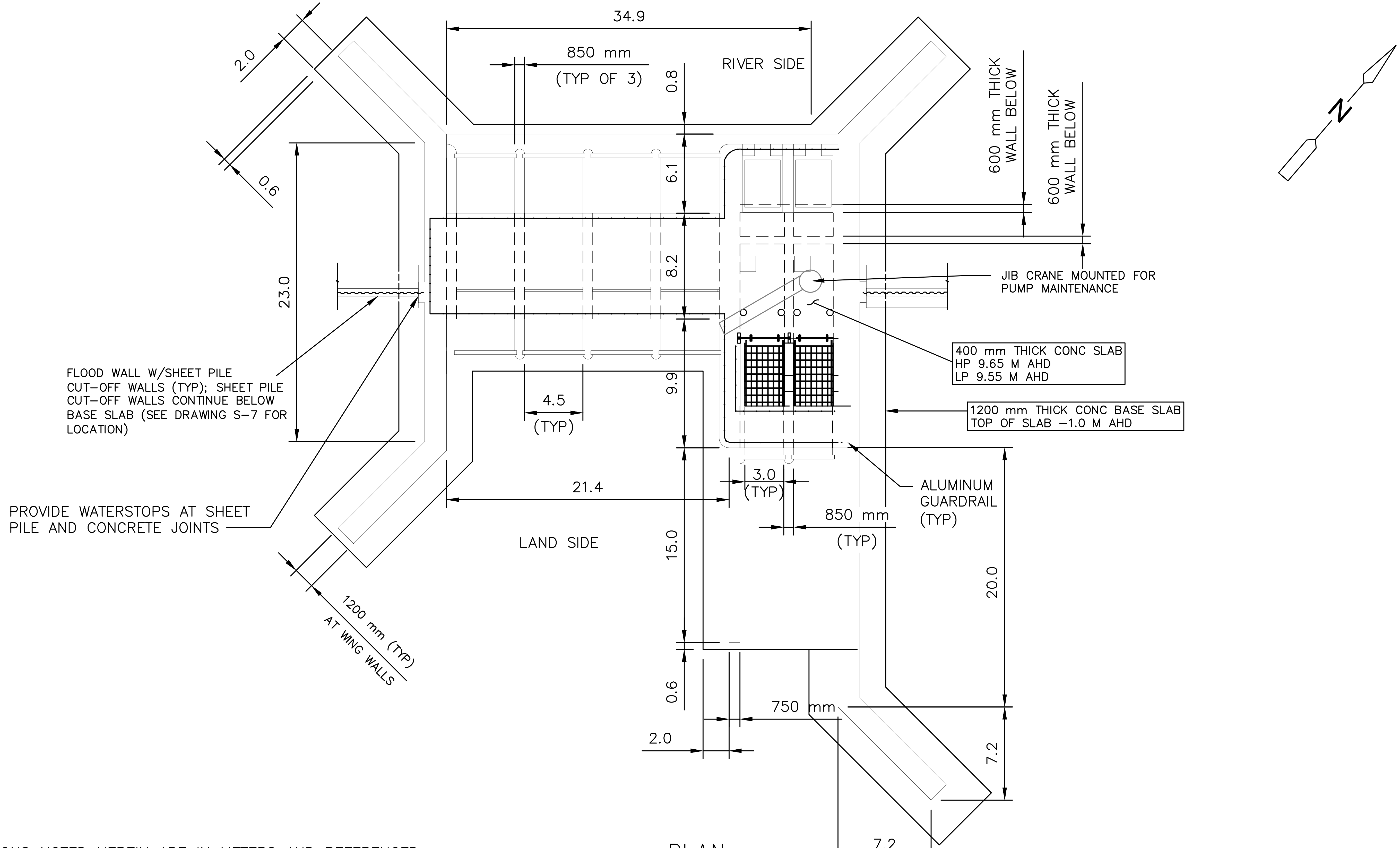
DESIGNER: CDM Smith — cdmsmith.com

CLIENT: Queensland Government

PROJECT NO. BEN170175-01

TITLE: BUNDABERG CREEK PUMPSTATION AND FLOOD GATE STRUCTURE SECTION 2

STATUS	CDM SMITH DRG NO.	REV.
BASE CASE	BEN170175-01-DRG-STR-6011	0



PLAN

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).

2. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.

3. SEE DRAWING S−7 FOR PILE LAYOUT.

CAD FILE: \\bga1svr1\DAS-Asia-Projects\Bundaberg East Levee\2018\working files\BEN170175.01-DRG-STR-6001.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE
1:300
0 5 15m
A3 ORIGINAL SIZE

DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

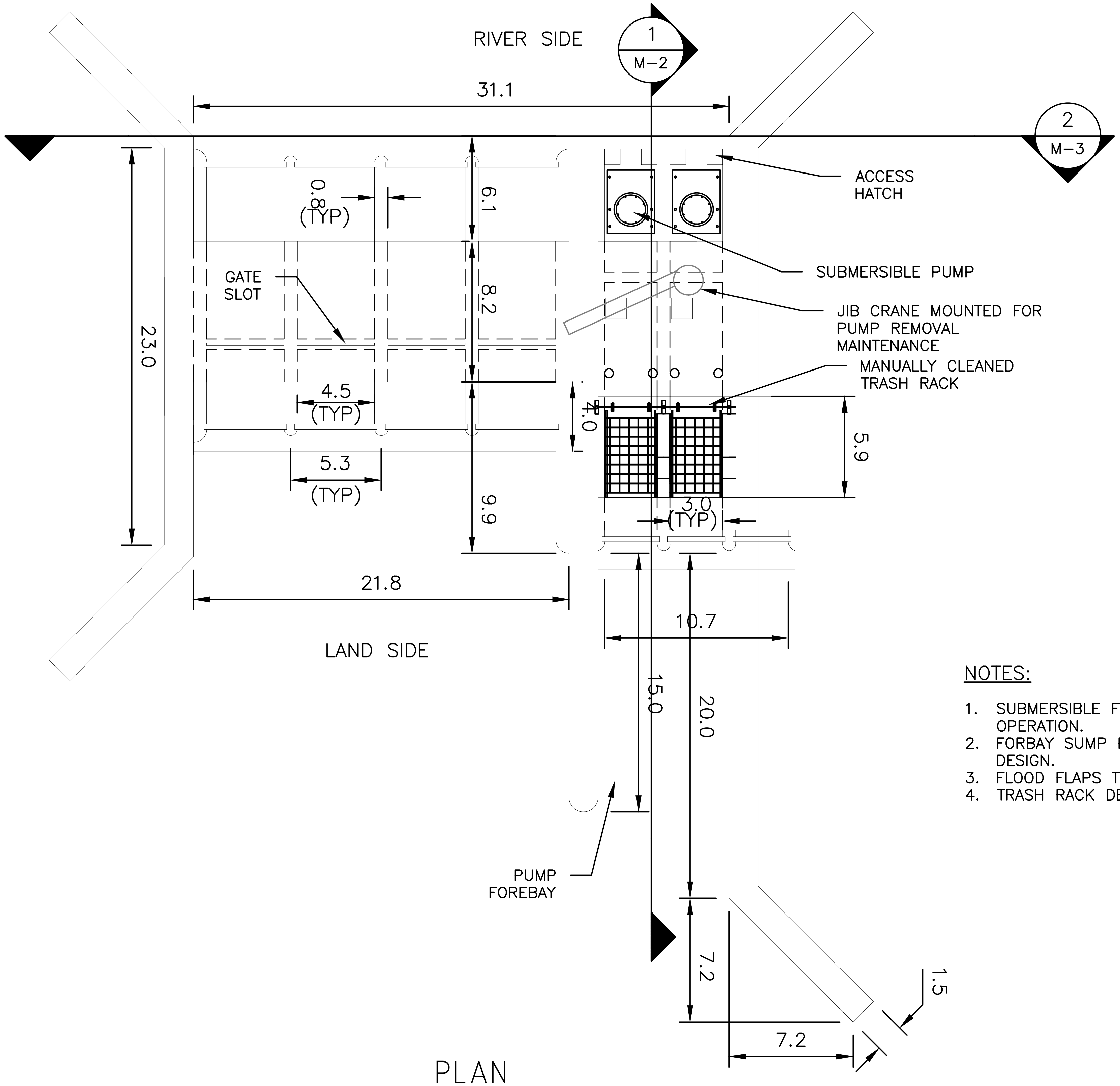
PROJECT NO. BEN170175-01

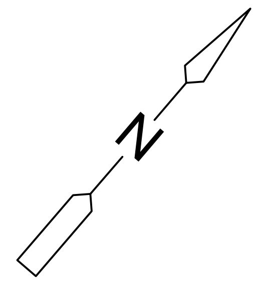
TITLE
BUNDABERG CREEK PUMP STATION AND FLOOD GATE STRUCTURUAL PLAN

STATUS FOR INFORMATION

CDM SMITH DRG NO. BEN170175-01-STR-6001

REV. 0





PLAN

NOTES:

1. SUBMERSIBLE FLOOD PUMP AND TRASH RACK SERVICING VIA MOBILE CRANE OPERATION.
2. FORBAY SUMP PUMP AND FURTHER DETAILS TO BE PROVIDED WITHIN DETAILED DESIGN.
3. FLOOD FLAPS TO BE PROVIDED ON RIVER SIDE OF PUMP DUSCHARGE PIPES.
4. TRASH RACK DESIGN CRITERIA PER CONCEPT ENGINEERING REPORT.

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	NH	22.03.18	FOR INFORMATION	SB

DESIGNED	NH	CHECKED	SB
DRAWN	NH	CHECKED	EOB
APPROVED	SB	DATE	22.03.18
RPEQ NO. AND SIGNATURE			

SCALE
1:300
0 5 10 15
A3 ORIGINAL SIZE

DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

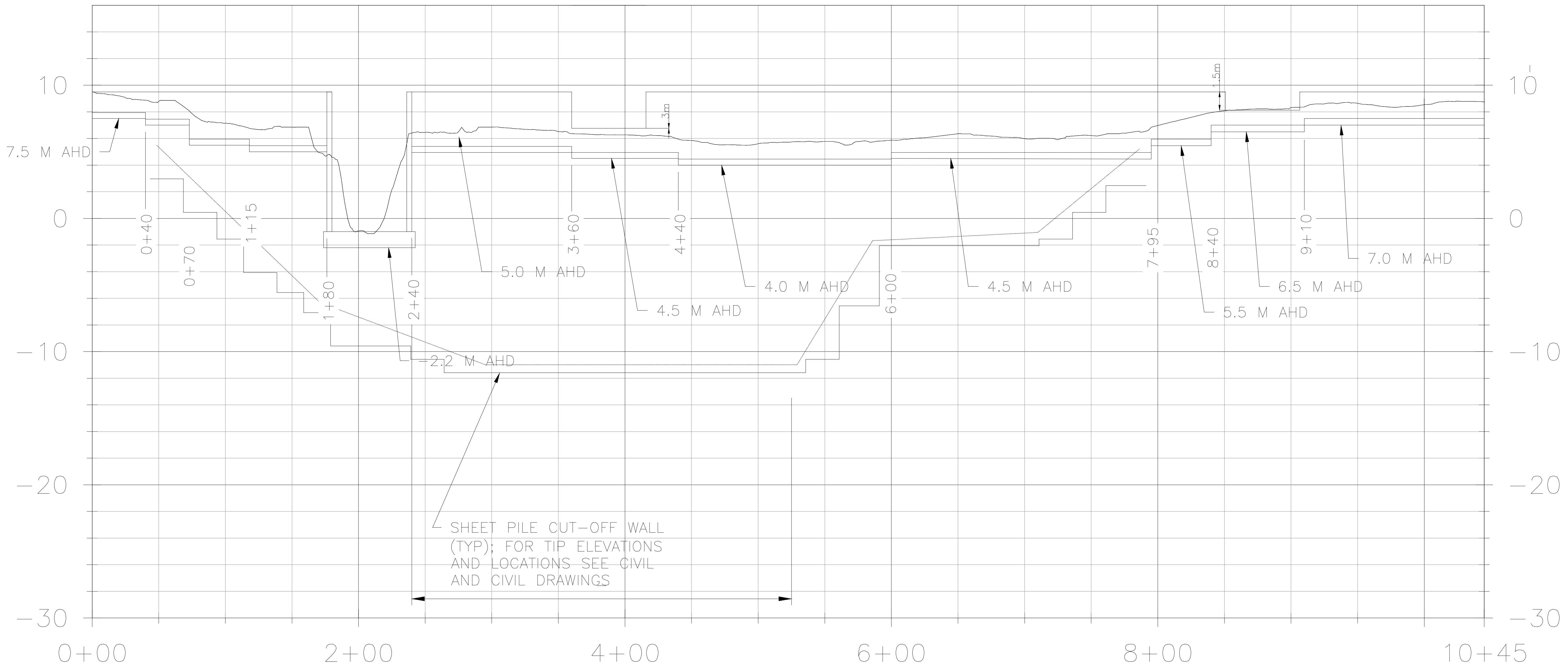
PROJECT NO. BEN170175-01

TITLE
BUNDABERG CREEK PUMP STATION
FLOOD GATE STRUCTURE
PLAN

STATUS BASE CASE

CDM SMITH DRG NO. BEN170175-01-STR-6009

REV. 0



NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. SHEET PILE CUT-OFF WALL FOR PROPOSED TIED DUAL SHEET PILES EMBEDDED SHALL BE A MINIMUM OF 0.5 METERS INTO THE ELLIOT FORMATION.
3. SHEET PILE CUT OFF WALL BELOW PROPOSED FLOOD WALL SHALL BE MINIMUM OF 3METERS BELOW THE BOTTOM OF PILE CAP
4. SHEET PILE CUT-OFF WALL BELOW PROPOSED LEVEE SHALL BE MINIMUM 5.5METERS BELOW THE LEVEE BOTTOM.
5. REFER TO DRAWING S-3 FOR FLOOD WALL PILE TIP EMBANKMENT LENGTHS IN ELLIOT FORMATION

STATIONING IN METERS

CITY ALIGNMENT CROSS-SECTION

CAD FILE: \\bogafsvr1\DAS-Asia-Projects\Bundaberg East Levee\2019\working files\Structural drawings\March 2019\SHEET-PILE-FIGURES C1 AND C2.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE
HORIZONTAL SCALE: 1M = 3000M
0 30 60 150m
VERTICAL SCALE: 1M = 300M
0 3 6 15m
A3 ORIGINAL SIZE

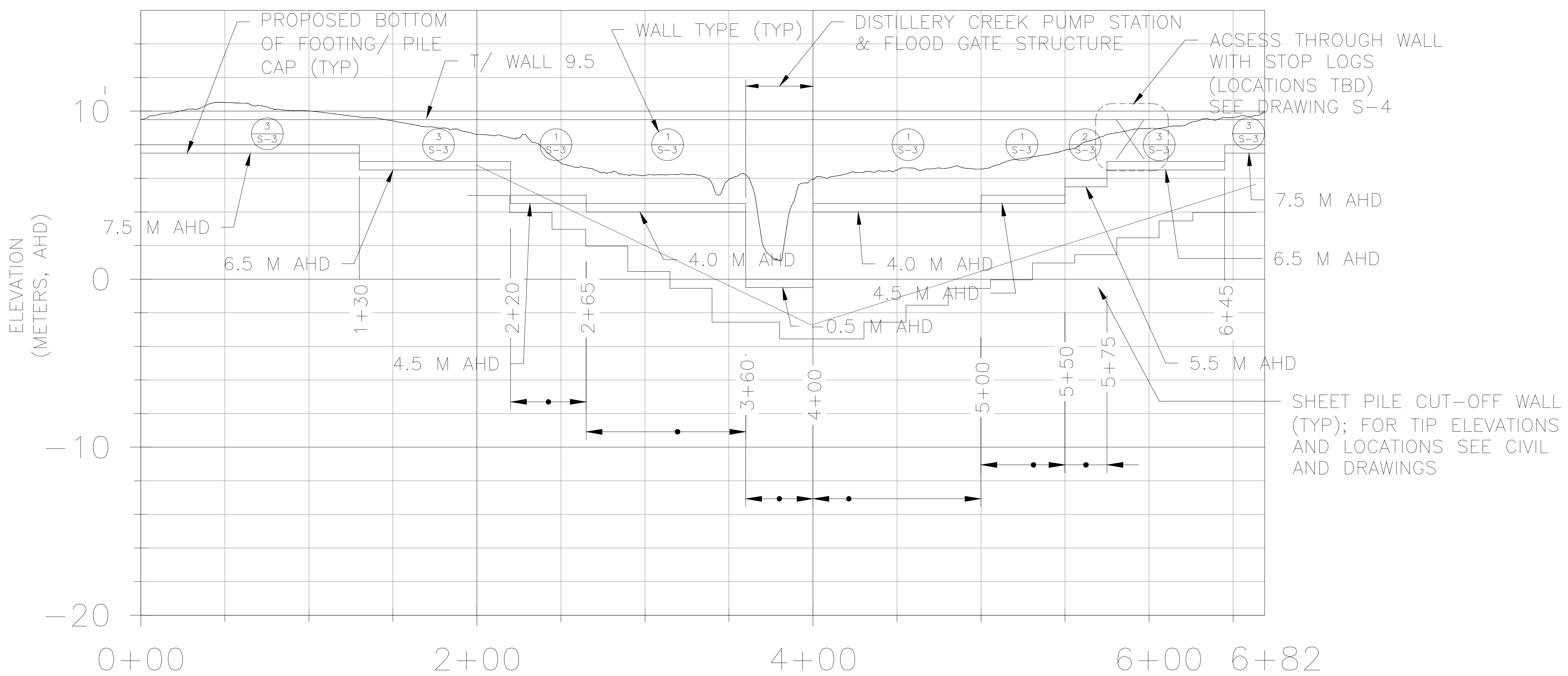
DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

PROJECT NO.

TITLE
CITY ALIGNMENT FLOOD WALL
CROSS-SECTION
MARCH 2019

STATUS: FOR INFORMATION
CDM SMITH DRG NO.: BEN170175-01-DRG-S-1
REV.: A



STATIONING IN METERS

DISTILLERY ALIGNMENT CROSS-SECTION

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. SHEET PILE CUT-OFF WALL FOR PROPOSED TIED DUAL SHEET PILES EMBEDDED SHALL BE A MINIMUM OF 0.5 METERS INTO THE ELLIOT FORMATION.
3. SHEET PILE CUT OFF WALL BELOW PROPOSED FLOOD WALL SHALL BE MINIMUM OF 3METERS BELOW THE BOTTOM OF PILE CAP
4. SHEET PILE CUT-OFF WALL BELOW PROPOSED LEVEE SHALL BE MINIMUM 5.5METERS BELOW THE LEVEE BOTTOM.
5. REFER TO DRAWING S-3 FOR FLOOD WALL PILE TIP EMBANKMENT LENGTHS IN ELLIOT FORMATION

NO.	BY	DATE	DESCRIPTION	CHKD
A	SW	23.03.18	FOR INFORMATION	

REVISIONS

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE
HORIZONTAL SCALE: 1M = 3000M
0 30 60 150m
VERTICAL SCALE: 1M = 300M
0 3 6 15m
A3 ORIGINAL SIZE

DESIGNER: CDM Smith cdmsmith.com

CLIENT: Queensland Government

PROJECT NO.

TITLE: DISTILLERY ALIGNMENT FLOOD WALL CROSS-SECTION MARCH 2019

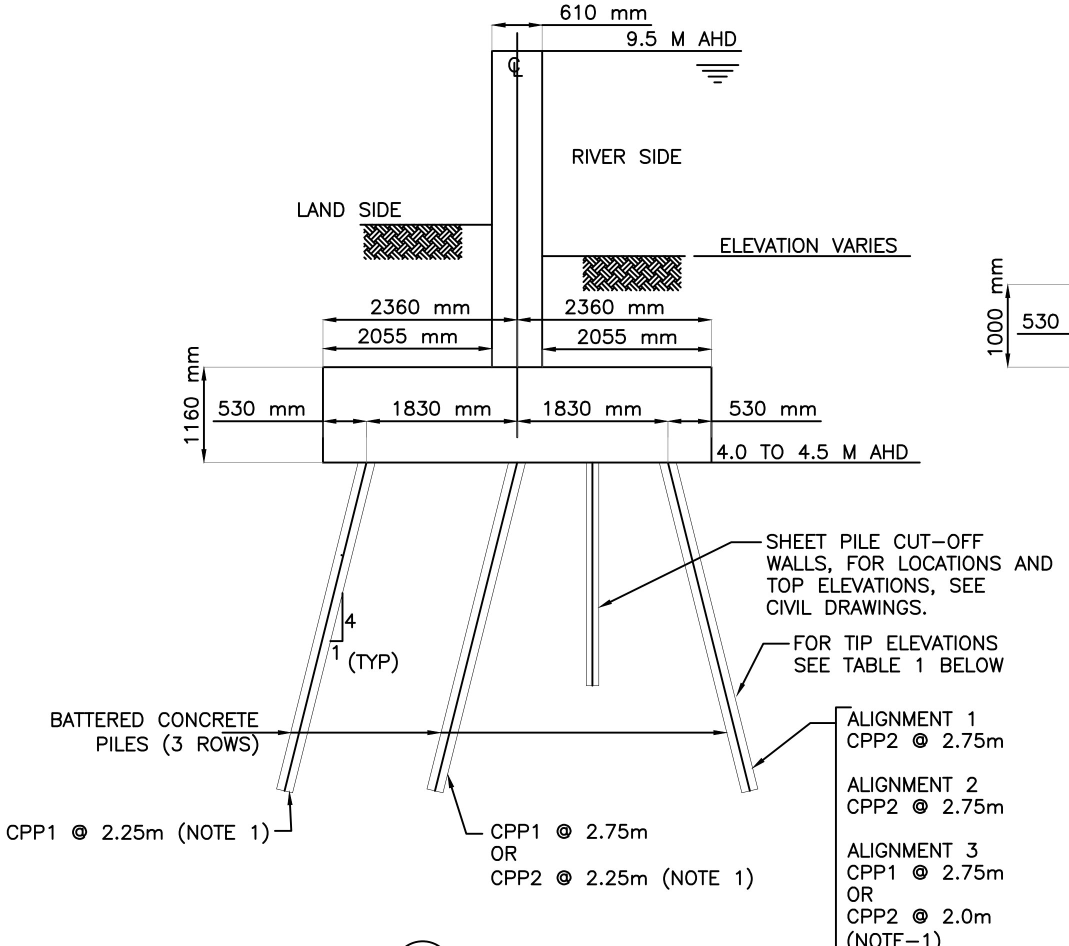
STATUS: FOR INFORMATION

CDM SMITH DRG NO.: BEN170175-01-DRG-S-2

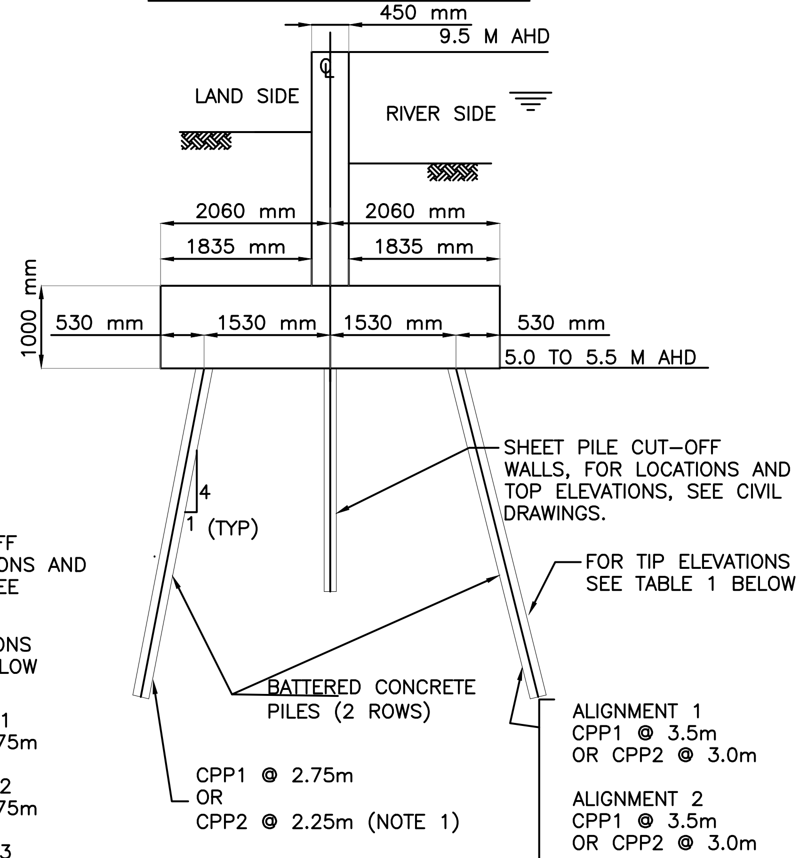
REV.: A

CAD FILE: \\bgafsvr1\DAS-Asia-Projects\Bundaberg East Levee\2019\working files\Structural drawings\March 2019\SHEET-PILE-FIGURES C1 AND C2.dwg

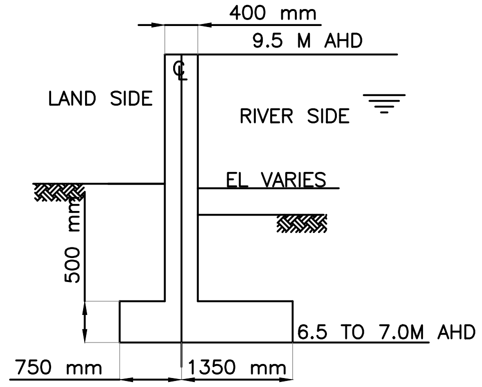
MAIN FLOOD WALL TYPES



1 WALL TYPE 1

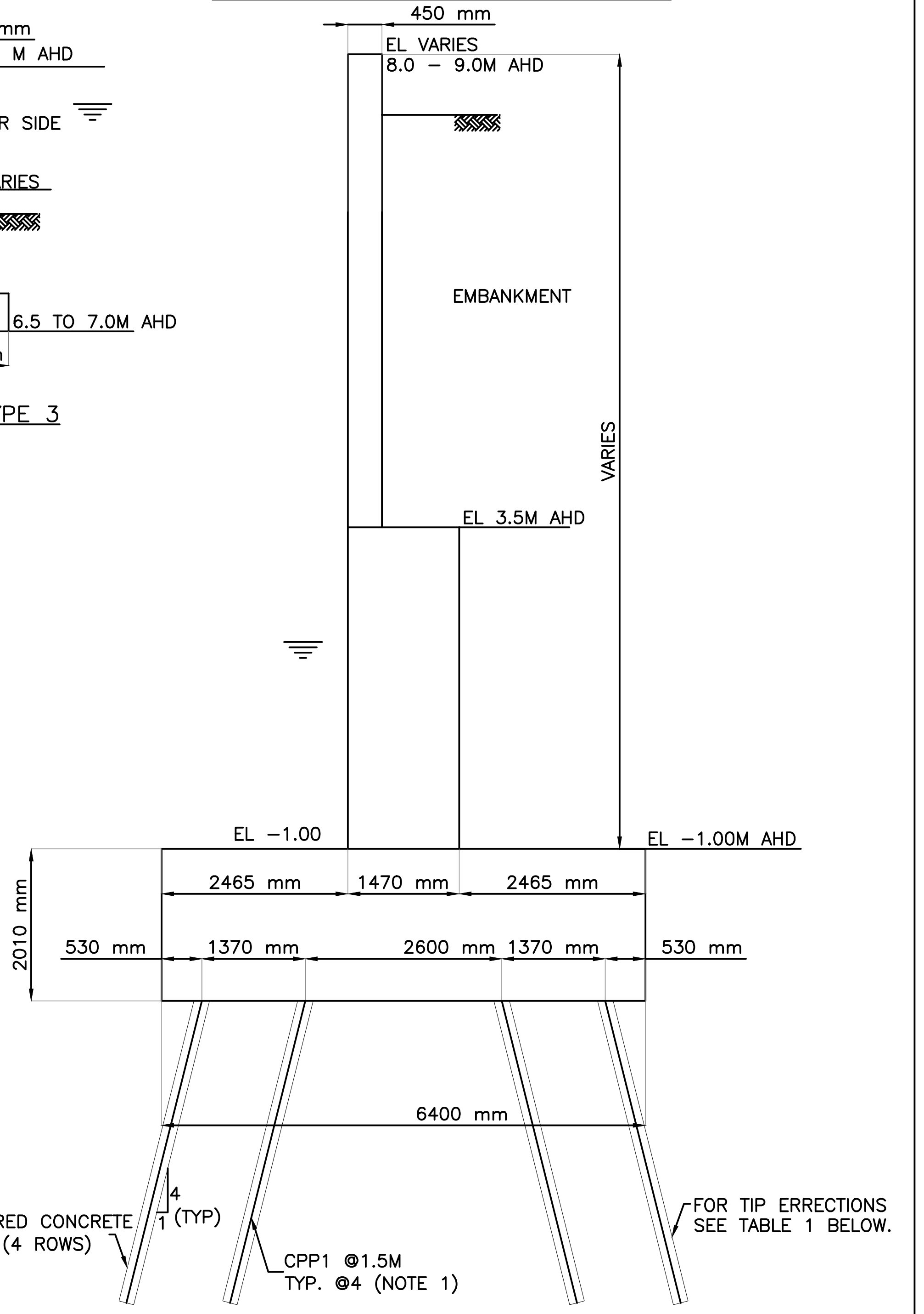


2 WALL TYPE 2



3 WALL TYPE 3

SALTWATER CREEK – WING WALL

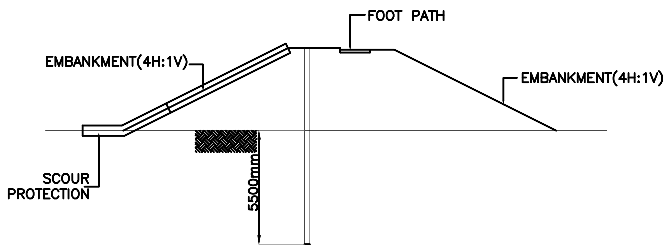


4 EXTERIOR WING WALL

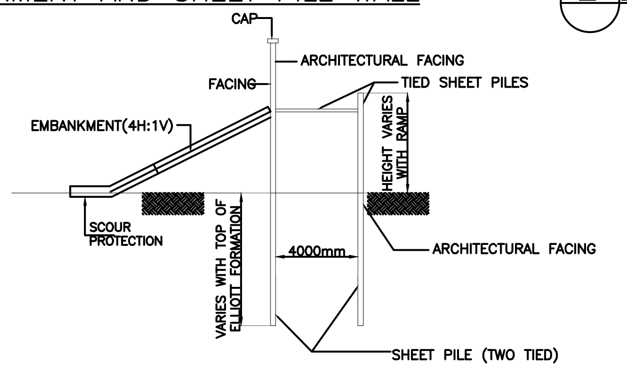
TABLE 1 PILE CAPACITY AND MINIMUM EMBEDMENT

FLOOD WALL ALIGNMENT STRUCTURE	STATION (M)	PILE TYPE	PILE CAPACITY (KN)	MAXIMUM EMBEDMENT IN ELLIOTT FORMATION (m)
FLOOD WALL ALIGNMENT 1 CITY ALIGNMENT	0+50 TO 3.75	CPP1	1000	8
		CPP2	750	5
FLOOD WALL ALIGNMENT 2 CITY ALIGNMENT	3.75 TO 8.75	CPP1	1000	17
		CPP2	750	12
FLOOD WALL ALIGNMENT 3 DISTILLERY CREEK ALIGNMENT	3+00 TO 5+25	CPP1	1000	12
		CPP2	750	9
SALTWATER CREEK PUMP STATION	NOT APPLICABLE	CPP1	1000	12
		B1CPP1	2000	9
		B1CPP2	4000	25

PARK EARTH EMBANKMENT AND SHEET PILE WALL



PARK CROSS SECTION A TO B



RAMP CROSS SECTION B TO C

NOTES:

1. SHEET PILE CUT–OFF WALL BELOW PROPOSED FLOOD WALL SHALL BE A MINIMUM OF 3M BELOW THE BOTTOM OF PILE CAP.
2. SHEET PILE CUT–OFF WALL FOR PROPOSED TIED DUAL SHEET PILES SHALL BE EMBEDDED A MINIMUM OF 0.5M INTO THE ELLIOTT FORMATION.
3. FLOOD WALL TOE DRAIN SHALL BE 1M BY 1M CRUSHED STONE DRAIN WITH PERFORATED HDPE PIPE AND SAND FILTER. DURING DETAILED DESIGN, ENGINEER WILL EVALUATE ALTERNATE DRAINAGE OPTIONS TO CONTROL SEEPAGE.

CAD FILE: \\bgstorr\dss-sala-project\Bundaberg East Levee\2019\working files\Structural drawings\March 2019\S3-FLOODWALL - TYP ES.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE: NTS

A3 ORIGINAL SIZE

DESIGNER: CDM Smith
cdmsmith.com

CLIENT: Queensland Government

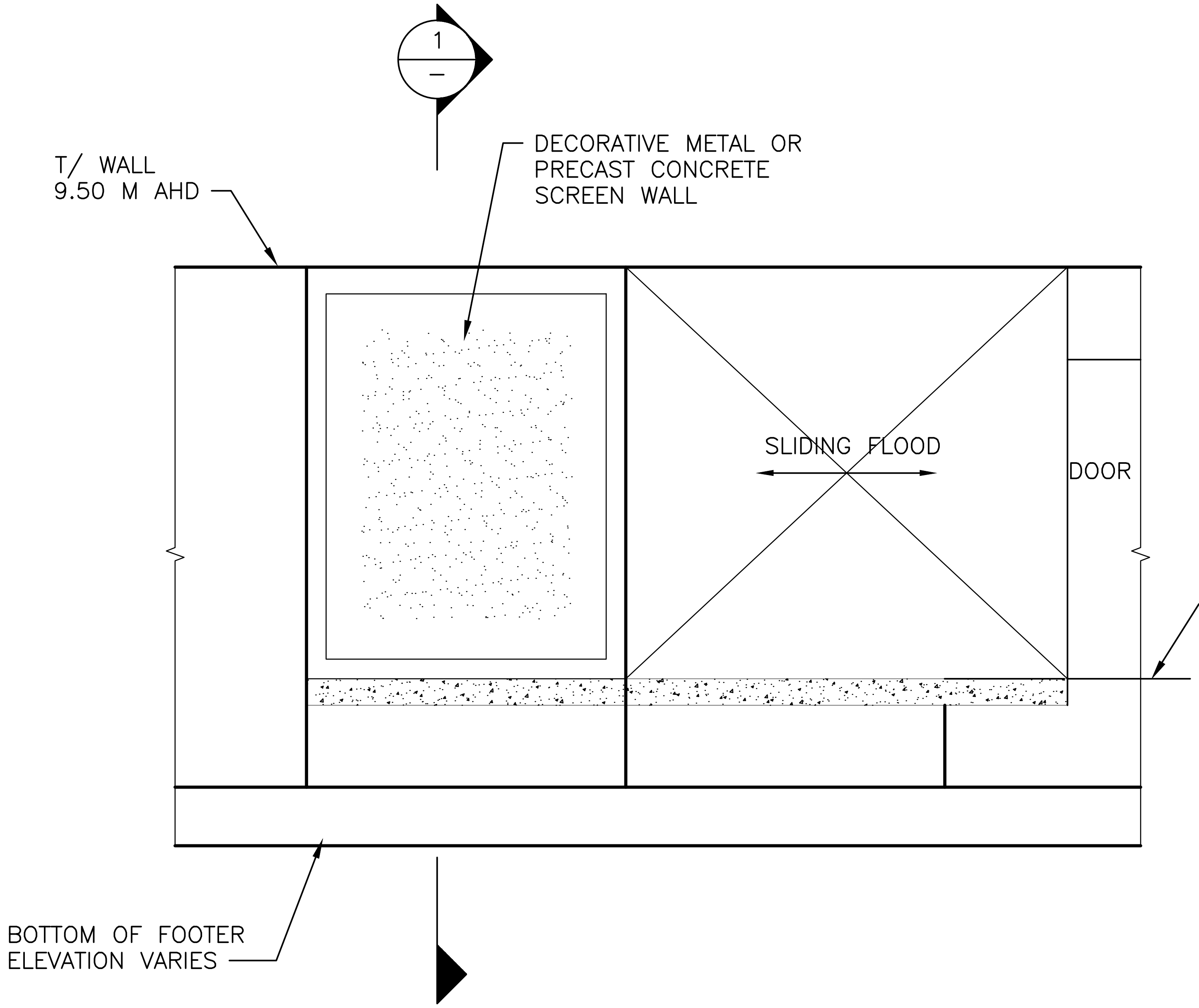
PROJECT NO. BEN170175-01

TITLE: FLOOD WALL TYPICAL SECTIONS MARCH 2019

STATUS: BASE CASE

CDM SMITH DRG NO. BEN170175-01-DRG-S3

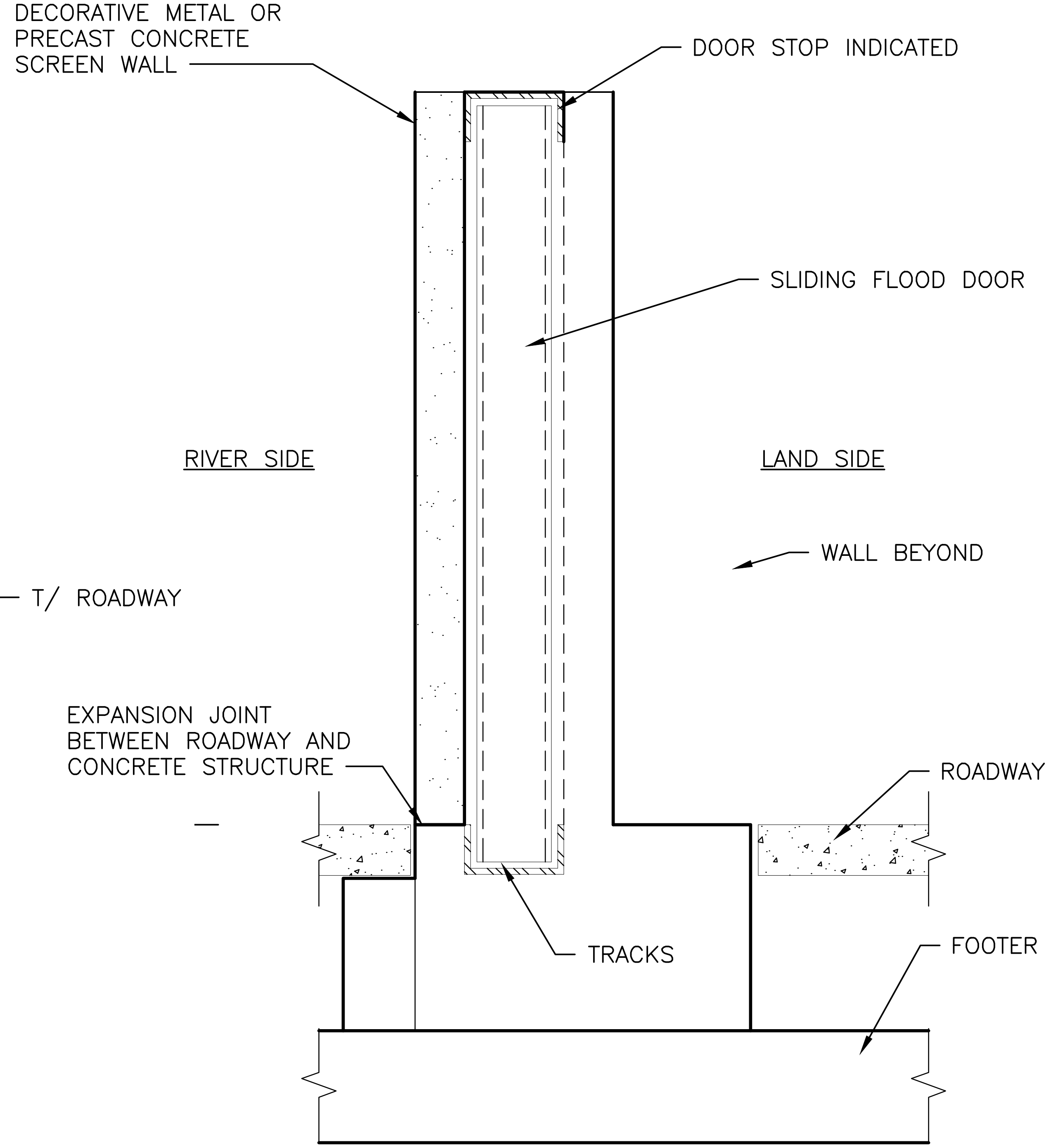
REV. 0



ACCESS THROUGH WALL (SLIDING FLOOD DOORS)

ELEVATION

NTS



SECTION 1 –

NTS

NOTES:

1. DETAIL TO BE PREPARED BY VENDOR

CAD FILE: \\bga1svr1\DAS-Asia-Projects\Bundaberg East Levee\2019\working files\Structural drawings\March 2019\S4 - STRUCTURAL SECTIONS.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE: NTS

A3 ORIGINAL SIZE

DESIGNER: CDM Smith — cdmsmith.com

CLIENT: Queensland Government

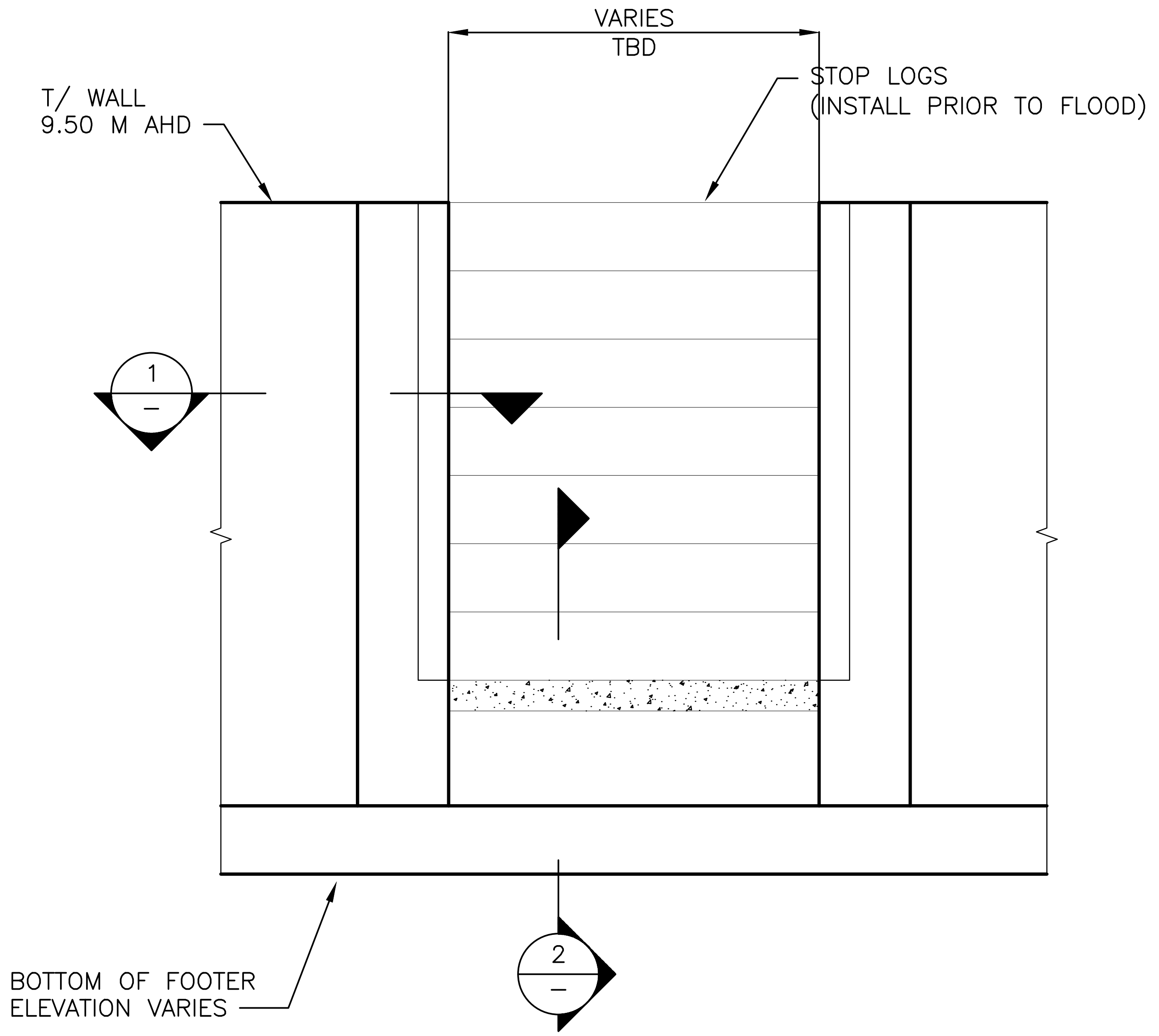
PROJECT NO.

TITLE: WALL ACCESS DETAILS
SLIDING FLOOD DOORS

STATUS: FOR INFORMATION

CDM SMITH DRG NO.: BEN170175-01-DRG-S-4

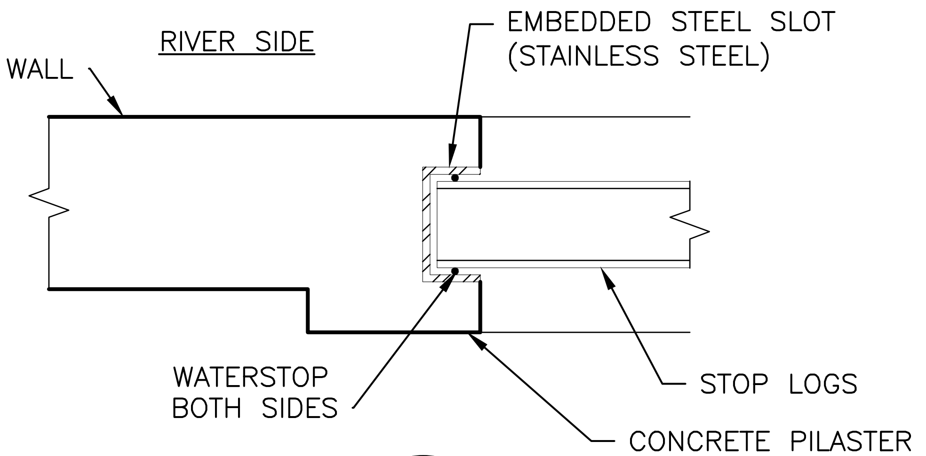
REV.: A



ACCESS THROUGH WALL (STOP LOG OPENINGS AS REQUIRED)

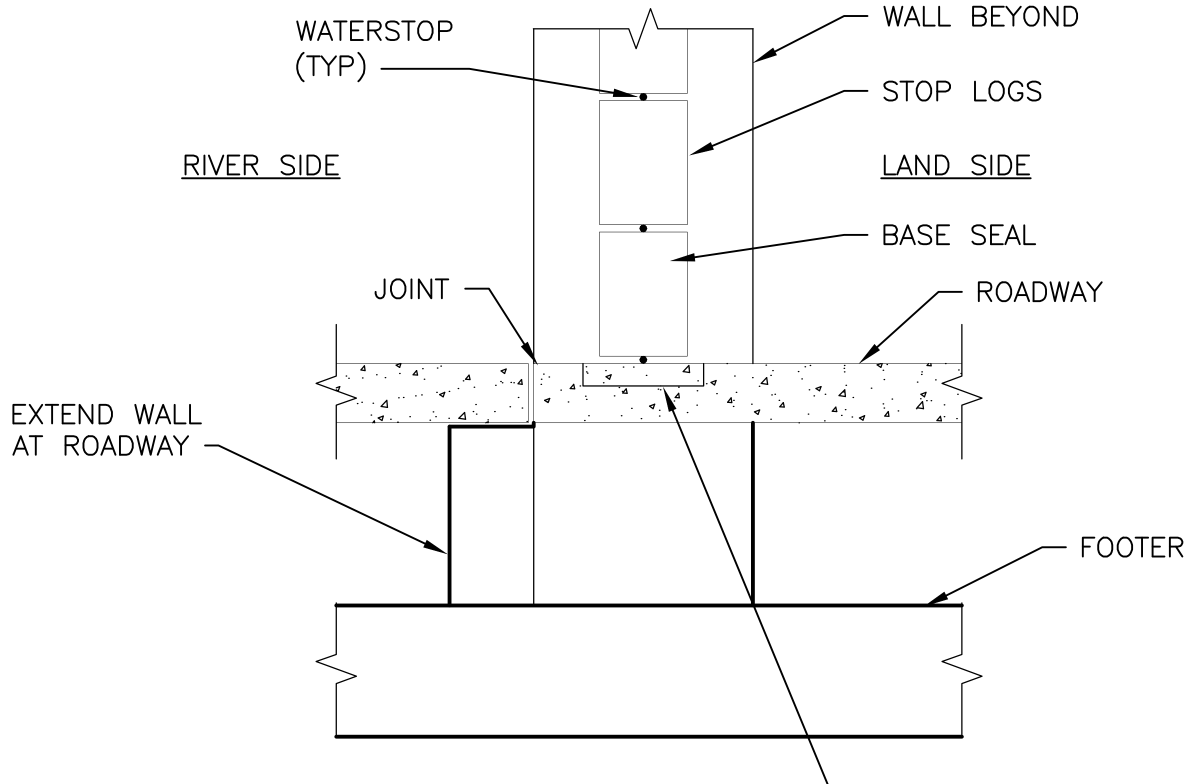
ELEVATION

NTS



SECTION 1 –

NTS



SECTION 2 –

NTS

CAD FILE: \\bga1svr1\DAS-Asia-Projects\Bundaberg East Levee\2019\working files\Structural drawings\March 2019\S5 - STRUCTURAL SECTIONS.dwg

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE: NTS

A3 ORIGINAL SIZE

DESIGNER: CDM Smith
cdmsmith.com

CLIENT: Queensland Government

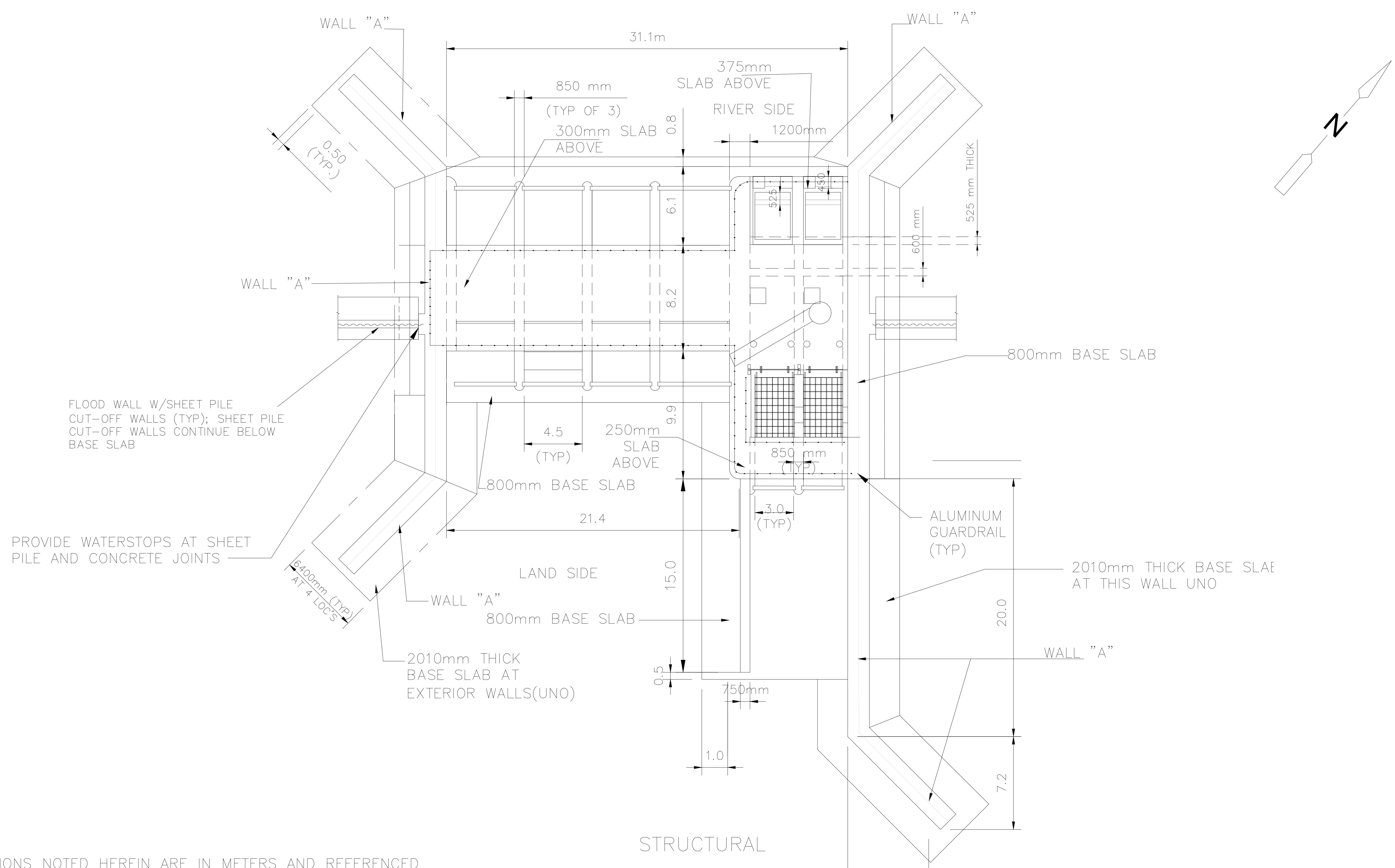
PROJECT NO.

TITLE: WALL ACCESS DETAILS
STOP LOGS

STATUS: FOR INFORMATION

CDM SMITH DRG NO.: BEN170175-01-DRG-S-5

REV.: A



STRUCTURAL

PLAN

WALL AND BASE SLAB LAYOUT

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.
3. SEE DRAWING S-7, S-8 AND S-9 FOR PILE LAYOUT.

REVISIONS

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

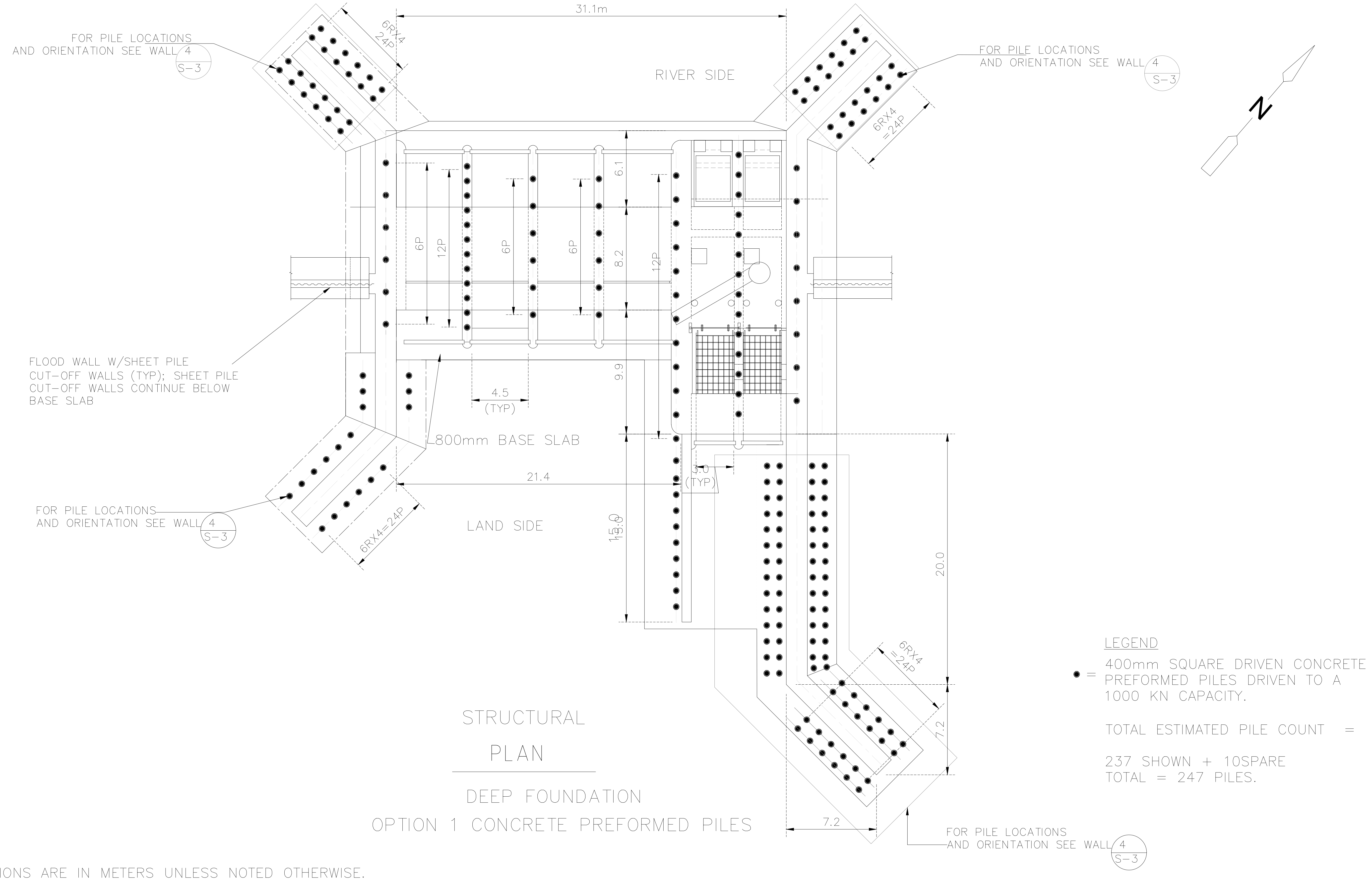
DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:300
0 5 15m
A3 ORIGINAL SIZE

DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

PROJECT NO. BEN170175-01
TITLE
BUNDABERG CREEK PUMP STATION
AND FLOOD GATE STRUCTURUAL PLAN
MARCH 2019
STATUS FOR INFORMATION
CDM SMITH DRG NO. BEN170175-01-S6
REV. 0



STRUCTURAL PLAN

DEEP FOUNDATION
OPTION 1 CONCRETE PREFORMED PILES

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

REVISIONS

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:300 (0 5 15m)
A3 ORIGINAL SIZE

DESIGNER: CDM Smith — cdmsmith.com

CLIENT: Queensland Government

PROJECT NO. BEN170175-01

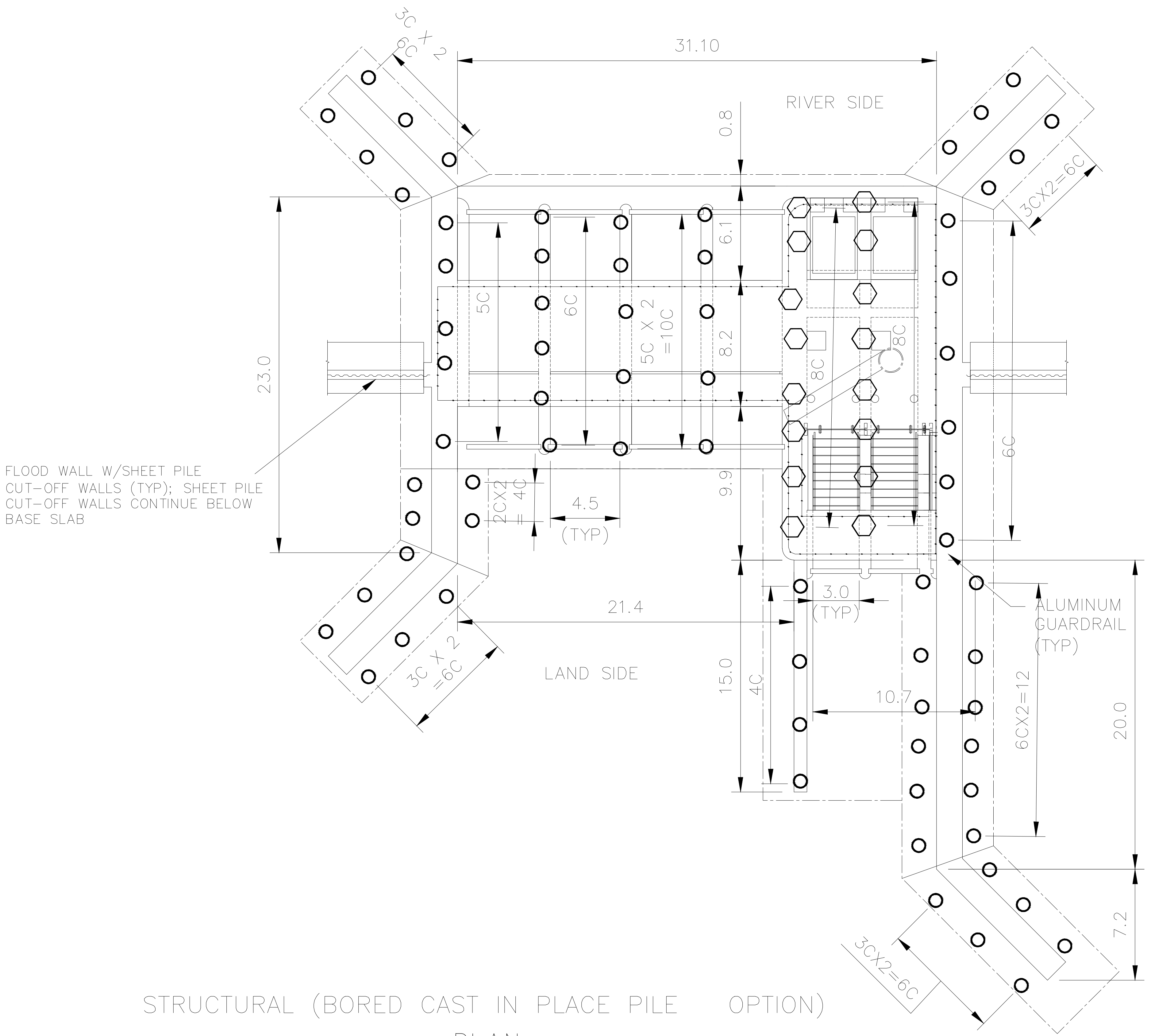
TITLE: BUNDABERG CREEK PUMP STATION
AND FLOOD GATE STRUCTURUAL PLAN
MARCH 2019

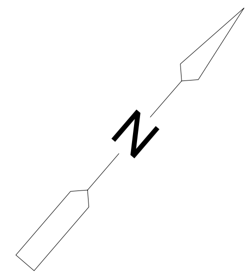
STATUS: FOR INFORMATION

CDM SMITH DRG NO. BEN170175-01-S7

REV. 0

CAD FILE: \\bgafsvr1\dav-asia-projects\Bundaberg East Levee\2019\working files\Structural drawings\March 2019\S7 - BEN170175-01-DRG-STR-6001 - PILE PLAN.dwg





LEGEND

200KN BORED PILES

400KN BORED PILES

TOTAL ESTIMATED PILE COUNT

2000KN = 71 SHOWN + 5 SPARES =76

4000KN = 16 SHOWN + 2 SPARES =18

STRUCTURAL (BORED CAST IN PLACE PILE OPTION)

PLAN

OPTION 2 ALL BORED CAST IN PLACE PILES

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

REVISIONS

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:300

0 5 15m

A3 ORIGINAL SIZE

DESIGNER: CDM Smith cdmsmith.com

CLIENT: Queensland Government

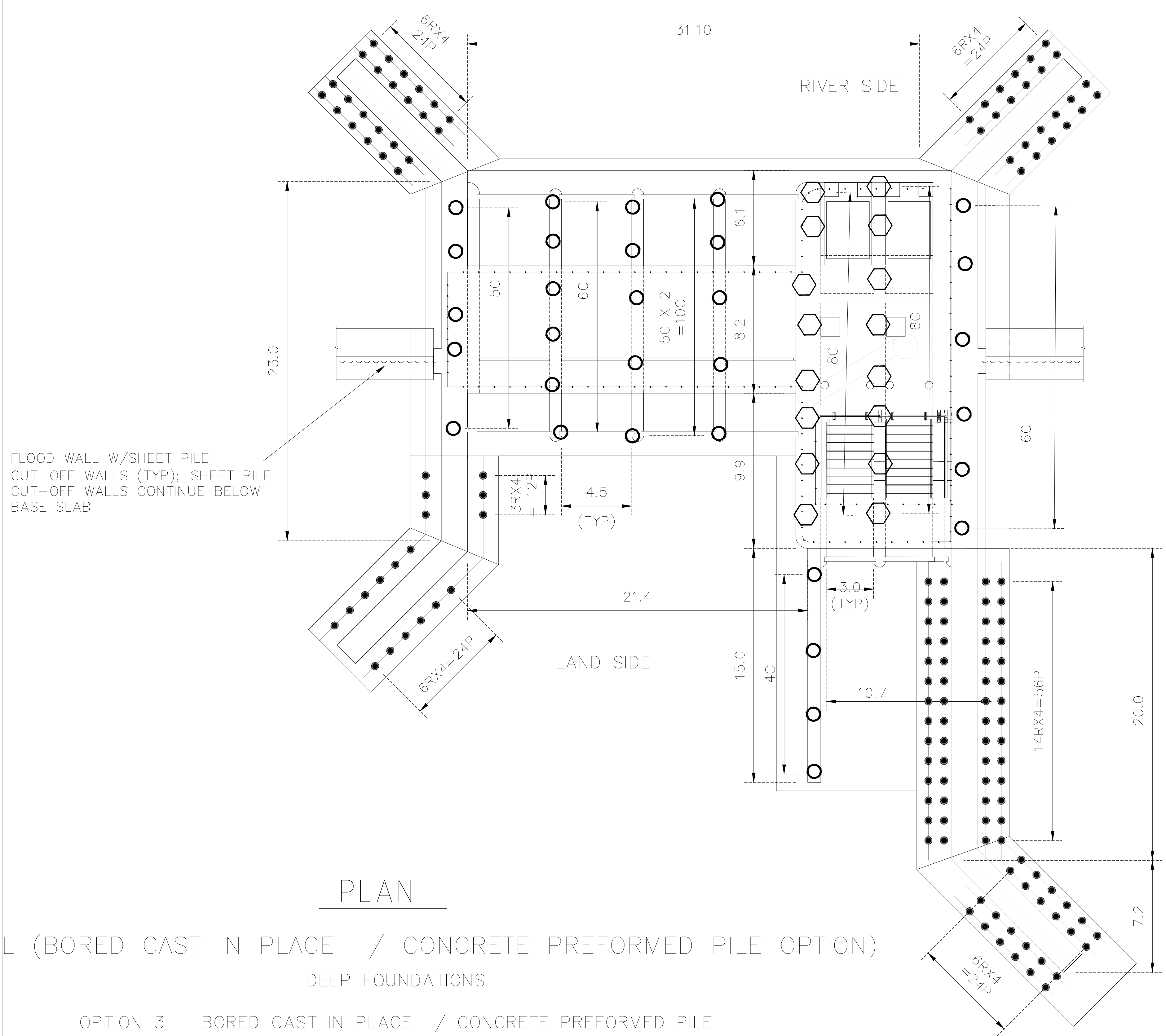
PROJECT NO. BEN170175-01

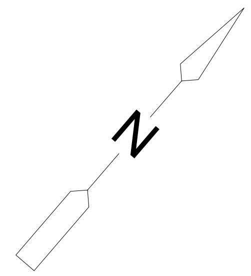
TITLE
BUNDABERG CREEK PUMP STATION
AND FLOOD GATE STRUCTURUAL PLAN
MARCH 2019

STATUS: FOR INFORMATION

CDM SMITH DRG NO. BEN170175-01-S8

REV. 0





PLAN

L (BORED CAST IN PLACE / CONCRETE PREFORMED PILE OPTION)

DEEP FOUNDATIONS

OPTION 3 – BORED CAST IN PLACE / CONCRETE PREFORMED PILE

LEGEND

- 400mm SQUARE DRIVEN CONCRETE PREFORMED PILES DRIVEN TO A CAPACITY OF 1000 KN
- 2000KN BORED CAST IN PLACE PILES
- 4000KN BORED CAST IN PLACE PILES

TOTAL ESTIMATED PILE COUNT

400mm SQUARE DRIVEN CONCRETE PREFORMED PILES = 164 SHOWN + 10 SPARES = 174

2000KN BORED PILES = 27 SHOWN + 5 SPARES = 32

4000KN BORED PILES = 16 SHOWN + 2 SPARES = 18

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.

NO.	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

REVISIONS

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:300 (0 – 5 – 15m)

A3 ORIGINAL SIZE

DESIGNER: CDM Smith — cdmsmith.com

CLIENT: Queensland Government

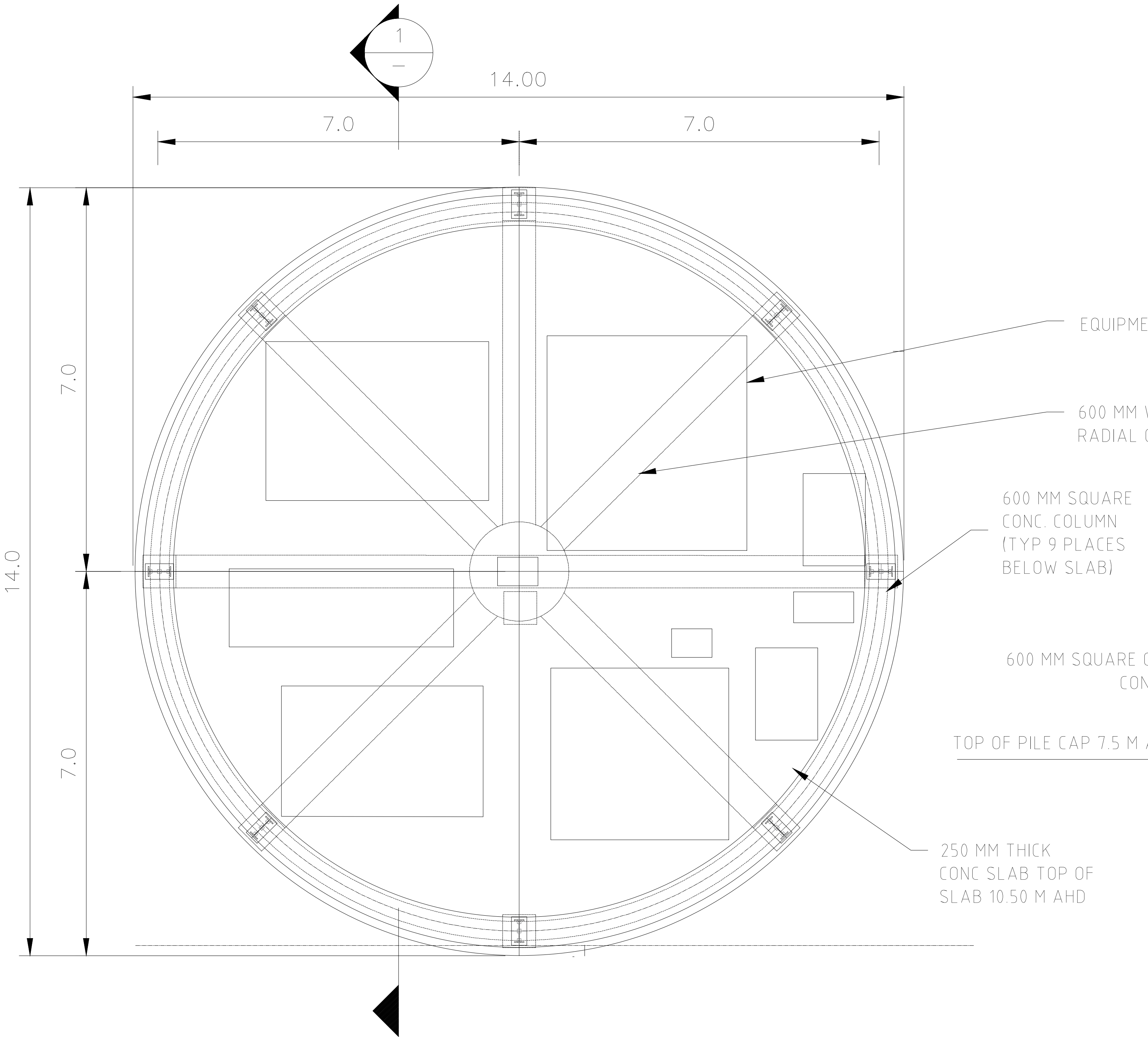
PROJECT NO. BEN170175-01

TITLE: BUNDABERG CREEK PUMP STATION AND FLOOD GATE STRUCTURUAL PLAN MARCH 2019

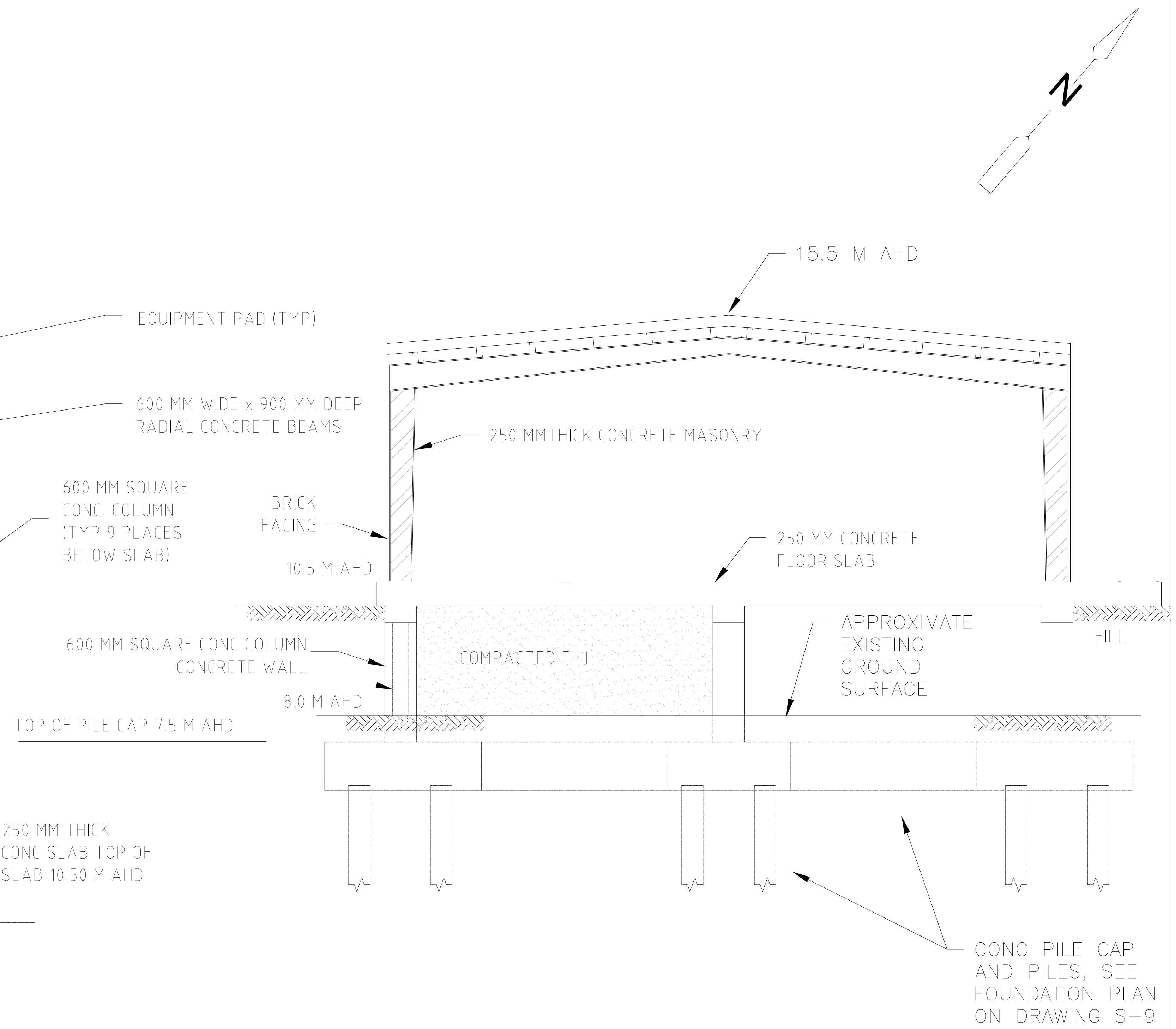
STATUS: FOR INFORMATION

CDM SMITH DRG NO. BEN170175-01-S9

REV. 0



STRUCTURAL
PLAN AT FLOOR



SECTION 1 –

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).

2. FACADE SHALL BE CMU BLOCK AND BRICK, PRECAST CONCRETE PANELS, OR INSULATED METAL PANELS.

3. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.

4. DESIGN TO BE DETERMINED BY ARCHITECT.

REVISIONS

NO	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	ARCHITECTURAL	SB
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:100

0 1 2 5m

A3 ORIGINAL SIZE

DESIGNER: CDM Smith — cdmsmith.com

CLIENT: Queensland Government

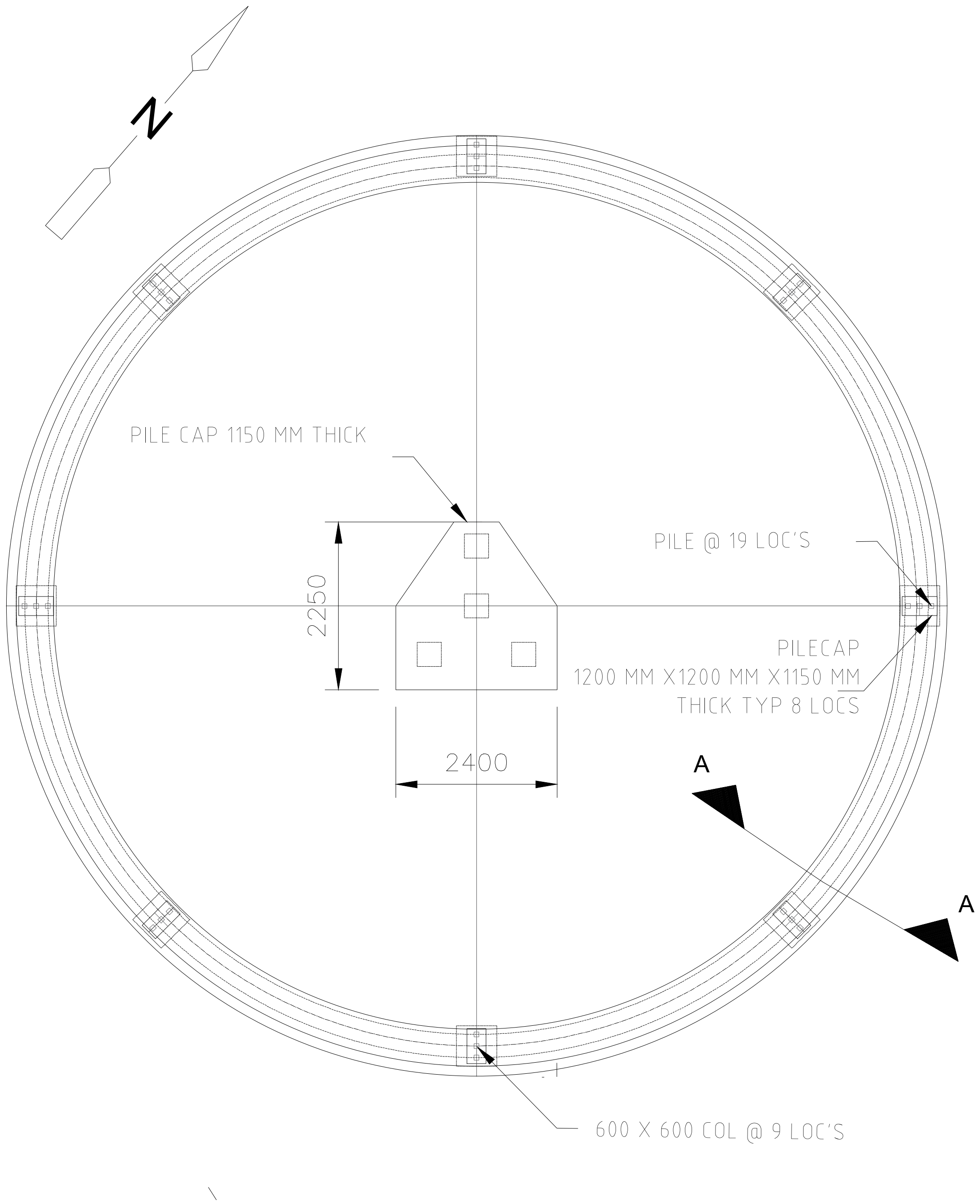
PROJECT NO. BEN170175-01

TITLE: BUNDABERG CREEK EQUIPMENT BUILDING
PLAN & SECTION
MARCH 2019

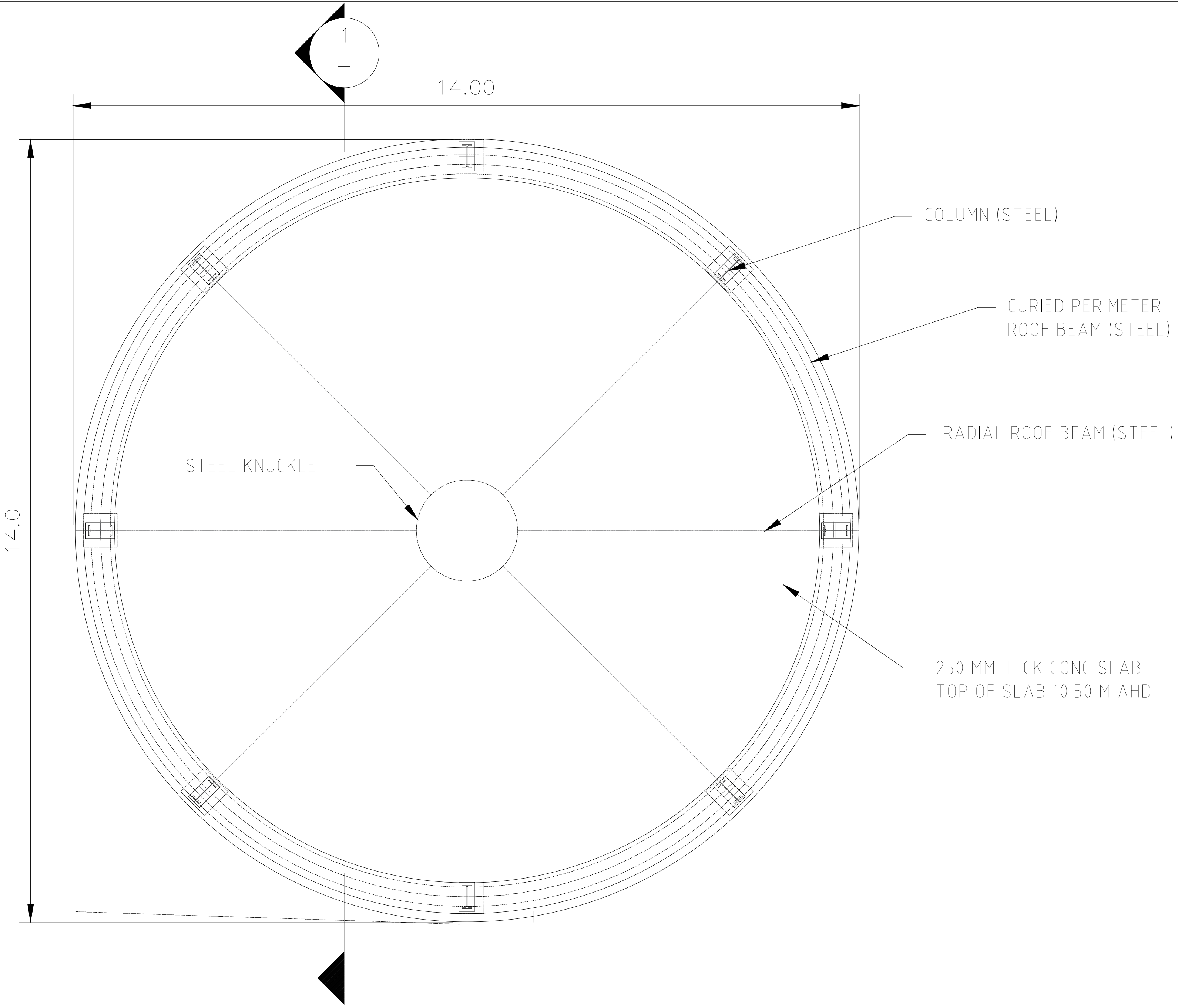
STATUS: BASE CASE

CDM SMITH DRG NO. BEN170175-01-S10-1

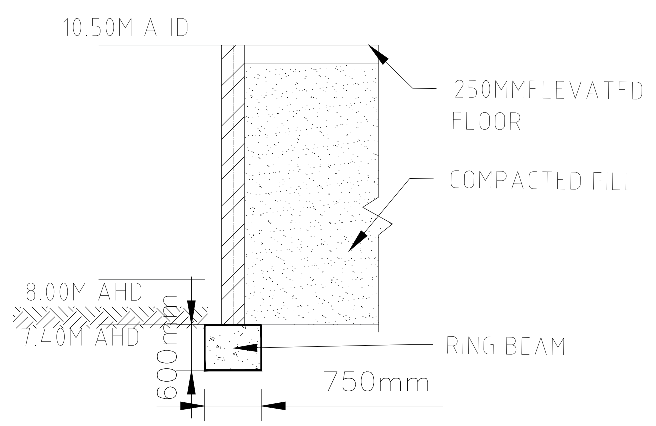
REV 0



PLAN AT FOUNDATIONS



PLAN AT ROOF



SECTION A

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.
3. PILES SHALL BE 400 mm SQUARE DRIVEN CONCRETE PREFORMED PILES (CPP) WITH AN ALLOWABLE CAPACITY OF 800 kN IN COMPRESSION AND 500 kN IN TENSION. ESTIMATED PILE TIP ELEVATION IS −18.0 M AHD.

REVISIONS

NO	BY	DATE	DESCRIPTION	CHKD
0	RR	09.08.18	BASE CASE	SB
A	SW	23.03.18	FOR INFORMATION	

DESIGNED	SW	CHECKED	SW
DRAWN	SW	CHECKED	EOB
APPROVED	SB	DATE	23.03.18
RPEQ NO. AND SIGNATURE			

SCALE 1:100

0 1 2 5m

A3 ORIGINAL SIZE

DESIGNER: CDM Smith
cdmsmith.com

CLIENT: Queensland Government

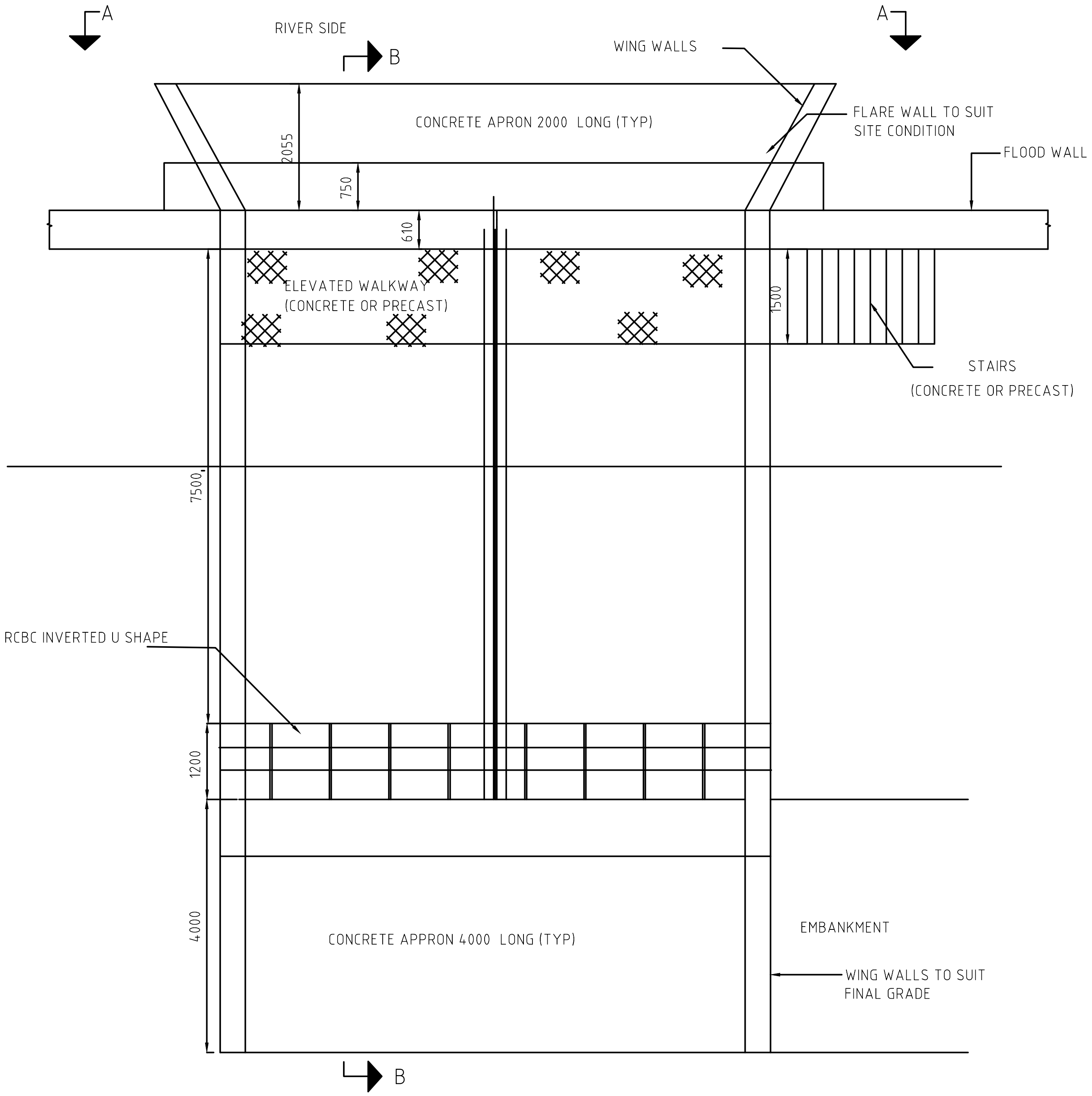
PROJECT NO. BEN170175-01

TITLE: BUNDABERG CREEK EQUIPMENT BUILDING FOUNDATION PLAN

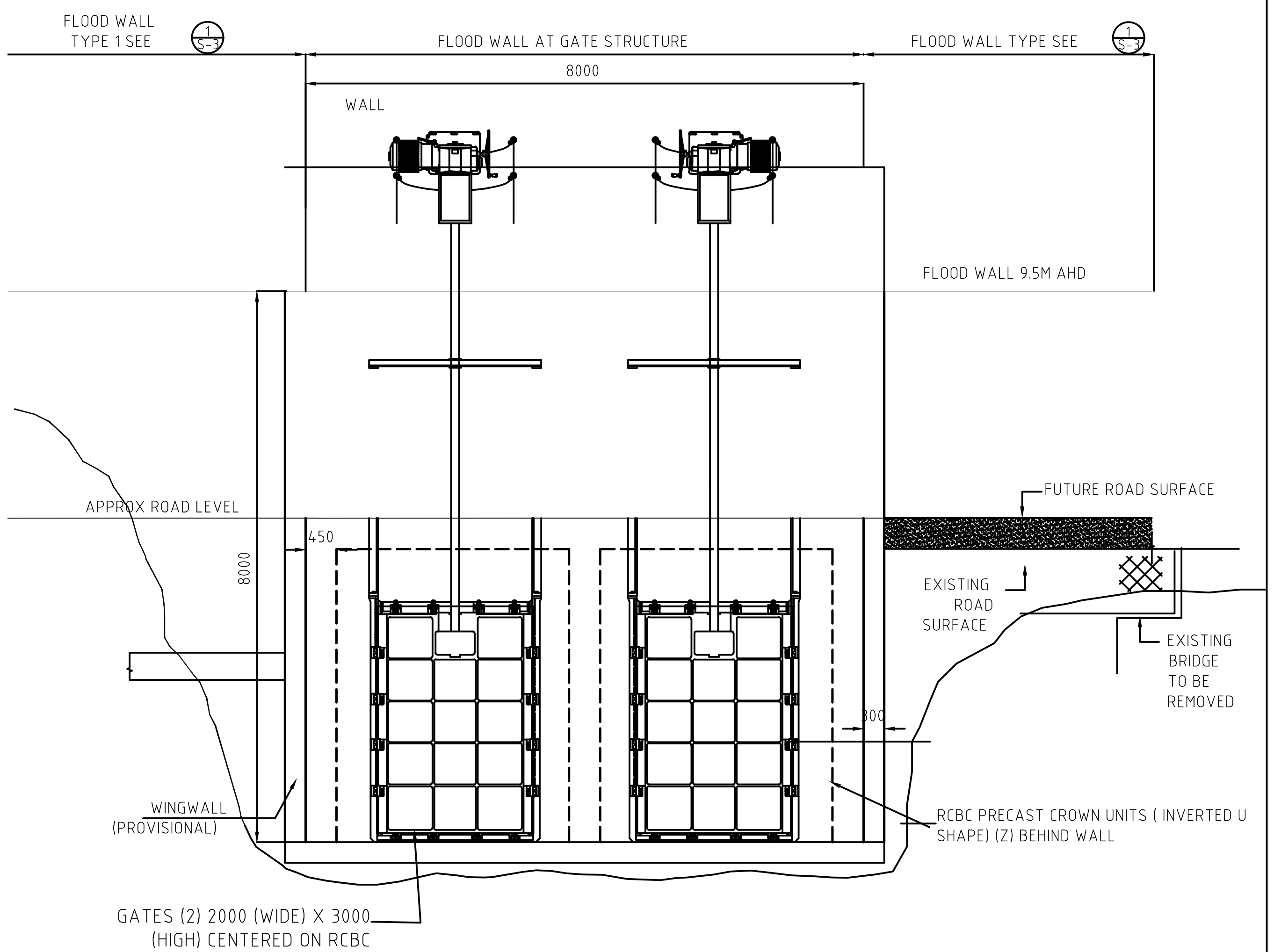
STATUS: BASE CASE

CDM SMITH DRG NO: BEN170175-01-S10-2

REV: 0



PLAN AT TOP OF CULVERT



SECTION A

NOTES:

1. ELEVATION BASED ON AHD IN METERS.

NO.	BY	DATE	DESCRIPTION	CHKD
A	RR	10.08.18	BASE CASE	

DESIGNED	EOB	CHECKED	SAB
DRAWN	RR	CHECKED	RM
APPROVED	SAB	DATE	27/08/2018
RPEQ NO. AND SIGNATURE			

SCALE 1:100
0 1 2 5m
A3 ORIGINAL SIZE

DESIGNER: CDM Smith
cdmsmith.com

CLIENT: Queensland Government

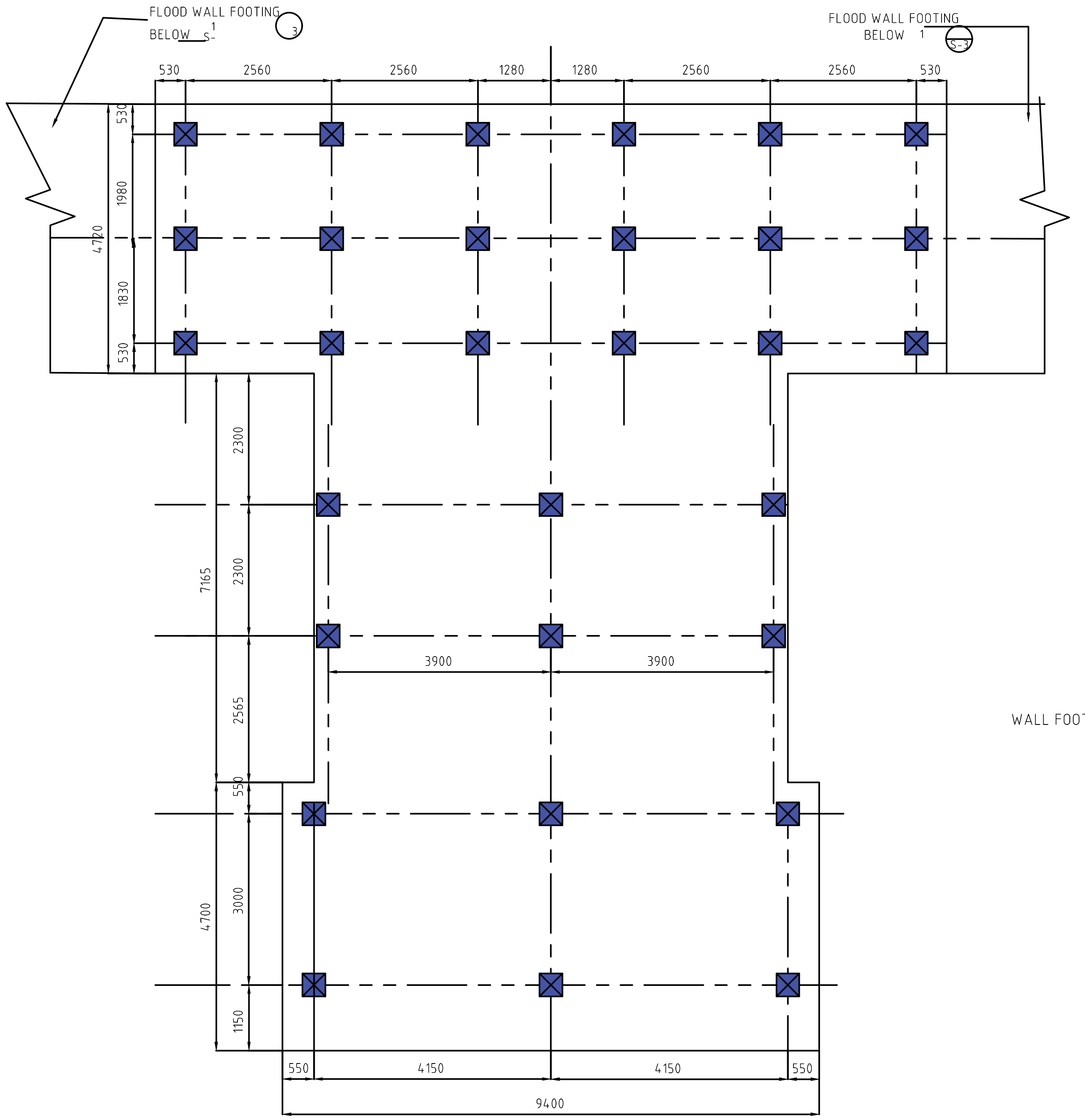
PROJECT NO. BEN170175-01

TITLE: DISTILLERY CREEK FLOOD GATE / WALL

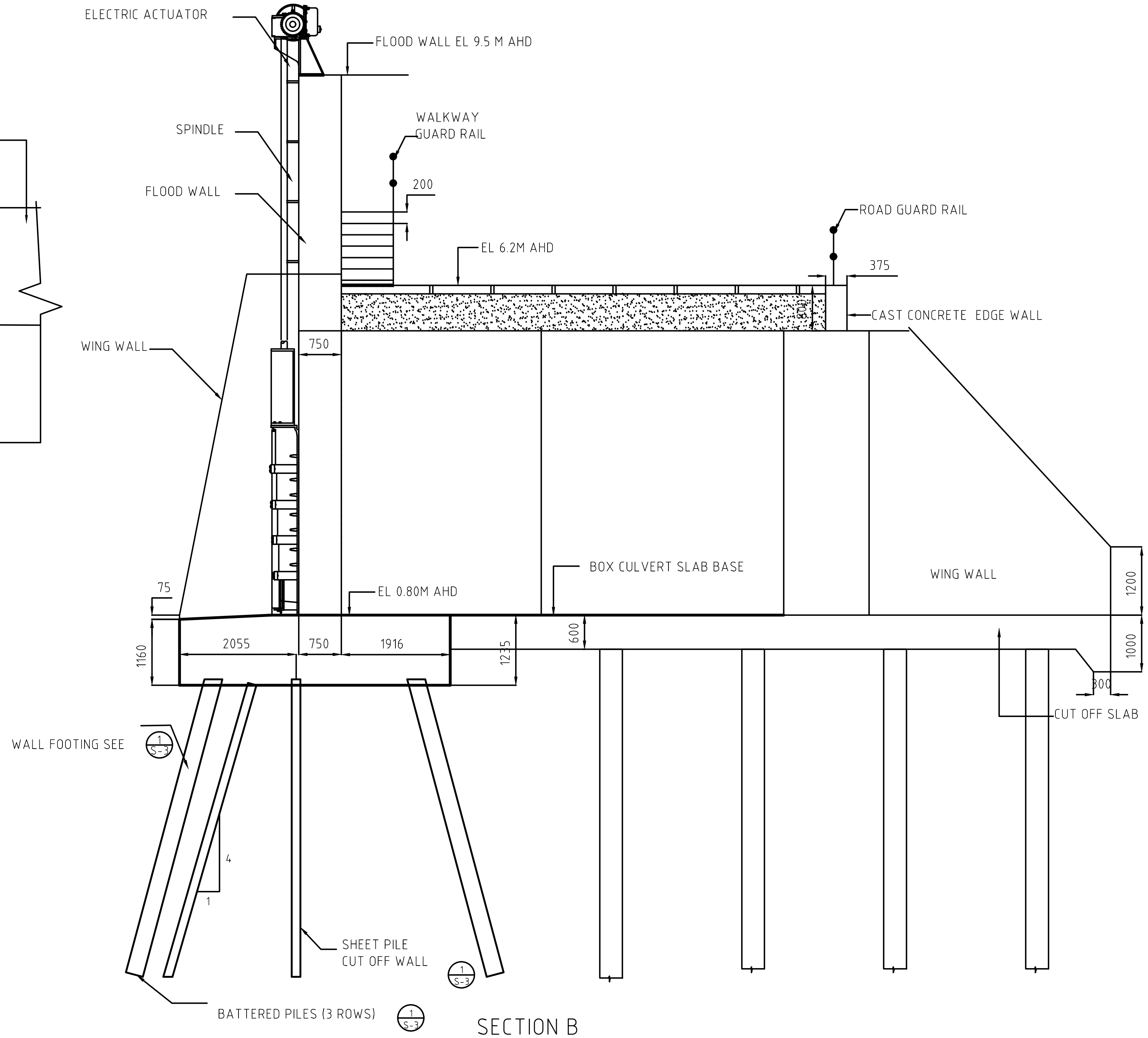
STATUS: BASE CASE

CDM SMITH DRG NO. BEN170175-01-S 11

REV.



PLAN AT PILES



SECTION B

NOTES:

1. ALL DIMESIONS ARE IN MILLIMETERS UNLESSNOTED OTHERWISE.
2. PILES SHALL BE PREFORMED PILES WITH AN ALLOWABLE CAPACITY OF 1000KN IN COMPRESSION AND 725KN IN TENSION ESITIMATED, PILE TIP ELAVATION IS −15M AHD.

REVISIONS				
NO.	BY	DATE	DESCRIPTION	CHKD
A	RR	10.08.18	BASE CASE	

DESIGNED		CHECKED	
DRAWN		CHECKED	
APPROVED		DATE	
RPEQ NO. AND SIGNATURE			

SCALE 1:100
0 1 2 5m
A3 ORIGINAL SIZE

DESIGNER: CDM Smith
cdmsmith.com

CLIENT: Queensland Government

PROJECT NO. BEN170175-01

TITLE: DISTILLERY ALIGNMENT STRUCTURAL PILE PLAN AND LONGITUDINAL-SECTION

STATUS: BASE CASE

CDM SMITH DRG NO. BEN170175-01-S 12

REV.

Appendix C Interpretive Geotechnical Report

DRAFT INTERPRETIVE GEOTECHNICAL REPORT

Bundaberg East Levee

Bundaberg, Queensland

Department of Local Government, Racing and Multicultural Affairs

2 March 2018

CDM Smith

Bundaberg East Levee

Bundaberg, Queensland

Draft Interpretive Geotechnical Report

2 March 2018

Prepared By:
CDM Smith

Reviewed By:
CDM Smith

John P. Briand III
Geotechnical Engineer

Stephen L. Whiteside
Vice President
Senior Geotechnical Engineer

Bernard J. Graves
Geotechnical Engineer

CDM Smith

Table of Contents

Figures

Tables

Appendices

Section 1

Introduction

1.1 Project Description

This report summarizes CDM Smith's geotechnical engineering evaluation and foundation design recommendations for the design and construction of the proposed Bundaberg East Levee project located in Bundaberg, Queensland. This work was completed for the Department of Local Government, Racing and Multicultural Affairs (DLGRMA), Brisbane.

The Bundaberg East Levee project will include the construction of levees and/or floodwalls to increase the flood protection, mitigate damage, and protect the Bundaberg East and Central Business District areas from the 100-year design flood event from the Burnett River. In addition, the project will include pump station and flood gate structures to mitigate interior flooding due to coincident rainfall in the protected area inboard of the levee and/or floodwall.

The results of the geotechnical field exploration and laboratory testing program for this project are included in the *Factual Geotechnical Report, Bundaberg East Levee* (FGR) dated 2 February 2018.

1.2 Project Datum

Elevations herein are in meters and referenced to the Australian Height Datum (AHD). The ground surface elevations discussed herein were approximated using publicly available LiDAR data for the City of Bundaberg.

Horizontal coordinates noted herein are in meters and referenced to the Geocentric Datum of Australia 1994 (GDA94) Map Grid of Australia (MGA) Zone 56.

1.3 Purpose and Scope

The purpose of this report is to summarize the subsurface conditions encountered during the geotechnical investigation and to provide geotechnical engineering recommendations for design and construction.

Specifically, CDM Smith's scope of work included:

- Review existing subsurface and laboratory testing data summarized in the FGR;
- Perform geotechnical analyses and develop conceptual geotechnical engineering recommendations for design and construction of the proposed floodwall and pump station and flood gate structures;
- Develop conceptual design drawings for the proposed structures;

- Prepare this Interpretive Geotechnical Report (IGR) presenting CDM Smith's conceptual recommendations, including an abbreviated summary of the data collected as part of the field and laboratory investigation.

1.4 Report Limitations

This report has been prepared for the Bundaberg East Levee project, located in Bundaberg, Queensland and is based upon information available at the time of this report and presented herein. This report has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made. In the event that changes in the design or location of the structures occur or a variation in the subsurface or hydrologic/hydraulic conditions is encountered, the conclusions and recommendations contained herein should not be considered valid unless verified in writing by CDM Smith.

Section 2

Site and Subsurface Conditions

2.1 Existing and Proposed Conditions

2.1.1 Existing Conditions

The proposed Bundaberg East Levee site is located in an urban, residential, and mixed-use area adjacent to the southern bank of the Burnett River in Bundaberg, Queensland. The project site is bounded by Walla Street to the west, Bourbong and Cran Streets to the South, the Bundaberg Rum Distillery to the east, and the Burnett River to the north. The ground surface elevation generally ranges from between approximately 2 m AHD to 11 m AHD across the project site with the low-lying areas located near Bundaberg Creek and the unnamed creek near the distillery (hereafter referred to as Distillery Creek).

2.1.2 Proposed Construction

The Bundaberg East Levee is proposed to run parallel to the southern bank of the Burnett River and across Bundaberg Creek and Distillery Creek. The levee is proposed to consist of concrete floodwall with an indicative top of wall elevation of RL 9.5 m AHD in the vicinity of the Bundaberg Creek-Burnett River confluence. This level is approximately 300 mm above the 100-year average return interval (ARI) design flood elevation at this location. The floodwall will be founded approximately 1.5 m below ground surface (BGS) on a stepped foundation system consisting of both shallow and deep foundations. The floodwall will consist of two main segments, the City Alignment and the Distillery Alignment as shown on **Figure 2-1**.

The City Alignment is approximately 900 m long and generally extends along the northern edge of Quay Street from the intersection of Toonburra Street across Bundaberg Creek to the intersection of Scotland Street. The alignment then follows Scotland Street to Cran Street where the alignment terminates shortly after the intersection.

The Distillery Alignment is approximately 500 m long and crosses Distillery Creek. The Distillery Alignment extends along the majority of Cran Street then parallels the river bank until it terminates north of the distillery.

Pump station and flood gate structures will be constructed at the Bundaberg Creek crossing and the Distillery Creek crossing. The pump station and flood gate structures will be significantly larger at Bundaberg Creek due to the larger size of the contributing upstream catchment.

2.2 Subsurface Conditions

Subsurface soil conditions at the Bundaberg East Levee project site were interpreted from the test borings conducted at the site and presented in the FGR. The test borings typically encountered fill over alluvial soils over the Elliott Formation. Refer to the FGR for a detailed

LEGEND:

B-1 DESIGNATION AND APPROXIMATE LOCATION OF AS-DRILLED TEST BORING DRILLED BY GEODRILL AUSTRALIA OF ILKLEY, QLD BETWEEN 11 AND 22 NOVEMBER 2017.

MW APPROXIMATE LOCATION OF GROUNDWATER MONITORING STATION.

A A' LEVEE ALIGNMENT.

NOTES:

1. ELEVATIONS NOTED HEREIN ARE IN METERS AND REFERENCED TO THE AUSTRALIAN HEIGHT DATUM (AHD).
2. THE AS-DRILLED TEST BORING LOCATIONS WERE LOCATED USING A HANDHELD GPS UNIT.
3. TEST BORINGS, SITE FEATURES AND STRUCTURE LOCATIONS ARE APPROXIMATE.

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BUNDABERG EAST LEVEE
BUNDABERG, QUEENSLAND

FIGURE NO. 2-1
SITE PLAN
MARCH 2018

discussion of the subsurface conditions. The following is an abbreviated summary of the subsurface conditions at the site. The levee alignment subsurface cross-sections summarizing the available data from the test borings including sampler blow counts, USCS classification symbols, and approximate layering are shown on **Figures 2-2** and **2-3**.

2.2.1 Fill

The fill layer was encountered at the ground surface in eleven of the fourteen test borings at the site, the exceptions being B-1, B-9, and B-11. The thickness of the fill layer ranged from 1.3 m to 5.5 m. The layer typically consisted of low plasticity clay (CL) and clayey sands (SC). Miscellaneous debris from a possible construction and demolition (C&D) debris landfill was encountered in test borings B-5 and B-14 and included wood, waste material, glass, ceramics, fabric and wire. In addition, test boring B-2 encountered gravel and cobble fill to 3 m BGS, and test borings B-12 and B-13 encountered metal scraps, boiler ash, and charcoal to 2.5 m BGS.

2.2.2 Alluvial Soils

The alluvial soils layer was encountered in ten of the fourteen test borings, being absent from B-1, B-8, B-11, and B-14. The alluvial soils layer was typically encountered below the fill layer except at test boring B-9 where it was encountered at the ground surface. The thickness of the alluvial soils layer ranged from 2.0 m to 17.5 m where the layer was fully penetrated. The layer typically consisted of very soft to soft high plasticity clays (CH), low plasticity clays (CL), and organic high plasticity clays (OH).

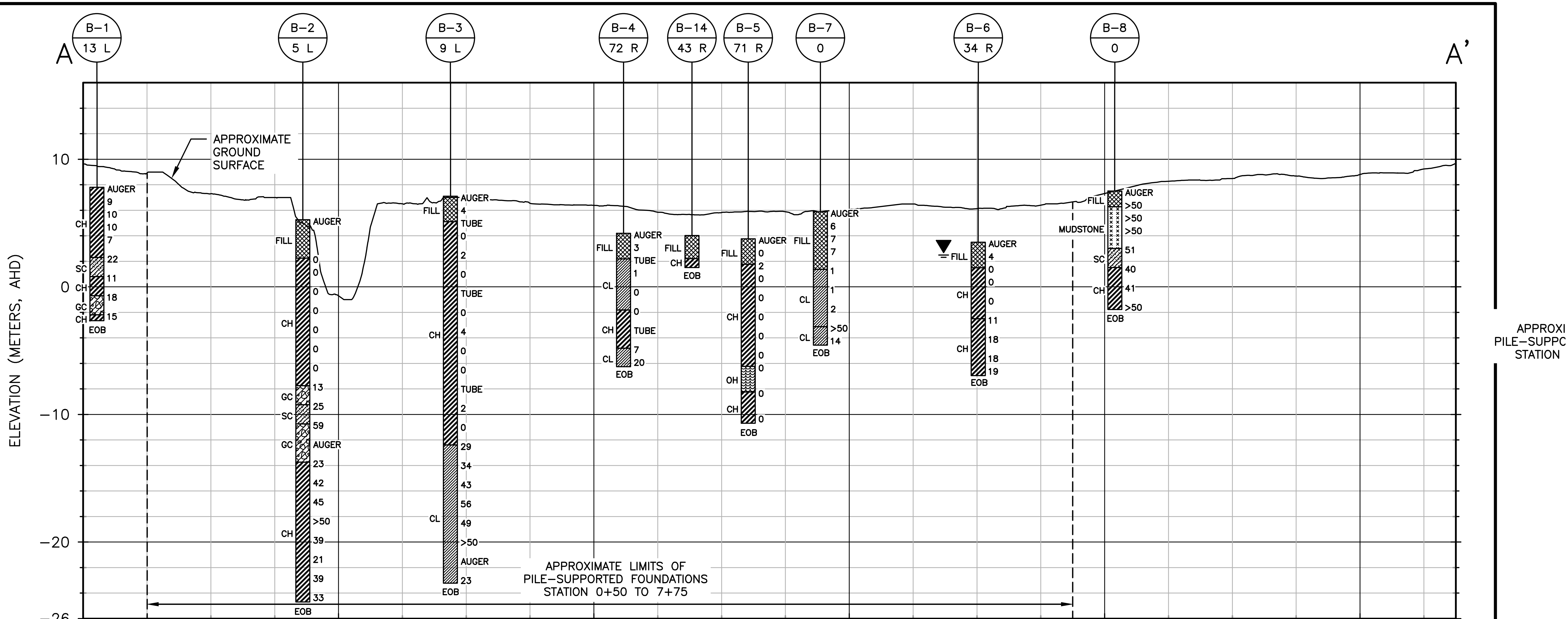
2.2.3 Elliott Formation

The Elliott Formation layer was encountered in twelve of the fourteen test borings except for test borings B-5 and B-14. The Elliott Formation layer was typically encountered below the alluvial soils layer except at test borings B-1 and B-11 where it was encountered at the ground surface and at test boring B-8 where it was encountered below the fill layer. The Elliott Formation layer was not fully penetrated at any of the test boring locations and was drilled and sampled to depths between 0.75 m and 16.95 m below the top of the layer. The layer typically consisted of high plasticity clay (CH), low plasticity clay (CL), clayey sand (SC), clayey gravel (GC), and poorly-graded sand (SP). In test boring B-8, a 3.2-m-thick layer of mudstone was encountered at the top of the Elliott Formation. In the vicinity of Bundaberg Creek, the Elliott Formation typically consisted of clayey soils (CH and CL). In the vicinity of Distillery Creek, the Elliott Formation typically consisted of coarse-grained soils (SC, GC and SP).

2.3 Groundwater Conditions

The depth to groundwater was recorded prior to backfilling at test boring B-6 and was measured at approximately 1 m bgs (2.5 m AHD). The groundwater measurement was taken within the steel casing at the test boring location and may not represent static groundwater conditions. No groundwater monitoring wells were installed as part of this test boring program.

A real-time groundwater monitoring station exists at Kendall Flats, approximately 200 m south of the proposed floodwall alignment. The average daily groundwater elevation at this station for 2017 was measured to be 1.5 m AHD with the average daily minimum measured at 0.9 m AHD, and the average daily maximum measured at 2.3 m AHD.



CITY ALIGNMENT CROSS-SECTION A-A'

LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY−GRADED GRAVEL
- HIGH PLASTICITY CLAY
- ORGANIC HIGH PLASTICITY CLAY
- LOW PLASTICITY CLAY
- MUDSTONE

B−1 — TEST BORING NUMBER
1 L/R — OFFSET DISTANCE, LEFT OR RIGHT (METERS)
13 — STANDARD PENETRATION RESISTANCE N−VALUE (BL/0.3M)
OBSERVED GROUNDWATER LEVEL
USCS CLASSIFICATION CHANGE
CL — USCS CLASSIFICATION
EOB — END OF BORING

NOTES:

1. REFER TO FIGURE 2−1 FOR NOTES.

VERTICAL SCALE: 1M = 300M
0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M
0 30 60 150 240 300 m

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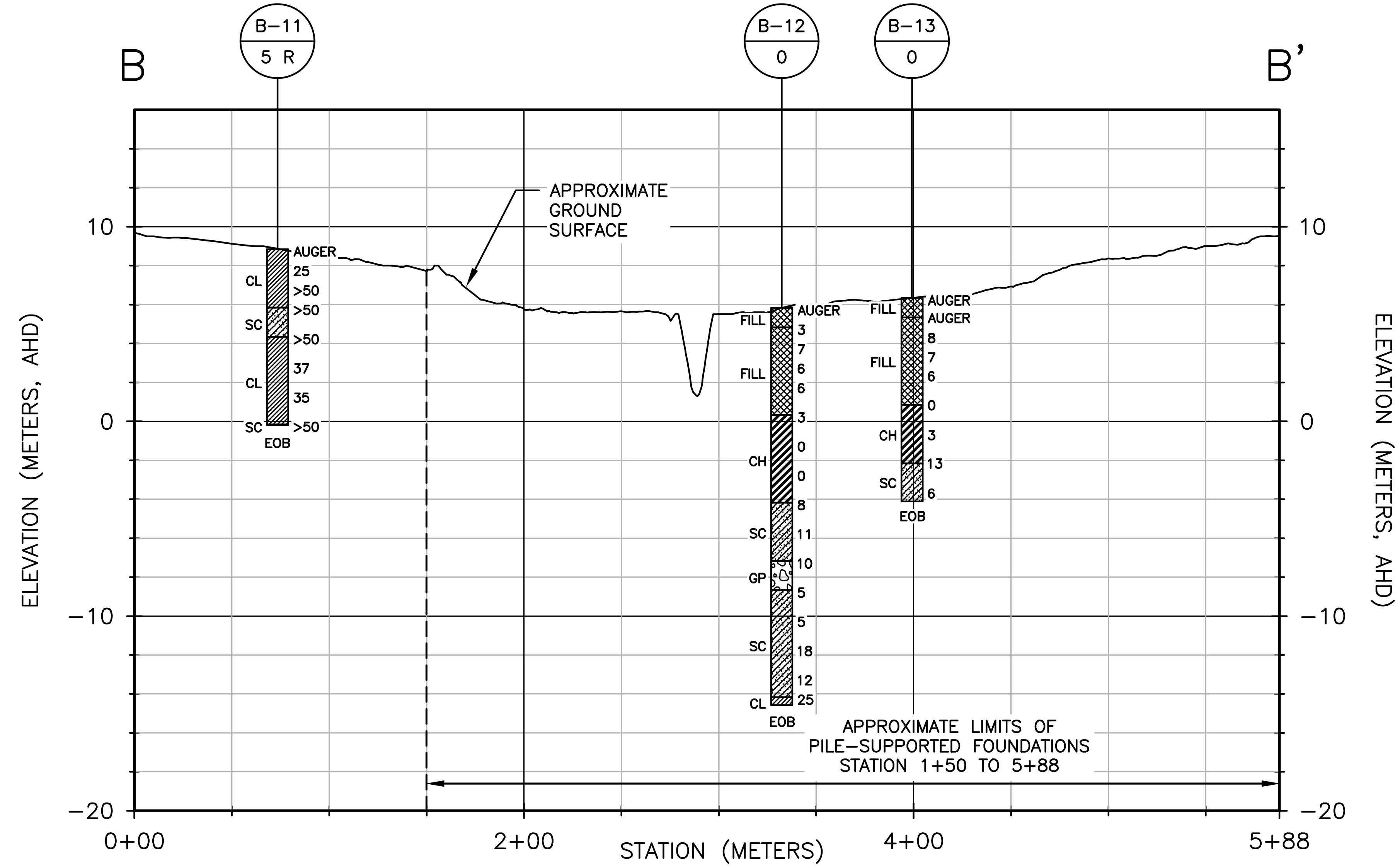
FIGURE NO. 2-2
CITY ALIGNMENT CROSS-SECTION A-A'
MARCH 2018



DISTILLERY ALIGNMENT CROSS-SECTION B-B'

LEGEND:

- FILL
- CLAYEY SAND
- CLAYEY GRAVEL
- POORLY-GRADED GRAVEL
- HIGH PLASTICITY CLAY
- ORGANIC HIGH PLASTICITY CLAY
- LOW PLASTICITY CLAY
- MUDSTONE

B-1 — TEST BORING NUMBER

1 L/R — OFFSET DISTANCE, LEFT OR RIGHT (METERS)

13 — STANDARD PENETRATION RESISTANCE N-VALUE (BL/0.3M)

OBSERVED GROUNDWATER LEVEL

USCS CLASSIFICATION CHANGE

CL — USCS CLASSIFICATION

EOB — END OF BORING

NOTES:

1. REFER TO FIGURE 2-1 FOR NOTES.

VERTICAL SCALE: 1M = 300M

0 3 6 15 24 30 m

HORIZONTAL SCALE: 1M = 3000M

0 30 60 150 240 300 m

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FIGURE NO. 2-3
DISTILLERY ALIGNMENT CROSS-SECTION B-B'
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2.4 Expected Variations in Subsurface Conditions

Subsurface conditions presented herein are based on soil and groundwater conditions observed at the test boring locations. However, subsurface conditions may vary at other locations within the site.

Groundwater levels may change with river and creek levels, time, season, temperature, and construction activities in the area, as well as with other factors. In addition, stabilized groundwater levels can be difficult to obtain in test borings drilled using mud rotary due to the presence of drilling fluid in the borehole. Therefore, groundwater conditions at the time of construction may be different from those observed at the time of the test borings.

Section 3

Geotechnical Engineering Analyses

3.1 General

Conceptual-level geotechnical engineering analyses have been performed as they relate to the proposed Bundaberg East Levee floodwall and the pump station and flood gate structures. In general, these evaluations are based on the results of the field and laboratory testing programs conducted for this study, published correlations with soil properties, and the minimum requirements of the relevant Australian Standards.

The geotechnical engineering analyses and evaluations were performed as described in this section including seepage and settlement analyses.

3.2 Seepage Analyses

3.2.1 Introduction

Seepage analyses were performed as part of the conceptual design studies. These analyses were performed in general accordance with accepted engineering practices and the applicable codes/references as indicated. The soil properties and subsurface profile for the analyses were developed based upon the LiDAR survey data, geotechnical investigation, existing survey data, and the preliminary alignment inspection.

The seepage analyses were performed to evaluate potential seepage issues for the proposed floodwall using the two-dimensional finite element modeling program SEEP/W version 8.16 by GEOSTUDIO 2016 from GEO-SLOPE International. The analyses were performed for the 100-year ARI flood event. Steady-state seepage analyses were performed based upon estimated hydraulic conductivities of the subsurface materials. The following items were evaluated in the seepage analyses:

- Exit gradient on the landside of the floodwall, and
- Uplift pressures on the proposed floodwall foundations.

3.2.2 Model Set-Up

CDM Smith developed two typical soil profiles, one for deep foundation alignments and one for shallow foundation alignments, for the seepage analyses. The soil profiles and properties were based on field and laboratory data collected during the geotechnical investigation, published correlations with soil properties, and engineering judgement from CDM Smith's past experience on similar projects. The soil profiles were imported into the proposed conditions model.

The first step in setting up the model was to select boundary conditions. The model has the side boundaries extending approximately 200 m from the centerline of the proposed floodwall. The water level on the riverside of the floodwall was assumed to be the 100-year flood level (RL 9.2 m

AHD), and the ground surface landside of the floodwall was assumed as a free drainage boundary with a groundwater level at 2.5 m AHD.

The SEEP/W models were run for the steady-state conditions using the parameters and boundary conditions described above.

3.2.3 Results

The seepage analyses results for the uplift pressures and landside exit gradient are shown below in **Table 3-1**.

Table 3-1 Summary of Seepage Analyses

Scenario No.	Modeling Scenario	Results			
		Uplift Pressure on Riverside, kPa	Uplift Pressure on Landside, kPa	Landside Exit Gradient	Exit Gradient Factor of Safety (1)
1	Deep Foundation with 3 m Sheetpile Wall	33.3	27.1	0.77	1.1
2	Deep Foundation with 7 m Sheetpile Wall	35.2	25.1	0.65	1.3
3	Deep Foundation with 13.5 m Sheetpile Wall	43.4	0.00	0	>2
4	Shallow Foundation, No Sheetpile Wall	22.8	5.0	0	>2

Notes:

1. The maximum allowable exit gradient for a levee or floodwall is 0.5 per United States Army Corps of Engineers (USACE) Engineering Manual (EM) 1110-2-1901.

For the Scenario No. 1 (i.e., minimum sheetpile length) and Scenario No. 2 (i.e., sheetpile extending through half of alluvial soils layer), results of the seepage analyses indicate that the exit gradient exceed the maximum allowable exit gradient of 0.5. However, for the Scenario No. 3 (i.e., sheetpile extending through entire alluvial soils layer) and Scenario No. 4, seepage is not anticipated to daylight on the landside of the levee during the 100-year flood event.

The results from all the SEEP/W analyses are included in **Appendix A**.

3.3 Deep Foundation Analyses

Deep foundation analyses were performed for the proposed floodwall and the pump station and flood gate structures for both driven and drilled foundation systems. The driven foundation systems, including 400-mm-square concrete preformed piles and 500-mm-diameter steel cast in place piles with a closed end, were designed for compression and uplift loads in accordance with Section 6 of the American Petroleum Institute *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (API Manual) dated December 2000. The drilled foundation systems, including a 1-m-diameter bored cast in place piles, were designed for compression and uplift loads in accordance with Section 13 of the Federal Highway Administration (FHWA) *Drilled Shafts: Construction Procedures and LRFD Design Methods* (FHWA Manual) dated May 2010. In addition, the deep foundation analyses were conducted in general accordance with Australia Standard (AS) *2159-2009 – Piling Design and Installation*.

Based on the deep foundation analyses, the proposed deep foundation systems will be embedded a minimum distance into the Elliott Formation. The estimated deep foundation embedment lengths are provided in **Section 4**.

The deep foundation analyses are included in **Appendix B**.

3.4 Geotechnical Analyses for Detailed Design

For the detailed design, the following additional geotechnical analyses will be conducted:

- Revised seepage analyses for the floodwall incorporating additional subsurface and laboratory testing data;
- Revised deep foundation analyses for the floodwall and pump station and flood gate structures incorporating additional subsurface and laboratory test data;
- Settlement analyses for the floodwall shallow foundation systems; and
- Scour evaluations.

Section 4

Geotechnical Engineering Evaluation and Foundation Design Recommendations

4.1 Geotechnical Engineering Evaluations

Geotechnical engineering evaluations have been made as they relate to the proposed floodwall and pump station and flood gate structure design in Bundaberg, Queensland. In general, these evaluations have been based on the results of the geotechnical investigation, laboratory test results, published correlations with soil properties, and the requirements of the relevant Australian Standards. In addition, recommended design criteria are based on performance tolerances, such as allowable settlement, as understood to relate to similar structures.

4.1.1 Primary Geotechnical Considerations

The primary geotechnical considerations related to the design of the proposed Bundaberg East Levee project include:

- **Site Constraints:** The alignments of the proposed floodwalls are to be constructed within roadway rights-of-way in close proximity to urban, residential, and mixed-use structures. Vibrations due to construction activities should be limited to the extent possible to reduce the potential for damage to the existing structures. In addition, the construction should limit the size of the work area to allow for the roadways to remain open during construction and the public to access their residences or businesses, unless permits for full or partial roadway closure are obtained.

- **Soft Alluvial Soils:** Based upon the test borings, soft, compressible alluvial soils are present at the foundation subgrade along the majority of the City and Distillery Alignments. The thickness of the layer varied between 2 and 17.5 m, where encountered. The alluvial soils are not considered suitable for shallow foundation support of the structures because of their compressibility and low shear strength.

- **Variability of Elliott Formation:** Based upon the test borings, significant variations were observed in the Elliott Formation layer density and soil types encountered along the City and Distillery Alignments. Along the City Alignment, the majority of the soils encountered were low plasticity and high plasticity clays with densities varying between medium stiff and hard with split spoon refusal encountered at some sampling depths. However, along the Distillery Alignment, the majority of the soils encountered were clayey sands and clayey gravels with densities varying between loose and medium dense.

- **High Groundwater Levels:** High design groundwater levels are anticipated at the project site due to the proximity to the Burnett River for the construction of the Bundaberg Creek flood gate. It is anticipated that groundwater water levels will vary between RL 0.9 m AHD and RL 2.3 m AHD based on the real-time groundwater monitoring station at Kendall Flats.

4.2 Foundation Design Recommendations

4.2.1 General

Based on the proposed alignment, anticipated dimensions, depths, and loadings of the proposed structures and subsurface conditions present at the site, the majority of the proposed floodwall and the pump station and flood gate structures should be supported on deep foundations bearing in the Elliott Formation. At select locations discussed below, portions of the floodwall may be supported on shallow foundations bearing in the Elliott Formation or on structural fill over the Elliott Formation placed after removal of unsuitable soils.

4.2.2 Recommendations for Design of Pile-Supported Foundations

Based on the available subsurface information, project requirements, and anticipated foundation loading conditions, we recommend that the floodwall along the City Alignment between Sta. 0+50 and Sta. 7+75 and the floodwall along the Distillery Alignment between Sta. 1+50 and Sta. 5+58 be supported on deep foundations. In addition, the pump stations and flood gates should be supported on deep foundations. Refer to Figures 2-2 and 2-3 for the subsurface conditions along the City and Distillery Alignments and approximate extents of the structures to be supported on pile foundations.

4.2.2.1 Pile Types

500-mm-diameter driven steel cast in place piles, 400-mm-square driven concrete preformed piles (CPP), and 1-m-diameter bored cast in place piles are considered suitable for the range of anticipated loads (i.e., 250 kN to 1,000 kN) for the proposed structures. Allowable capacities for the different pile types and minimum embedment depths into the Elliott Formation soil layer are provided below in **Table 4-1**. The allowable compression pile capacity is estimated based on skin friction and tip resistance developed in accordance with procedures outlined in the Federal Highway Administration "Design and Construction of Driven Pile Foundations" and "Drilled Shafts: Construction Procedures and LRFD Design Methods", using SPT N-values from test borings and other test results. A factor of safety of 1.39 is applied based on AS 2159-2009 Section 4.3.1 to the allowable compression and uplift capacities.

Table 4-1 Summary of Pile Capacities.

Applicable Structures	Foundation Size and Type	Total Allowable Compression Pile Capacity (kN)	Total Allowable Uplift Capacity (kN)	Minimum Embedment in Elliott Formation (m)
Bundaberg Creek Pump Station and Flood Gate and City Alignment Sta. 1+00 to Sta. 3+50	500-mm-Diameter Driven Steel Cast In Place Pile	250	200	1
		500	325	2
		750	475	5
		1000	725	9
	400-mm-Square Driven Concrete Preformed Pile	250	200	1
		500	325	2
		750	525	6
		1000	725	9
	1-m-Diameter Bored Cast In Place Pile	250	400	1
		500	400	1
		750	400	1
		1000	450	3
City Alignment Sta. 3+50 to Sta. 7+50	500-mm-Diameter Driven Steel Cast In Place Pile	250	150	2
		500	375	8
		750	525	12
		1000	750	17
	400-mm-Square Driven Concrete Preformed Pile	250	150	2
		500	375	8
		750	525	12
		1000	750	17
	1-m-Diameter Bored Cast In Place Pile	250	200	1
		500	250	3
		750	350	7
		1000	450	11
Distillery Creek Pump Station and Flood Gate and Distillery Alignment Sta. 2+50 to Sta. 7+00	500-mm-Diameter Driven Steel Cast In Place Pile	250	75	1
		500	175	4
		750	325	8
		1000	475	11
	400-mm-Square Driven Concrete Preformed Pile	250	75	1
		500	200	5
		750	375	9
		1000	525	12
	1-m-Diameter Bored Cast In Place Pile	250	250	2
		500	300	3
		750	375	5
		1000	400	6

Based on the available subsurface information, project requirements, anticipated foundation loading conditions, and our understanding of current market conditions, we recommend that the floodwall and pump station and flood gate structures be supported on 400-mm-square CPP bearing in the Elliott Formation for the following reasons:

- Based conversations with a local piling contractor (Wagstaff Piling PTY Ltd.), steel pipe piles are approximately 150 to 200 percent more expensive than CPP piles due to the cost of steel in the Australian market; and
- The pile lengths may vary along the length of the floodwall alignment due to the highly variable density and material types within the Elliott Formation (i.e., the bearing layer). This variation would result in difficulties correlating compression and uplift capacity using drilled pile methods. However, driven piles are considered a more-appropriate solution for highly variable soils because the compression and uplift capacity can be correlated to a driving criteria (resistance) recorded during pile driving.

4.2.2.2 CPP Installation Criteria

4.2.2.2.1 Pile Tip Embedment and Blow Count Criteria

Piles should be installed to a specified final driving resistance (criteria) and into the underlying Elliott Formation or to practical refusal, whichever is encountered first. Practical refusal is defined as a penetration of 2.5 cm or less for the final 10 blows with a properly functioning pile hammer operated at the maximum energy setting. Piles should not be driven harder than practical refusal. Piles may occasionally encounter refusal in the Elliott Formation prior to reaching the specified minimum embedment in the Elliott Formation. All piles must be driven to at least 1 m into the Elliott Formation. Piles with less than the minimum embedment into the Elliott Formation may be subject to allowable capacity reductions following evaluation by the geotechnical engineer.

The final driving resistance criteria should be determined based on a wave equation analysis conducted using the Contractor's proposed pile driving equipment and subsequently confirmed with the dynamic load tests. Regardless of the results of the wave equation analysis, the final driving resistance should not be less than an average of 3 hammer blows per 2.5 cm of penetration for the last 30 cm of pile driving.

4.2.2.2.2 Pile Details

CPP should be fabricated with steel plate tips to protect the pile during driving. Piles should be spaced no closer than three pile widths on center. Piles should be embedded into the pile caps no less than 7.6 cm. Pile connections into the pile caps should be designed in accordance with the relevant Australian Standards.

4.2.2.2.3 Estimated Driven Pile Lengths

Final pile lengths will vary due to the variation in the elevation of the bottom of structure and variations of subsurface conditions along the floodwall alignments. Assuming that piles are driven from the approximate bottom of the proposed foundations, we estimate that pile driven lengths will range between 5 and 20 m for the flood walls, between 10 and 13 m for the Bundaberg Creek pump station and flood gate structure, and between 8 and 10 m for the Distillery Creek pump station and flood gate structure. Pile splices are not anticipated to be required. All piles should be installed as one piece, and no splices are allowed. The use of followers for the installation of piles will not be permitted.

4.2.2.2.4 Indicator Piles and Pile Load Test

We recommend that indicator piles be driven at five percent of the production pile locations within the footprint of the pump station and flood gate structure and five percent of the production piles along the length of the floodwall to assist the Contractor in determining production pile lengths and confirming hammer performance, stresses in the pile during driving, and pile capacity. Dynamic pile testing (PDA testing) should be conducted on each of the indicator piles. The locations of the indicator piles selected by the Contractor should be approved by CDM Smith prior to installation. Indicator piles may be installed at production pile locations.

Dynamic pile testing using a Pile Driving Analyzer™ (PDA) should be conducted on all indicator piles in accordance with Australian Standard 2159-2009 Piling -Design and Installation (AS 2159) during initial driving and for restrikes. Restrikes should be conducted on all indicator piles a minimum of 7 days following the end of initial driving to evaluate "setup" or "pile freeze" effects in the Elliott Formation. A Case Pile Wave Analysis Program (CAPWAP®) should be performed to predict ultimate pile capacity in accordance with the AS 2159. A CAPWAP® analysis should be performed for each indicator pile for the end of initial driving and beginning of restrike.

4.2.2.3 Pile Cap and Grade Beam Depth

Pile caps and grade beams should not extend less than 1.5 m below any adjacent ground surface and interior pile caps and grade beams should extend at least 1.5 m below the top of the slab.

4.2.2.4 Foundation Settlement

Settlement of the pile-supported structures, under the anticipated loads and designed as recommended above, are expected to be less than 2.6 cm of total settlement and 1.3 cm of differential settlement.

4.2.3 Recommendations for Design of Shallow Foundations

Based on the proposed project site layout, anticipated dimensions, depths, and loadings of the proposed floodwall, and other design requirements, we recommend that the proposed floodwalls along the City Alignment between Sta. 0+00 and Sta. 0+50 and between Sta. 7+75 and Sta. 10+75 and the Distillery Alignment between Sta. 0+00 and Sta. 1+50 bearing on suitable foundation bearing soils. Suitable bearing soils consist of the Elliott Formation or structural fill over the Elliott Formation placed after removal of unsuitable soils. Unsuitable soils include existing fill, alluvial soils, organic soils, or any other soft, loose, or disturbed soil present at the foundation subgrade level. Foundations for the proposed floodwalls may be designed for a maximum allowable bearing pressure of 150 kPa provided they bear on suitable bearing soils.

Where the structure is founded on structural fill, the fill should extend two feet from the edge of the foundation, then outward and downward at a slope of 1 horizontal to 1 vertical (1H:1V) to suitable bearing soils.

4.2.3.1 Foundation Depth

All foundations supported on soil should bear at least 1.5 m below any adjacent ground surface exposed to freezing.

4.2.3.2 Foundation Settlement

Settlement of the shallow foundations, with maximum allowable footing bearing pressures and assumed loading indicated herein, is anticipated to be less than 2.6 cm of total settlement and 1.3 cm of differential settlement.

4.3 Design Groundwater Elevation

At the time of drilling, groundwater was encountered at approximately 2.5 m AHD at test boring B-6. In addition, the 100-year flood level for the site is RL 9.2 m AHD based on the hydrologic and hydraulic (H/H) analyses.

For the purpose of design, we recommend a design groundwater level at RL 9.2 m AHD on the riverside of the flood wall and at the ground surface on the landside of the flood wall.

4.4 Seismic Considerations

Based on "The 2012 National Earthquake Hazard Map of Australia", the project lies within a region with a peak ground acceleration of 0.05 g for the 500-year return period ground peak acceleration (PGA) hazard map.

Based on the subsurface soil conditions, the soils at the site are not considered susceptible to liquefaction.

4.5 Lateral Pressure on Below-Grade Walls and Floodwalls

Below-grade walls that are backfilled with engineered fill on one side and restrained against rotation at the top, should be designed for lateral pressures from soil and groundwater based on an equivalent fluid unit weight of 9.4 kN/m^3 above the design groundwater level and 14.1 kN/m^3 below the design groundwater level.

In addition, a pressure equal to 0.5 times surface surcharge loads from vehicular loads, building foundations, or other loads should be applied over the full height of all walls. Earthquake induced pressures should be included as applicable per the applicable Australian Standards.

Below-grade walls that are backfilled with engineered fill on one side and free to rotate at the top should be designed for lateral pressures from soil and groundwater based on an equivalent fluid unit weight of 6.3 kN/m^3 above the design groundwater level and 12.6 kN/m^3 below the design groundwater level.

Surface surcharges and other loads should be applied in the same manner as the restrained walls described above.

4.6 Resistance to Unbalanced Lateral Loads

Unbalanced lateral loads should be designed to be resisted by friction on the bottom of the shallow foundation bearing on the Elliott Formation or on structural fill placed directly over the Elliott Formation. For purposes of design, a coefficient of friction of 0.35 should be used. It is expected that the available friction will be sufficient to resist the unbalanced lateral loads. However, should lateral loads exceed the friction available, the additional loads may be resisted by passive pressures on the foundations, provided the walls are appropriately design for the pressures.

A passive lateral earth pressure resistance of up to a maximum equivalent fluid pressure of 31.5 kN/m^3 may be assumed provided the foundations are backfilled with structural fill compacted to a density of at least 98 percent of the maximum dry density as determined by laboratory test AS 1289.5.1.1. The resistance from the upper 0.6 m of soil should be neglected due to surface effects and potential for disturbance from frost action and other factors. Frictional resistance should be assumed to be mobilized first and to its full capacity before any passive pressure is developed.

For pile-supported foundations, lateral load resistance of 25 percent of the compression pile capacity summarized in Table 4-1 can be developed from piles battered at 1H:4V. The effects of passive soil resistance should not be considered. No frictional resistance may be assumed on the bottom of pile-supported foundations.

4.7 Resistance to Buoyancy

The proposed structures should be designed to resist flotation due to buoyancy under the design groundwater condition. Dead weight of the structure, the weight of soil vertically above the structure, and any extension of the foundation beyond the structure wall may be assumed to resist flotation. The unit weight of the backfill soil used to calculate resistance to flotation should be assumed to be 18.1 kN/m^3. In addition, for pile-supported foundations, uplift capacities as summarized in Table 4-1 may be used for design against uplift.

A minimum factor of safety against flotation of 1.25 should be used to evaluate uplift resistance under normal groundwater and 100-year flood conditions.

4.8 Additional Geotechnical Investigation – Detailed Design

Considering the variation in thickness, density, and soil types for the alluvial soils and Elliott Formation layers along the proposed floodwall alignments, we recommend conducting an additional geotechnical investigation and laboratory testing programs for the detailed design. This investigation would support the further development of geotechnical design recommendations and construction aspects, including planning and evaluation of pile load tests. Foundation recommendations for the floodwalls and pump station and flood gate structures should be reviewed and verified based on the results of the additional geotechnical investigation.

Appendix A

Seepage Analyses

Purpose:

This calculation package provides a preliminary estimate of the exit gradient and uplift pressures under the proposed inverted T floodwall for shallow foundations and deep foundation options with varying sheetpile lengths.

Method:

Seepage analyses were performed using the SEEP/W model developed by GEO-SLOPE International. Hydraulic conductivity values of the various subsurface layers were assumed based upon experience with similar geologic units. The seepage model was run under steady-state seepage conditions assuming the 100-year design flood of the Burnett River to calculate exit gradients and uplift pressures.

Soil Information:

Subsurface soil information is based upon existing geotechnical data from nearby borings B-2, B-3, and B-5 for the deep foundation cross-section and B-12 and B-13 for the shallow foundation cross-section. Soil parameters for seepage model are assumed by CDM Smith based on soil types and engineering experiences.

Datum:

Australian Height Datum (AHD)

Modeling Scenario:

100-year flood level at El. 9.2 m Australian Height Datum (AHD)

References:

1. CDM Smith, Draft Conceptual Flood Wall Drawings, February 2018.
2. CDM Smith, "Factual Geotechnical Report, Bundaberg East Levee," 2 February 2018.
3. GEO-SLOPE International Ltd, "Seepage Modeling with SEEP/W," June 2015.
4. United States Army Corps of Engineers, EM 1110-2-1913 "Design and Construction of Levees," 30 April 2000.
5. Ralph B. Peck, "Foundation Engineering, 2nd Edition," Page 43.
6. United States Army Corps of Engineers, EM 1110-2-1901 "Seepage Analysis and Control for Dams," 30 April 1993.

Assumptions

1. The selected cross-sections represent the most critical locations for seepage.
2. The problem can be simplified as 2-dimensional problem.
3. Seepage model boundary on protected side can be set at around 100 meters away from the floodwall and assumed as constant head boundary at EL 2.5 m (assumed groundwater level based on test boring B-6).
4. Riverside boundary is set as constant head boundary at EL 9.2 m (100-year flood elevation).
5. Assume maximum allowable exit gradient is 0.5 (factor of Safety = 2).
6. Assume the sheet pile depth varies between 3 m, 7 m (half the thickness of the alluvial soils layer), and 13.5 m (the full thickness of the alluvial soils layer).

Results

1. The preliminary estimates of uplift pressures and exit gradients can be found in Table 2.
2. Additional exploration is recommended during detailed design to collect additional data for the seepage analysis. The analyses presented in this calculation will be updated/revised once additional data are collected.

DLGRMA

Bundaberg East Levee

Table 1

Soil Layers and Parameters for Base Model

Layer	Material	Layer Thickness (m)		Hydraulic Conductivity, K_h	k_h / k_v	Bases of Parameter Selection
		Deep Foundation	Shallow Foundation	cm/sec		
1	Fill	1.5	1.5	1.0E-07	2	From Peck[(5)]; typical value for homogeneous clays
2	Alluvial Soils	13.5	NA	1.0E-06	5	From Peck[(5)]; typical value for stratified clay deposits
3	Elliott Formation	>15	>10	1.0E-8	5	From Peck[(5)]; typical value for homogeneous clays
4	Sheet Pile	NA	NA	1.0E-8	2	Assumed

Notes:

1. Soil layers and parameters are selected based on nearby boring data.

Abbreviations:

NA=Not Applicable.

DLGRMA
Bundaberg East Levee

Table 2
Modeling Scenarios and Results Summary

Run #	Modeling Scenario	100-Year Flood Water Level Elevation	Results			
			Uplift Pressure on River Side, kPa	Uplift Pressure on Land Side, kPa	Exit Gradient	Factor of Safety
1	Deep Foundation, City Alignment, 3 m Sheetpile Wall	EL 9.2	33.3	27.1	0.77	1.1
2	Deep Foundation, City Alignment, 7 m Sheetpile Wall	EL 9.2	35.2	25.1	0.65	1.3
3	Deep Foundation, City Alignment, 13 m Sheetpile Wall	EL 9.2	43.4	0	0	>2
4	Shallow Foundation, Distillery Alignment	EL 9.2	22.8	5	0	>2

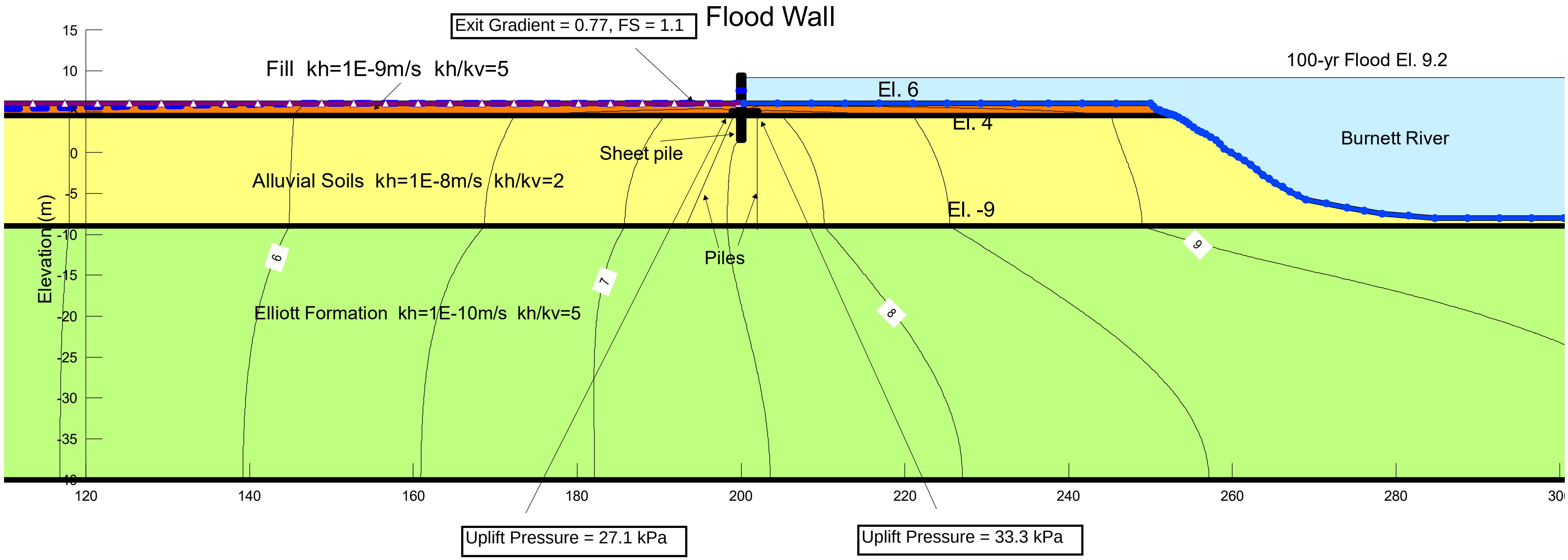
Notes:

1. Assume the sheetpile wall is permeable.

2. Critical gradient i_{cr} calculated based on EM 1110-2-1901, page 4-25.

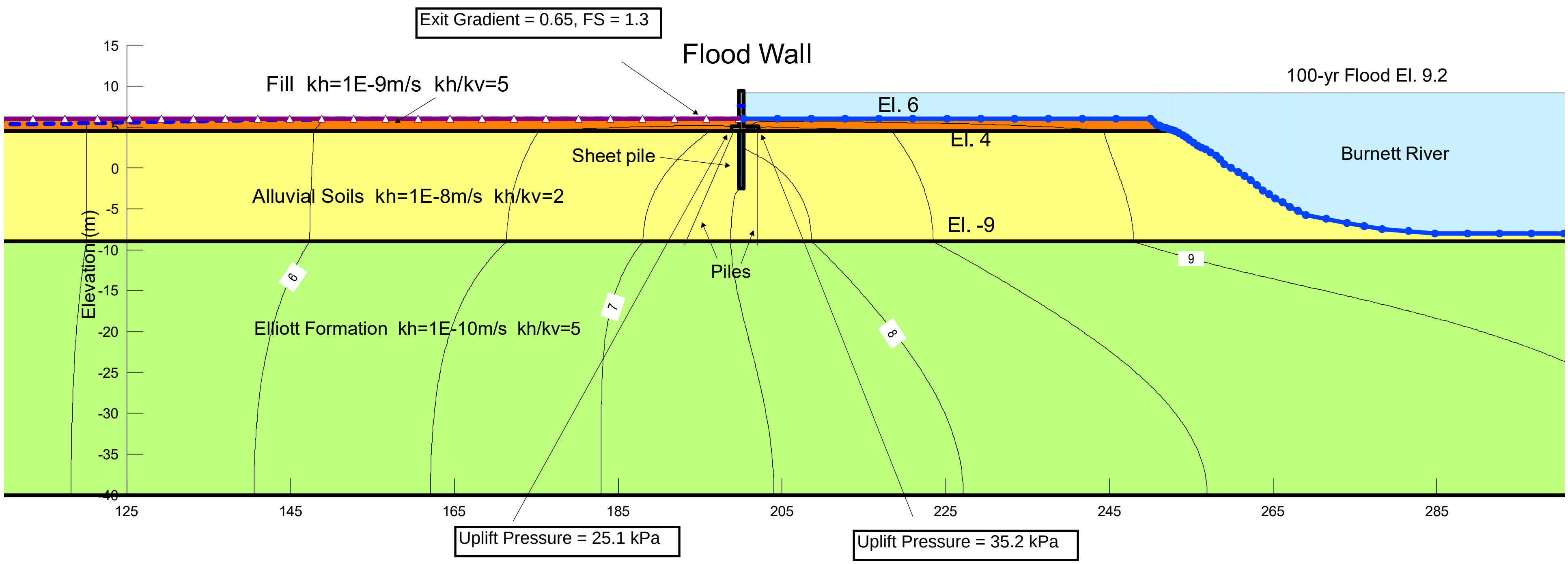
3. Uplift pressures taken at bottom corners of wall foundation.

3 Meter Sheetpile Wall



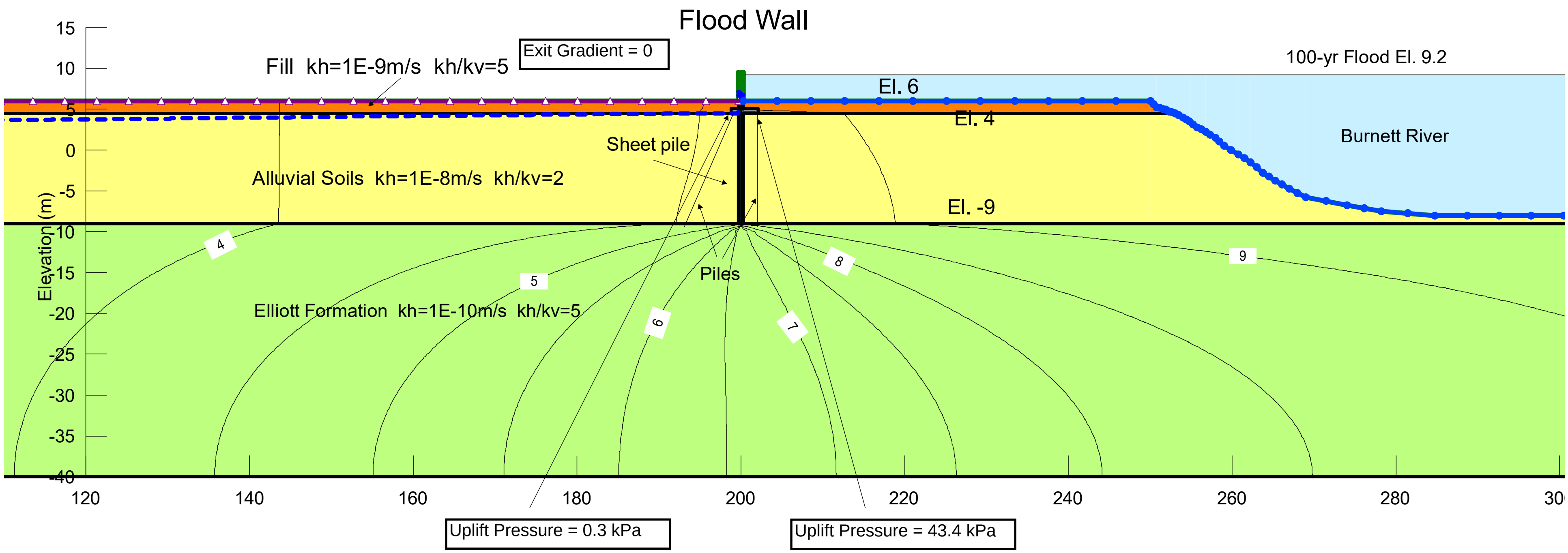
Exit Gradient = 0.77, FS = 1.1
Flood Wall
100-yr Flood El. 9.2
Fill kh=1E-9m/s kh/kv=5
El. 6
El. 4
Burnett River
Sheet pile
Alluvial Soils kh=1E-8m/s kh/kv=2
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
Uplift Pressure = 27.1 kPa
Uplift Pressure = 33.3 kPa

7 Meter Sheetpile Wall



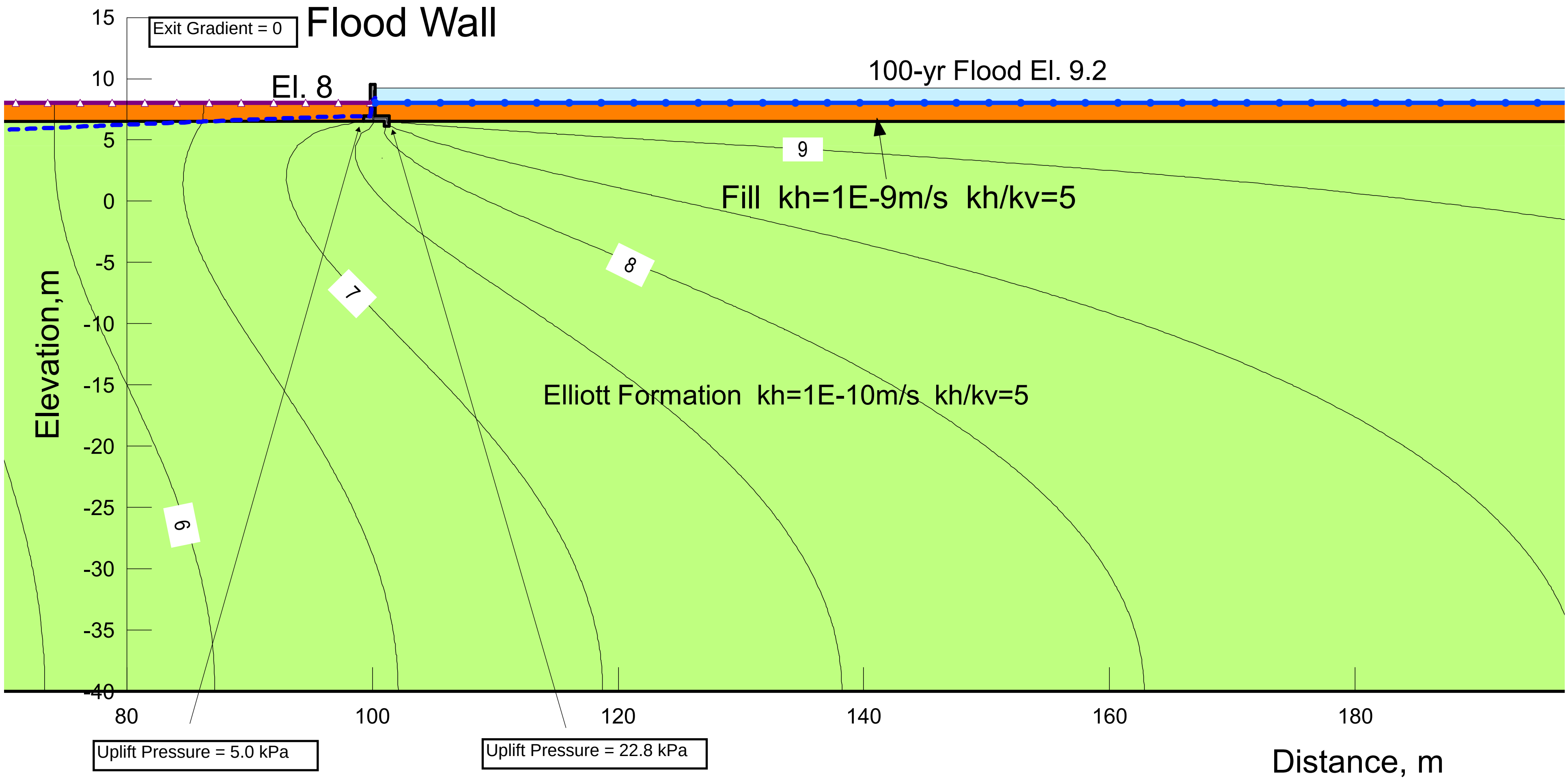
Exit Gradient = 0.65, FS = 1.3
Flood Wall
100-yr Flood El. 9.2
Fill kh=1E-9m/s kh/kv=5
El. 6
El. 4
Sheet pile
Burnett River
Alluvial Soils kh=1E-8m/s kh/kv=2
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
125
145
165
185
205
225
245
265
285
6
7
8
9
Uplift Pressure = 25.1 kPa
Uplift Pressure = 35.2 kPa

13.5 Meter Sheetpile Wall



Flood Wall
Exit Gradient = 0
Fill kh=1E-9m/s kh/kv=5
100-yr Flood El. 9.2
El. 6
El. 4
Burnett River
Sheet pile
Alluvial Soils kh=1E-8m/s kh/kv=2
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
120
140
160
180
200
220
240
260
280
4
5
6
7
8
9
Uplift Pressure = 0.3 kPa
Uplift Pressure = 43.4 kPa

Shallow Foundation



Flood Wall
Exit Gradient = 0
El. 8
100-yr Flood El. 9.2
Fill kh=1E-9m/s kh/kv=5
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation,m
Distance, m
Uplift Pressure = 5.0 kPa
Uplift Pressure = 22.8 kPa
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
80
100
120
140
160
180
6
7
8
9

Appendix B

Deep Foundation Analyses

Appendix B1

Driven 400-mm-Square Concrete Preformed Piles

Problem: Evaluate the vertical pile capacity of an assumed preformed concrete pile.

References:

1. Federal Highway Administration, "Design and Construction of Driven Pile Foundations," FHWA-HI-97-013, December 1996.
2. API Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
3. Australian Building and Construction Commission, "Code for the Tendering and Performance of Building Work 2016"
4. FHWA, "Design and Construction of Driven Pile Foundations, Workshop Manual - Volume I," September 2016.
5. AS 2159-2009, Australian Standard - Piling -Design and Installation.
6. FHWA, "Design and Construction of Driven Pile Foundations - Comprehensive Design Examples," September 2016.
7. "Factual Geotechnical Report, Bundaberg East Levee, Bundaberg, Queensland" CDM Smith, 31 January 2018

Pile Information: 400 mm square concrete pile

Datum: Australian Height Datum (AHD)

Assumptions:

1. The proposed pile cut-off elevation is assumed to be at 1.5 meters below ground surface.
2. Groundwater elevation is assumed at El. 2.5 based upon observed water level in test boring B-6.
3. Pile is a 400 mm square concrete pile.
4. Allowable structural capacity of the 400 mm concrete pile is 1,450 kN.
5. Assume 5 percent of piles are dynamically load tested.
6. Assume no downdrag displacement load due to negligible raise in grade.
7. Assume k=1.0 for pile per Reference No. 2.
8. Assume allowable compressive capacity required for each pile is 250, 500, 750, and 1,000 kN.

Soil Information: Soil layering, soil properties and groundwater elevation obtained from available boring logs[7].

Table 1 - Summary of Subsurface Conditions

	Alignment	1. City Alignment Sta. 0+50 to Sta. 3+50	2. City Alignment Sta. 3+50 to Sta. 7+75	3. Distillery Alignment Sta. 1+50 to Sta. 5+88
	Alluvial Soils Thickness(m)	13	7	5
	Elliott Formation Thickness(m)	>15	>15	>10
	Applicable Borings	B-2, B-3, B-5	B-4, B-6, B-7	B-12, B-13
Elliott Formation Properties	Su (kPa)	100	50	0
	δ (°)	0	0	20
	Φ (°)	0	0	30
	Limiting Skin Friction (kPa)	0	0	67
	Limiting End Bearing (MPa)	0	0	2.9

Analysis Method: Simplified API 1986 & 1993 Method

Q compression = $A_p \times q_p + \Sigma (A_s \times f_s)$ Eq. 6.4.1-1 Reference 2

where A_p= tip area, f_s=side friction, q_p=tip resistance, A_s=side area

Skin Friction (f_s):

For undrained clay (a-Method): $f_s = \alpha * S_u$ Eq. 6.4.2-1 and Eq. 6.4.2-2 Reference 2

where $\alpha = 0.5* (Su/\sigma_v')^{\wedge(-0.5)}$ for $(su/\sigma_v')<1$

$= 0.5* (Su/\sigma_v')^{\wedge(-025)} <1$ for $(su/\sigma_v')>1$

S_u =undrained shear strength

For drained clay/sand (b-Method): $f_s = K \tan\delta * \sigma'_v$ Eq. 6.4.3-1 Reference 2

where δ = soil - pile friction angle

K = lateral pressure coefficient

σ'_v = effective vertical pressure

Tip Resistance (q_p)

For undrained clay: $q_p = N_c * Su$ Eq. 6.4.2-3 Reference 2

where $N_c = 9$

Su = undrained shear strength at the pile tip

For drained clay/sand: $q_p = Nq * \sigma_v'$ Eq. 6.4.3-2 Reference 2

where $Nq = \exp(\pi*\tan\phi)*[\tan(45+\phi/2)]^2$ (Meyerhoff)

σ_v' = effective vertical pressure at the pile tip

Results:

A summary of the total allowable compressive and uplift capacity is summarized in Table 2 below.

Table 2 - Summary of Allowable Compressive and Uplift Pile Capacity

Soil Profile	Total Allowable Compressive Capacity (kN)	Total Allowable Uplift Capacity (kN)	Embedment in Elliott Formation (m)
1	250	200	1
1	500	325	2
1	750	550	6
1	1000	725	9
2	250	150	2
2	500	375	8
2	750	525	12
2	1000	750	17
3	250	75	1
3	500	200	5
3	750	375	9
3	1000	525	12

Notes:

1. Assumes a FS of 1.39 based on AS 2159-2009 Section 4.3.1 calculation.

References:

AS 2159-2009 Piling -- Design and Installation

4.3 GENERAL PRINCIPLES OF GEOTECHNICAL STRENGTH DESIGN

4.3.1 Design geotechnical strength

A pile shall be proportioned such that the design geotechnical strength ($R_{d,g}$) is not less than the design action effect (E_d) as detailed in Clause 3.2.2, that is—

$$R_{d,g} \geq E_d \quad \ldots 4.3.1(1)$$

The design geotechnical strength ($R_{d,g}$) shall be calculated as the design ultimate geotechnical strength ($R_{d,ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g), according to the following equation:

$$R_{d,g} = \phi_g R_{d,ug} \quad \ldots 4.3.1(2)$$

The geotechnical strength reduction factor (ϕ_g) shall be determined as follows:

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

where

ϕ_{gb} = basic geotechnical strength reduction factor as given in Clause 4.3.2

ϕ_{tf} = intrinsic test factor

= 0.9, for static load testing (see Section 8)

= 0.75, for rapid load testing (see Section 8)

= 0.8, for dynamic load testing of preformed piles (see Section 8)

= 0.75, for dynamic load testing of other than preformed piles (see Section 8)

= 0.85, for bi-directional load testing (see Section 8)

= ϕ_{gb}, for no testing

K = testing benefit factor

= $1.33p/(p + 3.3) \leq 1$, for static or rapid load testing

= $1.13p/(p + 3.3) \leq 1$, for dynamic load testing

p = percentage of the total piles that are tested and meet the specified acceptance criteria

References:

4.3.2 Assessment of basic geotechnical strength reduction factor (ϕ_{gb})

The basic geotechnical strength reduction factor (ϕ_{gb}) shall be calculated using a risk assessment procedure as set out below:

(a) Rate each risk factor in Table 4.3.2(A) on a scale from 1 to 5 for the nature of the site, the available site information and the pile design and installation procedures adopted. This will produce an individual risk rating (IRR) according to the assessed level of risk, as set out in Table 4.3.2(B)

(b) Determine the overall design average risk rating (ARR) using the weighted average of the product of all of the risk weighting factors (w_i) shown in column 2 of Table 4.3.2(A) times the relevant individual risk rating (IRR), as follows:

$$ARR = \Sigma(w_i IRR_i)/\Sigma w_i \quad \ldots 4.3.2$$

(c) Determine the basic geotechnical strength reduction factor (ϕ_{gb}) from Table 4.3.2(C) depending on the level of redundancy in the piling system. Systems with a high degree of redundancy would include large pile groups under large caps, piled rafts and pile groups with more than 4 piles. Systems with a low level of redundancy would include isolated heavily loaded piles and piles set out at large spacings.

TABLE 4.3.2(A)

WEIGHTING FACTORS AND INDIVIDUAL RISK RATINGS FOR RISK FACTORS

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Site				
Geological complexity of site	2	Horizontal strata, well-defined soil and rock characteristics	Some variability over site, but without abrupt changes in stratigraphy	Highly variable profile or presence of karstic features or steeply dipping rock levels or faults present on site, or combinations of these
Extent of ground investigation	2	Extensive drilling investigation covering whole site to an adequate depth	Some boreholes extending at least 5 pile diameters below the base of the proposed pile foundation level	Very limited investigation with few shallow boreholes
Amount and quality of geotechnical data	2	Detailed information on strength compressibility of the main strata	CPT probes over full depth of proposed piles or boreholes confirming rock as proposed founding level for piles	Limited amount of simple in situ testing (e.g., SPT) or index tests only
Design				
Experience with similar foundations in similar geological conditions	1	Extensive	Limited	None

(*continued*)

References:

TABLE 4.3.2(A) (*continued*)

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Method of assessment of geotechnical parameters for design	2	Based on appropriate laboratory or in situ tests or relevant existing pile load test data	Based on site-specific correlations or on conventional laboratory or in situ testing	Based on non-site-specific correlations with (for example) SPT data
Design method adopted	1	Well-established and soundly based method or methods	Simplified methods with well-established basis	Simple empirical methods or sophisticated methods that are not well established
Method of utilizing results of in situ test data and installation data	2	Design values based on minimum measured values on piles loaded to failure	Design methods based on average values	Design values based on maximum measured values on test piles loaded up only to working load, or indirect measurements used during installation, and not calibrated to static loading tests
Installation				
Level of construction control	2	Detailed with professional geotechnical supervision, construction processes that are well established and relatively straightforward	Limited degree of professional geotechnical involvement in supervision, conventional construction procedures	Very limited or no involvement by designer, construction processes that are not well established or complex
Level of performance monitoring of the supported structure during and after construction	0.5	Detailed measurements of movements and pile loads	Correlation of installed parameters with on-site static load tests carried out in accordance with this Standard	No monitoring

NOTE: The pile design shall include the risk circumstances for each individual risk category and consideration of all of the relevant site and construction factors.

TABLE 4.3.2(B)
INDIVIDUAL RISK RATING (IRR)

Risk level	Individual risk rating (IRR)
Very low	1
Low	2
Moderate	3
High	4
Very high	5

TABLE 4.3.2(C)
BASIC GEOTECHNICAL STRENGTH REDUCTION FACTOR (ϕ_{gb}) FOR AVERAGE RISK RATING

Range of average risk rating (ARR)	Overall risk category	ϕ_{gb} for low redundancy systems	ϕ_{gb} for high redundancy systems
ARR ≤1.5	Very low	0.67	0.76
1.5 < ARR ≤2.0	Very low to low	0.61	0.70
2.0 < ARR ≤2.5	Low	0.56	0.64
2.5 < ARR ≤3.0	Low to moderate	0.52	0.60
3.0 < ARR ≤3.5	Moderate	0.48	0.56
3.5 < ARR ≤4.0	Moderate to high	0.45	0.53
4.0 < ARR ≤4.5	High	0.42	0.50
>4.5	Very high	0.40	0.47

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

ϕ_{tf} =	0.8	for dynamic load testing	
K =	1.13p/(p+3.3)		
p=	5	percent of piles to be tested	
K=	0.68		
IRR=	50.5		
w_i =	14.5		
ARR=	3.48		
ϕ_{gb} =	0.56		
ϕ_g =	0.72	>=	0.56
FS=	1.39		

Table 1: Structural Capacity of Concrete Pile

Type 400 mm Square Preformed Concrete Pile
Shape square

Width (m)	Gross Area (sq m)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Total Structural Capacity (kN)
0.3	0.090	0.090	27575	**819**
0.35	0.123	0.123	27575	**1115**
0.4	0.160	0.160	27575	**1456**
0.45	0.203	0.203	27575	**1843**
0.5	0.250	0.250	27575	**2275**
0.55	0.303	0.303	27575	**2753**

Notes:

1 Allowable Concrete Stress = 0.33 f'c

Alignment 1

Client: DLGRMA
Project: Bundaberg East Levee
Job Number: 121923-221532
Detail: Driven Preformed Concrete Pile Alignment 1

Computed by: JPB
Date: 14/2/2018
Rev by: JPB
Date: 28/2/2018

Checked by: BJG
Date: 5/2/2018
Page: 6 & 7

AXIAL PILE CAPACITY ESTIMATES Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	100	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

Pile type =	400 mm Square Preformed Concrete Pile				
Pile shape =	square	(square or circle)			
Pile Diameter / Length of Side =	0.4	m			
Surface Area =	1.6	sq m/m length			Assume pile is 100% plugged
Wall Thickness =	0	m			
End Bearing Area - FULL AREA =	0.160	sq meters	=	0.160 sq meters	
Unit weight of pile =	24	kN/m³			

Design Parameters

K =	1	
Nc (clay) =	9	
Reduction on downdrag load by bitimen coating =	0	% (apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7	
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g
Downdrag load factor =	0	
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m³	σv' (kPa)	Su/σv'	α	Unit Skin Friction For Clay: fs clay (kPa)	Unit Skin Friction For Sand: fs sand (kPa)	Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing For Clay: qp clay (kPa)	Unit End Bearing For Sand: Nq	Unit End Bearing For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	11	42	30	5	9	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	54	39	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	36	67	48	16	31	22
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	50	82	59	22	43	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	65	97	70	29	55	40
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	81	113	81	35	68	49
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	97	129	93	42	81	58
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	130	162	117	57	108	78
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	166	197	142	72	137	98
8	-2	1	Alluvial Soils	22	15	0	0	0	8.2	96	0.23	1.0	22	0	125	0	0	198	0.0	0	201	232	167	88	165	119
9	-3	1	Alluvial Soils	22	15	0	0	0	8.2	104	0.21	1.0	22	0	147	0	0	198	0.0	0	236	268	193	103	193	139
10	-4	1	Alluvial Soils	22	15	0	0	0	8.2	113	0.20	1.0	22	0	169	0	0	198	0.0	0	271	303	218	119	222	160
11	-5	1	Alluvial Soils	22	15	0	0	0	8.2	121	0.18	1.0	22	0	191	0	0	198	0.0	0	306	338	243	134	250	180
12	-6	1	Alluvial Soils	22	15	0	0	0	8.2	129	0.17	1.0	22	0	213	0	0	198	0.0	0	342	373	269	149	279	200
13	-7	1	Alluvial Soils	22	15	0	0	0	8.2	137	0.16	1.0	22	0	235	0	0	198	0.0	0	377	408	294	165	307	221
14	-8	1	Elliott Formation	100	0	0	0	0	9.0	146	0.69	0.6	60	0	296	0	0	900	0.0	0	473	617	444	207	378	272
15	-9	1	Elliott Formation	100	0	0	0	0	9.0	155	0.65	0.6	62	0	358	0	0	900	0.0	0	573	717	516	251	452	325
16	-10	1	Elliott Formation	100	0	0	0	0	9.0	164	0.61	0.6	64	0	422	0	0	900	0.0	0	675	819	589	295	527	379
17	-11	1	Elliott Formation	100	0	0	0	0	9.0	173	0.58	0.7	66	0	488	0	0	900	0.0	0	780	924	665	341	605	435
18	-12	1	Elliott Formation	100	0	0	0	0	9.0	182	0.55	0.7	67	0	555	0	0	900	0.0	0	888	1,032	743	389	684	492
19	-13	1	Elliott Formation	100	0	0	0	0	9.0	191	0.52	0.7	69	0	624	0	0	900	0.0	0	999	1,143	822	437	765	551
20	-14	1	Elliott Formation	100	0	0	0	0	9.0	200	0.50	0.7	71	0	695	0	0	900	0.0	0	1,112	1,256	904	487	848	610
21	-15	1	Elliott Formation	100	0	0	0	0	9.0	209	0.48	0.7	72	0	767	0	0	900	0.0	0	1,228	1,372	987	537	933	671
22	-16	1	Elliott Formation	100	0	0	0	0	9.0	218	0.46	0.7	74	0	841	0	0	900	0.0	0	1,346	1,490	1,072	589	1019	733
23	-17	1	Elliott Formation	100	0	0	0	0	9.0	227	0.44	0.8	75	0	916	0	0	900	0.0	0	1,466	1,610	1,158	642	1107	797
24	-18	1	Elliott Formation	100	0	0	0	0	9.0	236	0.42	0.8	77	0	993	0	0	900	0.0	0	1,589	1,733	1,247	695	1197	861
25	-19	1	Elliott Formation	100	0	0	0	0	9.0	245	0.41	0.8	78	0	1,072	0	0	900	0.0	0	1,714	1,858	1,337	750	1289	927
26	-20	1	Elliott Formation	100	0	0	0	0	9.0	254	0.39	0.8	80	0	1,151	0	0	900	0.0	0	1,842	1,986	1,429	806	1382	994

Client: DLGRMA	**Computed by:** JPB	**Checked by:** BJG	
Project: Bundaberg East Levee	**Date:** 14/2/2018	**Date:** 5/2/2018	
Job Number: 121923-221532	**Rev by:** JPB	**Page:** 6 & 7	
Detail: Driven Preformed Concrete Pile Alignment 1	**Date:** 28/2/2018		

AXIAL PILE CAPACITY ESTIMATES Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	100	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

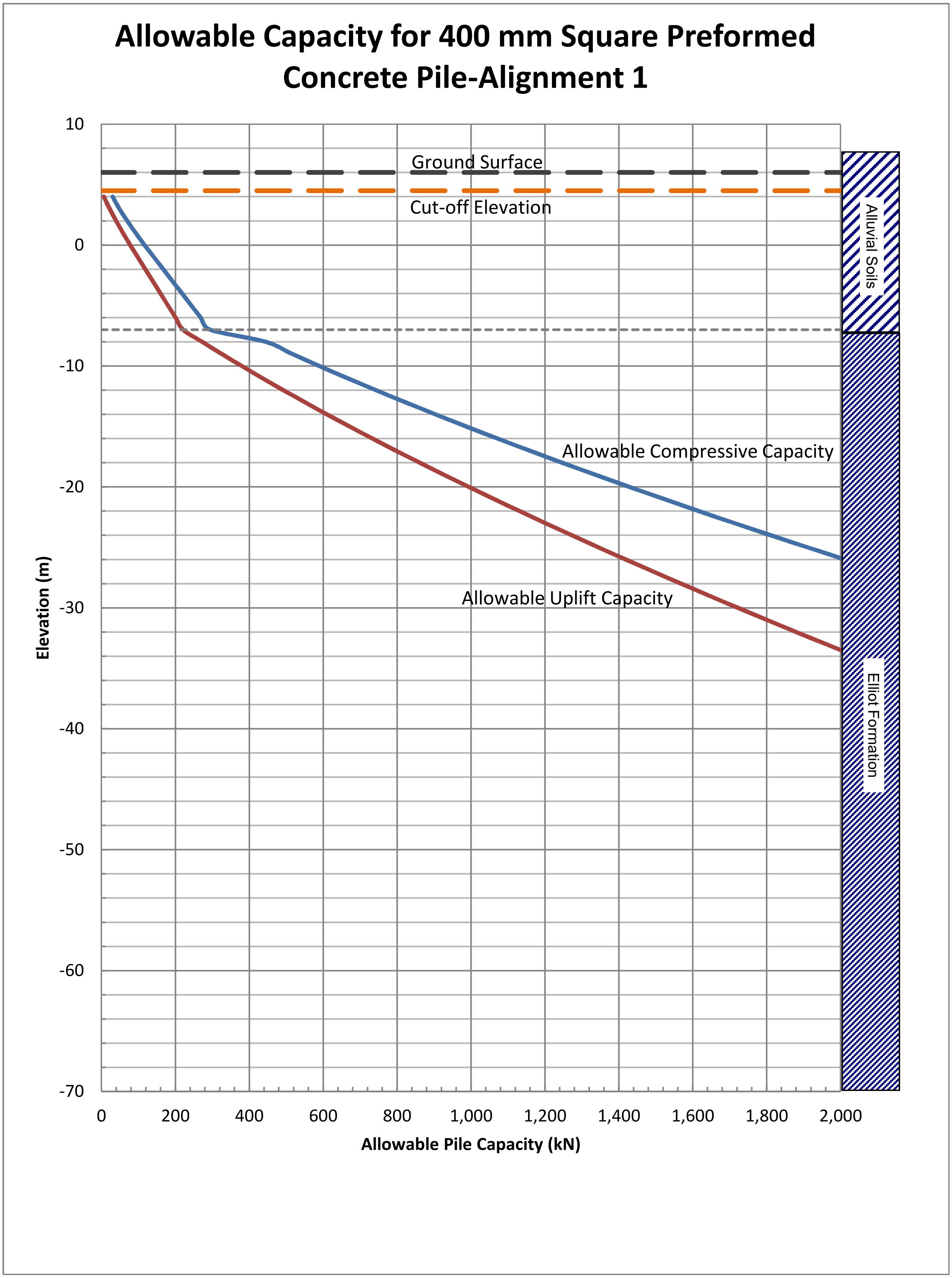
Pile type =	400 mm Square Preformed Concrete Pile		
Pile shape =	square	(square or circle)	
Pile Diameter / Length of Side =	0.4	m	
Surface Area =	1.6	sq m/m length	
Wall Thickness =	0	m	
End Bearing Area - FULL AREA =	0.160	sq meters	= 0.160 sq meters
Unit weight of pile =	24	kN/m³	

Assume pile is 100% plugged

Design Parameters

K =	1	
Nc (clay) =	9	
Reduction on downdrag load by bitimen coating =	0	% (apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7	
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g
Downdrag load factor =	0	
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1

																		COMPRESSION CAPACITY						UPLIFT CAPACITY		
													Unit Skin Friction					Unit End Bearing			Ult. Friction	Ult. Comp.	Allow. Comp.		Ultimate Uplift	Allow. Uplift.
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Capacity	Capacity	Capacity		Capacity	Capacity
27	-21	1	Elliott Formation	100	0	0	0	0	9.0	263	0.38	0.8	81	0	1,232	0	0	900	0.0	0	1,972	2,116	1,522	863	1476	1062
28	-22	1	Elliott Formation	100	0	0	0	0	9.0	272	0.37	0.8	82	0	1,315	0	0	900	0.0	0	2,104	2,248	1,617	920	1572	1131
29	-23	1	Elliott Formation	100	0	0	0	0	9.0	281	0.36	0.8	84	0	1,399	0	0	900	0.0	0	2,238	2,382	1,713	979	1670	1201
30	-24	1	Elliott Formation	100	0	0	0	0	9.0	290	0.34	0.9	85	0	1,484	0	0	900	0.0	0	2,374	2,518	1,811	1039	1769	1273
31	-25	1	Elliott Formation	100	0	0	0	0	9.0	299	0.33	0.9	86	0	1,570	0	0	900	0.0	0	2,512	2,656	1,911	1099	1870	1345
32	-26	1	Elliott Formation	100	0	0	0	0	9.0	308	0.32	0.9	88	0	1,658	0	0	900	0.0	0	2,653	2,797	2,012	1161	1972	1419
33	-27	1	Elliott Formation	100	0	0	0	0	9.0	317	0.32	0.9	89	0	1,747	0	0	900	0.0	0	2,795	2,939	2,115	1223	2075	1493
34	-28	1	Elliott Formation	100	0	0	0	0	9.0	326	0.31	0.9	90	0	1,837	0	0	900	0.0	0	2,940	3,084	2,218	1286	2180	1569
35	-29	1	Elliott Formation	100	0	0	0	0	9.0	335	0.30	0.9	92	0	1,929	0	0	900	0.0	0	3,086	3,230	2,324	1350	2287	1645
36	-30	1	Elliott Formation	100	0	0	0	0	9.0	344	0.29	0.9	93	0	2,022	0	0	900	0.0	0	3,235	3,379	2,431	1415	2394	1722
37	-31	1	Elliott Formation	100	0	0	0	0	9.0	353	0.28	0.9	94	0	2,116	0	0	900	0.0	0	3,385	3,529	2,539	1481	2503	1801
38	-32	1	Elliott Formation	100	0	0	0	0	9.0	362	0.28	1.0	95	0	2,211	0	0	900	0.0	0	3,537	3,681	2,648	1548	2614	1880
39	-33	1	Elliott Formation	100	0	0	0	0	9.0	371	0.27	1.0	96	0	2,307	0	0	900	0.0	0	3,691	3,835	2,759	1615	2725	1961
40	-34	1	Elliott Formation	100	0	0	0	0	9.0	380	0.26	1.0	97	0	2,405	0	0	900	0.0	0	3,847	3,991	2,871	1683	2838	2042
41	-35	1	Elliott Formation	100	0	0	0	0	9.0	389	0.26	1.0	99	0	2,503	0	0	900	0.0	0	4,005	4,149	2,985	1752	2952	2124
42	-36	1	Elliott Formation	100	0	0	0	0	9.0	398	0.25	1.0	100	0	2,603	0	0	900	0.0	0	4,165	4,309	3,100	1822	3068	2207
43	-37	1	Elliott Formation	100	0	0	0	0	9.0	407	0.25	1.0	100	0	2,703	0	0	900	0.0	0	4,325	4,469	3,215	1892	3184	2291
44	-38	1	Elliott Formation	100	0	0	0	0	9.0	416	0.24	1.0	100	0	2,803	0	0	900	0.0	0	4,485	4,629	3,330	1962	3300	2374
45	-39	1	Elliott Formation	100	0	0	0	0	9.0	425	0.24	1.0	100	0	2,903	0	0	900	0.0	0	4,645	4,789	3,445	2032	3415	2457
46	-40	1	Elliott Formation	100	0	0	0	0	9.0	434	0.23	1.0	100	0	3,003	0	0	900	0.0	0	4,805	4,949	3,560	2102	3531	2540
47	-41	1	Elliott Formation	100	0	0	0	0	9.0	443	0.23	1.0	100	0	3,103	0	0	900	0.0	0	4,965	5,109	3,675	2172	3647	2624
48	-42	1	Elliott Formation	100	0	0	0	0	9.0	452	0.22	1.0	100	0	3,203	0	0	900	0.0	0	5,125	5,269	3,791	2242	3763	2707
49	-43	1	Elliott Formation	100	0	0	0	0	9.0	461	0.22	1.0	100	0	3,303	0	0	900	0.0	0	5,285	5,429	3,906	2312	3878	2790
50	-44	1	Elliott Formation	100	0	0	0	0	9.0	470	0.21	1.0	100	0	3,403	0	0	900	0.0	0	5,445	5,589	4,021	2382	3994	2874
51	-45	1	Elliott Formation	100	0	0	0	0	9.0	479	0.21	1.0	100	0	3,503	0	0	900	0.0	0	5,605	5,749	4,136	2452	4110	2957
52	-46	1	Elliott Formation	100	0	0	0	0	9.0	488	0.20	1.0	100	0	3,603	0	0	900	0.0	0	5,765	5,909	4,251	2522	4226	3040
53	-47	1	Elliott Formation	100	0	0	0	0	9.0	497	0.20	1.0	100	0	3,703	0	0	900	0.0	0	5,925	6,069	4,366	2592	4341	3123
54	-48	1	Elliott Formation	100	0	0	0	0	9.0	506	0.20	1.0	100	0	3,803	0	0	900	0.0	0	6,085	6,229	4,481	2662	4457	3207
55	-49	1	Elliott Formation	100	0	0	0	0	9.0	515	0.19	1.0	100	0	3,903	0	0	900	0.0	0	6,245	6,389	4,596	2732	4573	3290
56	-50	1	Elliott Formation	100	0	0	0	0	9.0	524	0.19	1.0	100	0	4,003	0	0	900	0.0	0	6,405	6,549	4,711	2802	4689	3373
57	-51	1	Elliott Formation	100	0	0	0	0	9.0	534	0.19	1.0	100	0	4,103	0	0	900	0.0	0	6,565	6,709	4,826	2872	4805	3457
58	-52	1	Elliott Formation	100	0	0	0	0	9.0	543	0.18	1.0	100	0	4,203	0	0	900	0.0	0	6,725	6,869	4,942	2942	4920	3540
59	-53	1	Elliott Formation	100	0	0	0	0	9.0	552	0.18	1.0	100	0	4,303	0	0	900	0.0	0	6,885	7,029	5,057	3012	5036	3623
60	-54	1	Elliott Formation	100	0	0	0	0	9.0	561	0.18	1.0	100	0	4,403	0	0	900	0.0	0	7,045	7,189	5,172	3082	5152	3706
61	-55	1	Elliott Formation	100	0	0	0	0	9.0	570	0.18	1.0	100	0	4,503	0	0	900	0.0	0	7,205	7,349	5,287	3152	5268	3790


Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 1
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Alignment 2

Client: DLGRMA **Computed by:** JPB **Checked by:** BJG
Project: Bundaberg East Levee **Date:** 14/2/2018 **Date:** 5/2/2018
Job Number: 121923-221532 **Rev by:** JPB **Page:** 6 & 7
Detail: Driven Preformed Concrete Pile Alignment 2 **Date:** 28/2/2018

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	400 mm Square Preformed Concrete Pile		
Pile shape =	square	(square or circle)	
Pile Diameter / Length of Side =	0.4	m	
Surface Area =	1.6	sq m/m length	Assume pile is 100% plugged
Wall Thickness =	0	m	
End Bearing Area - FULL AREA =	0.160	sq meters	= 0.160 sq meters
Unit weight of pile =	24	kN/m^3	

Soil Properties

Alignment 2

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
φg =	0.76	Based on AS 2159-2009 Section 4.3.1	

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction For Clay: fs clay (kPa)	Unit Skin Friction For Sand: fs sand (kPa)	Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY Unit End Bearing For Clay: qp clay (kPa)	Unit End Bearing For Sand: Nq	Unit End Bearing For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	11	42	30	5	9	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	54	39	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	36	67	48	16	31	22
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	50	82	59	22	43	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	65	97	70	29	55	40
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	81	113	81	35	68	49
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	97	129	93	42	81	58
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	130	162	117	57	108	78
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	166	197	142	72	137	98
8	-2	1	Elliott Formation	50	0	0	0	0	9.0	96	0.52	0.7	35	0	138	0	0	450	0.0	0	221	293	211	97	179	129
9	-3	1	Elliott Formation	50	0	0	0	0	9.0	105	0.47	0.7	36	0	174	0	0	450	0.0	0	279	351	253	122	224	161
10	-4	1	Elliott Formation	50	0	0	0	0	9.0	114	0.44	0.8	38	0	212	0	0	450	0.0	0	340	412	296	149	270	194
11	-5	1	Elliott Formation	50	0	0	0	0	9.0	123	0.40	0.8	39	0	252	0	0	450	0.0	0	403	475	341	176	318	229
12	-6	1	Elliott Formation	50	0	0	0	0	9.0	132	0.38	0.8	41	0	292	0	0	450	0.0	0	468	540	388	205	367	264
13	-7	1	Elliott Formation	50	0	0	0	0	9.0	142	0.35	0.8	42	0	334	0	0	450	0.0	0	535	607	437	234	418	301
14	-8	1	Elliott Formation	50	0	0	0	0	9.0	151	0.33	0.9	43	0	378	0	0	450	0.0	0	604	676	487	264	470	338
15	-9	1	Elliott Formation	50	0	0	0	0	9.0	160	0.31	0.9	45	0	422	0	0	450	0.0	0	676	748	538	296	524	377
16	-10	1	Elliott Formation	50	0	0	0	0	9.0	169	0.30	0.9	46	0	468	0	0	450	0.0	0	749	821	591	328	579	417
17	-11	1	Elliott Formation	50	0	0	0	0	9.0	178	0.28	0.9	47	0	515	0	0	450	0.0	0	825	897	645	361	636	457
18	-12	1	Elliott Formation	50	0	0	0	0	9.0	187	0.27	1.0	48	0	564	0	0	450	0.0	0	902	974	701	395	694	499
19	-13	1	Elliott Formation	50	0	0	0	0	9.0	196	0.26	1.0	49	0	613	0	0	450	0.0	0	981	1,053	758	429	753	542
20	-14	1	Elliott Formation	50	0	0	0	0	9.0	205	0.24	1.0	50	0	663	0	0	450	0.0	0	1,061	1,133	815	464	812	585
21	-15	1	Elliott Formation	50	0	0	0	0	9.0	214	0.23	1.0	50	0	713	0	0	450	0.0	0	1,141	1,213	873	499	872	628
22	-16	1	Elliott Formation	50	0	0	0	0	9.0	223	0.22	1.0	50	0	763	0	0	450	0.0	0	1,221	1,293	930	534	932	671
23	-17	1	Elliott Formation	50	0	0	0	0	9.0	232	0.22	1.0	50	0	813	0	0	450	0.0	0	1,301	1,373	988	569	992	714
24	-18	1	Elliott Formation	50	0	0	0	0	9.0	241	0.21	1.0	50	0	863	0	0	450	0.0	0	1,381	1,453	1,045	604	1052	757
25	-19	1	Elliott Formation	50	0	0	0	0	9.0	250	0.20	1.0	50	0	913	0	0	450	0.0	0	1,461	1,533	1,103	639	1111	800
26	-20	1	Elliott Formation	50	0	0	0	0	9.0	259	0.19	1.0	50	0	963	0	0	450	0.0	0	1,541	1,613	1,160	674	1171	843

Client: DLGRMA
Project: Bundaberg East Levee
Job Number: 121923-221532
Detail: Driven Preformed Concrete Pile Alignment 2

Computed by: JPB
Date: 14/2/2018
Rev by: JPB
Date: 28/2/2018

Checked by: BJG
Date: 5/2/2018
Page: 6 & 7

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m — Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m — Per Test Boring B-6
Pile Cut-Off Elevation = 4.5 m

Soil Properties

	Alignment 2		
	Alluvial Soils	**Elliott Formation**	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 — Based on Bottom Elevation of Pile Cap.

Pile Information

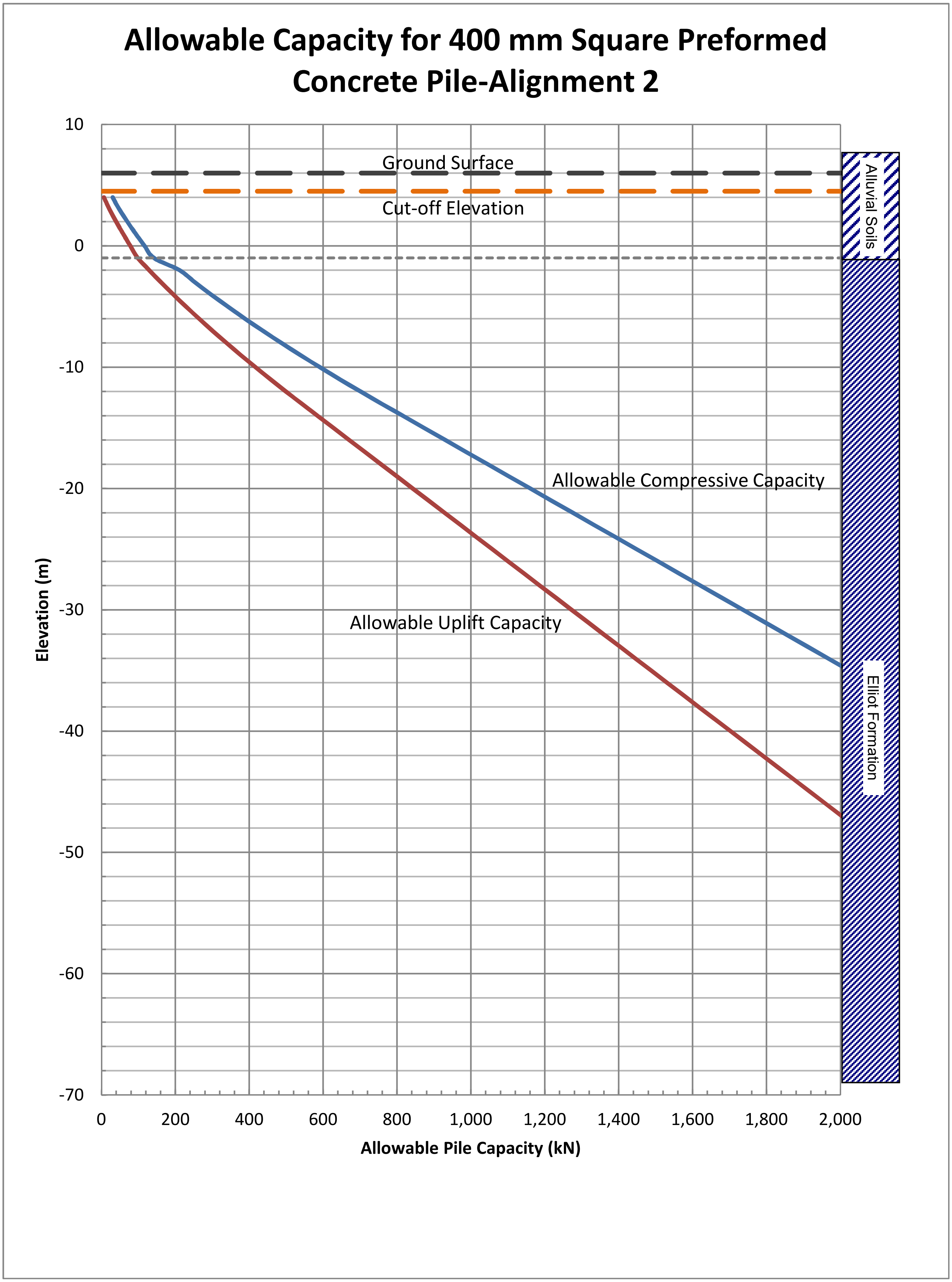
Pile type = 400 mm Square Preformed Concrete Pile
Pile shape = square (square or circle)
Pile Diameter / Length of Side = 0.4 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0 m
End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters
Unit weight of pile = 24 kN/m³

Assume pile is 100% plugged

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕ_g = 0.76 Based on AS 2159-2009 Section 4.3.1

													Unit Skin Friction					COMPRESSION CAPACITY Unit End Bearing			Ult. Friction	Ult. Comp.	Allow. Comp.	UPLIFT CAPACITY	Ultimate Uplift	Allow. Uplift.
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Capacity	Capacity	Capacity		Capacity	Capacity
27	-21	1	Elliott Formation	50	0	0	0	0	9.0	268	0.19	1.0	50	0	1,013	0	0	450	0.0	0	1,621	1,693	1,218	709	1231	886
28	-22	1	Elliott Formation	50	0	0	0	0	9.0	277	0.18	1.0	50	0	1,063	0	0	450	0.0	0	1,701	1,773	1,276	744	1291	929
29	-23	1	Elliott Formation	50	0	0	0	0	9.0	286	0.17	1.0	50	0	1,113	0	0	450	0.0	0	1,781	1,853	1,333	779	1350	972
30	-24	1	Elliott Formation	50	0	0	0	0	9.0	295	0.17	1.0	50	0	1,163	0	0	450	0.0	0	1,861	1,933	1,391	814	1410	1015
31	-25	1	Elliott Formation	50	0	0	0	0	9.0	304	0.16	1.0	50	0	1,213	0	0	450	0.0	0	1,941	2,013	1,448	849	1470	1058
32	-26	1	Elliott Formation	50	0	0	0	0	9.0	313	0.16	1.0	50	0	1,263	0	0	450	0.0	0	2,021	2,093	1,506	884	1530	1101
33	-27	1	Elliott Formation	50	0	0	0	0	9.0	322	0.16	1.0	50	0	1,313	0	0	450	0.0	0	2,101	2,173	1,563	919	1590	1144
34	-28	1	Elliott Formation	50	0	0	0	0	9.0	331	0.15	1.0	50	0	1,363	0	0	450	0.0	0	2,181	2,253	1,621	954	1649	1187
35	-29	1	Elliott Formation	50	0	0	0	0	9.0	340	0.15	1.0	50	0	1,413	0	0	450	0.0	0	2,261	2,333	1,678	989	1709	1230
36	-30	1	Elliott Formation	50	0	0	0	0	9.0	349	0.14	1.0	50	0	1,463	0	0	450	0.0	0	2,341	2,413	1,736	1024	1769	1273
37	-31	1	Elliott Formation	50	0	0	0	0	9.0	358	0.14	1.0	50	0	1,513	0	0	450	0.0	0	2,421	2,493	1,794	1059	1829	1316
38	-32	1	Elliott Formation	50	0	0	0	0	9.0	367	0.14	1.0	50	0	1,563	0	0	450	0.0	0	2,501	2,573	1,851	1094	1888	1359
39	-33	1	Elliott Formation	50	0	0	0	0	9.0	376	0.13	1.0	50	0	1,613	0	0	450	0.0	0	2,581	2,653	1,909	1129	1948	1402
40	-34	1	Elliott Formation	50	0	0	0	0	9.0	385	0.13	1.0	50	0	1,663	0	0	450	0.0	0	2,661	2,733	1,966	1164	2008	1445
41	-35	1	Elliott Formation	50	0	0	0	0	9.0	394	0.13	1.0	50	0	1,713	0	0	450	0.0	0	2,741	2,813	2,024	1199	2068	1488
42	-36	1	Elliott Formation	50	0	0	0	0	9.0	403	0.12	1.0	50	0	1,763	0	0	450	0.0	0	2,821	2,893	2,081	1234	2127	1531
43	-37	1	Elliott Formation	50	0	0	0	0	9.0	412	0.12	1.0	50	0	1,813	0	0	450	0.0	0	2,901	2,973	2,139	1269	2187	1574
44	-38	1	Elliott Formation	50	0	0	0	0	9.0	421	0.12	1.0	50	0	1,863	0	0	450	0.0	0	2,981	3,053	2,196	1304	2247	1617
45	-39	1	Elliott Formation	50	0	0	0	0	9.0	430	0.12	1.0	50	0	1,913	0	0	450	0.0	0	3,061	3,133	2,254	1339	2307	1660
46	-40	1	Elliott Formation	50	0	0	0	0	9.0	439	0.11	1.0	50	0	1,963	0	0	450	0.0	0	3,141	3,213	2,312	1374	2367	1703
47	-41	1	Elliott Formation	50	0	0	0	0	9.0	448	0.11	1.0	50	0	2,013	0	0	450	0.0	0	3,221	3,293	2,369	1409	2426	1746
48	-42	1	Elliott Formation	50	0	0	0	0	9.0	457	0.11	1.0	50	0	2,063	0	0	450	0.0	0	3,301	3,373	2,427	1444	2486	1789
49	-43	1	Elliott Formation	50	0	0	0	0	9.0	466	0.11	1.0	50	0	2,113	0	0	450	0.0	0	3,381	3,453	2,484	1479	2546	1832
50	-44	1	Elliott Formation	50	0	0	0	0	9.0	475	0.11	1.0	50	0	2,163	0	0	450	0.0	0	3,461	3,533	2,542	1514	2606	1875
51	-45	1	Elliott Formation	50	0	0	0	0	9.0	484	0.10	1.0	50	0	2,213	0	0	450	0.0	0	3,541	3,613	2,599	1549	2665	1918
52	-46	1	Elliott Formation	50	0	0	0	0	9.0	493	0.10	1.0	50	0	2,263	0	0	450	0.0	0	3,621	3,693	2,657	1584	2725	1961
53	-47	1	Elliott Formation	50	0	0	0	0	9.0	502	0.10	1.0	50	0	2,313	0	0	450	0.0	0	3,701	3,773	2,714	1619	2785	2004
54	-48	1	Elliott Formation	50	0	0	0	0	9.0	511	0.10	1.0	50	0	2,363	0	0	450	0.0	0	3,781	3,853	2,772	1654	2845	2047
55	-49	1	Elliott Formation	50	0	0	0	0	9.0	520	0.10	1.0	50	0	2,413	0	0	450	0.0	0	3,861	3,933	2,830	1689	2904	2090
56	-50	1	Elliott Formation	50	0	0	0	0	9.0	529	0.09	1.0	50	0	2,463	0	0	450	0.0	0	3,941	4,013	2,887	1724	2964	2133
57	-51	1	Elliott Formation	50	0	0	0	0	9.0	538	0.09	1.0	50	0	2,513	0	0	450	0.0	0	4,021	4,093	2,945	1759	3024	2176
58	-52	1	Elliott Formation	50	0	0	0	0	9.0	547	0.09	1.0	50	0	2,563	0	0	450	0.0	0	4,101	4,173	3,002	1794	3084	2219
59	-53	1	Elliott Formation	50	0	0	0	0	9.0	556	0.09	1.0	50	0	2,613	0	0	450	0.0	0	4,181	4,253	3,060	1829	3144	2262
60	-54	1	Elliott Formation	50	0	0	0	0	9.0	565	0.09	1.0	50	0	2,663	0	0	450	0.0	0	4,261	4,333	3,117	1864	3203	2305
61	-55	1	Elliott Formation	50	0	0	0	0	9.0	574	0.09	1.0	50	0	2,713	0	0	450	0.0	0	4,341	4,413	3,175	1899	3263	2348



Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 2
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
Allowable Pile Capacity (kN)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000

Alignment 3

Client: DLGRMA	**Computed by:** JPB	**Checked by:** BJG	
Project: Bundaberg East Levee	**Date:** 14/2/2018	**Date:** 5/2/2018	
Job Number: 121923-221532	**Rev by:** JPB	**Page:** 6 & 7	
Detail: Driven Preformed Concrete Pile Alignment 3	**Date:** 28/2/2018		

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

Alignment 3

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

Pile type =	400 mm Square Preformed Concrete Pile		
Pile shape =	square	(square or circle)	
Pile Diameter / Length of Side =	0.4	m	
Surface Area =	1.6	sq m/m length	
Wall Thickness =	0	m	
End Bearing Area - FULL AREA =	0.160	sq meters	= 0.160 sq meters
Unit weight of pile =	24	kN/m^3	

Assume pile is 100% plugged

Design Parameters

K =	1	
Nc (clay) =	9	
Reduction on downdrag load by bitimen coating =	0	% (apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7	
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g
Downdrag load factor =	0	
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	For Sand: Nq	qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY: Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	11	42	30	5	9	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	54	39	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	36	67	48	16	31	22
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	50	82	59	22	43	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	65	97	70	29	55	40
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	81	113	81	35	68	49
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	97	129	93	42	81	58
6	0	1	Elliott Formation	0	30	20	67	2.9	9.0	80	0.00	N/A	0	29	90	0	0	0	18.4	1,472	143	379	273	63	117	84
7	-1	1	Elliott Formation	0	30	20	67	2.9	9.0	89	0.00	N/A	0	32	122	0	0	0	18.4	1,637	195	457	329	85	157	113
8	-2	1	Elliott Formation	0	30	20	67	2.9	9.0	98	0.00	N/A	0	36	158	0	0	0	18.4	1,803	252	541	389	110	201	145
9	-3	1	Elliott Formation	0	30	20	67	2.9	9.0	107	0.00	N/A	0	39	197	0	0	0	18.4	1,969	315	630	453	138	249	179
10	-4	1	Elliott Formation	0	30	20	67	2.9	9.0	116	0.00	N/A	0	42	239	0	0	0	18.4	2,135	382	724	521	167	300	216
11	-5	1	Elliott Formation	0	30	20	67	2.9	9.0	125	0.00	N/A	0	46	284	0	0	0	18.4	2,301	455	823	592	199	354	255
12	-6	1	Elliott Formation	0	30	20	67	2.9	9.0	134	0.00	N/A	0	49	333	0	0	0	18.4	2,467	533	928	668	233	413	297
13	-7	1	Elliott Formation	0	30	20	67	2.9	9.0	143	0.00	N/A	0	52	385	0	0	0	18.4	2,633	616	1,038	747	270	475	342
14	-8	1	Elliott Formation	0	30	20	67	2.9	9.0	152	0.00	N/A	0	55	441	0	0	0	18.4	2,799	705	1,153	829	308	541	389
15	-9	1	Elliott Formation	0	30	20	67	2.9	9.0	161	0.00	N/A	0	59	499	0	0	0	18.4	2,900	799	1,263	909	350	610	439
16	-10	1	Elliott Formation	0	30	20	67	2.9	9.0	170	0.00	N/A	0	62	561	0	0	0	18.4	2,900	898	1,362	980	393	683	492
17	-11	1	Elliott Formation	0	30	20	67	2.9	9.0	179	0.00	N/A	0	65	626	0	0	0	18.4	2,900	1,002	1,466	1,055	438	760	547
18	-12	1	Elliott Formation	0	30	20	67	2.9	9.0	188	0.00	N/A	0	67	693	0	0	0	18.4	2,900	1,109	1,573	1,132	485	839	603
19	-13	1	Elliott Formation	0	30	20	67	2.9	9.0	197	0.00	N/A	0	67	760	0	0	0	18.4	2,900	1,217	1,681	1,209	532	918	660
20	-14	1	Elliott Formation	0	30	20	67	2.9	9.0	206	0.00	N/A	0	67	827	0	0	0	18.4	2,900	1,324	1,788	1,286	579	996	717
21	-15	1	Elliott Formation	0	30	20	67	2.9	9.0	215	0.00	N/A	0	67	894	0	0	0	18.4	2,900	1,431	1,895	1,363	626	1075	774
22	-16	1	Elliott Formation	0	30	20	67	2.9	9.0	224	0.00	N/A	0	67	961	0	0	0	18.4	2,900	1,538	2,002	1,440	673	1154	830
23	-17	1	Elliott Formation	0	30	20	67	2.9	9.0	233	0.00	N/A	0	67	1,028	0	0	0	18.4	2,900	1,645	2,109	1,518	720	1233	887
24	-18	1	Elliott Formation	0	30	20	67	2.9	9.0	242	0.00	N/A	0	67	1,095	0	0	0	18.4	2,900	1,753	2,217	1,595	767	1312	944
25	-19	1	Elliott Formation	0	30	20	67	2.9	9.0	251	0.00	N/A	0	67	1,162	0	0	0	18.4	2,900	1,860	2,324	1,672	814	1391	1000
26	-20	1	Elliott Formation	0	30	20	67	2.9	9.0	260	0.00	N/A	0	67	1,229	0	0	0	18.4	2,900	1,967	2,431	1,749	861	1469	1057

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m Per Test Boring B-6
Pile Cut-Off Elevation = 4.5 m

Soil Properties

Alignment 3

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

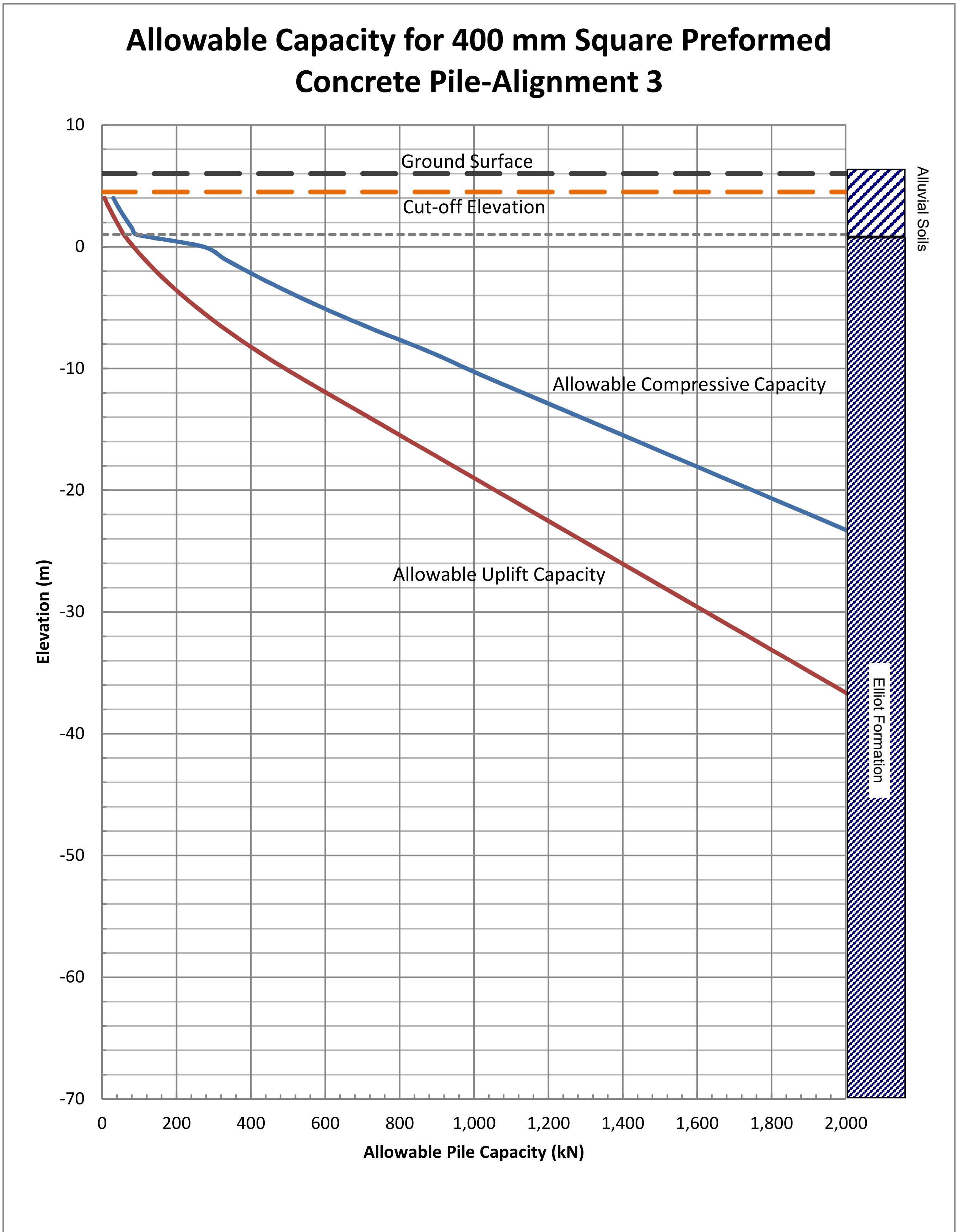
Pile type = 400 mm Square Preformed Concrete Pile
Pile shape = square (square or circle)
Pile Diameter / Length of Side = 0.4 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0 m
End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

																		COMPRESSION CAPACITY						UPLIFT CAPACITY		
													Unit Skin Friction					Unit End Bearing			Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
													For Clay	For Sand	Cum. fs			For Clay	For Sand							
27	-21	1	Elliott Formation	0	30	20	67	2.9	9.0	269	0.00	N/A	0	67	1,296	0	0	0	18.4	2,900	2,074	2,538	1,826	907	1548	1114
28	-22	1	Elliott Formation	0	30	20	67	2.9	9.0	278	0.00	N/A	0	67	1,363	0	0	0	18.4	2,900	2,181	2,645	1,903	954	1627	1170
29	-23	1	Elliott Formation	0	30	20	67	2.9	9.0	287	0.00	N/A	0	67	1,430	0	0	0	18.4	2,900	2,289	2,753	1,980	1001	1706	1227
30	-24	1	Elliott Formation	0	30	20	67	2.9	9.0	296	0.00	N/A	0	67	1,497	0	0	0	18.4	2,900	2,396	2,860	2,057	1048	1785	1284
31	-25	1	Elliott Formation	0	30	20	67	2.9	9.0	305	0.00	N/A	0	67	1,564	0	0	0	18.4	2,900	2,503	2,967	2,135	1095	1863	1341
32	-26	1	Elliott Formation	0	30	20	67	2.9	9.0	314	0.00	N/A	0	67	1,631	0	0	0	18.4	2,900	2,610	3,074	2,212	1142	1942	1397
33	-27	1	Elliott Formation	0	30	20	67	2.9	9.0	323	0.00	N/A	0	67	1,698	0	0	0	18.4	2,900	2,717	3,181	2,289	1189	2021	1454
34	-28	1	Elliott Formation	0	30	20	67	2.9	9.0	332	0.00	N/A	0	67	1,765	0	0	0	18.4	2,900	2,825	3,289	2,366	1236	2100	1511
35	-29	1	Elliott Formation	0	30	20	67	2.9	9.0	341	0.00	N/A	0	67	1,832	0	0	0	18.4	2,900	2,932	3,396	2,443	1283	2179	1567
36	-30	1	Elliott Formation	0	30	20	67	2.9	9.0	350	0.00	N/A	0	67	1,899	0	0	0	18.4	2,900	3,039	3,503	2,520	1330	2257	1624
37	-31	1	Elliott Formation	0	30	20	67	2.9	9.0	359	0.00	N/A	0	67	1,966	0	0	0	18.4	2,900	3,146	3,610	2,597	1376	2336	1681
38	-32	1	Elliott Formation	0	30	20	67	2.9	9.0	368	0.00	N/A	0	67	2,033	0	0	0	18.4	2,900	3,253	3,717	2,674	1423	2415	1737
39	-33	1	Elliott Formation	0	30	20	67	2.9	9.0	377	0.00	N/A	0	67	2,100	0	0	0	18.4	2,900	3,361	3,825	2,752	1470	2494	1794
40	-34	1	Elliott Formation	0	30	20	67	2.9	9.0	387	0.00	N/A	0	67	2,167	0	0	0	18.4	2,900	3,468	3,932	2,829	1517	2573	1851
41	-35	1	Elliott Formation	0	30	20	67	2.9	9.0	396	0.00	N/A	0	67	2,234	0	0	0	18.4	2,900	3,575	4,039	2,906	1564	2652	1908
42	-36	1	Elliott Formation	0	30	20	67	2.9	9.0	405	0.00	N/A	0	67	2,301	0	0	0	18.4	2,900	3,682	4,146	2,983	1611	2730	1964
43	-37	1	Elliott Formation	0	30	20	67	2.9	9.0	414	0.00	N/A	0	67	2,368	0	0	0	18.4	2,900	3,789	4,253	3,060	1658	2809	2021
44	-38	1	Elliott Formation	0	30	20	67	2.9	9.0	423	0.00	N/A	0	67	2,435	0	0	0	18.4	2,900	3,897	4,361	3,137	1705	2888	2078
45	-39	1	Elliott Formation	0	30	20	67	2.9	9.0	432	0.00	N/A	0	67	2,502	0	0	0	18.4	2,900	4,004	4,468	3,214	1752	2967	2134
46	-40	1	Elliott Formation	0	30	20	67	2.9	9.0	441	0.00	N/A	0	67	2,569	0	0	0	18.4	2,900	4,111	4,575	3,291	1799	3046	2191
47	-41	1	Elliott Formation	0	30	20	67	2.9	9.0	450	0.00	N/A	0	67	2,636	0	0	0	18.4	2,900	4,218	4,682	3,369	1845	3124	2248
48	-42	1	Elliott Formation	0	30	20	67	2.9	9.0	459	0.00	N/A	0	67	2,703	0	0	0	18.4	2,900	4,325	4,789	3,446	1892	3203	2304
49	-43	1	Elliott Formation	0	30	20	67	2.9	9.0	468	0.00	N/A	0	67	2,770	0	0	0	18.4	2,900	4,433	4,897	3,523	1939	3282	2361
50	-44	1	Elliott Formation	0	30	20	67	2.9	9.0	477	0.00	N/A	0	67	2,837	0	0	0	18.4	2,900	4,540	5,004	3,600	1986	3361	2418
51	-45	1	Elliott Formation	0	30	20	67	2.9	9.0	486	0.00	N/A	0	67	2,904	0	0	0	18.4	2,900	4,647	5,111	3,677	2033	3440	2475
52	-46	1	Elliott Formation	0	30	20	67	2.9	9.0	495	0.00	N/A	0	67	2,971	0	0	0	18.4	2,900	4,754	5,218	3,754	2080	3518	2531
53	-47	1	Elliott Formation	0	30	20	67	2.9	9.0	504	0.00	N/A	0	67	3,038	0	0	0	18.4	2,900	4,861	5,325	3,831	2127	3597	2588
54	-48	1	Elliott Formation	0	30	20	67	2.9	9.0	513	0.00	N/A	0	67	3,105	0	0	0	18.4	2,900	4,969	5,433	3,908	2174	3676	2645
55	-49	1	Elliott Formation	0	30	20	67	2.9	9.0	522	0.00	N/A	0	67	3,172	0	0	0	18.4	2,900	5,076	5,540	3,986	2221	3755	2701
56	-50	1	Elliott Formation	0	30	20	67	2.9	9.0	531	0.00	N/A	0	67	3,239	0	0	0	18.4	2,900	5,183	5,647	4,063	2268	3834	2758
57	-51	1	Elliott Formation	0	30	20	67	2.9	9.0	540	0.00	N/A	0	67	3,306	0	0	0	18.4	2,900	5,290	5,754	4,140	2314	3912	2815
58	-52	1	Elliott Formation	0	30	20	67	2.9	9.0	549	0.00	N/A	0	67	3,373	0	0	0	18.4	2,900	5,397	5,861	4,217	2361	3991	2871
59	-53	1	Elliott Formation	0	30	20	67	2.9	9.0	558	0.00	N/A	0	67	3,440	0	0	0	18.4	2,900	5,505	5,969	4,294	2408	4070	2928
60	-54	1	Elliott Formation	0	30	20	67	2.9	9.0	567	0.00	N/A	0	67	3,507	0	0	0	18.4	2,900	5,612	6,076	4,371	2455	4149	2985
61	-55	1	Elliott Formation	0	30	20	67	2.9	9.0	576	0.00	N/A	0	67	3,574	0	0	0	18.4	2,900	5,719	6,183	4,448	2502	4228	3042



Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 3
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Appendix B2

Driven 500-mm-Diameter Steel Cast In Place Piles

Problem: Evaluate the vertical pile capacity of an assumed steel cast in place circular pile.

References:

1. Federal Highway Administration, "Design and Construction of Driven Pile Foundations," FHWA-HI-97-013, December 1996.
2. API Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
3. Australian Building and Construction Commission, "Code for the Tendering and Performance of Building Work 2016"
4. FHWA, "Design and Construction of Driven Pile Foundations, Workshop Manual - Volume I," September 2016.
5. AS 2159-2009, Australian Standard - Piling -Design and Installation.
6. FHWA, "Design and Construction of Driven Pile Foundations - Comprehensive Design Examples," September 2016.
7. "Factual Geotechnical Report, Bundaberg East Levee, Bundaberg, Queensland" CDM Smith, 31 January 2018

Pile Information: 500 mm closed-end steel cast in place circular pile

Datum: Australian Height Datum (AHD)

Assumptions:

1. The proposed pile cut-off elevation is assumed to be at 1.5 meters below ground surface.
2. Groundwater elevation is assumed at El. 2.5 based upon observed water level in test boring B-6.
3. Pile is a 500 mm circular, 345 MPA steel pipe pile with a 15.87 mm wall thickness.
4. Allowable structural capacity of the 500 mm pile filled with 27.5 MPa grout is 2750 kN.
5. Assume the design life of the steel piles to be 100 years.
6. Assume the steel corrosion rate for the pile to be 0.08 mm/year or 8mm over the pile design life.
7. Assume 5 percent of piles are dynamically load tested.
8. Assume no downdrag load due to negligible raise in grade.
9. Assume k=1.0 for closed end pile per Reference No. 2.
10. Assume axial load required for each pile is 250, 500, 750, and 1,000 kN.
11. Assume friction interface reduction factor for uplift is 0.7.

Soil Information: Soil layering, soil properties and groundwater elevation obtained from available boring logs(7).

Table 1 - Summary of Subsurface Conditions

	Alignment	1. City Alignment Sta. 0+50 to Sta. 3+50	2. City Alignment Sta. 3+50 to Sta. 7+75	3. Distillery Alignment Sta. 1+50 to Sta. 5+88
	Alluvial Soils Thickness(m)	13	7	5
	Elliott Formation Thickness(m)	>15	>15	>10
	Applicable Borings	B-2, B-3, B-5	B-4, B-6, B-7	B-12, B-13
Elliott Formation Properties	Su (kPa)	100	50	0
	δ (°)	0	0	20
	Φ (°)	0	0	30
	Limiting Skin Friction (kPa)	0	0	67
	Limiting End Bearing (MPa)	0	0	2.9

Analysis Method: Simplified API 1986 & 1993 Method

$Q\ compression = A_p \times q_p + \Sigma (A_s \times f_s)$ Eq. 6.4.1-1 Reference 2

where A_p= tip area, f_s=side friction, q_p=tip resistance, A_s=side area

Skin Friction (f_s):

For undrained clay (a-Method): $f_s = \alpha * S_u$ Eq. 6.4.2-1 and Eq. 6.4.2-2 Reference 2

where $\alpha = 0.5^* (Su/\sigma_v')^{\wedge(-0.5)}$ for $(su/\sigma_v')<1$

$= 0.5^* (Su/\sigma_v')^{\wedge(-025)} <1$ for $(su/\sigma_v')>1$

S_u =undrained shear strength

For drained clay/sand (b-Method): $f_s = K \tan\delta * \sigma'_v$ Eq. 6.4.3-1 Reference 2

where δ = soil - pile friction angle

K = lateral pressure coefficient

σ'_v = effective vertical pressure

Tip Resistance (q_p)

For undrained clay: $q_p = N_c * Su$ Eq. 6.4.2-3 Reference 2

where $N_c = 9$

Su = undrained shear strength at the pile tip

For drained clay/sand: $q_p = Nq * \sigma_v'$ Eq. 6.4.3-2 Reference 2

where $Nq = \exp(\pi^*\tan\phi)^*[\tan(45+\phi/2)]^{\wedge}2$ (Meyerhoff)

σ_v' = effective vertical pressure at the pile tip

Results:

A summary of the total allowable compression and uplift capacity is summarized in Table 1 below.

Table 2 - Summary of Allowable Compression and Uplift Pile Capacity

Soil Profile	Total Allowable Compression Capacity (kN)	Total Allowable Uplift Capacity (kN)	Embedment in Elliott Formation (m)
1	250	200	1
1	500	325	2
1	750	475	5
1	1000	725	9
2	250	150	2
2	500	375	8
2	750	525	12
2	1000	750	17
3	250	75	1
3	500	175	4
3	750	325	8
3	1000	475	11

Notes:

1. Assumes a FS of 1.39 based on AS 2159-2009 Section 4.3.1 calculation.

References:

AS 2159-2009 Piling -- Design and Installation

4.3 GENERAL PRINCIPLES OF GEOTECHNICAL STRENGTH DESIGN

4.3.1 Design geotechnical strength

A pile shall be proportioned such that the design geotechnical strength ($R_{d.g}$) is not less than the design action effect (E_d) as detailed in Clause 3.2.2, that is—

$$R_{d.g} \geq E_d \quad \text{. . . 4.3.1(1)}$$

The design geotechnical strength ($R_{d.g}$) shall be calculated as the design ultimate geotechnical strength ($R_{d,ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g), according to the following equation:

$$R_{d.g} = \phi_g R_{d.ug} \quad \text{. . . 4.3.1(2)}$$

The geotechnical strength reduction factor (ϕ_g) shall be determined as follows:

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

where

ϕ_{gb} = basic geotechnical strength reduction factor as given in Clause 4.3.2

ϕ_{tf} = intrinsic test factor

= 0.9, for static load testing (see Section 8)

= 0.75, for rapid load testing (see Section 8)

= 0.8, for dynamic load testing of preformed piles (see Section 8)

= 0.75, for dynamic load testing of other than preformed piles (see Section 8)

= 0.85, for bi-directional load testing (see Section 8)

= ϕ_{gb}, for no testing

K = testing benefit factor

= $1.33p/(p + 3.3) \leq 1$, for static or rapid load testing

= $1.13p/(p + 3.3) \leq 1$, for dynamic load testing

p = percentage of the total piles that are tested and meet the specified acceptance criteria

References:

4.3.2 Assessment of basic geotechnical strength reduction factor (ϕ_{gb})

The basic geotechnical strength reduction factor (ϕ_{gb}) shall be calculated using a risk assessment procedure as set out below:

(a) Rate each risk factor in Table 4.3.2(A) on a scale from 1 to 5 for the nature of the site, the available site information and the pile design and installation procedures adopted. This will produce an individual risk rating (IRR) according to the assessed level of risk, as set out in Table 4.3.2(B)

(b) Determine the overall design average risk rating (ARR) using the weighted average of the product of all of the risk weighting factors (w_i) shown in column 2 of Table 4.3.2(A) times the relevant individual risk rating (IRR), as follows:

$$ARR = \Sigma(w_i \text{IRR}_i)/\Sigma w_i \quad \ldots 4.3.2$$

(c) Determine the basic geotechnical strength reduction factor (ϕ_{gb}) from Table 4.3.2(C) depending on the level of redundancy in the piling system. Systems with a high degree of redundancy would include large pile groups under large caps, piled rafts and pile groups with more than 4 piles. Systems with a low level of redundancy would include isolated heavily loaded piles and piles set out at large spacings.

TABLE 4.3.2(A)

WEIGHTING FACTORS AND INDIVIDUAL RISK RATINGS FOR RISK FACTORS

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Site				
Geological complexity of site	2	Horizontal strata, well-defined soil and rock characteristics	Some variability over site, but without abrupt changes in stratigraphy	Highly variable profile or presence of karstic features or steeply dipping rock levels or faults present on site, or combinations of these
Extent of ground investigation	2	Extensive drilling investigation covering whole site to an adequate depth	Some boreholes extending at least 5 pile diameters below the base of the proposed pile foundation level	Very limited investigation with few shallow boreholes
Amount and quality of geotechnical data	2	Detailed information on strength compressibility of the main strata	CPT probes over full depth of proposed piles or boreholes confirming rock as proposed founding level for piles	Limited amount of simple in situ testing (e.g., SPT) or index tests only
Design				
Experience with similar foundations in similar geological conditions	1	Extensive	Limited	None

(*continued*)

References:

TABLE 4.3.2(A) (*continued*)

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Method of assessment of geotechnical parameters for design	2	Based on appropriate laboratory or in situ tests or relevant existing pile load test data	Based on site-specific correlations or on conventional laboratory or in situ testing	Based on non-site-specific correlations with (for example) SPT data
Design method adopted	1	Well-established and soundly based method or methods	Simplified methods with well-established basis	Simple empirical methods or sophisticated methods that are not well established
Method of utilizing results of in situ test data and installation data	2	Design values based on minimum measured values on piles loaded to failure	Design methods based on average values	Design values based on maximum measured values on test piles loaded up only to working load, or indirect measurements used during installation, and not calibrated to static loading tests
Installation				
Level of construction control	2	Detailed with professional geotechnical supervision, construction processes that are well established and relatively straightforward	Limited degree of professional geotechnical involvement in supervision, conventional construction procedures	Very limited or no involvement by designer, construction processes that are not well established or complex
Level of performance monitoring of the supported structure during and after construction	0.5	Detailed measurements of movements and pile loads	Correlation of installed parameters with on-site static load tests carried out in accordance with this Standard	No monitoring

NOTE: The pile design shall include the risk circumstances for each individual risk category and consideration of all of the relevant site and construction factors.

TABLE 4.3.2(B)
INDIVIDUAL RISK RATING (IRR)

Risk level	Individual risk rating (IRR)
Very low	1
Low	2
Moderate	3
High	4
Very high	5

TABLE 4.3.2(C)
BASIC GEOTECHNICAL STRENGTH REDUCTION FACTOR (ϕ_{gb}) FOR AVERAGE RISK RATING

Range of average risk rating (ARR)	Overall risk category	ϕ_{gb} for low redundancy systems	ϕ_{gb} for high redundancy systems
ARR ≤1.5	Very low	0.67	0.76
1.5 < ARR ≤2.0	Very low to low	0.61	0.70
2.0 < ARR ≤2.5	Low	0.56	0.64
2.5 < ARR ≤3.0	Low to moderate	0.52	0.60
3.0 < ARR ≤3.5	Moderate	0.48	0.56
3.5 < ARR ≤4.0	Moderate to high	0.45	0.53
4.0 < ARR ≤4.5	High	0.42	0.50
>4.5	Very high	0.40	0.47

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

ϕ_{tf} =	0.8	for dynamic load testing
K =	1.13p/(p+3.3)	
p=	5	percent of piles to be tested
K=	0.68	
IRR=	50.5	
w_i =	14.5	
ARR=	3.48	
ϕ_{gb} =	0.56	
ϕ_g =	0.72	>= 0.56
FS=	1.39	

Table 1: Structural Capacity of Closed Steel Cast In Place Pile with No Corrosion

Type Closed End Pipe Pile (No Corrosion)
Shape circle

Outer Diameter (m)	Gross Area (sq m)	Wall Thickness (m)	Initial Area of Pipe Steel (sq m)	Material Loss (m)	Effective Area of Pipe Steel (sq m)	Fy (kPa)	Allowable (steel only) Load (kN)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Post Concrete Load (kN)	Total Allowable Load (kN)
0.3	0.0707	0.0159	0.01	0	0.01	200000	1419.1	0.06	27500	513	**1932**
0.35	0.0962	0.0159	0.02	0	0.02	200000	1668.9	0.08	27500	722	**2391**
0.4	0.1257	0.0159	0.02	0	0.02	200000	1918.6	0.11	27500	966	**2885**
0.45	0.1590	0.0159	0.02	0	0.02	200000	2168.4	0.14	27500	1247	**3415**
0.5	0.1963	0.0159	0.02	0	0.02	200000	2418.1	0.17	27500	1562	**3981**
0.55	0.2376	0.0159	0.03	0	0.03	200000	2667.9	0.21	27500	1914	**4582**

Notes:
1 Allowable Steel Stress = 0.5 Fy
2 Allowable Concrete Stress = 0.33 f'c

Table 2: Structural Capacity of Closed Steel Cast In Place Pile with Corrosion

Type Closed End Pipe Pile (corrosion - assumed 8 mm reduction in steel thickness)
Shape circle

Outer Diameter (m)	Gross Area (sq m)	Wall Thickness (m)	Initial Area of Pipe Steel (sq m)	Material Loss (m)	Effective Area of Pipe Steel (sq m)	Fy (kN/m2)	Allowable (steel only) Load (kN)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Post Concrete Load (kN)	Total Allowable Load (kN)
0.3	0.0707	0.0159	0.01	0.0080	0.0069	200000	685.2	0.06	27500	513	**1198**
0.35	0.0962	0.0159	0.02	0.0080	0.0081	200000	809.3	0.08	27500	722	**1531**
0.4	0.1257	0.0159	0.02	0.0080	0.0093	200000	933.4	0.11	27500	966	**1900**
0.45	0.1590	0.0159	0.02	0.0080	0.0106	200000	1057.5	0.14	27500	1247	**2304**
0.5	0.1963	0.0159	0.02	0.0080	0.0118	200000	1181.6	0.17	27500	1562	**2744**
0.55	0.2376	0.0159	0.03	0.0080	0.0131	200000	1305.7	0.21	27500	1914	**3220**

Notes:
1 Allowable Steel Stress = 0.5 Fy
2 Allowable Concrete Stress = 0.33 f'c
3 Assume the steel corrosion rate for the pile to be 0.08 mm/year or 8 mm over the pile design life based upon Reference No. 6 page 8-32.

Alignment 1

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B--6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	500 mm closed end steel cast in place circular pile			
Pile shape =	circle	(square or circle)		
Pile Diameter / Length of Side =	0.5	m		
Surface Area =	1.6	sq m/m length		Assume pile is 100% plugged
Wall Thickness =	0.0159	m		
End Bearing Area - FULL AREA =	0.196	sq meters	= 0.196 sq meters	
Unit weight of pile =	24	kN/m^3		

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	100	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.72	Based on AS 2159-2009 Section 4.3.1	

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	Unit End Bearing – For Sand: Nq	Unit End Bearing – For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	10	49	35	5	10	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	61	44	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	35	74	53	16	31	23
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	49	88	63	22	44	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	64	103	74	29	56	41
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	79	118	85	35	69	50
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	95	134	96	42	83	60
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	128	167	120	57	110	79
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	163	201	145	72	139	100
8	-2	1	Alluvial Soils	22	15	0	0	0	8.2	96	0.23	1.0	22	0	125	0	0	198	0.0	0	197	236	170	88	168	121
9	-3	1	Alluvial Soils	22	15	0	0	0	8.2	104	0.21	1.0	22	0	147	0	0	198	0.0	0	232	271	195	103	197	142
10	-4	1	Alluvial Soils	22	15	0	0	0	8.2	113	0.20	1.0	22	0	169	0	0	198	0.0	0	266	305	219	119	226	162
11	-5	1	Alluvial Soils	22	15	0	0	0	8.2	121	0.18	1.0	22	0	191	0	0	198	0.0	0	301	340	244	134	254	183
12	-6	1	Alluvial Soils	22	15	0	0	0	8.2	129	0.17	1.0	22	0	213	0	0	198	0.0	0	335	374	269	149	283	204
13	-7	1	Alluvial Soils	22	15	0	0	0	8.2	137	0.16	1.0	22	0	235	0	0	198	0.0	0	370	409	294	165	312	225
14	-8	1	Elliott Formation	100	0	0	0	0	9.0	146	0.69	0.6	60	0	296	0	0	900	0.0	0	465	641	461	207	383	276
15	-9	1	Elliott Formation	100	0	0	0	0	9.0	155	0.65	0.6	62	0	358	0	0	900	0.0	0	562	739	532	251	456	328
16	-10	1	Elliott Formation	100	0	0	0	0	9.0	164	0.61	0.6	64	0	422	0	0	900	0.0	0	663	840	604	295	531	382
17	-11	1	Elliott Formation	100	0	0	0	0	9.0	173	0.58	0.7	66	0	488	0	0	900	0.0	0	766	943	678	341	608	437
18	-12	1	Elliott Formation	100	0	0	0	0	9.0	182	0.55	0.7	67	0	555	0	0	900	0.0	0	872	1,049	755	389	687	494
19	-13	1	Elliott Formation	100	0	0	0	0	9.0	191	0.52	0.7	69	0	624	0	0	900	0.0	0	981	1,157	833	437	767	552
20	-14	1	Elliott Formation	100	0	0	0	0	9.0	200	0.50	0.7	71	0	695	0	0	900	0.0	0	1,092	1,268	913	487	850	611
21	-15	1	Elliott Formation	100	0	0	0	0	9.0	209	0.48	0.7	72	0	767	0	0	900	0.0	0	1,205	1,382	994	537	934	672
22	-16	1	Elliott Formation	100	0	0	0	0	9.0	218	0.46	0.7	74	0	841	0	0	900	0.0	0	1,321	1,498	1,078	589	1020	734
23	-17	1	Elliott Formation	100	0	0	0	0	9.0	227	0.44	0.8	75	0	916	0	0	900	0.0	0	1,440	1,616	1,163	642	1107	797
24	-18	1	Elliott Formation	100	0	0	0	0	9.0	236	0.42	0.8	77	0	993	0	0	900	0.0	0	1,560	1,737	1,250	695	1196	861
25	-19	1	Elliott Formation	100	0	0	0	0	9.0	245	0.41	0.8	78	0	1,072	0	0	900	0.0	0	1,683	1,860	1,338	750	1287	926
26	-20	1	Elliott Formation	100	0	0	0	0	9.0	254	0.39	0.8	80	0	1,151	0	0	900	0.0	0	1,808	1,985	1,428	806	1379	992

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m — Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m — Per Test Boring B--6
Pile Cut-Off Elevation = 4.5 m

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	100	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

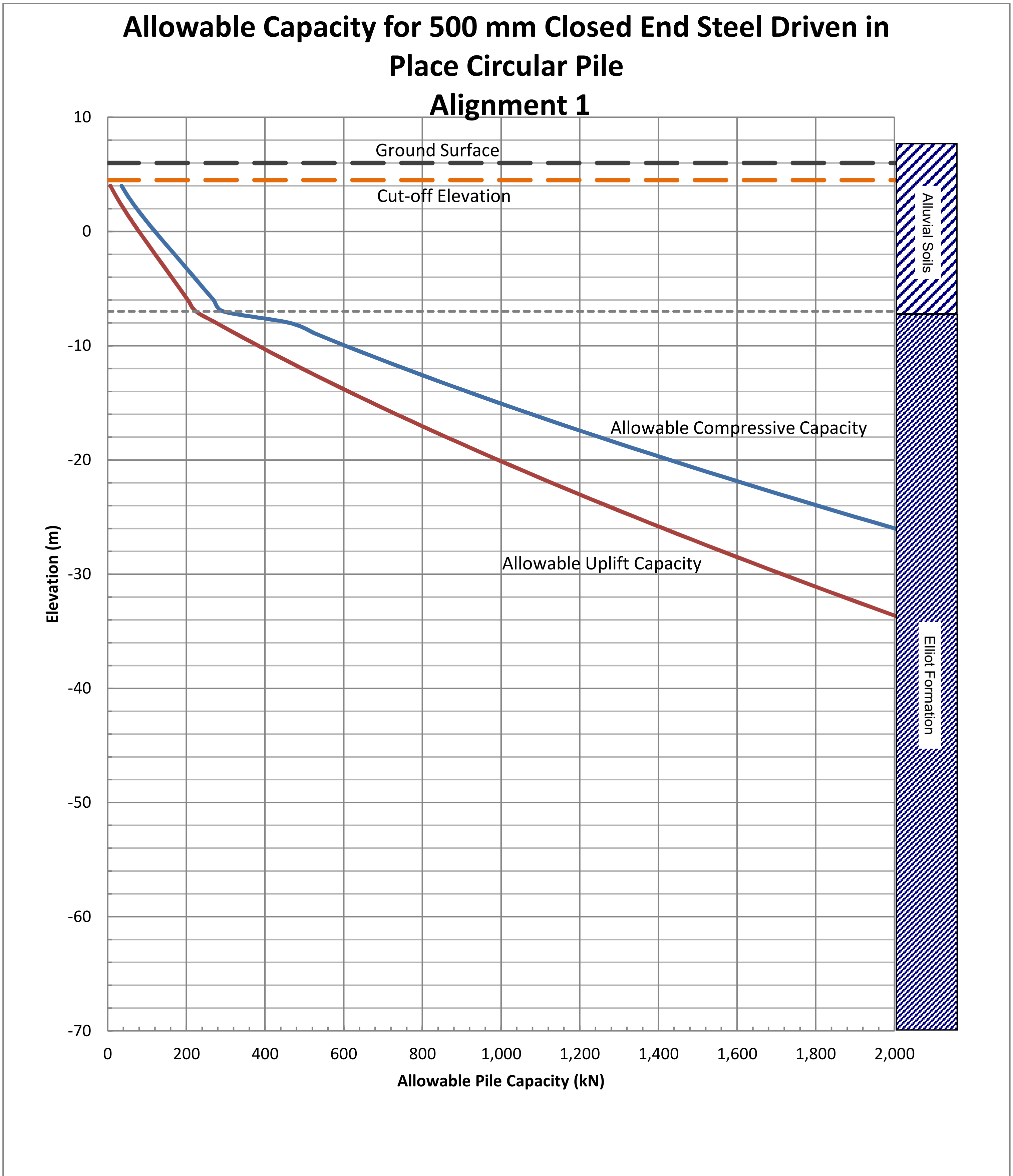
Pile type = 500 mm closed end steel cast in place circular pile
Pile shape = circle (square or circle)
Pile Diameter / Length of Side = 0.5 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0.0159 m
End Bearing Area - FULL AREA = 0.196 sq meters = 0.196 sq meters
Unit weight of pile = 24 kN/m³

Assume pile is 100% plugged

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7 (for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.72 Based on AS 2159-2009 Section 4.3.1

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing			Ult. Friction	Ult. Comp.	Allow. Comp.	UPLIFT CAPACITY	Ultimate Uplift	Allow. Uplift.
													For Clay	For Sand	Cum. fs			For Clay		For Sand	Capacity	Capacity	Capacity		Capacity	Capacity
27	-21	1	Elliott Formation	100	0	0	0	0	9.0	263	0.38	0.8	81	0	1,232	0	0	900	0.0	0	1,936	2,112	1,520	863	1473	1060
28	-22	1	Elliott Formation	100	0	0	0	0	9.0	272	0.37	0.8	82	0	1,315	0	0	900	0.0	0	2,065	2,242	1,613	920	1568	1128
29	-23	1	Elliott Formation	100	0	0	0	0	9.0	281	0.36	0.8	84	0	1,399	0	0	900	0.0	0	2,197	2,374	1,708	979	1665	1198
30	-24	1	Elliott Formation	100	0	0	0	0	9.0	290	0.34	0.9	85	0	1,484	0	0	900	0.0	0	2,331	2,507	1,804	1039	1763	1269
31	-25	1	Elliott Formation	100	0	0	0	0	9.0	299	0.33	0.9	86	0	1,570	0	0	900	0.0	0	2,466	2,643	1,902	1099	1863	1340
32	-26	1	Elliott Formation	100	0	0	0	0	9.0	308	0.32	0.9	88	0	1,658	0	0	900	0.0	0	2,604	2,781	2,001	1161	1964	1413
33	-27	1	Elliott Formation	100	0	0	0	0	9.0	317	0.32	0.9	89	0	1,747	0	0	900	0.0	0	2,744	2,921	2,101	1223	2067	1487
34	-28	1	Elliott Formation	100	0	0	0	0	9.0	326	0.31	0.9	90	0	1,837	0	0	900	0.0	0	2,886	3,063	2,203	1286	2171	1562
35	-29	1	Elliott Formation	100	0	0	0	0	9.0	335	0.30	0.9	92	0	1,929	0	0	900	0.0	0	3,030	3,207	2,307	1350	2276	1637
36	-30	1	Elliott Formation	100	0	0	0	0	9.0	344	0.29	0.9	93	0	2,022	0	0	900	0.0	0	3,176	3,352	2,412	1415	2383	1714
37	-31	1	Elliott Formation	100	0	0	0	0	9.0	353	0.28	0.9	94	0	2,116	0	0	900	0.0	0	3,323	3,500	2,518	1481	2490	1792
38	-32	1	Elliott Formation	100	0	0	0	0	9.0	362	0.28	1.0	95	0	2,211	0	0	900	0.0	0	3,473	3,649	2,625	1548	2600	1870
39	-33	1	Elliott Formation	100	0	0	0	0	9.0	371	0.27	1.0	96	0	2,307	0	0	900	0.0	0	3,624	3,801	2,734	1615	2710	1950
40	-34	1	Elliott Formation	100	0	0	0	0	9.0	380	0.26	1.0	97	0	2,405	0	0	900	0.0	0	3,777	3,954	2,844	1683	2822	2030
41	-35	1	Elliott Formation	100	0	0	0	0	9.0	389	0.26	1.0	99	0	2,503	0	0	900	0.0	0	3,932	4,109	2,956	1752	2935	2112
42	-36	1	Elliott Formation	100	0	0	0	0	9.0	398	0.25	1.0	100	0	2,603	0	0	900	0.0	0	4,089	4,265	3,069	1822	3050	2194
43	-37	1	Elliott Formation	100	0	0	0	0	9.0	407	0.25	1.0	100	0	2,703	0	0	900	0.0	0	4,246	4,423	3,182	1892	3164	2276
44	-38	1	Elliott Formation	100	0	0	0	0	9.0	416	0.24	1.0	100	0	2,803	0	0	900	0.0	0	4,403	4,580	3,295	1962	3279	2359
45	-39	1	Elliott Formation	100	0	0	0	0	9.0	425	0.24	1.0	100	0	2,903	0	0	900	0.0	0	4,560	4,737	3,408	2032	3393	2441
46	-40	1	Elliott Formation	100	0	0	0	0	9.0	434	0.23	1.0	100	0	3,003	0	0	900	0.0	0	4,717	4,894	3,521	2102	3508	2524
47	-41	1	Elliott Formation	100	0	0	0	0	9.0	443	0.23	1.0	100	0	3,103	0	0	900	0.0	0	4,874	5,051	3,634	2172	3622	2606
48	-42	1	Elliott Formation	100	0	0	0	0	9.0	452	0.22	1.0	100	0	3,203	0	0	900	0.0	0	5,031	5,208	3,747	2242	3737	2689
49	-43	1	Elliott Formation	100	0	0	0	0	9.0	461	0.22	1.0	100	0	3,303	0	0	900	0.0	0	5,188	5,365	3,860	2312	3852	2771
50	-44	1	Elliott Formation	100	0	0	0	0	9.0	470	0.21	1.0	100	0	3,403	0	0	900	0.0	0	5,345	5,522	3,973	2382	3966	2853
51	-45	1	Elliott Formation	100	0	0	0	0	9.0	479	0.21	1.0	100	0	3,503	0	0	900	0.0	0	5,502	5,679	4,086	2452	4081	2936
52	-46	1	Elliott Formation	100	0	0	0	0	9.0	488	0.20	1.0	100	0	3,603	0	0	900	0.0	0	5,660	5,836	4,199	2522	4195	3018
53	-47	1	Elliott Formation	100	0	0	0	0	9.0	497	0.20	1.0	100	0	3,703	0	0	900	0.0	0	5,817	5,993	4,312	2592	4310	3101
54	-48	1	Elliott Formation	100	0	0	0	0	9.0	506	0.20	1.0	100	0	3,803	0	0	900	0.0	0	5,974	6,150	4,425	2662	4425	3183
55	-49	1	Elliott Formation	100	0	0	0	0	9.0	515	0.19	1.0	100	0	3,903	0	0	900	0.0	0	6,131	6,308	4,538	2732	4539	3266
56	-50	1	Elliott Formation	100	0	0	0	0	9.0	524	0.19	1.0	100	0	4,003	0	0	900	0.0	0	6,288	6,465	4,651	2802	4654	3348
57	-51	1	Elliott Formation	100	0	0	0	0	9.0	534	0.19	1.0	100	0	4,103	0	0	900	0.0	0	6,445	6,622	4,764	2872	4768	3430
58	-52	1	Elliott Formation	100	0	0	0	0	9.0	543	0.18	1.0	100	0	4,203	0	0	900	0.0	0	6,602	6,779	4,877	2942	4883	3513
59	-53	1	Elliott Formation	100	0	0	0	0	9.0	552	0.18	1.0	100	0	4,303	0	0	900	0.0	0	6,759	6,936	4,990	3012	4998	3595
60	-54	1	Elliott Formation	100	0	0	0	0	9.0	561	0.18	1.0	100	0	4,403	0	0	900	0.0	0	6,916	7,093	5,103	3082	5112	3678
61	-55	1	Elliott Formation	100	0	0	0	0	9.0	570	0.18	1.0	100	0	4,503	0	0	900	0.0	0	7,073	7,250	5,216	3152	5227	3760



Allowable Capacity for 500 mm Closed End Steel Driven in Place Circular Pile
Alignment 1
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Alignment 2

Client: DLGRMA **Computed by:** BJG **Checked by:** JPB
Project: Bundaberg East Levee **Date:** 5/2/2018 **Date:** 14/2/2018
Job Number: 121923-221532 **Rev by & Date:** JPB, 28/2/2018 **Page:** 10 & 11

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	500 mm closed end steel cast in place circular pile		
Pile shape =	circle	(square or circle)	
Pile Diameter / Length of Side =	0.5	m	
Surface Area =	1.6	sq m/m length	
Wall Thickness =	0.0159	m	
End Bearing Area - FULL AREA =	0.196	sq meters	= 0.196 sq meters
Unit weight of pile =	24	kN/m^3	

Assume pile is 100% plugged

Soil Properties

Alignment 2

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1	

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α
0	6											
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0
8	-2	1	Elliott Formation	50	0	0	0	0	9.0	96	0.52	0.7
9	-3	1	Elliott Formation	50	0	0	0	0	9.0	105	0.47	0.7
10	-4	1	Elliott Formation	50	0	0	0	0	9.0	114	0.44	0.8
11	-5	1	Elliott Formation	50	0	0	0	0	9.0	123	0.40	0.8
12	-6	1	Elliott Formation	50	0	0	0	0	9.0	132	0.38	0.8
13	-7	1	Elliott Formation	50	0	0	0	0	9.0	142	0.35	0.8
14	-8	1	Elliott Formation	50	0	0	0	0	9.0	151	0.33	0.9
15	-9	1	Elliott Formation	50	0	0	0	0	9.0	160	0.31	0.9
16	-10	1	Elliott Formation	50	0	0	0	0	9.0	169	0.30	0.9
17	-11	1	Elliott Formation	50	0	0	0	0	9.0	178	0.28	0.9
18	-12	1	Elliott Formation	50	0	0	0	0	9.0	187	0.27	1.0
19	-13	1	Elliott Formation	50	0	0	0	0	9.0	196	0.26	1.0
20	-14	1	Elliott Formation	50	0	0	0	0	9.0	205	0.24	1.0
21	-15	1	Elliott Formation	50	0	0	0	0	9.0	214	0.23	1.0
22	-16	1	Elliott Formation	50	0	0	0	0	9.0	223	0.22	1.0
23	-17	1	Elliott Formation	50	0	0	0	0	9.0	232	0.22	1.0
24	-18	1	Elliott Formation	50	0	0	0	0	9.0	241	0.21	1.0
25	-19	1	Elliott Formation	50	0	0	0	0	9.0	250	0.20	1.0
26	-20	1	Elliott Formation	50	0	0	0	0	9.0	259	0.19	1.0

	Unit Skin Friction					COMPRESSION CAPACITY						UPLIFT CAPACITY		
	For Clay	For Sand	Cum. fs			Unit End Bearing For Clay	For Sand		Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
Bottom Depth (m)	fs clay (kPa)	fs sand (kPa)	Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	**qp clay** (kPa)	**Nq**	**qp sand** (kPa)	**Fs** (Σfs-downdrag) (kN)	**Fs+Qp** (kN)	**Total** Fs+Qp (kN)	Σ fs* (kN/m)	Fst + Weight (kN)	(kN)
0														
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	Pile Cut-Off Elevation at 4.5 m													
2	13	0	7	0	0	198	0.0	0	10	49	35	5	10	7
2.5	15	0	14	0	0	198	0.0	0	22	61	44	10	20	14
3	17	0	22	0	0	198	0.0	0	35	74	53	16	31	23
3.5	18	0	31	0	0	198	0.0	0	49	88	63	22	44	31
4	19	0	41	0	0	198	0.0	0	64	103	74	29	56	41
4.5	20	0	51	0	0	198	0.0	0	79	118	85	35	69	50
5	20	0	61	0	0	198	0.0	0	95	134	96	42	83	60
6	21	0	81	0	0	198	0.0	0	128	167	120	57	110	79
7	22	0	103	0	0	198	0.0	0	163	201	145	72	139	100
8	35	0	138	0	0	450	0.0	0	217	305	220	97	182	131
9	36	0	174	0	0	450	0.0	0	274	362	261	122	227	163
10	38	0	212	0	0	450	0.0	0	333	422	303	149	273	196
11	39	0	252	0	0	450	0.0	0	395	484	348	176	321	231
12	41	0	292	0	0	450	0.0	0	459	547	394	205	370	266
13	42	0	334	0	0	450	0.0	0	525	614	441	234	421	303
14	43	0	378	0	0	450	0.0	0	593	682	490	264	473	340
15	45	0	422	0	0	450	0.0	0	663	752	541	296	527	379
16	46	0	468	0	0	450	0.0	0	736	824	593	328	582	419
17	47	0	515	0	0	450	0.0	0	810	898	646	361	638	459
18	48	0	564	0	0	450	0.0	0	885	974	701	395	696	501
19	49	0	613	0	0	450	0.0	0	963	1,051	756	429	755	543
20	50	0	663	0	0	450	0.0	0	1,042	1,130	813	464	815	586
21	50	0	713	0	0	450	0.0	0	1,120	1,209	869	499	874	629
22	50	0	763	0	0	450	0.0	0	1,199	1,287	926	534	934	672
23	50	0	813	0	0	450	0.0	0	1,277	1,366	982	569	994	715
24	50	0	863	0	0	450	0.0	0	1,356	1,444	1,039	604	1053	758
25	50	0	913	0	0	450	0.0	0	1,434	1,523	1,095	639	1113	801
26	50	0	963	0	0	450	0.0	0	1,513	1,601	1,152	674	1172	843

Client: DLGRMA	**Computed by:** BJG	**Checked by:** JPB
Project: Bundaberg East Levee	**Date:** 5/2/2018	**Date:** 14/2/2018
Job Number: 121923-221532	**Rev by & Date:** JPB, 28/2/2018	**Page:** 10 & 11

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

Alignment 2

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

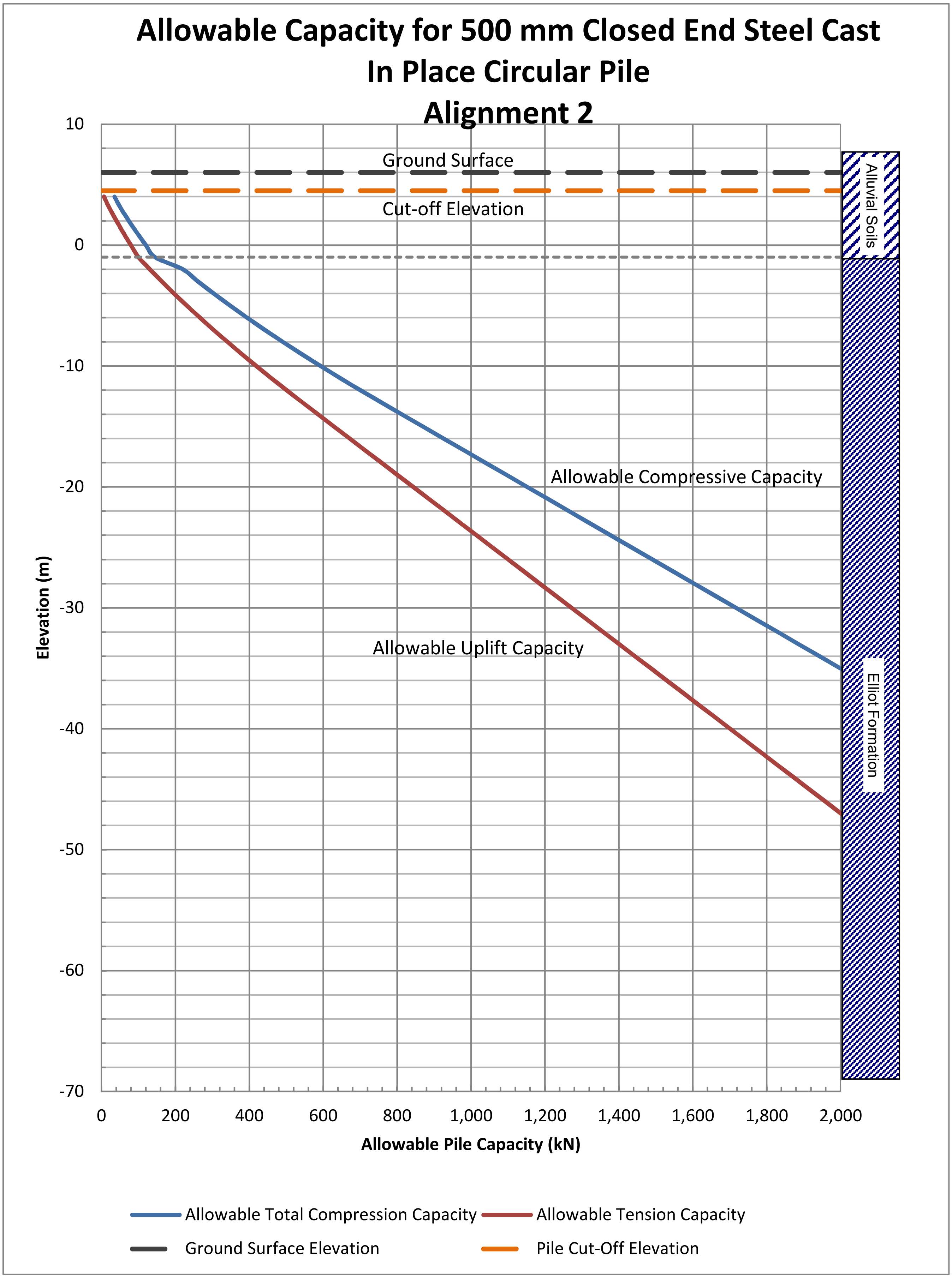
Pile Information

Pile type =	500 mm closed end steel cast in place circular pile		
Pile shape =	circle	(square or circle)	
Pile Diameter / Length of Side =	0.5	m	
Surface Area =	1.6	sq m/m length	Assume pile is
Wall Thickness =	0.0159	m	100%
End Bearing Area - FULL AREA =	0.196	sq meters	= 0.196 sq meters plugged
Unit weight of pile =	24	kN/m^3	

Design Parameters

K =	1	
Nc (clay) =	9	
Reduction on downdrag load by bitimen coating =	0	% (apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7	(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g
Downdrag load factor =	0	
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1

													Unit Skin Friction: For Clay	For Sand	Cum. fs			COMPRESSION CAPACITY: Unit End Bearing: For Clay	For Sand		Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity	UPLIFT CAPACITY	Ultimate Uplift Capacity	Allow. Uplift. Capacity
27	-21	1	Elliott Formation	50	0	0	0	0	9.0	268	0.19	1.0	50	0	1,013	0	0	450	0.0	0	1,591	1,680	1,208	709	1232	886
28	-22	1	Elliott Formation	50	0	0	0	0	9.0	277	0.18	1.0	50	0	1,063	0	0	450	0.0	0	1,670	1,758	1,265	744	1292	929
29	-23	1	Elliott Formation	50	0	0	0	0	9.0	286	0.17	1.0	50	0	1,113	0	0	450	0.0	0	1,749	1,837	1,321	779	1351	972
30	-24	1	Elliott Formation	50	0	0	0	0	9.0	295	0.17	1.0	50	0	1,163	0	0	450	0.0	0	1,827	1,915	1,378	814	1411	1015
31	-25	1	Elliott Formation	50	0	0	0	0	9.0	304	0.16	1.0	50	0	1,213	0	0	450	0.0	0	1,906	1,994	1,435	849	1470	1058
32	-26	1	Elliott Formation	50	0	0	0	0	9.0	313	0.16	1.0	50	0	1,263	0	0	450	0.0	0	1,984	2,073	1,491	884	1530	1101
33	-27	1	Elliott Formation	50	0	0	0	0	9.0	322	0.16	1.0	50	0	1,313	0	0	450	0.0	0	2,063	2,151	1,548	919	1590	1144
34	-28	1	Elliott Formation	50	0	0	0	0	9.0	331	0.15	1.0	50	0	1,363	0	0	450	0.0	0	2,141	2,230	1,604	954	1649	1187
35	-29	1	Elliott Formation	50	0	0	0	0	9.0	340	0.15	1.0	50	0	1,413	0	0	450	0.0	0	2,220	2,308	1,661	989	1709	1229
36	-30	1	Elliott Formation	50	0	0	0	0	9.0	349	0.14	1.0	50	0	1,463	0	0	450	0.0	0	2,298	2,387	1,717	1024	1768	1272
37	-31	1	Elliott Formation	50	0	0	0	0	9.0	358	0.14	1.0	50	0	1,513	0	0	450	0.0	0	2,377	2,465	1,774	1059	1828	1315
38	-32	1	Elliott Formation	50	0	0	0	0	9.0	367	0.14	1.0	50	0	1,563	0	0	450	0.0	0	2,455	2,544	1,830	1094	1888	1358
39	-33	1	Elliott Formation	50	0	0	0	0	9.0	376	0.13	1.0	50	0	1,613	0	0	450	0.0	0	2,534	2,622	1,887	1129	1947	1401
40	-34	1	Elliott Formation	50	0	0	0	0	9.0	385	0.13	1.0	50	0	1,663	0	0	450	0.0	0	2,612	2,701	1,943	1164	2007	1444
41	-35	1	Elliott Formation	50	0	0	0	0	9.0	394	0.13	1.0	50	0	1,713	0	0	450	0.0	0	2,691	2,779	2,000	1199	2067	1487
42	-36	1	Elliott Formation	50	0	0	0	0	9.0	403	0.12	1.0	50	0	1,763	0	0	450	0.0	0	2,770	2,858	2,056	1234	2126	1530
43	-37	1	Elliott Formation	50	0	0	0	0	9.0	412	0.12	1.0	50	0	1,813	0	0	450	0.0	0	2,848	2,936	2,113	1269	2186	1572
44	-38	1	Elliott Formation	50	0	0	0	0	9.0	421	0.12	1.0	50	0	1,863	0	0	450	0.0	0	2,927	3,015	2,169	1304	2245	1615
45	-39	1	Elliott Formation	50	0	0	0	0	9.0	430	0.12	1.0	50	0	1,913	0	0	450	0.0	0	3,005	3,094	2,226	1339	2305	1658
46	-40	1	Elliott Formation	50	0	0	0	0	9.0	439	0.11	1.0	50	0	1,963	0	0	450	0.0	0	3,084	3,172	2,282	1374	2365	1701
47	-41	1	Elliott Formation	50	0	0	0	0	9.0	448	0.11	1.0	50	0	2,013	0	0	450	0.0	0	3,162	3,251	2,339	1409	2424	1744
48	-42	1	Elliott Formation	50	0	0	0	0	9.0	457	0.11	1.0	50	0	2,063	0	0	450	0.0	0	3,241	3,329	2,395	1444	2484	1787
49	-43	1	Elliott Formation	50	0	0	0	0	9.0	466	0.11	1.0	50	0	2,113	0	0	450	0.0	0	3,319	3,408	2,452	1479	2543	1830
50	-44	1	Elliott Formation	50	0	0	0	0	9.0	475	0.11	1.0	50	0	2,163	0	0	450	0.0	0	3,398	3,486	2,508	1514	2603	1873
51	-45	1	Elliott Formation	50	0	0	0	0	9.0	484	0.10	1.0	50	0	2,213	0	0	450	0.0	0	3,476	3,565	2,565	1549	2663	1916
52	-46	1	Elliott Formation	50	0	0	0	0	9.0	493	0.10	1.0	50	0	2,263	0	0	450	0.0	0	3,555	3,643	2,621	1584	2722	1958
53	-47	1	Elliott Formation	50	0	0	0	0	9.0	502	0.10	1.0	50	0	2,313	0	0	450	0.0	0	3,633	3,722	2,678	1619	2782	2001
54	-48	1	Elliott Formation	50	0	0	0	0	9.0	511	0.10	1.0	50	0	2,363	0	0	450	0.0	0	3,712	3,800	2,734	1654	2841	2044
55	-49	1	Elliott Formation	50	0	0	0	0	9.0	520	0.10	1.0	50	0	2,413	0	0	450	0.0	0	3,791	3,879	2,791	1689	2901	2087
56	-50	1	Elliott Formation	50	0	0	0	0	9.0	529	0.09	1.0	50	0	2,463	0	0	450	0.0	0	3,869	3,957	2,847	1724	2961	2130
57	-51	1	Elliott Formation	50	0	0	0	0	9.0	538	0.09	1.0	50	0	2,513	0	0	450	0.0	0	3,948	4,036	2,904	1759	3020	2173
58	-52	1	Elliott Formation	50	0	0	0	0	9.0	547	0.09	1.0	50	0	2,563	0	0	450	0.0	0	4,026	4,115	2,960	1794	3080	2216
59	-53	1	Elliott Formation	50	0	0	0	0	9.0	556	0.09	1.0	50	0	2,613	0	0	450	0.0	0	4,105	4,193	3,017	1829	3139	2259
60	-54	1	Elliott Formation	50	0	0	0	0	9.0	565	0.09	1.0	50	0	2,663	0	0	450	0.0	0	4,183	4,272	3,073	1864	3199	2301
61	-55	1	Elliott Formation	50	0	0	0	0	9.0	574	0.09	1.0	50	0	2,713	0	0	450	0.0	0	4,262	4,350	3,130	1899	3259	2344



Allowable Capacity for 500 mm Closed End Steel Cast In Place Circular Pile
Alignment 2
Ground Surface
Cut-off Elevation
Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)
Allowable Total Compression Capacity
Allowable Tension Capacity
Ground Surface Elevation
Pile Cut-Off Elevation

Alignment 3

Client: DLGRMA **Computed by:** BJG **Checked by:** JPB
Project: Bundaberg East Levee **Date:** 5/2/2018 **Date:** 14/2/2018
Job Number: 121923-221532 **Rev by & Date:** JPB, 28/2/2018 **Page:** 13 & 14

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B--6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	500 mm closed end steel cast in place circular pile				
Pile shape =	circle	(square or circle)			
Pile Diameter / Length of Side =	0.5	m			
Surface Area =	1.6	sq m/m length			Assume pile is
Wall Thickness =	0.0159	m			100%
End Bearing Area - FULL AREA =	0.196	sq meters	=	0.196 sq meters	plugged
Unit weight of pile =	24	kN/m^3			

Soil Properties

Alignment 3

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1	

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing			Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity	UPLIFT CAPACITY	Ultimate Uplift Capacity	Allow. Uplift. Capacity
													For Clay	For Sand	Cum. fs			For Clay	For Sand							
Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	fs clay (kPa)	fs sand (kPa)	Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	**qp clay** (kPa)	**Nq**	**qp sand** (kPa)	**Fs** (Σfs-downdrag) (kN)	**Fs+Qp** (kN)	**Total** Fs+Qp (kN)	Σ fs* (kN/m)	Fst + Weight (kN)	(kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	10	49	35	5	10	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	61	44	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	35	74	53	16	31	23
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	49	88	63	22	44	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	64	103	74	29	56	41
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	79	118	85	35	69	50
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	95	134	96	42	83	60
6	0	1	Elliott Formation	0	30	20	67	2.9	9.0	80	0.00	N/A	0	29	90	0	0	0	18.4	1,472	141	430	309	63	119	86
7	-1	1	Elliott Formation	0	30	20	67	2.9	9.0	89	0.00	N/A	0	32	122	0	0	0	18.4	1,637	192	513	369	85	160	115
8	-2	1	Elliott Formation	0	30	20	67	2.9	9.0	98	0.00	N/A	0	36	158	0	0	0	18.4	1,803	248	602	433	110	204	146
9	-3	1	Elliott Formation	0	30	20	67	2.9	9.0	107	0.00	N/A	0	39	197	0	0	0	18.4	1,969	309	696	500	138	251	181
10	-4	1	Elliott Formation	0	30	20	67	2.9	9.0	116	0.00	N/A	0	42	239	0	0	0	18.4	2,135	375	795	572	167	302	217
11	-5	1	Elliott Formation	0	30	20	67	2.9	9.0	125	0.00	N/A	0	46	284	0	0	0	18.4	2,301	447	899	646	199	357	257
12	-6	1	Elliott Formation	0	30	20	67	2.9	9.0	134	0.00	N/A	0	49	333	0	0	0	18.4	2,467	523	1,008	725	233	415	299
13	-7	1	Elliott Formation	0	30	20	67	2.9	9.0	143	0.00	N/A	0	52	385	0	0	0	18.4	2,633	605	1,122	807	270	477	343
14	-8	1	Elliott Formation	0	30	20	67	2.9	9.0	152	0.00	N/A	0	55	441	0	0	0	18.4	2,799	692	1,242	893	308	542	390
15	-9	1	Elliott Formation	0	30	20	67	2.9	9.0	161	0.00	N/A	0	59	499	0	0	0	18.4	2,900	784	1,354	974	350	611	440
16	-10	1	Elliott Formation	0	30	20	67	2.9	9.0	170	0.00	N/A	0	62	561	0	0	0	18.4	2,900	882	1,451	1,044	393	684	492
17	-11	1	Elliott Formation	0	30	20	67	2.9	9.0	179	0.00	N/A	0	65	626	0	0	0	18.4	2,900	984	1,553	1,118	438	761	547
18	-12	1	Elliott Formation	0	30	20	67	2.9	9.0	188	0.00	N/A	0	67	693	0	0	0	18.4	2,900	1,089	1,659	1,193	485	839	603
19	-13	1	Elliott Formation	0	30	20	67	2.9	9.0	197	0.00	N/A	0	67	760	0	0	0	18.4	2,900	1,194	1,764	1,269	532	917	660
20	-14	1	Elliott Formation	0	30	20	67	2.9	9.0	206	0.00	N/A	0	67	827	0	0	0	18.4	2,900	1,300	1,869	1,345	579	995	716
21	-15	1	Elliott Formation	0	30	20	67	2.9	9.0	215	0.00	N/A	0	67	894	0	0	0	18.4	2,900	1,405	1,974	1,420	626	1074	772
22	-16	1	Elliott Formation	0	30	20	67	2.9	9.0	224	0.00	N/A	0	67	961	0	0	0	18.4	2,900	1,510	2,080	1,496	673	1152	829
23	-17	1	Elliott Formation	0	30	20	67	2.9	9.0	233	0.00	N/A	0	67	1,028	0	0	0	18.4	2,900	1,615	2,185	1,572	720	1230	885
24	-18	1	Elliott Formation	0	30	20	67	2.9	9.0	242	0.00	N/A	0	67	1,095	0	0	0	18.4	2,900	1,721	2,290	1,648	767	1309	941
25	-19	1	Elliott Formation	0	30	20	67	2.9	9.0	251	0.00	N/A	0	67	1,162	0	0	0	18.4	2,900	1,826	2,395	1,723	814	1387	998
26	-20	1	Elliott Formation	0	30	20	67	2.9	9.0	260	0.00	N/A	0	67	1,229	0	0	0	18.4	2,900	1,931	2,501	1,799	861	1465	1054

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m Per Test Boring B--6
Pile Cut-Off Elevation = 4.5 m

Pile Information

Pile type = 500 mm closed end steel cast in place circular pile
Pile shape = circle (square or circle)
Pile Diameter / Length of Side = 0.5 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0.0159 m
End Bearing Area - FULL AREA = 0.196 sq meters = 0.196 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Soil Properties

Alignment 3

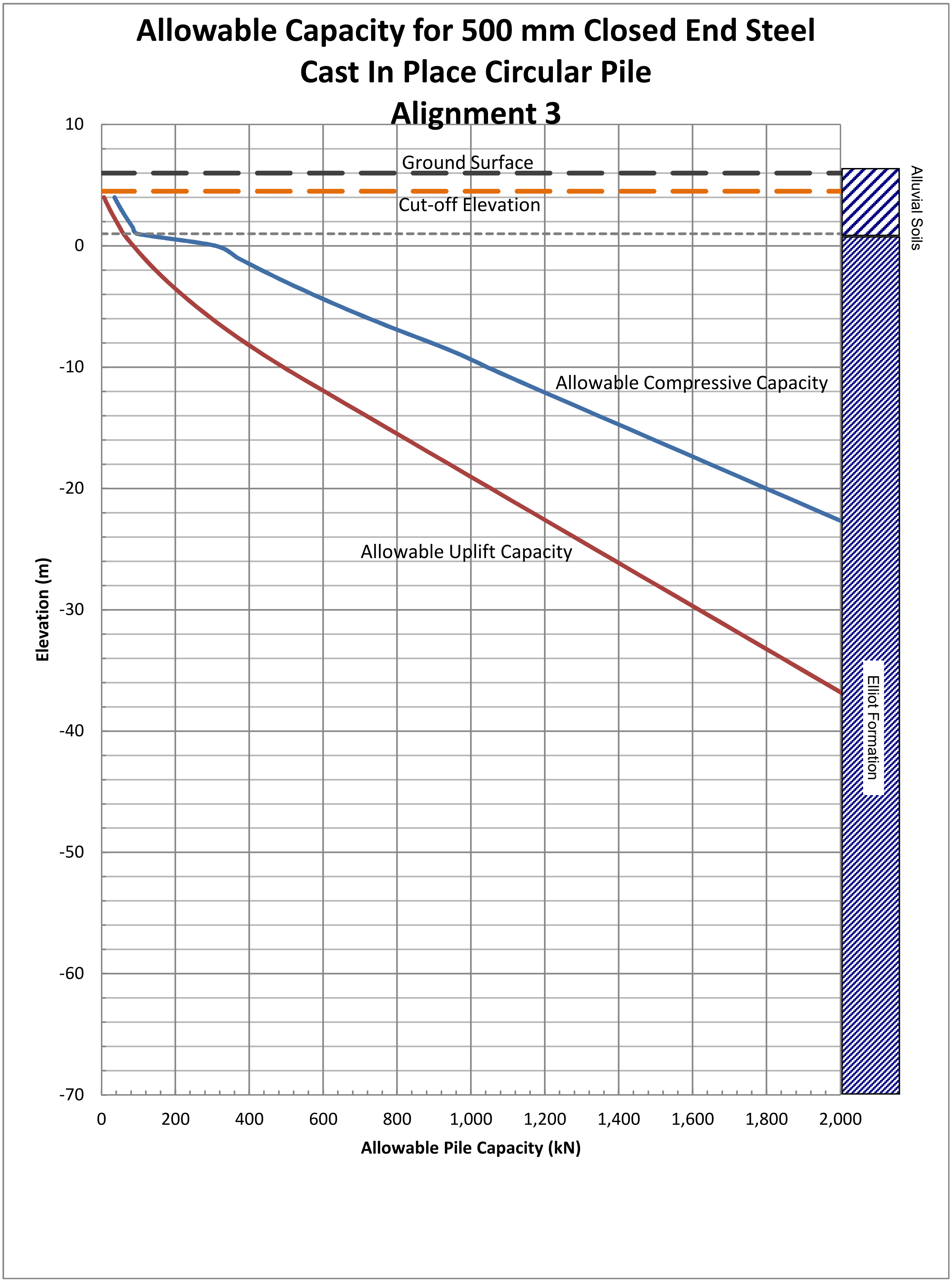
	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7 (for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing						UPLIFT CAPACITY		
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
27	-21	1	Elliott Formation	0	30	20	67	2.9	9.0	269	0.00	N/A	0	67	1,296	0	0	0	18.4	2,900	2,036	2,606	1,875	907	1543	1110
28	-22	1	Elliott Formation	0	30	20	67	2.9	9.0	278	0.00	N/A	0	67	1,363	0	0	0	18.4	2,900	2,142	2,711	1,950	954	1622	1167
29	-23	1	Elliott Formation	0	30	20	67	2.9	9.0	287	0.00	N/A	0	67	1,430	0	0	0	18.4	2,900	2,247	2,816	2,026	1001	1700	1223
30	-24	1	Elliott Formation	0	30	20	67	2.9	9.0	296	0.00	N/A	0	67	1,497	0	0	0	18.4	2,900	2,352	2,922	2,102	1048	1778	1279
31	-25	1	Elliott Formation	0	30	20	67	2.9	9.0	305	0.00	N/A	0	67	1,564	0	0	0	18.4	2,900	2,457	3,027	2,178	1095	1857	1336
32	-26	1	Elliott Formation	0	30	20	67	2.9	9.0	314	0.00	N/A	0	67	1,631	0	0	0	18.4	2,900	2,563	3,132	2,253	1142	1935	1392
33	-27	1	Elliott Formation	0	30	20	67	2.9	9.0	323	0.00	N/A	0	67	1,698	0	0	0	18.4	2,900	2,668	3,237	2,329	1189	2013	1448
34	-28	1	Elliott Formation	0	30	20	67	2.9	9.0	332	0.00	N/A	0	67	1,765	0	0	0	18.4	2,900	2,773	3,343	2,405	1236	2092	1505
35	-29	1	Elliott Formation	0	30	20	67	2.9	9.0	341	0.00	N/A	0	67	1,832	0	0	0	18.4	2,900	2,878	3,448	2,480	1283	2170	1561
36	-30	1	Elliott Formation	0	30	20	67	2.9	9.0	350	0.00	N/A	0	67	1,899	0	0	0	18.4	2,900	2,984	3,553	2,556	1330	2248	1617
37	-31	1	Elliott Formation	0	30	20	67	2.9	9.0	359	0.00	N/A	0	67	1,966	0	0	0	18.4	2,900	3,089	3,658	2,632	1376	2326	1674
38	-32	1	Elliott Formation	0	30	20	67	2.9	9.0	368	0.00	N/A	0	67	2,033	0	0	0	18.4	2,900	3,194	3,763	2,708	1423	2405	1730
39	-33	1	Elliott Formation	0	30	20	67	2.9	9.0	377	0.00	N/A	0	67	2,100	0	0	0	18.4	2,900	3,299	3,869	2,783	1470	2483	1786
40	-34	1	Elliott Formation	0	30	20	67	2.9	9.0	387	0.00	N/A	0	67	2,167	0	0	0	18.4	2,900	3,405	3,974	2,859	1517	2561	1843
41	-35	1	Elliott Formation	0	30	20	67	2.9	9.0	396	0.00	N/A	0	67	2,234	0	0	0	18.4	2,900	3,510	4,079	2,935	1564	2640	1899
42	-36	1	Elliott Formation	0	30	20	67	2.9	9.0	405	0.00	N/A	0	67	2,301	0	0	0	18.4	2,900	3,615	4,184	3,010	1611	2718	1955
43	-37	1	Elliott Formation	0	30	20	67	2.9	9.0	414	0.00	N/A	0	67	2,368	0	0	0	18.4	2,900	3,720	4,290	3,086	1658	2796	2012
44	-38	1	Elliott Formation	0	30	20	67	2.9	9.0	423	0.00	N/A	0	67	2,435	0	0	0	18.4	2,900	3,826	4,395	3,162	1705	2875	2068
45	-39	1	Elliott Formation	0	30	20	67	2.9	9.0	432	0.00	N/A	0	67	2,502	0	0	0	18.4	2,900	3,931	4,500	3,238	1752	2953	2124
46	-40	1	Elliott Formation	0	30	20	67	2.9	9.0	441	0.00	N/A	0	67	2,569	0	0	0	18.4	2,900	4,036	4,605	3,313	1799	3031	2181
47	-41	1	Elliott Formation	0	30	20	67	2.9	9.0	450	0.00	N/A	0	67	2,636	0	0	0	18.4	2,900	4,141	4,711	3,389	1845	3109	2237
48	-42	1	Elliott Formation	0	30	20	67	2.9	9.0	459	0.00	N/A	0	67	2,703	0	0	0	18.4	2,900	4,247	4,816	3,465	1892	3188	2293
49	-43	1	Elliott Formation	0	30	20	67	2.9	9.0	468	0.00	N/A	0	67	2,770	0	0	0	18.4	2,900	4,352	4,921	3,540	1939	3266	2350
50	-44	1	Elliott Formation	0	30	20	67	2.9	9.0	477	0.00	N/A	0	67	2,837	0	0	0	18.4	2,900	4,457	5,026	3,616	1986	3344	2406
51	-45	1	Elliott Formation	0	30	20	67	2.9	9.0	486	0.00	N/A	0	67	2,904	0	0	0	18.4	2,900	4,562	5,132	3,692	2033	3423	2462
52	-46	1	Elliott Formation	0	30	20	67	2.9	9.0	495	0.00	N/A	0	67	2,971	0	0	0	18.4	2,900	4,667	5,237	3,768	2080	3501	2519
53	-47	1	Elliott Formation	0	30	20	67	2.9	9.0	504	0.00	N/A	0	67	3,038	0	0	0	18.4	2,900	4,773	5,342	3,843	2127	3579	2575
54	-48	1	Elliott Formation	0	30	20	67	2.9	9.0	513	0.00	N/A	0	67	3,105	0	0	0	18.4	2,900	4,878	5,447	3,919	2174	3658	2631
55	-49	1	Elliott Formation	0	30	20	67	2.9	9.0	522	0.00	N/A	0	67	3,172	0	0	0	18.4	2,900	4,983	5,553	3,995	2221	3736	2688
56	-50	1	Elliott Formation	0	30	20	67	2.9	9.0	531	0.00	N/A	0	67	3,239	0	0	0	18.4	2,900	5,088	5,658	4,070	2268	3814	2744
57	-51	1	Elliott Formation	0	30	20	67	2.9	9.0	540	0.00	N/A	0	67	3,306	0	0	0	18.4	2,900	5,194	5,763	4,146	2314	3892	2800
58	-52	1	Elliott Formation	0	30	20	67	2.9	9.0	549	0.00	N/A	0	67	3,373	0	0	0	18.4	2,900	5,299	5,868	4,222	2361	3971	2857
59	-53	1	Elliott Formation	0	30	20	67	2.9	9.0	558	0.00	N/A	0	67	3,440	0	0	0	18.4	2,900	5,404	5,974	4,298	2408	4049	2913
60	-54	1	Elliott Formation	0	30	20	67	2.9	9.0	567	0.00	N/A	0	67	3,507	0	0	0	18.4	2,900	5,509	6,079	4,373	2455	4127	2969
61	-55	1	Elliott Formation	0	30	20	67	2.9	9.0	576	0.00	N/A	0	67	3,574	0	0	0	18.4	2,900	5,615	6,184	4,449	2502	4206	3026



Allowable Capacity for 500 mm Closed End Steel
Cast In Place Circular Pile
Alignment 3
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Appendix B3

1-m-Diameter Bored Cast In Place Piles

Purpose: To determine the compressive and uplift capacity of bored cast in place piles.

Problem: Determine the allowable compressive and uplift capacities for bored cast in place piles.

References:
1. "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010.
2. "Factual Geotachnical Report, Bundaberg East Levee, Bundaberg, Queensland" CDM Smith, 31 January 2018

Soil Information: Soil layering, soil properties and ground water elevation obtained from available boring logs[2].

Datum: Australian Height Datum (AHD)

Method: Conduct evaluation for compression and uplift capacity of bored cast in place piles for the support of the new flood wall. Based on the results of the evaluation, select the most appropriate bored cast in place pile diameter and minimum embedment length.

Assumptions:
1. The drilled shaft diameter is assumed to be 1 meter.
2. Neglect downdrag load on the bored cast in place pile since no raise in grade is required.
3. Assume the factor of safety is 1.39.
4. Groundwater elevation is assumed at El. 2.5 based upon observed water level readings in test boring B-6.
5. Bored cast in place pile cut-off is assumed at El. 4.5.
6. Assume 5 percent of shafts dynamically load tested.
7. Assume a friction interface reduction factor for uplift of 0.7.
8. Minimum of 1 meter embedment in elliott formation.

Equations:
1. $R_T = (R_{SN} + R_{BN})/FS$ Eq. 13-2
2. $R_{SN} = \Sigma (f_{SNi} \pi B \Delta z_i)$ Eq. 13-3
3. $R_{SNi} = f_{SNi} \pi B \Delta z_i$ Eq. 13-3
4. $R_{BN} = 0.25 q_{BN} (\pi B^2)$ Eq. 13-4

Cohesionless Soils:
4. $f_{SN} = \beta \sigma'_v$ Eq. 13-7
5. $\beta \approx (1-\sin\varphi')(\sigma'_p/\sigma'_v)^{(\sin\varphi')}(\tan\varphi') <= K_p \tan\varphi'$ Eq. 13-6 & Eq. 13-11

Where
$\sigma'p/\sigma'v = 0.47 * N_{60}^{m}$ and where m = 0.6 for clean sands and m = 0.8 for silty sands or sandy silts.
6a. qBN = 0.6(N60) for 0 <= N60 at Shaft Tip <= 50 Eq. 13-14
6b. qBN = 2872 kPa for N60 at Shaft Tip > 50 Eq. 13-14

Cohesive Soils:
7. $f_{SNi} = \alpha s_{ui}$ Eq. 13-15
8a. $\alpha = 0.55$ for $s_u/p_a <= 1.5$
8b. $\alpha = 0.55$ to 0.45 (linearly) for $1.5 <= s_u/p_a <= 2.5$
9. $p_a = 101.3$ kPa
10. $q_{BN} = N^*_c s_{ui}$ Eq. 13-16
11. N^*_c (see Table 13-2 in FHWA Drilled Shafts Manual)

Variables:
R_T = Total axial compressive resistance (kN)
R_{SN} = Nominal side resistance (kN)
R_{SNi} = Nominal side resistance of element "i" (kN)
R_{BN} = Nominal base resistance (kN)
B = Shaft diameter (m)
Δz_i = Thickness of layer "i" (m)
f_{SNi} = Nominal unit side resistance of element "i" (kPa)
q_{BN} = Nominal unit base resistance (kPa)
β = Cohessionless resistance factor
FS = Factor of safety
σ'_v = Vertical effective stress (kPa)
σ'_p = Vertical effective preconsolidation stress (kPa)
φ' = Soil drained angle of internal friction (deg.)
Kp = Passive lateral earth pressure coefficient
N_{60} = SPT N-value
α = Cohesive resistance factor
s_{ui} = Undrained shear strength of element "i" (kPa)
p_a = Atmospheric pressure (kPa)
Z = Depth from ground surface to middle of soil layer or shaft segment for element "i" (m)

Results:
A summary of the total allowable compression and uplift capacity is summarized in Table 1 below.

Table 1 - Summary of Compression and Uplift Pile Capacity

Soil Profile	Total Allowable Compression Capacity (kN)	Total Allowable Uplift Capacity (kN)	Embedment in Elliott Formation (m)
1	250	400	1
1	500	400	1
1	750	400	1
1	1000	450	3
2	250	200	1
2	500	250	3
2	750	350	7
2	1000	450	11
3	250	250	2
3	500	300	3
3	750	375	5
3	1000	400	6

Notes:
1. Assumes a FS of 1.39 based on AS 2159-2009 Section 4.3.1 calculation.

CDM Smith

References:

AS 2159-2009 Piling -- Design and Installation

21 **AS 2159—2009**

4.3 GENERAL PRINCIPLES OF GEOTECHNICAL STRENGTH DESIGN

4.3.1 Design geotechnical strength

A pile shall be proportioned such that the design geotechnical strength ($R_{d,g}$) is not less than the design action effect (E_d) as detailed in Clause 3.2.2, that is—

$$R_{d,g} \geq E_d \qquad \text{. . . 4.3.1(1)}$$

The design geotechnical strength ($R_{d,g}$) shall be calculated as the design ultimate geotechnical strength ($R_{d,ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g), according to the following equation:

$$R_{d,g} = \phi_g R_{d,ug} \qquad \text{. . . 4.3.1(2)}$$

The geotechnical strength reduction factor (ϕ_g) shall be determined as follows:

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

where

ϕ_{gb} = basic geotechnical strength reduction factor as given in Clause 4.3.2

ϕ_{tf} = intrinsic test factor

= 0.9, for static load testing (see Section 8)

= 0.75, for rapid load testing (see Section 8)

= 0.8, for dynamic load testing of preformed piles (see Section 8)

= 0.75, for dynamic load testing of other than preformed piles (see Section 8)

= 0.85, for bi-directional load testing (see Section 8)

= ϕ_{gb}, for no testing

K = testing benefit factor

= $1.33p/(p + 3.3) \leq 1$, for static or rapid load testing

= $1.13p/(p + 3.3) \leq 1$, for dynamic load testing

p = percentage of the total piles that are tested and meet the specified acceptance criteria

References:

4.3.2 Assessment of basic geotechnical strength reduction factor (ϕ_{gb})

The basic geotechnical strength reduction factor (ϕ_{gb}) shall be calculated using a risk assessment procedure as set out below:

(a) Rate each risk factor in Table 4.3.2(A) on a scale from 1 to 5 for the nature of the site, the available site information and the pile design and installation procedures adopted. This will produce an individual risk rating (IRR) according to the assessed level of risk, as set out in Table 4.3.2(B)

(b) Determine the overall design average risk rating (ARR) using the weighted average of the product of all of the risk weighting factors (w_i) shown in column 2 of Table 4.3.2(A) times the relevant individual risk rating (IRR), as follows:

$$ARR = \Sigma(w_i \mathrm{IRR}_i)/\Sigma w_i \quad \ldots 4.3.2$$

(c) Determine the basic geotechnical strength reduction factor (ϕ_{gb}) from Table 4.3.2(C) depending on the level of redundancy in the piling system. Systems with a high degree of redundancy would include large pile groups under large caps, piled rafts and pile groups with more than 4 piles. Systems with a low level of redundancy would include isolated heavily loaded piles and piles set out at large spacings.

TABLE 4.3.2(A)

WEIGHTING FACTORS AND INDIVIDUAL RISK RATINGS FOR RISK FACTORS

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Site				
Geological complexity of site	2	Horizontal strata, well-defined soil and rock characteristics	Some variability over site, but without abrupt changes in stratigraphy	Highly variable profile or presence of karstic features or steeply dipping rock levels or faults present on site, or combinations of these
Extent of ground investigation	2	Extensive drilling investigation covering whole site to an adequate depth	Some boreholes extending at least 5 pile diameters below the base of the proposed pile foundation level	Very limited investigation with few shallow boreholes
Amount and quality of geotechnical data	2	Detailed information on strength compressibility of the main strata	CPT probes over full depth of proposed piles or boreholes confirming rock as proposed founding level for piles	Limited amount of simple in situ testing (e.g., SPT) or index tests only
Design				
Experience with similar foundations in similar geological conditions	1	Extensive	Limited	None

(continued)

References:

TABLE 4.3.2(A) *(continued)*

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Method of assessment of geotechnical parameters for design	2	Based on appropriate laboratory or in situ tests or relevant existing pile load test data	Based on site-specific correlations or on conventional laboratory or in situ testing	Based on non-site-specific correlations with (for example) SPT data
Design method adopted	1	Well-established and soundly based method or methods	Simplified methods with well-established basis	Simple empirical methods or sophisticated methods that are not well established
Method of utilizing results of in situ test data and installation data	2	Design values based on minimum measured values on piles loaded to failure	Design methods based on average values	Design values based on maximum measured values on test piles loaded up only to working load, or indirect measurements used during installation, and not calibrated to static loading tests
Installation				
Level of construction control	2	Detailed with professional geotechnical supervision, construction processes that are well established and relatively straightforward	Limited degree of professional geotechnical involvement in supervision, conventional construction procedures	Very limited or no involvement by designer, construction processes that are not well established or complex
Level of performance monitoring of the supported structure during and after construction	0.5	Detailed measurements of movements and pile loads	Correlation of installed parameters with on-site static load tests carried out in accordance with this Standard	No monitoring

NOTE: The pile design shall include the risk circumstances for each individual risk category and consideration of all of the relevant site and construction factors.

TABLE 4.3.2(B)

INDIVIDUAL RISK RATING (IRR)

Risk level	Individual risk rating (IRR)
Very low	1
Low	2
Moderate	3
High	4
Very high	5

TABLE 4.3.2(C)

BASIC GEOTECHNICAL STRENGTH REDUCTION FACTOR (ϕ_{gb}) FOR AVERAGE RISK RATING

Range of average risk rating (ARR)	Overall risk category	ϕ_{gb} for low redundancy systems	ϕ_{gb} for high redundancy systems
ARR ≤1.5	Very low	0.67	0.76
1.5 < ARR ≤2.0	Very low to low	0.61	0.70
2.0 < ARR ≤2.5	Low	0.56	0.64
2.5 < ARR ≤3.0	Low to moderate	0.52	0.60
3.0 < ARR ≤3.5	Moderate	0.48	0.56
3.5 < ARR ≤4.0	Moderate to high	0.45	0.53
4.0 < ARR ≤4.5	High	0.42	0.50
>4.5	Very high	0.40	0.47

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

ϕ_{tf} =	0.8	for dynamic load testing
K =	1.13p/(p+3.3)	
p=	5	percent of piles to be tested
K=	0.68	
IRR=	50.5	
w_i =	14.5	
ARR=	3.48	
ϕ_{gb} =	0.56	
ϕ_g =	0.72	>= 0.56
FS=	1.39	

Design Soil Profile:

	Alignment	1. City Alignment Sta. 1+00 to Sta. 3+50	2. City Alignment Sta. 3+50 to Sta. 7+50	3. Distillery Alignment Sta. 2+50 to Sta. 7+00
	Alluvial Soils Thickness (m)	13	7	5
	Elliott Formation Thickness (m)	>15	>15	>10
	Applicable Borings	B-2, B-3, B-5	B-4, B-6, B-7	B-12, B-13
Alluvial Soil Properties	Su (kPa)	22	22	22
	δ (°)	0	0	0
	Φ(°)	15	15	15
	Average N-Value	1	1	1
	Unit Weight (kN/m^3)	18.0	18.0	18.0
Elliott Formation Properties	Su (kPa)	100	50	0
	δ (°)	0	0	20
	Φ(°)	0	0	30
	Average N-Value	48	15	22
	Unit Weight (kN/m^3)	18.8	18.8	18.8

Table 1: Structural Capacity of Bored Cast In Place Concrete Pile

Type 1 m Bored Cast In Place Concrete Pile
Shape Circular

Diameter (m)	Gross Area (sq m)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Total Structural Capacity (kN)
0.5	0.196	0.196	27575	**1787**
0.75	0.442	0.442	27575	**4020**
1	0.785	0.785	27575	**7147**
1.25	1.227	1.227	27575	**11167**
1.5	1.767	1.767	27575	**16081**

Notes:
1 Allowable Concrete Stress = 0.33 f'c

Alignment 1

CLIENT: DLGRMA
PROJECT: Bundaberg East Levee
DETAIL: 121923-221532
FILE NAME: Bored Cast In Place Pile Calculation

JOB NO: 121923-221532
DATE CHK: 14/2/2018
CHECKED BY: JPB

COMPUTED BY: BJG
DATE: 7/2/2018
PAGE: 7

GS EL =	6.0	m
Shaft Cut-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_c	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.39

Stratum	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 1 parameters
Elliott Formation	18.82	100	0	48	Alignment 1 parameters

Cast In Place Pile Information

Pile Diameter=	1.0	m
Surface Area=	3.14	m^2/m length
End Bearing Area=	0.79	m^2
Unit Weight of Pile=	24	kN/m^3

Soil Stratum and Properties																Shaft Length Below Bottom of Cap	f_{SNi} sand[9]	f_{SNi} clay[10]	Total Side-Resistance [11&12]	q_{BN}[13]	Total Base-Resistance [14]	Total Compressive Resistance[15]	Total Allowable Compressive Resistance[15]	Total Allowable Compressive Resistance	Total Allowable Uplift Resistance
Top of Depth Interval BGS	Bottom of Depth Interval BGS	Drilled Caisson Tip EL	Strata Thickness	Mid-Layer Depth BGS	Stratum	Unit Type	γ_b[2]	Effective Vertical Stress		Friction Angle[3]	Average Undrained Shear Strength[4]	α Factor[5]	Average SPT N-Value[6]	m Factor[7]	β Factor[8]										
(m)	(m)	(m)	(m)	(m)			(tcm)	σ'$_v$ (kPa)	σ'$_v$ (mPa)	(°)	s_u (kPa)		N_{60} (bpf)			(m)	(kPa)	(kPa)	$R_{SN,i}$ (Kn)	(kPa)	$R_{SN,i}$ (kN)	R_T (kN)	R_T (kips)	R_T (kN)	F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Alluvial Soils	clay	18.0	5	0.00	15	22	0.55	1	---	---	-1.0	0.0	0.0	0.00	0.00	0	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Alluvial Soils	clay	18.0	14	0.01	15	22	0.55	1	---	---	-0.5	0.0	0.0	0.00	0.00	0	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Alluvial Soils	clay	18.0	23	0.02	15	22	0.55	1	---	---	0.0	0.0	12.1	19.0	143.0	0	19	3	14	27
1.5	2.0	4.0	0.5	1.8	Alluvial Soils	clay	18.0	32	0.03	15	22	0.55	1	---	---	0.5	0.0	12.1	38.0	143.0	0	38	6	27	39
2.0	2.5	3.5	0.5	2.3	Alluvial Soils	clay	18.0	41	0.04	15	22	0.55	1	---	---	1.0	0.0	12.1	57.0	143.0	0	57	9	41	51
2.5	3.0	3.0	0.5	2.8	Alluvial Soils	clay	18.0	50	0.05	15	22	0.55	1	---	---	1.5	0.0	12.1	76.0	143.0	0	76	12	55	63
3.0	3.5	2.5	0.5	3.3	Alluvial Soils	clay	18.0	59	0.06	15	22	0.55	1	---	---	2.0	0.0	12.1	95.0	143.0	0	95	15	68	75
3.5	4.0	2.0	0.5	3.8	Alluvial Soils	clay	8.2	65	0.07	15	22	0.55	1	---	---	2.5	0.0	12.1	114.0	143.0	0	114	18	82	87
4.0	4.5	1.5	0.5	4.3	Alluvial Soils	clay	8.2	69	0.07	15	22	0.55	1	---	---	3.0	0.0	12.1	133.0	143.0	0	133	22	96	99
4.5	5.0	1.0	0.5	4.8	Alluvial Soils	clay	8.2	73	0.07	15	22	0.55	1	---	---	3.5	0.0	12.1	152.1	143.0	0	152	25	109	111
5.0	5.5	0.5	0.5	5.3	Alluvial Soils	clay	8.2	78	0.08	15	22	0.55	1	---	---	4.0	0.0	12.1	171.1	143.0	0	171	28	123	123
5.5	6.0	0.0	0.5	5.8	Alluvial Soils	clay	8.2	82	0.08	15	22	0.55	1	---	---	4.5	0.0	12.1	190.1	143.0	0	190	31	137	135
6.0	7.0	-1.0	1.0	6.5	Alluvial Soils	clay	8.2	88	0.09	15	22	0.55	1	---	---	5.5	0.0	12.1	228.1	143.0	0	228	37	164	159
7.0	8.0	-2.0	1.0	7.5	Alluvial Soils	clay	8.2	96	0.10	15	22	0.55	1	---	---	6.5	0.0	12.1	266.1	143.0	0	266	43	191	183
8.0	9.0	-3.0	1.0	8.5	Alluvial Soils	clay	8.2	104	0.10	15	22	0.55	1	---	---	7.5	0.0	12.1	304.1	143.0	0	304	49	219	207
9.0	10.0	-4.0	1.0	9.5	Alluvial Soils	clay	8.2	113	0.11	15	22	0.55	1	---	---	8.5	0.0	12.1	342.1	143.0	0	342	55	246	231
10.0	11.0	-5.0	1.0	10.5	Alluvial Soils	clay	8.2	121	0.12	15	22	0.55	1	---	---	9.5	0.0	12.1	380.1	143.0	0	380	62	273	255
11.0	12.0	-6.0	1.0	11.5	Alluvial Soils	clay	8.2	129	0.13	15	22	0.55	1	---	---	10.5	0.0	12.1	418.1	143.0	0	418	68	301	279
12.0	13.0	-7.0	1.0	12.5	Alluvial Soils	clay	8.2	137	0.14	15	22	0.55	1	---	---	11.5	0.0	12.1	456.2	143.0	0	456	74	328	303
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	clay	9.0	146	0.15	0	100	0.55	48	---	---	12.5	0.0	55.0	628.9	650.0	510.5	1139	184	820	421
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	clay	9.0	155	0.15	0	100	0.55	48	---	---	13.5	0.0	55.0	801.7	650.0	510.5	1312	212	944	445
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	clay	9.0	164	0.16	0	100	0.55	48	---	---	14.5	0.0	55.0	974.5	650.0	510.5	1485	240	1068	469
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	clay	9.0	173	0.17	0	100	0.55	48	---	---	15.5	0.0	55.0	1147.3	650.0	510.5	1658	268	1193	493
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	clay	9.0	182	0.18	0	100	0.55	48	---	---	16.5	0.0	55.0	1320.1	650.0	510.5	1831	296	1317	517
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	clay	9.0	191	0.19	0	100	0.55	48	---	---	17.5	0.0	55.0	1492.9	650.0	510.5	2003	324	1441	541
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	clay	9.0	200	0.20	0	100	0.55	48	---	---	18.5	0.0	55.0	1665.7	650.0	510.5	2176	352	1566	565
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	clay	9.0	209	0.21	0	100	0.55	48	---	---	19.5	0.0	55.0	1838.5	650.0	510.5	2349	380	1690	589
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	clay	9.0	218	0.22	0	100	0.55	48	---	---	20.5	0.0	55.0	2011.2	650.0	510.5	2522	408	1814	613
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	clay	9.0	227	0.23	0	100	0.55	48	---	---	21.5	0.0	55.0	2184.0	650.0	510.5	2695	436	1939	637
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	clay	9.0	236	0.24	0	100	0.55	48	---	---	22.5	0.0	55.0	2356.8	650.0	510.5	2867	464	2063	661
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	clay	9.0	245	0.25	0	100	0.55	48	---	---	23.5	0.0	55.0	2529.6	650.0	510.5	3040	492	2187	685
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	clay	9.0	254	0.25	0	100	0.55	48	---	---	24.5	0.0	55.0	2702.4	650.0	510.5	3213	520	2311	709
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	clay	9.0	263	0.26	0	100	0.55	48	---	---	25.5	0.0	55.0	2875.2	650.0	510.5	3386	548	2436	733
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	clay	9.0	272	0.27	0	100	0.55	48	---	---	26.5	0.0	55.0	3048.0	650.0	510.5	3558	576	2560	757
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	clay	9.0	281	0.28	0	100	0.55	48	---	---	27.5	0.0	55.0	3220.8	650.0	510.5	3731	604	2684	781
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	clay	9.0	290	0.29	0	100	0.55	48	---	---	28.5	0.0	55.0	3393.5	650.0	510.5	3904	632	2809	805
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	clay	9.0	299	0.30	0	100	0.55	48	---	---	29.5	0.0	55.0	3566.3	650.0	510.5	4077	660	2933	829
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	clay	9.0	308	0.31	0	100	0.55	48	---	---	30.5	0.0	55.0	3739.1	650.0	510.5	4250	688	3057	853
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	clay	9.0	317	0.32	0	100	0.55	48	---	---	31.5	0.0	55.0	3911.9	650.0	510.5	4422	716	3182	877
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	clay	9.0	326	0.33	0	100	0.55	48	---	---	32.5	0.0	55.0	4084.7	650.0	510.5	4595	744	3306	901
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	clay	9.0	335	0.34	0	100	0.55	48	---	---	33.5	0.0	55.0	4257.5	650.0	510.5	4768	772	3430	925
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	clay	9.0	344	0.34	0	100	0.55	48	---	---	34.5	0.0	55.0	4430.3	650.0	510.5	4941	800	3555	949
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	clay	9.0	353	0.35	0	100	0.55	48	---	---	35.5	0.0	55.0	4603.1	650.0	510.5	5114	828	3679	973
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	clay	9.0	362	0.36	0	100	0.55	48	---	---	36.5	0.0	55.0	4775.8	650.0	510.5	5286	856	3803	997
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	clay	9.0	371	0.37	0	100	0.55	48	---	---	37.5	0.0	55.0	4948.6	650.0	510.5	5459	884	3927	1021
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	clay	9.0	380	0.38	0	100	0.55	48	---	---	38.5	0.0	55.0	5121.4	650.0	510.5	5632	912	4052	1045
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	clay	9.0	365	0.37	0	100	0.55	48	---	---	39.5	0.0	55.0	5294.2	650.0	510.5	5805	940	4176	1069
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	clay	9.0	374	0.37	0	100	0.55	48	---	---	40.5	0.0	55.0	5467.0	650.0	510.5	5978	968	4300	1093
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	clay	9.0	383	0.38	0	100	0.55	48	---	---	41.5	0.0	55.0	5639.8	650.0	510.5	6150	996	4425	1117
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	clay	9.0	392	0.39	0	100	0.55	48	---	---	42.5	0.0	55.0	5812.6	650.0	510.5	6323	1024	4549	1141
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	clay	9.0	401	0.40	0	100	0.55	48	---	---	43.5	0.0	55.0	5985.4	650.0	510.5	6496	1051	4673	1165
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	clay	9.0	410	0.41	0	100	0.55	48	---	---	44.5	0.0	55.0	6158.1	650.0	510.5	6669	1079	4798	1189
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	clay	9.0	419	0.42	0	100	0.55	48	---	---	45.5	0.0	55.0	6330.9	650.0	510.5	6841	1107	4922	1213
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	clay	9.0	428	0.43	0	100	0.55	48	---	---	46.5	0.0	55.0	6503.7	650.0	510.5	7014	1135	5046	1237
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	clay	9.0	437	0.44	0	100	0.55	48	---	---	47.5	0.0	55.0	6676.5	650.0	510.5	7187	1163	5171	1261
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	clay	9.0	446	0.45	0	100	0.55	48	---	---	48.5	0.0	55.0	6849.3	650.0	510.5	7360	1191	5295	1285
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	clay	9.0	455	0.46	0	100	0.55	48	---	---	49.5	0.0	55.0	7022.1	650.0	510.5	7533	1219	5419	1309
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	clay	9.0	464	0.46	0	100	0.55	48	---	---	50.5	0.0	55.0	7194.9	650.0	510.5	7705	1247	5543	1333
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	clay	9.0	473	0.47	0	100	0.55	48	---	---	51.5	0.0	55.0	7367.7	650.0	510.5	7878	1275	5668	1357
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	clay	9.0	482	0.48	0	100	0.55	48	---	---	52.5	0.0	55.0	7540.5	650.0	510.5	8051	1303	5792	1381
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	clay	9.0	491	0.49	0	100	0.55	48	---	---	53.5	0.0	55.0	7713.2	650.0	510.5	8224	1331	5916	1405
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	clay	9.0	500	0.50	0	100	0.55	48	---	---	54.5	0.0	55.0	7886.0	650.0	510.5	8397	1359	6041	1429
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	clay	9.0	509	0.51	0	100	0.55	48	---	---	55.5	0.0	55.0	8058.8	650.0	510.5	8569	1387	6165	1453
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	clay	9.0	518	0.52	0	100	0.55	48	---	---	56.5	0.0	55.0	8231.6	650.0	510.5	8742	1415	6289	1477
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	clay	9.0	527	0.53	0	100	0.55	48	---	---	57.5	0.0	55.0	8404.4	650.0	510.5	8915	1443	6414	1501
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	clay	9.0	536	0.54	0	100	0.55	48	---	---	58.5	0.0	55.0	8577.2	650.0	510.5	9088	1471	6538	1525
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	clay	9.0	545	0.55	0	100	0.55	48	---	---	59.5	0.0	55.0	8750.0	650.0	510.5	9260	1499	6662	1549

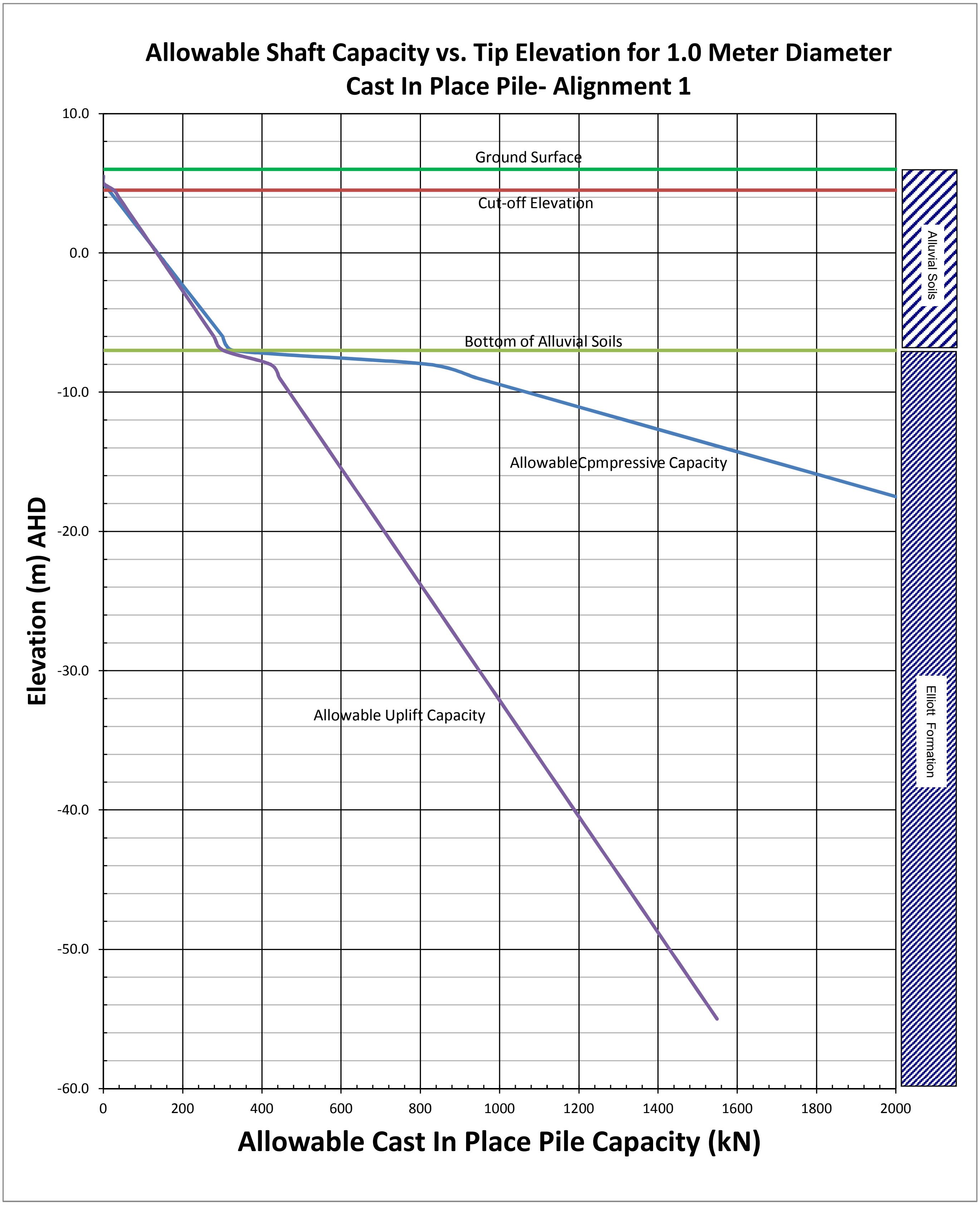
Notes:

1 Water table elevation based upon test boring B-6
2 Unit weights were estimated based upon lab testing of representative soils.
3 Friction angles were estimated based upon lab testing of representative soils.
4 Undrained shear strength values were estimated based upon lab testing of representative soils.
5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018
7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).
8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).
9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).
10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).
14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:
Alluvial Soils
Elliott Formation
Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
F_{SNi}	Side Friction



Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter Cast In Place Pile- Alignment 1
Ground Surface
Cut-off Elevation
Bottom of Alluvial Soils
AllowableCpmpressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliott Formation
Elevation (m) AHD
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Allowable Cast In Place Pile Capacity (kN)

Alignment 2

CLIENT: DLGRMA
PROJECT: Bundaberg East Levee
DETAIL: 121923-221532
FILE NAME: Bored Cast In Place Pile Calculation

JOB NO: 21923-221532
DATE CHK: 14/2/2018
CHECKED BY: JPB

COMPUTED BY: BJG
DATE: 7/2/2018
PAGE: 9

GS EL =	6.0	m
Shaft Cut-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_c	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.39

Stratum	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 2 parameters
Elliott Formation	18.82	50	0	15	Alignment 2 parameters

Cast In Place Pile Information

Pile Diameter=	1.0	m
Surface Area=	3.14	m^2/m length
End Bearing Area=	0.79	m^2
Unit Weight of Pile=	24	kN/m^3

Soil Stratum and Properties

Top of Depth Interval BGS (m)	Bottom of Depth Interval BGS (m)	Drilled Caisson Tip EL (m)	Strata Thickness (m)	Mid-Layer Depth BGS (m)	Stratum	Unit Type	γ_b[2] (tcm)	Effective Vertical Stress σ'_v (kPa)	Effective Vertical Stress σ'_v (mPa)	Friction Angle[3] (°)	Average Undrained Shear Strength[4] s_u (kPa)	α Factor[5]	Average SPT N-Value[6] N_{60} (bpf)	m Factor[7]	β Factor[8]	Shaft Length Below Bottom of Cap (m)	f_{SNi} sand[9] (kPa)	f_{SNi} clay[10] (kPa)	Total Side-Resistance[11&12] $R_{SN,i}$ (Kn)	q_{BN}[13] (kPa)	Total Base-Resistance[14] $R_{SN,i}$ (kN)	Total Axial Compressive Resistance[15] R_T (kN)	Total Allowable Axial Compressive Resistance[15] R_T (kips)	Total Allowable Compressive Resistance R_T (kN)	Total Allowable Uplift Resistance F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Alluvial Soils	clay	18.0	5	0.00	15	22.00	0.55	1	---	---	-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Alluvial Soils	clay	18.0	14	0.01	15	22.00	0.55	1	---	---	-0.5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Alluvial Soils	clay	18.0	23	0.02	15	22.00	0.55	1	---	---	0.0	0.00	12.10	19.0	143.0	0.00	19	3	14	27
1.5	2.0	4.0	0.5	1.8	Alluvial Soils	clay	18.0	32	0.03	15	22.00	0.55	1	---	---	0.5	0.00	12.10	38.0	143.0	0.00	38	6	27	39
2.0	2.5	3.5	0.5	2.3	Alluvial Soils	clay	18.0	41	0.04	15	22.00	0.55	1	---	---	1.0	0.00	12.10	57.0	143.0	0.00	57	9	41	51
2.5	3.0	3.0	0.5	2.8	Alluvial Soils	clay	18.0	50	0.05	15	22.00	0.55	1	---	---	1.5	0.00	12.10	76.0	143.0	0.00	76	12	55	63
3.0	3.5	2.5	0.5	3.3	Alluvial Soils	clay	18.0	59	0.06	15	22.00	0.55	1	---	---	2.0	0.00	12.10	95.0	143.0	0.00	95	15	68	75
3.5	4.0	2.0	0.5	3.8	Alluvial Soils	clay	8.2	65	0.07	15	22.00	0.55	1	---	---	2.5	0.00	12.10	114.0	143.0	0.00	114	18	82	87
4.0	4.5	1.5	0.5	4.3	Alluvial Soils	clay	8.2	69	0.07	15	22.00	0.55	1	---	---	3.0	0.00	12.10	133.0	143.0	0.00	133	22	96	99
4.5	5.0	1.0	0.5	4.8	Alluvial Soils	clay	8.2	73	0.07	15	22.00	0.55	1	---	---	3.5	0.00	12.10	152.1	143.0	0.00	152	25	109	111
5.0	5.5	0.5	0.5	5.3	Alluvial Soils	clay	8.2	78	0.08	15	22.00	0.55	1	---	---	4.0	0.00	12.10	171.1	143.0	0.00	171	28	123	123
5.5	6.0	0.0	0.5	5.8	Alluvial Soils	clay	8.2	82	0.08	15	22.00	0.55	1	---	---	4.5	0.00	12.10	190.1	143.0	0.00	190	31	137	135
6.0	7.0	-1.0	1.0	6.5	Alluvial Soils	clay	8.2	88	0.09	15	22.00	0.55	1	---	---	5.5	0.00	12.10	228.1	143.0	0.00	228	37	164	159
7.0	8.0	-2.0	1.0	7.5	Elliott Formation	clay	9.0	96	0.10	0	50.00	0.55	15	---	---	6.5	0.00	27.50	314.5	325.0	255.3	570	92	410	216
8.0	9.0	-3.0	1.0	8.5	Elliott Formation	clay	9.0	105	0.11	0	50.00	0.55	15	---	---	7.5	0.00	27.50	400.9	325.0	255.3	656	106	472	240
9.0	10.0	-4.0	1.0	9.5	Elliott Formation	clay	9.0	114	0.11	0	50.00	0.55	15	---	---	8.5	0.00	27.50	487.3	325.0	255.3	743	120	534	264
10.0	11.0	-5.0	1.0	10.5	Elliott Formation	clay	9.0	123	0.12	0	50.00	0.55	15	---	---	9.5	0.00	27.50	573.7	325.0	255.3	829	134	596	288
11.0	12.0	-6.0	1.0	11.5	Elliott Formation	clay	9.0	132	0.13	0	50.00	0.55	15	---	---	10.5	0.00	27.50	660.0	325.0	255.3	915	148	658	312
12.0	13.0	-7.0	1.0	12.5	Elliott Formation	clay	9.0	142	0.14	0	50.00	0.55	15	---	---	11.5	0.00	27.50	746.4	325.0	255.3	1002	162	721	336
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	clay	9.0	151	0.15	0	50.00	0.55	15	---	---	12.5	0.00	27.50	832.8	325.0	255.3	1088	176	783	360
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	clay	9.0	160	0.16	0	50.00	0.55	15	---	---	13.5	0.00	27.50	919.2	325.0	255.3	1174	190	845	384
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	clay	9.0	169	0.17	0	50.00	0.55	15	---	---	14.5	0.00	27.50	1005.6	325.0	255.3	1261	204	907	408
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	clay	9.0	178	0.18	0	50.00	0.55	15	---	---	15.5	0.00	27.50	1092.0	325.0	255.3	1347	218	969	432
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	clay	9.0	187	0.19	0	50.00	0.55	15	---	---	16.5	0.00	27.50	1178.4	325.0	255.3	1434	232	1031	456
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	clay	9.0	196	0.20	0	50.00	0.55	15	---	---	17.5	0.00	27.50	1264.8	325.0	255.3	1520	246	1094	480
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	clay	9.0	205	0.20	0	50.00	0.55	15	---	---	18.5	0.00	27.50	1351.2	325.0	255.3	1606	260	1156	504
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	clay	9.0	214	0.21	0	50.00	0.55	15	---	---	19.5	0.00	27.50	1437.6	325.0	255.3	1693	274	1218	528
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	clay	9.0	223	0.22	0	50.00	0.55	15	---	---	20.5	0.00	27.50	1524.0	325.0	255.3	1779	288	1280	552
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	clay	9.0	232	0.23	0	50.00	0.55	15	---	---	21.5	0.00	27.50	1610.4	325.0	255.3	1866	302	1342	576
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	clay	9.0	241	0.24	0	50.00	0.55	15	---	---	22.5	0.00	27.50	1696.8	325.0	255.3	1952	316	1404	600
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	clay	9.0	250	0.25	0	50.00	0.55	15	---	---	23.5	0.00	27.50	1783.2	325.0	255.3	2038	330	1466	624
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	clay	9.0	259	0.26	0	50.00	0.55	15	---	---	24.5	0.00	27.50	1869.6	325.0	255.3	2125	344	1529	648
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	clay	9.0	268	0.27	0	50.00	0.55	15	---	---	25.5	0.00	27.50	1956.0	325.0	255.3	2211	358	1591	672
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	clay	9.0	277	0.28	0	50.00	0.55	15	---	---	26.5	0.00	27.50	2042.3	325.0	255.3	2298	372	1653	696
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	clay	9.0	286	0.29	0	50.00	0.55	15	---	---	27.5	0.00	27.50	2128.7	325.0	255.3	2384	386	1715	720
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	clay	9.0	295	0.29	0	50.00	0.55	15	---	---	28.5	0.00	27.50	2215.1	325.0	255.3	2470	400	1777	744
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	clay	9.0	304	0.30	0	50.00	0.55	15	---	---	29.5	0.00	27.50	2301.5	325.0	255.3	2557	414	1839	768
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	clay	9.0	313	0.31	0	50.00	0.55	15	---	---	30.5	0.00	27.50	2387.9	325.0	255.3	2643	428	1902	792
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	clay	9.0	322	0.32	0	50.00	0.55	15	---	---	31.5	0.00	27.50	2474.3	325.0	255.3	2730	442	1964	816
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	clay	9.0	331	0.33	0	50.00	0.55	15	---	---	32.5	0.00	27.50	2560.7	325.0	255.3	2816	456	2026	840
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	clay	9.0	340	0.34	0	50.00	0.55	15	---	---	33.5	0.00	27.50	2647.1	325.0	255.3	2902	470	2088	864
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	clay	9.0	349	0.35	0	50.00	0.55	15	---	---	34.5	0.00	27.50	2733.5	325.0	255.3	2989	484	2150	888
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	clay	9.0	358	0.36	0	50.00	0.55	15	---	---	35.5	0.00	27.50	2819.9	325.0	255.3	3075	498	2212	912
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	clay	9.0	367	0.37	0	50.00	0.55	15	---	---	36.5	0.00	27.50	2906.3	325.0	255.3	3162	512	2274	936
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	clay	9.0	376	0.38	0	50.00	0.55	15	---	---	37.5	0.00	27.50	2992.7	325.0	255.3	3248	526	2337	960
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	clay	9.0	385	0.38	0	50.00	0.55	15	---	---	38.5	0.00	27.50	3079.1	325.0	255.3	3334	540	2399	984
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	clay	9.0	365	0.37	0	50.00	0.55	15	---	---	39.5	0.00	27.50	3165.5	325.0	255.3	3421	554	2461	1008
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	clay	9.0	374	0.37	0	50.00	0.55	15	---	---	40.5	0.00	27.50	3251.9	325.0	255.3	3507	568	2523	1032
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	clay	9.0	383	0.38	0	50.00	0.55	15	---	---	41.5	0.00	27.50	3338.3	325.0	255.3	3594	582	2585	1056
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	clay	9.0	392	0.39	0	50.00	0.55	15	---	---	42.5	0.00	27.50	3424.7	325.0	255.3	3680	596	2647	1080
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	clay	9.0	401	0.40	0	50.00	0.55	15	---	---	43.5	0.00	27.50	3511.0	325.0	255.3	3766	610	2710	1104
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	clay	9.0	410	0.41	0	50.00	0.55	15	---	---	44.5	0.00	27.50	3597.4	325.0	255.3	3853	624	2772	1128
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	clay	9.0	419	0.42	0	50.00	0.55	15	---	---	45.5	0.00	27.50	3683.8	325.0	255.3	3939	638	2834	1152
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	clay	9.0	428	0.43	0	50.00	0.55	15	---	---	46.5	0.00	27.50	3770.2	325.0	255.3	4025	652	2896	1176
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	clay	9.0	437	0.44	0	50.00	0.55	15	---	---	47.5	0.00	27.50	3856.6	325.0	255.3	4112	666	2958	1200
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	clay	9.0	446	0.45	0	50.00	0.55	15	---	---	48.5	0.00	27.50	3943.0	325.0	255.3	4198	680	3020	1224
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	clay	9.0	455	0.46	0	50.00	0.55	15	---	---	49.5	0.00	27.50	4029.4	325.0	255.3	4285	694	3082	1248
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	clay	9.0	464	0.46	0	50.00	0.55	15	---	---	50.5	0.00	27.50	4115.8	325.0	255.3	4371	708	3145	1272
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	clay	9.0	473	0.47	0	50.00	0.55	15	---	---	51.5	0.00	27.50	4202.2	325.0	255.3	4457	722	3207	1296
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	clay	9.0	482	0.48	0	50.00	0.55	15	---	---	52.5	0.00	27.50	4288.6	325.0	255.3	4544	736	3269	1320
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	clay	9.0	491	0.49	0	50.00	0.55	15	---	---	53.5	0.00	27.50	4375.0	325.0	255.3	4630	749	3331	1344
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	clay	9.0	500	0.50	0	50.00	0.55	15	---	---	54.5	0.00	27.50	4461.4	325.0	255.3	4717	763	3393	1368
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	clay	9.0	509	0.51	0	50.00	0.55	15	---	---	55.5	0.00	27.50	4547.8	325.0	255.3	4803	777	3455	1392
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	clay	9.0	518	0.52	0	50.00	0.55	15	---	---	56.5	0.00	27.50	4634.2	325.0	255.3	4889	791	3518	1416
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	clay	9.0	527	0.53	0	50.00	0.55	15	---	---	57.5	0.00	27.50	4720.6	325.0	255.3	4976	805	3580	1440
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	clay	9.0	536	0.54	0	50.00	0.55	15	---	---	58.5	0.00	27.50	4807.0	325.0	255.3	5062	819	3642	1464
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	clay	9.0	545	0.55	0	50.00	0.55	15	---	---	59.5	0.00	27.50	4893.3	325.0	255.3	5149	833	3704	1488

Notes:

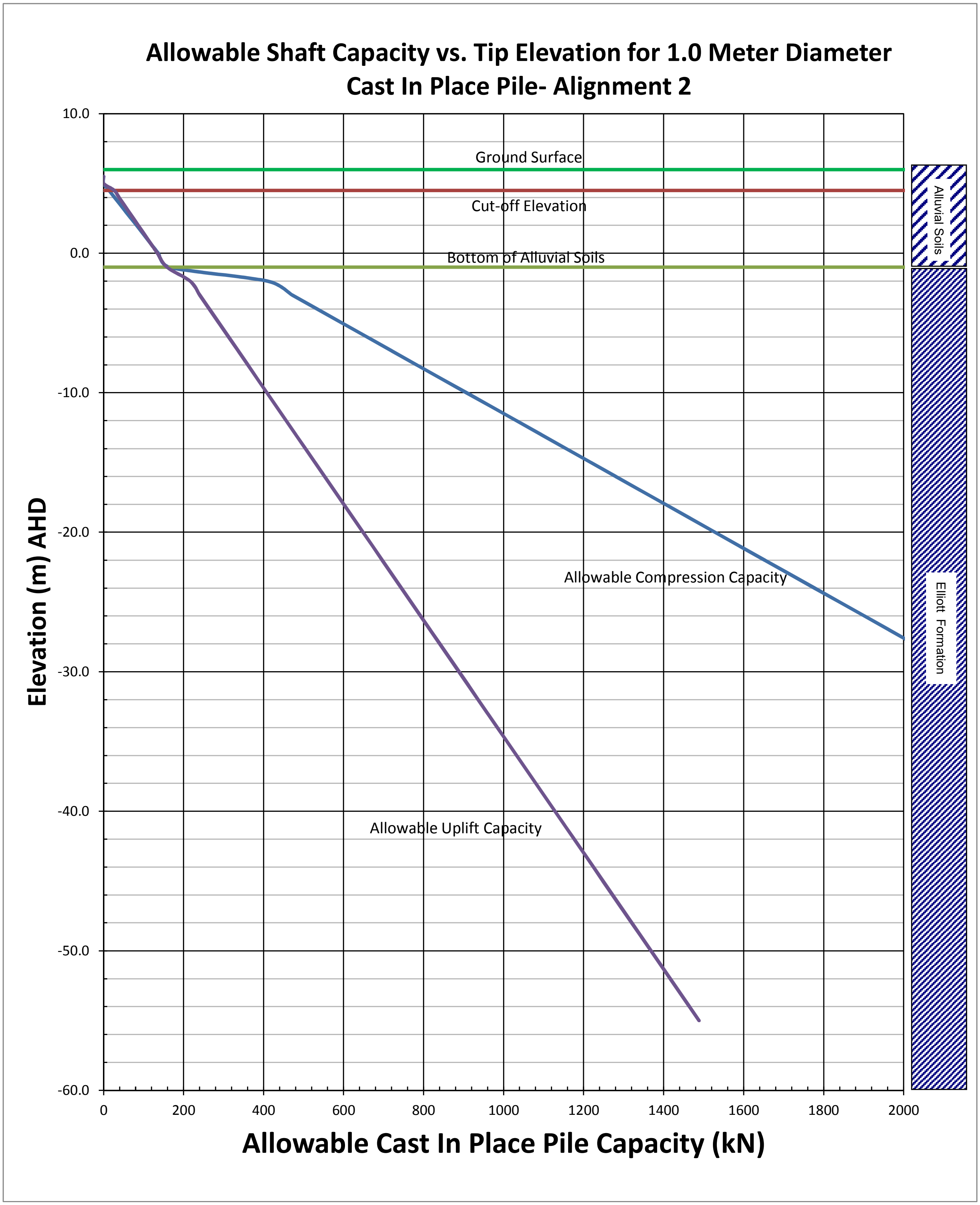
1 Water table elevation based upon test boring B-6
2 Unit weights were estimated based upon lab testing of representative soils.
3 Friction angles were estimated based upon lab testing of representative soils.
4 Undrained shear strength values were estimated based upon lab testing of representative soils.
5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018
7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).
8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).
9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).
10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).
14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:
Alluvial Soils
Elliott Formation
Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
Fs	Side Friction

CDM Smith



Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter Cast In Place Pile- Alignment 2
Ground Surface
Cut-off Elevation
Bottom of Alluvial Soils
Allowable Compression Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliott Formation
Elevation (m) AHD
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Allowable Cast In Place Pile Capacity (kN)

Alignment 3

CLIENT:	DLGRMA	**JOB NO:**	21923-221532	**COMPUTED BY:**	BJG
PROJECT:	Bundaberg East Levee	**DATE CHK:**	14/2/2018	**DATE:**	7/2/2018
DETAIL:	121923-221532	**CHECKED BY:**	JPB	**PAGE:**	11
FILE NAME:	Bored Cast In Place Pile Calculation				

GS EL =	6.0	m
Shaft Cut-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_c	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.32

Stratum	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 3 parameters
Elliott Formation	18.82	0	30	22	Alignment 3 parameters

Cast In Place Pile Information

Pile Diameter=	1.0	m
Surface Area=	3.14	m^2/m length
End Bearing Area=	0.79	m^2
Unit Weight of Pile=	24	kN/m^3

Soil Stratum and Properties																Shaft Length Below Bottom of Cap	f_{SNi} sand[9]	f_{SNi} clay[10]	Total Side-Resistance [11&12]	q_{BN}[13]	Total Base-Resistance [14]	Total Axial Compressive Resistance[15]	Total Allowable Axial Compressive Resistance[15]	Total Allowable Compressive Resistance for FS=1.32	Total Allowable Uplift Resistance for FS=1.32
Top of Depth Interval BGS	Bottom of Depth Interval BGS	Drilled Caisson Tip EL	Strata Thickness	Mid-Layer Depth BGS	Stratum	Unit Type	γ_b[2]	Effective Vertical Stress		Friction Angle[3]	Average Undrained Shear Strength[4]	α Factor[5]	Average SPT N-Value[6]	m Factor[7]	β Factor[8]										
(m)	(m)	(m)	(m)	(m)			(tcm)	σ'_v (kPa)	σ'_v (mPa)	(°)	s_u (kPa)		N_{60} (bpf)			(m)	(kPa)	(kPa)	$R_{SN,i}$ (Kn)	(kPa)	$R_{SN,i}$ (kN)	R_T (kN)	R_T (kips)	R_T (kN)	F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Alluvial Soils	clay	18.0	5	0.00	15	22.00	0.55	1	---	---	-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Alluvial Soils	clay	18.0	14	0.01	15	22.00	0.55	1	---	---	-0.5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Alluvial Soils	clay	18.0	23	0.02	15	22.00	0.55	1	---	---	0.0	0.00	12.10	19.0	143.0	0.00	19	3	14	27
1.5	2.0	4.0	0.5	1.8	Alluvial Soils	clay	18.0	32	0.03	15	22.00	0.55	1	---	---	0.5	0.00	12.10	38.0	143.0	0.00	38	6	29	39
2.0	2.5	3.5	0.5	2.3	Alluvial Soils	clay	18.0	41	0.04	15	22.00	0.55	1	---	---	1.0	0.00	12.10	57.0	143.0	0.00	57	10	43	51
2.5	3.0	3.0	0.5	2.8	Alluvial Soils	clay	18.0	50	0.05	15	22.00	0.55	1	---	---	1.5	0.00	12.10	76.0	143.0	0.00	76	13	58	63
3.0	3.5	2.5	0.5	3.3	Alluvial Soils	clay	18.0	59	0.06	15	22.00	0.55	1	---	---	2.0	0.00	12.10	95.0	143.0	0.00	95	16	72	75
3.5	4.0	2.0	0.5	3.8	Alluvial Soils	clay	8.2	65	0.07	15	22.00	0.55	1	---	---	2.5	0.00	12.10	114.0	143.0	0.00	114	19	86	87
4.0	4.5	1.5	0.5	4.3	Alluvial Soils	clay	8.2	69	0.07	15	22.00	0.55	1	---	---	3.0	0.00	12.10	133.0	143.0	0.00	133	23	101	99
4.5	5.0	1.0	0.5	4.8	Alluvial Soils	clay	8.2	73	0.07	15	22.00	0.55	1	---	---	3.5	0.00	12.10	152.1	143.0	0.00	152	26	115	111
5.0	5.5	0.5	0.5	5.3	Elliott Formation	Silty Sand	9.0	78	0.08	30	0.00	---	22	0.8	0.68	4.0	52.96	0.00	235.2	13.2	10.4	246	42	186	212
5.5	6.0	0.0	0.5	5.8	Elliott Formation	Silty Sand	9.0	82	0.08	30	0.00	---	22	0.8	0.68	4.5	56.03	0.00	323.2	13.2	10.4	334	57	253	231
6.0	7.0	-1.0	1.0	6.5	Elliott Formation	Silty Sand	9.0	89	0.09	30	0.00	---	22	0.8	0.68	5.5	60.64	0.00	513.7	13.2	10.4	524	89	397	265
7.0	8.0	-2.0	1.0	7.5	Elliott Formation	Silty Sand	9.0	98	0.10	30	0.00	---	22	0.8	0.68	6.5	66.78	0.00	723.5	13.2	10.4	734	125	556	303
8.0	9.0	-3.0	1.0	8.5	Elliott Formation	Silty Sand	9.0	107	0.11	30	0.00	---	22	0.8	0.68	7.5	72.92	0.00	952.6	13.2	10.4	963	164	730	340
9.0	10.0	-4.0	1.0	9.5	Elliott Formation	Silty Sand	9.0	116	0.12	30	0.00	---	22	0.8	0.68	8.5	79.07	0.00	1201.0	13.2	10.4	1211	206	918	378
10.0	11.0	-5.0	1.0	10.5	Elliott Formation	Silty Sand	9.0	125	0.13	30	0.00	---	22	0.8	0.68	9.5	85.21	0.00	1468.8	13.2	10.4	1479	252	1121	415
11.0	12.0	-6.0	1.0	11.5	Elliott Formation	Silty Sand	9.0	134	0.13	30	0.00	---	22	0.8	0.68	10.5	91.36	0.00	1755.8	13.2	10.4	1766	301	1338	453
12.0	13.0	-7.0	1.0	12.5	Elliott Formation	Silty Sand	9.0	143	0.14	30	0.00	---	22	0.8	0.68	11.5	97.50	0.00	2062.1	13.2	10.4	2072	353	1570	490
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	Silty Sand	9.0	152	0.15	30	0.00	---	22	0.8	0.68	12.5	103.64	0.00	2387.7	13.2	10.4	2398	409	1817	528
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	Silty Sand	9.0	161	0.16	30	0.00	---	22	0.8	0.68	13.5	109.79	0.00	2732.6	13.2	10.4	2743	468	2078	565
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	Silty Sand	9.0	170	0.17	30	0.00	---	22	0.8	0.68	14.5	115.93	0.00	3096.8	13.2	10.4	3107	530	2354	603
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	Silty Sand	9.0	179	0.18	30	0.00	---	22	0.8	0.68	15.5	122.08	0.00	3480.3	13.2	10.4	3491	595	2644	640
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	Silty Sand	9.0	188	0.19	30	0.00	---	22	0.8	0.68	16.5	128.22	0.00	3883.1	13.2	10.4	3893	664	2950	678
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	Silty Sand	9.0	197	0.20	30	0.00	---	22	0.8	0.68	17.5	134.36	0.00	4305.2	13.2	10.4	4316	736	3269	715
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	Silty Sand	9.0	206	0.21	30	0.00	---	22	0.8	0.68	18.5	140.51	0.00	4746.7	13.2	10.4	4757	811	3604	753
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	Silty Sand	9.0	215	0.22	30	0.00	---	22	0.8	0.68	19.5	146.65	0.00	5207.4	13.2	10.4	5218	889	3953	791
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	Silty Sand	9.0	224	0.22	30	0.00	---	22	0.8	0.68	20.5	152.80	0.00	5687.4	13.2	10.4	5698	971	4316	828
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	Silty Sand	9.0	233	0.23	30	0.00	---	22	0.8	0.68	21.5	158.94	0.00	6186.7	13.2	10.4	6197	1056	4695	866
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	Silty Sand	9.0	242	0.24	30	0.00	---	22	0.8	0.68	22.5	165.08	0.00	6705.3	13.2	10.4	6716	1145	5088	903
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	Silty Sand	9.0	251	0.25	30	0.00	---	22	0.8	0.68	23.5	171.23	0.00	7243.3	13.2	10.4	7254	1236	5495	941
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	Silty Sand	9.0	260	0.26	30	0.00	---	22	0.8	0.68	24.5	177.37	0.00	7800.5	13.2	10.4	7811	1331	5917	978
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	Silty Sand	9.0	269	0.27	30	0.00	---	22	0.8	0.68	25.5	183.51	0.00	8377.0	13.2	10.4	8387	1430	6354	1016
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	Silty Sand	9.0	278	0.28	30	0.00	---	22	0.8	0.68	26.5	189.66	0.00	8972.8	13.2	10.4	8983	1531	6805	1053
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	Silty Sand	9.0	287	0.29	30	0.00	---	22	0.8	0.68	27.5	195.80	0.00	9588.0	13.2	10.4	9598	1636	7271	1091
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	Silty Sand	9.0	296	0.30	30	0.00	---	22	0.8	0.68	28.5	201.95	0.00	10222.4	13.2	10.4	10233	1744	7752	1128
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	Silty Sand	9.0	305	0.31	30	0.00	---	22	0.8	0.68	29.5	208.09	0.00	10876.1	13.2	10.4	10887	1856	8247	1166
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	Silty Sand	9.0	314	0.31	30	0.00	---	22	0.8	0.68	30.5	214.23	0.00	11549.2	13.2	10.4	11560	1970	8757	1203
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	Silty Sand	9.0	323	0.32	30	0.00	---	22	0.8	0.68	31.5	220.38	0.00	12241.5	13.2	10.4	12252	2088	9282	1241
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	Silty Sand	9.0	332	0.33	30	0.00	---	22	0.8	0.68	32.5	226.52	0.00	12953.1	13.2	10.4	12964	2210	9821	1278
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	Silty Sand	9.0	341	0.34	30	0.00	---	22	0.8	0.68	33.5	232.67	0.00	13684.1	13.2	10.4	13694	2334	10375	1316
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	Silty Sand	9.0	350	0.35	30	0.00	---	22	0.8	0.68	34.5	238.81	0.00	14434.3	13.2	10.4	14445	2462	10943	1353
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	Silty Sand	9.0	359	0.36	30	0.00	---	22	0.8	0.68	35.5	244.95	0.00	15203.9	13.2	10.4	15214	2593	11526	1391
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	Silty Sand	9.0	368	0.37	30	0.00	---	22	0.8	0.68	36.5	251.10	0.00	15992.7	13.2	10.4	16003	2728	12124	1428
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	Silty Sand	9.0	377	0.38	30	0.00	---	22	0.8	0.68	37.5	257.24	0.00	16800.9	13.2	10.4	16811	2866	12736	1466
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	Silty Sand	9.0	387	0.39	30	0.00	---	22	0.8	0.68	38.5	263.38	0.00	17628.3	13.2	10.4	17639	3007	13363	1503
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	Silty Sand	9.0	365	0.37	30	0.00	---	22	0.8	0.68	39.5	248.83	0.00	18410.0	13.2	10.4	18420	3140	13955	1495
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	Silty Sand	9.0	374	0.37	30	0.00	---	22	0.8	0.68	40.5	254.97	0.00	19211.0	13.2	10.4	19221	3276	14562	1533
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	Silty Sand	9.0	383	0.38	30	0.00	---	22	0.8	0.68	41.5	261.11	0.00	20031.3	13.2	10.4	20042	3416	15183	1570
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	Silty Sand	9.0	392	0.39	30	0.00	---	22	0.8	0.68	42.5	267.26	0.00	20871.0	13.2	10.4	20881	3559	15819	1608
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	Silty Sand	9.0	401	0.40	30	0.00	---	22	0.8	0.68	43.5	273.40	0.00	21729.9	13.2	10.4	21740	3706	16470	1645
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	Silty Sand	9.0	410	0.41	30	0.00	---	22	0.8	0.68	44.5	279.55	0.00	22608.1	13.2	10.4	22618	3855	17135	1683
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	Silty Sand	9.0	419	0.42	30	0.00	---	22	0.8	0.68	45.5	285.69	0.00	23505.6	13.2	10.4	23516	4008	17815	1720
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	Silty Sand	9.0	428	0.43	30	0.00	---	22	0.8	0.68	46.5	291.83	0.00	24422.4	13.2	10.4	24433	4165	18510	1758
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	Silty Sand	9.0	437	0.44	30	0.00	---	22	0.8	0.68	47.5	297.98	0.00	25358.6	13.2	10.4	25369	4324	19219	1795
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	Silty Sand	9.0	446	0.45	30	0.00	---	22	0.8	0.68	48.5	304.12	0.00	26314.0	13.2	10.4	26324	4487	19943	1833
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	Silty Sand	9.0	455	0.46	30	0.00	---	22	0.8	0.68	49.5	310.26	0.00	27288.7	13.2	10.4	27299	4653	20681	1870
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	Silty Sand	9.0	464	0.46	30	0.00	---	22	0.8	0.68	50.5	316.41	0.00	28282.7	13.2	10.4	28293	4823	21434	1908
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	Silty Sand	9.0	473	0.47	30	0.00	---	22	0.8	0.68	51.5	322.55	0.00	29296.1	13.2	10.4	29306	4995	22202	1945
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	Silty Sand	9.0	482	0.48	30	0.00	---	22	0.8	0.68	52.5	328.70	0.00	30328.7	13.2	10.4	30339	5171	22984	1983
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	Silty Sand	9.0	491	0.49	30	0.00	---	22	0.8	0.68	53.5	334.84	0.00	31380.6	13.2	10.4	31391	5351	23781	2020
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	Silty Sand	9.0	500	0.50	30	0.00	---	22	0.8	0.68	54.5	340.98	0.00	32451.9	13.2	10.4	32462	5533	24593	2058
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	Silty Sand	9.0	509	0.51	30	0.00	---	22	0.8	0.68	55.5	347.13	0.00	33542.4	13.2	10.4	33553	5719	25419	2095
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	Silty Sand	9.0	518	0.52	30	0.00	---	22	0.8	0.68	56.5	353.27	0.00	34652.2	13.2	10.4	34663	5908	26260	2133
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	Silty Sand	9.0	527	0.53	30	0.00	---	22	0.8	0.68	57.5	359.42	0.00	35781.4	13.2	10.4	35792	6101	27115	2170
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	Silty Sand	9.0	536	0.54	30	0.00	---	22	0.8	0.68	58.5	365.56	0.00	36929.8	13.2	10.4	36940	6297	27985	2208
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	Silty Sand	9.0	545	0.55	30	0.00	---	22	0.8	0.68	59.5	371.70	0.00	38097.6	13.2	10.4	38108	6496	28870	2245

Notes:

1 Water table elevation based upon test boring B-6

2 Unit weights were estimated based upon lab testing of representative soils.

3 Friction angles were estimated based upon lab testing of representative soils.

4 Undrained shear strength values were estimated based upon lab testing of representative soils.

5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).

6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018

7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).

8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).

9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).

10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).

11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).

12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).

13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).

14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).

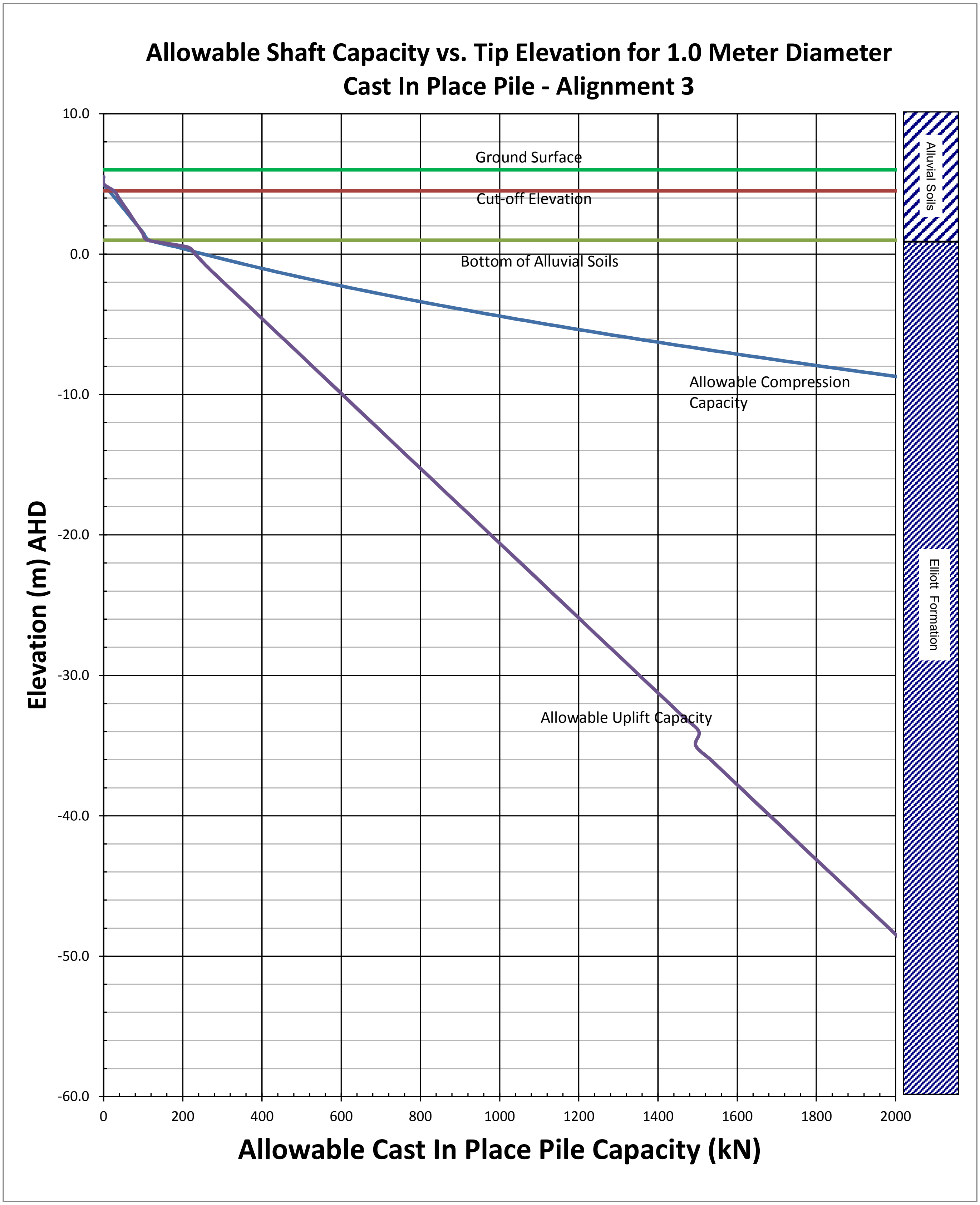
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:

- Alluvial Soils
- Elliott Formation
- Clay
- Silty Sand/Sandy Silt/Clayey Sand/Sandy Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
Fs	Side Friction


Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter Cast In Place Pile - Alignment 3
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
Elevation (m) AHD
Ground Surface
Cut-off Elevation
Bottom of Alluvial Soils
Allowable Compression Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliott Formation
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Allowable Cast In Place Pile Capacity (kN)

CDM Smith

Memorandum

To: *Stuart Brown*
Russell Merz

From: *John P. Briand*

Reviewed By: *Stephen L. Whiteside*

Date: *14 March 2019*

Subject: *Conceptual-Level Value Engineering Geotechnical Design Memorandum*
Department of Local Government, Racing and Multicultural Affairs (DLGRMA)
Bundaberg East Levee
Bundaberg, Queensland

1 Introduction

1.1 Project Description

This memorandum summarizes CDM Smith's conceptual-level value engineering evaluation for the design and construction of the proposed Bundaberg East Levee project located in Bundaberg, Queensland. This work was completed for the Department of Local Government, Racing and Multicultural Affairs (DLGRMA), Brisbane.

The Bundaberg East Levee project will include the construction of levees and/or floodwalls to increase the flood protection, mitigate damage, and protect the Bundaberg East and Central Business District areas from the 100-year design flood event from the Burnett River. In addition, the project will include pump station and flood gate structures to mitigate interior flooding due to coincident rainfall in the protected area inboard of the levee and/or floodwall.

1.2 Project Background

CDM Smith completed a conceptual-level engineering design for the proposed Bundaberg East Levee in early 2018. As part of this package, CDM Smith conducted a geotechnical field exploration and laboratory testing program (geotechnical investigation) for the project, which is summarized in the *Factual Geotechnical Report, Bundaberg East Levee* (FGR) dated 2 February 2018. Subsequently, CDM Smith performed a conceptual-level evaluation and provided foundation design recommendations for the project, which is summarized in the *Draft Interpretive Geotechnical Report, Bundaberg East Levee* (DIGR) dated 22 March 2018.

Following a review of the conceptual-level design and cost estimate, DLGRMA requested that CDM Smith perform a value engineering evaluation of the foundations for the proposed floodwall and pump station and flood gate structures as well as the depth of the sheet pile wall below the floodwalls. The purpose of the value engineering phase was to further refine the foundation and seepage control design and reduce the cost contingency associated with these aspects of work for the level of design (i.e., conceptual design). It should be noted that the alignment of the floodwall was modified during the architectural review of the conceptual design. The revised foundation design and seepage analyses contained herein are based upon the original floodwall alignments. Therefore, during detailed design, the revised floodwall alignments shall be coordinated during to confirm the original design assumptions.

This memorandum is written as an addendum to the FGR and DIGR. Therefore, this memorandum provides a brief overview of the supplemental geotechnical investigation program, revised geotechnical engineering analyses, and revised foundation design and seepage control recommendations. This memorandum does not provide further evaluation of the site and subsurface conditions, pile installation criteria, design of shallow foundations, and construction considerations.

1.3 Purpose and Scope

The purpose of the conceptual-level value engineering was to conduct a supplemental geotechnical investigation to observe subsurface conditions encountered at the proposed structures and to provide revised geotechnical engineering recommendations for design and construction. Specifically, the scope of work included the following:

- Conduct a subsurface exploration program consisting of nine (9) supplemental test borings (BH101 through BH109) to evaluate subsurface conditions and obtain soil samples for geotechnical laboratory testing;
- Perform geotechnical laboratory tests on select soil samples to assist with the classification of soils encountered and to estimate the engineering properties of the soils;
- Perform geotechnical analyses and develop revised conceptual-level geotechnical engineering recommendations for design and construction of the proposed floodwall and pump station and flood gate structures; and
- Prepare this addenda memorandum presenting CDM Smith's revised conceptual-level recommendations, including an abbreviated summary of the data collected as part of the value engineering field and laboratory investigations.

2 Site and Subsurface Conditions

2.1 Supplemental Geotechnical Investigation Program

A supplemental geotechnical investigation program was conducted to investigate the subsurface conditions at the proposed Bundaberg East Levee site. The program consisted of nine (9) test borings (BH101 through BH109). Seven (7) of the test borings were drilled by Core Consultants Pty Ltd (Core Consultants) of Fortitude Valley, Queensland including BH101 through BH104 and BH106 through BH109, and two (2) of the test borings were drilled by C.M. Testing Service (C.M. Testing) of East Bundaberg, Queensland including BH104 and BH105. The test borings were drilled between 12 November and 11 December 2018 to depths up to 24.1 meters below ground surface.

The Geotechnical Investigation Factual Report dated 2019 February prepared by Core Consultants is included in **Attachment A1**. The test boring logs prepared by C.M. Testing are included in **Attachment A2**.

2.2 Geotechnical Laboratory Testing

Geotechnical laboratory tests were performed on select split spoon and Shelby tube soil samples obtained from the supplemental subsurface exploration program. Geotechnical laboratory index tests on split spoon samples were performed at C.M. Testing in Bundaberg, Queensland. Geotechnical laboratory index, triaxial, and consolidation tests on split spoon and Shelby tube samples were performed at Trilab Pty. Ltd. (Trilab) in Geebund, Queensland. Laboratory testing included the following tests:

- C.M. Testing
  - Fifteen (15) grain size analyses with wash of the 0.075 mm sieve were performed in accordance with AS 1289.3.6.1;
  - Eleven (11) Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1;
  - Eleven (11) linear shrinkage tests were performed in accordance with AS 1289.3.4.1; and
  - Three (3) Emerson classification tests were performed in accordance with AS 1289.3.8.1.
- Trilab
  - Five (5) moisture content tests were performed in accordance with Australian Standard (AS) 1289.2.1.1;

- Five (5) grain size analyses with wash of the 0.075 mm sieve were performed in accordance with AS 1289.3.6.1;
- Five (5) Atterberg limits tests were performed in accordance with AS 1289.3.1.2, AS 1289.3.2.1 and AS 1289.3.3.1;
- Five (5) linear shrinkage tests were performed in accordance with AS 1289.3.4.1;
- Two (2) Emerson classification tests were performed in accordance with AS 1289.3.8.1;
- Three (3) permeability by constant head tests were performed in accordance with AS 1289.6.7.3;
- Two (2) consolidated undrained triaxial tests were performed in accordance with AS 1289.6.4.2; and
- One (1) consolidation test was performed in accordance with AS 1289.6.6.1 and AS 1289.3.5.1.

The geotechnical laboratory test results performed by C.M. Testing are included in **Attachment B1.** The geotechnical laboratory test results performed by Trilab are included in **Attachment B2.**

2.3 Expected Variations in Subsurface Conditions

Subsurface conditions presented herein are based on soil and groundwater conditions observed at the test boring locations. However, subsurface conditions may vary at other locations within the site.

Groundwater levels may change with river and creek levels, time, season, temperature, and construction activities in the area, as well as with other factors. In addition, stabilized groundwater levels can be difficult to obtain in test borings drilled using mud rotary due to the presence of drilling fluid in the borehole. Therefore, groundwater conditions at the time of construction may be different from those observed at the time of the test borings.

3 Geotechnical Engineering Analyses

3.1 General

Conceptual-level geotechnical engineering analyses have been performed as they relate to the proposed Bundaberg East Levee floodwall and the pump station and flood gate structures. In general, these evaluations are based on the results of the field and laboratory testing programs conducted for this study, published correlations with soil properties, and the minimum requirements of the relevant Australian Standards.

The geotechnical engineering analyses and evaluations were performed as described in this section including seepage and settlement analyses.

3.2 Seepage Analyses

3.2.1 Introduction

Seepage analyses were performed as part of the conceptual design studies. These analyses were performed in general accordance with accepted engineering practices and the applicable codes/references as indicated. The soil properties and subsurface profile for the analyses were developed based upon the LiDAR survey data, geotechnical investigation, existing survey data, and the preliminary alignment inspection.

The seepage analyses were performed to evaluate potential seepage issues for the proposed floodwall using the two-dimensional finite element modeling program SEEP/W version 8.16 by GEOSTUDIO 2016 from GEO-SLOPE International. The analyses were performed for the 100-year ARI flood event. Steady-state seepage analyses were performed based upon estimated hydraulic conductivities of the subsurface materials. The following items were evaluated in the seepage analyses:

- Exit gradient on the landside of the floodwall, and
- Uplift pressures on the proposed floodwall foundations.

3.2.2 Model Set-Up

CDM Smith developed two typical soil profiles, one for deep foundation alignments and one for shallow foundation alignments, for the seepage analyses. The soil profiles and properties were based on field and laboratory data collected during the geotechnical investigation, published correlations with soil properties, and engineering judgement from CDM Smith's past experience on similar projects. The soil profiles were imported into the proposed conditions model.

The first step in setting up the model was to select boundary conditions. The model has the side boundaries extending approximately 200 m from the centerline of the proposed floodwall. The water level on the riverside of the floodwall was assumed to be the 100-year flood level (river level (RL) 9.3 m AHD), and the ground surface landside of the floodwall was assumed as a free drainage boundary with a groundwater level at 2.5 m AHD.

The SEEP/W models were run for the steady-state conditions using the parameters and boundary conditions described above.

3.2.3 Results

The seepage analysis results for the uplift pressures and landside exit gradient are shown below in **Table 1**.

Table 1. Summary of Seepage Analyses

Scenario No.	Modeling Scenario	Results			
		Uplift Pressure on Riverside, kPa	Uplift Pressure on Landside, kPa	Landside Exit Gradient	Exit Gradient Factor of Safety (1)
1	Deep Foundation with 3 m Sheetpile Wall	33.3	27.1	0.77	1.1
2	Deep Foundation with 7 m Sheetpile Wall	35.2	25.1	0.65	1.3
3	Deep Foundation with 13.5 m Sheetpile Wall	43.4	0.0	0	>2
4	Shallow Foundation, No Sheetpile Wall	22.8	5.0	0	>2
5	Deep Foundation with 3 m Sheetpile Wall and Toe Drain	26.3	2.9	0	>2

Notes:

1. The maximum allowable exit gradient for a levee or floodwall is 0.5 per United States Army Corps of Engineers (USACE) Engineering Manual (EM) 1110-2-1901.

For the Scenario No. 1 (i.e., minimum sheetpile length) and Scenario No. 2 (i.e., sheetpile extending through half of alluvial soils layer), results of the seepage analyses indicate that the exit gradients exceed the maximum allowable exit gradient of 0.5. However, for the Scenario No. 3 (i.e., sheetpile extending through entire alluvial soils layer), Scenario No. 4 (i.e., shallow foundation), and Scenario No. 5 (i.e., minimum sheet pile length with toe drain), seepage is not anticipated to daylight on the landside of the levee during the 100-year flood event.

The results from all the SEEP/W analyses are included in **Attachment C**.

3.3 Deep Foundation Analyses

Deep foundation analyses were performed for the proposed floodwall and the pump station and flood gate structures for both driven and drilled foundation systems. The driven foundation systems, including 400-mm-square concrete preformed piles and 500-mm-diameter steel cast in place piles (steel pipe piles filled with concrete) with a closed end, were designed for compression and uplift loads in accordance with Section 6 of the American Petroleum Institute *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (API Manual) dated December 2000. The drilled foundation systems, including 1-m-diameter bored cast in place piles, were designed for compression and uplift loads in accordance with Section 13 of the Federal Highway Administration (FHWA) *Drilled Shafts: Construction Procedures and LRFD Design Methods* (FHWA Manual) dated May 2010. In addition, the deep foundation analyses were conducted in general accordance with Australia Standard (AS) *2159-2009 – Piling Design and Installation*.

Based on the deep foundation analyses, the proposed deep foundation systems will be embedded a minimum distance into the Elliott Formation. The estimated deep foundation embedment lengths are provided in **Section 4**.

The deep foundation analyses are included in **Attachments D1** through **D3**.

4 Geotechnical Engineering Evaluation and Foundation Design Recommendations

4.1 Geotechnical Engineering Evaluations

Geotechnical engineering evaluations have been made as they relate to the proposed floodwall and pump station and flood gate structure design in Bundaberg, Queensland. In general, these evaluations have been based on the results of the geotechnical investigations, laboratory test results, published correlations with soil properties, and the requirements of the relevant Australian Standards. In addition, recommended design criteria are based on performance tolerances, such as allowable settlement, as understood to relate to similar structures.

4.2 Foundation Design Recommendations

4.2.1 General

Based on the proposed alignment, anticipated dimensions, depths, and loadings of the proposed structures and subsurface conditions present at the site, the majority of the proposed floodwall and the pump station and flood gate structures should be supported on deep foundations bearing in the Elliott Formation. At select locations discussed below, portions of the floodwall may be supported on shallow foundations bearing in the Elliott Formation or on structural fill placed over the Elliott Formation after removal of unsuitable soils, which are not discussed further in this memorandum.

4.2.2.1 Pile Types

500-mm-diameter driven steel cast in place piles, 400-mm-square driven concrete preformed piles (CPP), and 1-m-diameter bored cast in place piles (BCIPP) are considered suitable for the range of anticipated loads (i.e., 250 kN to 6,000 kN) for the proposed structures. Allowable capacities for the different pile types and minimum embedment depths into the Elliott Formation soil layer are provided below in **Table 2**. The allowable compression pile capacities are estimated based on skin friction and tip resistance developed in accordance with procedures outlined in the Federal Highway Administration "Design and Construction of Driven Pile Foundations" and "Drilled Shafts: Construction Procedures and LRFD Design Methods", using SPT N-values from

Table 2. Summary of Pile Capacities

Applicable Structures	Foundation Size and Type	Total Allowable Compression Pile Capacity (kN)	Total Allowable Uplift Capacity (kN)	Minimum Embedment in Elliott Formation (m)
Bundaberg Creek Pump Station and Flood Gate	500-mm-Diameter Driven Steel Cast In Place Pile	250	200	--
		500	325	--
		750	475	--
		1000	725	--
	400-mm-Square Driven Concrete Preformed Pile	250	200	3
		500	325	5
		750	525	9
		1000	725	12
	1-m-Diameter Bored Cast In Place Pile	250	400	1
		500	400	1
		750	400	1
		1000	450	3
		2000	650	9
		4000	1050	25
		6000	1400	40
City Alignment Sta. 1+00 to Sta. 3+50	500-mm-Diameter Driven Steel Cast In Place Pile	250	200	1
		500	325	2
		750	475	5
		1000	725	8
	400-mm-Square Driven Concrete Preformed Pile	250	200	1
		500	325	2
		750	525	5
		1000	725	8
	1-m-Diameter Bored Cast In Place Pile	250	400	1
		500	400	1
		750	400	1
		1000	450	2
		2000	650	8
		4000	1050	25
		6000	1400	40
City Alignment Sta. 3+50 to Sta. 7+50	500-mm-Diameter Driven Steel Cast In Place Pile	250	150	2
		500	375	8
		750	525	12
		1000	750	17
	400-mm-Square Driven Concrete Preformed Pile	250	150	2
		500	375	8
		750	525	12
		1000	750	17
	1-m-Diameter Bored Cast In Place Pile	250	200	1
		500	250	3
		750	350	7
		1000	450	11
Distillery Creek Pump Station and Flood Gate and Distillery Alignment Sta. 2+50 to Sta. 7+00	500-mm-Diameter Driven Steel Cast In Place Pile	250	75	1
		500	175	4
		750	325	8
		1000	475	11
	400-mm-Square Driven Concrete Preformed Pile	250	75	1
		500	200	5
		750	375	9
		1000	525	12
	1-m-Diameter Bored Cast In Place Pile	250	250	2
		500	300	3
		750	375	5
		1000	400	6

test borings and other test results. A factor of safety is applied based on AS 2159-2009 Section 4.3.1 to the allowable compression and uplift capacities.

Based on the available subsurface information, project requirements, anticipated foundation loading conditions, and our understanding of current market conditions, we recommend that the floodwalls and Distillery Creek pump station and flood gate be supported on 400-mm-square CPP bearing in the Elliott Formation, and Bundaberg Creek pump station and flood gate structure be supported on 400-mm-square CPP bearing and/or 1-m-diameter BCIPP in the Elliott Formation for the following reasons:

- Based conversations with a local piling contractor (Wagstaff Piling PTY Ltd.), steel cast in place piles are approximately 150 to 200 percent more expensive than CPP piles due to the cost of steel in the Australian market;
- The pile lengths may vary along the length of the floodwall alignment due to the highly variable density and material types within the Elliott Formation (i.e., the bearing layer). This variation would result in difficulties correlating compression and uplift capacity using drilled pile methods. However, driven piles are considered a more-appropriate solution for highly variable soils because the compression and uplift capacity can be correlated to a driving criteria (resistance) recorded during pile driving; and
- CDM Smith has considered a combination of 400-mm-square CPP and/or 1-m-diameter BCIPP at the Bundaberg Creek pump station and flood gate structure. Therefore, the cost estimator may determine the most cost effective piling solution for this heavily loaded structure.

5 Closing

These recommendations have been prepared for the Bundaberg East Levee project, located in Bundaberg, Queensland as understood at this time and described in this memorandum. These recommendations have been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made. In the event that changes in the design or structure location occur, the conclusions and recommendations contained herein should not be considered valid unless verified in writing by CDM Smith.

Attachments:

Attachment A – Geotechnical Subsurface Data
- **Attachment A1** – Core Consultants Geotechnical Investigation Factual Report
- **Attachment A2** – C. M. Testing Test Boring Logs

Attachment B – Geotechnical Laboratory Test Results
- **Attachment B1** – C. M. Testing Geotechnical Laboratory Test Results
- **Attachment B2** – Trilab Geotechnical Laboratory Test Results

Attachment C – Seepage Analyses

Attachment D – Deep Foundation Analyses
- **Attachment D1** – Driven 400-mm-Square Concrete Preformed Piles
- **Attachment D2** – Driven 500-mm-Diameter Steel Cast In Place Piles
- **Attachment D3** – 1-m-Diameter Bored Cast In Place Piles

Attachment A

Geotechnical Subsurface Data

Attachment A1

Core Consultants Geotechnical Investigation Factual Report

Geotechnical Investigation Factual Report

Proposed Bundaberg East Flood Levee

Quay St East, Scotland St and Cran St, Bundaberg East

Prepared for:
Mr Stuart Brown
CDM Smith
Level 4, 51 Alfred Street
Fortitude Valley QLD 4006

Email: brownsa@cdmsmith.com

Report Number: J000800-001-R-Rev0

February 2019

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Tables

Figures

Appendices

1.0 INTRODUCTION

CDM Smith (CDM) engaged Core Consultants Pty Ltd (Core) to carry out a geotechnical investigation for the proposed Bundaberg East flood levee project located in East Bundaberg.

The work is being carried out in accordance with Core proposal Q001793-002-L-Rev0.

This factual report presents the fieldwork methodology together with the results of the investigation.

2.0 PROPOSED LEVEE ALIGNMENT

The proposed levee alignment starts at the western end of Quay Street East. The levee will run east along Quay Street East to the intersection with Scotland Street, the levee then continues east along Scotland Street to its intersection with Cran Street. At Cran Street the levee will run north and north-east, before heading north-west to its termination at the Bundaberg sugar refinery (refer Figure 1).

3.0 REGIONAL MAPPING

Reference to the Geological Survey of Queensland's 1:1250,000 series "Bundaberg" Geological Map indicates that the area of the proposed levee is underlain by Quaternary aged flood plain alluvial deposits. The alluvial deposits are underlain by the Early Miocene aged Elliott Formation typically comprising heavily weathered *"conglomerate, siltstone, sandstone and shale"*.

The results of the field investigation indicate ground conditions are representative of the published geology.

4.0 FIELD INVESTIGATION

The investigation fieldwork was undertaken between 12 November and 15 November 2018 and comprised the drilling and sampling of nine (9) boreholes denoted BH101 to BH109.

The test locations were nominated by CDM and are shown on the test location plan (refer Figure 1).

The nominated borehole locations were assessed for underground services by a licensed service locator prior to drilling, using electromagnetic wand and/or ground penetrating radar (GPR) techniques.

Boreholes BH101 to BH103 and BH106 to BH109 were drilled using a truck-mounted Hydrapower Scout drilling rig. The boreholes were advanced from the ground surface using rotary auger drilling, followed by cased 'wash-boring' using a rotating blade bit to between 10.5 m and 24.1 m depth.

The boreholes denoted BH104 and BH105 were drilled using a trailer mounted GD-10 auger drill rig to 10.5 m and 10 m depth respectively. These boreholes were drilled under the supervision of an employee from CMT Testing. The borehole logs for these boreholes will be provided to CDM by CMT.

Standard penetration testing (SPT) was typically conducted at 1.5 m intervals from either 1 m or 1.5 m depth. SPT's were replaced with undisturbed tube sampling (U50) where suitable clay soils were encountered, and pocket penetrometer testing and shear vane testing was undertaken on the ends of the tube samples.

On completion of drilling standpipes were installed to the base of the boreholes BH101 and BH105 and are shown on the logs in Appendix A. The remaining boreholes were backfilled with the excavated spoil.

The supervision of boreholes BH101 to BH103 and BH106 to BH109 were undertaken by an engineering geologist from Core who logged the subsurface conditions in accordance with AS1726-2017. Groundwater observations were also made during drilling and the boreholes depths are summarised in Table 1.

Table 1: Geotechnical Borehole Summary.

Borehole No.	Target Depth (m)	Termination Depth (m)	Note
BH101	20	20	Standpipe Installed
BH102	20	24.1	Refusal
BH103	20	21.45	Standpipe
BH104	10	10.5	Target depth
BH105	10	10	Standpipe Installed
BH106	10	10.95	Target depth
BH107	20	19.5	Target depth
BH108	20	19.95	Target depth
BH109	10	10.5	Target depth

5.0 SUMMARY OF GROUND CONDITIONS

Details of subsurface conditions encountered in the boreholes are given on the borehole report sheets included in Appendix A. These should be read in conjunction with the explanatory notes which comment on the sampling methods, soil descriptions, and symbols and abbreviations used in their preparation, also included in Appendix A.

In summary, the ground conditions encountered in the boreholes comprised **fill** overlying **flood plain alluvial soils,** underlain by the **Elliott Formation**. In more detail, the boreholes encountered the following:

- **Fill:** silty sand, sand, silty clay and ash fill was encountered from the surface in all boreholes to between 0.2 m and 2.2 m depth
- **Alluvial Soils:** loose silty sand, generally firm silty clay and sandy clay were encountered below the fill in all boreholes to between 1.2 m and 19.3 m depth. Boreholes BH104 and BH105 were terminated within the alluvial soils at 10.5 m and 10 m depth respectively.
- **Elliott Formation:** stiff to hard sandy clay, silty clay, medium dense to dense silty sand, clayey sand or sand and gravel were encountered below the alluvial soils in all boreholes except for BH104 and BH105. Indurated very dense clayey sand or hard sandy clay was encountered between 1.6 m and 8.6 m depth in BH106 and between 5.2 m and 7.4 m depth in BH107. BH101 and BH103 to BH109 were drilled to target depths of between 10.5 m and 21.45 m. BH102 was terminated at a refusal depth of 24.1 m.

Groundwater seepage was noted at approximately 4 m and 5 m depth in BH104 and BH105 respectively. No groundwater or groundwater seepages were encountered in the remaining boreholes, prior to employing washboring drilling techniques.

6.0 LIMITATIONS

Your attention is drawn to the document, ‘Limitations’ which is attached in Appendix B.

Yours sincerely,

Core Consultants Pty Ltd

Andrew Short BSc (Hons)
Engineering Geologist

Geoff Hurley MSc DIC C.Geol RPEQ
Director

AS/GH/as A.B.N. 75 603 384 050

Drawing Adapted from CDM Smith, Levee Alignment Drawing

Legend

⊕ - Approximate Borehole Location

core consultants pty ltd	CLIENT CDM Smith		PROJECT Proposed Bundaberg East Levee		
	DRAWN AS	DATE 07/02/2019	TITLE **TEST LOCATION PLAN**		
	CHECKED GH	DATE 07/02/2019			
www.coreconsultants.com.au	SCALE As shown		PROJECT No J000800	FIGURE No 1	REV No 0 A4

Note: The * typed beside the initials indicates that the original drawing was signed or checked by that respective person

TMP-014 Site Plan 28/10/2015 Ver. 1.01

Appendix A:
Borehole Report Sheets

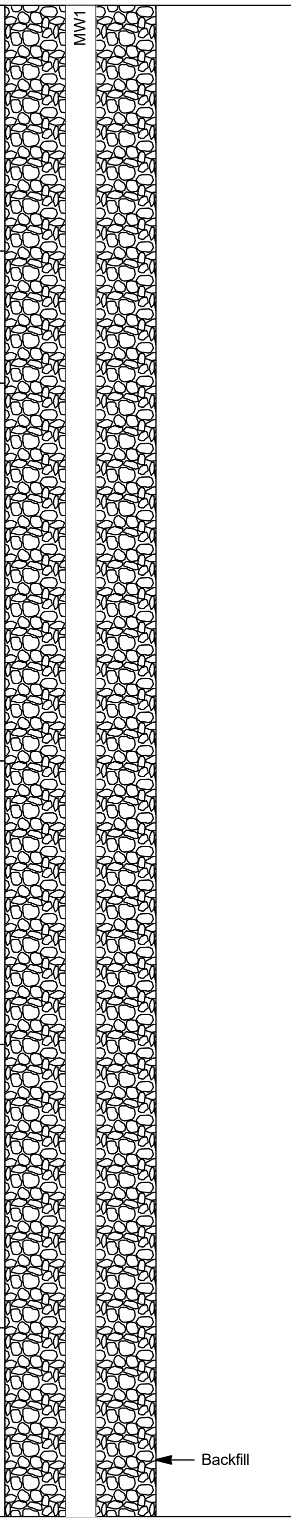
REPORT OF BOREHOLE: BH101

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435071.3 m	SHEET	1 OF 3
PROJECT:	Proposed Levee	NORTH:	7250126.7 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.75 m	LOGGED DATE:	12/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
ADT	L	Not Encountered	0	5.75	D 0.50-0.60 m D 1.00-1.10 m	SM	SAND (FILL): fine to medium grained, orange brown and brown, with trace angular to sub-rounded, fine to medium grained gravel	M	L
ADT	L	Not Encountered	1.30	4.45	SPT 1.50-1.95 m 3/3/5 N = 8	CI	SILTY CLAY (ALLUVIAL): medium plasticity, dark grey, with trace fine grained sand	M	F
ADT / WB	L	Not Encountered	2.00	3.75	SPT 3.00-3.45 m 3/3/4 N = 7	SM	SILTY SAND (ALLUVIAL): fine to medium grained, orange and brown, with interbedded bands of firm silty clay	M	L
WB	L	Not Encountered	4.00	1.75	SPT 4.50-4.95 m 2/4/4 N = 8	CI	SANDY CLAY (ALLUVIAL): medium plasticity, orange brown and brown	M	F
WB	L	Not Encountered	5.50	0.25	U50 6.00-6.40 m PP 6.00 m =100 kPa	CH	SILTY CLAY (RESIDUAL SOIL): medium plasticity, red brown, yellow brown and grey	M	St
WB	L	Not Encountered	7.00	-1.25	SPT 7.50-7.95 m WOH N = 0 PP 7.50 m =60 kPa	CH	SILTY CLAY (MARINE CLAY): medium plasticity, becoming dark grey, with thinly bedded bands of fine sand	M	F

PIEZOMETER DETAILS



This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

REPORT OF BOREHOLE: BH101

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435071.3 m	SHEET	2 OF 3
PROJECT:	Proposed Levee	NORTH:	7250126.7 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.75 m	LOGGED DATE:	12/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	PIEZOMETER DETAILS
WB	L	Not Encountered	8					CH	SILTY CLAY (MARINE CLAY): medium plasticity, becoming dark grey, with thinly bedded bands of fine sand	M	F	
			9		SPT 9.00-9.45 m 0/0/1 N = 1							
			10									
					SPT 10.50-10.95 m 0/0/1 N = 1							
			11									
			12		U50 12.00-12.40 m PP 12.00 m =90 kPa FV 12.00 m Sv=30 kPa							
			13									
					SPT 13.50-13.95 m WOH N = 0 PP 13.50 m =80 kPa							
			14									
			15		SPT 15.00-15.45 m WOH N = 0 PP 15.00 m =900 kPa							
			16									Bentonite

This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

core
consultants pty ltd

REPORT OF BOREHOLE: BH101

CLIENT:	CDM Smith	EAST:	435071.3 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250126.7 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.75 m	LOGGED DATE:	12/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

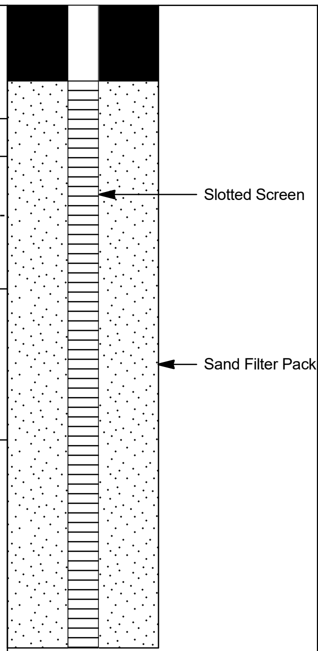
Drilling | **Sampling** | **Field Material Description**

Method: WB; Penetration Resistance: L; Water: Not Encountered

DEPTH (metres) / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
16		CH	SILTY CLAY (MARINE CLAY): medium plasticity, becoming dark grey, with thinly bedded bands of fine sand	M	F
16.60 -10.85	SPT 16.50-16.95 m 5/12/17 N = 29	CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, grey, medium grained sand	M	St
16.80 -11.05		SM	SILTY SAND (ELLIOT FORMATION): medium to coarse grained, grey, with trace rounded, medium quartz gravel	M	MD - D
17.50 -11.75	SPT 18.00-18.45 m 2/5/11 N = 16	CI	SILTY CLAY (ELLIOT FORMATION): medium plasticity, grey	M	St
18.30 -12.55	SPT 19.50-19.95 m 6/3/5 N = 8	SP	GRAVELLY SAND (ELLIOT FORMATION): medium grained, grey, fine to coarse and sub-angular to rounded gravel	M	MD
19.85		CI	SILTY CLAY (ELLIOT FORMATION): medium plasticity, grey, red brown and yellow brown	M	St
20.00			END OF BOREHOLE @ 20.00 m TARGET DEPTH STANDPIPE INSTALLED		

Depth scale: 16, 17, 18, 19, 20, 21, 22, 23, 24

PIEZOMETER DETAILS



This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

CORE 1.00 LIB.GLB Log IS AU BOREHOLE 3 J000800_6.02.2018.GPJ <<DrawingFile>> 07/02/2019 13:40 10.0.000 Datgel Fence and Map Tool | Lib: DGDT-P 3.05.0 2016-01-20 Prj: DGDT-P 3.05.0 2016-01-20

REPORT OF BOREHOLE: BH102

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435141.5 m	SHEET	1 OF 4
PROJECT:	Proposed Levee	NORTH:	7250142.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.40 m	LOGGED DATE:	13/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Method	Penetration Resistance	Water	Depth / RL	Sample or Field Test	USCS Symbol	Soil/Rock Material Description	Moisture Condition	Consistency Density	Structure and Additional Observations
ADT	L	Groundwater inflow encountered at 0.5 m depth	0.00 / 7.40		SM	SAND (FILL): fine to medium grained, orange brown and brown, with trace fine to medium, angular to sub-angular gravel and metal fragments	M	MD	0.00: Variable drilling
ADT	L		0.60 / 6.80	SPT 1.50-1.95 m 6/8/10 N = 18	CI	SILTY CLAY (FILL): medium plasticity, dark brown, with trace fine sand and concrete fragments	M	VSt	1.50: Boulder encountered
ADT / WB	L		2.00 / 5.40	2.50 m PP 2.50 m =180 kPa	CI	SILTY CLAY (ALLUVIUM): medium plasticity, brown and dark orange brown, with trace fine sand	M	St	
WB	L	Not Encountered	2.70 / 4.70	SPT 3.00-3.45 m 2/4/3 N = 7	SM	SILTY SAND (ALLUVIUM): fine to medium grained, orange brown, with some angular to sub-angular, fine to coarse sized gravel	M	L	
WB	L		3.60 / 3.80	U50 4.50-4.90 m PP 4.50 m =130 kPa	CI	SILTY CLAY (ALLUVIUM): brown and dark orange brown, with trace fine sand	M	St	
WB	L		5.60 / 1.80			Becoming grey and orange brown	M	St	
WB	L		6.00 / 1.40	SPT 6.00-6.45 m 2/1/3 N = 4		Becoming firm	M	F	
WB	L		7.20 / 0.20	SPT 7.50-7.95 m WOH N = 0 PP 7.50 m =80 kPa	CH	SILTY CLAY (MARINE CLAY): high plasticity, dark grey, with thinly bedded bands of fine sand	M	F	

Depth scale (metres): 0 – 8

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REPORT OF BOREHOLE: BH102

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435141.5 m	SHEET	2 OF 4
PROJECT:	Proposed Levee	NORTH:	7250142.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.40 m	LOGGED DATE:	13/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8					CH	SILTY CLAY (MARINE CLAY): high plasticity, dark grey, with thinly bedded bands of fine sand	M	F	
			9		SPT 9.00-9.45 m WOH N = 0 PP 9.00 m =70 kPa							
			10									
					SPT 10.50-10.95 m 0/0/1 N = 1							
			11									
			12	*12.00* -4.60	PP 12.00 m =60 kPa				With some organic matter and shell fragments			
			13									
					SPT 13.50-13.95 m WOH N = 0 PP 13.50 m =60 kPa							
			14									
			15	*15.00* -7.60	U50 15.00-15.40 m PP 15.00 m =100 kPa FV 15.00 m Sv=42 kPa				Becoming firm/stiff			
			16									

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REPORT OF BOREHOLE: BH102

core consultants pty ltd

CLIENT: CDM Smith	EAST: 435141.5 m		
PROJECT: Proposed Levee	NORTH: 7250142.5 m	SHEET	3 OF 4
LOCATION: East Bundaberg	SURFACE RL 7.40 m	LOGGED:	AS
JOB NO: J000800	CONTRACTOR: Geodrill	LOGGED DATE:	13/11/18
	DRILL RIG: Hydra Power Scout	CHECKED:	AS
	INCLINATION: -90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16			CH	SILTY CLAY (MARINE CLAY): high plasticity, dark grey, with thinly bedded bands of fine sand	M	F	
					SPT 16.50-16.95 m 0/0/4 N = 4					
			18	18.00 -10.60	SPT 18.00-18.45 m 4/3/0 N = 3	CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, orange brown and grey, medium to coarse grained sand			
				18.75 -11.35		CH	SILTY CLAY (ELLIOT FORMATION): high plasticity, dark grey, with thinly bedded bands of fine sand			
				19.30 -11.90	SPT 19.50-19.95 m 5/13/22 N = 35	CL	SANDY CLAY (ELLIOT FORMATION): low plasticity, pale grey and red brown, medium to coarse grained sand, with trace sub-angular to rounded gravel		H	
				20.50 -13.10	SPT 21.00-21.45 m 7/5/8 N = 13		With some gravel		St	
	H			21.50 -14.10	SPT 22.50-22.95 m 8/15/16 N = 31	CI	SANDY CLAY (ELLIOT FORMATION): orange brown, medium to coarse grained sand, with some sub-angular to rounded, medium to coarse grained gravel		H	
			24	24.00						

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REPORT OF BOREHOLE: BH102

core consultants pty ltd

CLIENT: CDM Smith	EAST: 435141.5 m	SHEET	4 OF 4
PROJECT: Proposed Levee	NORTH: 7250142.5 m	LOGGED:	AS
LOCATION: East Bundaberg	SURFACE RL 7.40 m	LOGGED DATE:	13/11/18
JOB NO: J000800	CONTRACTOR: Geodrill	CHECKED:	AS
	DRILL RIG: Hydra Power Scout	CHECKED DATE:	26/11/18
	INCLINATION: -90° HOLE DIA. 100 mm		

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
	H	Not Encountered	24	24.10	SPT 24.00-24.07 m 30 for 70 mm				SANDY GRAVEL (POSSIBLE CONGLOMERATE): brown, medium to coarse grained sand, with angular to sub-angular, medium to coarse quartz	M	VD	
									END OF BOREHOLE @ 24.10 m REFUSAL BACKFILLED			
			25									
			26									
			27									
			28									
			29									
			30									
			31									
			32									

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REPORT OF BOREHOLE: BH103

consultants pty ltd

CLIENT: CDM Smith	EAST: 435203.1 m		
PROJECT: Proposed Levee	NORTH: 7250150.9 m	SHEET	1 OF 3
LOCATION: East Bundaberg	SURFACE RL 6.40 m	LOGGED:	AS
JOB NO: J000800	CONTRACTOR: Geodrill	LOGGED DATE:	13/11/18
	DRILL RIG: Hydra Power Scout	CHECKED:	AS
	INCLINATION: -90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT (0–2.5)	L	Not Encountered	0	6.40 / 0.20		SM	SILTY SAND (FILL): fine grained, orange brown and grey	M	L	
				6.20		CI	SILTY CLAY (ALLUVIAL): medium plasticity, dark brown		VSt	
			1.5		SPT 1.50-1.95 m 6/8/10 N = 18					
WB (2.5–8)			3	3.00 / 3.40	U50 3.00-3.40 m PP 3.00 m =110 kPa		Becoming stiff		St	
			4.5	4.50 / 1.90	SPT 4.50-4.95 m 0/3/3 N = 6		Orange brown and grey, becoming firm		F	
			6		SPT 6.00-6.45 m WOH N = 0 PP 6.00 m =60 kPa					
				6.30 / 0.10		CH	SILTY CLAY (MARINE CLAY): high plasticity, grey			
			7.5		SPT 7.50-7.95 m WOH N = 0 PP 7.50 m =50 kPa					

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REPORT OF BOREHOLE: BH103

core consultants pty ltd

		EAST:	435203.1 m		
		NORTH:	7250150.9 m	SHEET	2 OF 3
CLIENT:	CDM Smith	SURFACE RL	6.40 m	LOGGED:	AS
PROJECT:	Proposed Levee	CONTRACTOR:	Geodrill	LOGGED DATE:	13/11/18
LOCATION:	East Bundaberg	DRILL RIG:	Hydra Power Scout	CHECKED:	AS
JOB NO:	J000800	INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8					CH	SILTY CLAY (MARINE CLAY): high plasticity, grey	M	F	
			9		U50 9.00-9.40 m PP 9.00 m =90 kPa							
			10		SPT 10.50-10.95 m WOH N = 0 PP 10.50 m =70 kPa							
			11									
			12	*12.00* -5.60	SPT 12.00-12.45 m WOH N = 0 PP 12.00 m =70 kPa				Some organics present			
			13		SPT 13.50-13.95 m WOH N = 0 PP 13.50 m =70 kPa FV 13.50 m Sv=30 kPa							
			14	*14.80* -8.40				SC	CLAYEY SAND (ELLIOT FORMATION): medium to coarse grained, grey		L	
			15		SPT 15.00-15.45 m 0/1/1 N = 2							
			16									

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core consultants pty ltd

REPORT OF BOREHOLE: BH103

CLIENT:	CDM Smith	EAST:	435203.1 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250150.9 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	6.40 m	LOGGED DATE:	13/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16					SC	CLAYEY SAND (ELLIOT FORMATION): medium to coarse grained, grey	M	L	
				16.50 / -10.10	SPT 16.50-16.95 m 2/4/4 N = 8				Fine to medium grained grained			
			17									
				17.80 / -11.40					Orange brown and grey, interbedded bands of fine grained sand			
			18		SPT 18.00-18.45 m 6/4/4 N = 8							
			19									
				19.40 / -13.00	SPT 19.50-19.95 m 3/4/7 N = 11			CL	SILTY CLAY (ELLIOT FORMATION): low plasticity, pale grey, red brown and orange brown, with trace fine sand		St	
			20									
			21	21.00 / -14.60	SPT 21.00-21.45 m 5/8/9 N = 17				No sand, very stiff		VSt	
				21.45					END OF BOREHOLE @ 21.45 m TARGET DEPTH BACKFILLED			
			22									
			23									
			24									

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CORE 1.00 LIB.GLB Log IS AU BOREHOLE 3 J000800_6.02.2018.GPJ <<DrawingFile>> 07/02/2019 13:40 10.0.000 Datgel Fence and Map Tool | Lib: DGDT-P 3.05.0 2016-01-20 Prj: DGDT-P 3.05.0 2016-01-20

core consultants pty ltd

REPORT OF BOREHOLE: BH106

CLIENT:	CDM Smith	EAST:	435925.8 m
PROJECT:	Proposed Levee	NORTH:	7250439.9 m
LOCATION:	East Bundaberg	SURFACE RL	7.92 m
JOB NO:	J000800	CONTRACTOR:	Geodrill
		DRILL RIG:	Hydra Power Scout
		INCLINATION:	-90° HOLE DIA. 100 mm

SHEET	1 OF 2
LOGGED:	AS
LOGGED DATE:	14/11/18
CHECKED:	AS
CHECKED DATE:	26/11/18

Drilling | **Sampling** | **Field Material Description**

DEPTH (m)	RL	METHOD	PENETRATION RESISTANCE	WATER	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0	7.92	ADT	L	Not Encountered		CI-CH	SILTY CLAY (FILL): medium plasticity, dark brown, with some brick and concrete fragments	M	F	
0.60	7.32	ADT	L			CI	SILTY CLAY (ALLUVIUM): medium plasticity, grey and orange brown	M	F	
1.20	6.72	ADT	L		SPT 1.50-1.63 m 30 for 130 mm	CI	SILTY CLAY (ELLIOT FORMATION): medium plasticity, grey, brown and yellow brown, with some fine sand, trace fine to medium grained angular to sub-rounded gravel	M	F	
1.60	6.32	ADT	H		SPT 10 blows to 100 mm then bouncing		SANDSTONE (INDURATED/CEMENTED): grey and brown, highly weathered, fine to medium grained	M	VD	
1.80	6.12	ADT	L				Becomes very low strength, highly weathered	M	VD	
2.50	5.42	WB	L			CI	SILTY CLAY (INDURATED/CEMENTED): medium plasticity, red brown, yellow brown and brown grey, with some fine to medium grained	M	H	
3.00	4.92	WB	L (to 4.0), M		SPT 3.00-3.28 m 7/30 for 125 mm; SPT 4.50-4.79 m 30 for 140 mm; SPT 6.00-6.44 m 12/18/30 for 140 mm	SC	CLAYEY SAND (INDURATED/CEMENTED): fine to medium grained, pale grey, with red brown and yellow brown and brown bands	M	VD	
7.30	0.62	WB	H		SPT 7.50-7.53 m 30 for 30 mm		SILTSTONE (INDURATED/CEMENTED): pale grey, moderately weathered	M	H	
8										

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REPORT OF BOREHOLE: BH106

CLIENT:	CDM Smith	EAST:	435925.8 m		
PROJECT:	Proposed Levee	NORTH:	7250439.9 m	SHEET	2 OF 2
LOCATION:	East Bundaberg	SURFACE RL	7.92 m	LOGGED:	AS
JOB NO:	J000800	CONTRACTOR:	Geodrill	LOGGED DATE:	14/11/18
		DRILL RIG:	Hydra Power Scout	CHECKED:	AS
		INCLINATION:	-90° HOLE DIA. 100 mm	CHECKED DATE:	26/11/18

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
RR	L	Not Encountered	8						SILTSTONE (INDURATED/CEMENTED): pale grey, moderately weathered	M	H	
				8.60 -0.68	SPT 9.00-9.45 m 3/5/4 N = 9			CI-CH	SANDY CLAY (INDURATED/CEMENTED): pale grey, fine to coarse grained sand		St	
			9									
			10									
				10.50 -2.58	SPT 10.50-10.95 m 6/8/15 N = 23				CLAY (INDURATED/CEMENTED): pale grey, becoming stiff		VSt	
				10.95					END OF BOREHOLE @ 10.95 m TARGET DEPTH BACKFILLED			
			11									
			12									
			13									
			14									
			15									
			16									

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REPORT OF BOREHOLE: BH107

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435889.2 m	SHEET	1 OF 3
PROJECT:	Proposed Levee	NORTH:	7250543.0 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling	Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L	Not Encountered	0	5.82				SM	SILTY SAND (FILL): fine grained, dark brown and yellow brown, with ash fragments and some angular to sub-angular, medium to course grained gravel and cobbles	M	L	
				0.60 / 5.22				CL	SILTY CLAY (FILL): low plasticity, dark brown, red brown, and yellow brown, with ash fragments and some angular to sub-angular, medium to course grained gravel and cobbles	M	F	
			1	1.00 / 4.82	SPT 1.50-1.95 m 2/2/1 N = 3				Dark brown, with ash fragments	D	L	
WB			2	2.20 / 3.62	SPT 3.00-3.45 m 2/3/6 N = 9			CH	SILTY CLAY (ALLUVIUM): high plasticity, dark brown, orange and dark grey	M	St	
			4	4.00 / 1.82	SPT 4.50-4.95 m WOH N = 0 PP 4.50 m =70 kPa			CH	SILTY CLAY (ELLIOT FORMATION): high plasticity, pale grey and yellow brown, with trace of fine grained sand	M	F	
	H		5	5.20 / 0.62	SPT 6.00-6.05 m 30 for 50 mm				SILTSTONE (INDURATED/CEMENTED): red brown, orange brown and grey, highly weathered, recovered as fine to coarse grained angular to sub-angular gravel (possibly indurated clay/sand)	M	H	
RR			7	7.40 / -1.58	SPT 7.50-7.75 m 19/30 for 50 mm			CL	SILTY CLAY (INDURATED/CEMENTED): low plasticity, pale grey, with trace of fine sand	M	H	
			8									

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REPORT OF BOREHOLE: BH107

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435889.2 m	SHEET	2 OF 3
PROJECT:	Proposed Levee	NORTH:	7250543.0 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
RR	H	Not Encountered	8			CL	SILTY CLAY (INDURATED/CEMENTED): low plasticity, pale grey, with trace of fine sand	M	H	
WB	L		9	9.00 / -3.18	SPT 9.00-9.45 m 6/5/5 N = 10	SC	CLAYEY SAND (INDURATED/CEMENTED): fine to coarse grained, pale grey		L / MD	
			10	10.20 / -4.38	SPT 10.50-10.95 m 6/9/11 N = 18	CI	SANDY CLAY (INDURATED/CEMENTED): low plasticity, dark grey, fine to coarse grained sand, with some fine grained angular to sub angular gravel		VSt	
			12	12.00 / -6.18	SPT 12.00-12.45 m 4/4/4 N = 8	SC	CLAYEY SAND (INDURATED/CEMENTED): fine to coarse grained, orange brown		L	
			13		SPT 13.50-13.95 m 3/2/2 N = 4					
			15	15.00 / -9.18	SPT 15.00-15.45 m 2/3/4 N = 7		Becoming pale grey and orange brown			
			16							

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REPORT OF BOREHOLE: BH107

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435889.2 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250543.0 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	14/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16		SPT 16.50-16.95 m 3/4/5 N = 9 does not drill like a gravel deposit, drills like a rock			SC	CLAYEY SAND (INDURATED/CEMENTED): fine to coarse grained, orange brown	M	L	16.50: does not drill like a gravel deposit, drills like a rock
			17									
			18	18.30 -12.48	SPT 18.00-18.45 m 5/6/8 N = 14			GW-GC	GRAVEL (INDURATED/CEMENTED): fine to medium grained, pale grey, with band of sub-rounded to rounded gravel		MD	
			19	19.95	SPT 19.50-19.95 m 3/4/4 N = 8						L	
			20						END OF BOREHOLE @ 19.95 m TARGET DEPTH BACKFILLED			
			21									
			22									
			23									
			24									

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REPORT OF BOREHOLE: BH108

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435868.9 m	SHEET	1 OF 3
PROJECT:	Proposed Levee	NORTH:	7250568.2 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L	Not Encountered	0	5.82		SM	SILTY SAND (FILL): fine grained, brown	M	L	
				0.20 / 5.62	SPT 1.50-1.95 m 2/2/1 N = 3	SM	SAND (FILL): black, ash fill	D	VL	
				1.90 / 3.92		CH	SILTY CLAY (ALLUVIUM): high plasticity, brown orange brown, and dark grey		F	
WB	L			3.00 / 2.82	U50 3.00-3.45 m PP 3.00 m =200 kPa U50 4.50-4.95 m PP 4.50 m =120 kPa		Grey, orange brown and brown, with trace fine sand		VSt	
				4.95 / 0.87			Becoming dark grey and orange brown	M	St	
				5.80 / 0.02	SPT 6.00-6.45 m WOH N = 0 PP 6.00 m =80 kPa U50 7.50-7.95 m PP 7.50 m =80 kPa (change of strata within U50 sample)	CH	SILTY CLAY (MARINE CLAY): high plasticity, grey, dark grey and orange brown, with strong hydrocarbon odour in marine clay		F	

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8

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REPORT OF BOREHOLE: BH108

core consultants pty ltd

CLIENT:	CDM Smith	EAST:	435868.9 m	SHEET	2 OF 3
PROJECT:	Proposed Levee	NORTH:	7250568.2 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling	Field Material Description				
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8		SPT 9.00-9.45 m WOH N = 0 PP 9.00 m =60 kPa	CH	SILTY CLAY (MARINE CLAY): high plasticity, grey, dark grey and orange brown, with strong hydrocarbon odour in marine clay	M	F	
				9.80 -3.98			Grey, dark grey and orange brown, with trace fine sand			
				10.30 -4.48	SPT 10.50-10.95 m 1/2/2 N = 4	SC	CLAYEY SAND (ELLIOT FORMATION): fine to coarse grained, grey, with some silt		L	
				11.70 -5.88	SPT 12.00-12.45 m 4/4/4 N = 8	CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, blue green, dark brown, and brown, fine to coarse grained sand, with some medium to coarse grained gravel		F	
				12.90 -7.08	SPT 13.50-13.95 m 4/3/4 N = 7		Becoming orange brown and brown, no gravel present			
			16	14.70 -8.88	SPT 15.00-15.45 m 5/4/4 N = 8		Pale grey, with some fine to coarse grained angular gravel			

This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

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REPORT OF BOREHOLE: BH108

CLIENT:	CDM Smith	EAST:	435868.9 m	SHEET	3 OF 3
PROJECT:	Proposed Levee	NORTH:	7250568.2 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	5.82 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	16					CI	SANDY CLAY (ELLIOT FORMATION): low plasticity, blue green, dark brown, and brown, fine to coarse grained sand, with some medium to coarse grained gravel	M	F	
				16.50 -10.68	SPT 16.50-16.95 m 5/5/10 N = 15				Becoming orange brown, pale grey and brown		St / VSt	
			17									
			18	18.00 -12.18	SPT 18.00-18.45 m 11/5/5 N = 10			GP	GRAVEL (ELLIOT FORMATION): fine to coarse subangular to rounded, pale grey and brown, becomes stiff		MD	
			19									
					SPT 19.50-19.95 m 17/21/16 N = 37						D	
				19.95								
			20						END OF BOREHOLE @ 19.95 m TARGET DEPTH BACKFILLED			
			21									
			22									
			23									
			24									

This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

CORE 1.00 LIB.GLB Log IS AU BOREHOLE 3 J000800_6.02.2018.GPJ <<DrawingFile>> 07/02/2019 13:40 10.0.000 Datgel Fence and Map Tool | Lib: DGDT-P 3.05.0 2016-01-20 Prj: DGDT-P 3.05.0 2016-01-20

REPORT OF BOREHOLE: BH109

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CLIENT:	CDM Smith	EAST:	435788.5 m	SHEET	1 OF 2
PROJECT:	Proposed Levee	NORTH:	7250696.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.03 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling | **Sampling** | **Field Material Description**

DEPTH / RL	SAMPLE OR FIELD TEST	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
0.00 / 7.03 – 0.20 / 6.83		SM	SAND (FILL): brown	M	L
0.20 / 6.83 – 1.20 / 5.83		CI	SILTY CLAY (FILL): medium plasticity, brown and red brown, with ash fragments	M	L
1.20 / 5.83 – 1.40 / 5.63		SM	SILTY SAND (FILL): red brown, with some ash fragments	M	MD
1.40 / 5.63 – 2.10 / 4.93	SPT 1.50-1.95 m 3/5/6 N = 11		Becoming orange brown	M	MD
2.10 / 4.93 – 4.20 / 2.83	SPT 3.00-3.45 m 4/5/6 N = 11	CI	SILTY CLAY (ALLUVIUM): high plasticity, red brown, orange brown and dark grey	M	St
4.20 / 2.83 – 7.00 / 0.03	SPT 4.50-4.95 m 12/13/15 N = 28; SPT 6.00-6.45 m 0/2/2 N = 4		Becoming dark grey and orange brown	M	St, VSt, F
7.00 / 0.03 –	U50 7.50-7.95 m PP 7.50 m =550 kPa	CI	SILTY CLAY (ELLIOT FORMATION): high plasticity, pale grey and orange	M	H

METHOD: ADT (0–2.5 m); WB (2.5–8 m)
PENETRATION RESISTANCE: L
WATER: Not Encountered

STRUCTURE AND ADDITIONAL OBSERVATIONS

This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

REPORT OF BOREHOLE: BH109

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CLIENT:	CDM Smith	EAST:	435788.5 m	SHEET	2 OF 2
PROJECT:	Proposed Levee	NORTH:	7250696.5 m	LOGGED:	AS
LOCATION:	East Bundaberg	SURFACE RL	7.03 m	LOGGED DATE:	15/11/18
JOB NO:	J000800	CONTRACTOR:	Geodrill	CHECKED:	AS
		DRILL RIG:	Hydra Power Scout	CHECKED DATE:	26/11/18
		INCLINATION:	-90° HOLE DIA. 100 mm		

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L	Not Encountered	8 – 10.50	10.50	SPT 9.00-9.45 m 10/12/18 N = 30			CI	SILTY CLAY (ELLIOT FORMATION): high plasticity, pale grey and orange	M	H	
			10.50 – 16						END OF BOREHOLE @ 10.50 m TARGET DEPTH BACKFILLED			

This report must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

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EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT REPORTS

DRILLING/EXCAVATION METHOD

AS*	Auger Screwing	RD	Rotary blade or drag bit	NQ	Diamond Core - 47 mm
AD*	Auger Drilling	RT	Rotary Tricone bit	NMLC	Diamond Core - 52 mm
*V	V-Bit	RAB	Rotary Air Blast	HQ	Diamond Core - 63 mm
*T	TC-Bit, e.g. ADT	RC	Reverse Circulation	HMLC	Diamond Core – 63mm
HA	Hand Auger	PT	Push Tube	BH	Tractor Mounted Backhoe
ADH	Hollow Auger	CT	Cable Tool Rig	EX	Tracked Hydraulic Excavator
DTC	Diatube Coring	JET	Jetting	EE	Existing Excavation
WB	Washbore or Bailer	NDD	Non-destructive digging	HAND	Excavated by Hand Methods

PENETRATION/EXCAVATION RESISTANCE

L **Low resistance.** Rapid penetration possible with little effort from the equipment used.

M **Medium resistance.** Excavation/possible at an acceptable rate with moderate effort from the equipment used.

H **High resistance** to penetration/excavation. Further penetration is possible at a slow rate and requires significant effort from the equipment.

R **Refusal or Practical Refusal.** No further progress possible without the risk of damage or unacceptable wear to the digging implement or machine.

These assessments are subjective and are dependent on many factors including the equipment power, weight, condition of excavation or drilling tools, and the experience of the operator.

WATER

▽	Water level at date shown	◁	Partial water loss
▷	Water inflow	◀	Complete water loss

GROUNDWATER NOT OBSERVED — The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

GROUNDWATER NOT ENCOUNTERED — The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11 N=18	4,7,11 = Blows per 150mm. N = Blows per 300mm penetration following 150mm seating
30/80mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
DS	Disturbed sample
BDS	Bulk disturbed sample
G	Gas Sample
W	Water Sample
FP	Field permeability test over section noted
FV	Field vane shear test expressed as uncorrected shear strength (s_v = peak value, s_r = residual value)
PID	Photoionisation Detector reading in ppm
PM	Pressuremeter test over section noted
PP	Pocket penetrometer test expressed as instrument reading in kPa
U63	Thin walled tube sample - number indicates nominal sample diameter in millimetres
WPT	Water pressure tests
DCP	Dynamic cone penetration test
CPT	Static cone penetration test
CPTu	Static cone penetration test with pore pressure (u) measurement

Ranking of Visually Observable Contamination and Odour (for specific soil contamination assessment projects)

R = 0	No visible evidence of contamination	R = A	No non-natural odours identified
R = 1	Slight evidence of visible contamination	R = B	Slight non-natural odours identified
R = 2	Visible contamination	R = C	Moderate non-natural odours identified
R = 3	Significant visible contamination	R = D	Strong non-natural odours identified

ROCK CORE RECOVERY

TCR = Total Core Recovery (%)

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100$$

SCR = Solid Core Recovery (%)

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100$$

RQD = Rock Quality Designation (%)

$$= \frac{\sum \text{Axial lengths of core} > 100 \text{ mm}}{\text{Length of core run}} \times 100$$

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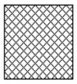
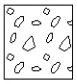
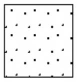
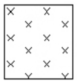
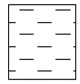
METHOD OF SOIL DESCRIPTION USED ON BOREHOLE AND TEST PIT REPORTS

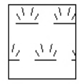

FILL

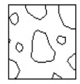

GRAVEL (GP or GW)


SAND (SP or SW)


SILT (ML or MH)


CLAY (CL, CI or CH)


ORGANIC SOILS (OL or OH or Pt)


COBBLES or BOULDERS

Combinations of these basic symbols may be used to indicate mixed materials such as sandy clay.

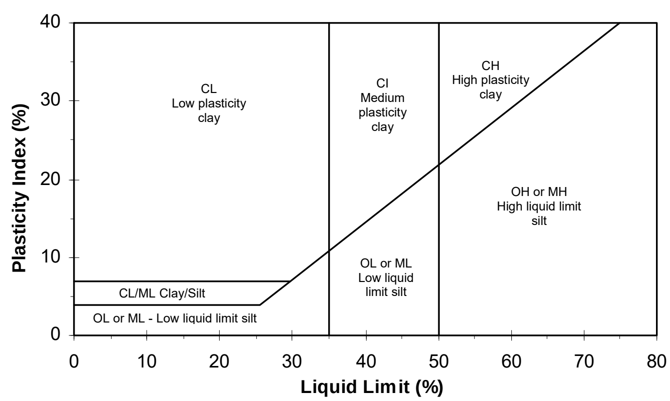
CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil and Rock is classified and described in Reports of Boreholes and Test Pits using the preferred method given in AS1726 – 1993, (Amdt1 – 1994 and Amdt2 – 1994), Appendix A. The material properties are assessed in the field by visual/tactile methods.

Particle Size

Major Division	Sub Division	Particle Size
BOULDERS		> 200 mm
COBBLES		63 to 200 mm
GRAVEL	Coarse	20 to 63 mm
	Medium	6.0 to 20 mm
	Fine	2.0 to 6.0 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties



MOISTURE CONDITION

AS1726 - 1993

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays & Silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition & may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

CONSISTENCY AND DENSITY

AS1726 - 1993

Symbol	Term	Undrained Shear Strength
VS	Very Soft	0 to 12 kPa
S	Soft	12 to 25 kPa
F	Firm	25 to 50 kPa
St	Stiff	50 to 100 kPa
VSt	Very Stiff	100 to 200 kPa
H	Hard	Above 200 kPa

Symbol	Term	Density Index %	SPT "N" #
VL	Very Loose	Less than 15	0 to 4
L	Loose	15 to 35	4 to 10
MD	Medium Dense	35 to 65	10 to 30
D	Dense	65 to 85	30 to 50
VD	Very Dense	Above 85	Above 50

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.

SPT correlations are not stated in AS1726 – 1993, and may be subject to corrections for overburden pressure and equipment type.

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TERMS FOR ROCK MATERIAL STRENGTH & WEATHERING AND ABBREVIATIONS FOR DEFECT DESCRIPTIONS

STRENGTH

Symbol	Term	Point Load Index, $Is_{(50)}$ (MPa)	Field Guide
EL	Extremely Low	< 0.03	Easily remoulded by hand to a material with soil properties.
VL	Very Low	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm can be broken by finger pressure.
L	Low	0.1 to 0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blows of pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
M	Medium	0.3 to 1	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
H	High	1 to 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken with pick with a single firm blow; rock rings under hammer.
VH	Very High	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
EH	Extremely High	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

ROCK STRENGTH TEST RESULTS

▼	Point Load Strength Index, $I_s(50)$, Axial test (MPa)
◀	Point Load Strength Index, $I_s(50)$, Diametral test (MPa)

Relationship between $I_s(50)$ and UCS (unconfined compressive strength) will vary with rock type and strength, and should be determined on a site-specific basis. UCS is typically 10 to 30 x $I_s(50)$, but can be as low as 5.

ROCK MATERIAL WEATHERING

Symbol		Term	Field Guide
RS		Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
EW		Extremely Weathered	Rock is weathered to such an extent that it has soil properties - i.e. it either disintegrates or can be remoulded, in water.
DW	HW	Distinctly Weathered	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores. In some environments it is convenient to subdivide into Highly Weathered and Moderately Weathered, with the degree of alteration typically less for MW.
	MW		
SW		Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength relative to fresh rock.
FR		Fresh	Rock shows no sign of decomposition or staining.

ABBREVIATIONS FOR DEFECT TYPES AND DESCRIPTIONS

Defect Type

B	Bedding parting
X	Foliation
C	Contact
L	Cleavage
J	Joint
SS/SZ	Sheared seam/zone (Fault)
CS/CZ	Crushed seam/zone (Fault)
DS/DZ	Decomposed seam/zone
IS/IZ	Infilled seam/zone
S	Schistocity
V	Vein

Coating or Infilling

Cn	Clean
Sn	Stain
Vr	Veneer
Ct	Coating or Infill

Planarity

Pl	Planar
Un	Undulating
St	Stepped

Roughness

Sl	Slickensided
Sm	Smooth
Ro	Rough

Vertical Boreholes – The dip (inclination from horizontal) of the defect is given.
Inclined Boreholes – The inclination is measured as the acute angle to the core axis.

Appendix B: Limitations

LIMITATIONS

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Attachment A2

C.M. Testing Test Boring Logs

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY

PO Box 5421 West Bundaberg Qld 4670 2 Turner St Bundaberg Qld 4670 Ph 07 4152 7644 Fax 07 4152 1405 Email: mark@cmtesting.com.au

SOIL PROFILE LOG

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY
PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2
LOCATION: REFER SKETCH
METHOD: GD-10 AUGER RIG

CERTIFICATE NUMBER: C134131
JOB NUMBER: BC13130
HOLE NO.: 104
DATE LOGGED: 12/11/18

Depth (m)	Sample	Test	Graphic Log	Moisture	Consistency	Symbol	Materials Description		Comments
							ASPHALT		
0.4				SM	MD	GP	SANDY GRAVEL Low Plasticity	Brown MPS to 30mm	
1.8				M	ST	CI	SANDY CLAY Medium Plasticity	Brown Fine Particles	SPT 1.5m 2/3/5
4.0				VM	F/S	CI	SANDY CLAY Medium Plasticity	Grey Brown Fine Particles	SPT 3.0m ow/2/3 (Water Seepage)
5.2				VM	F	CI	SILTY CLAY Medium Plasticity	Red Mottled Grey	SPT 4.5m 1/2/2
6.0 6.5 10.5	6.0–6.5	TUBE		VM/S	F/S	CH	SILTY CLAY High Plasticity	Dark Grey	Tube 6.0-6.5m SPT 7.5m 1/2/2 SPT 9.0m 1/2/3
							END OF HOLE 10.5m		SPT 10.5 1/2/3

Sample:
H – hand

Test:
V – shear vane
HP – penetrometer
UCS – 50mm tube

Moisture:
D – dry
SM – slightly moist
M – moist
VM – very moist
S - saturated
W – free water

Consistency Cohesive:
VS – very soft
S – soft
F – firm
St – stiff
VSt – very stiff
H - hard

Consistency Noncohesive:
VL - very loose
L - loose
MD – medium dense
D - dense
VD – very dense

Density:
VL – very loose
L – loose
MD – medium dense
D – dense
VD – very dense

Soils:
G - gravel
C - clay
S - sand
M - silt
XW, DW, SW, FR, (ROCK)

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY

PO Box 5421 West Bundaberg Qld 4670 2 Turner St Bundaberg Qld 4670 Ph 07 4152 7644 Fax 07 4152 1405 Email: mark@cmtesting.com.au

SOIL PROFILE LOG

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY	**CERTIFICATE NUMBER:** C134132
PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2	**JOB NUMBER:** BC13130
LOCATION: REFER SKETCH	**HOLE NO.:** 105
METHOD: GD-10 AUGER RIG	**DATE LOGGED:** 12/11/18

Depth (m)	Sample	Test	Graphic Log	Moisture	Consistency	Symbol	Materials Description	Comments
							ASPHALT	
				M	MD	GP	GRAVEL, Low Plasticity — Brown, MPS to 30mm	
0.4				M	F/ST	CI	SANDY CLAY, Medium Plasticity — Grey Brown, Fine Particles	SPT 1.0m 1/2/2 SPT 2.5m 2/4/4
3.8				VM	F	CI	SANDY CLAY, High Plasticity — Grey, Fine Particles	SPT 4.0m 2/3/4 (Water Seepage)
5.0				VM/S	S/F	CH	SILTY CLAY, High Plasticity — Dark Grey	SPT 5.5m 1/2/2 SPT 7.0m ow/1/1 SPT 8.5m 1/2/2
8.8				VM/S	S/F	CH	SILTY CLAY (TRACE COARSE SAND & GRAVEL TO 10mm), High Plasticity — Dark Grey	
10.0							END OF HOLE 10.0m	SPT 10.0m 1/3/3

Sample:
H – hand

Test:
V – shear vane
HP – penetrometer
UCS – 50mm tube

Moisture:
D – dry
SM – slightly moist
M – moist
VM – very moist
S - saturated
W – free water

Consistency Cohesive:
VS – very soft
S – soft
F – firm
St – stiff
VSt – very stiff
H - hard

Consistency Noncohesive:
VL - very loose
L - loose
MD – medium dense
D - dense
VD – very dense

Density:
VL – very loose
L – loose
MD – medium dense
D – dense
VD – very dense

Soils:
G - gravel
C - clay
S - sand
M - silt
XW, DW, SW, FR, (ROCK)

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY

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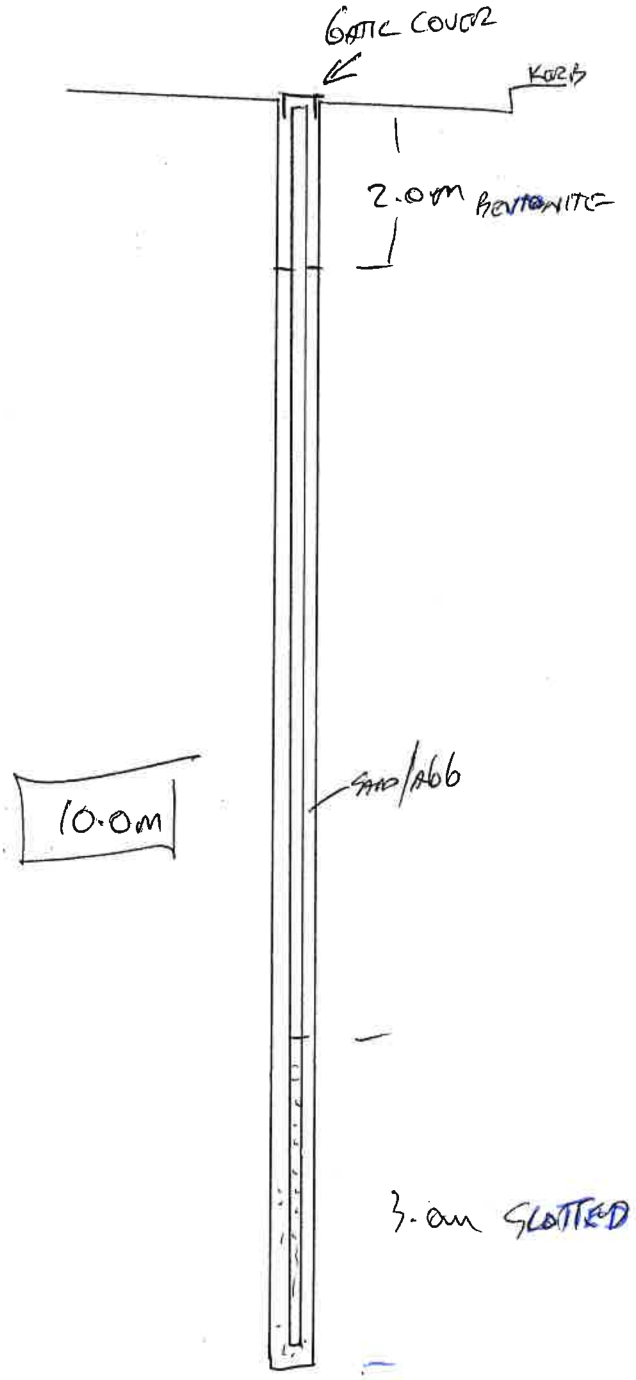
Ph 07 4152 7644 Fax 07 4152 1405 Email: mark@cmtesting.com.au

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NO:** C134138

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NO:** BC13130

DATE ISSUED: 27/11/18

BOREHOLE 105



SITE SKETCH NOT TO SCALE

AUTHORISED SIGNATORY: MARK ROHDMANN

Attachment B

Geotechnical Laboratory Test Results

Attachment B1

C.M. Testing Geotechnical Laboratory Test Results

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

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Email: mark@cmtesting.com.au

PLASTIC PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER**: C134493

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER**: BC13130

DATE ISSUED: 20/12/18 **DATE TESTED:** 13-14/12/18

SAMPLED BY: CLIENT **SAMPLE DATE:** 12/11/18

SAMPLE NO.:	34318	34320	34323	34324
SOIL DESCRIPTION:	DARK GREY SILTY CLAY	ORANGE BROWN SANDY CLAY	PALE GREY RED BROWN ORANGE BROWN SILTY CLAY	BROWN SANDY CLAY
SOURCE:	BH-102 13.5m	BH -102 22.5m	BH -103 19.5m	BH-104 1.5m
LENGTH OF MOULD:	125.0mm	125.0mm	127.0mm	127.0mm
LIQUID LIMIT (%):	**71**	**38**	**32**	**32**
PLASTIC LIMIT (%)	**22**	**16**	**18**	**17**
PLASTICITY INDEX (%)	**49**	**22**	**14**	**15**
LINEAR SHRINKAGE (%)	**14.0**	**8.5**	**4.5**	**6.5**

Test Method:

LL	AS1289 3.1.2
PL	AS1289 3.2.1
PI	AS1289 3.3.1
LS	AS1289 3.4.1

Authorised Signatory: Mark Rohdmann

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
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Ph 07 4152 7644 Fax 07 4152 1405 Email: mark@cmtesting.com.au

PLASTIC PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY	**CERTIFICATE NUMBER**: C134496
PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2	**JOB NUMBER**: BC13130
DATE ISSUED: 20/12/18	**DATE TESTED:** 17-18/12/18
SAMPLED BY: CLIENT	**SAMPLE DATE:** 12/11/18

SAMPLE NO.:	34327	34330	34331	34337
SOIL DESCRIPTION:	DARK GREY SILTY CLAY	PALE GREY SILTY CLAY	PALE GREY YELLOW BROWN SILTY CLAY	DARK GREY ORANGE BROWN SILTY CLAY
SOURCE:	BH-105 5.5m	BH -106 7.5m	BH -107 4.5m	BH-108 6.0m
LENGTH OF MOULD:	125.0mm	127.0mm	127.0mm	127.0mm
LIQUID LIMIT (%):	**61**	**38**	**55**	**53**
PLASTIC LIMIT (%)	**20**	**16**	**20**	**21**
PLASTICITY INDEX (%)	**41**	**22**	**35**	**32**
LINEAR SHRINKAGE (%)	**12.0**	**8.5**	**15.5**	**12.0**

Test Method:

LL	AS1289 3.1.2
PL	AS1289 3.2.1
PI	AS1289 3.3.1
LS	AS1289 3.4.1

Authorised Signatory: Mark Rohdmann

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Accreditation Number: 2062
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PLASTIC PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER**: C134508

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER**: BC13130

DATE ISSUED: 20/12/18 **DATE TESTED:** 19/12/18

SAMPLED BY: CLIENT **SAMPLE DATE:** 12/11/18

SAMPLE NO.:	34341	34342	34343
SOIL DESCRIPTION:	RED BROWN ORANGE BROWN DARK GREY SILTY CLAY	PALE GREY ORANGE SILTY CLAY	PALE GREY ORANGE SILTY CLAY
SOURCE:	BH - 109 3.0m	BH -109 7.5-7.9m	BH -109 9.0m
LENGTH OF MOULD:	127.0mm	125.0mm	125.0mm
LIQUID LIMIT (%):	**42**	**28**	**39**
PLASTIC LIMIT (%)	**18**	**19**	**18**
PLASTICITY INDEX (%)	**24**	**9**	**21**
LINEAR SHRINKAGE (%)	**10.0**	**3.0**	**5.5**

Test Method:

LL	AS1289 3.1.2
PL	AS1289 3.2.1
PI	AS1289 3.3.1
LS	AS1289 3.4.1

Authorised Signatory: Mark Rohdmann

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
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Email: mark@cmtesting.com.au

EMERSON CLASS DISPERSION CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134497

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18

SAMPLED BY: CLIENT **TEST METHOD:** AS1289.3.8.1

HOLE NO.	SAMPLE NO.	SOURCE	SOIL DESCRIPTION	EMERSON CLASS
BH-107	34331	4.5m	PALE GREY YELLOW BROWN SILTY CLAY	3
BH-104	34324	1.5m	BROWN SANDY CLAY	3
BH-109	34341	3.0m	RED BROWN ORANGE BROWN DARK GREY SILTY CLAY	5

DEMINERALISED WATER AT 23°C USED IN TEST

Authorised Signatory: Mark Rohdmann

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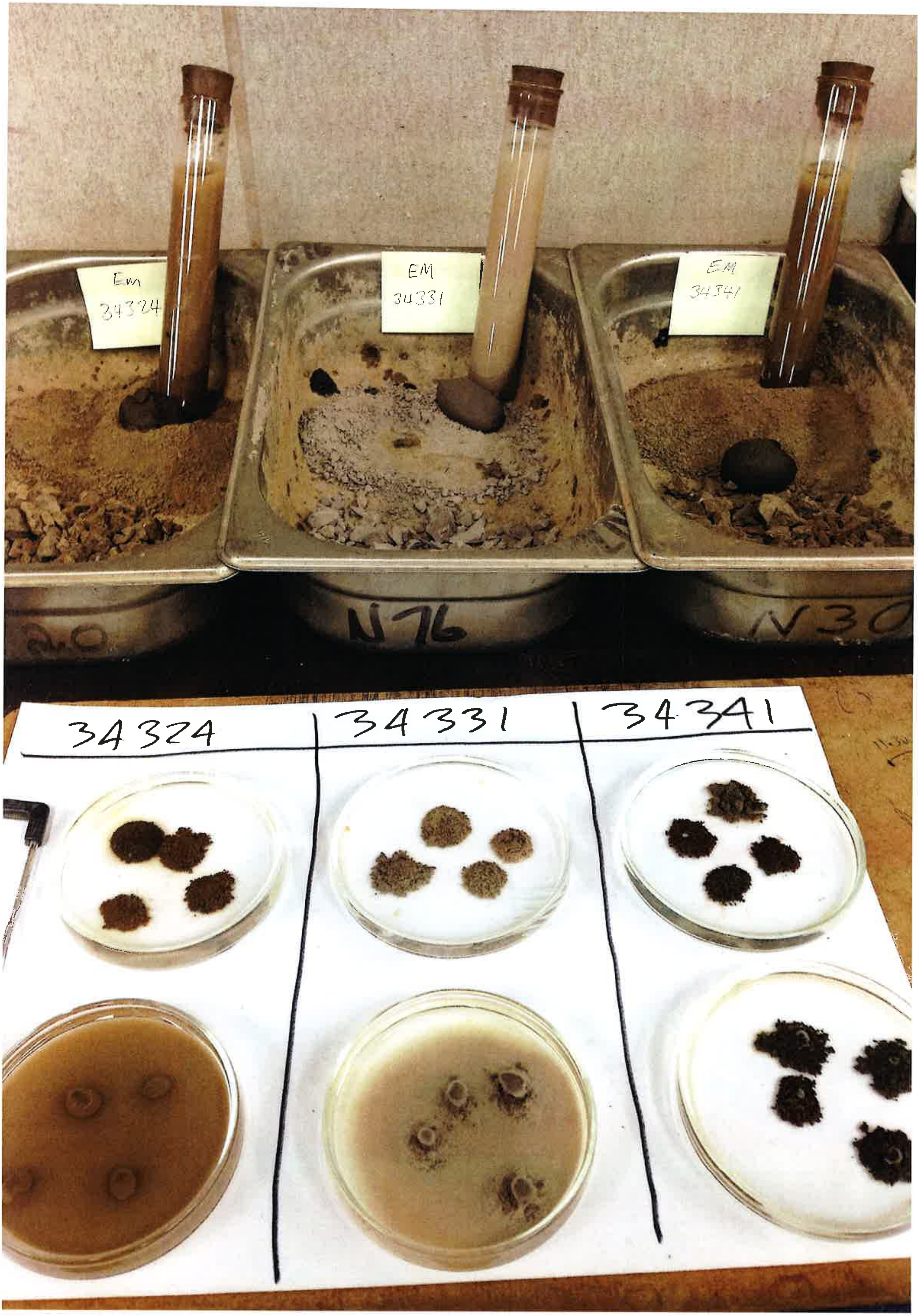
Em
34324
EM
34331
EM
34341
N76
N30
34324
34331
34341

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134490

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

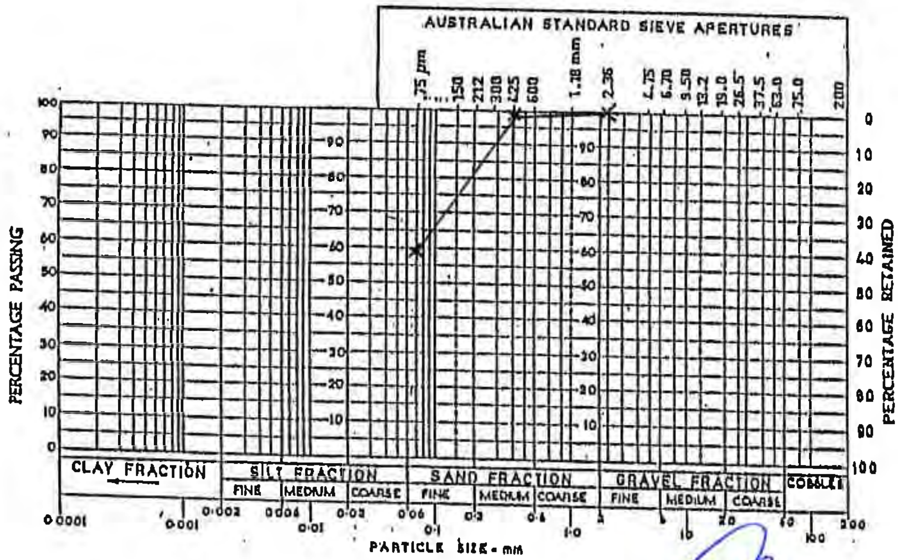
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: ORANGE BROWN SILTY CLAYEY SAND **SAMPLE NO.:** 34313

SOURCE: BH-101 - 3.0-3.4m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	
2.36	100
1.18	
0.600	
0.425	99
0.300	
0.150	
0.075	59
0.0135	



PSD samples oven dried 105-110° oven
ATT samples oven dried 50° oven.
Shrinkage mould **mm length.
Moisture content determined using AS1289.2.1.1/Q102A.
If Sampled by CMTS it is in accordence with AS1289 1.2.1/Q050/Q060.

Authorised Signatory: Mark Rohdmann

NATA Accredited for Technical Competence

Accreditation Number: 2062
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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134491

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

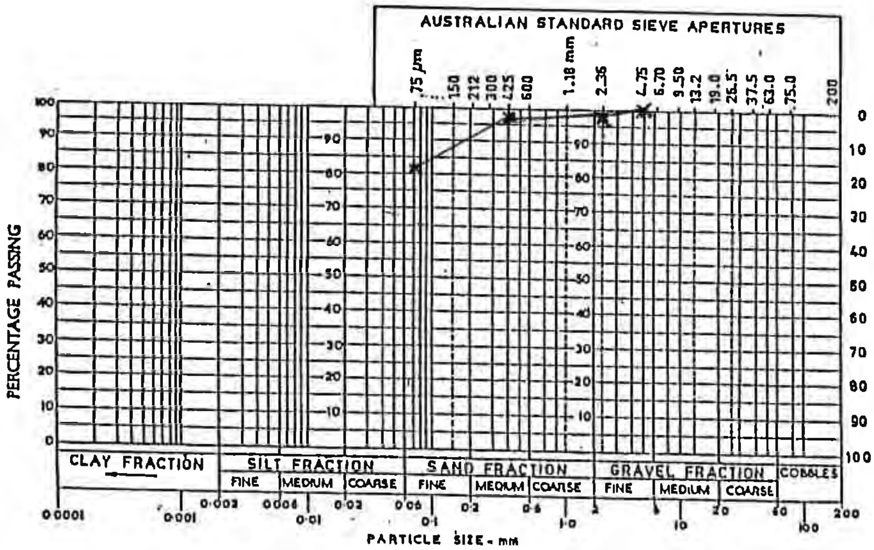
MATERIAL: RED BROWN & YELLOW BROWN SILTYCLAY **SAMPLE NO.:** 34314

SOURCE: BH-101 - 6.0-6.4m

PARTICLE SIZE DISTRIBUTION

TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	100
2.36	99
1.18	
0.600	
0.425	97
0.300	
0.150	
0.075	81
0.0135	



OTHER TESTS:

LIQUID LIMIT	42%	AS1289.3.1.2
PLASTIC LIMIT	16%	AS1289.3.2.1
PLASTICITY INDEX	26%	AS1289.3.3.1
LINEAR SHRINKAGE	9.5%	AS1289.3.4.1

PSD samples oven dried 105-110° oven

ATT samples oven dried 50° oven.

Shrinkage mould 150.0mm length.

Moisture content determined using AS1289.2.1.1/Q102A.

If Sampled by CMTS it is in accordance with AS1289.1.2.1/Q050/Q060.

Accreditation Number: 2062 Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134492

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

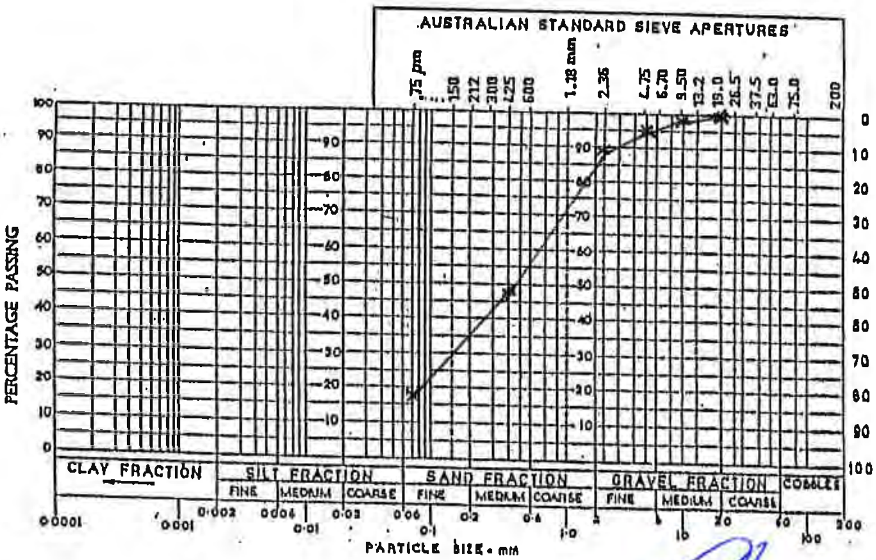
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: GREY SANDY CLAY **SAMPLE NO.:** 34316

SOURCE: BH-101 - 16.5m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	100
9.5	99
6.7	
4.75	95
2.36	89
1.18	
0.600	
0.425	48
0.300	
0.150	
0.075	17
0.0135	



PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven
Shrinkage mould **mm length.
Moisture content determined using AS1289.2 1 1/Q102A.
If Sampled by CMTS it is in accordance with AS1289 1 2 1/Q050/Q060

Authorised Signatory: Mark Rohdmann

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134494

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

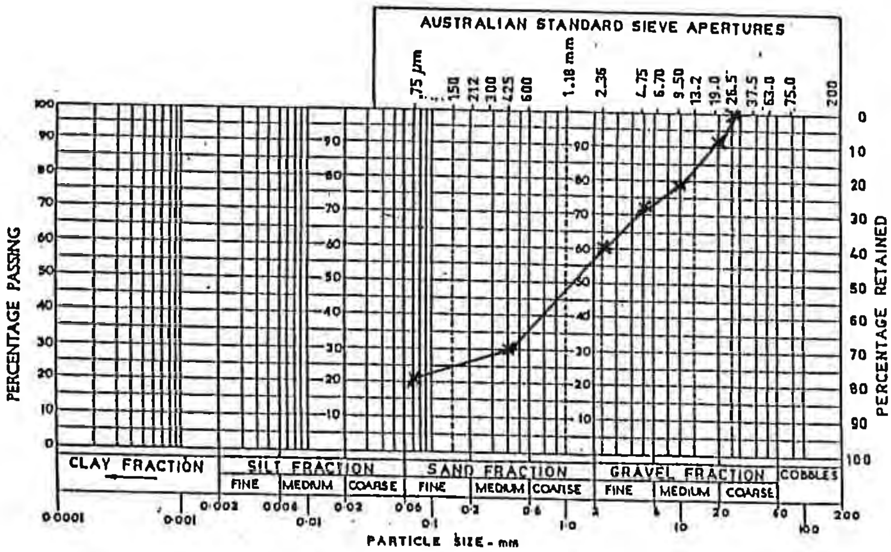
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: PALE GREY RED BROWN SANDY CLAY **SAMPLE NO.:** 34319

SOURCE: BH-102 - 19.5m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	100
19.0	91
9.5	79
6.7	
4.75	72
2.36	60
1.18	
0.600	
0.425	30
0.300	
0.150	
0.075	20
0.0135	



OTHER TESTS:

LIQUID LIMIT	40%	AS1289.3.1.2
PLASTIC LIMIT	16%	AS1289.3.2.1
PLASTICITY INDEX	24%	AS1289.3.3.1
LINEAR SHRINKAGE	11.5%	AS1289.3.4.1

PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven.
Shrinkage mould 125.0mm length.
Moisture content determined using AS1289 2 1 1/Q102A
If Sampled by CMTS it is in accordance with AS1289 1 2.1/Q050/Q060.

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134495

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

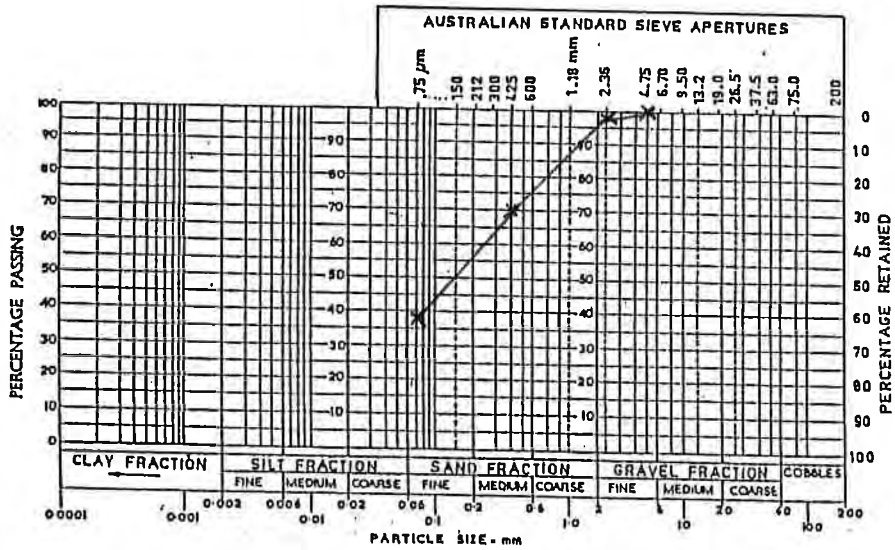
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: GREY CLAYEY SAND **SAMPLE NO.:** 34322

SOURCE: BH-103 - 15.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	100
2.36	99
1.18	
0.600	
0.425	70
0.300	
0.150	
0.075	38
0.0135	



OTHER TESTS:

LIQUID LIMIT	21%	AS1289.3.1.2
PLASTIC LIMIT	14%	AS1289.3.2.1
PLASTICITY INDEX	7%	AS1289.3.3.1
LINEAR SHRINKAGE	3.0%	AS1289.3.4.1

PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven.
Shrinkage mould 125 0mm length
Moisture content determined using AS1289.2.1.1/Q102A.
If Sampled by CMTS it is in accordance with AS1289 1.2.1/Q050/Q060

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134498

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

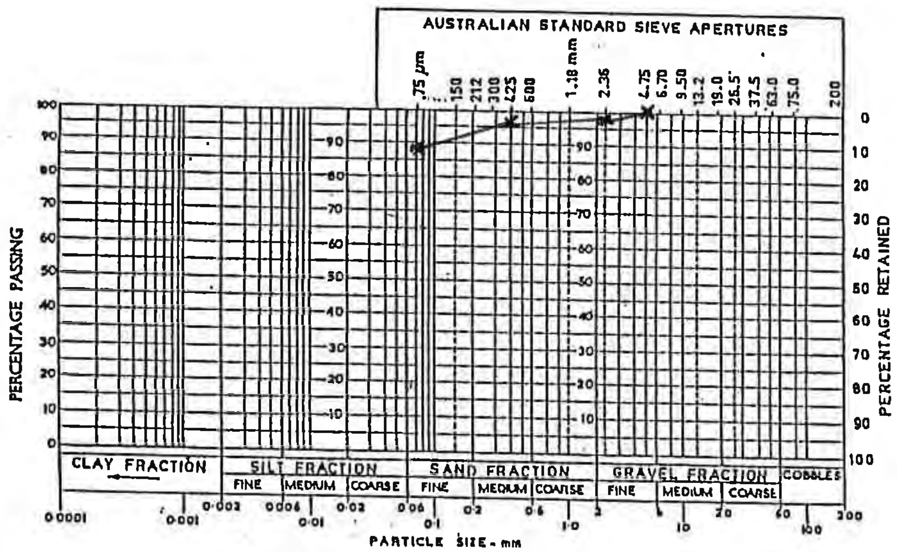
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: GREY BROWN SANDY CLAY **SAMPLE NO.:** 34326

SOURCE: BH-105 - 1.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	
6.7	
4.75	100
2.36	99
1.18	
0.600	
0.425	98
0.300	
0.150	
0.075	89
0.0135	



OTHER TESTS:

LIQUID LIMIT	35%	AS1289.3.1.2
PLASTIC LIMIT	19%	AS1289.3.2.1
PLASTICITY INDEX	16%	AS1289.3.3.1
LINEAR SHRINKAGE	8.5%	AS1289.3.4.1

PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven.
Shrinkage mould 125 0mm length.
Moisture content determined using AS1289.2.1 1/Q102A.
If Sempled by CMTS it is in accordence with AS1289 1 2 1/Q050/Q060

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Authorised Signatory: Mark Rohdmann

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134499

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

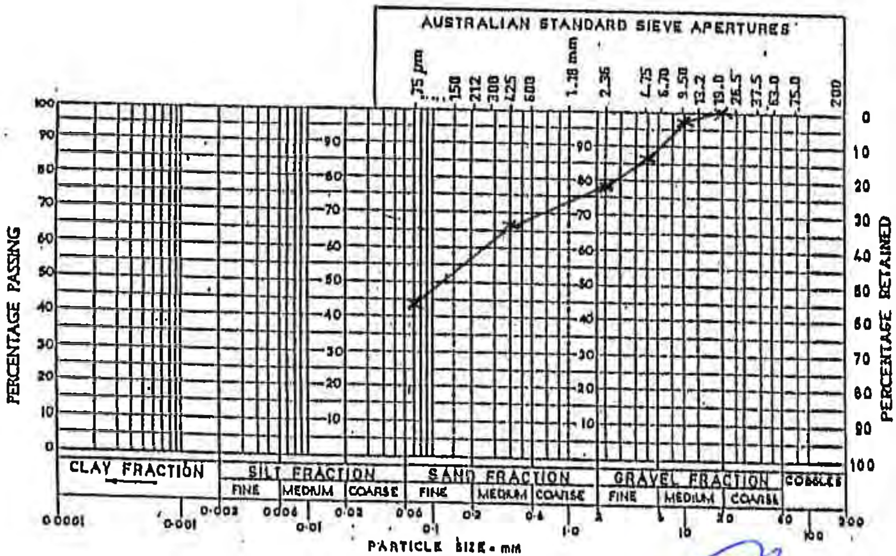
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: GREY BROWN CLAYEY SAND **SAMPLE NO.:** 34328

SOURCE: BH-106 - 1.5m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	100
9.5	98
6.7	
4.75	86
2.36	78
1.18	
0.600	
0.425	66
0.300	
0.150	
0.075	44
0.0135	



PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven
Shrinkage mould **mm length.
Moisture content determined using AS1289.2.1.1/Q102A
If Sampled by CMTS it is in accordance with AS1289.1.2 1/Q050/Q060

Authorised Signatory: Mark Rohdmann

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134500

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

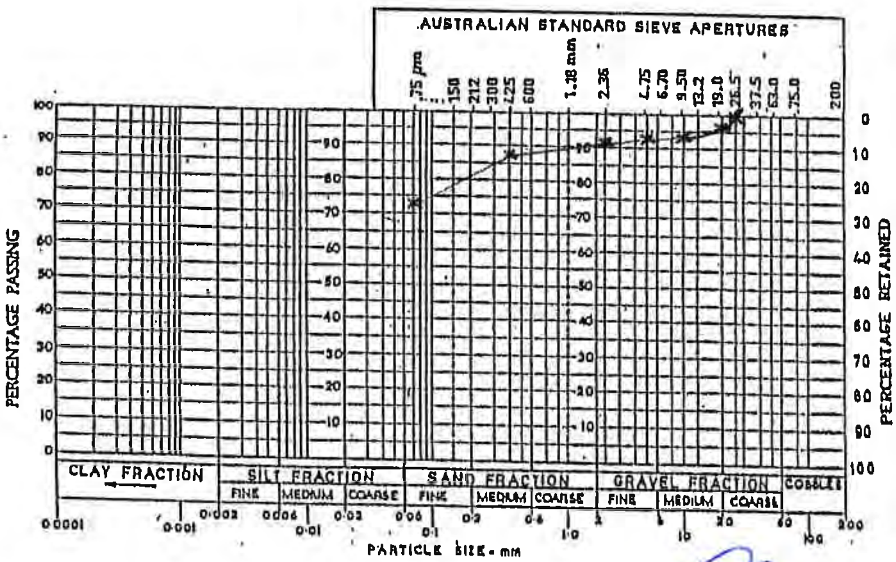
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: PALE GREY RED BROWN YELLOW BROWN CLAYEY SAND **SAMPLE NO.:** 34329

SOURCE: BH-106 - 3.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	100
19.0	96
9.5	94
6.7	
4.75	93
2.36	92
1.18	
0.600	
0.425	87
0.300	
0.150	
0.075	73
0.0135	



PSD samples oven dried 105-110° oven
ATT samples oven dried 50° oven.
Shrinkage mould **mm length.
Moisture content determined using AS1289.2.1.1/Q102A.
If Sampled by CMTS it is in accordance with AS1289 1 2 1/Q050/Q060.

Authorised Signatory: Mark Rohdmann

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

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Ph 07 4152 7644 Fax 07 4152 1405 Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134501

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

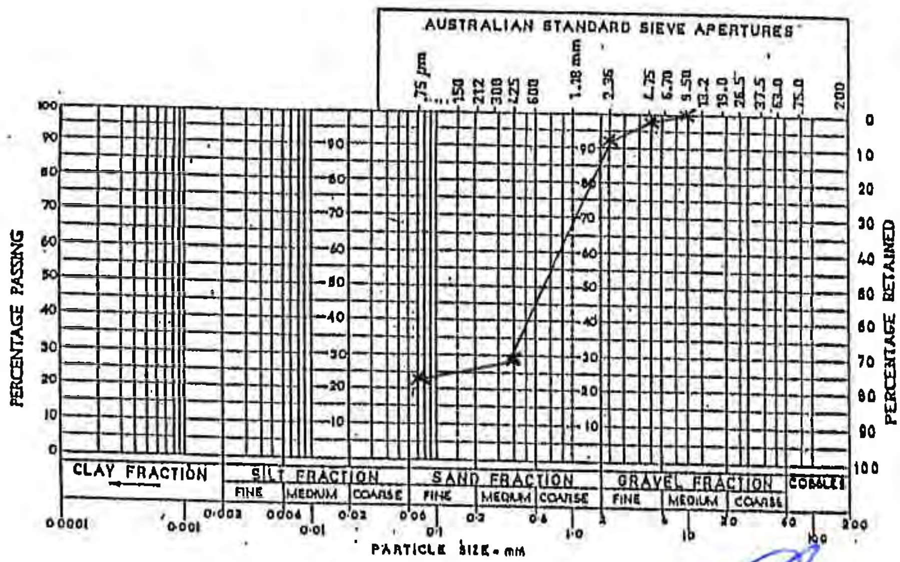
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: PALE GREY CLAYEY SAND **SAMPLE NO.:** 34332

SOURCE: BH-107 - 9.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	100
6.7	
4.75	99
2.36	93
1.18	
0.600	
0.425	29
0.300	
0.150	
0.075	22
0.0135	



PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven.
Shrinkage mould **mm length
Moisture content determined using AS1289.2.1.1/Q102A
If Sampled by CMTS it is in accordance with AS1289.1.2.1/Q050/Q060.

Authorised Signatory: Mark Rohdmann

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

C.M. Testing Service

MATERIALS TESTING LABORATORY
NATA Cert. No. 2062

PO Box 5421 West Bundaberg Qld 4670 2 Turner St Bundaberg Qld 4670
Ph 07 4152 7644 Fax 07 4152 1405 Email: mark@cmtesting.com.au

MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134502

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

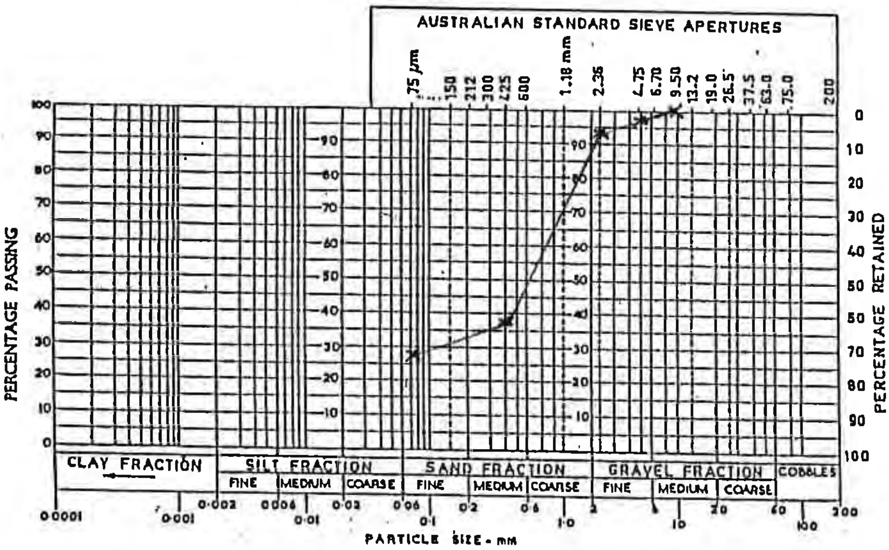
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: DARK GREY SANDY CLAY **SAMPLE NO.:** 34333

SOURCE: BH-107 - 10.5m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	100
6.7	
4.75	98
2.36	94
1.18	
0.600	
0.425	37
0.300	
0.150	
0.075	27
0.0135	



OTHER TESTS:

LIQUID LIMIT	56%	AS1289.3.1.2
PLASTIC LIMIT	17%	AS1289.3.2.1
PLASTICITY INDEX	39%	AS1289.3.3.1
LINEAR SHRINKAGE	13.0%	AS1289.3.4.1

PSD samples oven dried 105-110° oven
ATT samples oven dried 50° oven.
Shrinkage mould 125 0mm length.
Moisture content determined using AS1289.2.1.1/Q102A.
If Sampled by CMTS it is in accordance with AS1289 1 2 1/Q050/Q060.

Authorised Signatory: Mark Rohdmann

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134503

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

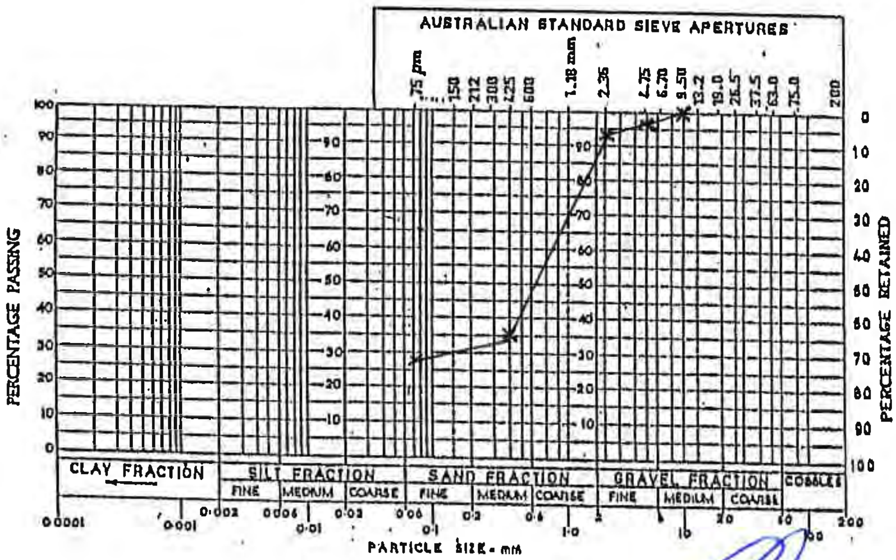
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: ORANGE BROWN CLAYEY SAND **SAMPLE NO.:** 34334

SOURCE: BH-107 - 15.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	100
6.7	
4.75	98
2.36	93
1.18	
0.600	
0.425	35
0.300	
0.150	
0.075	28
0.0135	



PSD samples oven dried 105-110° oven
ATT samples oven dried 50° oven.
Shrinkage mould **mm length
Moisture content determined using AS1289 2 1 1/Q102A
If Sampled by CMTS it is in accordance with AS1289.1.2 1/Q050/Q060

Authorised Signatory: Mark Rohdmann

Accreditation Number: 2062
Accredited for compliance with
ISO/IEC 17025 - Testing

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134504

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

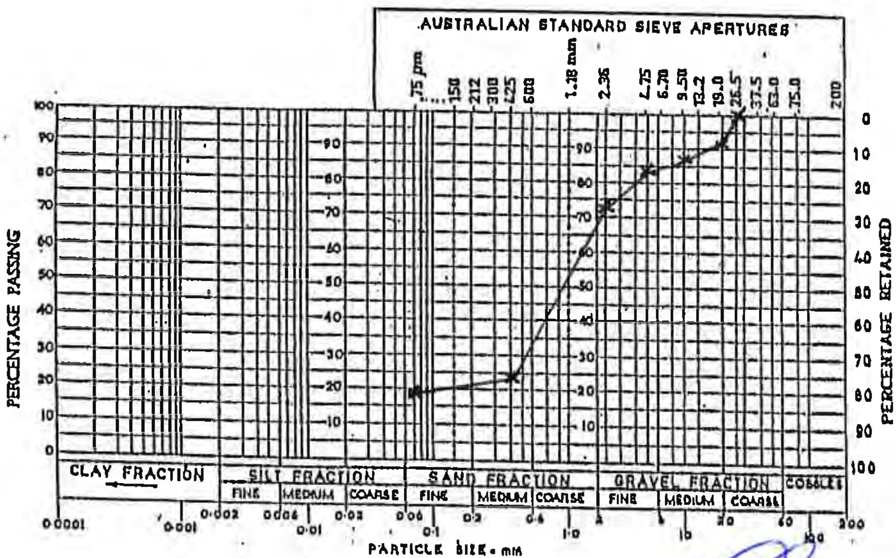
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: PALE GREY GRAVEL **SAMPLE NO.:** 34335

SOURCE: BH-107 - 18.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	100
19.0	91
9.5	88
6.7	
4.75	84
2.36	73
1.18	
0.600	
0.425	24
0.300	
0.150	
0.075	19
0.0135	



PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven
Shrinkage mould **mm length.
Moisture content determined using AS1289.2.1.1/Q102A.
If Sampled by CMTS it is in accordence with AS1289 1 2 1/Q050/Q060

Authorised Signatory: Mark Rohdmann

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134505

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

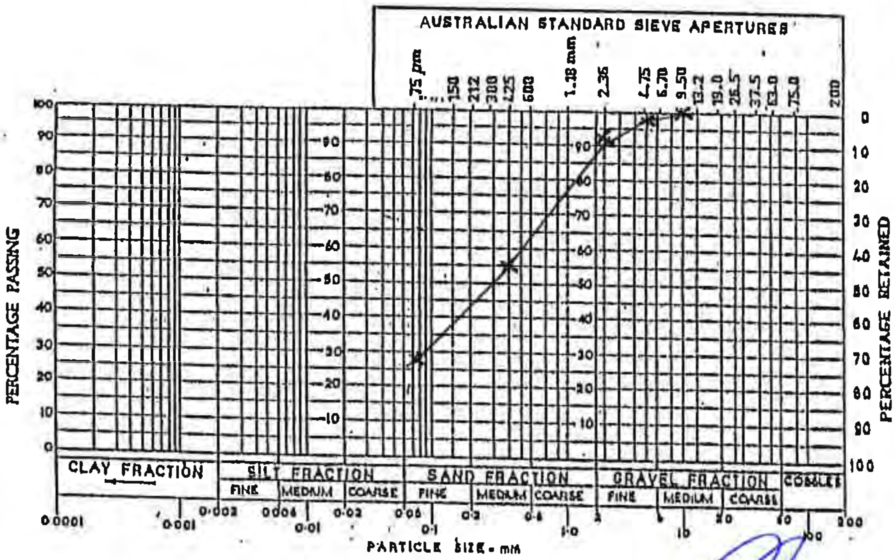
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: GREY CLAYEY SAND **SAMPLE NO.:** 34338

SOURCE: BH-108 - 10.5m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	
9.5	100
6.7	
4.75	98
2.36	92
1.18	
0.600	
0.425	55
0.300	
0.150	
0.075	28
0.0135	



PSD samples oven dried 105-110° oven
ATT samples oven dried 50° oven.
Shrinkage mould **mm length
Moisture content determined using AS1289.2 1 1/Q102A
If Sampled by CMTS it is in accordance with AS1289.1.2 1/Q050/Q060

Authorised Signatory: Mark Rohdmann

Accreditation Number: 2062
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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134506

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

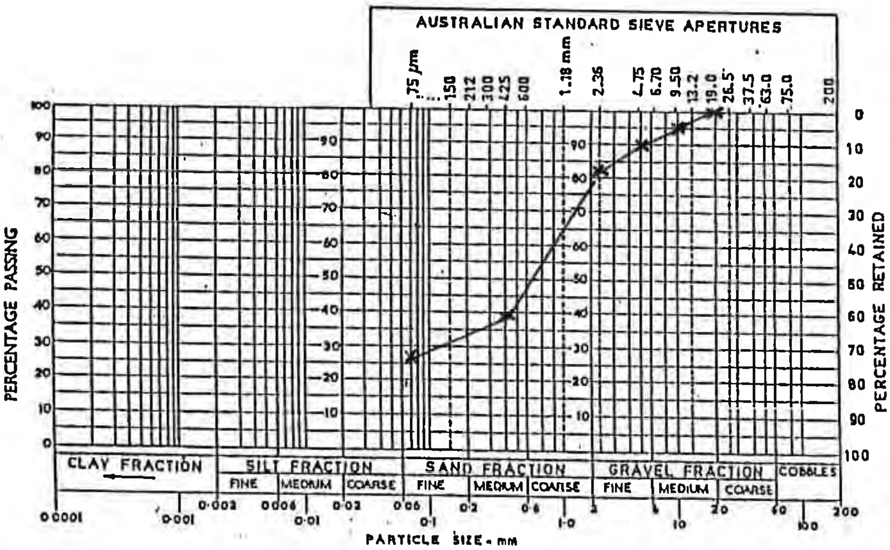
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: BLUE GREEN DARK BROWN SANDY CLAY **SAMPLE NO.:** 34339

SOURCE: BH-108 - 12.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	
19.0	100
9.5	95
6.7	
4.75	90
2.36	82
1.18	
0.600	
0.425	39
0.300	
0.150	
0.075	26
0.0135	



OTHER TESTS:

LIQUID LIMIT	37%	AS1289.3.1.2
PLASTIC LIMIT	18%	AS1289.3.2.1
PLASTICITY INDEX	19%	AS1289.3.3.1
LINEAR SHRINKAGE	7.5%	AS1289.3.4.1

PSD samples oven dried 105-110° oven.
ATT samples oven dried 50° oven
Shrinkage mould 125 0mm length.
Moisture content determined using AS1289.2 1.1/Q102A
If Sampled by CMTS it is in accordance with AS1289.1 2.1/Q050/Q060.

Authorised Signatory: Mark Rohdmann

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

ROHD FOUR PTY LTD ACN 103228726 ABN 34103228726 T/A

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MATERIAL PROPERTIES CERTIFICATE

CLIENT: CDM SMITH AUSTRALIA PTY LTD - FORTITUDE VALLEY **CERTIFICATE NUMBER:** C134507

PROJECT: EAST BUNDABERG FLOOD LEVEE INVESTIGATIONS - STAGE 2 **JOB NUMBER:** BC13130

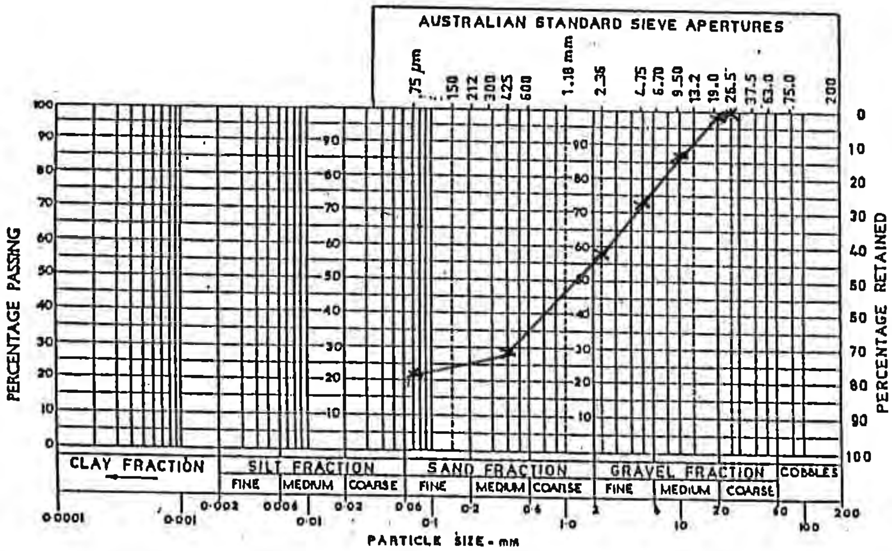
DATE ISSUED: 20/12/18 **DATE SAMPLED:** 12/11/18 BY CLIENT

MATERIAL: PALE GREY BROWN GRAVEL **SAMPLE NO.:** 34340

SOURCE: BH-108 - 18.0m

PARTICLE SIZE DISTRIBUTION TEST METHOD AS1289.3.6.1

SIEVE SIZE (mm)	PERCENT PASSING
75	
53	
37.5	
26.5	100
19.0	97
9.5	86
6.7	
4.75	73
2.36	58
1.18	
0.600	
0.425	29
0.300	
0.150	
0.075	21
0.0135	



PSD samples oven dried 105-110° oven
ATT samples oven dried 50° oven
Shrinkage mould **mm length.
Moisture content determined using AS1289.2.1.1/Q102A
If Sampled by CMTS it is in accordance with AS1289.1.2.1/Q050/Q060.

Authorised Signatory: Mark Rohdmann

Accreditation Number: 2062
Accredited for compliance with ISO/IEC 17025 - Testing

Attachment B2

Trilab Geotechnical Laboratory Test Results

Trilab
Soil Rock Calibration

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	CM Testing Service Pty Ltd	**Report No.**	18120392-G
		Workorder No.	5299
Address	PO Box 5421 BUNDABERG QLD 4670	**Report Date**	09/01/2019
Project	BC-13130		

Sample No.	18120392	18120393	18120394	18120395	18120396		
Test Date	4/01/2019	9/01/2019	4/01/2019	9/01/2019	4/01/2019		
Client ID	34315 - BH101	34317 - BH102	34321 - BH103	34325 - BH104	34336 - BH108		
Depth (m)	12.0-12.4	4.50-4.90	3.00-3.40	6.00-6.50	3.00-3.45		
Moisture (%)	52.2	26.0	25.6	34.5	25.9		
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75							
2.36							
1.18		100					
0.600		99		100	100		
0.425	100	98		99	99		
0.300	99	97	100	99	98		
0.150	98	94	99	98	97		
0.075	90	82	96	93	94		

NOTES/REMARKS:

Sample/s supplied by the client

Trilab
Soil Rock Calibration

Brisbane
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Geebung
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2 Kimmer Place,
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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	CM Testing Service Pty Ltd	**Report No.**	18120392-AL
		Workorder No.	0005299
Address	PO Box 5421 BUNDABERG QLD 4670	**Report Date**	10/01/2019
Project	BC-13130		

Sample No.	18120392	18120393	18120394	18120395	18120396	
Test Date	19/12/2018	8/01/2019	19/12/2018	8/01/2019	19/12/2018	
Client ID	34315 - BH101	34317 - BH102	34321 - BH103	34325 - BH104	34336 - BH108	
Depth (m)	12.0-12.4	4.50-4.90	3.00-3.40	6.00-6.50	3.00-3.45	
Liquid Limit (%)	70	39	37	59	46	
Plastic Limit (%)	24	16	18	16	21	
Plasticity Index (%)	46	23	19	43	25	
Linear Shrinkage (%)	18.0 +	11.0 +	11.0 +	15.0 +	12.5 +	
Moisture Content (%)	52.2	26.0	25.6	34.5	25.9	

Sample No.						
Test Date						
Client ID						
Depth (m)						
Liquid Limit (%)						
Plastic Limit (%)						
Plasticity Index (%)						
Linear Shrinkage (%)						
Moisture Content (%)						

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Park

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

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EMERSON CLASS NUMBER TEST REPORT

Test Method: AS 1289 3.8.1

Client	CM Testing Service Pty Ltd	**Report No.**	18120394-EM
		Workorder No.	5299
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	07/01/2019
		Report Date	09/01/2019
Project	BC-13130		

Sample No.	18120394	18120396	-	-	-	-	-
Client ID	34321 - BH103	34336 - BH108	-	-	-	-	-
Depth (m)	3.00-3.40	3.00-3.45	-	-	-	-	-
Description	Silty CLAY - dark brown	Silty CLAY - dark brown/grey	-	-	-	-	-
Emerson Class Number	**3**	**3**	**-**	**-**	**-**	**-**	**-**

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	**-**	**-**	**-**	**-**	**-**	**-**	**-**

NOTES/REMARKS:

Sample/s supplied by the client   Tested with Distilled water at 22°C

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Authorised Signatory

C. Park

Tested at Trilab Brisbane Laboratory

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

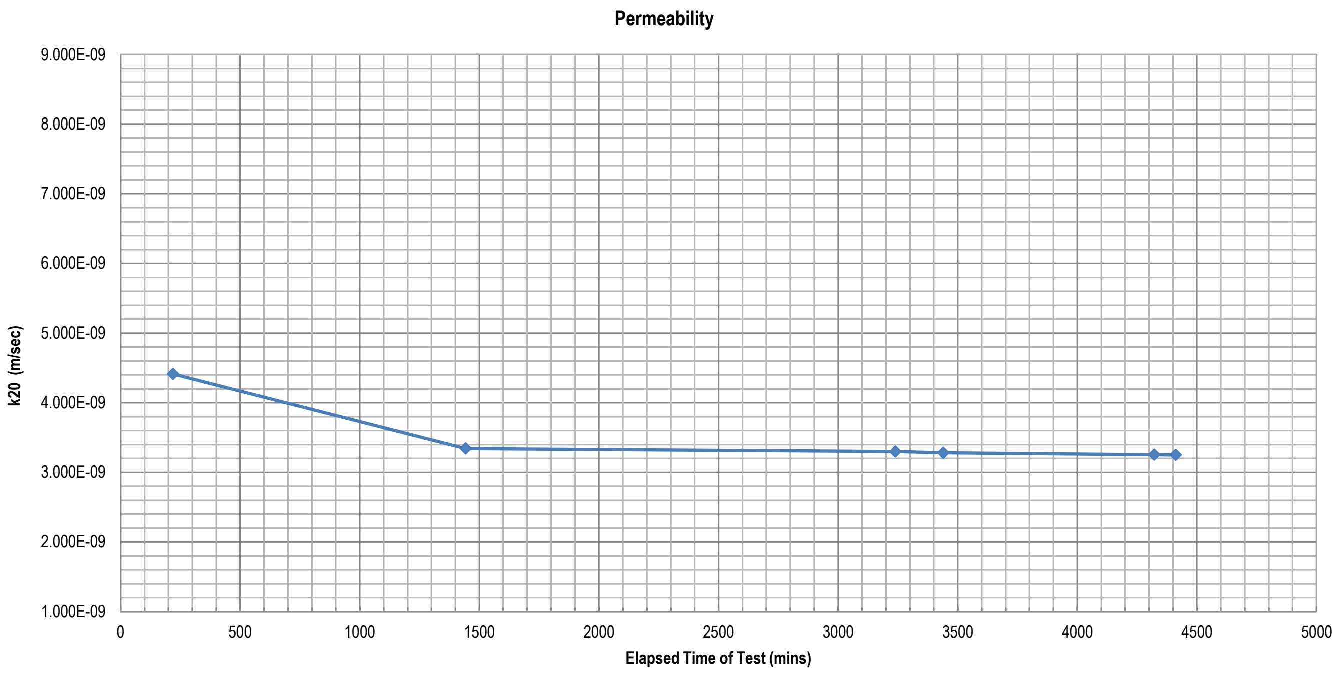
Test Method AS 1289 6.7.3

Client	CM Testing Service Pty Ltd	**Report No.**	18120393-CHP
		Workorder No.	0005299
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	7/01/2019
		Report Date	15/01/2019
Project	BC-13130		
Client ID	34317 - BH102	**Depth (m)**	4.50-4.90
Description	SANDY SILTY CLAY - brown/grey/orange	**Sample Type**	Undisturbed Soil Specimen.

RESULTS OF TESTING

Dry Density (t/m^3)	**1.58**	Confining Pressure (kPa)	**525**
Received Wet Density (t/m^3)	**1.99**	Inlet Pressure / Outlet Pressure (kPa)	**450 / 400**
Received Moisture Content (%)	**26.0**	Mean Effective Stress (kPa)	**100**
Sample Height and Diameter (mm)	**92 / 47.2 mm**	Water Type	**De-Ionized**

PERMEABILITY $k_{(20)} = 3.2 \times 10^{-09}$ **(m/sec)**



Remarks:

Sample/s supplied by client | Tested as received | **Page: 1 of 1** | REP06601

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

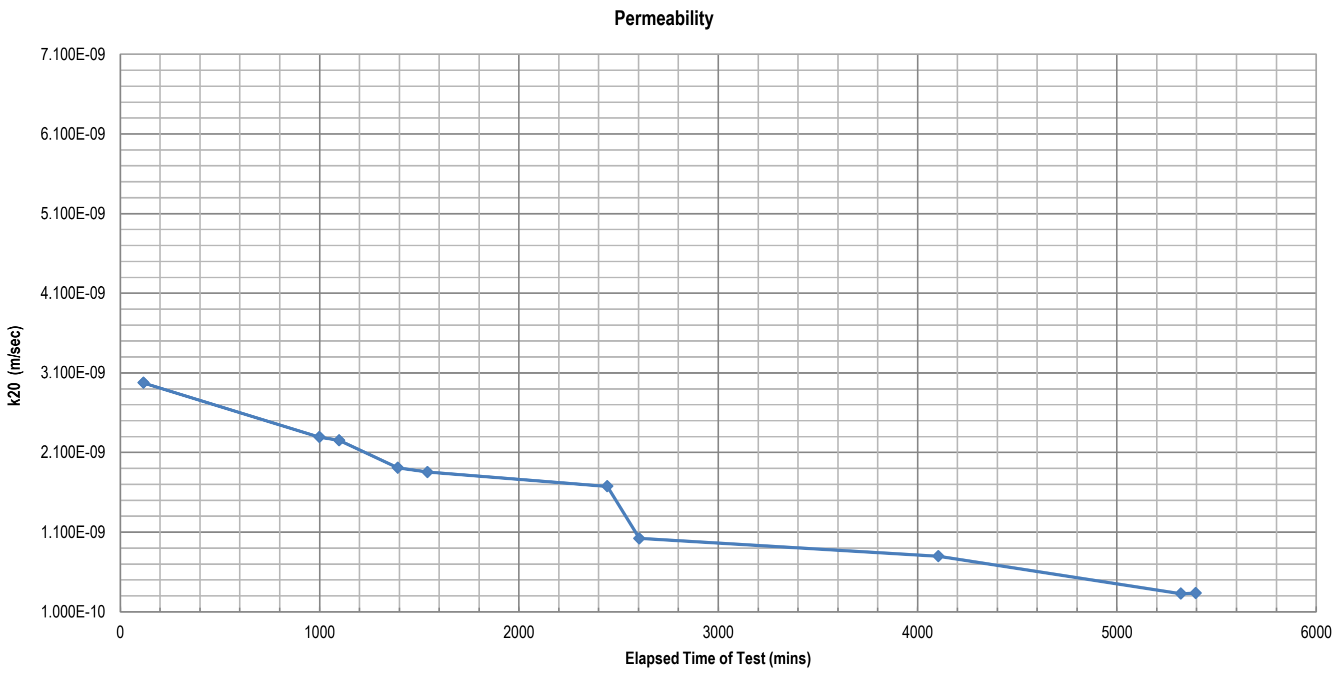
Test Method AS 1289 6.7.3

Client	CM Testing Service Pty Ltd	**Report No.**	18120395-CHP
		Workorder No.	0005299
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	15/01/2019
		Report Date	21/01/2019
Project	BC-13130		
Client ID	34325 - BH104	**Depth (m)**	6.00-6.50
Description	SILTY CLAY - dark grey	**Sample Type**	Undisturbed Soil Specimen.

RESULTS OF TESTING

Dry Density (t/m^3)	**1.37**	Confining Pressure (kPa)	**525**
Received Wet Density (t/m^3)	**1.85**	Inlet Pressure / Outlet Pressure (kPa)	**450 / 400**
Received Moisture Content (%)	**34.5**	Mean Effective Stress (kPa)	**100**
Sample Height and Diameter (mm)	**83.8 / 47 mm**	Water Type	**De-Ionized**

PERMEABILITY $k_{(20)} = 3.3 \times 10^{-10}$ **(m/sec)**



Remarks:

Sample/s supplied by client   Tested as received   **Page: 1 of 1**   REP06601

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

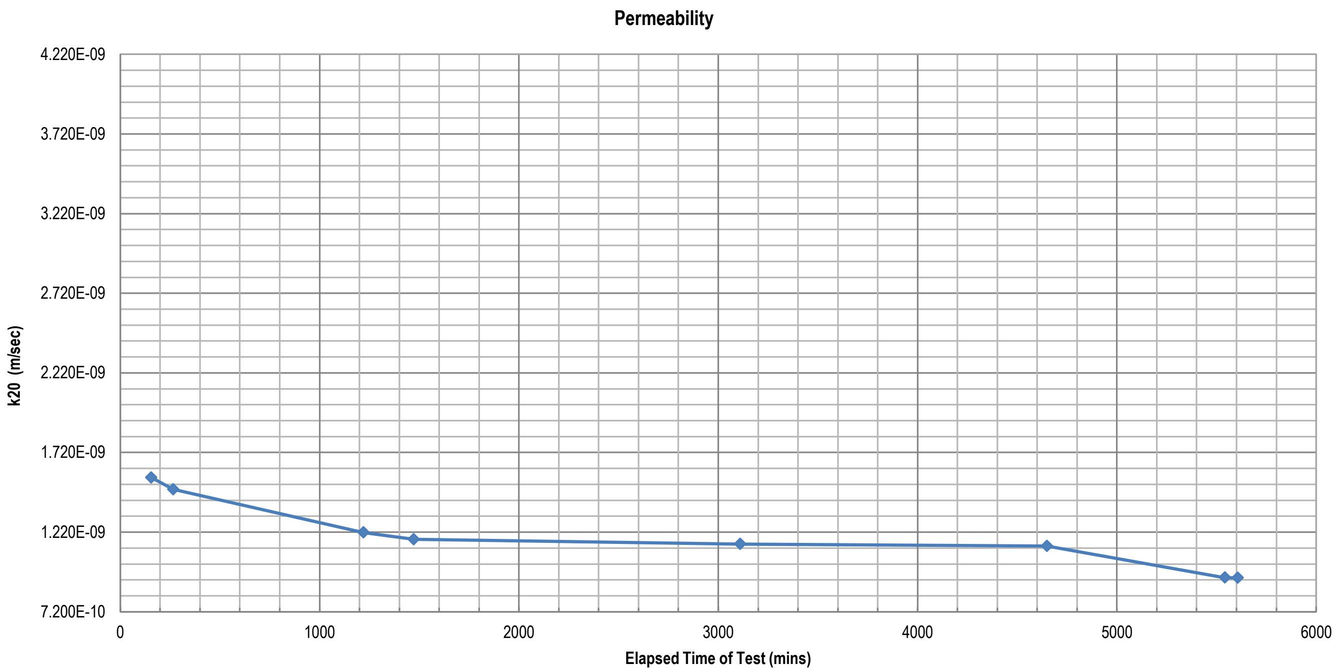
Test Method AS 1289 6.7.3

Client	CM Testing Service Pty Ltd	**Report No.**	18120396-CHP
		Workorder No.	0005299
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date**	20/12/2019
		Report Date	7/01/2019
Project	BC-13130		
Client ID	34336 - BH108	**Depth (m)**	3.00-3.45
Description	CLAY - dark brown	**Sample Type**	Undisturbed Soil Specimen.

RESULTS OF TESTING

Dry Density (t/m^3)	**1.57**	Confining Pressure (kPa)	**525**
Received Wet Density (t/m^3)	**1.98**	Inlet Pressure / Outlet Pressure (kPa)	**450 / 400**
Received Moisture Content (%)	**25.9**	Mean Effective Stress (kPa)	**100**
Sample Height and Diameter (mm)	**54.9 / 46.8 mm**	Water Type	**De-Ionized**

PERMEABILITY $k_{(20)}$ = 9.3×10^{-10} (m/sec)



Remarks:

Sample/s supplied by client | Tested as received | **Page: 1 of 1** | REP06601

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18120392 - CU
		Workorder No.	0005299
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	2/01/2019
		Report Date:	11/01/2019
Project:	BC-13130		
Client Id.:	34315 - BH101	**Depth (m):**	12.0-12.4
Description:	SILTY CLAY - grey		

SAMPLE & TEST DETAILS

Initial Height:	102.5	mm	Initial Moisture Content:	52.2	%	Rate of Strain:	0.005	%/min
Initial Diameter:	47.6	mm	Final Moisture Content:	47.9	%	B Response:	99	%
L/D Ratio:	2.2 : 1		Wet Density:	1.66	t/m^3			
			Dry Density:	1.09	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
92 kPa	591 kPa	499 kPa	499 kPa	548 kPa	150 kPa	43 kPa	3.479	107 kPa	2.04 %
140 kPa	641 kPa	501 kPa	501 kPa	572 kPa	194 kPa	69 kPa	2.813	125 kPa	3.46 %
211 kPa	712 kPa	501 kPa	501 kPa	604 kPa	255 kPa	108 kPa	2.359	147 kPa	5.99 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**29.1**	**34.8**	**32.0**
Angle of Shear Resistance Φ' (Degrees) :	**15.2**	**12.5**	**13.6**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

REP03001

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Authorised Signatory

T. Lockhart

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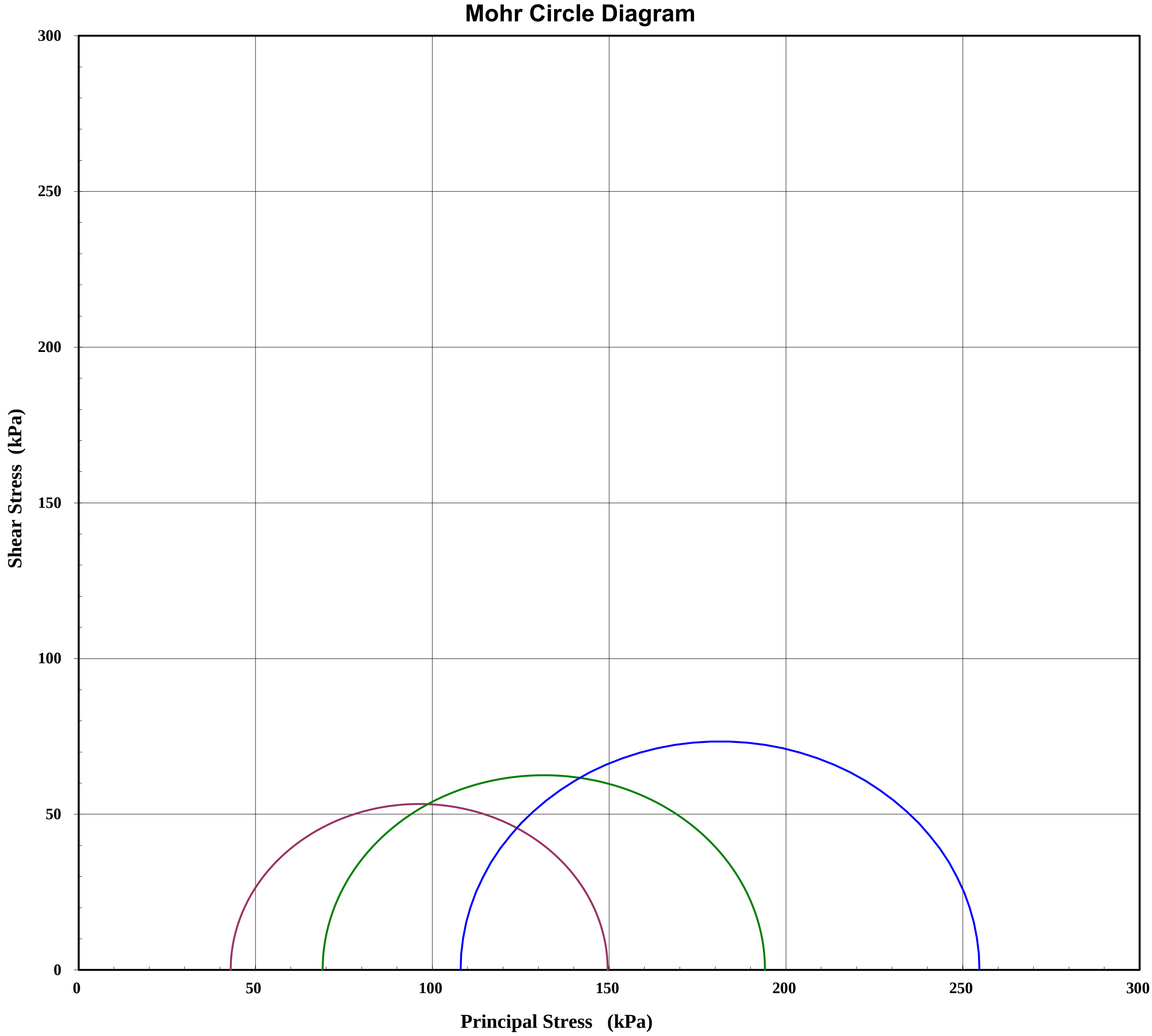
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120392 - CU

Mohr Circle Diagram



Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**29.1**	**34.8**	**32.0**
Angle of Shear Resistance Φ' (Degrees) :	**15.2**	**12.5**	**13.6**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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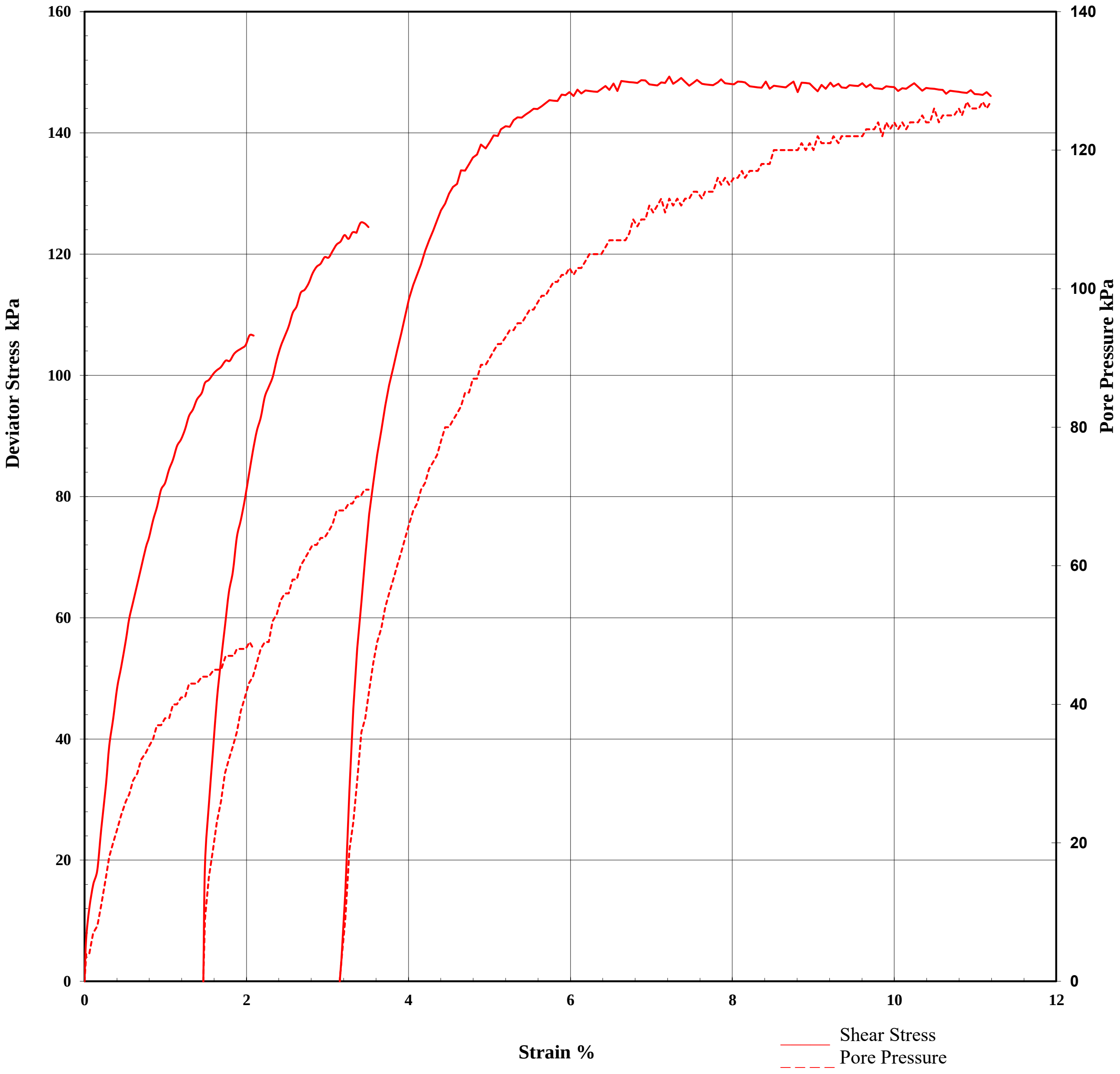
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120392 - CU

Stress/Strain & Pore Pressure/Strain Diagram



Remarks: Tested as Received

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Note: Graph not to scale

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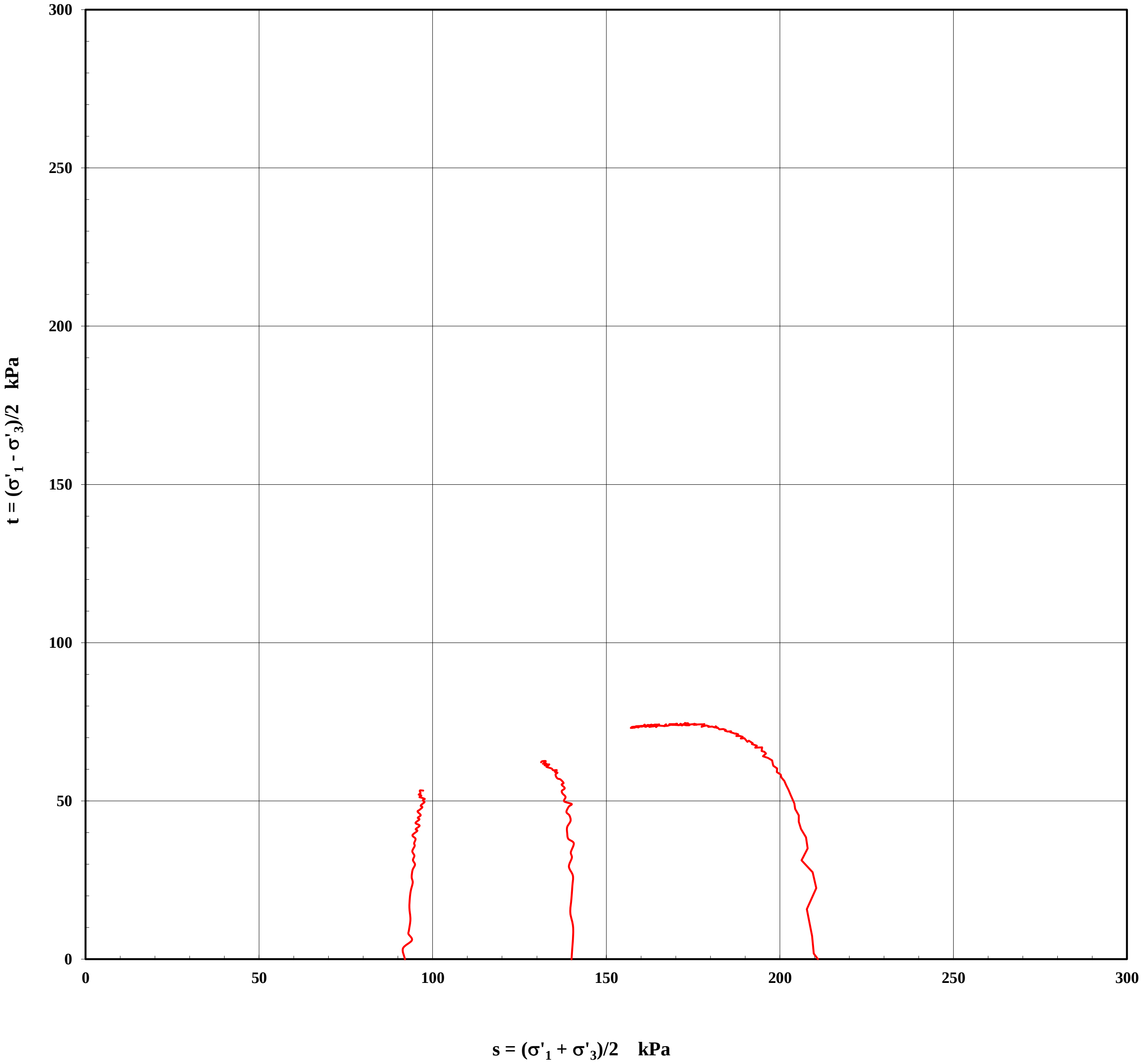
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120392 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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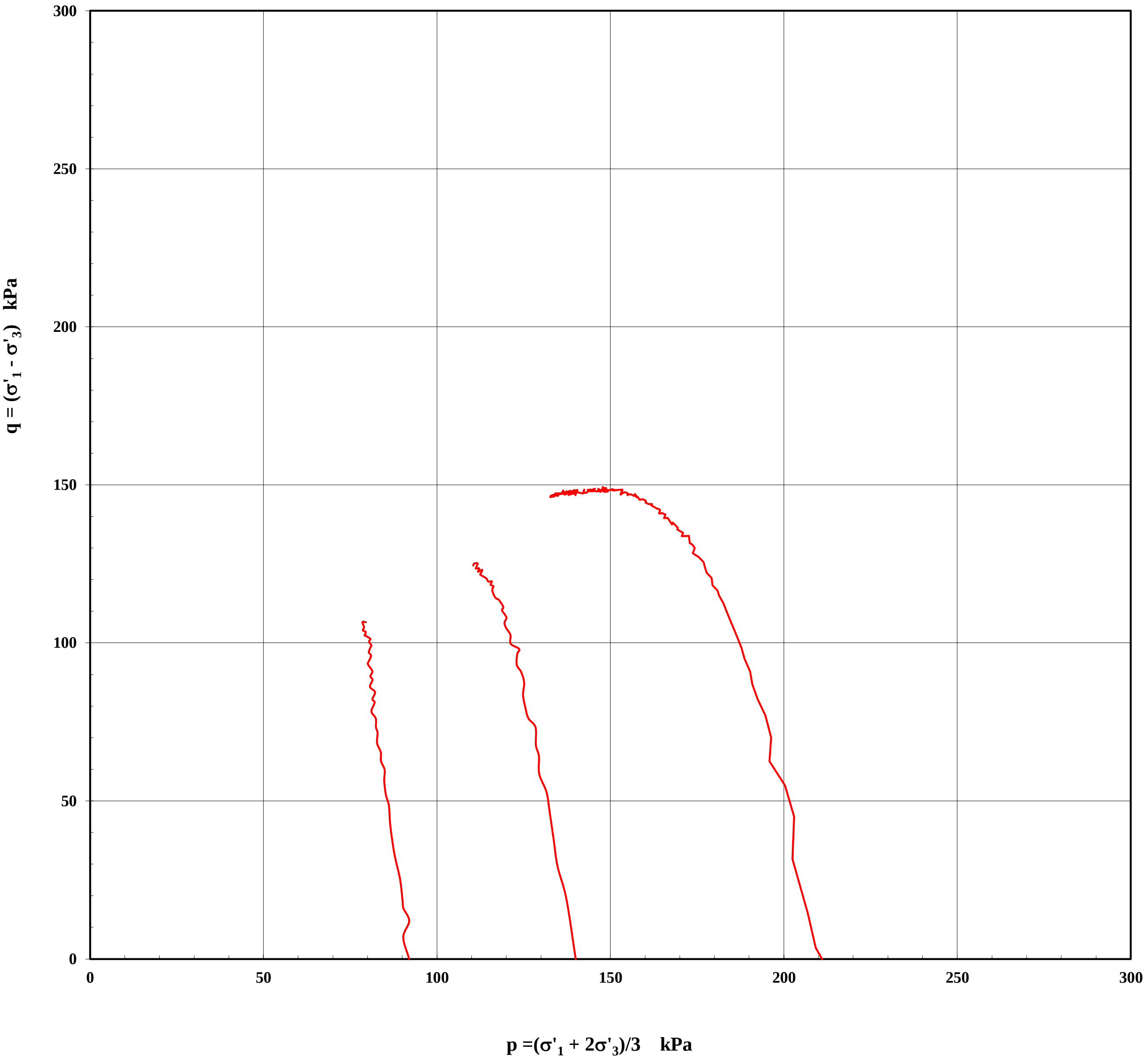
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120392 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120392 - CU

Remarks: Tested as Received

Sample/s supplied by the client

Note: Photo not to scale

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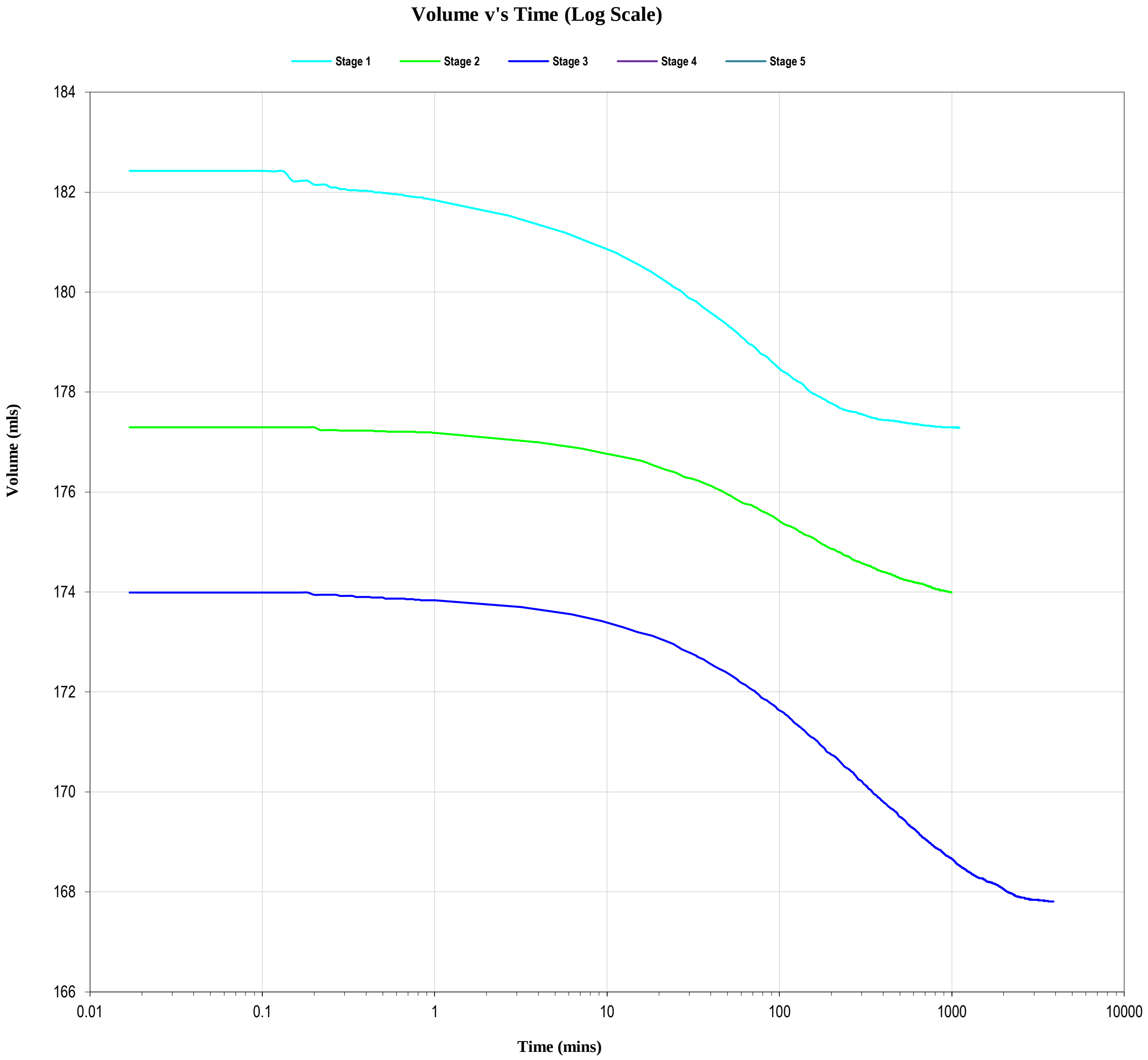
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120392 - CU



	Stage 1	Stage 2	Stage 3
Cv (m^2/year) **:**	**0.20**	**0.25**	**0.05**
Mv (m^2/MN) **:**	**0.291**	**0.311**	**0.377**
k (m/s) **:**	**1.76E-11**	**2.44E-11**	**5.54E-12**

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	CM Testing Service Pty Ltd	**Report No.:**	18120396 - CU
		Workorder No.	0005299
Address	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	2/01/2019
		Report Date:	11/01/2019
Project:	BC-13130		
Client Id.:	34336 - BH108	**Depth (m):**	3.00-3.45
Description:	SILTY CLAY - dark grey/brown		

SAMPLE & TEST DETAILS

Initial Height:	101.9	mm	Initial Moisture Content:	25.9	%	Rate of Strain:	0.005	%/min
Initial Diameter:	46.6	mm	Final Moisture Content:	27.3	%	B Response:	98	%
L/D Ratio:	2.2 : 1		Wet Density:	1.97	t/m^3			
			Dry Density:	1.56	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
38 kPa	539 kPa	501 kPa	501 kPa	518 kPa	81 kPa	21 kPa	3.843	60 kPa	1.55 %
57 kPa	559 kPa	502 kPa	502 kPa	524 kPa	117 kPa	35 kPa	3.335	82 kPa	2.19 %
88 kPa	588 kPa	500 kPa	500 kPa	535 kPa	173 kPa	53 kPa	3.262	120 kPa	3.17 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**8.3**	**2.1**	**5.3**
Angle of Shear Resistance Φ' (Degrees) :	**26.1**	**31.0**	**29.1**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

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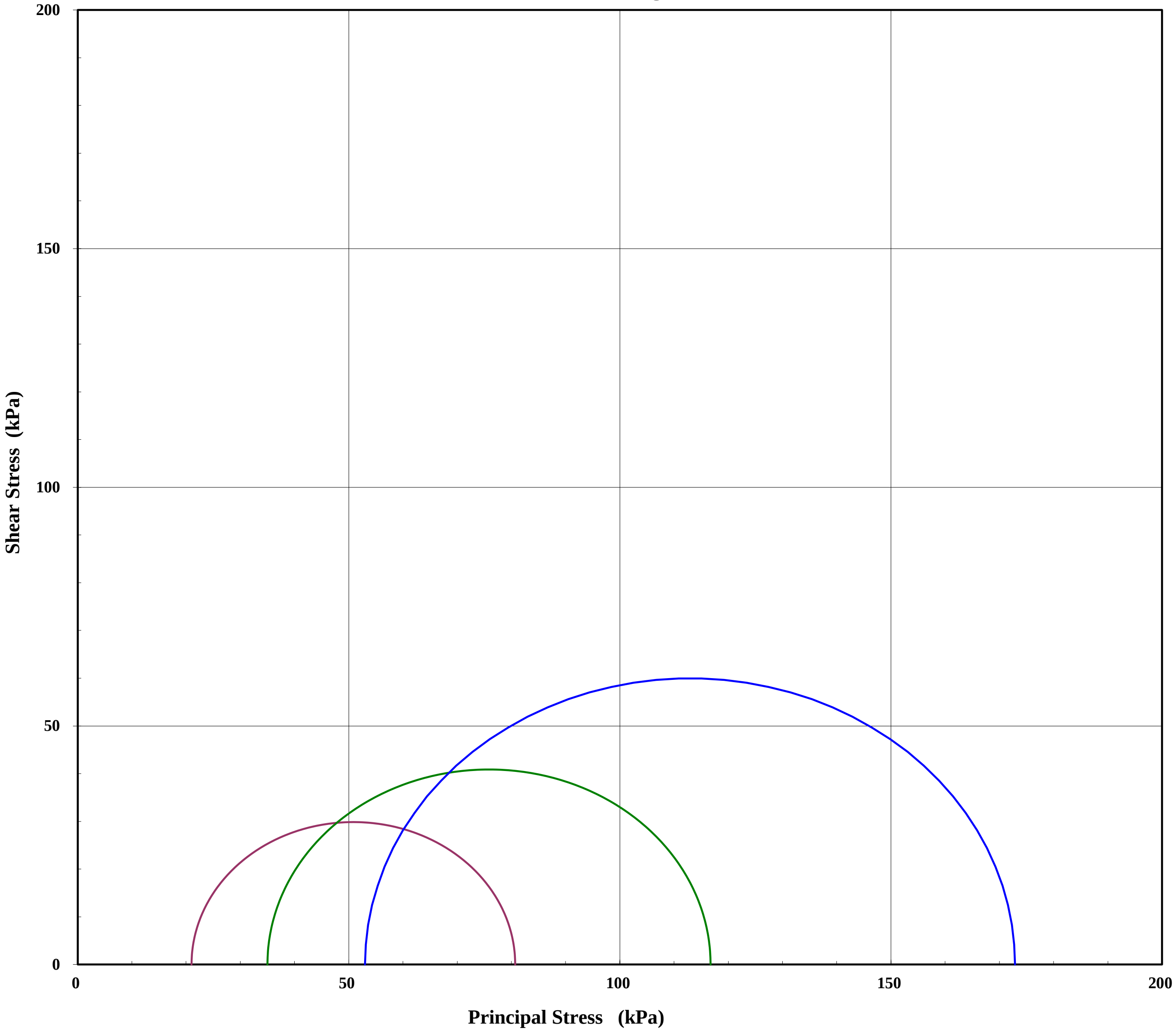
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120396 - CU

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	8.3	2.1	5.3
Angle of Shear Resistance Φ' (Degrees) :	26.1	31.0	29.1
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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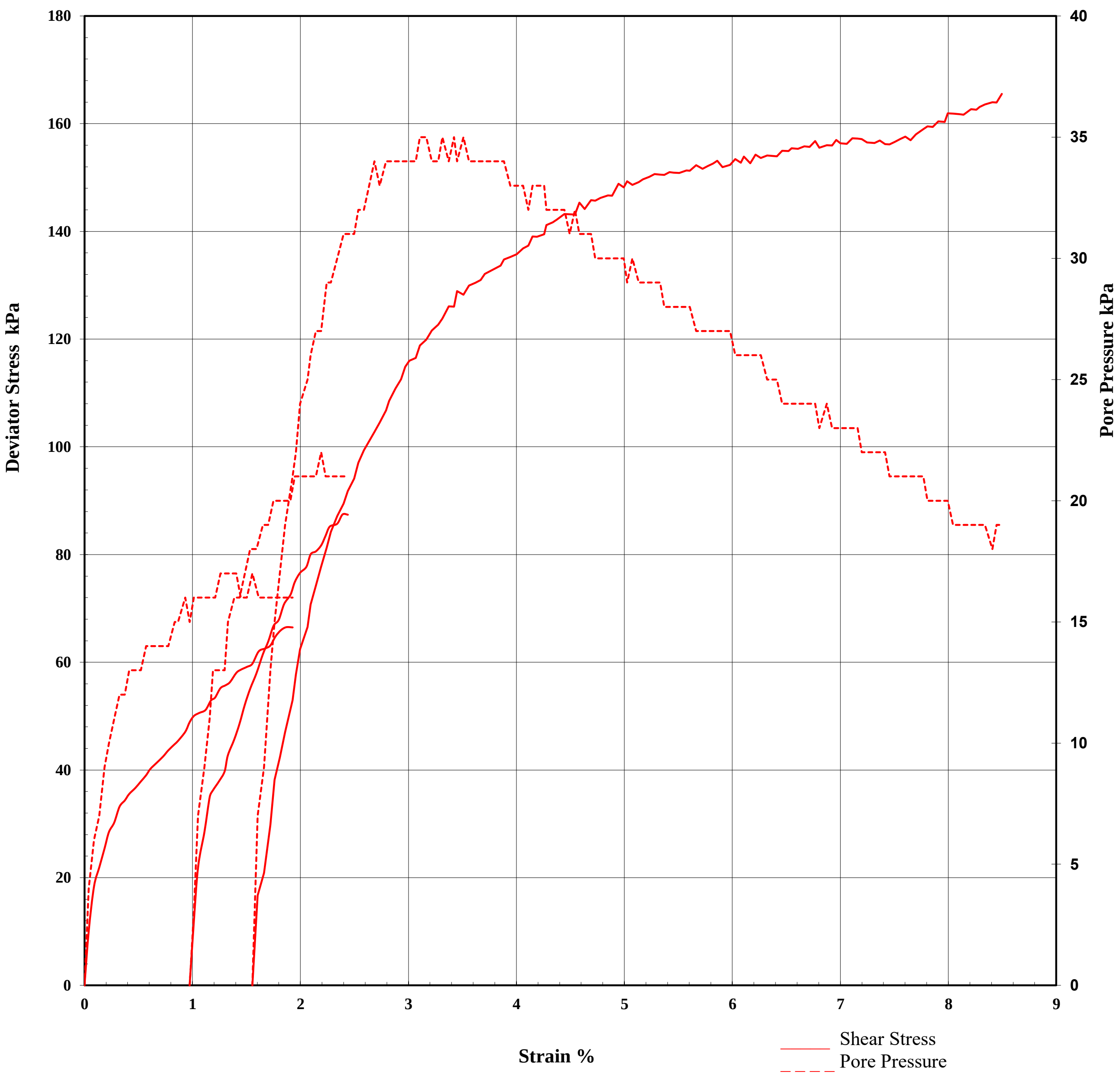
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120396 - CU

Stress/Strain & Pore Pressure/Strain Diagram



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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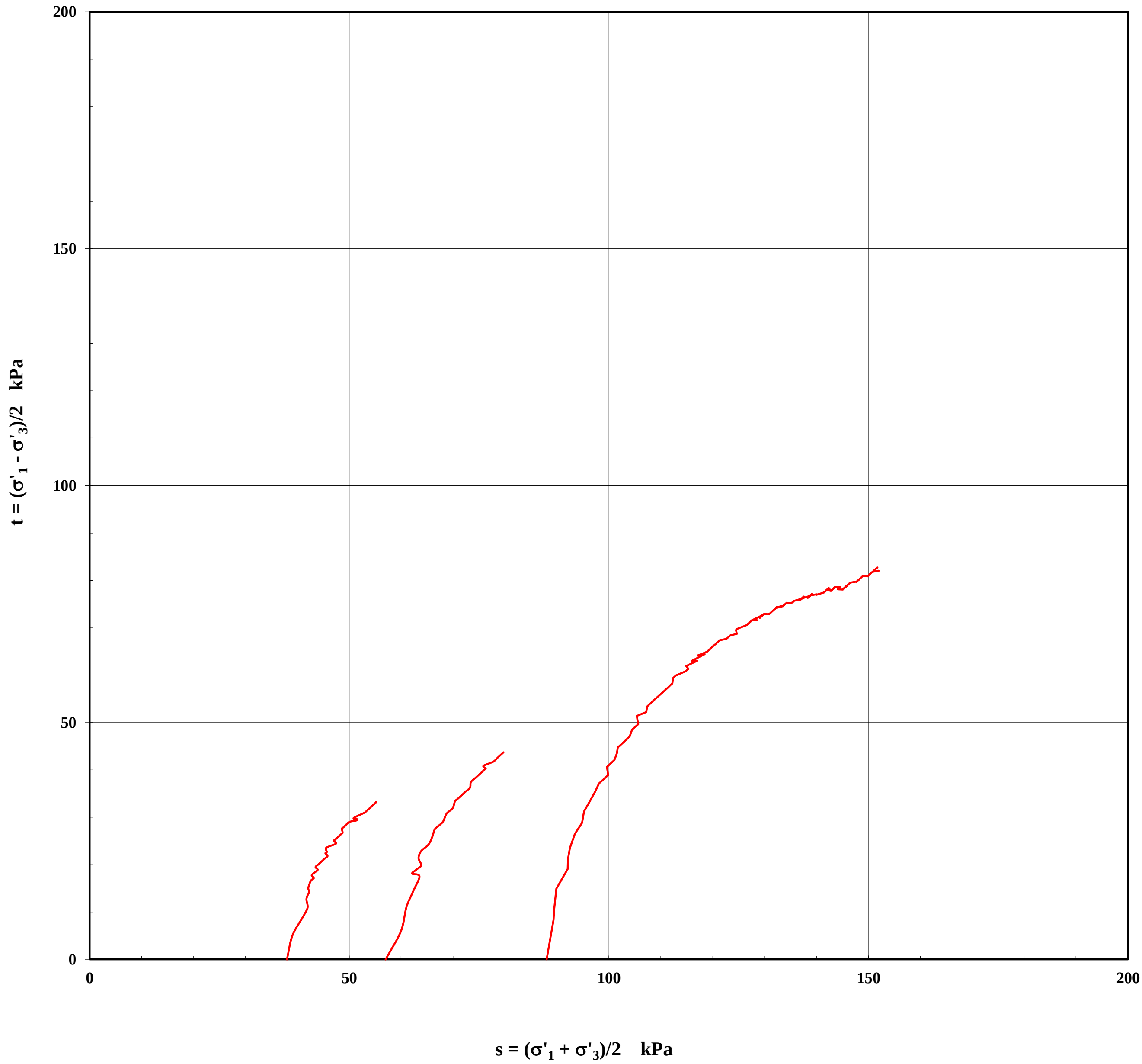
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120396 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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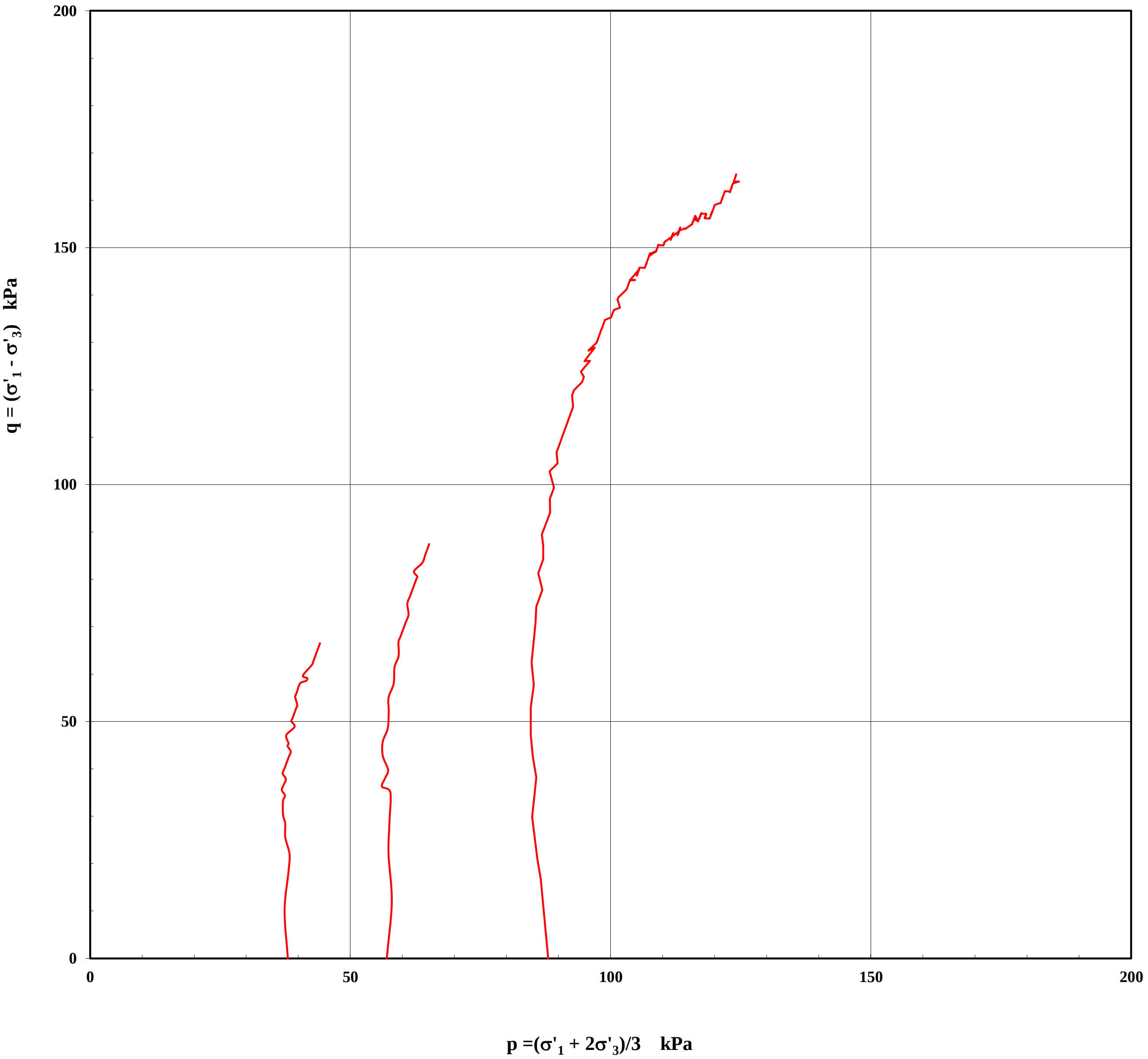
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120396 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd	**Report No.:** 18120396 - CU

Remarks: Tested as Received

Sample/s supplied by the client

Note: Photo not to scale

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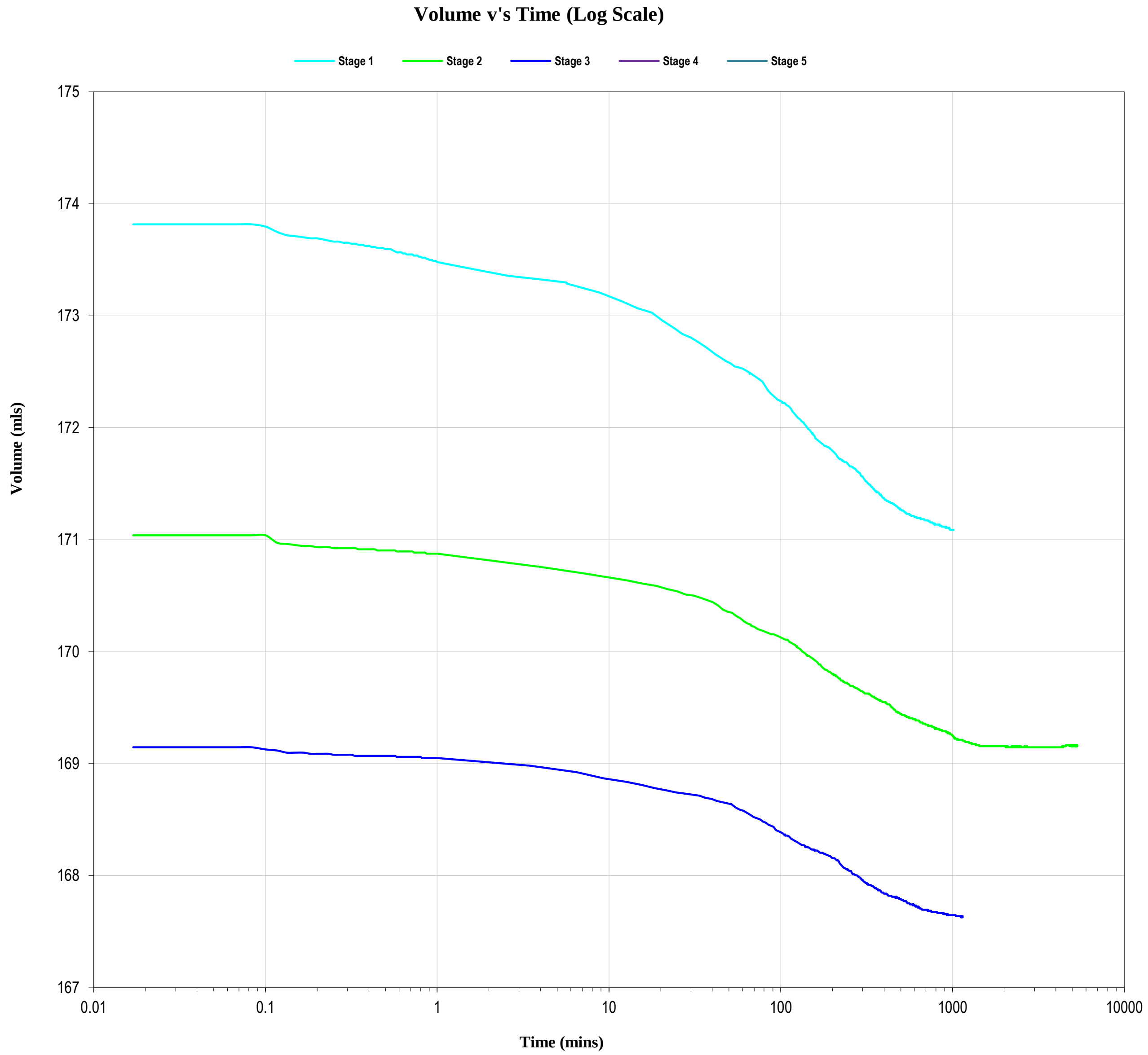
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: CM Testing Service Pty Ltd

Report No.: 18120396 - CU



	Stage 1	Stage 2	Stage 3
Cv (m^2/year) **:**	0.10	0.09	0.15
Mv (m^2/MN) **:**	0.380	0.467	0.398
k (m/s) **:**	1.13E-11	1.33E-11	1.79E-11

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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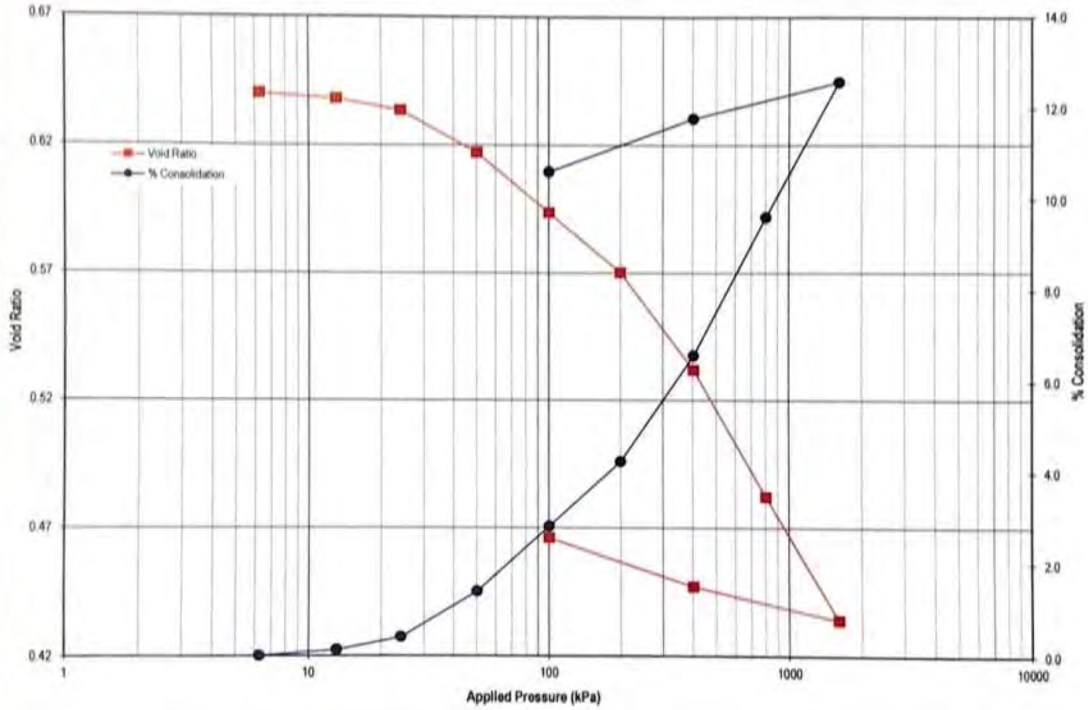
OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	CM Testing Service Pty Ltd	**Report No.:**	18120394-OED
		Workorder No.	5299
Address:	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	17/12/2018
		Report Date:	14/01/2019
Project:	BC-13130		
Client Id.:	34321 - BH103	**Depth (m):**	3.00-3.40
Description:	SILTY CLAY- dark brown		



Wet Density (t/m³): 1.97	Initial Moisture (%): 26.4	Test Condition: Inundated on load
Particle Density (t/m³): 2.55	Initial Voids Ratio: 0.640	Initial Degree of Saturation (%): 100.0
Undisturbed sample supplied by the client	Remarks: Tested as Received	Page 1 of 2

REP03102

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Authorised Signatory

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	CM Testing Service Pty Ltd	**Report No.:**	18120394-OED
		Workorder No.	5299
Address:	PO Box 5421 BUNDABERG QLD 4670	**Test Date:**	17/12/2018
		Report Date:	14/01/2019
Project:	BC-13130		
Client Id.:	34321 - BH103	**Depth (m):**	3.00-3.40
Description:	SILTY CLAY- dark brown		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6.25-13	0.007	2.9E-09	1.48	48.37	0.192	0.17	0.1
2	13-24	0.017	7.9E-09	0.94	102.59	0.248	0.72	0.4
3	24-50	0.052	4.9E-09	0.77	40.80	0.387	1.15	1.4
4	50-100	0.078	5.9E-10	0.83	6.52	0.290	1.26	2.8
5	100-199	0.078	9.7E-10	0.81	21.10	0.148	1.60	4.3
6	199-402	0.125	4.7E-10	0.90	12.59	0.120	2.01	6.6
7	402-801	0.166	6.3E-11	0.83	2.51	0.081	2.18	9.6
8	801-1600	0.161	3.2E-11	0.74	2.52	0.041	2.84	12.6
9	1600-400	0.022	7.9E-11	2.02	33.46	0.008	0.58	11.8
10	400-100	0.032	2.3E-10	0.40	17.19	0.044	1.97	10.6

Remarks: Tested as Received

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Attachment C

Seepage Analyses

Purpose:

This calculation package provides a preliminary estimate of the exit gradient and uplift pressures under the proposed inverted T floodwall for shallow foundations and deep foundation options with varying sheetpile lengths.

Method:

Seepage analyses were performed using the SEEP/W model developed by GEO-SLOPE International. Hydraulic conductivity values of the various subsurface layers were assumed based upon experience with similar geologic units. The seepage model was run under steady-state seepage conditions assuming the 100-year design flood of the Burnett River to calculate exit gradients and uplift pressures.

Soil Information:

Subsurface soil information is based upon existing geotechnical data from nearby borings B-2, B-3, and B-5 for the deep foundation cross-section and B-12 and B-13 for the shallow foundation cross-section. Soil parameters for seepage model are assumed by CDM Smith based on soil types and engineering experiences.

Datum:

Australian Height Datum (AHD)

Modeling Scenario:

100-year flood level at El. 9.2 m Australian Height Datum (AHD)

References:

1. CDM Smith, Draft Conceptual Flood Wall Drawings, February 2018.
2. CDM Smith, "Factual Geotechnical Report, Bundaberg East Levee," 2 February 2018.
3. GEO-SLOPE International Ltd, "Seepage Modeling with SEEP/W," June 2015.
4. United States Army Corps of Engineers, EM 1110-2-1913 "Design and Construction of Levees," 30 April 2000.
5. Ralph B. Peck, "Foundation Engineering, 2nd Edition," Page 43.
6. United States Army Corps of Engineers, EM 1110-2-1901 "Seepage Analysis and Control for Dams," 30 April 1993.

Assumptions

1. The selected cross-sections represent the most critical locations for seepage.
2. The problem can be simplified as 2-dimensional problem.
3. Seepage model boundary on protected side can be set at around 100 meters away from the floodwall and assumed as constant head boundary at EL 2.5 m (assumed groundwater level based on test boring B-6).
4. Riverside boundary is set as constant head boundary at EL 9.2 m (100-year flood elevation).
5. Assume maximum allowable exit gradient is 0.5 (factor of Safety = 2).
6. Assume the sheet pile depth varies between 3 m, 7 m (half the thickness of the alluvial soils layer), and 13.5 m (the full thickness of the alluvial soils layer).

Results

1. The preliminary estimates of uplift pressures and exit gradients can be found in Table 2.
2. Additional exploration is recommended during detailed design to collect additional data for the seepage analysis. The analyses presented in this calculation will be updated/revised once additional data are collected.

DLGRMA

Bundaberg East Levee

Table 1

Soil Layers and Parameters for Base Model

Layer	Material	Layer Thickness (m)		Hydraulic Conductivity, K_h	k_h / k_v	Bases of Parameter Selection
		Deep Foundation	Shallow Foundation	cm/sec		
1	Fill	1.5	1.5	1.0E-07	5	From Peck[(1)]; typical value for homogeneous clays
2	Alluvial Soils	13.5	NA	1.0E-06	2	From Peck[(1)]; typical value for stratified clay deposits
3	Elliott Formation	>15	>10	1.0E-8	5	From Peck[(1)]; typical value for homogeneous clays
4	Sheet Pile	NA	NA	1.0E-8	2	Assumed based on liturature research
5	Underdrain	NA	NA	100	1	From Peck[(1)]; typical value for clean gravel

Notes:

1. Soil layers and parameters are selected based on nearby boring data.

Reference:

1. Ralph B. Peck, Walter E. Hanson, Thomas H. Thornburn: Foundation Engineering, Second Edition, 1974.

Abbreviations:

NA=Not Applicable.

DLGRMA
Bundaberg East Levee

Table 2
Modeling Scenarios and Results Summary

Run #	Modeling Scenario	100-Year Flood Water Level Elevation	Results		
			Uplift Pressure on Land Side, kPa	Exit Gradient	Factor of Safety
1	Deep Foundation, City Alignment, 3 m Sheetpile Wall	EL 9.2	27.1	0.77	1.1
2	Deep Foundation, City Alignment, 7 m Sheetpile Wall	EL 9.2	25.1	0.65	1.3
3	Deep Foundation, City Alignment, 13 m Sheetpile Wall	EL 9.2	0	0	>2
4	Shallow Foundation, Distillery Alignment	EL 9.2	5	0	>2
5	Deep Foundation, City Alignment, 3 m Sheetpile Wall, with underdrain	EL 9.2	14.9	0.01	85

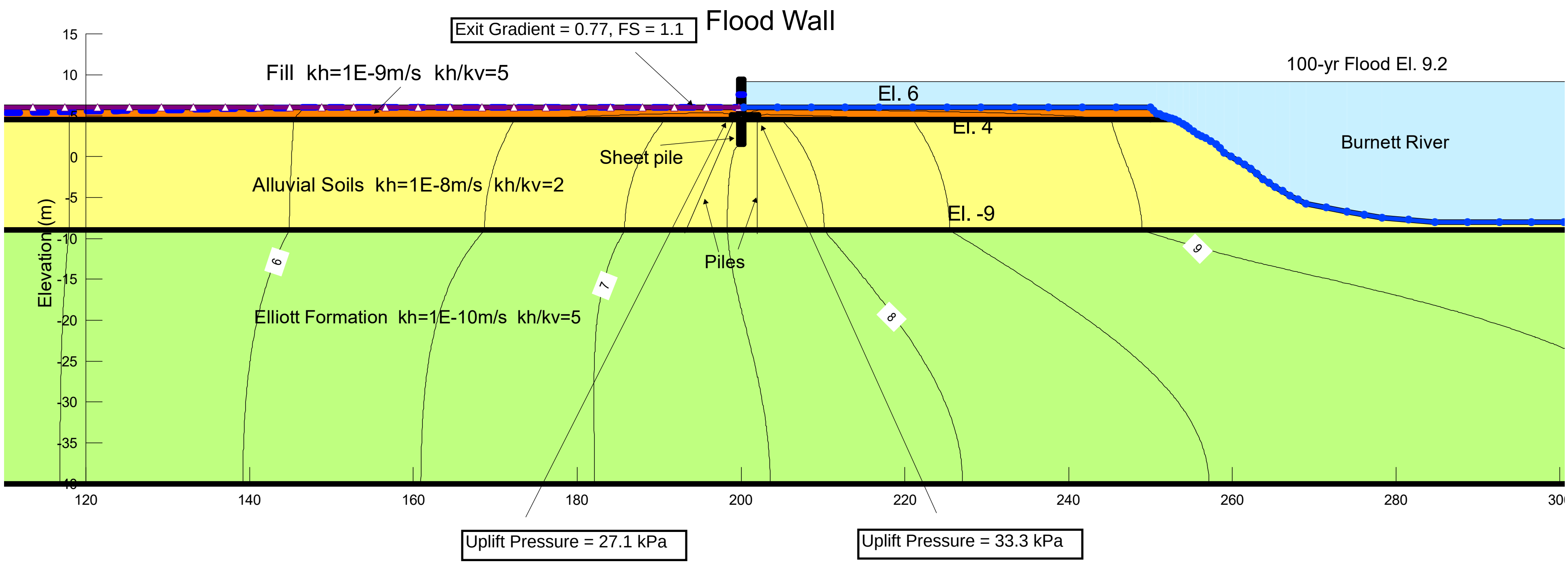
Notes:

1. For conservative purposes, assume the sheetpile wall is permeable (leaking) in the model.

2. Critical gradient i_{cr} calculated based on EM 1110-2-1901, page 4-25.

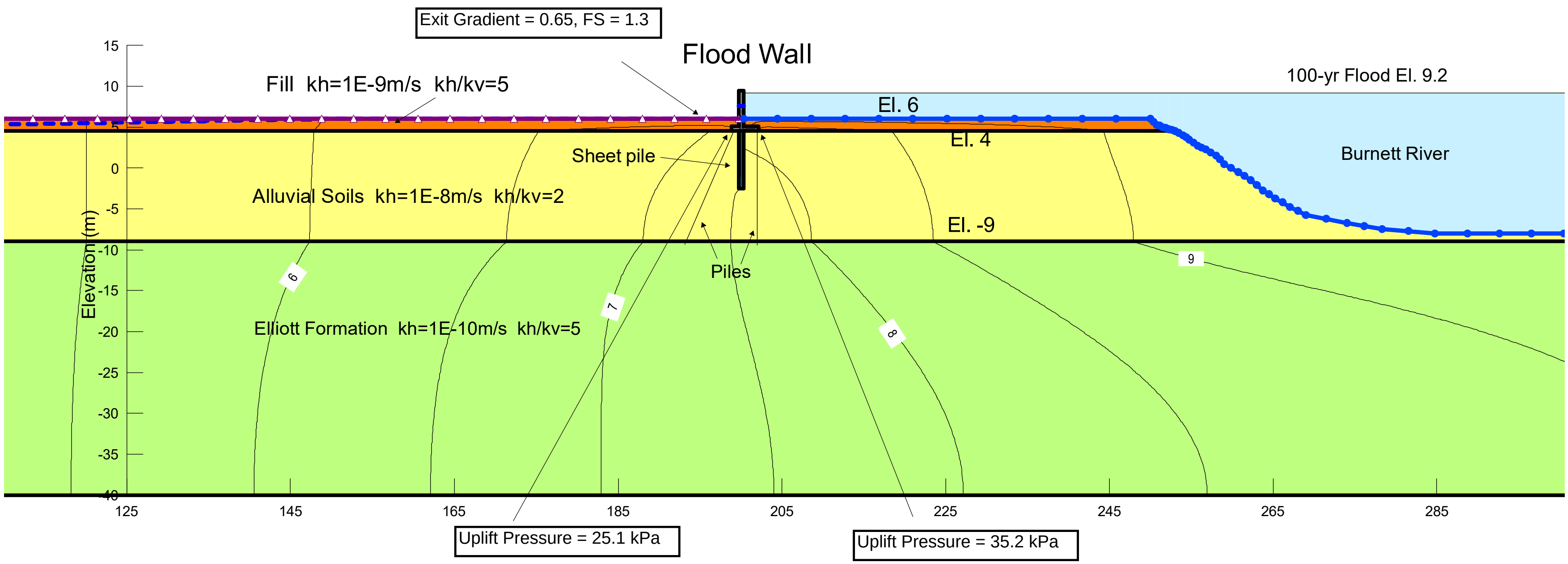
3. Uplift pressures taken at bottom corners of wall foundation.

3 Meter Sheetpile Wall



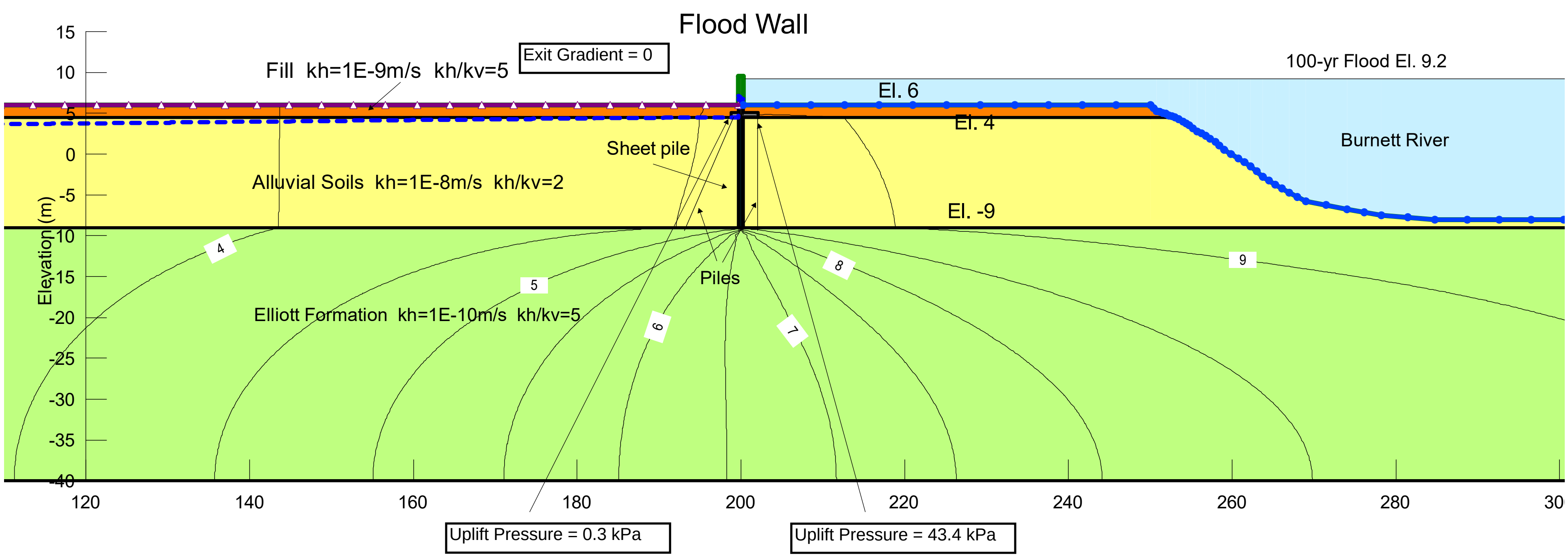
Exit Gradient = 0.77, FS = 1.1
Flood Wall
Fill kh=1E-9m/s kh/kv=5
100-yr Flood El. 9.2
El. 6
El. 4
Burnett River
Sheet pile
Alluvial Soils kh=1E-8m/s kh/kv=2
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
15
10
0
-5
-10
-15
-20
-25
-30
-35
6
7
8
9
120
140
160
180
200
220
240
260
280
Uplift Pressure = 27.1 kPa
Uplift Pressure = 33.3 kPa

7 Meter Sheetpile Wall

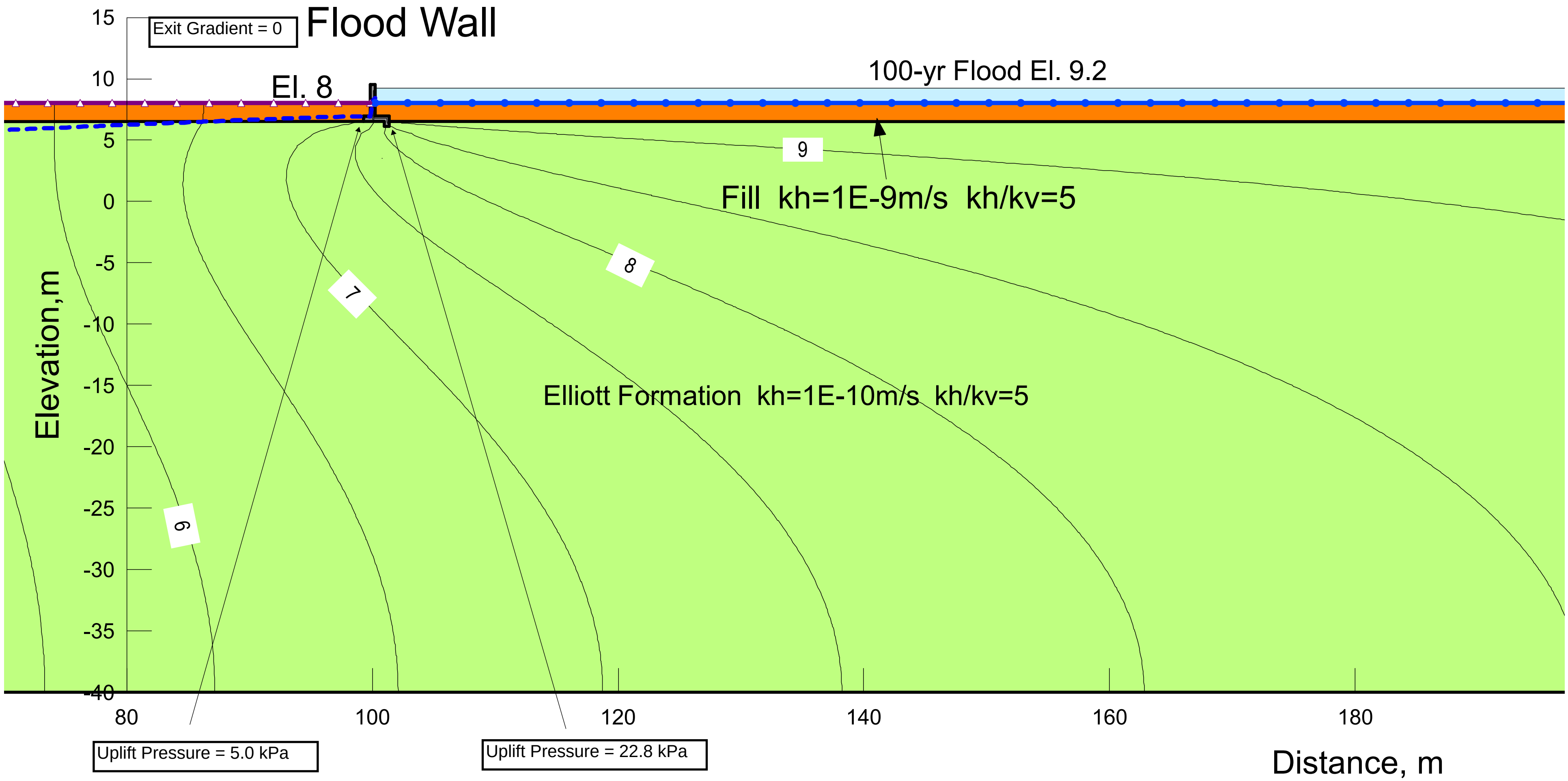


Exit Gradient = 0.65, FS = 1.3
Flood Wall
Fill kh=1E-9m/s kh/kv=5
100-yr Flood El. 9.2
El. 6
El. 4
Sheet pile
Burnett River
Alluvial Soils kh=1E-8m/s kh/kv=2
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
6
7
8
9
125
145
165
185
205
225
245
265
285
Uplift Pressure = 25.1 kPa
Uplift Pressure = 35.2 kPa

13.5 Meter Sheetpile Wall

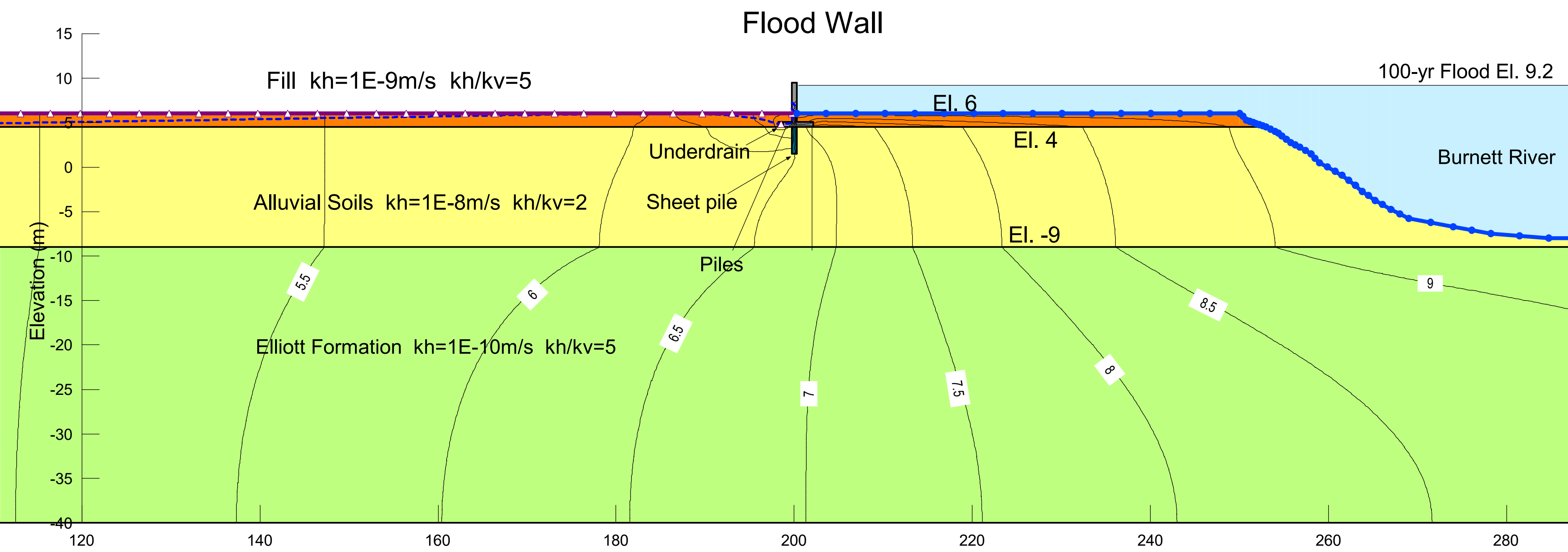

Flood Wall
Exit Gradient = 0
Fill kh=1E-9m/s kh/kv=5
100-yr Flood El. 9.2
El. 6
El. 4
Burnett River
Sheet pile
Alluvial Soils kh=1E-8m/s kh/kv=2
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
Uplift Pressure = 0.3 kPa
Uplift Pressure = 43.4 kPa

Shallow Foundation



Exit Gradient = 0
Flood Wall
100-yr Flood El. 9.2
El. 8
9
Fill kh=1E-9m/s kh/kv=5
8
7
Elliott Formation kh=1E-10m/s kh/kv=5
6
Elevation,m
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
80
100
120
140
160
180
Distance, m
Uplift Pressure = 5.0 kPa
Uplift Pressure = 22.8 kPa

3 Meter Sheetpile wall
with Underdrain System


Flood Wall
100-yr Flood El. 9.2
Fill kh=1E-9m/s kh/kv=5
El. 6
El. 4
Underdrain
Burnett River
Alluvial Soils kh=1E-8m/s kh/kv=2
Sheet pile
El. -9
Piles
Elliott Formation kh=1E-10m/s kh/kv=5
Elevation (m)
5.5
6
6.5
7
7.5
8
8.5
9
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
120
140
160
180
200
220
240
260
280

Attachment D

Deep Foundation Analyses

Attachment D1

Driven 400-mm-Square Concrete Preformed Piles

Problem: Evaluate the vertical pile capacity of an assumed preformed concrete pile.

References:
1. Federal Highway Administration, "Design and Construction of Driven Pile Foundations," FHWA-HI-97-013, December 1996.
2. API Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
3. Australian Building and Construction Commission, "Code for the Tendering and Performance of Building Work 2016"
4. FHWA, "Design and Construction of Driven Pile Foundations, Workshop Manual - Volume I," September 2016.
5. AS 2159-2009, Australian Standard - Piling -Design and Installation.
6. FHWA, "Design and Construction of Driven Pile Foundations - Comprehensive Design Examples," September 2016.
7. "Factual Geotechnical Report, Bundaberg East Levee, Bundaberg, Queensland" CDM Smith, 31 January 2018
8. "Geotechnical Investigation Factual Report" Core Consultants Pty Ltd., November 2018

Pile Information: 400 mm square concrete pile

Datum: Australian Height Datum (AHD)

Assumptions:
1. The proposed pile cut-off elevation is assumed to be at 1.5 meters below ground surface.
2. Groundwater elevation is assumed at El. 2.5 based upon observed water level in test boring B-6.
3. Pile is a 400 mm square concrete pile.
4. Allowable structural capacity of the 400 mm concrete pile is 1,450 kN.
5. Assume 5 percent of piles are dynamically load tested.
6. Assume no downdrag displacement load due to negligible raise in grade.
7. Assume k=1.0 for pile per Reference No. 2.
8. Assume allowable compressive capacity required for each pile is 250, 500, 750, and 1,000 kN.

Soil Information: Soil layering, soil properties and groundwater elevation obtained from available boring logs[7].

Table 1 - Summary of Subsurface Conditions

	Alignment	1. City Alignment Sta. 0+50 to Sta. 3+75	2. City Alignment Sta. 3+75 to Sta. 7+85	3. Distillery Alignment Sta. 3+00 to Sta. 5+25
	Alluvial Soils Thickness(m)	13	7	5
	Elliott Formation Thickness(m)	>15	>15	>10
	Applicable Borings	B-2, B-3, B-5, BH-101, BH-102	B-4, B-6, B-7, BH-103, BH-104, BH-105	B-12, B-13, BH-107, BH-108, BH-109
Elliott Formation Properties	Su (kPa)	150	50	0
	δ (°)	0	0	20
	Φ (°)	0	0	30
	Limiting Skin Friction (kPa)	0	0	67
	Limiting End Bearing (MPa)	0	0	2.9

Analysis Method: Simplified API 1986 & 1993 Method

Q compression = A_p x q_p + Σ (A_s x f_s)   Eq. 6.4.1-1 Reference 2

where A_p= tip area f_s=side friction

q_p=tip resistance A_s=side area

Skin Friction (f_s):

For undrained clay (a-Method): $f_s = \alpha * S_u$ Eq. 6.4.2-1 and Eq. 6.4.2-2 Reference 2

where $\alpha = 0.5*(Su/\sigma_v')^{(-0.5)}$ for $(su/\sigma_v')<1$

$= 0.5*(Su/\sigma_v')^{(-025)} <1$ for $(su/\sigma_v')>1$

S_u =undrained shear strength

For drained clay/sand (b-Method): $f_s = K \tan\delta * \sigma'_v$ Eq. 6.4.3-1 Reference 2

where δ = soil - pile friction angle

K = lateral pressure coefficient

σ'_v = effective vertical pressure

Tip Resistance (q_p)

For undrained clay: $q_p = N_c * Su$ Eq. 6.4.2-3 Reference 2

where $N_c = 9$

Su = undrained shear strength at the pile tip

For drained clay/sand: $q_p = Nq * \sigma_v'$ Eq. 6.4.3-2 Reference 2

where Nq = exp(π*tanϕ)*[tan(45+ϕ/2)]^2   (Meyerhoff)

σ_v' = effective vertical pressure at the pile tip

Results:

A summary of the total allowable compressive and uplift capacity is summarized in Table 2 below.

Table 2 - Summary of Allowable Compressive and Uplift Pile Capacity

Soil Profile	Total Allowable Compressive Capacity (kN)	Total Allowable Uplift Capacity (kN)	Embedment in Elliott Formation (m)
1	250	200	1
1	500	325	2
1	750	550	5
1	1000	725	8
1a	250	200	3
1a	500	325	5
1a	750	550	9
1a	1000	725	12
2	250	150	2
2	500	375	8
2	750	525	12
2	1000	750	17
3	250	75	1
3	500	200	5
3	750	375	9
3	1000	525	12

Notes:
1. Assumes a FS of 1.39 based on AS 2159-2009 Section 4.3.1 calculation.

Client:	DLGRMA	**Checked by:**	JPB	**Computed by:**	BJG
Project:	Bundaberg East Levee	**Date:**	14/2/2018	**Date:**	5/2/2018
Job Number:	121923-221532	**Rev by:**	JPB	**Page:**	2
Detail:	Driven Preformed Concrete Pile	**Date:**	28/2/2018		

References:

AS 2159-2009 Piling -- Design and Installation

21 AS 2159—2009

4.3 GENERAL PRINCIPLES OF GEOTECHNICAL STRENGTH DESIGN

4.3.1 Design geotechnical strength

A pile shall be proportioned such that the design geotechnical strength ($R_{d,g}$) is not less than the design action effect (E_d) as detailed in Clause 3.2.2, that is—

$$R_{d,g} \geq E_d \qquad \ldots 4.3.1(1)$$

The design geotechnical strength ($R_{d,g}$) shall be calculated as the design ultimate geotechnical strength ($R_{d,ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g), according to the following equation:

$$R_{d,g} = \phi_g R_{d,ug} \qquad \ldots 4.3.1(2)$$

The geotechnical strength reduction factor (ϕ_g) shall be determined as follows:

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

where

ϕ_{gb} = basic geotechnical strength reduction factor as given in Clause 4.3.2

ϕ_{tf} = intrinsic test factor

= 0.9, for static load testing (see Section 8)

= 0.75, for rapid load testing (see Section 8)

= 0.8, for dynamic load testing of preformed piles (see Section 8)

= 0.75, for dynamic load testing of other than preformed piles (see Section 8)

= 0.85, for bi-directional load testing (see Section 8)

= ϕ_{gb}, for no testing

K = testing benefit factor

= $1.33p/(p + 3.3) \leq 1$, for static or rapid load testing

= $1.13p/(p + 3.3) \leq 1$, for dynamic load testing

p = percentage of the total piles that are tested and meet the specified acceptance criteria

References:

4.3.2 Assessment of basic geotechnical strength reduction factor (ϕ_{gb})

The basic geotechnical strength reduction factor (ϕ_{gb}) shall be calculated using a risk assessment procedure as set out below:

(a) Rate each risk factor in Table 4.3.2(A) on a scale from 1 to 5 for the nature of the site, the available site information and the pile design and installation procedures adopted. This will produce an individual risk rating (IRR) according to the assessed level of risk, as set out in Table 4.3.2(B)

(b) Determine the overall design average risk rating (ARR) using the weighted average of the product of all of the risk weighting factors (w_i) shown in column 2 of Table 4.3.2(A) times the relevant individual risk rating (IRR), as follows:

$$ARR = \Sigma(w_i \text{IRR}_i)/\Sigma w_i \quad \ldots 4.3.2$$

(c) Determine the basic geotechnical strength reduction factor (ϕ_{gb}) from Table 4.3.2(C) depending on the level of redundancy in the piling system. Systems with a high degree of redundancy would include large pile groups under large caps, piled rafts and pile groups with more than 4 piles. Systems with a low level of redundancy would include isolated heavily loaded piles and piles set out at large spacings.

TABLE 4.3.2(A)

WEIGHTING FACTORS AND INDIVIDUAL RISK RATINGS FOR RISK FACTORS

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Site				
Geological complexity of site	2	Horizontal strata, well-defined soil and rock characteristics	Some variability over site, but without abrupt changes in stratigraphy	Highly variable profile or presence of karstic features or steeply dipping rock levels or faults present on site, or combinations of these
Extent of ground investigation	2	Extensive drilling investigation covering whole site to an adequate depth	Some boreholes extending at least 5 pile diameters below the base of the proposed pile foundation level	Very limited investigation with few shallow boreholes
Amount and quality of geotechnical data	2	Detailed information on strength compressibility of the main strata	CPT probes over full depth of proposed piles or boreholes confirming rock as proposed founding level for piles	Limited amount of simple in situ testing (e.g., SPT) or index tests only
Design				
Experience with similar foundations in similar geological conditions	1	Extensive	Limited	None

(continued)

References:

TABLE 4.3.2(A) *(continued)*

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Method of assessment of geotechnical parameters for design	2	Based on appropriate laboratory or in situ tests or relevant existing pile load test data	Based on site-specific correlations or on conventional laboratory or in situ testing	Based on non-site-specific correlations with (for example) SPT data
Design method adopted	1	Well-established and soundly based method or methods	Simplified methods with well-established basis	Simple empirical methods or sophisticated methods that are not well established
Method of utilizing results of in situ test data and installation data	2	Design values based on minimum measured values on piles loaded to failure	Design methods based on average values	Design values based on maximum measured values on test piles loaded up only to working load, or indirect measurements used during installation, and not calibrated to static loading tests
Installation				
Level of construction control	2	Detailed with professional geotechnical supervision, construction processes that are well established and relatively straightforward	Limited degree of professional geotechnical involvement in supervision, conventional construction procedures	Very limited or no involvement by designer, construction processes that are not well established or complex
Level of performance monitoring of the supported structure during and after construction	0.5	Detailed measurements of movements and pile loads	Correlation of installed parameters with on-site static load tests carried out in accordance with this Standard	No monitoring

NOTE: The pile design shall include the risk circumstances for each individual risk category and consideration of all of the relevant site and construction factors.

TABLE 4.3.2(B)
INDIVIDUAL RISK RATING (IRR)

Risk level	Individual risk rating (IRR)
Very low	1
Low	2
Moderate	3
High	4
Very high	5

TABLE 4.3.2(C)
BASIC GEOTECHNICAL STRENGTH REDUCTION FACTOR (ϕ_{gb}) FOR AVERAGE RISK RATING

Range of average risk rating (ARR)	Overall risk category	ϕ_{gb} for low redundancy systems	ϕ_{gb} for high redundancy systems
ARR ≤1.5	Very low	0.67	0.76
1.5 < ARR ≤2.0	Very low to low	0.61	0.70
2.0 < ARR ≤2.5	Low	0.56	0.64
2.5 < ARR ≤3.0	Low to moderate	0.52	0.60
3.0 < ARR ≤3.5	Moderate	0.48	0.56
3.5 < ARR ≤4.0	Moderate to high	0.45	0.53
4.0 < ARR ≤4.5	High	0.42	0.50
>4.5	Very high	0.40	0.47

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

ϕ_{tf} =	0.8	for dynamic load testing	
K =	1.13p/(p+3.3)		
p=	5	percent of piles to be tested	
K=	0.68		
IRR=	50.5		
w_i =	14.5		
ARR=	3.48		
ϕ_{gb} =	0.56		
ϕ_g =	0.72	>=	0.56
FS=	1.39		

Table 1: Structural Capacity of Concrete Pile

Type 400 mm Square Preformed Concrete Pile
Shape square

Width (m)	Gross Area (sq m)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Total Structural Capacity (kN)
0.3	0.090	0.090	27575	**819**
0.35	0.123	0.123	27575	**1115**
0.4	0.160	0.160	27575	**1456**
0.45	0.203	0.203	27575	**1843**
0.5	0.250	0.250	27575	**2275**
0.55	0.303	0.303	27575	**2753**

Notes:
1 Allowable Concrete Stress = 0.33 f'c

Alignment 1

Client:	DLGRMA	**Computed by:** JPB		**Checked by:** BJG	
Project:	Bundaberg East Levee	**Date:** 14/2/2018		**Date:** 5/2/2018	
Job Number:	121923-221532	**Rev by:** JPB		**Page:** 6 & 7	
Detail:	Driven Preformed Concrete Pile Alignment 1	**Date:** 28/2/2018		**Updated by/date:** MDC, 10/12/2018	

AXIAL PILE CAPACITY ESTIMATE: Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m — Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m — Per Test Boring B-6
Pile Cut-Off Elevation = 4.5 m

Pile Information

Pile type = 400 mm Square Preformed Concrete Pile
Pile shape = square (square or circle)
Pile Diameter / Length of Side = 0.4 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0 m
End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Soil Properties

	Alignment 1	
	Alluvial Soils	**Elliott Formation**
γ (kN/M^3)	18.0	18.8
Su (kPa)	22	150
δ (°)	0	0
Φ (°)	15	0
Limiting Skin Friction (kPa)	0	0
Limiting End Bearing (MPa)	0	0

value shown as a force

Limiting Skin Friction: Based on typical API values
Limiting End Bearing: Based on typical API values

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	Unit End Bearing – For Sand: Nq	Unit End Bearing – For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	11	42	30	5	9	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	54	39	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	36	67	48	16	31	22
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	50	82	59	22	43	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	65	97	70	29	55	40
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	81	113	81	35	68	49
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	97	129	93	42	81	58
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	130	162	117	57	108	78
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	166	197	142	72	137	98
8	-2	1	Alluvial Soils	22	15	0	0	0	8.2	96	0.23	1.0	22	0	125	0	0	198	0.0	0	201	232	167	88	165	119
9	-3	1	Alluvial Soils	22	15	0	0	0	8.2	104	0.21	1.0	22	0	147	0	0	198	0.0	0	236	268	193	103	193	139
10	-4	1	Alluvial Soils	22	15	0	0	0	8.2	113	0.20	1.0	22	0	169	0	0	198	0.0	0	271	303	218	119	222	160
11	-5	1	Alluvial Soils	22	15	0	0	0	8.2	121	0.18	1.0	22	0	191	0	0	198	0.0	0	306	338	243	134	250	180
12	-6	1	Alluvial Soils	22	15	0	0	0	8.2	129	0.17	1.0	22	0	213	0	0	198	0.0	0	342	373	269	149	279	200
13	-7	1	Alluvial Soils	22	15	0	0	0	8.2	137	0.16	1.0	22	0	235	0	0	198	0.0	0	377	408	294	165	307	221
14	-8	1	Elliott Formation	150	0	0	0	0	9.0	146	1.03	0.5	74	0	310	0	0	1,350	0.0	0	496	712	512	217	394	284
15	-9	1	Elliott Formation	150	0	0	0	0	9.0	155	0.97	0.5	76	0	386	0	0	1,350	0.0	0	618	834	600	270	483	348
16	-10	1	Elliott Formation	150	0	0	0	0	9.0	164	0.92	0.5	78	0	465	0	0	1,350	0.0	0	743	959	690	325	575	414
17	-11	1	Elliott Formation	150	0	0	0	0	9.0	173	0.87	0.5	81	0	545	0	0	1,350	0.0	0	872	1,088	783	382	669	481
18	-12	1	Elliott Formation	150	0	0	0	0	9.0	182	0.82	0.6	83	0	628	0	0	1,350	0.0	0	1,004	1,220	878	439	765	550
19	-13	1	Elliott Formation	150	0	0	0	0	9.0	191	0.79	0.6	85	0	712	0	0	1,350	0.0	0	1,140	1,356	975	499	864	621
20	-14	1	Elliott Formation	150	0	0	0	0	9.0	200	0.75	0.6	87	0	799	0	0	1,350	0.0	0	1,278	1,494	1,075	559	964	694
21	-15	1	Elliott Formation	150	0	0	0	0	9.0	209	0.72	0.6	89	0	887	0	0	1,350	0.0	0	1,420	1,636	1,177	621	1067	768
22	-16	1	Elliott Formation	150	0	0	0	0	9.0	218	0.69	0.6	90	0	978	0	0	1,350	0.0	0	1,564	1,780	1,281	684	1172	843
23	-17	1	Elliott Formation	150	0	0	0	0	9.0	227	0.66	0.6	92	0	1,070	0	0	1,350	0.0	0	1,712	1,928	1,387	749	1279	920
24	-18	1	Elliott Formation	150	0	0	0	0	9.0	236	0.64	0.6	94	0	1,164	0	0	1,350	0.0	0	1,863	2,079	1,495	815	1389	999
25	-19	1	Elliott Formation	150	0	0	0	0	9.0	245	0.61	0.6	96	0	1,260	0	0	1,350	0.0	0	2,016	2,232	1,606	882	1500	1079
26	-20	1	Elliott Formation	150	0	0	0	0	9.0	254	0.59	0.7	98	0	1,358	0	0	1,350	0.0	0	2,172	2,388	1,718	950	1613	1160

Client: DLGRMA | **Computed by:** JPB | **Checked by:** BJG

Project: Bundaberg East Levee | **Date:** 14/2/2018 | **Date:** 5/2/2018

Job Number: 121923-221532 | **Rev by:** JPB | **Page:** 6 & 7

Detail: Driven Preformed Concrete Pile Alignment 1 | **Date:** 28/2/2018 | **Updated by/date:** MDC, 10/12/2018

AXIAL PILE CAPACITY ESTIMATES Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m — Estimated Finished Grade

Effective Overburden = 27 kPa

Groundwater Elevation = 2.5 m — Per Test Boring B-6

Pile Cut-Off Elevation = 4.5 m

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	150	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 — Based on Bottom Elevation of Pile Cap.

Pile Information

Pile type = 400 mm Square Preformed Concrete Pile

Pile shape = square (square or circle)

Pile Diameter / Length of Side = 0.4 m

Surface Area = 1.6 sq m/m length

Wall Thickness = 0 m

End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters

Assume pile is 100% plugged

Unit weight of pile = 24 kN/m³

Design Parameters

K = 1

Nc (clay) = 9

Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)

Friction Interface Reduction Factor for Uplift = 0.7

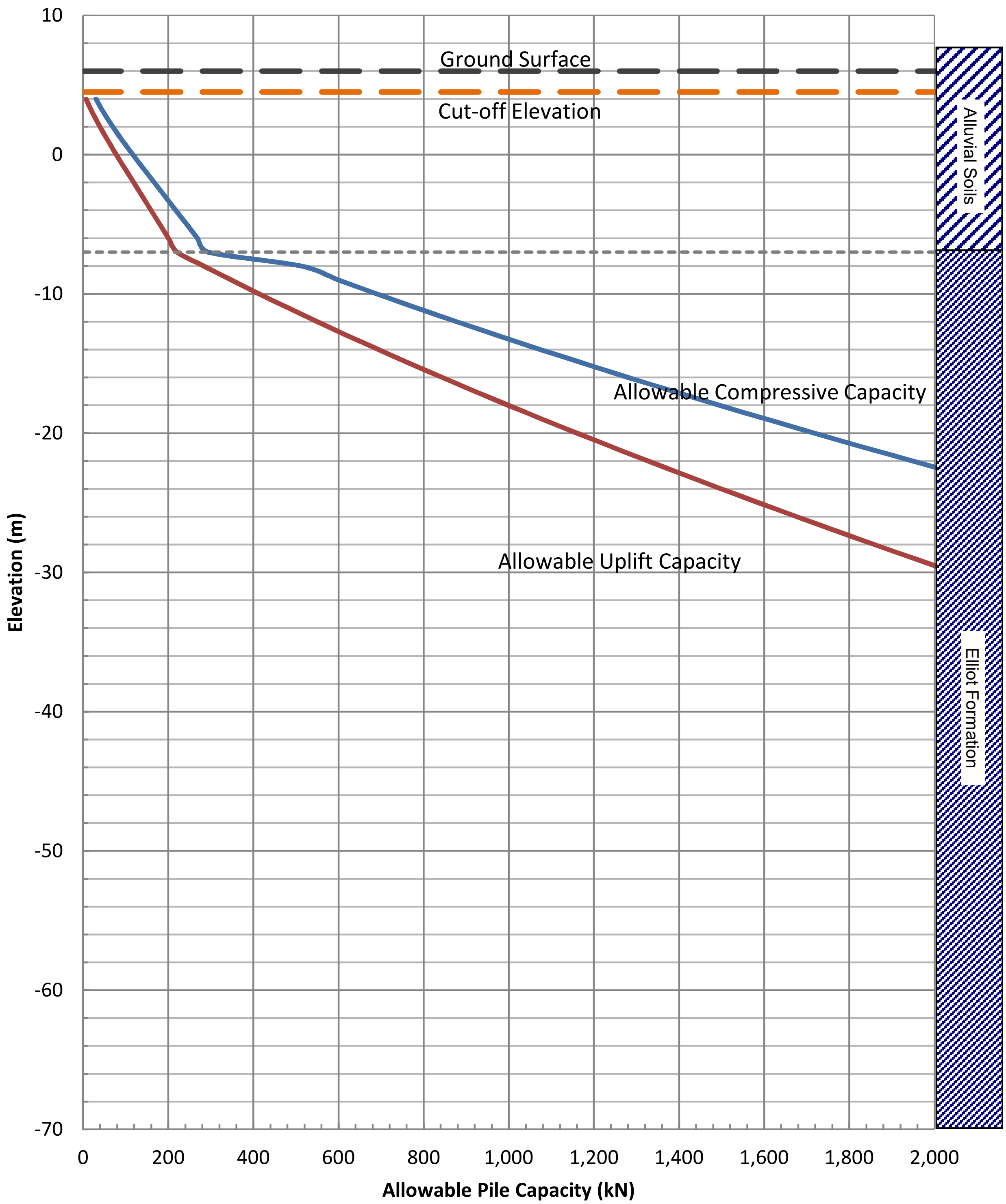
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g

Downdrag load factor = 0

ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

																		COMPRESSION CAPACITY						UPLIFT CAPACITY		
													Unit Skin Friction					Unit End Bearing			Ult. Friction	Ult. Comp.	Allow. Comp.		Ultimate Uplift	Allow. Uplift.
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Capacity	Capacity	Capacity		Capacity	Capacity
27	-21	1	Elliott Formation	150	0	0	0	0	9.0	263	0.57	0.7	99	0	1,457	0	0	1,350	0.0	0	2,331	2,547	1,832	1020	1728	1243
28	-22	1	Elliott Formation	150	0	0	0	0	9.0	272	0.55	0.7	101	0	1,558	0	0	1,350	0.0	0	2,493	2,709	1,949	1090	1845	1327
29	-23	1	Elliott Formation	150	0	0	0	0	9.0	281	0.53	0.7	103	0	1,661	0	0	1,350	0.0	0	2,657	2,873	2,067	1162	1963	1413
30	-24	1	Elliott Formation	150	0	0	0	0	9.0	290	0.52	0.7	104	0	1,765	0	0	1,350	0.0	0	2,824	3,040	2,187	1235	2084	1499
31	-25	1	Elliott Formation	150	0	0	0	0	9.0	299	0.50	0.7	106	0	1,871	0	0	1,350	0.0	0	2,993	3,209	2,309	1309	2206	1587
32	-26	1	Elliott Formation	150	0	0	0	0	9.0	308	0.49	0.7	107	0	1,978	0	0	1,350	0.0	0	3,165	3,381	2,432	1385	2331	1677
33	-27	1	Elliott Formation	150	0	0	0	0	9.0	317	0.47	0.7	109	0	2,087	0	0	1,350	0.0	0	3,340	3,556	2,558	1461	2456	1767
34	-28	1	Elliott Formation	150	0	0	0	0	9.0	326	0.46	0.7	111	0	2,198	0	0	1,350	0.0	0	3,517	3,733	2,685	1538	2584	1859
35	-29	1	Elliott Formation	150	0	0	0	0	9.0	335	0.45	0.7	112	0	2,310	0	0	1,350	0.0	0	3,696	3,912	2,814	1617	2713	1952
36	-30	1	Elliott Formation	150	0	0	0	0	9.0	344	0.44	0.8	114	0	2,424	0	0	1,350	0.0	0	3,878	4,094	2,945	1696	2844	2046
37	-31	1	Elliott Formation	150	0	0	0	0	9.0	353	0.42	0.8	115	0	2,539	0	0	1,350	0.0	0	4,062	4,278	3,078	1777	2977	2142
38	-32	1	Elliott Formation	150	0	0	0	0	9.0	362	0.41	0.8	117	0	2,655	0	0	1,350	0.0	0	4,248	4,464	3,212	1859	3111	2238
39	-33	1	Elliott Formation	150	0	0	0	0	9.0	371	0.40	0.8	118	0	2,773	0	0	1,350	0.0	0	4,437	4,653	3,348	1941	3247	2336
40	-34	1	Elliott Formation	150	0	0	0	0	9.0	380	0.39	0.8	119	0	2,893	0	0	1,350	0.0	0	4,628	4,844	3,485	2025	3385	2435
41	-35	1	Elliott Formation	150	0	0	0	0	9.0	389	0.39	0.8	121	0	3,013	0	0	1,350	0.0	0	4,821	5,037	3,624	2109	3524	2535
42	-36	1	Elliott Formation	150	0	0	0	0	9.0	398	0.38	0.8	122	0	3,136	0	0	1,350	0.0	0	5,017	5,233	3,765	2195	3665	2636
43	-37	1	Elliott Formation	150	0	0	0	0	9.0	407	0.37	0.8	124	0	3,259	0	0	1,350	0.0	0	5,215	5,431	3,907	2281	3807	2739
44	-38	1	Elliott Formation	150	0	0	0	0	9.0	416	0.36	0.8	125	0	3,384	0	0	1,350	0.0	0	5,415	5,631	4,051	2369	3950	2842
45	-39	1	Elliott Formation	150	0	0	0	0	9.0	425	0.35	0.8	126	0	3,510	0	0	1,350	0.0	0	5,617	5,833	4,196	2457	4096	2947
46	-40	1	Elliott Formation	150	0	0	0	0	9.0	434	0.35	0.9	128	0	3,638	0	0	1,350	0.0	0	5,821	6,037	4,343	2547	4242	3052
47	-41	1	Elliott Formation	150	0	0	0	0	9.0	443	0.34	0.9	129	0	3,767	0	0	1,350	0.0	0	6,027	6,243	4,492	2637	4391	3159
48	-42	1	Elliott Formation	150	0	0	0	0	9.0	452	0.33	0.9	130	0	3,897	0	0	1,350	0.0	0	6,236	6,452	4,641	2728	4540	3266
49	-43	1	Elliott Formation	150	0	0	0	0	9.0	461	0.33	0.9	132	0	4,029	0	0	1,350	0.0	0	6,446	6,662	4,793	2820	4691	3375
50	-44	1	Elliott Formation	150	0	0	0	0	9.0	470	0.32	0.9	133	0	4,162	0	0	1,350	0.0	0	6,659	6,875	4,946	2913	4844	3485
51	-45	1	Elliott Formation	150	0	0	0	0	9.0	479	0.31	0.9	134	0	4,296	0	0	1,350	0.0	0	6,873	7,089	5,100	3007	4998	3596
52	-46	1	Elliott Formation	150	0	0	0	0	9.0	488	0.31	0.9	135	0	4,431	0	0	1,350	0.0	0	7,090	7,306	5,256	3102	5153	3707
53	-47	1	Elliott Formation	150	0	0	0	0	9.0	497	0.30	0.9	137	0	4,568	0	0	1,350	0.0	0	7,308	7,524	5,413	3197	5310	3820
54	-48	1	Elliott Formation	150	0	0	0	0	9.0	506	0.30	0.9	138	0	4,705	0	0	1,350	0.0	0	7,529	7,745	5,572	3294	5468	3934
55	-49	1	Elliott Formation	150	0	0	0	0	9.0	515	0.29	0.9	139	0	4,844	0	0	1,350	0.0	0	7,751	7,967	5,732	3391	5627	4049
56	-50	1	Elliott Formation	150	0	0	0	0	9.0	524	0.29	0.9	140	0	4,985	0	0	1,350	0.0	0	7,976	8,192	5,893	3489	5788	4164
57	-51	1	Elliott Formation	150	0	0	0	0	9.0	534	0.28	0.9	141	0	5,126	0	0	1,350	0.0	0	8,202	8,418	6,056	3588	5950	4281
58	-52	1	Elliott Formation	150	0	0	0	0	9.0	543	0.28	1.0	143	0	5,269	0	0	1,350	0.0	0	8,430	8,646	6,220	3688	6114	4399
59	-53	1	Elliott Formation	150	0	0	0	0	9.0	552	0.27	1.0	144	0	5,413	0	0	1,350	0.0	0	8,660	8,876	6,386	3789	6279	4517
60	-54	1	Elliott Formation	150	0	0	0	0	9.0	561	0.27	1.0	145	0	5,558	0	0	1,350	0.0	0	8,892	9,108	6,553	3890	6445	4637
61	-55	1	Elliott Formation	150	0	0	0	0	9.0	570	0.26	1.0	146	0	5,704	0	0	1,350	0.0	0	9,126	9,342	6,721	3993	6612	4757

Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 1



Alignment 1a

Client: DLGRMA | **Computed by:** MDC | **Checked by:**

Project: Bundaberg East Levee | **Date:** 14/12/2018 | **Date:**

Job Number: 121923-221532 | **Rev by:** | **Page:** 8&9

Detail: Driven Preformed Concrete Pile Alignment 1 | **Date:**

AXIAL PILE CAPACITY ESTIMATES Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m — Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m — Per Test Boring B-6
Pile Cut-Off Elevation = 4.5 m

Soil Properties

Alignment 1	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	150	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 — Based on Bottom Elevation of Pile Cap.

Pile Information

Pile type = 400 mm Square Preformed Concrete Pile
Pile shape = square (square or circle)
Pile Diameter / Length of Side = 0.4 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0 m
End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters
Unit weight of pile = 24 kN/m³

Assume pile is 100% plugged

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m³	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	Unit End Bearing – For Sand: Nq	Unit End Bearing – For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Water	0	0	0	0	0	0.0	0	#DIV/0!	N/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Water	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Water	0	0	0	0	0	0.0	0	0.00	N/A	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Water	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	2	1
2.5	3.5	0.5	Water	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	4	3
3	3	0.5	Water	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	6	4
3.5	2.5	0.5	Water	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	8	5
4	2	0.5	Wzter	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	9	7
4.5	1.5	0.5	Wzter	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	11	8
5	1	0.5	Wzter	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	13	9
6	0	1	Wzter	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	17	12
7	-1	1	Wzter	0	0	0	0	0	0.0	0	0.00	N/A	0	0	0	0	0	0	1.0	0	0	0	0	0	21	15
8	-2	1	Alluvial Soils	22	15	0	0	0	8.2	4	5.34	0.3	7	0	7	0	0	198	0.0	0	12	43	31	5	33	23
9	-3	1	Alluvial Soils	22	15	0	0	0	8.2	12	1.78	0.4	10	0	17	0	0	198	0.0	0	27	58	42	12	47	34
10	-4	1	Alluvial Soils	22	15	0	0	0	8.2	21	1.07	0.5	11	0	28	0	0	198	0.0	0	44	76	55	19	63	45
11	-5	1	Alluvial Soils	22	15	0	0	0	8.2	29	0.76	0.6	13	0	40	0	0	198	0.0	0	64	96	69	28	81	58
12	-6	1	Alluvial Soils	22	15	0	0	0	8.2	37	0.59	0.6	14	0	54	0	0	198	0.0	0	87	119	85	38	101	72
13	-7	1	Alluvial Soils	22	15	0	0	0	8.2	45	0.49	0.7	16	0	70	0	0	198	0.0	0	112	144	104	49	122	88
14	-8	1	Elliott Formation	150	0	0	0	0	9.0	54	2.78	0.4	58	0	128	0	0	1,350	0.0	0	205	421	303	90	191	137
15	-9	1	Elliott Formation	150	0	0	0	0	9.0	63	2.38	0.4	60	0	189	0	0	1,350	0.0	0	302	518	373	132	262	189
16	-10	1	Elliott Formation	150	0	0	0	0	9.0	72	2.09	0.4	62	0	251	0	0	1,350	0.0	0	402	618	444	176	336	242
17	-11	1	Elliott Formation	150	0	0	0	0	9.0	81	1.85	0.4	64	0	315	0	0	1,350	0.0	0	505	721	518	221	412	296
18	-12	1	Elliott Formation	150	0	0	0	0	9.0	90	1.67	0.4	66	0	381	0	0	1,350	0.0	0	610	826	594	267	489	352
19	-13	1	Elliott Formation	150	0	0	0	0	9.0	99	1.52	0.5	68	0	449	0	0	1,350	0.0	0	718	934	672	314	569	409
20	-14	1	Elliott Formation	150	0	0	0	0	9.0	108	1.39	0.5	69	0	518	0	0	1,350	0.0	0	829	1,045	752	363	650	468
21	-15	1	Elliott Formation	150	0	0	0	0	9.0	117	1.28	0.5	70	0	589	0	0	1,350	0.0	0	942	1,158	833	412	733	527
22	-16	1	Elliott Formation	150	0	0	0	0	9.0	126	1.19	0.5	72	0	660	0	0	1,350	0.0	0	1,056	1,272	915	462	817	588
23	-17	1	Elliott Formation	150	0	0	0	0	9.0	135	1.11	0.5	73	0	733	0	0	1,350	0.0	0	1,173	1,389	1,000	513	902	649
24	-18	1	Elliott Formation	150	0	0	0	0	9.0	144	1.04	0.5	74	0	808	0	0	1,350	0.0	0	1,292	1,508	1,085	565	989	712
25	-19	1	Elliott Formation	150	0	0	0	0	9.0	153	0.98	0.5	76	0	883	0	0	1,350	0.0	0	1,413	1,629	1,172	618	1078	776
26	-20	1	Elliott Formation	150	0	0	0	0	9.0	162	0.93	0.5	78	0	961	0	0	1,350	0.0	0	1,538	1,754	1,262	673	1169	841

Client: DLGRMA **Computed by:** MDC **Checked by:**
Project: Bundaberg East Levee **Date:** 14/12/2018 **Date:**
Job Number: 121923-221532 **Rev by:** **Page:** 8&9
Detail: Driven Preformed Concrete Pile Alignment 1 **Date:**

AXIAL PILE CAPACITY ESTIMATES Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m Per Test Boring B-6
Pile Cut-Off Elevation = 4.5 m

Pile Information

Pile type = 400 mm Square Preformed Concrete Pile
Pile shape = square (square or circle)
Pile Diameter / Length of Side = 0.4 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0 m
End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Soil Properties

Alignment 1

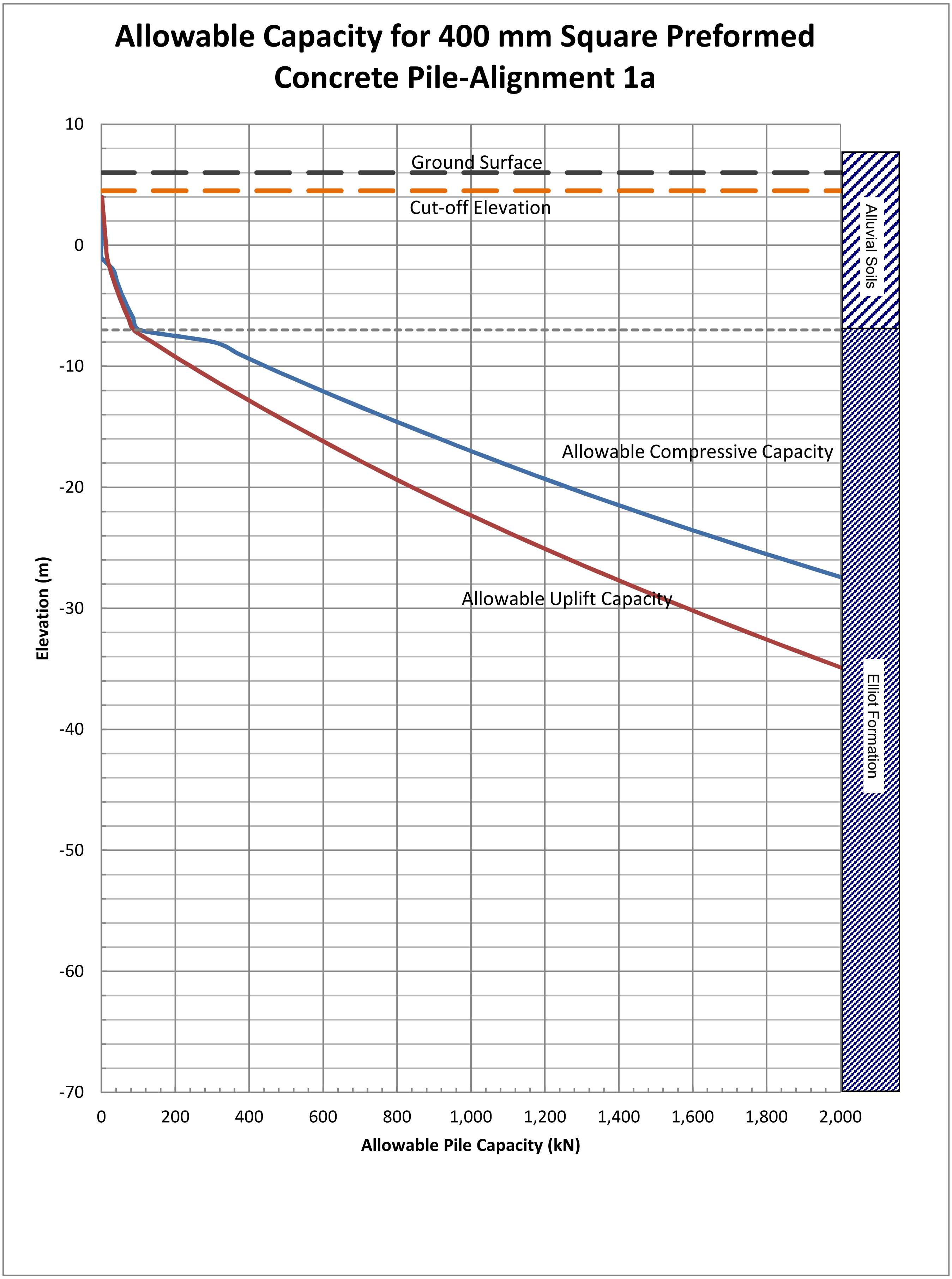
	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	150	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing						UPLIFT CAPACITY		
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
27	-21	1	Elliott Formation	150	0	0	0	0	9.0	171	0.88	0.5	80	0	1,041	0	0	1,350	0.0	0	1,666	1,882	1,354	729	1263	908
28	-22	1	Elliott Formation	150	0	0	0	0	9.0	180	0.83	0.5	82	0	1,124	0	0	1,350	0.0	0	1,798	2,014	1,449	787	1358	977
29	-23	1	Elliott Formation	150	0	0	0	0	9.0	189	0.79	0.6	84	0	1,208	0	0	1,350	0.0	0	1,933	2,149	1,546	845	1456	1048
30	-24	1	Elliott Formation	150	0	0	0	0	9.0	198	0.76	0.6	86	0	1,294	0	0	1,350	0.0	0	2,070	2,286	1,645	906	1557	1120
31	-25	1	Elliott Formation	150	0	0	0	0	9.0	207	0.72	0.6	88	0	1,382	0	0	1,350	0.0	0	2,212	2,428	1,746	968	1659	1194
32	-26	1	Elliott Formation	150	0	0	0	0	9.0	216	0.69	0.6	90	0	1,472	0	0	1,350	0.0	0	2,356	2,572	1,850	1031	1764	1269
33	-27	1	Elliott Formation	150	0	0	0	0	9.0	225	0.67	0.6	92	0	1,564	0	0	1,350	0.0	0	2,503	2,719	1,956	1095	1871	1346
34	-28	1	Elliott Formation	150	0	0	0	0	9.0	234	0.64	0.6	94	0	1,658	0	0	1,350	0.0	0	2,653	2,869	2,064	1160	1979	1424
35	-29	1	Elliott Formation	150	0	0	0	0	9.0	243	0.62	0.6	96	0	1,753	0	0	1,350	0.0	0	2,805	3,021	2,174	1227	2090	1504
36	-30	1	Elliott Formation	150	0	0	0	0	9.0	252	0.59	0.6	97	0	1,851	0	0	1,350	0.0	0	2,961	3,177	2,286	1295	2203	1585
37	-31	1	Elliott Formation	150	0	0	0	0	9.0	261	0.57	0.7	99	0	1,950	0	0	1,350	0.0	0	3,119	3,335	2,400	1365	2317	1667
38	-32	1	Elliott Formation	150	0	0	0	0	9.0	270	0.55	0.7	101	0	2,050	0	0	1,350	0.0	0	3,280	3,496	2,515	1435	2434	1751
39	-33	1	Elliott Formation	150	0	0	0	0	9.0	279	0.54	0.7	102	0	2,153	0	0	1,350	0.0	0	3,444	3,660	2,633	1507	2552	1836
40	-34	1	Elliott Formation	150	0	0	0	0	9.0	288	0.52	0.7	104	0	2,257	0	0	1,350	0.0	0	3,611	3,827	2,753	1580	2673	1923
41	-35	1	Elliott Formation	150	0	0	0	0	9.0	297	0.50	0.7	106	0	2,362	0	0	1,350	0.0	0	3,780	3,996	2,874	1654	2795	2010
42	-36	1	Elliott Formation	150	0	0	0	0	9.0	306	0.49	0.7	107	0	2,469	0	0	1,350	0.0	0	3,951	4,167	2,998	1729	2918	2100
43	-37	1	Elliott Formation	150	0	0	0	0	9.0	315	0.48	0.7	109	0	2,578	0	0	1,350	0.0	0	4,125	4,341	3,123	1805	3044	2190
44	-38	1	Elliott Formation	150	0	0	0	0	9.0	324	0.46	0.7	110	0	2,688	0	0	1,350	0.0	0	4,301	4,517	3,250	1882	3171	2281
45	-39	1	Elliott Formation	150	0	0	0	0	9.0	333	0.45	0.7	112	0	2,800	0	0	1,350	0.0	0	4,480	4,696	3,379	1960	3300	2374
46	-40	1	Elliott Formation	150	0	0	0	0	9.0	342	0.44	0.8	113	0	2,914	0	0	1,350	0.0	0	4,662	4,878	3,509	2039	3431	2468
47	-41	1	Elliott Formation	150	0	0	0	0	9.0	351	0.43	0.8	115	0	3,028	0	0	1,350	0.0	0	4,845	5,061	3,641	2120	3563	2563
48	-42	1	Elliott Formation	150	0	0	0	0	9.0	360	0.42	0.8	116	0	3,145	0	0	1,350	0.0	0	5,031	5,247	3,775	2201	3697	2660
49	-43	1	Elliott Formation	150	0	0	0	0	9.0	369	0.41	0.8	118	0	3,262	0	0	1,350	0.0	0	5,220	5,436	3,911	2284	3833	2757
50	-44	1	Elliott Formation	150	0	0	0	0	9.0	378	0.40	0.8	119	0	3,381	0	0	1,350	0.0	0	5,410	5,626	4,048	2367	3970	2856
51	-45	1	Elliott Formation	150	0	0	0	0	9.0	387	0.39	0.8	121	0	3,502	0	0	1,350	0.0	0	5,603	5,819	4,186	2451	4109	2956
52	-46	1	Elliott Formation	150	0	0	0	0	9.0	397	0.38	0.8	122	0	3,624	0	0	1,350	0.0	0	5,798	6,014	4,327	2537	4249	3057
53	-47	1	Elliott Formation	150	0	0	0	0	9.0	406	0.37	0.8	123	0	3,747	0	0	1,350	0.0	0	5,996	6,212	4,469	2623	4391	3159
54	-48	1	Elliott Formation	150	0	0	0	0	9.0	415	0.36	0.8	125	0	3,872	0	0	1,350	0.0	0	6,195	6,411	4,612	2710	4534	3262
55	-49	1	Elliott Formation	150	0	0	0	0	9.0	424	0.35	0.8	126	0	3,998	0	0	1,350	0.0	0	6,397	6,613	4,757	2799	4679	3366
56	-50	1	Elliott Formation	150	0	0	0	0	9.0	433	0.35	0.8	127	0	4,125	0	0	1,350	0.0	0	6,601	6,817	4,904	2888	4826	3472
57	-51	1	Elliott Formation	150	0	0	0	0	9.0	442	0.34	0.9	129	0	4,254	0	0	1,350	0.0	0	6,806	7,022	5,052	2978	4974	3578
58	-52	1	Elliott Formation	150	0	0	0	0	9.0	451	0.33	0.9	130	0	4,384	0	0	1,350	0.0	0	7,014	7,230	5,202	3069	5123	3686
59	-53	1	Elliott Formation	150	0	0	0	0	9.0	460	0.33	0.9	131	0	4,515	0	0	1,350	0.0	0	7,224	7,440	5,353	3161	5274	3794
60	-54	1	Elliott Formation	150	0	0	0	0	9.0	469	0.32	0.9	133	0	4,648	0	0	1,350	0.0	0	7,437	7,653	5,505	3253	5426	3904
61	-55	1	Elliott Formation	150	0	0	0	0	9.0	478	0.31	0.9	134	0	4,782	0	0	1,350	0.0	0	7,651	7,867	5,659	3347	5580	4014



Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 1a
Ground Surface
Cut-off Elevation
Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Alignment 2

Client: DLGRMA	**Computed by:** JPB	**Checked by:** BJG	
Project: Bundaberg East Levee	**Date:** 14/2/2018	**Date:** 5/2/2018	
Job Number: 121923-221532	**Rev by:** JPB	**Page:** 6 & 7	
Detail: Driven Preformed Concrete Pile Alignment 2	**Date:** 28/2/2018		

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	400 mm Square Preformed Concrete Pile		
Pile shape =	square	(square or circle)	
Pile Diameter / Length of Side =	0.4	m	
Surface Area =	1.6	sq m/m length	Assume pile is 100% plugged
Wall Thickness =	0	m	
End Bearing Area - FULL AREA =	0.160	sq meters	= 0.160 sq meters
Unit weight of pile =	24	kN/m^3	

Soil Properties

Alignment 2

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1	

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction For Clay: fs clay (kPa)	Unit Skin Friction For Sand: fs sand (kPa)	Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY Unit End Bearing For Clay: qp clay (kPa)	Unit End Bearing For Sand: Nq	qp sand (kPa)	Ult. Friction Capacity Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity Fs+Qp (kN)	Allow. Comp. Capacity Total Fs+Qp (kN)	UPLIFT CAPACITY Σ fs* (kN/m)	Ultimate Uplift Capacity Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	11	42	30	5	9	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	54	39	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	36	67	48	16	31	22
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	50	82	59	22	43	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	65	97	70	29	55	40
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	81	113	81	35	68	49
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	97	129	93	42	81	58
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	130	162	117	57	108	78
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	166	197	142	72	137	98
8	-2	1	Elliott Formation	50	0	0	0	0	9.0	96	0.52	0.7	35	0	138	0	0	450	0.0	0	221	293	211	97	179	129
9	-3	1	Elliott Formation	50	0	0	0	0	9.0	105	0.47	0.7	36	0	174	0	0	450	0.0	0	279	351	253	122	224	161
10	-4	1	Elliott Formation	50	0	0	0	0	9.0	114	0.44	0.8	38	0	212	0	0	450	0.0	0	340	412	296	149	270	194
11	-5	1	Elliott Formation	50	0	0	0	0	9.0	123	0.40	0.8	39	0	252	0	0	450	0.0	0	403	475	341	176	318	229
12	-6	1	Elliott Formation	50	0	0	0	0	9.0	132	0.38	0.8	41	0	292	0	0	450	0.0	0	468	540	388	205	367	264
13	-7	1	Elliott Formation	50	0	0	0	0	9.0	142	0.35	0.8	42	0	334	0	0	450	0.0	0	535	607	437	234	418	301
14	-8	1	Elliott Formation	50	0	0	0	0	9.0	151	0.33	0.9	43	0	378	0	0	450	0.0	0	604	676	487	264	470	338
15	-9	1	Elliott Formation	50	0	0	0	0	9.0	160	0.31	0.9	45	0	422	0	0	450	0.0	0	676	748	538	296	524	377
16	-10	1	Elliott Formation	50	0	0	0	0	9.0	169	0.30	0.9	46	0	468	0	0	450	0.0	0	749	821	591	328	579	417
17	-11	1	Elliott Formation	50	0	0	0	0	9.0	178	0.28	0.9	47	0	515	0	0	450	0.0	0	825	897	645	361	636	457
18	-12	1	Elliott Formation	50	0	0	0	0	9.0	187	0.27	1.0	48	0	564	0	0	450	0.0	0	902	974	701	395	694	499
19	-13	1	Elliott Formation	50	0	0	0	0	9.0	196	0.26	1.0	49	0	613	0	0	450	0.0	0	981	1,053	758	429	753	542
20	-14	1	Elliott Formation	50	0	0	0	0	9.0	205	0.24	1.0	50	0	663	0	0	450	0.0	0	1,061	1,133	815	464	812	585
21	-15	1	Elliott Formation	50	0	0	0	0	9.0	214	0.23	1.0	50	0	713	0	0	450	0.0	0	1,141	1,213	873	499	872	628
22	-16	1	Elliott Formation	50	0	0	0	0	9.0	223	0.22	1.0	50	0	763	0	0	450	0.0	0	1,221	1,293	930	534	932	671
23	-17	1	Elliott Formation	50	0	0	0	0	9.0	232	0.22	1.0	50	0	813	0	0	450	0.0	0	1,301	1,373	988	569	992	714
24	-18	1	Elliott Formation	50	0	0	0	0	9.0	241	0.21	1.0	50	0	863	0	0	450	0.0	0	1,381	1,453	1,045	604	1052	757
25	-19	1	Elliott Formation	50	0	0	0	0	9.0	250	0.20	1.0	50	0	913	0	0	450	0.0	0	1,461	1,533	1,103	639	1111	800
26	-20	1	Elliott Formation	50	0	0	0	0	9.0	259	0.19	1.0	50	0	963	0	0	450	0.0	0	1,541	1,613	1,160	674	1171	843

Client: DLGRMA
Project: Bundaberg East Levee
Job Number: 121923-221532
Detail: Driven Preformed Concrete Pile Alignment 2

Computed by: JPB
Date: 14/2/2018
Rev by: JPB
Date: 28/2/2018

Checked by: BJG
Date: 5/2/2018
Page: 6 & 7

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

	Alignment 2		
	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

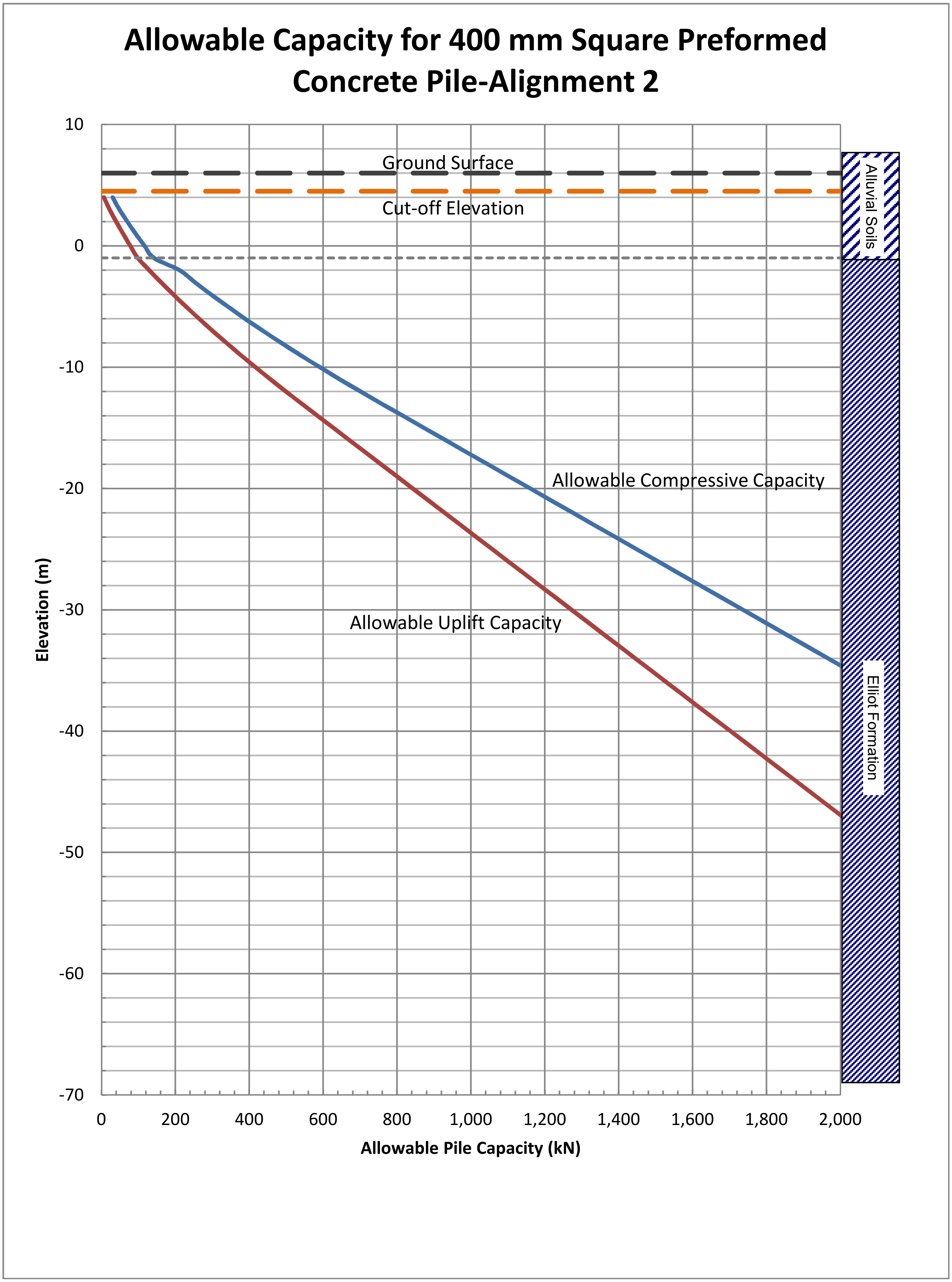
Pile type =	400 mm Square Preformed Concrete Pile		
Pile shape =	square	(square or circle)	
Pile Diameter / Length of Side =	0.4	m	
Surface Area =	1.6	sq m/m length	
Wall Thickness =	0	m	
End Bearing Area - FULL AREA =	0.160	sq meters	= 0.160 sq meters
Unit weight of pile =	24	kN/m³	

Assume pile is 100% plugged

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕ_g =	0.76	Based on AS 2159-2009 Section 4.3.1	

																		COMPRESSION CAPACITY						UPLIFT CAPACITY		
													Unit Skin Friction					Unit End Bearing			Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
													For Clay	For Sand	Cum. fs			For Clay	For Sand							
27	-21	1	Elliott Formation	50	0	0	0	0	9.0	268	0.19	1.0	50	0	1,013	0	0	450	0.0	0	1,621	1,693	1,218	709	1231	886
28	-22	1	Elliott Formation	50	0	0	0	0	9.0	277	0.18	1.0	50	0	1,063	0	0	450	0.0	0	1,701	1,773	1,276	744	1291	929
29	-23	1	Elliott Formation	50	0	0	0	0	9.0	286	0.17	1.0	50	0	1,113	0	0	450	0.0	0	1,781	1,853	1,333	779	1350	972
30	-24	1	Elliott Formation	50	0	0	0	0	9.0	295	0.17	1.0	50	0	1,163	0	0	450	0.0	0	1,861	1,933	1,391	814	1410	1015
31	-25	1	Elliott Formation	50	0	0	0	0	9.0	304	0.16	1.0	50	0	1,213	0	0	450	0.0	0	1,941	2,013	1,448	849	1470	1058
32	-26	1	Elliott Formation	50	0	0	0	0	9.0	313	0.16	1.0	50	0	1,263	0	0	450	0.0	0	2,021	2,093	1,506	884	1530	1101
33	-27	1	Elliott Formation	50	0	0	0	0	9.0	322	0.16	1.0	50	0	1,313	0	0	450	0.0	0	2,101	2,173	1,563	919	1590	1144
34	-28	1	Elliott Formation	50	0	0	0	0	9.0	331	0.15	1.0	50	0	1,363	0	0	450	0.0	0	2,181	2,253	1,621	954	1649	1187
35	-29	1	Elliott Formation	50	0	0	0	0	9.0	340	0.15	1.0	50	0	1,413	0	0	450	0.0	0	2,261	2,333	1,678	989	1709	1230
36	-30	1	Elliott Formation	50	0	0	0	0	9.0	349	0.14	1.0	50	0	1,463	0	0	450	0.0	0	2,341	2,413	1,736	1024	1769	1273
37	-31	1	Elliott Formation	50	0	0	0	0	9.0	358	0.14	1.0	50	0	1,513	0	0	450	0.0	0	2,421	2,493	1,794	1059	1829	1316
38	-32	1	Elliott Formation	50	0	0	0	0	9.0	367	0.14	1.0	50	0	1,563	0	0	450	0.0	0	2,501	2,573	1,851	1094	1888	1359
39	-33	1	Elliott Formation	50	0	0	0	0	9.0	376	0.13	1.0	50	0	1,613	0	0	450	0.0	0	2,581	2,653	1,909	1129	1948	1402
40	-34	1	Elliott Formation	50	0	0	0	0	9.0	385	0.13	1.0	50	0	1,663	0	0	450	0.0	0	2,661	2,733	1,966	1164	2008	1445
41	-35	1	Elliott Formation	50	0	0	0	0	9.0	394	0.13	1.0	50	0	1,713	0	0	450	0.0	0	2,741	2,813	2,024	1199	2068	1488
42	-36	1	Elliott Formation	50	0	0	0	0	9.0	403	0.12	1.0	50	0	1,763	0	0	450	0.0	0	2,821	2,893	2,081	1234	2127	1531
43	-37	1	Elliott Formation	50	0	0	0	0	9.0	412	0.12	1.0	50	0	1,813	0	0	450	0.0	0	2,901	2,973	2,139	1269	2187	1574
44	-38	1	Elliott Formation	50	0	0	0	0	9.0	421	0.12	1.0	50	0	1,863	0	0	450	0.0	0	2,981	3,053	2,196	1304	2247	1617
45	-39	1	Elliott Formation	50	0	0	0	0	9.0	430	0.12	1.0	50	0	1,913	0	0	450	0.0	0	3,061	3,133	2,254	1339	2307	1660
46	-40	1	Elliott Formation	50	0	0	0	0	9.0	439	0.11	1.0	50	0	1,963	0	0	450	0.0	0	3,141	3,213	2,312	1374	2367	1703
47	-41	1	Elliott Formation	50	0	0	0	0	9.0	448	0.11	1.0	50	0	2,013	0	0	450	0.0	0	3,221	3,293	2,369	1409	2426	1746
48	-42	1	Elliott Formation	50	0	0	0	0	9.0	457	0.11	1.0	50	0	2,063	0	0	450	0.0	0	3,301	3,373	2,427	1444	2486	1789
49	-43	1	Elliott Formation	50	0	0	0	0	9.0	466	0.11	1.0	50	0	2,113	0	0	450	0.0	0	3,381	3,453	2,484	1479	2546	1832
50	-44	1	Elliott Formation	50	0	0	0	0	9.0	475	0.11	1.0	50	0	2,163	0	0	450	0.0	0	3,461	3,533	2,542	1514	2606	1875
51	-45	1	Elliott Formation	50	0	0	0	0	9.0	484	0.10	1.0	50	0	2,213	0	0	450	0.0	0	3,541	3,613	2,599	1549	2665	1918
52	-46	1	Elliott Formation	50	0	0	0	0	9.0	493	0.10	1.0	50	0	2,263	0	0	450	0.0	0	3,621	3,693	2,657	1584	2725	1961
53	-47	1	Elliott Formation	50	0	0	0	0	9.0	502	0.10	1.0	50	0	2,313	0	0	450	0.0	0	3,701	3,773	2,714	1619	2785	2004
54	-48	1	Elliott Formation	50	0	0	0	0	9.0	511	0.10	1.0	50	0	2,363	0	0	450	0.0	0	3,781	3,853	2,772	1654	2845	2047
55	-49	1	Elliott Formation	50	0	0	0	0	9.0	520	0.10	1.0	50	0	2,413	0	0	450	0.0	0	3,861	3,933	2,830	1689	2904	2090
56	-50	1	Elliott Formation	50	0	0	0	0	9.0	529	0.09	1.0	50	0	2,463	0	0	450	0.0	0	3,941	4,013	2,887	1724	2964	2133
57	-51	1	Elliott Formation	50	0	0	0	0	9.0	538	0.09	1.0	50	0	2,513	0	0	450	0.0	0	4,021	4,093	2,945	1759	3024	2176
58	-52	1	Elliott Formation	50	0	0	0	0	9.0	547	0.09	1.0	50	0	2,563	0	0	450	0.0	0	4,101	4,173	3,002	1794	3084	2219
59	-53	1	Elliott Formation	50	0	0	0	0	9.0	556	0.09	1.0	50	0	2,613	0	0	450	0.0	0	4,181	4,253	3,060	1829	3144	2262
60	-54	1	Elliott Formation	50	0	0	0	0	9.0	565	0.09	1.0	50	0	2,663	0	0	450	0.0	0	4,261	4,333	3,117	1864	3203	2305
61	-55	1	Elliott Formation	50	0	0	0	0	9.0	574	0.09	1.0	50	0	2,713	0	0	450	0.0	0	4,341	4,413	3,175	1899	3263	2348



Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 2
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Alignment 3

Client: DLGRMA **Computed by:** JPB **Checked by:** BJG
Project: Bundaberg East Levee **Date:** 14/2/2018 **Date:** 5/2/2018
Job Number: 121923-221532 **Rev by:** JPB **Page:** 6 & 7
Detail: Driven Preformed Concrete Pile Alignment 3 **Date:** 28/2/2018

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

Alignment 3

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

Pile type =	400 mm Square Preformed Concrete Pile	
Pile shape =	square	(square or circle)
Pile Diameter / Length of Side =	0.4	m
Surface Area =	1.6	sq m/m length
Wall Thickness =	0	m
End Bearing Area - FULL AREA =	0.160	sq meters = 0.160 sq meters
Unit weight of pile =	24	kN/m^3

Assume pile is 100% plugged

Design Parameters

K =	1	
Nc (clay) =	9	
Reduction on downdrag load by bitimen coating =	0	% (apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7	
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g
Downdrag load factor =	0	
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	Unit End Bearing – For Sand: Nq	Unit End Bearing – For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	11	42	30	5	9	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	54	39	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	36	67	48	16	31	22
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	50	82	59	22	43	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	65	97	70	29	55	40
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	81	113	81	35	68	49
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	97	129	93	42	81	58
6	0	1	Elliott Formation	0	30	20	67	2.9	9.0	80	0.00	N/A	0	29	90	0	0	0	18.4	1,472	143	379	273	63	117	84
7	-1	1	Elliott Formation	0	30	20	67	2.9	9.0	89	0.00	N/A	0	32	122	0	0	0	18.4	1,637	195	457	329	85	157	113
8	-2	1	Elliott Formation	0	30	20	67	2.9	9.0	98	0.00	N/A	0	36	158	0	0	0	18.4	1,803	252	541	389	110	201	145
9	-3	1	Elliott Formation	0	30	20	67	2.9	9.0	107	0.00	N/A	0	39	197	0	0	0	18.4	1,969	315	630	453	138	249	179
10	-4	1	Elliott Formation	0	30	20	67	2.9	9.0	116	0.00	N/A	0	42	239	0	0	0	18.4	2,135	382	724	521	167	300	216
11	-5	1	Elliott Formation	0	30	20	67	2.9	9.0	125	0.00	N/A	0	46	284	0	0	0	18.4	2,301	455	823	592	199	354	255
12	-6	1	Elliott Formation	0	30	20	67	2.9	9.0	134	0.00	N/A	0	49	333	0	0	0	18.4	2,467	533	928	668	233	413	297
13	-7	1	Elliott Formation	0	30	20	67	2.9	9.0	143	0.00	N/A	0	52	385	0	0	0	18.4	2,633	616	1,038	747	270	475	342
14	-8	1	Elliott Formation	0	30	20	67	2.9	9.0	152	0.00	N/A	0	55	441	0	0	0	18.4	2,799	705	1,153	829	308	541	389
15	-9	1	Elliott Formation	0	30	20	67	2.9	9.0	161	0.00	N/A	0	59	499	0	0	0	18.4	2,900	799	1,263	909	350	610	439
16	-10	1	Elliott Formation	0	30	20	67	2.9	9.0	170	0.00	N/A	0	62	561	0	0	0	18.4	2,900	898	1,362	980	393	683	492
17	-11	1	Elliott Formation	0	30	20	67	2.9	9.0	179	0.00	N/A	0	65	626	0	0	0	18.4	2,900	1,002	1,466	1,055	438	760	547
18	-12	1	Elliott Formation	0	30	20	67	2.9	9.0	188	0.00	N/A	0	67	693	0	0	0	18.4	2,900	1,109	1,573	1,132	485	839	603
19	-13	1	Elliott Formation	0	30	20	67	2.9	9.0	197	0.00	N/A	0	67	760	0	0	0	18.4	2,900	1,217	1,681	1,209	532	918	660
20	-14	1	Elliott Formation	0	30	20	67	2.9	9.0	206	0.00	N/A	0	67	827	0	0	0	18.4	2,900	1,324	1,788	1,286	579	996	717
21	-15	1	Elliott Formation	0	30	20	67	2.9	9.0	215	0.00	N/A	0	67	894	0	0	0	18.4	2,900	1,431	1,895	1,363	626	1075	774
22	-16	1	Elliott Formation	0	30	20	67	2.9	9.0	224	0.00	N/A	0	67	961	0	0	0	18.4	2,900	1,538	2,002	1,440	673	1154	830
23	-17	1	Elliott Formation	0	30	20	67	2.9	9.0	233	0.00	N/A	0	67	1,028	0	0	0	18.4	2,900	1,645	2,109	1,518	720	1233	887
24	-18	1	Elliott Formation	0	30	20	67	2.9	9.0	242	0.00	N/A	0	67	1,095	0	0	0	18.4	2,900	1,753	2,217	1,595	767	1312	944
25	-19	1	Elliott Formation	0	30	20	67	2.9	9.0	251	0.00	N/A	0	67	1,162	0	0	0	18.4	2,900	1,860	2,324	1,672	814	1391	1000
26	-20	1	Elliott Formation	0	30	20	67	2.9	9.0	260	0.00	N/A	0	67	1,229	0	0	0	18.4	2,900	1,967	2,431	1,749	861	1469	1057

Client: DLGRMA **Computed by:** JPB **Checked by:** BJG
Project: Bundaberg East Levee **Date:** 14/2/2018 **Date:** 5/2/2018
Job Number: 121923-221532 **Rev by:** JPB **Page:** 6 & 7
Detail: Driven Preformed Concrete Pile Alignment 3 **Date:** 28/2/2018

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m Per Test Boring B-6
Pile Cut-Off Elevation = 4.5 m

Pile Information

Pile type = 400 mm Square Preformed Concrete Pile
Pile shape = square (square or circle)
Pile Diameter / Length of Side = 0.4 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0 m
End Bearing Area - FULL AREA = 0.160 sq meters = 0.160 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Soil Properties

Alignment 3

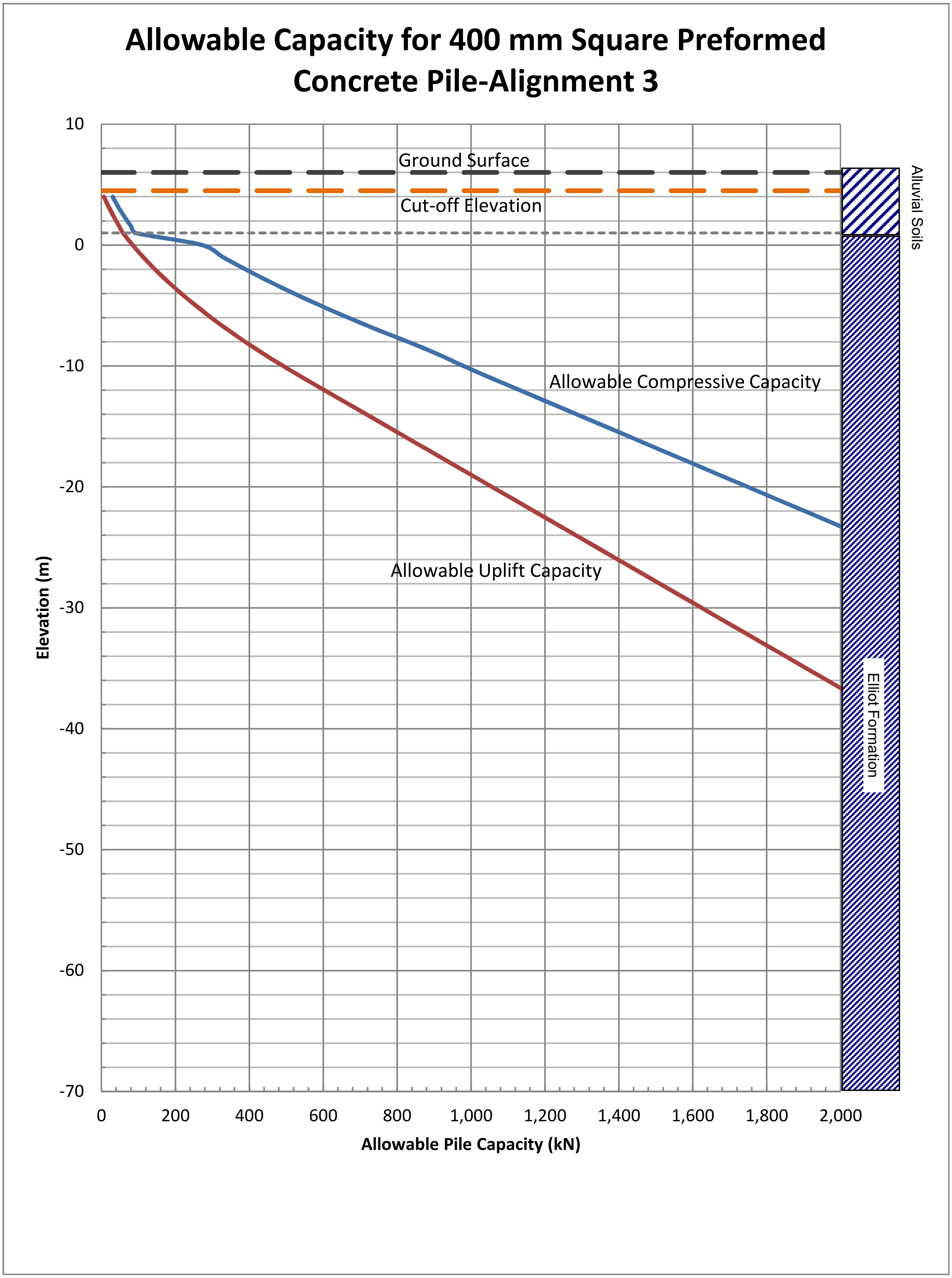
	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing			Ult. Friction	Ult. Comp.	Allow. Comp.	UPLIFT CAPACITY	Ultimate Uplift	Allow. Uplift.
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Capacity	Capacity	Capacity		Capacity	Capacity
27	-21	1	Elliott Formation	0	30	20	67	2.9	9.0	269	0.00	N/A	0	67	1,296	0	0	0	18.4	2,900	2,074	2,538	1,826	907	1548	1114
28	-22	1	Elliott Formation	0	30	20	67	2.9	9.0	278	0.00	N/A	0	67	1,363	0	0	0	18.4	2,900	2,181	2,645	1,903	954	1627	1170
29	-23	1	Elliott Formation	0	30	20	67	2.9	9.0	287	0.00	N/A	0	67	1,430	0	0	0	18.4	2,900	2,289	2,753	1,980	1001	1706	1227
30	-24	1	Elliott Formation	0	30	20	67	2.9	9.0	296	0.00	N/A	0	67	1,497	0	0	0	18.4	2,900	2,396	2,860	2,057	1048	1785	1284
31	-25	1	Elliott Formation	0	30	20	67	2.9	9.0	305	0.00	N/A	0	67	1,564	0	0	0	18.4	2,900	2,503	2,967	2,135	1095	1863	1341
32	-26	1	Elliott Formation	0	30	20	67	2.9	9.0	314	0.00	N/A	0	67	1,631	0	0	0	18.4	2,900	2,610	3,074	2,212	1142	1942	1397
33	-27	1	Elliott Formation	0	30	20	67	2.9	9.0	323	0.00	N/A	0	67	1,698	0	0	0	18.4	2,900	2,717	3,181	2,289	1189	2021	1454
34	-28	1	Elliott Formation	0	30	20	67	2.9	9.0	332	0.00	N/A	0	67	1,765	0	0	0	18.4	2,900	2,825	3,289	2,366	1236	2100	1511
35	-29	1	Elliott Formation	0	30	20	67	2.9	9.0	341	0.00	N/A	0	67	1,832	0	0	0	18.4	2,900	2,932	3,396	2,443	1283	2179	1567
36	-30	1	Elliott Formation	0	30	20	67	2.9	9.0	350	0.00	N/A	0	67	1,899	0	0	0	18.4	2,900	3,039	3,503	2,520	1330	2257	1624
37	-31	1	Elliott Formation	0	30	20	67	2.9	9.0	359	0.00	N/A	0	67	1,966	0	0	0	18.4	2,900	3,146	3,610	2,597	1376	2336	1681
38	-32	1	Elliott Formation	0	30	20	67	2.9	9.0	368	0.00	N/A	0	67	2,033	0	0	0	18.4	2,900	3,253	3,717	2,674	1423	2415	1737
39	-33	1	Elliott Formation	0	30	20	67	2.9	9.0	377	0.00	N/A	0	67	2,100	0	0	0	18.4	2,900	3,361	3,825	2,752	1470	2494	1794
40	-34	1	Elliott Formation	0	30	20	67	2.9	9.0	387	0.00	N/A	0	67	2,167	0	0	0	18.4	2,900	3,468	3,932	2,829	1517	2573	1851
41	-35	1	Elliott Formation	0	30	20	67	2.9	9.0	396	0.00	N/A	0	67	2,234	0	0	0	18.4	2,900	3,575	4,039	2,906	1564	2652	1908
42	-36	1	Elliott Formation	0	30	20	67	2.9	9.0	405	0.00	N/A	0	67	2,301	0	0	0	18.4	2,900	3,682	4,146	2,983	1611	2730	1964
43	-37	1	Elliott Formation	0	30	20	67	2.9	9.0	414	0.00	N/A	0	67	2,368	0	0	0	18.4	2,900	3,789	4,253	3,060	1658	2809	2021
44	-38	1	Elliott Formation	0	30	20	67	2.9	9.0	423	0.00	N/A	0	67	2,435	0	0	0	18.4	2,900	3,897	4,361	3,137	1705	2888	2078
45	-39	1	Elliott Formation	0	30	20	67	2.9	9.0	432	0.00	N/A	0	67	2,502	0	0	0	18.4	2,900	4,004	4,468	3,214	1752	2967	2134
46	-40	1	Elliott Formation	0	30	20	67	2.9	9.0	441	0.00	N/A	0	67	2,569	0	0	0	18.4	2,900	4,111	4,575	3,291	1799	3046	2191
47	-41	1	Elliott Formation	0	30	20	67	2.9	9.0	450	0.00	N/A	0	67	2,636	0	0	0	18.4	2,900	4,218	4,682	3,369	1845	3124	2248
48	-42	1	Elliott Formation	0	30	20	67	2.9	9.0	459	0.00	N/A	0	67	2,703	0	0	0	18.4	2,900	4,325	4,789	3,446	1892	3203	2304
49	-43	1	Elliott Formation	0	30	20	67	2.9	9.0	468	0.00	N/A	0	67	2,770	0	0	0	18.4	2,900	4,433	4,897	3,523	1939	3282	2361
50	-44	1	Elliott Formation	0	30	20	67	2.9	9.0	477	0.00	N/A	0	67	2,837	0	0	0	18.4	2,900	4,540	5,004	3,600	1986	3361	2418
51	-45	1	Elliott Formation	0	30	20	67	2.9	9.0	486	0.00	N/A	0	67	2,904	0	0	0	18.4	2,900	4,647	5,111	3,677	2033	3440	2475
52	-46	1	Elliott Formation	0	30	20	67	2.9	9.0	495	0.00	N/A	0	67	2,971	0	0	0	18.4	2,900	4,754	5,218	3,754	2080	3518	2531
53	-47	1	Elliott Formation	0	30	20	67	2.9	9.0	504	0.00	N/A	0	67	3,038	0	0	0	18.4	2,900	4,861	5,325	3,831	2127	3597	2588
54	-48	1	Elliott Formation	0	30	20	67	2.9	9.0	513	0.00	N/A	0	67	3,105	0	0	0	18.4	2,900	4,969	5,433	3,908	2174	3676	2645
55	-49	1	Elliott Formation	0	30	20	67	2.9	9.0	522	0.00	N/A	0	67	3,172	0	0	0	18.4	2,900	5,076	5,540	3,986	2221	3755	2701
56	-50	1	Elliott Formation	0	30	20	67	2.9	9.0	531	0.00	N/A	0	67	3,239	0	0	0	18.4	2,900	5,183	5,647	4,063	2268	3834	2758
57	-51	1	Elliott Formation	0	30	20	67	2.9	9.0	540	0.00	N/A	0	67	3,306	0	0	0	18.4	2,900	5,290	5,754	4,140	2314	3912	2815
58	-52	1	Elliott Formation	0	30	20	67	2.9	9.0	549	0.00	N/A	0	67	3,373	0	0	0	18.4	2,900	5,397	5,861	4,217	2361	3991	2871
59	-53	1	Elliott Formation	0	30	20	67	2.9	9.0	558	0.00	N/A	0	67	3,440	0	0	0	18.4	2,900	5,505	5,969	4,294	2408	4070	2928
60	-54	1	Elliott Formation	0	30	20	67	2.9	9.0	567	0.00	N/A	0	67	3,507	0	0	0	18.4	2,900	5,612	6,076	4,371	2455	4149	2985
61	-55	1	Elliott Formation	0	30	20	67	2.9	9.0	576	0.00	N/A	0	67	3,574	0	0	0	18.4	2,900	5,719	6,183	4,448	2502	4228	3042



Allowable Capacity for 400 mm Square Preformed Concrete Pile-Alignment 3
Ground Surface
Cut-off Elevation
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Attachment D2

Driven 500-mm-Diameter Steel Cast In Place Piles

Client: DLGRMA	**Checked by:** JPB	**Computed by:** BJG
Project: Bundaberg East Levee	**Date:** 14/2/2018	**Date:** 5/2/2018
Job Number: 121923-221532	**Rev by & Date:** JPB, 28/2/2018	**Page:** 1
Detail: Driven Steel Cast In Place Circular Pile		**Updated by/date:** MDC, 10/12/2018

Problem: Evaluate the vertical pile capacity of an assumed steel cast in place circular pile.

References:

1. Federal Highway Administration, "Design and Construction of Driven Pile Foundations," FHWA-HI-97-013, December 1996.
2. API Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
3. Australian Building and Construction Commission, "Code for the Tendering and Performance of Building Work 2016"
4. FHWA, "Design and Construction of Driven Pile Foundations, Workshop Manual - Volume I," September 2016.
5. AS 2159-2009, Australian Standard - Piling -Design and Installation.
6. FHWA, "Design and Construction of Driven Pile Foundations - Comprehensive Design Examples," September 2016.
7. "Factual Geotechnical Report, Bundaberg East Levee, Bundaberg, Queensland" CDM Smith, 31 January 2018
8. "Geotechnical Investigation Factual Report" Core Consultants Pty Ltd., November 2018

Pile Information: 500 mm closed-end steel cast in place circular pile

Datum: Australian Height Datum (AHD)

Assumptions:

1. The proposed pile cut-off elevation is assumed to be at 1.5 meters below ground surface.
2. Groundwater elevation is assumed at El. 2.5 based upon observed water level in test boring B-6.
3. Pile is a 500 mm circular, 345 MPA steel pipe pile with a 15.87 mm wall thickness.
4. Allowable structural capacity of the 500 mm pile filled with 27.5 MPa grout is 2750 kN.
5. Assume the design life of the steel piles to be 100 years.
6. Assume the steel corrosion rate for the pile to be 0.08 mm/year or 8mm over the pile design life.
7. Assume 5 percent of piles are dynamically load tested.
8. Assume no downdrag load due to negligible raise in grade.
9. Assume k=1.0 for closed end pile per Reference No. 2.
10. Assume axial load required for each pile is 250, 500, 750, and 1,000 kN.
11. Assume friction interface reduction factor for uplift is 0.7.

Soil Information: Soil layering, soil properties and groundwater elevation obtained from available boring logs[7].

Table 1 - Summary of Subsurface Conditions

	Alignment	1. City Alignment Sta. 0+50 to Sta. 3+75	2. City Alignment Sta. 3+75 to Sta. 7+85	3. Distillery Alignment Sta. 3+00 to Sta. 5+25
	Alluvial Soils Thickness(m)	13	7	5
	Elliott Formation Thickness(m)	>15	>15	>10
	Applicable Borings	B-2, B-3, B-5, BH-101, BH102	B-4, B-6, B-7, BH-103, BH-104, BH-105	B-12, B-13, BH-107, BH-108, BH-109
Elliott Formation Properties	Su (kPa)	150	50	0
	δ (°)	0	0	20
	Φ (°)	0	0	30
	Limiting Skin Friction (kPa)	0	0	67
	Limiting End Bearing (MPa)	0	0	2.9

Analysis Method: Simplified API 1986 & 1993 Method

$Q\ compression = A_p \times q_p + \Sigma (A_s \times f_s)$ Eq. 6.4.1-1 Reference 2

where A_p= tip area f_s=side friction
q_p=tip resistance A_s=side area

Skin Friction (f_s):

For undrained clay (a-Method): $f_s = \alpha * S_u$ Eq. 6.4.2-1 and Eq. 6.4.2-2 Reference 2

where $\alpha = 0.5^* (Su/\sigma_v')^{\wedge(-0.5)}$ for $(su/\sigma_v')<1$
$= 0.5^* (Su/\sigma_v')^{\wedge(-025)} <1$ for $(su/\sigma_v')>1$
S_u =undrained shear strength

For drained clay/sand (b-Method): $f_s = K \tan\delta * \sigma'_v$ Eq. 6.4.3-1 Reference 2

where δ = soil - pile friction angle
K = lateral pressure coefficient
σ'_v = effective vertical pressure

Tip Resistance (q_p)

For undrained clay: $q_p = N_c * Su$ Eq. 6.4.2-3 Reference 2

where $N_c = 9$
Su = undrained shear strength at the pile tip

For drained clay/sand: $q_p = Nq * \sigma_v'$ Eq. 6.4.3-2 Reference 2

where $Nq = \exp(\pi^*\tan\phi)^*[\tan(45+\phi/2)]^{\wedge}2$ (Meyerhoff)
σ_v' = effective vertical pressure at the pile tip

Results:
A summary of the total allowable compression and uplift capacity is summarized in Table 1 below.

Table 2 - Summary of Allowable Compression and Uplift Pile Capacity

Soil Profile	Total Allowable Compression Capacity (kN)	Total Allowable Uplift Capacity (kN)	Embedment in Elliott Formation (m)
1	250	200	1
1	500	325	2
1	750	475	5
1	1000	725	8
2	250	150	2
2	500	375	8
2	750	525	12
2	1000	750	17
3	250	75	1
3	500	175	4
3	750	325	8
3	1000	475	11

Notes:
1. Assumes a FS of 1.39 based on AS 2159-2009 Section 4.3.1 calculation.

References:

AS 2159-2009 Piling -- Design and Installation

4.3 GENERAL PRINCIPLES OF GEOTECHNICAL STRENGTH DESIGN

4.3.1 Design geotechnical strength

A pile shall be proportioned such that the design geotechnical strength ($R_{d.g}$) is not less than the design action effect (E_d) as detailed in Clause 3.2.2, that is—

$$R_{d.g} \geq E_d \quad \ldots 4.3.1(1)$$

The design geotechnical strength ($R_{d.g}$) shall be calculated as the design ultimate geotechnical strength ($R_{d.ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g), according to the following equation:

$$R_{d.g} = \phi_g R_{d.ug} \quad \ldots 4.3.1(2)$$

The geotechnical strength reduction factor (ϕ_g) shall be determined as follows:

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

where

ϕ_{gb} = basic geotechnical strength reduction factor as given in Clause 4.3.2

ϕ_{tf} = intrinsic test factor

= 0.9, for static load testing (see Section 8)

= 0.75, for rapid load testing (see Section 8)

= 0.8, for dynamic load testing of preformed piles (see Section 8)

= 0.75, for dynamic load testing of other than preformed piles (see Section 8)

= 0.85, for bi-directional load testing (see Section 8)

= ϕ_{gb}, for no testing

K = testing benefit factor

= $1.33p/(p + 3.3) \leq 1$, for static or rapid load testing

= $1.13p/(p + 3.3) \leq 1$, for dynamic load testing

p = percentage of the total piles that are tested and meet the specified acceptance criteria

References:

4.3.2 Assessment of basic geotechnical strength reduction factor (ϕ_{gb})

The basic geotechnical strength reduction factor (ϕ_{gb}) shall be calculated using a risk assessment procedure as set out below:

(a) Rate each risk factor in Table 4.3.2(A) on a scale from 1 to 5 for the nature of the site, the available site information and the pile design and installation procedures adopted. This will produce an individual risk rating (IRR) according to the assessed level of risk, as set out in Table 4.3.2(B).

(b) Determine the overall design average risk rating (ARR) using the weighted average of the product of all of the risk weighting factors (w_i) shown in column 2 of Table 4.3.2(A) times the relevant individual risk rating (IRR), as follows:

$$ARR = \Sigma(w_i \mathrm{IRR}_i)/\Sigma w_i \qquad \ldots 4.3.2$$

(c) Determine the basic geotechnical strength reduction factor (ϕ_{gb}) from Table 4.3.2(C) depending on the level of redundancy in the piling system. Systems with a high degree of redundancy would include large pile groups under large caps, piled rafts and pile groups with more than 4 piles. Systems with a low level of redundancy would include isolated heavily loaded piles and piles set out at large spacings.

TABLE 4.3.2(A)

WEIGHTING FACTORS AND INDIVIDUAL RISK RATINGS FOR RISK FACTORS

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Site				
Geological complexity of site	2	Horizontal strata, well-defined soil and rock characteristics	Some variability over site, but without abrupt changes in stratigraphy	Highly variable profile or presence of karstic features or steeply dipping rock levels or faults present on site, or combinations of these
Extent of ground investigation	2	Extensive drilling investigation covering whole site to an adequate depth	Some boreholes extending at least 5 pile diameters below the base of the proposed pile foundation level	Very limited investigation with few shallow boreholes
Amount and quality of geotechnical data	2	Detailed information on strength compressibility of the main strata	CPT probes over full depth of proposed piles or boreholes confirming rock as proposed founding level for piles	Limited amount of simple in situ testing (e.g., SPT) or index tests only
Design				
Experience with similar foundations in similar geological conditions	1	Extensive	Limited	None

(*continued*)

Client: DLGRMA **Checked by:** JPB **Computed by:** BJG
Project: Bundaberg East Levee **Date:** 14/2/2018 **Date:** 5/2/2018
Job Number: 121923-221532 **Rev by & Date:** JPB, 28/2/2018 **Page:** 4
Detail: Driven Steel Cast In Place Circular Pile

References:

TABLE 4.3.2(A) *(continued)*

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Method of assessment of geotechnical parameters for design	2	Based on appropriate laboratory or in situ tests or relevant existing pile load test data	Based on site-specific correlations or on conventional laboratory or in situ testing	Based on non-site-specific correlations with (for example) SPT data
Design method adopted	1	Well-established and soundly based method or methods	Simplified methods with well-established basis	Simple empirical methods or sophisticated methods that are not well established
Method of utilizing results of in situ test data and installation data	2	Design values based on minimum measured values on piles loaded to failure	Design methods based on average values	Design values based on maximum measured values on test piles loaded up only to working load, or indirect measurements used during installation, and not calibrated to static loading tests
Installation				
Level of construction control	2	Detailed with professional geotechnical supervision, construction processes that are well established and relatively straightforward	Limited degree of professional geotechnical involvement in supervision, conventional construction procedures	Very limited or no involvement by designer, construction processes that are not well established or complex
Level of performance monitoring of the supported structure during and after construction	0.5	Detailed measurements of movements and pile loads	Correlation of installed parameters with on-site static load tests carried out in accordance with this Standard	No monitoring

NOTE: The pile design shall include the risk circumstances for each individual risk category and consideration of all of the relevant site and construction factors.

TABLE 4.3.2(B)
INDIVIDUAL RISK RATING (IRR)

Risk level	Individual risk rating (IRR)
Very low	1
Low	2
Moderate	3
High	4
Very high	5

TABLE 4.3.2(C)
BASIC GEOTECHNICAL STRENGTH REDUCTION FACTOR (ϕ_{gb}) FOR AVERAGE RISK RATING

Range of average risk rating (ARR)	Overall risk category	ϕ_{gb} for low redundancy systems	ϕ_{gb} for high redundancy systems
ARR ≤1.5	Very low	0.67	0.76
1.5 < ARR ≤2.0	Very low to low	0.61	0.70
2.0 < ARR ≤2.5	Low	0.56	0.64
2.5 < ARR ≤3.0	Low to moderate	0.52	0.60
3.0 < ARR ≤3.5	Moderate	0.48	0.56
3.5 < ARR ≤4.0	Moderate to high	0.45	0.53
4.0 < ARR ≤4.5	High	0.42	0.50
>4.5	Very high	0.40	0.47

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

ϕ_{tf} = 0.8 for dynamic load testing

K = 1.13p/(p+3.3)
p= 5 percent of piles to be tested
K= 0.68
IRR= 50.5
w_i = 14.5
ARR= 3.48
ϕ_{gb} = 0.56

ϕ_g = 0.72 >= 0.56

FS= 1.39

Table 1: Structural Capacity of Closed Steel Cast In Place Pile with No Corrosion

Type Closed End Pipe Pile (No Corrosion)
Shape circle

Outer Diameter (m)	Gross Area (sq m)	Wall Thickness (m)	Initial Area of Pipe Steel (sq m)	Material Loss (m)	Effective Area of Pipe Steel (sq m)	Fy (kPa)	Allowable (steel only) Load (kN)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Post Concrete Load (kN)	Total Allowable Load (kN)
0.3	0.0707	0.0159	0.01	0	0.01	200000	1419.1	0.06	27500	513	**1932**
0.35	0.0962	0.0159	0.02	0	0.02	200000	1668.9	0.08	27500	722	**2391**
0.4	0.1257	0.0159	0.02	0	0.02	200000	1918.6	0.11	27500	966	**2885**
0.45	0.1590	0.0159	0.02	0	0.02	200000	2168.4	0.14	27500	1247	**3415**
0.5	0.1963	0.0159	0.02	0	0.02	200000	2418.1	0.17	27500	1562	**3981**
0.55	0.2376	0.0159	0.03	0	0.03	200000	2667.9	0.21	27500	1914	**4582**

Notes:
1 Allowable Steel Stress = 0.5 Fy
2 Allowable Concrete Stress = 0.33 f'c

Table 2: Structural Capacity of Closed Steel Cast In Place Pile with Corrosion

Type Closed End Pipe Pile (corrosion - assumed 8 mm reduction in steel thickness)
Shape circle

Outer Diameter (m)	Gross Area (sq m)	Wall Thickness (m)	Initial Area of Pipe Steel (sq m)	Material Loss (m)	Effective Area of Pipe Steel (sq m)	Fy (kN/m2)	Allowable (steel only) Load (kN)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Post Concrete Load (kN)	Total Allowable Load (kN)
0.3	0.0707	0.0159	0.01	0.0080	0.0069	200000	685.2	0.06	27500	513	**1198**
0.35	0.0962	0.0159	0.02	0.0080	0.0081	200000	809.3	0.08	27500	722	**1531**
0.4	0.1257	0.0159	0.02	0.0080	0.0093	200000	933.4	0.11	27500	966	**1900**
0.45	0.1590	0.0159	0.02	0.0080	0.0106	200000	1057.5	0.14	27500	1247	**2304**
0.5	0.1963	0.0159	0.02	0.0080	0.0118	200000	1181.6	0.17	27500	1562	**2744**
0.55	0.2376	0.0159	0.03	0.0080	0.0131	200000	1305.7	0.21	27500	1914	**3220**

Notes:
1 Allowable Steel Stress = 0.5 Fy
2 Allowable Concrete Stress = 0.33 f'c
3 Assume the steel corrosion rate for the pile to be 0.08 mm/year or 8 mm over the pile design life based upon Reference No. 6 page 8-32.

Alignment 1

Client: DLGRMA
Project: Bundaberg East Levee
Job Number: Bundaberg East Levee

Computed by: BJG
Date: 5/2/2018
Rev by & Date: JPB, 28/2/2018

Checked by: JPB
Date: 14/2/2018
Page: 7 & 8
Updated by/date: MDC, 10/12/2018

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m — Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m — Per Test Boring B--6
Pile Cut-Off Elevation = 4.5 m

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	150	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 — Based on Bottom Elevation of Pile Cap.

Pile Information

Pile type = 500 mm closed end steel cast in place circular pile
Pile shape = circle (square or circle)
Pile Diameter / Length of Side = 0.5 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0.0159 m
End Bearing Area - FULL AREA = 0.196 sq meters = 0.196 sq meters
Unit weight of pile = 24 kN/m³

Assume pile is 100% plugged

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7 (for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.72 Based on AS 2159-2009 Section 4.3.1

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m³	σv' (kPa)	Su/σv'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	Unit End Bearing – For Sand: Nq	Unit End Bearing – For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	10	49	35	5	10	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	61	44	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	35	74	53	16	31	23
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	49	88	63	22	44	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	64	103	74	29	56	41
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	79	118	85	35	69	50
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	95	134	96	42	83	60
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	128	167	120	57	110	79
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	163	201	145	72	139	100
8	-2	1	Alluvial Soils	22	15	0	0	0	8.2	96	0.23	1.0	22	0	125	0	0	198	0.0	0	197	236	170	88	168	121
9	-3	1	Alluvial Soils	22	15	0	0	0	8.2	104	0.21	1.0	22	0	147	0	0	198	0.0	0	232	271	195	103	197	142
10	-4	1	Alluvial Soils	22	15	0	0	0	8.2	113	0.20	1.0	22	0	169	0	0	198	0.0	0	266	305	219	119	226	162
11	-5	1	Alluvial Soils	22	15	0	0	0	8.2	121	0.18	1.0	22	0	191	0	0	198	0.0	0	301	340	244	134	254	183
12	-6	1	Alluvial Soils	22	15	0	0	0	8.2	129	0.17	1.0	22	0	213	0	0	198	0.0	0	335	374	269	149	283	204
13	-7	1	Alluvial Soils	22	15	0	0	0	8.2	137	0.16	1.0	22	0	235	0	0	198	0.0	0	370	409	294	165	312	225
14	-8	1	Elliott Formation	150	0	0	0	0	9.0	146	1.03	0.5	74	0	310	0	0	1,350	0.0	0	487	752	541	217	399	287
15	-9	1	Elliott Formation	150	0	0	0	0	9.0	155	0.97	0.5	76	0	386	0	0	1,350	0.0	0	607	872	627	270	487	350
16	-10	1	Elliott Formation	150	0	0	0	0	9.0	164	0.92	0.5	78	0	465	0	0	1,350	0.0	0	730	995	716	325	578	416
17	-11	1	Elliott Formation	150	0	0	0	0	9.0	173	0.87	0.5	81	0	545	0	0	1,350	0.0	0	856	1,121	807	382	671	483
18	-12	1	Elliott Formation	150	0	0	0	0	9.0	182	0.82	0.6	83	0	628	0	0	1,350	0.0	0	986	1,251	900	439	766	551
19	-13	1	Elliott Formation	150	0	0	0	0	9.0	191	0.79	0.6	85	0	712	0	0	1,350	0.0	0	1,119	1,384	996	499	864	622
20	-14	1	Elliott Formation	150	0	0	0	0	9.0	200	0.75	0.6	87	0	799	0	0	1,350	0.0	0	1,255	1,520	1,093	559	964	693
21	-15	1	Elliott Formation	150	0	0	0	0	9.0	209	0.72	0.6	89	0	887	0	0	1,350	0.0	0	1,394	1,659	1,193	621	1066	767
22	-16	1	Elliott Formation	150	0	0	0	0	9.0	218	0.69	0.6	90	0	978	0	0	1,350	0.0	0	1,536	1,801	1,296	684	1170	842
23	-17	1	Elliott Formation	150	0	0	0	0	9.0	227	0.66	0.6	92	0	1,070	0	0	1,350	0.0	0	1,681	1,946	1,400	749	1276	918
24	-18	1	Elliott Formation	150	0	0	0	0	9.0	236	0.64	0.6	94	0	1,164	0	0	1,350	0.0	0	1,829	2,094	1,506	815	1384	996
25	-19	1	Elliott Formation	150	0	0	0	0	9.0	245	0.61	0.6	96	0	1,260	0	0	1,350	0.0	0	1,979	2,244	1,614	882	1494	1075
26	-20	1	Elliott Formation	150	0	0	0	0	9.0	254	0.59	0.7	98	0	1,358	0	0	1,350	0.0	0	2,132	2,397	1,725	950	1606	1155

Client: DLGRMA
Project: Bundaberg East Levee
Job Number: Bundaberg East Levee

Computed by: BJG
Date: 5/2/2018
Rev by & Date: JPB, 28/2/2018

Checked by: JPB
Date: 14/2/2018
Page: 7 & 8
Updated by/date: MDC, 10/12/2018

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B--6
Pile Cut-Off Elevation =	4.5	m	

Soil Properties

Alignment 1

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	150	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

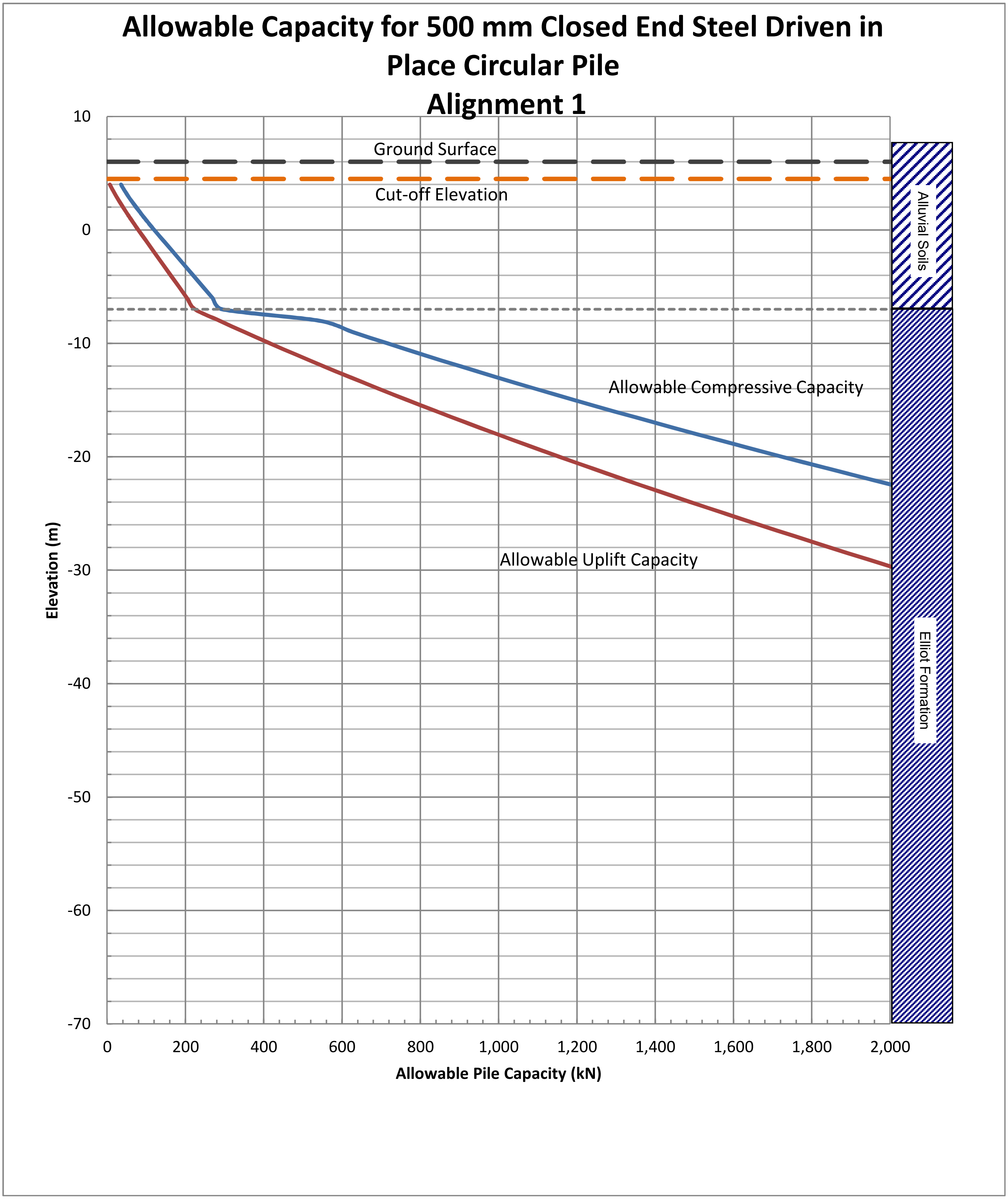
Pile Information

Pile type =	500 mm closed end steel cast in place circular pile			
Pile shape =	circle	(square or circle)		
Pile Diameter / Length of Side =	0.5	m		
Surface Area =	1.6	sq m/m length		Assume pile is
Wall Thickness =	0.0159	m		100%
End Bearing Area - FULL AREA =	0.196	sq meters	= 0.196 sq meters	plugged
Unit weight of pile =	24	kN/m³		

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.72	Based on AS 2159-2009 Section 4.3.1	

																		COMPRESSION CAPACITY						UPLIFT CAPACITY		
													Unit Skin Friction					Unit End Bearing			Ult. Friction	Ult. Comp.	Allow. Comp.		Ultimate Uplift	Allow. Uplift.
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Capacity	Capacity	Capacity		Capacity	Capacity
27	-21	1	Elliott Formation	150	0	0	0	0	9.0	263	0.57	0.7	99	0	1,457	0	0	1,350	0.0	0	2,288	2,553	1,837	1020	1720	1237
28	-22	1	Elliott Formation	150	0	0	0	0	9.0	272	0.55	0.7	101	0	1,558	0	0	1,350	0.0	0	2,447	2,712	1,951	1090	1836	1321
29	-23	1	Elliott Formation	150	0	0	0	0	9.0	281	0.53	0.7	103	0	1,661	0	0	1,350	0.0	0	2,608	2,873	2,067	1162	1953	1405
30	-24	1	Elliott Formation	150	0	0	0	0	9.0	290	0.52	0.7	104	0	1,765	0	0	1,350	0.0	0	2,772	3,037	2,185	1235	2072	1491
31	-25	1	Elliott Formation	150	0	0	0	0	9.0	299	0.50	0.7	106	0	1,871	0	0	1,350	0.0	0	2,938	3,204	2,305	1309	2193	1578
32	-26	1	Elliott Formation	150	0	0	0	0	9.0	308	0.49	0.7	107	0	1,978	0	0	1,350	0.0	0	3,107	3,372	2,426	1385	2316	1666
33	-27	1	Elliott Formation	150	0	0	0	0	9.0	317	0.47	0.7	109	0	2,087	0	0	1,350	0.0	0	3,279	3,544	2,549	1461	2441	1756
34	-28	1	Elliott Formation	150	0	0	0	0	9.0	326	0.46	0.7	111	0	2,198	0	0	1,350	0.0	0	3,452	3,717	2,674	1538	2567	1847
35	-29	1	Elliott Formation	150	0	0	0	0	9.0	335	0.45	0.7	112	0	2,310	0	0	1,350	0.0	0	3,628	3,894	2,801	1617	2695	1939
36	-30	1	Elliott Formation	150	0	0	0	0	9.0	344	0.44	0.8	114	0	2,424	0	0	1,350	0.0	0	3,807	4,072	2,929	1696	2825	2032
37	-31	1	Elliott Formation	150	0	0	0	0	9.0	353	0.42	0.8	115	0	2,539	0	0	1,350	0.0	0	3,988	4,253	3,060	1777	2956	2126
38	-32	1	Elliott Formation	150	0	0	0	0	9.0	362	0.41	0.8	117	0	2,655	0	0	1,350	0.0	0	4,171	4,436	3,191	1859	3088	2222
39	-33	1	Elliott Formation	150	0	0	0	0	9.0	371	0.40	0.8	118	0	2,773	0	0	1,350	0.0	0	4,356	4,621	3,325	1941	3223	2319
40	-34	1	Elliott Formation	150	0	0	0	0	9.0	380	0.39	0.8	119	0	2,893	0	0	1,350	0.0	0	4,544	4,809	3,460	2025	3359	2416
41	-35	1	Elliott Formation	150	0	0	0	0	9.0	389	0.39	0.8	121	0	3,013	0	0	1,350	0.0	0	4,733	4,999	3,596	2109	3496	2515
42	-36	1	Elliott Formation	150	0	0	0	0	9.0	398	0.38	0.8	122	0	3,136	0	0	1,350	0.0	0	4,925	5,190	3,734	2195	3635	2615
43	-37	1	Elliott Formation	150	0	0	0	0	9.0	407	0.37	0.8	124	0	3,259	0	0	1,350	0.0	0	5,120	5,385	3,874	2281	3776	2716
44	-38	1	Elliott Formation	150	0	0	0	0	9.0	416	0.36	0.8	125	0	3,384	0	0	1,350	0.0	0	5,316	5,581	4,015	2369	3918	2819
45	-39	1	Elliott Formation	150	0	0	0	0	9.0	425	0.35	0.8	126	0	3,510	0	0	1,350	0.0	0	5,514	5,779	4,158	2457	4061	2922
46	-40	1	Elliott Formation	150	0	0	0	0	9.0	434	0.35	0.9	128	0	3,638	0	0	1,350	0.0	0	5,715	5,980	4,302	2547	4206	3026
47	-41	1	Elliott Formation	150	0	0	0	0	9.0	443	0.34	0.9	129	0	3,767	0	0	1,350	0.0	0	5,917	6,182	4,448	2637	4353	3131
48	-42	1	Elliott Formation	150	0	0	0	0	9.0	452	0.33	0.9	130	0	3,897	0	0	1,350	0.0	0	6,122	6,387	4,595	2728	4500	3238
49	-43	1	Elliott Formation	150	0	0	0	0	9.0	461	0.33	0.9	132	0	4,029	0	0	1,350	0.0	0	6,328	6,593	4,744	2820	4650	3345
50	-44	1	Elliott Formation	150	0	0	0	0	9.0	470	0.32	0.9	133	0	4,162	0	0	1,350	0.0	0	6,537	6,802	4,894	2913	4800	3454
51	-45	1	Elliott Formation	150	0	0	0	0	9.0	479	0.31	0.9	134	0	4,296	0	0	1,350	0.0	0	6,748	7,013	5,045	3007	4952	3563
52	-46	1	Elliott Formation	150	0	0	0	0	9.0	488	0.31	0.9	135	0	4,431	0	0	1,350	0.0	0	6,960	7,225	5,198	3102	5106	3673
53	-47	1	Elliott Formation	150	0	0	0	0	9.0	497	0.30	0.9	137	0	4,568	0	0	1,350	0.0	0	7,175	7,440	5,352	3197	5261	3785
54	-48	1	Elliott Formation	150	0	0	0	0	9.0	506	0.30	0.9	138	0	4,705	0	0	1,350	0.0	0	7,391	7,656	5,508	3294	5417	3897
55	-49	1	Elliott Formation	150	0	0	0	0	9.0	515	0.29	0.9	139	0	4,844	0	0	1,350	0.0	0	7,610	7,875	5,665	3391	5574	4010
56	-50	1	Elliott Formation	150	0	0	0	0	9.0	524	0.29	0.9	140	0	4,985	0	0	1,350	0.0	0	7,830	8,095	5,824	3489	5733	4125
57	-51	1	Elliott Formation	150	0	0	0	0	9.0	534	0.28	0.9	141	0	5,126	0	0	1,350	0.0	0	8,052	8,317	5,984	3588	5893	4240
58	-52	1	Elliott Formation	150	0	0	0	0	9.0	543	0.28	1.0	143	0	5,269	0	0	1,350	0.0	0	8,276	8,541	6,145	3688	6055	4356
59	-53	1	Elliott Formation	150	0	0	0	0	9.0	552	0.27	1.0	144	0	5,413	0	0	1,350	0.0	0	8,502	8,767	6,307	3789	6218	4473
60	-54	1	Elliott Formation	150	0	0	0	0	9.0	561	0.27	1.0	145	0	5,558	0	0	1,350	0.0	0	8,730	8,995	6,471	3890	6382	4591
61	-55	1	Elliott Formation	150	0	0	0	0	9.0	570	0.26	1.0	146	0	5,704	0	0	1,350	0.0	0	8,959	9,224	6,636	3993	6547	4710


Allowable Capacity for 500 mm Closed End Steel Driven in Place Circular Pile
Alignment 1
Ground Surface
Cut-off Elevation
Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Alignment 2

Client: DLGRMA **Computed by:** BJG **Checked by:** JPB
Project: Bundaberg East Levee **Date:** 5/2/2018 **Date:** 14/2/2018
Job Number: 121923-221532 **Rev by & Date:** JPB, 28/2/2018 **Page:** 10 & 11

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	500 mm closed end steel cast in place circular pile		
Pile shape =	circle	(square or circle)	
Pile Diameter / Length of Side =	0.5	m	
Surface Area =	1.6	sq m/m length	
Wall Thickness =	0.0159	m	
End Bearing Area - FULL AREA =	0.196	sq meters	= 0.196 sq meters
Unit weight of pile =	24	kN/m³	

Assume pile is 100% plugged

Soil Properties

Alignment 2

	Alluvial Soils	Elliott Formation	
γ (kN/M³)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1	

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m³	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction: For Clay fs clay (kPa)	Unit Skin Friction: For Sand fs sand (kPa)	Unit Skin Friction: Cum. fs Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY: Unit End Bearing For Clay qp clay (kPa)	Unit End Bearing For Sand Nq	Unit End Bearing For Sand qp sand (kPa)	Ult. Friction Capacity Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity Fs+Qp (kN)	Allow. Comp. Capacity Total Fs+Qp (kN)	UPLIFT CAPACITY: Σ fs* (kN/m)	Ultimate Uplift Capacity Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	10	49	35	5	10	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	61	44	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	35	74	53	16	31	23
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	49	88	63	22	44	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	64	103	74	29	56	41
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	79	118	85	35	69	50
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	95	134	96	42	83	60
6	0	1	Alluvial Soils	22	15	0	0	0	8.2	80	0.28	1.0	21	0	81	0	0	198	0.0	0	128	167	120	57	110	79
7	-1	1	Alluvial Soils	22	15	0	0	0	8.2	88	0.25	1.0	22	0	103	0	0	198	0.0	0	163	201	145	72	139	100
8	-2	1	Elliott Formation	50	0	0	0	0	9.0	96	0.52	0.7	35	0	138	0	0	450	0.0	0	217	305	220	97	182	131
9	-3	1	Elliott Formation	50	0	0	0	0	9.0	105	0.47	0.7	36	0	174	0	0	450	0.0	0	274	362	261	122	227	163
10	-4	1	Elliott Formation	50	0	0	0	0	9.0	114	0.44	0.8	38	0	212	0	0	450	0.0	0	333	422	303	149	273	196
11	-5	1	Elliott Formation	50	0	0	0	0	9.0	123	0.40	0.8	39	0	252	0	0	450	0.0	0	395	484	348	176	321	231
12	-6	1	Elliott Formation	50	0	0	0	0	9.0	132	0.38	0.8	41	0	292	0	0	450	0.0	0	459	547	394	205	370	266
13	-7	1	Elliott Formation	50	0	0	0	0	9.0	142	0.35	0.8	42	0	334	0	0	450	0.0	0	525	614	441	234	421	303
14	-8	1	Elliott Formation	50	0	0	0	0	9.0	151	0.33	0.9	43	0	378	0	0	450	0.0	0	593	682	490	264	473	340
15	-9	1	Elliott Formation	50	0	0	0	0	9.0	160	0.31	0.9	45	0	422	0	0	450	0.0	0	663	752	541	296	527	379
16	-10	1	Elliott Formation	50	0	0	0	0	9.0	169	0.30	0.9	46	0	468	0	0	450	0.0	0	736	824	593	328	582	419
17	-11	1	Elliott Formation	50	0	0	0	0	9.0	178	0.28	0.9	47	0	515	0	0	450	0.0	0	810	898	646	361	638	459
18	-12	1	Elliott Formation	50	0	0	0	0	9.0	187	0.27	1.0	48	0	564	0	0	450	0.0	0	885	974	701	395	696	501
19	-13	1	Elliott Formation	50	0	0	0	0	9.0	196	0.26	1.0	49	0	613	0	0	450	0.0	0	963	1,051	756	429	755	543
20	-14	1	Elliott Formation	50	0	0	0	0	9.0	205	0.24	1.0	50	0	663	0	0	450	0.0	0	1,042	1,130	813	464	815	586
21	-15	1	Elliott Formation	50	0	0	0	0	9.0	214	0.23	1.0	50	0	713	0	0	450	0.0	0	1,120	1,209	869	499	874	629
22	-16	1	Elliott Formation	50	0	0	0	0	9.0	223	0.22	1.0	50	0	763	0	0	450	0.0	0	1,199	1,287	926	534	934	672
23	-17	1	Elliott Formation	50	0	0	0	0	9.0	232	0.22	1.0	50	0	813	0	0	450	0.0	0	1,277	1,366	982	569	994	715
24	-18	1	Elliott Formation	50	0	0	0	0	9.0	241	0.21	1.0	50	0	863	0	0	450	0.0	0	1,356	1,444	1,039	604	1053	758
25	-19	1	Elliott Formation	50	0	0	0	0	9.0	250	0.20	1.0	50	0	913	0	0	450	0.0	0	1,434	1,523	1,095	639	1113	801
26	-20	1	Elliott Formation	50	0	0	0	0	9.0	259	0.19	1.0	50	0	963	0	0	450	0.0	0	1,513	1,601	1,152	674	1172	843

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation =	6	m	Estimated Finished Grade
Effective Overburden =	27	kPa	
Groundwater Elevation =	2.5	m	Per Test Boring B-6
Pile Cut-Off Elevation =	4.5	m	

Pile Information

Pile type =	500 mm closed end steel cast in place circular pile		
Pile shape =	circle	(square or circle)	
Pile Diameter / Length of Side =	0.5	m	
Surface Area =	1.6	sq m/m length	
Wall Thickness =	0.0159	m	
End Bearing Area - FULL AREA =	0.196	sq meters	= 0.196 sq meters
Unit weight of pile =	24	kN/m^3	

Assume pile is 100% plugged

Soil Properties

Alignment 2

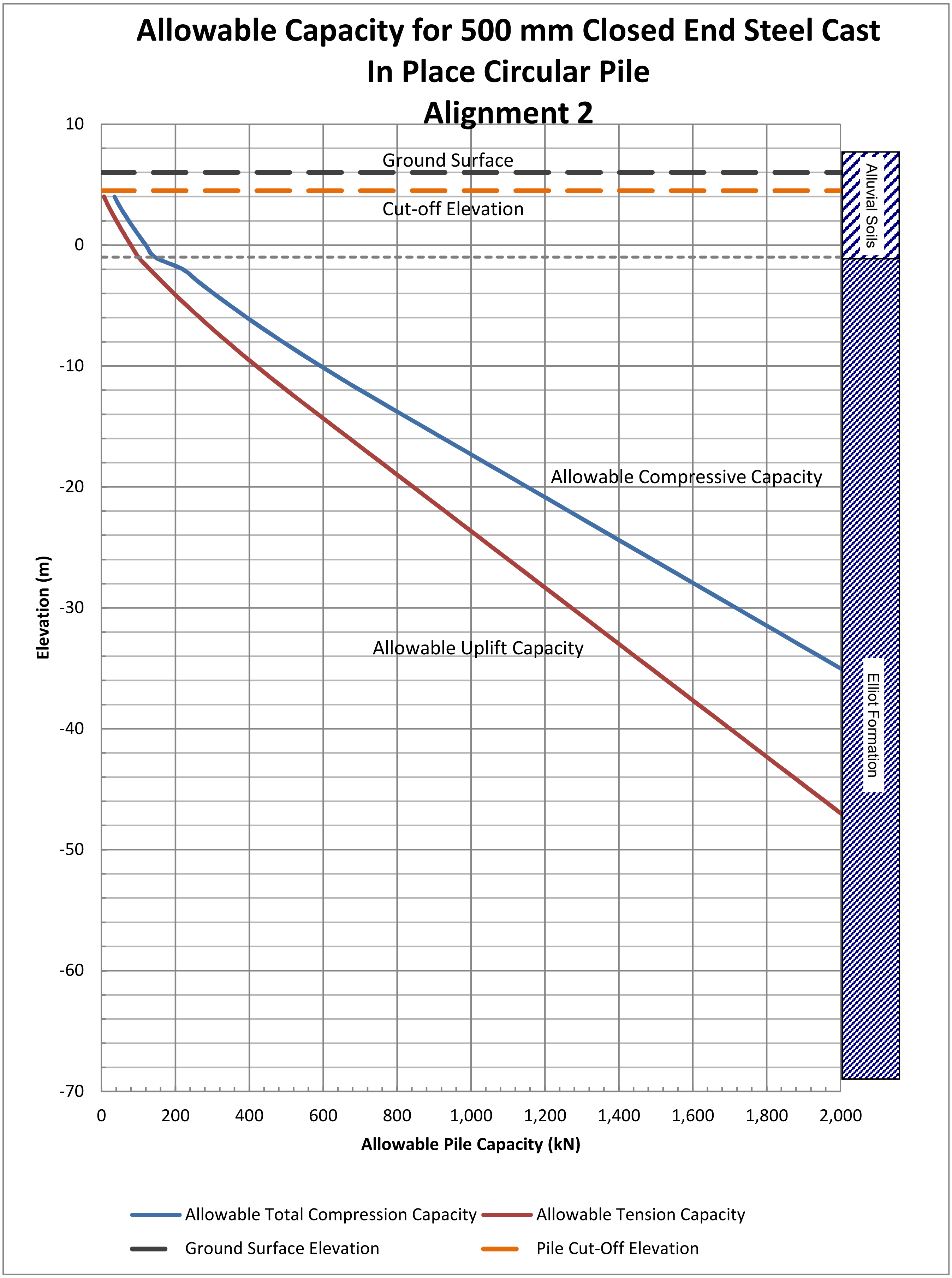
	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	50	
δ (°)	0	0	
Φ (°)	15	0	
Limiting Skin Friction (kPa)	0	0	Based on typical API values
Limiting End Bearing (MPa)	0	0	Based on typical API values

Design Parameters

K =	1		
Nc (clay) =	9		
Reduction on downdrag load by bitimen coating =	0	%	(apply for all skin friction)
Friction Interface Reduction Factor for Uplift =	0.7		(for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable =	1.39	Based on ϕ_g	
Downdrag load factor =	0		
ϕg =	0.76	Based on AS 2159-2009 Section 4.3.1	

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing						UPLIFT CAPACITY		
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
27	-21	1	Elliott Formation	50	0	0	0	0	9.0	268	0.19	1.0	50	0	1,013	0	0	450	0.0	0	1,591	1,680	1,208	709	1232	886
28	-22	1	Elliott Formation	50	0	0	0	0	9.0	277	0.18	1.0	50	0	1,063	0	0	450	0.0	0	1,670	1,758	1,265	744	1292	929
29	-23	1	Elliott Formation	50	0	0	0	0	9.0	286	0.17	1.0	50	0	1,113	0	0	450	0.0	0	1,749	1,837	1,321	779	1351	972
30	-24	1	Elliott Formation	50	0	0	0	0	9.0	295	0.17	1.0	50	0	1,163	0	0	450	0.0	0	1,827	1,915	1,378	814	1411	1015
31	-25	1	Elliott Formation	50	0	0	0	0	9.0	304	0.16	1.0	50	0	1,213	0	0	450	0.0	0	1,906	1,994	1,435	849	1470	1058
32	-26	1	Elliott Formation	50	0	0	0	0	9.0	313	0.16	1.0	50	0	1,263	0	0	450	0.0	0	1,984	2,073	1,491	884	1530	1101
33	-27	1	Elliott Formation	50	0	0	0	0	9.0	322	0.16	1.0	50	0	1,313	0	0	450	0.0	0	2,063	2,151	1,548	919	1590	1144
34	-28	1	Elliott Formation	50	0	0	0	0	9.0	331	0.15	1.0	50	0	1,363	0	0	450	0.0	0	2,141	2,230	1,604	954	1649	1187
35	-29	1	Elliott Formation	50	0	0	0	0	9.0	340	0.15	1.0	50	0	1,413	0	0	450	0.0	0	2,220	2,308	1,661	989	1709	1229
36	-30	1	Elliott Formation	50	0	0	0	0	9.0	349	0.14	1.0	50	0	1,463	0	0	450	0.0	0	2,298	2,387	1,717	1024	1768	1272
37	-31	1	Elliott Formation	50	0	0	0	0	9.0	358	0.14	1.0	50	0	1,513	0	0	450	0.0	0	2,377	2,465	1,774	1059	1828	1315
38	-32	1	Elliott Formation	50	0	0	0	0	9.0	367	0.14	1.0	50	0	1,563	0	0	450	0.0	0	2,455	2,544	1,830	1094	1888	1358
39	-33	1	Elliott Formation	50	0	0	0	0	9.0	376	0.13	1.0	50	0	1,613	0	0	450	0.0	0	2,534	2,622	1,887	1129	1947	1401
40	-34	1	Elliott Formation	50	0	0	0	0	9.0	385	0.13	1.0	50	0	1,663	0	0	450	0.0	0	2,612	2,701	1,943	1164	2007	1444
41	-35	1	Elliott Formation	50	0	0	0	0	9.0	394	0.13	1.0	50	0	1,713	0	0	450	0.0	0	2,691	2,779	2,000	1199	2067	1487
42	-36	1	Elliott Formation	50	0	0	0	0	9.0	403	0.12	1.0	50	0	1,763	0	0	450	0.0	0	2,770	2,858	2,056	1234	2126	1530
43	-37	1	Elliott Formation	50	0	0	0	0	9.0	412	0.12	1.0	50	0	1,813	0	0	450	0.0	0	2,848	2,936	2,113	1269	2186	1572
44	-38	1	Elliott Formation	50	0	0	0	0	9.0	421	0.12	1.0	50	0	1,863	0	0	450	0.0	0	2,927	3,015	2,169	1304	2245	1615
45	-39	1	Elliott Formation	50	0	0	0	0	9.0	430	0.12	1.0	50	0	1,913	0	0	450	0.0	0	3,005	3,094	2,226	1339	2305	1658
46	-40	1	Elliott Formation	50	0	0	0	0	9.0	439	0.11	1.0	50	0	1,963	0	0	450	0.0	0	3,084	3,172	2,282	1374	2365	1701
47	-41	1	Elliott Formation	50	0	0	0	0	9.0	448	0.11	1.0	50	0	2,013	0	0	450	0.0	0	3,162	3,251	2,339	1409	2424	1744
48	-42	1	Elliott Formation	50	0	0	0	0	9.0	457	0.11	1.0	50	0	2,063	0	0	450	0.0	0	3,241	3,329	2,395	1444	2484	1787
49	-43	1	Elliott Formation	50	0	0	0	0	9.0	466	0.11	1.0	50	0	2,113	0	0	450	0.0	0	3,319	3,408	2,452	1479	2543	1830
50	-44	1	Elliott Formation	50	0	0	0	0	9.0	475	0.11	1.0	50	0	2,163	0	0	450	0.0	0	3,398	3,486	2,508	1514	2603	1873
51	-45	1	Elliott Formation	50	0	0	0	0	9.0	484	0.10	1.0	50	0	2,213	0	0	450	0.0	0	3,476	3,565	2,565	1549	2663	1916
52	-46	1	Elliott Formation	50	0	0	0	0	9.0	493	0.10	1.0	50	0	2,263	0	0	450	0.0	0	3,555	3,643	2,621	1584	2722	1958
53	-47	1	Elliott Formation	50	0	0	0	0	9.0	502	0.10	1.0	50	0	2,313	0	0	450	0.0	0	3,633	3,722	2,678	1619	2782	2001
54	-48	1	Elliott Formation	50	0	0	0	0	9.0	511	0.10	1.0	50	0	2,363	0	0	450	0.0	0	3,712	3,800	2,734	1654	2841	2044
55	-49	1	Elliott Formation	50	0	0	0	0	9.0	520	0.10	1.0	50	0	2,413	0	0	450	0.0	0	3,791	3,879	2,791	1689	2901	2087
56	-50	1	Elliott Formation	50	0	0	0	0	9.0	529	0.09	1.0	50	0	2,463	0	0	450	0.0	0	3,869	3,957	2,847	1724	2961	2130
57	-51	1	Elliott Formation	50	0	0	0	0	9.0	538	0.09	1.0	50	0	2,513	0	0	450	0.0	0	3,948	4,036	2,904	1759	3020	2173
58	-52	1	Elliott Formation	50	0	0	0	0	9.0	547	0.09	1.0	50	0	2,563	0	0	450	0.0	0	4,026	4,115	2,960	1794	3080	2216
59	-53	1	Elliott Formation	50	0	0	0	0	9.0	556	0.09	1.0	50	0	2,613	0	0	450	0.0	0	4,105	4,193	3,017	1829	3139	2259
60	-54	1	Elliott Formation	50	0	0	0	0	9.0	565	0.09	1.0	50	0	2,663	0	0	450	0.0	0	4,183	4,272	3,073	1864	3199	2301
61	-55	1	Elliott Formation	50	0	0	0	0	9.0	574	0.09	1.0	50	0	2,713	0	0	450	0.0	0	4,262	4,350	3,130	1899	3259	2344



Allowable Capacity for 500 mm Closed End Steel Cast In Place Circular Pile
Alignment 2
Ground Surface
Cut-off Elevation
Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)
Allowable Total Compression Capacity
Allowable Tension Capacity
Ground Surface Elevation
Pile Cut-Off Elevation

Alignment 3

Client: DLGRMA **Computed by:** BJG **Checked by:** JPB
Project: Bundaberg East Levee **Date:** 5/2/2018 **Date:** 14/2/2018
Job Number: 121923-221532 **Rev by & Date:** JPB, 28/2/2018 **Page:** 13 & 14

AXIAL PILE CAPACITY ESTIMATI Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m Per Test Boring B--6
Pile Cut-Off Elevation = 4.5 m

Pile Information

Pile type = 500 mm closed end steel cast in place circular pile
Pile shape = circle (square or circle)
Pile Diameter / Length of Side = 0.5 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0.0159 m
End Bearing Area - FULL AREA = 0.196 sq meters = 0.196 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Soil Properties

Alignment 3

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7 (for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Bottom Depth (m)	El. (m)	Layer Thickness (m)	Soil Stratum	Su (kPa)	Phi (deg)	Soil-pile friction angle δ (°)	Limiting Skin Friction (kPa)	Limiting End Bearing (MPa)	Effective Unit weight kN/m^3	σ_v' (kPa)	Su/σ_v'	α	Unit Skin Friction – For Clay: fs clay (kPa)	Unit Skin Friction – For Sand: fs sand (kPa)	Unit Skin Friction – Cum. fs: Σ fs (kN/m)	Downdrag (kN/m)	Factored Downdrag (kN/m)	COMPRESSION CAPACITY – Unit End Bearing – For Clay: qp clay (kPa)	Unit End Bearing – For Sand: Nq	Unit End Bearing – For Sand: qp sand (kPa)	Ult. Friction Capacity: Fs (Σfs-downdrag) (kN)	Ult. Comp. Capacity: Fs+Qp (kN)	Allow. Comp. Capacity: Total Fs+Qp (kN)	UPLIFT CAPACITY – Σ fs* (kN/m)	Ultimate Uplift Capacity: Fst + Weight (kN)	Allow. Uplift. Capacity (kN)
0	6																									
0.5	5.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	5	4.88	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	0.5	Alluvial Soils	22	15	0	0	0	18.0	14	1.63	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	4.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	23	0.98	0.5	Pile Cut-Off Elevation at 4.5 m													
2	4	0.5	Alluvial Soils	22	15	0	0	0	18.0	32	0.70	0.6	13	0	7	0	0	198	0.0	0	10	49	35	5	10	7
2.5	3.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	41	0.54	0.7	15	0	14	0	0	198	0.0	0	22	61	44	10	20	14
3	3	0.5	Alluvial Soils	22	15	0	0	0	18.0	50	0.44	0.8	17	0	22	0	0	198	0.0	0	35	74	53	16	31	23
3.5	2.5	0.5	Alluvial Soils	22	15	0	0	0	18.0	59	0.38	0.8	18	0	31	0	0	198	0.0	0	49	88	63	22	44	31
4	2	0.5	Alluvial Soils	22	15	0	0	0	8.2	65	0.34	0.9	19	0	41	0	0	198	0.0	0	64	103	74	29	56	41
4.5	1.5	0.5	Alluvial Soils	22	15	0	0	0	8.2	69	0.32	0.9	20	0	51	0	0	198	0.0	0	79	118	85	35	69	50
5	1	0.5	Alluvial Soils	22	15	0	0	0	8.2	73	0.30	0.9	20	0	61	0	0	198	0.0	0	95	134	96	42	83	60
6	0	1	Elliott Formation	0	30	20	67	2.9	9.0	80	0.00	N/A	0	29	90	0	0	0	18.4	1,472	141	430	309	63	119	86
7	-1	1	Elliott Formation	0	30	20	67	2.9	9.0	89	0.00	N/A	0	32	122	0	0	0	18.4	1,637	192	513	369	85	160	115
8	-2	1	Elliott Formation	0	30	20	67	2.9	9.0	98	0.00	N/A	0	36	158	0	0	0	18.4	1,803	248	602	433	110	204	146
9	-3	1	Elliott Formation	0	30	20	67	2.9	9.0	107	0.00	N/A	0	39	197	0	0	0	18.4	1,969	309	696	500	138	251	181
10	-4	1	Elliott Formation	0	30	20	67	2.9	9.0	116	0.00	N/A	0	42	239	0	0	0	18.4	2,135	375	795	572	167	302	217
11	-5	1	Elliott Formation	0	30	20	67	2.9	9.0	125	0.00	N/A	0	46	284	0	0	0	18.4	2,301	447	899	646	199	357	257
12	-6	1	Elliott Formation	0	30	20	67	2.9	9.0	134	0.00	N/A	0	49	333	0	0	0	18.4	2,467	523	1,008	725	233	415	299
13	-7	1	Elliott Formation	0	30	20	67	2.9	9.0	143	0.00	N/A	0	52	385	0	0	0	18.4	2,633	605	1,122	807	270	477	343
14	-8	1	Elliott Formation	0	30	20	67	2.9	9.0	152	0.00	N/A	0	55	441	0	0	0	18.4	2,799	692	1,242	893	308	542	390
15	-9	1	Elliott Formation	0	30	20	67	2.9	9.0	161	0.00	N/A	0	59	499	0	0	0	18.4	2,900	784	1,354	974	350	611	440
16	-10	1	Elliott Formation	0	30	20	67	2.9	9.0	170	0.00	N/A	0	62	561	0	0	0	18.4	2,900	882	1,451	1,044	393	684	492
17	-11	1	Elliott Formation	0	30	20	67	2.9	9.0	179	0.00	N/A	0	65	626	0	0	0	18.4	2,900	984	1,553	1,118	438	761	547
18	-12	1	Elliott Formation	0	30	20	67	2.9	9.0	188	0.00	N/A	0	67	693	0	0	0	18.4	2,900	1,089	1,659	1,193	485	839	603
19	-13	1	Elliott Formation	0	30	20	67	2.9	9.0	197	0.00	N/A	0	67	760	0	0	0	18.4	2,900	1,194	1,764	1,269	532	917	660
20	-14	1	Elliott Formation	0	30	20	67	2.9	9.0	206	0.00	N/A	0	67	827	0	0	0	18.4	2,900	1,300	1,869	1,345	579	995	716
21	-15	1	Elliott Formation	0	30	20	67	2.9	9.0	215	0.00	N/A	0	67	894	0	0	0	18.4	2,900	1,405	1,974	1,420	626	1074	772
22	-16	1	Elliott Formation	0	30	20	67	2.9	9.0	224	0.00	N/A	0	67	961	0	0	0	18.4	2,900	1,510	2,080	1,496	673	1152	829
23	-17	1	Elliott Formation	0	30	20	67	2.9	9.0	233	0.00	N/A	0	67	1,028	0	0	0	18.4	2,900	1,615	2,185	1,572	720	1230	885
24	-18	1	Elliott Formation	0	30	20	67	2.9	9.0	242	0.00	N/A	0	67	1,095	0	0	0	18.4	2,900	1,721	2,290	1,648	767	1309	941
25	-19	1	Elliott Formation	0	30	20	67	2.9	9.0	251	0.00	N/A	0	67	1,162	0	0	0	18.4	2,900	1,826	2,395	1,723	814	1387	998
26	-20	1	Elliott Formation	0	30	20	67	2.9	9.0	260	0.00	N/A	0	67	1,229	0	0	0	18.4	2,900	1,931	2,501	1,799	861	1465	1054

Client: DLGRMA **Computed by:** BJG **Checked by:** JPB
Project: Bundaberg East Levee **Date:** 5/2/2018 **Date:** 14/2/2018
Job Number: 121923-221532 **Rev by & Date:** JPB, 28/2/2018 **Page:** 13 & 14

AXIAL PILE CAPACITY ESTIMAT Simplified API 1986&1993 Method

Input in Red

Not Applicable Above Pile Cut-Off in Blue

Site Information

Ground Elevation = 6 m Estimated Finished Grade
Effective Overburden = 27 kPa
Groundwater Elevation = 2.5 m Per Test Boring B--6
Pile Cut-Off Elevation = 4.5 m

Soil Properties

Alignment 3

	Alluvial Soils	Elliott Formation	
γ (kN/M^3)	18.0	18.8	value shown as a force
Su (kPa)	22	0	
δ (°)	0	20	
Φ (°)	15	30	
Limiting Skin Friction (kPa)	0	67	Based on typical API values
Limiting End Bearing (MPa)	0	2.9	Based on typical API values

ASSUMES DOWNDRAG TO EL. = 4.5 Based on Bottom Elevation of Pile Cap.

Pile Information

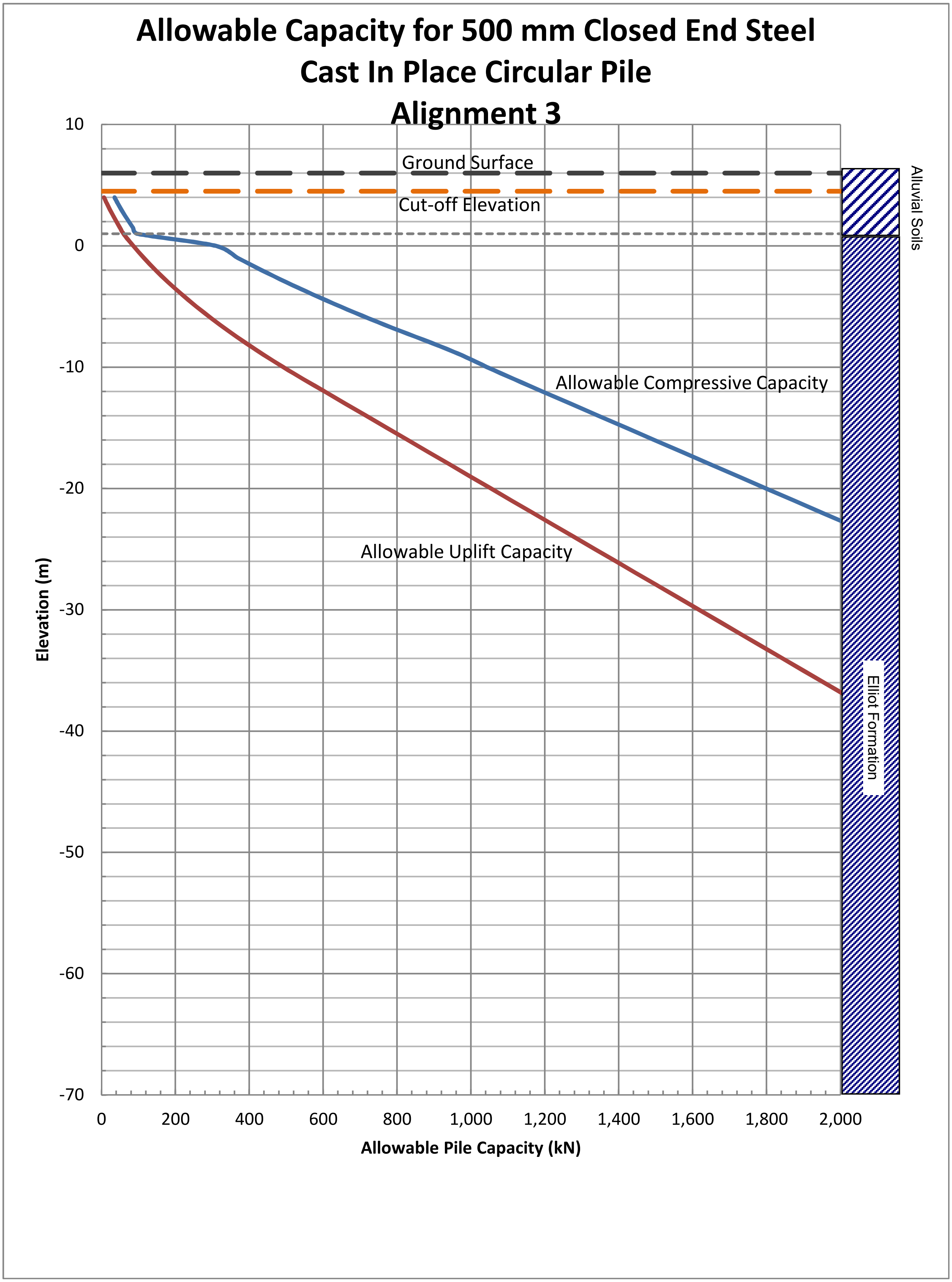
Pile type = 500 mm closed end steel cast in place circular pile
Pile shape = circle (square or circle)
Pile Diameter / Length of Side = 0.5 m
Surface Area = 1.6 sq m/m length
Wall Thickness = 0.0159 m
End Bearing Area - FULL AREA = 0.196 sq meters = 0.196 sq meters
Unit weight of pile = 24 kN/m^3

Assume pile is 100% plugged

Design Parameters

K = 1
Nc (clay) = 9
Reduction on downdrag load by bitimen coating = 0 % (apply for all skin friction)
Friction Interface Reduction Factor for Uplift = 0.7 (for pipe pile filled with 30 MPA concrete)
Factor of Safety to Calc. Allowable = 1.39 Based on ϕ_g
Downdrag load factor = 0
ϕg = 0.76 Based on AS 2159-2009 Section 4.3.1

													Unit Skin Friction					COMPRESSION CAPACITY: Unit End Bearing						UPLIFT CAPACITY		
													For Clay	For Sand	Cum. fs			For Clay	For Sand		Ult. Friction Capacity	Ult. Comp. Capacity	Allow. Comp. Capacity		Ultimate Uplift Capacity	Allow. Uplift. Capacity
27	-21	1	Elliott Formation	0	30	20	67	2.9	9.0	269	0.00	N/A	0	67	1,296	0	0	0	18.4	2,900	2,036	2,606	1,875	907	1543	1110
28	-22	1	Elliott Formation	0	30	20	67	2.9	9.0	278	0.00	N/A	0	67	1,363	0	0	0	18.4	2,900	2,142	2,711	1,950	954	1622	1167
29	-23	1	Elliott Formation	0	30	20	67	2.9	9.0	287	0.00	N/A	0	67	1,430	0	0	0	18.4	2,900	2,247	2,816	2,026	1001	1700	1223
30	-24	1	Elliott Formation	0	30	20	67	2.9	9.0	296	0.00	N/A	0	67	1,497	0	0	0	18.4	2,900	2,352	2,922	2,102	1048	1778	1279
31	-25	1	Elliott Formation	0	30	20	67	2.9	9.0	305	0.00	N/A	0	67	1,564	0	0	0	18.4	2,900	2,457	3,027	2,178	1095	1857	1336
32	-26	1	Elliott Formation	0	30	20	67	2.9	9.0	314	0.00	N/A	0	67	1,631	0	0	0	18.4	2,900	2,563	3,132	2,253	1142	1935	1392
33	-27	1	Elliott Formation	0	30	20	67	2.9	9.0	323	0.00	N/A	0	67	1,698	0	0	0	18.4	2,900	2,668	3,237	2,329	1189	2013	1448
34	-28	1	Elliott Formation	0	30	20	67	2.9	9.0	332	0.00	N/A	0	67	1,765	0	0	0	18.4	2,900	2,773	3,343	2,405	1236	2092	1505
35	-29	1	Elliott Formation	0	30	20	67	2.9	9.0	341	0.00	N/A	0	67	1,832	0	0	0	18.4	2,900	2,878	3,448	2,480	1283	2170	1561
36	-30	1	Elliott Formation	0	30	20	67	2.9	9.0	350	0.00	N/A	0	67	1,899	0	0	0	18.4	2,900	2,984	3,553	2,556	1330	2248	1617
37	-31	1	Elliott Formation	0	30	20	67	2.9	9.0	359	0.00	N/A	0	67	1,966	0	0	0	18.4	2,900	3,089	3,658	2,632	1376	2326	1674
38	-32	1	Elliott Formation	0	30	20	67	2.9	9.0	368	0.00	N/A	0	67	2,033	0	0	0	18.4	2,900	3,194	3,763	2,708	1423	2405	1730
39	-33	1	Elliott Formation	0	30	20	67	2.9	9.0	377	0.00	N/A	0	67	2,100	0	0	0	18.4	2,900	3,299	3,869	2,783	1470	2483	1786
40	-34	1	Elliott Formation	0	30	20	67	2.9	9.0	387	0.00	N/A	0	67	2,167	0	0	0	18.4	2,900	3,405	3,974	2,859	1517	2561	1843
41	-35	1	Elliott Formation	0	30	20	67	2.9	9.0	396	0.00	N/A	0	67	2,234	0	0	0	18.4	2,900	3,510	4,079	2,935	1564	2640	1899
42	-36	1	Elliott Formation	0	30	20	67	2.9	9.0	405	0.00	N/A	0	67	2,301	0	0	0	18.4	2,900	3,615	4,184	3,010	1611	2718	1955
43	-37	1	Elliott Formation	0	30	20	67	2.9	9.0	414	0.00	N/A	0	67	2,368	0	0	0	18.4	2,900	3,720	4,290	3,086	1658	2796	2012
44	-38	1	Elliott Formation	0	30	20	67	2.9	9.0	423	0.00	N/A	0	67	2,435	0	0	0	18.4	2,900	3,826	4,395	3,162	1705	2875	2068
45	-39	1	Elliott Formation	0	30	20	67	2.9	9.0	432	0.00	N/A	0	67	2,502	0	0	0	18.4	2,900	3,931	4,500	3,238	1752	2953	2124
46	-40	1	Elliott Formation	0	30	20	67	2.9	9.0	441	0.00	N/A	0	67	2,569	0	0	0	18.4	2,900	4,036	4,605	3,313	1799	3031	2181
47	-41	1	Elliott Formation	0	30	20	67	2.9	9.0	450	0.00	N/A	0	67	2,636	0	0	0	18.4	2,900	4,141	4,711	3,389	1845	3109	2237
48	-42	1	Elliott Formation	0	30	20	67	2.9	9.0	459	0.00	N/A	0	67	2,703	0	0	0	18.4	2,900	4,247	4,816	3,465	1892	3188	2293
49	-43	1	Elliott Formation	0	30	20	67	2.9	9.0	468	0.00	N/A	0	67	2,770	0	0	0	18.4	2,900	4,352	4,921	3,540	1939	3266	2350
50	-44	1	Elliott Formation	0	30	20	67	2.9	9.0	477	0.00	N/A	0	67	2,837	0	0	0	18.4	2,900	4,457	5,026	3,616	1986	3344	2406
51	-45	1	Elliott Formation	0	30	20	67	2.9	9.0	486	0.00	N/A	0	67	2,904	0	0	0	18.4	2,900	4,562	5,132	3,692	2033	3423	2462
52	-46	1	Elliott Formation	0	30	20	67	2.9	9.0	495	0.00	N/A	0	67	2,971	0	0	0	18.4	2,900	4,667	5,237	3,768	2080	3501	2519
53	-47	1	Elliott Formation	0	30	20	67	2.9	9.0	504	0.00	N/A	0	67	3,038	0	0	0	18.4	2,900	4,773	5,342	3,843	2127	3579	2575
54	-48	1	Elliott Formation	0	30	20	67	2.9	9.0	513	0.00	N/A	0	67	3,105	0	0	0	18.4	2,900	4,878	5,447	3,919	2174	3658	2631
55	-49	1	Elliott Formation	0	30	20	67	2.9	9.0	522	0.00	N/A	0	67	3,172	0	0	0	18.4	2,900	4,983	5,553	3,995	2221	3736	2688
56	-50	1	Elliott Formation	0	30	20	67	2.9	9.0	531	0.00	N/A	0	67	3,239	0	0	0	18.4	2,900	5,088	5,658	4,070	2268	3814	2744
57	-51	1	Elliott Formation	0	30	20	67	2.9	9.0	540	0.00	N/A	0	67	3,306	0	0	0	18.4	2,900	5,194	5,763	4,146	2314	3892	2800
58	-52	1	Elliott Formation	0	30	20	67	2.9	9.0	549	0.00	N/A	0	67	3,373	0	0	0	18.4	2,900	5,299	5,868	4,222	2361	3971	2857
59	-53	1	Elliott Formation	0	30	20	67	2.9	9.0	558	0.00	N/A	0	67	3,440	0	0	0	18.4	2,900	5,404	5,974	4,298	2408	4049	2913
60	-54	1	Elliott Formation	0	30	20	67	2.9	9.0	567	0.00	N/A	0	67	3,507	0	0	0	18.4	2,900	5,509	6,079	4,373	2455	4127	2969
61	-55	1	Elliott Formation	0	30	20	67	2.9	9.0	576	0.00	N/A	0	67	3,574	0	0	0	18.4	2,900	5,615	6,184	4,449	2502	4206	3026



Allowable Capacity for 500 mm Closed End Steel
Cast In Place Circular Pile
Alignment 3
Ground Surface
Cut-off Elevation
Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Elliot Formation
Elevation (m)
10
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Allowable Pile Capacity (kN)

Attachment D3

1-m-Diameter Bored Cast In Place Piles

Purpose: To determine the compressive and uplift capacity of bored cast in place piles.

Problem: Determine the allowable compressive and uplift capacities for bored cast in place piles.

References:
1. "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010.
2. "Factual Geotachnical Report, Bundaberg East Levee, Bundaberg, Queensland" CDM Smith, 31 January 2018
3. "Geotechnical Investigation Factual Report" Core Consultants Pty Ltd., November 2018.

Soil Information: Soil layering, soil properties and ground water elevation obtained from available boring logs.[2]

Datum: Australian Height Datum (AHD)

Method: Conduct evaluation for compression and uplift capacity of bored cast in place piles for the support of the new flood wall. Based on the results of the evaluation, select the most appropriate bored cast in place pile diameter and minimum embedment length.

Assumptions:
1. The bored cast in place pile diameter is assumed to be 1 meter.
2. Neglect downdrag load on the bored cast in place pile since no raise in grade is required.
3. Assume the factor of safety is 1.39.
4. Groundwater elevation is assumed at El. 2.5 based upon observed water level readings in test boring B-6.
5. Bored cast in place pile cut-off is assumed at El. 4.5.
6. Assume 5 percent of shafts dynamically load tested. a
7. Assume a friction interface reduction factor for uplift of 0.7.
8. Minimum of 1 meter embedment in Elliott Formation.

Equations:
1. $R_T = (R_{SN} + R_{BN})/FS$ — Eq. 13-2
2. $R_{SN} = \Sigma (f_{SNi} \pi B \Delta z_i)$ — Eq. 13-3
3. $R_{SNi} = f_{SNi} \pi B \Delta z_i$ — Eq. 13-3
4. $R_{BN} = 0.25 q_{BN} (\pi B^2)$ — Eq. 13-4

Cohesionless Soils:

4. $f_{SN} = \beta \sigma'_v$ — Eq. 13-7
5. $\beta \approx (1-\sin\varphi')(\sigma'_p/\sigma'_v)^{(\sin\varphi')}(\tan\varphi') <= K_p \tan\varphi'$ — Eq. 13-6 & Eq. 13-11

Where
$\sigma'p/\sigma'v = 0.47*N_{60}^{m}$ and where m = 0.6 for clean sands and m = 0.8 for silty sands or sandy silts.

6a. qBN = 0.6(N60) for 0 <= N60 at Shaft Tip <= 50 — Eq. 13-14
6b. qBN = 2872 kPa for N60 at Shaft Tip > 50 — Eq. 13-14

Cohesive Soils:

7. $f_{SNi} = \alpha s_{ui}$ — Eq. 13-15
8a. $\alpha = 0.55$ for $s_u/p_a <= 1.5$
8b. $\alpha = 0.55$ to 0.45 (linearly) for $1.5 <= s_u/p_a <= 2.5$
9. $p_a = 101.3$ kPa
10. $q_{BN} = N^*_c s_{ui}$ — Eq. 13-16
11. N^*_c (see Table 13-2 in FHWA Drilled Shafts Manual)

Variables:
- R_T = Total axial compressive resistance (kN)
- R_{SN} = Nominal side resistance (kN)
- R_{SNi} = Nominal side resistance of element "i" (kN)
- R_{BN} = Nominal base resistance (kN)
- B = Shaft diameter (m)
- Δz_i = Thickness of layer "i" (m)
- f_{SNi} = Nominal unit side resistance of element "i" (kPa)
- q_{BN} = Nominal unit base resistance (kPa)
- β = Cohessionless resistance factor
- FS = Factor of safety
- σ'_v = Vertical effective stress (kPa)
- σ'_p = Vertical effective preconsolidation stress (kPa)
- φ' = Soil drained angle of internal friction (deg.)
- Kp = Passive lateral earth pressure coefficient
- N_{60} = SPT N-value
- α = Cohesive resistance factor
- s_{ui} = Undrained shear strength of element "i" (kPa)
- p_a = Atmospheric pressure (kPa)
- Z = Depth from ground surface to middle of soil layer or shaft segment for element "i" (m)

Results:

A summary of the total allowable compressive and uplift capacity is summarized in Table 1 below.

Table 1 - Summary of Axial and Uplift Pile Capacity

Soil Profile	Total Allowable Compression Capacity (kN)	Total Allowable Uplift Capacity (kN)	Embedment in Elliott Formation (m)
1	250	400	1
1	500	400	1
1	750	400	1
1	1000	450	2
1	2000	650	8
1	4000	1050	25
1	6000	1400	40
1a	250	400	1
1a	500	400	1
1a	750	400	1
1a	1000	450	3
1a	2000	650	9
1a	4000	1050	25
1a	6000	1400	40
2	250	200	1
2	500	250	3
2	750	350	7
2	1000	450	11
3	250	250	2
3	500	300	3
3	750	375	5
3	1000	400	6

Notes:
1. Assumes a FS of 1.54 based on AS 2159-2009 Section 4.3.1 calculation.

References:

AS 2159-2009 Piling -- Design and Installation

21 AS 2159—2009

4.3 GENERAL PRINCIPLES OF GEOTECHNICAL STRENGTH DESIGN

4.3.1 Design geotechnical strength

A pile shall be proportioned such that the design geotechnical strength ($R_{d,g}$) is not less than the design action effect (E_d) as detailed in Clause 3.2.2, that is—

$$R_{d,g} \geq E_d \qquad \ldots 4.3.1(1)$$

The design geotechnical strength ($R_{d,g}$) shall be calculated as the design ultimate geotechnical strength ($R_{d,ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g), according to the following equation:

$$R_{d,g} = \phi_g R_{d,ug} \qquad \ldots 4.3.1(2)$$

The geotechnical strength reduction factor (ϕ_g) shall be determined as follows:

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

where

ϕ_{gb} = basic geotechnical strength reduction factor as given in Clause 4.3.2

ϕ_{tf} = intrinsic test factor

= 0.9, for static load testing (see Section 8)

= 0.75, for rapid load testing (see Section 8)

= 0.8, for dynamic load testing of preformed piles (see Section 8)

= 0.75, for dynamic load testing of other than preformed piles (see Section 8)

= 0.85, for bi-directional load testing (see Section 8)

= ϕ_{gb}, for no testing

K = testing benefit factor

= $1.33p/(p + 3.3) \leq 1$, for static or rapid load testing

= $1.13p/(p + 3.3) \leq 1$, for dynamic load testing

p = percentage of the total piles that are tested and meet the specified acceptance criteria

References:

4.3.2 Assessment of basic geotechnical strength reduction factor (ϕ_{gb})

The basic geotechnical strength reduction factor (ϕ_{gb}) shall be calculated using a risk assessment procedure as set out below:

(a) Rate each risk factor in Table 4.3.2(A) on a scale from 1 to 5 for the nature of the site, the available site information and the pile design and installation procedures adopted. This will produce an individual risk rating (IRR) according to the assessed level of risk, as set out in Table 4.3.2(B)

(b) Determine the overall design average risk rating (ARR) using the weighted average of the product of all of the risk weighting factors (w_i) shown in column 2 of Table 4.3.2(A) times the relevant individual risk rating (IRR), as follows:

$$ARR = \Sigma(w_i \text{IRR}_i)/\Sigma w_i \quad \ldots 4.3.2$$

(c) Determine the basic geotechnical strength reduction factor (ϕ_{gb}) from Table 4.3.2(C) depending on the level of redundancy in the piling system. Systems with a high degree of redundancy would include large pile groups under large caps, piled rafts and pile groups with more than 4 piles. Systems with a low level of redundancy would include isolated heavily loaded piles and piles set out at large spacings.

TABLE 4.3.2(A)

WEIGHTING FACTORS AND INDIVIDUAL RISK RATINGS FOR RISK FACTORS

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Site				
Geological complexity of site	2	Horizontal strata, well-defined soil and rock characteristics	Some variability over site, but without abrupt changes in stratigraphy	Highly variable profile or presence of karstic features or steeply dipping rock levels or faults present on site, or combinations of these
Extent of ground investigation	2	Extensive drilling investigation covering whole site to an adequate depth	Some boreholes extending at least 5 pile diameters below the base of the proposed pile foundation level	Very limited investigation with few shallow boreholes
Amount and quality of geotechnical data	2	Detailed information on strength compressibility of the main strata	CPT probes over full depth of proposed piles or boreholes confirming rock as proposed founding level for piles	Limited amount of simple in situ testing (e.g., SPT) or index tests only
Design				
Experience with similar foundations in similar geological conditions	1	Extensive	Limited	None

(continued)

Client: DLGRMA	**Job Number:** 121923-22153	**Computed by:** BJG	
Project: Bundaberg East Levee	**Date CHK:** 14/2/2018	**Date:** 5/2/2018	
Detail: Bored Cast In Place Pile Calculation	**Checked By:** JPB	**Page:** 4	

References:

TABLE 4.3.2(A) *(continued)*

Risk factor	Weighting factor (w_i)	Typical description of risk circumstances for individual risk rating (IRR)		
		1 (Very low risk)	3 (Moderate)	5 (Very high risk)
Method of assessment of geotechnical parameters for design	2	Based on appropriate laboratory or in situ tests or relevant existing pile load test data	Based on site-specific correlations or on conventional laboratory or in situ testing	Based on non-site-specific correlations with (for example) SPT data
Design method adopted	1	Well-established and soundly based method or methods	Simplified methods with well-established basis	Simple empirical methods or sophisticated methods that are not well established
Method of utilizing results of in situ test data and installation data	2	Design values based on minimum measured values on piles loaded to failure	Design methods based on average values	Design values based on maximum measured values on test piles loaded up only to working load, or indirect measurements used during installation, and not calibrated to static loading tests
Installation				
Level of construction control	2	Detailed with professional geotechnical supervision, construction processes that are well established and relatively straightforward	Limited degree of professional geotechnical involvement in supervision, conventional construction procedures	Very limited or no involvement by designer, construction processes that are not well established or complex
Level of performance monitoring of the supported structure during and after construction	0.5	Detailed measurements of movements and pile loads	Correlation of installed parameters with on-site static load tests carried out in accordance with this Standard	No monitoring

NOTE: The pile design shall include the risk circumstances for each individual risk category and consideration of all of the relevant site and construction factors.

TABLE 4.3.2(B)

INDIVIDUAL RISK RATING (IRR)

Risk level	Individual risk rating (IRR)
Very low	1
Low	2
Moderate	3
High	4
Very high	5

TABLE 4.3.2(C)

BASIC GEOTECHNICAL STRENGTH REDUCTION FACTOR (ϕ_{gb}) FOR AVERAGE RISK RATING

Range of average risk rating (ARR)	Overall risk category	ϕ_{gb} for low redundancy systems	ϕ_{gb} for high redundancy systems
ARR ≤1.5	Very low	0.67	0.76
1.5 < ARR ≤2.0	Very low to low	0.61	0.70
2.0 < ARR ≤2.5	Low	0.56	0.64
2.5 < ARR ≤3.0	Low to moderate	0.52	0.60
3.0 < ARR ≤3.5	Moderate	0.48	0.56
3.5 < ARR ≤4.0	Moderate to high	0.45	0.53
4.0 < ARR ≤4.5	High	0.42	0.50
>4.5	Very high	0.40	0.47

$$\phi_g = \phi_{gb} + (\phi_{tf} - \phi_{gb})K \geq \phi_{gb}$$

ϕ_{tf} = 0.9 for static load testing

K = 1.13*p/(p+3.3)
p= 1 percent of piles to be tested
K= 0.26
IRR= 50.5
w_i = 14.5
ARR= 3.48
ϕ_{gb} = 0.56

ϕ_g = 0.65 >= 0.56

FS= 1.54

TABLE 13-2 BEARING CAPACITY FACTOR N^*_c

Undrained shear strength, s_u (lb/ft^2)	$I_r \approx \frac{E_u}{3s_u}$	N^*_c
500	50	6.5
1,000	150	8.0
2,000	250 - 300	9.0

E_u = Undrained Young's Modulus

Table 13-2[(1)]

Design Soil Profile:

	Alignment	1. City Alignment Sta. 0+50 to Sta. 3+75	2. City Alignment Sta. 3+75 to Sta. 7+85	3. Distillery Alignment Sta. 3+00 to Sta. 5+25
	Alluvial Soils Thickness (m)	13	7	5
	Elliott Formation Thickness (m)	>15	>15	>10
	Applicable Borings	B-2, B-3, B-5, BH-101, BH-102	B-4, B-6, B-7, BH-103, BH-104, BH-105	B-12, B-13, BH-107, BH-108, BH-109
Alluvial Soil Properties	Su (kPa)	22	22	22
	δ (°)	0	0	0
	Φ(°)	15	15	15
	Average N-Value	1	1	1
	Unit Weight (kN/m^3)	18.0	18.0	18.0
Elliott Formation Properties	Su (kPa)	150	50	0
	δ (°)	0	0	20
	Φ(°)	0	0	30
	Average N-Value	37	21	20
	Unit Weight (kN/m^3)	18.8	18.8	18.8

Table 1: Structural Capacity of Bored Cast In Place Concrete Pile

Type 1 m Bored Cast In Place Concrete Pile
Shape Circular

Diameter (m)	Gross Area (sq m)	Area of conc. (sq m)	Concrete Strength fc (kPa)	Total Structural Capacity (kN)
0.5	0.196	0.196	27575	**1787**
0.75	0.442	0.442	27575	**4020**
1	0.785	0.785	27575	**7147**
1.25	1.227	1.227	27575	**11167**
1.5	1.767	1.767	27575	**16081**

Notes:
1 Allowable Concrete Stress = 0.33 f'c

Alignment 1

CLIENT: DLGRMA
PROJECT: Bundaberg East Levee
DETAIL: 121923-221532
FILE NAME: Bored Cast In Place Pile Calculation

JOB NO: 121923-221532
DATE CHK: 14/2/2018
CHECKED BY: JPB

COMPUTED BY: BJG
DATE: 7/2/2018
PAGE: 7
REV BY/DATE: MDC, 10/12/2018

GS EL =	6.0	m
Shaft Cut-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_c	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.54

Stratum	Unit Weight (kN/m³)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 1 parameters
Elliott Formation	18.82	150	0	37	Alignment 1 parameters

Cast In Place Pile Information

Pile Diameter=	1.0	m
Surface Area=	3.14	m²/m length
End Bearing Area=	0.79	m²
Unit Weight of Pile=	24	kN/m³

Soil Stratum and Properties

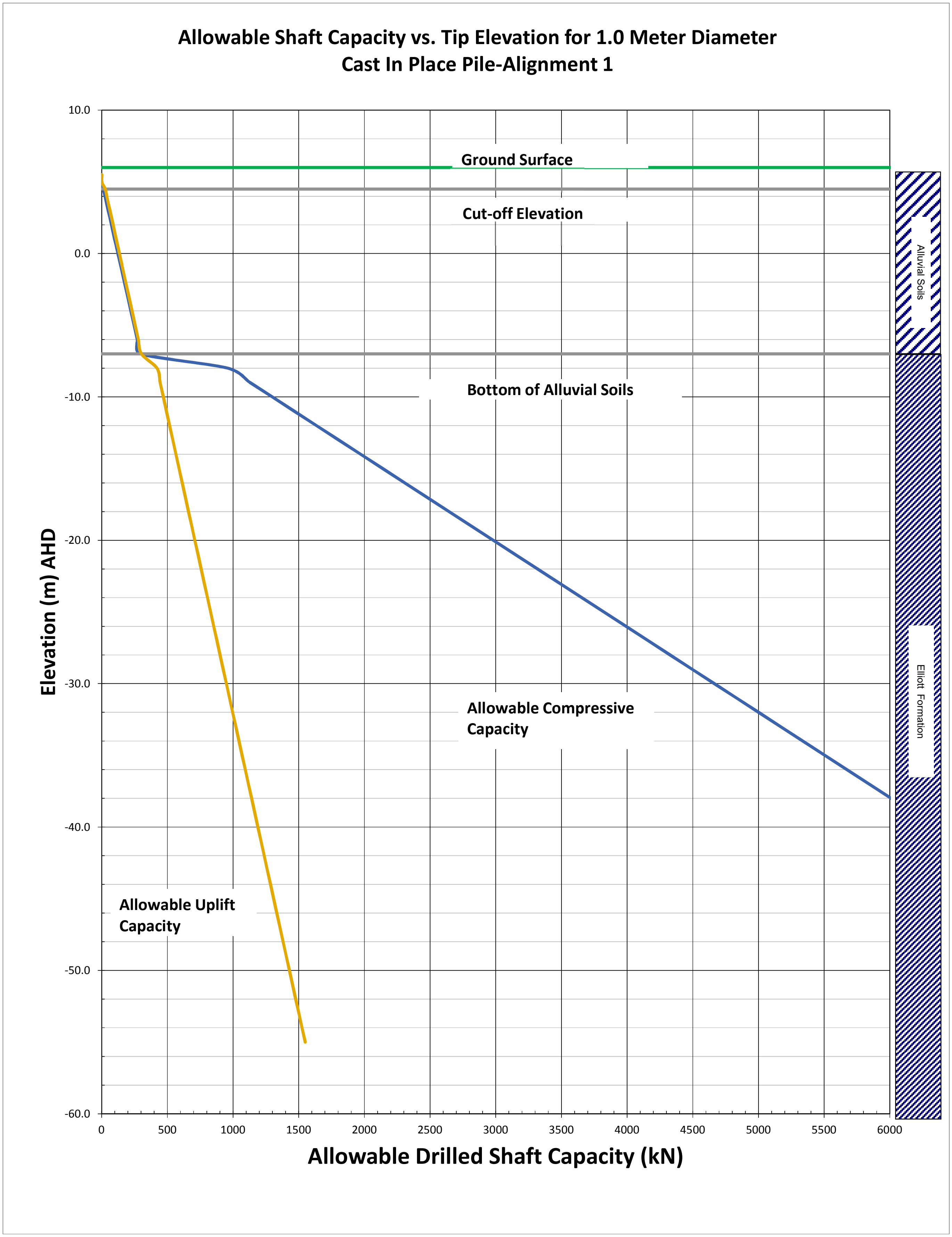
Top of Depth Interval BGS	Bottom of Depth Interval BGS	Drilled Caisson Tip EL	Strata Thickness	Mid-Layer Depth BGS	Stratum	Unit Type	γ_b[2]	Effective Vertical Stress		Friction Angle[3]	Average Undrained Shear Strength[4]	α Factor[5]	Average SPT N-Value[6]	m Factor[7]	β Factor[8]	Shaft Length Below Bottom of Cap	f_{SNi} sand[9]	f_{SNi} clay[10]	Total Side-Resistance[11&12]	q_{BN}[13]	Total Base-Resistance[14]	Total Compressive Resistance[15]	Total Allowable Compressive Resistance[15]	Total Allowable Compressive Resistance	Total Allowable Uplift Resistance
(m)	(m)	(m)	(m)	(m)			(tcm)	σ'_v (kPa)	σ'_v (mPa)	(°)	s_u (kPa)		N_{60} (bpf)			(m)	(kPa)	(kPa)	$R_{SN,i}$ (Kn)	(kPa)	$R_{SN,i}$ (kN)	R_T (kN)	R_T (kips)	R_T (kN)	F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Alluvial Soils	clay	18.0	5	0.00	15	22.00	0.55	1	---	---	-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Alluvial Soils	clay	18.0	14	0.01	15	22.00	0.55	1	---	---	-0.5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Alluvial Soils	clay	18.0	23	0.02	15	22.00	0.55	1	---	---	0.0	0.00	12.10	19.0	143.0	0.00	19	3	12	27
1.5	2.0	4.0	0.5	1.8	Alluvial Soils	clay	18.0	32	0.03	15	22.00	0.55	1	---	---	0.5	0.00	12.10	38.0	143.0	0.00	38	6	25	39
2.0	2.5	3.5	0.5	2.3	Alluvial Soils	clay	18.0	41	0.04	15	22.00	0.55	1	---	---	1.0	0.00	12.10	57.0	143.0	0.00	57	8	37	51
2.5	3.0	3.0	0.5	2.8	Alluvial Soils	clay	18.0	50	0.05	15	22.00	0.55	1	---	---	1.5	0.00	12.10	76.0	143.0	0.00	76	11	49	63
3.0	3.5	2.5	0.5	3.3	Alluvial Soils	clay	18.0	59	0.06	15	22.00	0.55	1	---	---	2.0	0.00	12.10	95.0	143.0	0.00	95	14	62	75
3.5	4.0	2.0	0.5	3.8	Alluvial Soils	clay	8.2	65	0.07	15	22.00	0.55	1	---	---	2.5	0.00	12.10	114.0	143.0	0.00	114	17	74	87
4.0	4.5	1.5	0.5	4.3	Alluvial Soils	clay	8.2	69	0.07	15	22.00	0.55	1	---	---	3.0	0.00	12.10	133.0	143.0	0.00	133	19	86	99
4.5	5.0	1.0	0.5	4.8	Alluvial Soils	clay	8.2	73	0.07	15	22.00	0.55	1	---	---	3.5	0.00	12.10	152.1	143.0	0.00	152	22	99	111
5.0	5.5	0.5	0.5	5.3	Alluvial Soils	clay	8.2	78	0.08	15	22.00	0.55	1	---	---	4.0	0.00	12.10	171.1	143.0	0.00	171	25	111	123
5.5	6.0	0.0	0.5	5.8	Alluvial Soils	clay	8.2	82	0.08	15	22.00	0.55	1	---	---	4.5	0.00	12.10	190.1	143.0	0.00	190	28	123	135
6.0	7.0	-1.0	1.0	6.5	Alluvial Soils	clay	8.2	88	0.09	15	22.00	0.55	1	---	---	5.5	0.00	12.10	228.1	143.0	0.00	228	33	148	159
7.0	8.0	-2.0	1.0	7.5	Alluvial Soils	clay	8.2	96	0.10	15	22.00	0.55	1	---	---	6.5	0.00	12.10	266.1	143.0	0.00	266	39	173	183
8.0	9.0	-3.0	1.0	8.5	Alluvial Soils	clay	8.2	104	0.10	15	22.00	0.55	1	---	---	7.5	0.00	12.10	304.1	143.0	0.00	304	44	197	207
9.0	10.0	-4.0	1.0	9.5	Alluvial Soils	clay	8.2	113	0.11	15	22.00	0.55	1	---	---	8.5	0.00	12.10	342.1	143.0	0.00	342	50	222	231
10.0	11.0	-5.0	1.0	10.5	Alluvial Soils	clay	8.2	121	0.12	15	22.00	0.55	1	---	---	9.5	0.00	12.10	380.1	143.0	0.00	380	56	247	255
11.0	12.0	-6.0	1.0	11.5	Alluvial Soils	clay	8.2	129	0.13	15	22.00	0.55	1	---	---	10.5	0.00	12.10	418.1	143.0	0.00	418	61	272	279
12.0	13.0	-7.0	1.0	12.5	Alluvial Soils	clay	8.2	137	0.14	15	22.00	0.55	1	---	---	11.5	0.00	12.10	456.2	143.0	0.00	456	67	296	303
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	clay	9.0	146	0.15	0	150.00	0.55	37	---	---	12.5	0.00	82.50	715.3	975.0	765.8	1481	216	962	481
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	clay	9.0	155	0.15	0	150.00	0.55	37	---	---	13.5	0.00	82.50	974.5	975.0	765.8	1740	254	1130	505
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	clay	9.0	164	0.16	0	150.00	0.55	37	---	---	14.5	0.00	82.50	1233.7	975.0	765.8	1999	292	1298	529
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	clay	9.0	173	0.17	0	150.00	0.55	37	---	---	15.5	0.00	82.50	1492.9	975.0	765.8	2259	330	1467	553
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	clay	9.0	182	0.18	0	150.00	0.55	37	---	---	16.5	0.00	82.50	1752.1	975.0	765.8	2518	368	1635	577
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	clay	9.0	191	0.19	0	150.00	0.55	37	---	---	17.5	0.00	82.50	2011.2	975.0	765.8	2777	406	1803	601
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	clay	9.0	200	0.20	0	150.00	0.55	37	---	---	18.5	0.00	82.50	2270.4	975.0	765.8	3036	444	1972	625
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	clay	9.0	209	0.21	0	150.00	0.55	37	---	---	19.5	0.00	82.50	2529.6	975.0	765.8	3295	481	2140	649
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	clay	9.0	218	0.22	0	150.00	0.55	37	---	---	20.5	0.00	82.50	2788.8	975.0	765.8	3555	519	2308	673
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	clay	9.0	227	0.23	0	150.00	0.55	37	---	---	21.5	0.00	82.50	3048.0	975.0	765.8	3814	557	2476	697
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	clay	9.0	236	0.24	0	150.00	0.55	37	---	---	22.5	0.00	82.50	3307.2	975.0	765.8	4073	595	2645	721
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	clay	9.0	245	0.25	0	150.00	0.55	37	---	---	23.5	0.00	82.50	3566.3	975.0	765.8	4332	633	2813	745
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	clay	9.0	254	0.25	0	150.00	0.55	37	---	---	24.5	0.00	82.50	3825.5	975.0	765.8	4591	671	2981	769
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	clay	9.0	263	0.26	0	150.00	0.55	37	---	---	25.5	0.00	82.50	4084.7	975.0	765.8	4850	709	3150	793
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	clay	9.0	272	0.27	0	150.00	0.55	37	---	---	26.5	0.00	82.50	4343.9	975.0	765.8	5110	747	3318	817
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	clay	9.0	281	0.28	0	150.00	0.55	37	---	---	27.5	0.00	82.50	4603.1	975.0	765.8	5369	784	3486	841
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	clay	9.0	290	0.29	0	150.00	0.55	37	---	---	28.5	0.00	82.50	4862.2	975.0	765.8	5628	822	3655	865
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	clay	9.0	299	0.30	0	150.00	0.55	37	---	---	29.5	0.00	82.50	5121.4	975.0	765.8	5887	860	3823	889
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	clay	9.0	308	0.31	0	150.00	0.55	37	---	---	30.5	0.00	82.50	5380.6	975.0	765.8	6146	898	3991	913
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	clay	9.0	317	0.32	0	150.00	0.55	37	---	---	31.5	0.00	82.50	5639.8	975.0	765.8	6406	936	4159	937
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	clay	9.0	326	0.33	0	150.00	0.55	37	---	---	32.5	0.00	82.50	5899.0	975.0	765.8	6665	974	4328	961
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	clay	9.0	335	0.34	0	150.00	0.55	37	---	---	33.5	0.00	82.50	6158.1	975.0	765.8	6924	1012	4496	985
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	clay	9.0	344	0.34	0	150.00	0.55	37	---	---	34.5	0.00	82.50	6417.3	975.0	765.8	7183	1049	4664	1009
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	clay	9.0	353	0.35	0	150.00	0.55	37	---	---	35.5	0.00	82.50	6676.5	975.0	765.8	7442	1087	4833	1033
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	clay	9.0	362	0.36	0	150.00	0.55	37	---	---	36.5	0.00	82.50	6935.7	975.0	765.8	7701	1125	5001	1057
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	clay	9.0	371	0.37	0	150.00	0.55	37	---	---	37.5	0.00	82.50	7194.9	975.0	765.8	7961	1163	5169	1081
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	clay	9.0	380	0.38	0	150.00	0.55	37	---	---	38.5	0.00	82.50	7454.1	975.0	765.8	8220	1201	5338	1105
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	clay	9.0	365	0.37	0	150.00	0.55	37	---	---	39.5	0.00	82.50	7713.2	975.0	765.8	8479	1239	5506	1129
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	clay	9.0	374	0.37	0	150.00	0.55	37	---	---	40.5	0.00	82.50	7972.4	975.0	765.8	8738	1277	5674	1153
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	clay	9.0	383	0.38	0	150.00	0.55	37	---	---	41.5	0.00	82.50	8231.6	975.0	765.8	8997	1315	5842	1177
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	clay	9.0	392	0.39	0	150.00	0.55	37	---	---	42.5	0.00	82.50	8490.8	975.0	765.8	9257	1352	6011	1201
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	clay	9.0	401	0.40	0	150.00	0.55	37	---	---	43.5	0.00	82.50	8750.0	975.0	765.8	9516	1390	6179	1225
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	clay	9.0	410	0.41	0	150.00	0.55	37	---	---	44.5	0.00	82.50	9009.1	975.0	765.8	9775	1428	6347	1249
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	clay	9.0	419	0.42	0	150.00	0.55	37	---	---	45.5	0.00	82.50	9268.3	975.0	765.8	10034	1466	6516	1273
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	clay	9.0	428	0.43	0	150.00	0.55	37	---	---	46.5	0.00	82.50	9527.5	975.0	765.8	10293	1504	6684	1297
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	clay	9.0	437	0.44	0	150.00	0.55	37	---	---	47.5	0.00	82.50	9786.7	975.0	765.8	10552	1542	6852	1321
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	clay	9.0	446	0.45	0	150.00	0.55	37	---	---	48.5	0.00	82.50	10045.9	975.0	765.8	10812	1580	7021	1345
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	clay	9.0	455	0.46	0	150.00	0.55	37	---	---	49.5	0.00	82.50	10305.1	975.0	765.8	11071	1617	7189	1369
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	clay	9.0	464	0.46	0	150.00	0.55	37	---	---	50.5	0.00	82.50	10564.2	975.0	765.8	11330	1655	7357	1393
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	clay	9.0	473	0.47	0	150.00	0.55	37	---	---	51.5	0.00	82.50	10823.4	975.0	765.8	11589	1693	7525	1417
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	clay	9.0	482	0.48	0	150.00	0.55	37	---	---	52.5	0.00	82.50	11082.6	975.0	765.8	11848	1731	7694	1441
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	clay	9.0	491	0.49	0	150.00	0.55	37	---	---	53.5	0.00	82.50	11341.8	975.0	765.8	12108	1769	7862	1465
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	clay	9.0	500	0.50	0	150.00	0.55	37	---	---	54.5	0.00	82.50	11601.0	975.0	765.8	12367	1807	8030	1489
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	clay	9.0	509	0.51	0	150.00	0.55	37	---	---	55.5	0.00	82.50	11860.1	975.0	765.8	12626	1845	8199	1513
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	clay	9.0	518	0.52	0	150.00	0.55	37	---	---	56.5	0.00	82.50	12119.3	975.0	765.8	12885	1883	8367	1537
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	clay	9.0	527	0.53	0	150.00	0.55	37	---	---	57.5	0.00	82.50	12378.5	975.0	765.8	13144	1920	8535	1561
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	clay	9.0	536	0.54	0	150.00	0.55	37	---	---	58.5	0.00	82.50	12637.7	975.0	765.8	13403	1958	8704	1585
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	clay	9.0	545	0.55	0	150.00	0.55	37	---	---	59.5	0.00	82.50	12896.9	975.0	765.8	13663	1996	8872	1609

Notes:
1 Water table elevation based upon test boring B-6
2 Unit weights were estimated based upon lab testing of representative soils.
3 Friction angles were estimated based upon lab testing of representative soils.
4 Undrained shear strength values were estimated based upon lab testing of representative soils.
5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018
7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).
8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).
9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).
10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).
14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:
Alluvial Soils
Elliott Formation
Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
F_{SNi}	Side Friction



Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter
Cast In Place Pile-Alignment 1
Ground Surface
Cut-off Elevation
Bottom of Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliott Formation
Elevation (m) AHD
Allowable Drilled Shaft Capacity (kN)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000

Alignment 1a

CLIENT: DLGRMA
PROJECT: Bundaberg East Levee
DETAIL: 121923-221532
FILE NAME: Bored Cast In Place Pile Calculation

JOB NO: 121923-221532
DATE CHK:
CHECKED BY:

COMPUTED BY: MDC
DATE: 14/12/2018
PAGE: 7

GS EL =	6.0	m
Shaft Cutt-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_c	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.54

Stratum	Unit Weight (kN/m³)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 1 parameters
Elliott Formation	18.82	150	0	37	Alignment 1 parameters

Cast In Place Pile Information

Pile Diameter=	1.0	m
Surface Area=	3.14	m²/m length
End Bearing Area=	0.79	m²
Unit Weight of Pile=	24	kN/m³

Soil Stratum and Properties

Top of Depth Interval BGS	Bottom of Depth Interval BGS	Drilled Caisson Tip EL	Strata Thickness	Mid-Layer Depth BGS	Stratum	Unit Type	γ_b[2]	Effective Vertical Stress		Friction Angle[3]	Average Undrained Shear Strength[4]	α Factor[5]	Average SPT N-Value[6]	m Factor[7]	β Factor[8]	Shaft Length Below Bottom of Cap	f_{SNi} sand[9]	f_{SNi} clay[10]	Total Side-Resistance[11&12]	q_{BN}[13]	Total Base-Resistance[14]	Total Compressive Resistance[15]	Total Allowable Compressive Resistance[15]	Total Allowable Compressive Resistance	Total Allowable Uplift Resistance
(m)	(m)	(m)	(m)	(m)			(tcm)	σ'_v (kPa)	σ'_v (mPa)	(°)	s_u (kPa)		N_{60} (bpf)			(m)	(kPa)	(kPa)	R_{SNi} (Kn)	(kPa)	R_{SNi} (kN)	R_T (kN)	R_T (kips)	R_T (kN)	F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	-0.5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	0.0	0.00	0.00	0.0	0.0	0.00	0	0	0	0
1.5	2.0	4.0	0.5	1.8	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	0.5	0.00	0.00	0.0	0.0	0.00	0	0	0	12
2.0	2.5	3.5	0.5	2.3	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	1.0	0.00	0.00	0.0	0.0	0.00	0	0	0	24
2.5	3.0	3.0	0.5	2.8	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	1.5	0.00	0.00	0.0	0.0	0.00	0	0	0	36
3.0	3.5	2.5	0.5	3.3	Water	--	0.0	0	0.00	0	0.00	---	0	---	--	2.0	0.00	0.00	0.0	0.0	0.00	0	0	0	48
3.5	4.0	2.0	0.5	3.8	Water	--	-9.8	-2	0.00	0	0.00	---	0	---	--	2.5	0.00	0.00	0.0	0.0	0.00	0	0	0	60
4.0	4.5	1.5	0.5	4.3	Water	--	-9.8	-7	-0.01	0	0.00	---	0	---	--	3.0	0.00	0.00	0.0	0.0	0.00	0	0	0	72
4.5	5.0	1.0	0.5	4.8	Water	--	-9.8	-12	-0.01	0	0.00	---	0	---	--	3.5	0.00	0.00	0.0	0.0	0.00	0	0	0	84
5.0	5.5	0.5	0.5	5.3	Water	--	-9.8	-17	-0.02	0	0.00	---	0	---	--	4.0	0.00	0.00	0.0	0.0	0.00	0	0	0	96
5.5	6.0	0.0	0.5	5.8	Water	--	-9.8	-22	-0.02	0	0.00	---	0	---	--	4.5	0.00	0.00	0.0	0.0	0.00	0	0	0	108
6.0	7.0	-1.0	1.0	6.5	Water	--	-9.8	-29	-0.03	0	0.00	---	0	---	--	5.5	0.00	0.00	0.0	0.0	0.00	0	0	0	132
7.0	8.0	-2.0	1.0	7.5	Alluvial Soils	clay	8.2	-30	-0.03	15	22.00	0.55	1	---	---	6.5	0.00	12.10	38.0	143.0	0.00	38	6	25	183
8.0	9.0	-3.0	1.0	8.5	Alluvial Soils	clay	8.2	-22	-0.02	15	22.00	0.55	1	---	---	7.5	0.00	12.10	76.0	143.0	0.00	76	11	49	207
9.0	10.0	-4.0	1.0	9.5	Alluvial Soils	clay	8.2	-14	-0.01	15	22.00	0.55	1	---	---	8.5	0.00	12.10	114.0	143.0	0.00	114	17	74	231
10.0	11.0	-5.0	1.0	10.5	Alluvial Soils	clay	8.2	-5	-0.01	15	22.00	0.55	1	---	---	9.5	0.00	12.10	152.1	143.0	0.00	152	22	99	255
11.0	12.0	-6.0	1.0	11.5	Alluvial Soils	clay	8.2	3	0.00	15	22.00	0.55	1	---	---	10.5	0.00	12.10	190.1	143.0	0.00	190	28	123	279
12.0	13.0	-7.0	1.0	12.5	Alluvial Soils	clay	8.2	11	0.01	15	22.00	0.55	1	---	---	11.5	0.00	12.10	228.1	143.0	0.00	228	33	148	303
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	clay	9.0	20	0.02	0	150.00	0.55	37	---	---	12.5	0.00	82.50	487.3	975.0	765.8	1253	183	814	481
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	clay	9.0	29	0.03	0	150.00	0.55	37	---	---	13.5	0.00	82.50	746.4	975.0	765.8	1512	221	982	505
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	clay	9.0	38	0.04	0	150.00	0.55	37	---	---	14.5	0.00	82.50	1005.6	975.0	765.8	1771	259	1150	529
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	clay	9.0	47	0.05	0	150.00	0.55	37	---	---	15.5	0.00	82.50	1264.8	975.0	765.8	2031	297	1319	553
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	clay	9.0	56	0.06	0	150.00	0.55	37	---	---	16.5	0.00	82.50	1524.0	975.0	765.8	2290	335	1487	577
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	clay	9.0	65	0.06	0	150.00	0.55	37	---	---	17.5	0.00	82.50	1783.2	975.0	765.8	2549	372	1655	601
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	clay	9.0	74	0.07	0	150.00	0.55	37	---	---	18.5	0.00	82.50	2042.3	975.0	765.8	2808	410	1823	625
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	clay	9.0	83	0.08	0	150.00	0.55	37	---	---	19.5	0.00	82.50	2301.5	975.0	765.8	3067	448	1992	649
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	clay	9.0	92	0.09	0	150.00	0.55	37	---	---	20.5	0.00	82.50	2560.7	975.0	765.8	3326	486	2160	673
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	clay	9.0	101	0.10	0	150.00	0.55	37	---	---	21.5	0.00	82.50	2819.9	975.0	765.8	3586	524	2328	697
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	clay	9.0	110	0.11	0	150.00	0.55	37	---	---	22.5	0.00	82.50	3079.1	975.0	765.8	3845	562	2497	721
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	clay	9.0	119	0.12	0	150.00	0.55	37	---	---	23.5	0.00	82.50	3338.3	975.0	765.8	4104	600	2665	745
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	clay	9.0	128	0.13	0	150.00	0.55	37	---	---	24.5	0.00	82.50	3597.4	975.0	765.8	4363	637	2833	769
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	clay	9.0	137	0.14	0	150.00	0.55	37	---	---	25.5	0.00	82.50	3856.6	975.0	765.8	4622	675	3002	793
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	clay	9.0	146	0.15	0	150.00	0.55	37	---	---	26.5	0.00	82.50	4115.8	975.0	765.8	4882	713	3170	817
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	clay	9.0	155	0.15	0	150.00	0.55	37	---	---	27.5	0.00	82.50	4375.0	975.0	765.8	5141	751	3338	841
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	clay	9.0	164	0.16	0	150.00	0.55	37	---	---	28.5	0.00	82.50	4634.2	975.0	765.8	5400	789	3506	865
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	clay	9.0	173	0.17	0	150.00	0.55	37	---	---	29.5	0.00	82.50	4893.3	975.0	765.8	5659	827	3675	889
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	clay	9.0	182	0.18	0	150.00	0.55	37	---	---	30.5	0.00	82.50	5152.5	975.0	765.8	5918	865	3843	913
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	clay	9.0	191	0.19	0	150.00	0.55	37	---	---	31.5	0.00	82.50	5411.7	975.0	765.8	6177	903	4011	937
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	clay	9.0	200	0.20	0	150.00	0.55	37	---	---	32.5	0.00	82.50	5670.9	975.0	765.8	6437	940	4180	961
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	clay	9.0	209	0.21	0	150.00	0.55	37	---	---	33.5	0.00	82.50	5930.1	975.0	765.8	6696	978	4348	985
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	clay	9.0	218	0.22	0	150.00	0.55	37	---	---	34.5	0.00	82.50	6189.3	975.0	765.8	6955	1016	4516	1009
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	clay	9.0	227	0.23	0	150.00	0.55	37	---	---	35.5	0.00	82.50	6448.4	975.0	765.8	7214	1054	4685	1033
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	clay	9.0	236	0.24	0	150.00	0.55	37	---	---	36.5	0.00	82.50	6707.6	975.0	765.8	7473	1092	4853	1057
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	clay	9.0	245	0.25	0	150.00	0.55	37	---	---	37.5	0.00	82.50	6966.8	975.0	765.8	7733	1130	5021	1081
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	clay	9.0	254	0.25	0	150.00	0.55	37	---	---	38.5	0.00	82.50	7226.0	975.0	765.8	7992	1168	5189	1105
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	clay	9.0	365	0.37	0	150.00	0.55	37	---	---	39.5	0.00	82.50	7485.2	975.0	765.8	8251	1205	5358	1129
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	clay	9.0	374	0.37	0	150.00	0.55	37	---	---	40.5	0.00	82.50	7744.3	975.0	765.8	8510	1243	5526	1153
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	clay	9.0	383	0.38	0	150.00	0.55	37	---	---	41.5	0.00	82.50	8003.5	975.0	765.8	8769	1281	5694	1177
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	clay	9.0	392	0.39	0	150.00	0.55	37	---	---	42.5	0.00	82.50	8262.7	975.0	765.8	9028	1319	5863	1201
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	clay	9.0	401	0.40	0	150.00	0.55	37	---	---	43.5	0.00	82.50	8521.9	975.0	765.8	9288	1357	6031	1225
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	clay	9.0	410	0.41	0	150.00	0.55	37	---	---	44.5	0.00	82.50	8781.1	975.0	765.8	9547	1395	6199	1249
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	clay	9.0	419	0.42	0	150.00	0.55	37	---	---	45.5	0.00	82.50	9040.2	975.0	765.8	9806	1433	6368	1273
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	clay	9.0	428	0.43	0	150.00	0.55	37	---	---	46.5	0.00	82.50	9299.4	975.0	765.8	10065	1471	6536	1297
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	clay	9.0	437	0.44	0	150.00	0.55	37	---	---	47.5	0.00	82.50	9558.6	975.0	765.8	10324	1508	6704	1321
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	clay	9.0	446	0.45	0	150.00	0.55	37	---	---	48.5	0.00	82.50	9817.8	975.0	765.8	10584	1546	6872	1345
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	clay	9.0	455	0.46	0	150.00	0.55	37	---	---	49.5	0.00	82.50	10077.0	975.0	765.8	10843	1584	7041	1369
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	clay	9.0	464	0.46	0	150.00	0.55	37	---	---	50.5	0.00	82.50	10336.2	975.0	765.8	11102	1622	7209	1393
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	clay	9.0	473	0.47	0	150.00	0.55	37	---	---	51.5	0.00	82.50	10595.3	975.0	765.8	11361	1660	7377	1417
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	clay	9.0	482	0.48	0	150.00	0.55	37	---	---	52.5	0.00	82.50	10854.5	975.0	765.8	11620	1698	7546	1441
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	clay	9.0	491	0.49	0	150.00	0.55	37	---	---	53.5	0.00	82.50	11113.7	975.0	765.8	11879	1736	7714	1465
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	clay	9.0	500	0.50	0	150.00	0.55	37	---	---	54.5	0.00	82.50	11372.9	975.0	765.8	12139	1774	7882	1489
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	clay	9.0	509	0.51	0	150.00	0.55	37	---	---	55.5	0.00	82.50	11632.1	975.0	765.8	12398	1811	8051	1513
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	clay	9.0	518	0.52	0	150.00	0.55	37	---	---	56.5	0.00	82.50	11891.2	975.0	765.8	12657	1849	8219	1537
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	clay	9.0	527	0.53	0	150.00	0.55	37	---	---	57.5	0.00	82.50	12150.4	975.0	765.8	12916	1887	8387	1561
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	clay	9.0	536	0.54	0	150.00	0.55	37	---	---	58.5	0.00	82.50	12409.6	975.0	765.8	13175	1925	8555	1585
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	clay	9.0	545	0.55	0	150.00	0.55	37	---	---	59.5	0.00	82.50	12668.8	975.0	765.8	13435	1963	8724	1609

Notes:

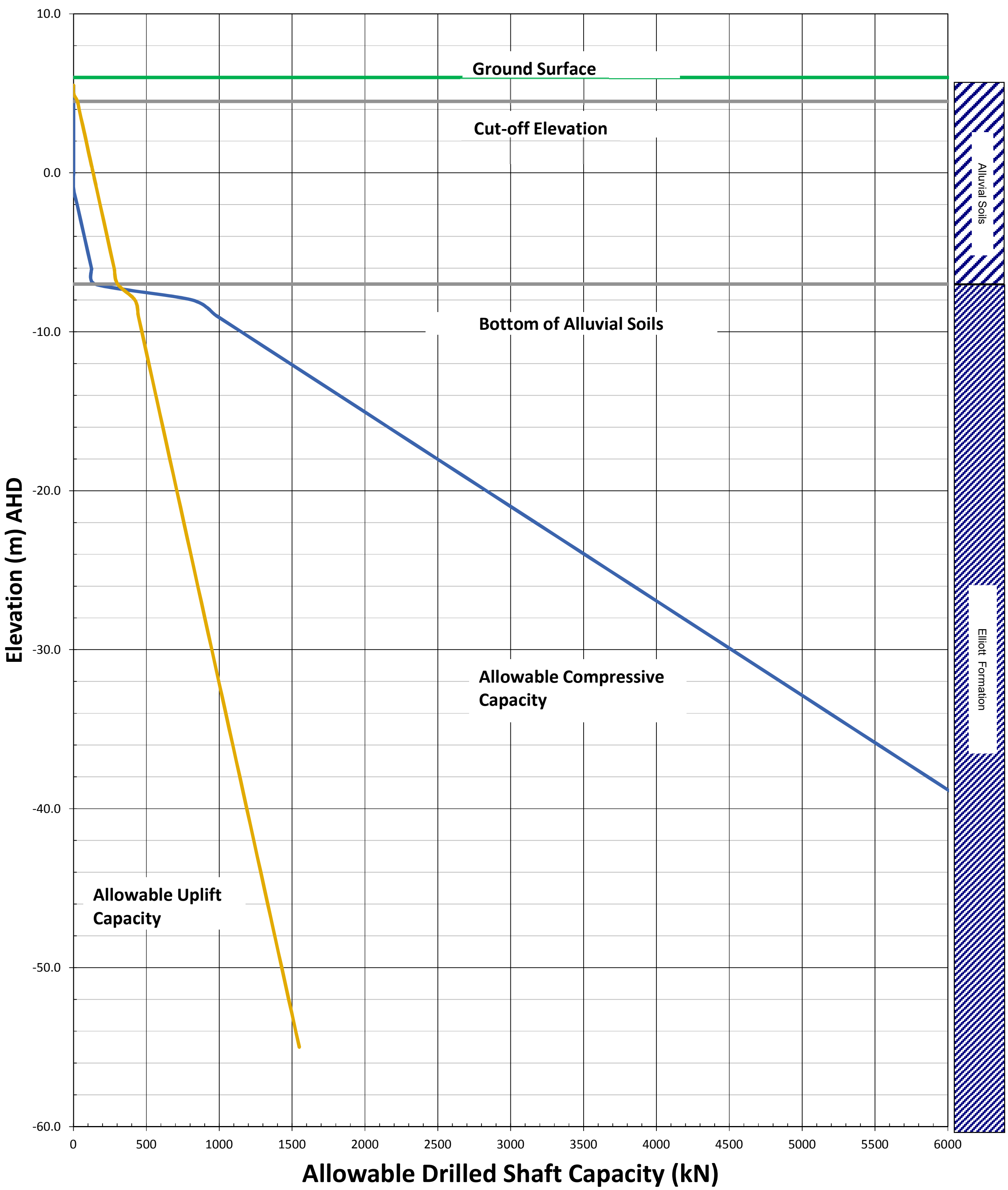
1 Water table elevation based upon test boring B-6
2 Unit weights were estimated based upon lab testing of representative soils.
3 Friction angles were estimated based upon lab testing of representative soils.
4 Undrained shear strength values were estimated based upon lab testing of representative soils.
5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018
7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).
8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).
9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).
10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).
14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:
- Water
- Alluvial Soils
- Elliott Formation
- Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
F_{SNi}	Side Friction

Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter Cast In Place Pile-Alignment 1a



Alignment 2

CLIENT: DLGRMA
PROJECT: Bundaberg East Levee
DETAIL: 121923-221532
FILE NAME: Bored Cast In Place Pile Calculation

JOB NO: 21923-221532
DATE CHK: 14/2/2018
CHECKED BY: JPB
UPDATED BY/DATE: MDC, 10/122018

COMPUTED BY: BJG
DATE: 7/2/2018
PAGE: 9

GS EL =	6.0	m
Shaft Cutt-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_c	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.54

Stratum	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 2 parameters
Elliott Formation	18.82	50	0	21	Alignment 2 parameters

Cast In Place Pile Information

Pile Diameter=	1.0	m
Surface Area=	3.14	m^2/m length
End Bearing Area=	0.79	m^2
Unit Weight of Pile=	24	kN/m^3

Soil Stratum and Properties

Top of Depth Interval BGS	Bottom of Depth Interval BGS	Drilled Caisson Tip EL	Strata Thickness	Mid-Layer Depth BGS	Stratum	Unit Type	γ_b[2]	Effective Vertical Stress		Friction Angle[3]	Average Undrained Shear Strength[4]	α Factor[5]	Average SPT N-Value[6]	m Factor[7]	β Factor[8]	Shaft Length Below Bottom of Cap	f_{SNi} sand[9]	f_{SNi} clay[10]	Total Side-Resistance[11&12]	q_{BN}[13]	Total Base-Resistance[14]	Total Axial Compressive Resistance[15]	Total Allowable Axial Compressive	Total Allowable Compressive Resistance	Total Allowable Uplift Resistance
(m)	(m)	(m)	(m)	(m)			(tcm)	σ'$_v$ (kPa)	σ'$_v$ (mPa)	(°)	s_u (kPa)		N_{60} (bpf)			(m)	(kPa)	(kPa)	$R_{SN,i}$ (Kn)	(kPa)	$R_{SN,i}$ (kN)	R_T (kN)	R_T (kips)	R_T (kN)	F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Alluvial Soils	clay	18.0	5	0.00	15	22.00	0.55	1	---	---	-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Alluvial Soils	clay	18.0	14	0.01	15	22.00	0.55	1	---	---	-0.5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Alluvial Soils	clay	18.0	23	0.02	15	22.00	0.55	1	---	---	0.0	0.00	12.10	19.0	143.0	0.00	19	3	12	27
1.5	2.0	4.0	0.5	1.8	Alluvial Soils	clay	18.0	32	0.03	15	22.00	0.55	1	---	---	0.5	0.00	12.10	38.0	143.0	0.00	38	6	25	39
2.0	2.5	3.5	0.5	2.3	Alluvial Soils	clay	18.0	41	0.04	15	22.00	0.55	1	---	---	1.0	0.00	12.10	57.0	143.0	0.00	57	8	37	51
2.5	3.0	3.0	0.5	2.8	Alluvial Soils	clay	18.0	50	0.05	15	22.00	0.55	1	---	---	1.5	0.00	12.10	76.0	143.0	0.00	76	11	49	63
3.0	3.5	2.5	0.5	3.3	Alluvial Soils	clay	18.0	59	0.06	15	22.00	0.55	1	---	---	2.0	0.00	12.10	95.0	143.0	0.00	95	14	62	75
3.5	4.0	2.0	0.5	3.8	Alluvial Soils	clay	8.2	65	0.07	15	22.00	0.55	1	---	---	2.5	0.00	12.10	114.0	143.0	0.00	114	17	74	87
4.0	4.5	1.5	0.5	4.3	Alluvial Soils	clay	8.2	69	0.07	15	22.00	0.55	1	---	---	3.0	0.00	12.10	133.0	143.0	0.00	133	19	86	99
4.5	5.0	1.0	0.5	4.8	Alluvial Soils	clay	8.2	73	0.07	15	22.00	0.55	1	---	---	3.5	0.00	12.10	152.1	143.0	0.00	152	22	99	111
5.0	5.5	0.5	0.5	5.3	Alluvial Soils	clay	8.2	78	0.08	15	22.00	0.55	1	---	---	4.0	0.00	12.10	171.1	143.0	0.00	171	25	111	123
5.5	6.0	0.0	0.5	5.8	Alluvial Soils	clay	8.2	82	0.08	15	22.00	0.55	1	---	---	4.5	0.00	12.10	190.1	143.0	0.00	190	28	123	135
6.0	7.0	-1.0	1.0	6.5	Alluvial Soils	clay	8.2	88	0.09	15	22.00	0.55	1	---	---	5.5	0.00	12.10	228.1	143.0	0.00	228	33	148	159
7.0	8.0	-2.0	1.0	7.5	Elliott Formation	clay	9.0	96	0.10	0	50.00	0.55	21	---	---	6.5	0.00	27.50	314.5	325.0	255.3	570	83	370	216
8.0	9.0	-3.0	1.0	8.5	Elliott Formation	clay	9.0	105	0.11	0	50.00	0.55	21	---	---	7.5	0.00	27.50	400.9	325.0	255.3	656	96	426	240
9.0	10.0	-4.0	1.0	9.5	Elliott Formation	clay	9.0	114	0.11	0	50.00	0.55	21	---	---	8.5	0.00	27.50	487.3	325.0	255.3	743	108	482	264
10.0	11.0	-5.0	1.0	10.5	Elliott Formation	clay	9.0	123	0.12	0	50.00	0.55	21	---	---	9.5	0.00	27.50	573.7	325.0	255.3	829	121	538	288
11.0	12.0	-6.0	1.0	11.5	Elliott Formation	clay	9.0	132	0.13	0	50.00	0.55	21	---	---	10.5	0.00	27.50	660.0	325.0	255.3	915	134	594	312
12.0	13.0	-7.0	1.0	12.5	Elliott Formation	clay	9.0	142	0.14	0	50.00	0.55	21	---	---	11.5	0.00	27.50	746.4	325.0	255.3	1002	146	650	336
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	clay	9.0	151	0.15	0	50.00	0.55	21	---	---	12.5	0.00	27.50	832.8	325.0	255.3	1088	159	707	360
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	clay	9.0	160	0.16	0	50.00	0.55	21	---	---	13.5	0.00	27.50	919.2	325.0	255.3	1174	172	763	384
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	clay	9.0	169	0.17	0	50.00	0.55	21	---	---	14.5	0.00	27.50	1005.6	325.0	255.3	1261	184	819	408
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	clay	9.0	178	0.18	0	50.00	0.55	21	---	---	15.5	0.00	27.50	1092.0	325.0	255.3	1347	197	875	432
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	clay	9.0	187	0.19	0	50.00	0.55	21	---	---	16.5	0.00	27.50	1178.4	325.0	255.3	1434	209	931	456
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	clay	9.0	196	0.20	0	50.00	0.55	21	---	---	17.5	0.00	27.50	1264.8	325.0	255.3	1520	222	987	480
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	clay	9.0	205	0.20	0	50.00	0.55	21	---	---	18.5	0.00	27.50	1351.2	325.0	255.3	1606	235	1043	504
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	clay	9.0	214	0.21	0	50.00	0.55	21	---	---	19.5	0.00	27.50	1437.6	325.0	255.3	1693	247	1099	528
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	clay	9.0	223	0.22	0	50.00	0.55	21	---	---	20.5	0.00	27.50	1524.0	325.0	255.3	1779	260	1155	552
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	clay	9.0	232	0.23	0	50.00	0.55	21	---	---	21.5	0.00	27.50	1610.4	325.0	255.3	1866	273	1211	576
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	clay	9.0	241	0.24	0	50.00	0.55	21	---	---	22.5	0.00	27.50	1696.8	325.0	255.3	1952	285	1268	600
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	clay	9.0	250	0.25	0	50.00	0.55	21	---	---	23.5	0.00	27.50	1783.2	325.0	255.3	2038	298	1324	624
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	clay	9.0	259	0.26	0	50.00	0.55	21	---	---	24.5	0.00	27.50	1869.6	325.0	255.3	2125	310	1380	648
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	clay	9.0	268	0.27	0	50.00	0.55	21	---	---	25.5	0.00	27.50	1956.0	325.0	255.3	2211	323	1436	672
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	clay	9.0	277	0.28	0	50.00	0.55	21	---	---	26.5	0.00	27.50	2042.3	325.0	255.3	2298	336	1492	696
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	clay	9.0	286	0.29	0	50.00	0.55	21	---	---	27.5	0.00	27.50	2128.7	325.0	255.3	2384	348	1548	720
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	clay	9.0	295	0.29	0	50.00	0.55	21	---	---	28.5	0.00	27.50	2215.1	325.0	255.3	2470	361	1604	744
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	clay	9.0	304	0.30	0	50.00	0.55	21	---	---	29.5	0.00	27.50	2301.5	325.0	255.3	2557	374	1660	768
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	clay	9.0	313	0.31	0	50.00	0.55	21	---	---	30.5	0.00	27.50	2387.9	325.0	255.3	2643	386	1716	792
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	clay	9.0	322	0.32	0	50.00	0.55	21	---	---	31.5	0.00	27.50	2474.3	325.0	255.3	2730	399	1772	816
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	clay	9.0	331	0.33	0	50.00	0.55	21	---	---	32.5	0.00	27.50	2560.7	325.0	255.3	2816	411	1829	840
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	clay	9.0	340	0.34	0	50.00	0.55	21	---	---	33.5	0.00	27.50	2647.1	325.0	255.3	2902	424	1885	864
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	clay	9.0	349	0.35	0	50.00	0.55	21	---	---	34.5	0.00	27.50	2733.5	325.0	255.3	2989	437	1941	888
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	clay	9.0	358	0.36	0	50.00	0.55	21	---	---	35.5	0.00	27.50	2819.9	325.0	255.3	3075	449	1997	912
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	clay	9.0	367	0.37	0	50.00	0.55	21	---	---	36.5	0.00	27.50	2906.3	325.0	255.3	3162	462	2053	936
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	clay	9.0	376	0.38	0	50.00	0.55	21	---	---	37.5	0.00	27.50	2992.7	325.0	255.3	3248	475	2109	960
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	clay	9.0	385	0.38	0	50.00	0.55	21	---	---	38.5	0.00	27.50	3079.1	325.0	255.3	3334	487	2165	984
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	clay	9.0	365	0.37	0	50.00	0.55	21	---	---	39.5	0.00	27.50	3165.5	325.0	255.3	3421	500	2221	1008
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	clay	9.0	374	0.37	0	50.00	0.55	21	---	---	40.5	0.00	27.50	3251.9	325.0	255.3	3507	512	2277	1032
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	clay	9.0	383	0.38	0	50.00	0.55	21	---	---	41.5	0.00	27.50	3338.3	325.0	255.3	3594	525	2333	1056
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	clay	9.0	392	0.39	0	50.00	0.55	21	---	---	42.5	0.00	27.50	3424.7	325.0	255.3	3680	538	2390	1080
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	clay	9.0	401	0.40	0	50.00	0.55	21	---	---	43.5	0.00	27.50	3511.0	325.0	255.3	3766	550	2446	1104
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	clay	9.0	410	0.41	0	50.00	0.55	21	---	---	44.5	0.00	27.50	3597.4	325.0	255.3	3853	563	2502	1128
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	clay	9.0	419	0.42	0	50.00	0.55	21	---	---	45.5	0.00	27.50	3683.8	325.0	255.3	3939	576	2558	1152
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	clay	9.0	428	0.43	0	50.00	0.55	21	---	---	46.5	0.00	27.50	3770.2	325.0	255.3	4025	588	2614	1176
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	clay	9.0	437	0.44	0	50.00	0.55	21	---	---	47.5	0.00	27.50	3856.6	325.0	255.3	4112	601	2670	1200
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	clay	9.0	446	0.45	0	50.00	0.55	21	---	---	48.5	0.00	27.50	3943.0	325.0	255.3	4198	613	2726	1224
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	clay	9.0	455	0.46	0	50.00	0.55	21	---	---	49.5	0.00	27.50	4029.4	325.0	255.3	4285	626	2782	1248
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	clay	9.0	464	0.46	0	50.00	0.55	21	---	---	50.5	0.00	27.50	4115.8	325.0	255.3	4371	639	2838	1272
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	clay	9.0	473	0.47	0	50.00	0.55	21	---	---	51.5	0.00	27.50	4202.2	325.0	255.3	4457	651	2894	1296
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	clay	9.0	482	0.48	0	50.00	0.55	21	---	---	52.5	0.00	27.50	4288.6	325.0	255.3	4544	664	2951	1320
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	clay	9.0	491	0.49	0	50.00	0.55	21	---	---	53.5	0.00	27.50	4375.0	325.0	255.3	4630	676	3007	1344
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	clay	9.0	500	0.50	0	50.00	0.55	21	---	---	54.5	0.00	27.50	4461.4	325.0	255.3	4717	689	3063	1368
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	clay	9.0	509	0.51	0	50.00	0.55	21	---	---	55.5	0.00	27.50	4547.8	325.0	255.3	4803	702	3119	1392
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	clay	9.0	518	0.52	0	50.00	0.55	21	---	---	56.5	0.00	27.50	4634.2	325.0	255.3	4889	714	3175	1416
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	clay	9.0	527	0.53	0	50.00	0.55	21	---	---	57.5	0.00	27.50	4720.6	325.0	255.3	4976	727	3231	1440
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	clay	9.0	536	0.54	0	50.00	0.55	21	---	---	58.5	0.00	27.50	4807.0	325.0	255.3	5062	740	3287	1464
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	clay	9.0	545	0.55	0	50.00	0.55	21	---	---	59.5	0.00	27.50	4893.3	325.0	255.3	5149	752	3343	1488

Notes:

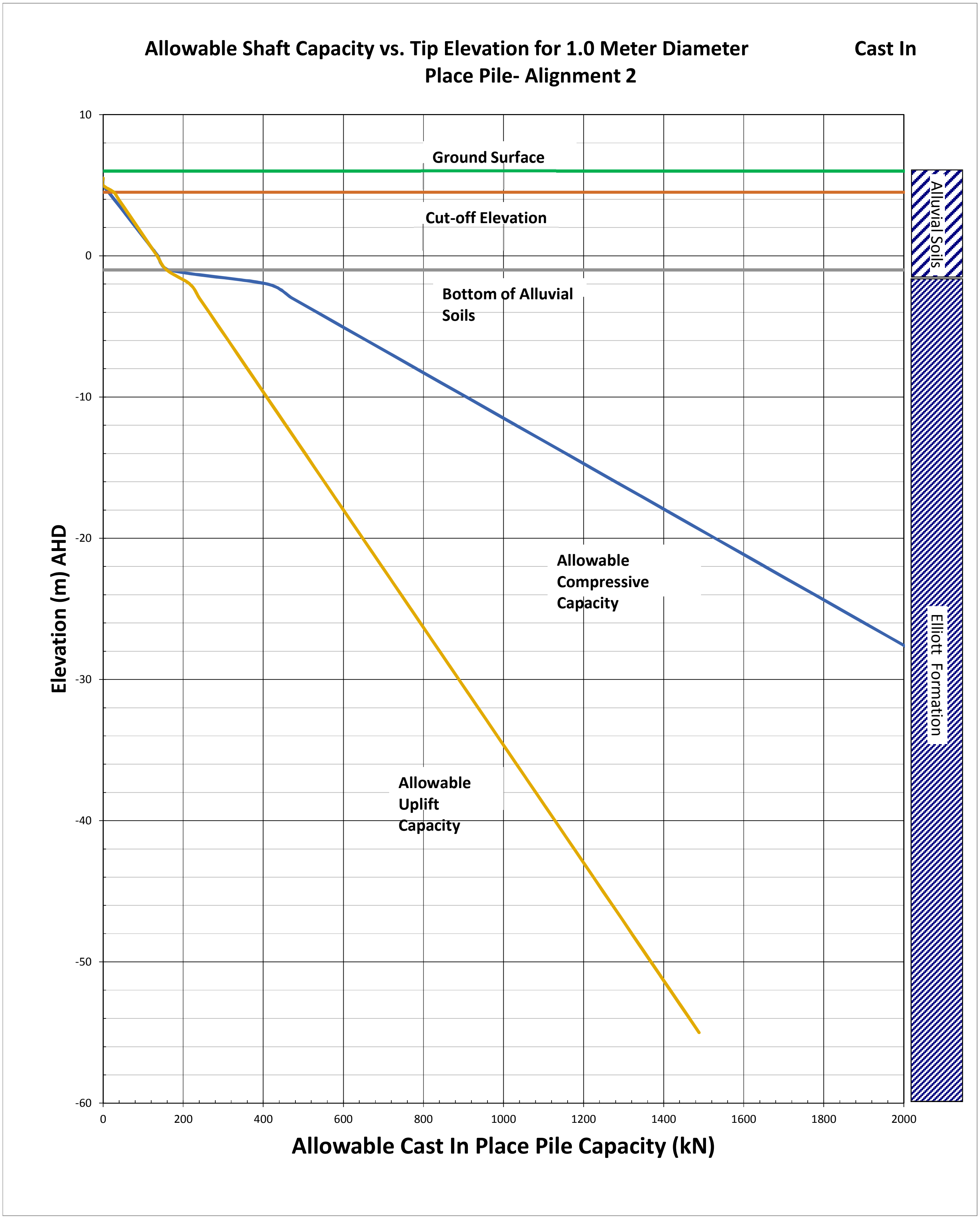
1 Water table elevation based upon test boring B-6
2 Unit weights were estimated based upon lab testing of representative soils.
3 Friction angles were estimated based upon lab testing of representative soils.
4 Undrained shear strength values were estimated based upon lab testing of representative soils.
5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018
7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).
8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).
9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).
10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).
14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:

- Alluvial Soils
- Elliott Formation
- Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
Fs	Side Friction


Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter Cast In Place Pile- Alignment 2
Ground Surface
Cut-off Elevation
Bottom of Alluvial Soils
Allowable Compressive Capacity
Allowable Uplift Capacity
Alluvial Soils
Elliott Formation
Elevation (m) AHD
10
0
-10
-20
-30
-40
-50
-60
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Allowable Cast In Place Pile Capacity (kN)

Alignment 3

CLIENT: DLGRMA	**JOB NO:** 21923-221532	**COMPUTED BY:**	BJG
PROJECT: Bundaberg East Levee	**DATE CHK:** 14/2/2018	**DATE:**	7/2/2018
DETAIL: 121923-221532	**CHECKED BY:** JPB	**PAGE:**	7
FILE NAME: Bored Cast In Place Pile Calculation	**UPDATED BY/DATE:** MDC, 10/12/2018		

GS EL =	6.0	m
Shaft Cutt-off EL =	4.5	m
Water Table EL[1] =	2.5	m
Shaft Diameter =	1.0	m
For Side Friction, Neglect Upper	0.0	m
N^*_{∞}	6.5	
Friction Interface Reduction Factor for Uplift:	0.7	

Factor of Safety 1= 1.54

Stratum	Unit Weight (kN/m³)	Undrained Shear Strength (kPa)	Friction Angle (°)	Average N-Value	
Alluvial Soils	18.03	22	15	1	Alignment 3 parameters
Elliott Formation	18.82	0	30	22	Alignment 3 parameters

Drilled Shaft Information

Shaft Diameter=	1.0	m
Surface Area=	3.14	m²/m length
End Bearing Area=	0.79	m²
Unit Weight of Pile=	24	kN/m³

Soil Stratum and Properties																									
Top of Depth Interval BGS	Bottom of Depth Interval BGS	Drilled Caisson Tip EL	Strata Thickness	Mid-Layer Depth BGS	Stratum	Unit Type	γ_b[2]	Effective Vertical Stress		Friction Angle[3]	Average Undrained Shear Strength[4]	α Factor[5]	Average SPT N-Value[6]	m Factor[7]	β Factor[8]	Shaft Length Below Bottom of Cap	f_{SN} sand[9]	f_{SN} clay[10]	Total Side-Resistance [11&12]	q_{BN}[13]	Total Base-Resistance[14]	Total Axial Compressive Resistance[15]	Total Allowable Axial Compressive	Total Allowable Compressive Resistance for FS=1.32	Total Allowable Uplift Resistance for FS=1.32
(m)	(m)	(m)	(m)	(m)			(tcm)	σ'v (kPa)	σ'v (mPa)	(°)	s_u (kPa)		N_{60} (bpf)			(m)	(kPa)	(kPa)	$R_{SN,i}$ (Kn)	(kPa)	$R_{BN,i}$ (kN)	R_T (kN)	R_T (kips)	R_T (kN)	F_{SN} + Weight
0.0	0.5	5.5	0.5	0.3	Alluvial Soils	clay	18.0	5	0.00	15	22.00	0.55	1	---	---	-1.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
0.5	1.0	5.0	0.5	0.8	Alluvial Soils	clay	18.0	14	0.01	15	22.00	0.55	1	---	---	-0.5	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
1.0	1.5	4.5	0.5	1.3	Alluvial Soils	clay	18.0	23	0.02	15	22.00	0.55	1	---	---	0.0	0.00	12.10	19.0	143.0	0.00	19	3	12	27
1.5	2.0	4.0	0.5	1.8	Alluvial Soils	clay	18.0	32	0.03	15	22.00	0.55	1	---	---	0.5	0.00	12.10	38.0	143.0	0.00	38	6	25	39
2.0	2.5	3.5	0.5	2.3	Alluvial Soils	clay	18.0	41	0.04	15	22.00	0.55	1	---	---	1.0	0.00	12.10	57.0	143.0	0.00	57	8	37	51
2.5	3.0	3.0	0.5	2.8	Alluvial Soils	clay	18.0	50	0.05	15	22.00	0.55	1	---	---	1.5	0.00	12.10	76.0	143.0	0.00	76	11	49	63
3.0	3.5	2.5	0.5	3.3	Alluvial Soils	clay	18.0	59	0.06	15	22.00	0.55	1	---	---	2.0	0.00	12.10	95.0	143.0	0.00	95	14	62	75
3.5	4.0	2.0	0.5	3.8	Alluvial Soils	clay	8.2	65	0.07	15	22.00	0.55	1	---	---	2.5	0.00	12.10	114.0	143.0	0.00	114	17	74	87
4.0	4.5	1.5	0.5	4.3	Alluvial Soils	clay	8.2	69	0.07	15	22.00	0.55	1	---	---	3.0	0.00	12.10	133.0	143.0	0.00	133	19	86	99
4.5	5.0	1.0	0.5	4.8	Alluvial Soils	clay	8.2	73	0.07	15	22.00	0.55	1	---	---	3.5	0.00	12.10	152.1	143.0	0.00	152	22	99	111
5.0	5.5	0.5	0.5	5.3	Elliott Formation	Silty Sand	9.0	78	0.08	30	0.00	---	22	0.8	0.68	4.0	52.96	0.00	235.2	13.2	10.4	246	36	159	212
5.5	6.0	0.0	0.5	5.8	Elliott Formation	Silty Sand	9.0	82	0.08	30	0.00	---	22	0.8	0.68	4.5	56.03	0.00	323.2	13.2	10.4	334	49	217	231
6.0	7.0	-1.0	1.0	6.5	Elliott Formation	Silty Sand	9.0	89	0.09	30	0.00	---	22	0.8	0.68	5.5	60.64	0.00	513.7	13.2	10.4	524	77	340	265
7.0	8.0	-2.0	1.0	7.5	Elliott Formation	Silty Sand	9.0	98	0.10	30	0.00	---	22	0.8	0.68	6.5	66.78	0.00	723.5	13.2	10.4	734	107	477	303
8.0	9.0	-3.0	1.0	8.5	Elliott Formation	Silty Sand	9.0	107	0.11	30	0.00	---	22	0.8	0.68	7.5	72.92	0.00	952.6	13.2	10.4	963	141	625	340
9.0	10.0	-4.0	1.0	9.5	Elliott Formation	Silty Sand	9.0	116	0.12	30	0.00	---	22	0.8	0.68	8.5	79.07	0.00	1201.0	13.2	10.4	1211	177	787	378
10.0	11.0	-5.0	1.0	10.5	Elliott Formation	Silty Sand	9.0	125	0.13	30	0.00	---	22	0.8	0.68	9.5	85.21	0.00	1468.8	13.2	10.4	1479	216	960	415
11.0	12.0	-6.0	1.0	11.5	Elliott Formation	Silty Sand	9.0	134	0.13	30	0.00	---	22	0.8	0.68	10.5	91.36	0.00	1755.8	13.2	10.4	1766	258	1147	453
12.0	13.0	-7.0	1.0	12.5	Elliott Formation	Silty Sand	9.0	143	0.14	30	0.00	---	22	0.8	0.68	11.5	97.50	0.00	2062.1	13.2	10.4	2072	303	1346	490
13.0	14.0	-8.0	1.0	13.5	Elliott Formation	Silty Sand	9.0	152	0.15	30	0.00	---	22	0.8	0.68	12.5	103.64	0.00	2387.7	13.2	10.4	2398	350	1557	528
14.0	15.0	-9.0	1.0	14.5	Elliott Formation	Silty Sand	9.0	161	0.16	30	0.00	---	22	0.8	0.68	13.5	109.79	0.00	2732.6	13.2	10.4	2743	401	1781	565
15.0	16.0	-10.0	1.0	15.5	Elliott Formation	Silty Sand	9.0	170	0.17	30	0.00	---	22	0.8	0.68	14.5	115.93	0.00	3096.8	13.2	10.4	3107	454	2018	603
16.0	17.0	-11.0	1.0	16.5	Elliott Formation	Silty Sand	9.0	179	0.18	30	0.00	---	22	0.8	0.68	15.5	122.08	0.00	3480.3	13.2	10.4	3491	510	2267	640
17.0	18.0	-12.0	1.0	17.5	Elliott Formation	Silty Sand	9.0	188	0.19	30	0.00	---	22	0.8	0.68	16.5	128.22	0.00	3883.1	13.2	10.4	3893	569	2528	678
18.0	19.0	-13.0	1.0	18.5	Elliott Formation	Silty Sand	9.0	197	0.20	30	0.00	---	22	0.8	0.68	17.5	134.36	0.00	4305.2	13.2	10.4	4316	631	2802	715
19.0	20.0	-14.0	1.0	19.5	Elliott Formation	Silty Sand	9.0	206	0.21	30	0.00	---	22	0.8	0.68	18.5	140.51	0.00	4746.7	13.2	10.4	4757	695	3089	753
20.0	21.0	-15.0	1.0	20.5	Elliott Formation	Silty Sand	9.0	215	0.22	30	0.00	---	22	0.8	0.68	19.5	146.65	0.00	5207.4	13.2	10.4	5218	762	3388	791
21.0	22.0	-16.0	1.0	21.5	Elliott Formation	Silty Sand	9.0	224	0.22	30	0.00	---	22	0.8	0.68	20.5	152.80	0.00	5687.4	13.2	10.4	5698	832	3700	828
22.0	23.0	-17.0	1.0	22.5	Elliott Formation	Silty Sand	9.0	233	0.23	30	0.00	---	22	0.8	0.68	21.5	158.94	0.00	6186.7	13.2	10.4	6197	905	4024	866
23.0	24.0	-18.0	1.0	23.5	Elliott Formation	Silty Sand	9.0	242	0.24	30	0.00	---	22	0.8	0.68	22.5	165.08	0.00	6705.3	13.2	10.4	6716	981	4361	903
24.0	25.0	-19.0	1.0	24.5	Elliott Formation	Silty Sand	9.0	251	0.25	30	0.00	---	22	0.8	0.68	23.5	171.23	0.00	7243.3	13.2	10.4	7254	1060	4710	941
25.0	26.0	-20.0	1.0	25.5	Elliott Formation	Silty Sand	9.0	260	0.26	30	0.00	---	22	0.8	0.68	24.5	177.37	0.00	7800.5	13.2	10.4	7811	1141	5072	978
26.0	27.0	-21.0	1.0	26.5	Elliott Formation	Silty Sand	9.0	269	0.27	30	0.00	---	22	0.8	0.68	25.5	183.51	0.00	8377.0	13.2	10.4	8387	1225	5446	1016
27.0	28.0	-22.0	1.0	27.5	Elliott Formation	Silty Sand	9.0	278	0.28	30	0.00	---	22	0.8	0.68	26.5	189.66	0.00	8972.8	13.2	10.4	8983	1312	5833	1053
28.0	29.0	-23.0	1.0	28.5	Elliott Formation	Silty Sand	9.0	287	0.29	30	0.00	---	22	0.8	0.68	27.5	195.80	0.00	9588.0	13.2	10.4	9598	1402	6233	1091
29.0	30.0	-24.0	1.0	29.5	Elliott Formation	Silty Sand	9.0	296	0.30	30	0.00	---	22	0.8	0.68	28.5	201.95	0.00	10222.4	13.2	10.4	10233	1495	6645	1128
30.0	31.0	-25.0	1.0	30.5	Elliott Formation	Silty Sand	9.0	305	0.31	30	0.00	---	22	0.8	0.68	29.5	208.09	0.00	10876.1	13.2	10.4	10887	1591	7069	1166
31.0	32.0	-26.0	1.0	31.5	Elliott Formation	Silty Sand	9.0	314	0.31	30	0.00	---	22	0.8	0.68	30.5	214.23	0.00	11549.2	13.2	10.4	11560	1689	7506	1203
32.0	33.0	-27.0	1.0	32.5	Elliott Formation	Silty Sand	9.0	323	0.32	30	0.00	---	22	0.8	0.68	31.5	220.38	0.00	12241.5	13.2	10.4	12252	1790	7956	1241
33.0	34.0	-28.0	1.0	33.5	Elliott Formation	Silty Sand	9.0	332	0.33	30	0.00	---	22	0.8	0.68	32.5	226.52	0.00	12953.1	13.2	10.4	12964	1894	8418	1278
34.0	35.0	-29.0	1.0	34.5	Elliott Formation	Silty Sand	9.0	341	0.34	30	0.00	---	22	0.8	0.68	33.5	232.67	0.00	13684.1	13.2	10.4	13694	2001	8893	1316
35.0	36.0	-30.0	1.0	35.5	Elliott Formation	Silty Sand	9.0	350	0.35	30	0.00	---	22	0.8	0.68	34.5	238.81	0.00	14434.3	13.2	10.4	14445	2110	9380	1353
36.0	37.0	-31.0	1.0	36.5	Elliott Formation	Silty Sand	9.0	359	0.36	30	0.00	---	22	0.8	0.68	35.5	244.95	0.00	15203.9	13.2	10.4	15214	2223	9879	1391
37.0	38.0	-32.0	1.0	37.5	Elliott Formation	Silty Sand	9.0	368	0.37	30	0.00	---	22	0.8	0.68	36.5	251.10	0.00	15992.7	13.2	10.4	16003	2338	10392	1428
38.0	39.0	-33.0	1.0	38.5	Elliott Formation	Silty Sand	9.0	377	0.38	30	0.00	---	22	0.8	0.68	37.5	257.24	0.00	16800.9	13.2	10.4	16811	2456	10916	1466
39.0	40.0	-34.0	1.0	39.5	Elliott Formation	Silty Sand	9.0	387	0.39	30	0.00	---	22	0.8	0.68	38.5	263.38	0.00	17628.3	13.2	10.4	17639	2577	11454	1503
40.0	41.0	-35.0	1.0	40.5	Elliott Formation	Silty Sand	9.0	365	0.37	30	0.00	---	22	0.8	0.68	39.5	248.83	0.00	18410.0	13.2	10.4	18420	2691	11961	1495
41.0	42.0	-36.0	1.0	41.5	Elliott Formation	Silty Sand	9.0	374	0.37	30	0.00	---	22	0.8	0.68	40.5	254.97	0.00	19211.0	13.2	10.4	19221	2808	12481	1533
42.0	43.0	-37.0	1.0	42.5	Elliott Formation	Silty Sand	9.0	383	0.38	30	0.00	---	22	0.8	0.68	41.5	261.11	0.00	20031.3	13.2	10.4	20042	2928	13014	1570
43.0	44.0	-38.0	1.0	43.5	Elliott Formation	Silty Sand	9.0	392	0.39	30	0.00	---	22	0.8	0.68	42.5	267.26	0.00	20871.0	13.2	10.4	20881	3051	13559	1608
44.0	45.0	-39.0	1.0	44.5	Elliott Formation	Silty Sand	9.0	401	0.40	30	0.00	---	22	0.8	0.68	43.5	273.40	0.00	21729.9	13.2	10.4	21740	3176	14117	1645
45.0	46.0	-40.0	1.0	45.5	Elliott Formation	Silty Sand	9.0	410	0.41	30	0.00	---	22	0.8	0.68	44.5	279.55	0.00	22608.1	13.2	10.4	22618	3305	14687	1683
46.0	47.0	-41.0	1.0	46.5	Elliott Formation	Silty Sand	9.0	419	0.42	30	0.00	---	22	0.8	0.68	45.5	285.69	0.00	23505.6	13.2	10.4	23516	3436	15270	1720
47.0	48.0	-42.0	1.0	47.5	Elliott Formation	Silty Sand	9.0	428	0.43	30	0.00	---	22	0.8	0.68	46.5	291.83	0.00	24422.4	13.2	10.4	24433	3570	15865	1758
48.0	49.0	-43.0	1.0	48.5	Elliott Formation	Silty Sand	9.0	437	0.44	30	0.00	---	22	0.8	0.68	47.5	297.98	0.00	25358.6	13.2	10.4	25369	3706	16473	1795
49.0	50.0	-44.0	1.0	49.5	Elliott Formation	Silty Sand	9.0	446	0.45	30	0.00	---	22	0.8	0.68	48.5	304.12	0.00	26314.0	13.2	10.4	26324	3846	17094	1833
50.0	51.0	-45.0	1.0	50.5	Elliott Formation	Silty Sand	9.0	455	0.46	30	0.00	---	22	0.8	0.68	49.5	310.26	0.00	27288.7	13.2	10.4	27299	3989	17727	1870
51.0	52.0	-46.0	1.0	51.5	Elliott Formation	Silty Sand	9.0	464	0.46	30	0.00	---	22	0.8	0.68	50.5	316.41	0.00	28282.7	13.2	10.4	28293	4134	18372	1908
52.0	53.0	-47.0	1.0	52.5	Elliott Formation	Silty Sand	9.0	473	0.47	30	0.00	---	22	0.8	0.68	51.5	322.55	0.00	29296.1	13.2	10.4	29306	4282	19030	1945
53.0	54.0	-48.0	1.0	53.5	Elliott Formation	Silty Sand	9.0	482	0.48	30	0.00	---	22	0.8	0.68	52.5	328.70	0.00	30328.7	13.2	10.4	30339	4433	19701	1983
54.0	55.0	-49.0	1.0	54.5	Elliott Formation	Silty Sand	9.0	491	0.49	30	0.00	---	22	0.8	0.68	53.5	334.84	0.00	31380.6	13.2	10.4	31391	4586	20384	2020
55.0	56.0	-50.0	1.0	55.5	Elliott Formation	Silty Sand	9.0	500	0.50	30	0.00	---	22	0.8	0.68	54.5	340.98	0.00	32451.9	13.2	10.4	32462	4743	21079	2058
56.0	57.0	-51.0	1.0	56.5	Elliott Formation	Silty Sand	9.0	509	0.51	30	0.00	---	22	0.8	0.68	55.5	347.13	0.00	33542.4	13.2	10.4	33553	4902	21788	2095
57.0	58.0	-52.0	1.0	57.5	Elliott Formation	Silty Sand	9.0	518	0.52	30	0.00	---	22	0.8	0.68	56.5	353.27	0.00	34652.2	13.2	10.4	34663	5064	22508	2133
58.0	59.0	-53.0	1.0	58.5	Elliott Formation	Silty Sand	9.0	527	0.53	30	0.00	---	22	0.8	0.68	57.5	359.42	0.00	35781.4	13.2	10.4	35792	5229	23241	2170
59.0	60.0	-54.0	1.0	59.5	Elliott Formation	Silty Sand	9.0	536	0.54	30	0.00	---	22	0.8	0.68	58.5	365.56	0.00	36929.8	13.2	10.4	36940	5397	23987	2208
60.0	61.0	-55.0	1.0	60.5	Elliott Formation	Silty Sand	9.0	545	0.55	30	0.00	---	22	0.8	0.68	59.5	371.70	0.00	38097.6	13.2	10.4	38108	5568	24745	2245

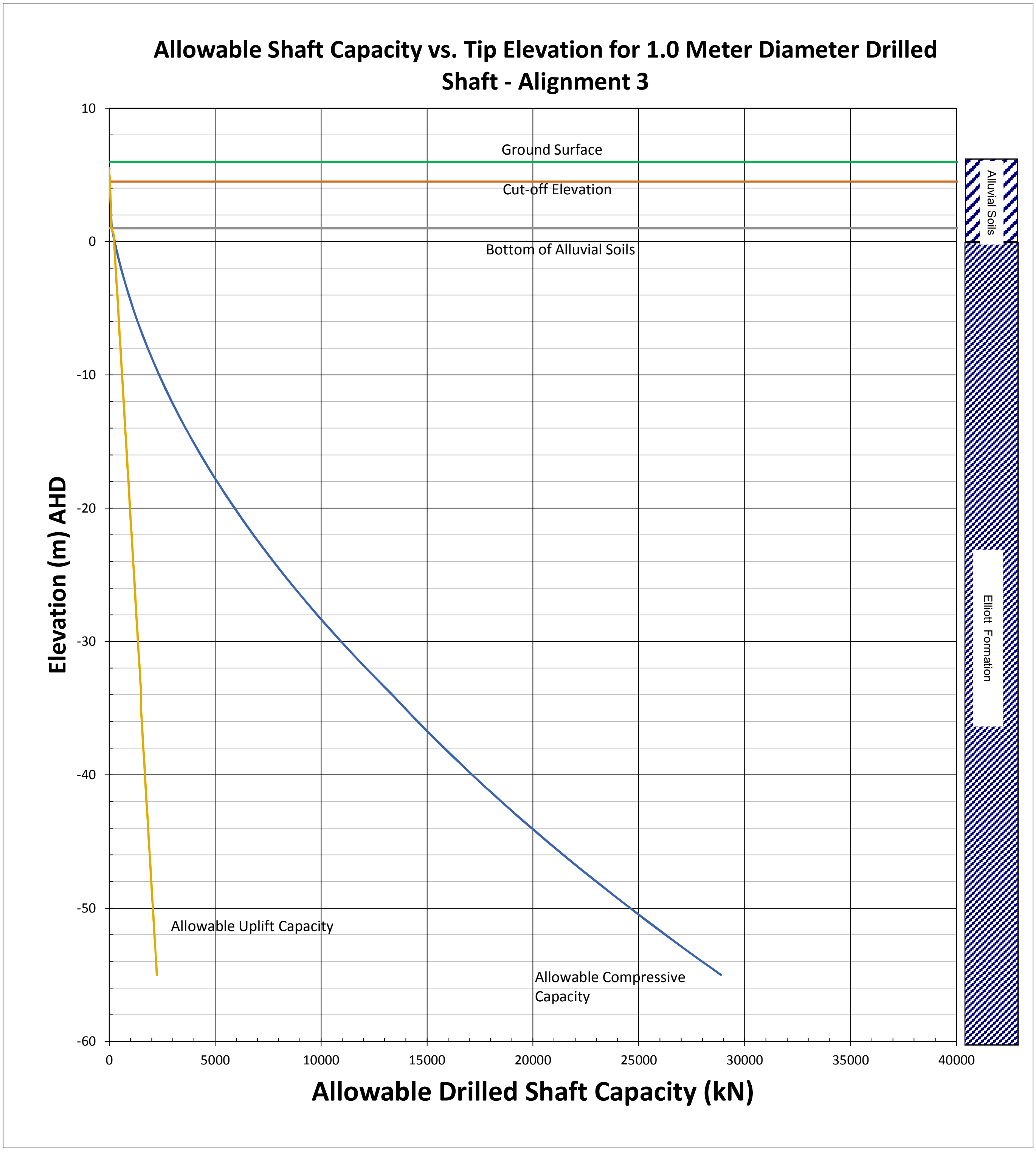
Notes:

1 Water table elevation based upon test boring B-6
2 Unit weights were estimated based upon lab testing of representative soils.
3 Friction angles were estimated based upon lab testing of representative soils.
4 Undrained shear strength values were estimated based upon lab testing of representative soils.
5 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
6 Average SPT N-Values were estimated based upon boring information in the vicinity of the proposed allignment contained in the CDM Smith Report "Factual Geotechnical Report, Bundaber East Levee, Bundaberg Queensland" dated 31 January 2018
7 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-11, Page 13-12).
8 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-13, Page 13-13).
9 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-7, Page 13-11).
10 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16).
11 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
12 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-3, Page 13-10).
13 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-14, Page 13-15 and Equation 13-4, Page 13-10).
14 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-15, Page 13-16 and Equation 13-4, Page 13-10).
15 "Drilled Shafts: Construction Procedures and LRFD Design Methods", FHWA, Publication No. FHWA-NHI-10-016, May 2010, (Equation 13-2, Page 13-10 and Table 10-5, Page 10-12).

Legend:
Alluvial Soils
Elliott Formation
Clay
Silty Sand/Sandy Silt/Clayey Sand/Sandy Clay

Abbreviations:

BGS	Below Ground Surface
EL	Elevation
FHWA	Federal Highway Administration
Fs	Side Friction



Allowable Shaft Capacity vs. Tip Elevation for 1.0 Meter Diameter Drilled Shaft - Alignment 3
Ground Surface
Cut-off Elevation
Bottom of Alluvial Soils
Allowable Uplift Capacity
Allowable Compressive Capacity
Alluvial Soils
Elliott Formation
Elevation (m) AHD
10
0
-10
-20
-30
-40
-50
-60
0
5000
10000
15000
20000
25000
30000
35000
40000
Allowable Drilled Shaft Capacity (kN)

Appendix D Surface Water Technical Report

Department of Local Government Racing and Multicultural Affairs

Burnett River Surface Water Modelling Technical Report

14 February 2019

CDM Smith

Table of Contents

Figures

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Tables

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Section 1 Introduction

1.1 Purpose

The purpose of this report is to document the work undertaken in building hydrologic and hydraulic models of the lower Burnett River, to support the projects being undertaken as part of the Bundaberg 10-Year Action Plan. The work documented herein builds upon the previous work by GHD in their 2013 study of the Burnett River (GHD, 2013), by:

- Updating the hydrologic modelling to account for improvements in historic rainfall data availability;
- Updating the design hydrology to reflect the recent changes occasioned by the introduction of Australian Rainfall and Runoff 2016 (Ball J, 2016), the 4th edition of the national guideline document, data and software suite used for the estimation of design flood characteristics in Australia;
- Developing a Flood Frequency curve that considers an additional 3 years of peak discharges;
- Building a new 2D hydraulic model from the Walla streamflow gauge to the mouth of the Burnett River;
- Building a new 2D hydraulic sub-model that covers the town reach, with a focus on North Bundaberg.

Furthermore, this report documents the following activities that have been carried out in support of the Bundaberg Ten-Year Action Plan generally, and concept design of the Bundaberg East Levee specifically:

- Assessment of hydraulic impacts arising from concept designs for new vehicle viaducts (to allow flood evacuation) in North Bundaberg;
- Assessment of flood hazards, in terms of velocity-depth products, in North Bundaberg, to facilitate decisions for a potential house buy-back scheme;
- Assessment of time of closure on flood-prone local roads at several rural localities upstream of Bundaberg;
- Investigation into coincident floods risks, to determine the likelihood and consequences of both Bundaberg Creek and the Burnett River experiencing flood conditions simultaneously;
- Development and back-testing of a set of operating rules for the Bundaberg East Levee floodgate and pump system; and,
- Analysis of flood impacts caused by construction of a levee in East Bundaberg, and the selection of a design levee crest elevation.

For ease and consistency of presentation, each of these activities is described as sub-sections in the report, as derived from stand-alone technical memoranda.

1.2 Previous Studies

Numerous studies associated with Burnett River flooding have been produced over the past two decades, the most recent and comprehensive of which was GHD's 2013 report entitled "Burnett River Flood Study – Final Report (October 2013)", referred to herein as "GHD (2013)". Readers are encouraged to familiarise themselves with the 2013 report, as it largely forms the basis for the work documented in the following sections of this report.

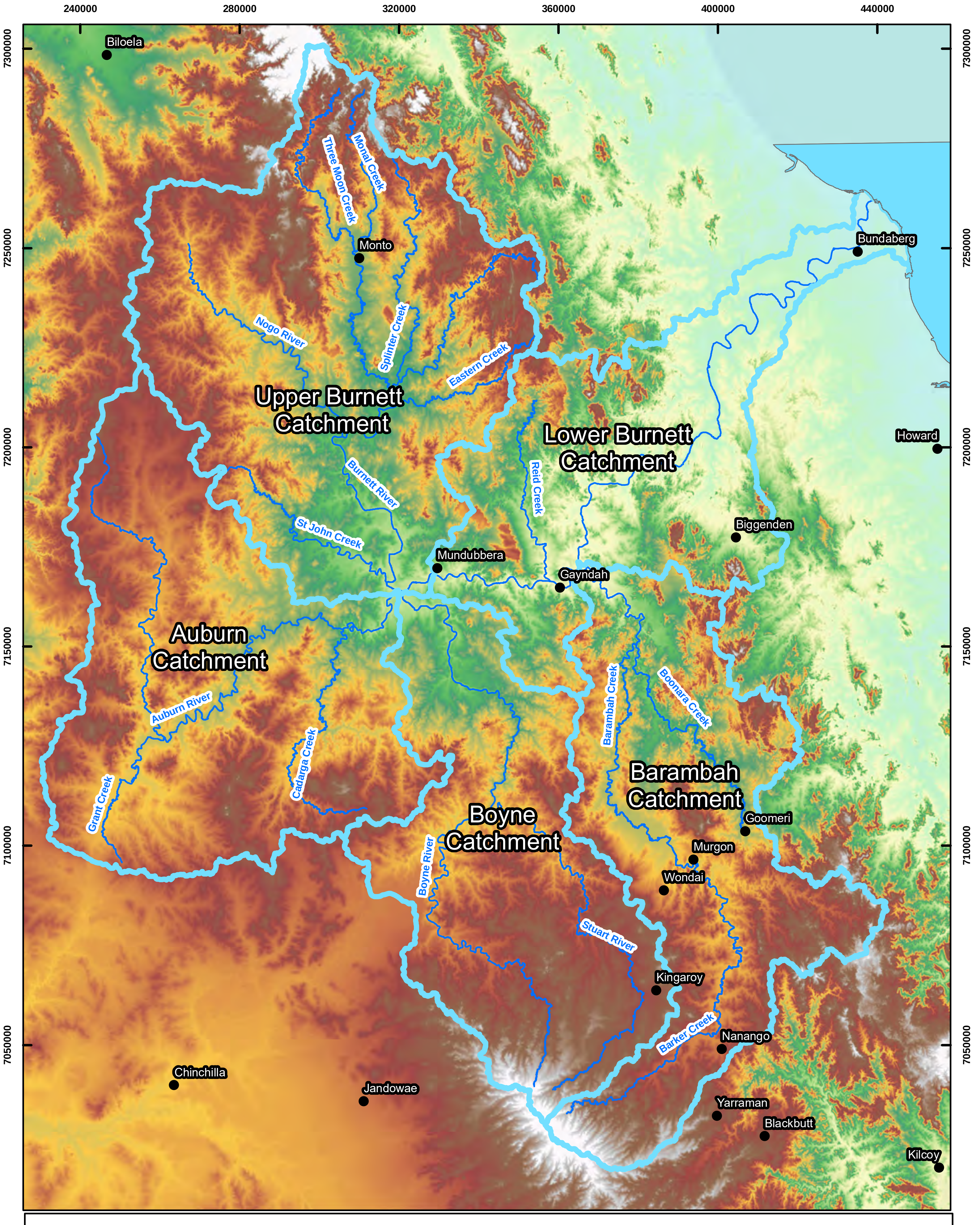
1.3 Catchment Description

The Burnett River catchment spans an area of some 32,000 km^2 in the Wide Bay-Burnett region of Central Queensland. Spanning approximately 300 km from north to south, and about 200 km from east to west at its widest points, the catchment is generally considered to be comprised of 5 major sub-catchment areas, namely:

- **Upper Burnett.** The most northerly portion of the basin, which includes the Nogo River, Three Moon Creek, and the headwaters of the Burnett River;
- **Auburn**. To the west of Mundubbera, incorporating the Auburn River, Johnson Creek, and Cadarga Creek;
- **Boyne.** Rising in the Bunya Mountains to the south of Kingaroy, the Boyne and Stuart Rivers flow in a northerly direction to a confluence with the Burnett River near Mundubbera;
- **Barker and Barambah Creeks.** To the east of the Boyne subcatchment, also flowing in a generally northerly direction to a confluence with the Burnett River near Gayndah; and
- **Lower Burnett.** For the purposes of this study, defined as the Burnett River downstream from the town of Mundubbera, to the ocean outfall near Burnett Heads.

Annual rainfall totals exhibit some variability across the catchment. The majority of the catchment inland from the coastal range receives around 800mm annually, whilst the coastal east is significantly wetter at around 1200mm annually. Orographic effects in the Upper Burnett - around the Burnett, Dawes, and Hogback ranges - can be pronounced, leading to high daily rainfall totals and a corresponding increase in annual averages compared to lower elevations.

The catchment shape and size are such that heavy rainfall in any one of the major sub-catchment areas can be sufficient to cause a flood event in the lower Burnett. Flooding is relatively infrequent, and typically requires sustained rainfall normally associated with tropical low-pressure systems. For a thorough description and thematic maps of the rainfall patterns leading to the major floods on record, readers should refer to Figures 6-1 through 6-5 of GHD's 2013 report (GHD, 2013).



N

Coordinate System = GDA 1994 MGA Zone 56

Legend

Catchment Boundary

Watercourse

Elevation (m) AHD

High : 1100

Low : 0

Figure 1-1

Burnett River Catchment

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017
DigitalGlobe, 2015

CDM Smith

Date: 30/04/18
Drawn: J Parnwell

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Section 2 Hydrologic Modelling

2.1 Model Use

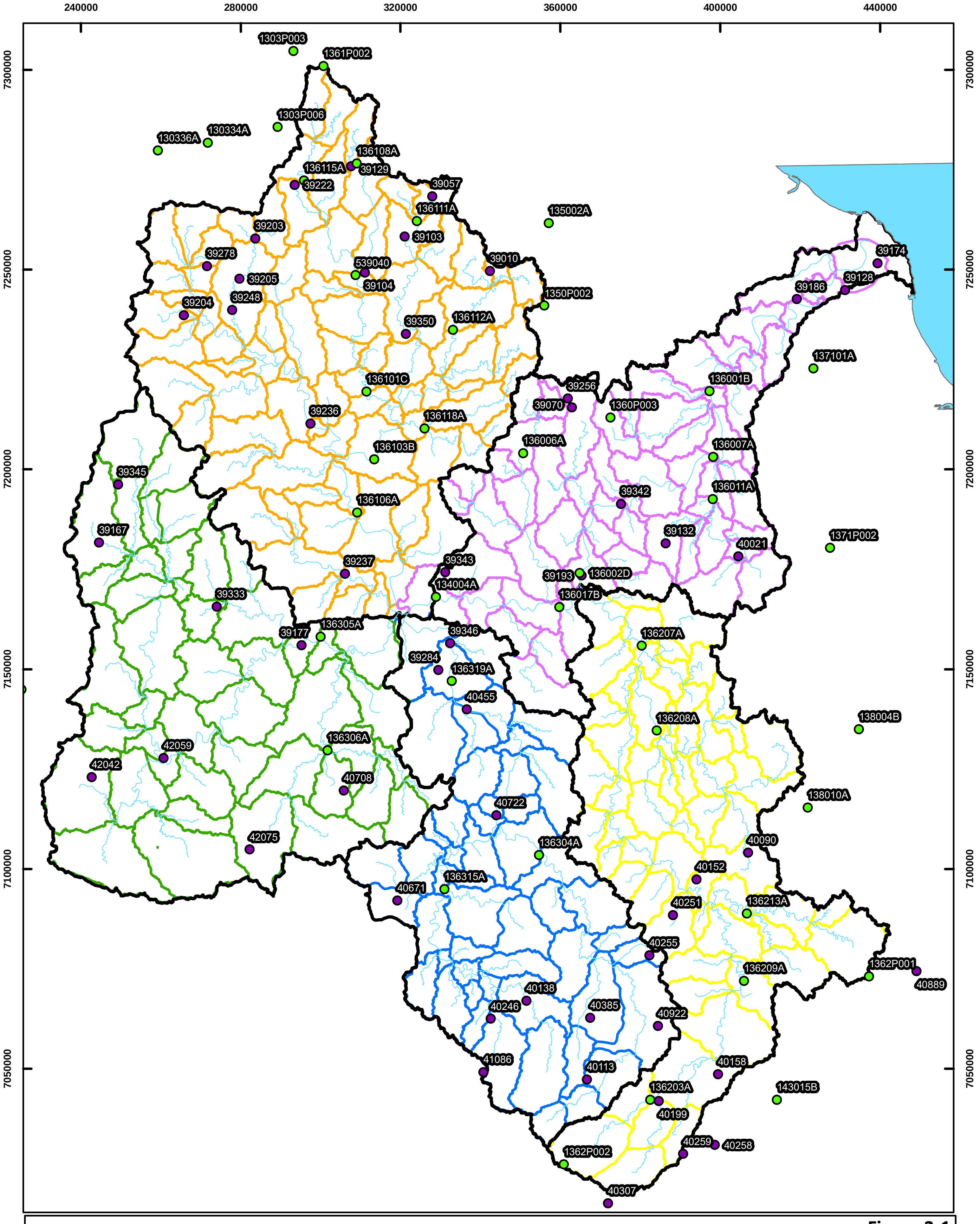
The hydrologic model is built with the intention of determining a set of rainfall-runoff model parameters that reproduce observed river flow conditions at a gauged location. These parameters are then adopted for use in determining probabilistic design flood estimates. In the case of the Burnett River, the most-downstream gauging station for which an accurate rating curve exists is that of Walla (DNRM 136001B), located approximately 1km north of the Bruce Highway crossing of the Burnett River. Downstream of this point, river heights are recorded at Bundaberg, but due to the complex nature of the floodplain, no reliable rating curve is known to exist. Thus, to determine flood behaviour downstream of Walla, hydrologic model hydrographs are required to be routed through a hydrodynamic model, the development of which is discussed in Section 4.

2.2 Schematisation

The conceptual runoff routing model URBS (Carroll, 2016) was used to model the behaviour of the catchment. URBS is a computer-based, hydrologic modelling program that enables the simulation of catchment storage and runoff response by a network of conceptual storages representing the stream network and reservoirs.

The URBS “split model” mode, which was used in this study, identifies the catchment and channel routing in each sub-catchment and calculates their effects separately. First, the excess rainfall on a sub-catchment is routed to the creek channel. This inflow from the sub-catchment into the channel is assumed to occur at the centroid of the sub-catchment. The lag of the sub-catchment storage is assumed to be proportional to the square root of the sub-catchment area. Next, the inflow is routed along a reach using a linear Muskingum method, in which the lag time is assumed to be proportional to the length (or derivative) of the reach.

A plan showing the reach and catchment schematisation, and the location of rainfall and gauging stations used in the study is shown in Figure 2-1.



Legend

- URBS channel reaches
- DNRM Rainfall Gauge
- BOM Rainfall Gauge
- Catchment Boundary

URBS sub-areas

- Auburn
- Barambah
- Boyne
- Lower Burnett
- Upper Burnett

Coordinate System =
GDA 1994 MGA Zone 56

Date: 30/04/18
Drawn: J Parnwell

Figure 2-1
URBS Model Schematisation and Gauging Station Locations

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017
DigitalGlobe, 2015

CDM Smith

PARNWELLJA \\brbsvr1\PRO\Project\BEN170175.01 - Bundaberg East Levee\04_Deliverables\Surface Water Technical Report (Appendix D)\Figures\Fig 2 R1 SubCatchments.mxd 30/04/2018

2.3 Data

2.3.1 Rainfall Data

The availability of historic rainfall data used to reproduce historic floods is shown below in Table 2-1:

Table 2-1 Rainfall Data Availability

Count	Station Number	Station Name	Coordinates (m)		Type	Owner
			Easting	Northing		
1	136203A	Brooklands	382530	7042182	Pluviograph	DNRM
2	136011A	Coringa	398206	7192487	Pluviograph	DNRM
3	136111A	Dakiel	324064	7262122	Pluviograph	DNRM
4	136208A	Ettiewyn	384194	7134571	Pluviograph	DNRM
5	136007A	Figtree Creek	398253	7203103	Pluviograph	DNRM
6	130336A	Folding Hillls	259273	7279792	Pluviograph	DNRM
7	136209A	Glenmore	406053	7071921	Pluviograph	DNRM
8	137101A	Isis Hwy	423401	7225287	Pluviograph	DNRM
9	138010A	Kilkivan	421906	7115288	Pluviograph	DNRM
10	136118A	Lands End	326093	7210206	Pluviograph	DNRM
11	138004B	Marodian	434806	7134887	Pluviograph	DNRM
12	136006A	Mungy	350707	7203987	Pluviograph	DNRM
13	130334A	Pump Station	271798	7281742	Pluviograph	DNRM
14	135002A	Springfield	357139	7261627	Pluviograph	DNRM
15	143015B	Tarameo	414239	7042131	Pluviograph	DNRM
16	136108A	Upper Monal	309057	7276569	Pluviograph	DNRM
17	136213A	West Barambah	406708	7088788	Pluviograph	DNRM
18	130344A	Windamere	188057	7117843	Pluviograph	DNRM
19	136112A	Yarrol	333201	7234888	Pluviograph	DNRM
20	136101C	Abercorn	311541	7219473	Pluviograph	DNRM
21	136207A	Ban Ban	380442	7155806	Pluviograph	DNRM
22	136306A	Brovinia Station	301751	7129658	Pluviograph	DNRM
23	136319A	Cooranga	332838	7146966	Pluviograph	DNRM
24	136305A	Dykehead	300053	7158081	Pluviograph	DNRM
25	136106A	Eidsvold	309207	7189155	Pluviograph	DNRM
26	136304A	Proston Rifle Range	354707	7103387	Pluviograph	DNRM
27	136001B	Walla	397407	7219587	Pluviograph	DNRM
28	1303P003	Kroombit Tops	293272	7304673	Pluviograph	DNRM
29	1303P006	Blue Hills	289248	7285648	Pluviograph	DNRM
30	1350P002	Bania	355981	7240939	Pluviograph	DNRM
31	1360P003	Briggs Creek	372531	7212980	Pluviograph	DNRM
32	136115A	Cania Dam HW	295842	7272319	Pluviograph	DNRM
33	1361P002	Boolaroo Tops	300708	7300899	Pluviograph	DNRM
34	1362P001	Mortimer	437269	7073015	Pluviograph	DNRM
35	1362P002	Dandabah	360858	7026000	Pluviograph	DNRM
36	1371P002	Fairlies Knob	427544	7180318	Pluviograph	DNRM
37	042059	Auburn	260670	7127668	Daily Total	BOM
38	039345	Barwood	249360	7196179	Daily Total	BOM
39	042075	Bawnduggie	282285	7215590	Daily Total	BOM
40	039186	Bingera Sugar Mill	419225	7242565	Daily Total	BOM
41	039128	Bundaberg Aero	431330	7244846	Daily Total	BOM
42	039174	Bundaberg Ashfield Rd	439380	7251527	Daily Total	BOM
43	039204	Colodan	265753	7238587	Daily Total	BOM
44	039278	Glenhaven	271611	7250875	Daily Total	BOM
45	042042	Kilbeggan	242725	7122893	Daily Total	BOM
46	040152	Murgon PO	394130	7097304	Daily Total	BOM
47	040158	Nanango	399507	7048609	Daily Total	BOM
48	039203	Tannymorel	283637	7257718	Daily Total	BOM

Count	Station Number	Station Name	Coordinates (m)		Type	Owner
			Easting	Northing		
49	039248	Tecoma	277856	7239896	Daily Total	BOM
50	039205	Wingfield	279751	7247684	Daily Total	BOM
51	040255	Wooroolin PO	382316	7078370	Daily Total	BOM

Rainfall depths were applied to each of the URBS model sub-catchments) through application of the inverse distance squared method. This method assesses all rainfall data included in the calibration event and assigns weightings based on the proximity of the sub-catchment centroid to each gauge. The temporal pattern from the nearest pluviograph station was then adopted at each sub-catchment.

36 pluviograph stations and 15 daily rainfall stations were available for use in the analysis. Pluviographs were distributed reasonably well over the eastern half of the catchment, but relatively sparsely over the western half. Only two pluviograph gauges sit inside the Auburn catchment (136036A – Brovinia Station, and 136305A – Auburn River at Dykehead), whilst no sub-daily data were available in for the Nogoa River (Upper Burnett catchment) above Wuruma Dam. In both cases, multiple gauges with daily totals were available to complete the historic rainfall picture and the model is built on the assumption that the temporal pattern from the closest available pluviograph is representative of the temporal pattern at the daily station.

2.3.2 Dam Details

Five significant storages exist within the catchment, as described in Table 2-2.

Table 2-2 Dam Details

Dam Name	Sub-catchment	Watercourse	Full Supply Level	Storage @ FSL
Boondooma	Boyne	Boyne River	280.4 m AHD	204,200 ML
Bjelke-Petersen	Barambah	Barker Creek	307.3 m AHD	134,975 ML
Cania	Upper Burnett	Three Moon Creek	331 m AHD	88,580 ML
Wuruma	Upper Burnett	Nogo River	228.3 m AHD	165,410 ML
Paradise	Lower Burnett	Burnett River	67.6 m AHD	300,560 ML

Dam storage curves and spillway rating curves were obtained from SunWater. All five dams are represented in the URBS model. For calibration, dam storage was set to the recorded historical level at the beginning of the simulation. For design event runs, dams were assumed to contain the full supply level prior to the onset of rainfall.

2.3.3 Rating Curves

Spillway rating curves and dam storage data were obtained from SunWater, and were accepted as given. River rating curves were obtained from the DNRM Water Information Monitoring portal (https://water-monitoring.information.qld.gov.au/). These were also accepted as given, with the exception of Walla, where the GHD-derived rating curve was used as outlined in Section 3.2.1. The DNRM river rating curves are not typically designed to be used to rate extreme floods, which is reflected in the rating quality parameter (Good, Fair, or Poor) assigned to each height ordinate on the rating curve. Review of this parameter revealed that significant uncertainty exists at some gauges, especially for large floods. A summary of gauge quality and the network topology, is presented below in Figure 2-2.

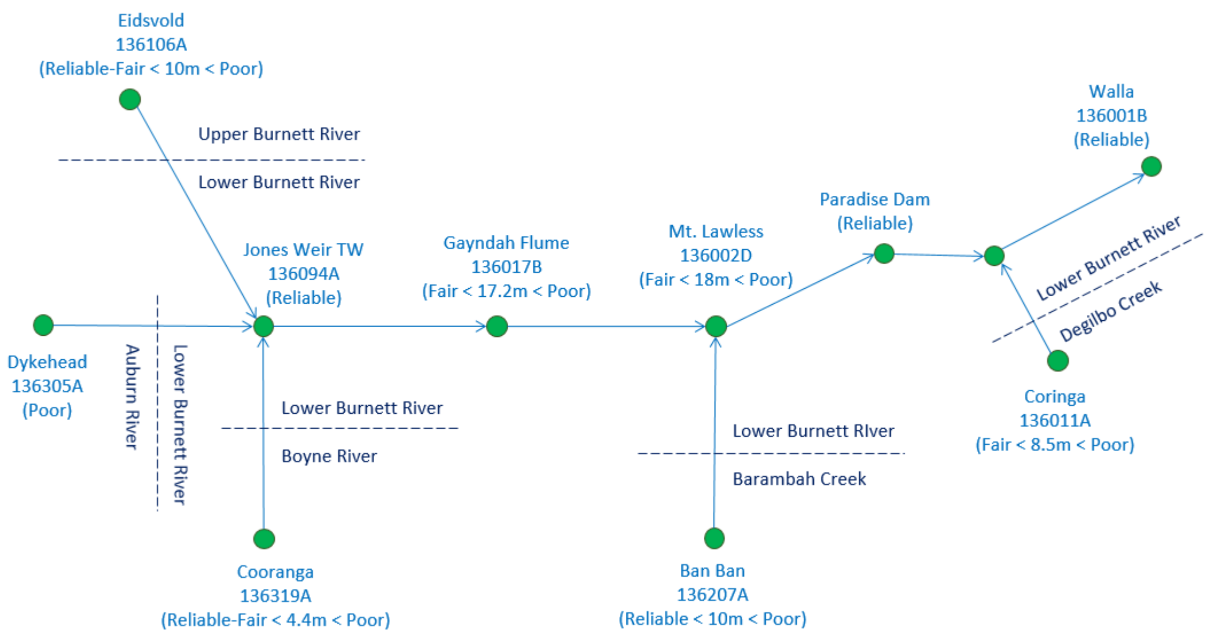


Figure 2-2 River Gauge Rating Quality and Network Topology

The low-quality ratings on the Boyne River, Upper Burnett River and Barambah Creek are mitigated somewhat by the well-rated dam spillways at Boomdooma, Cania, Wuruma, and Bjelke-Petersen dams, respectively. At these locations, comparison of modelled and observed heights/flows can be carried out with some certainty. Rating curve quality is much better in the Lower Burnett. Jones Weir provides a comparison point that includes discharge from the combined Upper-Auburn-Boyne system, whilst flows from the entirety of the upper catchment (Upper, Auburn, Boyne & Barambah) passes through Paradise Dam. For these reasons, the focal points for calibration are Paradise Dam and the gauge at Walla.

2.4 Model Calibration

Model calibration focussed on reproducing the characteristics of the January 2013 rainfall event; the event which produced the flood of record at Bundaberg.

Two sets of calibration parameters were derived to give the best fit to the observed data at the various gauges throughout the catchment:

- Loss parameters: Initial loss (IL) in mm, Continuing loss (CL) in mm/h; and
- Runoff routing parameters; channel lag parameter (alpha α), catchment lag parameter (beta β) and catchment non-linearity parameter (m).

To aid with this task, the URBS model was run as 5 separate sub-models, in accordance with Figure 2-2. In each case, the initial loss was selected to match the start of the rise of the calculated hydrograph to the recorded hydrograph. The continuing loss rate was selected as the value that gave the best overall fit to the shape of the runoff hydrograph, taking into account the timing and magnitude of the peak.

Alpha, β and m were then adjusted to match the rising limb, magnitude and timing of the recorded peak, and the shape of the hydrographs. Calibration was focused on matching the start of rise and time to peak at the low-accuracy gauging locations, whilst absolute values for height and flow were considered at stations known to have higher accuracy rating curves. In a process of test-and-review, hydrographs generated from the upper catchments were passed to the lower catchment model, and results were assessed at Paradise Dam and Walla.

A summary of the adopted calibration parameters is provided in Table 2-3.

Table 2-3 2013 Flood Event – URBS Calibration Parameters

Sub-catchment	Initial Loss (mm)	Continuing Loss (mm/h)	α	β	m
Upper Burnett	180	1.5	0.18	3	0.7
Auburn	160	1.5	0.25	3	0.7
Boyne	180	1.5	0.15	2.5	0.7
Barker & Barambah	170	1.5	0.16	3	0.7
Lower Burnett	110	1.5	0.15	2.6	0.7

Model calibration parameters were found to be reasonably consistent across the 5 sub-catchments. The variance in initial loss figure likely reflects the spatial and temporal variation in antecedent rainfall, whilst the continuing loss parameter of 1.5 mm/h was able to be applied uniformly across all sub-catchments.

In the Auburn sub-catchment $\alpha = 0.25$ was adopted, a value that was much higher than in the other 4 model areas. Even with this value, only a poor fit to the observed hydrograph was achieved. It is suspected that this is due to the lack of pluviograph data and the poor quality of the rating curve at Dykehead. However, as peak discharge from this gauge comprises only approximately 5% of the observed peak discharge at Paradise Dam, it was deemed unlikely to have a material effect upon the results.

Applying these parameters to the model yielded the hydrographs shown below in Figure 2-3 (stream/spillway discharges) and Figure 2-4 (stream/spillway heights). Observed values are plotted in blue; modelled values in orange.

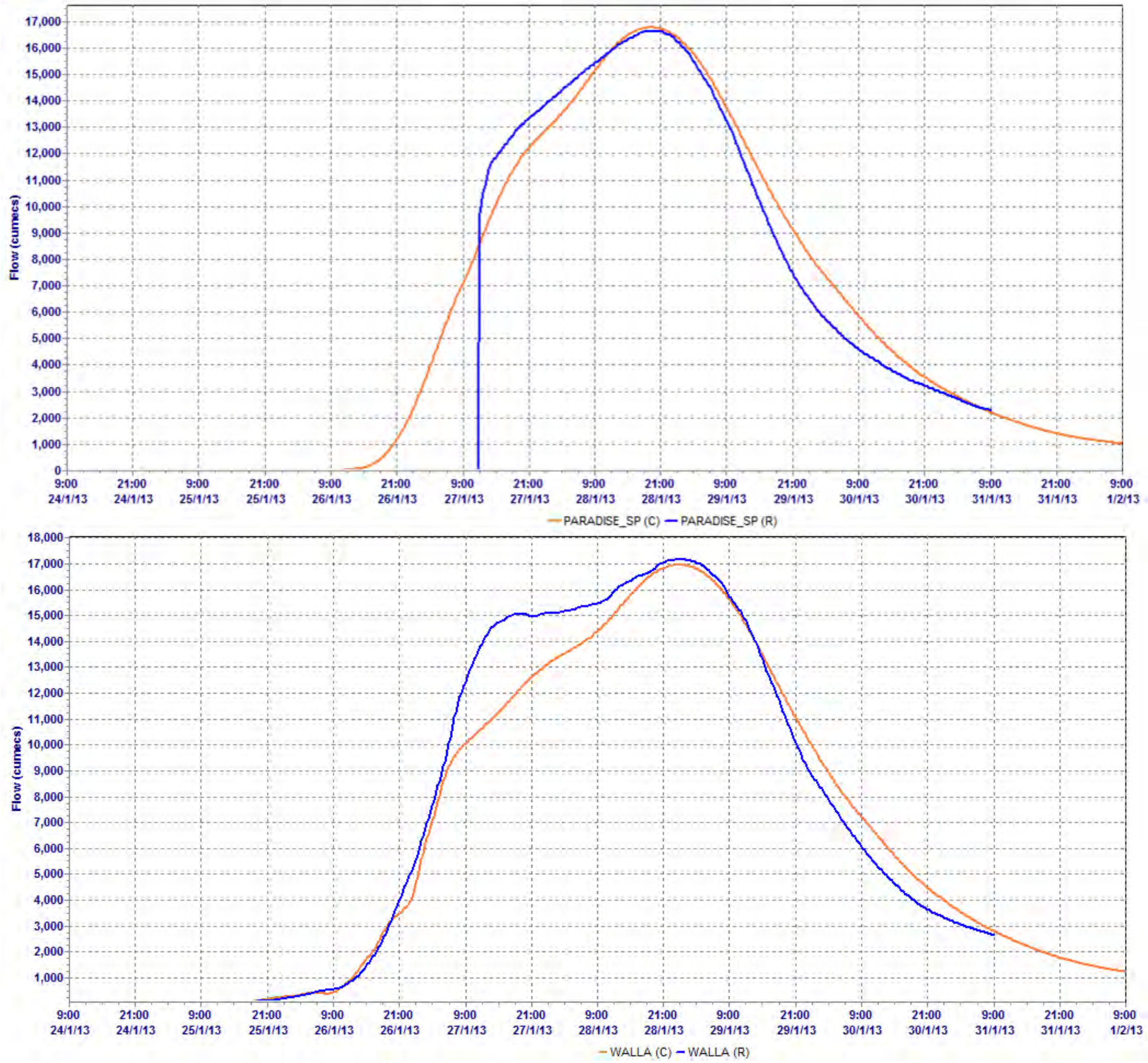


Figure 2-3 2013 Flood Event – Discharge at Paradise Dam and Walla

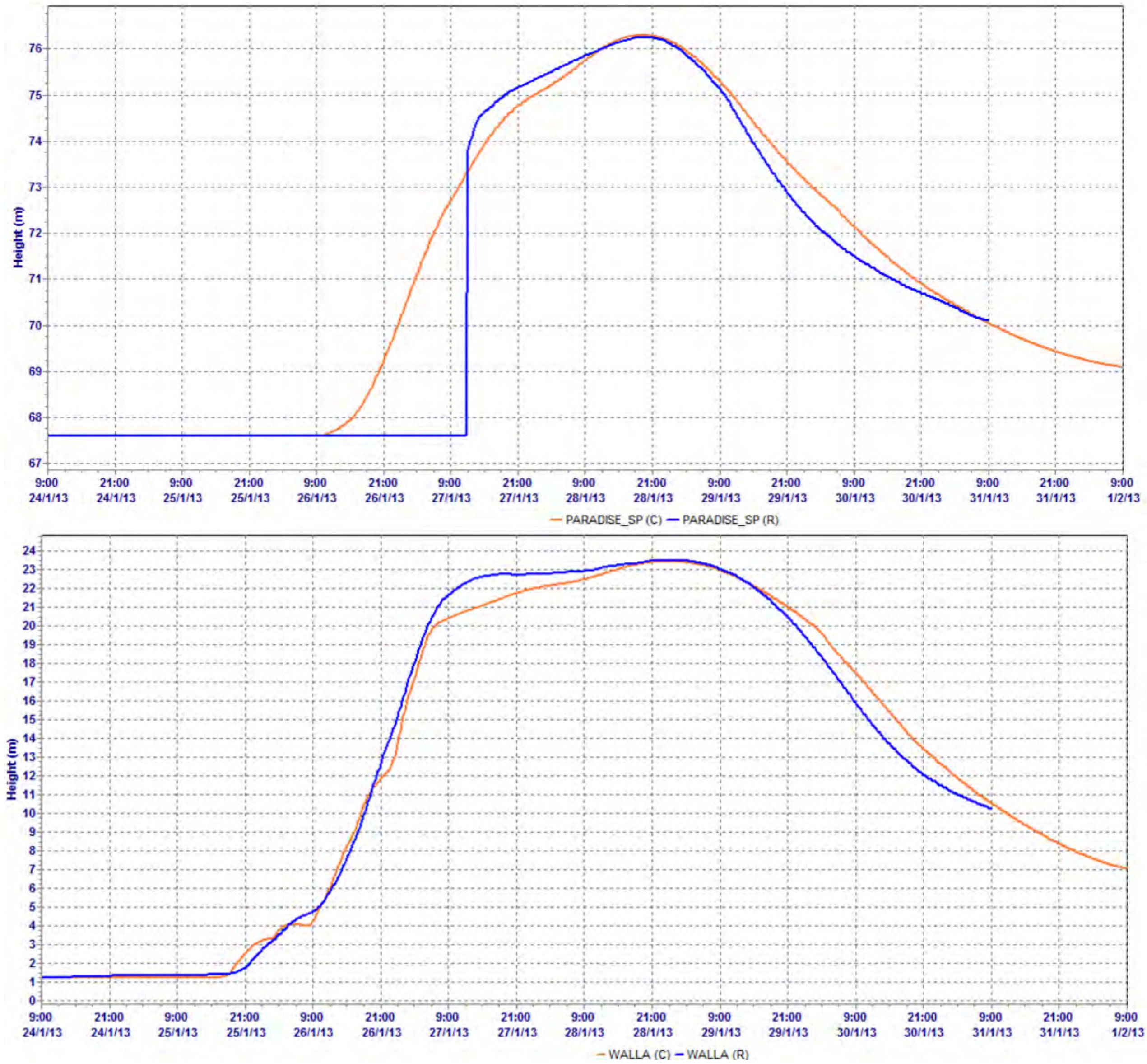


Figure 2-4 2013 Flood Event – Stream Heights at Paradise Dam and Walla.

Table 2-4 2013 Flood Event – Peak Result Values

Location	Variable	Peak Value		Difference
		Observed	Modelled	
Paradise Dam	Height (m)	76.25	76.30	+ 0.05 m
	Flow (m^3/s)	16,630	16,770	+ 0.8 %
Walla	Height (m)	23.50	23.42	- 0.07 m
	Flow (m^3/s)	17,200	16,970	- 1.3 %

The results presented in Table 2-4 indicate that the model can accurately re-create the conditions observed in the catchment during the 2013 flood event. Thus, the model parameters from Table 2-4 were adopted for use in developing probabilistic flood discharge estimates, discussed below.

2.5 Design Event Hydrology

The URBS model was used to develop design flood hydrographs, following the guidance provided ARR16 (Ball J, 2016). The guidelines provide methodologies for estimating design flood characteristics in Australia. Of relevance to this study, advice is given for the estimation of key design parameters, including:

- Rainfall depths;
- Rainfall areal reduction factors;
- Rainfall temporal patterns; and,
- Rainfall initial loss values.

Rainfall depths were calculated from Intensity-Frequency-Duration (IFD) tables, developed from the online tool hosted at the Bureau of Meteorology website (Australian Government Bureau of Meteorology, 2017).

The Burnett catchment sits within the "East Coast North" zone, as defined by ARR16. Temporal patterns and areal reduction factors for this zone were downloaded from the ARR16 "Data Hub" website (Australian Rainfall and Runoff, 2016).

An "ensemble" of ten temporal patterns is provided for each rainfall duration and exceedance probability. The patterns are varied - some are heavily front-end loaded, some distributed quite evenly, others back-end loaded – and designed to capture the underlying natural variability in observed rainfall patterns. For the purposes of this study, the temporal pattern that produced the hydrograph with the median discharge value (technically, rank 6 of 10) at the Walla gauge was selected as the representative hydrograph for the particular flood event under consideration.

It is assumed that initial loss values are event-specific, depending heavily on antecedent catchment conditions, whereas continuing loss values are generally regarded to be an inherent property of the catchment, related to soil type and vegetation cover. For this reason, an initial loss value of 38 mm was adopted in accordance with ARR16, whilst the continuing loss value (i.e., 1.5 mm/h) was adopted from the calibrated hydrologic model.

Design hydrology results at Walla are presented in Table 2-5**,** below.

Table 2-5 Design Hydrology – Peak Discharge at Walla

Probability Classification in		Critical Storm Duration (h)	Peak Discharge (m^3/s)
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)		
50 %	1.44 year	48	2,077
20 %	4.48 year	48	4,673
10 %	9.5 year	48	7,150
5 %	20 year	36	10,677
2 %	50 year	36	14,768
1 %	100 year	36	18,001
0.5 %	200 year	36	21,387
0.2 %	500 year	36	25,426

To determine the level of confidence in these results, the design hydrology peak discharges are compared to the results of a flood frequency analysis in the following section.

Section 3 Flood Frequency Analysis

3.1 Overview

A flood frequency analysis was carried out with the goal of characterising the AEP of historic flood events by analysing annual peak discharges and fitting them against a probability function. Results from the assessment could then be used as a point of comparison against the design discharge estimates obtained from the runoff routing model.

3.2 Data

3.2.1 Rating Curve

For the purposes of this study, CDM Smith has adopted the revised Walla rating curve, as described by GHD in Section 4.4 of their 2013 report. Based on a previous rating curve developed by DNRM, the revised rating curve was developed by analysing the 2013 spillway discharges at Paradise Dam, routing through a hydrologic model, and a final check against results produced by a hydraulic model simulation of the same event.

In checking to ensure that the revised rating curve was appropriate for use in this study, CDM Smith contacted Ray Maynard, a DNRM hydrographer from Bundaberg, for his opinion. Mr Maynard has more than 30 years' experience in gauging flood flows and developing rating curves, with a focus on the Burnett catchment. He confirmed that the rating curve should generally be considered as reliable, and that it should be used in preference to previous DNRM curves. The adopted rating curve is reproduced below in Figure 3-1.

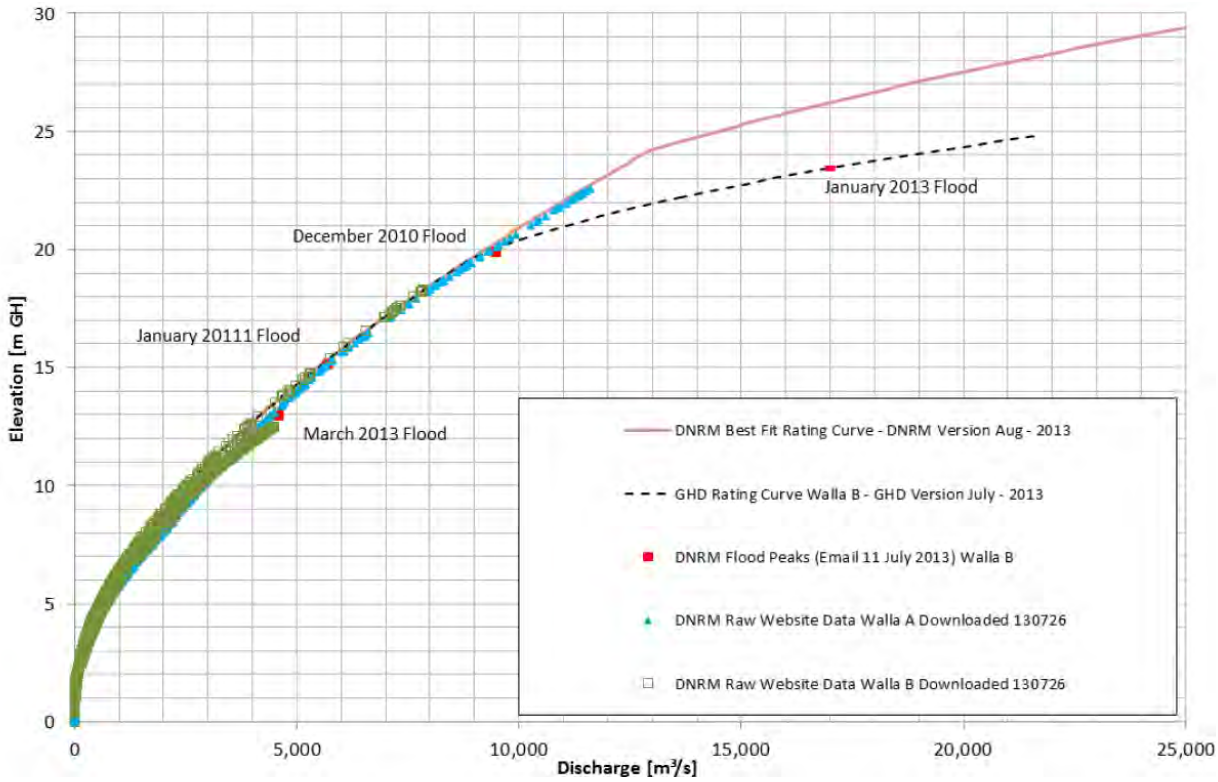


Figure 3-1 Rating Curve at Walla (from GHD 2013)

The following assumptions apply to the use of the rating curve in this study:

- That the discharge information used in developing the rating curve (Paradise Dam rating curve and spillway discharges, physical gaugings during flood events) is correct;
- That the physical characteristics of the river channel (bed elevation, channel cross-section, vegetation cover) at the Walla gauge do not exhibit significant temporal variations; and
- That the construction of the new Bruce Highway embankments and bridge (approximately 1km downstream of the gauge) has not significantly altered the longitudinal flood profile.

3.2.2 Annual Maxima

A time series of annual height maxima at Walla was obtained from the DNRM's Water Monitoring Information Portal website (Department of Natural Resources and Mines, 2017). The site contains near-real time streamflow and rainfall information for 27 active locations in the Burnett catchment, as well as historic records for a further 55 closed monitoring sites. Two locations were used to reconstruct the streamflow record at Walla:

- 136001A Burnett River at Walla. From 30/09/1910 to 29/11/1965; and
- 136001B Burnett River at Walla. From 01/10/1965 to 30/09/2017.

Heights were transformed using the Walla rating curve (Figure 3-1) to obtain peak discharges. Sensitivity testing upon the effects of data homogenisation is covered in detail in Section 4.5 of GHD (2013); the main finding being that an increase of 5% to flow rates for floods occurring after 1982 was an appropriate adjustment to account for the progressive construction of the 5 major catchment storages. As such, the 5% factor has also been applied in this analysis. The homogenised time series of annual flow maxima is presented in Figure 3-2.

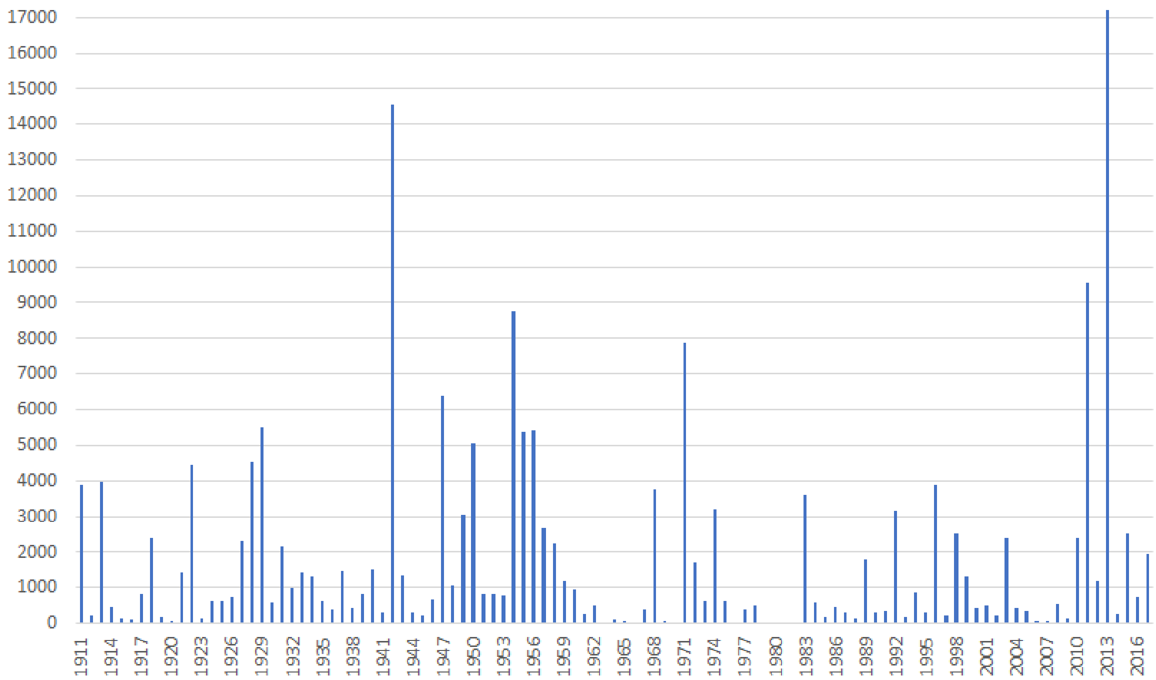


Figure 3-2 Annual Flow Maxima at Walla

Two historical flood peaks were also considered in the analysis:

Table 3-1 Historical Flood Peaks (from GHD 2013)

Flood Event	Height (m AHD)	Peak Flow (m^3/s)
January 1890	39.66	16,974
February 1893	39.41	16,233

Utilising these two points adds two gaps to the flow record; the periods 1891-1892, and 1894-1910. In accordance with the Bayesian approach of FLIKE (Kuczera, 2015), these gaps were included as censored periods in the record, each with a threshold value (sometimes called a “perception value”) of 16,000 m^3/s. That is, across these time periods, any floods which may have occurred are assumed to have had a flowrate of less than the threshold value, on the basis that anything larger would have been significant enough to appear in the historical records.

The record of flood peaks at Bundaberg shows the occurrence of a large flood in 1875, measured at 8.66 m on the gauge. This is likely large enough to also have caused flood conditions at Walla, potentially at a height of around 21.5 to 23.5 metres, for a peak flowrate in the order of 12,000 to 17,000 m^3/s (per the rating curve of Section 3.2.1 and gauge height relationships developed in Section 5.3.1). It is likely that inclusion of this data point would influence the shape of the fitted flood frequency curve, however at the risk of introducing a large degree of uncertainty. Therefore, given the lack of any independent information of the observed height at Walla, this flood peak has been excluded from the analysis.

3.3 Results

3.3.1 Fitted Curve

Several fitting models were tested in the FLIKE software. A Log-Pearson Type 3 distribution, with the exclusion of annual maximum flows of less than 400 m^3/s, was found to provide the best overall fit, and is presented below in Figure 3-3.

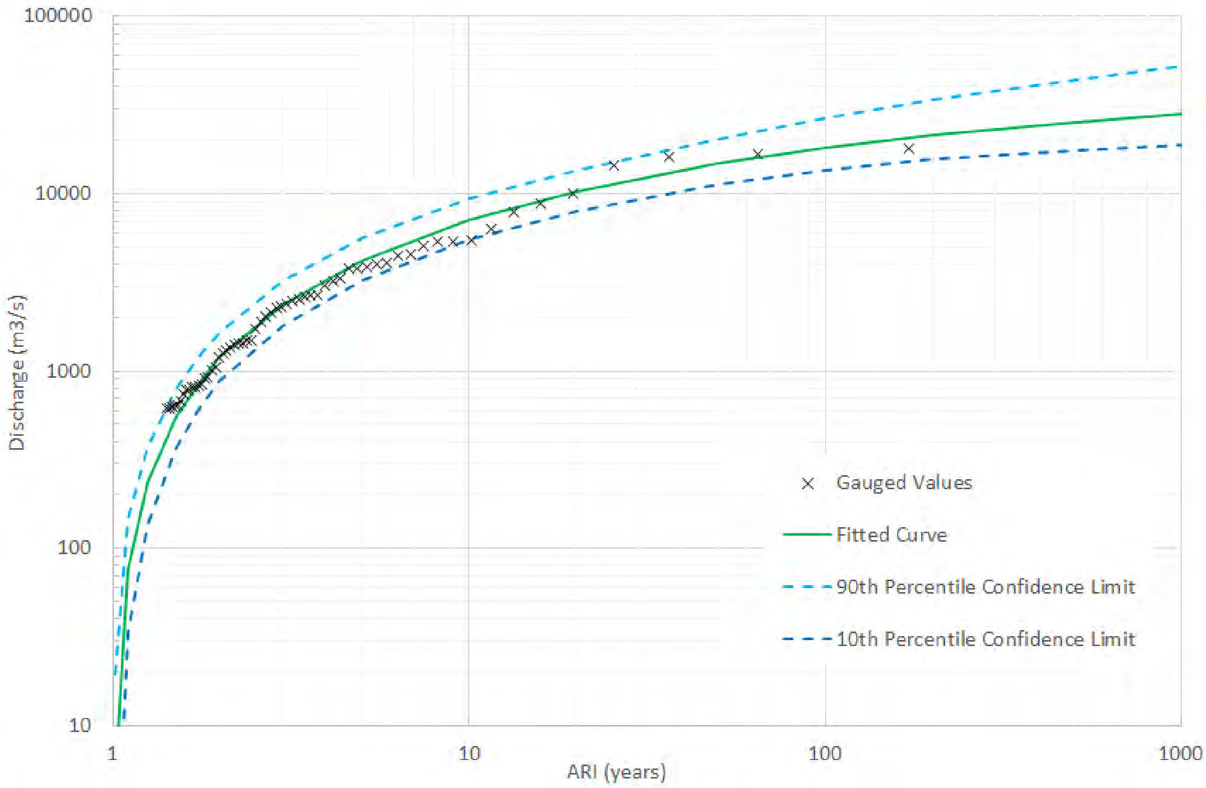


Figure 3-3 Flood Frequency Curve at Walla

The fitted curve generally shows good agreement with the gauged values in the ARI range of 1.5 years to 20 years. For very frequent floods (ie < 1.5 year ARI), the fitted curve shows a divergence from the gauged values, however remains inside the confidence limits. As the focus of this study is on extreme events, it is proposed that this is an acceptable outcome. At magnitudes of 20 years and greater, the relative paucity of data creates difficulty in assessing the quality of the fit, other than to note that this portion of the curve includes the two oldest peaks on record, and that any error in the estimation of flowrate for these peaks would be likely to influence the result.

3.3.2 Comparison to Design Hydrology Estimates

Peak discharge estimates from the fitted flood frequency curve were compared to estimates obtained from the URBS model, as shown below in Table 3-2 and Figure 3-4:

Table 3-2 Comparison between Runoff Model and Flood Frequency Analysis

Probability Classification		Peak Discharge (m³/s)		Difference (%)
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	URBS Runoff Model	FLIKE Flood Frequency Analysis	
10 %	9.5 year	7,150	7,146	- 0.1
5 %	20 year	10,677	10,356	- 3.0
2 %	50 year	14,768	14,736	- 0.2
January 2013		17,200 (gauged)		n/a
1 %	100 year	18,001	18,071	+ 0.4
0.5 %	200 year	21,387	21,267	- 0.6
0.2 %	500 year	25,426	25,235	- 0.8

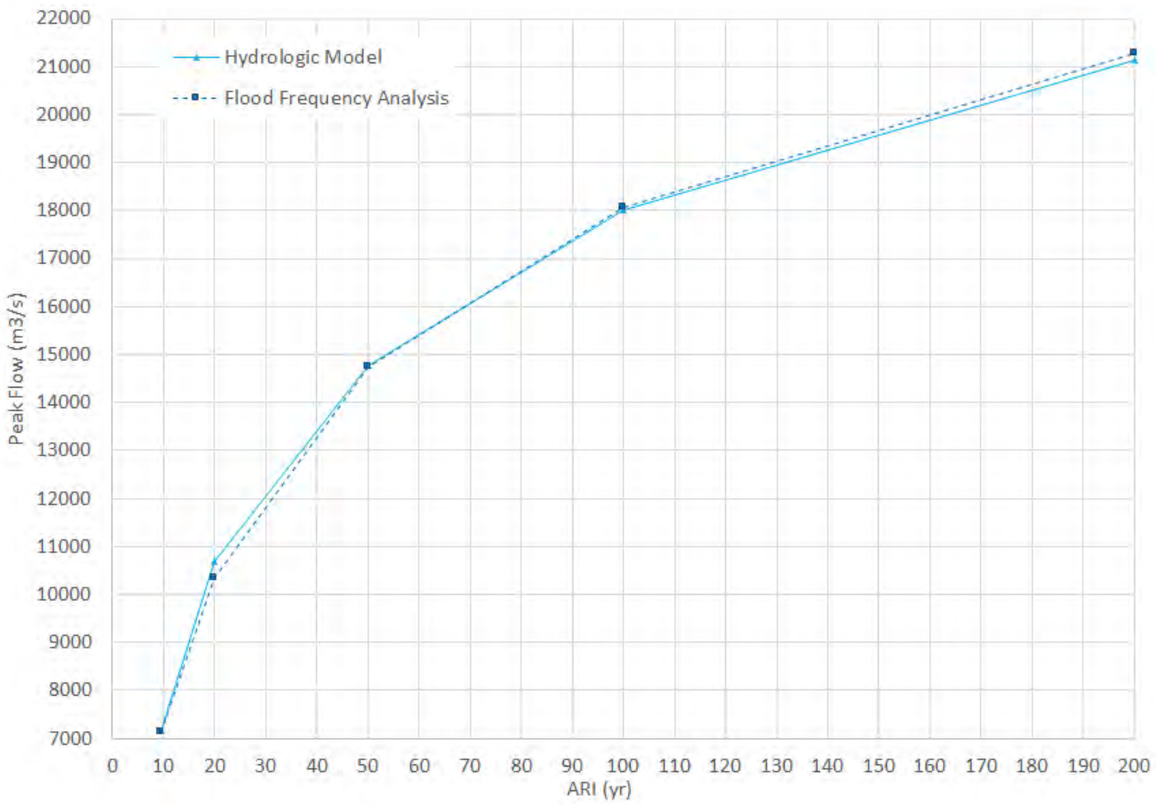


Figure 3-4 Comparison between Runoff Model and Flood Frequency Analysis

3.3.3 Discussion

The flood frequency analysis agrees closely with the results obtained from the calibrated runoff model, giving confidence that the design hydrographs are suitable for use as inputs to the hydraulic model.

In turn, this close agreement suggests that the assumptions on data homogeneity are not overly important. Flows post-1982 were scaled up by 5% to attempt to represent the effects of the dams, however the quantum of change introduced by this could easily be overshadowed by any of the following:

- The assumed rainfall losses in the runoff routing model;
- The choice of probability model against which to fit the frequency curve;
- The estimation of the oldest floods on record, and assumption on the threshold value for non-gauged years in the record; and.
- The extent to which low flows are censored from the data.

Predicted design discharges, from both the flood frequency analysis and the runoff routing model, are generally slightly higher than those calculated in the previous flood study. With respect to the frequency analysis, this is likely due to the additional length of flow record. The 4 extra years of record (ie. 2014-2017) did not contain any significant flooding, which has the effect of pushing the large floods further to the right (ie. increasing the AEP of their plotting positions) on the curve.

The extent to which the URBS design flood discharge estimates have increased is most likely due to the changes in design rainfall depths and areal reduction factors occasioned by the introduction of ARR16. Flood frequency estimates were matched against runoff model peak discharge estimates arising from the "median" design temporal pattern, suggesting that use of the median is appropriate in this instance.

It must be noted that both the flood frequency analysis and the runoff routing model have been constructed with imperfect knowledge. The former relying on relatively few large flood events to fill out the majority of the curve; the latter relying on the temporal and spatial completeness of the historical rainfall record to obtain calibration parameters from which design hydrographs are obtained. There will always be some measure of uncertainty associated with the underlying flood producing variables, and it is possible that future information (for example, information on paleo floods, or the occurrence of a new flood of record) will change the interpretation of flood risk probabilities.

However, based on the information available, the results of the comparison give confidence that the runoff model provides a realistic representation of our current understanding of flood behaviour in the Burnett catchment.

Section 4 Hydraulic Modelling

4.1 Purpose

The hydrologic model was used to develop historic and design discharge hydrographs. In the case of the Burnett River, the most-downstream gauging station for which an accurate rating curve exists is that of Walla (DNRM 136001B), located approximately 1 km north of the Bruce Highway crossing of the Burnett River. Downstream of this point, river heights are recorded at Bundaberg but due to the complex nature of the floodplain, no reliable rating curve is known to exist.

Thus, to determine flood behaviour downstream of Walla (i.e., for the Bundaberg reach of the Burnett River), hydrologic model hydrographs are required to be routed through a hydrodynamic model. The goal is to produce a model that can accurately reproduce the system dynamics (travel time, attenuation, peak heights) for a known flood event. The ultimate purpose of the hydraulic model was to calculate design flood elevations, depths and velocities to support the following components of the Bundaberg Ten Year Action Plan:

- Upgrades/raisings of flood-prone roads in the Givelda locality, west of Bundaberg (SMEC);
- Improvements to evacuation routes through the construction of a viaduct along Hinkler Avenue in North Bundaberg (HIG);
- Recommendations on house buybacks for the most at-risk properties (Jacobs); and,
- Bundaberg East Levee Concept Design (CDM Smith).

4.2 Model Schematisation

4.2.1 Note on Model Versions

HEC-RAS version 5.0.3 was adopted at the beginning of this project as the current release version available at that time (early 2018). In late 2018 version 5.0.5 was released as a significant upgrade, including the reformulation of certain numerical aspects of the computation engine that necessitated (per USACE recommendation) recalibration of the model. Pleasingly, this resulted in an improved fit to the 2013 calibration event (discussed below in Section 4.4) whilst also validating the earlier assumptions as they related to changing bathymetric conditions.

4.2.2 Regional Model

The hydrodynamic model HEC-RAS (US Army Corps of Engineers, 2017) was used to model the hydraulic characteristics of the Burnett River along a reach extending from the Walla streamflow gauge to the river mouth at Burnett Heads, a stream centreline distance of approximately 100 km.

The model was set up as a 2D semi-structured mesh with a default cell size of 90 m. This resolution would typically be considered too coarse for river channel modelling in a traditional gridded model. However, HEC-RAS utilises a sub-grid sampling routine (in which the characteristics of the underlying 1 m LiDAR grid are incorporated into the cell and face hydraulic properties) that allows for detailed hydraulic characteristics to be captured on a relatively large grid. Further detail on this methodology is provided in the HEC-RAS user's manual, which is freely available from the US Army Corps of Engineers website (US Army Corps of Engineers, 2017).

Key hydraulic controls (such as tops of banks, embankments, bridge abutments, channel constrictions) were captured by the addition of breaklines, which serve to align cell faces along the control, ensuring that the hydraulic effects are adequately represented in the model. Additionally, so-called "refinement regions" were used to set finer cell sizes, giving greater resolution in areas where additional model detail was desired, such as at hydraulic controls (50 m), or at narrow sections of the river channel (50 m).

The regional model was created for the following purposes:

- To efficiently conduct the initial calibration process by routing the 2013 discharge hydrograph from Walla to Bundaberg. The long duration of this flood event coupled with the distance to Bundaberg required the avoidance of unnecessary computational overhead to keep simulation times manageable. Large sections of the river are not of interest to the project, and any additional detail beyond the minimum required to describe flood wave routing would be wasted.
- To provide boundary conditions to a HEC-RAS sub-model of the town reach. Isolating the town reach in a detailed sub-model allowed a reduction in run time to be traded for an increase in model resolution – a change that was necessary to describe the localised hydraulic effects in North Bundaberg in a time-efficient and hydraulically accurate manner.

4.2.3 Town Reach Model

The town reach model was constructed to cover that portion of the Burnett River and floodplain spanning a section from about 2km upstream of the tidal barrage, through the town reach, ending at a point on the river just downstream of Gooburrum. These locations were selected for the model extent as they presented predominately 1D flow conditions. On the upstream end, flows were found to be contained entirely within the channel for events up to a magnitude of 500 years, allowing for the boundary conditions to be implemented as a discharge hydrograph. At the downstream end there was limited overbank flow and only minor lateral variations in flow properties, allowing for the downstream boundaries to be represented by two stage hydrographs, one for the main channel and floodplain, the other for a high-level breakout channel through the township of Gooburrum.

The model was set up as a 2D semi-structured mesh with a default cell size of 35 m. More than 300 breaklines were added to align cell faces to important hydraulic features and to reduce the cell size in areas of specific interest. For example, to model the influence of bridge piers required cells in the order of 2m to 5m, whilst in North Bundaberg breaklines were used to set a grid size of 15m and align cell faces with the street layout. Figure 4-1 illustrates this concept; breaklines are drawn in red, cell faces in black.

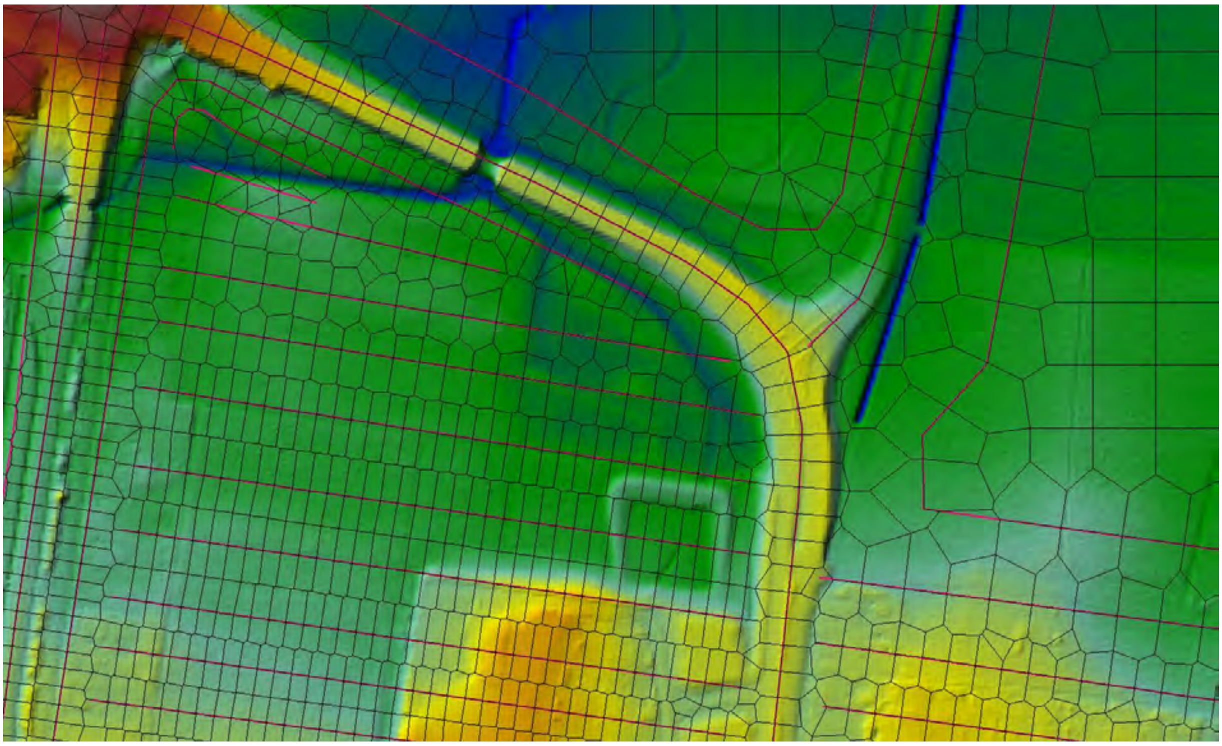


Figure 4-1 Breakline and Cell Detail, North Bundaberg

4.2.4 Quay Street Detailed Mesh

A refinement to the Town Reach Model, the Quay Street Detailed Mesh was developed to address stakeholder queries relating to possible changes to the hydraulic regime, on the sub-lot scale, that might affect land owners immediately adjacent to and on the river-side of the levee as a result of the levee's construction.

These concerns were addressed by creating a "Refinement Region" in the HEC-RAS model, lowering the default cell size from 35 m to 4 m in the area around the proposed alignment. Significant structures were represented as very high 2D weir obstructions with a 2 m cell spacing (similar to the bridge representations discussed in Section 4.3.4), that forces water to flow around the building footprint. So as not remove volume from the floodplain, structures represented in this fashion were left open on the downstream side, allowing the partially enclosed area to fill via backwater, in a process analogous to a flooded house filling with water. This implementation, and the comparative mesh refinement are illustrated below in Figure 4-2:

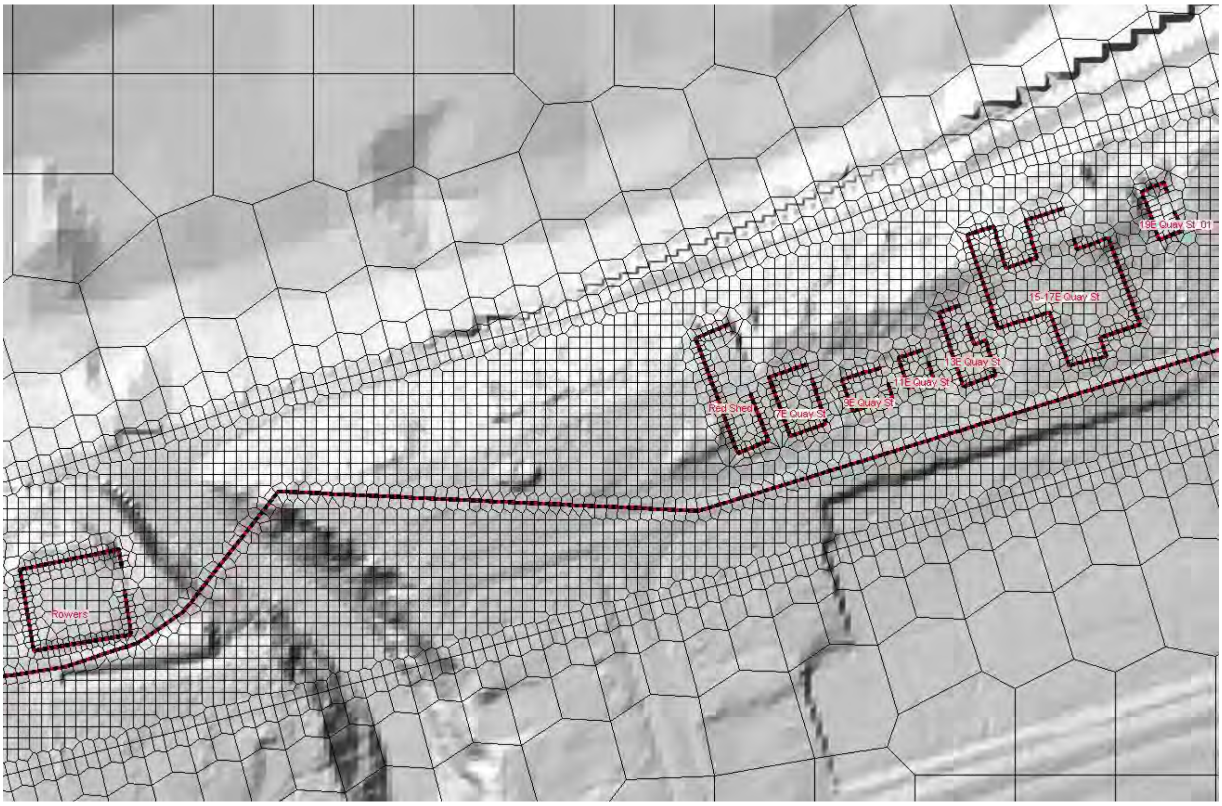


Figure 4-2 Refined Mesh on river side of Quay Street, East Bundaberg

Results from the detailed mesh simulation are discussed in Section **Error! Reference source not found.**

4.3 Model Data

4.3.1 Digital Elevation Models

A digital elevation model was developed to form the spatial basis for the HEC-RAS model, comprised of the following data:

Topographic Data

Topographic data were provided by DLGRMA, in the form of 1m resolution LiDAR grids. Originally commissioned by DNRM, 5 datasets were available for use in the project:

- Booyal, Monduran (2010)
- Bundaberg (2011)
- Buxton, Isis River (2010)
- Childers, Gin Gin, Woodgate, Winfield (2011)

An implicit assumption in the use of these data is that across the majority of the grid, elevation values have not materially changed in the time since the data were captured. The 4 datasets were mosaicked together, overlapping tiles removed, and the mosaic clipped to match the general shape of the river floodplain, and the data exported for use in the HEC-RAS model.

Bathymetric Data

The choice of bathymetric data set is an important consideration, as the Burnett River has only limited floodplain along most of its course between Walla and Bundaberg. Consequently, the majority of discharge is conveyed within the channel, even for very large floods. Changes to the assumed river bed level directly affect the conveyance capacity of the system and can influence predicted flood levels to a greater degree than would be the case for a river with a small channel capacity and large floodplain volume.

Bathymetric datasets from were available as outlined in Table 4-1:

Table 4-1 Bathymetric Data Availability

Survey Date	Source	Extents	Notes
09/01/2011	MSQ^ (F005053)	Burnett Bridge to Bulk Sugar Terminal	Pre- 2011 flood
25/01/2011	MSQ (F005054)	Burnett Bridge to Port Bundaberg	Post- 2011 flood
21/03/2012	DLGRMA	Paradise Dam to Burnett Bridge	As used in GHD study. Likely source MSQ
12/03/2013	MSQ (F005056)	Burnett Bridge to Bulk Sugar Terminal	Post-2013 flood
21/03/2015	MSQ (F005065)	Burnett Bridge to Bulk Sugar Terminal	Post Cyclone Marcia
06/04/2017	MSQ (F005068)	Sailing Club to Bulk Sugar Terminal	
11/05/2017	MSQ (F002054)	Bulk Sugar Terminal to Sea Wall	
11/05/2017	MSQ (F002055)	Bulk Sugar Terminal and Oil Berths	

^ Maritime Safety Queensland

Only a single dataset covered the reach upstream of the Burnett Bridge, and so this was automatically included in the bathymetric data formulation.

In the reach downstream of the Burnett Bridge, datasets were available from 2011 (both pre and post flood), 2013 (post flood), 2015 (post Cyclone Marcia), and 2017 (routine maintenance dredging of the port). An initial review showed significant differences in the datasets, suggesting that large floods can cause mobilisation and scour of the bed. This phenomenon can be problematic with respect to selecting a bathymetry for use in design event modelling. As an example of the type of error that can be introduced to a model, curves of channel cross-section vs gauge height at Walla are presented in Figure 4-3:

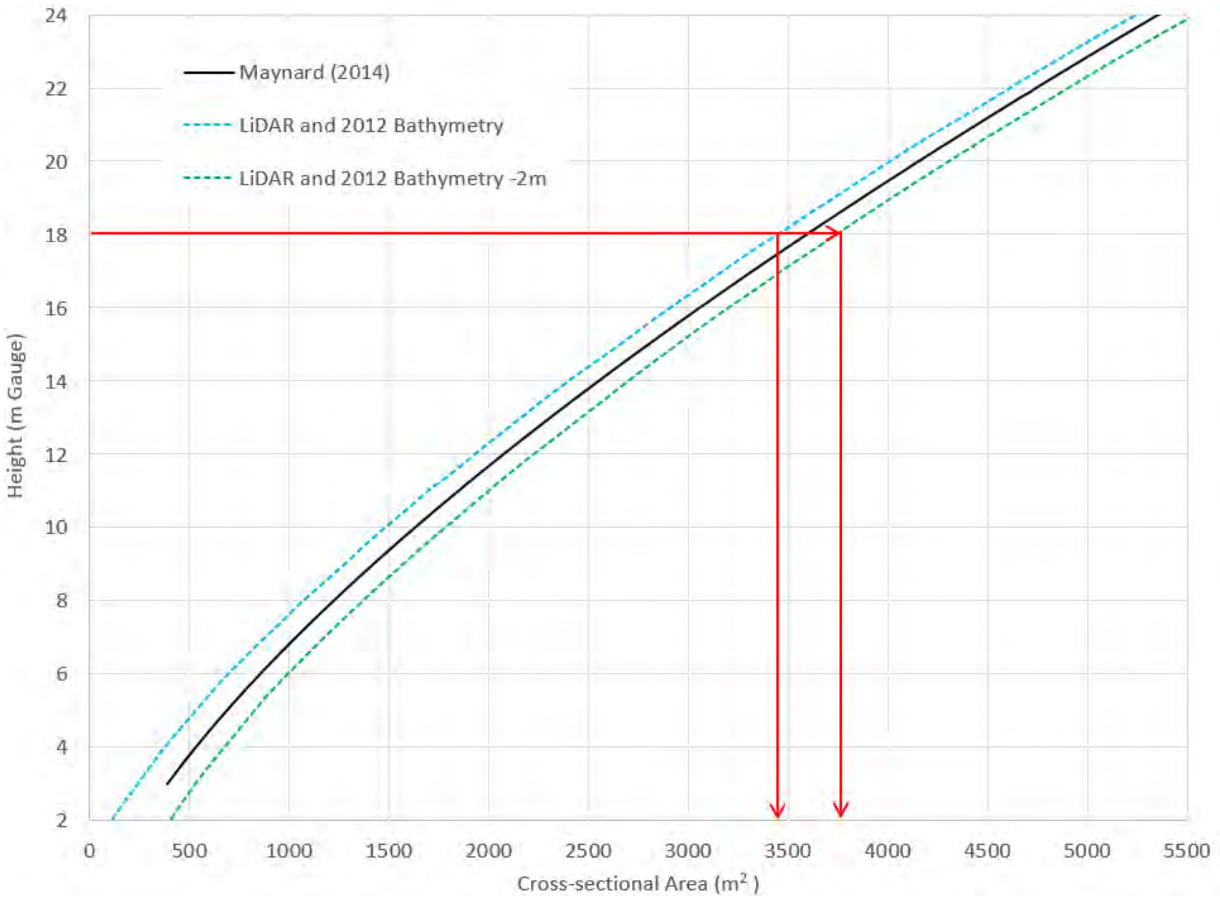


Figure 4-3 Estimates of Burnett River Cross-section at Walla

Three curves are presented:

- In black, the results of a 2014 survey and rating exercise carried out by DNRM hydrographer Ray Maynard;
- In blue, a cross-section through the same location, sampled from the LiDAR and 2012 bathymetry; and,
- In green, sampled from the LiDAR, but with an arbitrary -2m vertical shift applied to the bathymetry

It can be seen that although the curves take roughly the same shape, there are noticeable differences between the estimated cross-sectional area at any given height. For example, at RL 18m, area could vary between approximately 3,450 m^2 and 3,800 m^2, a range of about 10%. More conservatively, even between the surveyed curve and the blue curve, the difference in assumed cross-sectional area is around 5%. This is an important consideration to understand, as it imposes a fundamental constraint on the absolute accuracy of any modelling that it undertaken using these datasets.

Further discussion on the influence of bathymetry choice on modelled water levels is presented in Section 4.4

4.3.2 Boundary Conditions

Discharge Hydrographs

Design hydrographs from the URBS model (Section 2.5) were applied as inflow boundary conditions to the HEC-RAS model domain. For each design flood event 9 hydrographs were specified, one for the calculated Burnett River discharge at Walla, and the remaining 8 corresponding to local catchments in the Lower Burnett River below Walla.

Tidal Data

Tidal plane data were obtained from Maritime Safety Queensland (MSQ), and historic tidal conditions applied to the regional model for the 2013 calibration runs.

A fixed tailwater elevation of Mean High Water Springs, 1.17 m AHD, was applied as a downstream boundary condition for design event simulations.

4.3.3 Land Use Data

Land use categories were assessed using an aerial ortho-mosaic of the Burnett River and surrounds, dating from 2014.

4.3.4 Hydraulic Structures

Numerous bridges and other hydraulic structures cross the Burnett River inside the HEC-RAS model domain. These are listed below in order from upstream to downstream:

1) Bruce Highway at Walla.
2) McClennan Drive (Old Bruce Highway)
3) Walla Weir
4) Cane Rail Bridge
5) Cedars Road, South Bingera
6) Tidal Barrage
7) Tallon Bridge
8) North Coast Rail Bridge
9) Burnett Bridge

The Walla Weir and Tidal Barrage were implemented as weir structures within the 2D domain, using information taking from as-built drawings supplied by DLGRMA. Inclusion of the Walla Weir (not to be confused with the Walla streamflow gauge) would be expected to produce localised hydraulic effects in the model, although under extreme flows it is likely that the weir would become drowned. In either case, the weir is located far away from the general areas of interest. The Tidal Barrage functions primarily to quarantine upstream areas from saltwater influence, and as such, it is a low-level structure with little storage capacity, that is regularly overtopped. It has been included in the model for the sake of completeness, however it is not expected to greatly influence water levels and velocities in the hydraulic model.

The upstream bridges (Bruce, McLennan, Cedars) were not explicitly modelled. The Bruce Highway bridge is high enough to remain unsubmerged during extreme floods, and its effect on flow conditions is largely a factor of the contraction and expansion losses caused by the floodplain embankments and bridge abutments; both of which are represented in the terrain data. The McClennan Dive and Cedars Road bridges are not located near any areas of interest and are low-level structures that are likely to be drowned out under moderate flood conditions with little impact upon flood behaviour.

The town-reach bridges (Tallon, North Coast Rail, Burnett) were represented in the town-reach submodel (only), via an explicit representation of the piers as small, very high 2D weir obstructions that force water to flow around. The effects of this can be seen in the plot below:

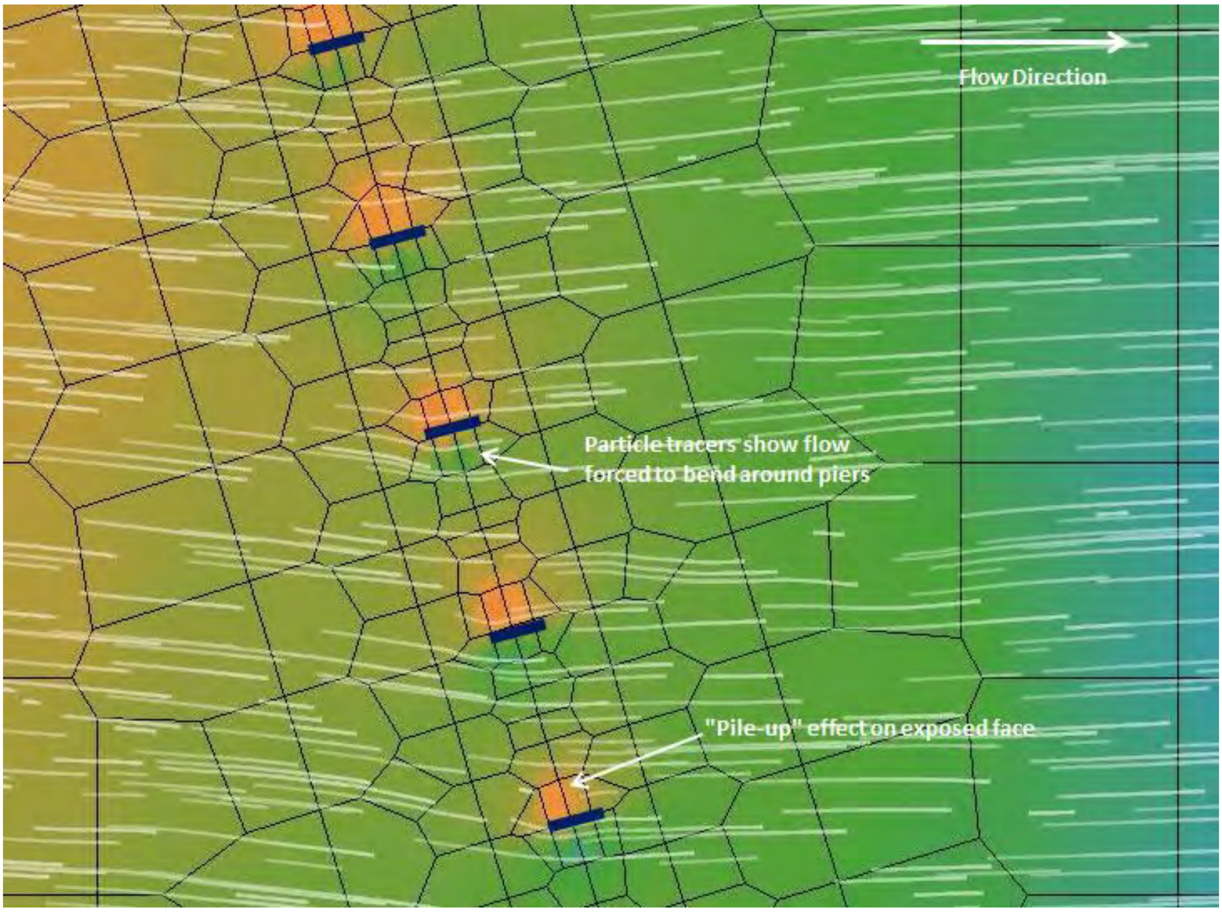


Figure 4-4 Example of Bridge Pier Representation

It is noted that this approach cannot model pressure flow, however the only situation where significant pressure flow is likely to exist is at the Burnett Bridge for floods greater than 500 year ARI in magnitude.

4.4 Model Calibration & Sensitivity Testing

4.4.1 Regional Model

The general calibration process was one of parameter testing and review, after which incremental changes were applied to the model for the subsequent iteration. A choice of bathymetric data had to be made for the reach downstream of the Burnett Bridge. The 2011 dataset (MSQ F005054) was selected initially, however it became apparent that this was no longer representative of conditions in the river at the time of the 2013 flood – at the Targo Street gauge, a reasonable match to the shape and height of the observed stage hydrograph could only be made by adopting unrealistically low values for manning's roughness. Using more typical values for roughness resulted in levels that were around 0.3 m too high at the gauge, and which were generally higher throughout the model than those observed. In contrast, the 2013 post-flood bathymetric dataset (MSQ F005054) gave a much closer match to observed values around the time of the peak but offered a poorer fit on the rising limb (noting that it was later found that the rising limb issue was partly related to the inclusion of local hydrograph inflows). Figure 4-5 shows the comparison between the two sets of data for an early (v5.0.3) calibration run (ie. not the final calibrated model, but an example included to illustrate the concept):

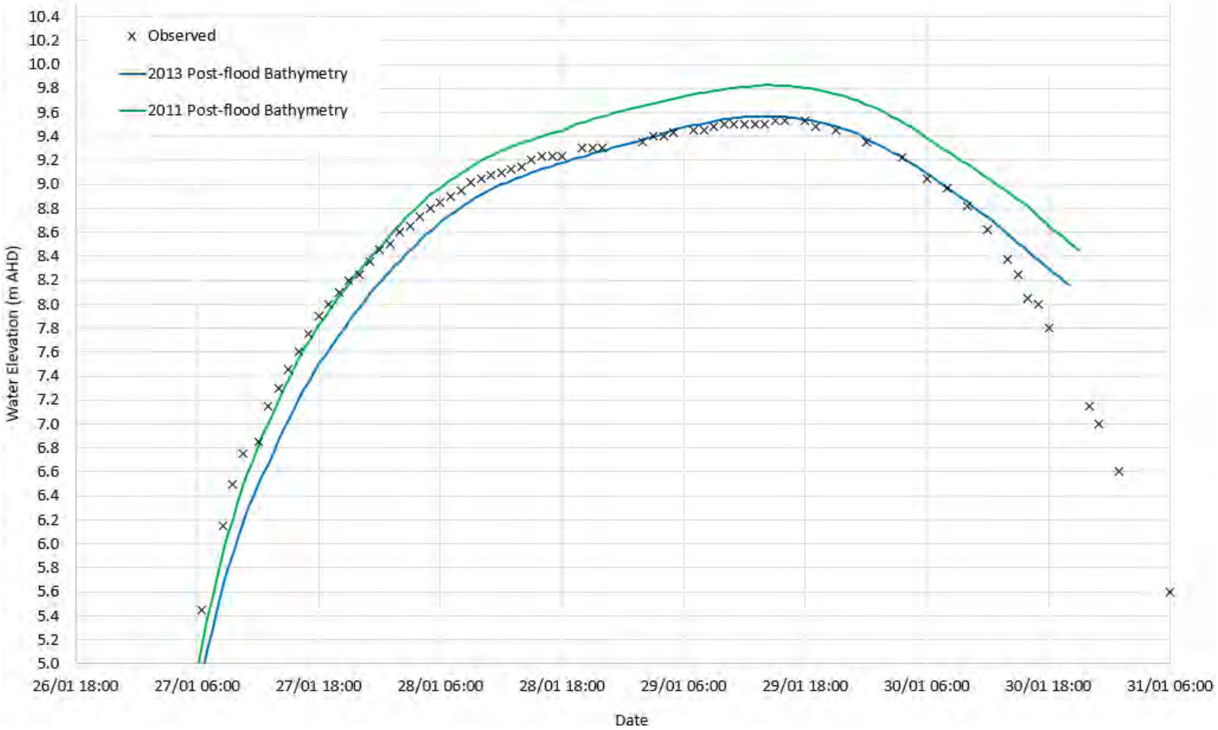


Figure 4-5 Effect of Bathymetry on Modelled Water Levels (note: HEC-RAS v5.0.3)

It is thought that this effect may be at least partly explained by the mobilisation of the bed during large floods. Anecdotes and surveyed data show that bed levels change significantly pre- and post-flood, however the rate of change and dynamics of the process cannot be readily quantified. Adding to this complexity is the restriction that only a single bathymetric representation can be used in any one simulation. The results displayed in Figure 4-5 suggest during the early phases of the 2013 flood, significant bed mobilisation had not yet occurred, and bed levels more closely represented those of the post-2011 survey. With increasing stream power, scour of the river bed and banks allowed for greater conveyance in the channel, and the 2013 post-flood bathymetric survey data became more representative of actual conditions at that point of the flood event.

Similarly, the vegetated profile of the riverbanks and floodplain appears to undergo large changes during major flood events. Along much of the reach between Walla and Bundaberg, the river is contained in an incised channel that measures up to 30 metres vertically from the top of banks to the river bed. Much of the banks are vegetated with tall, established trees, presenting a significant obstruction to flow. However, visual evidence suggests that large floods have sufficient power to knock down many such trees, reducing the effective roughness value in the channel. An example of this is presented in Figure 4-6, below:

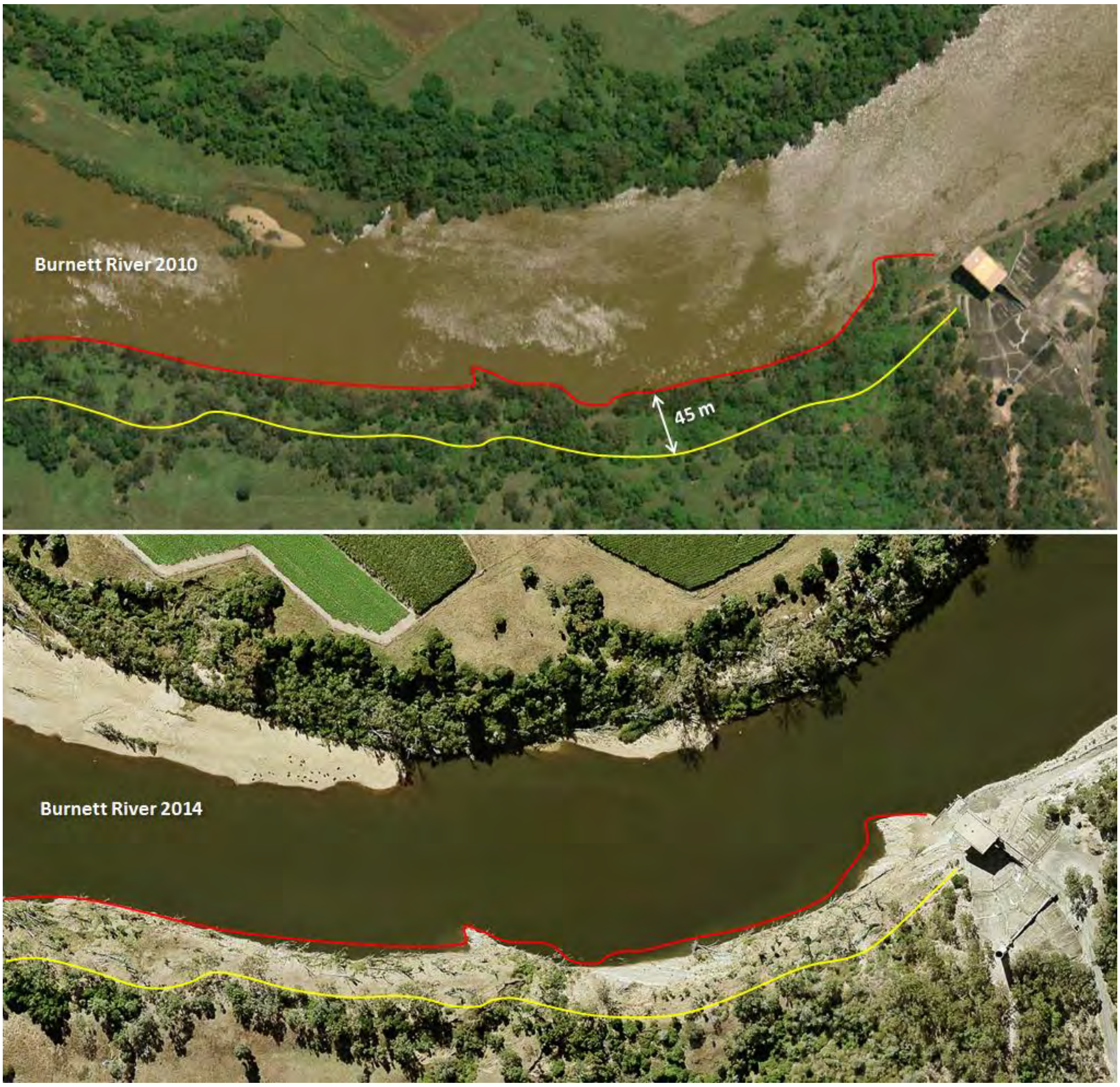


Figure 4-6 Example of Bank Scour, Burnett River near Pine Creek

The figure shows a substantial change in vegetation between 2010 and 2014, particularly on the outside bend, where a 45m wide strip of trees has been almost completed removed. Meanwhile, significant deposition is evident on the inside bend, presumably deposited with lessening stream power on the falling limb of the flood, and potentially changing the hydraulic characteristics of the channel.

Further downstream, the same process can be observed in the flatter floodplain reaches near Bundaberg. Figure 4-7 shows changes that occurred to a narrow portion of the river just upstream of Harriet Island:

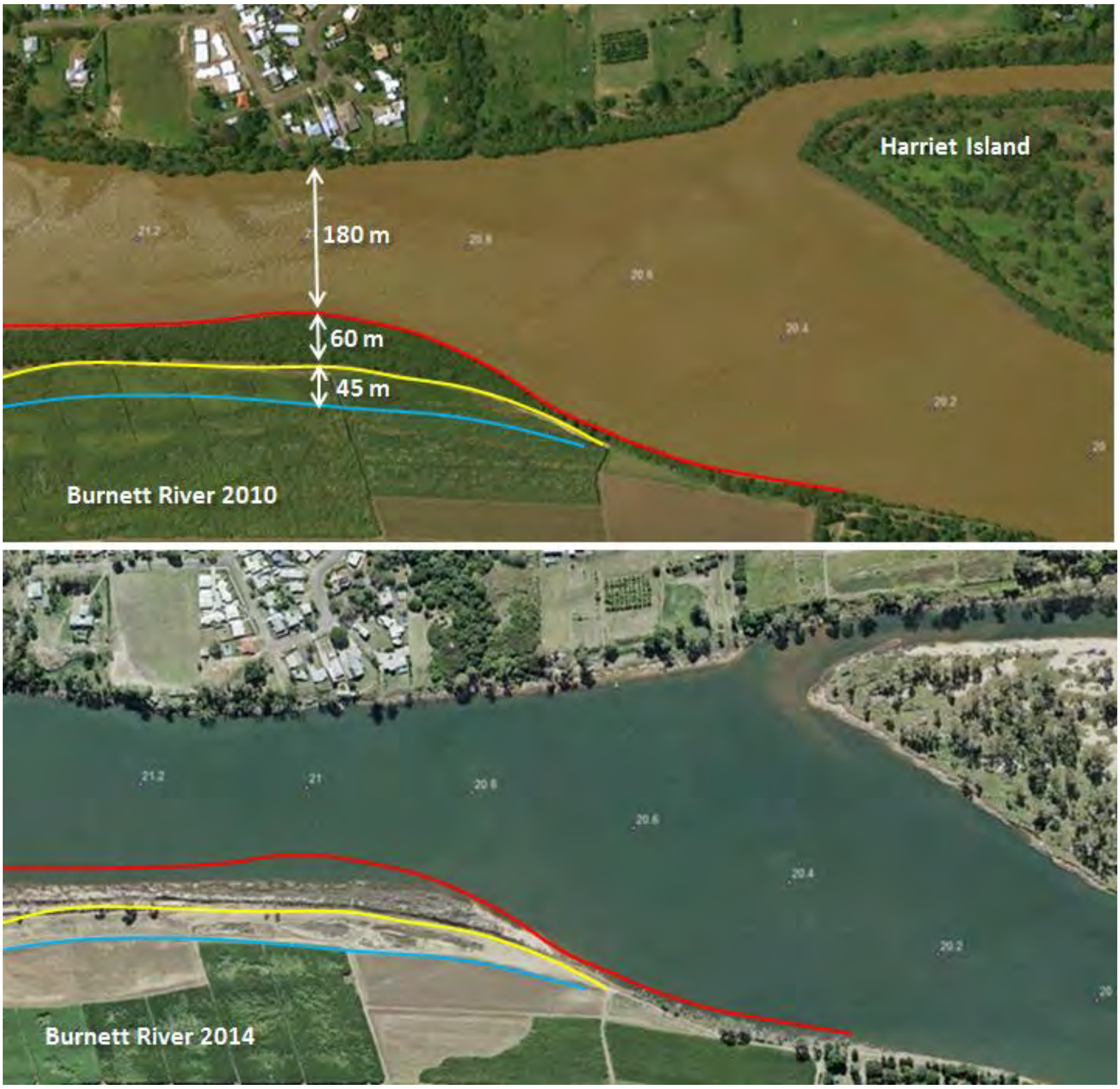


Figure 4-7 Example of Bank Scour, Burnett River near Harriet Island

Here, 60 metres of mangrove at 45 metres of sugar cane were scoured away, adding an additional 105 metres of low-roughness extent to the channel. The previous channel constriction has become wider and more hydraulically efficient. Judging by the lack of regrowth in the 2014 photo, it is most likely that the damage occurred during the 2013 flood. Many more similar examples can be seen by reviewing the historical imagery using the time-slider function available in Google Earth.

As with the bathymetry, this presents a temporal aspect to the calibration parameters that hydrodynamic software is ill-equipped to handle. It seems likely that over the course of the 2013 flood, both the channel cross-sectional area and the roughness profile underwent changes at many locations, adding to the difficulty of creating a calibrated model.

For any point on the river, modelled flood levels will vary in accordance with the underlying assumptions made about the flood producing variables for each particular calibration attempt. An assumption that produces good agreement at one location or point in time, may produce a poor fit to observed values elsewhere. In this fashion, calibration may be thought of as an envelope of probabilities, rather than a single given value. To illustrate this concept, Figure 4-8 presents a calibration envelope for the 2013 flood event at the Targo Street gauge, encompassing eight different combinations of bathymetric and roughness assumptions:

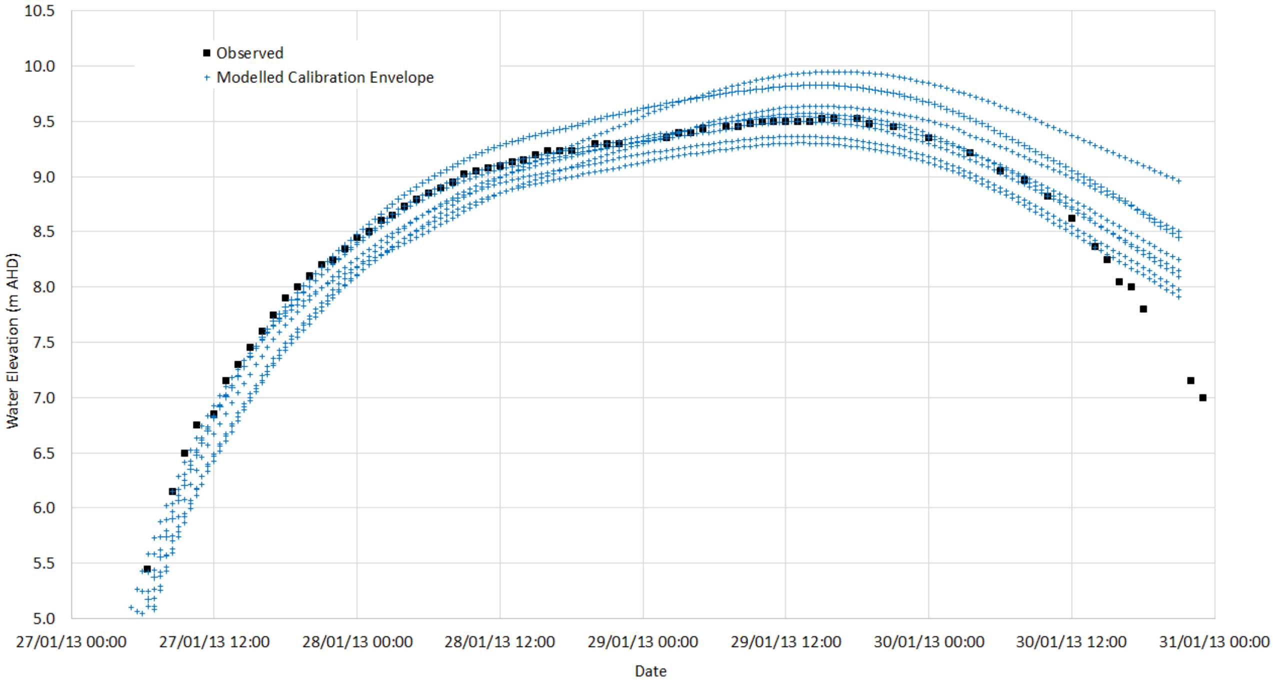


Figure 4-8 Envelope of Calibration Tests, 2013 Flood Event (note: HEC-RAS v5.0.3)

Figure 4-8 is of relevance to North Bundaberg, in that the severity of flooding is determined in part by the capacity of the main channel through the town reach and downstream. Main channel capacity is exceeded first downstream of town, and the first flooding of North Bundaberg occurs via a backwater from Tantitha Creek and Paddy Creek. As discharge increases, a subsequent breakout occurs near the old North Bundaberg railway junction, travelling though the Botanic Gardens to meet the Tantitha/Paddy backwater. At this point, severe flooding of North Bundaberg may begin to occur. For very large floods, further breakouts are likely to occur in the vicinity of the golf courses. However, the evidence suggests that channel capacity - inasmuch as it is influenced by bed levels and surface roughness – is liable to be different with each major flood event. It would therefore be reasonable to expect that the severity of flooding in North Bundaberg might differ from one flood event to the next, even for floods of similar magnitude.

Ultimately, the HEC-RAS model was able to give a good reproduction of the 2013 flood event, as presented below in Figure 4-9 and Table 4-2. The rising and falling limbs of the modelled hydrograph match well to the observed data, as do the timing and height of the modelled peak.

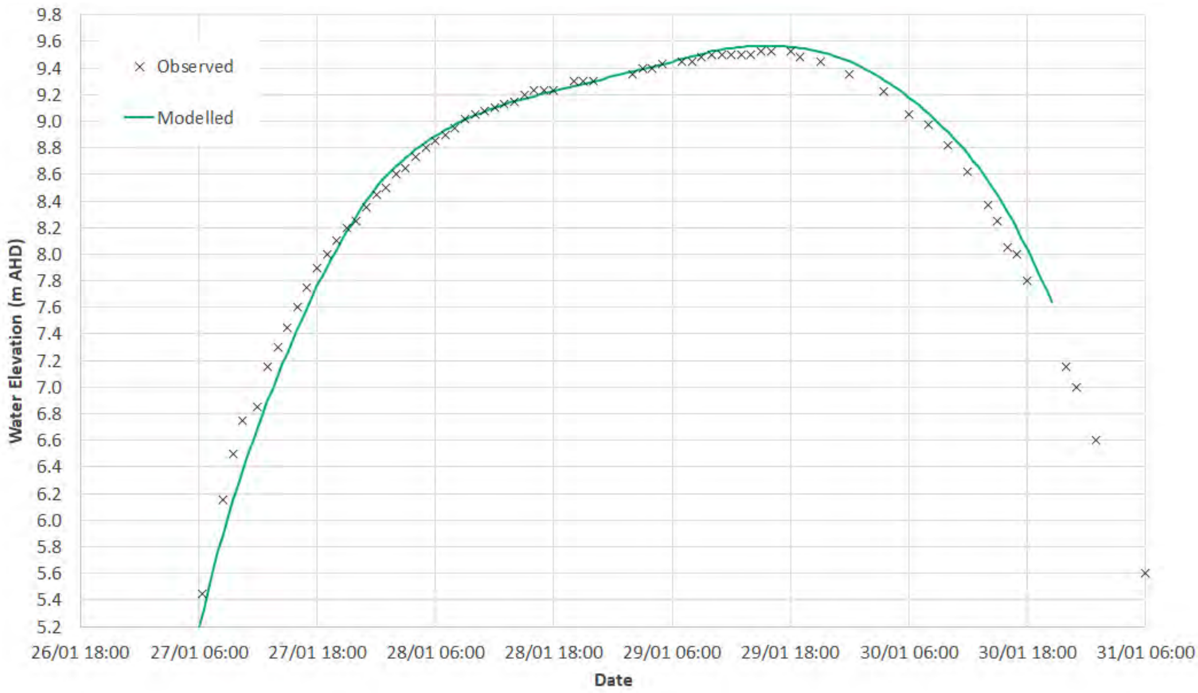


Figure 4-9 Calibration Hydrograph at Targo Street Gauge

Table 4-2 Peak Level Comparison at Targo Street Gauge

Location	Peak River Height		Difference (2 – 1)
	Observed (1)	Modelled (2)	
Targo Street Gauge	9.53 m AHD	9.57 m AHD	+ 0.04 m

This fit to the observed data was achieved using:

- 2012 bathymetric data upstream of the Burnett Bridge (the only data available for this reach
- 2013 post-flood bathymetric data downstream of the Burnett Bridge
- Manning's roughness values as outlined in the table below:

Table 4-3 Adopted Manning's Roughness Values

Land Use Category	Roughness Value 'n'
Agriculture	0.07
Cane - mature	0.08
Cane - low	0.06
Channel	0.02
Fallow fields	0.03
Mangrove	0.12
Pasture	0.03
Pavement	0.018
Urban	0.075

Land Use Category	Roughness Value ‘n’
Vegetation – light	0.04
Vegetation – medium	0.06
Vegetation – dense	0.1
Structures (when implemented as 2D weirs)	0.2

4.4.2 Town Reach Model

Discharge and stage hydrographs were extracted from the regional model and applied to the town reach model as upstream and downstream boundary conditions, respectively. Results were exported to GIS, where peak water levels were compared against debris marker levels and surveyed flood heights from the 2013 flood. Differences (modelled minus observed) were plotted to assess the spread of errors, which is shown in Figure 4-10 and tabulated in Table 4-4:

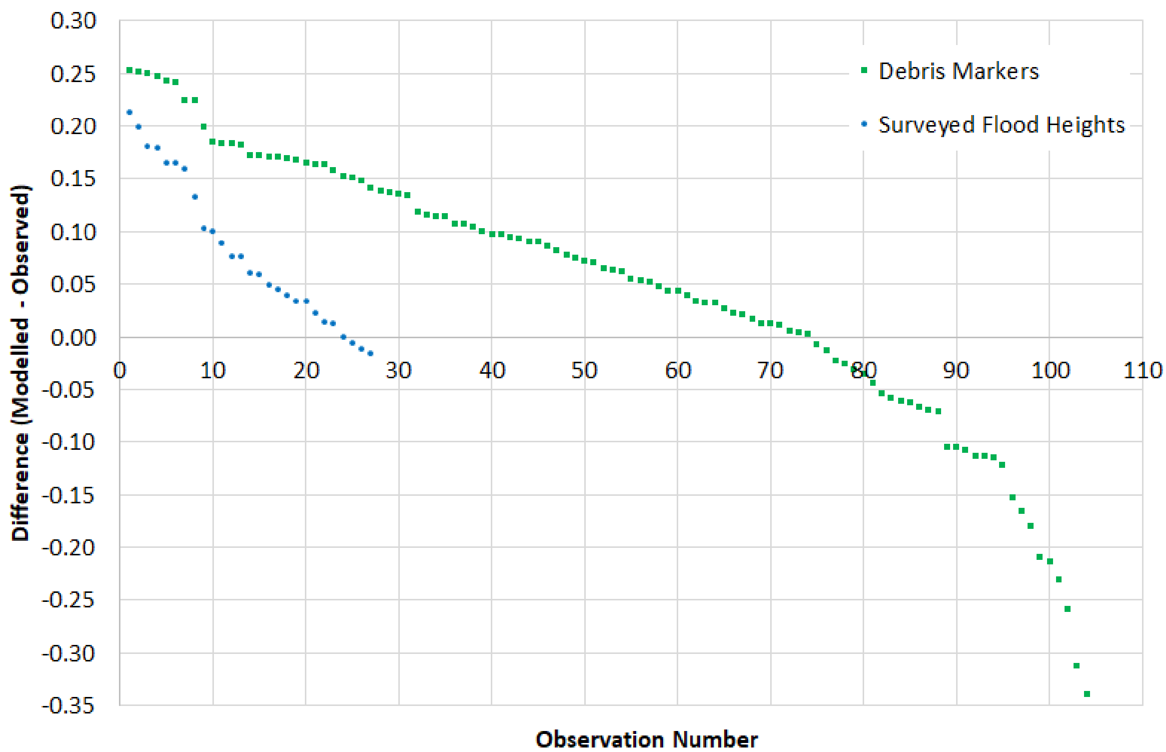


Figure 4-10 Difference between Observed and Modelled Peak Flood Levels.

Table 4-4 Calibration Comparison Statistics

Observation			Differences		
Type	Total No.	No. within +/- 150 mm	Average	Absolute Average	Standard Deviation
Surveyed	27	74%	0.08	0.07	0.07
Debris	105	70%	0.04	0.12	0.13
All Points	132	70%	0.05	0.11	0.12

The average difference to modelled levels was in the range of 0.04 - 0.08 metres, suggesting a slight bias towards over-representation of flood levels in the model. Modelled levels were within +/- 150mm of surveyed levels for 74% of observations. For debris makers this figure fell to 70%, reflecting the lower accuracy typically associated with measuring debris post-flood. Overall, 70% of modelled values fell within 150mm of their observed equivalents. This is considered to be a good result in light of the uncertainties surrounding bed levels and hydraulic roughness, discussed in the previous section, and the effects of these on hydraulic properties.

For those flood level observations that fell in or near the main river channel, a comparison was made to the longitudinal water level profile (at the peak) predicted by the town reach submodel, as presented in Figure 4-11:

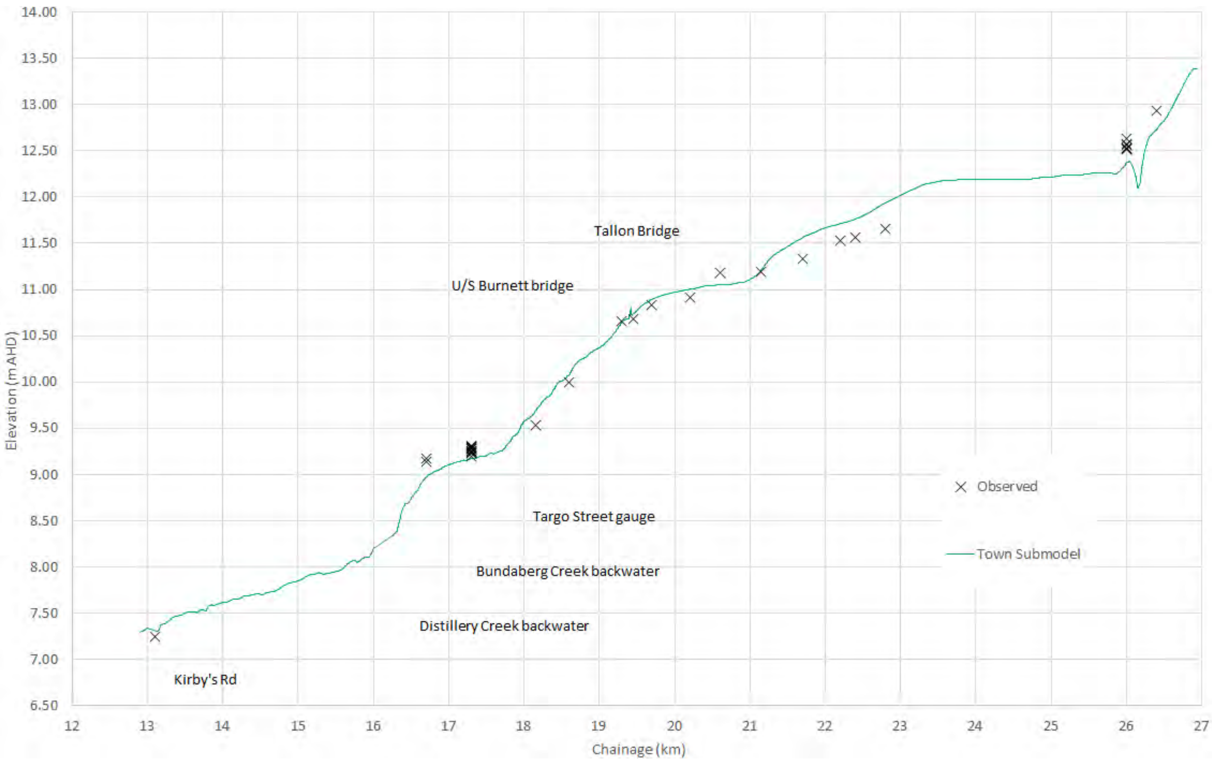


Figure 4-11 Comparison of Longitudinal Flood Profiles

4.5 Results & Analysis

4.5.1 Design Event Simulations

Runoff hydrographs for the range of probabilistic flood events (as discussed in Section 2.2.2) were routed through the regional HEC-RAS model. A uniform tailwater level of Mean High Water Springs (MHWS); 1.17 m AHD; was applied as the downstream model boundary at the river mouth. The resultant peak flood levels at the Targo Street gauge location are presented in Table 4-5 below.

Table 4-5 Design Hydraulics, Peak Flood Levels at Bundaberg

Probability Classification in		Peak Flood Level (m AHD)	
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	Targo Street Gauge	Saltwater Creek/Burnett River Confluence
50 %	1.44 year	3.80	3.71

Probability Classification in		Peak Flood Level (m AHD)	
Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	Targo Street Gauge	Saltwater Creek/Burnett River Confluence
20 %	4.48 year	5.46	5.35
10 %	9.5 year	6.63	6.46
5 %	20 year	8.02	7.76
2 %	50 year	9.00	8.65
1 %	100 year	9.50	9.20
January 2013 (modelled)		9.57	9.30
0.5%	200 year	9.79	9.49
0.2 %	500 year	10.46	10.18

Of note is the fact that the 1% AEP (100-year ARI) design flood level at Bundaberg is lower than the 2013 observed flood level, despite the opposite being true upstream at Walla. This is due to the extreme volume and extended duration of the 2013 flood, which had the effect of utilising most of the available floodplain storage. As a result, only minor attenuation of the flood peak occurred between Walla and Bundaberg. In contrast, the 1% AEP design flood has a higher peak runoff value but a smaller total volume; consequently, the flood wave undergoes a greater degree of attenuation, leading to a predicted lower peak flood level at Bundaberg.

4.5.2 Time of Closure Calculations

Background

As part of the Bundaberg Ten Year Action Plan, consulting engineering firm SMEC was commissioned to investigate the possibility of upgrading flood-prone local roads in rural areas near the Burnett River, upstream from Bundaberg.

To support SMEC in this investigation, CDM Smith was asked to use the HEC-RAS hydrodynamic model to extract height vs time hydrographs for a number of rural roads in the Burnett catchment, and to develop rating curves at suitable locations to enable the calculation of more detailed annual times of road closure due to flooding over each road. The purpose of this section of the report is to describe the works undertaken in extracting data; it was left to SMEC to carry out the detailed time of inundation/closure calculations.

Study Locations

CDM Smith received from SMEC a list of ten flood-prone roads in the localities of Givelda, Electra and Pine Creek, around 25km south-west of Bundaberg. The locations were interrogated in GIS, to establish the approximate lowest elevation of each road in the vicinity of its respective creek crossing, as summarised in Table 4-6, below:

Table 4-6 Time of Closure Study Locations

Location Name	Watercourse	Road Crossing Details	
		Coordinates (m E, m N) ^	Elevation (m AHD)*
Back Electra Rd 1	Unnamed Tributary 1	409780, 7237510	16.16
Back Electra Rd 2	Unnamed Tributary 2	411215, 7237440	21.82
Back Electra Rd 3	Unnamed Tributary 2	411475, 7237350	20.83
Back Electra Rd 4	Unnamed Tributary 2	411780, 7237240	12.47

Location Name	Watercourse	Road Crossing Details	
		Coordinates (m E, m N) ^	Elevation (m AHD)*
Pine Creek Rd 1	Unnamed Tributary 2	410745, 7236550	22.99
Pine Creek Rd 2	Cherry Creek	415185, 7235190	11.12
Pine Creek Rd 3	Pine Creek	415860, 7234350	10.59
Matts Rd	Pine Cree	415575, 7232980	9.76
Haylocks Rd	Cherry Creek	414615, 7234390	16.96
Crosswells Rd	Pine Creek	415320, 7231710	13.34

^ Coordinates in MGA Zone 56

+ Approximate lowest road elevation, from LiDAR

In each case, the topography suggested that the road locations would predominately be affected by backwater flooding from the Burnett River. Closures due to local creek flooding may also be possible, however these are likely to be much shorter in duration (ie. flash flooding immediately following heavy storms) and are therefore not considered in this analysis.

Inundation Hydrographs and Rating Curves

Flooding was assessed at the 2% AEP (ie. 50-year ARI) design flood event, for storm durations of 36, 48, 72, and 96 hours. Model results were analysed to produce hydrographs of water surface elevation versus time. It should be noted that the 72-hour storm event produced a hydrograph that was noticeably different in shape to the other three durations. This is due to the requirement of ARR16 to test an "ensemble" of ten rainfall temporal patterns. The pattern that produces the "median" peak flow (technically Rank 6, or median +1) at the area of interest (Walla gauge) was deemed to be the "representative" hydrograph for use in the hydraulic model. In this case, the temporal pattern selected for the 72-hour event was back-end loaded, resulting in the late onset of flooding seen with respect to the other durations.

Ten individual locations were provided for analysis, however it was not necessary to extract ten sets of hydrographs, as the road locations fall into three distinct backwater regions. These backwater regions act as off-stream storages for Burnett River flooding, meaning that within each region the water surface elevation varies with time, but is flat with respect to longitudinal distance from the Burnett River confluence. The three regions, their corresponding road locations, and the approximate hydrograph extraction coordinates are shown below in Table 4-7:

Table 4-7 Backwater Regions

Back Electra Rd 1	Unnamed Tributary 1	409785, 7237585
Back Electra Rd 2	Unnamed Tributary 2	411770,7237680
Back Electra Rd 3	Unnamed Tributary 2	
Back Electra Rd 4	Unnamed Tributary 2	
Pine Creek Rd 1	Unnamed Tributary 2	
Pine Creek Rd 2	Cherry Creek/Pine Creek	415810,7235250
Pine Creek Rd 3	Cherry Creek/Pine Creek	
Matts Rd	Cherry Creek/Pine Creek	
Haylocks Rd	Cherry Creek/Pine Creek	
Crosswells Rd	Cherry Creek/Pine Creek	

^ Coordinates in MGA Zone 56

Similarly, three rating curves were required, and were taken across suitable sections of the main river channel, downstream of the confluence with each of the respective backwater regions. Ratings were derived from the 2013 calibration event. The ratings were derived from concurrent height-flow pairs across the entirety of the simulation. As such, the hysteresis loop-effect can be seen, and was left to SMEC's discretion to use or discard the falling limb portion of each curve. Details of the rating curve locations are shown in Table 4-8, whilst the ratings are plotted on Figure 4-12.

Table 4-8 Rating Curve Locations

Location Name	Backwater Region	Rating Curve Section Coordinates (m E, m N)
Rating Curve 1	Unnamed Tributary 1	From: 410065, 7238600 To: 410015, 7238185
Rating Curve 2	Unnamed Tributary 2	From: 411990, 7238620 via: 412010, 7238120 To: 412035, 7237880
Rating Curve 3	Cherry Creek/Pine Creek	From: 416460, 7235705 via: 416435, 7235515 To: 416470, 7234910

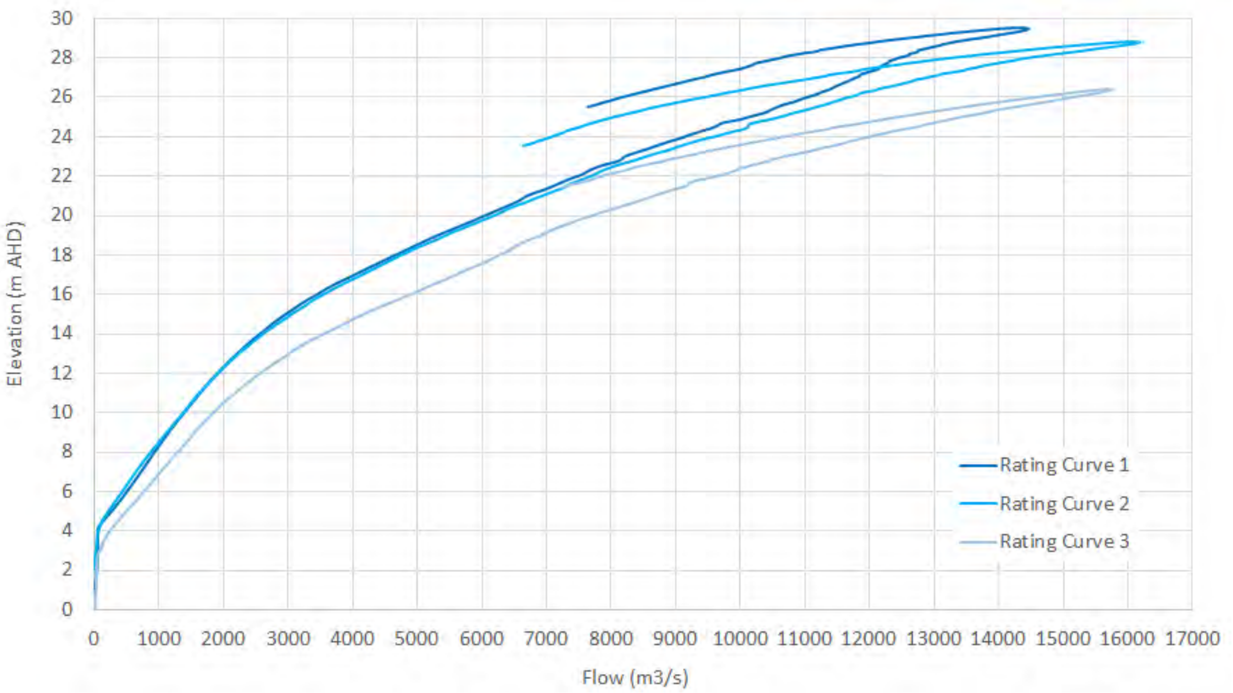


Figure 4-12 Rating Curves, Burnett River near Givelda

4.5.3 Hinkler Avenue Viaduct Options

The contents of Section 4.5.3 were originally published in a letter to DLGRMA entitled “Comparison of Flood Model Results – North Bundaberg Bridges Alternative Model Build”, on 17 April 2018, and are reproduced below.

Background

As part of the Bundaberg Ten Year Action Plan, consulting engineering firm HIG was commissioned to investigate the possibility of constructing a vehicle viaduct through North Bundaberg, for the purpose of improving egress during flood emergencies. Running parallel to Hinkler Avenue, the viaduct would connect the existing Tallon Bridge in the south, to the high ground at the Gin Gin Road roundabout in the north.

To support HIG in this investigation, CDM Smith was asked to perform hydraulic modelling to assess the impacts that proposed bridge upgrades might have upon flood levels in North Bundaberg. Modelling was carried out with a suite of bridge configuration options using the calibrated town reach model described in Section 4.4.2.

Four final bridge options were considered, each extending the existing Tallon Bridge from its current embankment at North Bundaberg, across the floodplain to the high ground at the Gin Gin road intersection. The proposed bridge options are broadly similar, differing only with respect to ramp configurations, span count, and span distance.

Specific details of each option are provided below:

- Option 2: A new two-lane viaduct, with a southbound on-ramp in the vicinity of Gavin Street, and a southbound off-ramp near the Gin Gin road intersection.
- Option 2a: A variant of Option 2, identical but for the southbound on-ramp, which is moved north, closer to Steuart Street.
- Option 8: A new two-lane viaduct, without any on- or off-ramps.
- Option 7: A variant of Option 8, identical but for the inclusion of the southbound off-ramp per Option 2.

The concept bridge drawings upon which the hydraulic model implementations were based are included as Appendix B to this report

HEC-RAS Model Results

Each of the 4 proposed options was simulated in the model, using the 1% AEP (100 year ARI) design flood as the reference flood event. Peak flood water levels were calculated across the model domain, and then subtracted from the existing case (ie. bridges across the river in their current configuration; Hinkler Avenue at-grade) peak flood levels to produce a map of flood impacts that showed the likely effect of bridge construction on flood levels. Results are presented below.

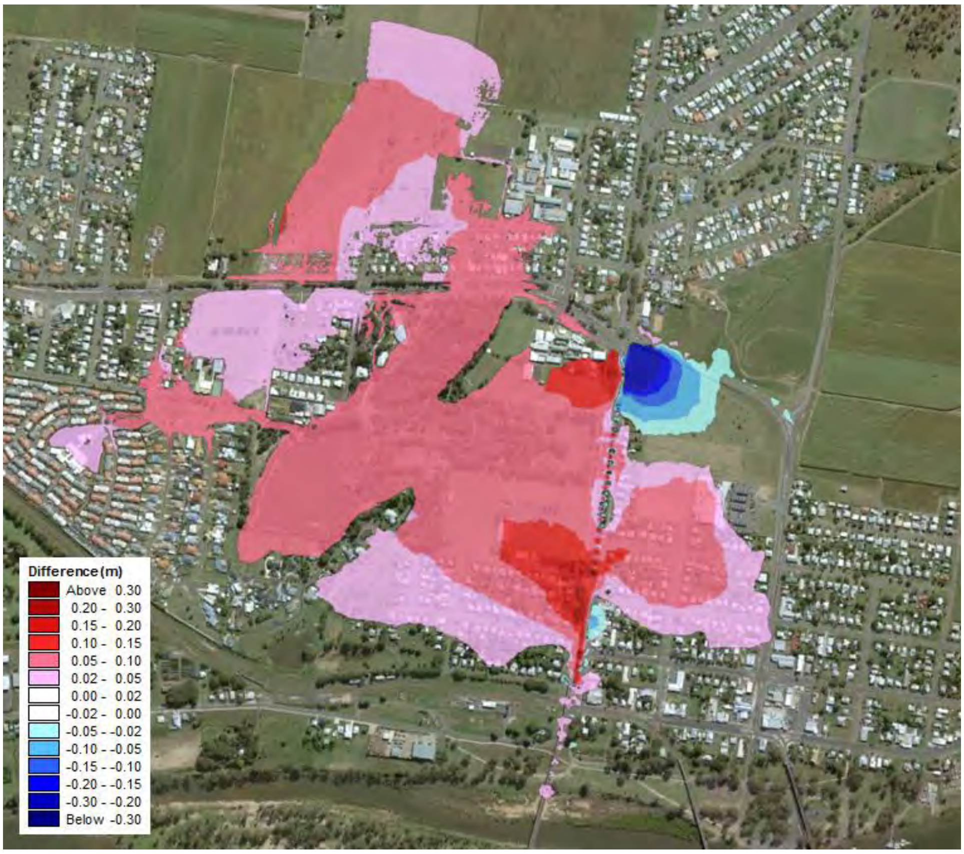


Figure 4-13 Water Level Difference Map – Bridge Option 2

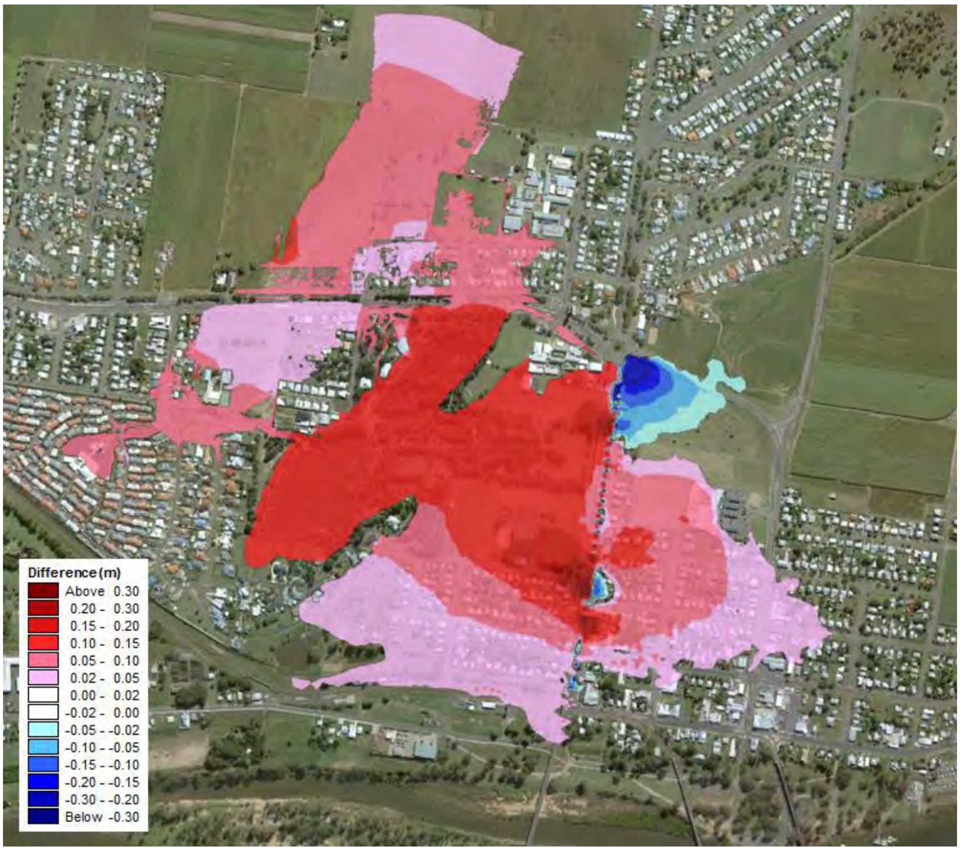


Figure 4-14 Water Level Difference Map – Bridge Option 2a

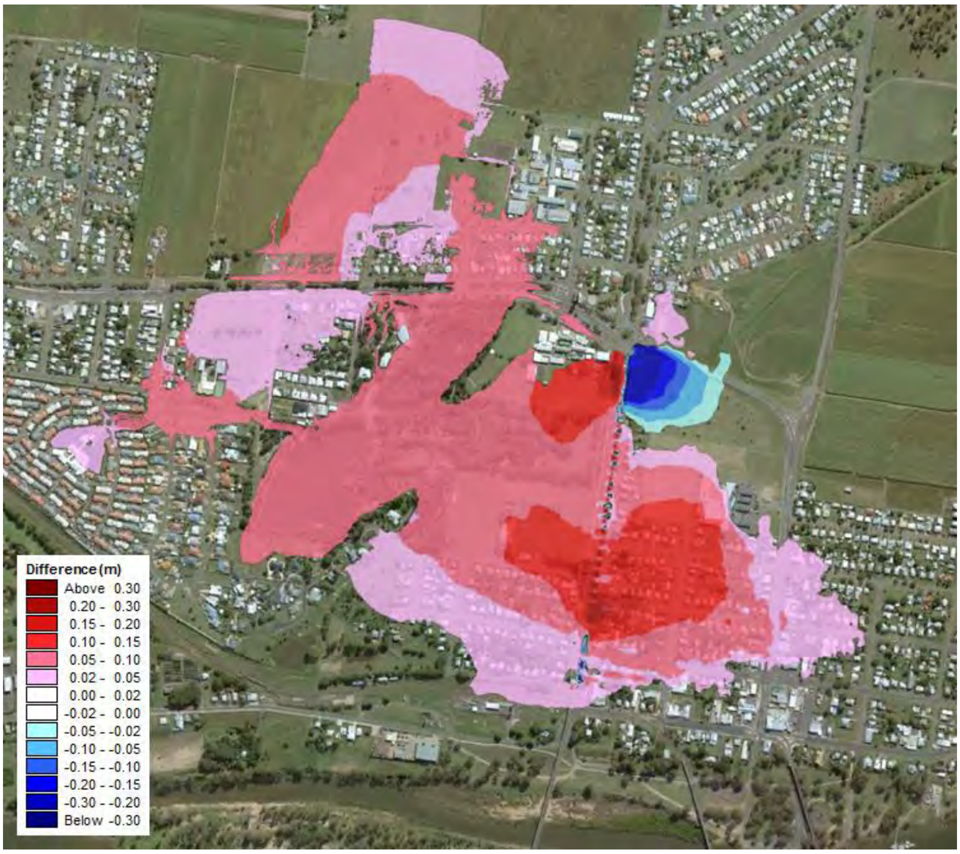


Figure 4-15 Water Level Difference Map – Bridge Option 7

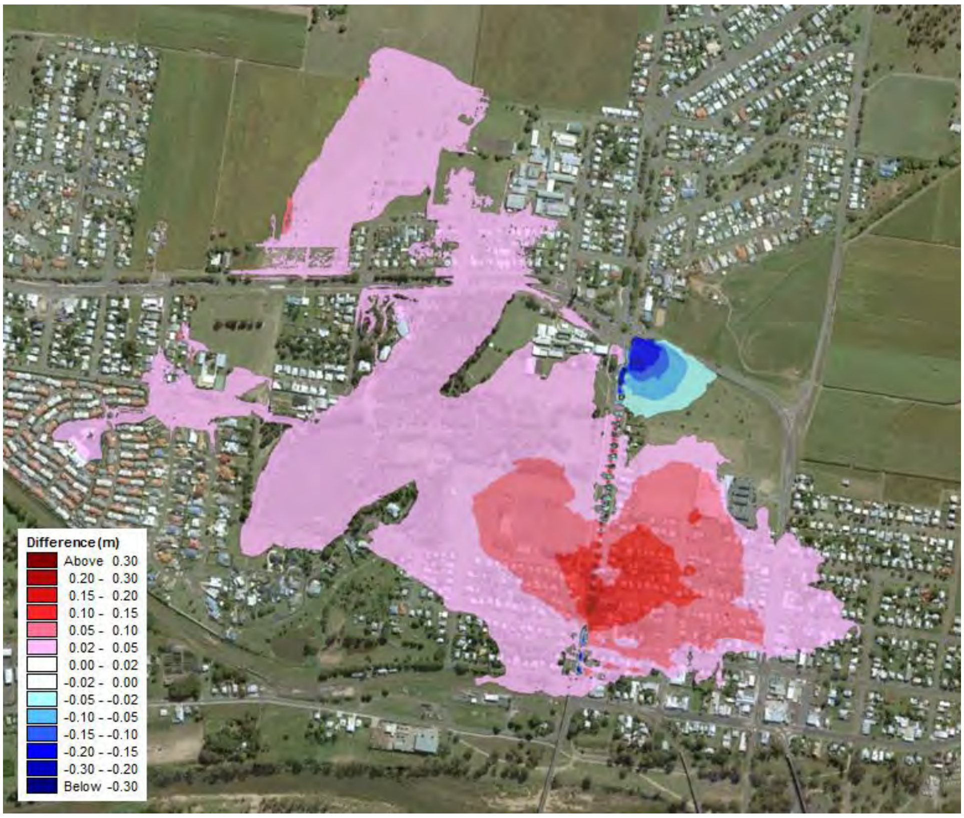


Figure 4-16 Water Level Difference Map – Bridge Option 8

Generally speaking, the model predicted changes in peak water levels in the range of +50mm to +200mm in the vicinity of the bridges, with increases most pronounced on the immediate upstream side of new on/off ramps. This is to be expected, as the new ramps constitute a large obstruction to flow which does not exist currently. Slightly more unusual was the spatial distribution of change, which showed increases also on the downstream side of the bridges, a result not typically seen. Finally, the magnitude of the predicted increases was questioned by the bridge designers, who noted that these were larger than those predicted for other bridge projects on which they had been involved.

These flow phenomena were discussed in a technical review session held at CDM Smith's Brisbane office on 08 March 2018. Model results were presented to DLGRMA's technical reviewer, Mr Bill Weeks. Mr Weeks noted that whilst the model build appeared sound, the results seemed somewhat unusual with respect to magnitude and distribution of impacts, and requested that CDM Smith validate these results by assessing the bridge options in a different hydrodynamic modelling package.

Alternative Model Build

Validation modelling was carried out using the MIKE21 software package (DHI Water and Environment, 2016). The program models free surface flows based on a two-dimensional implementation of the St Venant equations, for both the sub- and super-critical flow regimes. It has the functionality to model bridges, weirs, embankments, and other flow obstructions.

Bridge Option 2a was selected as the test case. Insofar as it was possible, the setup focussed on creating a model that was identical to HEC-RAS. Model topography (including bathymetric definition) was exported from HEC-RAS, down-sampled from 2m resolution to 10m resolution, and converted to the MIKE21 rectangular grid format. Model boundaries were placed in identical locations to the HEC-RAS model, and likewise comprised a single time-variant inflow boundary on the upstream side, and two time-variant water level boundaries at the downstream side.

Bridges embankments and ramps were represented by 2D weir/levee line elements (named a "dike" in MIKE21), in which an xyz text file describes the centreline Easting, Northing and crest elevation, respectively. This presents an obstruction to flow, up to the point of overtopping, after which the weir equation applies. Importantly, this implementation can handle partially submerged (ie. sloping crest) flow conditions such as those that would be experienced as bridge ramp is progressively submerged. This implementation is fundamentally the same as that used in the HEC-RAS model.

Bridge piers were represented through the use of the pier resistance routine. This method is commonly used to model drag effects from pier elements that are smaller than the model cell size. Piers are described in terms of their location and geometry; details which are used to calculate drag, which is then applied as a head loss to the cell. This implementation is fundamentally different to that used in the HEC-RAS model. HEC-RAS does not have the functionality to consider the sub-grid scale effects of pier drag, so instead piers were represented in HEC-RAS as 2D weir/levee elements, with the simplification that each dual-pier headstock was modelled as a single blade. Countering this simplification however, was the fine-scale cell resolution (2m-5m) around the HEC-RAS piers, which provided a physically realistic view of flow phenomena, including the "pile-up" effect on the face most exposed to the flow.

A summary of key model characteristics is provided below in Table 4-9.

Table 4-9 Comparison of model characteristics

Item	HEC-RAS Model	MIKE21 Model
Model Type	Semi-structured mesh	Rectangular Grid
Numerical Solution	Fully 2D	Fully 2D
Cell size	Varies between 2 m and 35 m	10 m everywhere
Calibration	Model results calibrated to 2013 flood	Uncalibrated
Bridge Piers represented as	2D weir elements	Pier resistance file
Embankments/Ramps represented as	2D weir/levee elements	2D weir/levee elements

Results and Discussion

Model results were processed to derive a map of maximum flood levels. The difference in maximum flood levels between the bridge case and the existing case was then calculated, to produce a map of peak flood level differences. Figure 4-17 shows a side-by-side comparison of these results. HEC-RAS model results are shown on the left; MIKE21 on the right:

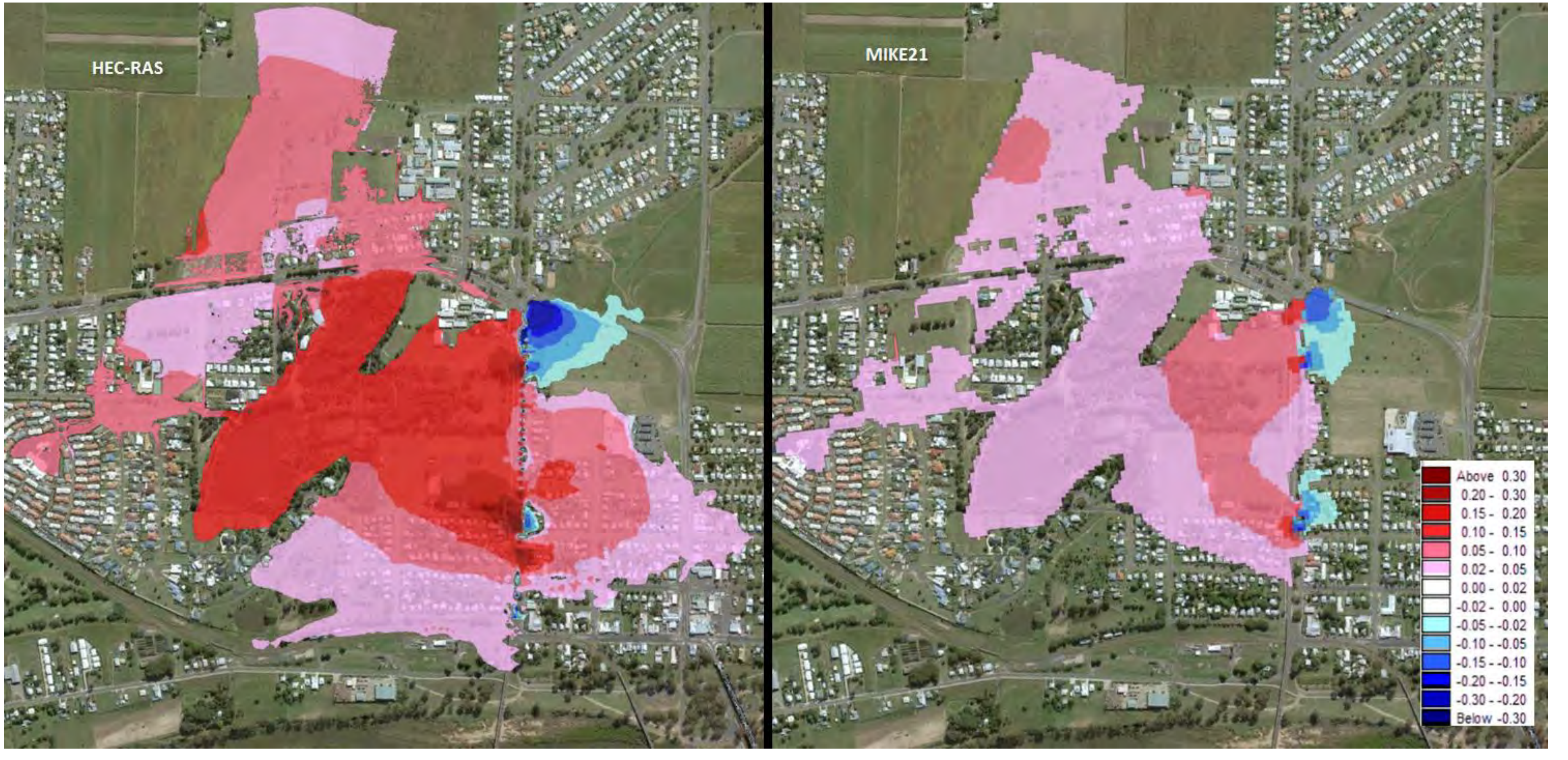


Figure 4-17 Water Level Difference Comparison – Option 2a

The MIKE21 model generally predicted impacts that were reduced in both extent and magnitude than those of the HEC-RAS model. However, similarities were seen in the region immediately surrounding the proposed on- and off-ramps, with both models predicting increases on the upstream side of the bridge and decreases on the downstream side.

It was noted that the MIKE21 pier implementation did not produce any appreciable effect upon flood levels; an unusual finding that is currently being investigated by the software manufacturer. Conversely, the HEC-RAS bridge piers had a noticeable effect on the flow regime, most readily seen when viewing peak flow velocity vectors. A side-by-side comparison through North Bundaberg is shown below in Figure 4-18. Vectors show the computed flow direction, and are plotted over a false-colour representation of current speed (blue = low; red = high).

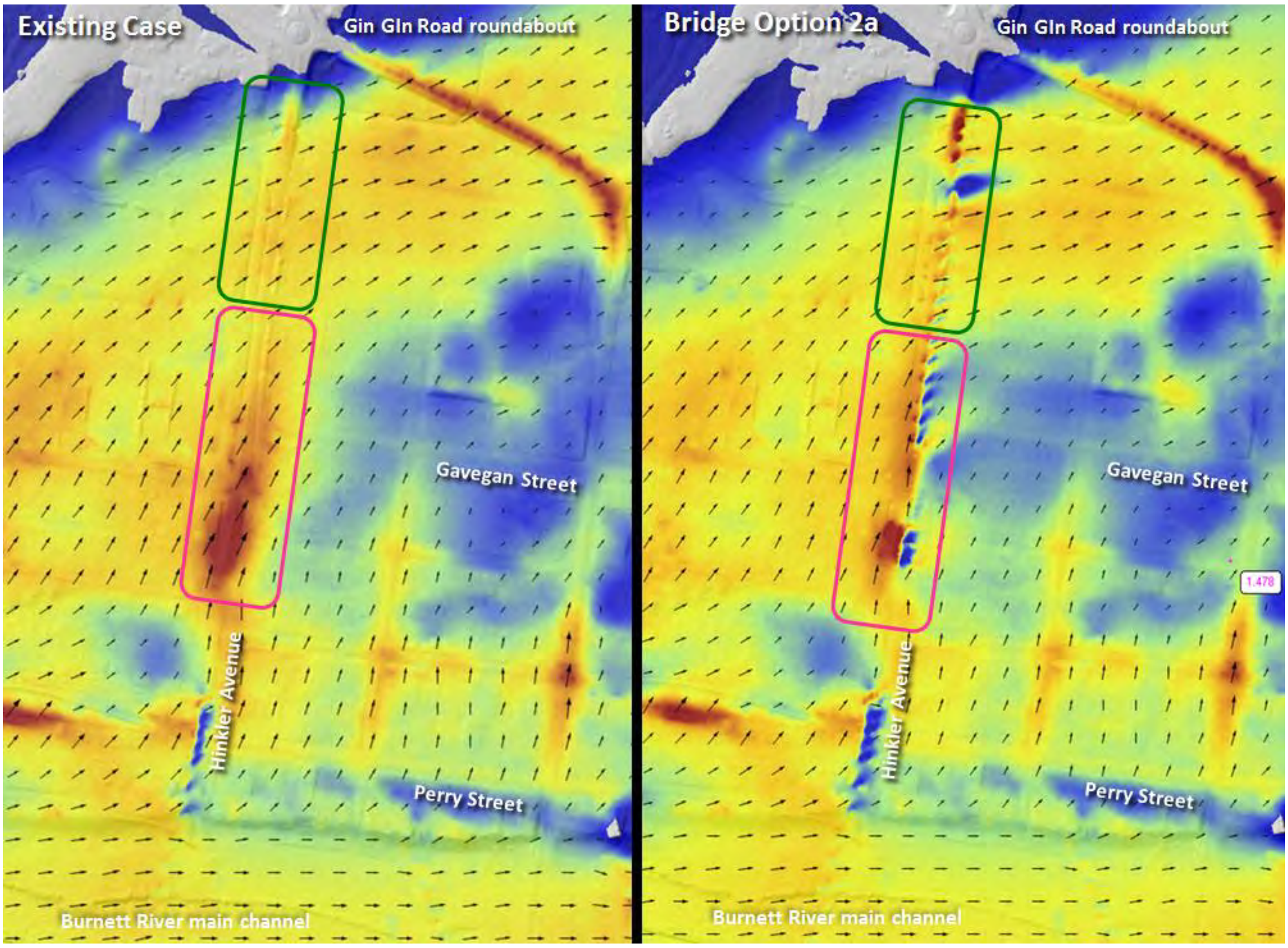


Figure 4-18 HEC-RAS Velocity Vector Comparison – Existing Case vs Option 2a

In the existing case, flow leaving the main channel near the North Bundaberg railway yards is predicted to travel in a northerly direction, before gradually turning to the north-east with increasing proximity to the high ground at the Gin Gin Road roundabout. When compared to the Option 2a case, it can be seen that this gradual curvature is interrupted by the placement of the bridge ramps and piers. Referring to the pink highlight box on Figure 2, flow is first forced to travel in a more northerly direction, whilst the green highlight box shows vectors facing more eastwards than in the existing case. Meanwhile, the false-colour map of current speed shows the new bridge piers exerting a noticeable wake-effect. Taken together, these changes to the flow could be expected to cause locally significant changes to peak water levels in North Bundaberg.

Given that the HEC-RAS piers are represented as blade elements, it is possible that head losses are over-represented with respect to those that might occur in a twin cylindrical pier configuration, as the blade exerts a strong training effect whereas water is free (when not obstructed by debris) to pass between cylindrical columns. To test this hypothesis, the pier elements from Option 2a were deleted from the HEC-RAS model, and the simulation re-run. Model results were processed as described above, giving the side-by-side water level difference comparison shown in Figure 4-19:

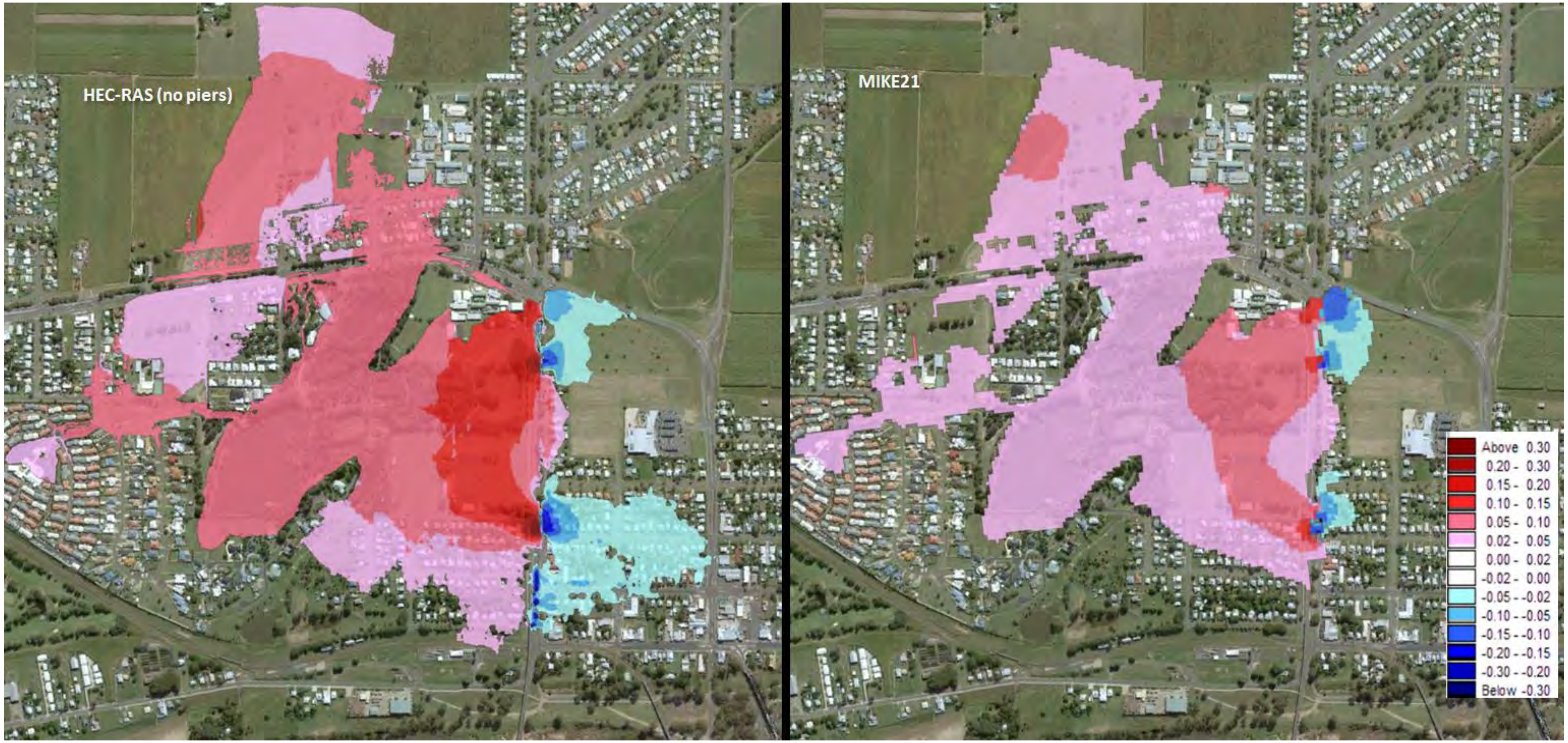


Figure 4-19 Water Level Difference Comparison – Option 2a (no piers case)

The results show that absent the HEC-RAS piers, both models predict an afflux pattern that is broadly similar in shape and sign, although the HEC-RAS model still predicts slightly larger impacts with respect to magnitude than MIKE21. This is possibly due to the differences in model resolution. The HEC-RAS geometry mesh samples the underlying topographic data (in this case, 1m LiDAR) and uses this to build hydraulic property tables for each cell face in the mesh, whereas MIKE21 relies on just single elevation point in each grid cell. As a result, hydraulic connectivity at shallow depths is likely to be better represented in HEC-RAS, as are hydraulic controls such as channel constrictions and embankments, which should lead to a better definition of flooded extent, and thus flood impacts.

Conclusions and Recommendations

Based on the works described above, the following conclusions are drawn:

- Both models predict flood impacts that are of the order that could be reasonably be expected, were the bridge to be constructed in any of the four layout options.
- HEC-RAS generally predicts larger impacts, in both the with-pier and no-pier cases, than MIKE21. This is likely due to the differences in underlying model resolution.
- It was demonstrated that the majority of the increase in flood levels on the downstream side of the proposed bridge was due to the pier implementation in HEC-RAS. As the MIKE21 pier implementation appeared to be unsuccessful, no definitive comparison between pier head losses can be made at this time.

From these conclusions, we make the following recommendations:

- This comparison task was carried out in support of a concept bridge design, and the results described herein should be considered as guidance for further work. Should the bridge design progress further, it is recommended that detailed hydraulic modelling associated with the bridge geometry be conducted; work which may include such things as 1D calibration of pier losses or the construction of a physical model.

4.5.4 Hinkler Avenue Updated Option 7

The contents of Section 4.5.3 were originally published in a letter to DLGRMA entitled “Refinement of Flood Modelling – North Bundaberg Evacuation Route, Bridge Option 7”, on 11 October 2018, and are reproduced below.

Background

CDM Smith was commissioned by the Department of Local Government Racing and Multicultural Affairs (DLGRMA) to perform hydraulic modelling to assess the impacts that proposed bridge upgrades might have upon flood levels in North Bundaberg. Work on this matter was initially carried out in HEC-RAS RAS (v5.0.3), utilising CDM Smith’s calibrated hydrodynamic model of the Burnett River.

Model results were presented to DLGRMA’s technical reviewer, Mr Bill Weeks. Mr Weeks noted that whilst the model build appeared sound, the results seemed somewhat unusual with respect to magnitude and distribution of impacts, and requested that CDM Smith validate these results by assessing the bridge options in a different hydrodynamic modelling package. A model validation exercise was thereafter carried out using the MIKE21 software package, and it was found that:

- MIKE21 could reproduce the general patterns of flood impacts predicted by HEC-RAS, as they related to the placement of embankments within the floodplain;
- MIKE 21 could not reproduce impacts arising from the placement of new bridge piers. It was suspected that the model was not correctly implementing the bridge pier routine, caused by a software bug.

- The HEC-RAS model was suspected of over-representing the losses associated with piers, owing to their representation in the model as blade elements (a practical software limitation at the time), as opposed to the twin cylinder configuration proposed by the design. Removing the piers from the HEC-RAS model gave good agreement with the equivalent bridge when modelled in MIKE21.
- Without being able to assess the effects of bridge piers in MIKE21, no conclusive findings could be drawn as to the likely scale of impacts arising from the construction of the proposed bridges.

Further discussion on the model set up and results can be found in CDM Smith's letter "Comparison of Flood Model Results – North Bundaberg Bridges Alternative Model Build", dated 17 April 2018.

Recent Developments

After publishing our previous letter:

- It was confirmed by DHI (the software vendor) on 05 April 2018 that a fault in their software code prevented the implementation of pier losses within MIKE21 versions 2016 and 2017. The model would accept pier resistance inputs without any indication of error, however the data were erroneously excluded from the hydrodynamic calculations. In the following weeks a "hotfix" to the model code was released and applied to the MIKE21 software installations at CDM Smith.
- HIG continued to develop their proposed bridge options. Following community consultation with residents of North Bundaberg, a refined version of Option 7 was selected as the preferred configuration.
- As a key stakeholder, the Department of Transport and Main Roads (TMR) was invited by DLGRMA to comment on the modelling results (per our letter of 17 April 2018). CDM Smith attended a meeting with TMR on 06 September 2018, outlining the findings to date. The TMR general view was in line with that of Mr Bill Weeks, in that the predicted impacts appeared large, given the scale and type of the proposed bridge.

In light of these developments, it was agreed that CDM Smith should update the MIKE21 hydraulic model with the latest Option 7 configuration details, so that the effects of pier losses and embankment ramps could be assessed with greater confidence. The purpose of this letter is to document these additional works.

Model Build

The previously developed MIKE21 model was re-used, and updated with the following information:

- **Pier Details**. The centreline coordinates and geometric configuration of the Option 7 piers were obtained from designers Bornhorst & Ward. As currently designed, the bridge is comprised of 72 cylindrical piers of 1.2 m diameter, in a twin configuration. Each pair of piers rises to a headstock 1.8 m wide (transverse to the alignment) by 1.45 m deep (vertical). Pier and headstock information was translated into the MIKE21 dfs1 pier resistance format.
- **Abutment and Ramp Details – as designed**. The northern end of the bridge features a new embankment/ abutment (ie. from the new bridge) connection to the existing roundabout, a revised grading of the existing Hinkler Avenue approach to the roundabout, and a new ramp to enable southbound traffic to travel from the roundabout to the Hinkler Avenue service road. Details of these alignments were obtained from HIG in the form of 3D alignment strings. These were implemented in MIKE21 as "dikes" whereby an xyz text file describes the centreline Easting, Northing and crest elevation, respectively. A dike presents an obstruction to flow, up to the point of overtopping, after which the weir equation applies. Importantly, this implementation can handle partially submerged (ie. sloping crest) flow conditions such as those that would be experienced as a ramp is progressively submerged in flood conditions.

Three simulations were considered:

- **Existing Case:** Incorporating bridge pier, abutment, and off-ramp details for the Burnett Bridge, Queensland Rail Bridge, and Don Tallon Bridge.

- **Option 7 – as designed:** As above, plus the incorporation of pier, abutment and ramp details corresponding to the currently proposed configuration of the Option 7 bridge.
- **Option 7a – delete off-ramp:** A sensitivity test in which the proposed off-ramp (allowing southbound passage from the Gin Gin Road roundabout to the Hinkler Avenue service road) is removed, to assess the effect of this ramp on flood impacts.

Results and Discussion

The 100-year ARI 36-hour duration design event flood was simulated in the model, using boundary conditions from the regional HEC-RAS model described in the CDM Smith report "Burnett River Surface Water Modelling Technical Report", dated 04 May 2018.

Model results were processed to derive a map of maximum flood levels. The difference in maximum flood levels between the existing case and the design cases was then calculated, to produce a map of peak flood level differences, as shown in Figure 4-20 and Figure 4-21.

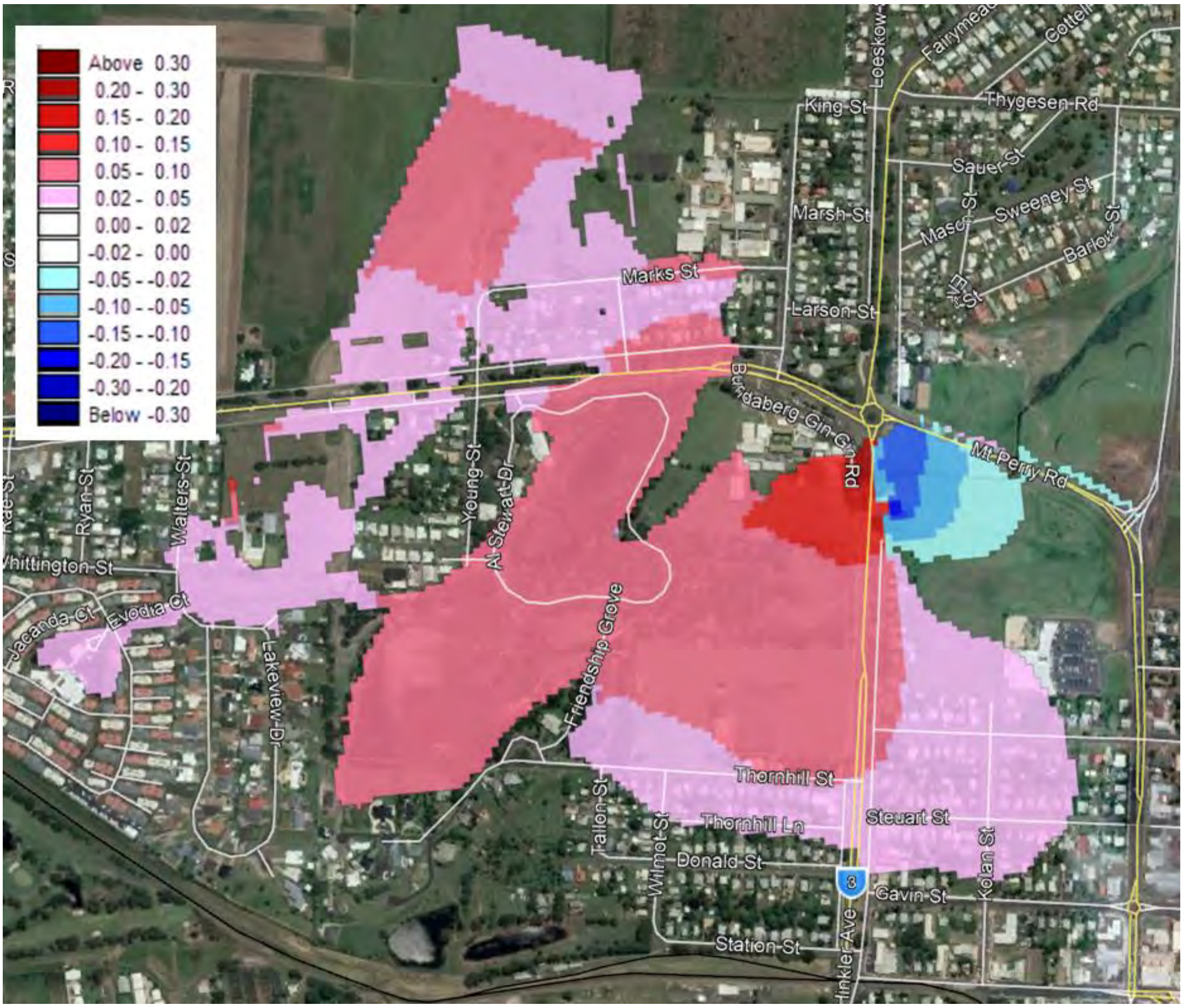


Figure 4-20 Peak Water Level Difference – Option 7 Bridge vs Existing Case

Figure 4-20 indicates that construction of the bridge could generally be expected to increase upstream water levels. Increases of up to about 150 mm are predicted immediately upstream of the new off-ramp, with commensurate decreases on the downstream side; a typical result where a new embankment reduces conveyance in an active flow area. It is likely that the bridge abutment and off ramp contribute much of the predicted afflux. Water level increases in the range of 50 mm to 100 mm are predicted throughout much of the upstream floodplain, however a potentially mitigating factor is that the largest increases are largely confined to waterways and open parkland. As with the previous modelling, increases are also seen on the downstream side of the bridge in the vicinity of Gavegan and Steuart Streets.

Overall the extent of predicted impacts is reduced, when compared to the previous modelling works. GIS was used to overlay the water level difference map onto the cadastral boundaries, in order to calculate the number of affected lots. It was found that approximately 200 lots could expect peak water level increases of greater than 20 mm.

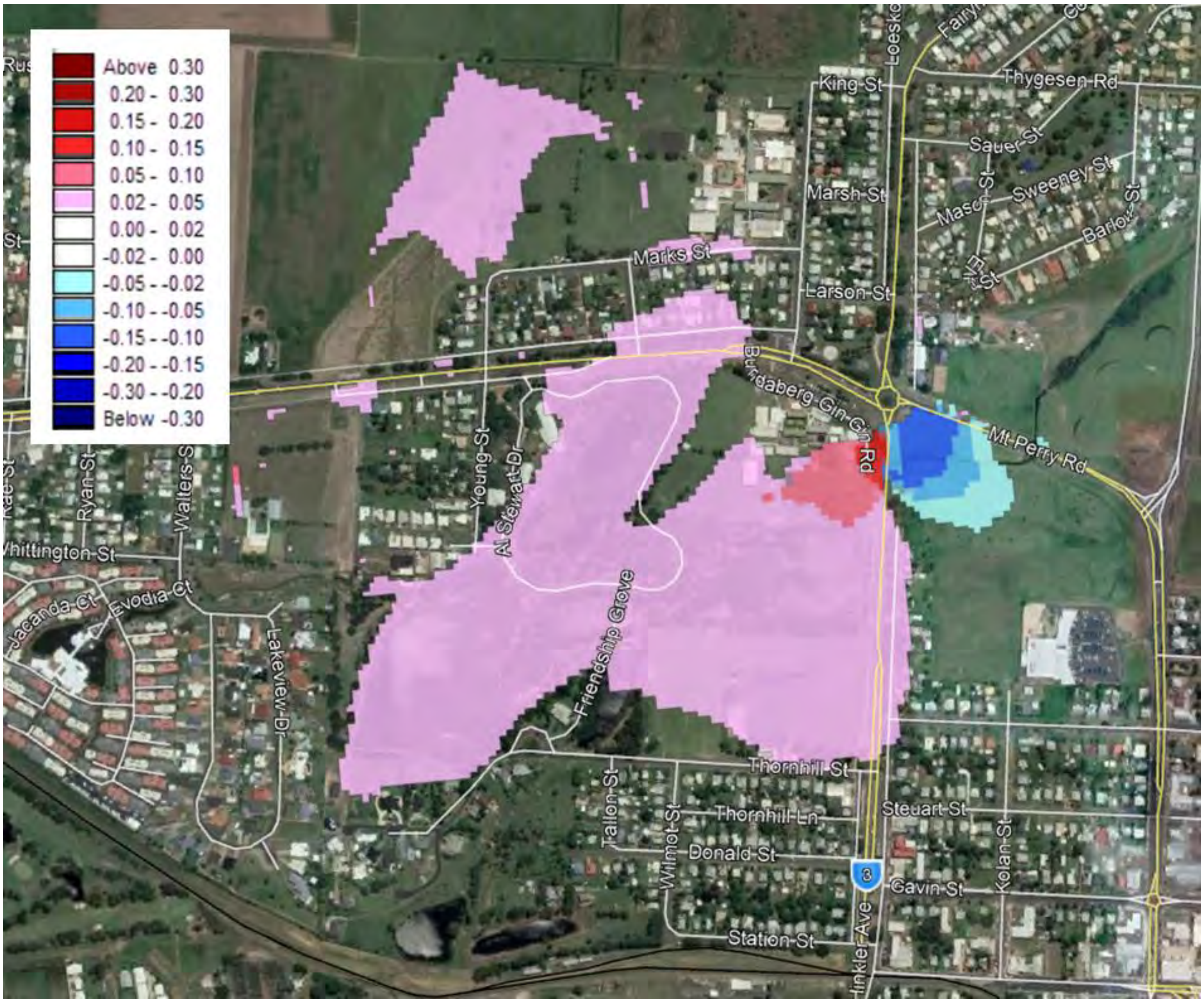


Figure 4-21 Peak Water Level Difference – Option 7a Bridge (delete off ramp) vs Existing Case

The effects of removing the off ramp are clearly seen in Figure 2, with predicted impacts lessened in both extent and magnitude. The largest increases are now restricted to the area immediately upstream of the bridge abutment, as this represents the only major flow obstruction for this simulation case. Elsewhere in the floodplain, impacts are confined to the range of 20 mm to 50mm. A detailed analysis of land parcel tenure has not been undertaken, but review of the aerial photo suggests that the majority of the impacted area is public land, as opposed to private freehold.

The number of affected lots was again counted, and it was found that in the no-ramp case, approximately 40 lots could expect peak water level increases of greater than 20 mm. The distribution of impacts for both cases is described in Table 4-10, from which it can be seen that removal of the off-ramp greatly reduces the number of properties affected by water level increases:

Table 4-10 Water Surface Level Increase by Number of Lots Affected

Option 7 Case	Number of lots with peak WSL increase of…			
	20 mm to < 50 mm	50 mm to < 100 mm	≤ 100 mm	Total
As-designed	168	32	2	202
No off-ramp	40	0	1	41

It should also be noted that the results in Table 1 are based on a count of *lots*, as defined by cadastral boundaries, rather than a count of individual structures or houses.

Conclusions and Recommendations

Based on the works described above, the following conclusions are drawn:

- The revised modelling approach, using updated software and the latest bridge configuration, continues to predict increases to peak water levels attributed to the construction of the Option 7 bridge.
- Given the sensitivity of this area to flooding, and the nature of the project generally, such increases are unlikely to be acceptable to the local community or to TMR.
- Modification of the bridge design to remove the off-ramp significantly reduced the extent and magnitude of peak water level increases.
- Water level increases resulting from the modified design are more likely to be acceptable to the local community and to TMR.
- The above point notwithstanding, removal of the off-ramp may also face opposition from some members of the local community, as it were vocal residents of North Bundaberg who first advocated for the inclusion of this off-ramp during the community consultation phase of the Bundaberg Ten Year Action Plan.

From these conclusions, we make the following recommendation:

- That TMR review consider the information presented herein in determining their position on this proposed bridge project.

4.5.5 North Bundaberg Flood Hazard Analysis

As part of the Bundaberg Ten Year Action Plan, consulting engineering firm Jacobs was commissioned to investigate the possibility of conducting a house buy-back scheme for the most vulnerable properties in North Bundaberg. To support Jacobs in this investigation, CDM Smith was asked to perform hydraulic modelling to characterise flood hazard in terms of the velocity-depth (V.d) product. The following events were considered in the modelling:

- 5% AEP (20 year ARI) Design Flood Event
- 2% AEP (50 year ARI) Design Flood Event
- 1% AEP (100 year ARI) Design Flood Event
- 0.5% AEP (500 year ARI) Design Flood Event
- 2013 Historic Flood Event

The V.d product was calculated at each reporting timestep in the model results, and the maximum value recorded across this time series, at each point in the grid, was selected as the maximum V.d product for that simulation. Maps of the velocity-depth product are presented in Appendix C.

4.5.6 Bundaberg East Levee Design

The levee alignment encloses two flood-prone areas (i.e., Bundaberg Creek, and Distillery Creek) which act predominately as backwater storages during river flood events. As a result of this topography, peak flood levels do not vary greatly along (i.e., in the direction of flow) the proposed alignment.

Therefore, for the purposes of the Concept Engineering Design Report, the following design crest level has been adopted:

- Design crest level (without freeboard) = 9.3 m AHD
- Design crest level (with freeboard) = 9.5 m AHD

The design crest level with freeboard places the top of the levee above both the 2013 historic flood and 1% AEP design flood events. During the detailed design phase, consideration could be given to refining the crest elevation towards the distillery, which would likely lead to a slight reduction in elevation and necessitate one or more “steps” in the levee top profile.

The effect of levee construction upon river flood levels was tested in the town reach model. A 2D weir element was implemented along the proposed alignment, and set with an arbitrarily high crest elevation to ensure no overtopping could occur. The 1% AEP (100 year ARI) design flood was routed through the model, and the results compared against the existing case. A time series of water levels was extracted just upstream of the western end of the levee (in the river channel, approximately in line with Walla Street), where impacts would be expected to be at their greatest and was compared to the results of the existing case (ie. no levee) simulation, as shown below:

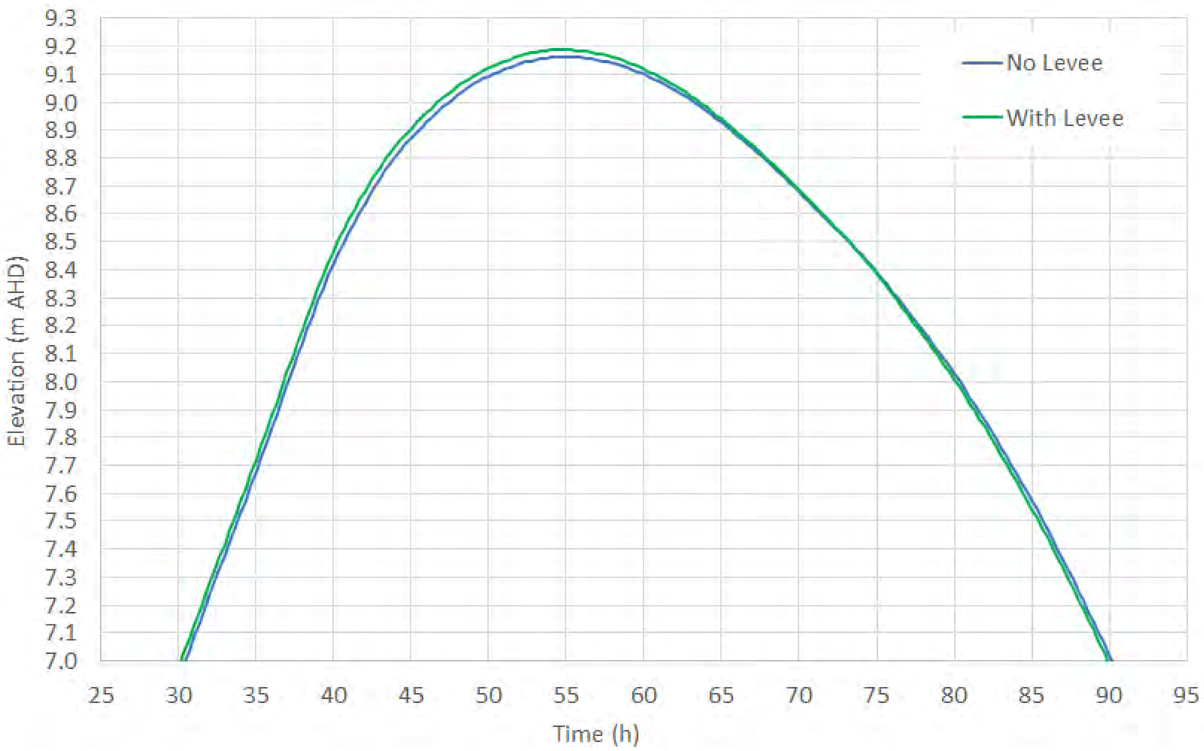


Figure 4-22 Effect of Levee on River Water Levels, 1% AEP (100 year ARI) Design Flood

Changes to river flood levels caused by the levee are predicted to be minor. Storage will no longer be available within Bundaberg Creek, however this represents a negligible volume in the context of the broader floodplain. The levee footprint does not intrude into any active flowpaths, and as such will not result in a loss of channel conveyance.

4.5.7 Quay Street Hydraulic Assessment

In coordination with DLGRMA, CDM Smith carried out community consultation activities in Bundaberg on the 5th and 6th of June 2018, in which the concept design for the Bundaberg East Levee was presented to members of the public. The presentation included a discussion on the likely hydraulic effects that levee construction could cause (refer Section 4.5.6), which was generally received with scepticism, particularly by those landowners directly adjacent to and on the unprotected side of the levee. Concerns were centred around the idea that levee construction could cause localised increases in flood velocity that would lead to additional flood damages.

Acknowledging that the hydraulic modelling result did not necessarily represent small scale hydraulic effects (ie. that the default 35m cell size could possibly be masking localised effects), CDM Smith prepared additional simulations using a refined model mesh, as discussed in Section 4.2.4. As with the previous simulations, the 1% AEP (100 year ARI) design flood was routed through the model, and the results compared against the existing case.

The results of this assessment broadly agreed with the previous simulations, in that construction of the levee was not found to result in a material change to flood levels on the northern side of Quay Street. Results for selected properties on Quay Street are presented in the table below.

Table 4-11 Peak Water Surface Elevations, with and without levee.

Location			
	No Levee (1)	With Levee (2)	Difference (2) – (1)
Saltwater Creek confluence with Burnett River	9.17	9.19	+ 0.02
Future recreational green space (1 East Quay St)	9.17	9.19	+ 0.02
5 East Quay St (Red Shed) western boundary	9.17	9.19	+ 0.02
7 East Quay St, northern (river) end of lot	9.17	9.19	+ 0.02
9 East Quay St, northern (river) end of lot	9.17	9.19	+ 0.02
11 East Quay St, northern (river) end of lot	9.18	9.19	+ 0.01
13 East Quay St, northern (river) end of lot	9.19	9.19	0.00
15-17 East Quay St, northern (river) end of lot	9.18	9.19	+ 0.01
19-21 East Quay St, northern (river) end of lot	9.20	9.20	0.00
23 East Quay St, northern (river) end of lot	9.19	9.19	0.00
25 East Quay St, northern (river) end of lot	9.19	9.19	0.00
27 East Quay St, northern (river) end of lot	9.20	9.19	- 0.01

Velocities were assessed on the same basis, and generally predicted to decrease in the with-levee case, albeit from a low starting point. Whilst this result might initially seem counter-intuitive, it arises from the fact that hydraulic connectivity exists between Kendall Flats and the Burnett River. During large floods, water crosses Quay Street to move between these two regions, a pathway that would be eliminated by levee construction. As a result, the with-levee case predicts lower velocities than the no-levee case, as documented in Table 4-12:

Table 4-12 Peak Velocities, with and without levee.

Location			
	No Levee (1)	With Levee (2)	Difference (2) – (1)
Saltwater Creek confluence with Burnett River	0.37	0.41	- 0.21
Future recreational green space (1 East Quay St)	0.41	0.17	-0.24
5 East Quay St (Red Shed) western boundary	0.36	0.17	-0.19
7 East Quay St, northern (river) end of lot	0.06	0.08	0.02
9 East Quay St, northern (river) end of lot	0.33	0.04	-0.29
11 East Quay St, northern (river) end of lot	0.40	0.20	-0.20
13 East Quay St, northern (river) end of lot	0.9	0.16	-0.74
15-17 East Quay St, northern (river) end of lot	0.31	0.34	0.03
19-21 East Quay St, northern (river) end of lot	0.59	0.32	-0.27
23 East Quay St, northern (river) end of lot	0.47	0.28	-0.19
25 East Quay St, northern (river) end of lot	0.73	0.35	-0.38
27 East Quay St, northern (river) end of lot	0.63	0.35	-0.28

From this assessment it can be concluded that construction of the levee is unlikely to cause material changes to the hydraulic conditions experienced by landholders on the unprotected, northern side of East Quay Street.

Section 5 Coincident Flood Risks

5.1 Background

CDM Smith's concept design for the Bundaberg East Levee includes a flood gate and pump station set adjacent to the Burnett River mouth at Saltwater Creek. The flood gates are to be closed when the Burnett River is elevated so as to prevent backwater flooding of the CBD, whilst the pump station serves to remove runoff that might accumulate behind the levee as a result of local rainfall during the time when the gates are closed.

In the previous design work (Jacobs' Mitigation Options Assessment Report of December 2016) it was implicitly assumed that some pump-out capacity would also be required to guard against the threat of inundation from local rainfall in the instance where this occurs concurrently with elevated river levels.

The Jacobs report adopted an arbitrary daily rainfall total of 100 mm, multiplied this number by the catchment area to obtain a total runoff volume, and divided the answer by 86,400 (ie. the number of seconds in one day) to arrive at an instantaneous pump rate of 40 m^3/s. Whilst this was a suitable calculation for the purposes of the Mitigation Options Assessment report, it considered neither the temporal aspects of rainfall, nor the attenuating effects of flood storage that might be available in the floodplain behind the levee. Furthermore, no discussion was provided on treatment of the small creek adjacent to the Bundaberg Sugar property, which will be cut by the levee and likely require some combination of floodgates and pumps.

Therefore, the objectives of this section are to:

- Describe the works undertaken to develop a dynamic rainfall runoff model to investigate the interplay between rainfall depths, rainfall durations, flood storage levels, and pump rates;
- Determine the maximum elevation to which water can be stored behind the levee without impacting local residents;
- Analyse the model results to quantify behind-the-levee flood risks, in the context of concurrent river flooding;
- Recommend a pump rate to be used in the concept design of pump station and flood gates;
- Investigate the correlation between river level peaks and local daily rainfall totals;
- Determine the likely travel time and flood peak relationship between Walla and Bundaberg gauges;
- Back-test the performance of the system by simulating historic rainfall and river flooding events, to gain an idea of the likelihood of concurrent flooding; and
- Develop a set of levee operating principles.

5.2 Interior Flooding Analysis

5.2.1 Behind-Levee Flood Storage

Two tributaries of significance exist behind the town section of the proposed levee. Saltwater Creek, which drains the CBD area as far south-west as the airport, and Bundaberg Creek, which rises at a lowland divide near Windemere and travels in a generally north-westerly direction through Ashfield and Kepnock. Saltwater Creek has its confluence with Bundaberg Creek at the south-western edge of the CBD (near Wondooma Street), after which the combined system travels a further 750m to the confluence with the

Burnett River. The total catchment area draining to the river is approximately 3,450 ha. This topography allows the two creeks to be analysed as a single system.

One significant watercourse exists behind the distillery section of levee. This watercourse is apparently un-named and is hereafter referred to as "Distillery Creek" in this letter. The catchment divide is located in a residential area near Kalkie, with the predominant flow path travelling in a south-westerly direction through the industrial area adjacent to the Bundaberg Sugar railyards, around the back of the sugar mill, and joining the Burnett River near Cran Street.

Analysis of the natural ground elevations behind the levee show areas of low-lying ground that could possibly be utilised to temporarily hold local runoff in the case where river levels are elevated and local rainfall occurs. Volumetric storage curves for both creeks were calculated from the LiDAR, and are shown below:

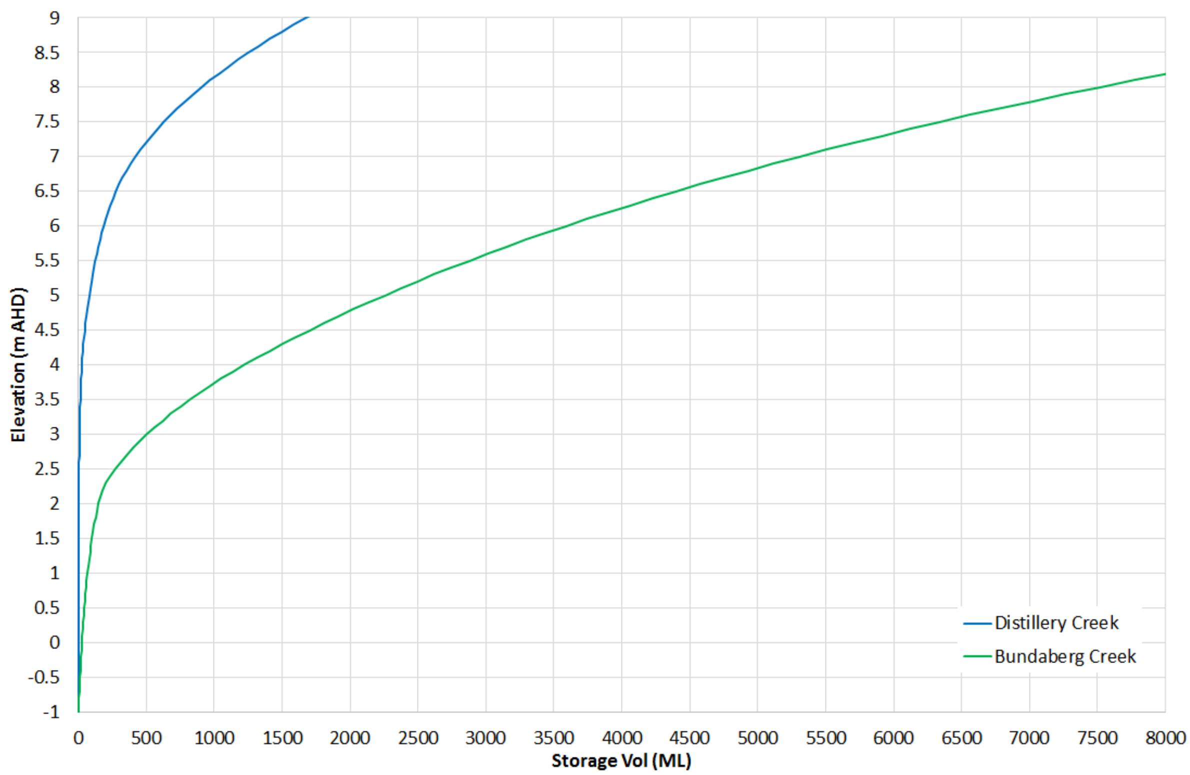


Figure 5-1 Storage Curves Behind Levee

Floodplain storage has been calculated to the lowest level observable in the LiDAR, approximately -1 m AHD. Whilst it is acknowledged that the floodplain is somewhat tidally influenced, the majority of the floodplain storage that is sought for use in the design sits in the band from 2 m to 5 m AHD – well above the tidal range. Moreover, even in the case of unusually high tides, the diurnal tidal cycle provides for at least one low tide to occur within the likely flood warning time window (ie. in the time period between the flood being observed at Paradise and the effects being noticed at Bundaberg).

It is noted that the Saltwater Creek storage curve includes the floodplain volume currently protected by the Kendall Flats levee system. For the purposes of this report it is assumed that this storage will be made available via the removal of the Kendall Flats levee, however other methods (such as provision of culverts and penstocks) could also be considered, which would allow for the levee to be retained to protect against local flooding.

5.2.2 Rainfall Runoff Models

The delay between the onset of rain and the start of runoff at a given location (in this case, the storage area behind the levee) is known as the catchment response time. It is affected by such things as: catchment size, catchment shape, land-use patterns, and rainfall losses. To represent these phenomena together with the catchment storage in order to test various pump rates, XP-RAFTS (Innovyze, 2016) runoff models were built for each of the creek catchments as summarised in

Table 5-1. The models are uncalibrated.

Table 5-1 XP-RAFTS Model Details

Item	Model	
	Saltwater/Bundaberg Creek	Distillery Creek
Total Catchment Area	3456 ha	192 ha
No. of model sub-catchments	15	6
Floodplain Storage represented as	Retarding Basin node	
Pump rate represented as	Defined spillway level-discharge relationship	
Design Storm Durations	10 minutes to 1440 minutes	
Design Storm Magnitudes	5, 10, 20, 50 & 100 year ARIs	
Design Rainfall Data	2016 IFD curves for Bundaberg, from Bureau of Meteorology website	
Parameters Tested	Initial Loss; Continuing Loss; Design Pump Rate	

5.2.3 Rainfall Loss and Pump Rate Analysis

The runoff response time and available storage volume are properties inherent to each catchment, whilst design rainfall depths are explicitly specified for each combination of storm duration and magnitude. This leaves two parameters to test in the model: pump rate, and rainfall loss rate.

The previous work by Jacobs effectively set an upper bound on the design pump rate of 40 m^3/s, whilst the theoretical (albeit unlikely) lower bound is 0 m^3/s in a "no-pump" scenario. Rainfall losses are less well understood and in the absence of gauged data with which to calibrate the model, no definitive value adopted.

Limited guidance is available from the ARR Data Hub (http://data.arr-software.org), which suggests applying initial and continuing rainfall losses of 40 mm and 4.1 mm/h, respectively, at Bundaberg. Included with this suggestion is a note that states "These losses are for rural use and are not for use in urban areas". Unfortunately, no further information is provided as to how urban areas, or mixed rural/urban catchments (such as those under consideration here) should be treated. It is worth noting however that XP-RAFTS will apply lower losses to urbanized areas, proportional to the percentage of impervious surfaces. For a fully impervious catchment surface (eg. a concrete car park) no losses will be applied at all, and 100% of incident rainfall will be transformed into runoff. The effects of impervious surfaces have been accounted for in the development of the Saltwater Creek and Distillery Creek models.

With this in mind, a sensitivity test was carried out to assess the influence of assumed rainfall losses on peak stages. Five combinations were tested:

- Initial Loss 0 mm, Continuing Loss 0 mm/h (fully saturated or entirely impervious catchment)
- Initial Loss 0 mm, Continuing Loss 2.5 mm/h
- Initial Loss 0 mm, Continuing Loss 4.1 mm/h
- Initial Loss 10 mm, Continuing Loss 4.1 mm/h
- Initial Loss 40 mm, Continuing Loss 4.1 mm/h (ARR recommendation for this location)

Results of this assessment are presented below in Figure 5-2:

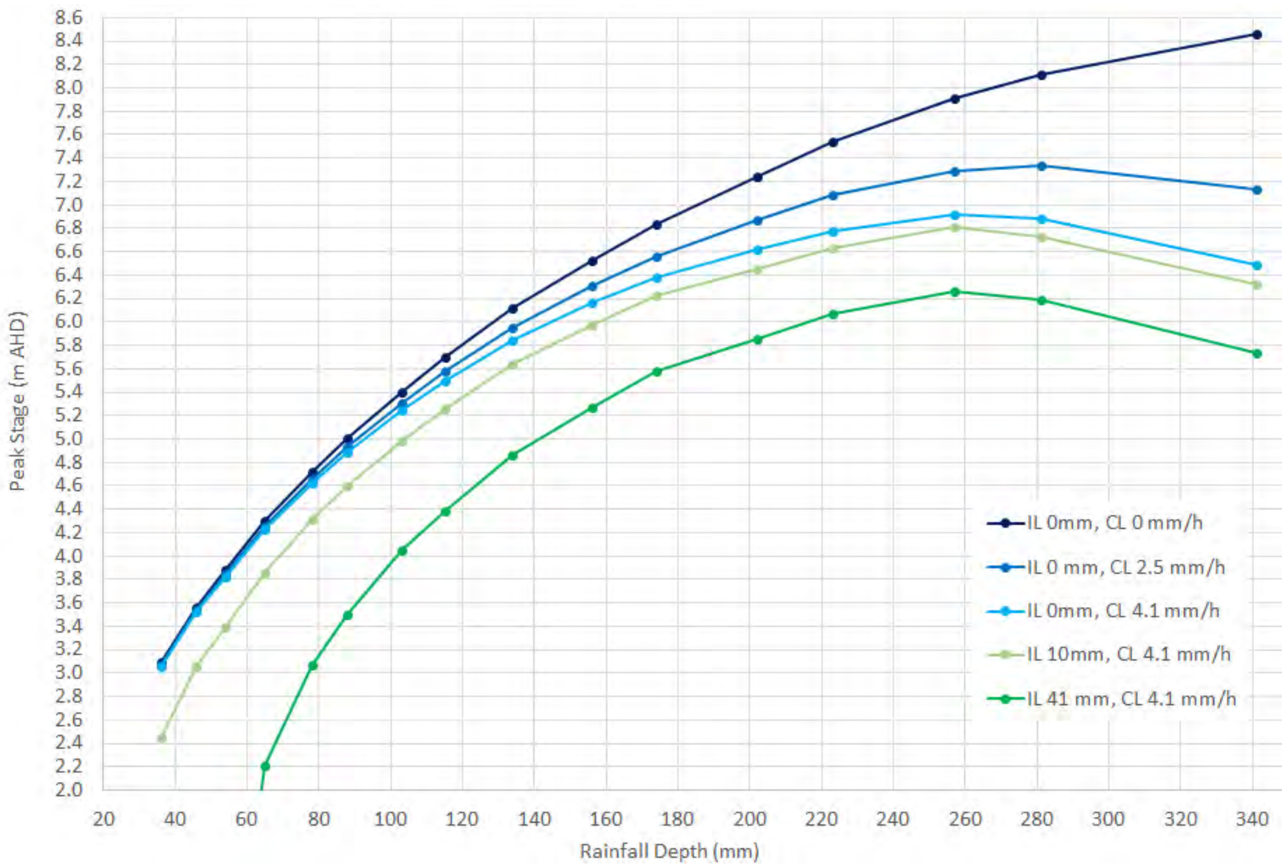


Figure 5-2 Peak Levels Behind Levee for various rainfall losses, Saltwater/Bundaberg Creeks, 20-Year ARI Standard Rainfall Durations

It can be seen that the initial loss has a strong influence on the peak level, particularly for the short duration events – up to a duration of 90 minutes. There is little difference in predicted level between any of the cases modelled with zero initial loss (ie. the three blue curves), whereas the 10/4.1 and 40/4.1 cases (green curves) produce levels that are markedly lower. With increasing storm duration, the effect of the continuing loss becomes more important, as can be seen by the divergence in curves on the right hand side of the figure. Figure 5-2 was derived using a design pump rate of 14 m^3/s, however values of 7, 21, 28 and 35 m^3/s were also tested. The shape of the peak stage curves, and the influence of the loss parameters, was generally found to hold true across the range of pump rates and design storm magnitudes.

As a result of these tests, initial and continuing losses of 10 mm and 4.1 mm/h, respectively, were adopted for the purpose of this analysis. Although subjective, this choice would appear to provide some conservatism by assuming a relatively low initial loss rate, whilst also acknowledging ARR's guidance on the continuing loss parameter.

A similar methodology was employed in testing the sensitivity of pump rate on peak levels behind the levee. To simplify this analysis, a combination floodgate and pump station is envisioned at the levee. For this analysis, the floodgate is assumed to be completely closed during the entire event; that is, the only way for water to exit Saltwater Creek is via the pump station where water is pumped from Saltwater Creek across the levee into the Burnett River. Figure 5-3 shows the predicted peak water level behind the city section of levee, for the 5% AEP (20 year ARI) design rainfall event, with standard durations ranging from 10 minutes (41 mm total rainfall depth) to 2160 minutes (317 mm total rainfall depth). Six curves are plotted, for pump rates ranging between 0 m^3/s (i.e., no pump) and 35 m^3/s, in increments of 7 m^3/s.

Following this, the differences in peak water level are plotted in Figure 5-4, with respect to the no-pump case.

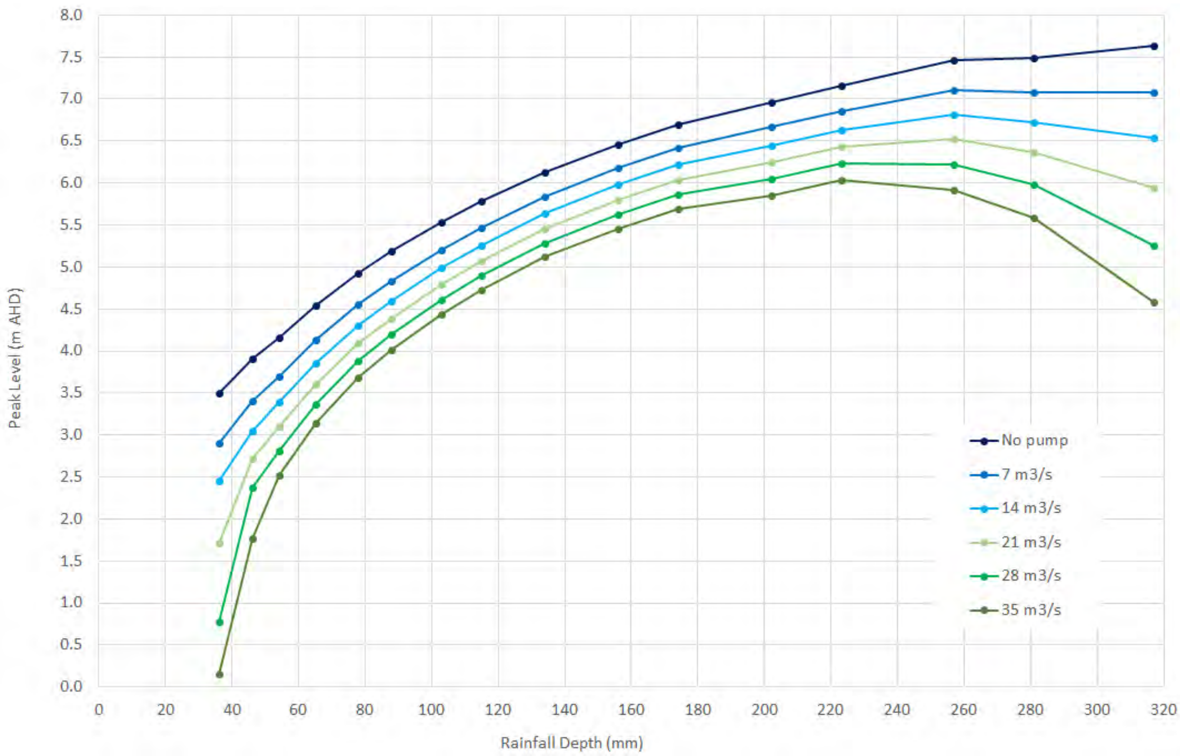


Figure 5-3 Peak Levels Behind Levee for various pump rates, Saltwater/Bundaberg Creek, 5% AEP (20 Year ARI) Standard Rainfall Durations

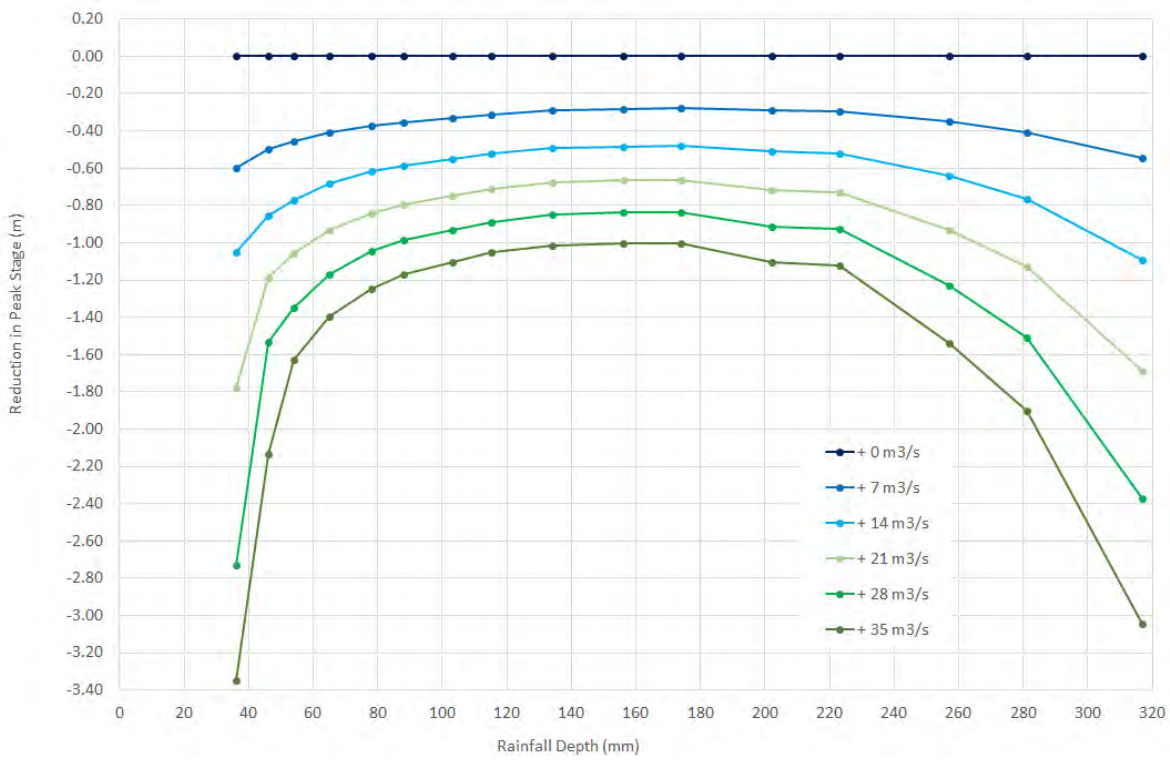


Figure 5-4 Peak Level Differences for various pump rates, Saltwater/Bundaberg Creek, 5% AEP (20 Year ARI) Standard Rainfall Durations

The results indicate that pump rate has only a weak influence upon peak level throughout much of the curve, although effects were more pronounced for very small rainfall depths (small total volume, easily pumped away) and very large rainfall depths (corresponding to long storm durations, and thus distributed over a longer time frame, giving smaller peak inflows). Generally, however, it appears that the cost of larger pumps would not be justified by the reduction in peak level.

For example, when comparing the 7 m^3/s case to the 35 m^3/s case, it can be seen that for storms ranging in duration between 30 minutes (65 mm total rainfall depth) and 12 hours (223 mm total rainfall depth), the incremental reduction in peak level is around 0.8m – unlikely to be significant enough to justify a 5-fold increase in capital expenditure.

Tables of levels and differences for the complete suite of tests are provided as an attachment to this letter.

From this analysis, it can be concluded that it is the available floodplain storage and total rainfall depths that are the main drivers of peak flood levels behind the levee. Based on this result, the following design pump rates (duty capacity) have been adopted:

- Bundaberg/Saltwater Creek: 7 m^3/s
- Distillery Creek: 1 m^3/s

In both cases, the design pump rate in tandem with available floodplain storage is sufficient to accommodate a storm with a total rainfall depth of up to approximately 100 mm, without causing undue impacts to the built environment behind the levee.

5.3 Operating Strategy

5.3.1 Gauge Height Relationships and Flood Wave Travel Time

Of importance to levee operations is the ability to estimate the magnitude and timing of the flood peak at Bundaberg based on predictions from further upstream.

Gauge Height Relationships

The gauge height relationship currently used by Bundaberg Regional Council is reproduced below:

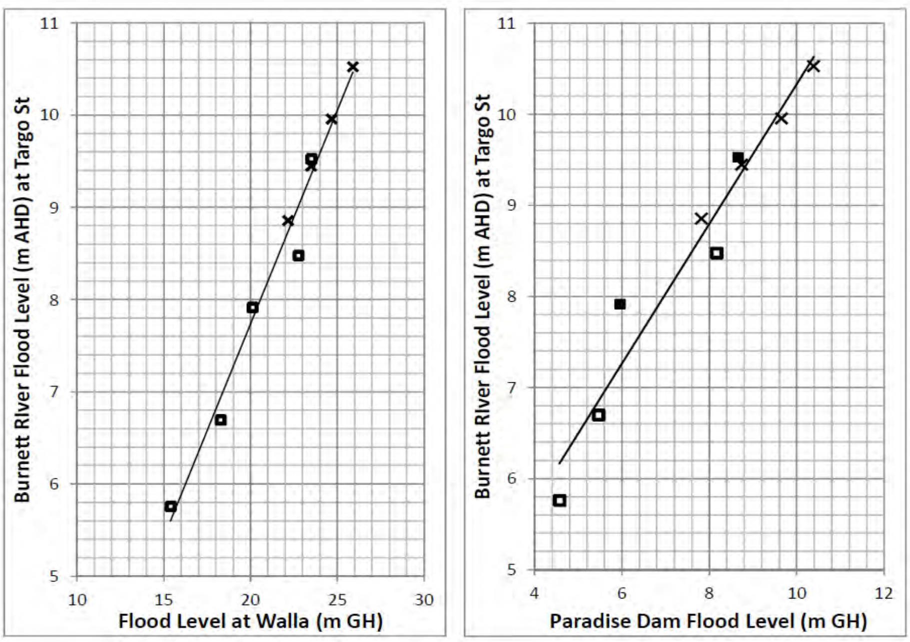


Figure 5-5 Current Flood Level Relationships (from Bundaberg Regional Council)

As part of this study, the relationship between flood heights at Walla and at the Bundaberg Targo Street gauge was analysed, across 23 flood events where flood peak information was available at both Walla and Bundaberg. This dataset was comprised of 16 historic floods spanning the time period between 1929 and 2013, and 7 design flood events (5, 10, 20, 50, 100, 200 & 500 year ARI) from the calibrated HEC-RAS model. The ratio between the two flood peaks was plotted, as shown in Figure 5-6. Data at both locations are referenced to the gauge datum.

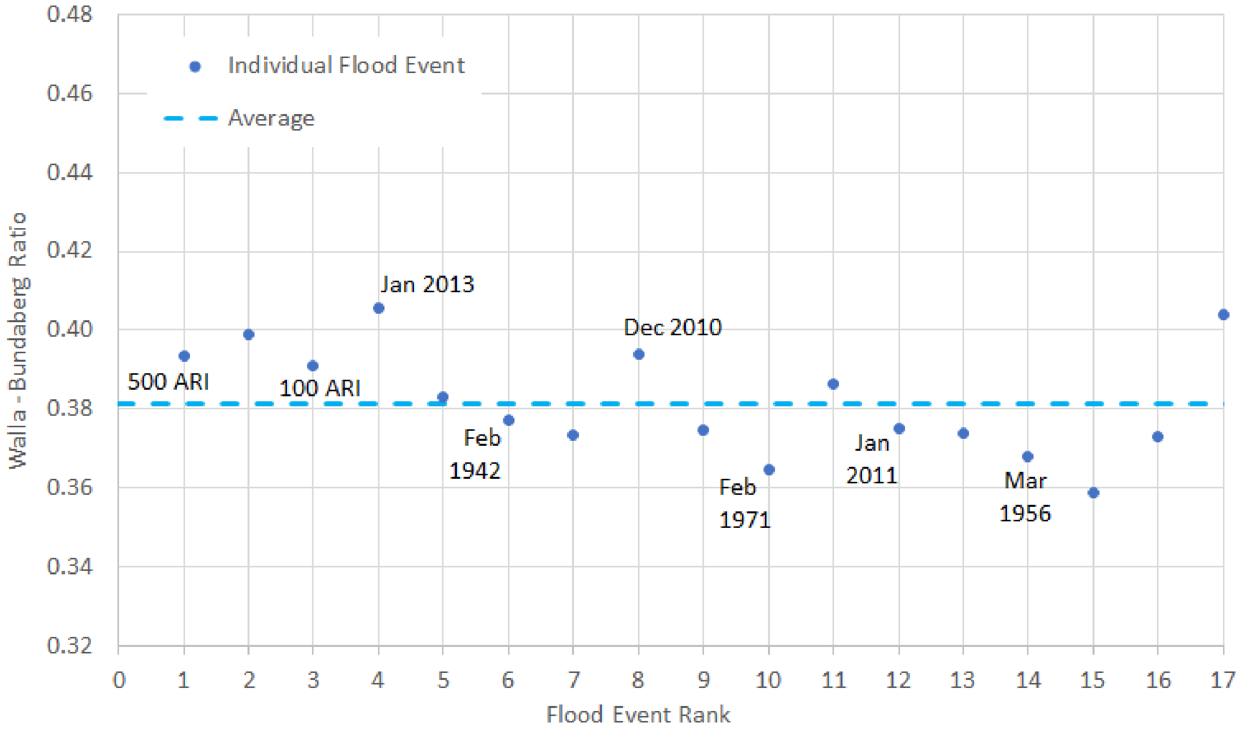


Figure 5-6 Simplified Flood Level Ratios

For the 17 floods that peaked at greater than 13m on the gauge at Walla, a remarkably consistent relationship emerged. Across 84 years of record and including the design floods, the Walla-Bundaberg flood peak ratio sat in a narrow band of between 0.36 and 0.41. The average ratio across all 17 floods was found to be 0.38. Of note is the January 2013 event, which due to its extreme volume returned a value of 0.41 (ie. all available floodplain storage was utilised, resulting in relatively little attenuation of the flood peak compared to the other results).

Overall this result suggests that the existing flood level relationship charts can be simplified whilst retaining their predictive power and minimising the likelihood of misinterpretation. This report proposes calling it the "40% Rule", which could be written in plain English as follows:

"As a rule of thumb, the peak flood height at the Bundaberg gauge will be approximately 40% of the peak height at the Walla gauge, when the Walla peak is 13 metres or greater"

Flood Wave Travel Time

There are 11 flood events (7 design floods and 4 observed floods) for which time-of-peak data were available at both Bundaberg and Walla gauges. Subtracting the time-of-peak at each location gives the peak-to-peak travel time for each event, which has been plotted against the Bundaberg peak flood height, as tabulated below in Table 5-2 and illustrated in Figure 5-7.

Table 5-2 Flood Peak Travel Time - Walla to Bundaberg

Flood Event	Flood Event	Peak Height at Bundaberg (m AHD)	Peak-to-Peak Travel Time (h)
February 1942 ^		8.50	19.5
December 2010		7.92	23.0
January 2011		5.76	12.5

Flood Event	Flood Event	Peak Height at Bundaberg (m AHD)	Peak-to-Peak Travel Time (h)
January 2013		9.53	16.0
March 2013		4.95	14.0
	5 year ARI	5.54	15.0
	10 year ARI	6.72	14.5
5 % AEP	20 year ARI	7.76	16.0
2 % AEP	50 year ARI	8.67	14.0
1 % AEP	100 year ARI	9.28	15.0
0.5 % AEP	200 year ARI	9.81	13.5
	Average – All Events		**15.6**
	Average – ex 1942 & 2010		**14.5**

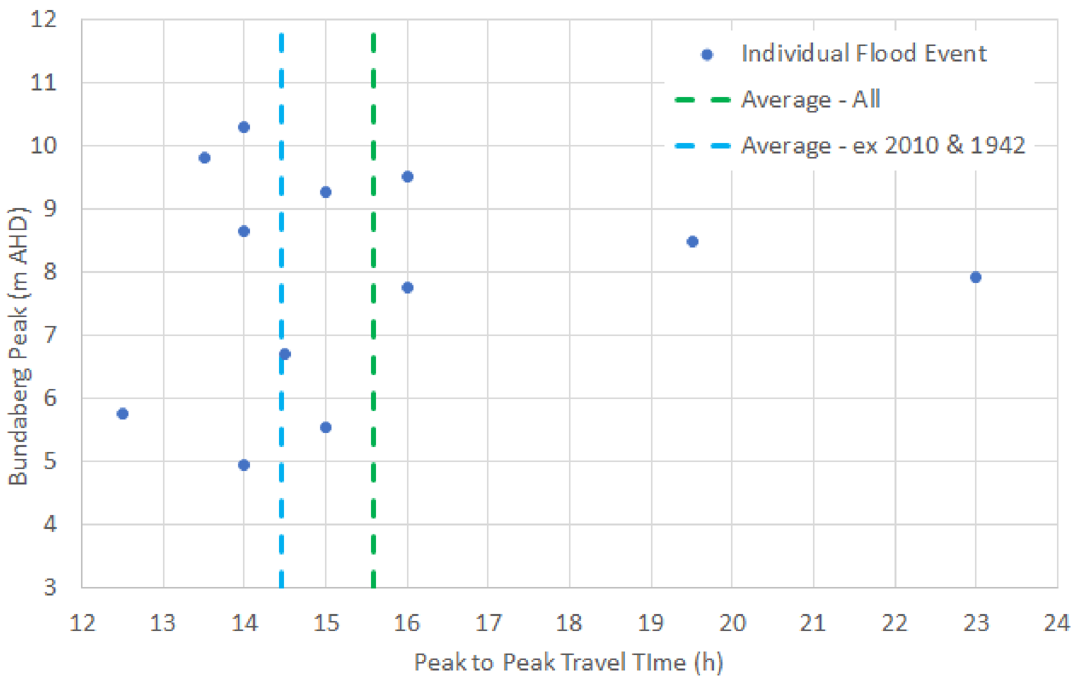


Figure 5-7 Flood Peak Travel Time - Walla to Bundaberg

No clear relationship can be seen between flood height and travel time, suggesting that other factors may have a larger influence on the outcome, such as flood duration and total flood volume. Nonetheless, with the exclusion of the two “slow” floods (1942 and 2010), the remaining peak-to-peak travel times are grouped quite closely in the range of 13 to 16 hours. Two sets of averages were plotted suggesting that for operational purposes a reasonable estimate of peak-to-peak travel time is of the order of 15 hours between Walla and Bundaberg.

5.3.2 Saltwater Creek Drawdown Time

It is useful to have an estimate of the time required to reduce internal ponding from one level to another. Using the XP-RAFTS model described in Section 5.2.2, the starting water level was set to 9 m AHD and a no-rainfall simulation was run. This had the effect of simply drawing down the storage at a rate of 7 m^3/s until the minimum storage level of -1.1 m AHD was reached. The resultant time series of ponded water levels –

the cumulative time drawdown curve – is presented in Figure 5-8, and table of *incremental* draw down times is shown in Table 5-3.

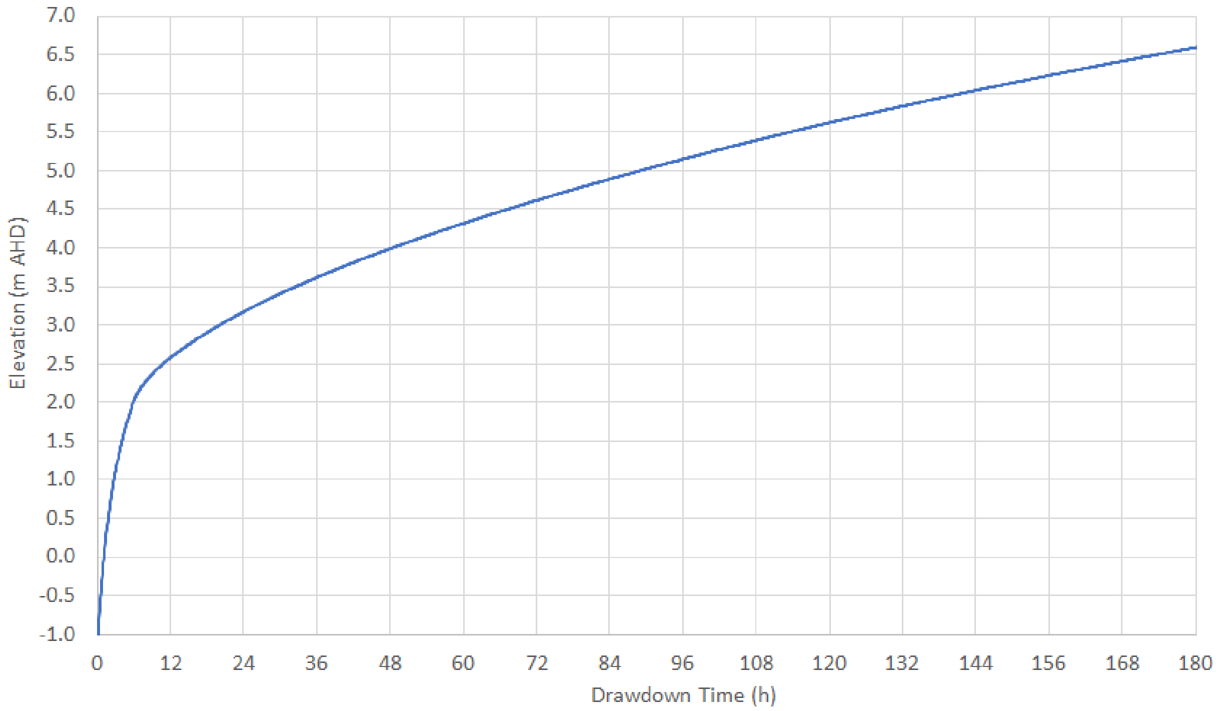


Figure 5-8 Cumulative Drawdown Curve for Saltwater/Bundaberg Creek Storage

Table 5-3 Incremental Drawdown Times for Saltwater/Bundaberg Creek Storage

Ponded Water Level		Incremental Drawdown Time in..	
Initial (m AHD)	Final (m AHD)	Minutes	Hours
9.0	8.5	3610	60.17
8.5	8.0	3200	53.33
8.0	7.5	2785	46.42
7.5	7.0	2435	40.58
7.0	6.5	2155	35.92
6.5	6.0	1910	31.83
6.0	5.5	1685	28.08
5.5	5.0	1475	24.58
5.0	4.5	1310	21.83
4.5	4.0	1130	18.83
4.0	3.5	950	15.83
3.5	3.0	750	12.50
3.0	2.5	555	9.25
2.5	2.0	295	4.92
2.0	1.5	110	1.83
1.5	1.0	80	1.33
1.0	0.5	55	0.92
0.5	0.0	40	0.67
0.0	-0.5	35	0.58
-0.5	-1.0	25	0.42

The drawdown times reflect the non-linear shape of the storage curve, with the effect that it takes much longer to pump down high ponded levels than it does low levels. For example, from a ponded level of RL 3 m AHD, the entire storage can be emptied (ie. total decrease in level of 4 metres) in around 18 hours, whereas it would take approximately the same amount of time to achieve just a 0.5 metre decrease from RL 4.5 m AHD to RL 4.0 m AHD.

5.3.3 Historic River Level and Daily Rainfall Correlation

In the preceding section, the effects of local rainfall behind the levee were calculated in isolation – that is, the floodgates were simply assumed to be closed and the pumps turned on for the duration of the local rainfall event. No consideration was given to the likelihood of concurrent river flooding. However, the level of the Burnett River will be a prime determinant of when the floodgates should be closed or opened. Five broad possibilities exist:

1) Low river level; no local rainfall predicted or occurring.
2) Low river level; some local rainfall predicted or occurring.
3) Rising or High river level; no local rainfall predicted or occurring.
4) Rising or High river level; some local rainfall predicted or occurring.

Of these, the first two represent default states. The Burnett River is not in flood, and so the levee floodgates remain open to allow local runoff to drain to the river as it occurs. Possibilities 3 and 4 are more complex; the gates must be shut to protect against a large flood, but once closed the system is reliant on the pumps to remove accumulated local runoff. The occurrence of significant local rainfall (ie. >100mm in 24 hours) during this time has the possibility to create interior flooding.

To investigate the likelihood of concurrent flooding, daily rainfall data were collected from 3 gauges proximate to the project site:

Table 5-4 Local Rainfall Gauges

Station No.	Name	Distance from Project^	Length of Record
039037	Fairymead Sugar Mill	7.5 km North	1911 – 2017 (106 years)
039063	Bundaberg Ashfield Rd	4.5 km East-Northeast	1966 – 2017 (52 years)
039174	Millaquin Sugar Mill	2 km Northeast	1887 – 1977 (91 years)

^ Measured from Saltwater Creek floodgate location

Burnett River flood peaks were also collated. Since settlement, 43 flood events have been recorded at Bundaberg, as detailed in Table 5-5:

Table 5-5 Historic Flood Peaks at Bundaberg (Targo St Gauge)

Year	Date of Peak	Height of Peak (m AHD)		Year	Date of Peak	Height of Peak (m AHD)
1875	28/02/1875	8.66		1949	05/03/1949	4.19
1890	26/01/1890	9.04		1950	01/03/1950	5.08
1893	13/02/1893	7.87		1954	11/02/1954	4.80
1893	05/02/1893	8.12		1954	15/07/1954	7.26
1893	18/02/1893	8.91		1955	28/03/1955	5.33
1905	17/01/1905	4.88		1956	11/02/1956	5.28
1908	18/03/1908	5.31		1956	12/03/1956	5.49
1910	05/02/1910	5.16		1956	24/12/1956	3.35
1911	05/02/1911	5.08		1958	22/02/1958	2.08
1913	17/01/1913	5.64		1968	12/01/1968	3.91
1918	02/02/1918	3.23		1971	06/02/1971	6.70
1921	30/12/1921	4.50		1974	29/01/1974	3.78

Year	Date of Peak	Height of Peak (m AHD)		Year	Date of Peak	Height of Peak (m AHD)
1925	22/01/1925	3.50		1983	04/05/1983	3.88
1926	21/12/1926	3.78		1992	21/02/1992	1.78
1927	03/02/1927	4.66		1992	17/03/1992	3.24
1927	03/04/1927	6.02		1996	11/01/1996	3.30
1928	22/02/1928	7.92		1998	07/05/1998	2.50
1929	22/01/1929	5.64		2010	30/12/2010	7.92
1931	05/02/1931	2.74		2011	13/01/2011	5.76
1942	12/02/1942	8.48		2013	29/01/2013	9.53
1947	13/02/1947	3.50		2013	04/03/2013	4.95
1947	01/03/1947	6.48				

To the extent that the gauged records allowed, daily rainfall data were analysed to calculate the average rainfall totals that occurred on the 4 days prior to, and the 4 days after (9 days in total) the flood peak date. No rainfall data were available for the 1875 flood, thus giving 42 events for analysis. The resulting curves are shown in Figure 5-9, whilst the underlying dataset used to create the figure is included as an attachment to this letter.

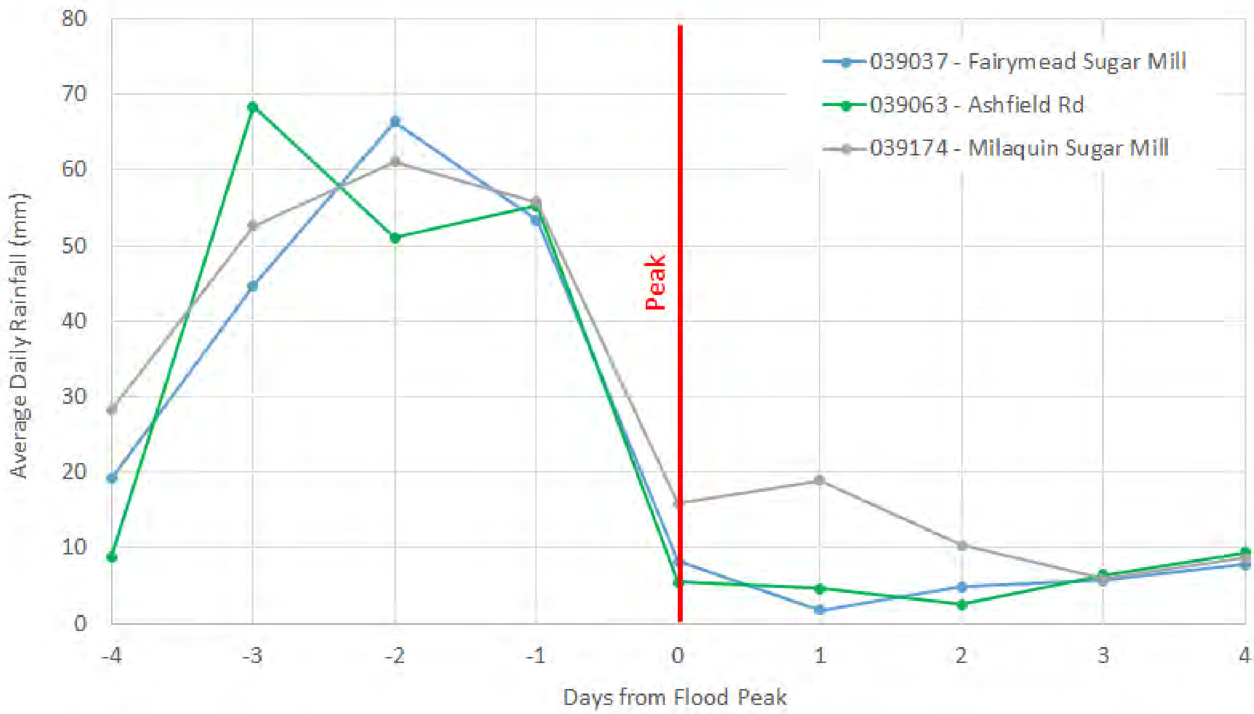


Figure 5-9 Daily Rainfall Around Date of Flood Peak, Averaged over 42 Historic Flood Events

The figure shows that large low-pressure weather systems (of the type that typically cause large floods in the Burnett) usually produce one or two days of widespread heavy falls. These falls can be seen at the local gauges on days P_{-3} through P_{-1}, but the peak of the flood wave has yet to arrive from further upstream, and does so one or two days later, by which time the local runoff has drained from Saltwater Creek.

From this result, we would expect that in most flood events there will be sufficient time to allow local runoff to drain to the river before the rising river level necessitates closure of the flood gates.

However, the analysis above does not account for the magnitude of each flood peak, nor the rate of river rise with respect to the occurrence (or absence) of local rainfall. These dynamics are investigated further in Section 5.3.4.

5.3.4 Back-testing of Historic Flood Events

The XP-RAFTS model was used to test the effectiveness of the design pump rate (7 m^3/s) by simulating the local runoff that might have occurred during historical Burnett River floods. Floods with a water level peak of 5 m AHD or higher (n = 23), plus the March 2013 flood (Peak = 4.95 m AHD) were selected for testing. The following methodology was employed:

- **Construct Burnett River hydrograph.**
  - For floods more recent than 2010, hydrographs were obtained directly from the BOM's river time series at the Targo Street gauge.
  - Prior to 2010, only peak heights were recorded. For floods that occurred between 1926 and 2010, the river stage hydrograph was scaled from Walla to match the Bundaberg peak, and the timing of the peak shifted forwards in time by 15 hours.
  - Prior to 1926, only peak heights were recorded, and no river stages were available at Walla. For these floods, HEC-RAS design hydrographs were scaled to match the Bundaberg Peak. The river peak was arbitrarily defined to occur at 9pm, this being the mid-point of the rainfall day (in which rainfall totals are counted in the 24 hours to 9am on each day).
- **Construct Local Rainfall Record.**
  - For floods more recent than 1963, Half-hourly rainfall data from the Bundaberg Aero gauge (039128) were applied directly to the runoff model.
  - For floods older than 1963, daily rainfall totals were disaggregated into hourly time steps using an AR&R 24-hour temporal pattern. Implicit in this assumption is that the daily rainfall total was spread across the day, as opposed to occurring in a shorter sub-daily burst.
- **Simulate Local Runoff Conditions and Select Gate-closure Time.** Historic local rainfall was applied to the model to generate a runoff hydrograph. A gate-closure decision was then made by comparing the runoff hydrograph to the Burnett River level. Post-closure, the pumps are deemed to be activated, and the storage behind the levee fills or empties as dictated by the flow conditions.
- **Review results and iterate on Gate-closure Time if Required**. When the choice of gate-closure time was found to result in a poor outcome – for example, where interior levels were calculated to be higher than Burnett river levels at any point in the simulation – additional, later, times of closure were tested.

Results plots and discussions on several interesting cases are provided below:

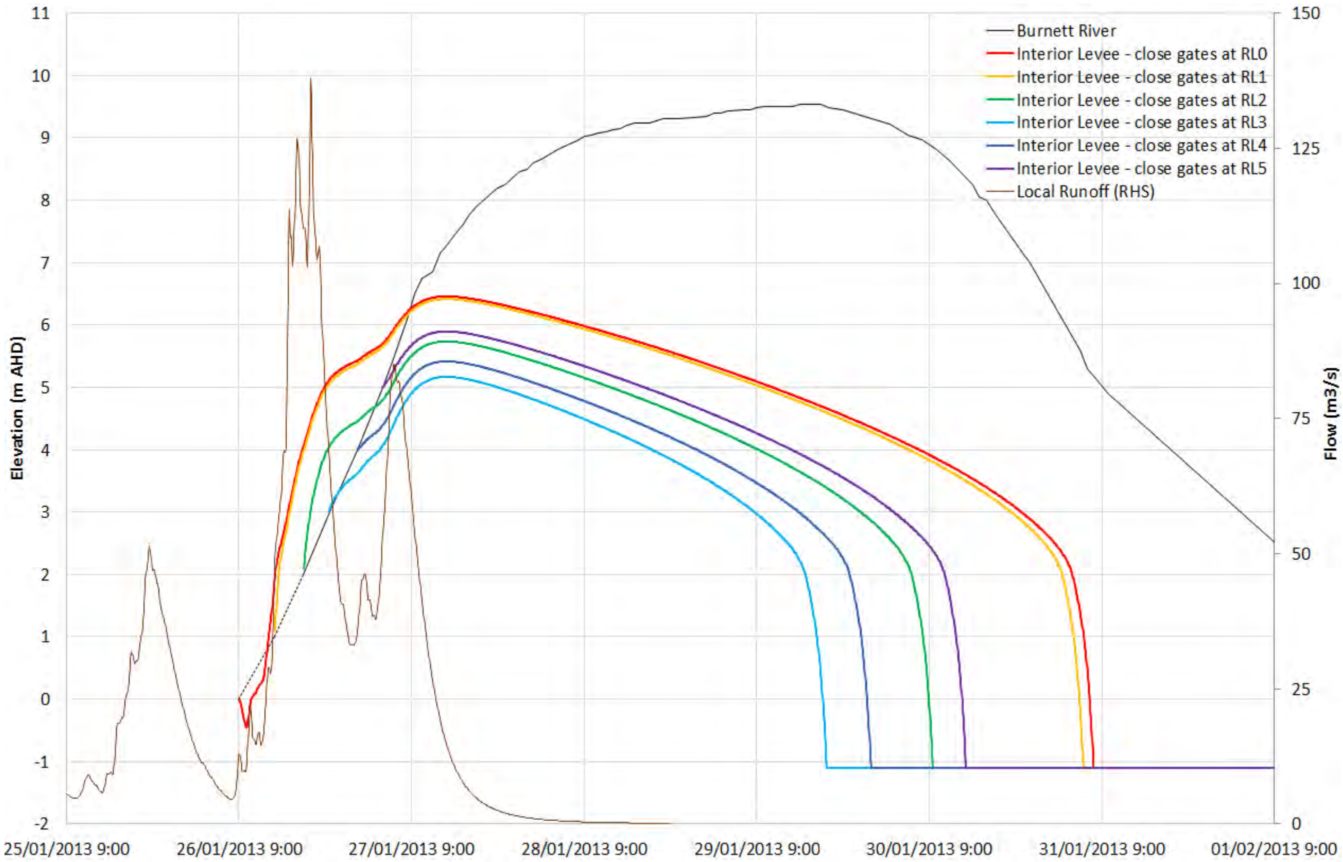


Figure 5-10 Gate-closure Analysis, January 2013 Flood Event

The January 2013 event currently stands as the flood of record in the Burnett River at Bundaberg, peaking at 9.53 m AHD. Six gate closure cases were simulated, at metre increments beginning at zero. In this case, whilst it was known that a large flood was travelling towards Bundaberg, closing the gates immediately upon observation of rising river levels would have proved to be sub-optimal, as local rainfall on the 26th and 27th resulted in two large runoff peaks in in Saltwater Creek. Figure Figure 5-11 demonstrates that closing the gates at a river level of 0 m, 1 m, or 2 m AHD would have quickly resulted in an interior level higher than that of the river – an intolerable result. In practice, such an outcome would lead to the gates being re-opened to allow levels to equalise. Having done this, the gates could be re-closed at RL 4 m AHD for a satisfactory outcome in which the interior level was predicted to peak at approximately 5.5 m AHD; some 4 metres lower than the river flood peak.

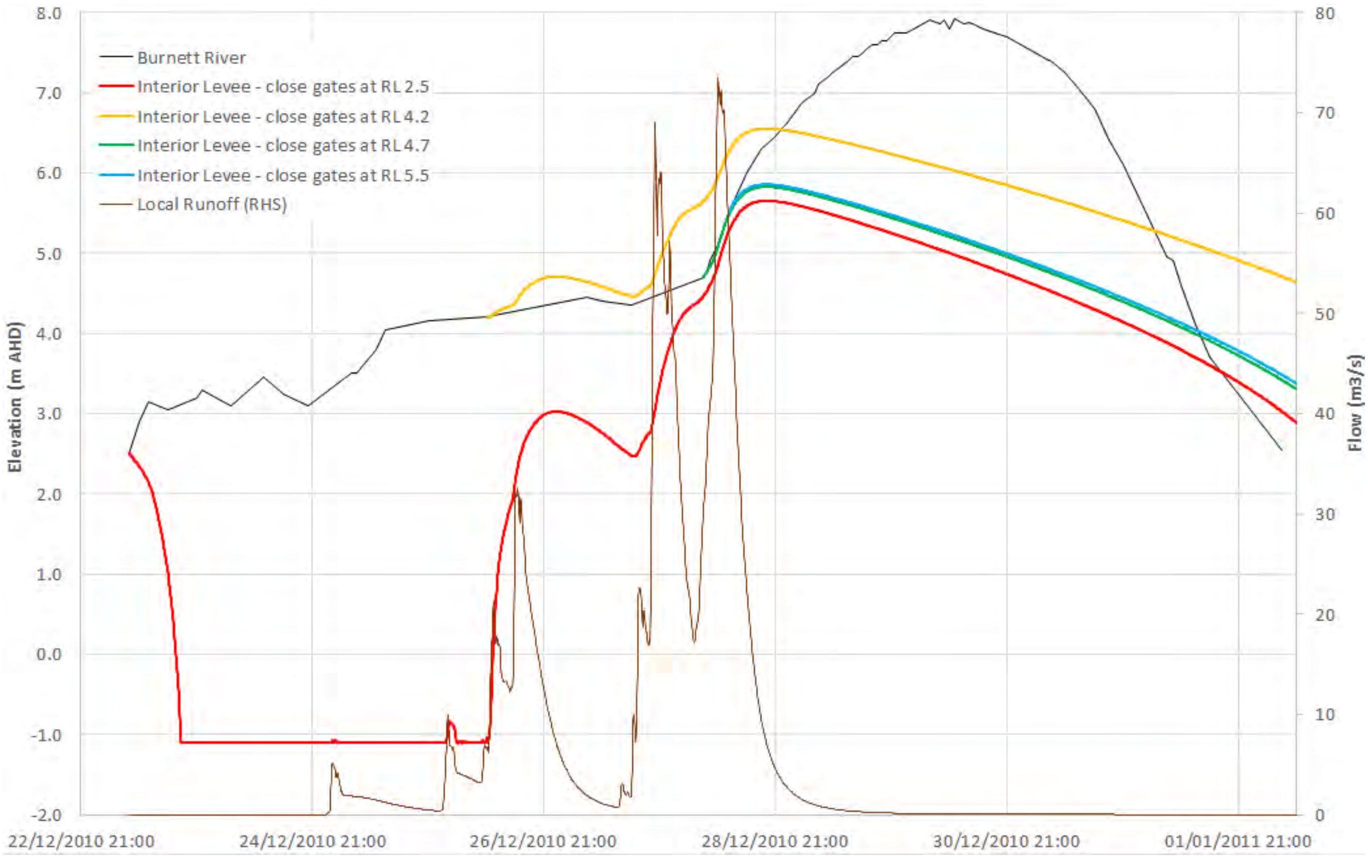


Figure 5-11 Gate-closure Analysis, December 2010 Flood Event

The December 2010 event was a large flood, peaking at 7.92 m. It was notable for the long time period over which the river level was elevated at moderate flood levels (3-5 m AHD) prior to the two day period of 28-30 December when the peak occurred. Three periods of rainfall were recorded while the river was at elevated levels, with subsequent effects on interior storage. Closing the gates at the beginning of the river time series (RL 2.5 m AHD) would have allowed sufficient time to pump the interior storage down to empty, before being filled by local runoff to a level of about 5.7 m AHD. At this level, properties on the inside of the levee experience inundation, however had the levee been in place at the time of this flood, it would have resulted in a net reduction in flood levels of about 2.3 m

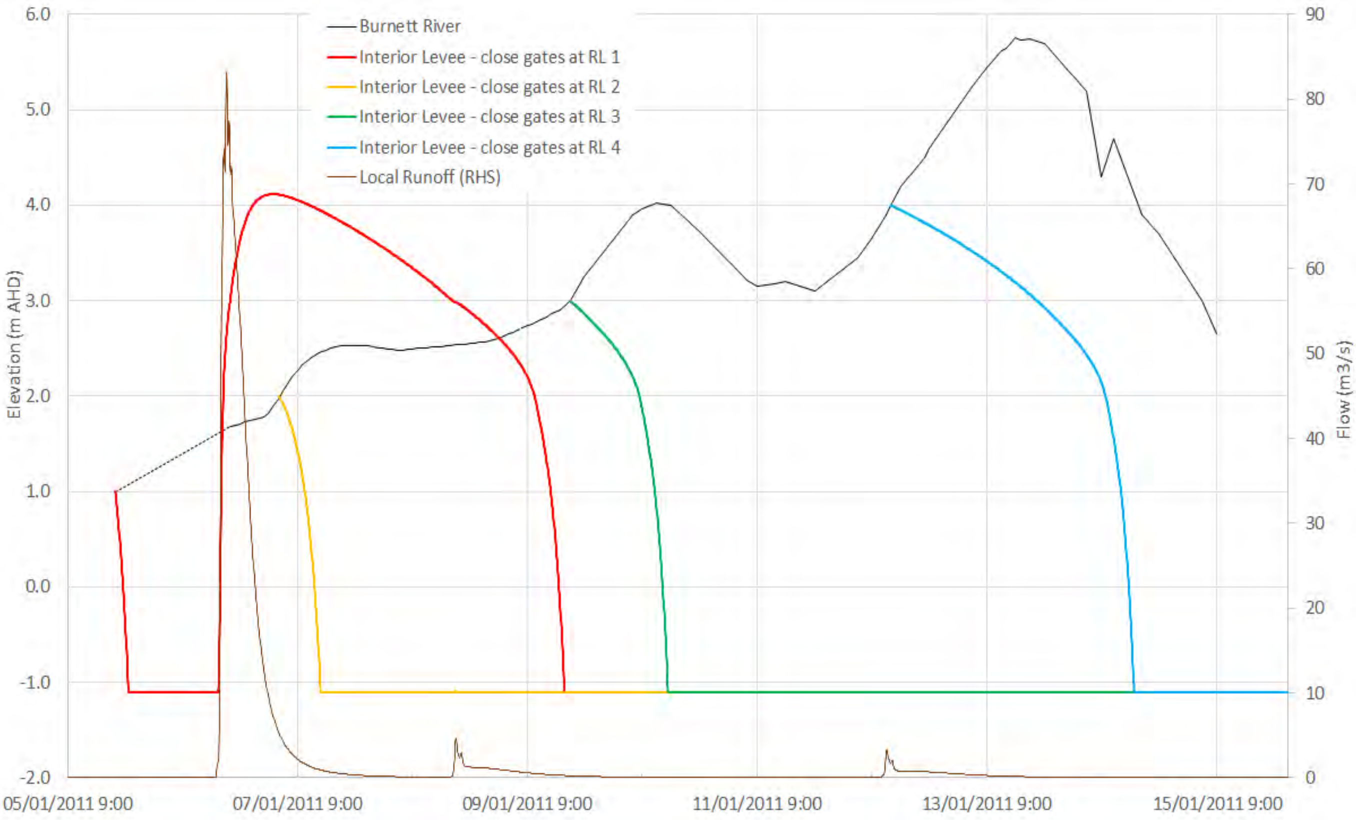


Figure 5-12 Gate-closure Analysis, January 2011 Flood Event

A moderate flood occurred in January of 2011, peaking at 5.76 m AHD. One significant local rainfall burst was recorded, early in the flood. This scenario highlights the importance of anticipating local rainfall and allowing any subsequent runoff to drain from the system before closing the flood gates, to the extent that river levels allow. Closing the gates prior to the rainfall burst (red line) would have resulted in 4 metres of water accumulating on the inside of the levee, whereas waiting and then closing the gates at RL 2m (yellow line) would have quickly drained the system down to the minimum level.

Further back in time, the lower quality of data introduces an element of uncertainty to the results, however the following observations can be made:

- In 22 of 23 cases (96%) (the exception being the 1913 flood event), peak levels behind the levee were predicted to be lower than peak river levels.
- In 8 of 23 cases (35%), interior levels were at their highest at the time of gate closure (ie. the river level), and thereafter pumped down to the minimum storage level.
- In 18 of 23 cases (78%), interior levels were predicted to peak at no greater than 5 m AHD.
- When significant local rainfall occurs after the gates are closed, and the river is elevated (such as in the December 2010 flood), interior flooding above 5 m AHD could be expected to occur, however these levels would be lower than any concurrent flood level in the river (or else the gates could simply be opened to equalise levels), and thus a net overall benefit is maintained.

Several assumptions have been made in this analysis, including:

- The shape of historic river hydrographs prior to 2010, and
- The disaggregation of daily rainfall totals into sub-daily increments.

These assumptions may influence the predicted results, and it is possible that were more accurate/complete information available, that different results would be predicted.

A summary of operational back test results is provided below in Table 5-6, and the same data presented graphically in Figure 5-13

Table 5-6 Summary of Operational Back-Tests

No.	Year	Burnett River		Levee Interior Peak Level (2)	Difference (2 -1)
		Date of Peak	Peak Level (1)		
1	1890	26/01/1890	9.04	1.00	- 8.04
2	1893	05/02/1893	8.12	1.96	- 6.16
3	1893	13/02/1893	7.87	5.77	- 2.10
4	1893	18/02/1893	8.91	3.57	- 5.34
5	1908	18/03/1908	5.31	1.00	- 4.31
6	1910	05/02/1910	5.16	1.00	- 4.16
7	1911	05/02/1911	5.08	1.00	- 4.08
8	1913	17/01/1913	5.64	5.78	+ 0.14
9	1927	03/04/1927	6.02	1.34	- 4.68
10	1928	22/02/1928	7.92	1.70	- 6.22
11	1929	22/01/1929	5.64	1.00	- 4.64
12	1942	12/02/1942	8.48	1.00	- 7.48
13	1947	01/03/1947	6.48	3.24	- 3.24
14	1950	01/03/1950	5.08	1.00	- 4.08
15	1954	15/07/1954	7.26	1.50	- 5.76
16	1955	28/03/1955	5.33	3.01	- 2.32
17	1956	11/02/1956	5.28	4.99	- 0.30
18	1956	12/03/1956	5.49	2.75	- 2.74
19	1971	06/02/1971	6.70	5.49	- 1.21
20	2010	30/12/2010	7.92	5.65	- 2.27
21	2011	13/01/2011	5.76	2.00	- 3.76
22	2013	29/01/2013	9.53	5.51	- 4.02
23	2013	04/03/2013	4.95	3.09	- 1.86

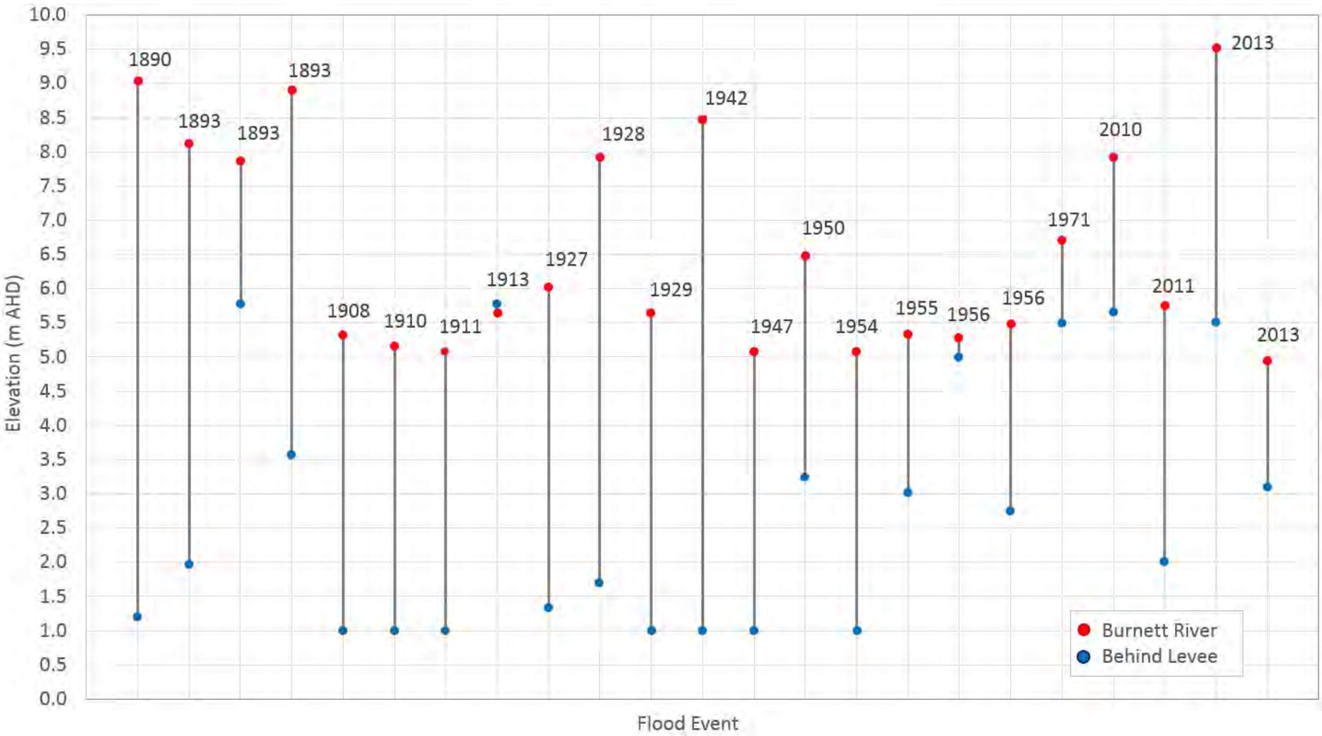


Figure 5-13 Summary of Operational Back-Tests

5.3.5 Draft Operating Principles

A comprehensive set of operating procedures is beyond the scope of this document and is a matter for detailed design. Nonetheless, a brief set of operating principles can be drafted, informed by the works described in the preceding sections:

1) **Pre-flood: River Predictions.** When a flood is expected, the following data sources should be monitored on an ongoing basis to determine the likely magnitude of the flood peak at Bundaberg:

   – BOM Flood Warning Centre (http://www.bom.gov.au/qld/warnings/)

   – DNRM stream height data from the Walla gauge (https://water-monitoring.information.qld.gov.au/)

   For minor floods (< 3.5 m AHD) the lowest-risk option may be to leave the gates open. For floods up to the moderate level (5.5 m AHD), closing the gates is likely to be required, but the decision should be undertaken with regard to the rainfall forecast. For flood predictions above the moderate level the gates will need to be closed, and the key consideration becomes the appropriate time at which to carry out this action.

2) **Pre-flood: Rainfall Predictions.** Simultaneously with Item 1, the local rainfall forecast and the current rain radar should be monitored to assess the likelihood of local rainfall. Predictions should be reviewed against the predicted rate of river rise and time to peak. The most common weather pattern (low pressure system, per Figure 5-9) is for the majority of rainfall to occur prior to the river peak, in which case it may be possible to drain the local catchment before needing to close the gates.

3) **During flood: Real-time data.** Good information is key to making informed operating decisions. Weather stations monitoring rainfall accumulation, stream height, and discharge, should be installed at strategic locations in the catchment behind the levee. It is anticipated that these weather stations will serve a dual purpose. First, after a sufficient observation record has been established it will become possible to calibrate runoff models, allowing for runoff forecasts to be made on the basis of

either rainfall prediction, or real-time rainfall. Second, the gauges (if supported by accurate rating curves) will allow for an estimate of the total volume of runoff that is likely to present to the pump station.

4) **During flood: Decision Support System.** The above 3 items taken together will allow for the construction and operation of a Decision Support System (DSS). A DSS comprises a set of heuristics that considers all available information to make informed operating recommendations.

Section 6 References

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Appendix A URBS Calibration Plots

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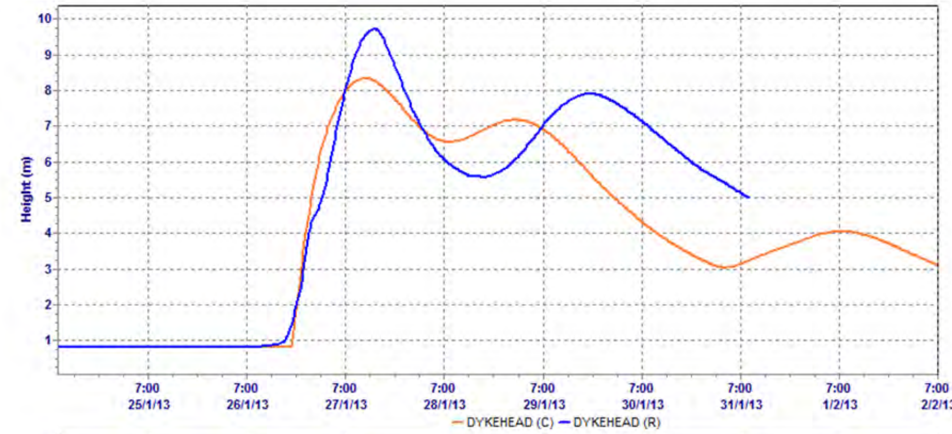
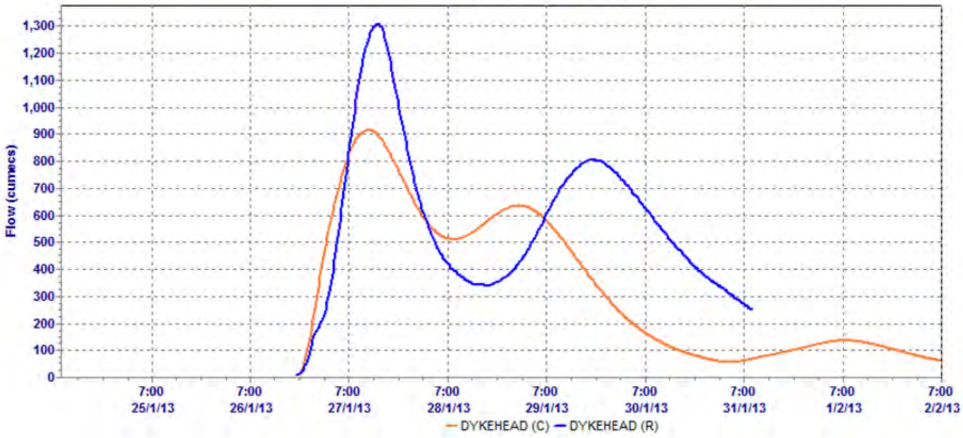
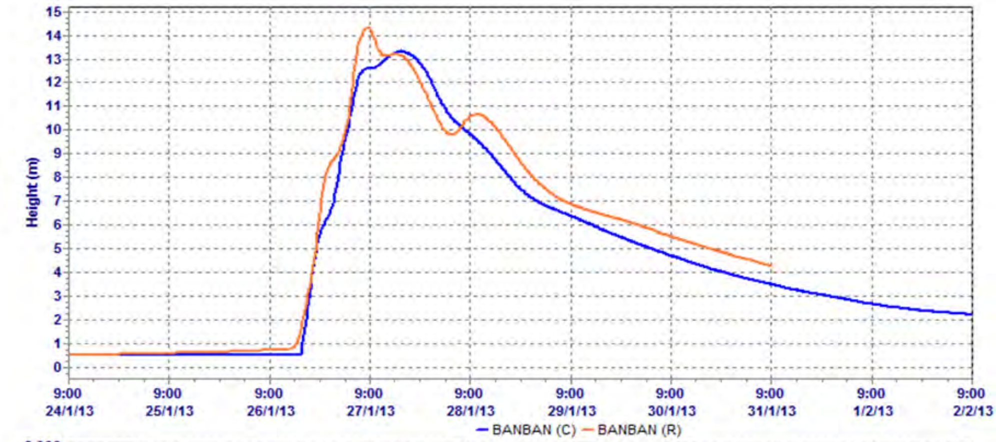
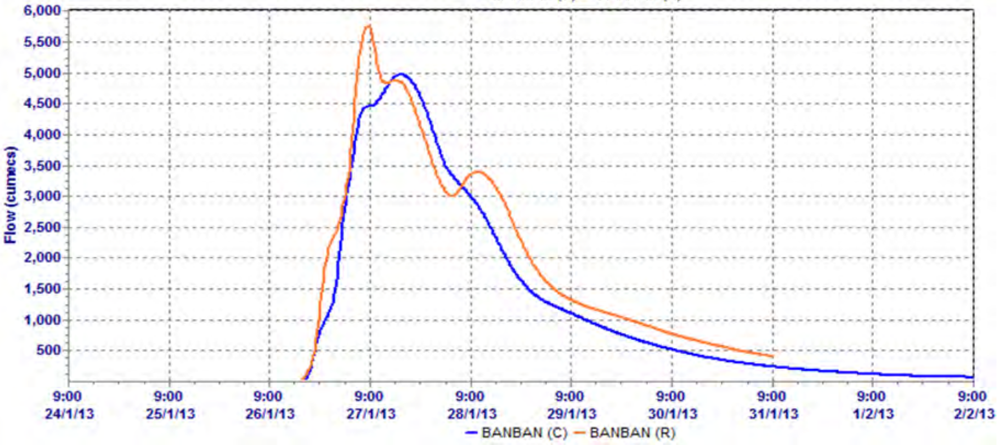


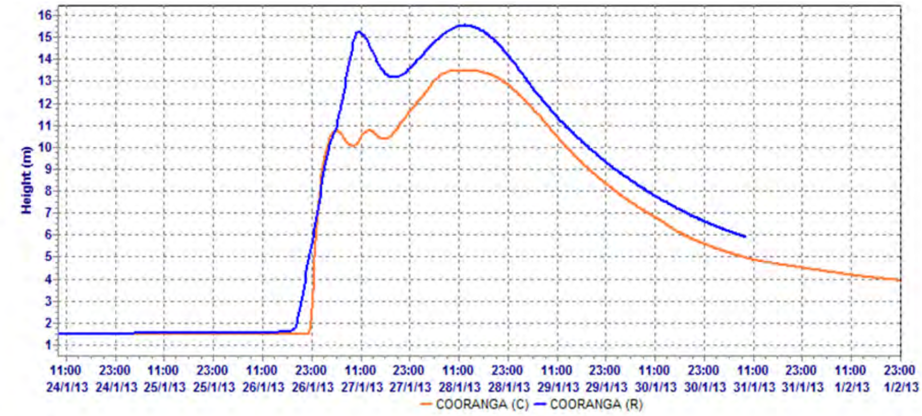


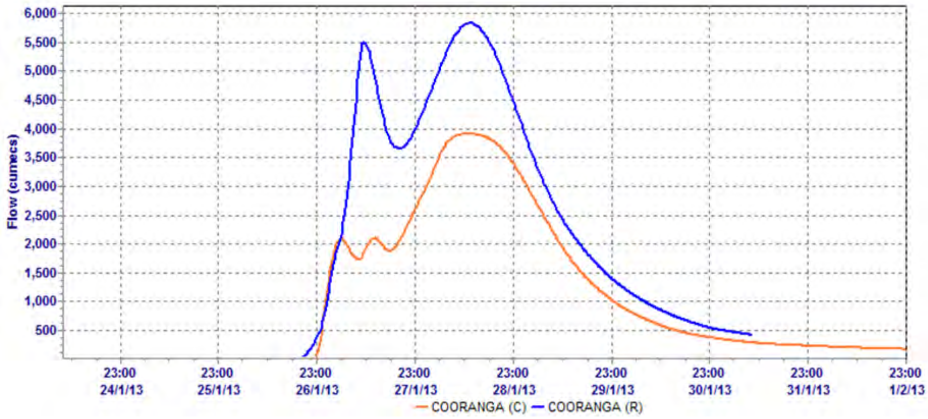
Barambah Creek at Ban Ban



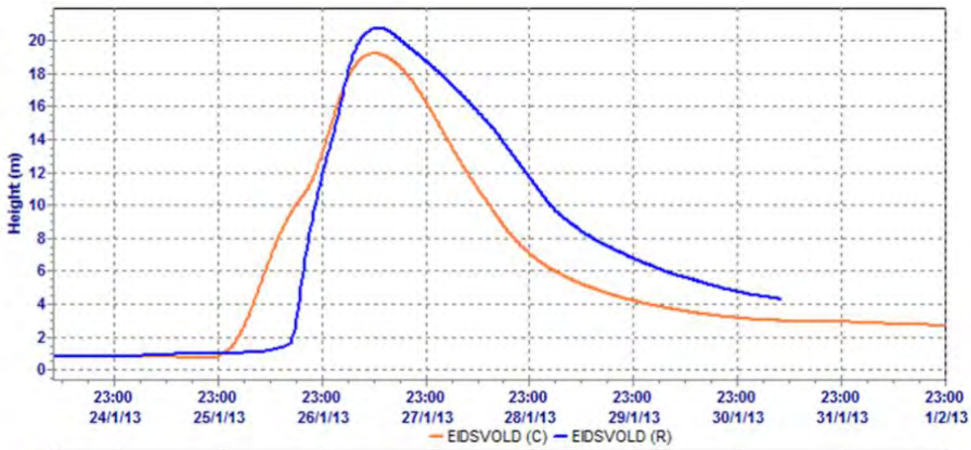


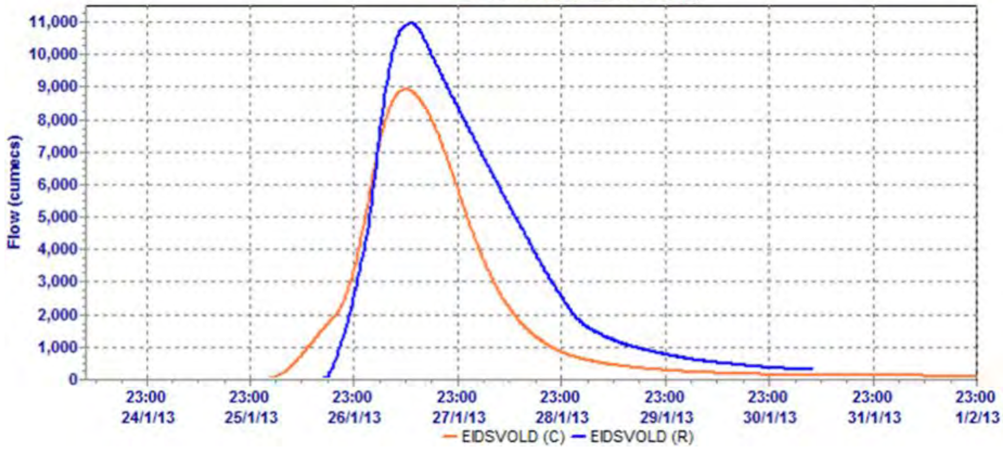
Boyne River at Cooranga



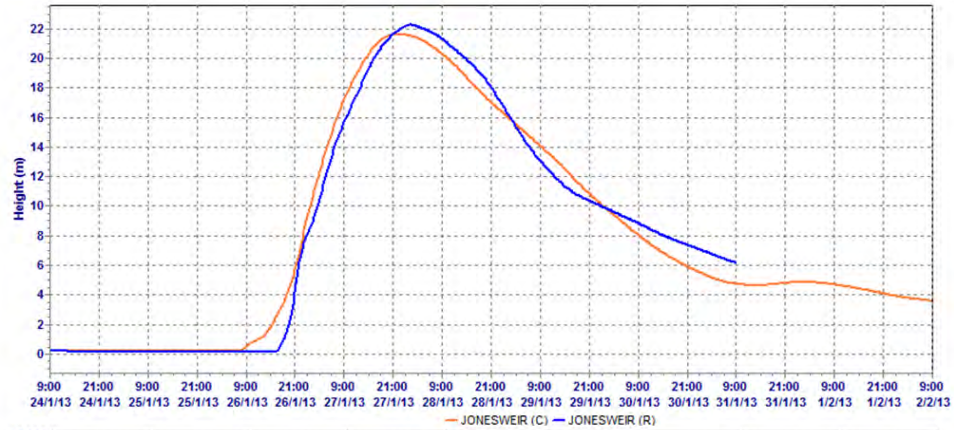


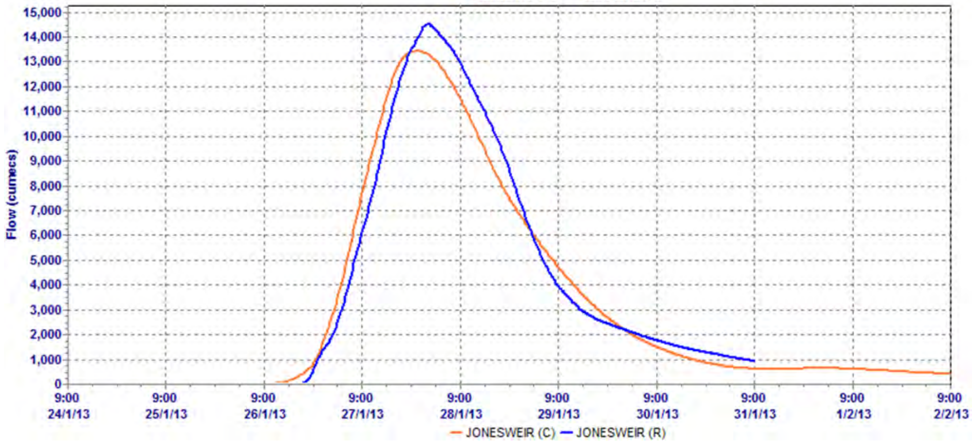
Upper Burnett River at Eidsvold



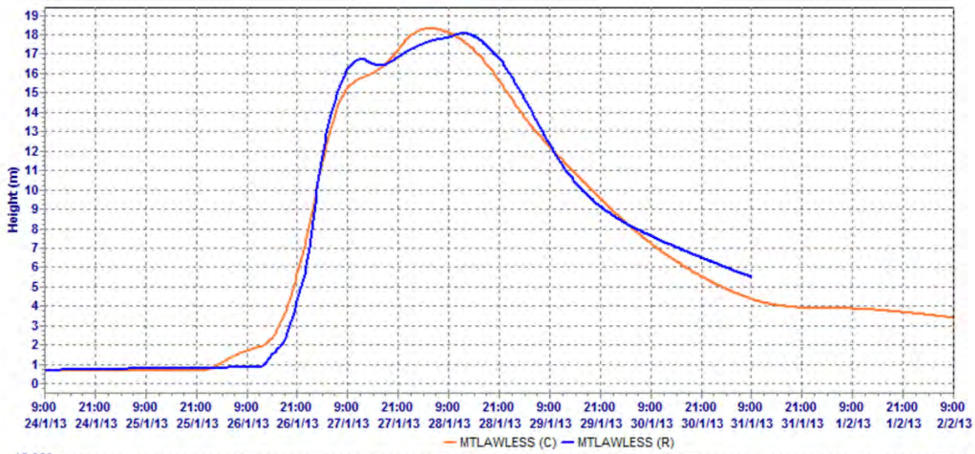


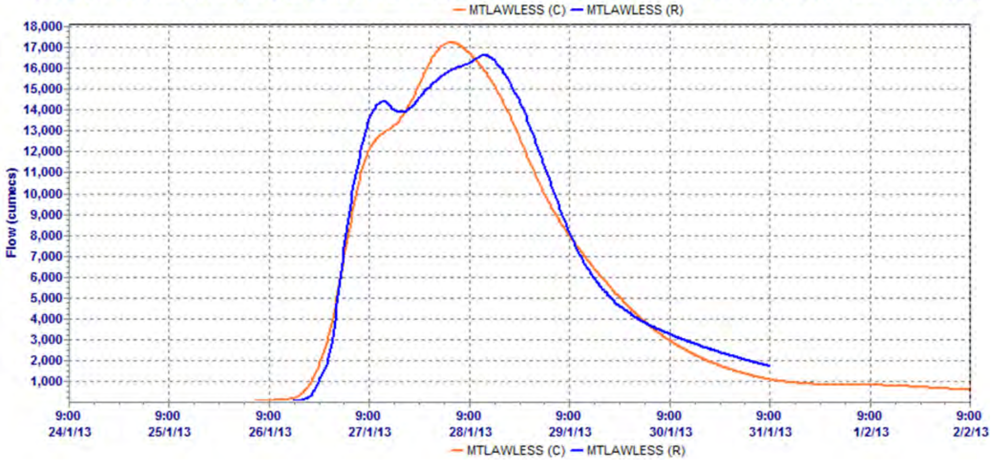
Lower Burnett River at Jones Weir (Mundubbera)



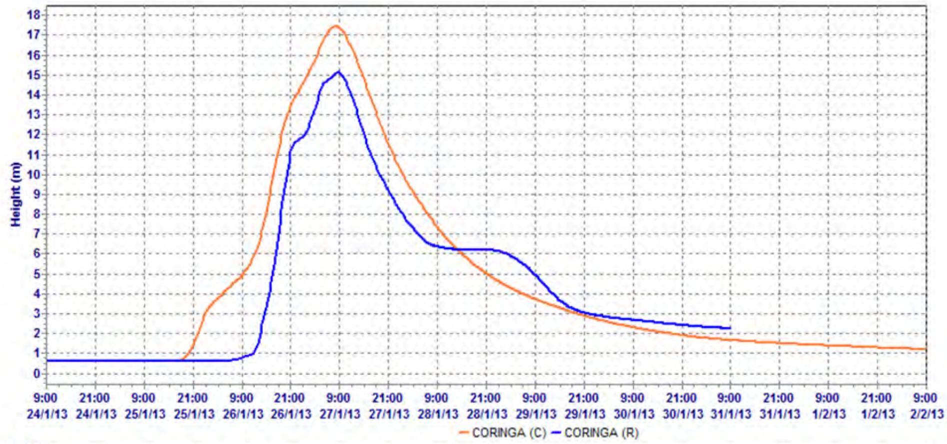


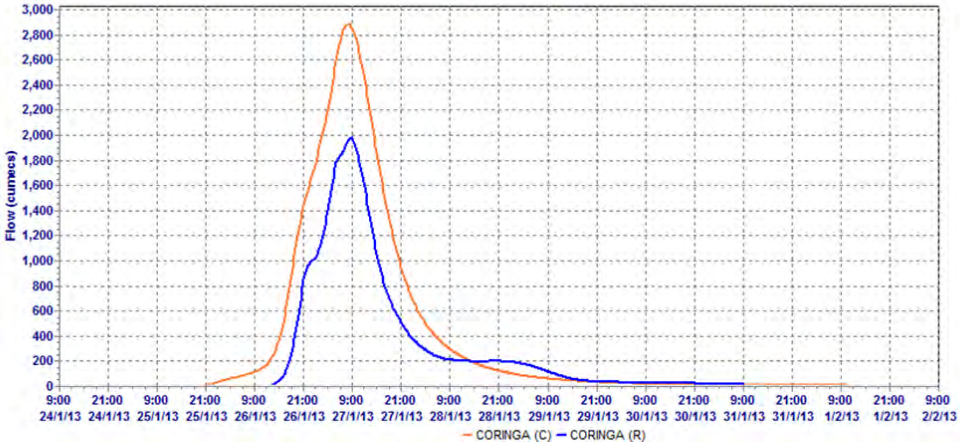
Lower Burnett River at Mt. Lawless



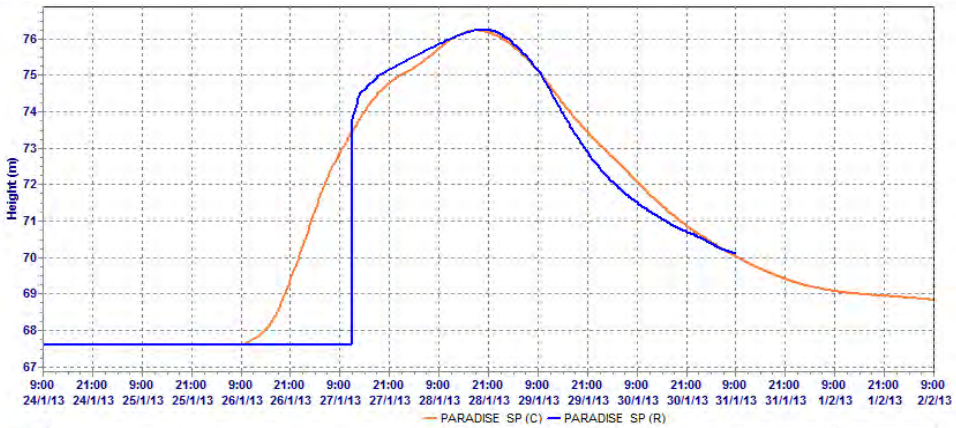


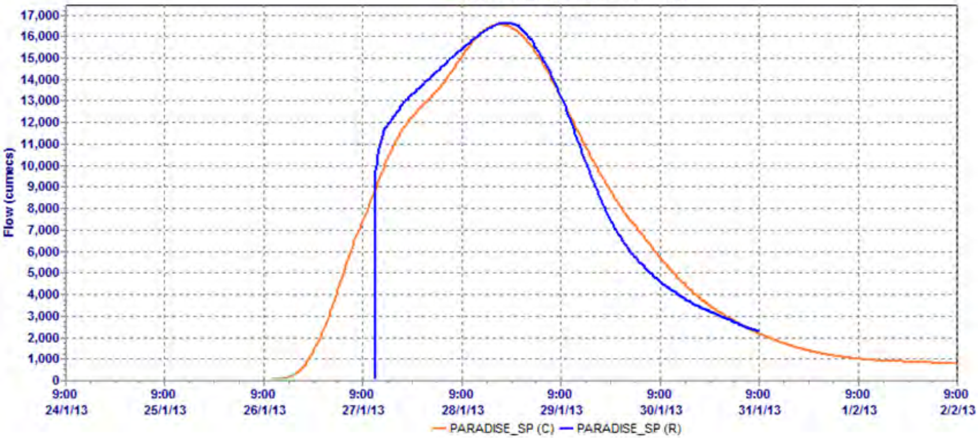
Degilbo Creek at Coringa



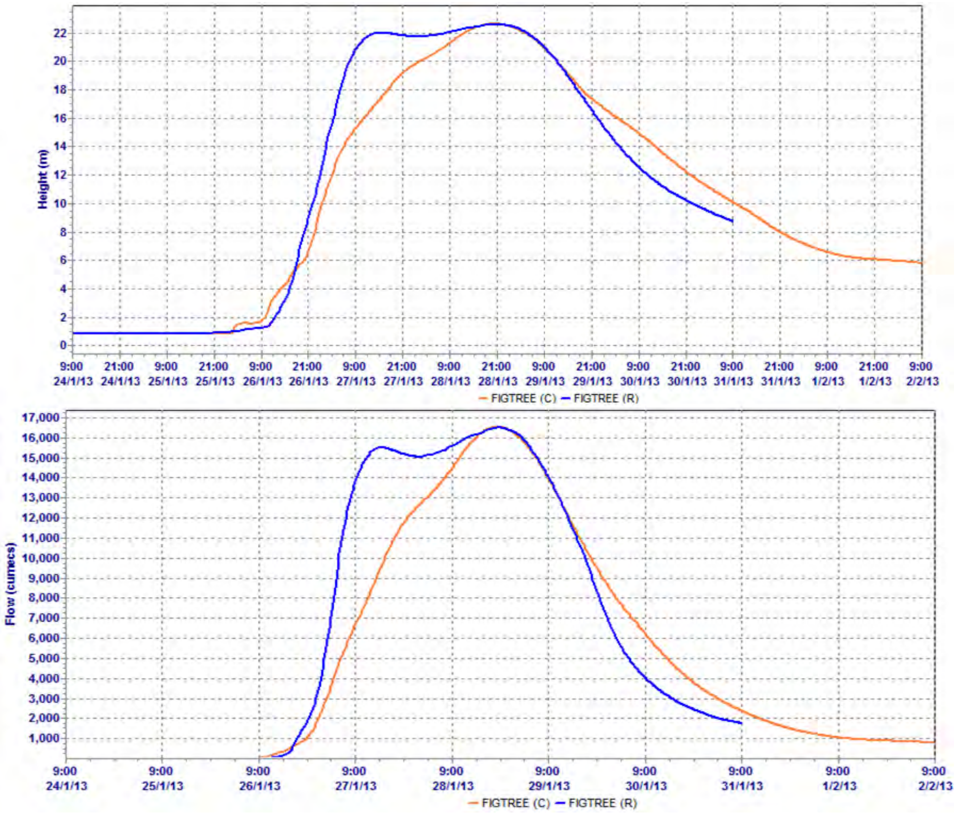


Burnett River at Paradise Dam

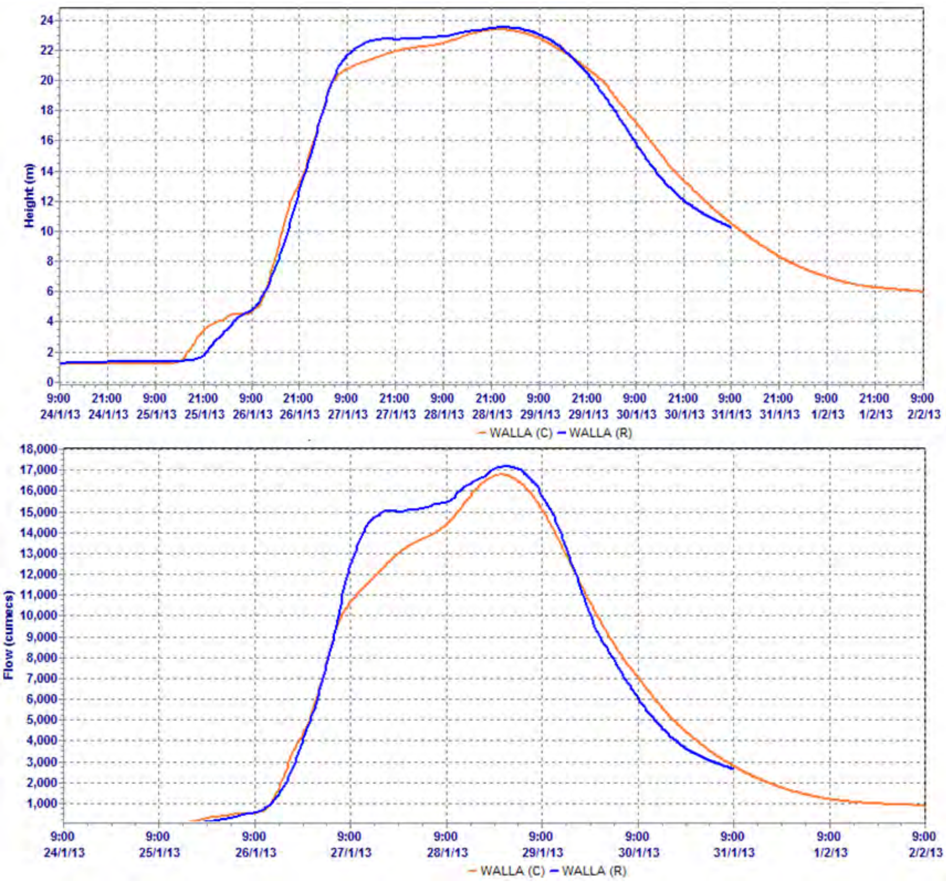




Burnett River at Figtree Creek



Burnett River at Walla



Appendix B Hinkler Avenue Concept Bridge Designs

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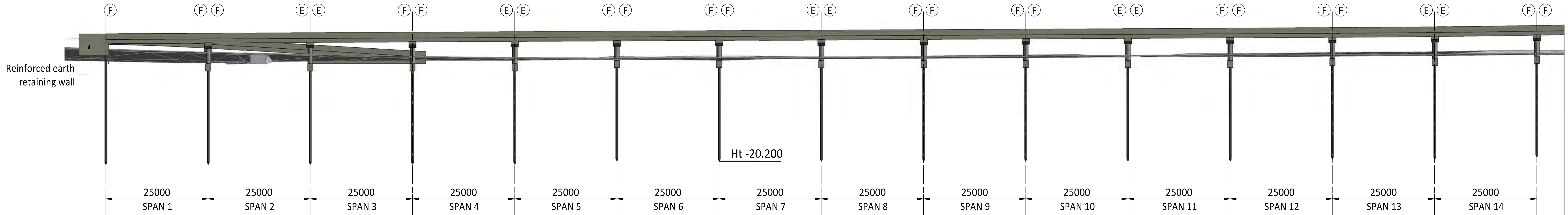
(F) denotes fixed bearing



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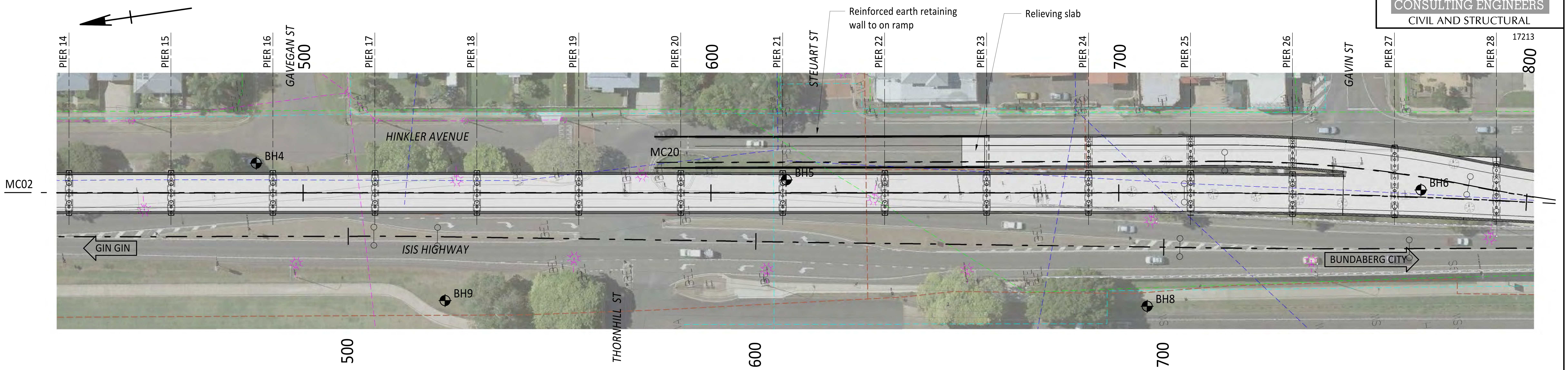

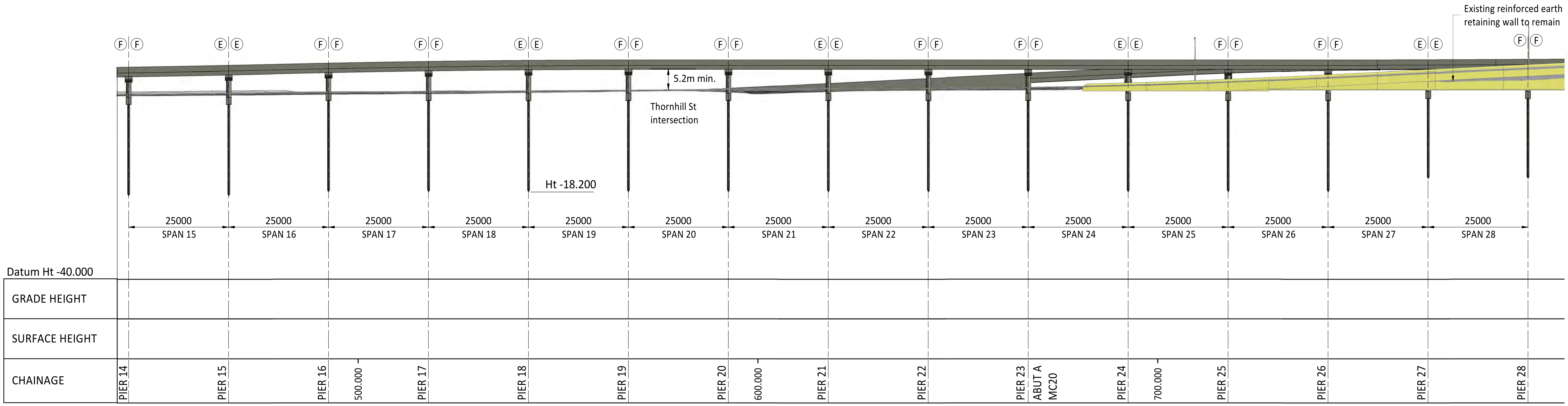

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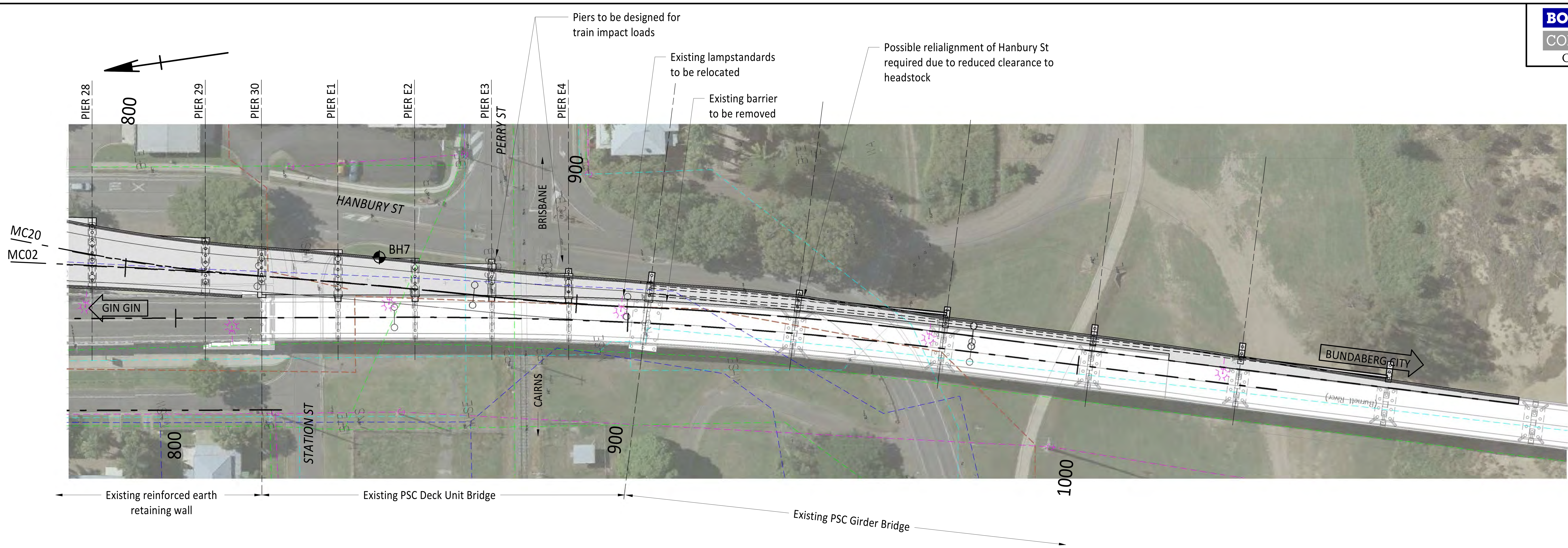

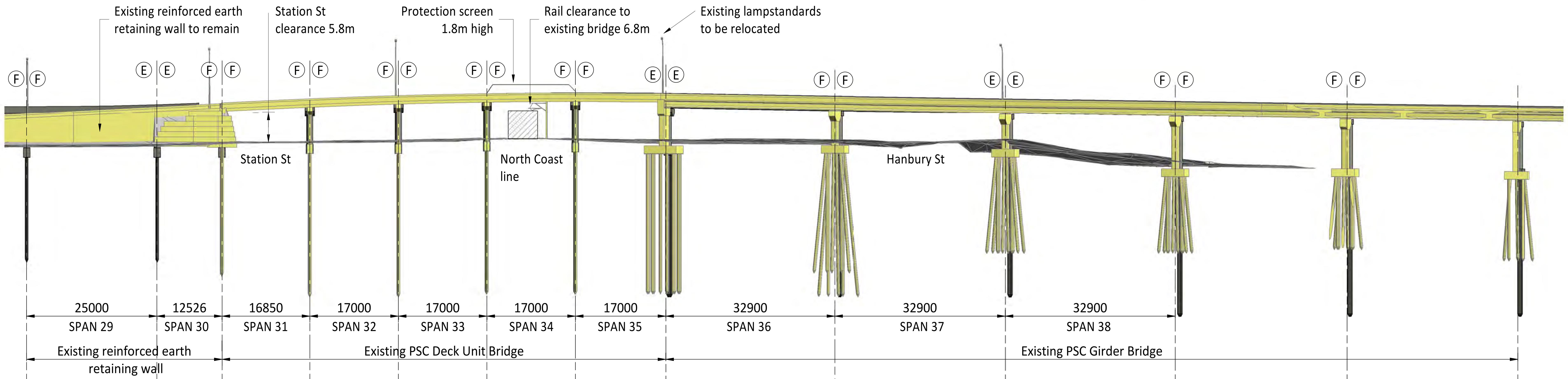

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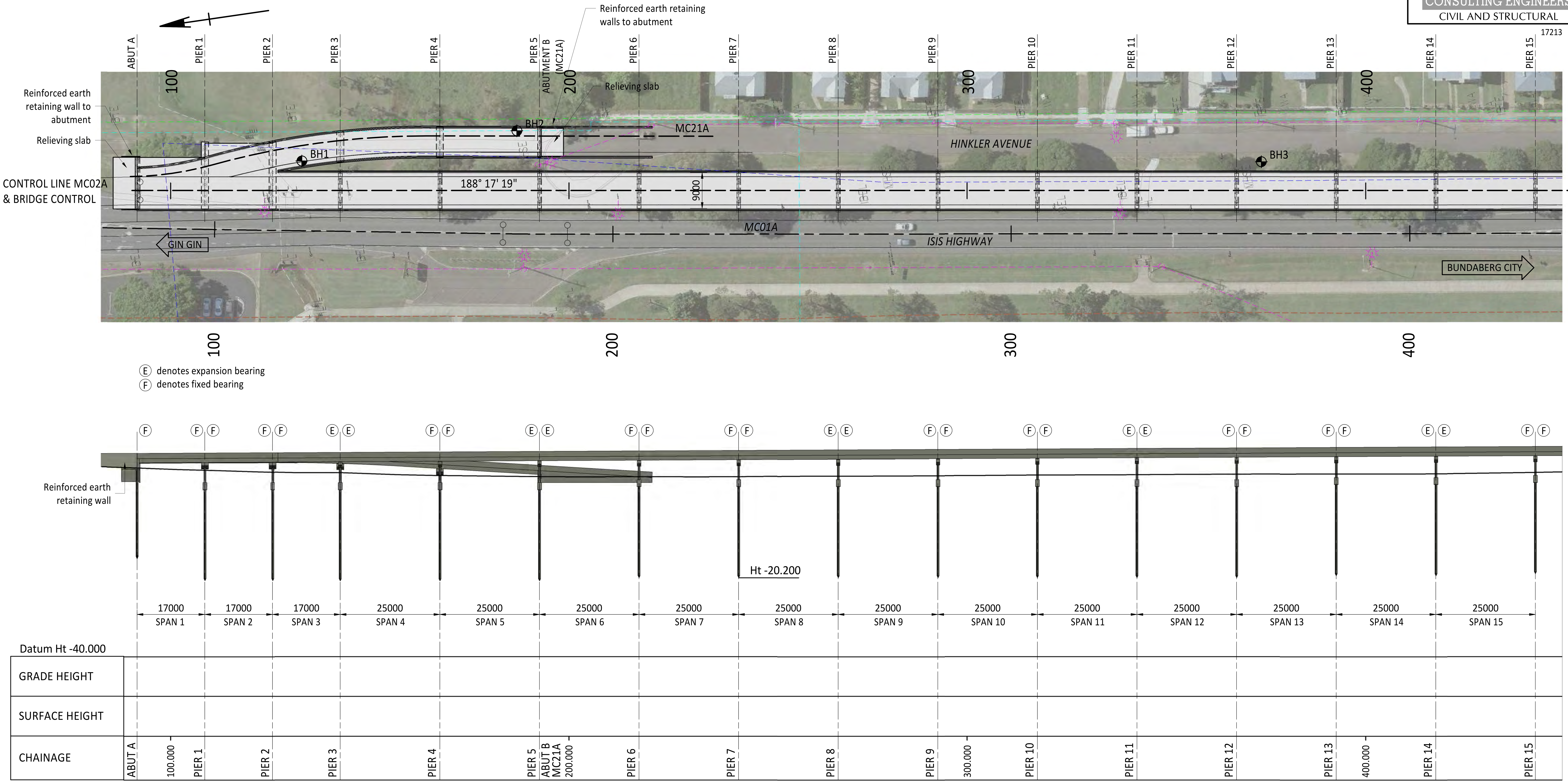

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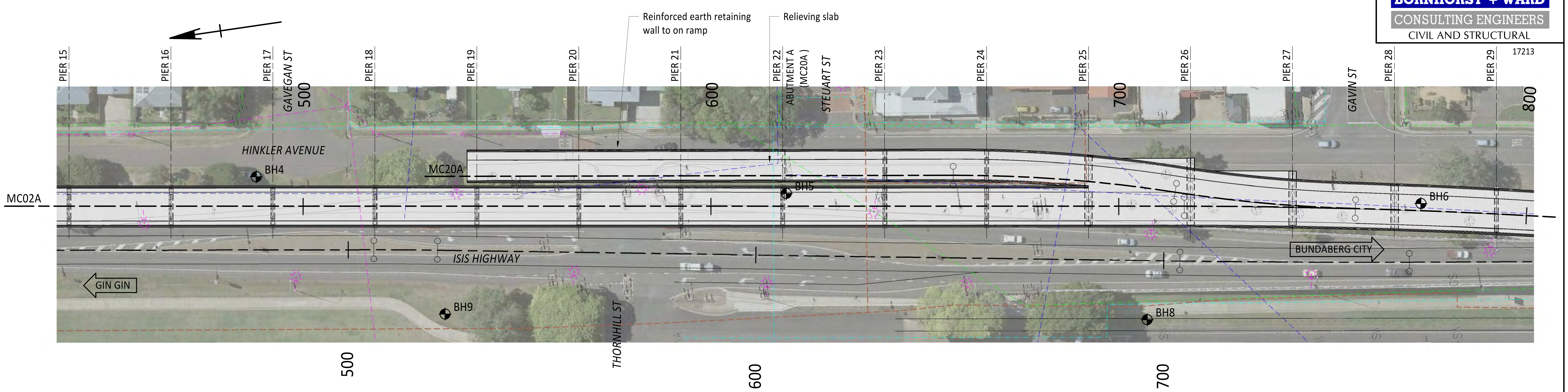

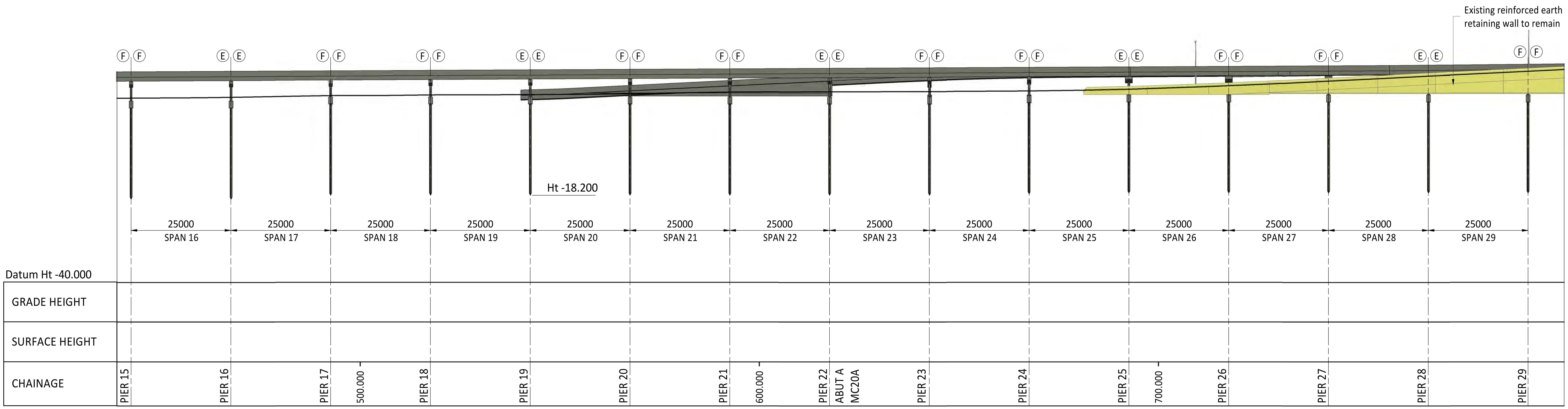

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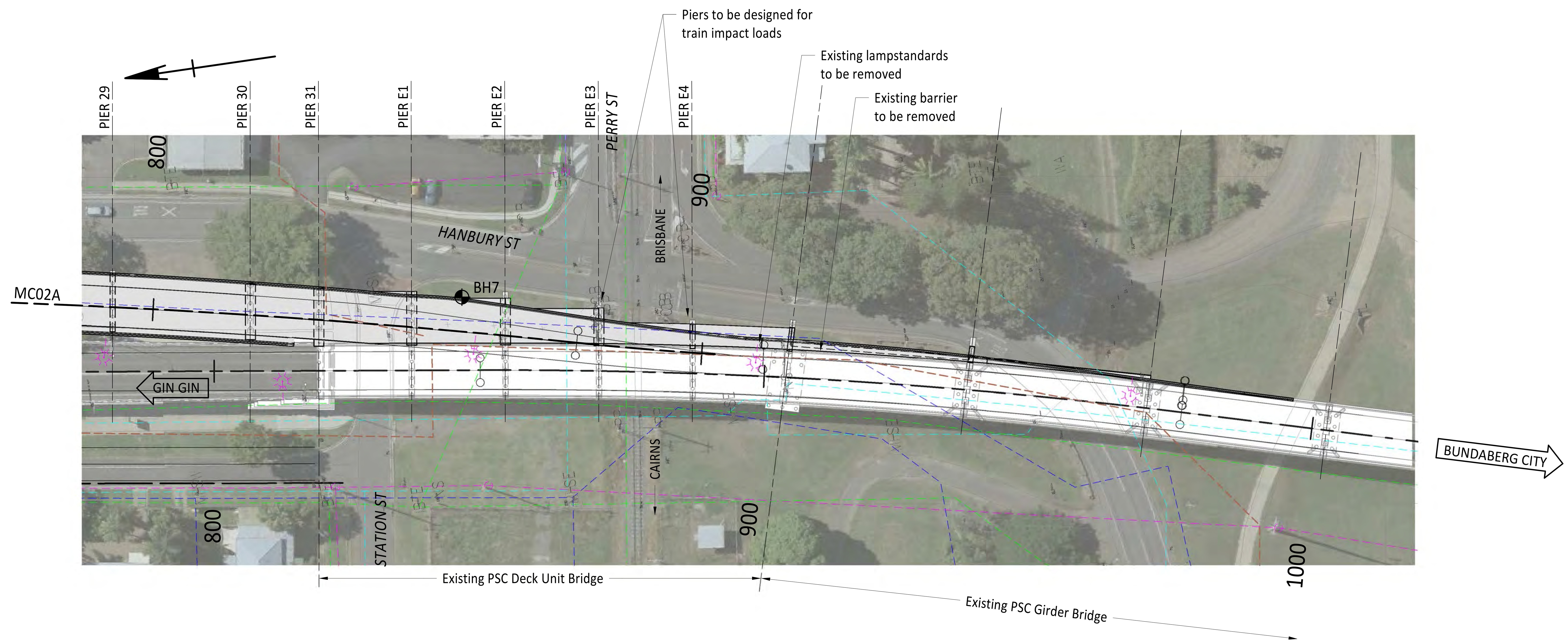

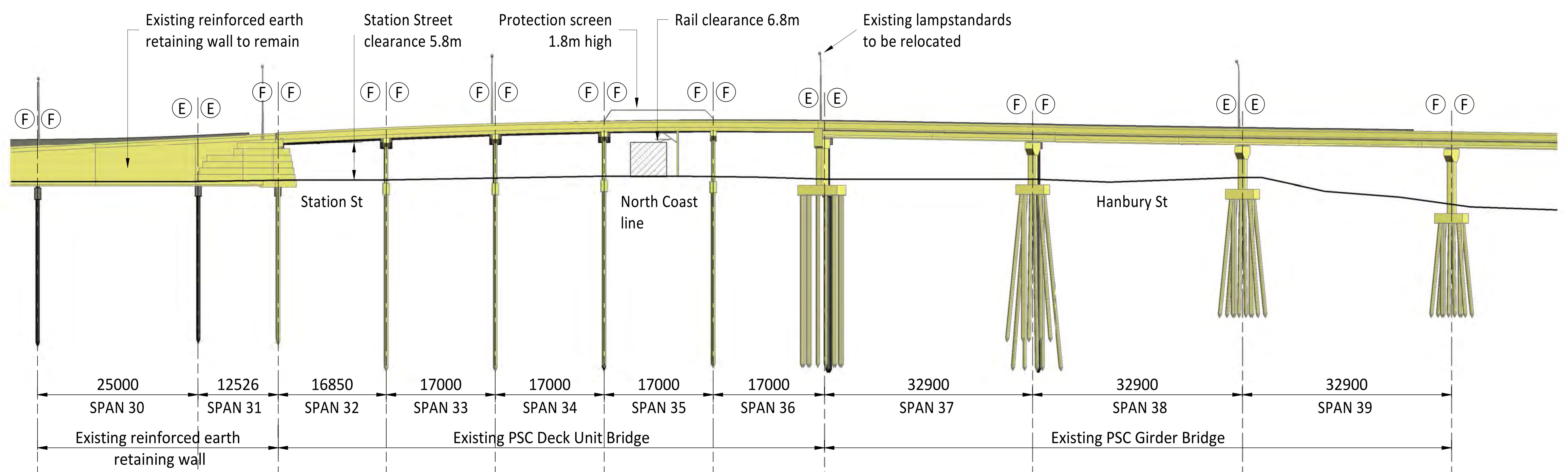

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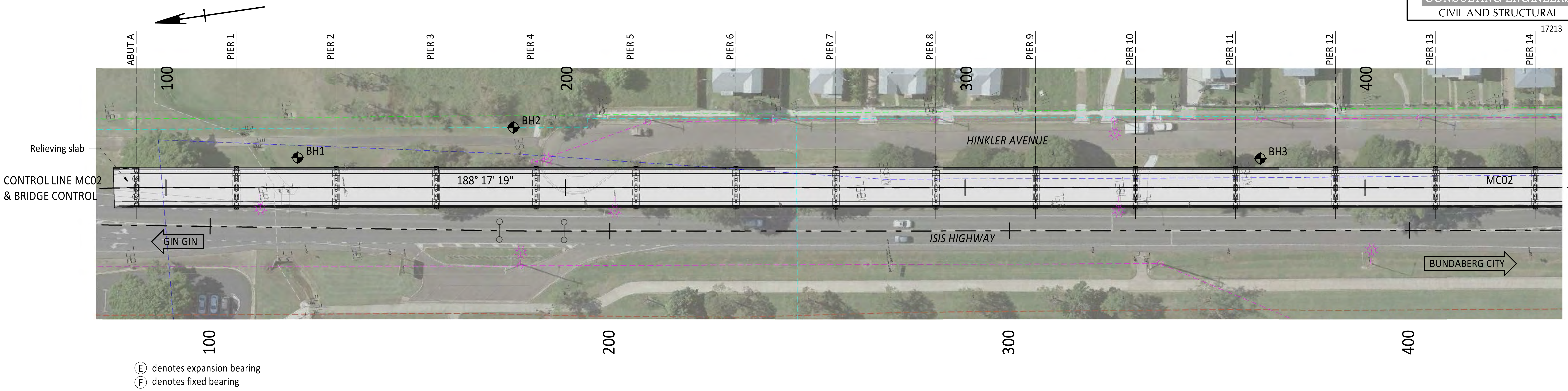

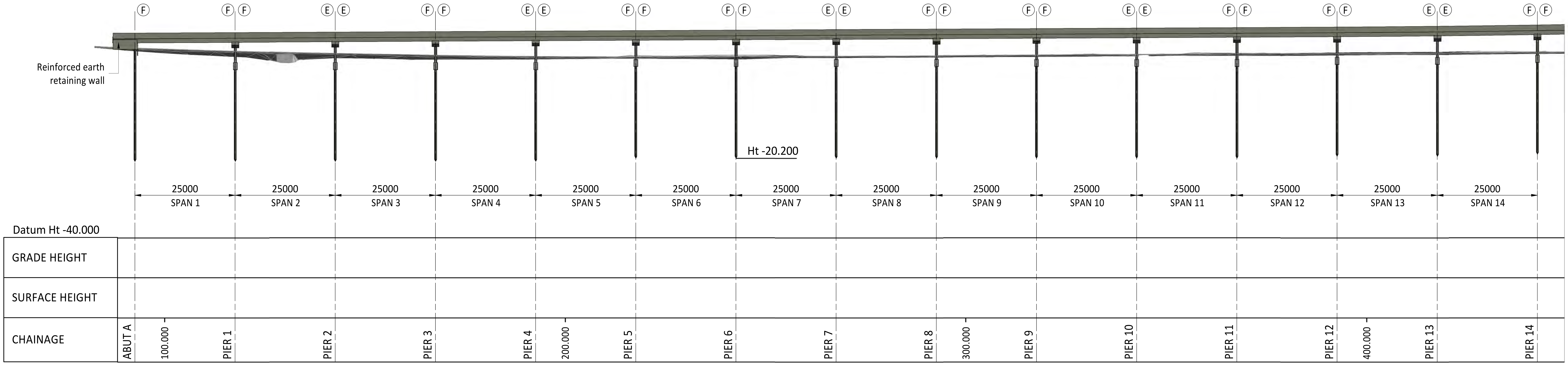

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OPTION 8 GENERAL ARRANGEMENT - SHEET 1

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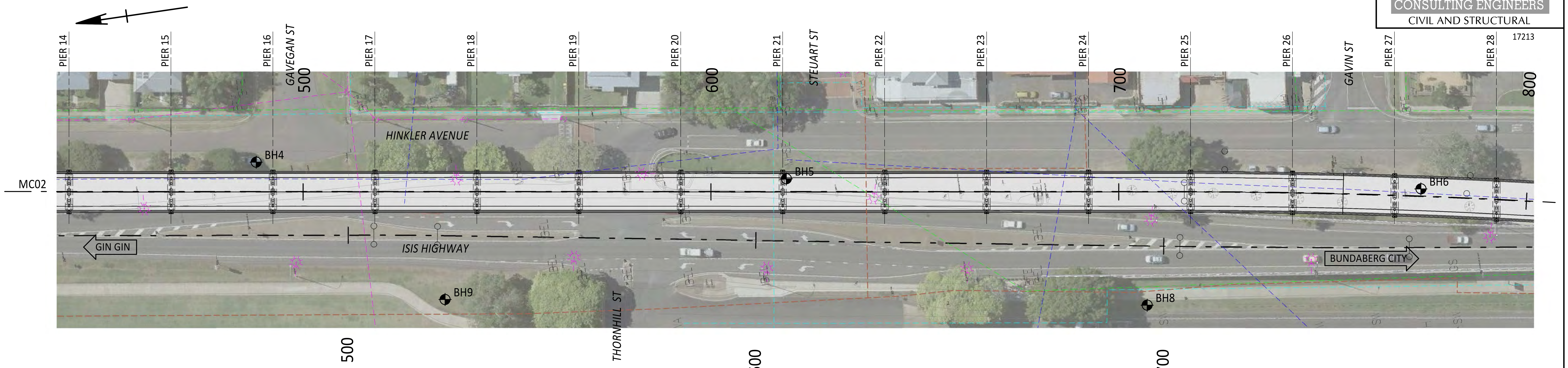

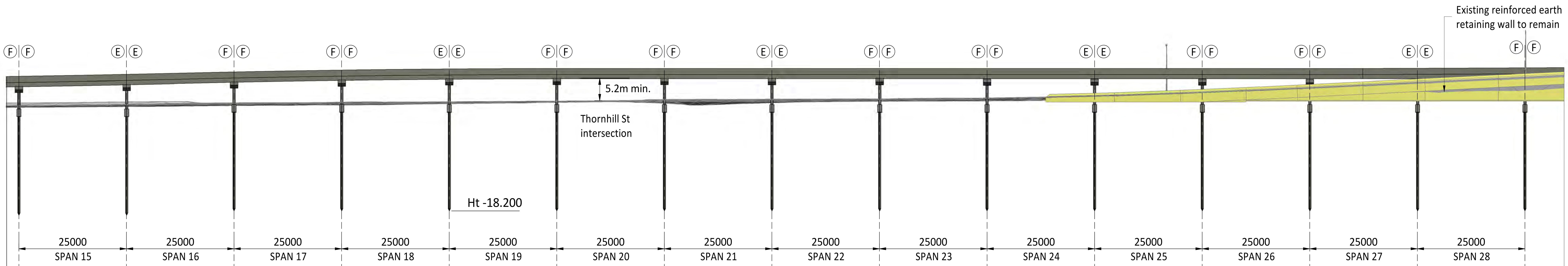

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SURFACE HEIGHT	
CHAINAGE	PIER 14, PIER 15, PIER 16, 500.000, PIER 17, PIER 18, PIER 19, PIER 20, 600.000, PIER 21, PIER 22, PIER 23, PIER 24, 700.000, PIER 25, PIER 26, PIER 27, PIER 28

BRIDGE DESIGN CRITERIA: DESIGN CODE: AS 5100:2017 DESIGN LOADING: T44 and HLP320 DESIGN SPEED: EARTHQUAKE ZONE: BARRIER PERFORMANCE LEVEL: Regular BRIDGE TYPE: BIS No.

BUNDABERG REGIONAL COUNCIL
ISIS HIGHWAY (BUNDABERG-CHILDERS)
CTL CHGE CTRL CHGE XX.XXX - XX.XXX

BUNDABERG NORTH FLOOD EVACUATION ROUTE
OPTION 8 GENERAL ARRANGEMENT - SHEET 2

Associated Job Nos | Survey Data | Datum
Auxiliary Drg Nos | Horiz. Grid | Height Origin | Survey Books

Scales 1:500 0 10 20m

Dimensions shown in millimetres except where shown otherwise

Reference Points: Preceding RP | Dist. to start of job (km) | From start to end of job | From end to Following RP | Following RP

Through Chainage from

Drawn | Checked | Designed No. | Verified No. | Design Reviews (RPEQ) | No. Date:

ENGINEERING CERTIFICATION (RPEQ): ENG. AREA | NAME | SIGNATURE | NO. | DATE

Queensland Government

Job No. XX/19A/XX
Contract No. XX-XXX-XX
Drawing No.
Series Number BR8-GA-02 of
MRB_Detail (02/14) BR Drgs

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Revisions / Descriptions | Certification | Date | Microfilmed

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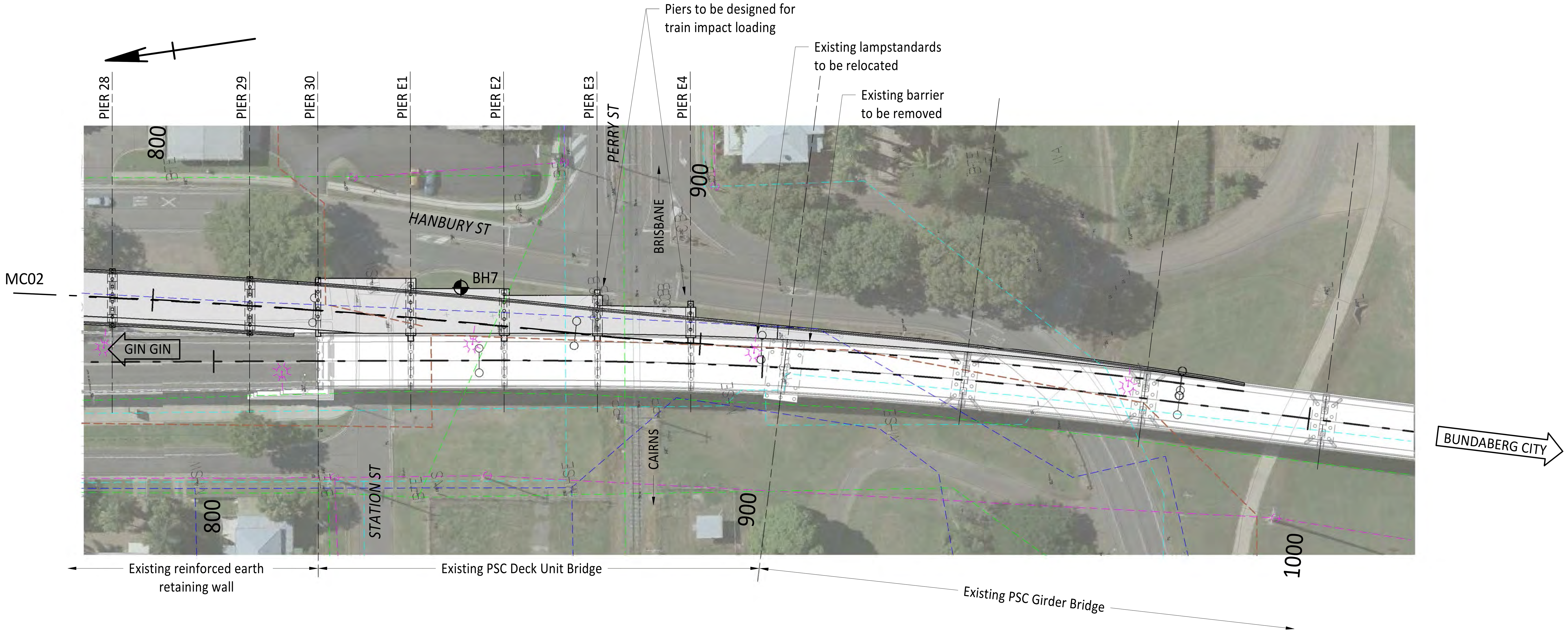
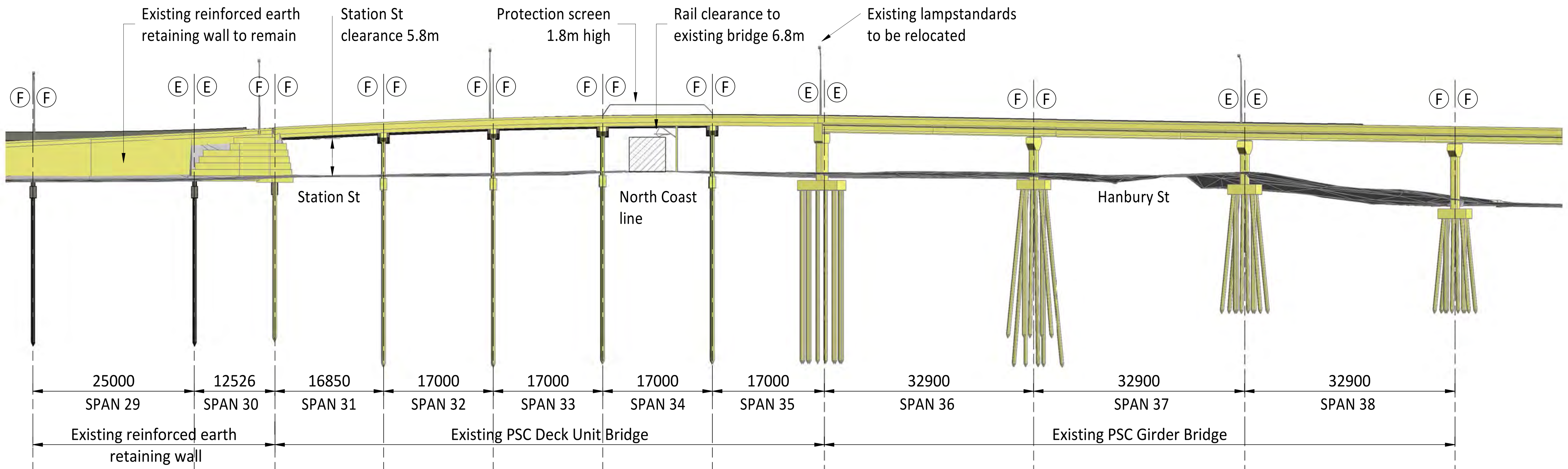
17213





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SURFACE HEIGHT	
CHAINAGE	PIER 28, 800.000, PIER 29, PIER 30, PIER E1, PIER E2, PIER E3, PIER E4, 900.000

BRIDGE DESIGN CRITERIA: DESIGN CODE: AS 5100:2017 DESIGN LOADING: T44 and HLP320 DESIGN SPEED: EARTHQUAKE ZONE: BARRIER PERFORMANCE LEVEL: Regular BRIDGE TYPE: BIS No.

Associated Job Nos | Survey Data: Datum, Horiz. Grid, Height Origin, Survey Books | Auxiliary Drg Nos

Scales 1:500 0 10 20m

Dimensions shown in millimetres except where shown otherwise

BUNDABERG REGIONAL COUNCIL
ISIS HIGHWAY (BUNDABERG-CHILDERS)
CTL CHGE CTRL CHGE XX.XXX - XX.XXX

Reference Points: Preceding RP | Dist. to start of job (km) | From start to end of job | From end to Following RP | Following RP

Through Chainage from

Drawn | Checked | Designed No. | Verified No. | Design Reviews (RPEQ) | No. Date:

BUNDABERG NORTH FLOOD EVACUATION ROUTE OPTION 8 GENERAL ARRANGEMENT - SHEET 3

ENGINEERING CERTIFICATION (RPEQ): ENG. AREA | NAME | SIGNATURE | NO. | DATE

Queensland Government

Job No. XX/19A/XX
Contract No. XX-XXX-XX
Drawing No.
Series Number BR8-GA-03 of
MRB_Detail (02/14) BR Drgs

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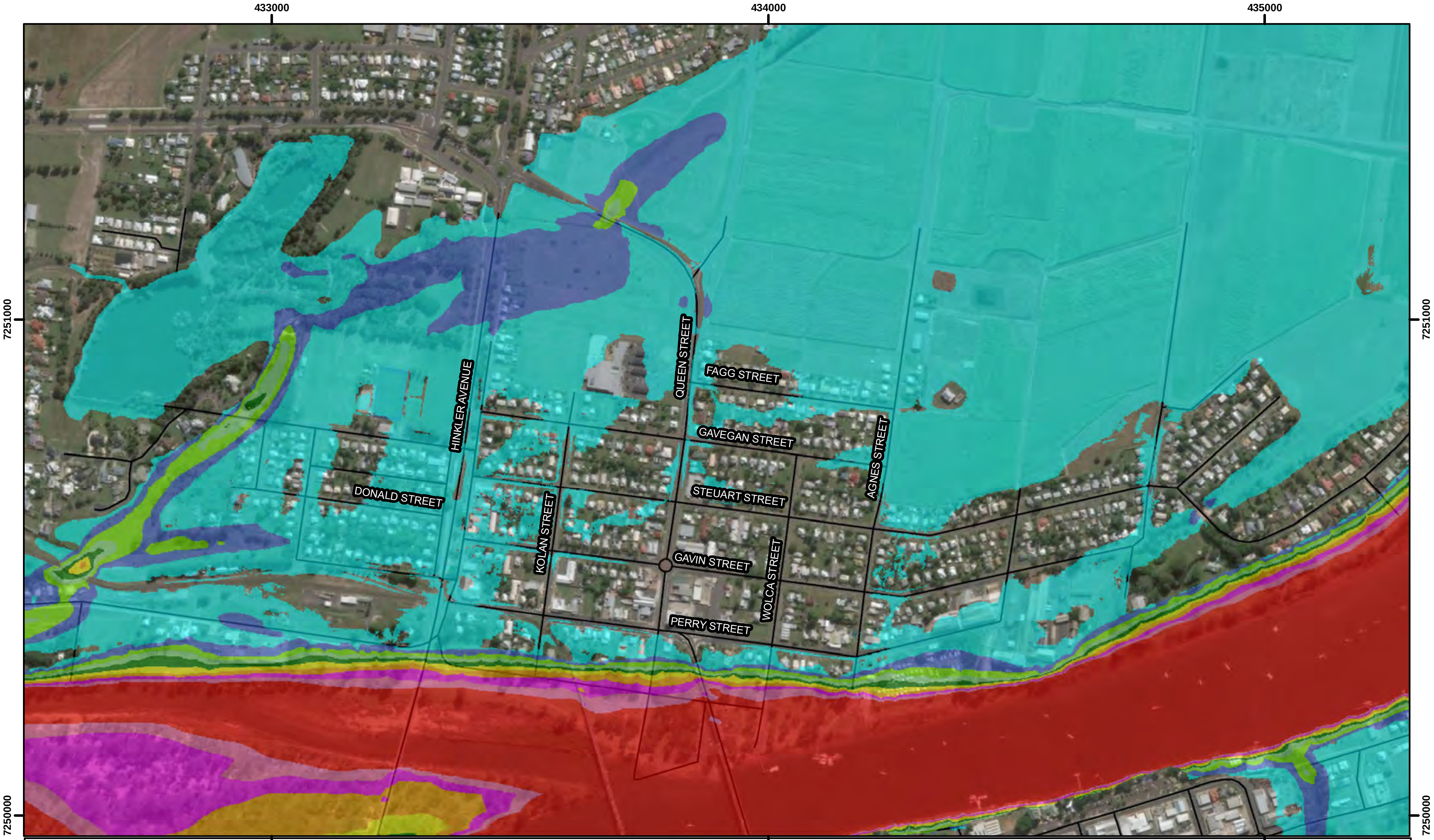
Appendix C North Bundaberg Flood Hazard Maps



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Coordinate System =
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Date: 03/05/18
Drawn: J Parnwell

Legend

Roads

Velocity-Depth Product (m^2/s)

0 - 1	5 - 6
1 - 2	6 - 7
2 - 3	7 - 8
3 - 4	8 - 9
4 - 5	>9

Figure C1
North Bundaberg Flood Hazard
20 year ARI Design Flood Event
Peak Velocity-Depth Product

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017
DigitalGlobe, 2015

CDM Smith

PARNWELLJA \\brbsvr1\PRO\Project\BEN170175.01 - Bundaberg East Levee\04_Deliverables\Surface Water Technical Report (Appendix D)\Fig 3 R1 20 yr ARI.mxd 3/05/2018

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Coordinate System =
GDA 1994 MGA Zone 56

Date: 03/05/18
Drawn: J Parnwell

Legend

Roads

Velocity-Depth Product (m^2/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- >9

Figure C2

North Bundaberg Flood Hazard
50 year ARI Design Flood Event
Peak Velocity-Depth Product

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017
DigitalGlobe, 2015

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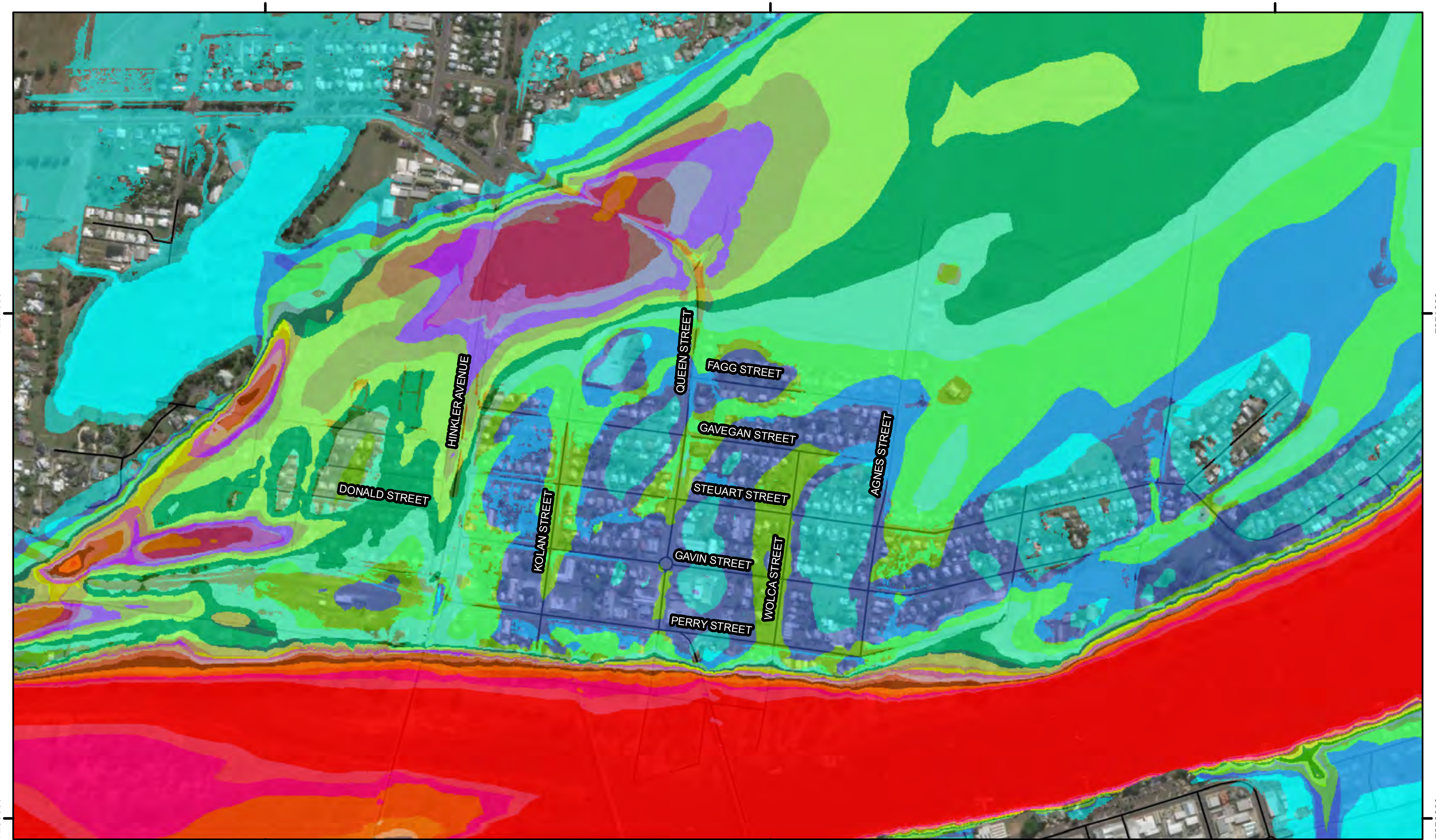

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Coordinate System =
GDA 1994 MGA Zone 56

Date: 03/05/18
Drawn: J Parnwell

Legend

Roads

Velocity-Depth Product (m^2/s)

0 - 1	5 - 6
1 - 2	6 - 7
2 - 3	7 - 8
3 - 4	8 - 9
4 - 5	>9

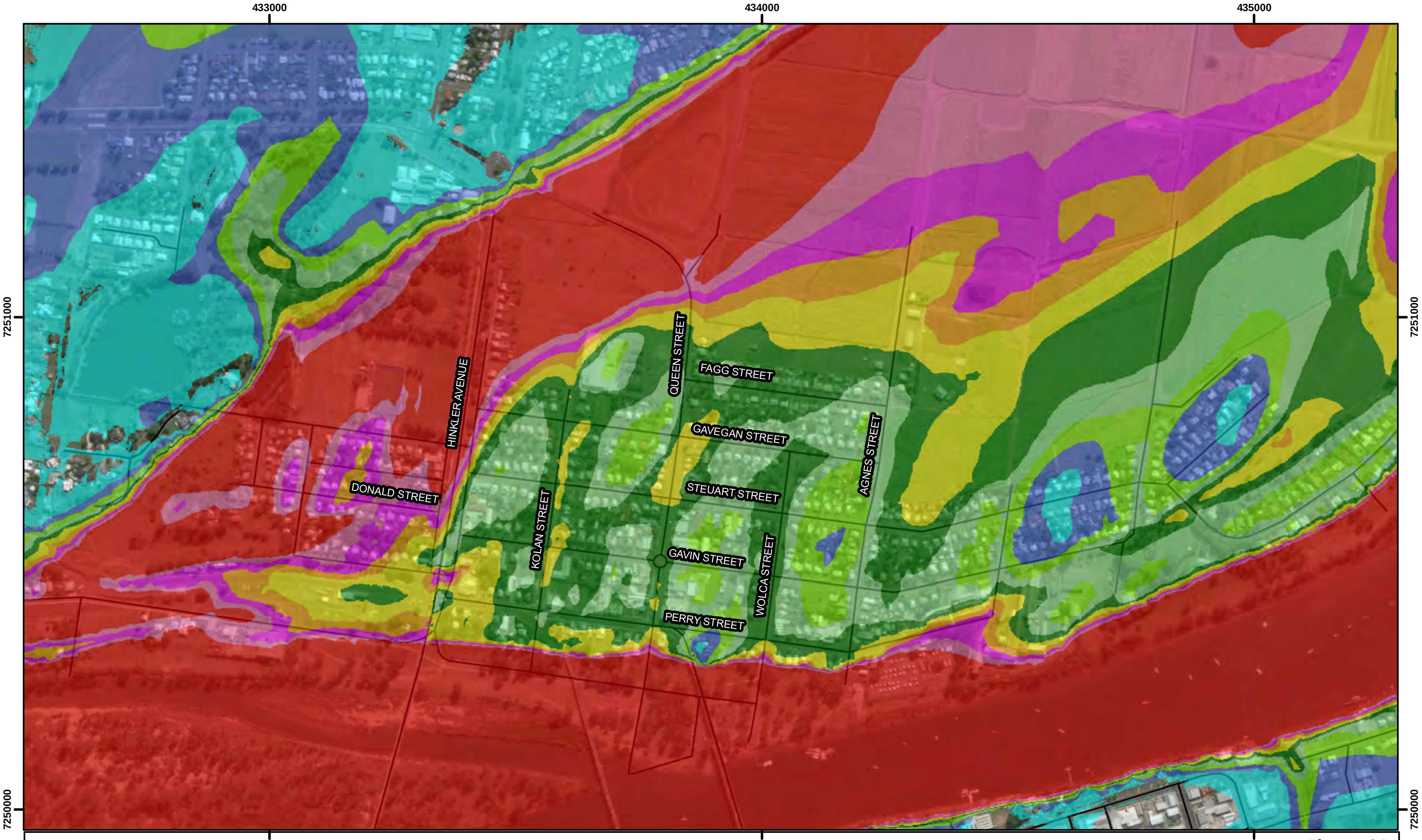
Figure C3

North Bundaberg Flood Hazard
100 year ARI Design Flood Event
Peak Velocity-Depth Product

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017
DigitalGlobe, 2015

CDM Smith

PARNWELLJA \\brbsvr1\PRO\Project\BEN170175.01 - Bundaberg East Levee\04_Deliverables\Surface Water Technical Report (Appendix D)\App C3 R2 100 yr ARI.mxd 3/05/2018



Coordinate System =
GDA 1994 MGA Zone 56

Date: 03/05/18
Drawn: J Parnwell

Legend

Roads

Velocity-Depth Product (m^2/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- >9

Figure C4

North Bundaberg Flood Hazard
500 year ARI Design Flood Event
Peak Velocity-Depth Product

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017
DigitalGlobe, 2015

CDM Smith

Appendix E Environmental Advice Statement

Department of Local Government, Racing and Multicultural Affairs

Bundaberg East Levee - Environmental Advice Statement

23 March 2018

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Plates

Tables

Document history & status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	19/03/2018	E. O'Brien	M. Jordan	21/03/2018	Draft
B	23/03/2018	M. Jordan	M. Jordan	23/03/2018	Draft

Distribution of copies

Version	Date issued	Quantity	Electronic	Issued to

Printed:	23 March 2018
Last Saved:	23 March 2018
File Name:	BEN170175.01_RPT_Enviro Advice Statement_Draft_RevB_23032018.docx
Author:	Scott Mainey, Matt Jordan
Project Manager:	Stuart Brown
Client:	Department of Local Government, Racing and Multicultural Affairs
Document Title:	**Bundaberg East Levee - Environmental Advice Statement**
Document Version:	Rev B
Project Number:	BEN170175.01

Section 1 Introduction

The Bundaberg East Levee Project (the Project) will include the construction of levees and/or floodwalls to increase the flood protection, mitigate damage, and protect the Bundaberg East area from the 100-year design flood event from the Burnett River and associated catchment. In addition, the Project will include flood gates and pump stations to mitigate interior flooding due to coincident rainfall in the protected area inboard of the levee and/or floodwall. The Project is located within the Bundaberg Regional Council (Figure 1).

1.1 Purpose and Scope

The purpose of this report is to:

- Present a summary of environmental matters potentially impacting the proposed levee alignment. The review context relates the levee alignment and ancillary facilitating activities;
- Give consideration to Commonwealth, State and Local environmental matters of significance (MNES, MSES and MLES);
- Review the proposed development to identify the environmental permits and statutory planning approvals required to be attained so as to lawfully construct the levee;
- Identify development application drafting requirements and the associated timeframes for achieving the permit and application approvals; and
- Make recommendations relating to an effective approval strategy.

1.2 Project Strategic Need

In January 2013, rainfall runoff associated with ex-tropical cyclone Oswald inundated the Bundaberg region. The flooding resulted in approximately 2,400 properties and 600 businesses being impacted, and required the evacuation of approximately 7,000 people [Department of Local Government, Racing and Multicultural Affairs (DLGRMA) 2017]. As a result, the Queensland Government developed a 10 year action plan for major flood mitigation in Bundaberg. As part of the action plan an option to construct a levee along the south bank of the Bundaberg River to reduce flooding in Bundaberg East was identified. As a result of the action Plan, CDM Smith was commissioned to preparing preliminary levee design options 3 and making a recommendation for a preferred levee alignment.

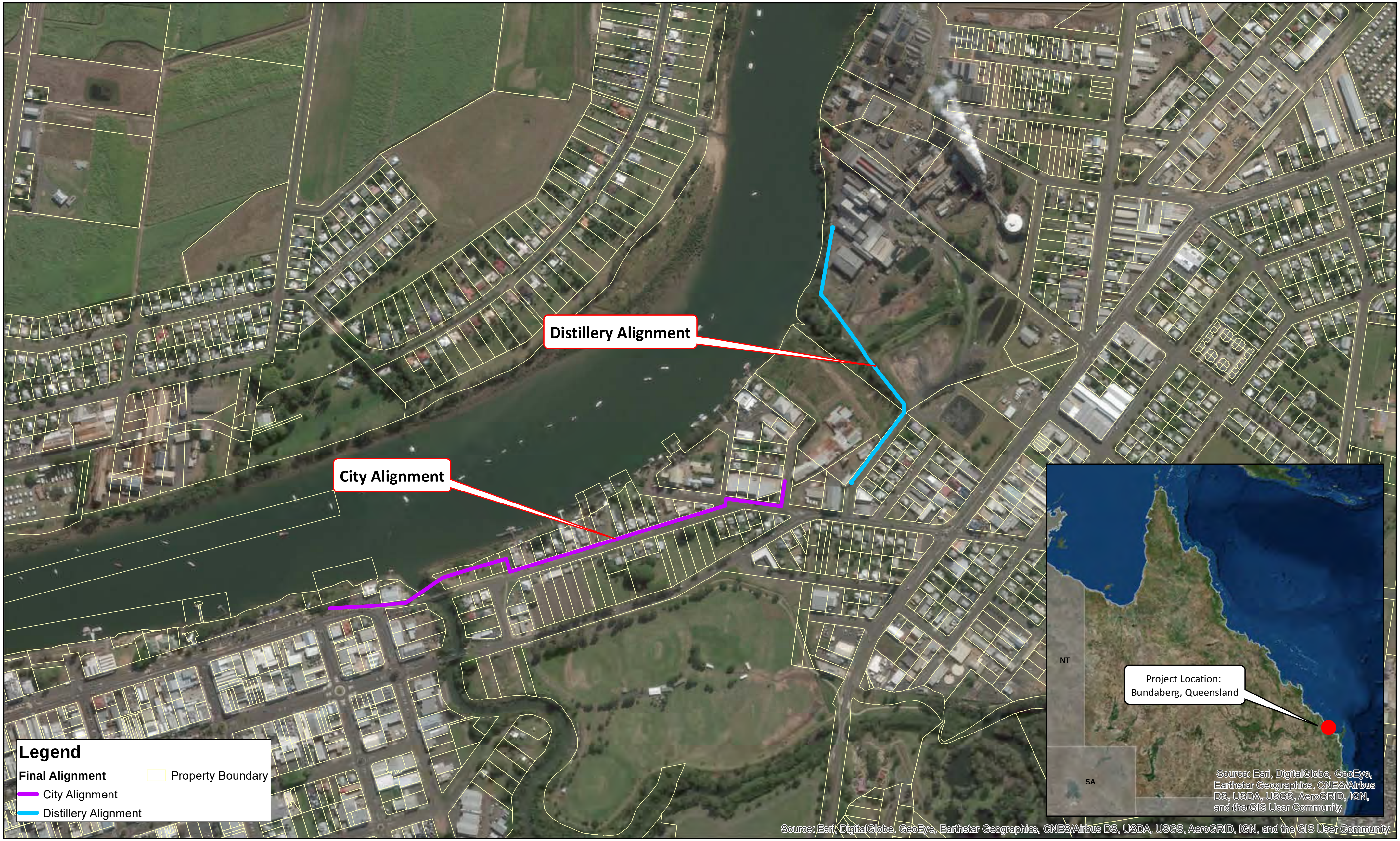

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FIGURE 1
Project Location

DRG Ref: A3L_BEN170175.01-001-Location

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Section 2 Project Description

2.1 Site Context

The proposed Bundaberg East Levee site is in an urban, residential, and mixed-use area adjacent to the southern bank of the Burnett River in Bundaberg, Queensland. The project site is bounded by Walla Street to the west, Bourbong and Cran Streets to the South, the Bundaberg Distillery to the east, and the Burnett River to the north. Unless otherwise indicated, elevations herein are in meters and referenced to the Australian Height Datum (AHD). The ground surface elevation generally ranges from approximate elevations of 2 m AHD to 11 m AHD across the project site with the low-lying areas near the Saltwater Creek and the unnamed creek near the distillery (UNC1).

2.2 Proposed Alignment and Construction

The proposed alignment for the Bundaberg East Levee runs parallel to the southern bank of the Burnett River and across Saltwater Creek and UNC1. The levee wall will consist of two main segments, referred to as the City Alignment and the Distillery Alignment (refer to Figure 1). The levee consists of a concrete flood wall with an approximate top of wall elevation of 9.5 m AHD. The base of the flood wall will sit on a foundation of piles, driven to an appropriate depth to meet the geotechnical design requirements for stability and safety. Further information on the design of the wall can be found in the Concept Engineering Report.

Section 3 Planning Context

3.1 Land Use, Planning Context and Tenure

3.1.1 Land Use

The Project is in an area comprising multiple land uses including residential, commercial and light industrial. Utilising the Queensland Government Land Use State Wide Mapping (refer to Figure 2), land uses within close proximity to the Project include residential, services, river, march/wetland, manufacturing and industrial.

3.1.2 Planning Context

The land use zones traversed by the Project identified by the Bundaberg Planning Scheme 2015 zone mapping include:

- Principle centre zone; and
- Industry zone.

Each of these zones have land use development codes that prescribe and guide the design, function and form of future development within these zones.

3.1.3 Tenure

The land traversed by the Project includes Freehold land (refer to Figure 3). The Project is impacts 7 lots and runs adjacent to 26 lots as identified in Table 1. The project alignment also impacts state land identified as road reserve and water course (refer to Figure 3).

Table 1 Lot and Tenure

Lot/Plan	Tenure
Located Within	
5/CP880929	Freehold
15/RP24765	Freehold
14/RP24765	Freehold
13/RP24765	Freehold
12/RP24765	Freehold
16/RP24765	Freehold
2/RP43264	Freehold
Located Immediately Adjacent	
5/SP172458	Freehold
6/SP172458	Freehold
16/SP240501	Freehold
11/RP24765	Freehold
10/RP24765	Freehold
9/RP24765	Freehold
8/RP24765	Freehold
7/RP24765	Freehold
36/RP24761	Freehold
2/RP48025	Freehold
1/RP182629	Freehold
2/RP182629	Freehold
7/RP51112	Freehold
6/SP162026	Freehold

Lot/Plan	Tenure
5/SP162026	Freehold
4/RP51112	Freehold
3/RP210896	Freehold
2/RP210896	Freehold
1/RP54684	Freehold
33/RP24800	Freehold
4/RP24808	Freehold
1/SP192930	Freehold
2/RP24809	Freehold
2/RP24810	Freehold
23/SP207852	Freehold
1/RP54418	Freehold
3/SP199578	Freehold

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FIGURE 2
Queensland Land Use Mapping

DRG Ref: A3L_BEN170175.01-001-LandUse

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FIGURE 3

Lot and Tenure Map

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Section 4 Characteristics and Associated Legislation

This section of the report considers the significant environmental and social characteristics and the major infrastructure components found within the project study area and considers statutory approval required to be attained for the project to be lawfully constructed.

Environmental Characteristics

4.1 Hydrology

4.1.1 Water Act 2000 Legislative Context

The *Water Act 2000* legislation is triggered when a proposed development seeks to impact a defined water course or significant drainage feature through undertaking works either in over or above an identified water feature.

Watercourse

A watercourse is defined under the *Water Act 2000* as 'a river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the flow events'. Watercourses are generally considered sensitive environmental features susceptible to erosion and impacts to both upstream and downstream users.

Drainage feature

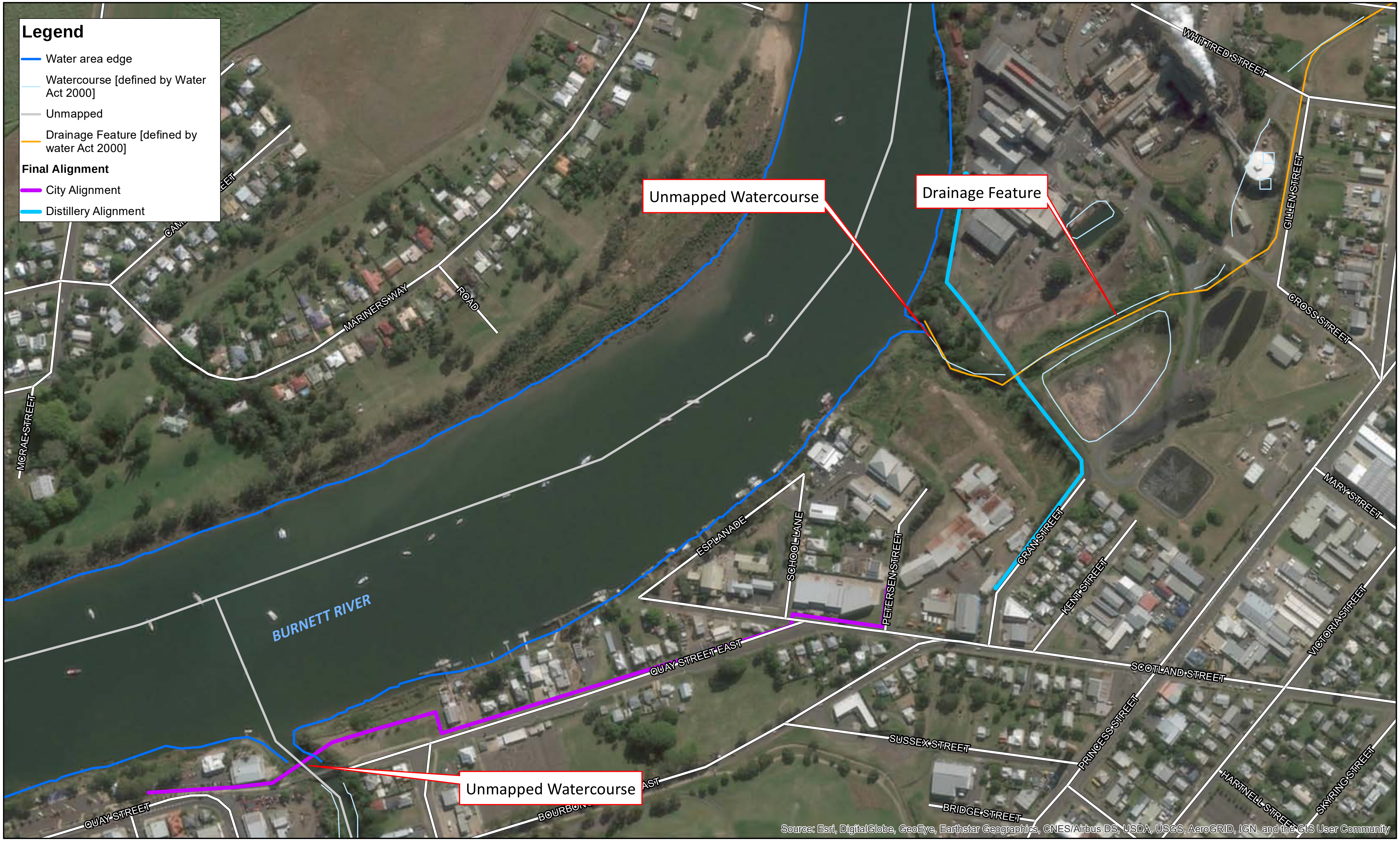
A 'drainage feature' is considered overland flow water and may require an authorisation to take or interfere with this water. A 'yet to be mapped' water feature is a feature that is not currently mapped as either a watercourse or drainage feature, this type of feature will require the proponent to gain advice from the Department of Natural Resources, Mines and Energy (DNRME) to obtain advice as to whether this feature is a watercourse, drainage feature, lake or spring under the *Water Act 2000*.

4.1.2 Implications to Study Area

The study area is located entirely within the Burnett Basin and is regulated by the *Water Plan (Burnett Basin) 2014* and the *Burnett Basin Resource Operations Plan.* The study area is adjacent to the Burnett River which is classed as a major watercourse. The Burnett River has a catchment area of 32,220 km^2. The Burnett River is tidally influenced and flows in a southwest direction.

There are two minor water courses within the study area, Bundaberg Creek and UNC1. The City Alignment option intersects Bundaberg Creek, which is yet to be mapped under the *Water Act 2000*. The Distillery Alignment option intercepts UNC1 and is mapped as 'yet to be mapped' and as a 'drainage feature' as defined by the *Water Act 2000*.

As the proposed levee alignment proposes to undertake development /works either in over or above an identified water feature the proposed development will trigger approval for works permits as identified in Section 5.



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GCS GDA 1994 MGA Zone 55

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FIGURE 4

Watercourse Mapping

A3L_BEN170175.01-001-Watercourse Mapping

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4.2 Wetlands

4.2.1 Directory of Important Wetlands Listing

The Directory of Important Wetlands is a list and map, managed by the Commonwealth Department of the Environment and Energy managed, that describes nationally important wetlands. Such wetlands are considered to have significant social, cultural and environmental values. There are no wetlands of national or international importance within the study area or the surrounding area.

4.2.2 Referable Wetlands

Referable wetlands are wetland protection areas or wetlands of high ecological significance as shown on the Map of Referable Wetlands under the EP Regulation. High ecological significance wetlands areas are listed as Matters of State Environmental Significance, as such the Department of Environment and Heritage Protection (DEHP) regulates 'high impact earthworks'. However, there are no wetland protection areas or wetlands of high ecological significance within the study area or the surrounding area. Bundaberg Creek is classified as a wetland of general environmental significance; however, general significance wetlands are not identified as MSES and as such are not managed under the *Planning Act 2016* and do not require offsets under the *Environmental Offsets Act 2014*.

4.2.3 Listed Wetlands

Listed wetlands are those features included on the Queensland Government Wetland Info database managed by DEHP. This constraint covers only those features which are not listed as referable wetlands; however, due to the ecological importance of wetlands they would necessitate environmental studies if impacted.

The Burnett River and Bundaberg Creek are mapped on the Wetland Info database as estuarine systems(e.g. mangroves, salt flats and estuaries); however, as these are not high ecological significance wetlands, no approvals are anticipated.

4.2.4 Implications to Study Area

There are no wetlands of national or international importance or high ecological significance wetlands within the study area or the surrounding area.

Bundaberg Creek is classified as a wetland of general environmental significance; however, general significance wetlands are not identified as MSES and as such are not managed under the *Planning Act 2016* and do not require offsets under the *Environmental Offsets Act 2014*.

4.3 Vegetation

4.3.1 Matters of National Environmental Significance

The EPBC Protected Matters search tool report refer to Appendix A identified one listed threatened ecological community– Lowland Rainforest of Subtropical Australia– as having the potential to occur in the study area. However, the study area has been extensively cleared with vegetation largely limited to the waterways. Current RE mapping indicates there are no REs present that may be considered Lowland Rainforest, and therefore this threatened ecological community is considered unlikely to occur within the study area.

4.3.2 Regional Ecosystems

There is one regional ecosystem (RE) listed as least concern under the *Vegetation Management Act 1999* (VM Act) within the study area Table 2.

Table 2 Regional Ecosystem

Regional Ecosystem	VM Act Class	Description	Location
12.1.3	Least concern	Mangrove shrubland to low closed forest on marine clay plains and estuaries.	Limited to the Bundaberg Creek area which is intersected by the City Alignment.

Bundaberg Creek is also mapped as wildlife habitat (on the southern side of the bridge, not intersected by the alignments) and regulated vegetation (intersecting a watercourse). These are both Matters of State Environmental Significance (MSES) (Refer to Appendix B for a MSES Report). Any destruction or disturbance to this type of vegetation will require relevant permits (refer to Section 5).

4.3.3 Implications to Study Area

RE11.1.3 is situated within the Bundaberg Creek. Any destruction or disturbance to this type of vegetation will require relevant permits (refer to Section 5).

4.4 Coastal Environment

The City Alignment is located in a Coastal Management District (CMD). Development in this area will require a relevant approval (refer to Section 5). The City Alignment is located in between two polygons identified as Tidal Waterways (refer to Figure 6), despite this contact with the Department of Environment and Science should be made to identify whether a mapping error has been made and whether this area that the levee traverses should be mapped as a tidal waterway. The City Alignment is located in a section of the Bundaberg Creek which is a Major (Level 4) waterway for waterway barrier works and as such obstruction within this waterway will require a relevant approval (refer to Section 5).

The Project is also located in a High Risk Marine Development Zone and as such, a Development Application for Tidal Works will require referral to the State and require assessment against State Code 7: Maritime Safety.

4.4.1 Implications to Study Area

The Project is located within a CMD and as such will require a relevant approval (refer to Section 5).

The City Alignment is in a section of the Bundaberg Creek which is a Major (Level 4) waterway for waterway barrier works and as such obstruction within this waterway will require a relevant approval (refer to Section 5).

4.5 Agriculture

According to SPP Mapping, the City Alignment intersects an area identified as ‘Important agricultural areas’;

4.5.1 Implications to Study Area

No further approvals will be required.

4.6 Steep Land

According to Bundaberg Regional Council Mapping, the site is in an area mapped as Steep Land (slopes >15%). As such, assessment against the Steep Land Overlay Code will be required for any *Bundaberg Planning Scheme 2015* Development Approval and may require a site-specific geotechnical assessment. Given geotechnical investigations have been undertaken for the Project, this type of assessment may not be required.

4.6.1 Implications to Study Area

The proposed development will require assessment against the relevant sections of the Bundaberg Planning Scheme 2015: Steep Land Code, to support this application a site-specific geotechnical assessment report will be required.

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FIGURE 5

MSES and RE Mapping

A3L_BEN170175.01-001-MSES and RE Mapping

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FIGURE 6

Coastal Mapping

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4.7 Contaminated Land

Prior to detail design commencing it is recommended a search of the Environmental Management Register (EMR) and Contaminated Land Register (CLR) database be undertaken to determine whether a notifiable activity has been undertaken on lots traversed by the Project.

The EMR provides information on historic and current land uses, including whether the land has been, or is currently used for a notifiable activity, or has been contaminated by hazardous material. The CLR includes land that has been proven (through investigation) to be contaminated, and is causing or has the potential to cause serious environmental harm. Therefore, land will only be recorded on the CLR when an investigation shows it is contaminated and action must be undertaken to remediate or manage the land.

4.7.1 Implications to Study Area

Should a lot be identified on the EMR a stage 1 site investigation and additional supporting studies to inform the required management and mitigation measure may need to be undertaken. In the event of removal of contaminated materials being required a permit will need to be attained.

4.8 Hazards

The Project study area has a number of environmental characteristics that have also been identified State Planning Policy (SPP) Mapping (Figure 7) as areas requiring hazard management across both sections of the alignment. The identified potential hazards requiring management include:

- Flood Hazard Area – Local Government Flood Mapping Area;
- Erosion prone area;
- Medium storm tide inundation area;
- High storm tide inundation area.

4.8.1 Implications to Study Area

The above matters will be considered when assessing a development application. The SPP includes state interests regarding hazards that relevant development applications will be required to be assessed against.

4.9 Acid Sulfate Soils

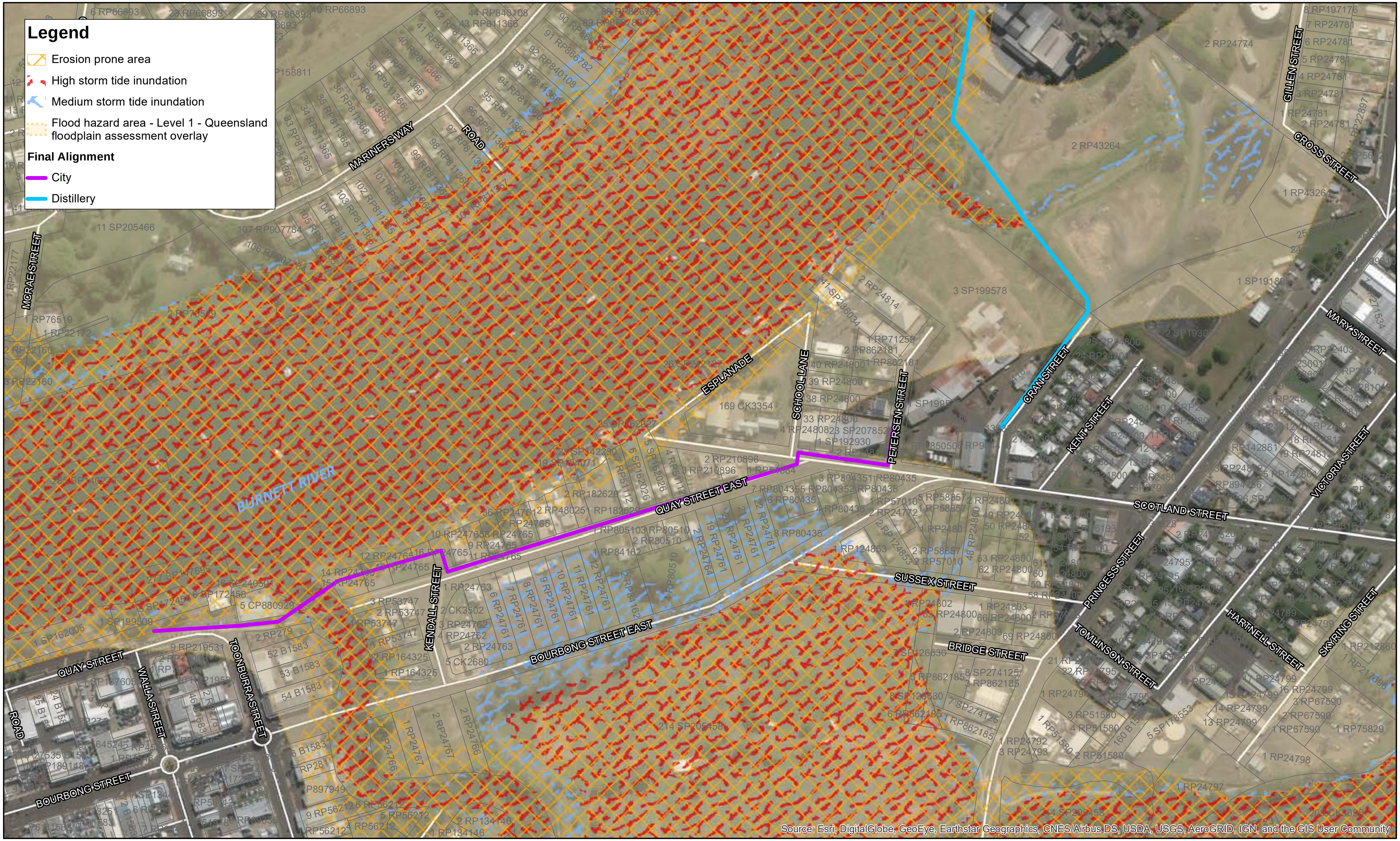
According to the Bundaberg Regional Council Mapping, the site is located in:

- Area 1 - Land at or below 5m AHD; and
- Area 2 - Land above 5m AHD and

As such, assessment against the Acid Sulfate Soils Overlay Code will be required for any *Bundaberg Planning Scheme 2015* Development Approval and is likely to require an Acid Sulfate Soils Investigation.

4.9.1 Implications to Study Area

Assessment against the Acid Sulfate Soils Overlay Code will be required for any *Bundaberg Planning Scheme 2015* Development Approval and is likely to require an Acid Sulfate Soils Investigation (refer to Section 5).



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APPROVED	MD	DATE	20/03/18

Notes:

N W E S
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Scale @ A3 - 1:4,000
GCS GDA 1994 MGA Zone 55

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

DATA SOURCE
QLD Government Open Source Data

DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

FIGURE 7

Hazard Mapping

DRG Ref: BEN170175.01-001-Hazard Mapping

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Social Characteristics

4.10 Indigenous and Non-Indigenous Cultural Heritage

Indigenous and non-Indigenous cultural heritage is protected under a range of State legislation, primarily the *Aboriginal Cultural Heritage Act 2003* (ACH Act) (Indigenous heritage) and *Queensland Heritage Act 1992* (QH Act) (non-Indigenous heritage).

Indigenous Cultural Heritage

The ACH Act contains provisions for identifying significant Aboriginal cultural heritage. The ACH Act requires that, when carrying out an activity, all reasonable and practicable measures are taken to ensure that the activity does not harm Aboriginal cultural heritage. This is referred to as the cultural heritage duty of care. The ACH Act also identifies when a cultural heritage management plan is required to be developed.

The ACH Act provides for the establishment and maintenance of the Aboriginal Cultural Heritage Register. The register has been reviewed and locational data utilised to determine known Indigenous heritage sites within the study area. A search of the Aboriginal Cultural Heritage Register identified that there were no heritage sites located within the study area. Refer to Appendix C for further information.

The Port Curtis Coral Coast Claim has been identified as the applicable Aboriginal parties within the study area. The Port Curtis Coral Coast Claim has a registered Native Title claim (QUD6026/2001, QC2001/029) covering portions of the study area. Parts of the Project are located on freehold land, as such Native Title is expected to be extinguished. For the sections where the Project is located in road reserves and waterways a Native Title Claim may be applicable.

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APPROVED	MD	DATE	20/03/18

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Metres
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DATA SOURCE
QLD Government Open Source Data

DESIGNER
CDM Smith
cdmsmith.com

CLIENT
Queensland Government

FIGURE 8

Heritage Mapping

DRG_REF BEN170175.01-001-Heritage Register

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Non-Indigenous Cultural Heritage

The QH Act provides for the conservation and protection of post European settlement cultural heritage. Under the QH Act, one must not enter or interfere with an area containing a place of cultural heritage significance that has been declared by a regulation to be a protected area, without a permit or reasonable excuse.

The QH Act provides for the establishment and maintenance of the Queensland Heritage Register which contains a record of all non-Indigenous State heritage places and protected areas. Data from the register has been accessed to identify recorded sites within and surrounding the study area.

A search of the Queensland Heritage Register identified three registered non-Indigenous heritage sites in the surrounding area. The Saltwater Creek Railway Bridge (Plate 1) is located on Quay Street within close proximity to the City Alignment. This bridge has is no longer used for rail and has been converted to a pedestrian footbridge. The Kennedy Bridge (Plate 2) is approximately 100 m upstream of the Saltwater Creek Railway Bridge approximately 130 m south from the City Alignment. The East Water Tower (Plate 3) is located at 17 Sussex Street, approximately 300 m south east of the City Alignment. Note that measurements have been taken from the closest point of the alignment option to the culturally significant locations.

There are no locally listed cultural heritage sites within either of the alignment options or buffer areas.

Source: Queensland Government 2016

Plate 1 Saltwater Creek Railway Bridge

Source: Queensland Government 2009

Plate 2 Kennedy Bridge

Source: Queensland Government 2009

Plate 3 East Water Tower

4.10.1 Implications to Study Area

For the sections where the Project is in road reserves and waterways a Native Title Claim may be applicable. The proponent may have a duty of care to ensure that the Project does not require and Cultural Heritage Management Plans for sections of the Project.

The Saltwater Creek Railway Bridge is the closest heritage site to the Project. Usually, development application for an impact on a Queensland Heritage Place is required; however, as the Levee is a project carried out by the state, the development is not considered assessable development (refer to Section 5).

Infrastructure Components

4.11 Transport, Aviation and Ports

Quay Street located to the west of the City Alignment is a State controlled road. As identified in Schedule 10, Part 9, Division 4, Subdivision 2, a development application located within 25m of a State transport corridor will be referred to the Department of Transport and Main Roads. As the City Alignment is located within 25 m of Quay Street, future development requiring a material change of use, reconfiguring of lot, or operational works application on the site will require referral to the Department of Transport and Main Roads.

The Project is located approximately 5.5 km to the north east of the Bundaberg Airport, as such, according to SPP Mapping the Project is located in the following areas:

- Obstacle limitation surface area;
- Lighting area buffer 6 km; and
- Wildlife hazard buffer zone.

It should be noted that the according to SPP Mapping the Project is not located in a height restriction zone.

The Project is also located approximately 100 m to the east of a Strategic Port area located in the Burnett River. The Port Authority is the Gladstone Ports Corporation.

4.11.1 Implications to Study Area

Future development requiring a material change of use, reconfiguring of lot, or operational works application on the site will require referral to the Department of Transport and Main Roads.

The Project will be assessable against the relevant SPP Codes and Overlays given the Project proximity to the Bundaberg Airport and Strategic Port.

Section 5 Statutory Approvals

5.1 Commonwealth Matters

The EPBC Act provides a legal framework to protect and manage Matters of National Environmental Significance (MNES) including nationally and internationally important flora, fauna, ecological communities, heritage places and water resources. The EPBC Act establishes a process for assessment and approval of proposed actions that have, or are likely to have, a significant impact on MNES.

5.1.1 Implications to Study Area

The Project is unlikely to have a significant impact on MNES therefore not requiring an EPBC Referral, however this needs to be confirmed during the detailed design phase.

5.2 State Matters

5.2.1 Planning Act 2016

The *Planning Act 2016* (Planning Act) replaced the *Sustainable Planning Act 2009* (Sustainable Planning Act). The new Act is Queensland's principal planning legislation and comprises of three main elements: plan making, development assessment and dispute resolution. Specific development is identified and regulated under the *Planning Regulation 2017*.

The Project involves the construction of a Category 3 Levee, as identified in Schedule 10, Part 19, Division 4, Subdivision 1 (32) of the *Planning Regulation 2017*, assessable development includes construction of a new Category 3 Levee. This is assessable development and will require approval prior to construction commencing. This will be in the form of an Operational Works Application for construction of a levee.

Levee Status

As identified in Table 3, the levee category, level of assessment and assessor is indicated with the Project reflecting a Category 3 Levee.

Table 3 Levee Categories

Category	Definition	Level of Assessment	Assessor
Category 1	A levee that has no off property impact	Self-assessment	Applicant
Category 2	A levee that has an off property impact and for which the affected population is less than 3	Code assessment	Local government
Category 3	A levee that has an off property impact and for which the affected population is at least 3	Impact assessment	Local government with Queensland Government as referral agency

The Guidelines for the Construction or Modification of Category 2 and 3 Levees is a document that provides information to help proponents meet requirements for the construction of levees. The Application process for the construction or modification for a Category 3 Levee is summarised in Figure 9.

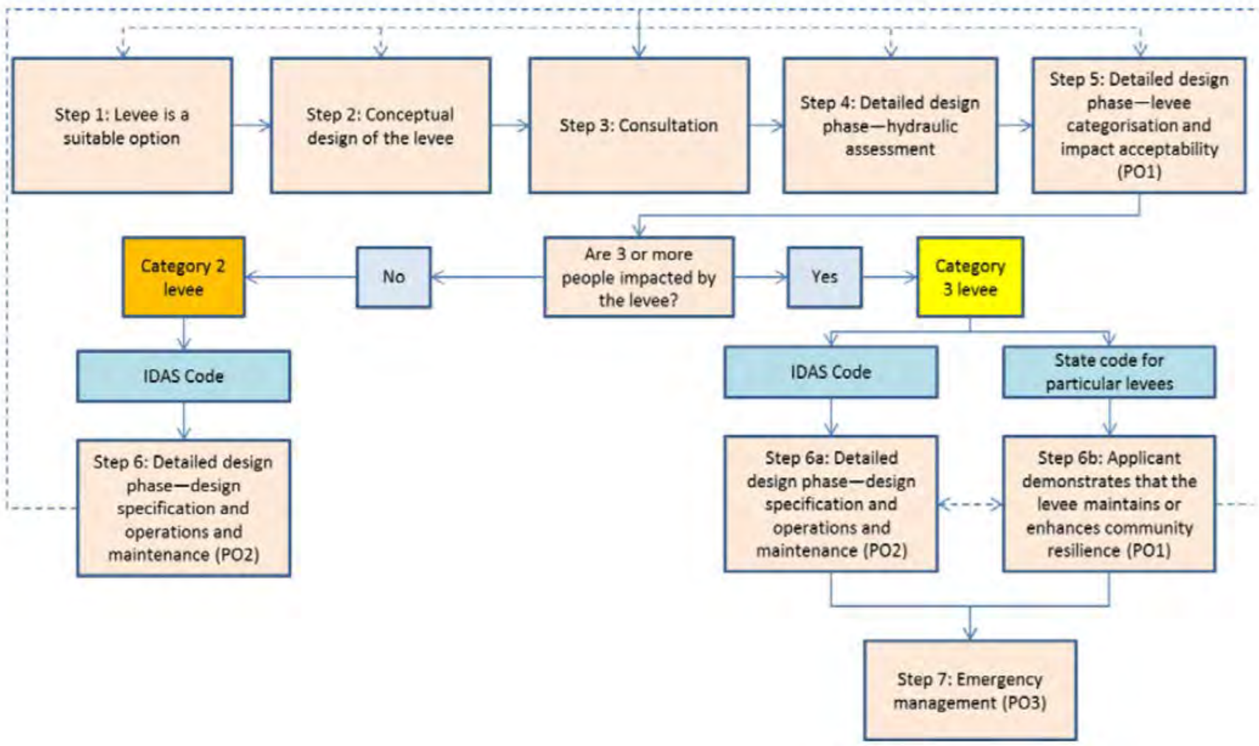
The Project will be assessed against 'State Code 10: Category 3 Levees' as well as the local planning scheme requirements and stat interests will be coordinated by the State Assessment and Referral Agency.

State Code 10 has been produced to ensure the community's resilience to the impacts of flood events, levee failure or levee overtopping are maintained or enhanced by the levee. Both the Guideline and State Code 10 identify additional studies and requirements for constructing a Category 3 levee and include:

- A vulnerability and tolerability assessment report;
- Hydrological/hydraulic assessment;
- Levee categorisation and impact acceptability;
- Design specification and operations and maintenance manual; and
- Emergency action plan in the local governments local disaster management plan.

For category 3 levees, the applicant may provide an appraisal report, signed off by a suitably qualified person. This appraisal report should describe the alternative options that have been considered and compared these to the levee option. This process should address the potential social, economic and environmental impacts as well as the technical aspects of the proposed levee.

Figure 9 Application Process for Construction of a Category 3 Levee



5.2.2 Environmental Protection Act 1994

The (EP Act) provides the key legislative framework for environmental management and protection in Queensland. Under the EP Act, an entity must comply with the general environmental duty not to undertake: : 'An activity that causes, or is likely to cause, environmental harm unless…all reasonable and practicable measures to prevent or minimise the harm are taken' (Section 319). The EP Act contains a range of subordinate legislation for water, air and noise emissions that apply to construction and operational works.

The EP Act provides for the identification of wetlands and of wetland management or protection areas on the state map of referable wetland database. No referrable wetlands are located in close proximity to the site.

5.3 Local Matters

The Project is managed under the *Bundaberg Planning Scheme 2015*. As previously stated the Project is located within the Principle Centre Zone and Industry Zone. Part 5 of the *Bundaberg Planning Scheme 2015* identifies the relevant assessment criteria for a material change of use and operational works application.

5.3.1 Material Change of Use

The *Bundaberg Planning Scheme 2015* does not have a clear use definition for the Project. A request is required to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with. As identified in the 'Regulation of Levees in Queensland: Consultation Regulatory Impact Statement' (Department of Natural Resources and Mines, 2013), a number of local governments have not generally incorporated levees into their primary planning considerations. Some local governments have dealt with these types of structures by listing development that involves water cycle management infrastructure for flood mitigation as being exempt development.

Schedule 1 of the planning scheme identifies use definitions. The most likely use definition for the Project is 'Utility Installation', which is defined as a:

> *Premises used to provide the public with the following services:*
>
> - *supply or treatment of water, hydraulic power or gas*
> - *sewerage, drainage or stormwater services*
> - *transport services including road, rail or water*
> - *waste management facilities or*
> - *network infrastructure.*
>
> *The use includes maintenance and storage depots and other facilities for the operation of the use*

Utility installation is identified as exempt development under each of the above zones, if it is considered a local utility. A local utility as defined in Schedule 1 of the *Bundaberg Planning Scheme 2015* includes:

> *A utility installation involving one or more of the following:*
>
> *(a) any undertaking by the Council or other public sector entity for:*
>
> *(i) the reticulation or conveyance of water, sewerage and stormwater drainage*
>
> *(ii) the provision or maintenance of roads and traffic controls or*
>
> *(iii) a public purpose carried out by the Council pursuant to the Local Government Act 2009*
>
> *(b) the reticulation of power (including electricity and gas)*
>
> *(c) activities and associated facilities that support the effective functioning of public transport services, including bus, rail, road and water transport*
>
> *(d) activities and associated facilities that support the effective management of a State Forest, National Park or Conservation Park*
>
> *(e) the provision of postal services or*
>
> *(f) the provision of telecommunication services not involving the erection of a telecommunications facility.*
>
> *The term includes ancillary maintenance and storage depots and other facilities for the operation of the local utility.*

5.3.2 Operational Works

Part 5, Section 7 of the *Bundaberg Planning Scheme 2015* identifies categories of development and assessment for operational work. Potential operational work approvals are identified below.

Operational work - engineering work or landscaping work

This covers operational work involving:

- Engineering work or landscaping work that **IS** associated with a material change of use; and
- Engineering work **NOT** associated with a material change of use or reconfiguring a lot.

Refer to the below table for requirements of each of these operational works.

Table 4 Operational work - engineering work or landscaping work

Development	Categories of Development	Status
Operational work involving engineering work or landscaping work associated with a material change of use	**Accepted subject** to requirements if for the following work:- (a) on-site landscaping; (b) internal vehicle circulation, manoeuvring and car parking areas; (c) on-site stormwater management and incidental stormwater pipe and outlets; (d) access driveways	The Project may be classified as on-site stormwater management. If a material change of use is required, this development may be identified as accepted and therefore an application is not required.
	Code assessment if not accepted subject to requirements.	If the Project does require a material change of use and is not for any of the accepted uses, the Project will be code assessable.
Operational work involving engineering work not associated with a material change of use or reconfiguring a lot	**Code assessment**	If a material change of use is not required, the Project will be code assessable as it requires engineering work.

Operational work – excavating or filling

Operational work involving excavating or filling is expected. As sections of the Project are not on council owned land or rural zoned land and will require excavating or filling more than 50 m^3, the development is likely to be code assessable.

5.4 Approvals Matrix

An approvals matrix has been prepared, classifying approvals into one of the three following categories (refer to Table 5):

- Unlikely to be required;
- Likely required; and
- Required.

An indicative preparation and assessment timeframe matrix has also been prepared, provided as Table 6.

Table 5 Summary of Related Legislation and Approvals

Legislation	Approval	Trigger	Justification	Status
Commonwealth				
Environment Protection and Biodiversity Conservation Act 1999	Referral under the EPBC Act	The EPBC Act provides a legal framework to protect and manage Matters of National Environmental Significance (MNES) including nationally and internationally important flora, fauna, ecological communities, heritage places and water resources. The EPBC Act establishes a process for assessment and approval of proposed actions that have, or are likely to have, a significant impact on MNES.	The review has considered MNES and the location of MNES in proximity to the site. These are considered in Section 4.3.1. The Project is unlikely to have a significant impact on MNES therefore not requiring an EPBC Referral, however this needs to be confirmed during the detailed design phase..	**Unlikely – Requiring Confirmation**
Queensland				
Environmental Protection Regulation 2008	Environmental Authority (EA) application for Environmentally Relevant Activity	This regulation also sets out Environmentally Relevant Activities (ERA) which require environmental authorities.	A preliminary review of ERA's has been undertaken, with the ERA 16 Extractive and Screening Activities identified as a potential ERA. Should construction be confirmed, a review of ERA's as identified in the *Environmental Protection Regulation 2008* should be undertaken.	**Likely – Requiring Confirmation**
Vegetation Management Act 1999	Operational works for vegetation clearing	This Act regulates the conservation and management of vegetation communities and provides protection for regional ecosystems (RE) classified as 'endangered', 'of concern' or 'least concern' under the VM Act. The VM Act also regulates essential habitat which are areas considered essential for the maintenance of protected wildlife.	A search of regional ecosystems has been undertaken. These areas in proximity to the site are identified in Section 4.3.2. Both alignments are located in Category X vegetation under the VM Act. There is however a portion of mapped Category B Remanent Vegetation located immediately to the south of the alignment. It is recommended a vegetation survey be undertaken to confirm the location and presence of vegetation located in the vicinity of the pipeline. This will confirm whether an application to clear vegetation is required.	**Likely – Requiring Confirmation**

Legislation	Approval	Trigger	Justification	Status
Nature Conservation Act 1992	Clearing permit (protected plants)	This Act seeks to gather relevant information, identify critical habitat areas, manage protected areas, protect wildlife and promote ecologically sustainable development.	The Protected Plants Flora Survey Trigger Map shows areas which are applicable to provisions of the NC Act. A search of flora survey trigger areas has identified that the site is not within a flora survey trigger area (refer to Appendix D). Under Section 256 of the *Nature Conservation (Wildlife Management) Regulation 2006*, a flora survey is required before any clearing is undertaken in a high-risk area. It is recommended a pre-clearance survey be undertaken prior to work. This may identify protected plants at which point a clearing permit may still be required.	**Unlikely – Requiring Confirmation based on Pre-Clearance Survey**
Water Act 2000	Operational works for construction of a levee	As identified in Schedule 10, Part 19, Division 4, Subdivision 1 (32) of the *Planning Regulation 2017*, assessable development includes construction of a new category 3 levee.	The Project involves the construction of a Category 3 Levee. This is assessable development and will require approval prior to construction commencing.	**Required**
	Riverine Protection Permit	Provides a structured system for the planning, protection, allocation and use of Queensland's surface waters and groundwater. A Riverine Protection Permit is required where excavation and fill are required within the bed and banks of a watercourse.	There are two watercourses that are intersected by the Project. A Riverine Protection Permit for interfering or diverting a watercourse is expected.	**Required**
Aboriginal Cultural Heritage Act 2003	Cultural Heritage Clearance	Contains provisions for identifying significant Aboriginal cultural heritage. The ACH Act requires that, when carrying out an activity, all reasonable and practicable measures are taken to ensure that the activity does not harm Aboriginal cultural heritage. This is referred to as the cultural heritage duty of care. The ACH Act provides for the establishment and maintenance of the Aboriginal Cultural Heritage Register.	A review of this register identified there are no aboriginal cultural heritage sites within close proximity to the Project.	**Likely – Requiring Confirmation**

Legislation	Approval	Trigger	Justification	Status
Queensland Heritage Act 1992	Material change of use for development on a Queensland Heritage Place	Provides for the conservation and protection of post European settlement cultural heritage. The Act requires person to not enter or interfere with an area containing a place of cultural heritage significance that has been declared by a regulation to be a protected area without a permit or with reasonable excuse. The QH Act provides for the Queensland Heritage Register which contains a record of all non-Indigenous State heritage places and protected areas. As identified in Schedule 10, Part 8, Division 2, Subdivision 1, development on a Queensland Heritage Place is assessable development, unless the development is carried out by the State (15c).	There are two Queensland Heritage places in close proximity to the Project. As the Levee is a project carried out by the state, the development is not considered assessable development. Under the QH Act, a person is required to report to the Department of Environment and Heritage Protection (EHP) the discovery of any archaeological artefact or underwater cultural heritage artefact that is an important source of information about an aspect of Queensland history.	**Unlikely – Requiring Confirmation**
Coastal Protection and Management Act 1995	Operational works for tidal works and works in a CMD	The Act defines coastal management districts (CMD) and erosion prone areas where works undertaken in these areas may require an approval. Certain development may require an approval for conducting works within a CMD including Operational Works such as tidal works and interfering with quarry material. Under Schedule 10, Part 17, Division 1 Assessable development includes operational work that is tidal works or work in a CMD if the works is tidal works or is disposing of dredge, spoil or other solid waste material in tidal water.	The site is within a within a CMD and is located between two mapped tidal waterways. It is expected that the section between the two tidal polygons is indeed tidal water. It is also assumed that the Project is likely to involve some placing of spoil or other solid material in tidal water. As such, an application for Tidal Works or Works in a CMD is expected.	**Required**
Fisheries Act 1994	Operational Works for removal, destruction or damage of a marine plant is assessable development	Developed to manage, use develop and protect fisheries resources and fish habitats. Under Schedule 10, Part 6, Division 3 of the *Sustainable Planning Regulation 2017*, assessable development includes operational work that is the removal, destruction or damage of a marine plant is assessable development	The mapped RE (12.1.3) includes Least concern Mangrove shrubland to low closed forest on marine clay plains and estuaries. This is a marine plant, as such damage or disturbance to these plants will require an operational works development permit.	**Required**
	Operational works for waterway barrier works	Under Schedule 10, Part 6, Division 4 of the *Sustainable Planning Regulation 2017*, assessable development includes construction or raising waterway barrier works.	There is mapped Major (Level 4) waterway for waterway barrier works that the City Alignment crosses. It is expected that the construction and operation of the levee will impede fish passage in this waterway, as such an operational works development permit for Waterway Barrier Works is expected	**Required**

Legislation	Approval	Trigger	Justification	Status
Local				
Bundaberg Regional Council Planning Scheme 2015	Material change of use for Utility Installation.	As identified in Section 5.3.1 a possible use for the Proejct includes 'Utility Installation' Utility installation is identified as exempt development under each of the above zones, if it is considered a local utility. As such, the Project may be identified as a local utility as defined in Schedule 1 of the *Bundaberg Planning Scheme 2015*.	As the Project does not have a clear use definition a request would need to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with	**Likely – Requiring Confirmation**
	Operational work - engineering work or landscaping work	As identified in Section 5.3.2 an operational works permit may be required for engineering work or landscaping work. This depends on whether the development is identified an exempt material change of use or if it is classified as on-site stormwater management.	As the Project does not have a clear use definition and is not understood to be exempt development or not, a request would need to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with.	**Likely – Requiring Confirmation**
	Operational work – excavating or filling	Operational work involving excavating or filling is expected. As the Project is not on council owned land or rural zoned land and will require excavating or filling more than 50 m^3, the development is likely to be code assessable.	As the Project involves significant excavation and filling, this is expected.	**Required**

Table 6 Approval Timeframes and Supporting Material

Approval	Justification	Status	Time Frame	Supporting Material
Commonwealth				
Referral under the EPBC Act	The Project is unlikely to have a significant impact on MNES therefore not requiring an EPBC Referral, however this needs to be confirmed during the detailed design phase.	**Unlikely – Requiring Confirmation**	**N/A**	**N/A**
Queensland				
Environmental Authority (EA) application for Environmentally Relevant Activity	A preliminary review of ERA's has been undertaken, with the ERA 16 Extractive and Screening Activities identified as a potential ERA. Should construction be confirmed, a review of ERA's as identified in the *Environmental Protection Regulation 2008* should be undertaken.	**Likely – Requiring Confirmation**	**Preparation of Application – 2-3 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Method of operation; ▪ Construction methods; ▪ Vegetation assessment; ▪ Environmental controls; and ▪ Owners consent.
Operational works for vegetation clearing	A search of regional ecosystems has been undertaken. These areas in proximity to the site are identified in Section 4.3.2. Both alignments are located in Category X vegetation under the VM Act. There is however a portion of mapped Category B Remanet Vegetation located immediately to the south of the alignment. It is recommended a vegetation survey be undertaken to confirm the location and presence of vegetation located in the vicinity of the pipeline. This will confirm whether an application to clear vegetation is required.	**Likely – Requiring Confirmation**	**Preparation of Application – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Method of operation; ▪ Construction methods; ▪ Vegetation assessment; and ▪ Owners consent.
Clearing permit (protected plants)	The Protected Plants Flora Survey Trigger Map shows areas which are applicable to provisions of the NC Act. A search of flora survey trigger areas has identified that the site is not within a flora survey trigger area (refer to Appendix D). Under Section 256 of the *Nature Conservation (Wildlife Management) Regulation 2006*, a flora survey is required before any clearing is undertaken in a high risk area. It is recommended a pre-clearance survey be undertaken prior to work. This may identify protected plants at which point a clearing permit may still be required.	**Unlikely – Requiring Confirmation based on Pre-Clearance Survey**	**Preclearance Survey – 1 Week**	▪ Protected Plants Assessment Guidelines

Approval	Justification	Status	Time Frame	Supporting Material
Operational works for construction of a levee	The Project involves the construction of a Category 3 Levee. This is assessable development and will require approval prior to construction commencing.	**Required**	**Preparation of Application and Supporting Information – 2-3 Months** **Assessment Timeframe – 5-6 Months**	▪ A vulnerability and tolerability assessment report; ▪ Hydrological/hydraulic assessment; ▪ Levee categorisation and impact acceptability; ▪ Design specification and operations and maintenance manual; ▪ Emergency action plan in the local governments local disaster management plan; and ▪ Owners consent.
Riverine Protection Permit	There are two watercourses that are intersected by the Project. A Riverine Protection Permit for interfering or diverting a watercourse is expected.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout; ▪ Method of operation; ▪ Construction methods; and ▪ Owners consent.
Cultural Heritage Clearance	A review of this register identified there are no aboriginal cultural heritage sites within close proximity to the Project; however, a cultural heritage management plan may be required for	**Unlikely – Requiring Confirmation**	**N/A**	**N/A**
Material change of use for development on a Queensland Heritage Place	There are two Queensland Heritage places in close proximity to the Project. As the Levee is a project carried out by the state, the development is not considered assessable development. Under the QH Act, a person is required to report to the Department of Environment and Heritage Protection (EHP) the discovery of any archaeological artefact or underwater cultural heritage artefact that is an important source of information about an aspect of Queensland history.	**Unlikely – Requiring Confirmation**	**N/A**	**N/A**

Approval	Justification	Status	Time Frame	Supporting Material
Operational works for tidal works and works in a CMD	The site is within a within a CMD and is located between two mapped tidal waterways. It is expected that the section between the two tidal polygons is indeed tidal water. It is also assumed that the Project is likely to involve some placing of spoil or other solid material in tidal water. As such, an application for Tidal Works or Works in a CMD is expected.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout ▪ Clearing method ▪ Owners consent
Operational Works for removal, destruction or damage of a marine plants	The mapped RE (12.1.3) includes Least concern Mangrove shrubland to low closed forest on marine clay plains and estuaries. This is a marine plant, as such damage or disturbance to these plants will require an operational works development permit.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout ▪ Clearing method ▪ Owners consent
Operational works for waterway barrier works	There is mapped Major (Level 4) waterway for waterway barrier works that the City Alignment crosses. It is expected that the construction and operation of the levee will impede fish passage in this waterway, as such an operational works development permit for Waterway Barrier Works is expected	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Details of construction materials ▪ Details of proposed barrier ▪ Details of construction method ▪ Owners consent
Local				
Material change of use for Utility Installation.	As the Project does not have a clear use definition a request would need to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with	**Likely – Requiring Confirmation**	**Preparation of Application and Supporting Information – 1-2 Months** **Assessment Timeframe – 3-4 Months**	▪ Design details and layout ▪ Details of construction materials ▪ Acid sulfate soil investigation; ▪ Site-specific geotechnical assessment
Operational work - engineering work or landscaping work	As the Project does not have a clear use definition and is not understood to be exempt development or not, a request would need to be made to the Bundaberg Regional Council to confirm which use definition the infrastructure best aligns with.	**Likely – Requiring Confirmation**	**Preparation of Application and Supporting Information – 1-2 Months** **Assessment Timeframe – 3-4 Months**	▪ Design details and layout ▪ Details of construction materials ▪ Acid sulfate soil investigation; ▪ Drawings showing fill and excavation proposed; ▪ Fill and excavation amount; and ▪ Onwers consent.

Approval	Justification	Status	Time Frame	Supporting Material
Operational work – excavating or filling	As the Project involves significant excavation and filling, this is expected.	**Required**	**Preparation of Application and Supporting Information – 3-4 Weeks** **Assessment Timeframe – 2-3 Months**	▪ Design details and layout ▪ Details of construction materials ▪ Acid sulfate soil investigation; ▪ Drawings showing fill and excavation proposed; ▪ Fill and excavation amount; and ▪ Owners consent.

Section 6 Development Approval

6.1 Bundaberg Regional Council Planning Scheme

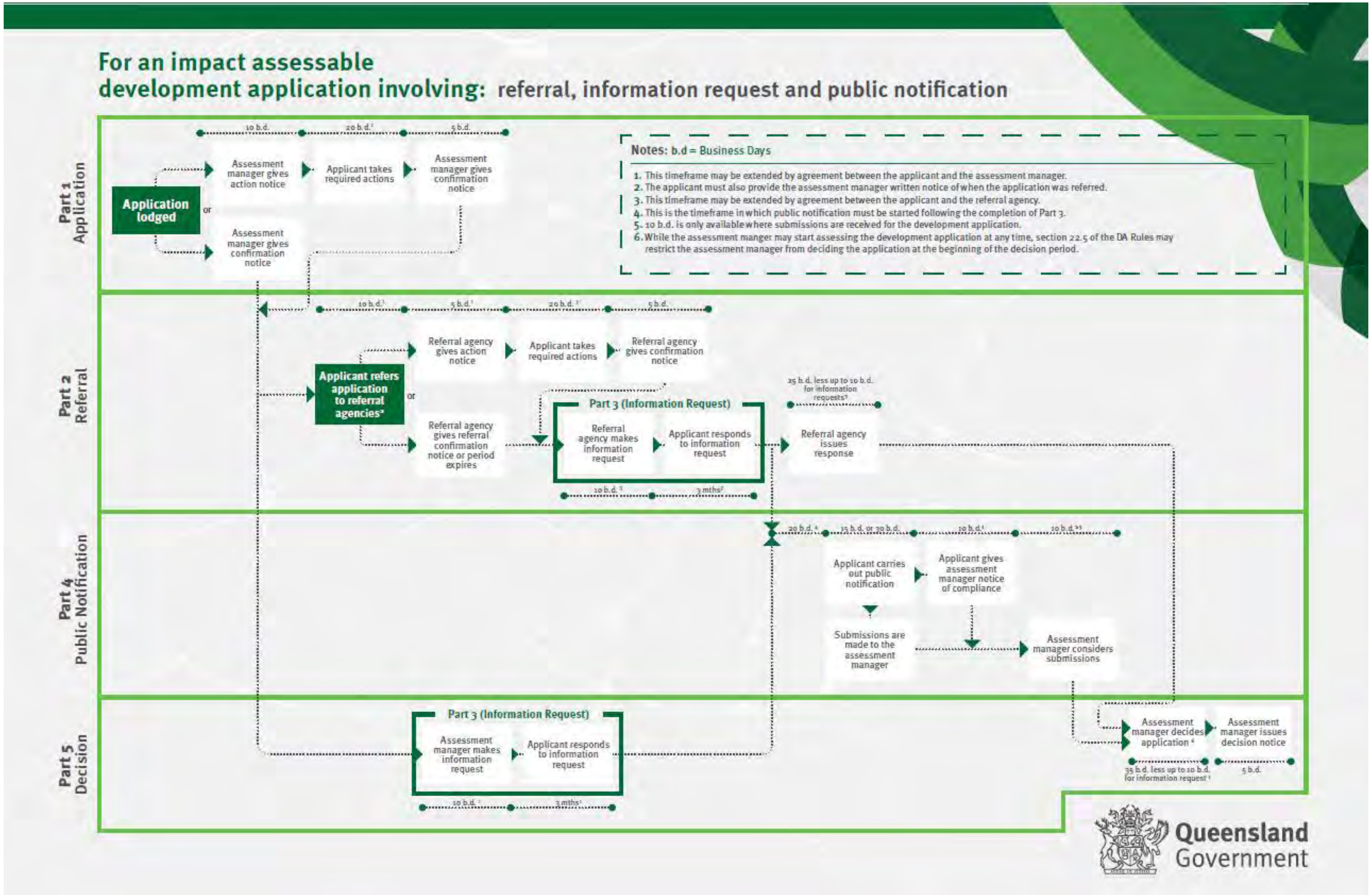
The proposed development of the Bundaberg Levee will require a development application to be lodged with the Bundaberg Regional Council as the assessment manager. The application for a category 3 levee will require referral to the State Government for coordination and assessment of the state interests.

The project will also be assessed against the relevant sections of the applicable codes of the Bundaberg Regional Council Planning Scheme 2015 the information required to support the required development application is identified in the approvals matrix (Table 5).

The time frame associated with attaining the applicable approvals for the proposed development is in the order of 4 to 6 months (Figure 10). The drafting of the development application and the appropriate level of assessment will need to be defined by the Assessment Manager in the case of a Material Change of Use application it will be Bundaberg Regional Council. The applications will require liaison with the applicable state agencies. The timelines for the assessment of the application are variable based on a range of matters including:

- Request for future information;
- Variability of state agency review and comment times; and
- Variability of assessment managers response times.

Figure 10 Development Application Flowchart



Section 7 Recommendations for Next Steps

It is understood that the Bundaberg levee is to be constructed during the 2019 dry season commencing work on site in April 2019. Given the proposed project delivery timeframe it is recommend that the development applications and supporting information are lodge no later than July- August 2018. This should provide for the enough time for the development approvals and associated conditions of approval to be included with the construction tender documentation.

Appendix A EPBC Review

Australian Government
Department of the Environment and Energy

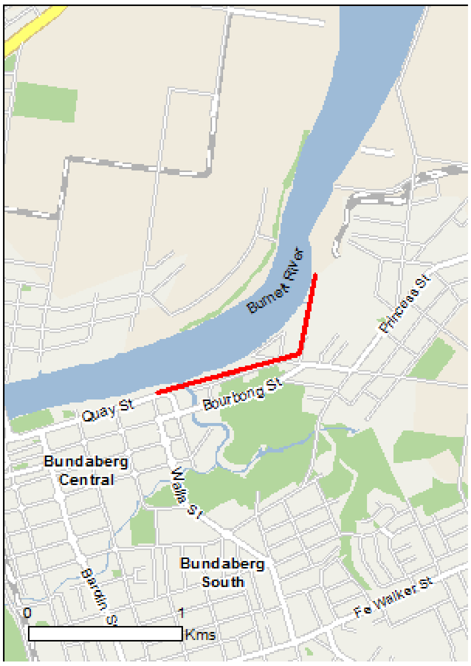
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

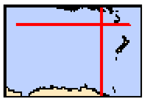
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 08/03/18 14:09:11



Coordinates
Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	44
Listed Migratory Species:	36

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	1
Listed Marine Species:	41
Whales and Other Cetaceans:	2
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	26
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Lowland Rainforest of Subtropical Australia	Critically Endangered	Community may occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Species or species habitat may occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Species or species habitat may occur within area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species habitat likely to occur within area
Mammals		
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Nyctophilus corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat may occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Roosting known to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Acacia attenuata [10690]	Vulnerable	Species or species habitat likely to occur within area
Cupaniopsis shirleyana Wedge-leaf Tuckeroo [3205]	Vulnerable	Species or species habitat likely to occur within area
Cycas megacarpa [55794]	Endangered	Species or species habitat may occur within area
Cycas ophiolitica [55797]	Endangered	Species or species habitat may occur within

Name	Status	Type of Presence
		area
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat may occur within area
Macadamia integrifolia Macadamia Nut, Queensland Nut Tree, Smooth-shelled Macadamia, Bush Nut, Nut Oak [7326]	Vulnerable	Species or species habitat may occur within area
Phaius australis Lesser Swamp-orchid [5872]	Endangered	Species or species habitat likely to occur within area
Samadera bidwillii Quassia [29708]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat known to occur within area
Elseya albagula Southern Snapping Turtle, White-throated Snapping Turtle [81648]	Critically Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding may occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat may occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding may occur within area

Name	Threatened	Type of Presence
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat likely to occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat known to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Bundaberg Post Office	QLD	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Breeding likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Cuculus saturatus Oriental Cuckoo, Himalayan Cuckoo [710]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat likely to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat known to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat likely to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area

Extra Information

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Lonchura punctulata Nutmeg Mannikin [399]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Dolichandra unguis-cati Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw		Species or species

Name	Status	Type of Presence
Creeper, Funnel Creeper [85119]		habitat likely to occur within area
Eichhornia crassipes		
Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Hymenachne amplexicaulis		
Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		Species or species habitat likely to occur within area
Jatropha gossypifolia		
Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara		
Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Opuntia spp.		
Prickly Pears [82753]		Species or species habitat likely to occur within area
Parthenium hysterophorus		
Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur within area
Salvinia molesta		
Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-24.86292 152.35528,-24.86085 152.36369,-24.85657 152.36463

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

Appendix B MSES Report

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
Longitude: 152.360771 Latitude: -24.861889 with 2 kilometre radius

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

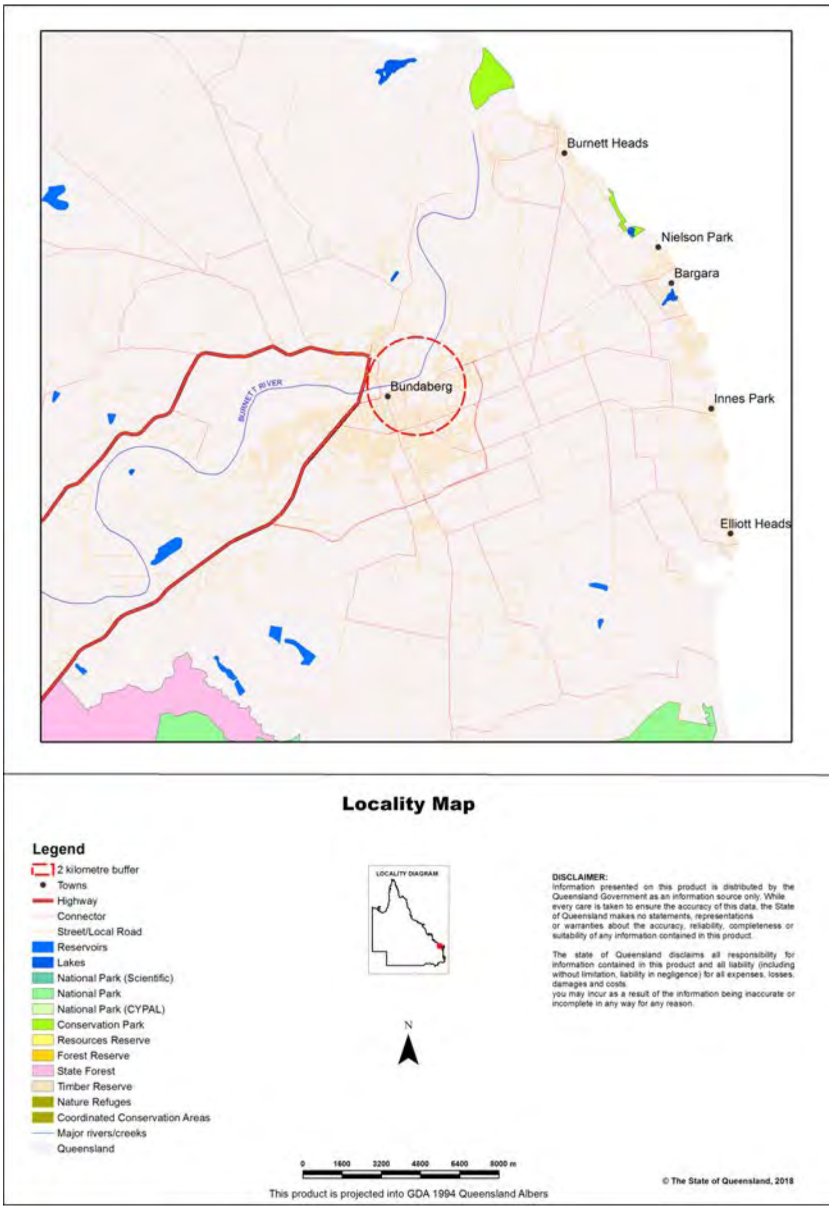
Table of Contents

Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI Longitude: 152.360771 Latitude: -24.861889 with 2 kilometre radius

Size (ha)	1,256.55
Local Government(s)	Bundaberg Regional
Bioregion(s)	Southeast Queensland
Subregion(s)	Burnett - Curtis Coastal Lowlands
Catchment(s)	Burnett



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

  • Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;

  • Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;

  • Category R areas on the regulated vegetation management map;

  • Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;

  • Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Referable Wetlands under the Environmental Protection Regulation 2008;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;

- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	1.42 ha	0.1%
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways **	0.0 km	Not applicable
7 Threatened species and Iconic species	27.72 ha	2.2%
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	8.5 ha	0.7%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	0.0 ha	0.0 %
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0.0 ha	0.0 %
8d Regulated Vegetation - Essential habitat	0.0 ha	0.0 %
8e Regulated Vegetation - intersecting a watercourse **	15.2 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	2.28 ha	0.2%
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Referable Wetlands

Natural wetlands that are 'High Ecological Significance' (HES) on the Map of Referable Wetlands are present.

6a. High Ecological Value (HEV) waters - wetlands

(no results)

6b. High Ecological Value (HEV) waters - waterways

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7. Threatened wildlife and special least concern animal

Threatened species and iconic species	Act	Species least concern animal	Koala Bushland Habitat	Dugong Protection	VMA Essential 2014 Habitat
Threat wildlife & Spec LeastC animals	NCA, VMA	None	None	None	None

Threatened species and iconic species	Act	Species least concern animal	Koala Bushland Habitat	Dugong Protection	VMA Essential 2014 Habitat
Threat wildlife & Spec LeastC animals	NCA, VMA	Echidna	None	None	None
Threat wildlife & Spec LeastC animals	NCA	Echidna	None	None	None

Threatened and special least concern species records

Scientific name	Common name	NCA status	EPBC status
Tachyglossus aculeatus	short-beaked echidna	SL	None
Cupaniopsis shirleyana	wedge-leaf tuckeroo	V	V

Note: The Threatened and Special Least Concern Animal (7) layer originates from the previous MSES version (4.1, dated at 2014). The layer does not represent all currently listed species and is subject to review.

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3 - MSES - Species** for an overview of the relevant MSES.

MSES - Regulated Vegetation

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
12.5.13b	E-dom	rem_end
12.3.17	O-dom	rem_oc
12.3.3	E-dom	rem_end

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Not applicable

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Not applicable

8d. Regulated Vegetation - Essential habitat

Not applicable

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Regulated vegetation map category	Map number	RVM rule
B	9348	2

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

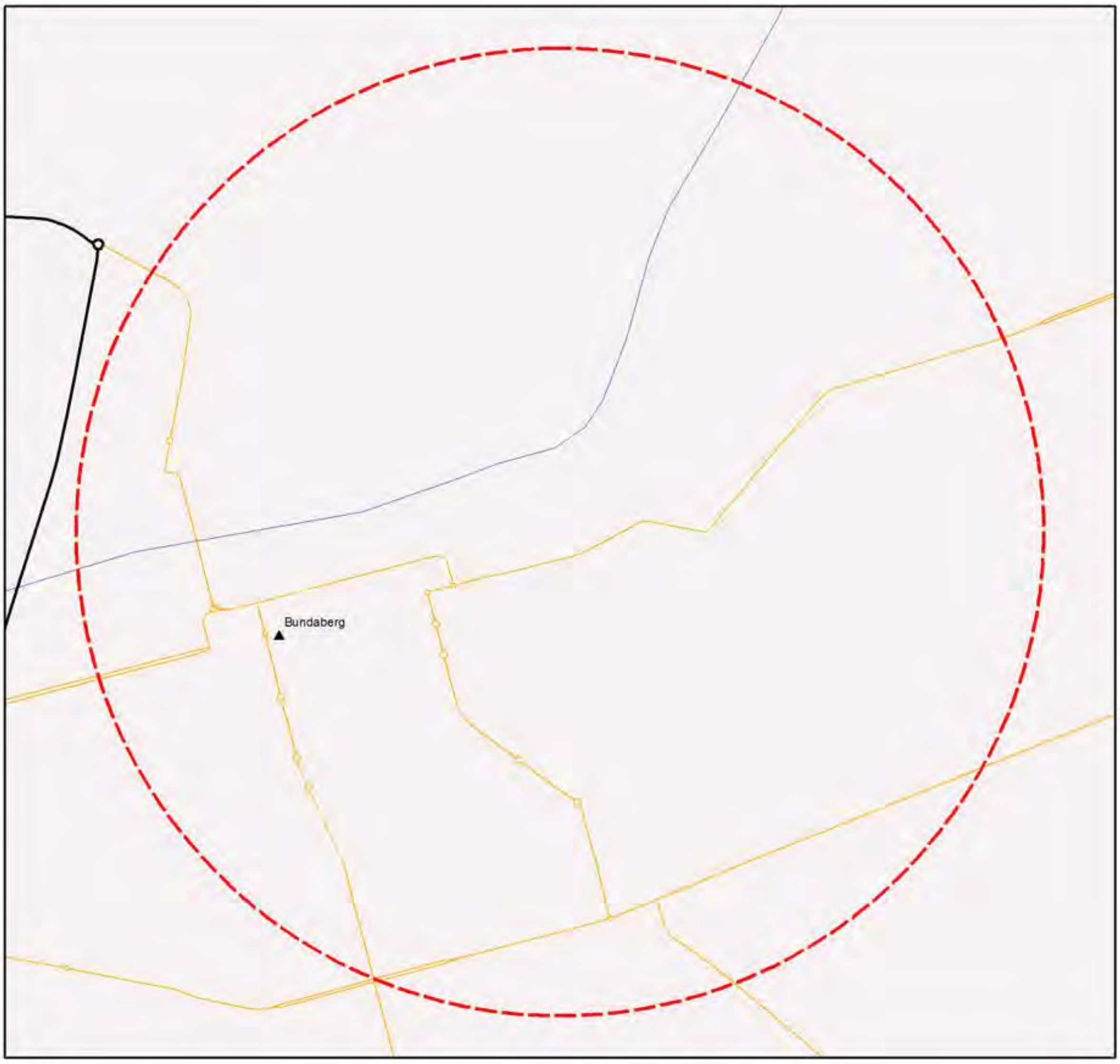
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

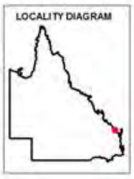
Map 1 - MSES - State Conservation Areas



MSES - State Conservation Areas

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)



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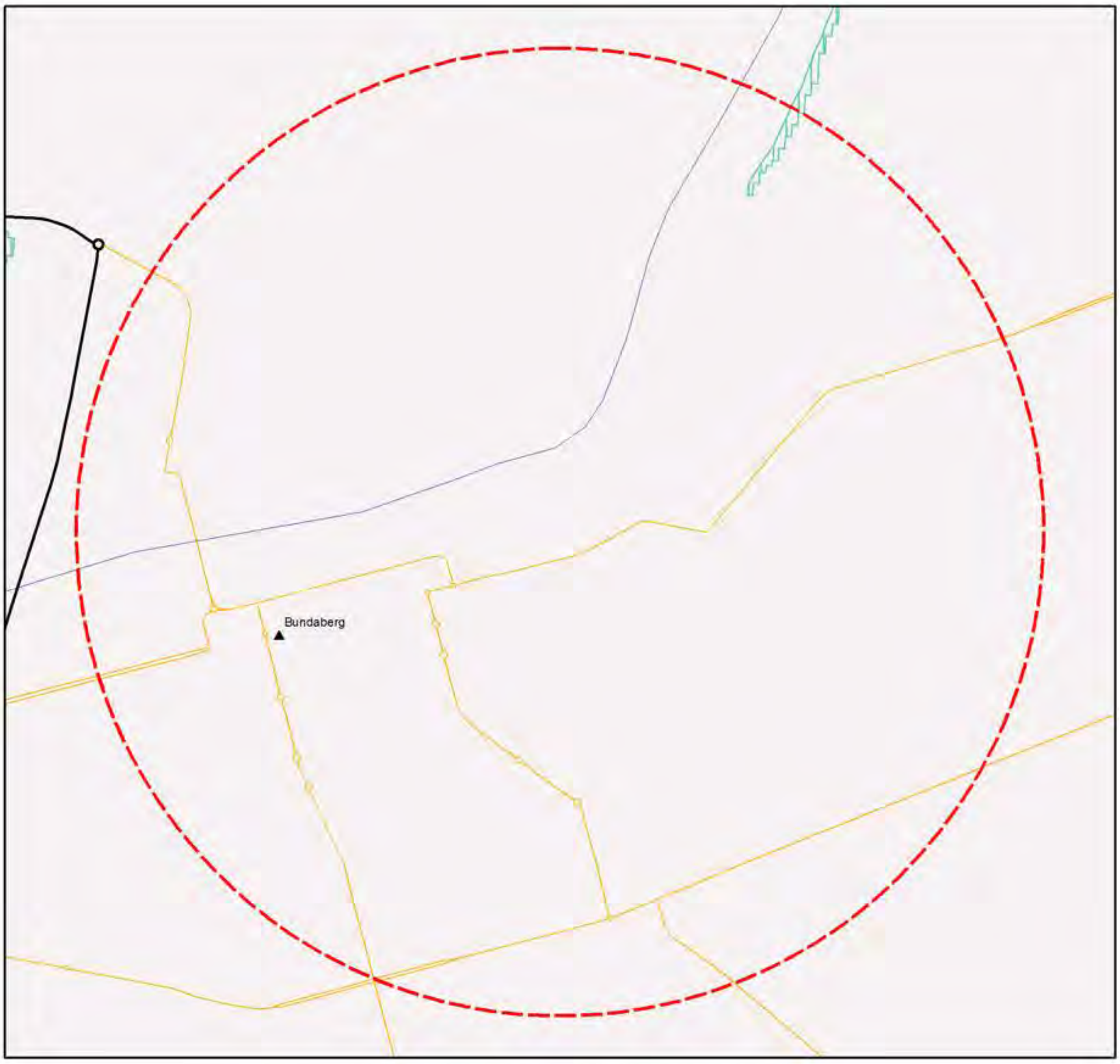
N

0 250 500 750 1000 1250 m

This product is projected into GDA 1994 Queensland Albers

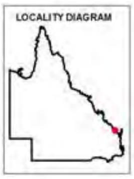
Map 2 - MSES - Wetlands and Waterways



MSES - Wetlands and Waterways

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Declared high ecological value waters (watercourse)
- Strategic environmental area (designated precinct)
- Declared high ecological value waters (wetland)
- High ecological significance wetlands



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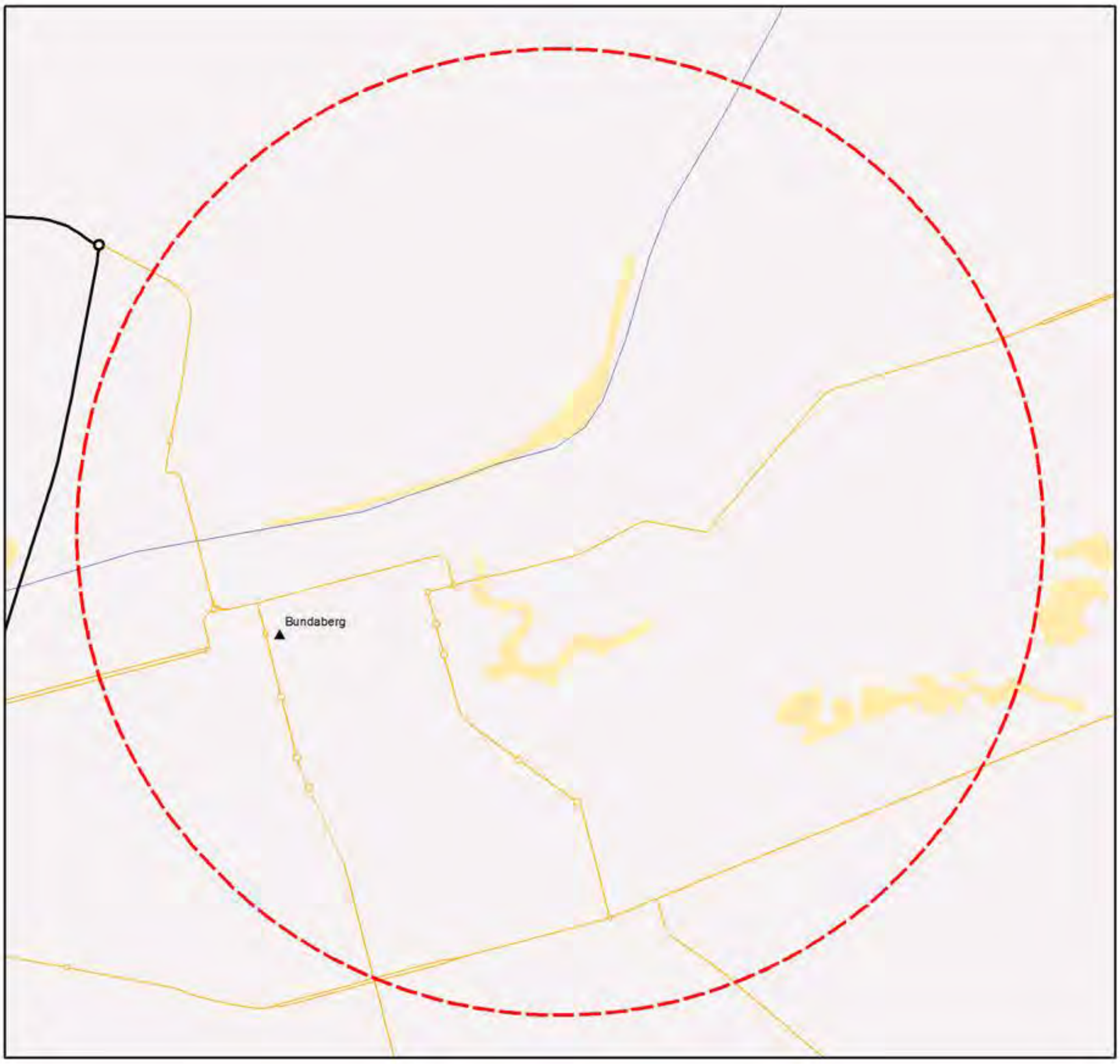
This product is projected into GDA 1994 Queensland Albers

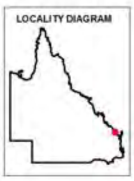
Map 3 - MSES - Species



MSES - Species

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Threatened wildlife and special least concern animal



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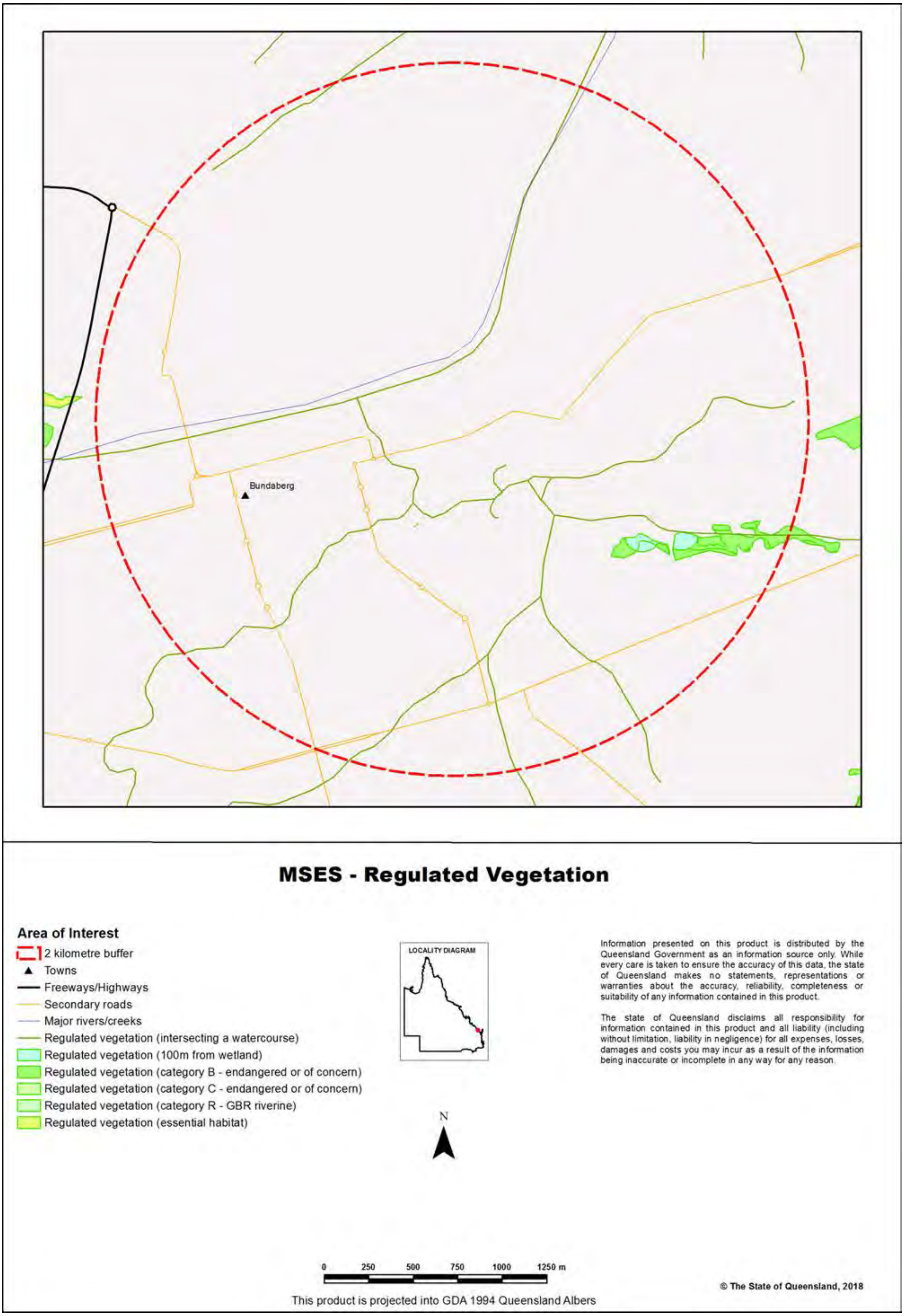
The state of Queensland disclaims all responsibility for information contained in this product and all liability (including without limitation, liability in negligence) for all expenses, losses, damages and costs you may incur as a result of the information being inaccurate or incomplete in any way for any reason.

N

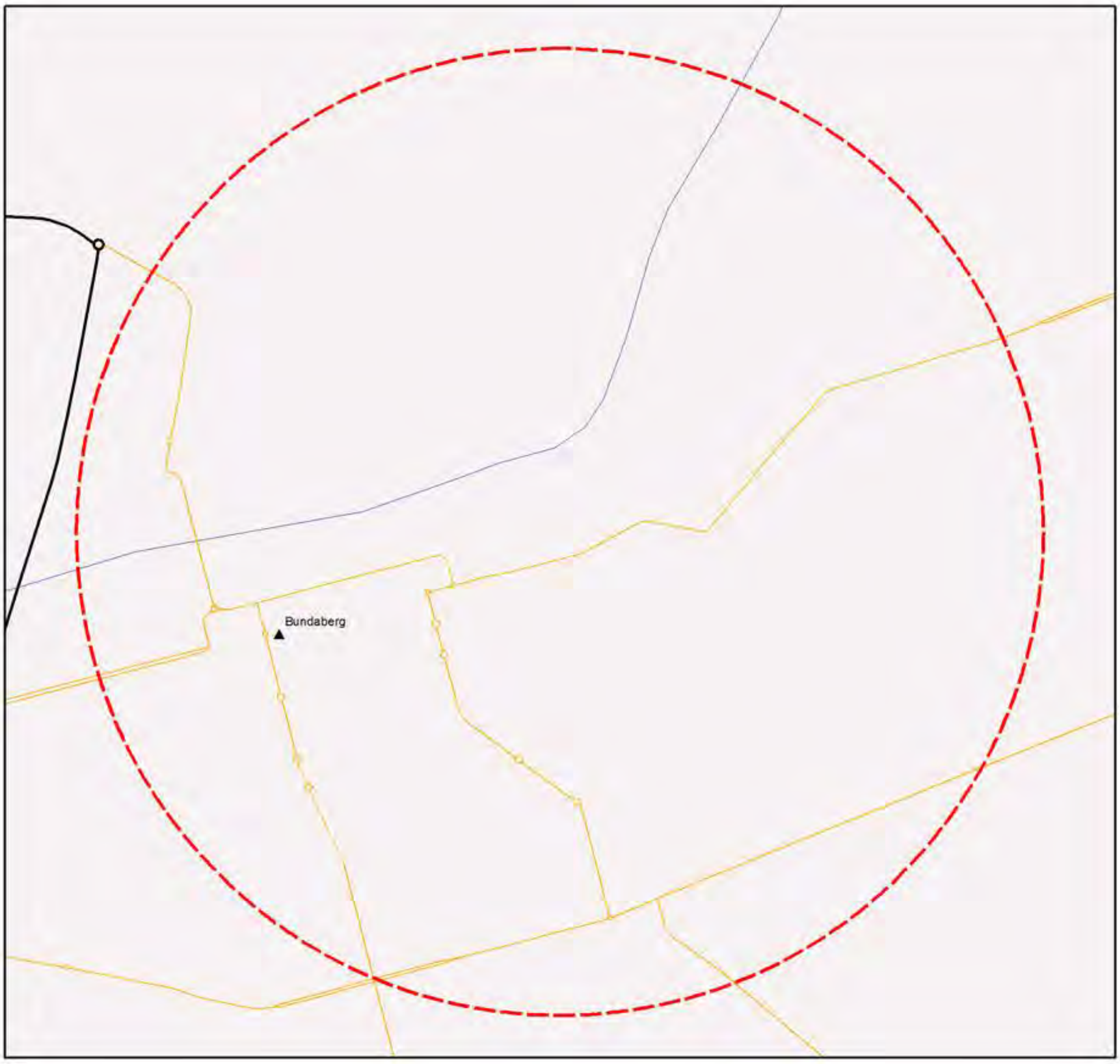
0 250 500 750 1000 1250 m

This product is projected into GDA 1994 Queensland Albers

Map 4 - MSES - Regulated Vegetation



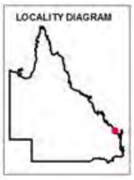
Map 5 - MSES - Offset Areas



MSES - Offsets

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Legally secured offset area (offset register)
- Legally secured offset area (vegetation offsets)



N

0 250 500 750 1000 1250 m

This product is projected into GDA 1994 Queensland Albers

Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.ingormation.qld.gov.au)**
Protected Areas-Estates and Nature Refuges	- Protected areas of Queensland - Nature Refuges - Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Referable Wetland - wetland layers: - Wetland management area wetlands - Wetland protection area wetlands
wetlands in HEV waters	HEV waters: - EPP Water (multiple locations) intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 4, 2015) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000) - latest version 1.4
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various)
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map - latest version 8.0
VMA Essential Habitat	Vegetation management - essential habitat map - latest version 4.41
VMA Wetlands	Vegetation management wetlands map - latest version 2.41
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map - latest version 1.41

Appendix 3 - Acronyms and Abbreviations

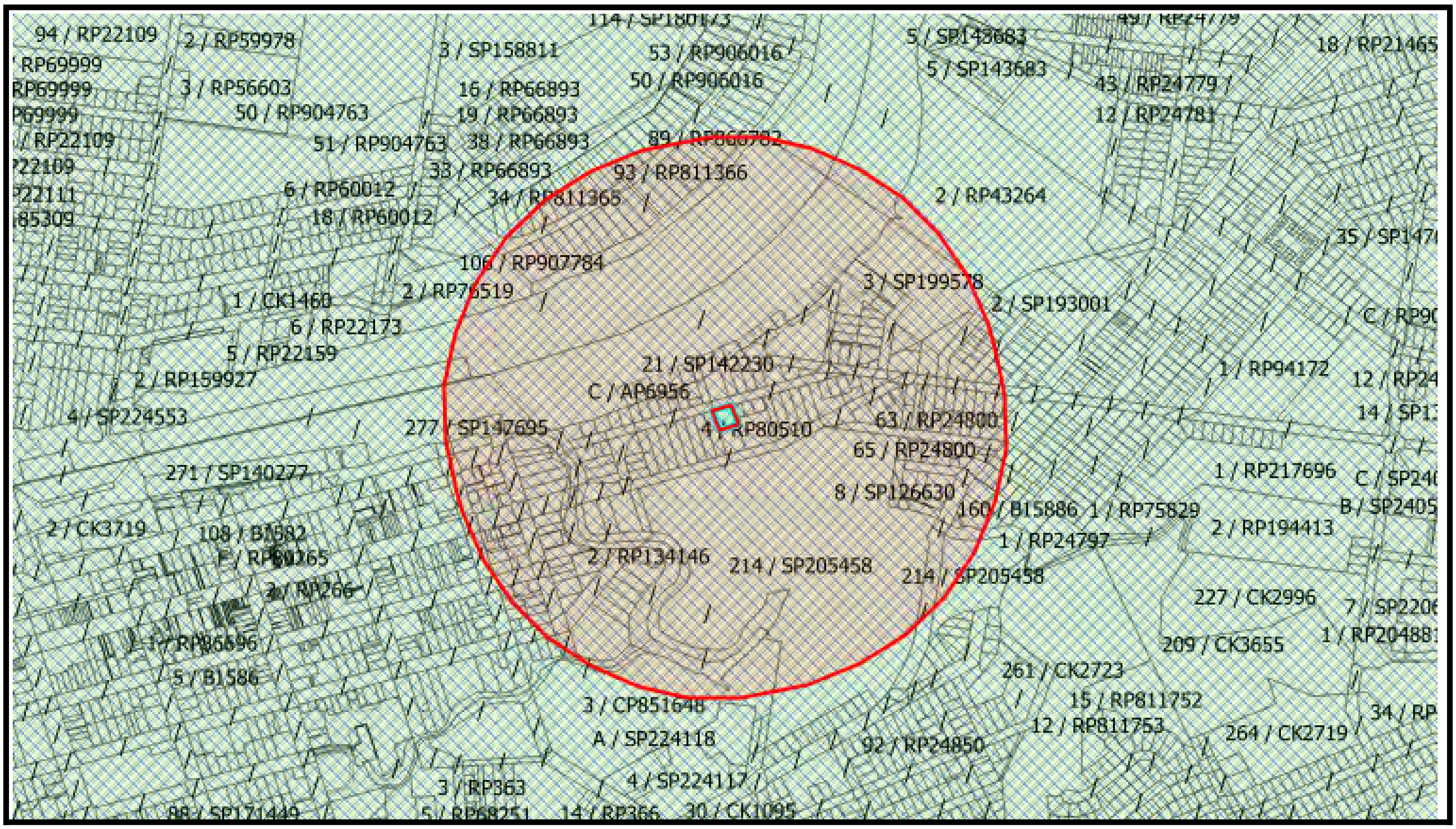
AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- *Environmental Protection Act 1994*
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- *Vegetation Management Act 1999*

Appendix C Cultural Heritage Search

Queensland Government
Department of Aboriginal and Torres Strait Islander Partnerships

Lot on Plan Search

Reference Number:	27390
Lot:	1
Plan:	RP84162
LGA:	Bundaberg Regional
Buffer Distance:	600 metres



There are no Aboriginal cultural heritage site points recorded in your specific search area.

There are no Aboriginal cultural heritage site polygons recorded in your specific search area.

Lot on Plan Search

Cultural heritage party for the area is:

QC Ref Number	QUD Ref Number	Party Name	Contact Details
QC2001/029	QUD6026/2001	Port Curtis Coral Coast Claim	Queensland South Native Title Services Level 10, 307 Queen St (PO Box 10832, Adelaide Street) BRISBANE QLD 4000 Phone: (07) 3224 1200 Fax: (07) 3229 9880

Cultural heritage body for the area is:

Body Name	Contact Details
Gidarjil Cultural Heritage Corporation	Mr Kerry Blackman Manager PO Box 2773 Bundaberg QLD 4670 Phone: (07) 4130 7700 Fax: (07) 4130 7777 Mobile: 0412 760 501 Email: reception@gidarjil.com.au

There are no cultural heritage management plans recorded in your specific search area.

There are no Designated Landscape Areas (DLA) recorded in your specific search area.

There are no Registered Study Cultural Heritage Areas recorded in your specific search area.

Regional Coordinator:

Name	Position	Phone	Mobile	Email
Greg Heath	Cultural Heritage Coordinator Central Region	07 4938 4100	0427 406 004	Gregory.Heath@datsip.qld.gov.au

Lot on Plan Search

I refer to your application in which you requested advice on Aboriginal cultural heritage places recorded on the above location.

I wish to advise that no Aboriginal cultural heritage is recorded on the Cultural Heritage Database and Register in your specific search area, from the data provided by you. However, it is probable that the absence of recorded Aboriginal cultural heritage places reflects a lack of previous cultural heritage surveys of the area. Therefore, our records are not likely to reflect a true picture of the Aboriginal cultural heritage values of the area.

All significant Aboriginal cultural heritage in Queensland is protected under the Aboriginal Cultural Heritage Act 2003, and penalty provisions apply for any unauthorized harm. Under the legislation a person carrying out an activity must take all reasonable and practical measures to ensure the activity does not harm Aboriginal Cultural Heritage. This applies whether or not such places are recorded in an official register and whether or not they are located in, on or under private land.

Aboriginal cultural heritage, which may occur on the subject property, is protected under the terms of the Aboriginal Cultural Heritage Act 2003 even if the Department of Aboriginal and Torres Strait Islander Partnerships has no records relating to it.

Please refer to our website www.datsip.qld.gov.au/people-communities/aboriginal-and-torres-strait-islander-cultural-heritage for a copy of the gazetted Cultural Heritage duty of care guidelines, which set out reasonable and practical measures for meeting the duty of care.

Should you have any further queries, please do not hesitate to contact the approval officer on 1300 378 401.

Kind regards

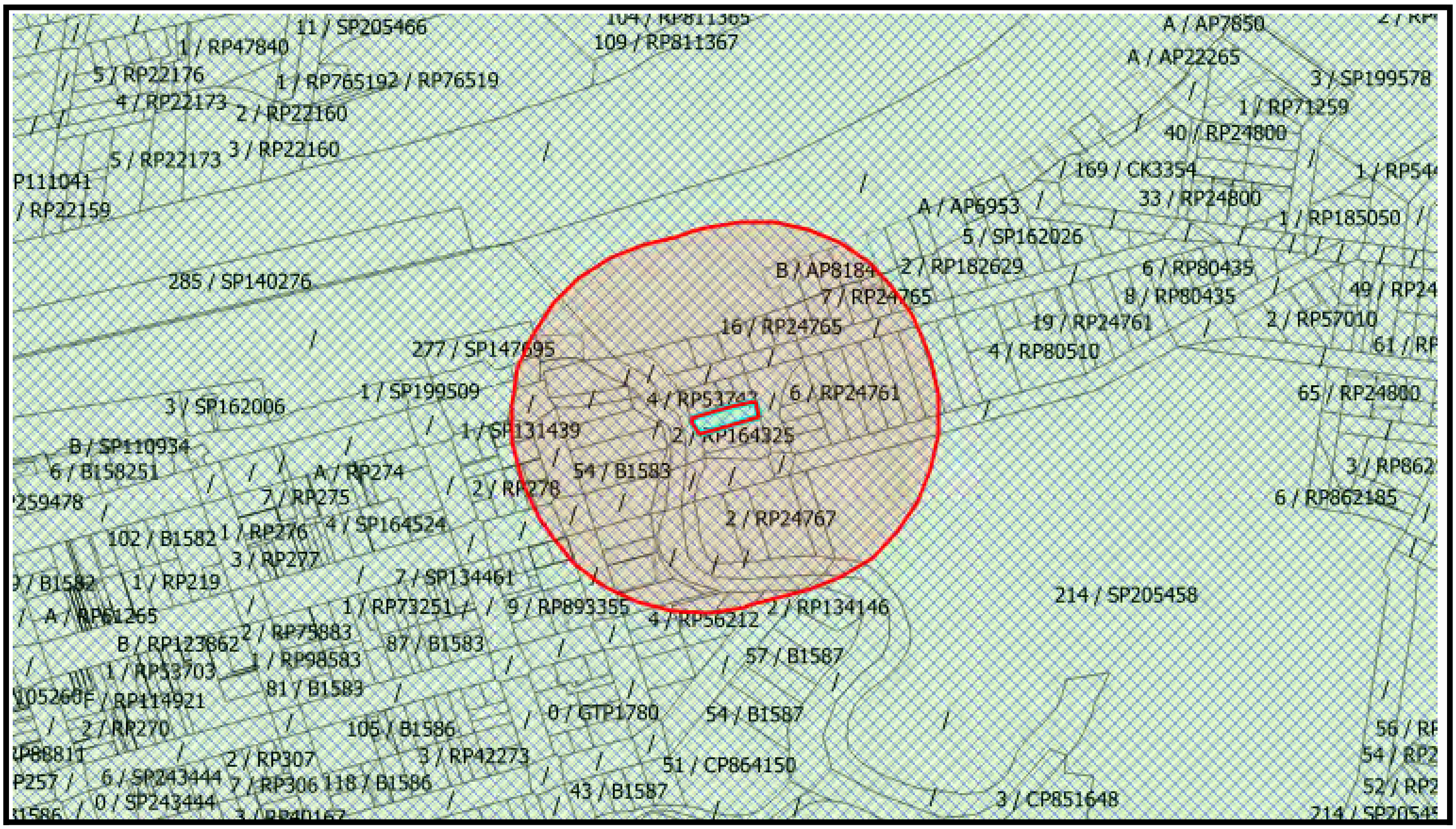
The Director
Cultural Heritage | Community Participation | Department of Aboriginal and Torres Strait Islander Partnerships

Queensland Government

Department of Aboriginal and Torres Strait Islander Partnerships

Lot on Plan Search

Reference Number:	27390
Lot:	1
Plan:	RP53747
LGA:	Bundaberg Regional
Buffer Distance:	200 metres



There are no Aboriginal cultural heritage site points recorded in your specific search area.

There are no Aboriginal cultural heritage site polygons recorded in your specific search area.

Sep 25, 2017, 9:31 AM

Queensland Government
Department of Aboriginal and Torres Strait Islander Partnerships

Lot on Plan Search

Cultural heritage party for the area is:

QC Ref Number	QUD Ref Number	Party Name	Contact Details
QC2001/029	QUD6026/2001	Port Curtis Coral Coast Claim	Queensland South Native Title Services Level 10, 307 Queen St (PO Box 10832, Adelaide Street) BRISBANE QLD 4000 Phone: (07) 3224 1200 Fax: (07) 3229 9880

Cultural heritage body for the area is:

Body Name	Contact Details
Gidarjil Cultural Heritage Corporation	Mr Kerry Blackman Manager PO Box 2773 Bundaberg QLD 4670 Phone: (07) 4130 7700 Fax: (07) 4130 7777 Mobile: 0412 760 501 Email: reception@gidarjil.com.au

There are no cultural heritage management plans recorded in your specific search area.

There are no Designated Landscape Areas (DLA) recorded in your specific search area.

There are no Registered Study Cultural Heritage Areas recorded in your specific search area.

Regional Coordinator:

Name	Position	Phone	Mobile	Email
Greg Heath	Cultural Heritage Coordinator Central Region	07 4938 4100	0427 406 004	Gregory.Heath@datsip.qld.gov.au

Queensland Government
Department of Aboriginal and Torres Strait Islander Partnerships

Lot on Plan Search

I refer to your application in which you requested advice on Aboriginal cultural heritage places recorded on the above location.

I wish to advise that no Aboriginal cultural heritage is recorded on the Cultural Heritage Database and Register in your specific search area, from the data provided by you. However, it is probable that the absence of recorded Aboriginal cultural heritage places reflects a lack of previous cultural heritage surveys of the area. Therefore, our records are not likely to reflect a true picture of the Aboriginal cultural heritage values of the area.

All significant Aboriginal cultural heritage in Queensland is protected under the Aboriginal Cultural Heritage Act 2003, and penalty provisions apply for any unauthorized harm. Under the legislation a person carrying out an activity must take all reasonable and practical measures to ensure the activity does not harm Aboriginal Cultural Heritage. This applies whether or not such places are recorded in an official register and whether or not they are located in, on or under private land.

Aboriginal cultural heritage, which may occur on the subject property, is protected under the terms of the Aboriginal Cultural Heritage Act 2003 even if the Department of Aboriginal and Torres Strait Islander Partnerships has no records relating to it.

Please refer to our website www.datsip.qld.gov.au/people-communities/aboriginal-and-torres-strait-islander-cultural-heritage for a copy of the gazetted Cultural Heritage duty of care guidelines, which set out reasonable and practical measures for meeting the duty of care.

Should you have any further queries, please do not hesitate to contact the approval officer on 1300 378 401.

Kind regards

The Director
Cultural Heritage | Community Participation | Department of Aboriginal and Torres Strait Islander Partnerships

Appendix D Flora Survey Trigger Map

01/03/2018 14:47:04
Longitude: 152.361991 Latitude: -24.831684

Protected Plants Flora Survey Trigger Map

This map shows areas where particular provisions of the Nature Conservation Act 1992 apply to the clearing of protected plants.

This map is produced at a scale relevant to the size of the area selected and should be printed as A4 size in portrait orientation.

For further information or assistance with interpretation of this product, please contact the Department of Environment and Science at palm@ehp.qld.gov.au

Legend

- Coordinates
- High risk area
- Cadastral line
  Property boundaries shown are provided as a locational aid only
- Freeways / motorways / highways
- Secondary roads / streets

N

0 480 960 1,440 1,920 2,400 m

This product is projected into:
GDA 1994 Queensland Albers

Appendix F Probable Construction Cost Estimate

Dept. of Local Government Racing & Multicultural Affairs (DLGRMA)

Cost Estimate - Bundaberg East Flood Levee

28 March 2019

CDM Smith

Executive Summary

The Department of Local Government, Racing and Multicultural Affairs (DLGRMA) engaged CDM Smith Ltd to prepare a concept engineering design for the Bundaberg East flood levee and flood control works. This cost estimate summary exists as Appendix F to the main engineering report, and identifies the estimated costs associated with the flood control works construction for the Bundaberg East Levee. Initial cost estimates were completed by ECS in consultation with CDM Smith project engineers and associated vender quotations. This report identifies the capital (CAPEX), build costs, overheads and the construction of the Bundaberg East Flood Levee, flood gates and pump stations. Initial 'base case' estimates were completed on the initial engineering concept design, followed by an adjusted estimate following a value engineering (VE) workshop. The VE estimate was refined by taking into account further geotechnical investigations along with basic indicative architectural cost workups to improve the public amenity of the scheme.

The primary flood control works consist of a concrete flood control wall constructed on a pile cap supported by 400mm square concrete piles, with an integrated sheet pile wall below the ground level to reduce under wall seepage to an acceptable factor of safety. The flood levee section between Saltwater Creek and Quay Street consists of earth embankment with an internal sheet pile wall for erosion and seepage control during a flood event.

The reinforced cast in situ wall has a height of 9.5m AHD, providing protection to at least the 1% AEP flood level. Other components of the flood control work covered within the estimate include a concrete flood dam located at Saltwater Creek which has four cable operated leaf flood gates and two axial flood pumps located in a pump-out forebay on the creek side of the flood dam. Another flood control structure is located near the Distillery Creek end of the flood levee and consists of a flood wall with penstock outlets with an integrated box culvert road crossing.

The following table identifies the anticipated costs for construction of the flood levee and flood prevention works for Bundaberg East. This followed completion of the value engineering (VE) of the scheme in conjunction with DLGRMA, US CDM Smith and Australian engineering teams along with the project estimator (ECS):

Total for all items	Cost ($)	Notes
CAPEX cost	$ 55,079,548	Updated – further piling quote
Client costs – Concept (excluded)	n/a	Excluded as complete, per DLGRMA
Client costs – Development	$ 4,710,000	Now includes $3.5m for property acquisition, resumption and disruption
Client costs – Implementation	$ 4,819,389	Updated for PUPs VE reduction
Client costs – Principal's materials	$ 4,286,212	Per base estimate (incl. architectural)
Client costs – Finalisation	$ 550,796	Per base estimate
Escalation costs (excluded)	n/a	Excluded, as instructed DLGRMA
Contingency VE	$14,574,220	Applied to construction value and architectural elements
TOTAL	**$ 84,020,165**	With adjustments (VE)

This report provides a summary of the key estimation assumptions, vendor quote summary and Bill of Quantity (BoQ) workups, whilst flood levee engineering drawings for the scheme are provided within the main reports.

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Section 1 Background

1.1 Introduction

As part of the overall Bundaberg East flood levee project this cost estimate report identifies the anticipated construction costs associated with the Bundaberg East flood levee scheme. This estimate is based upon the concept design, specifically the flood protection height and flood pump station rates set by the flood modelling performed for the 'behind the levee catchment' and Burnett River system and further investigations associated with the value engineering. The scheme consists of proposed floodwalls, pump station and flood gate structures and associated support facilities located in East Bundaberg, Queensland. These flood management facilities are recommended to increase the flood protection, mitigate damage, and protect the Bundaberg East area from the 100-year average recurrence interval (ARI) design flood event from the Burnett River and associated localised flooding 'behind the levee' from Saltwater and Distillery Creeks. This cost estimate is based upon the result of value engineering workshops, further geotechnical testing and refinement of the 'base case cost estimate' , appropriate construction methodology for the works along with current vendor quotes for key equipment costs, piling requirements and standard construction costs in South East Queensland were used for the cost basis. The base case cost and value engineered costs are included within this report for reference.

1.2 Concept Design

Following on from the development of the concept engineering design 'base case' a refined Value Engineering (VE) cost estimate was further developed as part of the flood infrastructure works. The main aspects of the design include:

- Concrete reinforced concrete (RC) wall cast in-situ flood wall to protect against a 1% Australian Exceedance Probability (AEP) to a height of 9.5m AHD wall.
- Flood wall to be built on concrete driven piles for support along a reinforced concrete pile cap footing with driven sheet pile under the wall foundations to protect against under wall under-seepage and provide further protection for the structure during a flood event.
- Construction of two flood prevention dam structures at Saltwater Creek and Distillery Creek with the larger structure situated at Saltwater creek including an integrated flood pump station, summary of each of the dams as follows:
  - Saltwater Creek flood control dam with four (4) floodgates (4x4m leaf types) and two large axial flood discharge pumps (discharge rates each of 3.5 m^3/s).
  - Distillery Creek flood control levee wall with two penstock (2x3m) flood gates and provision for a portable mine dewatering pump (discharge rate 1.0 m^3/s) to be used during a flood event, these mobile pumps will be trailer mounted and can be moved into position when required.
- As part of the architectural and community upgrades to the Saltwater Creek park area, flood wall structure beautification along with the flood control structures all of which will be integrated into the overall Bundaberg Regional Council development plan for the area, to improve the public amenity of the area as well as providing community benefits.
- The engineering design assumed for the Saltwater Park architectural park was a contoured earth levee with a central core of sheet piling to control potential wall breaches during a flood event and reduce under levee seepage.
- The wall itself will have an embossed effect and associated architectural features which have been costed accordingly with the wall finish assumed to be Class 2 concrete finish and painted with a graffiti resistant finish.

The overall general alignment of the flood wall and location of the flood control dam structures is shown below in Figure 1-1. Further alignment, engineering and geotechnical related drawings are included within the main Concept Engineering Report and drawing packages.

Figure 1-1 East Bundaberg Flood Levee Alignment

Further geotechnical testing was performed to help to rationalise the cost implications of the base case with a view to value-engineering the scheme to reduce the overall capital cost. Part of this cost estimate also includes an estimate of the operation and maintenance costs (O&M) and ongoing construction cost projection. These have been determined based on vendor feedback and are included within the Appendix. A summary of the cost estimate performed by ECS is included within the appendices.

Section 2 Cost Assumptions

Development of the cost estimate is based upon the concept engineering design and seeks to further develop the base case concept engineering design cost estimates for the Bundaberg East Levee and flood control infrastructure. Following the provision of some new potential architectural features to the scheme the cost estimated was adjusted to include the addition of these further items. Cost estimates have been based upon the following standards:

- Transport and Main Roads (TMR) standards.
- Queensland State Government estimation guidelines.
- Rawlinson standard cost guidelines 2018.
- Queensland Government Project Assessment Framework (PAF).
- Vendor estimates for the following items: flood pumps, flood gates, jib crane and hoist, emergency generator sets for pump and gate operations during a blackout the vendor cost estimate summary is indicated in Table 3-1.

An estimate of the operation and maintenance costs have also established based upon pump and floodgate manufacturer requirements, standard maintenance requirements for the flood wall and flood gate structure design lifespan.

2.1 Asset Design Lifespan

Following discussions with client, vendors, operators, flood control equipment manufacturers and the CDM Smith US team the following table indicates the anticipated lifespan of the assets which forms part of the Bundaberg East flood control scheme. These asset lifespans were used during calculation of the yearly current estimated operational costs which were passed onto the project economic consultant (nine squared).

Table 2-1 Design Lifespan

Flood Scheme Asset Type	Lifespan (Years)
Floodgates and flood control devices (stoplogs, gates etc per vendor)	25
Penstocks for Distillery Creek	50
Flood Wall and associated concrete structures	80
Stormwater control structures	80
Flood pumps and motors, including the control equipment and jib lifter	25
Civil flood dam structures	80
Piling and pile caps	80

NOTE: * 'Lawn service' removal required for flood pump servicing every four years (vendor)
Mechanical trash racks service life 25 years therefore manual racks will have at least this lifespan

Section 3 Vendor Quote Summary

Several vendor quotes were obtained for several the long lead time items required for the scheme specifically the flood control items such as the gates, stop logs and trash racks which require fabrication in Melbourne, Australia. The following table identifies some of the main vendor quotes which have come regarding major equipment needed for the Bundaberg East Flood levee scheme full quotations are included within the appendix.

Table 3-1 Vendor Cost Estimates

Item	Vendor	Description	Cost
Flood gates	AWMA	4x main cable raised gates	Refer A6
Penstocks	AWMA	2x Distillery Creek actuated penstocks	Refer A6
Flood pumps	Ornel / fluid engineering, Grundfos, KSB	2 x axial flood lift pumps with formed suction inlet or strainer; 3.5 m3/s flowrate per pump	\$407,903 (cpt floodlifter x1) \$325,2000 (KSB axial pump x1)
Trash racks	AWMA	Mechanical (base case) and manually cleaned options	\$55,000 Separate quote
Stop logs	AWMA	Manually installed with guides	Refer A6
Gensets	Caterpillar, Cummins	350 kVa genset with internal tank	\$75,000
Cube tank – fuel	Fuel tank supplier	110% bunded 6.3kL	\$12,000
Jib crane (pump lift)	JDN Crane	Stock IP56 jib crane	\$72,000
Motor driven flood wall (Quay St)	AWMA	Special order for Crane Street	\$150,000
Other road flood crossings	AWMA	Stop log system to 3m	Refer A6 footnote
Skid mounted flood pump	NPE and Ornel	Mine pump specification	\$403,454
Mechanical trash racks	AWMA	Also refer A6	\$840,000

The general vendor cost estimates were included within the main cost workups completed by ESC and the engineering team. Further information was also sourced from companies with soft soil experience specifically bentonite and cement fixing of this material during construction of the flood control dams and flood walls, we also sought advice from piling contractors specific to the concept design regarding constructability and the cost implications for soft soil construction costs.

Section 4 Bundaberg East Cost Estimate

The cost estimates developed by ECS in conjunction with the project team are based upon the overall concept engineering design report, general construction methodology (Section 6), structural drawings and vendor quotes for specific equipment. The cost estimate was further refined regarding some of the design elements following further detailed geotechnical program and soil testing along the final flood levee alignment. This further testing allowed for the clarification of several geotechnical issues to help further rationalise the cost estimate and reduce the contingency.

4.1 Estimate Assumptions

4.1.1 ECS Methodology

Where sufficient information was available within the Reference Design Documentation, ECS undertook a first principles estimate based on their extensive knowledge of the applicable construction activities and current local market rates and conditions. Areas where insufficient documentation was available to provide a first principles estimate, discussions were held between ECS, CDM Smith representatives to determine the assumptions on which to base the estimate. These assumptions, where applicable, have been detailed below.

4.1.2 Estimate Scope

The estimate scope comprised the design and construction of all civil works associated for the Bundaberg Levee, including the following:

- Preliminary design.
- Geotechnical investigation.
- Site establishment including:
  - Setup of site facilities.
  - Service locations.
  - Survey set-out.
  - Clearing & grubbing.
  - Stripping topsoil.
- Environmental and Safety Management.
- Earthworks including:
  - Remove and replace unsuitable.
  - Cut to fill.
  - Import fill.
  - Surcharge / preload at dam abutments.
  - Topsoil respread and landscaping.
- PUP demolition, relocation and new installation allowances.
- Drainage works.
- Concrete structures including retaining walls, culverts, buildings and floodgates.
- Interface with and connection to existing roads.

At the time of creating the base case P50 estimate, Client Costs weren't tabled for inclusion in the estimate. ECS provided some indicative allowances for review by CDM Smith with the Client. These reviewed allowances have since been added to the P50 estimate. There have been several vendor quotations which have been included within the cost estimate as well as further geotechnical testing along the alignment.

4.1.3 Estimate Structure

The structure of the estimate follows the Quantity take-off completed by ECS, and where possible has been assigned DTMR item numbers and references. Details on the various rate types are as follows:

- **Labour Rates.** Labour Rates consistent with current market conditions and Labour Agreements have been used in the estimate.
- **Plant Rates.** Plant Rates consistent with current market conditions received on recently estimated projects in the region have been used in the estimate.
- **Materials and Subcontract Rates.** ECS has used material and subcontract rates that have been based on recent pricing received for similar items on previous projects in the region.

4.2 Direct Cost Estimate

Direct costs estimates have been identified as part of the overall project works and general issue of the main work program for the general project and programming of works for the facility. Other issues which are associated with the construction of the flood control works include the following. The base case was adjusted following a workshop with DLGRMA to remove the GST component and clarification of several other estimate assumptions.

Table 4-1 Bundaberg East Cost Summary (P50) – Adjusted Base Case

Total for all items	Cost ($)	Notes
CAPEX cost	$ 49,767,591	Updated with distillery creek
CAPEX architectural elements*	$ 6,500,000*	P50 estimated cost (basic)*
Client costs – Concept (excluded)	$ 2,066,285	Per P50 estimate
Client costs – Development	$ 4,637,332	Assuming $2m in property acquisition and resumption costs
Client costs – Implementation	$ 8,235,548	Including high PUPs rate at $3.1m
Client costs – Principal's materials	$ 1,200,876	Per P50 estimate
Client costs – Finalisation	$ 622,095	Per P50 estimate
Escalation costs (excluded)	$ 1,555,237	Per P50 estimate
Contingency P90	$ 34,215,220	50% applied to above
TOTAL	**$ 108,800,184**	Estimated base case adjusted (P50)

The new VE adjusted cost was completed based upon a workshop in conjunction with DLGRMA

Table 4-2 Bundaberg East Cost Summary (VE) – Adjusted VE Case

Total for all items	Cost ($)	Notes
CAPEX cost	$ 55,079,548	Updated – further piling quote
Client costs – Concept (excluded)	n/a	Excluded as complete, per DLGRMA
Client costs – Development	$ 4,710,000	Now includes $3.5m for property acquisition, resumption and disruption
Client costs – Implementation	$ 4,819,389	Updated for PUPs VE reduction
Client costs – Principal's materials	$ 4,286,212	Per base estimate (incl. architectural)
Client costs – Finalisation	$ 550,796	Per base estimate
Escalation costs (excluded)	n/a	Excluded, as instructed DLGRMA
Contingency VE	$14,574,220	Applied to construction value and architectural elements
TOTAL	**$ 84,020,165**	With adjustments (VE)

4.1 Operational Cost Estimate

The overall operational cost estimate was based upon several assumptions and vendor provided information as follows:

- The asset lifespan has determined the 50-year operational cost estimate.
- Staff costs for maintenance of the scheme were determined assuming a standard electrician rate.
- Staff costs from Council regarding routine maintenance and paint retouching of the levee wall.
- Routine flood pump maintenance (lawn service) based on vendor feedback at similar schemes.
- Routine gardening and caretaker maintenance to be provided by Council.
- Routine cube tank diesel fuel replacement.

The operation cost workup is included within Appendix A4 and is included within the nine squared project economic assessment.

Section 5 Construction Methodology

A general construction methodology was developed for the project to inform the cost estimate by ECS, some of the key areas include the management of the works and construction program. Major components of construction for the scheme are as follows.

- Bundaberg Creek Structure
- Distillery Creek Structure
- Below Ground Concrete Structure and associated piling.
- Above Ground Concrete Levee Wall.

Following further geotechnical investigations, testing and other further alignment surveys the concept design of the scheme was altered and then adjusted accordingly. The general construction methodology is described for each one of these specific areas mentioned above as follows.

5.1 Bundaberg Creek Structure

This structure is in a tidal water way and takes some overland flows from behind the levee during and rainfall events, the flow volumes and estimated flood pump-out rates are calculated with in the CER report. As there is significant water flowing into and out of the creek daily with tidal movements, it has been proposed that the final structure shall be completed in two stages to maintain water flows into and out of Saltwater Creek and reduce the potential impact upon the existing marine environment.

The sheet piling will provide two stages across the creek in order to reduce interruption to tidal flows, with temporary sheet piling installed to facilitate this process. There has been a significant allowance for precast driven pile work and permanent sheet piling to the foundation of the structure, and as such, an adequate allowance for a piling pad has been made to permit piling rigs access within the existing creek bed. Pile lengths nominated on the drawings for the base case design are up to 29 m long.

Pumps and associated pump control house items have been allowed for, with standby electric powered pumps favoured as the most reliable and cost effective for the application. Following discussions with the pump vendors it was established that over the longer term these should also prove to be cost effective to maintain and operate on an intermittent basis. Vendor discussions indicate that two 350 kVa gensets are enough to operate the pumps during a flood event, and the provision of a 6,000L diesel ‘cube self-bunded ‘fuel tank will provide enough fuel for approximately two days of operation after which the facility should be accessible by fuel tanker for re-supply.

5.2 Distillery Creek Structure

The Distillery creek structure has been based on a conventional culvert, rather than a cast in-situ structure. To facilitate the stability of the structure in the marine environment, the design has incorporated pile support to the overall structure. This option reduces the amount of work to be completed within the waterway, and reduces any subsequent environmental, safety and programme impacts. Similar to the Bundaberg Creek scope, allowances have been made for temporary sheet piling and a platform for the piling rigs. Part of the concept design is the routing of the current mill discharge via a concrete pipe to discharge on the river side of the flood wall via a penstock. This option has been included within the architectural lump sum amount.

5.3 Flood Levee Wall Structure

5.3.1 Below Ground Concrete Structure and Associated Piling

There will be significant excavation and piling works to the foundations, requiring shoring, pre-fabrication of the reinforcing for the base and detailed excavation to pour concrete directly up to the walls of the excavated trench.

Public utilities will need to be relocated/protected during this process to ensure that services are not interrupted or damaged. The public utility plan (Pup) identifies these services which have also been checked during field inspections with the view to relocation in an early works package prior to the main construction activities. A separate PUP location plan is included within the main report and general relocation cost has been included in Appendix A2 along with the relevant PUPs plan along the alignment.

5.3.2 Above Ground Concrete Levee Wall

Consideration for minimal disruption to residence and businesses within the project boundaries has been reviewed in conjunction with the different potential construction methods. B-Double access over the existing Distillery Creek will be disrupted during the construction of the structure, and therefore, alternative routes for these vehicles with the appropriate permits will need to be obtained prior to the closure of this access. Given the required size and costs to construct a temporary access capable of handling B-Double loads, a temporary bridge was not considered to be viable.

5.3.3 Resident Notification

Residents will need to be notified of access constraints to property during construction of the above ground walls, with a possibility of pedestrian access only to properties whilst crews are working locally. Securing vehicles from vandalism whilst they are unable to access their properties may be necessary. A separate provisional amount is included within the cost summary for community consultation as well as potential further land acquisition costs should this be required. This estimated nominal amount has been based upon the average residential land valuations for the area indicated within Appendix A1.

5.3.4 Project Delivery Strategy

The Project has been priced on the basis of a Construct Only Contract. This is due to the level of detail provided in the Reference Design Documentation, with a number of key assumptions having been made during compiling the estimate. These key assumptions are as follows:

- All statutory approvals to be obtained by the Principal prior to site access.
- Geotechnical investigations provide accurate information on ground conditions to facilitate piling and construction activities.
- Details are confirmed on long lead items for pumps and flood control equipment to enable early procurement.

Section 6 Recommendations

The following table identifies the anticipated costs for construction of the flood levee and flood prevention works for Bundaberg East. This followed was completed following the value engineering (VE) workshop and further geotechnical investigations of the scheme in conjunction with DLGRMA, US CDM Smith and the Australian engineering teams along with the project estimator (ECS):

Total for all items	Cost ($)	Notes
CAPEX cost	$ 55,079,548	Updated – further piling quote
Client costs – Concept (excluded)	n/a	Excluded as complete, per DLGRMA
Client costs – Development	$ 4,710,000	Now includes $3.5m for property acquisition, resumption and disruption
Client costs – Implementation	$ 4,819,389	Updated for PUPs VE reduction
Client costs – Principal's materials	$ 4,286,212	Per base estimate (incl. architectural)
Client costs – Finalisation	$ 550,796	Per base estimate
Escalation costs (excluded)	n/a	Excluded, as instructed DLGRMA
Contingency VE	$14,574,220	Applied to construction value and architectural elements
TOTAL	**$ 84,020,165**	With adjustments (VE)

It is recommended that this estimate be used as a guide for the construction of the Bundaberg East flood control scheme. The next stage is to complete detailed engineering design with the view to rationalising the concept design and further clarify the cost estimate presented within this report.

Appendices – OPCC Estimate Summary

A.1 Land Estimates Quay Street

The land that would need to be acquired to accommodate the public realm elements of the Bundaberg East Flood Levee are lots 12-16 of RP24765 (commonly referred to as 1E Quay Street). The freehold title of this land is for 4,919 m^2 and is currently held by Glendette Pty Ltd. Additional riverbank land would also form part of the flood levee public realm elements.

Sales records do not provide a date for when Glendette Pty Ltd purchased Lots 12-16 of RP24765. A 'for sale' history of the land indicates that the land was placed on the market most recently in late October 2014 for a list price of $850,000. The property did not sell at that price.

The current (30 June 2017) statutory valuation for the land is $390,000 having fallen from a previous statutory valuation of $640,000 in 2011.

Given that the subject land and much of the land surrounding it was inundated in recent flood events, there are a limited number of 'normal' sales in the area.

Recent normal sales are summarized in the Table below. These lots a significantly smaller than the subject holding.

Table A-1-1 Recent Normal Sales (Quay Street)

AddressLot/RP		Area (m2)	Date	Price	Unit Price
2E Quay Street	Lot 4 RP53747	1,181	11/10/2017	$300,000	$254/$m^2$
26E Quay Street	Lot 5 RP80435	850	13/03/2017	$185,000	$218/ m^2
33E Quay Street	Lot 1 RP54684	447	03/02/2017	$165,000	$369/ m^2
3 Kendall Street	Lot 2 RP164325	1,558	30/05/2018	$155,000	$99/ m^2

The only recent sale in the area that achieved a comparatively high sale price was 2 Kendall Street (Lot5 CK2680 and Lot 6 RP24762). This property is approximately 1,508 sqm and sold in September 2015 for $732,745. 2 Kendall Street differs from the subject land because 2 Kendall Street is an operating service station, which represents a significant improvement of the land for an income earning purpose.

Based on the above, it would be reasonable to assume that the acquisition cost of 12-16 of RP24765 (commonly referred to as 1E Quay Street) would be in the order of $1 million to $1.25 million. This is significantly above the previous marketed price of $850,000 for which the property did not attract a buyer. To be clear this does not represent a property valuation, but rather identification of an appropriate allowance for business case purposes. The real value of the land could be significantly less than this allowance. The allowance should not prejudice any future valuation of the subject land for acquisition purposes.

Based on current levee designs the land is unlikely to experience value uplift by being taken out of the flood zone.

A.2 PUP Relocation Estimate

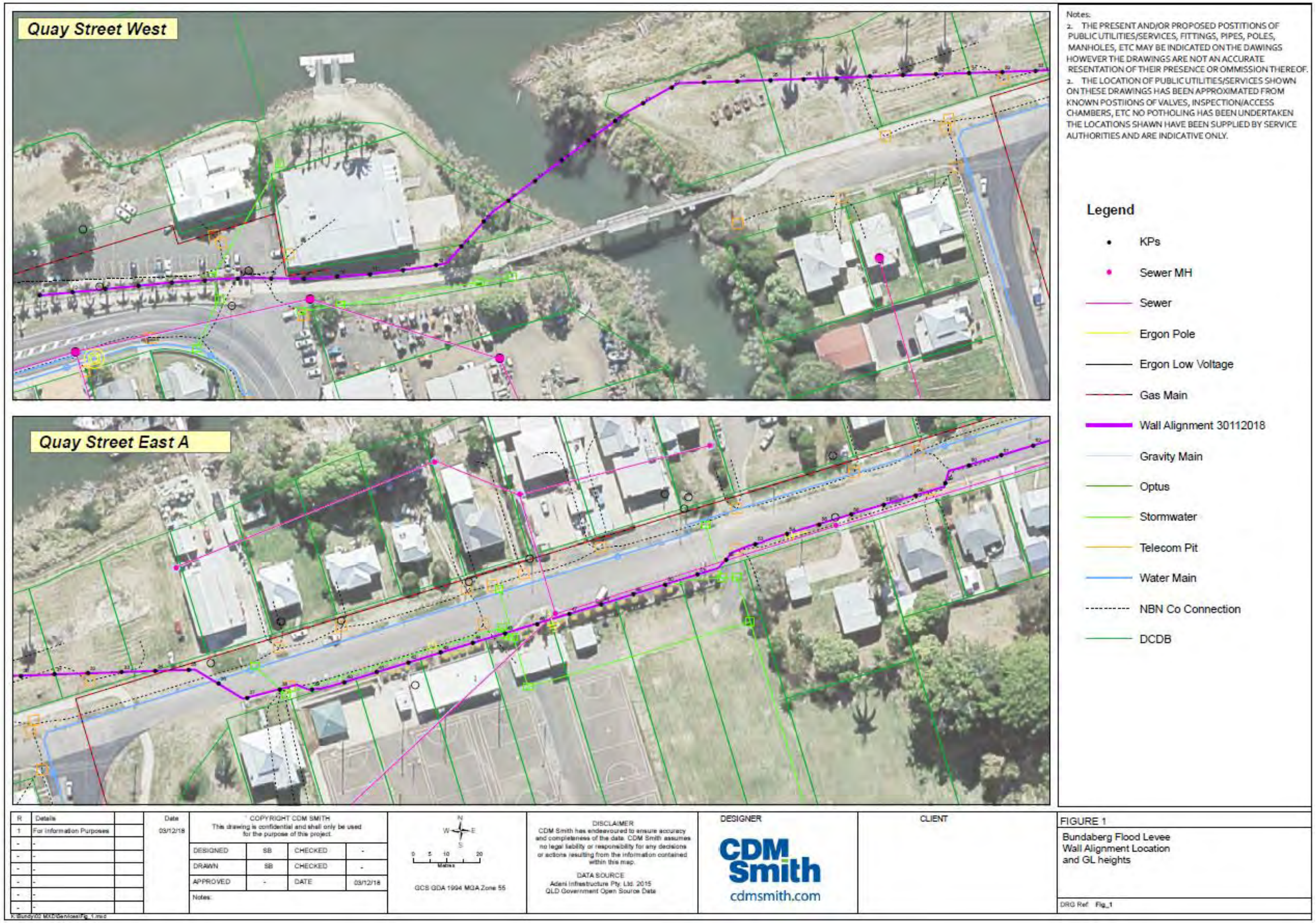
PUPs Existing and potential relocations (per new alignment)

No	Chainage	Type	Location	PUP detail	Relocation	Rate	Unit	LM	Cost	Notes	Details
1	5	SW	Quay St kurb drain	SW pipe	No	$160	1		$160	Pothole nominal amount - away from site - check depth	375mm RC pipe
2	7	Power	Crossing footpath - rowers	Overhead power	No - shut down	$5,000	1		$5,000	Shut down for construction	Shut down
3	12, 33	Gas	Quay St / Esplanade	Gas line PE pipe	No	$5,000	3		$15,000	Crossing - pothole then seal off through wall	63mm PE80 SDR 17
4	2, 13	Telco	Telco crossing points rowers	Teco cable	Yes and reinstate	$4,000	3		$12,000	Pothole and Telco cable crossings near rowers	Cable
5	30	Telco	In park area near levee	Cable check and relocate	Yes	$40		15	$600	Pothole and relocation - shown DBYD no pit identified	Cable
6	30	Telco	On Quay street	Telco pit - NBN	Reinstate	$150	1		$150	Existing telco pit	Cable pit to reinstate
7	36	Telco	Cable through pile cap	Cable only and water stop	Reinstate	$3,000	1		$3,000	NBN Cable point	Cable penetration
8	33	Power	Quay Street crossing	Overhead power	No - shut down	$1,500	2		$3,000	Shut down for construction - new power pole install (1)	Shut down reinstate
9	35	Water	Quay Street crossing	Water main	Reinstate	$15,000	1		$15,000	Sheet pile around water main & seal road gate valve pit	100mm asbestos cement pipe
10	35, 45	SW	Quay Street crossing	SW pipe crossing	Blank off - pipe rate $130Lm	$25,000	3	150	94500	Reinstate RC pipe to the riverside via park and SW pit	300mm RC pipe to kurb drain
11	35, 45	SW	Side of Quay St	SW pipe	Reinstate	$130		1	$130	Relocate RC pipe to service trench near pipe cap	300mm RC pipe
12	46	SWR	Across Quay Street	SWR pipe	One way valve & spindle pit	$6,000	1		$6,000	Install check / one way valve and pit at wall toe	150mm Vitrified Clay Pipe
13	50	SW	Across Quay Street	SW pipe	Realign with other SW & mh	$160	1	40	$12,400	Redrain RC pipe to the riverside via park and SW pit	Hook into SW pit (no 7)
14	40, 65	Telco	On Quay Street	Cable and pit to move	Reinstate	$150	4	20	1400	4 Telco pits to relocate along with cable	NBN cable and std pits
15	46 - 70	SWR	Side of Quay Street	SWR pipe service	Service line aligned & mh	$160	3	240	44190	Relocate RC pipe to service trench near pipe cap	525mm Vitrified Clay pipe
16	35 -75	Water	Along Quay Street length *	Water offtake penetrations	Existing and blank to meter	$51	20	200	90200	Pipe penetrations, puddle flange and water stops	100mm mPVC main pipe tapping
17	35, 75	Water	Main water pipe gate valve shut off	Water pipe valve pits	Either end of Quay Street	$21,000	2		$42,000	Isolate quay street supply 1 exist upgrade 1 (SCADA controls)	100mm mPVC PN16 and AC pipe
19	35, 70	Power	Along Quay Street length *	Electricity	Shut down power	$18,000	1		$18,000	Shutdown and shore up poles as required mid section	Reinstate power line crossings (4)
20	73	SWR	Across Quay Street	SWR pipe	One way valve	$12,000	1		$12,000	Install check / one way valve and pit at wall toe	150mm Vitrified Clay Pipe
21	77	Water	Scotland Street crossing	Water pipe crossing	AC pipe crossing	$12,000	1		$12,000	Sheet pile around water main & seal road gate valve pit (13)	100mm asbestos cement pipe
22	80 - 90	Water	Along Scotland Street	Water pipe	Realign if required	$51		80	$4,080	Locate pipe within the service alignment	100mm asbestos cement pipe
23	90	Water	Peterson Street	Water pipe	Crossing location	$12,000	1		$12,000	Pothole and may require minor wall crossing point	100mm uPVC pipe crossing
24	80 - 90	Water	Along Scotland and Peterson	SW pipe crossing	Crossing or penetration	$12,000		20	$240,000	PE pipe tapping offtakes through the wall	100mm uPVC tapping offtakes
25	New 10 - 55	Water	Along Cran street to Mill	Water pipe	Realign if required	$51		520	$26,520	PE pipe realigned to service trench - to pothole / assess	110mm PE water pipe
26	New 10 - 55	UG power	Along Cran street to Mill	Coated power cable	Full replacement cost	$12,500	1		$12,500	Coated UG power cable - assumed reinstatement costs only	50 mm HD UG Power cable
27	Outside	SW	Mill discharge line#	FRC drainage pipe	New pipe discharge	$225		293	$65,925	Pipe length based on google map distance with 45 bend	Assume 600mm (TBD from Mill)
27	Outside	SW	Mill discharge line	FRC drainage pipe	Trench and installation	$62		293	$18,166	Trench to install with bedding sand to suit	Assume Rawlinsons rate (p476)
28	Discharge	SW	Add in flood discharge flap valve	At distillery creek gate	Per AWMA quote	$25,000	1		$25,000	AWMA stainless flood flap gate nominal 600mm	Quotation
			Construction Estimate						**$790,921**		
			Additional Contingency (50%)						**$395,461**		
			Extras & client costs etc (below)						**$204,374**		
			TOTAL ESTIMATE (P50)						**$1,390,756**		

Extras	Costs
Client costs (BuCC assumed)	$40,000
Development phase*	
Detailed design / investigations	$37,682
Public consultation	$20,000
Implentation Phase	
Admin costs (BuCC)	$25,000
Internal Admin (1%)	$7,909
Contract Admin (6%)	$47,455
PAI admin (0.8%)	$6,327
Principals materials	$20,000
Escalation	$0
Total (Extras - NO CONTINGENCY)	**$204,374**

NOTE: PUPS relocation costs based on 'Rawlinsons 2018 36th edition'

A.3 PUP Location Plans


Quay Street West
Quay Street East A
Notes:
2. THE PRESENT AND/OR PROPOSED POSTITIONS OF PUBLIC UTILITIES/SERVICES, FITTINGS, PIPES, POLES, MANHOLES, ETC MAY BE INDICATED ON THE DAWINGS HOWEVER THE DRAWINGS ARE NOT AN ACCURATE RESENTATION OF THEIR PRESENCE OR OMMISSION THEREOF.
2. THE LOCATION OF PUBLIC UTILITIES/SERVICES SHOWN ON THESE DRAWINGS HAS BEEN APPROXIMATED FROM KNOWN POSTIIONS OF VALVES, INSPECTION/ACCESS CHAMBERS, ETC NO POTHOLING HAS BEEN UNDERTAKEN THE LOCATIONS SHAWN HAVE BEEN SUPPLIED BY SERVICE AUTHORITIES AND ARE INDICATIVE ONLY.
Legend
KPs
Sewer MH
Sewer
Ergon Pole
Ergon Low Voltage
Gas Main
Wall Alignment 30112018
Gravity Main
Optus
Stormwater
Telecom Pit
Water Main
NBN Co Connection
DCDB
R
Details
1
For information Purposes
Date
03/12/18
COPYRIGHT CDM SMITH
This drawing is confidential and shall only be used for the purpose of this project.
DESIGNED SB CHECKED -
DRAWN SB CHECKED -
APPROVED - DATE 03/12/18
Notes:
N
W
E
S
0 5 10 20
Metres
GCS GDA 1994 MGA Zone 55
DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.
DATA SOURCE
Adani Infrastructure Pty. Ltd. 2015
QLD Government Open Source Data
DESIGNER
CDM Smith
cdmsmith.com
CLIENT
FIGURE 1
Bundaberg Flood Levee
Wall Alignment Location
and GL heights
DRG Ref: Fig_1

Notes:

2. THE PRESENT AND/OR PROPOSED POSTITIONS OF PUBLIC UTILITIES/SERVICES, FITTINGS, PIPES, POLES, MANHOLES, ETC MAY BE INDICATED ON THE DAWINGS HOWEVER THE DRAWINGS ARE NOT AN ACCURATE RESENTATION OF THEIR PRESENCE OR OMMISSION THEREOF.

2. THE LOCATION OF PUBLIC UTILITIES/SERVICES SHOWN ON THESE DRAWINGS HAS BEEN APPROXIMATED FROM KNOWN POSTIIONS OF VALVES, INSPECTION/ACCESS CHAMBERS, ETC NO POTHOLING HAS BEEN UNDERTAKEN THE LOCATIONS SHAWN HAVE BEEN SUPPLIED BY SERVICE AUTHORITIES AND ARE INDICATIVE ONLY.

Legend

- KPs
- Sewer MH
- Sewer
- Ergon Pole
- Ergon Low Voltage
- Gas Main
- Wall Alignment 30112018
- Gravity Main
- Optus
- Stormwater
- Telecom Pit
- Water Main
- NBN Co Connection
- DCDB

R	Details		Date
1	For Information Purposes		03/12/18
-	-		
-	-		
-	-		
-	-		
-	-		
-	-		

© COPYRIGHT CDM SMITH
This drawing is confidential and shall only be used for the purpose of this project.

DESIGNED	SB	CHECKED	-
DRAWN	SB	CHECKED	-
APPROVED	-	DATE	03/12/18

Notes:

N / W / E / S
0 5 10 20
Metres
GCS GDA 1994 MGA Zone 55

DISCLAIMER
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DATA SOURCE
Adani Infrastructure Pty. Ltd. 2015
QLD Government Open Source Data

DESIGNER
CDM Smith
cdmsmith.com

CLIENT

FIGURE INSET 2
Bundaberg Flood Levee
Wall Alignment Location
and GL heights

DRG Ref: Fig_2

K:\Bundy\02 MXD\Services\Fig_2.mxd

Notes:

2. THE PRESENT AND/OR PROPOSED POSTITIONS OF PUBLIC UTILITIES/SERVICES, FITTINGS, PIPES, POLES, MANHOLES, ETC MAY BE INDICATED ON THE DAWINGS HOWEVER THE DRAWINGS ARE NOT AN ACCURATE RESENTATION OF THEIR PRESENCE OR OMMISSION THEREOF.
2. THE LOCATION OF PUBLIC UTILITIES/SERVICES SHOWN ON THESE DRAWINGS HAS BEEN APPROXIMATED FROM KNOWN POSTIIONS OF VALVES, INSPECTION/ACCESS CHAMBERS, ETC NO POTHOLING HAS BEEN UNDERTAKEN THE LOCATIONS SHAWN HAVE BEEN SUPPLIED BY SERVICE AUTHORITIES AND ARE INDICATIVE ONLY.

Legend

- KPs
- Sewer MH
- Sewer
- Ergon Pole
- Ergon Low Voltage
- Gas Main
- Wall Alignment 30112018
- Gravity Main
- Optus
- Stormwater
- Telecom Pit
- Water Main
- NBN Co Connection
- DCDB

R	Details		Date
1	For Information Purposes		03/12/18
-	-		
-	-		
-	-		
-	-		
-	-		
-	-		

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DESIGNED	SB	CHECKED	-
DRAWN	SB	CHECKED	-
APPROVED	-	DATE	03/12/18

Notes:

0 12.5 25 50
Metres

GCS GDA 1994 MGA Zone 55

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

DATA SOURCE
Adani Infrastructure Pty. Ltd. 2015
QLD Government Open Source Data

DESIGNER

CDM Smith
cdmsmith.com

CLIENT

FIGURE 3
Bundaberg Flood Levee
Wall Alignment Location
and GL heights

DRG Ref: Fig_3

A.4 Architectural Additions

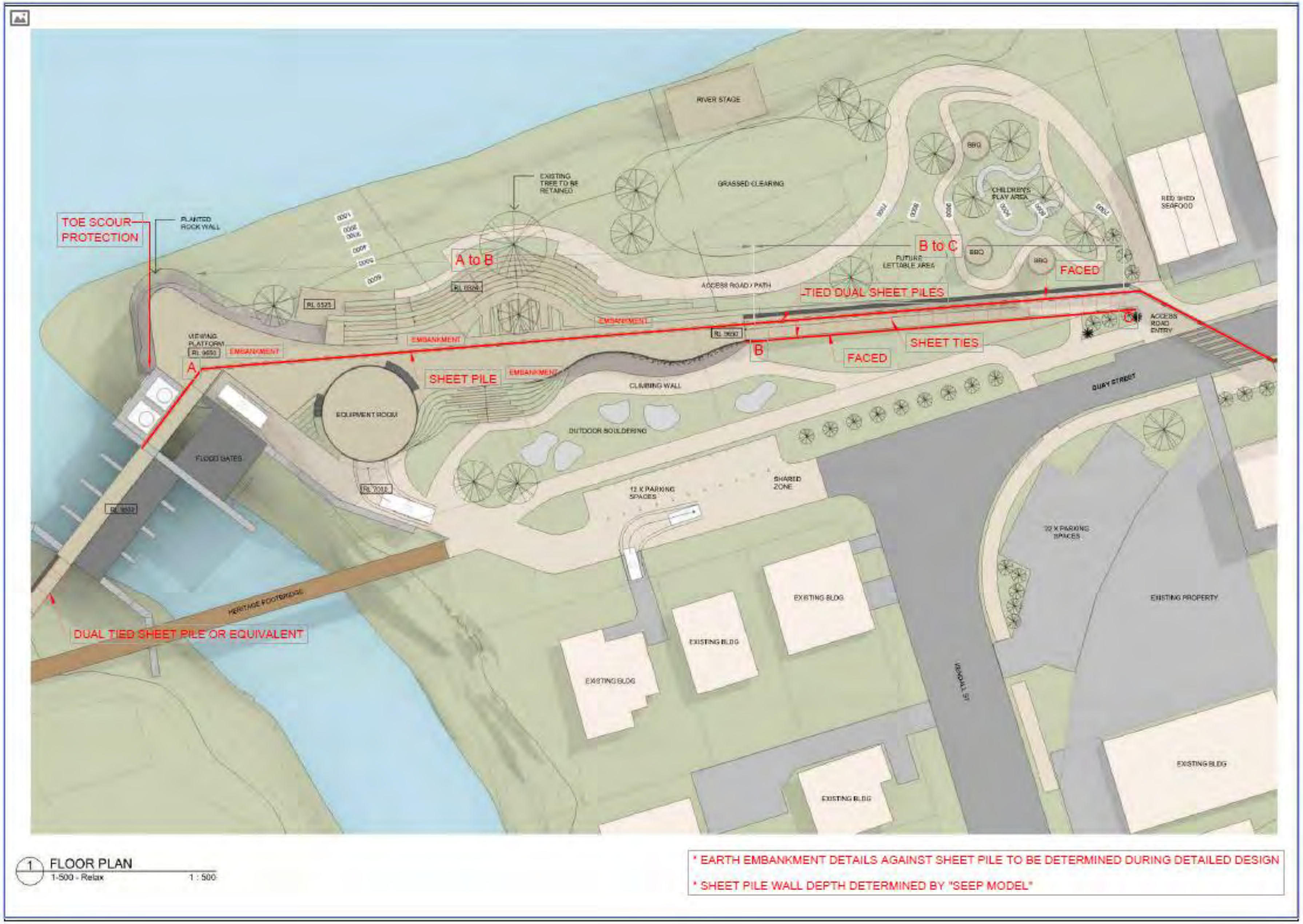
Bundaberg East Levee - Alignment Breakdown (additional items)

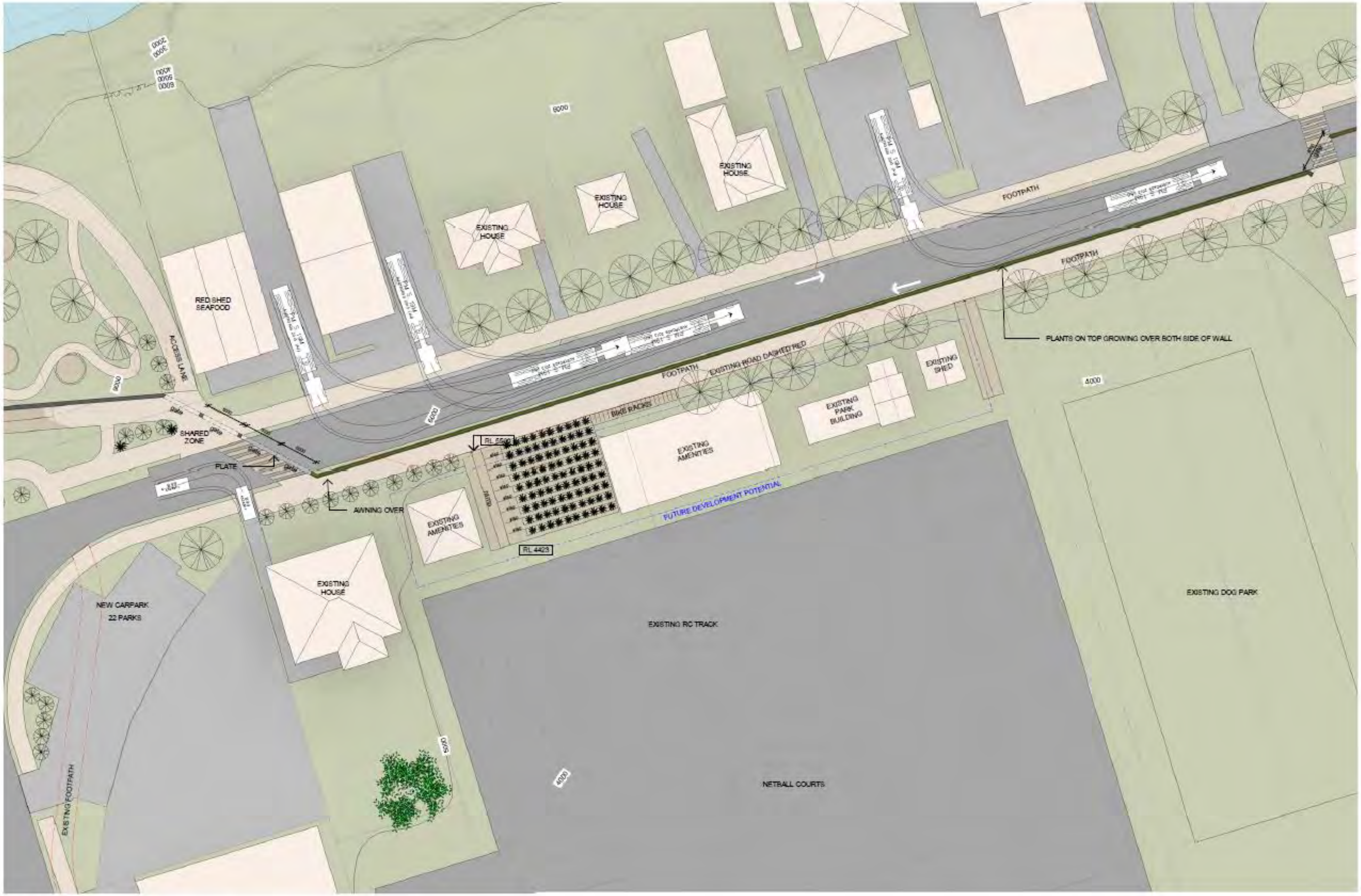
Item	Start Location - end	Details	Extra items (Rawlinsons etc)	Notes	General notes	Units	Rate per unit	Take off	Total rate
1	Rowers car park to	Footpath to jn. overbridge	Earth build up & compact	p678, 681	Based on general EW	cum	$91.69	1782.00	$163,391.58
	footbridge over dam	Footpath material and curb	Concrete & finish	p687 Rawlinsons	1200 width	m	$76.90	132.00	$10,150.80
		Handrail on the wall side	Gal finish with connectors	p312 Gal	Handrail on wall	m	$101.00	80.00	$8,080.00
		Balustrading fence	Gal finish, rails, stanchions & handrails	p311 900 high, rails, bst	Separate	m	$410.00	110.00	$45,100.00
		Potential future link	Landing to suit	Lump sum	With sleepers etc	1	$5,000.00	1.00	$5,000.00
		Terracing effect (drop off)	Earth build up and retaining capping	p678, 681	Based on general EW	cum	$91.69	45.00	$4,126.05
2	Walkway over dam	Footpath to overbridge	Earth build and compact	p678, 681 trimming	Standard	cum	$91.69	10.00	$916.90
		Gantry walkway over	Gal / alum pdr finish on unit and connectors	p302	Aluminium / bond deck	m	$909.00	35.00	$31,815.00
		Expansion joints	Either end & middle	p238	Water stop eq	m	$51.80	10.00	$518.00
		Bracing, reinforcing & rails	Over the dam structure Al to suit walkway	p312 Gal	Powder coat	m	$435.00	70.00	$30,450.00
		Sundry landscaping	Topsoil, grass and vegetation no trees	p229	Standard rates	cum	$60.50	25.00	$1,512.50
3	Deck and observation area	Wooden deck	Hardwood with pencil round finish & oil	p336	Jarrah, pencil finished	sqm	$206.00	100.00	$20,600.00
	to wall ramp area	Balustrading gate side, viewing	Gal finish, rails, stanchions & handrails	p311 900 high, rails, bst	Galvanised complete	m	$101.00	55.00	$5,555.00
		Footpath and built up area	Earth build up & compact	p678, 681	EW standard	cum	$91.69	5250.00	$481,372.50
		Footpath materials and curb	Concrete and finish	p687 Rawlinsons	Standard 1200	m	$76.90	2100.00	$161,490.00
		Terracing effect	Earth build up compact and terrace form	p678, 681	EW standard	cum	$91.69	2812.50	$257,878.13
		Under kiosk area	Basic finish level no fit out	p61 Rawlinsons fit out	Neighbourhood shop	sqm	$750.00	70.00	$52,500.00
		Rock climbing area	Per US spec rate per meter square	Per US based sqft rates	General	sqm	$400.00	75.00	$30,000.00
		New access road & paths	Finish to exposed aggregate concrete & stencil	Assumed p683	Layers	sqm	$72.87	1000.00	$72,870.00
		New BBQ areas	Per standard electric BBQ for parks	Grillex	To estimate	3	$2,000.00	3.00	$6,000.00
		BBQ powersupply	Underground conduit supply	To supply the BBQ	Est Required	m	$75.00	70.00	$5,250.00
		Landscaping areas sundry	Across the news park area	p56	General	sqm	$65.00	5200.00	$338,000.00
		New extra packing apron	At the end of Quay Street	As per roads Rawlinsons	p683	sqm	$72.87	315.00	$22,954.05
		New access road extension	Quay street to the flood gate	p687 Rawlinsons	Estimated good ground	sqm	$76.90	55.00	$4,229.50
		Sundry park furniture	Park seats and fountains	Per grillex	To estimate	5	$1,000.00	5.00	$5,000.00
		New stormwater & drainage	Across the new park area	Estimated	Lump sum	1	$15,000.00	1.00	$15,000.00
		Balustrading to rock climb wall	Terrace to rock climbing wall then ramp start	p311 900 high, rails, bst	Galvanised complete	m	$410.00	25.00	$10,250.00
		Brick building extra cost	Estimated on base foundation cost	Estimated	Lump sum	1	$60,000.00	1.00	$60,000.00
		Brick building	7.5m radius - assumed extra cost on bld (brick)	Over steel frame	Brick building	pp (1000)	$960.00	42.39	$40,694.40
4	Down Ramp to Big Red Shed	Footpath ramp down to grade	Earth build up and compact	p678, 681	EW standard	cum	$91.69	337.50	$30,945.38
		Footpath material and curb	Concrete & finish	p687 Rawlinsons	Standard 1200	m	$76.90	54.00	$4,152.60
		Handrail on wall side	Gal handrail and fixing	p312 Gal	Fixed to flood wall	m	$101.00	50.00	$5,050.00
		Balustrading	On ramp down side to the access entry	p311 900 high, rails, bst	Galvanised complete	m	$410.00	50.00	$20,500.00
		Access path / road entry	Graded footpath to redshed entry	As per roads Rawlinsons	p683	m	$72.90	24.00	$1,749.60
		PUPS around entry	Estimated on base foundation cost	Estimated	Standard	1	$50,000.00	1.00	$50,000.00
		Landscaping around entry	Sundry landscaping items	p229	Standard rates assumed	cum	$60.50	24.00	$1,452.00
5	Big red shed to mid road wall	Stop log crossing (new)	2x 12m each (mid stanchions)	Awma assumed	Awma	2	$35,000.00	2.00	$70,000.00
		New line work	Crossing signs & sundries	Signs ($400)	Signs and others	1	$1,500.00	1.00	$1,500.00
		Demolish power lines	x3 power poles and 1 transformer	Disconnect & demolish	To estimate	1	$25,000.00	1.00	$25,000.00
		Reinstate power lines	x3 power poles and 1 transformer	Reconnect & reinstate	To estimate	1	$60,000.00	1.00	$60,000.00
		Adjust wall curve lead in	Cast in-situ class 2 with stencil	Special item	To estimate	1	$20,000.00	1.00	$20,000.00
		Add in ampitheatre	Earth wall with steps added in	Special item	Finish back with terrace	cum	$100.00	150.00	$15,000.00
		Ampitheatre handrails	Handrails & landing points	Per balustrading	Aluminium pdr coat	m	$390.00	15.00	$5,850.00
		Sundry landscaping	Reinstatement & landscaping	p229	Standard rates	cum	$60.50	120.00	$7,260.00
		Footpath on netball court side	Earth build up and concrete footpath	p687 Rawlinsons	Not built up (to add)	m	$76.90	144.00	$11,073.60
		Footpath balustrading	To suit footpath on one side	p311 900 high, rails, bst	Separate	m	$410.00	80.00	$32,800.00
6	Gate crossing to Scotland	Stoplog crossing	6m crossing	Awma assumed	Awma	1	$35,000.00	1.00	$35,000.00

	Street intersection	Road furniture to suit	Road furniture, barriers & signage	Signs, barriers & marking	Lump sum	1	$2,500.00	1.00	$2,500.00
		Part demolish road for pile cap	Excavate & trench shield road to suit	Demolish and cart away	p206	sqm	$28.30	942.00	$26,658.60
		Recompact and reinstate road	Over the pile cap footing & recompact	Assumed road rate	Over std rate	sqm	$76.90	1413.00	$108,659.70
		Install footpath & curbing	Fill compact, footpath & curbing to suit	p687 Rawlinsons	Standard 1200	m	$76.90	157.00	$12,073.30
		Install 'metal awning cover'	Based on a basic lightweight al structure	p381 pdr coated	Al with brackets	sqm	$390.00	37.68	$14,695.20
		Install planter boxes	Lightweight powdercoated	p231 per unit	Pdr coatd per unit	31.4	$375.00	31.40	$11,775.00
		Install plant trellis for climbing	Lightweight powdercoated	Est based on sunshade	Trellis mesh pdr coat	sqm	$45.00	314.00	$14,130.00
		Soil for planting & plants	Mulch on planter boxes	p228	Soil to planters	cum	$68.50	31.40	$2,150.90
		Mulching	Mulch to the planters	p229	Mulch (not adjusted Ht)	cum	$76.00	31.40	$2,386.40
		Scotland Street Entry Sign	Ornamental sign at entry point	Based on architect	To estimate (dwg details)	1	$80,000.00	1.00	$80,000.00
		Stop log crossing (existing base)	x2 6m each with mid point stanchions	Awma assumed	Awma	2	$35,000.00	2.00	$70,000.00
		Road barrier & furniture	Scotland Street intersection	Road sgn p687	Add in barrier (p300)	1	$1,444.00	1.00	$1,444.00
7	Scotland Street Crossing to Cran Street	Stop log crossing (new)	x4 6m each with mid point stanchions	Awma assumed	Stop logs over road	4	$35,000.00	4.00	$140,000.00
		Stop log crossing (new) Peterson	x2 6m each with mid point stanchions	Awma assumed	Stop logs over road	2	$35,000.00	2.00	$70,000.00
		Crib wall construction	Other end of Peterson Street & Cran	p170 composite assumed	Blockwork faced	sqm	$524.00	72.00	$37,728.00
		Raised RCP crossing	Cran Street business	Lump sum	Demolish RCP install	1	$30,000.00	1.00	$30,000.00
8	Cran Street to Distillery end	Realign wall to inside tree line	Realignment of wall	Lump sum	Soil conditions ?	1	$50,000.00	1.00	$50,000.00
		Push access track	Removal of earth spoil piles	Lump sum	Remove and dump	1	$50,000.00	1.00	$50,000.00
		Include a stop log entry point	Inclusion of new stop log	Awma assumed	Awma	1	$35,000.00	1.00	$35,000.00
9	Site lighting	Public lighting + extras	Across the main walkway area	p493 Bollard type	Per point 2.2m spacing	40	$2,500.00	40.00	$100,000.00
		Public lighting + extras	Across the park areas	p493 Park lights	Per point	20	$3,500.00	20.00	$70,000.00
	Construction Estimate								$3,217,238.68
	Additional contingency (50%)	50%							$1,608,619.34
	Extras & client costs etc (below)		Client costs, design & development, etc						$871,673.75
	TOTAL ESTIMATE								$5,697,531.77

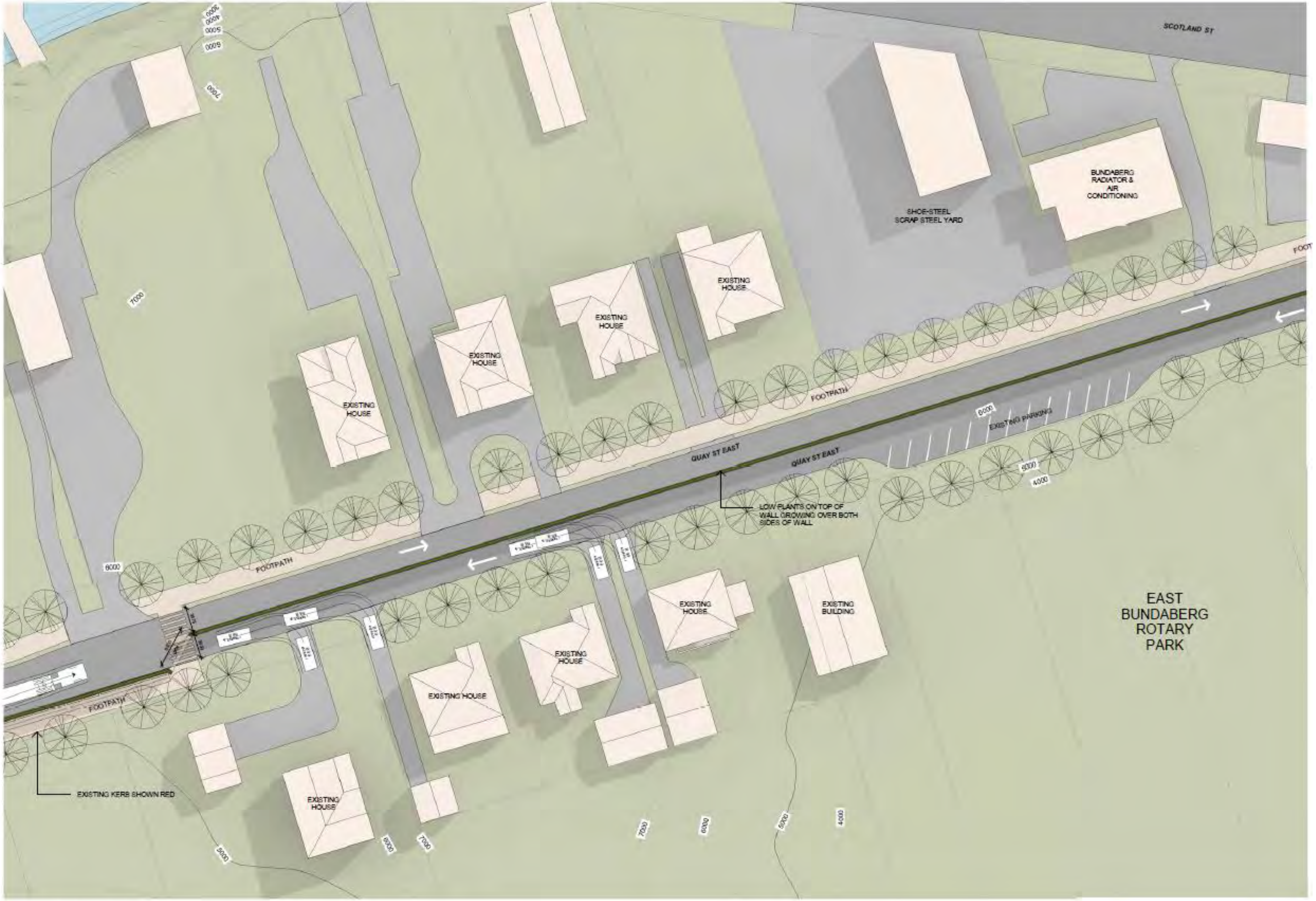
Extras	Costs	
Client costs (assumed)	$150,000	
Development phase*		
Detailed design (3.5%)	$112,603	
Public consultation	$80,000	
Implementation Phase		
Admin costs	$60,000	
Internal Admin (1%)	$32,172	
Contract admin (6%)	$193,034	
PAI Insurance (0.8%)	$112,603	
Q-Leave (0.35)	$11,260	
Principals materials*	$120,000	$871,674
Contingency (50%)	$1,608,619.34	
Escalation	0	

* Included in Eng. Estimate

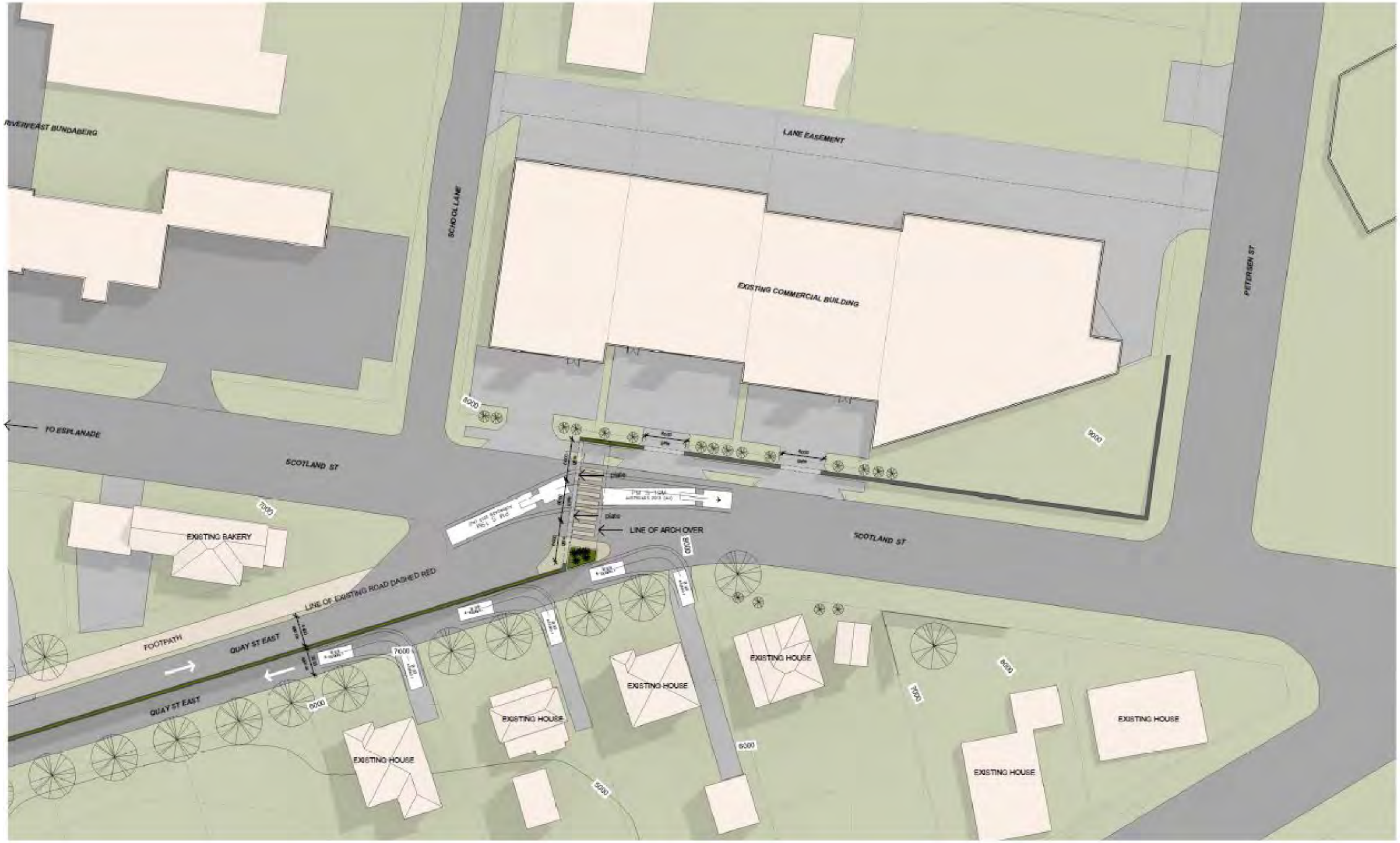

TOE SCOUR PROTECTION
PLANTED ROCK WALL
EXISTING TREE TO BE RETAINED
RIVER STAGE
GRASSED CLEARING
CHILDREN'S PLAY AREA
BBQ
RED SHED SEAFOOD
A to B
B to C
FACED
TIED DUAL SHEET PILES
FUTURE LETTABLE AREA
ACCESS ROAD / PATH
EMBANKMENT
VIEWING PLATFORM
A
B
SHEET PILE
SHEET TIES
ACCESS ROAD ENTRY
QUAY STREET
EQUIPMENT ROOM
CLIMBING WALL
OUTDOOR BOULDERING
FLOOD GATES
12 X PARKING SPACES
SHARED ZONE
22 X PARKING SPACES
EXISTING PROPERTY
EXISTING BLDG
HERITAGE FOOTBRIDGE
DUAL TIED SHEET PILE OR EQUIVALENT
1 FLOOR PLAN
1-500 - Relax
1 : 500
* EARTH EMBANKMENT DETAILS AGAINST SHEET PILE TO BE DETERMINED DURING DETAILED DESIGN
* SHEET PILE WALL DEPTH DETERMINED BY "SEEP MODEL"



1 FLOOR PLAN
1-500 PLAY 1 : 500



FLOOR PLAN
1-500 GROW 1 : 500



1 FLOOR PLAN
1-500 GATE 1 : 500

A.5 Operating Expenses Estimate

Bundaberg East - Levee (Operational and Maintenance costs)

Item	Unit rate	Years 1–50 (2021–2070)
Personnel		
Lead Operator / work crew ($90k per annum)	[illegible]	[illegible]
Electrician ($112k per annum) +	[illegible]	[illegible]
Technical Support ($130k per annum)+	[illegible]	[illegible]
Personnel Summary		[illegible]
Benefits, super, workers com (12.5% of salary)		[illegible]
Overtime assumed (20% of salary)		[illegible]
Total Personnel (cost)		[illegible]
Pump Station		
Pump station team service (every 4 years)		[illegible]
Electrical service for pump operation (yearly) - as+		
Fuel / power consumption (Saltwater)		[illegible]
Fuel / power consumption (Distillery)		[illegible]
Oils and lubes (routine replacement)	[illegible]	[illegible]
Pump station automation (replacement controls)	[illegible]	[illegible]
Pump station expenses - electrical	[illegible]	[illegible]
Pump station expenses - other equipment	[illegible]	[illegible]
Office supplies	[illegible]	[illegible]
Computers	[illegible]	[illegible]
Electrical service for auxiliary systems (specialist)	[illegible]	[illegible]
Preventative maintenance		
Overhaul parts only (all pumps)		[illegible]
Fuel replacement in sube tank & mine pump	[illegible]	[illegible]
Run the gensets - clean out oil water filters - as	[illegible]	[illegible]
General building maintenance	[illegible]	[illegible]
Flood gates, flaps and screens		[illegible]
Flood gate checking and maintenance - as		
Testing of the gate raising actuators	[illegible]	[illegible]
Lubrication of gate guides	[illegible]	[illegible]
Removal of debris from gate locations (machine)	[illegible]	[illegible]
Checking the backflow valves & maintain etc	[illegible]	[illegible]
Maintenance of the mechanical bar screen	[illegible]	[illegible]
Wall and scheme maintenance		
General Maintenance - as		
Minor crack maintenance & settling		[illegible]
Pump forebay cleaning		[illegible]
Check for scouring		[illegible]
Spot graffiti removal		[illegible]
Repainting the wall and others	[illegible]	[illegible]
General amenity maintenance (furniture)		[illegible]
Vegetation maintenance and gardening		[illegible]
TOTAL O&M costs		[illegible]
Contingency (assumed 20%)		[illegible]
TOTAL O&M (with contingency)		[illegible]

Pump overhaul every 4 years (or 1,000 hrs)	4 yr	Removal and maintenance of pump
Warranty on gates (from vendors)	30 yr	Workover required
Unit rate per year	yearly	On current 2018 assumed prices
Assumed start date in	2019	Per client discussions
Operational cost (assumed event @ every 5 years)	5 years	Saltwater
Operational cost (assumed event @ every 10 years)	10 years	Distillery

* Needs adjustment for PV @ say 8%
as (0) - as above (included in labour)

NOTE: Operating expenses forwarded to nine squared (spreadsheet in electronic format)

A.6 VE Cost Estimate Summary, Cashflow Estimate and Construction Schedule

Value Engineering Cost Summary

Item	Description	Unit	Quantity	Unit rate	Amount
	Project Preliminary Items				
	ENVIRONMENTAL MANAGEMENT (MRS51 Jul 17)				
20201	Weekly Environmental Inspections	LS	1.000	9,450.00	9,450
20202	Develop Environmental Management Plan (Construction)	LS	1.000	5,756.00	5,756
20203	Implement Environmental Management Plan (Construction)	LS	1.000	97,825.00	97,825
20204	Monthly Environmental Reporting	LS	1.000	4,387.00	4,387
20205	Environmental Records Management	LS	1.000	47,250.00	47,250
20207P	Water Quality Monitoring (Provisional Quantity, if ordered)	LS	1.000	16,695.00	16,695
20211	Cultural Heritage Management	LS	1.000	15,277.00	15,277
20212	Noise Assessment Report	LS	1.000	2,813.00	2,813
20213P	Develop Noise Management Plan, if ordered (Provisional Quantity)	LS	1.000	2,306.00	2,306
20217P	Implement Noise Management Plan, if ordered (Provisional Quantity)	LS	1.000	47,880.00	47,880
20221	Vibration Assessment Report	LS	1.000	2,812.00	2,812
20222P	Condition surveys, if ordered (Provisional Quantity)	each	30.000	1,464.75	43,943
20226P	Develop Vibration Management Plan, if ordered (Provisional Quantity)	LS	1.000	1,294.00	1,294
20230P	Implement Vibration Management Plan (Provisional Quantity, if ordered)	LS	1.000	60,480.00	60,480
20234P	Air quality monitoring, if ordered (Provisional Quantity)	each	1.000	16,695.00	16,695
20238P	Management of contaminated sites, if ordered (Provisional Quantity)	m3	100.000	112.50	11,250
20242P	Fauna management, if ordered (Provisional Quantity)	LS	1.000	9,090.00	9,090
20246P	Biosecurity Control, if ordered (Provisional Quantity)	LS	1.000	4,292.00	4,292
	Project Preliminary Items				399,495
	CONTRACTOR'S SITE FACILITIES AND CAMP (MRS28 July 17)				
20101	Contractor's site facilities	LS	1.000	243,231.00	243,231
	CONTRACTOR'S SITE FACILITIES AND CAMP				243,231
90100.01	Project Management & Site Supervision	ITEM	1.000	6,816,106.00	6,816,106
	CITY ALIGNMENT				
	RETAINING WALL				
	EXCAVATION				
32101.11	Excavation	m3	6,999.000	83.07	581,407
32126.11	Mass concrete blinding - assumed 20 MPa	m3	196.510	757.50	148,856
	PILING				
	PRECAST PRESTRESSED CONCRETE PILES (MRS65 July 17)				
70701.11	Preformed concrete piles, supply on Site, 400 X 400mm, 750KN	m	4,943.000	140.63	695,134
70701.11	Preformed concrete piles, supply on Site, 400 X 400mm, 750KN- infill wall either side of pump station	m	243.000	140.62	34,171
70701.12	Preformed concrete piles, supply on Site, 400 X 400mm, 1000KN	m	16,073.000	140.63	2,260,346
70701.13	Preformed concrete piles, supply on Site, 400 X 400mm, 1000KN - infill wall either side of pump station	m	824.000	140.63	115,879
70702.11	Transport to Site and storage of prestressed concrete piles, ex works [location]	LS	1.000	149,625.00	149,625

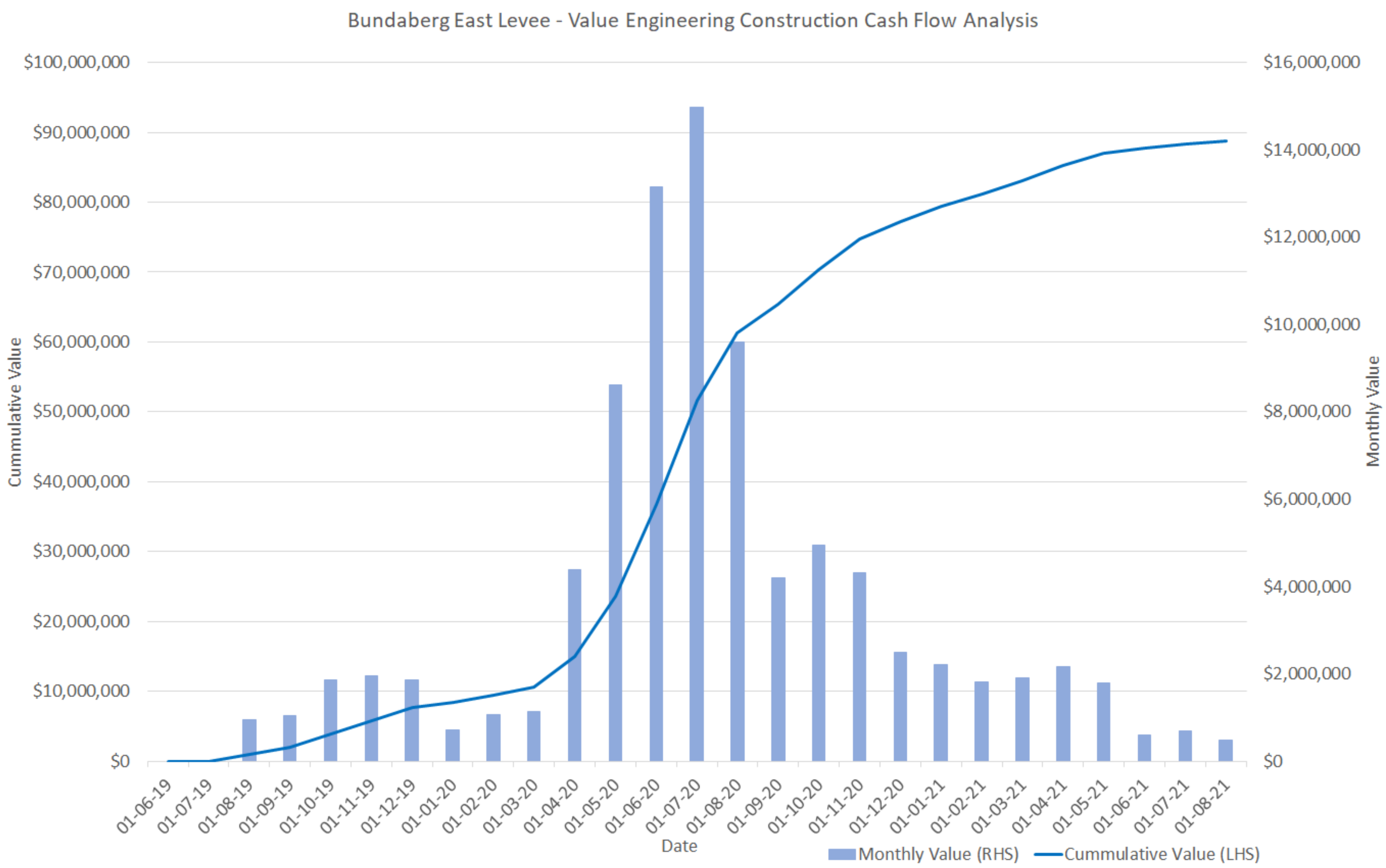
70703.11	Handling and pitching of prestressed concrete piles, 400 x 400 mm cross section shape	each	733.000	3,937.50	2,886,188
70704P.11	Driving prestressed concrete piles, 400 x 400mm cross section shape	m	22,082.000	67.50	1,490,535
70708.11	Setting up for pre-boring for prestressed concrete piles	LS	2.000	5,625.00	11,250
70709.11	Pre-boring for prestressed concrete piles	m	1,466.000	157.50	230,895
70710.11	Splicing of Prestressed Concrete Piles	each	733.000	885.94	649,394
70711.11	Stripping of prestressed concrete pile head, 400 x 400 mm [cross section shape]	each	733.000	1,193.40	874,762
70712P.11	Extension of prestressed concrete piles, [cross section size] mm [cross section shape] (Provisional Quantity) - assumed 5% of piles allowing additional 10m per pile extension	m	380.000	521.30	198,094
70716P.11	Setting up for re-driving of prestressed concrete piles (Provisional Quantity) - assumed 5%	each	35.000	2,812.50	98,438
70716P.12	Setting up for re-driving of prestressed concrete piles (Provisional Quantity) - assumed 5% - infill wall either side of pump station	each	3.000	2,812.00	8,436
70720.11	Monitoring the last 10 blows of the pile drive using a PM -	EACH	689.000	208.12	143,395
70720.12	Monitoring the last 10 blows of the pile drive using a PM - infill wall either side of pump station	EACH	44.000	208.12	9,157
	SHEET PILING				
92000.11	Sheet piling	m2	6,273.000	371.25	2,328,851
	CONCRETE WORK				
70302.11	Concrete Class [assumed compressive strength] 40MPa/20 in footing / pier pile cap	m3	4,180.000	889.10	3,716,438
70309.11	Concrete Class [40] MPa/20 in wall - assumed concrete mix	m3	1,955.000	1,667.76	3,260,471
	CITY ALIGNMENT				19,891,722
	PUP				
	PUP				
	BUNDABERG CREEK FLOOD GATE STRUCTURE				
90100.21	**TEMPORARY WORKS**	**Item**	**1.000**	**1,052,981.00**	**1,052,981**
	DEMOLITION / ALTERATION WORK				
90100.22	Allow to remove a section of the existing rail/pedestrian bridge and reinstate after construction. Next to Rowing Club/Burnett Creek	Item	1.000	168,750.00	168,750
	EXCAVATION				
32101.21	Excavation	m3	5,535.000	92.04	509,441
32126.21	Mass concrete blinding - assumed 20 MPa	m3	74.000	758.44	56,125
	PILING				
	PRECAST PRESTRESSED CONCRETE PILES (MRS65 July 17)				
70701.21	Prestressed concrete piles, supply on Site, 400 X 400mm, 1000KN	m	4,864.000	140.62	683,976
70702.21	Transport to Site and storage of prestressed concrete piles, ex works [location]	LS	1.000	69,187.00	69,187
70703.21	Handling and pitching of prestressed concrete piles, [cross section size] mm [cross section shape]	each	237.000	3,937.50	933,188
70704P.21	Driving prestressed concrete piles, 400 x 400mm cross section shape	m	4,864.000	67.50	328,320
70708.21	Setting up for pre-boring for prestressed concrete piles	LS	2.000	5,625.00	11,250
70709.21	Pre-boring for prestressed concrete piles	m	474.000	157.50	74,655
70711.21	Stripping of prestressed concrete pile head, 400 x 400 mm [cross section shape]	each	237.000	1,161.94	275,380
70712P.21	Extension of prestressed concrete piles, [cross section size] mm [cross section shape] (Provisional Quantity) - assumed 5%	m	120.000	526.59	63,191
70716P.21	Setting up for re-driving of prestressed concrete piles (Provisional Quantity) - assumed 5%	each	12.000	2,812.50	33,750

70720.21	Monitoring the last 10 blows of the pile drive using a PM	EACH	237.000	208.12	49,324
	SHEET PILING				
92000.21	Sheet piling	m2	141.000	371.25	52,346
	CONCRETE WORK				
70302.21	Concrete Class [assumed compressive strength] 40MPa/20 in footing / base slab / pier pile cap	m3	1,785.000	890.34	1,589,257
70309.21	Concrete Class [40] MPa/20 in walls - assumed concrete mix	m3	2,798.000	1,472.38	4,119,719
70309.21	Concrete Class [40] MPa/20 in suspended slabs, etc - assumed concrete mix	m3	108.000	4,359.69	470,847
70309.21	Concrete Class [40] MPa/20 in pipe encasement - assumed concrete mix	m3	63.000	940.92	59,278
	METALWORK & PLUMBING				
90110.21	**METALWORK**	**Item**	**1.000**	**94,117.00**	**94,117**
90115.21	**PLUMBING**	**Item**	**1.000**	**56,250.00**	**56,250**
90120.21	**PLANT**	**Item**	**1.000**	**1,243,977.00**	**1,243,977**
90130.21	**ELECTRICAL INSTALLATION - (Diesel Driven Pumps & Fuel Bund)**	**ITEM**	**1.000**	**1,406,032.00**	**1,406,032**
	SUNDRIES				
	BUNDABERG CREEK FLOOD GATE STRUCTURE				13,401,341
	BUNDABERG CREEK PUMP STATION				
	Drawing DWG-S-10				
	EXCAVATION				
32101.22	Excavation	m3	481.000	434.32	208,908
32126.22	Mass concrete blinding - assumed 20 MPa	m3	4.000	827.00	3,308
	PILING				
	PRECAST PRESTRESSED CONCRETE PILES (MRS65 July 17)				
70701.22	Prestressed concrete piles, supply on Site, 400 X 400mm [cross section shape]	m	686.000	140.63	96,472
70702.22	Transport to Site and storage of prestressed concrete piles, ex works [location]	LS	1.000	5,344.00	5,344
70703.22	Handling and pitching of prestressed concrete piles, [cross section size] mm [cross section shape]	each	19.000	3,937.50	74,813
70704P.22	Driving prestressed concrete piles, [cross section size] mm [cross section shape]	m	686.000	67.50	46,305
70708.22	Setting up for pre-boring for prestressed concrete piles	LS	1.000	5,625.00	5,625
70709.22	Pre-boring for prestressed concrete piles	m	38.000	157.50	5,985
70710.22	Splicing of Prestressed Concrete Piles	each	19.000	885.90	16,832
70711.22	Stripping of prestressed concrete pile head, 400 x 400 mm [cross section shape]	each	19.000	1,170.80	22,245
70712P.22	Extension of prestressed concrete piles, [cross section size] mm [cross section shape] (Provisional Quantity) - assumed 5%	m	20.000	573.50	11,470
70716P.22	Setting up for re-driving of prestressed concrete piles (Provisional Quantity) - assumed 5%	each	2.000	2,813.00	5,626
70720.22	Monitoring the last 10 blows of the pile drive using a PM	EACH	19.000	208.10	3,954
	CONCRETE WORK				
70302.22	Concrete Class [assumed compressive strength] 40MPa/20 in footing / pier pile cap	m3	21.000	1,220.20	25,624
70302.22	Concrete Class [assumed compressive strength] 40MPa/20 in ground beams	m3	54.000	1,272.52	68,716
70302.22	Concrete Class [assumed compressive strength] 40MPa/20 in columns	m3	8.000	4,982.70	39,862
70302.22	Concrete Class [assumed compressive strength] 40MPa/20 in walls	m3	22.000	2,590.50	56,991
70302.22	Concrete Class [assumed compressive strength] 40MPa/20 in ground slab & attached beams on fill	m3	93.000	943.80	87,773
	Building				

92020.22	Pre-engineered metal building complete 14.00m diameter (External dimensions) 3.50m high to underside of frame at eaves - note brick facing	m2	154.000	1,687.50	259,875
	BUNDABERG CREEK PUMP STATION				1,045,728
	DISTILLERY ALIGNMENT				
	RETAINING WALL				
	DEMOLITION				
90100.02	Demolish existing bridge	Item	1.000	61,875.00	61,875
	CULVERTS				
30253.31	Supply and installation of concrete box culvert components [2 x 3600 x 3600 RCBCs]	m	12.000	9,125.60	109,507
30254.31	Supply & place 300 Thick concrete topping slab (12 x 8 x .3)	m3	29.000	1,028.42	29,824
	EXCAVATION				
32101.31	Excavation	m3	5,875.000	103.31	606,946
32126.31	Mass concrete blinding - assumed 20 MPa	m3	108.000	757.43	81,802
	PILING				
	PRECAST PRESTRESSED CONCRETE PILES (MRS65 July 17)				
70701.31	Prestressed concrete piles, supply on Site, 400 X 400mm, 1000KN	m	8,449.000	140.62	1,188,098
70702.31	Transport to Site and storage of prestressed concrete piles, ex works [location]	LS	1.000	66,375.00	66,375
70703.31	Handling and pitching of prestressed concrete piles, [cross section size] mm [cross section shape]	each	365.000	3,937.50	1,437,188
70704P.31	Driving prestressed concrete piles, [cross section size] mm [cross section shape]	m	8,449.000	67.50	570,308
70708.31	Setting up for pre-boring for prestressed concrete piles	LS	2.000	5,625.00	11,250
70709.31	Pre-boring for prestressed concrete piles	m	730.000	157.50	114,975
70710.31	Splicing of Prestressed Concrete Piles	each	365.000	885.94	323,368
70711.31	Stripping of prestressed concrete pile head, 400 x 400 mm [cross section shape]	each	365.000	1,189.40	434,131
70712P.31	Extension of prestressed concrete piles, [cross section size] mm [cross section shape] (Provisional Quantity) - assumed 5%	m	190.000	523.14	99,397
70716P.31	Setting up for re-driving of prestressed concrete piles (Provisional Quantity) - assumed 5%	each	19.000	2,812.50	53,438
70720.31	Monitoring the last 10 blows of the pile drive using a PM	EACH	365.000	208.13	75,967
	SHEET PILING				
92000.31	Sheet piling	m2	2,011.000	371.25	746,584
	CONCRETE WORK				
70302.31	Concrete Class [assumed compressive strength] 40MPa/20 in footing / pier pile cap	m3	2,054.000	887.35	1,822,617
70309.31	Concrete Class [40] MPa/20 in wall - assumed concrete mix	m3	1,033.000	1,748.20	1,805,891
	DISTILLERY ALIGNMENT				9,639,541
	DISTILLERY CREEK FLOOD GATE STRUCTURE				
90100.32	**TEMPORARY WORKS**	**Item**	**1.000**	**348,711.00**	**348,711**
	EXCAVATION				
32101.32	Excavation	m3	881.000	82.38	72,577
32126.32	Mass concrete blinding - assumed 20 MPa	m3	18.000	745.30	13,415
	PILING				
	PRECAST PRESTRESSED CONCRETE PILES (MRS65 July 17)				
70701.11	Preformed concrete piles, supply on Site, 400 X 400mm, 750KN	m	385.000	140.62	54,139

70701.32	Prestressed concrete piles, supply on Site, 400 X 400mm, 1000KN	m	1,281.000	140.63	180,147
70702.32	Transport to Site and storage of prestressed concrete piles, ex works [location]	LS	1.000	11,813.00	11,813
70703.32	Handling and pitching of prestressed concrete piles, [cross section size] mm [cross section shape]	each	76.000	3,937.50	299,250
70704P.32	Driving prestressed concrete piles, [cross section size] mm [cross section shape]	m	1,666.000	67.50	112,455
70708.32	Setting up for pre-boring for prestressed concrete piles	LS	1.000	5,625.00	5,625
70709.32	Pre-boring for prestressed concrete piles	m	152.000	157.50	23,940
70711.32	Stripping of prestressed concrete pile head, 400 x 400 mm [cross section shape]	each	76.000	1,216.05	92,420
70712P.32	Extension of prestressed concrete piles, [cross section size] mm [cross section shape] (Provisional Quantity) - assumed 5%	m	40.000	546.47	21,859
70716P.32	Setting up for re-driving of prestressed concrete piles (Provisional Quantity) - assumed 5%	each	4.000	2,813.00	11,252
70720.32	Monitoring the last 10 blows of the pile drive using a PM	EACH	76.000	208.12	15,817
	SHEET PILING				
92000.32	Sheet piling	m2	144.000	371.25	53,460
	CONCRETE WORK				
70302.32	Concrete Class [assumed compressive strength] 40MPa/20 in footing / base slab / pier pile cap	m3	282.000	982.17	276,972
70309.32	Concrete Class [40] MPa/20 in walls - assumed concrete mix	m3	530.000	1,450.98	769,019
70309.32	Concrete Class [40] MPa/20 in ground slab - assumed concrete mix	m3	18.000	952.70	17,149
	METALWORK & PLUMBING				
90110.32	**METALWORK**	**Item**	**1.000**	**171,931.00**	**171,931**
90120.32	**PLANT**	**Item**	**1.000**	**416,250.00**	**416,250**
90130.32	**ELECTRICAL INSTALLATION**	**Item**	**1.000**	**33,750.00**	**33,750**
	SUNDRIES				
	DISTILLERY CREEK FLOOD GATE STRUCTURE				3,001,951
90150	**PROVISION FOR STOP LOG CROSSINGS & STANCHION (Refer email Stuart Brown 15 May 2018)**	**Item**	**1.000**	**640,433.00**	**640,433**
					640,433
	Total for Project				55,079,548
	CLIENT COSTS				
1	**Concept Phase**				
1.01	Administration Costs - Concept Phase	Item	1.000		
1.02	Non Contract Works & Unspecified Planning	Item	1.000		
1.04	Pavement Investigation	Item	1.000		
1.05	Survey	Item	1.000		
1.06	Geotechnical Investigations	Item	1.000		
1.07	Unspecified Resumption Costs	Item	1.000		
	Concept Phase				
2	**Development Phase**				
2.01	Administration Costs - Development	Item	1.000	60,000.00	60,000
2.02	Additional Survey	Item	1.000	18,000.00	18,000
2.03	Additional Geotechnical Investigations	Item	1.000	300,000.00	300,000

2.04	Detailed Design (Approx 1.25% of Construct. Cost)	Item	1.000	750,000.00	750,000
2.05	Property Acquisitions & Resumption Costs & Disruption	Item	1.000	3,500,000.00	3,500,000
2.06	Public Consultation	Item	1.000	32,000.00	32,000
2.07	Environmental Permits	Item	1.000	50,000.00	50,000
	Development Phase				4,710,000
3	**Implementation Phase**				
3.01	Administration Costs - Implementation	Item	1.000	30,000.00	30,000
3.02	Internal Administration (1% of Const. Cost)	Item	1.000	550,796.00	550,796
3.03	Contract Administration (4% of Const. Cost)	Item	1.000	2,203,186.00	2,203,186
3.04	Environmental Permits	Item	1.000	25,000.00	25,000
3.05	Public Utility Services Relocations (PUP)	Item	1.000	1,376,991.00	1,376,991
3.06	PAI Insurances (0.8% of Construct. Cost)	Item	1.000	440,637.00	440,637
3.07	Q-Leave Fees (0.35% of Construct. Cost)	Item	1.000	192,779.00	192,779
3.08	Miscellaneous	Item	1.000		
	Implementation Phase				4,819,389
4	**Principal's Materials**				
4.01	Accommodation Works	Item	1.000	50,000.00	50,000
4.02	Unspecified Principals Materials	Item	1.000	826,195.00	826,195
4.03	Relationship Management	Item	1.000	192,779.00	192,779
4.04	Architectural Elements	Item	1.000	3,217,238.00	3,217,238
	Principal's Materials				1,068,974
5	**Finalisation Phase**				
5.01	Finalisation Phase - Administration	Item	1.000	550,796.00	550,796
	Finalisation Phase				550,796
	CONTINGENCY				
6.01	Contingency	Item	1.000	14,574,220.00	14,574,220
	ESCALATION COSTS				
7.01	Escalation Costs	Item	1.000		
	Anticipated Project Cost (Forecast $)				84,020,165
	Total for project (excluding GST)				***84,020,165***
	GST for project (GST rate = 10.00)				***8,402,017***
	Total for project (including GST)				***92,422,182***



Bundaberg East Levee - Value Engineering Construction Cash Flow Analysis
$100,000,000
$90,000,000
$80,000,000
$70,000,000
$60,000,000
$50,000,000
$40,000,000
$30,000,000
$20,000,000
$10,000,000
$0
Cummulative Value
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
Monthly Value
01-06-19
01-07-19
01-08-19
01-09-19
01-10-19
01-11-19
01-12-19
01-01-20
01-02-20
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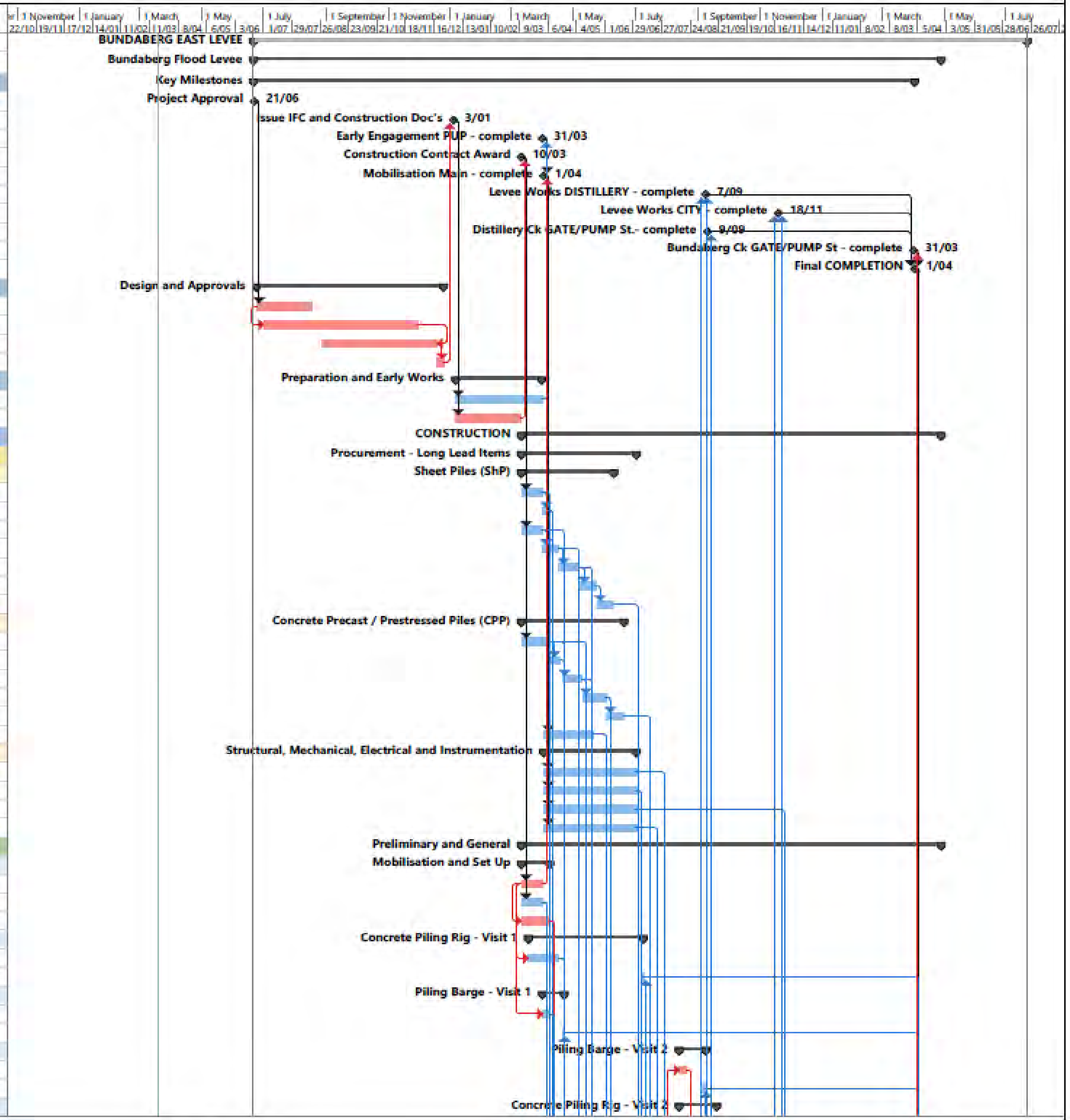
01-01-21
01-02-21
01-03-21
01-04-21
01-05-21
01-06-21
01-07-21
01-08-21
Date
Monthly Value (RHS)
Cummulative Value (LHS)

Bundaberg Flood Levee - rev. 1

ID	Task Name	Duration	Start	Finish
0	**BUNDABERG EAST LEVEE**	**520 days**	**Fri 21/06/19**	**Wed 21/07/21**
1	**Bundaberg Flood Levee**	**461 days**	**Fri 21/06/19**	**Tue 27/04/21**
2	**Key Milestones**	**446 days**	**Fri 21/06/19**	**Thu 1/04/21**
3	Project Approval	1 day	Fri 21/06/19	Fri 21/06/19
4	Issue IFC and Construction Doc's	1 day	Fri 3/01/20	Fri 3/01/20
5	Early Engagement PUP - complete	1 day	Tue 31/03/20	Tue 31/03/20
6	Construction Contract Award	1 day	Tue 10/03/20	Tue 10/03/20
7	Mobilisation Main - complete	1 day	Wed 1/04/20	Wed 1/04/20
8	Levee Works DISTILLERY - complete	1 day	Mon 7/09/20	Mon 7/09/20
9	Levee Works CITY - complete	1 day	Wed 18/11/20	Wed 18/11/20
10	Distillery Ck GATE/PUMP St.- complete	1 day	Wed 9/09/20	Wed 9/09/20
11	Bundaberg Ck GATE/PUMP St - complete	1 day	Wed 31/03/21	Wed 31/03/21
12	Final COMPLETION	1 day	Thu 1/04/21	Thu 1/04/21
13	**Design and Approvals**	**131 days**	**Mon 24/06/19**	**Tue 24/12/19**
14	Tender Detailed Engineering	40 days	Mon 24/06/19	Fri 16/08/19
15	Detailed Engineering and Construction Doc's	109 days	Mon 1/07/19	Fri 29/11/19
16	Approvals	80 days	Wed 28/08/19	Wed 18/12/19
17	Issue IFC and Construction Doc's	4 days	Thu 19/12/19	Tue 24/12/19
18	**Preparation and Early Works**	**60 days**	**Mon 6/01/20**	**Mon 30/03/20**
19	Early Engagement PUP works	60 days	Mon 6/01/20	Mon 30/03/20
20	Tendering for Main Construction	45 days	Mon 6/01/20	Mon 9/03/20
21	**CONSTRUCTION**	**282 days**	**Wed 11/03/20**	**Tue 27/04/21**
22	**Procurement - Long Lead Items**	**76 days**	**Wed 11/03/20**	**Wed 1/07/20**
23	**Sheet Piles (ShP)**	**60 days**	**Wed 11/03/20**	**Tue 9/06/20**
24	ShP - Temp. for Bundaberg Flood Gate	14 days	Wed 11/03/20	Mon 30/03/20
25	ShP - Temp. for Distillary Flood Gate	5 days	Tue 31/03/20	Mon 6/04/20
26	ShP - For Distillery Levee and Flood Gate	14 days	Wed 11/03/20	Mon 30/03/20
27	ShP - For City Levee (1/4) and Bundaberg Flood Gate	11 days	Tue 31/03/20	Thu 16/04/20
28	ShP - For City Levee (2/4)	12 days	Fri 17/04/20	Wed 6/05/20
29	ShP - For City Levee (3/4)	12 days	Thu 7/05/20	Fri 22/05/20
30	ShP - For City Levee (4/4)	11 days	Mon 25/05/20	Tue 9/06/20
31	**Concrete Precast / Prestressed Piles (CPP)**	**68 days**	**Wed 11/03/20**	**Fri 19/06/20**
32	CPP - for Distillery Levee incl. Distillery Ck Flood Gate	20 days	Wed 11/03/20	Tue 7/04/20
33	CPP - for City Levee (1/3)	6 days	Wed 8/04/20	Fri 17/04/20
34	CPP - for Bundaberg Ck Flood Gate and Pump Station	13 days	Mon 20/04/20	Fri 8/05/20
35	CPP - for City Levee (2/3)	15 days	Mon 11/05/20	Mon 1/06/20
36	CPP - for City Levee (3/3)	14 days	Tue 2/06/20	Fri 19/06/20
37	RCBC Culverts 3600x3600	30 days	Thu 2/04/20	Tue 19/05/20
38	**Structural, Mechanical, Electrical and Instrumentation**	**60 days**	**Thu 2/04/20**	**Wed 1/07/20**
39	S&M Items - for Bundaberg Ck Pump Station	60 days	Thu 2/04/20	Wed 1/07/20
40	S&M Items - for Distillery Ck Pump Station	60 days	Thu 2/04/20	Wed 1/07/20
41	E&I Items - for Bundaberg Ck Pump Station	60 days	Thu 2/04/20	Wed 1/07/20
42	E&I Items - for Distillery Ck Pump Station	60 days	Thu 2/04/20	Wed 1/07/20
43	**Preliminary and General**	**282 days**	**Wed 11/03/20**	**Tue 27/04/21**
44	**Mobilisation and Set Up**	**20 days**	**Wed 11/03/20**	**Tue 7/04/20**
45	Mobilisation of Main Contractor	15 days	Wed 11/03/20	Tue 31/03/20
46	Prepare and Submit Management Plans	15 days	Wed 11/03/20	Tue 31/03/20
47	Sheet Piling Land Rig - Mobilisation	20 days	Wed 11/03/20	Tue 7/04/20
48	**Concrete Piling Rig - Visit 1**	**76 days**	**Wed 18/03/20**	**Wed 8/07/20**
49	Concrete Piling Rigs - Mob 1	20 days	Wed 18/03/20	Thu 16/04/20
50	Concrete Piling Rigs - Demob 1	2 days	Tue 7/07/20	Wed 8/07/20
51	**Piling Barge - Visit 1**	**13 days**	**Wed 1/04/20**	**Tue 21/04/20**
52	Sheet Piling Barge Rig - Mob 1	5 days	Wed 1/04/20	Tue 7/04/20
53	Sheet Piling Barge Rig - Demob 1	2 days	Mon 20/04/20	Tue 21/04/20
54	**Piling Barge - Visit 2**	**18 days**	**Thu 13/08/20**	**Mon 7/09/20**
55	Sheet Piling Barge Rig - Mob 2	5 days	Thu 13/08/20	Wed 19/08/20
56	Sheet Piling Barge Rig - Demob 2	2 days	Fri 4/09/20	Mon 7/09/20
57	**Concrete Piling Rig - Visit 2**	**27 days**	**Thu 13/08/20**	**Fri 18/09/20**



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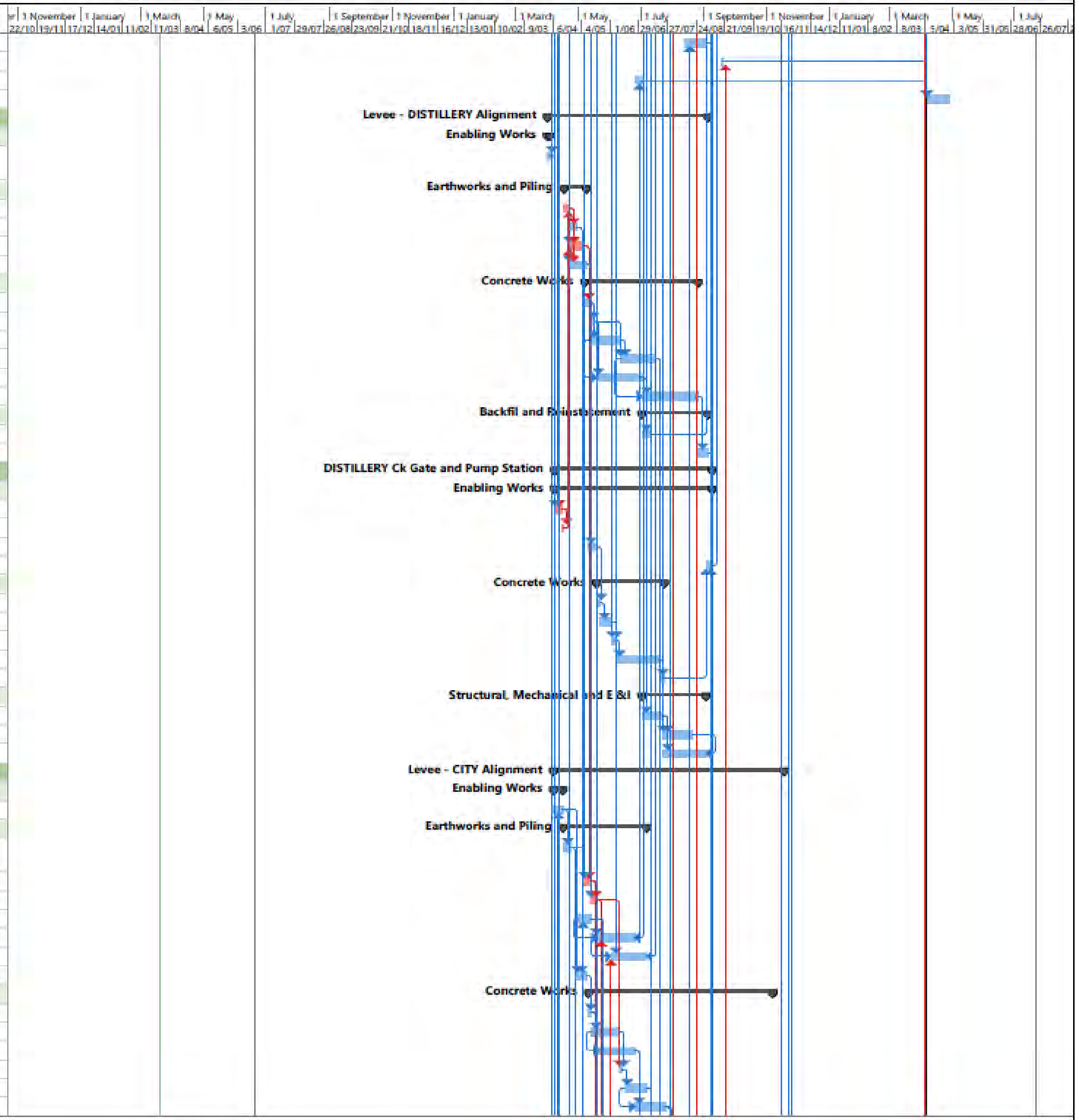
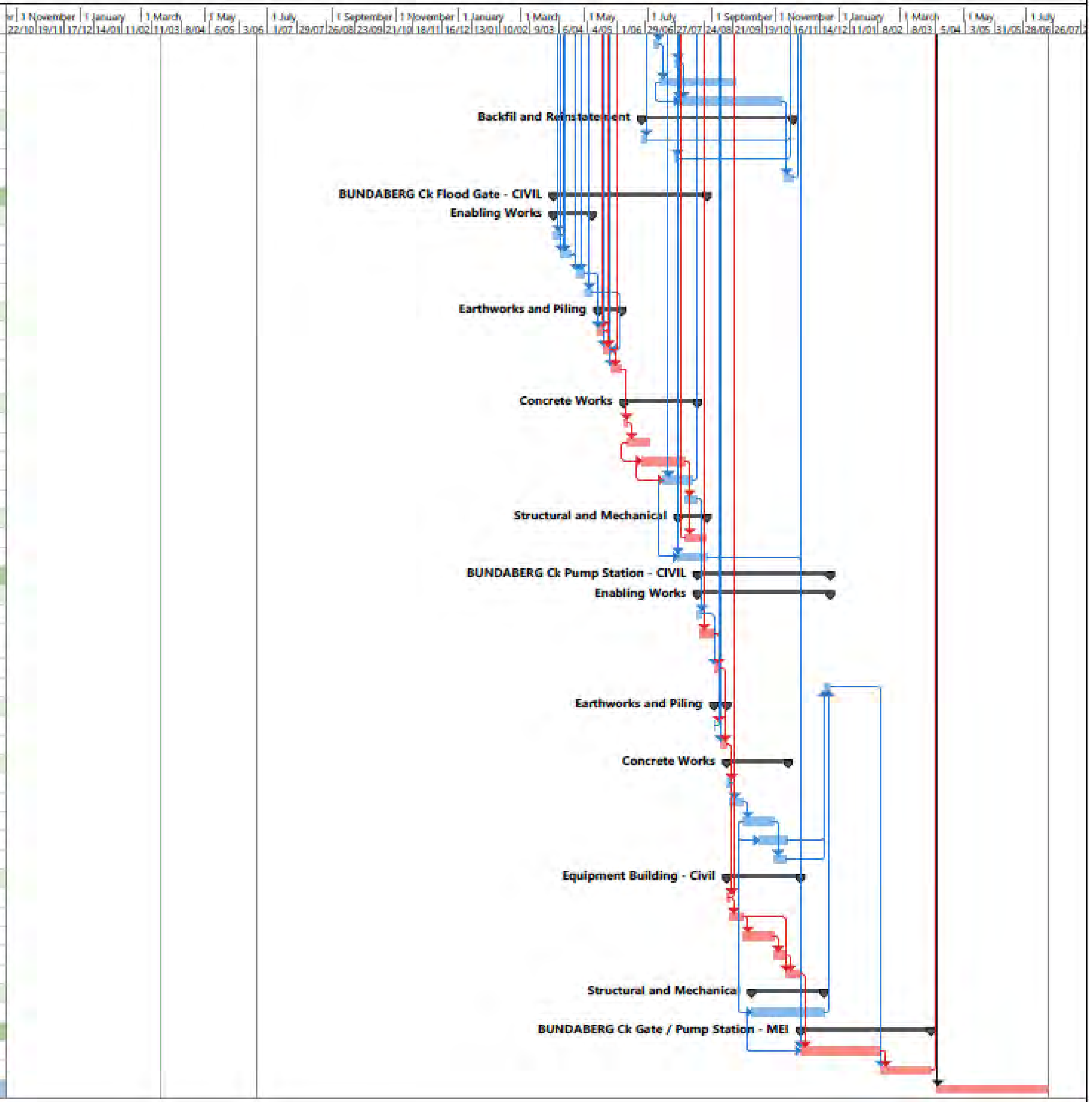
Bundaberg Flood Levee - rev. 1

ID	Task Name	Duration	Start	Finish
58	Concrete Piling Rigs - Mob 2	15 days	Thu 13/08/20	Wed 2/09/20
59	Concrete Piling Rigs - Demob 2	2 days	Thu 17/09/20	Fri 18/09/20
60	Sheet Piling Land Rig - Demob	5 days	Thu 25/06/20	Wed 1/07/20
61	Demobilisation of Main Contractor	15 days	Tue 6/04/21	Tue 27/04/21
62	**Levee - DISTILLERY Alignment**	**108 days**	**Wed 1/04/20**	**Fri 4/09/20**
63	**Enabling Works**	**2 days**	**Wed 1/04/20**	**Thu 2/04/20**
64	Set up Environmental Controls and Access Road to Distillery Flood Gate	2 days	Wed 1/04/20	Thu 2/04/20
65	**Earthworks and Piling**	**14 days**	**Fri 17/04/20**	**Fri 8/05/20**
66	Excavation to subgrade (Ch 682 to Ch 400)	3 days	Fri 17/04/20	Tue 21/04/20
67	Excavation to subgrade (Ch 360 to Ch 0)	5 days	Wed 22/04/20	Wed 29/04/20
68	ShP - Installation (Ch 575 to CH 220)	9 days	Wed 22/04/20	Wed 6/05/20
69	CPP - Installation (Ch 575 to Ch 220)	11 days	Wed 22/04/20	Fri 8/05/20
70	**Concrete Works**	**78 days**	**Thu 7/05/20**	**Tue 25/08/20**
71	Blinding (Ch 682 to Ch 400)	3 days	Thu 7/05/20	Mon 11/05/20
72	Blinding (Ch 400 to Ch 0)	4 days	Tue 12/05/20	Fri 15/05/20
73	FRP Base (Ch 682 to Ch 400)	21 days	Tue 12/05/20	Wed 10/06/20
74	FRP Base (Ch 360 to Ch 0)	25 days	Thu 11/06/20	Wed 15/07/20
75	FRP Wall (Ch 682 to Ch 400)	31 days	Tue 19/05/20	Wed 1/07/20
76	FRP Wall (Ch 360 to Ch 0)	39 days	Thu 2/07/20	Tue 25/08/20
77	**Backfil and Reinstatement**	**47 days**	**Thu 2/07/20**	**Fri 4/09/20**
78	Backfill (Ch 682 to Ch 400)	7 days	Thu 2/07/20	Fri 10/07/20
79	Backfill (Ch 360 to Ch 0)	8 days	Wed 26/08/20	Fri 4/09/20
80	**DISTILLERY Ck Gate and Pump Station**	**105 days**	**Wed 8/04/20**	**Tue 8/09/20**
81	**Enabling Works**	**105 days**	**Wed 8/04/20**	**Tue 8/09/20**
82	Temporary ShP - Installation	3 days	Wed 8/04/20	Tue 14/04/20
83	Temporary Working Platform in Coffer Dam	2 days	Wed 15/04/20	Thu 16/04/20
84	Excavation to subgrade	6 days	Mon 11/05/20	Mon 18/05/20
85	Remove Temporary Sheet Piling	4 days	Thu 3/09/20	Tue 8/09/20
86	**Concrete Works**	**47 days**	**Tue 19/05/20**	**Thu 23/07/20**
87	Blinding to Distil Gate	3 days	Tue 19/05/20	Thu 21/05/20
88	FRP Pile Cap and Base Slab	7 days	Fri 22/05/20	Tue 2/06/20
89	RCBC Culvert 2 * 3600x3600 - Install	3 days	Wed 3/06/20	Fri 5/06/20
90	FRP Wing walls and Topping Slab	30 days	Mon 8/06/20	Fri 17/07/20
91	Backfill against Wing Walls	4 days	Mon 20/07/20	Thu 23/07/20
92	**Structural, Mechanical and E &I**	**45 days**	**Thu 2/07/20**	**Wed 2/09/20**
93	Structural Steelwork - install	15 days	Thu 2/07/20	Wed 22/07/20
94	ME&I Items- install	20 days	Thu 23/07/20	Wed 19/08/20
95	Commissioning and Hand over	30 days	Thu 23/07/20	Wed 2/09/20
96	**Levee - CITY Alignment**	**155 days**	**Tue 7/04/20**	**Tue 17/11/20**
97	**Enabling Works**	**5 days**	**Tue 7/04/20**	**Wed 15/04/20**
98	Set up Environmental Controls	5 days	Tue 7/04/20	Wed 15/04/20
99	**Earthworks and Piling**	**55 days**	**Thu 16/04/20**	**Mon 6/07/20**
100	Excavation to subrade (incl. removal of Car Park and road pavement) (Ch 0 to Ch 180)	5 days	Thu 16/04/20	Wed 22/04/20
101	ShP - Installation (Ch 50 to Ch 180)	5 days	Thu 7/05/20	Wed 13/05/20
102	CPP - Installation (Ch 70 to Ch 180)	3 days	Thu 14/05/20	Mon 18/05/20
103	Excavation to subrade (Ch 240 to Ch 840)	7 days	Fri 1/05/20	Tue 12/05/20
104	ShP - Installation (Ch 240 to CH 840)	26 days	Tue 19/05/20	Wed 24/06/20
105	CPP - Installation (Ch 240 to CH 840)	25 days	Tue 2/06/20	Mon 6/07/20
106	Excavation to subrade (Ch 840 to Ch 1045)	6 days	Thu 30/04/20	Fri 8/05/20
107	**Concrete Works**	**128 days**	**Mon 11/05/20**	**Fri 6/11/20**
108	Blinding (Ch 840 to Ch 1045)	3 days	Mon 11/05/20	Wed 13/05/20
109	FRP Base (Ch 840 to Ch 1045)	18 days	Thu 14/05/20	Tue 9/06/20
110	FRP Wall (Ch 840 to Ch 1045)	24 days	Thu 21/05/20	Wed 24/06/20
111	Blinding (Ch 0 to Ch 180)	3 days	Wed 10/06/20	Fri 12/06/20
112	FRP Base (Ch 0 to Ch 180)	16 days	Mon 15/06/20	Mon 6/07/20
113	FRP Wall (Ch 0 to Ch 180)	22 days	Thu 25/06/20	Fri 24/07/20



Bundaberg Flood Levee - rev. 1

ID	Task Name	Duration	Start	Finish
114	Blinding (Ch 240 to Ch 840) (1/2)	4 days	Tue 7/07/20	Fri 10/07/20
115	Blinding (Ch 240 to Ch 840) (2/2)	4 days	Mon 27/07/20	Thu 30/07/20
116	FRP Base (Ch 240 to Ch 840)	52 days	Mon 13/07/20	Tue 22/09/20
117	FRP Wall (Ch 240 to Ch 840)	70 days	Fri 31/07/20	Fri 6/11/20
118	**Backfil and Reinstatement**	**103 days**	**Thu 25/06/20**	**Tue 17/11/20**
119	Backfill (Ch 840 to Ch 1045)	3 days	Thu 25/06/20	Mon 29/06/20
120	Backfill (Ch 0 to Ch 180)	3 days	Mon 27/07/20	Wed 29/07/20
121	Backfill (Ch 240 to Ch 840)	7 days	Mon 9/11/20	Tue 17/11/20
122	**BUNDABERG Ck Flood Gate - CIVIL**	**101 days**	**Wed 1/04/20**	**Wed 26/08/20**
123	**Enabling Works**	**23 days**	**Wed 1/04/20**	**Thu 7/05/20**
124	Set up Environmental Controls	4 days	Wed 1/04/20	Mon 6/04/20
125	Temporary ShP - Installation	6 days	Wed 8/04/20	Fri 17/04/20
126	Temporary Working Platform in Coffer Dam	5 days	Thu 23/04/20	Thu 30/04/20
127	Demolition of Part of Existing Bridge	4 days	Fri 1/05/20	Thu 7/05/20
128	**Earthworks and Piling**	**16 days**	**Thu 14/05/20**	**Fri 5/06/20**
129	ShP - Installation	3 days	Thu 14/05/20	Mon 18/05/20
130	CPP - Installation	5 days	Tue 19/05/20	Mon 25/05/20
131	Excavation to subrade (incl. removal of Temp. Work Platform)	8 days	Tue 26/05/20	Fri 5/06/20
132	**Concrete Works**	**51 days**	**Mon 8/06/20**	**Mon 17/08/20**
133	Blinding to Flood Gate	3 days	Mon 8/06/20	Wed 10/06/20
134	FRP Base to Flood Gate	15 days	Thu 11/06/20	Wed 1/07/20
135	FRP Walls to Flood Gate	30 days	Thu 25/06/20	Wed 5/08/20
136	FRP Supended Slab to Flood Gate	20 days	Thu 16/07/20	Wed 12/08/20
137	Backfill Western Bank	8 days	Thu 6/08/20	Mon 17/08/20
138	**Structural and Mechanical**	**20 days**	**Thu 30/07/20**	**Wed 26/08/20**
139	Existing Bridge - Reinstall	14 days	Thu 6/08/20	Tue 25/08/20
140	Structural Steelwork - install	20 days	Thu 30/07/20	Wed 26/08/20
141	**BUNDABERG Ck Pump Station - CIVIL**	**91 days**	**Tue 18/08/20**	**Wed 23/12/20**
142	**Enabling Works**	**91 days**	**Tue 18/08/20**	**Wed 23/12/20**
143	Set up Environmental Controls	4 days	Tue 18/08/20	Fri 21/08/20
144	Temporary ShP - Installation to Pump St. and removal from Flood Gate	10 days	Thu 20/08/20	Wed 2/09/20
145	Temporary Working Platform in Coffer Dam	4 days	Thu 3/09/20	Tue 8/09/20
146	Remove Temporary Sheet Piling	4 days	Fri 18/12/20	Wed 23/12/20
147	**Earthworks and Piling**	**8 days**	**Thu 3/09/20**	**Mon 14/09/20**
148	ShP – Installation	1 day	Thu 3/09/20	Thu 3/09/20
149	CPP - Installation	4 days	Wed 9/09/20	Mon 14/09/20
150	**Concrete Works**	**42 days**	**Tue 15/09/20**	**Thu 12/11/20**
151	Blinding to Pump Station	3 days	Tue 15/09/20	Thu 17/09/20
152	FRP Base to Pump Station	9 days	Fri 18/09/20	Wed 30/09/20
153	FRP Walls to Pump Station	20 days	Thu 1/10/20	Thu 29/10/20
154	FRP Supended Slab to Pump Station	20 days	Fri 16/10/20	Thu 12/11/20
155	Backfill Eastern Bank	8 days	Fri 30/10/20	Tue 10/11/20
156	**Equipment Building - Civil**	**50 days**	**Tue 15/09/20**	**Tue 24/11/20**
157	CPP - Installation	2 days	Tue 15/09/20	Wed 16/09/20
158	FRP Pile Caps and Ground Beams	10 days	Thu 17/09/20	Wed 30/09/20
159	FRP Columns and Ring Wall	20 days	Thu 1/10/20	Thu 29/10/20
160	Backfill To underside of Ground Slab	8 days	Fri 30/10/20	Tue 10/11/20
161	FRP Gground Slab	10 days	Wed 11/11/20	Tue 24/11/20
162	**Structural and Mechanical**	**50 days**	**Fri 9/10/20**	**Thu 17/12/20**
163	Structural Steelwork - install to Main Structure	50 days	Fri 9/10/20	Thu 17/12/20
164	**BUNDABERG Ck Gate / Pump Station - MEI**	**86 days**	**Wed 25/11/20**	**Tue 30/03/21**
165	ME&I Items - Installation	52 days	Wed 25/11/20	Wed 10/02/21
166	Commissioning and Hand over	34 days	Thu 11/02/21	Tue 30/03/21
167	Contingency	74 days	Tue 6/04/21	Wed 21/07/21



A.7 P50 Base Case Estimate (Extract)

Direct Cost Summary

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Line	Item	Description	Quantity	Unit	Rate	Total	
967							
968		***Supply, Erect & Strip Formwork***					
969		*Note: Finish on Concrete Work is Class 2*					
971							
972		***Supply Reinforcement***					
974		***Fix Reinforcement***					
976							
977		***Supply Concrete***					
978		*Note: Concrete Cure Method Required is per TMR standard specification MRTS70*					
980		***Pump, Place & Finish Concrete***					
982							
983		***Cure concrete***					
985							
986							
987		**METALWORK & PLUMBING**					
988		**METALWORK**	**1.000**	**Item**	**14,955.00**	**14,955**	**C+P**
993							
994		**PLANT**	**1.000**	**Item**	**70,000.00**	**70,000**	**C+P**
997							
998		**ELECTRICAL INSTALLATION**	**1.000**	**Item**	**30,000.00**	**30,000**	**C+P**
1001							
1002		**SUNDRIES**					
1003		Stop logs complete with waterstops	19.000	m2	75.00	1,425	C
1004							
1008							
1009		=sum(1:1008) Total for Project				49,767,591	F
1010							
1011		**CLIENT COSTS**					
1012	**1**	**Concept Phase**					
1013	1.01	Administration Costs - Concept Phase	1.000	Item	1,866,284.73	1,866,285	C
1014	1.02	Non Contract Works & Unspecified Planning	1.000	Item			C
1015	1.03	Options Analysis, B.C. & Prelim. Design	1.000	Item	100,000.00	100,000	C
1016	1.04	Pavement Investigation	1.000	Item			C
1017	1.05	Survey	1.000	Item			C
1018	1.06	Geotechnical Investigations	1.000	Item	100,000.00	100,000	C
1019	1.07	Unspecified Resumption Costs	1.000	Item			C
1020		=sum(1010:1019) Concept Phase				2,066,285	F
1021							
1022	**2**	**Development Phase**					
1023	2.01	Administration Costs - Development	1.000	Item	60,000.00	60,000	C
1024	2.02	Additional Survey	1.000	Item	18,000.00	18,000	C

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Direct Cost Summary

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Line	Item	Description	Quantity	Unit	Rate	Total	
967							
968		*Supply, Erect & Strip Formwork*					
969		*Note: Finish on Concrete Work is Class 2*					
971							
972		*Supply Reinforcement*					
974		*Fix Reinforcement*					
976							
977		*Supply Concrete*					
978		*Note: Concrete Cure Method Required is per TMR standard specification MRTS70*					
980		*Pump, Place & Finish Concrete*					
982							
983		*Cure concrete*					
985							
986							
987		**METALWORK & PLUMBING**					
988		**METALWORK**	**1.000**	**Item**	**14,955.00**	**14,955**	**C+P**
993							
994		**PLANT**	**1.000**	**Item**	**70,000.00**	**70,000**	**C+P**
997							
998		**ELECTRICAL INSTALLATION**	**1.000**	**Item**	**30,000.00**	**30,000**	**C+P**
1001							
1002		**SUNDRIES**					
1003		Stop logs complete with waterstops	19.000	m2	75.00	1,425	C
1004							
1008							
1009		=sum(1:1008) Total for Project				49,767,591	F
1010							
1011		**CLIENT COSTS**					
1012	**1**	**Concept Phase**					
1013	1.01	Administration Costs - Concept Phase	1.000	Item	1,866,284.73	1,866,285	C
1014	1.02	Non Contract Works & Unspecified Planning	1.000	Item			C
1015	1.03	Options Analysis, B.C. & Prelim. Design	1.000	Item	100,000.00	100,000	C
1016	1.04	Pavement Investigation	1.000	Item			C
1017	1.05	Survey	1.000	Item			C
1018	1.06	Geotechnical Investigations	1.000	Item	100,000.00	100,000	C
1019	1.07	Unspecified Resumption Costs	1.000	Item			C
1020		=sum(1010:1019) Concept Phase				2,066,285	F
1021							
1022	**2**	**Development Phase**					
1023	2.01	Administration Costs - Development	1.000	Item	60,000.00	60,000	C
1024	2.02	Additional Survey	1.000	Item	18,000.00	18,000	C

Direct Cost Summary

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Line	Item	Description	Quantity	Unit	Rate	Total	
1025	2.03	Additional Geotechnical Investigations	1.000	Item	300,000.00	300,000	C
1026	2.04	Detailed Design (3.5% of Construct. Cost)	1.000	Item	2,177,332.19	2,177,332	C
1027	2.05	Property Acquisitions & Resumption Costs	1.000	Item	2,000,000.00	2,000,000	C
1028	2.06	Public Consultation	1.000	Item	32,000.00	32,000	C
1029	2.07	Environmental Permits	1.000	Item	50,000.00	50,000	C
1030		=sum(1021:1029) Development Phase				4,637,332	F
1031							
1032	**3**	**Implementation Phase**					
1033	3.01	Administration Costs - Implementation	1.000	Item	30,000.00	30,000	C
1034	3.02	Internal Administration (1% of Const. Cost)	1.000	Item	622,094.91	622,095	C
1035	3.03	Contract Administration (6% of Const. Cost)	1.000	Item	3,732,569.46	3,732,569	C
1036	3.04	Environmental Permits	1.000	Item	25,000.00	25,000	C
1037	3.05	Public Utility Services Relocations (PUP)	1.000	Item	3,110,474.55	3,110,475	C
1038	3.06	PAI Insurances (0.8% of Construct. Cost)	1.000	Item	497,675.93	497,676	C
1039	3.07	Q-Leave Fees (0.35% of Construct. Cost)	1.000	Item	217,733.22	217,733	C
1040	3.08	Miscellaneous	1.000	Item			C
1041		=sum(1031:1040) Implementation Phase				8,235,548	F
1042							
1043	**4**	**Principal's Materials**					
1044	4.01	Accommodation Works	1.000	Item	50,000.00	50,000	C
1045	4.02	Unspecified Principals Materials	1.000	Item	933,142.37	933,142	C
1046	4.03	Relationship Management	1.000	Item	217,733.22	217,733	C
1047		=sum(1042:1046) Principal's Materials				1,200,876	F
1048							
1049	**5**	**Finalisation Phase**					
1050	5.01	Finalisation Phase - Administration	1.000	Item	622,094.91	622,095	C
1051		=sum(1048:1050) Finalisation Phase				622,095	F
1052							
1053		**CONTINGENCY**					
1054	6.01	Contingency	1.000	Item	34,215,220.05	34,215,220	C
1055							
1056		**ESCALATION COSTS**					
1057	7.01	Escalation Costs	1.000	Item	1,555,237.28	1,555,237	C
1058							
1059		=sum(1:1058) Anticipated Project Cost (Forecast $)				102,300,183	F
1060							
1061							
1062							
1063							

Expert Estimation 2014 SP2

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NOTE: P50 estimate does not include extra architectural costs at $6.5m (mainly Saltwater Creek park)

A.8 Vendor Quotes

A.8.1 Flood Gate Vendor

No.	Application	Item Description	Qty.	Dimensions	Unit Cost	Total	Comments
1	Distillery Creek	Penstocks	2	3.0m x 2.0m	$150k each	$300k	Material – SAF, Incl. Actuators
		Stoplogs	1 set	2 pieces (3.0m x 2.0m)	$75k	$75k	Aluminium, Suggest 1 set for service purposes
		Stoplog frames	2	-	$20k each	$40k	Material - SAF
2	Flood Wall	Stoplogs	11	3m x 3.5m	$30keach	$330k	Aluminium, no frames
3	Flood Wall	Demountable Flood Barrier	1	6m x 2m	$35k	$35k	Aluminium boards & galvanized posts
		Retractable Barrier	1	6m x 2m	($60k)	($60k)*	Aluminium *Alternative to demountable flood barrier.
4	Saltwater Creek	Mechanical trash screens	3	TBC	*$280k each	$840k	*Material – 316S/S (Alternative material SAF - $350keach)
5	Saltwater Creek	Pump forebay stoplogs	1 set	2 pieces (3.0m x 3.0m)	$80k	$80k	Aluminium, Suggest 1 set for service purposes
		Stoplog frames	3	-	$20k each	$60k	Material - SAF
6	Saltwater Creek	Floodgates	4	4.5m x 4.5m	$250k each	$1M	Material – SAF, Incl. cable motors and gearboxes
7	Saltwater Creek	Suction inlets & pipe 'cans'	2	-	n/a	n/a	Not our product line, to be supplied by others

NOTE: 40 weeks lead time on items above (detailed design, procurement and manufacture)

Further gate quotes*from AWMA –	17m x 3.35m	$150k (Quay Street – motorised gate)
	5m x 3.44m	$75k (Scotland street – demountable gate)
	3m x 3m	$60k (Distillery creek – stop log gate)

*Quotes refer to the final alignment with motorised sliding flood gate at Quay Street and demountable barriers at the two other locations (Scotland Street and the Distillery Creek end)
AWMA Duplex stainless steel 'flood flaps' to suit Saltwater Creek flood pump station - $25k AUD each (1m x 1m)
Manually cleaned bar trash racks suitable for strainer type pump - $52k AUD for two units (in lieu of mech trash racks)

A.8.2 Axial Flood Lift Pump Vendors

Fluid Engineering Pty Ltd
30-32 Bridge Road
Griffith NSW 2680

ABN: 50 151 207 528

Quotation

Issue Date: 29/6/2018

To

CDM Smith
51 Alfred Street
Fortitude Valley QLD 4006

Reference

Job No: 5089
Contact:
Email: brownsa@cdmsmith.com
Site: Level 4, 51 Alfred Street, Fortitude Valley, QLD, 4006

Dear Sir,
We are pleased to submit the following quotation for your consideration:To supply the following complete axial flow FLOODLIFTER Pump ex our Griffith Store

Thank you for your recent enquiry regarding the supply of an Axial flow lift pump. We have explored the options available and have selected a suitable pump from our range. The FE1005 axial flow FLOODLIFTER turbine will meet your duty requirements with ease. As standard our axial flow pumps are fitted with 316L Stainless propellors and 316L stainless wear rings. This ensures optimum operating efficiency over the lifetime of the pump. Our axial flow range uses industrial grade materials and best practice engineering techniques to provide a quality value for money solution. As such we offer a 24 month 8,000hr conditional warranty on all new pumps installed to Fluid Engineering specifications. Please see our detailed offer below. Should you have any questions please do not hesitate to contact me.

Requested Duty Point
Flow Rate: 302MLD 3500 l/s
Static Lift: 4.2m
Pump Losses: 1.49m
Discharge pipe loss: 0.1m
TDH: 19.2m
Column ID: 600mm

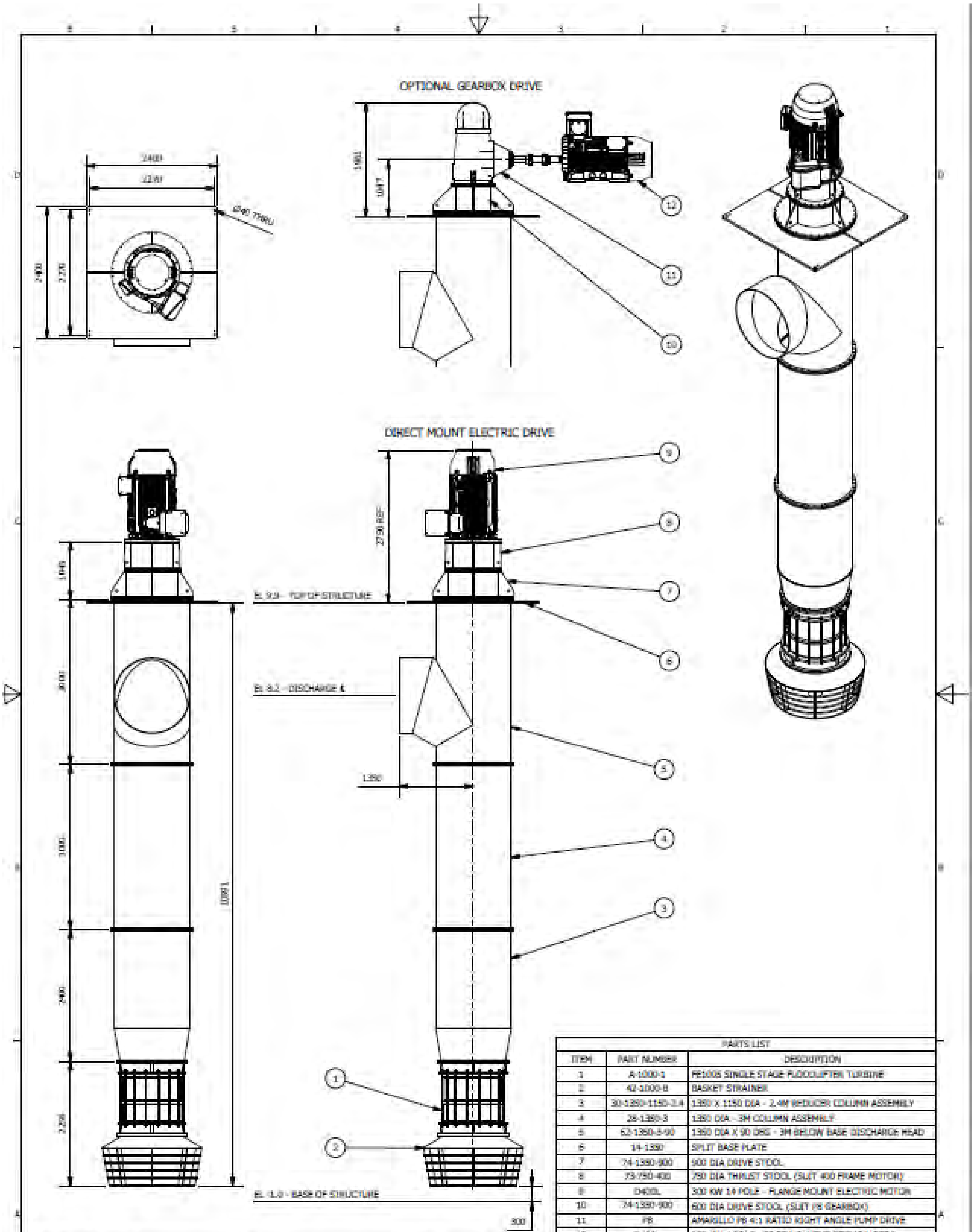
Duty Point Selection
FLOODLIFTER FE1005 Single stage Industrial bowl assembly c/w Basket strainer
Duty Point 1: 3500 l/sec 302ML/day @ 5.79m TDH x 85%, 233kW @ 375RPM

Wet End Construction
Bowl: Cast Iron Casting
Suction/Discharge Case: Cast Iron Casting
Propeller: 316L Stainless
Bowl Shaft: Ø4" 431 HT Stainless
Line Shaft: Ø2 3/4" 1045 mild steel - oil lubricated
Wear Ring: 316L Stainless
Bowl Suction Bearing: LG2 Bronze
Column and Discharge Head: Fabricated Mild steel Spigot Fits

Pump Construction
1 off 1 stg FE1005 Industrial Grade Cast Iron build bowl assy fitted 316L Stainless Propeller + Basket Strainer
1 off Ø1350 x Ø168 x Ø70 x 2.4m Water Lube flanged column assembly
1 off Ø1350 x Ø168 x Ø70 x 3.0m Water Lube flanged column assembly
1 off Ø1350 x Ø168 x Ø70 x 3.0m Water Lube flanged head assembly
1 off Ø500 drive stool assembly and adaptor plate
1 off Ø500 D500 thrust stool assembly
1 off TECO 350kW 14 pole 415V TEFC motor suitable for VFD operation
1 off stainless steel suction case greaseline
1 off Split Base Plate

Terms	Direct Debit	Cheque	Credit Card
Full payment within	Bank: Westpac	Cheques Payable to	Call (02) 69 629 601
30 Days EOM	BSB: 032 750	Fluid Engineering Pty Ltd	
	Account: 449 727	30-32 Bridge Road	
		Griffith NSW 2680	

Sub Total:	$370,820.95
GST:	$37,082.10
Total:	$407,903.05



PARTS LIST		
ITEM	PART NUMBER	DESCRIPTION
1	A-1000-1	FE1005 SINGLE STAGE FLOODLIFTER TURBINE
2	42-1000-B	BASKET STRAINER
3	30-1350-1150-2.4	1350 X 1150 DIA - 2.4M REDUCER COLUMN ASSEMBLY
4	28-1350-3	1350 DIA - 3M COLUMN ASSEMBLY
5	62-1350-3-90	1350 DIA X 90 DEG - 3M BELOW BASE DISCHARGE HEAD
6	14-1350	SPLIT BASE PLATE
7	74-1350-900	900 DIA DRIVE STOOL
8	73-750-400	750 DIA THRUST STOOL (SUIT 400 FRAME MOTOR)
9	D400L	300 KW 14 POLE - FLANGE MOUNT ELECTRIC MOTOR
10	74-1350-900	600 DIA DRIVE STOOL (SUIT P8 GEARBOX)
11	P8	AMARILLO P8 4:1 RATIO RIGHT ANGLE PUMP DRIVE
12	D400L	300 KW 4 POLE - FOOT MOUNT ELECTRIC MOTOR

REV	BY	CHK	DATE	DESCRIPTION
A	KS	FS	27/06/2018	FOR REVIEW

REVISION HISTORY

FLUID ENGINEERING PTY LTD
42 BRIDGE RD GRIFFITH NSW
PH: (02) 69620601
E: PUMPS@FLOODLIFTER.COM

SCALE 1 : 60

UNLESS NOTED OTHERWISE DIMENSIONS ARE IN MM TOLERANCES ARE ± 1MM REMOVE ALL EDGES REMOVE ALL SLAG AND SPATTER

DESIGNED	KS	27/06/2018
DRAWN	KS	27/06/2018
CHECKED	JS	27/06/2018
APPROVED		

JOB No. 5089

PART/ASSY 5089-A-1006-18-1350

TITLE
CDM SMITH - BUNDABERG CREEK FLOOD LEVEE
FE1005 FLOODLIFER PUMPS
GENERAL ASSEMBLY

SIZE A3

SHEET 1 / 1

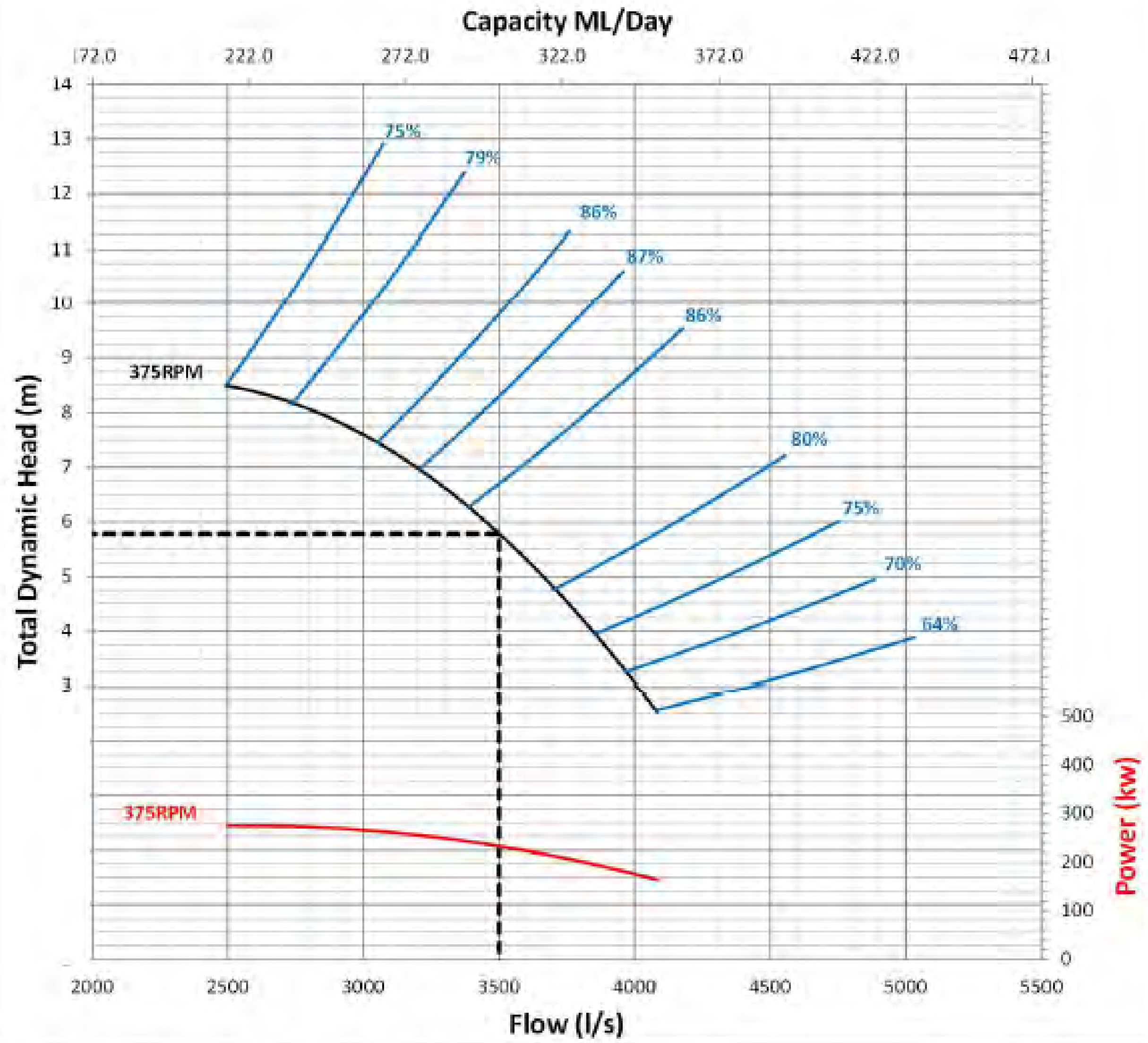
DWG No. 5089-GA-001

REV A

J:\Fluid Engineering\CDM Smith\Bundberg Creek\5089-A-1005-18-1350.iam

Fluid Engineering	MODEL No. FE1005	CURVE No. C-0035
	375RPM	DATE. 24/07/16
	BOWL DIA. 1100mm	DRAWN JS
	STANDARD CURVE ILLUSTRATES SINGLE STAGE PERFORMANCE ONLY	CHECKED JS

FLOW (l/s)	3500	TDH (m)	5.79	POWER (kW)	232.58	Efficiency (%)	85.37
FLOW (ML/Day)	302.4	TDH (ft)	18.98	POWER (HP)	311.77	Ns (ul)	9712



CLIENT:	Bundaberg Flood Levee	JOB/QUOTE:	CDM Smith
PROPELLER		BOWL	
PROPELLER OD	1029mm	PUMP LENGTH	400.2mm
EFFECTIVE EYE AREA	6.559 E-3 m2	ADDITIONAL STAGES	101.6mm
NUMBER OF BLADES	5	LATERAL STD.	12mm
WR2 PER PROPELLER	0.0005	SUCTION SIZE	900mm
MAX SPHERE SIZE	105mm	DISCHARGE SIZE	900mm
WEIGHT	0.6kg	SINGLE STAGE WEIGHT	

FLUID ENGINEERING PTY LTD

ABN 50 151 207 528

AXIAL FLOW FLOODLIFTER

PHONE: (02) 6962 9601
FAX: (02) 6962 7692
email: info@floodlifter.com

NUMBER OF STAGES FOR DUTY: 1

Quotation 1003288791

Account/customer number: 1002006161
External reference: Bundaberg East Flood Control Concept

Grundfos Pumps Pty Ltd
ABN 90 007 920 765

Creation Date: 19/06/18

Mr. Stuart Brown
CDM Smith Australia Pty Ltd
4/51 Alfred St
FORTITUDE VALLEY 4006
AUSTRALIA

Dear Mr. Brown

We thank you for the opportunity to present you with the enclosed quotation.

The prices quotes are in Net AUD and exclusive of GST, unless stated otherwise.

This offer is based on Grundfos Pumps Pty Ltd standard conditions of sale. For our full terms and conditions of sale, including warranty information, please refer to: http://au.grundfos.com/navfooter/legal-issues/GrundfosTermsConditions.html

The lead times listed are current at the time of this quotation and are subject to final confirmation at time of order placement.

Please reference this quotation on your order. Failure to do so may result in standard pricing and delivery being arranged.

We trust that this offer is competitive and should you have any questions or require further information, please contact the undersigned.

Total Net (AUD) without options and alternatives	101,293.50

Application of Order

To accept this quotation via Extranet, please go to extranet.grundfos.com. After logging in, find the 'Quotations' tab, and select this quotation number to place an order with the exact details of this quotation. Your $15.00 Processing Fee is waived by converting your quotation to order using Extranet.

If your quotation requires airfreight, please send your order to auorders@sales.grundfos.com as expedited airfreight orders will need to be manually processed.

Comments

CONTACT:
Quotation Created by: Brad Antrim
Tel: 1300 33 77 33
Pre-Sales/Spare Parts: ausales@sales.grundfos.com
Orders : auorders@sales.grundfos.com
Post-Sales/Service Offerings: auservice@grundfos.com
Website: au.Grundfos.com
Product Information: Grundfos Product Center
Service Offerings: Grundfos Service Portfolio
Legal Issues: Legal Issues
Extranet: extranet.grundfos.com

Account Manager: Brad Antrim
Email: bantrim@grundfos.com
Mobile: 0423 824 992

GRUNDFOS

Quotation 1003288791

Account/customer number: 1002006161
External reference: Bundaberg East Flood Control Concept

NOTE: Click the product code (article in blue) for more information in the Grundfos Product Center.

Pos	Product		Qty	Unit Net Price	Total Net Price
10	**KPL.1200.350.10.T.50.19.L.40 50 Hz**	Material pricing group: 01 Pricing for Budget Estimating Purposes only	1	90,600.00	90,600.00
20	**Acc, seat ring 1200/48" Column KPL**	Material pricing group: 01	1	1,470.00	1,470.00
Net amount :					92,070.00
Order Processing Fee					15.00
GST (10%)					9,208.50
				Total Net (AUD) without options and alternatives:	**101,293.50**

Validity of the quotation: 18/07/18

NOTE: Quote does not include: control gear, flood pump lift tubes, formed suction inlet (FSU), end strainer unit (would require screened trash rack)

GRUNDFOS

Company name:
Created by:
Phone:

Date: 19/06/2018

Position	Qty.	Description
	1	

Note! Product picture may differ from actual product

Product No.: On request

The KPL (submersible axialflow propeller pumps) and KWM (submersible mixedflow pumps), are a pump range specifically designed for column installation from DN500 to DN1800.

The KPL and KWM pumps are designed for applications such as:

- flood and stormwater control
- drainage/irrigation of large quantities of water
- raw-water intake
- transfer and circulation of liquids in large-scale municipal sewage treatment plants
- circulation of large quantities of water in water theme parks etc.
- aqua culture

The KPL and KWM pumps are suitable for permanent installation. The lifting bracket facilitates easy transportation and installation on site as well as cable fixation above the cable inlet. The pumps are made of resistant materials, such as cast iron and stainless steel. These materials ensure a proper operation.

The pumps are very service friendly with features like double shaft seal in the unique cartridge design and cable entry connector. The cartridge shaft seal allows change of shaft seal very quickly in the field without any special tools whereas the cable entry connector allow the cable to be dismantled without removing the motor top. These smartdesign features eliminates the risk of faulty installation.

To increase the efficiency the pumps are fittet with a innovative patented turbulence optimizer which reduce the turbulence between the pump casing and the column pipe.

To increase the efficiency the pumps are fittet with a innovative patented turbulence optimizer which reduce the turbulence between the pump casing and the column pipe.

Liquid:

Pumped liquid:	Any Newtonian liquid
Density:	998.2 kg/m³

Technical:

Actual calculated flow:	3500 l/s
No. of blades:	4
Blade angle:	19 deg.
Resulting head of the pump:	5.7 m
Actual impeller diameter:	860 mm
Type of impeller:	Propeller
Max. Particle:	170 mm
Rated driver speed:	580 rpm

GRUNDFOS

Company name:
Created by:
Phone:

Date: 19/06/2018

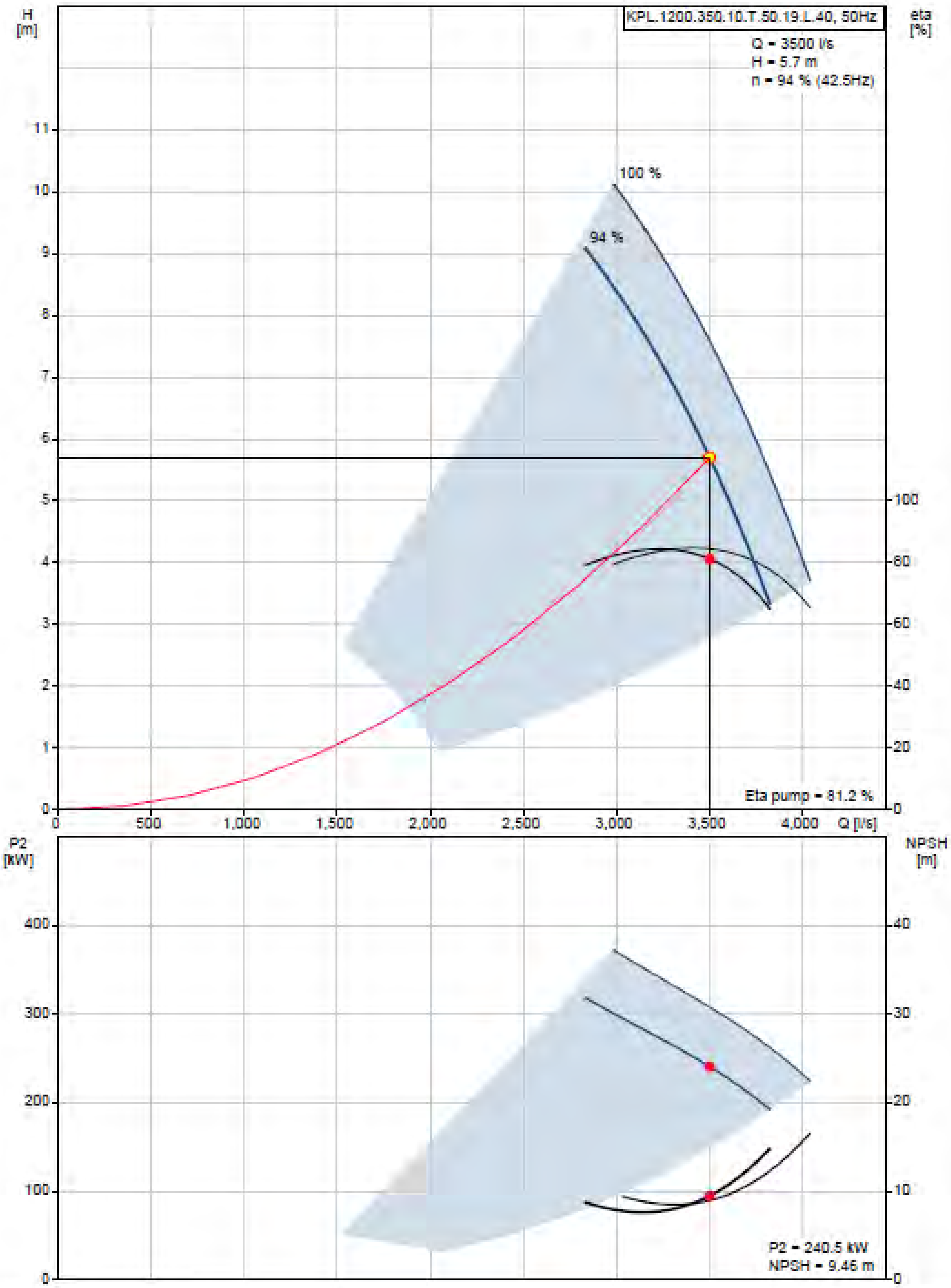
Position	Qty.	Description	
		Min flow rate:	2980 l/s
		Max flow rate:	4030 l/s
		Lifting height class:	L
		Materials:	
		Pump housing:	Cast iron EN 1561 EN-GJL-250
		Impeller:	Stainless steel EN 1.4308
		Installation:	
		Maximum ambient temperature:	40 °C
		Maximum operating pressure:	10 bar
		Type of connection:	DIN
		Pressure rating for pipe connection:	PN 10
		Size of connection:	DN 1200
		Electrical data:	
		Motor protec:	YES
		Insulation:	F
		Power input P1:	378.8 kW
		Moisture switch:	Y
		Length of power cable:	10 m
		Length of sensor cable:	10 m
		Mains frequency:	50 Hz
		Rated voltage:	400 V
		Max starts per. hour:	6
		Service factor:	1,10
		Motor efficiency at full load:	92.5 %
		Motor efficiency at 3/4 load:	92.5 %
		Motor efficiency at 1/2 load:	92.4 %
		Number of poles:	10
		Method of start:	Direct-on-line (DOL)
		Enclosure class (IEC 34-5):	IP68
		P2:	350 kW
		Others:	
		Net weight:	4500 kg
		Gross weight:	4800 kg
		Shipping volume:	9.98 m³
		Approvals:	CE,EAC

Printed from Grundfos Product Centre [2018.03.034] 2/6

Company name:
Created by:
Phone:

Date: 19/06/2018

On request KPL.1200.350.10.T.50.19.L.40 50 Hz



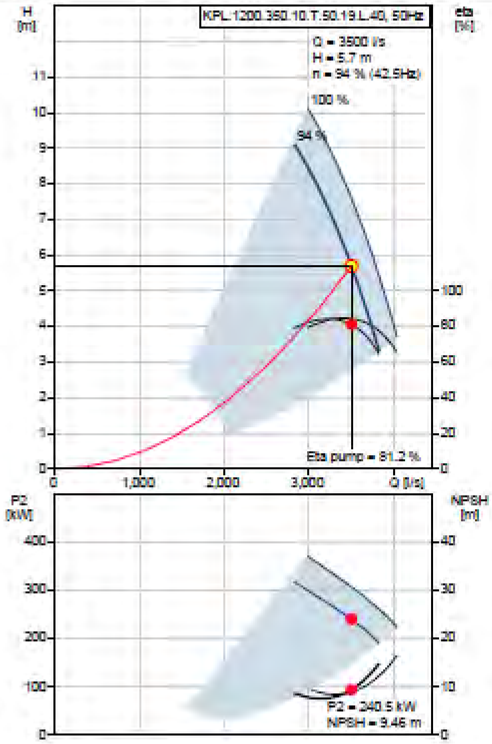
Printed from Grundfos Product Centre [2018.03.034]

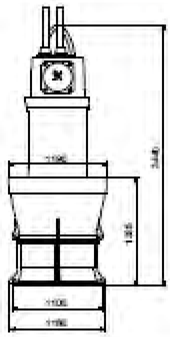
GRUNDFOS

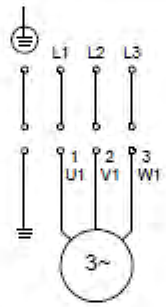
Company name:
Created by:
Phone:

Date: 19/06/2018

Description	Value
General information:	
Product name:	KPL.1200.350.10.T.50.19.L.40
Product No:	On request
EAN number:	On request
Technical:	
Actual calculated flow:	3500 l/s
No. of blades:	4
Blade angle:	19 deg.
Resulting head of the pump:	5.7 m
Actual impeller diameter:	860 mm
Type of impeller:	Propeller
Max. Particle:	170 mm
Rated driver speed:	580 rpm
Min flow rate:	2980 l/s
Max flow rate:	4030 l/s
Lifting height class:	L
Materials:	
Pump housing:	Cast iron
	EN 1561 EN-GJL-250
Impeller:	Stainless steel
	EN 1.4308
Installation:	
Maximum ambient temperature:	40 °C
Maximum operating pressure:	10 bar
Type of connection:	DIN
Pressure rating for pipe connection:	PN 10
Size of connection:	DN 1200
Liquid:	
Pumped liquid:	Any Newtonian liquid
Density:	998.2 kg/m³
Electrical data:	
Motor protec:	YES
Insulation:	F
Power input P1:	378.8 kW
Moisture switch:	Y
Length of power cable:	10 m
Length of sensor cable:	10 m
Mains frequency:	50 Hz
Rated voltage:	400 V
Max starts per. hour:	6
Service factor:	1,10
Motor efficiency at full load:	92.5 %
Motor efficiency at 3/4 load:	92.5 %
Motor efficiency at 1/2 load:	92.4 %
Number of poles:	10
Method of start:	Direct-on-line (DOL)
Enclosure class (IEC 34-5):	IP68
P2:	350 kW
Others:	
Net weight:	4500 kg
Gross weight:	4800 kg
Shipping volume:	9.98 m³
Approvals:	CE,EAC



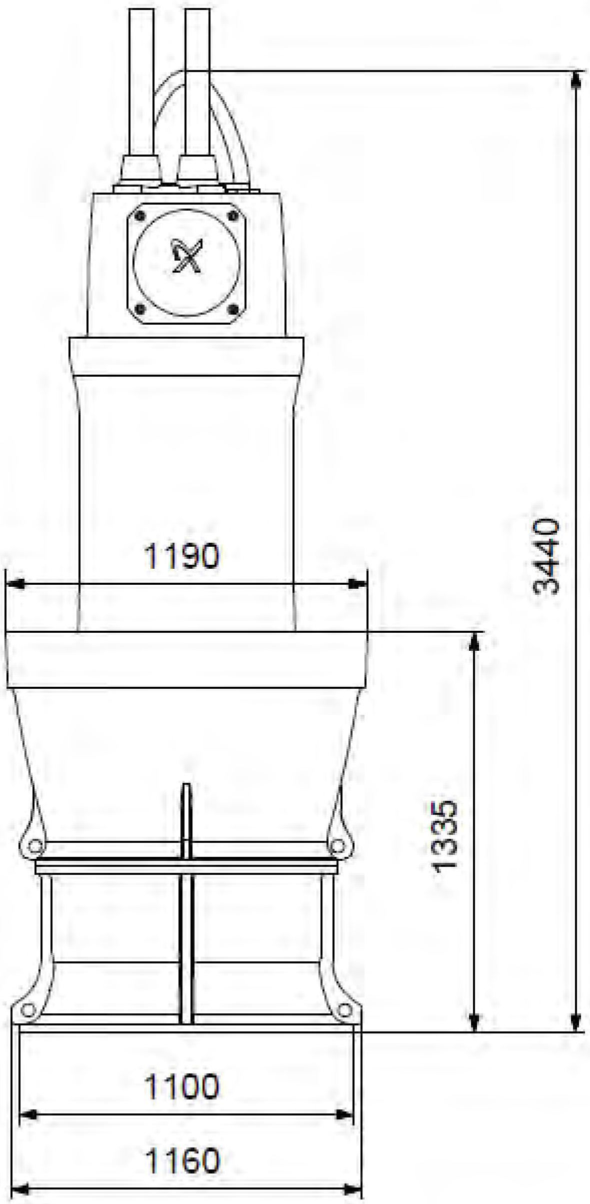




Company name:
Created by:
Phone:

Date: 19/06/2018

On request KPL.1200.350.10.T.50.19.L.40 50 Hz



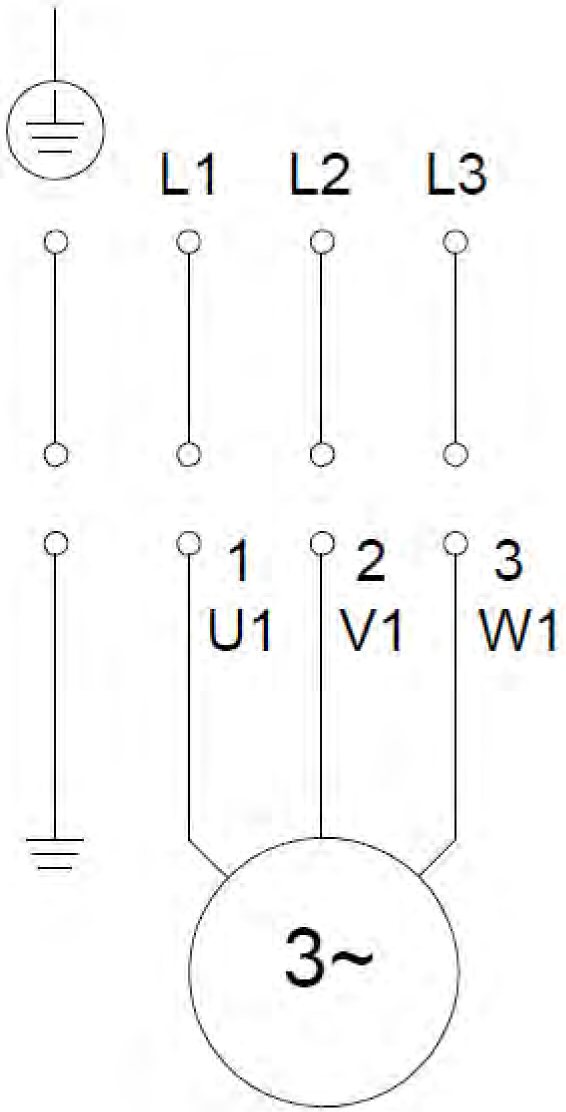
Note! All units are in [mm] unless others are stated.
Disclaimer: This simplified dimensional drawing does not show all details.

Printed from Grundfos Product Centre [2018.03.034]

Company name:
Created by:
Phone:

Date: 19/06/2018

On request KPL.1200.350.10.T.50.19.L.40 50 Hz



Note! All units are in [mm] unless others are stated.

Hello Stuart,

Some indicative price for this pump as follows:

Amacan PB4 1200-870/47010UTG1 : A$ 263,000.00 each (excl. GST, Ex- factory Bundamba QLD)
Performance test: A$ 2,200.00 each (excl. GST, Ex- factory Bundamba QLD)

You can estimate approx. 50-60 K for a discharge pipe in carbon steel.

Should yo have any query please let us know.

Best Regards

Mauricio Cle
Central Quotations Manager
KSB Australia Pty Ltd

13 Hawkins Crescent, Bundamba QLD 4304 Australia
P: +61 7 3436 8600 | D: +61 7 3436 8644
F: +61 7 3436 8699 | M: +61 (0) 417 337 837

Data sheet

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.: 100
Date: 27/07/2018
Page: 1 / 11

Amacan PB4 1200-870/47010UTG1

Version no.: 1

Operating data

Requested flow rate	3500.000 l/s	Actual flow rate	3481.437 l/s
Requested developed head	9.50 m	Actual developed head	9.40 m
Pumped medium	Water, rainwater with strainer Not containing chemical and mechanical substances which affect the materials	Efficiency	81.5 %
		Power absorbed	392.70 kW
		Pump speed of rotation	591 rpm
		NPSH required	10.41 m
		Head at min flow rate	10.64 m
Ambient air temperature	20.0 °C	Minimum water level t1 with suction umbrella	2471.0 mm
Fluid temperature	20.0 °C		
Fluid density	998 kg/m³		
Fluid viscosity	1.00 mm²/s	Minimum water level t1 without suction umbrella	3071.0 mm
Max. power on curve	444.57 kW		
Min. allowable flow rate	3073.451 l/s	Design	Single system 1 x 100 %
		Performance test	Yes

Design

Pump standard	Submersible motor pump in discharge tube, international execution	Propeller nominal diameter	870.0 mm
		Blade pitch angle	22.0 °
		Free passage size	210.0 mm
Design	Close-coupled submersible	DN of discharge tube	DN 1200
Orientation	Vertical	Direction of rotation from drive	Clockwise
Shaft seal	2 mech. seals in tandem arrangement with oil reservoir	Bearing type	Anti-friction bearings
		Lubrication type	Grease
Manufacturer	Burgmann	Temperature sensor PT100 inboard	With
Type	MG		
Material code	SIC/SIC/NBR	Temperature sensor PT100 mts	With
Mechanical seal leakage	float switch in leakage chamber		
Wear ring execution	Standard design		
Increased Clearance	without		

Driver, accessories

Driver type	Electric motor	Number of poles	10
Model (make)	KSB	Starting mode	Direct/Star-delta possible
Motor const. type	KSB Sub. motor	Connection mode	Delta
Frequency	50 Hz	Motor cooling method	Surface cooling
Rated voltage	400 V	Motor version	U
Rated power P2	470.00 kW	Cable design	Shielded control and power cables
Available reserve	5.72 %		
Rated current	927.0 A	Cable entry	Sealed along entire length
Starting current ratio	5.1	Power cable	S07RC4N8-F 4G50
Insulation class	H according IEC 34-1	Number of power cables	6
Motor enclosure	IP68	Control cable	S07RC4N8-F 12G1.5
Cos phi at 4/4 load	0.78	Number of control cables	1
Motor efficiency at 4/4 load	93.8 %	Moisture sensor	With
Temperature sensor	PTC resistor	Cable length	15.00 m
Motor winding	400 / 690 V		

Data sheet

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.: 100
Date: 27/07/2018
Page: 2 / 11

Amacan PB4 1200-870/47010UTG1

Version no.: 1

Materials G1

Pump bowl (112)	Cast iron EN-GJL-200	Lip seal (421)	Nitrile rubber NBR
Bellmouth (138)	Cast iron EN-GJL-200	Casing wear ring (502.1)	GX2CRNIMOCUN25-6-3-3 1.4517
Shaft (210)	Chrome steel 1.4021+QT800		
Axial propeller (ECB) (23-9)	GX2CRNIMOCUN25-6-3-3 1.4517	Motor housing (811)	Grey cast iron EN-GJL-250
		Motor hous cover (812)	Grey cast iron EN-GJL-250
Bearing bracket (330)	Grey cast iron EN-GJL-250	Motor cable (824)	Chloroprene rubber
Bearing housing (350)	Grey cast iron EN-GJL-250	Hexagon socket head cap screw (914)	CrNiMo steel A4
Bearing cover (360)	Grey cast iron EN-GJL-250		
O-Ring (412)	Nitrile rubber NBR	Material standard	International (ISO, EN)

Packaging

Packaging category	B1 Wooden or plywood case, cover provided with polypropylene cellular sheet, outdoor storage up to 3 months	Packaging for storage	Indoor
		Outdoor storage at -40°C to +50°C for up to 3 months. Packet must be covered. No corrosion protection, only transport protection.	
Packaging for transport	Ship		
IPPC Standard ISPM 15	Yes		

Nameplates

Nameplates language	International	Duplicate nameplate	With

Certifications

		Test participation	Non-witnessed
Hydraulic performance test		Quantity, non-witnessed	1
Acceptance standard	ISO 9906 class 1B	Quantity, witnessed	0
Quantity meas. points Q-H	5		
Certificate	Inspection cert. 3.1 to EN 10204		

Installation parts

Installation type	DU Discharge tube, with discharge nozzle above floor and open intake chamber	Carrier cable length	6.50 m
		Number of lifting rings	0
		Number of support (GFK)	0
Scope of supply	Pump with support cable Discharge tube not included in KSB's scope of supply.	Lower shackle made of stainless steel	No
Suction screen: Recommended - not included in our scope of devlery	No		
Bottom guide rib	Without		

Coating

KSB coating code	S2 to AA-0080-06-01 / 2	Final coating	2-component epoxy resin high solid
Surface preparation	Blasting, surface treatment quality SA 2 1/2	Color	Ultramarine blue (RAL 5002) KSB-blue
Primer	2-component epoxy-zinc dust	Total film thickness approx.	290 µm

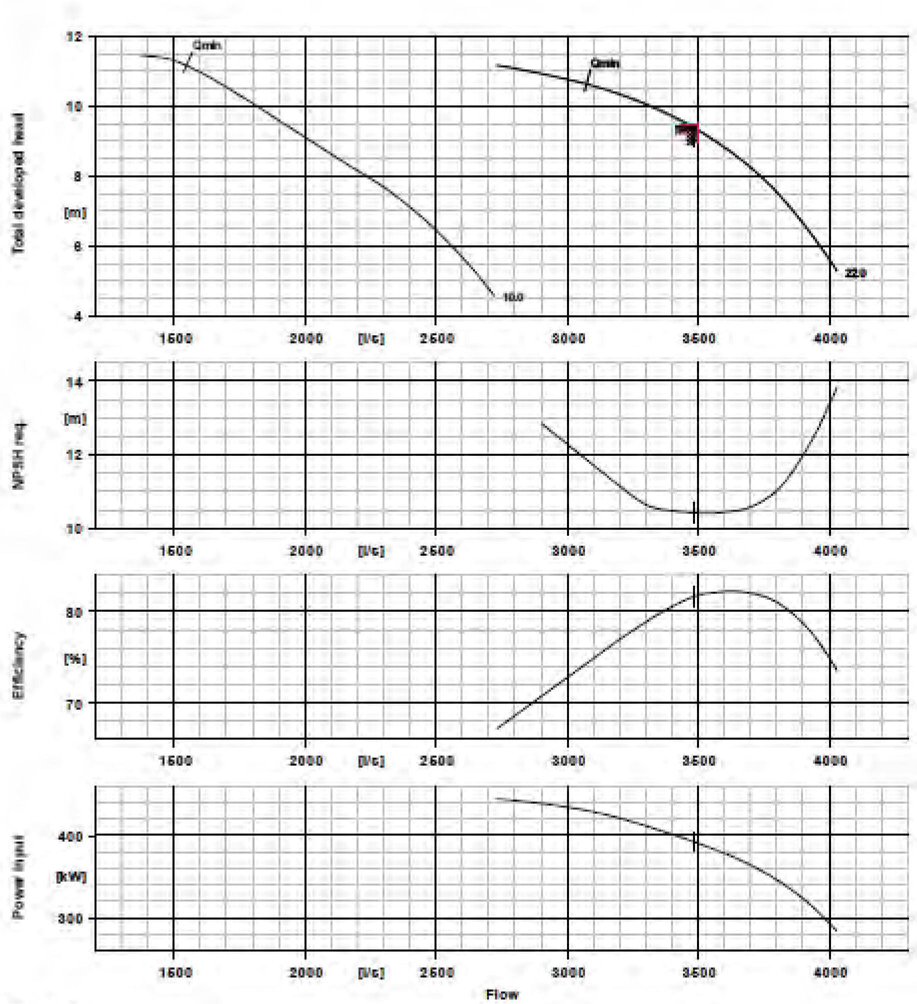
Performance curve

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
Page: 3 / 11

Version no.: 1

Amacan PB4 1200-870/47010UTG1



Curve data

Speed of rotation	591 rpm	Efficiency	81.5 %
Fluid density	998 kg/m³	Power absorbed	392.70 kW
Viscosity	1.00 mm²/s	NPSH required	10.41 m
Flow rate	3481.437 l/s	Curve number	K4200370s
Requested flow rate	3500.000 l/s	Impeller diameter	870.0 mm
Total developed head	9.40 m	Blade pitch angle	22.0 °
Requested developed head	9.50 m	Acceptance standard	ISO 9906 class 1B

Speed curve

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
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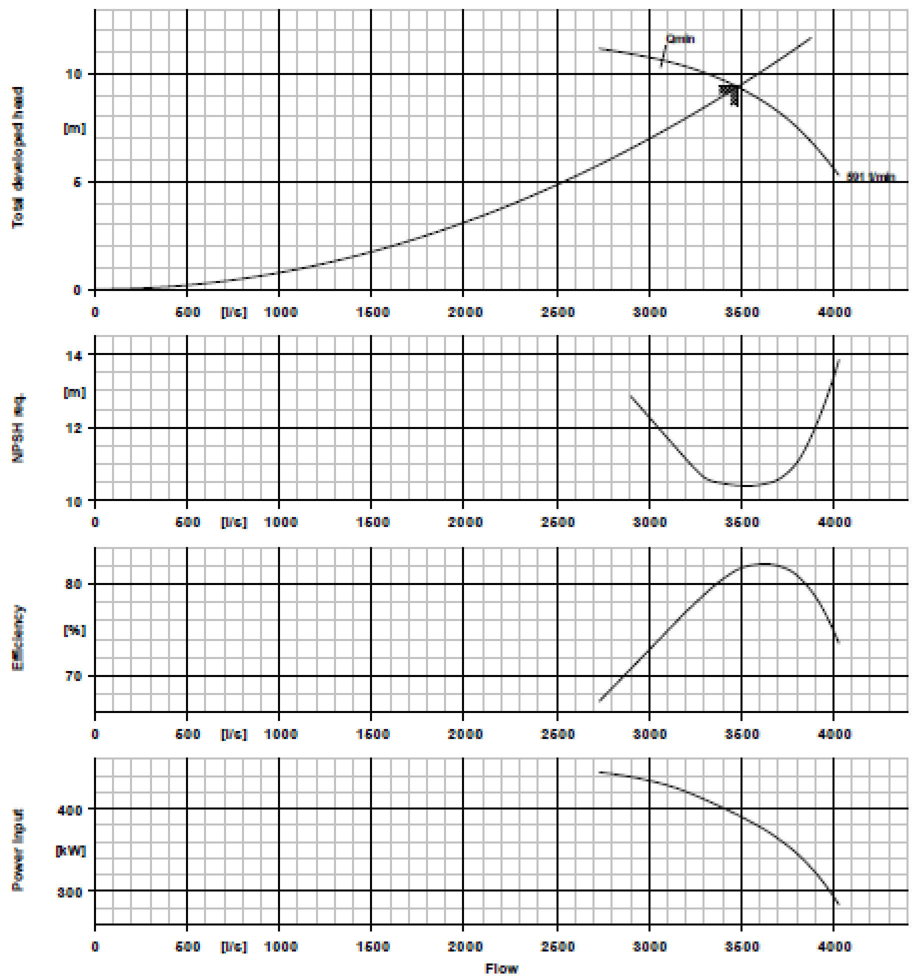
Amacan PB4 1200-870/47010UTG1

Version no.: 1



Curve data

Fluid density	998 kg/m³	Total developed head	9.40 m
Viscosity	1.00 mm²/s	Requested developed head	9.50 m
Flow rate	3481.437 l/s	Effective impeller diameter	0.0 mm
Requested flow rate	3500.000 l/s		

Motor data sheet

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
Page: 5 / 11

Amacan PB4 1200-870/47010UTG1

Version no.: 1

Motor data

Motor manufacturer	KSB	Starting mode	Direct/Star-delta possible
Motor size	470T	Power cable	S07RC4N8-F 4G50
Motor construction type	KSB Sub. motor	Number of power cables	6
Motor material	Grey cast iron EN-GJL-250	Power cable Ø min.	42.0 mm
Efficiency class	not classified	Power cable Ø max.	45.5 mm
Rated voltage	400 V	Control cable	S07RC4N8-F 12G1.5
Frequency	50 Hz	Number of control cables	1
Motor power	470.00 kW	Ctrl. cable diameter, min.	20.2 mm
Rated current	927.0 A	Ctrl. cable diameter, max.	21.2 mm
Rated speed	590 rpm	Cable standard	VDE
Starting current ratio	5.1	Switching frequency	10.00 1/h

Curve data

The no-load point is not a guarantee point within the meaning of IEC 60034

Load	0.0 %	25.0 %	50.0 %	75.0 %	100.0 %
P2	0.00 kW	117.50 kW	235.00 kW	352.50 kW	470.00 kW
n	600 rpm	598 rpm	595 rpm	592 rpm	590 rpm
P1	13.77 kW	129.70 kW	251.10 kW	374.60 kW	501.10 kW
I	398.0 A	468.0 A	585.0 A	741.0 A	927.0 A
Eta	0.0 %	90.6 %	93.6 %	94.1 %	93.8 %
cos phi	0.05	0.40	0.62	0.73	0.78

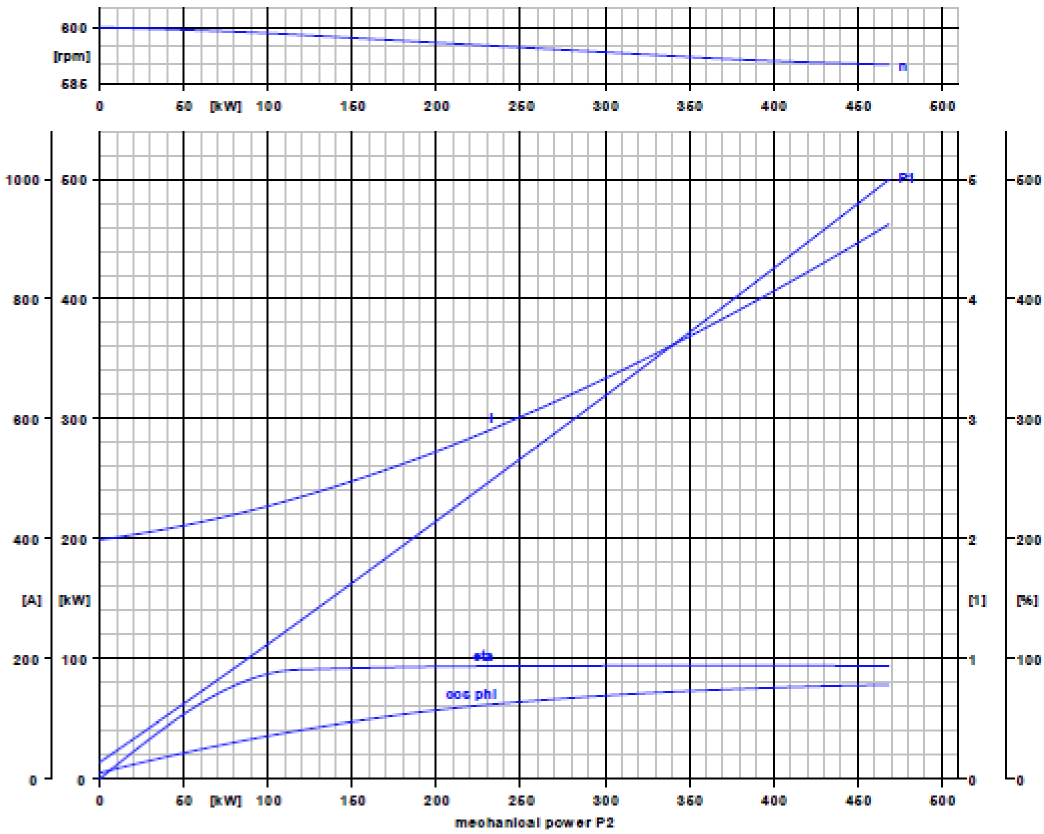
Motor data sheet

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
Page: 6 / 11

Amacan PB4 1200-870/47010UTG1

Version no.: 1



Installation plan

KSB

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
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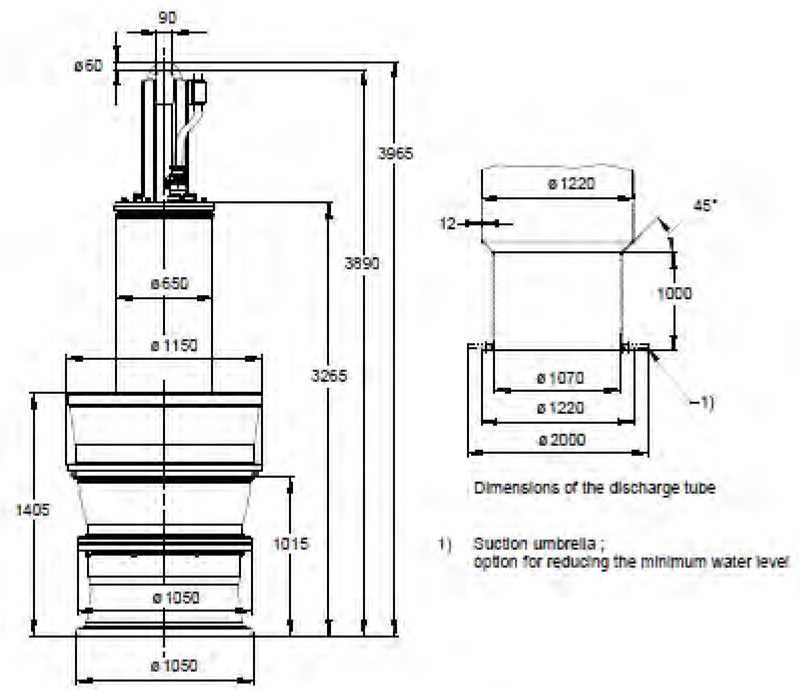
Amacan PB4 1200-870/47010UTG1

Version no.: 1



Drawing is not to scale *Dimensions in mm*

Motor

Motor manufacturer	KSB
Motor size	470T
Motor power	470.00 kW
Number of poles	10
Speed of rotation	590 rpm

Connections

Rated pressure disch.	PN 6

Weight net

Pump, Motor, Cable	5472 kg
Total	5472 kg

The discharge line must be connected to the discharge tube without transmitting any stresses or strains.

Dimensions without tolerances, middle tolerances to: ISO 2768-mH
Connection dimensions for pumps: EN735

Installation plan

KSB

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
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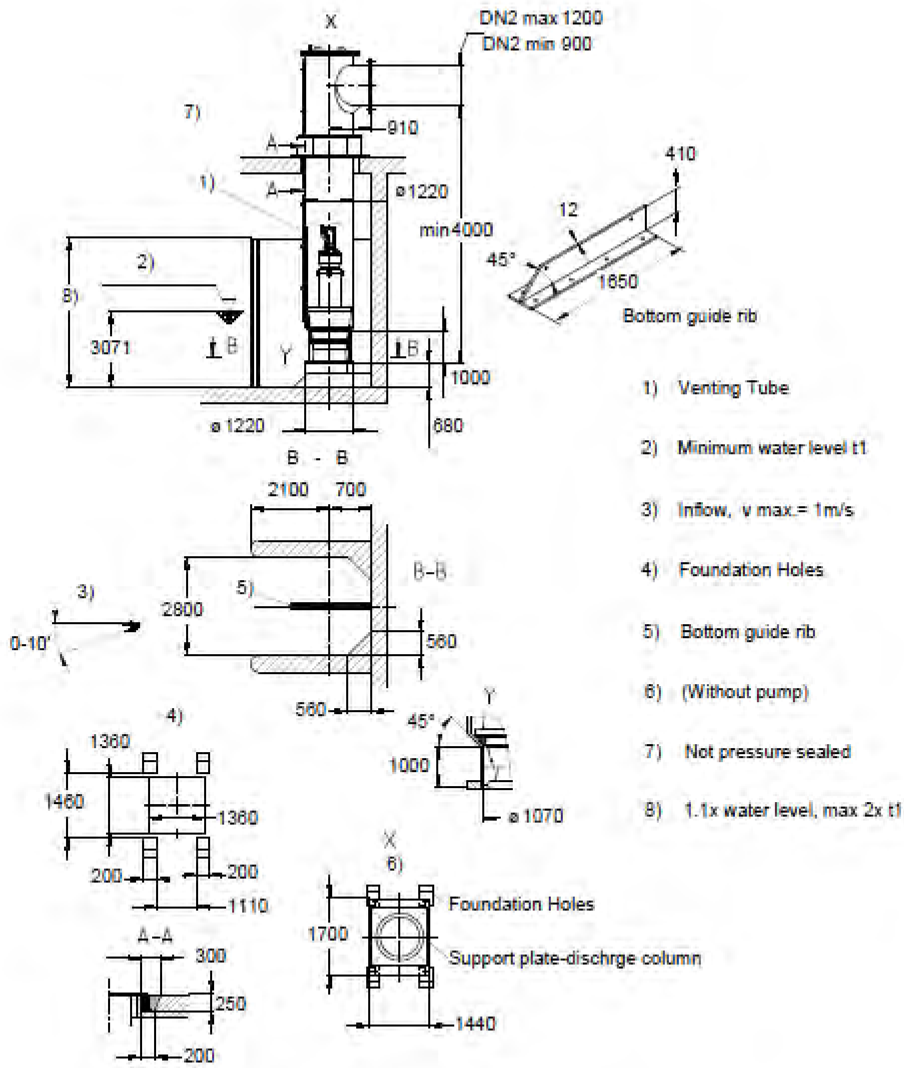
Amacan PB4 1200-870/47010UTG1

Version no.: 1



Drawing is not to scale

General arrangement drawing, installation example

Installation plan

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
Page: 9 / 11

Amacan PB4 1200-870/47010UTG1

Version no.: 1

DU Discharge tube, with discharge nozzle above floor and open intake chamber

Design of the intake chamber wall surfaces (to prevent vortex formation)

The flow-straightening vane is indispensable for the inlet conditions of the pump set. It prevents the development of a submerged vortex (floor vortex) which could cause a drop in performance, for example. In addition, the floor and wall surfaces of the intake chamber should be designed as a rough concrete surface. Rough surfaces minimise the separation of boundary layers that may cause wall and floor vortices.

Flow-straightening vane and intake chamber

- The anti-vortex vanes in the bellmouth must be aligned with the flow-straightening vane.

- The lifting lug is oriented in the same direction as the antivortex vanes in the bellmouth.

Installation plan

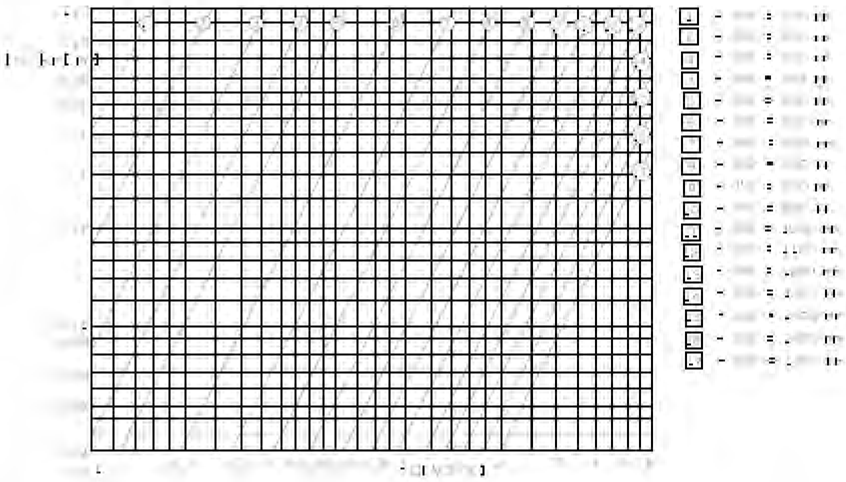
Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
Item no.:100
Date: 27/07/2018
Page: 10 / 11

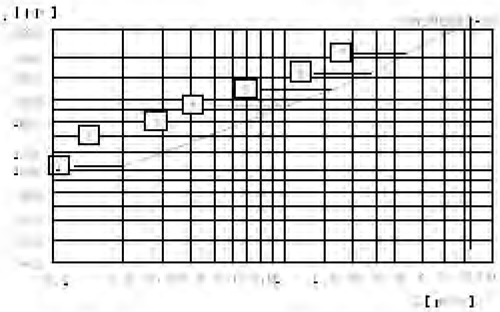
Amacan PB4 1200-870/47010UTG1

Version no.: 1

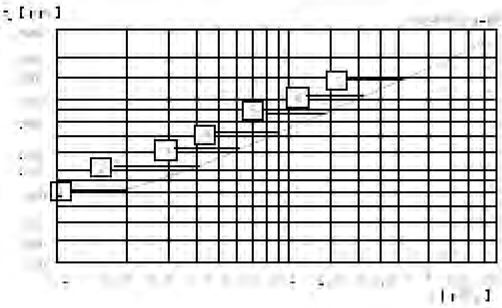
Loss diagram



Minimum fluid level diagram
Open intake chamber
(version without suction umbrella)



Minimum fluid level diagram
Open intake chamber
(version with suction umbrella)



Supplementary drawing for losses diagramm and minimum water level

Installation plan

Customer item no.:B'Berg East
Communication dated: 27/07/2018
Doc. no.: Bundaberg East Flood_CDM Smith
Quantity: 1

Number: ES 6127959
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Page: 11 / 11

Amacan PB4 1200-870/47010UTG1

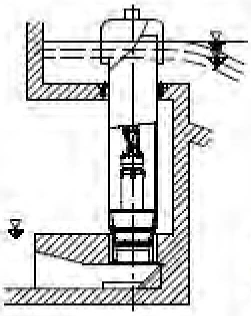
Version no.: 1

DU Discharge tube, with discharge nozzle above floor and open intake chamber

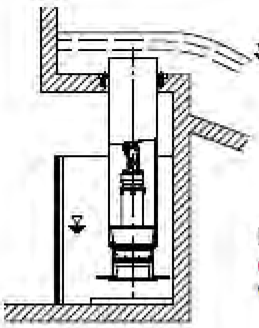
Calculation formulas:
H = Hgeo + Δ Hv
Δ Hv
- Loss in the elbow hV Kr (see diagram)
- Loss in the riser (pipe friction)
- HV System (valves, etc.)

HV Systemmust be determined for the specific system.

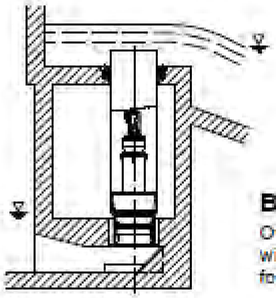
Types of installation



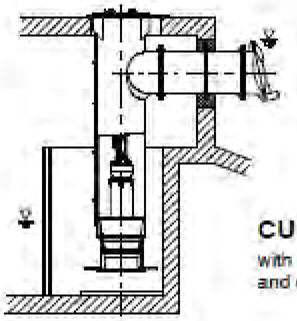
KH **Coaxial siphon (KSB patent)**
Regaining the height of fall from shaft tube outlet to upper water level for plants with fluctuations of the upper water level amounting to up to 0.5 m



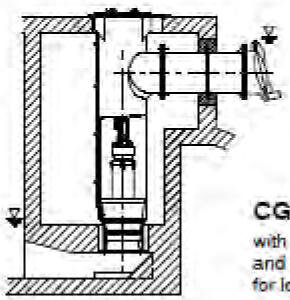
BU **Discharge tube**
Overflow design
with open intake chamber



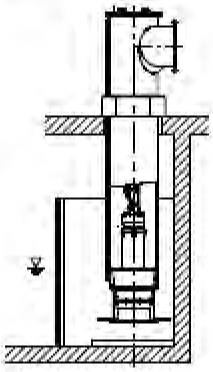
BG **Discharge tube**
Overflow design
with covered intake chamber
for low suction water levels



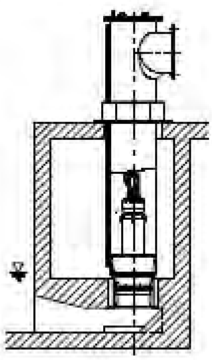
CU **Discharge tube**
with underfloor discharge
and open intake chamber



CG **Discharge tube**
with underfloor discharge
and covered intake chamber
for low suction water levels



DU **Discharge tube**
with discharge nozzle above
floor and open intake
chamber



DG **Discharge tube**
with discharge nozzle above
floor and covered intake
chamber for low suction
water levels

A.8.3 Flood Pump / Trash Rack Jib Lift Crane Vendor

JDN MONOCRANE

14 Freight Street, Yatala
Queensland, Australia 4207
Telephone + 61 07 3807 7852
Facsimile + 61 07 3807 3460
Email: sales_qld@jdn.com.au
http//www.jdn.com.au

Ref: QCDM1813201JC

TO	:	CDM Smith
ATTENTION	:	Mr Stuart Brown
PH No	:	0422 343 038
EMAIL	:	brownsa@cmdsmith.com
DATE	:	26 July, 2018
No. OF PAGES:		1/9

FROM: Tim Bradley

Dear Stuart

RE: 5 Tonne x 3 Metre Reach Jib Crane.
Budget Quotation No: QCDM1813201JC

We thank you for your valued enquiry & take pleasure in submitting our quotation.

JDN MONOCRANE is Australia's complete crane and hoist company.
Our services include the design, manufacture installation and servicing of an extensive range of cranes, hoists and componentry.

JDN MONOCRANE is an Australian owned and operated company, established in 1979.
We are an Australian wide with manufacturing and service operations in Victoria, Qld, SA, NSW and WA. We also have agency manufacture in Silverdale New Zealand.

JDN MONOCRANE Australian made Electric Wire Rope Hoists (AH Range) and Overhead Travelling Cranes range as standard from 1T to 200T in capacity complete with unparalleled technology options of:
HYPERSPEED™ | ***i-GLIDE***™ | ***PLANET***™ | ***+71***™ | SENTINEL ™

JDN MONOCRANE
(Head office - Victoria)
7-11 Nathan Road
Dandenong, Victoria 3175
T: +61 3 9797 5666
F: +61 3 9792 3033
E: sales_vic@jdn.com.au

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(Queensland)
14 Freight Street
Yatala, Queensland 4207
T: +61 7 3807 7852
F: +61 7 3807 3460
E: sales_qld@jdn.com.au

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(South Australia)
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Gillman, South Australia 5013
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F: +61 8 8447 2277
E: sales_sa@jdn.com.au

JDN MONOCRANE
(NSW)
Level 3, 81 Flushcombe Rd
Blacktown, NSW 2148
T: +61 2 9773 7714
E: sales@jdn.com.au

JDN MONOCRANE
(WA)
Trigg Western Australia 6029
T: +61 1300 006 272
E: sales@jdn.com.au

QCDM1813201JC

Page 2.

We have pleasure in providing our Budget quotation for the design, manufacture, supply and installation only of the following:

i) One (1) only JDN MONOCRANE Jib Crane

TYPE:	Free Standing - Underbraced
MRC:	5 Tonne
REACH:	3 metres
HEIGHT OF JIB	4 metres approx
HEIGHT OF LIFT:	10 metres total
HOIST MODEL:	KEAH 02012 – 21 -4/1 L040 V20V
HOIST TYPE:	Electric Wire Rope Hoist.
HOIST SPEED:	5.5/1.0 meters/minute
TROLLEY TYPE:	Electric Low headroom
TROLLEY SPEED:	20/05 metres/minute
SLEWING:	300° Electric – 0.5RPM
LOCATION:	Outdoor
POWER REQUIRMENTS:	3 Phase 50Hz 415 V
CONTROL TYPE:	Push button pendant attached to hoist
SURFACE FINISH:	Galvanized
FOOTING SIZE:	TBA. By others
SPECIAL FEATURES:	Rain hood over hoist in park position Manual Storm Lock

Clarifications:

- The jib crane shall be supplied with a main isolator switch, power is to be bought to the isolator by others.

BUDGET VALUE $ 52,000.00 NETT EXCLUDING GST.

A.8.4 Mobile Skid Mounted Flood Pump Vendor

NPE NATIONAL PUMP & ENERGY

SALES QUOTE

0000511117

National Pump and Energy Pty Ltd
ABN:83 098 812 492
PO Box 364
Buddina Queensland 4575
Tel: (07) 5438 4300
Fax: (07) 5437 8573
Email: accounts@nationalpump.com.au
Web: www.nationalpump.com.au

Quote To: CASH

CDM Smith

Quote Date: 20/08/2018

Quoted By: Billy Campbell

Requestor: Stuart Brown

Additional Information:

Line	Qty	Item No.	Description	Unit Price	Disc %	Disc Unit Price	Total
1	1	Direct Sales	BBA BA500G D675 Diesel Drive Silenced Canopy Pumpset Max Flow 4500m3/hour, Max Head 26m	366,777.00	0.00	366,777.00	366,777.00

National Pump and Energy Ltd Conditions of Sale apply to this transaction.

QUOTE VALID FOR 30 DAYS

Subtotal	$366,777.00
GST	$36,677.70
Quote Total	$403,454.70

National Pump & Energy have been appointed as the exclusive Australian supplier of BBA Pumps.
Please contact us for all of your hire or purchase requirements.