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Ports North

CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX AC: Dredging and Dredge Material Placement Assessment Report

BMT JFA Consultants

"Where will our knowledge take you?"

CAIRNS SHIPPING DEVELOPMENT PROJECT - REVISED DRAFT EIS

Dredging and Dredge Material Placement Assessment Report

Reference: R-J16021-2
Date: January 2017
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CAIRNS SHIPPING DEVELOPMENT PROJECT - REVISED DRAFT EIS

DREDGING AND DREDGE MATERIAL PLACEMENT ASSESSMENT REPORT

Prepared for

By

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1 INTRODUCTION

1.1 Project Background

Ports North (PN) commenced preparation of an Environmental Impact Statement (EIS) for the Cairns Shipping Development (CSD) Project in 2012. The CSD Project involves upgrading existing infrastructure for the Port of Cairns to accommodate larger cruise ships, including expansion of the existing shipping channel and swing basin and upgrades to the existing wharves and associated services. As a result of policy and legislation changes in 2015 the project has been re scoped and a Revised EIS is being prepared. Flanagan Consulting Group (FCG) have commissioned BMT to provided inputs on dredging and material placement aspects of the project.

1.2 Report Structure

This report summarises adopted dredging methodology and dredge material disposal management asssessments undertaken in supporting the revised EIS process. The report is structured as follows:

- Introduction – project background, scope and objectives
- Dredge Material Characterisation – summary of the laboratory testing and results of the material to be dredged.
- Dredging and Disposal Methodology – description of the proposed equipment that would be mobilised, installation process and the dredging and disposal methodology
- Material Characterisation for DMPA Assessments – results of the laboratory tests relating to the DMPA assessments and simulations.
- Dredge Material Placement Numerical Simulations – details and conclusions from the two phases of numerical simulations used to support the sizing and DMPA management.
- Appendix A – Referenced Drawings
- Appendix B – Model Calibration Results
- Appendix C – DMPA Simulation Parameters and Outcomes

2 DREDGE MATERIAL CHARACTERISATION AND VOLUMES

2.1 Geotechnical Investigations

Ports North in conjunction with Golder has refined the channel design for the proposed capital dredging program. Details of the proposed channel design and associated dredging are provided are summarised as follows:

- Volume of Soft Material: 698,755 m^3
- Volume of Stiff Clays: 92,309 m^3
- Total Volume: 791,064 m^3

The outcomes from a workshop held on 3 April 2017 concluded that a range of dredging volumes would be considered by various studies undertaken for the EIS as follows:

Table 2-1: Dredged Material Volumes

Scenario	Dredging Volume (insitu m^3)		
	Soft Material	Stiff Clay	Total
Lower Limit	710,000	80,000	790,000
Upper Limit	900,000	100,000	1,000,000

The distribution of the soft material throughout the dredging footprint is required for the preparation of dredge logs. This distribution has been determined by BMT JFA as a pro-rata of the volumes supplied by Golder and is detailed in the tables below.

Table 2-2: Soft Material Distribution – Lower Volume Limit: 710,000m^3

Dredge		Chainage (m)		Soft Material Volume (insitu m^3)		
Area	Location	Start	End	PASS	SNP^	Total
1	Outer Channel 1	22,500	24,500	-	6,857	6,857
2	Outer Channel 2	20,500	22,500	-	42,246	42,246
3	Outer Channel 3	18,500	20,500	-	203,333	203,333
4	Outer Channel 4	16,500	18,500	74,962	154,614	229,576
5	Outer Channel 5	14,500	16,500	124,722	13,131	137,853
6	Inner Channel	12,500	14,500	8,592	37,045	45,637
7	Inner Harbour	11,000	12,500	43,604	894	44,498
All				251,880	458,120	710,000

Notes:
^ Self-Neutralising PASS

Table 2-3: Soft Material Distribution – Upper Volume Limit: 900,000m^3

Dredge		Chainage (m)		Soft Material Volume (insitu m^3)		
Area	**Location**	**Start**	**End**	**PASS**	**SNP^**	**Total**
1	Outer Channel 1	22,500	24,500	-	8,691	8,691
2	Outer Channel 2	20,500	22,500	-	53,551	53,551
3	Outer Channel 3	18,500	20,500	-	257,746	257,746
4	Outer Channel 4	16,500	18,500	95,022	195,989	291,011
5	Outer Channel 5	14,500	16,500	158,099	16,645	174,744
6	Inner Channel	12,500	14,500	10,891	46,958	57,849
7	Inner Harbour	11,000	12,500	55,275	1,133	56,408
All				319,287	580,713	900,000

Notes:

^ Self-Neutralising PASS

3 DREDGING AND DISPOSAL METHODOLOGY

3.1 Dredge and Ancillary Equipment Mobilisation

The following typical dredging and ancillary equipment is expected to be mobilised to site to complete the dredging and disposal works:

Marine:

1. Small – Medium Sized Trailer Suction Hopper Dredge (TSHD)
2. Survey/Crew change vessel
3. Multicat
4. Tug
5. Sweep Bar/Plough
6. Floating and Submerged Pipelines
7. Temporary Mooring Facility at the TSHD Pump Out Location
8. Booster Pump Station

Land based:

1. Swamp dozers
2. Front end loaders
3. Excavators
4. Mobile cranes / telescopic handlers
5. Onshore pipelines (inbound)
6. Tailwater discharge pipelines
7. Water pumps
8. Booster Pump Stations

It is likely that the dredging of the stiff clays will require mobilisation of a backhoe/grab dredge and 2 barges to transport the dredged material to the shore for rehandling (by earthmoving equipment) and transport to a land based disposal area.

3.2 Pipelines, Boosters and Pump Out Station

Proposed pipeline route, pump out and booster locations for the Baron Delta disposal site is provided in the Appendix A.

3.2.1 Pipelines

The following temporary pipelines will be required for the project:

- Dredge material pipeline from the pump out location to the DMPA
- Return water pipeline(s) from the DMPA to the discharge point

The dredged material pipeline consists of a single pipeline nominally 1m diameter in size which will include some or all of the following components:

- Floating line
- Submerged pipeline and risers
- Onshore pipeline.

A small section of floating pipeline (e.g. up to 50m) may be used to connect the riser to the TSHD depending on the type of mooring.

A riser is a small section of flexible line used to bring submerged line to the surface for connection to the floating line / connection point the seaward end. A small pontoon/buoy anchored to the seafloor is used to provide access to the surface end of the riser and to maintain its position.

The submerged line is the component of the pipeline that connects the riser line to the onshore pipeline. This submerged line is made from steel and is not typically anchored, as it filled with seawater and / or dredged material at all times and holds its position on the seafloor through its self weight. Submerged pipeline will only be required for the Baron Delta disposal site.

The onshore pipeline connects the floating or submerged pipeline to the onshore disposal area. The onshore pipe is made from mild steel and is the same diameter as the submerged pipeline.

The return water pipeline is used remove the excess tailwater (with a pump where gravity fed is not possible – e.g. Barron Delta) to the proposed discharge point back into the environment.

<u>Laydown Areas</u>

The pipeline will be delivered to Cairns either by road transport or sea freight in components typically up to 12m in length. The pipe components will need to be transported by road to a laydown area(s) that is located near to both the DMPA and dredge material pipeline shore crossing location. Laydown areas of sufficient size will be required for pipe storage, handling and fabrication.

Preliminary calculations of pipeline distances for the Baron Delta sites are as follows:

Table 2-1: Preliminary Pipeline Distances

Pipeline	Baron Delta
Dredged Material (single)	
Floating	1.85km
Submerged	2.7 – 3.7km
Onshore	2.35 km
Pond insitu	1.2 km
Total	8.1 - 9.1 km
Return Water (dual)	0.1 – 1.4 km

Preliminary numbers number of truck movements required to transport this length of pipe are as follows:

- Barron Delta: 225 B-Double movements each way (i.e. 450 total mob and demob)

Based on the above laydown area of up to 1ha will be needed for pipe storage.

In addition, up to 0.5ha will be required for a submerged pipeline fabrication yard for the Baron Delta option, and the dredging contractor will need a further 1ha for his general works area (e.g. storage of plant and equipment, temporary workshop etc).

Pipe Installation

The submerged pipeline required for the Baron Delta DMPA site will be fabricated by welding pipe components together onshore into ‘strings’ between 300m to 1,000m long. Pipe strings will be capped with blank flanges to allow them to float and to be transported (towed) over water by multicat / tug.

A pipe fabrication yard will be needed to allow the pipes strings to be welded together. This could either be located close to the dredge pipeline shore crossing, or at an existing yard within the port. If the fabrication yard is located near the shore crossing, a temporary cutting may be required at the beach / through adjacent sand bars to allow the strings to be towed offshore.

If an existing yard within the port is used to fabricate strings, a multi-cat workboat and / or tugs will be used to pull the strings offshore and to transfer them either to a temporary storage location where they will be held until all strings are fabricated, or directly to the offshore submerged pipeline location. The temporary storage location could be a sheltered area within the port which allows the floating strings can be safely anchored, or they could be submerged to rest on the seafloor at a location that does not present a hazard to navigation.

Once the pipe strings are fabricated the first string can be towed to the submerged pipeline location by multi-cat and / or tugs for connection to the onshore pipeline. It will then be partially submerged with the seaward end kept afloat for connection to the next pipe string. Each pipe string is connected to the next by either a ball joint or a bolted flange connection one at a time and is also partially submerged to wait for the next. The process is repeated until the submerged pipeline reaches its desired length, before it if finally connected to the riser which brings the pipeline to the surface.

The floating pipeline is mild steel pipeline encapsulated in floatation material which keeps it buoyant even when filled with seawater and / or dredged material. It is fabricated onshore to the desired length and towed into position and provides the link between the riser and the TSHD at the pump out station.

The onshore pipeline will require a construction corridor and road access along the length of its route. The corridor needs to be of sufficient width to allow for delivery of the pipe by truck, the unloading and installation of pipe components, and vehicle access for inspection and maintenance throughout the dredging program. The pipeline corridor should preferably be of sufficient width (i.e. between 7m – 10m) to allow side by side unloading and placement by vacuum excavator. Where side by side unloading cannot be accommodated, the pipe can be unloaded separately and walked into position by the excavator on a single lane access track. The corridor still needs to be of sufficient width to accommodate both the excavator (e.g. CAT 330 / CAT 380) and the pipe(s).

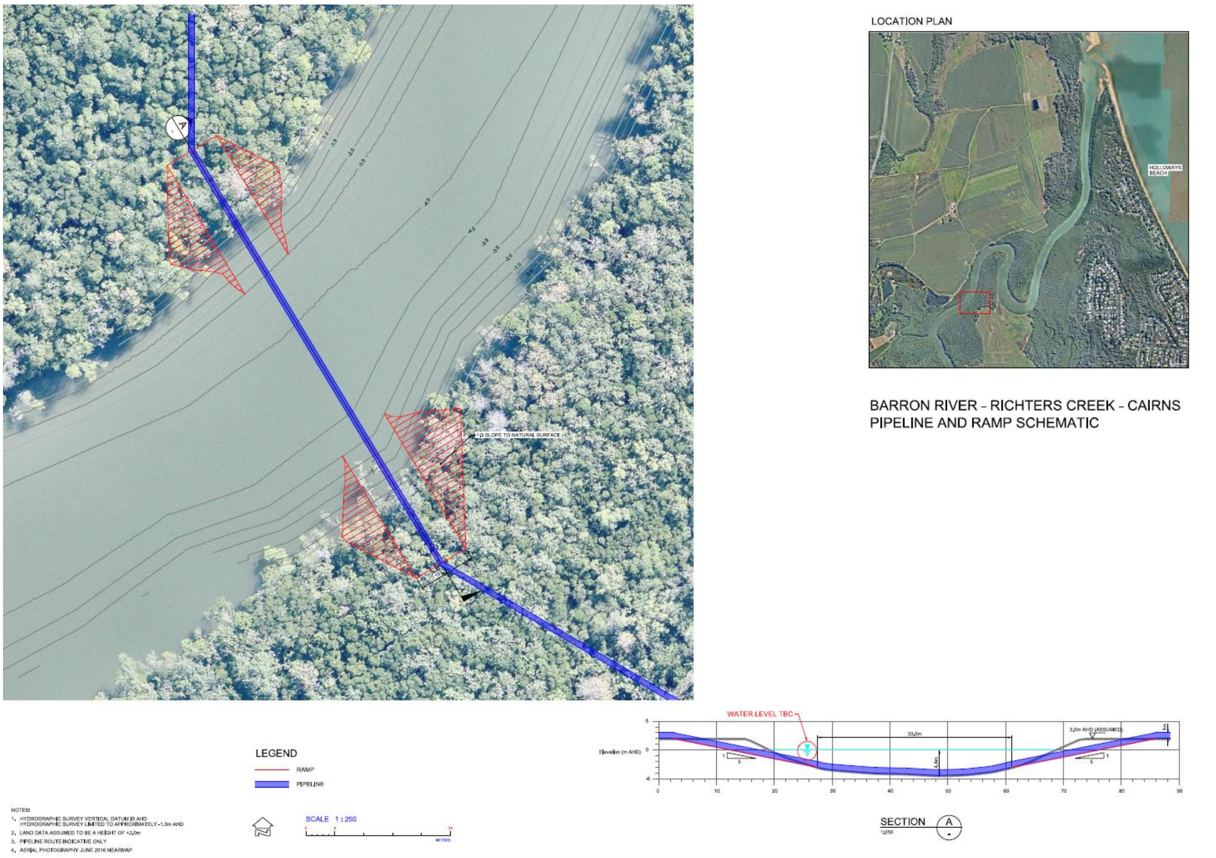


Figure 3-1: Typical arrangement for pipeline creek crossing.

It is not typical for the pipeline to require thrust blocks (e.g. at bends).

The onshore pipeline is joined by bolted, flanged connections and the pipe is seated on discrete earthen mounds of sufficient height to stabilise the pipe and to just elevate the flanges above ground.

3.2.2 Pump Out Station

The pump out station will include a temporary mooring that will facilitate the connection of the TSHD via its bow coupling to a floating section of the dredged material pipeline. The type of mooring used will be dependent on the site conditions, the dredging contractors plant and equipment, and will need to be determined in consultation with the Regional Harbour Master. Options may include:

<u>Dolphins</u>

This arrangement uses (nominally 2) steel breasting dolphins to moor the vessel for the pump out operation. Each dolphin would consist of a number of steel piles driven into the seabed, interconnected by bracing. The dolphins would be equipped with bollards to accommodate spring lines, and fenders may also be used as an efficient means of energy absorption during berthing. In addition to the breasting dolphins, additional dolphins or anchor piles may be required to accommodate head and stern lines. Once the TSHD is secured in position the connection is made between to the dredged pipeline via is its bow coupling.

The dolphins can be temporary in nature and removed at the completion of the dredging program.

Barge Mooring

Mooring the TSHD to a barge provides an alternative means to hold the TSHD in position during the pump out operations. A large spud barge of similar size to the TSHD would be mobilised and positioned prior to dredging commencing. The spud barge maintains its position by deploying four or more large, vertical “spud poles” through its deck into the seafloor. The spud poles hold the barge in position and provide a safe working platform for the crew. The barge would be orientated in a position that best mitigates dominant sea conditions and the TSHD would be brought alongside and made fast to the barge using mooring lines. Once the TSHD is secured in position, the connection is made between to dredged pipeline via is its bow coupling.

This option is more suitable for sheltered locations.

Anchor Mooring

Under this arrangement the TSHD drops its anchor(s) prior to connecting to the floating line through its bow coupling. The TSHD may either swing on its anchor to suit the prevailing conditions, or otherwise use its dynamic positioning system to maintain position.

As a result, the pump out station may need to be located further offshore to ensure sufficient draft is available for the dredge at all times.

In considering whether the TSHD can discharge while at anchor, consideration will be given to prevailing site conditions and potential marine safety hazards in consultation with the Regional Harbour Master.

3.2.3 Booster Pumping Stations

The effective pumping distance of a TSHD is determined by the size of its in board dredge pumps, available pumping power, the nature of the material to be dredged and head losses along the pipe route.

Given draft restrictions may limit TSHD size, and the long pumping distances, booster pumping stations are likely to be required to augment pumping pressures for some or all disposal sites.

A booster pump is a very large, portable pump which is connected into the dredge pipeline to boost pumping pressure. Multiple booster stations can be connected in series when required, and they can be either land based or located offshore on barges.

It is expected that between 2 and 4 booster pumps will be required for dredging with disposal within the Baron Delta precinct.

Floating booster stations are barged mounted and are towed to position before they are anchored to the seafloor. They are typically located close to the dredge and out of the surf zone. The booster pump station is connected either side to small lengths of floating line which are linked to the submerged line by risers.

Land based booster stations are delivered by road transport and sufficient access needs to be maintained at all times to allow inspections, maintenance and refuelling.

Some land based booster stations need to be located close to a suitable water source which can supply and receive large quantities of service water (for gland flushing) and in some cases for engine cooling water. Gland water leaves the system via the dredged pipeline along with the dredged material. Depending the type of pump selected by the contractor, cooling water may or may not be required. If cooling water is required, a small reticulation pond can be established to recycle the water in a closed system to minimise demand and avoid releases to the environment.

3.3 TSHD Dredging Process

Given the extent of the dredge footprint and distances to the proposed onshore disposal it is considered that a Trailer Suction Hopper Dredger (TSHD) will provide the most efficient means to transport the dredged material from the dredge area to the DMPA.

The majority of the dredged material is very soft to soft clays and can therefore easily be dredged by a TSHD. Whilst the drag head of a TSHD can be modified to dredge harder materials (e.g. through the installation of ripper teeth, and / or water jets), a back hoe dredger may also be required to dredge some of the expected firm to stiffer clays.

A TSHD is a self-propelled, sea-going dredger equipped with a hopper and dredging installations to fill and unload the hopper. TSHD's operate using one or more trailing suction pipes that are lowered from the vessel to the seabed. The dredging takes place at the draghead on the seabed which is connected to a suction pipe to fill the hopper. The dredging process and hopper filling takes place while the TSHD is sailing along the dredged areas. The trailing speed during dredging is in the order of 1 to 2 knots.

The dredging process of TSHD involves the following sequences:

1. Position TSHD at the dredging area
2. Lower the suction pipe(s) with draghead at the end
3. Dredging at draghead and hopper filling simultaneously while sailing
4. When the hopper is filled (the duration is typically dependant on the material being dredged and/or environmental constraints on loading and overflow allowances) to the dragheads are raised back onto the deck and the TSHD sails to a temporary mooring at the dredged material discharge site
5. TSHD connects to the dredged material discharge pipeline at the temporary mooring and the dredged material is pumped as a slurry to the DMPA.
6. When the hopper is empty, and the pipeline has been pumped clean of solid material with water, the TSHD disconnects from the dredged material pipeline and mooring, and returns to the dredging area to recommence the cycle.

The TSHD will operate 24 hours per day and seven days per week.

Once the TSHD has a full load it will sail to a temporary mooring at the pump out location where it will be made fast to facilitate connection to the dredge pipeline and the pump out operation.

<u>Pump Ashore Operations</u>

After the TSHD has been made fast to the temporary mooring and the bow connection to the dredge pipeline has been made, the TSHD is ready to commence the pump ashore operation. The connection process is expected to take approximately 15 minutes.

To allow the dredged material to be pumped long distances large quantities of seawater water are added and the material is pumped as a slurry of typically 10-15% solids (by volume). The seawater is introduced to the system by the TSHD dredge pumps and it is important that the minimum pumping velocities required to transport the dredged material are maintained throughout pumping to avoid blockages forming in the pipeline.

Pumping operations will continue until the hopper and pipeline are free of dredged material leaving only seawater remaining within the dredge pipeline. Upon completion of pumping, valves will be closed to ensure the dredge pipeline remains full of seawater until the next cycle commences.

The connection between the TSHD and the dredge pipeline will be broken, and mooring lines will be released to allow the TSHD to sail back to the dredge area to commence another dredge cycle.

It is noted that some clays may ‘stick’ to the internal hopper walls. To prevent this happening, water is sprayed by jets into the hopper to mobilise this material during unloading operations. Nevertheless, some material may remain after each load, and to prevent significant build ups and blockages to occur, the dredging contractor may need to open the bottom dump doors (e.g. once per day) to aid in the removal of this residual material. This would only occur when the hopper is ‘empty’, and could be scheduled to occur over the dredging footprint to minimise impacts.

3.4 Demobilisation

3.4.1 Dredge Plant Equipment and Pump Out Station

At the completion of the dredging the dredging contractors floating plant and shore based equipment will be demobilised from site.

3.4.2 Pump out station

Following the disconnection and removal of the dredge material pipeline, the mooring / pump out station will be demobilised and removed. Dolphin piles, if installed, would either be extracted (e.g. using a vibrating hammer from floating plant) or otherwise cut off below the seabed (divers) subject to approval conditions.

3.4.3 Pipeline Removal

Once dredging is complete the pipelines will be flushed with seawater to ensure they are free of all dredged material.

The floating line will be disconnected from the riser or onshore pipeline and towed to shore.

The submerged pipeline is then disconnected from the onshore pipeline and filled with compressed air from the seaward end. This forces all the water from pipeline at the shoreward end, allowing the submerged pipe to float back to the surface. The ball joints or bolted connections are then disconnected from the seaward end allowing each pipe string to be towed back to shore by multi-cat / tug. Once onshore, the pipe strings are cut back into pipe components of sufficient size to allow for their removal from site.

The onshore and return water pipelines are also disassembled back into their components in the field before they are removed from site.

3.4.4 Survey

A post dredge hydrographic survey will be completed at the end of the dredging program to confirm that the dredging has been completed in accordance with the specifications.

A survey of the DMPA may also be undertaken (subject to access conditions) to establish final levels and material quantities within the DMPA.

4 MATERIAL CHARACTERISATION FOR DMPA ASSESSMENTS

4.1 Introduction

The key objective of this work was to provide a more accurate estimation of the required dredged material placement area (DMPA) capacity for the proposed dredging program, including allowance for the storage of dredged material and for the clarification of the supernatant water to meet specified concentration limits prior to discharge. The scope of services for the study task included preparation of a laboratory testing plan, procurement and supervision of the necessary laboratory services, results interpretation and analysis, numerical reclamation model calibration and simulation, and reporting.

BMT JFA designed a testing program to assess the dredged material settling and consolidation behaviour of sediment samples collected from the dredging footprint across a wide range of soil concentrations utilising a range of laboratory testing methods. The results of the testing were then used to validate the subsequent numerical modelling that was undertaken as part of this study.

A vertical settling and consolidation numerical model tool was then used to assess the proposed dredged material placement activity.

4.2 Material Characterisation and Laboratory Testing

The laboratory testing plan was designed to clarify the constitutive relations involved in predicting short and longer term placed densities of the dredged material under self-weight loading, as well as suspended solid concentrations in the supernatant for use in the numerical model simulations. Two composite material samples were created from sediment samples collected from the dredging footprint by Golder Associates, being representative of ‘mud’ and ‘sediment’ soil units respectively. The laboratory testing included 24 ‘Standard’ (1 litre column) and 2 ‘Large Column’ (1.8m high) settling tests, and 2 ‘Slurry Consolidometer’ tests. The initial slurry concentration for tests ranged between 0.5 to 500 g/L, based on test methods proposed by USACE and expected settled densities for marine clay. Associated testing of the supernatant water and marine sediments was also completed as part of the testing program.

The testing was undertaken at the University of Queensland and ALS Laboratories and included:

- Soil and Water Characterisation Tests – Soil: particle density, Atterberg Limits, Particle Size Distribution (PSD), and Organic Content. Water – density, pH, conductivity, major cations and anions, total dissolved solids (TDS), and total suspended solids (TSS).
- Standard Settling Column (SC) Tests – Interface height and turbidity readings.
- Large Settling Column (LC) Tests – Interface height, turbidity readings, and settled soil density and PSD profile.
- Slurry Consolidometer Tests – height, applied force, pore pressure readings over test duration, and settled soil density profile.

4.2.1 Soil Characterisation Tests

Two composite material samples were created from sediment samples collected from the dredging footprint by Golder Associates, being representative of ‘mud’ and ‘sediment’ soil units respectively. The results from the sample analysis are provided in Table 4-1 below.

Table 4-1: Summary of Geotechnical Index Properties for Composite Samples

Property	Composite #1 (Widening “Muds”)	Composite #2 (Deepening “Sediments”)
Clay Plasticity	Highly Plastic	Highly Plastic
Liquid Limit (%)	56	70
Plastic Limit (%)	21	27
Plasticity Index (%)	35	43
Apparent Particle Density (t/m^3)	2.73	2.65
Organic Content (%)	3.5	4.3
% Fines (<60µm)	90%	98%

4.2.2 Standard Column Results

Standard column tests were carried out on both composite samples, for a range of varied starting concentrations (20g/l, 120g/l, 250g/l) to assess the impacts of changes in settlement characteristics at increasing sediment concentrations. Duplicate tests were carried out to provide further confidence in the results and reduce risk of outlier results impacting the assessments. The duration of the tests was typically 120hrs, with the exception of the tests on the higher starting concentrations of 250g/l where a longer duration was required due to the lower overall settling rates for the more concentrated material (hindered settling).

The standard column interface tracking results are presented in two formats in Figure 4-1 and Figure 4-2; interface height vs time, and inferred average placed dry density vs time (settled dry density inferred from the interface heights and starting concentrations). The behaviours indicated are as expected for cohesive sediment, with settling velocities decreasing with increasing concentration (hindered settling). Duplicate tests of the same material at the same concentration yielded very similar results, inferring the uniformity of test procedure and physical processes. At the higher concentrations, a small but distinct difference between Composites #1 and Composite #2 is evident: Composite #2 takes a longer time period to reach the same average placed dry density.

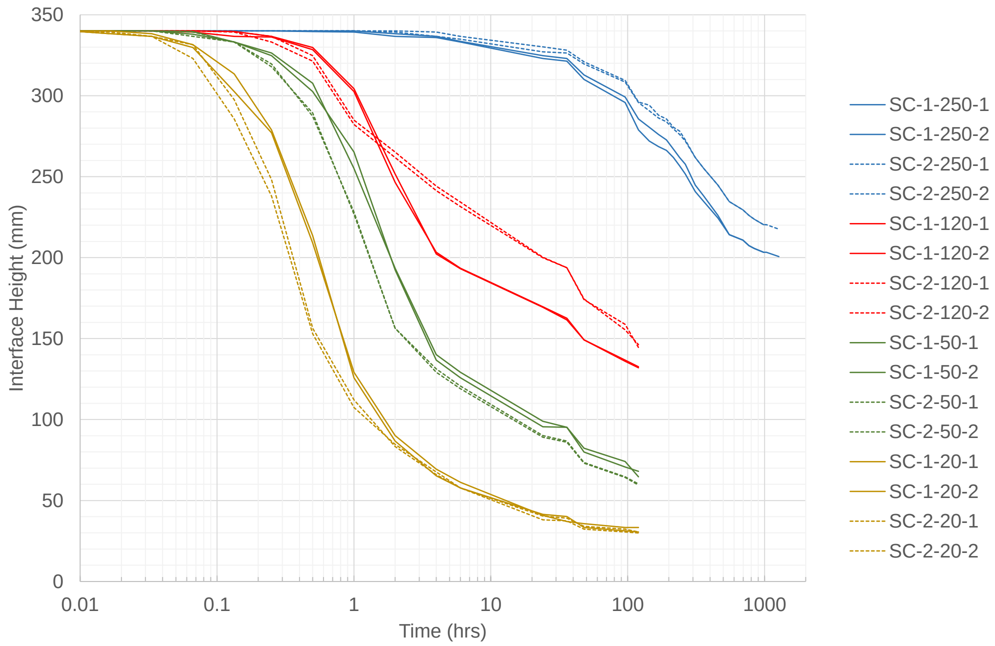


Figure 4-1 Interface Height Time Histories for Standard Column Settling Tests.

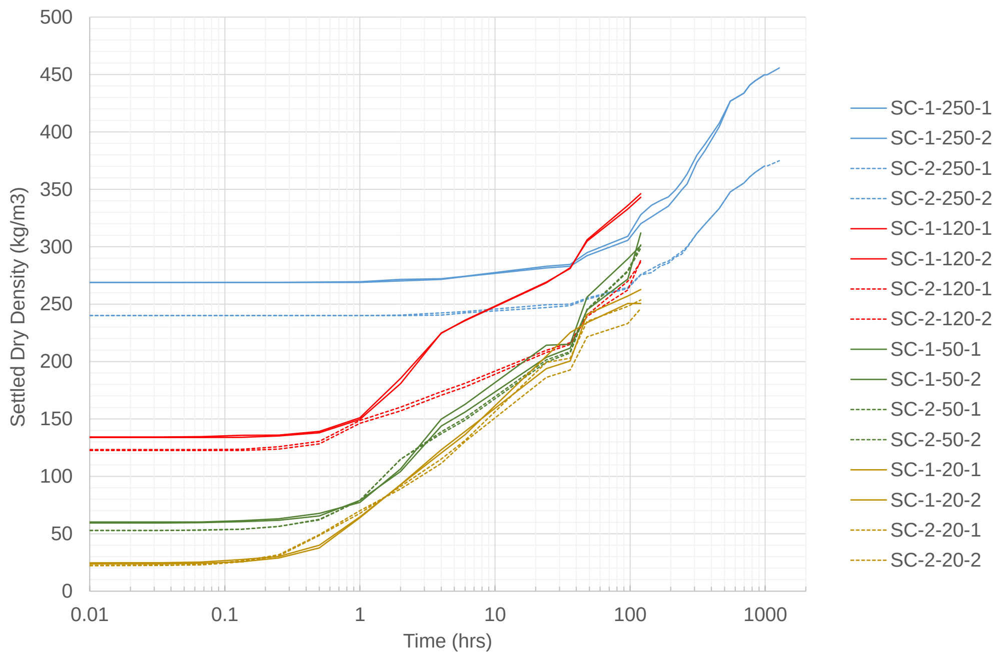


Figure 4-2: Inferred Average Placed Dry Density Time Histories for Standard Column Settling Tests

The nomenclature adopted for the tests is as follows “SC (Standard Column) – “Composite Sample Number” – “Sample Concentration in g/l” – “Test Replicate number”.

4.2.3 Large Column Settlement Times and Densities

Large Column tests were completed for Composite sample 1 (Widening) at an initial concentration of 250g/l, and for Composite Sample 2 (Deepening) at 120g/l. Test durations were 1008hrs and 800hrs respectively.

The large column results are presented in Figure 4-3, including interface height vs time, and inferred average settled dry density vs time. Both large column tests show similar ‘shape’ settling curves to their standard column counterparts. The increased time for the material to settle and consolidate due to the extra height of the taller large columns, compared with the much shorter standard columns, is evident in the final concentrations between the SC-1-250 and LC-250 tests (Composite #1) (370 vs 450 kg/m^3 at 1000hrs). A similar nomenclature is used for the large column tests as for the standard columns.

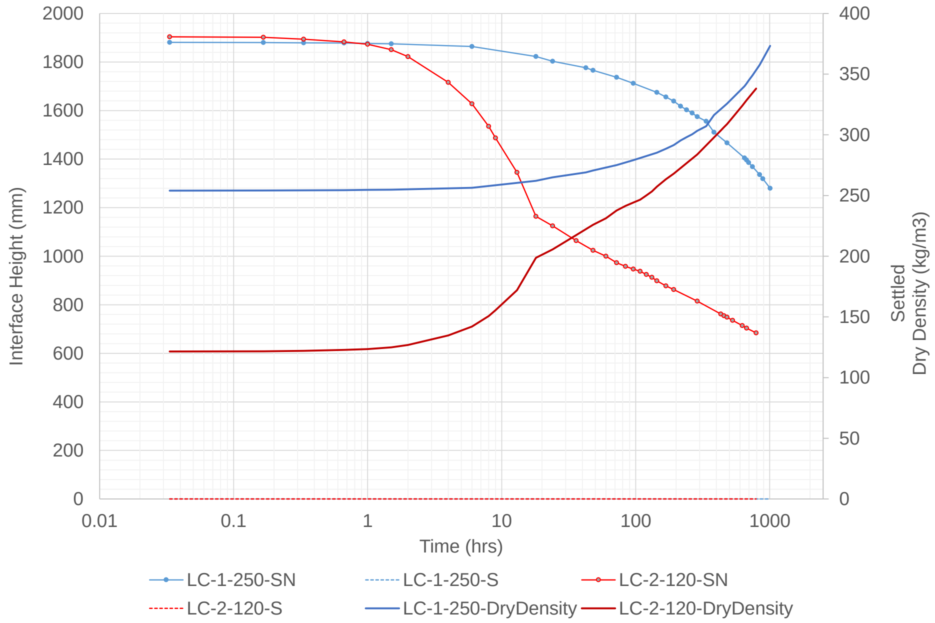


Figure 4-3: Interface Height and Inferred Averaged Settled Dry Density Time Histories for Large Column Settling Tests

At completion of the large column tests, the material was carefully extracted in segments and dried in order to assess the density profile within the settled material. The dry density profile results are presented in Figure 4-4. The profiles are as expected, with a distinct increasing density gradient from top to bottom, and a flatter component in the top region of the LC-250 test as the compaction wave moves from the bottom of the column upwards. It is worth noting the concentration in the upper 60% of the settled material of LC-250 has not progressed far beyond 300 kg/m^3 (from an initial concentration of 254 kg/m^3).

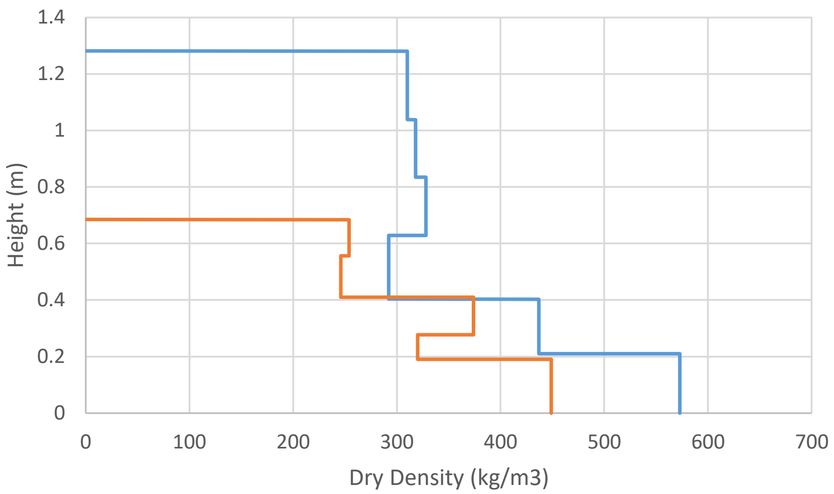


Figure 4-4: Settled Dry Density Profiles at Test Completion – LC-250 (blue) and LC-120 (orange)

4.2.4 *Supernatant Water*

The ‘supernatant’ water is the relatively clarified upper portion of the settling column, distinct from the high concentration sediment mixture beneath the supernatant. The supernatant is evident in the SC-20, SC-50, and SC-120 standard column tests shown in Figure 4-5.

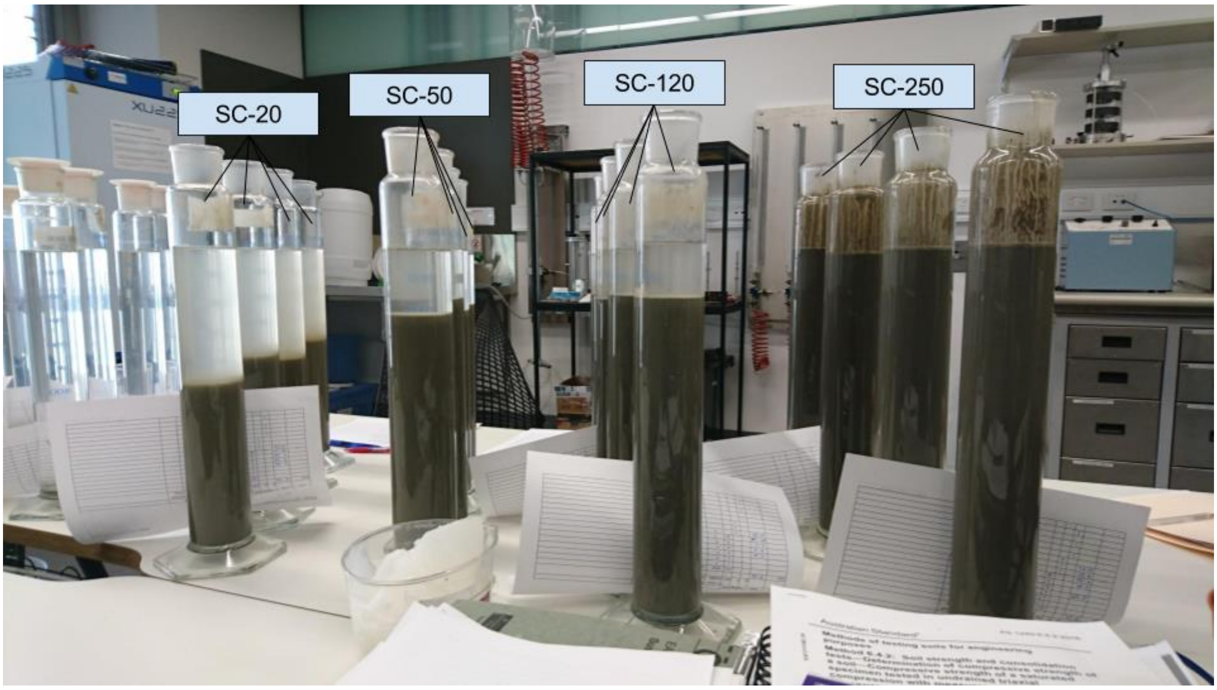


Figure 4-5: Development of Supernatant in Standard Column Test Series at 1hr

Testing of the supernatant was undertaken in order to characterize the low concentration settling behaviour of the test material. The settling of material at low concentrations was tested at several time points through the SC-3 and SC-0.5 test series, and in the large column supernatant, with singular point values obtained for the remaining standard column tests.

Concentrations in the supernatant were obtained directly from TSS testing on the SC-0.5 test series, and the LC-120 and LC-250 supernatant. These results can be used to infer a Turbidity vs TSS relation (Refer Figure 4-6). It is noted, however, that these relations can be quite variable depending on the local test conditions. For the purposes of the current assessment it is considered appropriate to use an average fit over the body of test data, which gives a best-fit linear relation of TSS (mg/L) = 1.67 x Turbidity (NTU).

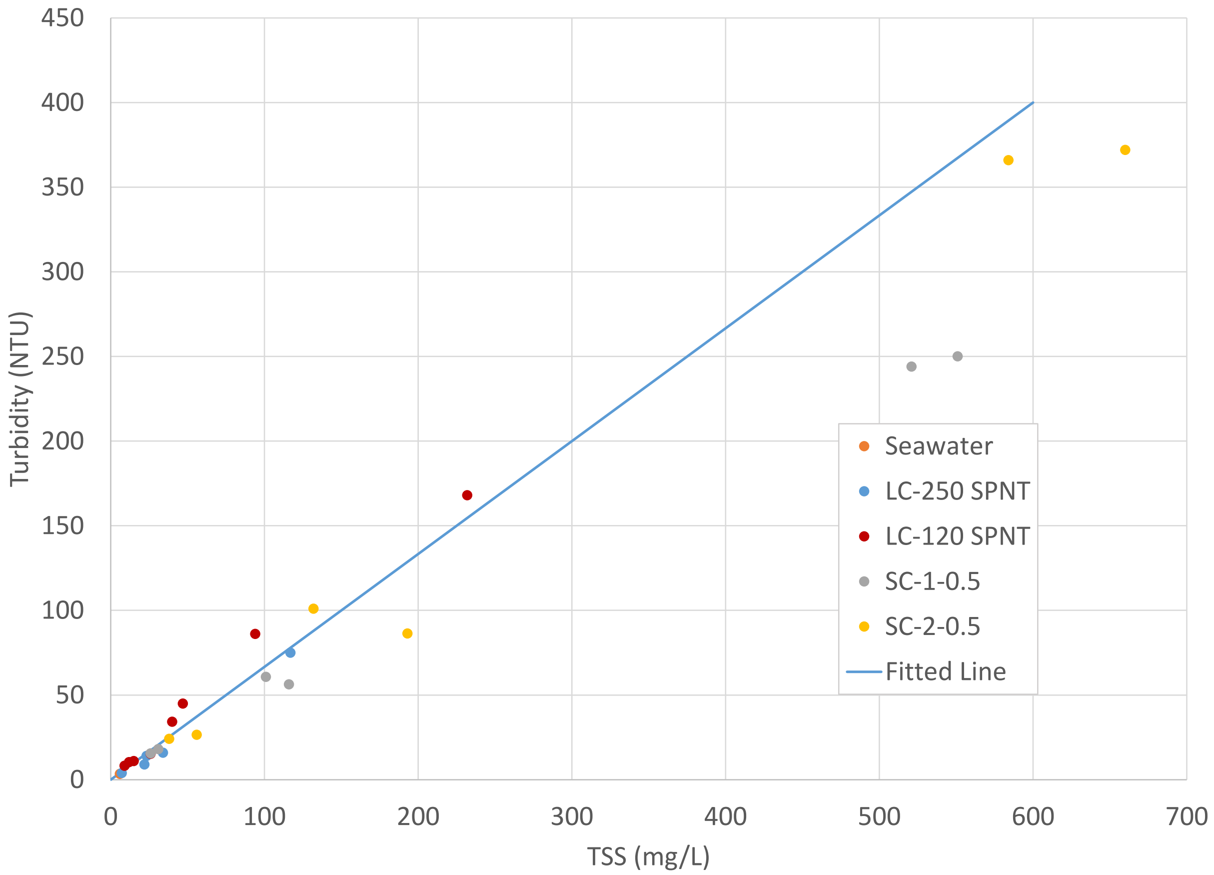


Figure 4-6: Turbidity vs TSS results

In addition to the TSS results, direct turbidity measurements were made in the supernatant at various stages during the small and large column tests. The collated supernatant turbidity results are provided on log-log scale in Figure 4-7. The results indicate the following:

- Generally consistent time-dependent concentration behaviour in the supernatant.
- A degree of log-log linearity which would be expected from van Rijn (1993).
- The similarity of the 'top' and 'bottom' readings (measurements taken at the top and bottom of the supernatant) over long time scales indicates the significant relative influence of diffusion at these low concentrations.
- The initial data point from LC-250 is noticeably high in value, which is an artefact of the very low settling speed of the supernatant interface in this column, which resulted in a small thickness of supernatant from which to extract the sample.

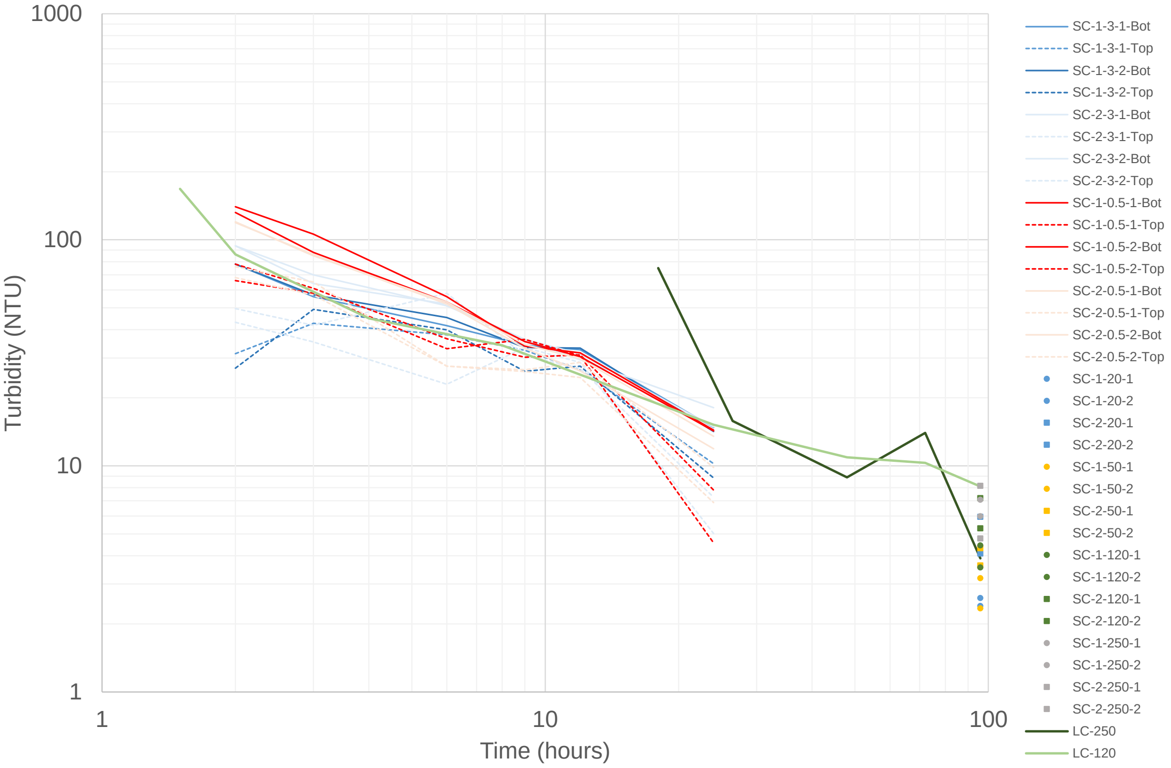


Figure 4-7: Turbidity Measurements in Supernatant for all Settling Tests

4.2.5 Slurry Consolidometer

Sample height and pore pressure results from both tests are presented in Figure 4-8. Note the effects of the power failure on Test 1 at t = 330 hrs. The pore pressure measurements indicate the effects of primary consolidation (excess pore pressure dissipation). The depth of pore pressure dissipation is evident from the pore pressure time history at a height of 200mm as the sample height approaches this value.

The resultant dry density profile (Figure 4-9) is consistent with expectations, with greatest compaction occurring at the top load plate where the magnitude of excess pore pressure dissipation is the greatest.

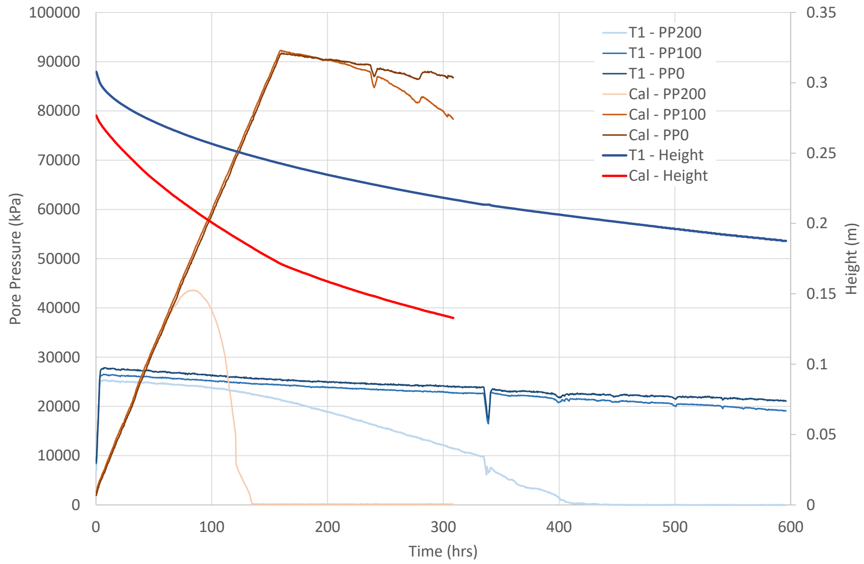


Figure 4-8: Pore Pressure and Sample Height Time Histories for Slurry Consolidometer Tests

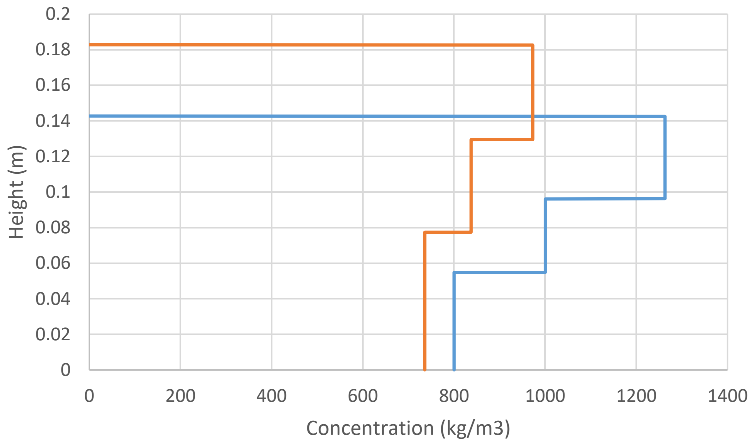


Figure 4-9: Density Profile at Test Completion – Calibration Test (Blue) and Test 1 (Orange)

Both composite material samples behaved as very fine-grained and homogeneous soft marine clays, exhibiting low settling velocities and consolidation rates. As it is anticipated that the majority (approx. 80%) of the capital material is comprised of the ‘mud’ soil unit the results of this composite sample were used as input to the numerical modelling.

5 DREDGE MATERIAL PLACEMENT NUMERICAL SIMULATIONS

5.1 Introduction

Numerical simulations were conducted using the BMT developed *Dredged Material Containment Assessment Tool* (DMCAT) to assess the proposed dredged material placement activity. In summary, the model consists of a vertical 1-D numerical model for the settling and consolidation of suspensions coupled to a quasi 1-D steady horizontal flow model. Inputs consist of the placement area geometry, a time history of the inflow characteristics (i.e. flow rate and sediment concentrations), and calibrated sediment settling and diffusion parameters (calibrated using the laboratory test results). The model returns the expected concentration and composition of the placed material and the outflow material. The corresponding key performance output parameters are the dry density of the placed material at the completion of the dredging campaign, and the suspended sediment concentration in the supernatant outflow. For the purpose of distinguishing between sediment carried in suspension and placed material, a concentration threshold of 100 kg/m^3 is applied (concentrations greater than this may still be flowable mud).

The modelling and assessments were undertaken in two phases, as the project details were developed and refined based on the outputs of the first phase, and inputs from other related studies were taken into consideration.. As a result some of the assumptions and parameters varied between the two phases. Section 5.3 addresses the first phase of modelling, whilst section 5.4 addresses the second phase.

5.2 Sediment Settling and Diffusion Characteristics

The parameters governing the sediment advection and diffusion were calibrated to the laboratory test results. The following calibrations were performed:

1. ***Combined Composite*** - all soil parameters to LC-250, LC-120, SC-1-250, SC-2-250.
2. ***Composite #1*** – all soil parameters to SC-1 series and LC-250.
3. ***Composite #2*** – all soil parameters to SC-2 series and LC-120.
4. ***Slurry Consolidometer Composite #1*** – permeability and effective stress closure relationships to Test 1.
5. ***Slurry Consolidometer Composite #1 with rate-dependence*** – permeability and effective stress closure relationships, and viscoplasticity, to Test 1.

The results of the calibration are detailed in Appendix B in the form of model predictions vs test results. Generally, the simulated results produced by calibration 2, 3, 4 and 5 are very good, particularly within the relatively important high concentration range. The results produced by calibration 1 underestimate placed densities for tests with Composite #1, and overestimate placed densities for tests with Composite #2, which merely reflects the difference in the settling and consolidation behaviour of the two samples. The results produced by calibration 4 and 5 are quite similar in their predictive capability, indicating the need to incorporate viscoplasticity is not demanded by the test results. However, if used for prediction at longer timeframes (i.e. Timeframes associated with soil creep) the parameterisation from 4 will tend to produce lower consolidation magnitudes.

BMT JFA assessed the approximate weighted average proportion of each soil unit within the Capital profile based on the geotechnical borehole datasheets supplied by Golder

Associates. The calculated weighted average proportions of each soil unit indicate that a large proportion (approx. 70-80%) of the capital material is comprised of the 'mud/widening' unit. Given this, calibration 2 (Composite #1 – 'Mud') was adopted as the input for all model simulations.

5.3 Phase 1 Simulations

Preliminary and Supplementary Simulations were run initially using the DMCAT model for an expected 770,000m3 dredging program. The Preliminary Simulations were simulated using a 'generic' placement geometry, while the Supplementary Simulations were simulated using geometry based on an initial Northern Sands DMPA conceptual layout provided by FCG.

The Preliminary Simulations provided the following key inputs to the Supplementary Simulations:

- Tuned model discretisation parameters – cell resolution in the vertical and horizontal dimensions, and time step.
- Tuned quasi 1-D flow parameters – bed viscosity, yield and resuspension thresholds, and enforced flow depths, to ensure smooth behaviours.
- Reference models for proofing of results.
- Expected volume of placed material, required to set the initial size of the ponds used in the Supplementary Simulations.

The details of the Preliminary and Supplementary Simulation scenarios are provided in the following sections.

5.3.1 DMPA inflow assumptions

The DMPA inflow time history consists of a sequence of bulk inflow rates and durations with associated sediment concentrations. The basis for the adopted inflow time histories for the Small-Medium TSHD (5,600 m^3 hopper capacity), and for the Medium TSHD (8,530 m^3 hopper capacity) sensitivity testing, is summarised in Table 5-7, and the adopted inflow time history breakdown is provided in Table 5-2.

For the purpose of the model simulations, a weighted average dredge cycle time has been used for the full dredging programme. Further, this weighted average cycle time incorporates the operational efficiency factor (i.e. accounts for down-time). This approach was adopted as the sequencing of the dredging program and timing of bunkering and other delays cannot be known at this stage of the project. As indicated in Table 5-7, the total inflow duration is approximately 60.8 days for the Small-Medium TSHD, and approximately 43.75 days for the Medium TSHD.

Table 5-1 Summary basis for adopted DMPA inflows

Parameter	Units	Small-Med TSHD	Medium TSHD
Dredge Hopper Capacity	m^3	5,600	8,530
Total dredging volume	m^3	770,000	770,000
Average in-situ dry density	t/m^3	0.96	0.96
Effective load	% In-situ m^3	50%	50%
Overflow duration	mins	0	0

Parameter	Units	Small-Med TSHD	Medium TSHD
Operational efficiency	%	80%	80%
Weighted average cycle time*	mins	317	348
Total number of cycles	-	275	181
Dredging Duration	days	60.8	43.75
Pump-out bulk flow-rate	m^3/s	3.9	3.9
Pump-out concentrations**	% Solids (by vol.)	8.0	8.0

*weighted average cycle time includes down-time (i.e. operational efficiency factor)

** Excludes priming and flushing water

Table 5-2 Adopted inflow time history breakdown

Parameter	Small-Med TSHD			Medium TSHD		
Activity	Duration (mins)	Bulk flowrate (m^3/s)	Material Concentration (g/L)	Duration (mins)	Bulk flowrate (m^3/s)	Material Concentration (g/L)
Dredging, sailing, and mooring.	217	-	-	217	-	-
Pipeline priming and flushing*	46	3.9	0.0	49	3.9	0.0
Hopper discharge	54	3.9	212.0	82	3.9	212.0

*flushing water represents the seawater retained in the pipeline from the previous dredge cycle

5.3.2 Preliminary simulations

Two placement scenarios were considered as part of the Preliminary Simulations and were identified as ***Prelim_Short_1*** and ***Prelim_Short_2*** respectively. The scenarios were formulated based on:

- Two 'generic' DMPA geometries, each comprising a single placement area (i.e. non-compartmentalised) with a length to width ratio of five, but with two different placement depths; 3.7m (***Prelim_Short_1***) and 7m (***Prelim_Short_2***).
- Width of the placement area was adjusted to reduce suspended sediment concentrations in the tailwater to approximately 100 mg/L.
- The inflows to the DMPA were derived from dredge logs developed by BMT JFA for a Small-Medium (5,600 m^3 hopper capacity) TSHD.
- Simulation duration limited to the active dredging period for the Small-Medium (5,600 m^3 hopper capacity) TSHD.

The first of the two placement depths (3.7m) adopted for the 'generic' placement areas was selected based upon BMT JFA's previous preliminary capacity assessment (prepared for the Dredged Material Placement Options Study), and the second placement depth (7m) was selected to enable assessment of the effect of an appreciably deeper placement as would be likely at the Northern Sands site.

The Small-Medium TSHD with 5,600 m^3 hopper capacity was selected to represent the class of TSHD that could be deployed after consideration of TSHD manoeuvrability within the channels and swing basins, draft limitations, hopper capacity and available pump discharge power.

5.3.3 Supplementary simulations

Supplementary Simulations were then run for the Northern Sands conceptual DMPA layout supplied. Separate scenarios were developed to assess DMPA performance over the active dredging period, and to assess the longer term consolidation and expected bed levels of the placed material post dredging and prior to the next wet season.

Active Dredging Simulations

A 'baseline' Supplementary Simulation scenario (referred to as ***NS_Short_1***) was formulated based on the following:

- Implied bulking factors from the Preliminary Simulations indicating at least 2,400,000 m3 of storage volume would be required (for assumed 770,000 m^3 dredging volume), with additional allowance for ponding depth to clarify the supernatant.
- The supplied Northern Sands layout including placement capacity of 1,484,305 m^3 to RL 0.0m AHD, and advice that that bunding, or additional excavation, could be used to increase capacity as required. Bunding around the perimeter of the placement area was assumed to provide additional capacity. Whilst only bunding was considered for simulation and reporting purposes, it is noted that the results are reflective of an equivalent volume that may otherwise be obtained by excavation of a deeper hole.
- A water level elevation within the placement area of +5.0m AHD was subsequently selected; this was assumed as the potential practical upper limit for the site given the requirement for additional freeboard for other geotechnical/operational considerations.
- DMPA inflows derived from dredge logs developed by BMT JFA for a Small-Medium (5,600 m^3 hopper capacity) TSHD.
- Simulation duration limited to the active dredging period for the Small-Medium (5,600 m^3 hopper capacity) TSHD.
- The specified 'placement' and 'treatment' zones were discretised separately in order to respect their boundaries in subsequent reporting (see Figure 5-1).

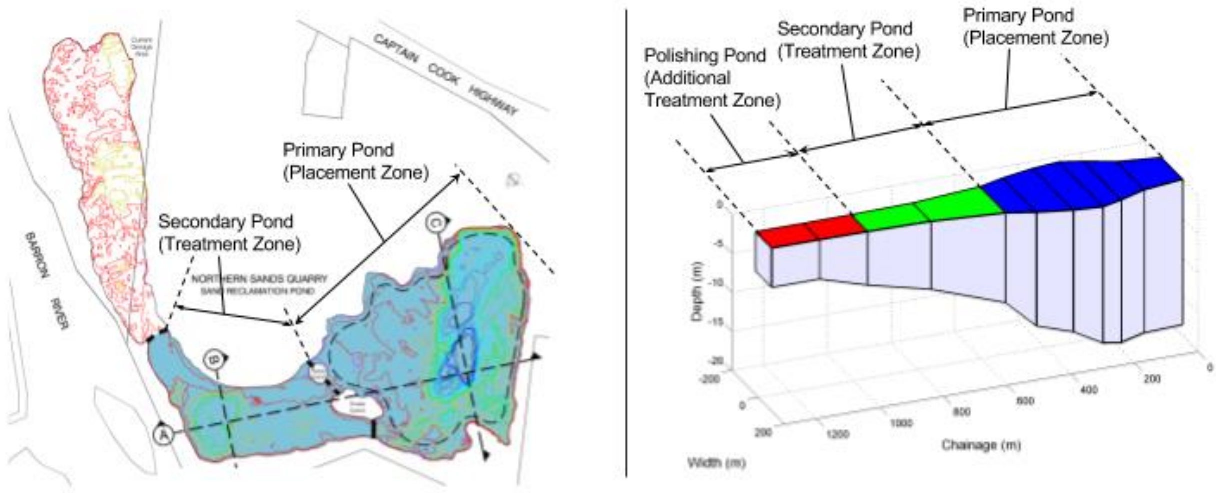


Figure 5-1: Northern Sands Supplied Concept Layout and DMCAT Simulation Geometry (NS_Short_1)

Two more scenarios were created as variations of the baseline to provide sensitivity assessment of the proposed Northern Sands placement.

The second scenario (referred to as ***NS_Short_2***) was formulated to assess the consequence of reducing the operating water level from RL +5.0m AHD to RL +3.25m AHD.

The third scenario (referred to as ***NS_Short_3***) was formulated to quantify the influence of dredging with higher production rates given the uncertainty in dredge selection will be dictated by market conditions and plant availability at the time of dredging. DMPA inflows for this scenario were developed from dredge logs for a Medium (8,530 m^3 hopper capacity) TSHD, to provide an ‘upper bound limit’ for impact assessment.

Post Dredging Simulations

Three additional simulations were undertaken to assess the consolidation behaviour within the DMPA after dredging had been completed (to assist in determining other project constraints related to longer term bed levels). The main objective of the post dredging simulations were to calculate the expected lowering of the dredged material surface level over the duration of the dry season or prior to the following wet season. The total duration of these simulations was 250 days with results extracted and reported at 200 days (i.e. between 4.5 to 5 months after active dredging).

These models were created by extracting the placed density profile at the end of the Active Dredging simulations, and using this as input to a lagrangian numerical model. This allows the assessment of rate dependent effects in addition to the primary consolidation.

The post dredging Supplementary Simulations were referred to as: ***NS_Long_1***, ***NS_Long_2*** and ***NS_Long_3***.

For all Supplementary Simulations an additional treatment zone (polishing pond) was added, as required, to the simulated geometry to in order to quantify the extra pond area and volume required to manage any non-conforming tailwater. The area of this polishing pond was determined through model iteration to produce acceptable tailwater concentrations (assuming a reference pond depth of 5m) at its outfall.

Table 5-3 provides a summary of the 8 Preliminary and Supplementary Simulations scenarios modelled:

Table 5-3: Model simulations list

Model Designation	Assumed Water Level	Average Placement Water Depth	Additional Treatment Pond Considered?	Dredge Inflow	Simulation Duration
Preliminary Simulations					
Prelim_Short_1	n/a	3.7m	No	TSHD 5,600 m3	60.8 days
Prelim_Short_2	n/a	7m	No	TSHD 5,600 m3	60.8 days
Supplementary Simulations – Active Dredging					
NS_Short_1	+5.0m AHD	16.6m / 8.7m	Yes	TSHD 5,600 m3	60.8 days
NS_Short_2	+3.25 m AHD	14.9m / 6.9m	Yes	TSHD 5,600 m3	60.8 days
NS_Short_3	+3.25 m AHD	14.9m / 6.9m	Yes	TSHD 8,530 m3	43.8 days
Supplementary Simulations – Post Dredging					
NS_Long_1	+5.0m AHD	16.6m / 8.7m	Yes	TSHD 5,600 m3	250 days
NS_ Long _2	+3.25 m AHD	14.9m / 6.9m	Yes	TSHD 5,600 m3	250 days
NS_ Long _3	+3.25 m AHD	14.9m / 6.9m	Yes	TSHD 8,530 m3	250 days

5.3.4 Phase 1 Simulation results

Key results are from both the Preliminary and Supplementary Simulations detailed in the following sections. A more complete tabulation is provided in Appendix C.

Preliminary simulations

Summary results for the Preliminary Simulations are provided in Table 5-4.

Table 5-4 Preliminary simulation results summary

Model Designation	Placement Water depth (m)	Area (Ha)	*Avg. placed dry density (kg/m^3)	Placed material occupied volume (Mm^3)	Bulking Factor (Implied)	Max. Outflow Supernatant Concentration (mg/L)
Prelim_Short_1	3.7	91	303	2.43	3.2	45
Prelim_Short_2	7.0	53	291	2.52	3.3	46

**represents the average settled material dry density of material above 100 kg/m^3 at the end of the simulation.*

Supplementary simulations

Summary results for the Supplementary Simulations are provided below. The post dredging simulation results were extracted from the model and reported at 200 days following commencement of the dredging campaign.

Table 5-5 Supplementary simulation results summary

Model Designation	Avg. Placement Water Depth (m)		Placement Area (Ha)	*Avg. placed dry density (kg/m^3)	Placed material occupied volume (Mm^3)	Bulking Factor (Implied)	Max. Outflow Supernatant Concentration (mg/L)	
	Prim. Pond	Sec. Pond					Sec. Pond	Polish. Pond
Active Dredging								
NS_Short_1	16.6	8.7	20	278	2.66	3.4	113,000	120
NS_Short_2	14.9	6.9	19	279	2.65	3.4	119,000	120
NS_Short_3	14.9	6.9	19	267	2.77	3.6	134,000	80
Post Dredging								
NS_Long_1	16.6	8.7	20	328	2.25	2.9	-	-
NS_Long_2	14.9	6.9	19	323	2.29	3.0	-	-
NS_Long_3	14.9	6.9	19	327	2.26	2.9	-	-

represents the average settled material dry density of material above 100 kg/m^3

Table 5-6: Supplementary simulations results summary – material distribution & tailwater vols.

Model Designation	Placed Material Distribution (m^3)			Average Material Surface RL (m AHD)		Polishing Area Required (Ha)
	Primary	Secondary	Polishing	Primary	Secondary	
Active Dredging						
NS_Short_1	2.33	0.29	0.04	4.6	1.5	9
NS_Short_2	2.00	0.36	0.28	2.9	3.1	30
NS_Short_3	2.00	0.36	0.40	2.9	3.0	32
Post Dredging						
NS_Long_1	2.00	0.22	0.03	2.6	0.7	9
NS_Long_2	1.76	0.29	0.23	1.1	1.9	30
NS_Long_3	1.68	0.27	0.30	0.6	1.4	32

In addition to the summary results presented in the tables, a vertical section through Cell 1 of the placement zone for model simulation ***NS_Long_1***, taken at completion of the dredging campaign, and 2, 4 and 6 months post dredging, is provided in Figure 5-4.

For this average placement depth of 16.6m in the primary pond, the average surface level of the placed material may reduce by approximately 1.8 – 2.1m (Appendix C) by the start of the following wet season. This represents an increase of the average in-situ density from approximately 280 to 320 kg/m3 or 14%.

By comparison, the secondary pond achieves greater density increases of approximately 22% to 30% in the long term, but due to its smaller averaged placed depth, the overall settlement magnitude is lower (approximately 0.8-1.2m).

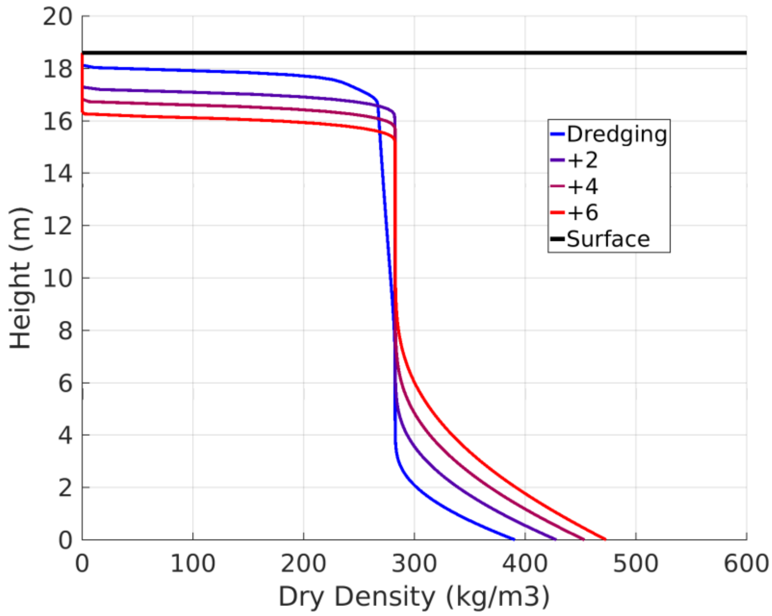


Figure 5-2: Primary pond vertical density profile results from completion of dredging to 6 months post dredge campaign – *NS_Long_1* simulation

5.3.5 Phase 1 Simulations – Key Conclusions

Conclusions drawn from the phase 1 simulations carried forward for use in future development to the DMPA concept design were as follows:

- An average placed dry density of approximately 280 kg/m3 (implied bulking factor of 3.4) should be used in determining the placed material volume for a deep (i.e. >5m deep) placement solution. Based on an insitu dredged volume of 770,000m3 this requires and expected placed material volume of 2.65Mm3.
- The dredged material should be enclosed in a containment volume approximately 10-15% larger than the placed material volume to ensure fluid mud does not pass into the polishing pond. The resulting required containment volume is approximately 2.95 Mm3.
- Subject to site constraints, a shallower placement area of a larger footprint would reduce the required placement volume.
- A polishing pond of approximately 5 Ha should be sufficient to meet target tailwater discharge quality limits, provided no fluid mud is entrained. The polishing pond provisionally requires a 1m minimum water depth, however further design is required to confirm requirements.
- Differential placement depths and the inclusion of an internal bund between the primary and secondary ponds result in differential long term settlements and bed levels between ponds. This can be counteracted by supplying a greater proportion of the total storage volume to the secondary pond.

5.4 Phase 2 Simulations

5.4.1 Inflows and Water Levels

The DMPA inflow time history consists of a sequence of bulk inflow rates and durations with associated sediment concentrations. The basis for the adopted inflow time is summarised in Table 5-7.

For the purpose of the model simulations, a weighted average dredge cycle time has been used for the full dredging programme. Further, this weighted average cycle time incorporates the operational efficiency factor (i.e. accounts for down-time). Two dredge volume scenarios were modelled, for the disposal site as shown on Drawing 3527-SK09C (Appendix A).

Table 5-7 Summary basis for adopted DMPA inflows

Parameter	Units	Scenario 1	Scenario 2
Total dredging volume	m^3	710,000 m3	900,000 m3
Dredge Size (Hopper Capacity)	m^3	5,600	5,600
Average in-situ dry density	t/m^3	0.96	0.96
Weighted average cycle time*	mins	327	321
Dredging Duration	days	64.8	80.9
Pump-out bulk flow-rate	m^3/s	3.9	3.9
Pump-out concentrations**	% Solids (by vol.)	8.0	8.0

*weighted average cycle time includes down-time (i.e. operational efficiency factor)

** Excludes priming and flushing water

The DMPA water level was set to 0.0m AHD for the first 14 days, at which point the 100 mg/l limit is triggered, and then the levels are raised continuously till the water level reaches 7.2m AHD. This is achieved with the outflow rate = 30% of the inflow rate, which allows the 12-hour averaged outflow concentration to hover just under the 50 g/l limit over the duration.

5.4.2 Geometry

The geometry was derived from the supplied drawing 3527-SK09C, along with supplied bathymetric and terrestrial survey data. For the purposes of reproducing the filling process from RL 0.0 to RL 7.2, a trapezoidal channel shape was assumed, with base width approximated from the measured ‘hole’ width (existing + future sand reclamation area). The shape of the trapezoid was adjusted to reproduce the storage volumes at both RL 0.0 and RL 7.2, which produced sufficiently accurate estimates of storage volume between these elevations.

5.4.3 Phase 2 Simulation Results

The model was calibrated against the laboratory test results and the final calibration indicates that the model has a good predictive capability, particularly in the more critical, higher concentration ranges. Modelling of the dredge placement scenarios was then undertaken. The resultant average material placement parameters are reported in Table 5-8, while Figure 5-3 indicates the densification of the material over the duration of the simulation, and Figure 5-4 illustrates the dry density profile at key reporting intervals at the deepest part of the placement area.

Regarding the overall performance:

- The 710,000m^3 scenario appears to fit within the placement area satisfying both placed volume and tailwater requirements, with some tailwater management required near completion.
- The 900,000m^3 scenario does not quite fit, with 80,000t (9%) "overflowing the weir" in the model. An additional 270,000m^3 (approximately) is required.

Regarding the tailwater quality:

- For Scenario 1 (64.8 days) and Scenario 2 (80.1 days) from day 58-66 there may be intermittent exceedance as dredge pumping slugs pass through the reclamation, but the duration is short (applies to tail end of Scenario 1, and Scenario 2).
- For Scenario 2 only, from day 66-76 there is permanent exceedance with an average discharge concentration of 15 g/l, but the concentrations are still low (ie relative to fluid mud) (Scenario 2).
- At day 76, mud reaches the weir level and capacity of the pond is reached.

Table 5-8 Simulation results

Model Designation	Avg. Settled Bed RL (m)	*Avg. placed dry density (kg/m^3)	Bulking Factor (Implied)	Outflow Concentration Threshold Exceedence
Scenario 1 (710k m3)	6.0**	286	3.35	N
Scenario 2 (900k m3)	6.0**	321	2.99	Y
6 months	5.1	349	2.75	N/A

**represents the average settled material dry density of material above 100 kg/m^3*
***average settled bed level is assessed 24 hrs after dredge campaign completion to allow a defined bed to form*

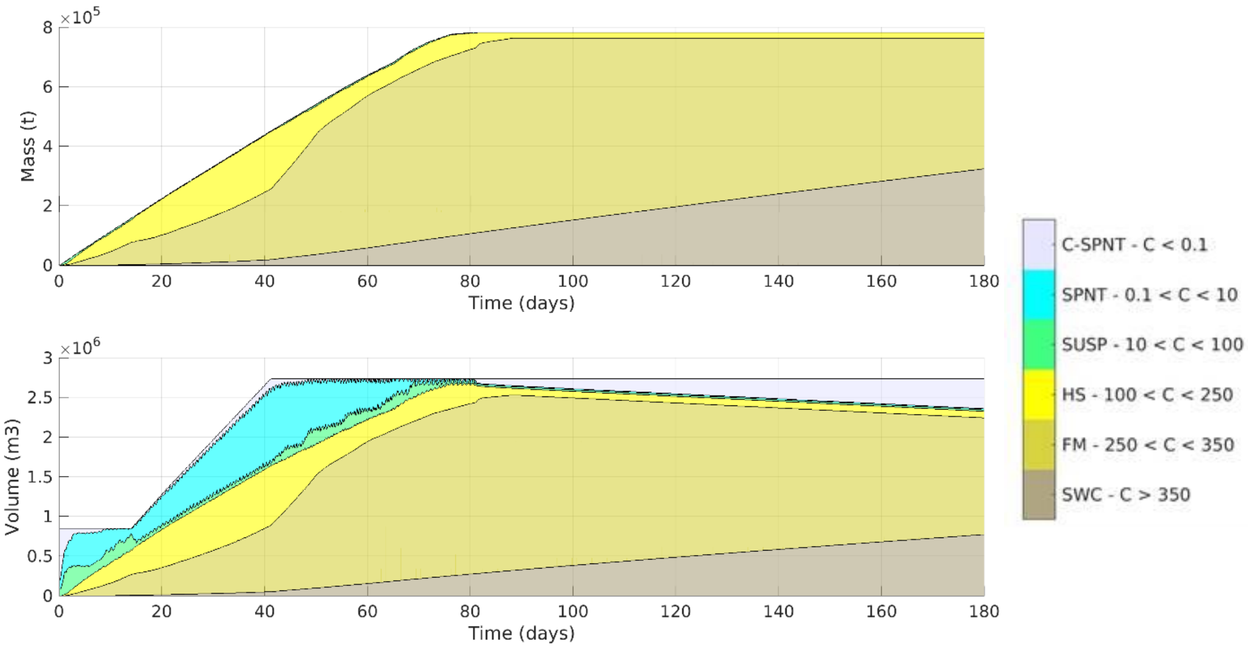


Figure 5-3: Progressive placed mass, stored volume, and proportions of material in the disposal site. The grey is clean supernatant while the light blue is supernatant which is beyond

the 100 mg/l limit but still of low concentration. Light yellow is fluid mud while dark yellow and brown are self-weight consolidating mud.

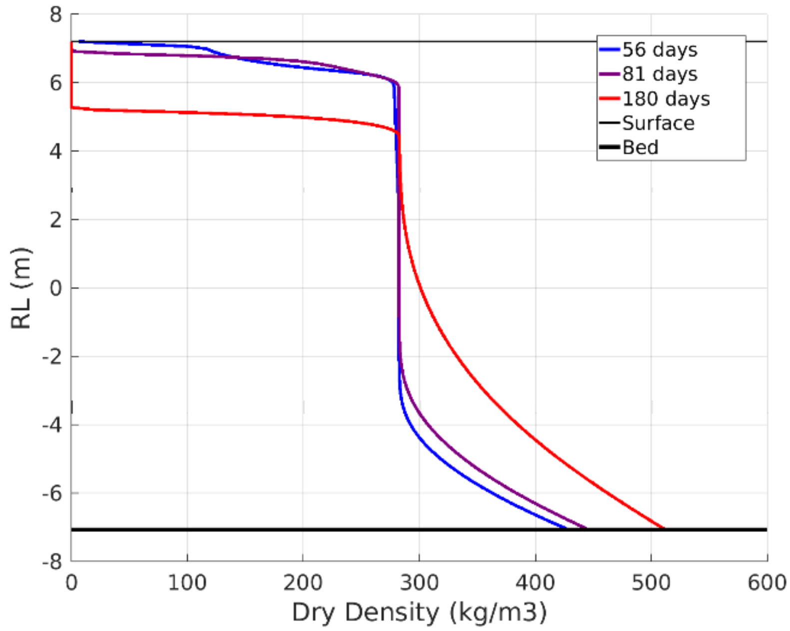


Figure 5-4: Vertical density profile results in the deepest part of the placement area, at several timepoints (measured from start of the dredging campaign)

5.4.4 Summary

The following key results were obtained from the simulations:

- An average placed dry density at the completion of the 710,000m^3 dredging campaign (short-term) of 286 kg/m^3 was obtained, implying a short-term bulking factor of 3.35. The bulking factor improves rapidly on completion of dredging as the solids settle out of the pond water into the bed surface.
- An average placed dry density at the start of the wet season (1 December) of 349 kg/m^3 was obtained, implying a bulking factor of 2.75.
- The proposed containment area, with MOWL at RL 7.20 enclosing a storage volume of 2,728,482 m^3, has sufficient capacity to contain the dredged material (710,100m^3 with an in-situ dry density of 0.96 t/m^3). The additional void volume required to contain the material for Scenario 2 (900,000 m^3) campaign is 287,000m^3, based on the MOWL of RL 7.20 and a bulking factor of 3.35. Refer also to Section 5.5.1 below for further discussion on the bulking factors.

5.5 Discussion and Recommendations

5.5.1 Solids Storage Capacity

It is noted the final assessed placed density (and hence volume occupied in the disposal area) and the associated inferred bulking factor are influenced by a range of variables in both the dredge material properties and the dredging methodology (including duration, average inflow rates and concentrations). The laboratory results (standard column) achieved dry densities up to 400-450kg/m^3 (bulking factor 2.1 - 2.4). The phase 1 simulations with the DMCAT model indicated lower densities in the range of 280kg/m^3 (bulking factor 3.3) upon completion of placement. The phase 2 simulations which reflected scenarios of likely water management practices during placement indicated an initial density of 286kg/m^3, but noting that rapid density increases occurred soon after the completion of works, with 349 kg/m^3 achieved before the wet season commences (bulking factor reduction from 3.35 to 2.75). Accordingly, the adoption of a bulking factor of 2.9 for concept design is an appropriate risk-mitigating approach.

Noting the potential variability of the bulking factor that may result in practice, it is recommended that the following contingencies and management measures be included for to mitigate risk:

1. Increases in the dredging volume, or higher end bulking factors, could be accommodated through a greater excavation of material from the disposal site prior to the start of dredging.
2. The settled dry density increases over time, thus reduction of the average dredge productivity (ie extension of the dredge program) will provide for increased capacity in the pond.

5.5.2 Tailwater Quality

Tailwater discharge quality limits may be exceeded towards the end of the dredging campaign for Scenario 1, and the last ~20 days of Scenario 2 when the ponding water available for supernatant clarification is at a minimum, and subject to influence by short term wind conditions. As the duration of exceedance for Scenario 1 is relatively short it is expected that suitable tailwater discharge quality can be achieved with the nominated pond capacity. With respect to Scenario 2, assuming fluid mud does not overflow the weir (ie pond volume is increased to accommodate solids), measures to address the discharge water quality exceedances include:

- The inclusion of a separate polishing pond of minimum depth of approximately 1.5m to reduce wind-generated resuspension within the supernatant. The size of the pond required will be strongly influenced by the other measures undertaken but is expected to be in the order of 5 Ha.
- The provision of extra volumetric capacity in a secondary pond to contain the discharged primary pond supernatant during the period of quality limit exceedance. This could be include pre-emptive drawdown of the secondary pond to increase tailwater retention time when the secondary pond is used.
- Active management of water levels (and hence available capacity) in the primary pond could achieve similar results by drawing down water levels as much as is practical in advance of periods when the discharge water quality is forecast to exceed allowable discharge quality limits.
- Incorporation of internal bunds to hold back deposited sediments and allow for skimming of supernatant waters prior to discharge.

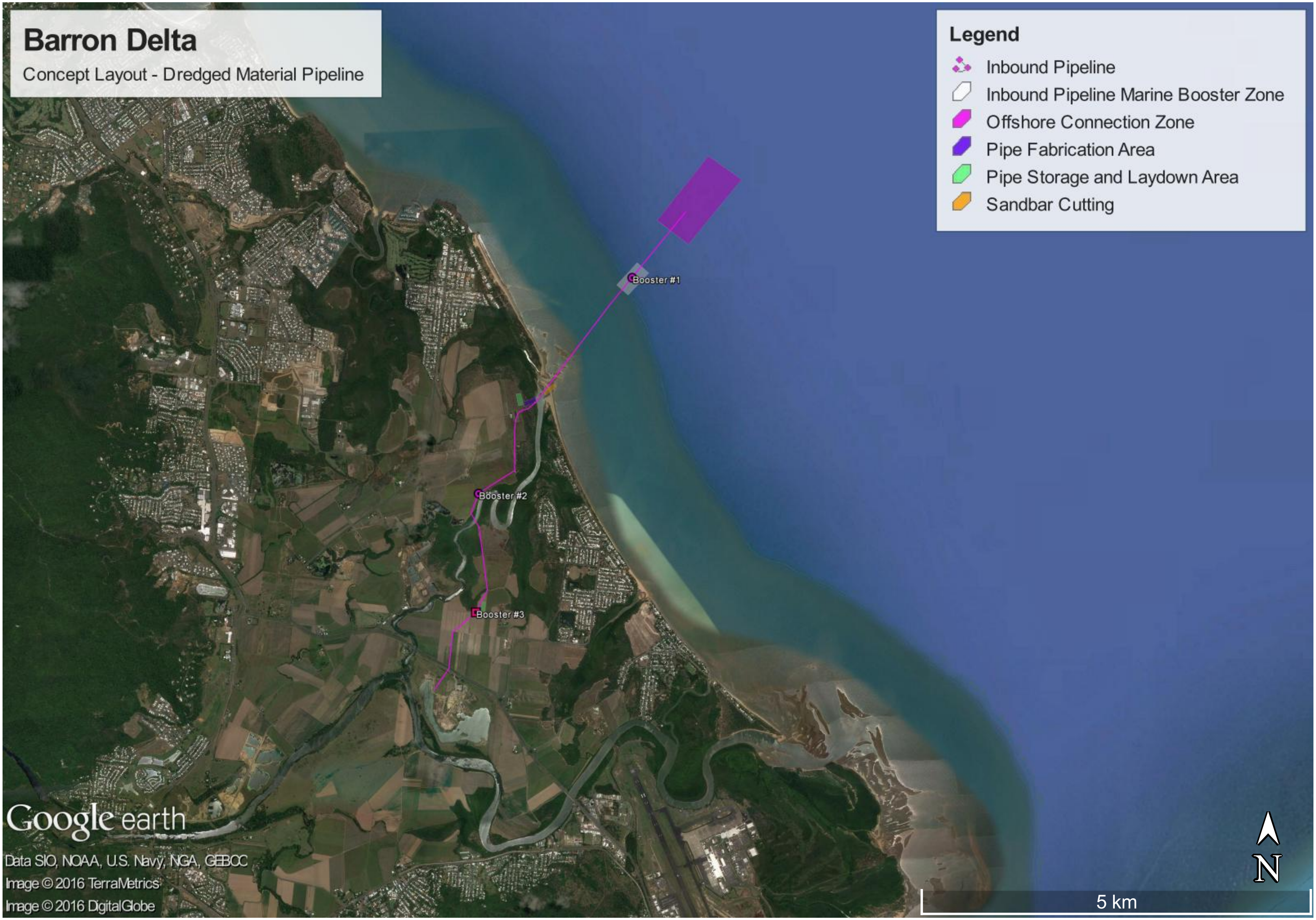
5.6 Limitations and Considerations

The outcomes of the completed study are considered suitable to inform the overall project definition and provide input design parameters for the development of the DMPA design and EIS studies.

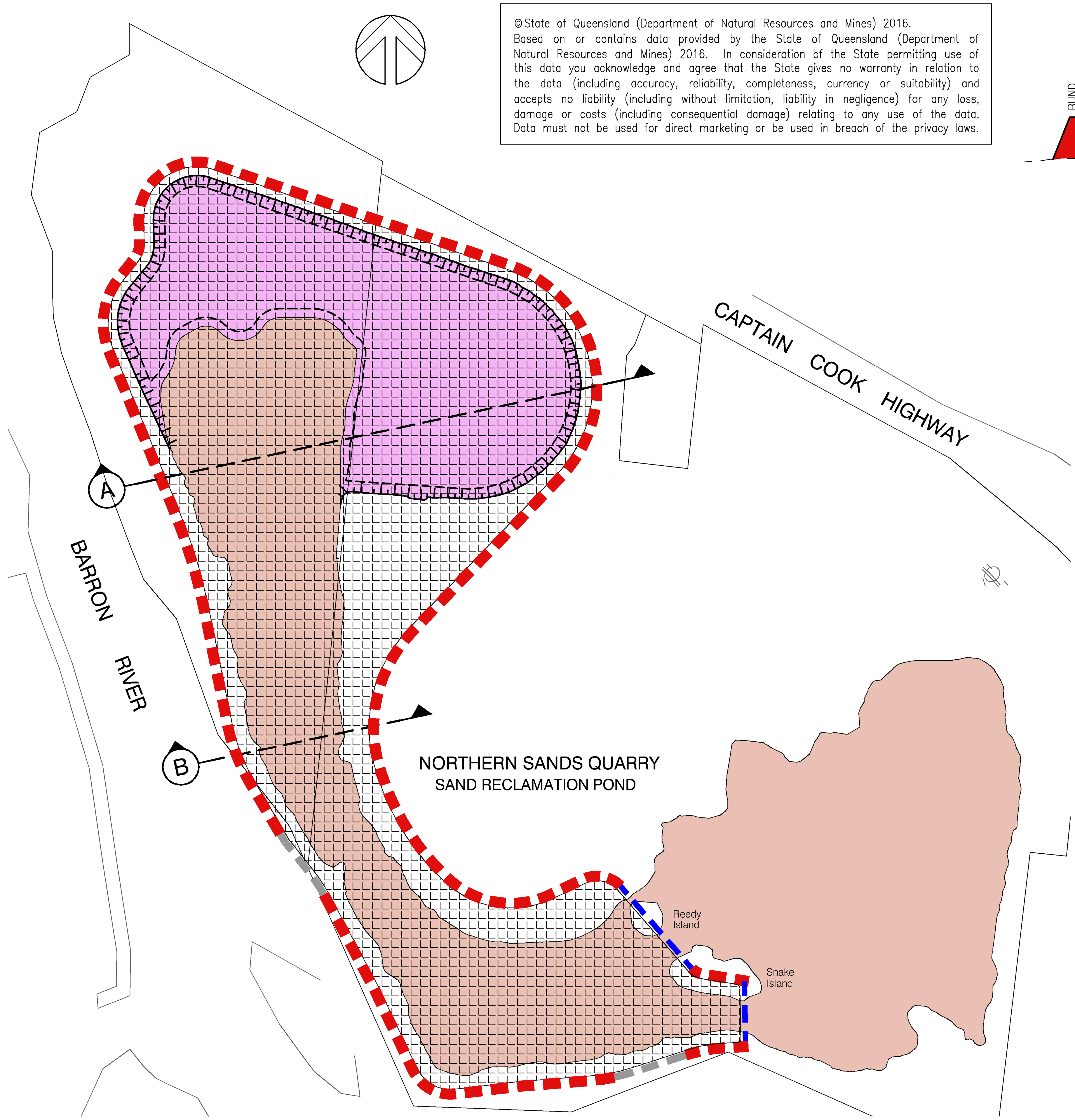
Key limitations to take into consideration for this study are summarised as follows:

- Material sampling and testing – the model has been calibrated to laboratory testing of one composite sample, composed of grab-samples from two locations within the Capital dredging profile. The samples are expected to be representative of similar materials identified from the geotechnical investigation but natural variations can and do occur.
- Deterministic simulations – the input parameters adopted for the model simulations are considered to represent the median, or best-fit, input value. Sensitivity or stochastic simulations have not been completed to assess the possible range in placement storage or area requirements.
- Water salinity – water salinity is known to affect the flocculation settling and consolidation of fine grained sediments by affecting the size of flocculated particles. At the time the laboratory testing was initiated, an alternate placement location (East Trinity) which involved dredged material placement in seawater was still under consideration. At Northern Sands, the existing water is known to be of lower salinity, however the pumped slurry entering the DMPA is mixed with seawater. It is not expected this will have a large effect on the final placement outcomes but may be addressed by future studies.
- Test apparatus – the proposed depth of placement (approximately 12m) is considerably larger than the placement depths tested in the laboratory. The model's predictive capability has been confirmed for placements to the height of the test apparatus (2m), and it is expected to be accurate for larger heights, consistent with BMT JFA's experience.
- The modelling does not take into account any effects of wind waves causing resuspension of fines into the supernatant water. This may impact on the water quality at the discharge point.
- No groundwater seepage (inwards or outwards) is included in the numerical model.
- In the numerical modelling, following completion of material placement the water level remains at a constant level (material remains saturated). In practice, it would be viable to draw down and drain the surface water (in addition to evaporation) which may result in surface drying of the placed material over time.

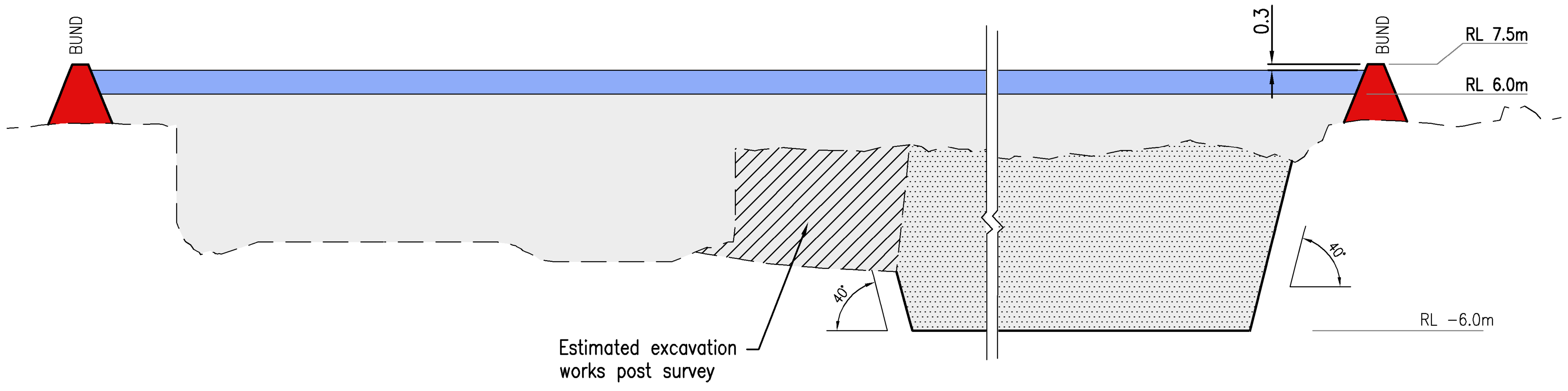
APPENDIX A
REFERENCED DRAWINGS



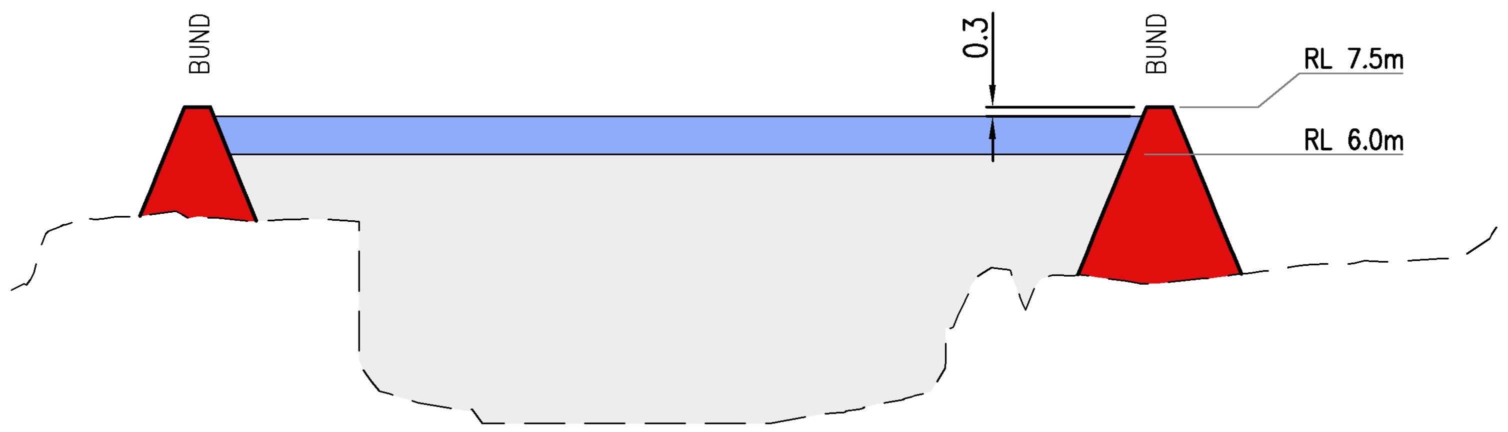
Barron Delta
Concept Layout - Dredged Material Pipeline
Legend
Inbound Pipeline
Inbound Pipeline Marine Booster Zone
Offshore Connection Zone
Pipe Fabrication Area
Pipe Storage and Laydown Area
Sandbar Cutting
Booster #1
Booster #2
Booster #3
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 TerraMetrics
Image © 2016 DigitalGlobe
5 km
N



DREDGE MATERIAL PLACEMENT ZONE
1:3000



SECTION A
1:1000 Horiz / 1:200 Vert



SECTION B
1:1000 Horiz / 1:200 Vert

STORAGE VOLUMES

LEVEL (AHD) (m)	VOLUME BELOW (m^3)	COMMENT
7.5	2,819,327	Top of Bund
7.2	2,728,482	Max Water Level
7.0	2,668,257	
6.5	2,518,856	
6.0	2,371,126	Top of Placed Material
5.5	2,225,163	
5.0	2,081,394	
4.5	1,939,774	
4.0	1,803,912	
3.5	1,674,465	
3.0	1,549,057	
2.5	1,427,232	
2.0	1,307,750	
1.5	1,189,951	
1.0	1,073,634	
0.68	1,000,000	Settled Volume
0.5	960,161	
0.0	851,455	
−0.5	743,178	
−1.0	636,100	
−1.5	531,122	
−2.0	440,915	
−2.5	357,815	
−3.0	289,916	
−3.5	229,943	
−4.0	179,996	
−4.5	132,535	
−5.0	88,373	
−5.5	45,085	
−6.0	2,735	
−6.5	0	

VOLUMES

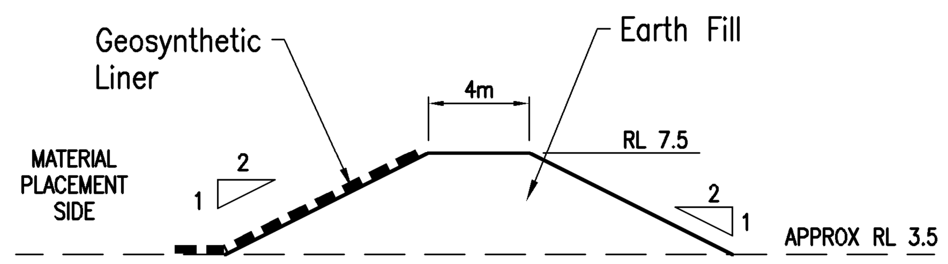
- EXCAVATION (778,000 m^3 approx)
- PERIMETER EARTH BUND (124,000 m^3 approx)
- POTENTIAL DREDGED MATERIAL STORAGE (2,371,120 m^3 approx)
- POTENTIAL WATER STORAGE (357,360 m^3 approx)

NOTES

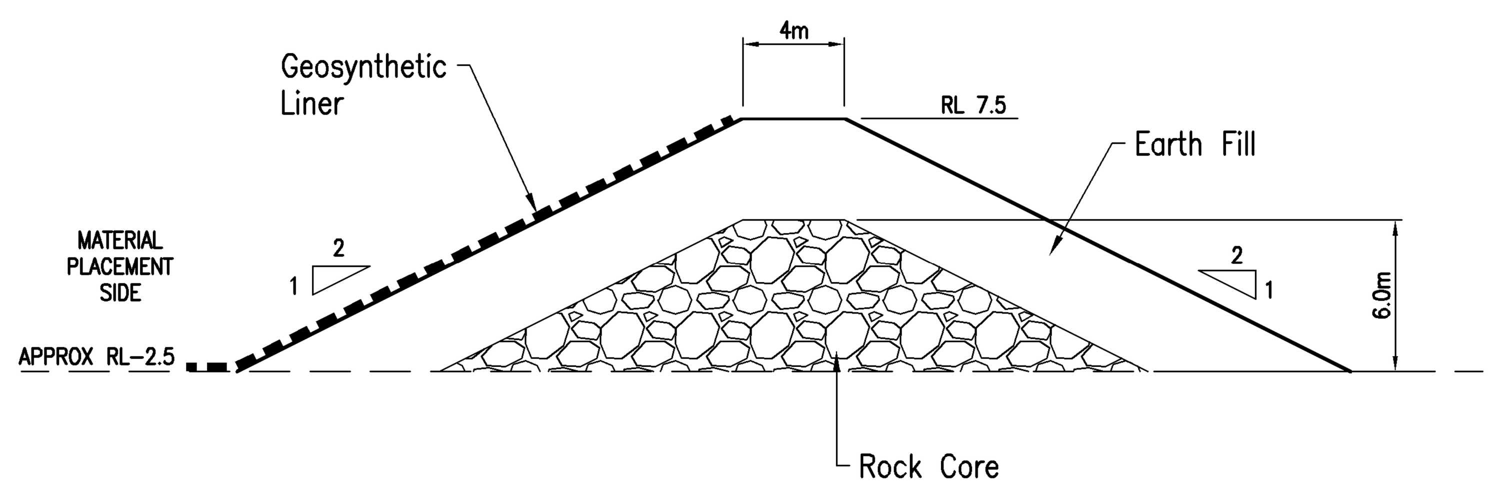
1. Volumes shown are approximate only and based on a combination of site hydrographic survey and LiDAR survey.

LEGEND

- EXISTING SAND RECLAMATION AREA
- FUTURE SAND RECLAMATION AREA (TO RL −6.0)
- DREDGE MATERIAL PLACEMENT ZONE (293,700 m^2 – SURFACE AREA AT RL 6.0)
- EARTH BUND (APPROX 2,750m)
- SEPARATION BUND (APPROX 195m)
- EXISTING EARTH BUND (APPROX 165m)



PERIMETER EARTH BUND
NTS



SEPARATION BUND
NTS

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NORTHERN SANDS

Dredge Material Placement
Bund Height RL 7.5m
Concept Only

3527-SK09C | 1:3000 | A1 Full Size

Acad No. 3527-SK09C | 16 March 2017

APPENDIX B:
MODEL CALIBRATION RESULTS

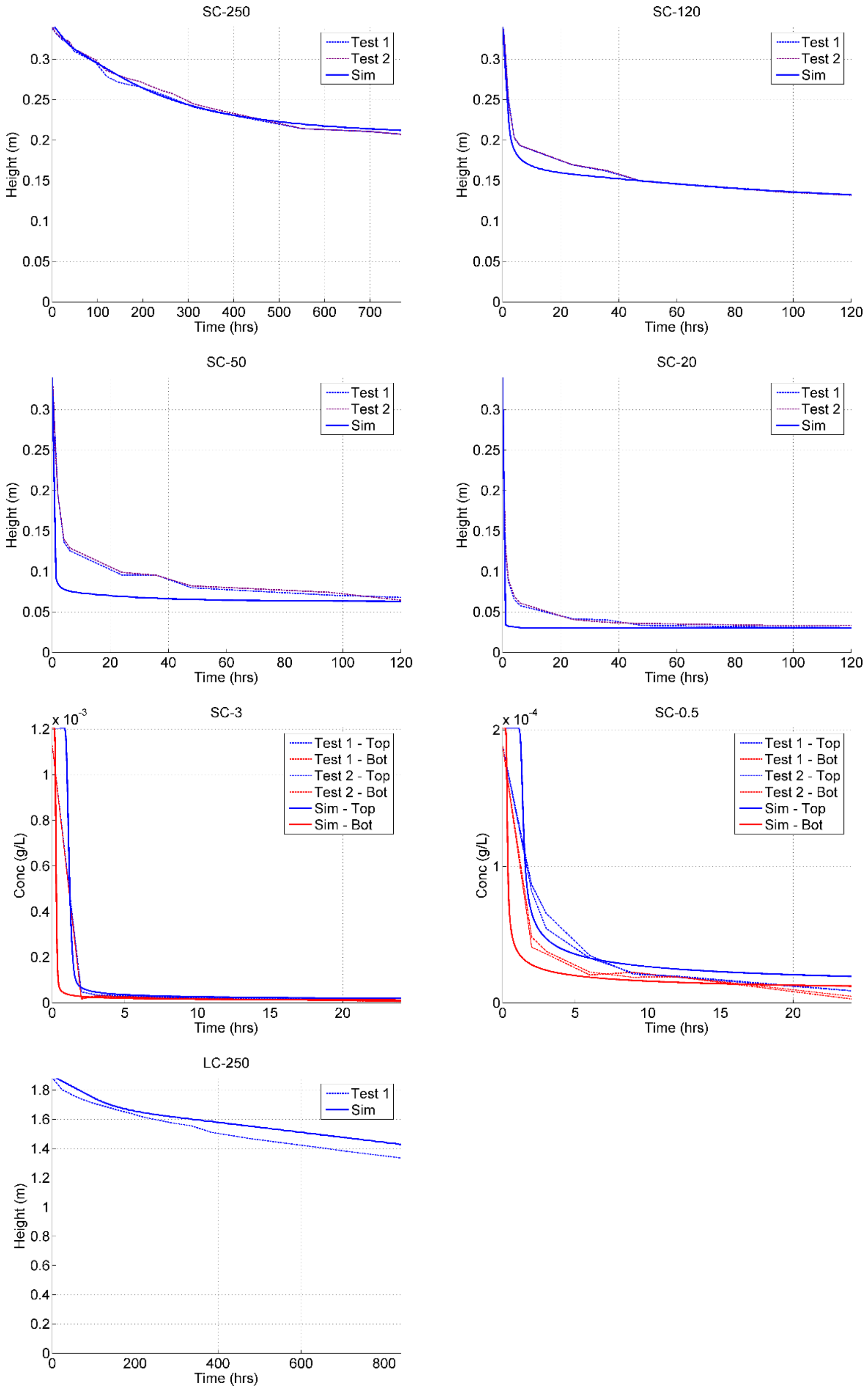

Figure 5-5: Calibrated Composite #1 Model (Solid Line) vs Test Results (Dashed Lines) – SC-250, SC-120, SC-50, SC-20, SC-3, SC-0.5, LC-250

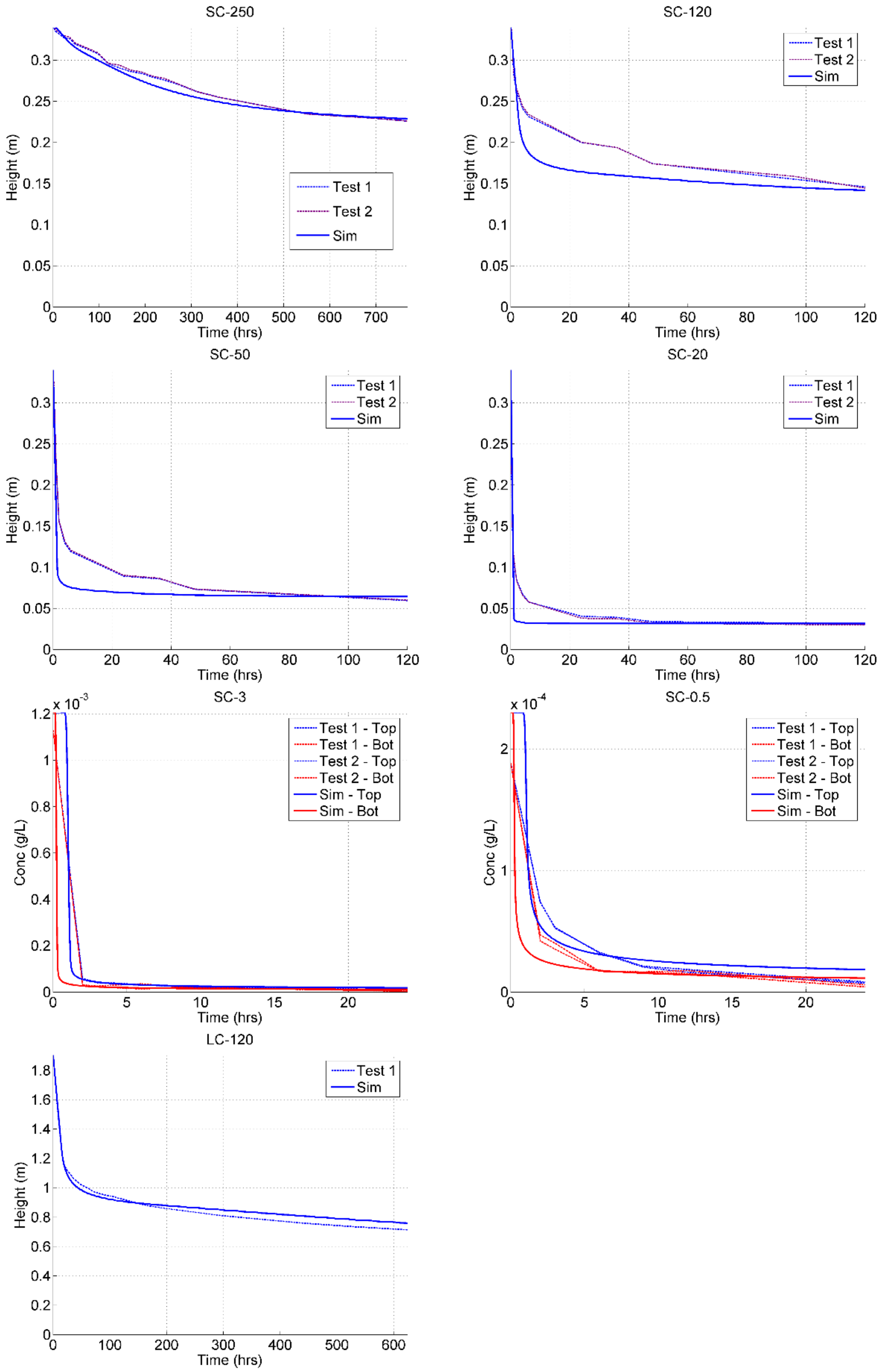

Figure 5-6: Calibrated Composite #2 Model (Solid Line) vs Test Results (Dashed Lines) – SC-250, SC-120, SC-50, SC-20, SC-3, SC-0.5, LC-120

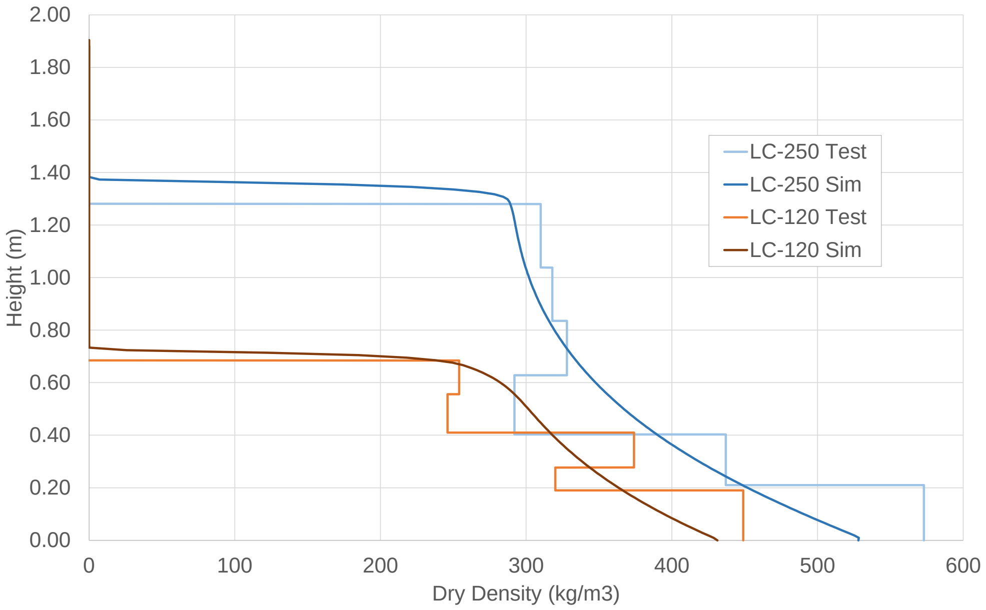

Figure 5-7: Final Dry Density Profiles, Calibrated Composite Models vs Test Results for LC-250, LC-120

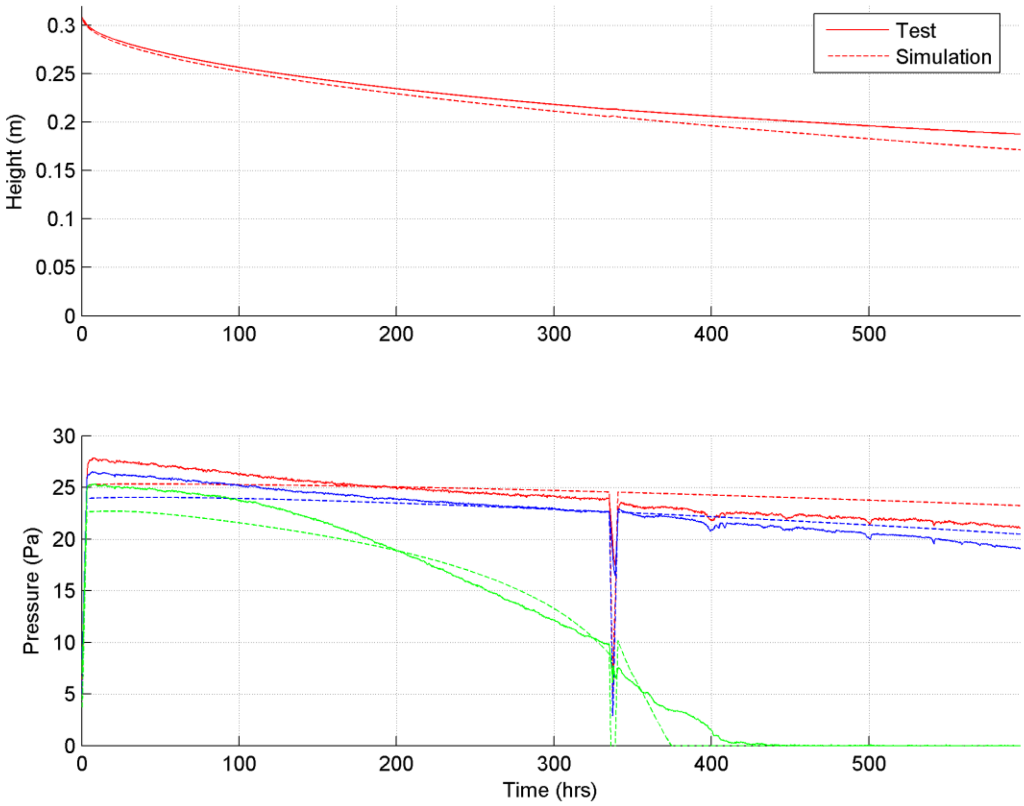

Figure 5-8: Calibrated Composite #1 Model for Slurry Consolidometer Test 1

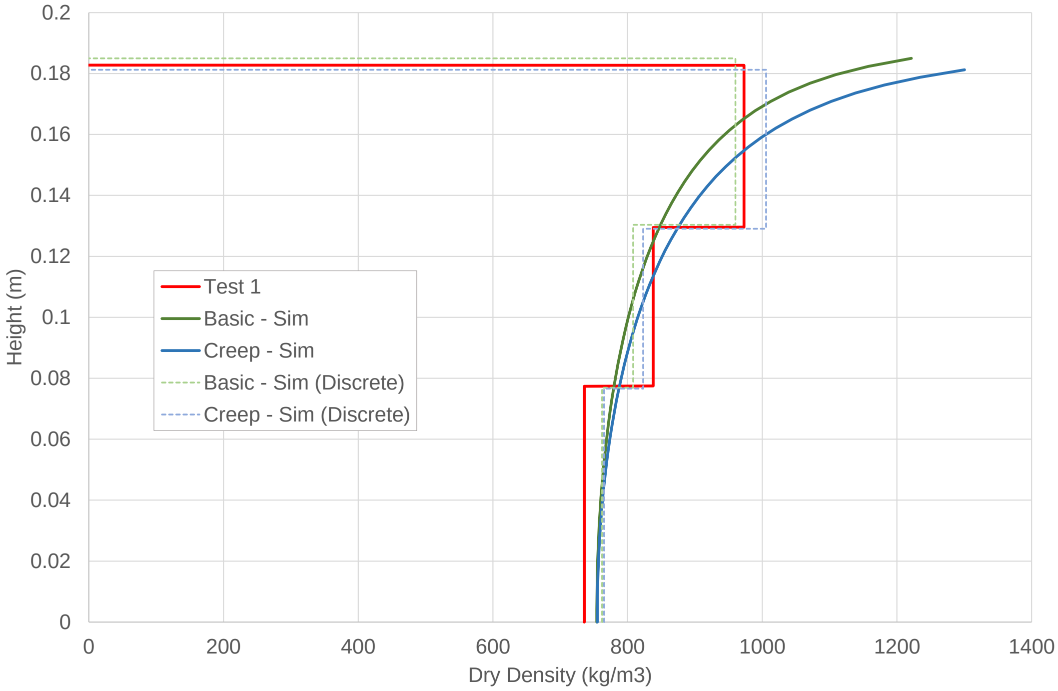

Figure 5-9: Final Dry Density Profile, Calibrated Composite #1 Model for Slurry Consolidometer Test 1

APPENDIX C:
DMPA PHASE 1 SIMULATION PARAMETERS AND OUTCOMES

Cairns Shipping Development Project - Revised EIS

DMPA Simulation Outcome Summary

Simulation Scenario							DMPA Parameter										
Simulation		Scenario					Containment Area				Containment Volume				Average Containment Depth		
#	Simulation	ID	Max Water Level	Dredge	Duration Dredge	Duration Simulation	Primary	Secondary	Polishing	Total	Primary	Secondary	Polishing	Total	Primary	Secondary	Polishing
			m AHD	hopper m3	days	days	ha	ha	ha	ha	Mm3	Mm3	Mm3	Mm3	m	m	m
1	Preliminary	Prelim_Short_1	n/a	5,600	60.8	60.8	91.0	-	-	91.0	3.37	-	-	3.37	3.7	-	-
2	Preliminary	Prelim_Short_2	n/a	5,600	60.8	60.8	53.0	-	-	53.0	3.71	-	-	3.71	7	-	-
3	Supplementary	NS_Short_1	5	5,600	60.8	60.8	14.4	5.7	9.0	29.1	2.39	0.49	0.45	3.33	16.6	8.7	5.0
4	Supplementary	NS_Short_2	3.25	5,600	60.8	60.8	13.8	5.4	30.0	49.2	2.05	0.37	1.50	3.93	14.9	6.9	5.0
5	Supplementary	NS_Short_3	3.25	8,530	43.8	43.8	13.8	5.4	32.0	51.2	2.05	0.37	1.60	4.03	14.9	6.9	5.0
6a	Supplementary	NS_Long_1	5	5,600	60.8	200.0	-	-	-	-	-	-	-	-	-	-	-
6b	Supplementary					240.8	-	-	-	-	-	-	-	-	-	-	-
7a	Supplementary	NS_Long_2	3.25	5,600	60.8	200.0	-	-	-	-	-	-	-	-	-	-	-
7b	Supplementary					240.8	-	-	-	-	-	-	-	-	-	-	-
8a	Supplementary	NS_Long_3	3.25	8,530	43.8	200.0	-	-	-	-	-	-	-	-	-	-	-
8b	Supplementary					240.8	-	-	-	-	-	-	-	-	-	-	-

Simulation Scenario							Simulation Outcomes								
Simulation		Scenario					Placed Material Volume	Avg. Placed Dry Density*	Bulking Factor	Avg. Dredge Material Level			Max Outfall Concentration		
#	Simulation	ID	Max Water Level	Dredge	Duration Dredge	Duration Simulation	Total	Implied	Implied	Primary	Secondary	Polishing	Primary	Secondary	Polishing
			m AHD	hopper m3	days	days	Mm3	kg/m3		m AHD	m AHD	m AHD	mg/L	mg/L	mg/L
1	Preliminary	Prelim_Short_1	n/a	5,600	60.8	60.8	2.43	303	3.2	-	-	-	45	-	-
2	Preliminary	Prelim_Short_2	n/a	5,600	60.8	60.8	2.52	291	3.3	-	-	-	46	-	-
3	Supplementary	NS_Short_1	5	5,600	60.8	60.8	2.66	278	3.4	4.6	1.5	-	-	112,805	120
4	Supplementary	NS_Short_2	3.25	5,600	60.8	60.8	2.65	279	3.4	2.9	3.1	-	-	119,140	120
5	Supplementary	NS_Short_3	3.25	8,530	43.8	43.8	2.77	267	3.6	2.9	3.0	-	-	133,962	80
6a	Supplementary	NS_Long_1	5	5,600	60.8	200.0	2.25	328	2.9	2.6	0.7	-	-	-	-
6b	Supplementary					240.8	2.21	335	2.9	2.3	0.5	-	-	-	-
7a	Supplementary	NS_Long_2	3.25	5,600	60.8	200.0	2.29	323	3.0	1.1	1.9	-	-	-	-
7b	Supplementary					240.8	2.23	331	2.9	0.8	1.7	-	-	-	-
8a	Supplementary	NS_Long_3	3.25	8,530	43.8	200.0	2.26	327	2.9	0.6	1.4	-	-	-	-
8b	Supplementary					240.8	2.20	335	2.9	0.3	1.3	-	-	-	-

Notes:

Dredged Material Summary		
Volume	770,000	insitu m3
Avg. insitu dry density	0.96	t/m3

**Average placed dry density represents the average settled material dry density of material above 100 kg/m3 at the end of the simulation.*