BMT

Causeway Lake Dredging - Engineering Feasibility Evaluation

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Executive Summary

An engineering evaluation for determining the feasibility of dredging Causeway Lake (the Lake) to restore its recreational and environmental values has been completed. A proposed dredge footprint was established to form the basis of the assessment and was characterised by (Figure 1):

- Two Zones: one for motorised boating activities (Zone 1) and one for non-motorised activities including swimming (Zone 2).
- A minimum of depth of 1.9m (lakebed level at -0.5 mAHD) when tidal waters do not exceed the sill level, with greater depths during periods of tidal exchange.
- In Zone 1, a channel width ranging from 75-100m to provide safe navigation for motorised boating activities.
- Gradual lakebed slopes between dredging and non-dredging areas to provide smooth transition for safe water access.
- The assumption that an operational and navigational management plan will be in place to manage the safety of different Lake activities, such as navigational markers to separate swimming and motorised boating areas.

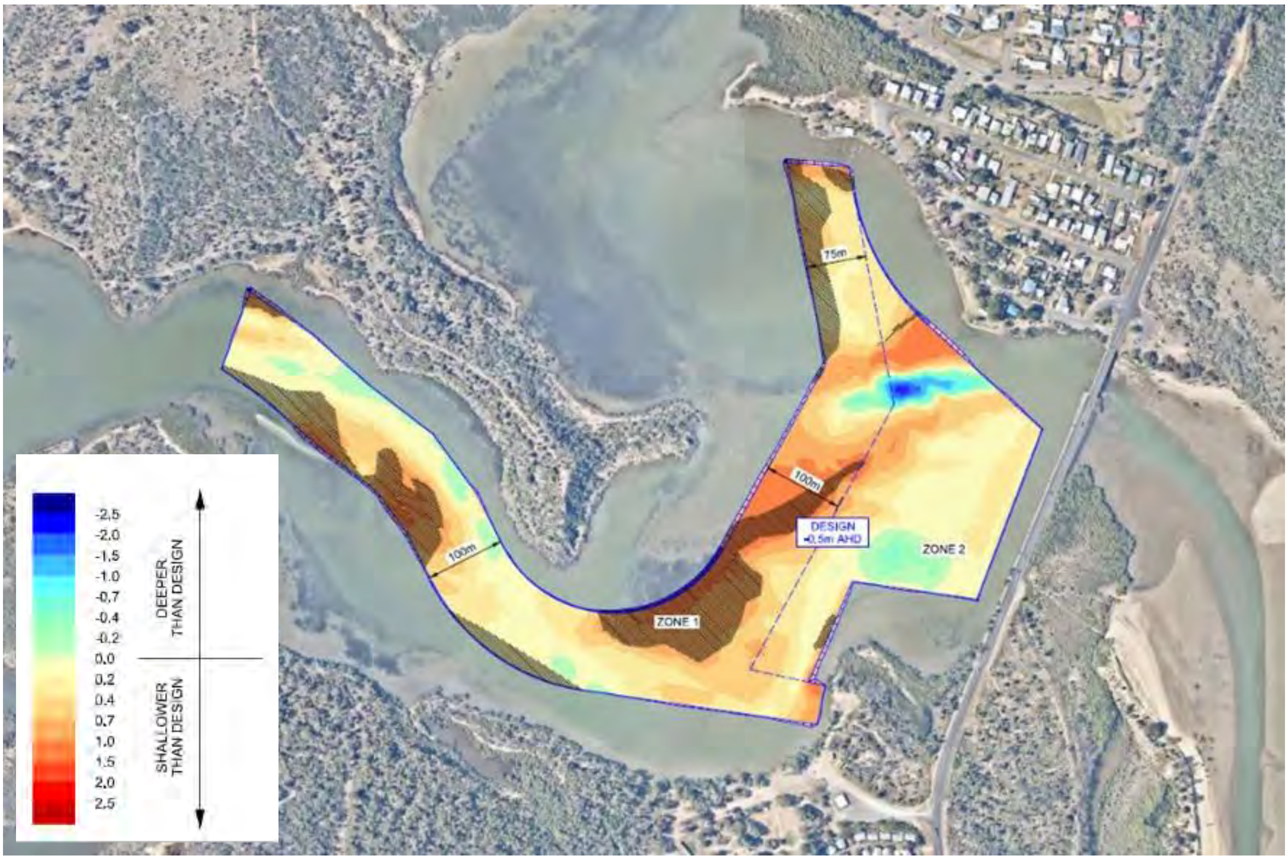

Figure 1 Dredge footprint and depth basis of assessment (dark shading indicates seagrass areas)

Dredging was assessed as feasible with the following conditions:

- Only a small Cutter Suction Dredge (CSD), amphibious excavator, or mini dredge (auger dredge) can access the site and deliver the production rates required to remove the estimated 165,000 m^3 of lakebed sediments.
- Transport of the dredged material as slurry via a pipeline to the placement areas is the recommended method based on cost and practicality.
- The preferred dredge material placement areas include nearshore reclamation within the Lake and beach nourishment of North Kinka Beach. Other potential placement options include Barlow's Earthmoving quarry on Kinka Beach Road or beach nourishment of South Kemp Beach.
- The potential impact to seagrass within the dredge footprint can be minimised but not completely avoided and, if approved, will require the payment of an environmental offset to the Queensland Government or establishment and delivery of a Direct Benefit Program (such as undertaking marine plant restoration and regeneration works).
- Infrequent maintenance dredging (estimated every 30 years) will be required to manage ongoing sedimentation and maintain the functionality of the Lake. Comprehensive bathymetric surveys will be required immediately after dredging and at regular intervals (minimum of 5 years) to monitor the actual sedimentation rate and assess the requirement for maintenance dredging.
- Supported catchment management measures to reduce the rate of sedimentation in the Lake include increasing vegetation cover and improving stormwater management in adjacent urban areas.

A Rough Order of Magnitude Cost Estimate (ROM Estimate) was developed for six feasible dredging scenarios, following a bottom-up approach with inputs from typical industry rates and analogous/comparative values from past BMT projects. The ROM Estimates are illustrated in Figure 2 and were broadly categorised into four streams: preliminaries, costs associated with dredging activities, costs associated with the transportation and placement of dredged material, and costs associated with environmental offsets. The small CSD was assessed as the most cost-effective option and is also the most efficient option (estimated completion within one year). Higher costs and longer durations are associated with the amphibious excavator and mini dredge options. The potential environmental impacts associated with each scenario vary, but not significantly.

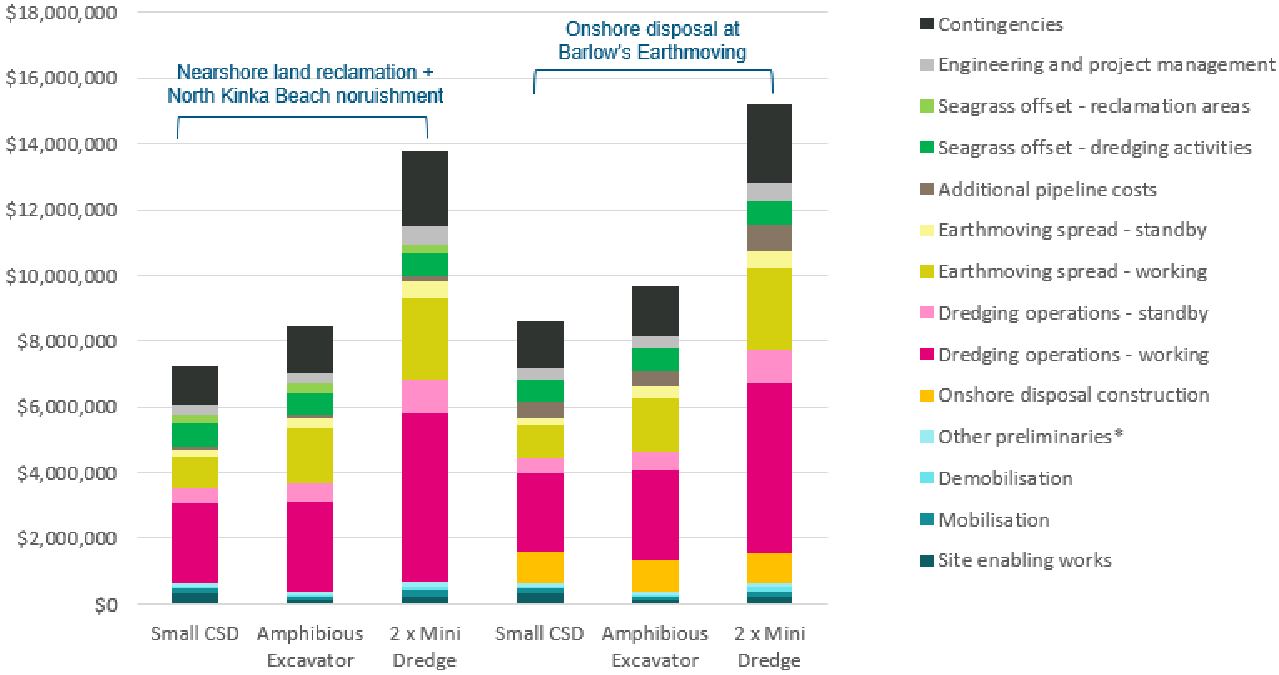

Figure 2 ROM Estimate for Six Dredging Scenarios ($AUD in 2021)

Several risks associated with the proposed dredging activities have been identified, including:

- Inaccessibility to the Lake site by heavy dredging machinery due to unsuitable roads and ramps leading to additional scope, time and cost associated with enabling the roads and ramps.
- Limited availability of the preferred small CSD dredging equipment delaying project commencement, leading to additional time and cost associated with using suboptimal dredging solutions.
- Disruption to the community during the construction phase of the project, including temporary closure of roads, partial closure of Lake, high levels of noise, etc.
- Direct impacts to seagrass that cannot be avoided.
- Access to material placement sites beyond the Lake shoreline.
- Challenges gaining State and Federal environmental approvals.

It's expected that these risks can be managed through a combination of early and ongoing engagement with:

- Dredging contractors to discuss fleet availability and scheduling, mobilisation/de-mobilisation requirements and pipeline alignment options.
- Stakeholders and the community about the expected disruption associated with the works.
- State and Federal regulators to confirm the approvals pathway and approach to managing unavoidable environmental impacts (such as an offset payment for the loss of seagrass).

Further planning and design studies are required to progress the option of dredging the Lake. An outline of the proposed workflow and timing is provided in Table 1.

Table 1 Proposed Workflow for Progressing the Planning and Design for Dredging the Lake

Activity	Description	Timing
Engagement & Master Plan Review/Update	• State agency engagement to discuss the outcomes of the dredging feasibility evaluation and development application requirements. • Considering the outcomes of the dredging feasibility assessment in the context of broader planning for Causeway Lake, including the opportunities and constraints associated with the proposed lakeshore reclamation footprints. • Stakeholder engagement.	6 months
Dredge and Placement Area Concept Design Phase	Building on the basis of assessment developed for this project and the proposed Master Plan Review/Update outcomes, refine the dredge and placement area design. The Concept design package to include: • Basis of Design report • Concept drawings • Outcomes from engagement with dredging contractors to confirm the availability of preferred equipment	6 months
Preliminary Design Phase (50%)	Preliminary design package to include: • Further geotechnical investigations • Design Drawing set including dredging and placement area general arrangement plans and cross sections • Technical Specifications • Proposed construction methodology (including engagement with dredging contractors) • Functional requirements such as shoreline access, amenity, drainage, vegetation management • Safety in Design report • Cost estimates	3 months
Environmental Approvals Phase *(State approvals requirements based on pre-lodgement advice in 2018; to be confirmed through further engagement)*	Undertake studies to support a development application for tidal work and work in a coastal management district, marine plant removal, material change of use for an Environmental Relevant Activity to gain the relevant state and federal approvals, including: • Environmental impact assessment, reviewing impacts to the Great Barrier Reef World Heritage Area, wetland values and protected species • Impact assessment to coastal processes and water quality, likely to require monitoring data and numerical modelling • Detailed sediment sampling and analysis to National Assessment Guidelines for Dredging (NAGD) standard • Offset Agreement for any residual impacts on marine plants (e.g. seagrass and mangrove) • Detailed terrestrial vegetation survey if removal cannot be avoided during placement activities	12 months
Detailed Design Phase (90% and 100%)	• 90% detailed design package to include (issued for client review) to include updated Basis of Design Report, Design Drawings, Technical Specification and Cost Estimate. • 100% detailed design package to include Issued for Construction (IFC) Drawings, Bill of Quantities, Approvals Documentation and final versions of the design reports.	3 months
Tendering Phase	For construction tendering	2 months

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1 Background

1.1 Study Area & Objectives

Causeway Lake (the 'Lake') is an impounded tidal basin between Mulambin and Kinka Beach, south of Yeppoon on the Capricorn Coast (Figure 1-1). The Lake is fed by Shoal Creek to the south and Mulambin Creek to the north. A rocky causeway and road bridge were constructed in 1939 across the mouth of the then estuary to link Yeppoon with Emu Park. The construction of the causeway changed the behaviour of the local estuarine and coastal processes and created the present-day tidal basin.

Livingstone Shire Council (the 'Shire') intends to revitalise the Lake area with the goal of optimising recreational use opportunities on the lake and facilitating supportive development along the lake's north and south shores. Restoration of the lake system is also desired to preserve the present-day environmental values that could be impacted by ongoing sedimentation. Long-term local efforts to identify a revitalisation path have consistently identified the lake's shallowing to be a major limitation.

In 2017, the Department of State Development, Manufacturing, Innovation and Planning (DSDMIP) engaged Bligh Tanner Pty Ltd and Otium Planning Group to undertake a Strategic Assessment of Service Requirement study (SASR) to evaluate the merit of Livingstone Shire Council's objectives for revitalisation of Lake. The Shire considers restoration of the lake's natural functions critical to achieving redevelopment of the broader precinct through support for increased recreational use on and adjacent to the lake and for generally fostering supportive economic development.

The SASR report determined that there is merit in pursuing lake restoration and recommended proceeding to the Preliminary Assessment stage. One of the key components of this stage involves evaluating the feasibility, logistics and costs of dredging the lake to facilitate other improvements essential to optimising the value of the asset to the community across many different benefit classes (Livingstone Shire RFQ 2021; Bligh Tanner and Otium 2018).

While the SASR report prescribes several assessment actions to facilitate Council's goals, the foremost priority centres on determining the feasibility of dredging, thus the focus of this project is on identifying viable options for dredging the Lake (active and passive techniques) to restore its community recreational and environmental values to sustainable levels (Livingstone Shire Council RFQ 2021; Bligh Tanner and Otium 2021).

Based on the above, the Shire engaged BMT Commercial Australia Pry Ltd (BMT) in March 2021 to study the feasibility of dredging the Lake and inform future applications for funding. The objective of the study is to help determine the feasibility of dredging in a way that considers cost-effectiveness, environmental factors sustainability and mitigate risks.

Title:
Study Area

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1-1

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1.2 Previous Investigations

There have been several studies of the artificial lake system and changes to the surrounding area following construction of the causeway. The gradual sedimentation of the lake has been the focus of several previous investigations. Some of key existing reports reviewed and considered as part of the present study include:

- Grigg and Piorewicz (1989) Causeway Lake / Kinka Beach Study Final Report, prepared for the Department of Main Roads
- Budi and Piorewicz (2005) Causeway Lake, Capricorn Coast Queensland, Numerical model analysis, Research Report No CE35, James Goldston Faculty of Engineering and Physical Systems, Central Queensland University.
- Piorewicz (2008) Causeway Lake Sedimentation for the Period 1986 – 2008 Required Dredging Volume and Methods of Reduction of Sedimentation in the Lake.

In addition to these technical studies, the SASR report referenced above has provided important context for the present study.

1.3 Scope of Services

The scope of services outlined in the Livingstone Council Shire RFQ (2021) included:

(1) Development and evaluation of viable dredging options and alternative sediment removal techniques to restore the recreational and environmental functionality of Lake, including:

    (a) Geotechnical investigations, mapping and modelling required to support proposed options (e.g., depth, nature, quality of sediment, transport modelling etc), including obtaining all relevant approvals to undertake any field sampling necessary

    (b) Suitable dredging techniques/methods to support proposed options

    (c) Review of alternative techniques/methods to remove sediment

    (d) Evaluation of suitable reuse and/or disposal of dredge materials

    (e) Preparation of a risk matrix identifying the major risks associated with the preferred dredging option and proposing suitable risk mitigation measures to manage the risks

    (f) Identification of ongoing measures and associated costs to manage siltation of Lake post dredging.

(2) Preparation of costs estimates commensurate with the Queensland Government's Project Assessment Framework - Preliminary Evaluation and Building Our Regions funding requirements

(3) Identification of any local, state and federal regulatory requirements and permits required for options proposed and how these may potentially impact & constrain the viability of proposed dredging options

(4) High-level desktop analysis, sufficient to identify and describe environmental issues associated with dredging options, including potential regulatory triggers and projected costs of meeting requirements

(5) Presentation of dredging options to Council staff.

The site investigations to cover bathymetric and land survey, marine plant mapping and sediment sampling (Scope items 1a) were undertaken by BMT in the field between April 9th – 10th 2021. The outcome of these investigations including survey results and maps, benthic habitat maps and sediment testing is documented in detail and presented in BMT Report 'Causeway Lake Geotechnical and Site Investigation' Reference R.A10946.001.00 dated May 2021 (Appendix A).

Environmental assessment and approval requirements, pertaining to Scope items 3 and 4, have been documented separately in a Briefing Paper (Appendix B).

This report covers the evaluation of dredging and placement / re-use methods, ongoing maintenance management measures, cost estimates and risk matrix which pertain to Scope items 1b-1f and 2.

2 Methodology

Figure 3.1 summarises the general logic and method adopted by BMT for the evaluation of dredging feasibility in the Lake.

In summary, BMT relied on the outcome of the site investigations conducted in April 2021, to better understand the bathymetry, sediment characteristics and seagrass extent in the Lake (Section 4). BMT built on this information to define basis of assessment, in terms of channel boundaries and depth, for both dredging and channel use purposes. This was achieved in consultation with the Shire and their representatives during a series of meetings held in the period May-June 2021. The outcome was a concept dredge design drawing that defines the dredge footprints and volumes (Section 6).

In addition to site investigation, BMT reviewed other site-specific information such as metocean conditions, site physical conditions and access, future development plans (Section 5) to inform subsequent evaluation of suitable dredging and placement methods (Sections 7 and 8). On preliminary review of dredging and placement methods, the clearly infeasible options due to size, access, and financial viability issues were eliminated. The remaining feasible options were then evaluated in terms of advantages/opportunities, disadvantages, important considerations, production, costing and risk assessment matrix. The outcome is presented in a short list of feasible dredging and placement options to inform the Shire. In addition, BMT has provided advice on expected ongoing future maintenance management measures and requirements, including indicative costs.

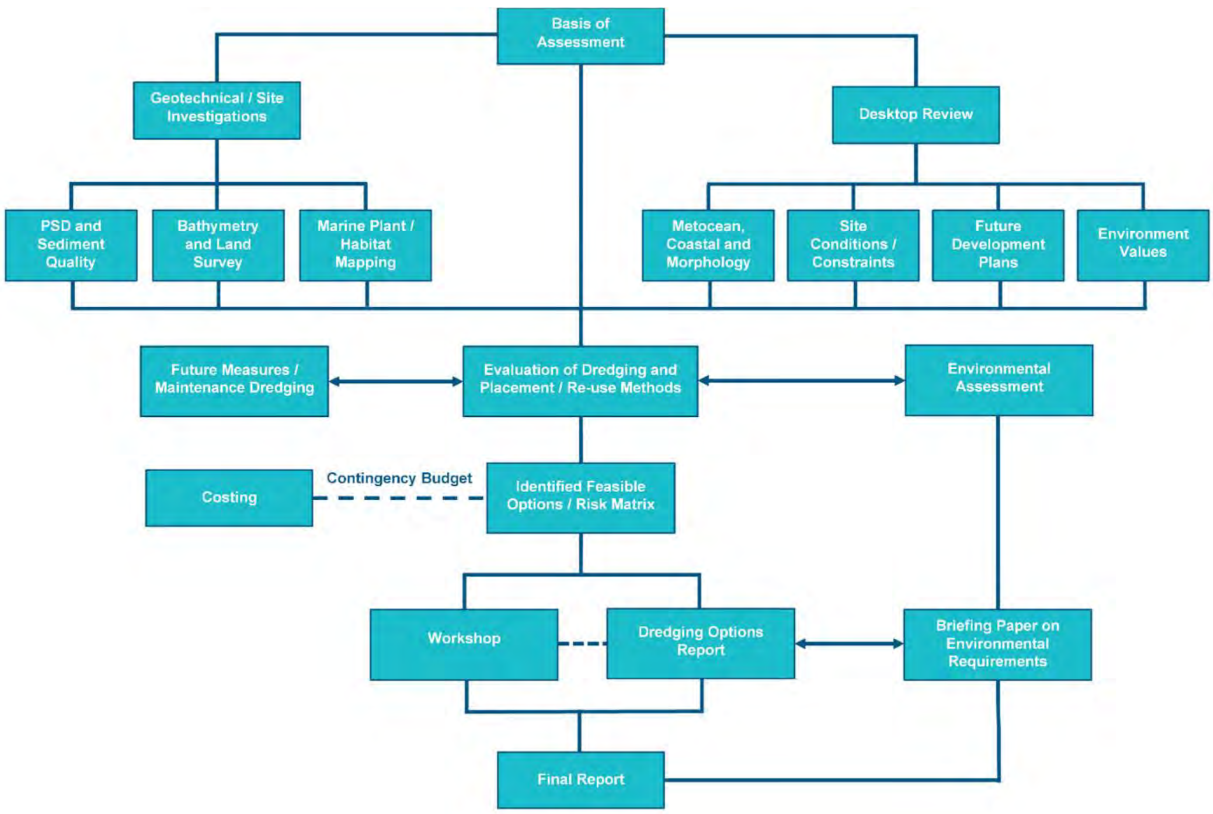


Figure 2-1 Evaluation Methodology Flowchart

3 Site Characteristics

3.1 Site facilities

Some of the following text in this Section has been adapted from the SASR Report (Bligh Tanner 2018).

Causeway Lake is a coastal estuarine lake located adjacent to Shoal Bay approximately 9 km south of Yeppoon. Causeway Lake is a semi-artificial water body created by the construction of a causeway, bridge and spillway at the mouths of Mulambin and Shoal Creeks. The Causeway is 600m in length; the water area of the lake is estimated to range from 66 to 86 ha.

The original causeway was completed in 1939 and provided access across the creeks as part of much needed road upgrades to link Yeppoon and Emu Park along the coast. The construction of the causeway crossing had a significant impact on the local creek waters with the spillway creating a barrier for creek waters and thereby creating the lake system. Construction of the causeway is estimated to have reduced tidal flow (in and out of the lake) by about 10 times.

The construction of the causeway initially created a large water body for recreational boating and fishing and swimming. However, over the years sedimentation has built up to the point where much of the Lake is too shallow for boat use and fish habitats. Despite its shallow depth, the Lake still supports a wide variety of different fishing options. It provides one of the best family fishing locations along the coast with shaded areas, tables and seats, barbecues, and play equipment.

Existing recreational facilities at the site include the North Shore area along Causeway Esplanade, and the South Shore area adjacent the Esplanade, providing access to the foreshore and the various recreational activities (swimming, sailing, boating, fishing, jet skiing and water skiing). The boathouse and kiosk on Causeway Esplanade provide the only commercial recreational activities on the foreshore.

The Lake provides safe swimming area for families on the landward side of the bridge, and a steady channel on the seaward side for anglers. Recreational concrete and dirt public boat ramps are located on both northern and southern sides of the lake.

Engagement with primary stakeholders suggest that dredging is the highest priority and most beneficial action required to improve lake activation (RCC 2017).

3.2 Lake access and logistics

Currently, the Lake has no navigational access to the ocean. Small motorboats and other water sports access the Lake from three internal boat ramps: two on the northern shore and one on the southern shore (Figure 3-1). All three boat ramps are situated on minor roads surrounding the Lake. The capacity of these ramps with respect to launching dredging equipment is briefly discussed below and considered further in Section 6.

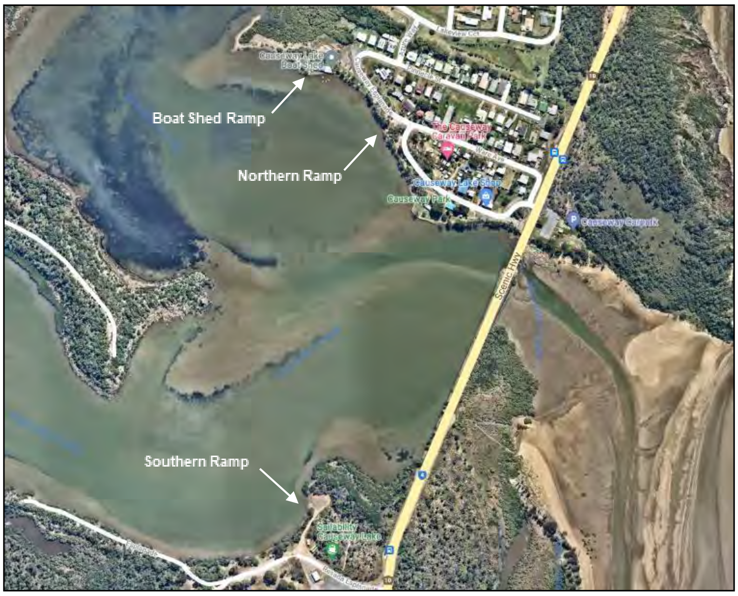


Figure 3-1 Existing boat ramps within Causeway Lake

3.2.1 Southern Boat Ramp

The southern ramp (Figure 3-2) is a public recreational boat ramp managed by the Department of Transport and Main Roads (TMR). It was upgraded in 2018 and is constructed of 4 m wide concrete planks, with a 0.75 m pavement buffer on each side. The launching area is accessible via an unpaved road connecting to Resada Esplanade. The road in ~4 m wide at the narrowest point. The ramp was designed for the launching of recreation vessels, in accordance with the design wheel loading shown in Figure 3-2. This roughly equates to a 5.5-tonne vehicle, towing a 6-tonne trailer. The dimensions and structure and structural capacity of this boat ramp are not suitable to launch most sizes of floating dredge vessels except for mini auger dredges.

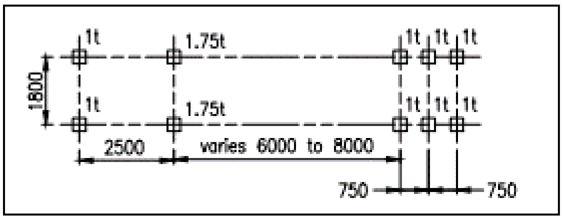


Figure 3-2 Southern boat ramp. Left: May 2021 aerial image of the boat ramp and access road, Right: design wheel loading (provided by TMR)

A more feasible alternative for launching larger dredging equipment may be to use the natural slope adjacent to the concrete ramp, which is considerably wider at ~12 m. The soil characteristics and associated bearing capacity of this surface would need to be investigated in the planning stage, to ensure the slope and soil bearing can support the expected loads during launching and retrieval of the dredge. Preliminary enabling earthworks may be required to reinforce the surface with a layer of gravel or similar, build up the ramp and increase its bearing capacity.

3.2.2 Northern Boat Ramp

The northern boat ramp is a small, natural surface ramp extending off Causeway Esplanade, a paved residential street. There is an unpaved parking lot adjacent to the boat ramp, measuring approximately 12 x 25 m. Several trees line the ramp and the approach, restricting the width and height of the ramp space. Clear dimensions for the ramp are unknown, however, it's likely to be comparable or smaller than the concrete southern ramp.

Figure 3-3 Northern boat ramp. <u>Left</u>: December 2020 aerial image of the boat ramp, <u>Right</u>: street view of the boat ramp, from Causeway Esplanade

3.2.3 Boat Shed Ramp

The concrete slab west of the Boat Shed is ~3.5 m wide. From available aerial imagery, it appears this slab doesn't extend into the water. There is a gate restricting access from Causeway Esplanade, and the grass meadow behind the slab indicates infrequent use. These factors, combined with the proximity to the Boat Shed, suggest this ramp is private use only. The ramp is unlikely to have been constructed to any design guidelines and is expected to be unsuitable for launching any dredges.

Figure 3-4 Boat Shed Ramp

3.3 Future development plans

The 2015 Active Living Landscapes Master Plan developed a concept for the redevelopment of the lakeshore and surrounding parklands as a major sport and recreation precinct (Bligh Tanner 2018). These are early conceptual master plan sketches that do not represent a formal commitment by the Shire or approved plans for future development of the Lake. Nevertheless, the Master Plan provides a sound basis for identify the social, recreational, and environmental opportunities that a current constrained due to the sedimentation issue. The key elements of the 2015 Master Plan included (Bligh Tanner 2018):

- Redevelopment of the “North Shore” including parking, active transport networks, jetties, hire kiosk, swimming beach, picnic facilities, water access and public boat ramp (Figure 3-5, Figure 3-6).
- Redevelopment of the “South Shore” including parking, active transport networks, jetties, public boat ramp, club facilities for Sailability and Sailing, kiosk, beachfront, swimming pontoons and picnic facilities (Figure 3-7).

Figure 3-5 Northshore West – Concept (Active Living Landscapes 2016)

Figure 3-6 Northshore East – Concept (Active Living Landscapes 2016)

Figure 3-7 Southshore Concept (Active Living Landscapes 2016)

4 Dredging Feasibility Site Investigations

BMT completed a site investigation between the 9th-11th of April 2021. Bathymetric and land survey data was collected, subtidal marine plants and benthic communities were mapped, instrumentation was deployed to record tidal, salinity and temperature variation, and sediment coring was performed to examine the physical nature of sediments and potential contaminants in the lakebed. This section provides a short description of the site and summarises the key findings directly influential to the dredging and disposal options study. A detailed account of the site investigation activities and findings is provided in Appendix A.

4.1 Water Level, Salinity, and Temperature

The construction of the causeway changed the behaviour of the estuary and coastal system (Grigg and Piorewicz, 1989). The present-day lake system is characterised by restricted tidal flows which influence the water level, salinity and temperature. The exchange of seawater within the lake is controlled by the concrete sill beneath the causeway road bridge. The sill elevation is approximately 3.7 m above Lowest Astronomical Tide (LAT), it has been estimated that 44% of high tides do not exceed the sill level (Piorewicz and Setanto 2005).

Tidal exchange within the lake occurs during periods of larger amplitude spring tides and is then restricted during periods of smaller amplitude neap tides. The ‘open’ or ‘closed’ tidal condition within the lake alternates approximately weekly. The published tidal planes for the Rosslyn Bay standard port location are provided in Table 4-1 and astronomic tide prediction over the site investigation period is indicated in Figure 4-1.

Table 4-1 Semidiurnal Tidal Planes for Rosslyn Bay (Maritime Safety Queensland 2020)

Tidal Plane	Height above Lowest Astronomical Tide (m LAT)	Height relative to Australia Height Datum (m AHD)
Highest Astronomical Tide (HAT)	5.14	2.78
Mean High Water Spring (MHWS)	4.23	1.87
Mean High Water Neap (MHWN)	3.24	0.88
Mean Sea Level (MSL)	2.42	0.06
Australia Heigh Datum (AHD)	2.36	0.00
Mean Low Water Neap (MLWN)	1.60	-0.76
Mean Low Water Spring (MLWS)	0.32	-2.04

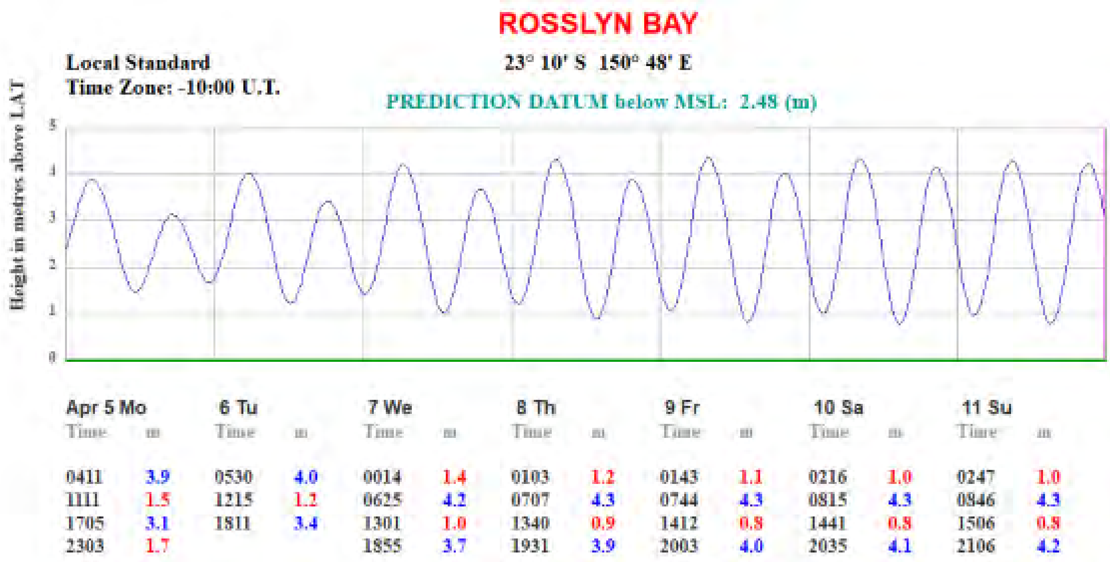


Figure 4-1 Rosslyn Bay Astronomic Tide Prediction: Site Investigation Period 9-11 April 2021 (Australian Hydrographic Office 2021)

4.1.1 2021 recordings

The time series of water level, salinity and temperature recordings during the site investigation period is shown in Figure 4-2, indicating a rapid rise in water level associated with incoming tide and relatively slow reduction in water level until the subsequent incoming tide rises above the concrete sill level. The first high tide in the series was the largest, and the ebbing tide did not have sufficient time to fall to the sill level before the next tide, unlike the smaller high tides which fell to approximately 3.77 m LAT. This shows that during the survey period, water levels were always elevated above the sill level (based on the previous and present reported sill height).

The salinity signal was highly variable and probably reflected carry-over freshwater from preceding rainfall mixing with saline ocean water. Peaks in salinity occurred at the top of the incoming tidal signal with sharp reductions and increases in salinity occurring at the onset of the incoming tide. This may be the result of eddying around the shallower bathymetry south of the boat hire building. Temperature appeared less affected by tides and followed diel pattern (warmer in the day) more closely.

Figure 4-2 Water level, salinity and temperature observations

4.2 Bathymetry and Land Survey

In the context of dredging feasibility, the objectives of the bathymetry and land survey were as follows:

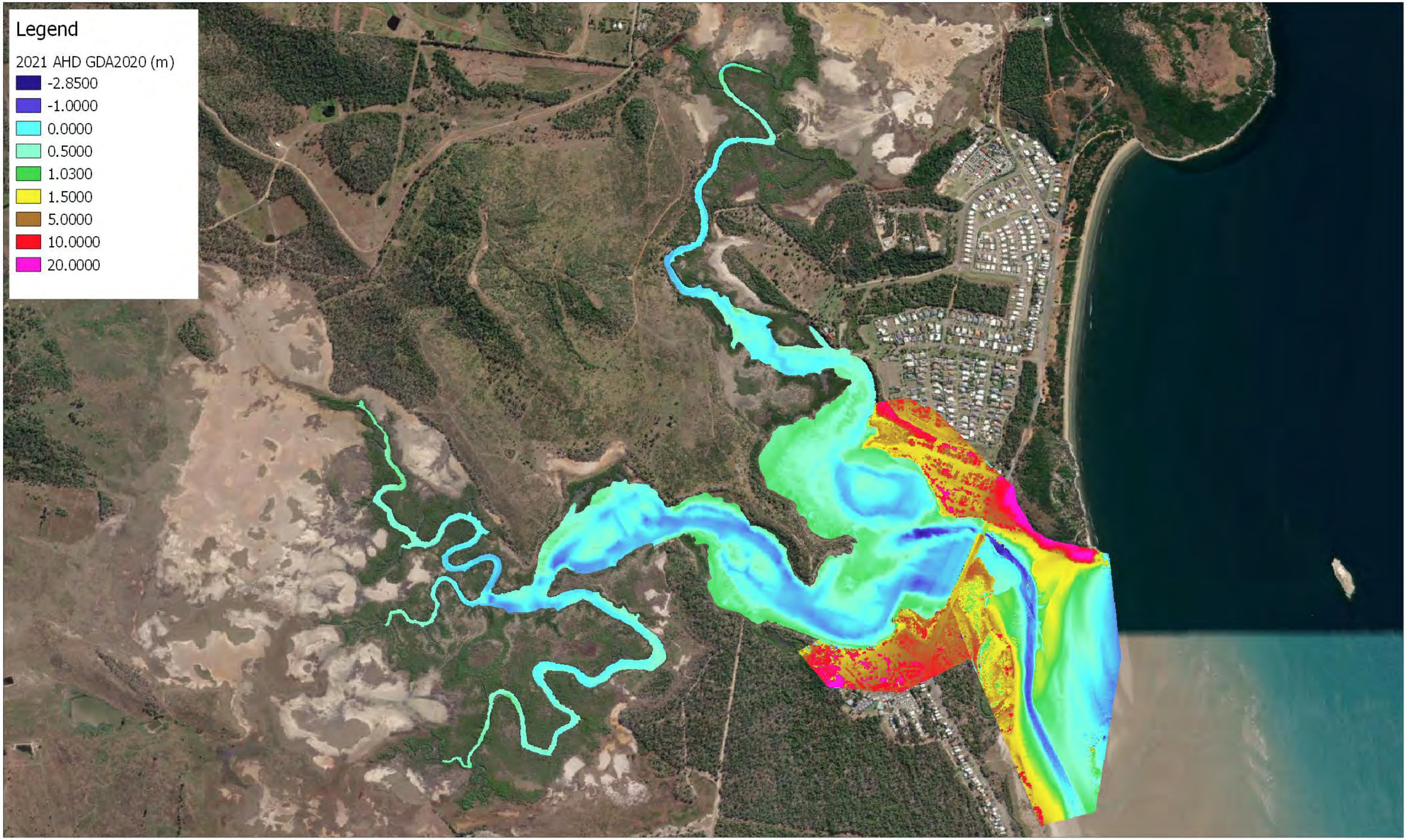
- Determine and map the current lakebed elevation and topography of the foreshore and nearby beach areas
- Assess the need to dredge, and quantify dredging and placement areas and volumes
- Provide additional information on sedimentation rates by means of comparing the results with historical survey results, and inform estimates of future maintenance dredging requirements.

The map of lakebed elevation is shown in Figure 4-3, relative to Australia Height Datum (AHD) which is approximately equivalent to Mean Sea Level (MSL). Except for the deeper channel that aligns with the concrete sill beneath the causeway road bridge, large areas of the lakebed are higher than 0.0m AHD, as indicated by the light blue and green colours in Figure 4-3.

The deepest pocket within the Lake is situated ~200 m west of the causeway sill and aligns with the path of the incoming tidal flow. It's likely that the relatively high tidal inflow velocities significantly contribute to the scouring in this area.

The lake shoreline elevations range from +0.5 mAHD to +1.0 mAHD. The exception is the basin adjacent to the causeway, where the lakebed is around -0.2 mAHD alongside the rock rubble wall. This basin extends westward ~200 m, maintaining similar bed elevations and therefore depths.

Causeway Lake is fed by Mulambin Creek to the north and Shoal Creek to the south-west. Mulambin Creek is considerably shallower over majority of its area. This is particularly apparent along the north-western bank, where bed elevations are in typically excess of +0.5m AHD. Conversely, a relatively deep channel runs through Shoal Creek, with bed elevations ranging from -0.3 m AHD to -0.6 m AHD.



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2021 Digital elevation model

Figure: 4-3

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4.3 Sediment geotechnical characteristics

4.3.1 2021 Investigation

BMT collected five cores, each of 1.0m – 1.2m core length, and two grab samples from the lakebed locations shown in Figure 4-5.

The samples were visually inspected in-situ, noting the material appearance and the presence of different sediment horizons per borehole. With the exception of BH3, images of cores indicate that the upper and lower sampled horizons of each core were dominated by sands, with a lower contribution of fines (silt and clay) and occasional gravel pieces. Most sites had a lighter coloured silt layer in the upper 2 cm, with muddy sands beneath the upper silt layer, with or without organic intrusions, down to the final recoverable depth (BMT 2021).

A summary of the laboratory results of the particle size distribution (PSD) analysis is shown in Figure 4-4. BH3 had a deep layer of fines, dark grey mud was present from 4-60 cm below lakebed, followed by a sandy mud layer from 60-110 cm, before giving way to muddy sand from 110-118 cm. This very abrupt change in sediment may coincide with sedimentation over the top the original sandy estuarine bed prior to the construction of the causeway. The correlation between BH3 and BH5 suggests that the lakebed surface material on the western side of the Lake, between the southern boat ramp and that of the Shoal Creek, tends to be on the finer side compared to the rest of Lake.

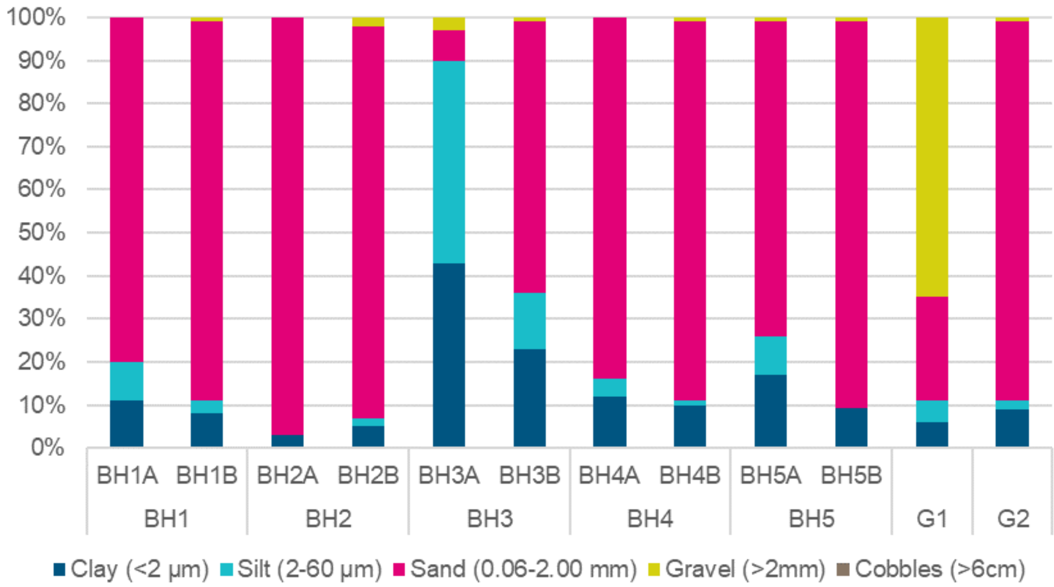

Figure 4-4 Particle size distributions for major grain-size fractions at each sample location

Legend

- Boreholes and surface grabs

Title:

Borehole and surface grab locations

Figure: 4-5

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4.3.2 1987 Investigation

The former Main Road Department undertook sediment sampling in December 1987 for the Causeway Lake Bridge Site Foundation Investigation. The boreholes depths are referenced from AHD, however, the horizontal datum is not clearly defined. The borehole locations are referenced from the centreline of the road, measured from the southern abutment of the bridge, and all boreholes are located 'left of the centreline' to the direction of chainage (north to south). Figure 4-6 shows the assumed locations based on BMT's interpretation of the reporting.

The samples extended to depths well in excess of the BMT sampling in 2021, and provide valuable insight into the presence of consolidated material. The upper sediment horizons are predominantly described as silty sand, being fine grained and very loose. In some samples, this silty sand layer extends the entire sample length, whereas in other cases the sediment transitions to a consolidated argillite layer at approximately -5.5 m to -8.0 m AHD (Main Road Department 1987).

Figure 4-6 1987 borehole location

4.4 Benthic habitat

Figure 4-7 shows the benthic habitat map for the Lake, using inputs of the different mapping methods adopted in this site (details provided in Appendix A). Areas of dense (50-100%) seagrass cover and moderate to dense (20-50%) seagrass cover are shown in this figure. It should be noted that low density seagrass (<5% cover) is likely to exist in many of the areas not covered in the map. The low-density cover does not form meadows and was not observable in satellite or aerial imagery.

The northern section of the Lake, extending into Mulambin Creek, is dominated by a large seagrass meadow. Additional seagrass meadows are present in the southern sections of the lake. It is noted that the seagrass meadows appear to be upper- and lower-limited in the depth-distribution. This is unusual for south-east and central Queensland, as seagrass in this region usually grows in the intertidal region. In this case, the seagrass meadows typically aligned with the shallower sections of the Lake, but not in the very shallowest sections nor the intertidal areas. This is likely the result of the conditions within the Lake, where the tidal influence depends on the neap and spring tide cycles. During neap tide cycles, the Lake may not achieve connectivity with the ocean and the very shallow areas within the Lake may be prone to high temperatures and excessive solar radiation (BMT 2021).

Review of aerial imagery between November 2014 and May 2021 show variability with time in the spatial distribution of the seagrass meadows. These images, shown in Figure 4-8, should only be considered as an indication of how the seagrass coverage can vary, and not to form any definite boundaries or observation on density. However, there is clear variability between the seagrass coverage between the earlier and later images, which span over 7 years.

As discussed in subsequent sections of this report, the seagrass coverage was influential in the evolution of the preliminary design basis, and the environmental offset associated with direct impact to seagrass forms a large cost component within the project budget. It is therefore recommended that additional benthic habitat surveys are completing during the detailed design phase of the project and again prior to the dredging campaign.

Title:

Benthic Habitats

Figure: **4-7**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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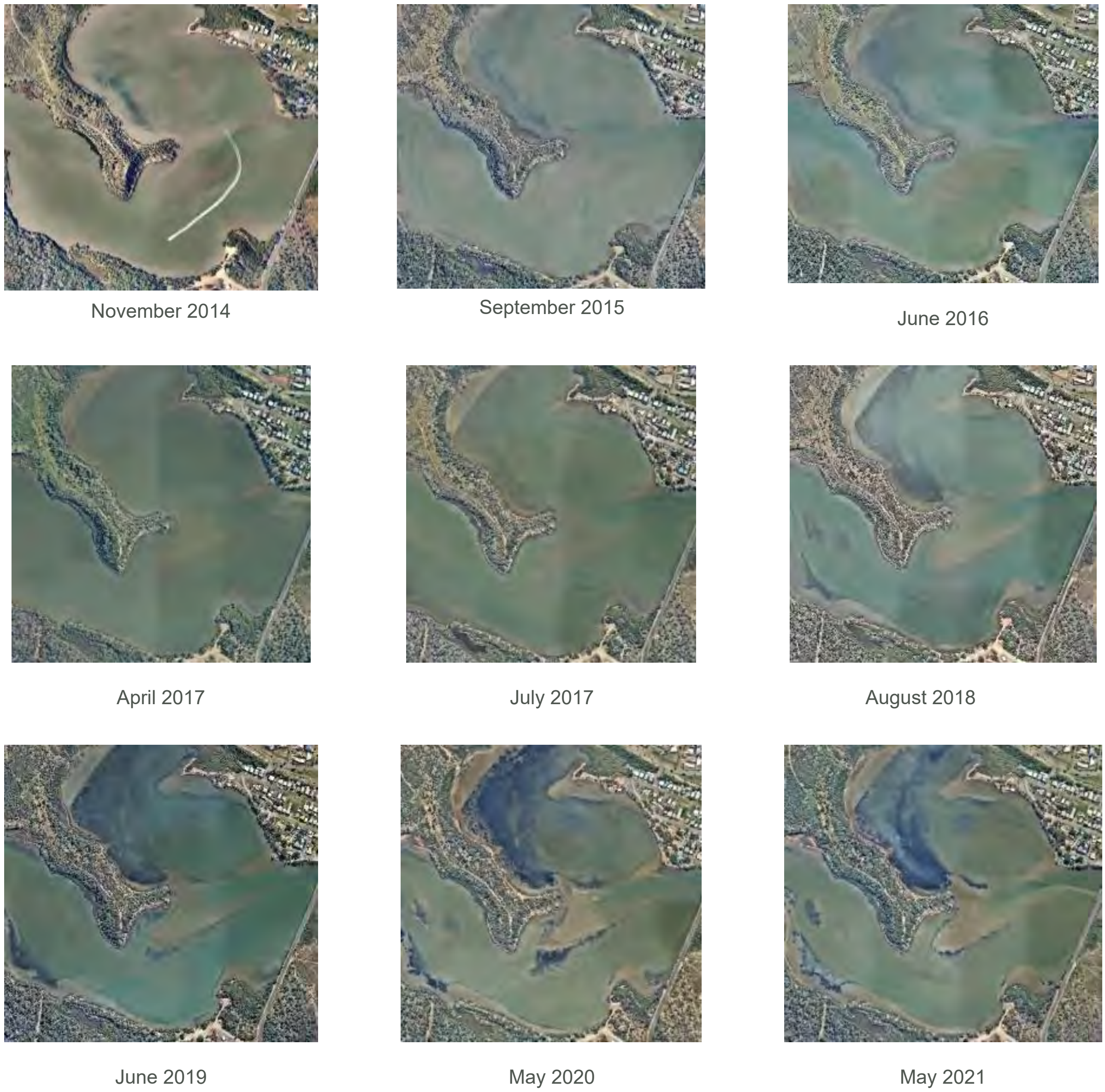

Figure 4-8 Historical aerial imagery showing seagrass variability

5 Dredging Feasibility Basis of Assessment

The basis of assessment involved defining the desired Lake footprint and depth for dredging purposes. The basis of assessment was developed iteratively and defined in consultation with the Shire of Livingstone through a series of meetings during the period May – June 2021. This process took into consideration several key drivers and the basis was defined based on optimising the dredging footprint and depth to address the following objectives:

- Suit the key current and future recreational uses of the Lake.
- Reduce dredge volumes and hence enhance project cost and time effectiveness.
- Minimise impact to environmental receptors, such as seagrass meadows.

5.1 Optimised lake usage

5.1.1 Dredging footprint

The key users and the typical activity boundaries in the Lake were captured in three conceptual plans (Figure 5-1, Figure 5-2, Figure 5-3) provided with the RFQ reference documents (Livingstone Shire Council - Causeway Lake Workshop Presentation).

Figure 5-1 illustrates the typical movement paths of the motorboats and other water sports, the areas used for shoreline fishing, and several key landmarks/infrastructures along the shoreline.

Shoreline fishing is predominantly situated along the causeway and bank nearest to the sill. This aligns with the deepest sections of the Lake, and those likely experiencing the highest current flows. The motorboat and water sports activities stem from the boat ramps and are focused near the Lake northern and southwestern shores leading to Mulambin and Shoal Creeks respectively.

Similarly, Figure 5-2 captures a conceptual layout for future users of the Lake, giving indication of the extended activities requiring access and usage areas. These include motor vessels such as small boats, jet skis, water-skiing and fishing boats, and non-motorised water sports / activities such as paddle sports such as canoeing or rowing, wind sports (small craft sailing and wind surfing), swimming and shore-based fishing.

Figure 5-1 Lakeshore infrastructure and movement paths for Lake users (Active Living Landscapes 2016)

Figure 5-2 Future users of Causeway Lake (Active Living Landscapes 2016)

Using this information as a foundation, two dredging areas were conceptualised in the preliminary master planning of the shoreline development (Figure 5-3):

- Dredging Area 1 for motorboat access and movement and non-motorised water sports along the northern shores
- Dredging Area 2 for water sports and swimming.

These boundaries were adopted as the preliminary basis for the dredge footprint, following discussions with the Shire in the progress meeting held on 13th May 2021.

Figure 5-3 Conceptual division of Lake into designated motorboat areas and swimming / water sports areas (Active Living Landscapes 2016)

5.1.2 Lake operational requirements

BMT undertook a high-level review of relevant guidelines and advice surrounding waterway usage for motorboats and water sports usage inside small water bodies. This information has been used for refinement of the dredging footprint and should be taken into consideration in future revisions of the shoreline development masterplan.

Table 5-1 Minimum operational requirements

Category	Description	Reference
Channel Depth	Minimum 1.5m channel depth from surface based on the following assumptions: • motorboat vessel draft 1m • wave height generated from boat wake 0.2m • under keel clearance of 0.3m for soft bed materials	AS3962
Widths	Minimum width 25m	AS3962 for interior channels
Direction of travel	When skiing in lakes, rivers and creeks, boats should travel in an anticlockwise pattern, unless local customs and conditions dictate otherwise.	Queensland Recreational Boating and Fishing Guide 2019-20
Prohibited areas	• Water skiing is prohibited in all 6 knot zones • Vessels must not operate at a speed of more than 6 knots within 30 m of people in the water, anchored vessels, diver's flags, jettied, pontoons or boat ramps Personal watercraft (jet skis) must not operate at a speed of more than 6 knots within 60 m of people in the water, anchored vessels, diver's flags, jettied, pontoons or boat ramps	Queensland Recreational Boating and Fishing Guide 2019-20

5.1.3 Dredging depth

The minimum water level in the Lake under normal conditions is assumed to be +1.4 mAHD (or approximately +3.7 mLAT), approximately equivalent as the sill level[1]. Based on a minimum channel depth of 1.5 m (Table 5-1, AS3962), a minimum dredging depth of -0.1 mAHD is required for motorboats with 1 m draft. A dredging depth of -0.5mAHD was assumed for the purposes of this assessment. The assumed dredging depth caters for safe navigation requirements and allows for additional insurance dredging to help reduce future maintenance dredging requirements.

5.2 Minimised environmental impact

With reference to Section 4 and Appendix A, large areas of the lakebed are covered by seagrass meadows. All seagrass is considered a 'marine plant' under the Queensland *Fisheries Act 1994*, regardless of density or condition. If the Lake is dredged it will not be possible to completely avoid impact to seagrass. Therefore, the definition of the dredging footprint has considered minimising impacts to seagrass by avoiding where practical and possible these areas and without significantly affecting the future uses of the Lake.

[1] This was confirmed via survey of the lake water level during a period with consecutive high tides lower than the sill level (S. Linnane, pers. comm., 20 August 2021)

If there is a residual impact by dredging to seagrass meadows (i.e. do not return to former condition within 5 years) an offset is required to be paid under the *Environmental Offsets Act 2004*. It is expected that an environmental offset would need to be paid to the State Government as part of the works, where the maintenance dredging and the placement of material result in permanent impacts to the seagrass. As dredging will reduce the depth of the lake, it is probable that seagrass will not return to the dredged areas, where light availability reduces.

5.3 Evolution of Basis of Assessment

The first iteration looked at dredging volumes within the whole Lake footprints as conceptualised by the preliminary master planning of Lake (Figure 5-3) without limitations on actual operational requirements and impacts on seagrass. This iteration provided a sensitivity on the impacts of dredging depths on dredging volumes (Figure 5-4) and provided an estimate of the seagrass areas impacted (Figure 5-5) if the whole Lake footprint is to be dredged.

This iteration was only for discussion with the Shire in the first progress meeting on 13th May 2021, to convey the scale of dredging volumes and corresponding impacts on capacity of dredge placement sites, seagrass, costs and time if the indicative Master Plan concept of 'whole lake' dredging was adopted.

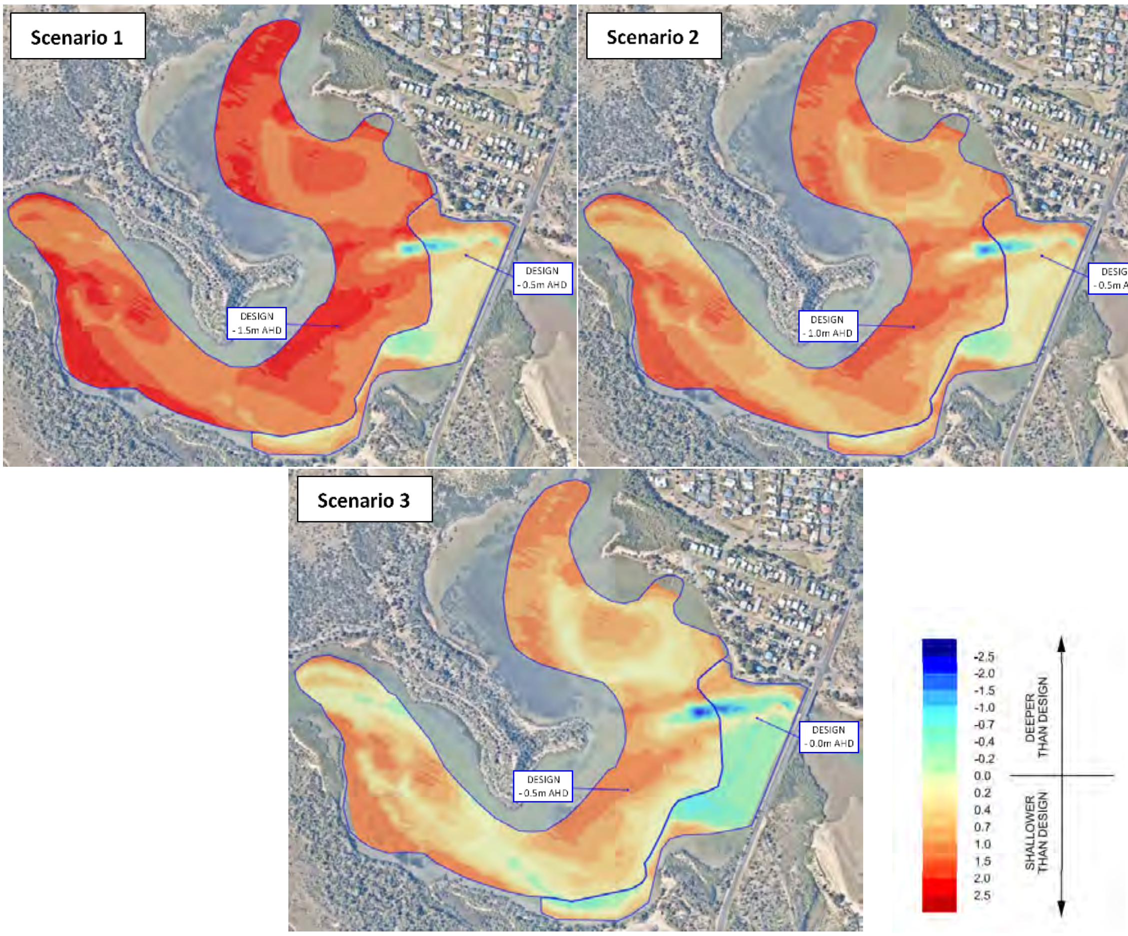

Figure 5-4 First concept dredge design iteration – impacts on dredging volumes

Table 5-2 First concept dredge design iteration - design depths and dredge volumes

	Scenario 1		Scenario 2		Scenario 3	
	Design Depth	Dredge Volume	Design Depth	Dredge Volume	Design Depth	Dredge Volume
Zone 1	-1.5 m AHD	590,000 m^3	-1.0 m AHD	408,000 m^3	-0.5 m AHD	226,000 m^3
Zone 2	-0.5 m AHD	31,000 m^3	-0.5 m AHD	31,000 m^3	0.0 m AHD	10,000 m^3
Total		**621,000 m^3**		**439,000 m^3**		**236,000 m^3**

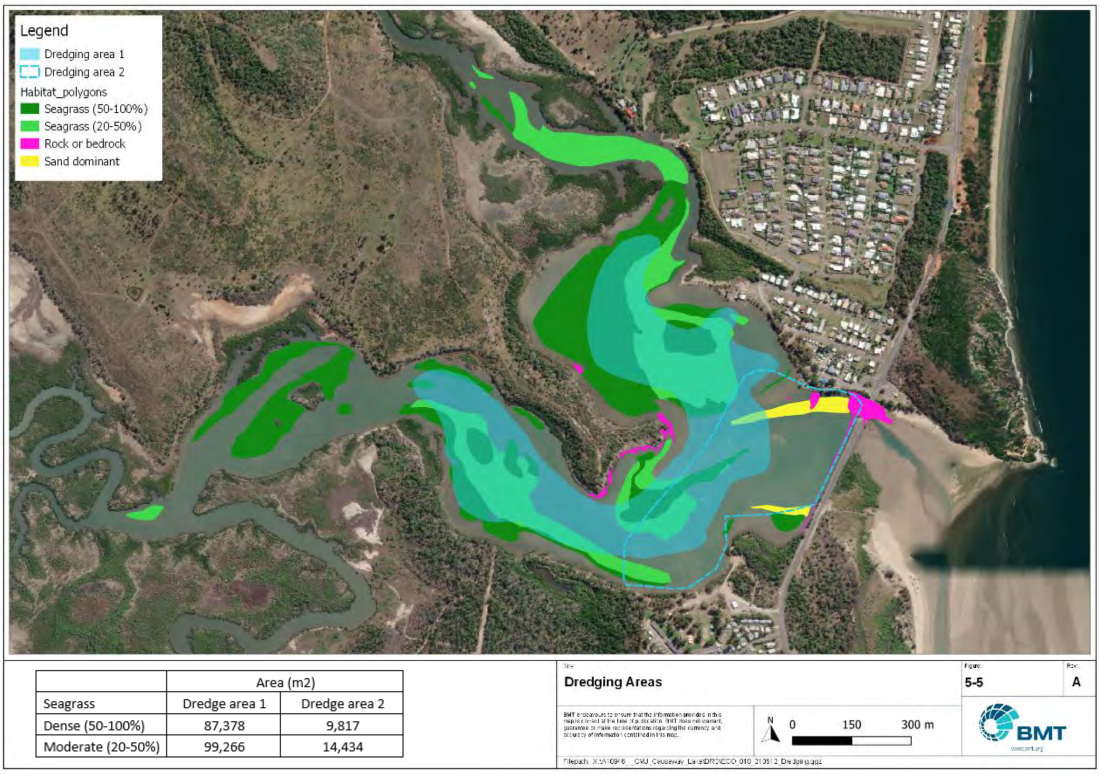

Figure 5-5 First concept dredge design iteration – Impacts on seagrass areas

The second iteration looked at maintaining the concept of having two dredging areas for motorboat and non-motorised activities including swimming, optimising Lake use opportunities, while minimising operational and environmental (seagrass) risks. From the benthic habitat mapping, it was confirmed that the northern section of the Lake, extending into Mulambin Creek, is dominated by a large seagrass meadow. Any area dredged in this section would yield an equal area of seagrass removal. The central and southern sections of the Lake have significantly less seagrass meadows compared to the northern section. Three conceptual options were established to assess the Lake usage areas versus seagrass areas (Figure 5-6). All three options avoided dredging in the northern section and hence limiting boat usage in the same area. This reduced the impact of dredging on seagrass in the Lake by a minimum of ~62% (option 2: down from ~210,000m^2 79,000m^2). With the limitation on motorboat movement to Mulambin Creek, option 1 was excluded as it additionally limited the movement to the Shoal Creek. Compared to option 2, option 3 further reduced impact on seagrass from 62% to 78% by reducing the width of channel to Shoal Creek; still within safe navigational channel width requirements.

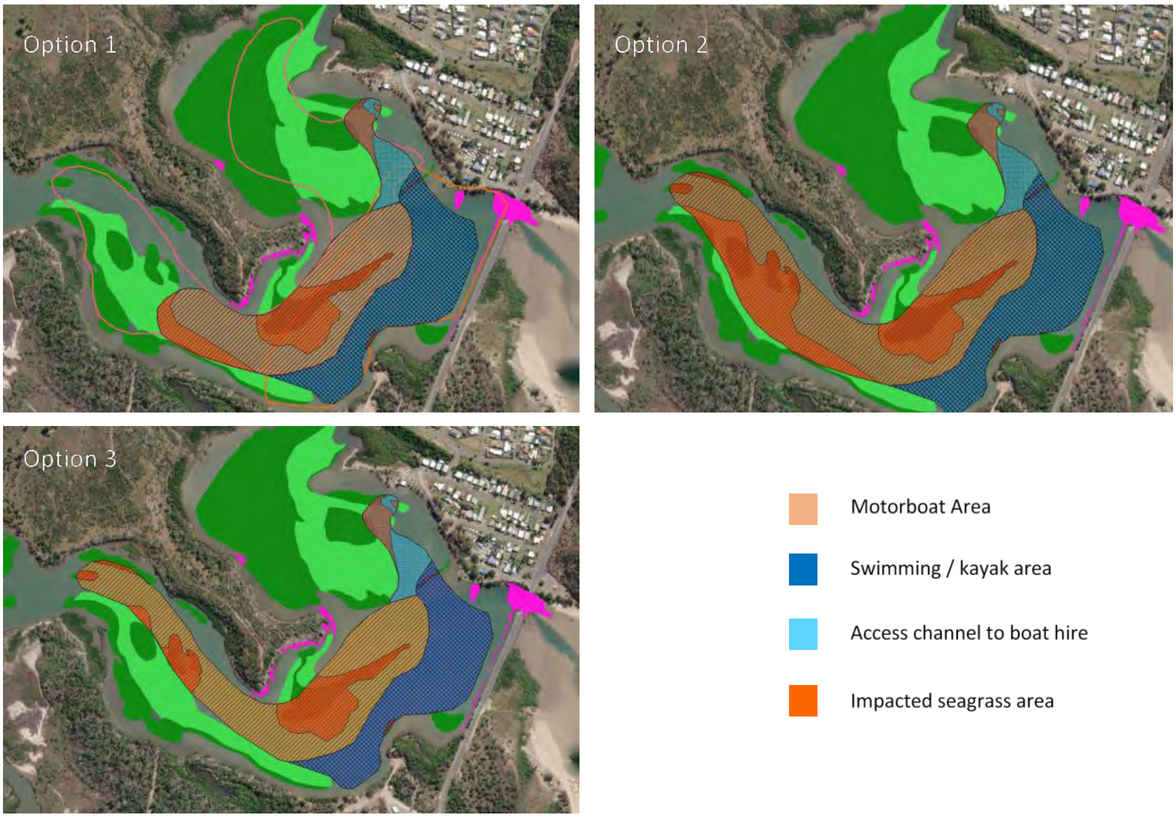

Figure 5-6 Lake usage versus impact on seagrass areas

Table 5-3 Conceptual dredge areas and impacted seagrass footprints for lake usage options

Option	Dredge Area (m^2)				Impacted seagrass area (m^2)
	Motorboat Area	Swimming/Kayak Area	Access Channel to boat hire	Total	
1	116,119	78,006	18,937	**213,062**	45,628
2	176,626	78,006	18,937	**273,569**	79,545
3	141,809	78,006	18,937	**238,752**	45,985

5.4 Basis of Assessment

Combining dredge footprint option 3 (Figure 5-6) and a dredge design depth of -0.5mAHD resulted in establishing the basis dredge plan that will be used for the purposes of this assessment (Figure 5-7). The plan was presented and discussed with the Shire during meeting on 10 June 2021.

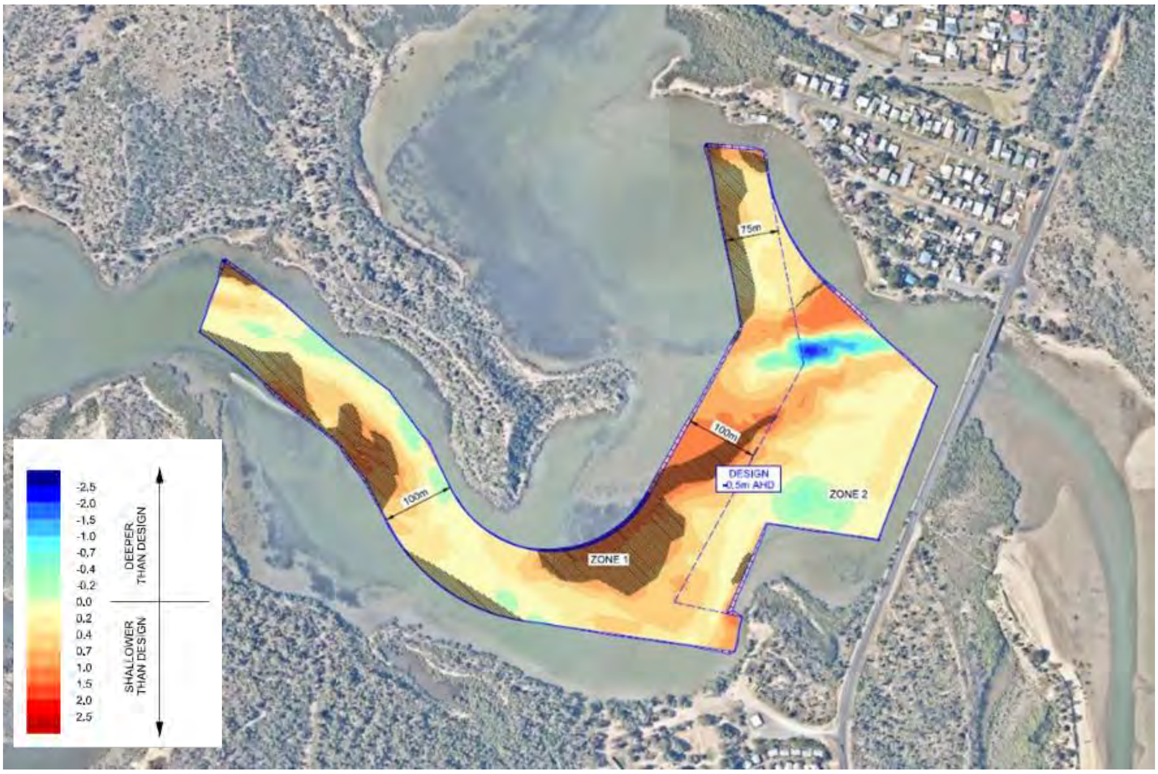

Figure 5-7 Dredge footprint and depth

The key features of the basis of assessment include:

- Maintain concept of two dredging areas; one for motorised activities and one for non-motorised activities including swimming.
- A dredge depth of -0.5m AHD targeted in both dredging areas. This will allow for a minimum of 1.9m channel depth from water surface at all times and increasing with water levels exceeding the sill level.
- An over dredging allowance of 0.3m (i.e. down to maximum -0.8m AHD) was assumed for conservative dredge volume calculations. This is common practice specification to provide the dredging contractor with some construction tolerance in achieving the exact design depth and allow for future dredging insurance.
- A conservative channel width ranging from 75-100m was assumed. This is considered sufficient for safe navigation of all motorised and non-motorised water sports activities.
- For the purpose of this assessment, a dredging slope of 1:5 was assumed to provide smooth transition between dredging areas and non-dredging areas, and is considered sufficient.

  Based on the above, the estimated dredge areas and volumes associated with the selected basis of assessment are summarised in Table 5-4.

- It is assumed that an operational and navigational management plan will be in place to manage the safety of different Lake activities. For example, it is expected that navigation markers will be placed to separate between swimming areas and motorised areas.

Table 5-4 Estimated Dredging Areas and Volumes

Area	Design RL (m AHD)	Estimated Dredging Area (m^2)	Estimated Dredging Volume (m^3)	Volume including Overdredging (m^3)	Impacted Seagrass Area (m^2)
1	-0.5	146,500	76,575	121,820	44,728
2	-0.5	71,500	22,600	42,775	776
	Total	**218,000**	**99,175**	**164,595**	**45,504**

6 Review of Dredging Methods

There are four main phases within any dredging project:

(1) Dislodging of the in-situ material;

(2) Raising of the material;

(3) Horizontal transport of the material away from the dredging (excavation) site; and

(4) Placement of the material at the receiving site.

This section summarises the available options for phases 1 – 3 and evaluates the feasibility of each against the specific objectives of this project. Phase 4, the placement of the material at the receiving site, is discussed in Section 7.

Dredges can be broadly categorised into two streams: mechanical or hydraulic excavation. With mechanical excavation, the material is dislodged and retrieved mechanically using a grab or bucket. Hydraulic excavation mixes the dredged material with water to form a hydraulic slurry, raises the dislodged material as a slurry via a suction pipe and associated centrifugal pump. For very loose sediments, the suction force may be persuasive enough to retrieve the material without any additional work. However, most hydraulic dredges also feature a cutting component used for the initial dislodgement of the material.

6.1 Site Specific Selection considerations

Several key factors need to be evaluated in the process of selecting a suitable dredge method and equipment for a specific project. These are discussed below.

6.1.1 Soil characteristics

The physical characteristics and quantity of material to be dredged influence the types of equipment available to the project. Key considerations regarding the material include:

- The presence of consolidated or densely packed materials (rock, clay and dense sands) will likely require cutting, while less dense sands and silts can be retrieved predominantly through suction.
- Following dislodgment of the material, the cohesion characteristics determine how the material will behave during transport and placement. For example, high concentrations of clay can cause blockages in the cutting equipment and the transportation pipeline, due to its tendency to consolidate and form dense masses.
- The characteristics of the dredged material, following transportation, should match the required characteristics of the sediment at the receiving site. To insure this, additional treatment measures may be required prior to, or during, placement.

The understanding of Lake soil characteristics is based on the 2021 and 1987 site geotechnical investigations (refer to Section 4.3.1 and Appendix A).

Most sample sites had silt layer in the upper 2 cm, with fine sands beneath the upper silt layer (BMT 2021). Particle Size Distributional (PSD) data for the cores and grab samples show that in most cases, samples were dominated by sandy sediments, with the exception of the surface horizon at

BH3, and grab 1, which were dominated by silt and gravel, respectively (BMT 2021). The 1987 geotechnical investigations identified layers of consolidated clays that are located at depths well below the proposed -0.5 m AHD baseline dredge depth. This, in conjunction with the results of the 2021 sediment analysis, indicate that the expected dredge material will be predominantly sand with some silt and unconsolidated clay particles. The latter are expected to be more prevalent on the lakebed surface.

Except for the north-eastern corner (near the sill) and the south eastern corner (near the boat ramp) of the dredging areas, the material to be dredged can be broadly classified as fine to medium sand ($D_{50} \approx$ 0.1-0.2mm). The coarser the grain, the easier it is to dredge until a certain limit is reached ($D_{50} \approx$ 0.5-0.6mm) after which the sedimentation behavior of the grains becomes dominant. The lower dredging rates associated with small grain diameter material (D_{50} < 0.1mm) result from the low permeability. It is therefore considered that the seabed soil material available in the Lake is 'easy' in terms of dredge-ability and in getting sheared loose from the in-situ seabed. Except for gravel spots, no rock material was detected within the dredging depth and which usually has impact on the selection of more intrusive dredging methods.

6.1.2 Site physical conditions

The site characteristics and access in the context of dredging were briefly discussed in Section 3, key considerations when selecting viable dredging equipment include:

- The location and accessibility of the dredging area:
  - Dredges come in a wide variety of sizes and configurations. Larger dredges are typically ocean going and require navigable access to the excavation site, whereas smaller dredges can be transported overland and assembled/launched at site.
  - Some sites require dredging in areas of restricted access, such as alongside wharfs, within marinas or other confined waterways (such as the Lake) that exclude certain types of dredges.
- The location, distance, and accessibility of the placement/receiving area:
  - These factors influence the selection of the transportation method, whether it be road, pipeline, dredges with in-built hopper or auxiliary barges.
- Local conditions (wave climate, currents, water depth, tidal range, dredge depth, waterway users):
  - The selected equipment should be capable of operating within the anticipated site conditions.
  - These conditions may also influence the timeline of the project, such as scheduling of dredging activities to avoid seasonal extreme weather and/or increased activity from other waterway users.

6.1.3 Budget and schedule requirements

Higher production rates are typically associated with higher operational cost rates, at the benefit of a reduced project timeline. Conversely, equipment with lower production rates are less expensive by unit rate but may incur a greater overall project cost due to an extended dredging campaign. Selection of equipment must factor in this balance of production vs duration.

6.1.4 Environmental constraints

All dredge methods involve some level of disturbance at the excavation site, as expected when dislodging and raising material through the water column. The immediate environmental impact, regardless of dredge method, is to any marine flora and fauna residing on the seabed at the excavation site, such as the seagrass meadows in the Lake. Council will need to provide strong justification for the need to remove or damage these marine plants during the approval phase.

All dredging methods generate turbidity plumes due to sediment being released to the water column. Mechanical dredging methods generally release less sediment in comparison to hydraulic methods. The increased turbidity can have impacts on the surrounding benthic habitat, dependent on the sensitivity of the marine flora and fauna, the dispersion rate of the plume and the sediment characteristics.

6.1.5 Availability of dredging equipment

Dredging is a niche market, with a finite number of contractors offering suitable dredging solutions to a local area. Equipment can be booked well in advance and it can be difficult to secure the optimal equipment spread to meet a strict project schedule. Early engagement with potential contractors is recommended.

6.2 Overview of Dredging Options

There are several dredging methods that are not feasible within the Lake due to their size and site access. Dredge types excluded from the overview of options presented in this section are summarised in Table 6-1. The remaining viable methods discussed in the following sections are either:

- Small ‘hydraulic’ dredge types that can be transported by road; or
- Small hybrid dredge types that can operate in ‘hydraulic’ or ‘mechanical’ modes

Table 6-1 Excluded dredge methods

Options	Reasons for exclusion	
Trailer Suction Hopper Dredge (TSHD) *All sizes*	• Transport by sea, requires navigable ocean access • Vessel operating draft likely to exceed available depths within Causeway Lake	
Cutter Suction Dredge (CSD) *Medium to large sizes*	• Transport by sea, requires navigable ocean access, or a large, commercial boat ramp • Vessel operating draft, for large options, likely to exceed available depths within Causeway Lake	
Backhoe (BHD) or grab bucket (GB) dredges in tandem with barges *All sizes*	• Transport by sea, large size options require navigable access to ocean • Vessel operating draft, for large options, likely to exceed available depths within Causeway Lake • The mini size BHD and barge options have very low production rate, not suited to project dredge volumes	
Land-based long-reach excavator *All sizes*	• Dredge area is predominantly located out of excavator operating reach	

6.2.1 Viable Dredge Methods

6.2.1.1 Cutter Suction Dredge (CSD)

A cutter suction dredge (CSD) uses a rotary cutter head on the end of a 'ladder' to dislodge material from the seabed, which is subsequently raised as a mix with water though a suction pipe within the 'ladder'. Material is then typically pumped as a slurry, through an inboard centrifugal pump, to the placement site through the pipeline transport method (discussed further in Section 6.3.1), although it can also be pumped directly into hopper barges if that method is more suitable. During dredging, the CSD is kept in position using anchors or spud poles; usually a combination of both. The main, or working, spud is used as a reaction point against which the dredge can push forward and move the cutter head into the cut. For dredges with a hydraulic ram system attached to the working spud, the dredge can be moved forward for the length of the spud carriage. The stepping, or auxiliary, spud is used to hold the dredge position while the working spud is reset. The spud also serves as the rotation point at the stern of the vessel. Using a system of anchors and wires, the CSD can rotate around this axis and move the cutter laterally along the seabed.

Figure 6-1 Typical cutter suction dredge configuration

CSD sizes are typically classified by their overall power and pipe size. Large size CSDs can be self-propelled and ocean-going vessels, be towed between sites with tugboats, or transferred on a barge transporter. These options are not feasible for the Lake, due to the absence of a navigable access to the ocean. Only small and mini CSDs are suitable for this site, as they are typically modular, making transport and assembly possibly. For example, small CSD's can be transported by trucks to the site and launched from a suitable boat ramp, sloped natural embankment, or lifted by cranes from land to water.

The CSD technique is suitable for dredging unconsolidated and consolidated seabed materials. The technique is also well suited to dredging in shallow water, where the rotary cutter head can excavate a passage in front of the dredge. The CSD technique is less suited to dredging in areas of high traffic vessel operations, as it is time consuming to move the dredge off-line and out of the navigation area to allow the passage of a vessel, and then to relocate the CSD over the progressively dredged interface. In comparison to mechanical dredging methods, CSD dredging can result in significant disturbance of the materials being dredged, leading to larger turbidity and plume generation. This needs to be considered in the environmental risk assessment and may require monitoring during the dredge campaign.

Figure 6-2 Cutter suction dredges

6.2.1.2 Auger Dredge

An auger suction dredge operates like a CSD, featuring a rotating tool for dislodgment of material and a suction pipe for retrieval. In this instance, the cutting tool is a rotating Archimedean screw, set perpendicular to the suction pipe and resting horizontally on the seabed. The rotation of the screw dislodges material and direct it to the mouth of the suction pipe, where it is then typically pumped as a slurry, though an inboard centrifugal pump, to the placement site through the pipeline transport method. Auger dredges typically have a turbidity shroud on the screw piece, which increases the suction vacuum and results in less turbidity than the conical cutter head on CSDs. Auger dredges are generally quite small, ranging from sizes comparable to mini CSDs, down to mini, unmanned and remote-controlled vessels. They were originally used for sludge removal applications from waste-water treatment plants and clean-up projects because they are designed for the removal of thin layers. Nowadays, they are also used in in smaller waterbodies like lakes, rivers and dams due to the reduced turbidity and relatively accurate operation. Because of the wide cutter head, augers are less effective in undulating seabed profiles. Unlike CSDs, auger dredges do not swing around a fixed spud, instead they dredge linearly. In smaller water bodies, shore-attached winches can be used to move the dredge along its intended path. Other augers are self-propelled, typically fitted with twin props at the stern. Figure 6-3 shows a typical, manned auger dredge with the ladder in the down position, and a close-up of an Archimedean screw-type cutter head.

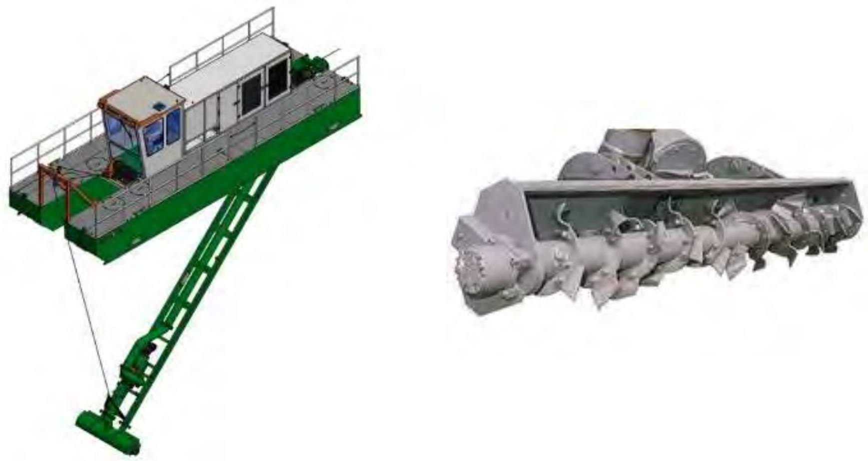

Figure 6-3 Left: typical auger dredge, Right: close-up of the Archimedean screw-type cutter head

6.2.2 Hybrid Amphibious Excavator

An amphibious excavator is a customised standard or long-reach excavator where the chassis crawler floats on a sealed pontoon (Figure 6-4). Amphibious excavators are well suited to manoeuvre in marshy, swampy area and soft terrain, as well as being able to float on the water. For added stability in deeper water, supplementary pontoons with a hydraulic-mechanical spud system can be attached to the outer side of the primary pontoons.

Figure 6-4 Amphibious excavator. Left: standard watertight pontoons, Right: supplementary pontoons with hydraulic-mechanical spud system

The excavator is usually fitted with a backhoe, following the same excavation mechanics as a mechanical land-based unit. However, some plants can accommodate a cutter head (Figure 6-5). This allows the amphibious excavator to operate along the same principles as a CSD. The material is dislodged by the cutter head, raised as a slurry mix with water though a flexible suction pipe and is subsequently pumped through a special pump, fitted within the boom of the excavator, to the placement site through the pipeline transport method. The setup has the benefit of being able to move unassisted between the shoreline and the waterbody, removing the need for ramps or specific cranes at the mobilisation and demobilisation stages. The excavator's proficiency in soft grounds mean it is better suited for launching off the existing natural slopes along the shoreline, reducing the site preparation works and costs.

Figure 6-5 Amphibious excavator fitted with a rose cutter attachment (source: Eddy pump 2021)

Another advantage of the amphibious excavator is the option for both the backhoe and cutter head attachments. Use of the backhoe could be useful for the dredging of areas adjacent to intended lakeshore placement sites (discussed further in Section 7), where excavated material can be placed more effectively without the need for the pipeline transport system.

Disadvantages include the scarcity of this type of equipment in the market. The cutter suction attachment is a relatively new addition to the market and will not have the extended project track record of traditional CSDs. Early engagement with contractors will be important to better understand the unique project constraints and benefits this option presents.

In addition, the amphibious excavator has reduced production rate in comparison to a small CSD option. The production rate will be restricted by the cutter size itself, as well as the size of the pipe and the onboard pumping capabilities.

6.3 Overview of Dredged Material Transportation Options

Dredge material transport options considered suitable to this project and compatible with the viable dredging methods are described below.

6.3.1 Pipeline Transport

Pipeline transport is applicable for material removed via hydraulic and sometimes hybrid dredging. The dredged sediments mixed with water form a slurry within the pipeline, which is subsequently pumped to the placement site. The distance to the placement site, whether nearshore, onshore or offshore, determines the feasibility of pipeline transport, provided there is a suitable pipeline route.

Additional booster pumping stations (Figure 6-6), can be situated along the pipeline route to extend the pumping distance; however, these substantially add to the project costs and can cause significant disturbance during operation due to noise.

Figure 6-6 Pipeline booster pumping station

For water sections of the pipeline route, the pipeline may be submerged or floating (Figure 6-7). Submerging the pipeline is particularly useful in high traffic areas, as it still allows for the transit of vessels on the surface. Dredged slurry material is typically transported hydraulically via a series of floating, submerged and land-based pipes to meet different site-specific constraints and placement sites.

When mixed with water, pipeline transport of dredged material as a slurry is considered one of the most economical options to transport large volumes of sand compared to transporting sand material by barge or trucks. Pipeline transport is also generally considered a safe transportation option, both from a health and safety, and environmental standpoint as it takes place in a closed system. The dredge inlet suction mouth, the pipeline outlet point, and any additional pumping stations are usually the only main contact points with the outside environment. Projects involving submerged or floating pipelines will require a navigational management plan, to ensure all users of the waterway are aware of the introduced hazards. Similarly, onshore pipelines may require traffic management plan if they traverse roads used by other vehicles.

The main disadvantage to pipeline transport of sand slurry is when the placement site is located on an onshore contained area. The slurry will then need to be dewatered and tailwater returned, often by additional water pumps to the originating water system. This adds to project scope, costs and time. In addition, it adds an additional layer of quality control. It is common that the tailwater is required to be of certain quality, from an environmental regulatory point of view, before discharging back to the water system. This often requires additional regulatory consultation, planning, and water quality monitoring during works. For beach and lakeshore nourishment and reclamation purposes, this is less of an issue as sand sediments settle naturally on the new beach profile while water mixed with fines return naturally to the water body following natural slopes.

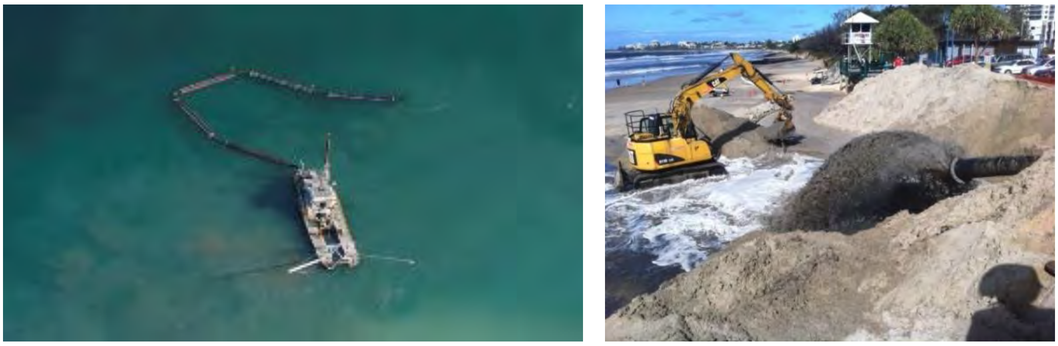

Figure 6-7 Left: floating pipeline supported by plastic floats, Right: pipeline outlet on beach nourishment site

6.3.2 Road transport

Road transport is feasible for onshore placement sites, provided there is a suitable haulage route. In some instances, such as land-based excavation, dredged material can be placed directly into trucks for transport to the placement site. The more commonly used approach is to form a temporary stockpile of the dredged material, near the excavation site. This method provides time for the material to drain of excess water, optimising the quantity that can be transported per truck cycle. In this instance, an additional earthmoving equipment will be required at the stockpile location for loading of the trucks.

The excavation production rate, stockpile quantity and distance to the placement site are all factors influencing the truck cycle duration and the number of trucks required to meet the project objectives. For large quantity projects, this method can have significantly higher associated costs in comparison to the pipeline transport method. In addition, there is comparatively greater environmental effects, such noise, exhaust gas, road usage and spillage. Road transport is unlikely to be suited to this project and has not been considered further.

6.4 Access, Launching and Retrieval of Dredge

Site access at the Lake is currently very restricted and is the key constraint that needs to be addressed through early engagement with dredging contractors. Small CSDs, auger dredges and amphibious excavators have been identified as generally suitable from an accessibility point of view; with many challenges though that need to be considered through consultation with dredging contractors during planning of any future dredging works.

These small type dredges are transportable as a single unit, either on the back of a semi-trailer (Figure 6-8) or within a shipping container (for auger units only). In many cases, the trailers are designed to function as a slipway for loading the dredge in and out of the water (Figure 6-9) provided there is a suitable ramp.

Figure 6-8 Small CSD loaded onto a semi-trailer for road transport

Figure 6-9 Launching of a small CSD off a semi-trailer, at a commercial boat ramp

It is likely that all the viable dredges, except the smallest of the auger dredges, will exceed the design load limits for the existing boat ramp on the southern side of the lake (refer Section 3.2). Alternative means of launching and retrieving the dredge from the Lake will need to be pursued. Launching from a dirt or gravel ramp is possible, provided the ground bearing capacity is capable to support the combined trailer and dredge loads. Although there is a relatively wide dirt ramp adjacent to the existing recreational concrete ramp south of the Lake, significant vegetation clearing would be required to either provide a sufficient turning circle for the truck to manoeuvre the trailer perpendicular to the water edge, or to clear a new access road from the Scenic Highway. Figure 6-10 illustrates a rough overlay of the turning circle requirements for a typical 19 m long by 3.8 m wide truck and semi-trailer combination to launch a dredge from the southern dirt ramp. Note that this combination is applicable for typical road use; bespoke dredge trailers may be larger and have more restrictive manoeuvring capabilities.

The Lake northern ramp is also likely to have access issues in its current configuration. Figure 6-11 suggests the orientation of the road is more accommodating for truck/trailer combination in comparison to the southern ramp. However, the existing ramp is very restrictive in terms of width and height, and unlikely to be compatible with any trailer launched dredges.

Scenario 1
Trailer reversed down access road

Scenario 2
Truck proceeds first down access road

Figure 6-10 Schematic - Compatibility of natural ramp area with a 19 m x 3.8 m trailer/truck combination

Figure 6-11 Schematic - Compatibility of the northern ramp area with a 19 m x 3.8 m trailer/truck combination

It is suggested that the early planning for the dredging activities be done in coordination with the master planning for the foreshore development. There is an opportunity to align the objectives of both these exercises for mutual benefit, such as constructing a new or upgraded existing boat ramp that can be used for launching/retrieval of the dredge and by the future recreational users of the Lake. This boat ramp does not necessarily need to be a structural concrete ramp but can be a wide dirt ramp with some degree of capacity to allow for the launch of dredges.

For example, the preliminary master plan indicates the construction of a new sailing boat ramp at the bend of Resada Esplanade (Figure 6-12). Considering the predominant vessel fleet frequenting the Lake is small recreational vessels, this ramp is likely to be of similar design capacity to the existing concrete ramp. Although the final ramp would be unsuitable for launching the dredge, the campaign could capitalise on the vegetation clearing for the shoreline development and build a temporary gravel ramp. The location already provides sufficient room to manoeuvre a truck and trailer to the shoreline, so there would be no requirement for a new access route from the Scenic Highway.

Figure 6-12 New southern sailing boat ramp, as proposed in preliminary master plan (Active Living Landscapes 2016)

The northern ramp presents a similar opportunity for achieving joint objectives. However, from the preliminary master plan (Figure 6-13) it appears large scale shoreline development is not planned for this area and the ramp is likely to remain unchanged or be upgraded to a concrete ramp of comparable size. Future revision of the master plan could consider a larger scale development of this area, with the required vegetation clearing for dredge mobilisation, however, this is likely to have a greater community impact. The northern ramp is situated close to the residential community and significant alteration of the shoreline vegetation may be poorly received by the community stakeholders.

The redevelopment of the ramp adjacent to the boat shed, also shown in Figure 6-13, may present a better opportunity on the northern shore. The preliminary master plan proposes a ramp suitable for sailing boat launching and retrieval but does not give indication on whether the ramp will be upgraded from the existing concrete slab. This area can be considered for inclusion as a potential launching/retrieval site in future planning studies.

Figure 6-13 Northern redevelopments, as proposed in preliminary master plan (Active Living Landscapes 2016)

Some smaller dredges do not come equipped with slipway trailers. These dredges require a crane to unload the equipment from the trailer and placed on the ramp, where it can be pushed into the water with an excavator or dozer (Figure 6-14). Depending on the size of the dredge, the earthmoving equipment used for the material placement could be an option for use in the dredge launching operation if suitable.

Craning directly from the bank into the water, also shown in Figure 6-14, depends on the Lake shoreline batter profile and how far the crane would need to reach in order to place the dredge in an adequate depth of water. A craned launch method incurs additional costs associated with the mobilisation/demobilisation and operating costs of additional crane(s).

Figure 6-14 Left: Mini CSD pushed into the waterway with a medium size excavator; Right: CSD launching with a two-crane lift

Generally, the Lake shoreline area is very shallow, without any suitable hardstand areas for the cranes at present. The deepest area is adjacent to the rock rubble wall of the causeway. However, the access is very narrow and restricted as illustrated in Figure 6-15. Engagement with the contractor would be required to determine the number and size of the cranes required for this kind of special lifting operation, and whether there is sufficient area along the causeway.

Figure 6-15 Restricted widths along causeway

An amphibious excavator will likely require the least amount of site preparation work for launching and retrieval. The ability for the excavator to move independently over land and into the Lake is an advantage over the other dredging options. Excavators are typically transported on drop-deck semi-trailers. However, unlike the other dredge options, the truck and trailer will not need access to the Lakeshore. Unloading can occur at a secondary location near the launching site, after which the excavator will be manoeuvred to the site under its own power. There are two existing locations along the Lake shoreline that potentially meet the criteria as a suitable launching site for an amphibious excavator and these are shown in Figure 6-16. Small-scale vegetation clearing may still be required to ensure sufficient width for the excavator's passage overland, and some preliminary shore works may be required to provide a suitable slope and stability for the entrance into the Lake.

It is reiterated that early engagement with potential dredging contractors will be crucial, as suitable launching methods and the extent of the required site preparation works will be very dependent on the dredge type and size selected for the project.

Figure 6-16 Potential launching sites for amphibious excavator in Causeway Lake

6.5 Additional Site Considerations

6.5.1 Pipe Laydown Area

The dredging contractor will require a laydown area for the duration of the dredging project. This area will need to accommodate the following equipment:

- The slurry pipe rack/s. These are transported to site on semi-trailers and unloaded with a crane (Figure 6-17). The pipeline is assembled, managed and disassembled with a small spread of earthmoving equipment.
- A large fuel tank (~10,000L)
- Site containers (mechanical workshop, spares, ablution facilities, site office if required).

The required footprint area will be defined by the contractor, and dependent on the size of the dredge and the required length of pipeline. The laydown area will need sufficient access, footprint area and ground characteristics to facilitate the delivery of the equipment by truck, unloading by crane and vice versa for demobilisation. For preliminary planning purposes, a footprint of 40 x 30 metres can be assumed. Potential locations with sufficient space include:

- North of the Boat Shed (shown in Figure 6-13) however this is close to the residential area and the Boat Shed itself; or
- Near the southern boat ramp, which may require the temporary road closure and/or some vegetation clearing.

It is recommended that potential contractors be engaged early to refine the requirements for the laydown area. As with the dredge launching locations, there is opportunity here to capitalise on the shoreline redevelopment to clear sufficient land for the laydown area.

Figure 6-17 Unloading of pipe racks from semi-trailer

6.6 Recommended Methodology

6.6.1 Suitable Dredging Methods

Dredges suitable for use in the Lake in terms of access and production rate are as listed below in order of preference:

(1) Small cutter suction dredge (CSD)

(2) Amphibious excavator with both backhoe and cutter / pump capability

(3) Mini auger dredge or mini CSD

All recommended options share the following benefits and opportunities:

- Well suited to dredging in shallow water, rivers and nearshore areas. The cutter heads on the CSDs and auger dredges can be used to excavate a passage in front of the dredge. This technique is also applicable for an amphibious excavator using a cutter head. Additionally, the excavator can work from shore with the backhoe attachment.
- Pipeline transport is the most suitable transport method. This is the most cost-effective transport method when compared to transport by trucks, as it does not require additional mechanical plant for this phase, such as barge hoppers, trucks and/or excavators for loading. Pipeline transport also presents less risk to the environment and community, as it is predominantly a closed system.
- The flow and production of sediments being pumped to the placement site can be controlled.
- Can be transported to site by road trucks, assembled on site provided a suitable laydown area and launched using existing ramps (after upgrading) or new ones, or cranes (after enabling /

reinforcing the crane bearing area). The amphibious excavator has the advantage of moving autonomously from shore to water without any ramp or crane support.

Method specific advantages and disadvantages are listed in Table 6-2. A risk assessment considering the short-listed dredge methods is presented in Section 10.

Table 6-2 Relative comparison between suitable dredging methods

Option	Small CSD	Amphibious excavator	Auger dredge or mini cutter suction dredge (CSD)
Transport by road	Yes	Yes	Yes
Modular	Yes	No	Yes
Requires launching facility and enabling works	Yes	No	Yes
Production	60-120 m^3/hr	40-80 m^3/hr	10-30 m^3/hr
Time efficiency	Highest	Middle	Lowest
Cost effectiveness (value for money)	Highest	Middle	Lowest
Mobilisation cost including enabling works	Highest	Lowest	Middle
Suitability	Highest	Middle	Lowest
Flexibility /versatility	Middle	Highest	Lowest
Availability	Relative highest	Lowest	Middle

7 Review of Material Placement Options

Options for re-use or placement of the dredged material include the following:

- Beneficial re-use as fill material for land and shore reclamation or development;
- Beneficial re-use as fill material for beach nourishment, such as restoring sediment reserves to erosion areas;
- Disposal into an onshore, contained or semi-contained area;
- Disposal at an offshore site; and
- Capping/infilling of landfill or mining sites.

Like the selection of a suitable dredging method, the selection of a viable material placement option is influenced by several logistical, economic and environmental factors. The availability of a suitable placement site and location relative to the excavation site strongly influence the decisions around transportation methodology and directly impacts the project costs. Increased distance between the excavation and placement sites typically leads to increased project costs. The recommended dredging and transportation method for this project is a small CSD or other, similar hydraulic dredge, using a pipeline transportation system. The achievable distance for pipeline transport is constrained by the available pumping power, among other things (pipeline route, pipeline size, etc). Booster pumps can increase the available power and extend the transportable distance, but these units significantly add to the project costs. The effective range of the pipeline will depend on the specific dredge selected for this project and the power of its onboard slurry pump, as well as the pipeline route, the material characteristics and the pipeline size. These factors can be refined through consultation with dredging contractors through the design stage and into the execution of the project. For this options study, it has been assumed that a booster pump will be required to reach placement locations further than 1 km from the excavation site, and for every additional 1 km from there on.

7.1 Placement Options

Figure 7-1 shows potential placement sites near the Lake and their respective distance from the assumed centre of the dredging footprint. Kinka Beach and Kemp Beach have been included as potential beneficial reuse sites where clean sand from the Lake could be used to nourish the beaches and mitigate shoreline erosion, as proposed by the LSC Coastal Hazard Adaptation Strategy (BMT 2021b). Locations further afield such as Lammermoor Beach and Emu Park have been excluded from further consideration, due to logistical constraints. The required pumping power and the length of pipeline required to reach these sites would not be economically viable. In addition, the pipeline route would be complex as it passes near or through several built-up areas.

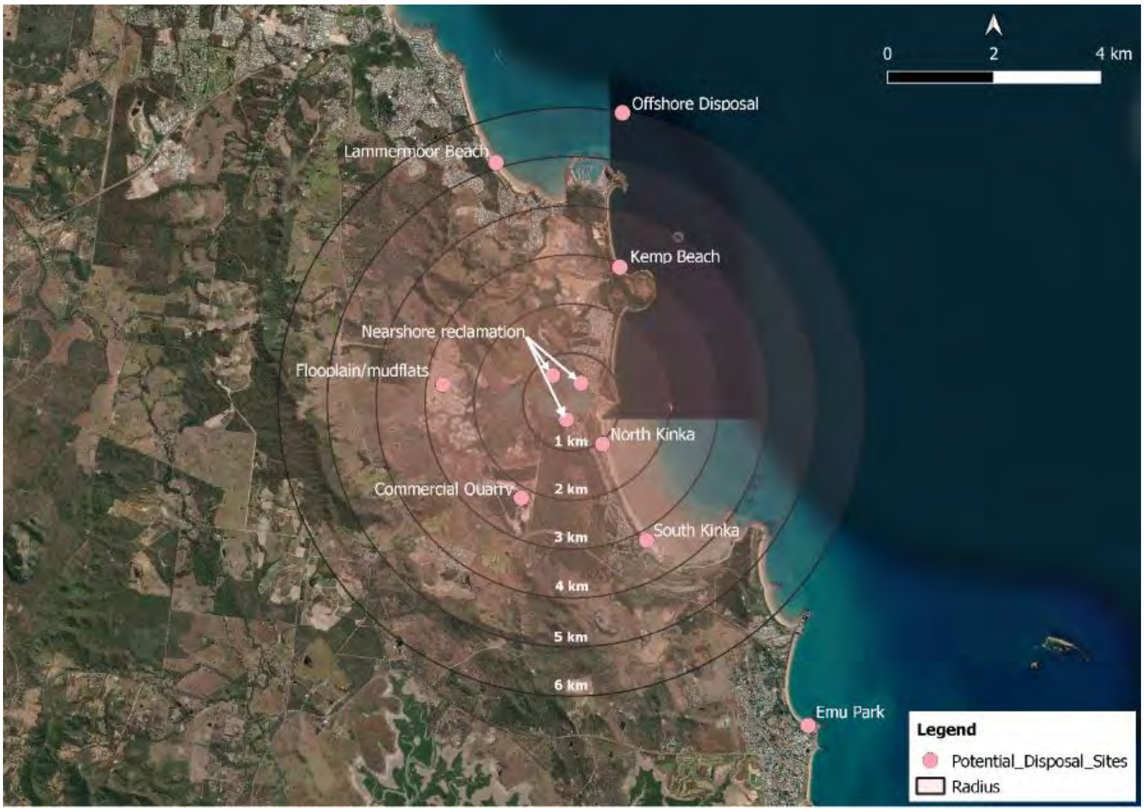

Figure 7-1 Summary of potential material placement sites

Rosslyn Bay Boat Harbour undergoes maintenance dredging campaigns overseen by TMR. Environmental approvals have been granted for offshore disposal at the location shown in Figure 7-1. Although plume modelling and other associated studies have been conducted on this site to meet the requirements of the environmental approvals, these would not be transferable to the Lake project, as the expected material quantities and characteristics are different. Additionally, use of this site is constrained by similar logistical challenges as Lammermoor Beach and Emu Park. For these reasons, this site is not considered appropriate and practical placement option and is not considered further.

Of the remaining viable options, it is recommended that nearshore reclamation within the Lake and beach nourishment of North Kinka Beach be pursued as the preferred options. They provide the shortest distance between dredging and placement sites, being situated within 1-2 km from the dredging footprint and have the highest potential for beneficial re-use of the dredged material. South Kinka and Kemp Beach are also viable options from a beneficial re-use point of view; however, they come with higher associated costs due to their increased transportation distance. Use of the commercial quarry requires early engagement with the commercial operator. Use of the floodplain/mudflats area is not recommended, as there is no existing access to this area for earthmoving equipment and the material has no beneficial re-use opportunities.

It is important to note that the volume of the dredged material will tend to bulk after excavation of compacted in-situ material and result in larger volume discharged at the placement site. The bulking of sand can increase the placed volume by roughly 5-10%. The increased volume will need to be factored into the design of the capacity of the placement areas.

7.1.1 Nearshore reclamation in Causeway Lake

Use of the dredged material for foreshore reclamation within the Lake is recommended as the preferred placement option. Three sites were selected as potential suitable candidates, based on existing or potential future shore-based infrastructure, the alignment of the proposed dredging footprint, the site's hydrodynamic characteristics, the current extent of seagrass coverage, and the preliminary future development master plans in the Lake. These sites, as shown in Figure 7-2, are situated within the main waterbody. Other sites further upstream were briefly investigated, however, placement of any significant volumes at these sites would reduce the navigability of the waterways and placement of small volumes would not be economically worthwhile due to the increased pipeline and pumping costs. Additionally, the deeper area near the causeway sill was removed from consideration, as it experiences strong current forces from tidal inflow and material placed here would likely be washed back into the dredge footprint.

As detailed in Section 4.3, the dredge material is expected to be predominantly sand with a portion of fines except for the dredged material near the southern shores. It anticipated that the particle size/ grading of dredged material is overall suitable for nearshore reclamation at the proposed locations. Management measures can be implemented during the execution of dredging and placement to strategically place dredged material with high fines contents areas. For example, this material can be placed in the lower sections of the beaches and subsequently overlaid by material with higher sand content.

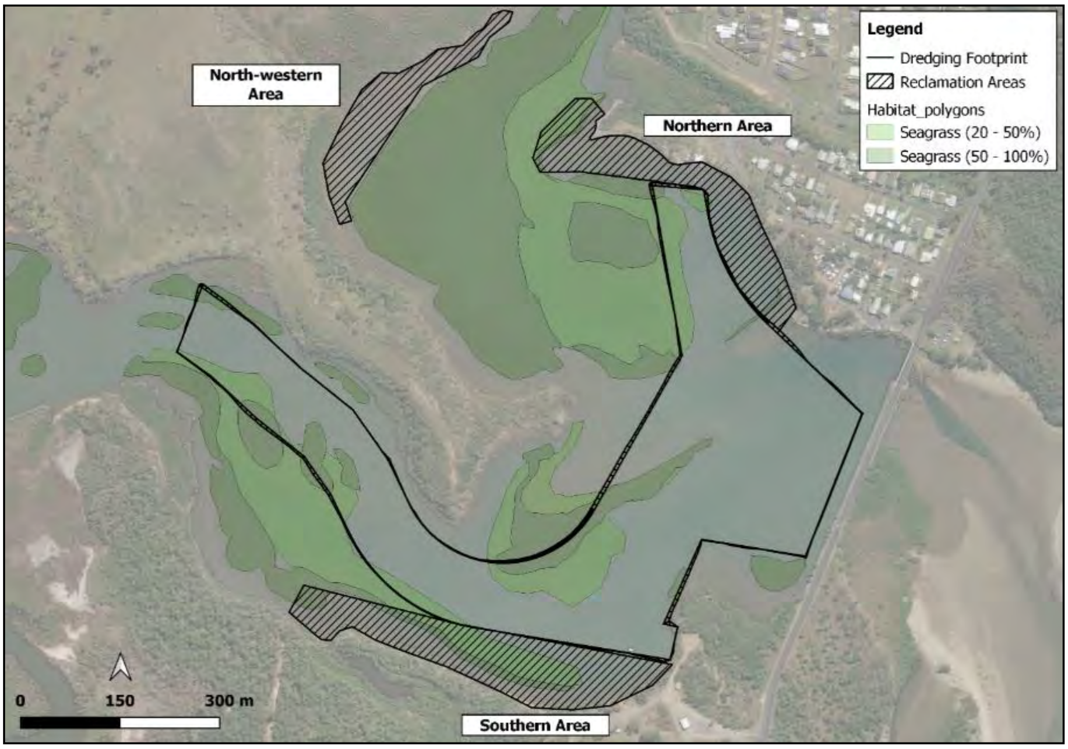

Figure 7-2 Potential Lake nearshore placement sites

It is also noted that all three nearshore reclamation areas align well with the conceptual future master plan of new sand beaches in these areas (Figure 7-3). This may be an excellent opportunity to re-use dredged material for the benefit of future master plan in a sustainable and effective manner.

The north-western area has no identifiable road or pedestrian access. However, the area is a good candidate for material placement as it offers a large footprint free of seagrass coverage and is setback from the main marine throughfare, posing little risk to navigability. Reclamation in this area could provide an opportunity to create a location of interest for recreational waterway users seeking a sheltered beach or swimming area away from the main thoroughfare and activity hubs. This area was highlighted in the preliminary master plan as a potential site for a new sand beach (Figure 7-3).

Aerial imagery of the southern and north western areas shows mangrove growth along the shorelines and further back into the low-lying flats. Further site investigations would be required to confirm the habitat characteristics in this area and quantify the vulnerability of the mangroves to placement of dredged material. The material placement area may need to be designed to incorporate a buffer between the formed beach and the shoreline, to ensure sufficient water supply to the mangrove forests and limit the disturbance during construction. There is an existing 4x4 track branching from the junction of Clayton Road and Mulambin Road, however, vegetation clearing would be required to provide access for pipe management and beach profiling earthmoving equipment.

For the purposes of this options study, the potential sites were considered as the maximum area extending between the shoreline and the boundaries of the basis dredging footprint. This gives an indication of the upper limit of volume capacity for each site. As seen in Figure 7-3, the proposed reclamation footprint extends significantly further into the lake than the preliminary master plan. It's recommended that future evolution of the master plan take the preliminary reclamation footprints into consideration and that the footprints be modified to align with the future iterations. It is also noted that the northern reclamation area disregards the existing boat ramp access off Causeway Esplanade. This should be considered in the redevelopment planning.

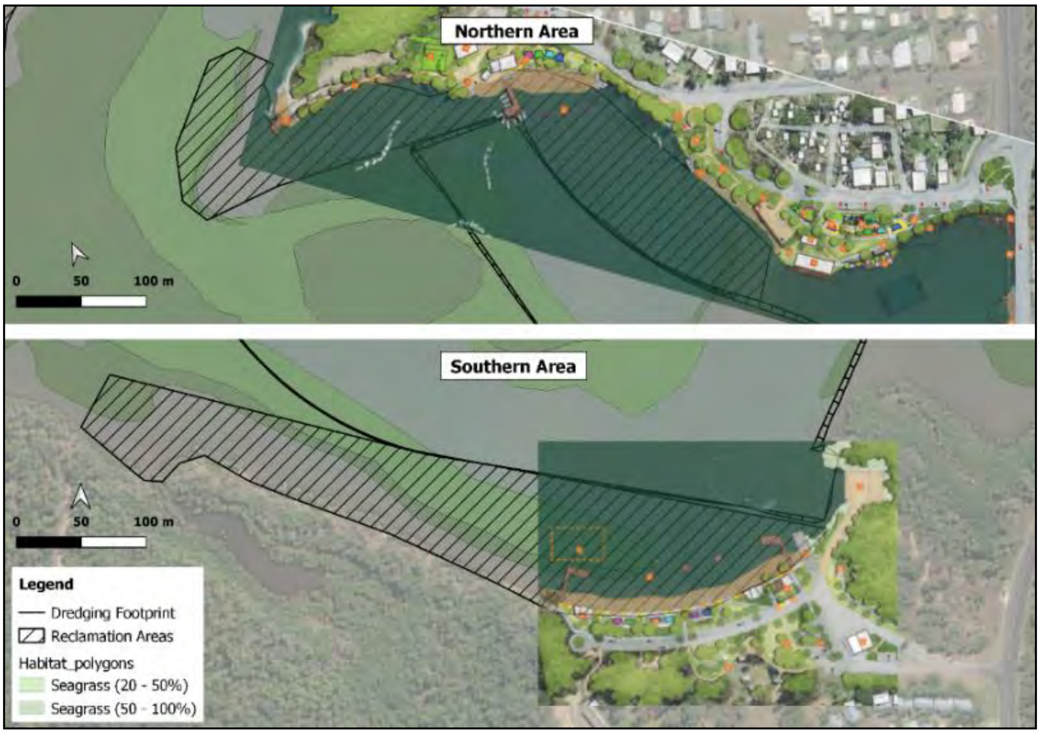

Figure 7-3 Potential beach reclamation sites for the northern and south sections of Causeway Lake

Another consideration for these areas is the impact on the existing seagrass meadows. Both the northern and southern reclamation footprints infringe on the current seagrass meadows, which is likely to have financial and regulatory ramifications, and reflected in increased offset costs. For reasons discussed in Section 5.2, it's recommended that another seagrass survey is conducted prior to dredging and beach reclamation.

To calculate a preliminary volume capacity for each site, two beach slopes were considered: 1:10 and 1:20. Gentler slopes, such as these, are typically required for beaches with frequent exposure to wave climates, to better absorb the wave impact and limit the erosion of the slope. In this instance, the gradual slope has been selected to promote easier access into the water, i.e. better for gradual wading. The volume capacity for each site would increase if a steeper slope (e.g. 1:7 or 1:5) was adopted. The height of the beach was assumed to marry with the existing natural height of the bank edge. Factoring in the available survey coverage data and observations from the BMT site investigation, the bank level was assumed to be +2.0 m AHD and the bank edge was reconstructed from aerial imagery. Figure 7-4 shows the reclamation footprints and slope extents for each location and Table 7-1 summarises the preliminary volume capacities.

Figure 7-4 Nearshore reclamation areas. Left: 1 in 10 batter, Right: 1 in 20 batter

Table 7-1 Estimate capacity volumes for the nearshore locations within Causeway Lake

Volume (m^3)	1 in 10 slope	1 in 20 slope
North-western Area	17,590	14,920
Northern Area	35,090	26,740
Southern Area	54,530	42,230
Total	**107,210**	**83,890**

As previously mentioned, this preliminary investigation considered the maximum available capacity at each site, irrespective of the preliminary master plan or typical beach widths. It is expected that the revised volumes, following evolution of the master plan, will likely be less than these values. The key outcomes from this exercise are as follows:

(1) The dredged material is likely to be suitable for beneficial re-use in nearshore beach reclamation

(2) There is sufficient dredge material to meet the reclamation demands of future shoreline development

(3) The three proposed nearshore locations are unable to accommodate the entirety of the expected dredged material volume, and auxiliary locations will need to be considered for disposal / re-use of excess material.

7.1.2 Beach Nourishment

7.1.2.1 North Kinka Beach

Placement of material along North Kinka Beach is recommended as a secondary location for remaining material, following reclamation of nearshore locations within the Lake. The two main characteristics of the beach are the broad tidal flats extending seaward, with slopes of above 1 in 500 between the mean sea level and the low water level (Beach Protection Authority, 1979), and the tidal channel connecting the Lake to the ocean. The area around Pinnacle Point experienced substantial change following the construction of the causeway in 1939 and now features a large sand spit extending southwards from Pinnacle Point. This sand spit forces the alignment of the tidal channel to follow the line of the frontal dunes are North Kinka Beach, which has been suggested to be a causal factor in the continual erosion of the beach, as it transports sand away from the system (Grigg and Piorewicz, 1989). The erosion of this area has historically presented a risk to the Scenic Highway and private properties along the beach. Management efforts in 1988 saw the excavation of a new tidal channel adjacent to Pinnacle Point. The excavated material was used to create a sand dam extending north-easterly from the existing beach, as seen in Figure 7-5. The purpose of the sand dam was to restrict flow through the old channel alignment, increasing the stability of the dredged channel (Piorewicz, 1990). It was estimated that a total of 15,000 m^3 of material was relocated in the operation. Gradually, the tidal lagoon partially infilled with sediment and new mangrove growth emerged. The channel eventually reverted to a southerly orientation, albeit westerly of its original path. A possible explanation for this is the reduction in tidal prism as the tidal dam infilled, reducing the volume and rate of flow through the channel and leaving it susceptible to accretion.

Although there appears to be no direct threat to the integrity of the Scenic Highway and coastal properties at present, dredged material could still be re-used beneficially to increase the available buffer and improve amenity on North Kinka Beach. As an initial investigation, placement footprints have been estimated from available current survey data (April 2021) and assuming nominal volumes of 50,000 m^3 and 100,000 m^3. As mentioned in the previous section, the volume capacity of the nearshore sites within Lake may require refinement to align with the future master planning outcomes. As such, there is no defined volume requiring placement at a secondary location. In the interim, these assumed volumes give an indication of the capacity of the beach and can be used as a starting point for further design of the reclamation area as the project progresses.

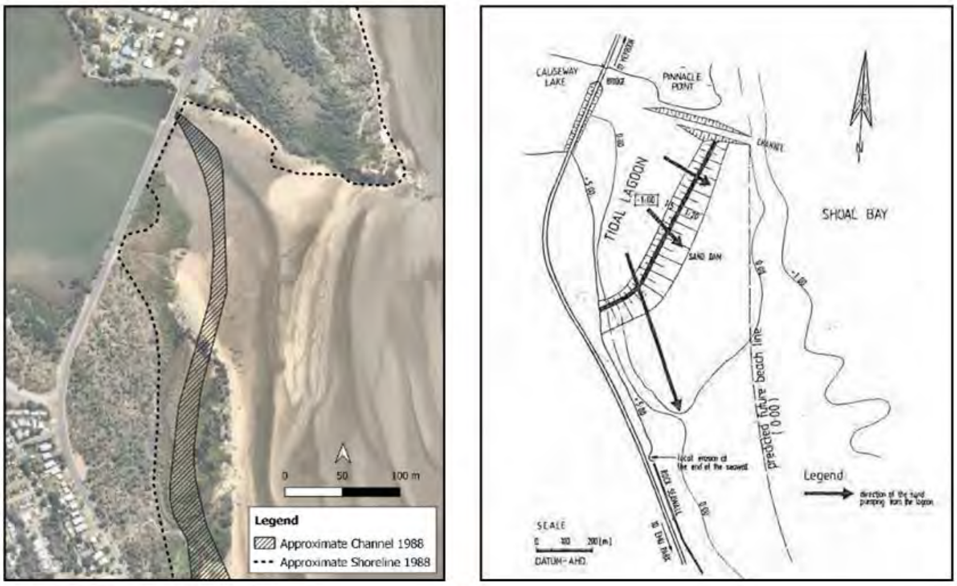

Figure 7-5 Left: approximate location of the shoreline and tidal channel in 1988 against May 2021 aerial imagery, Right: realignment of the tidal channel and orientation of the sand dam (Piorewicz, 1990)

Figure 7-6 shows the footprints and associated dredged volumes for two beach nourishment concepts. A beach slope of 1:20 has been assumed, adopted from the beach slope used for the 1988 sand dam (Piorewicz, 1990). The bank height has been assumed at +2.0 m AHD to marry the existing height of the dune. As with the nearshore reclamation areas, no consideration or additional design implementations have been included to deal with the proximity to the mangroves. This will need to be considered in future detailed design stages and depending on the as-is situation at the time of dredging.

In both scenarios, the channel alignment would be required to shift eastward to accommodate the dredged material. It's recommended that the disposal strategy be planned to gradually build the bank out, on the basis that the channel will realign naturally. However, some additional earthmoving operation may be required to induce or reinforce the natural realignment of the channel.

Figure 7-6 North Kinka Beach conceptual beach nourishment footprints

Table 7-2 Beach nourishment particulars for North Kinka Beach Nourishment Concepts

Variable	Scenario 1	Scenario 2
Footprint area	58,000 m^2	87,000 m^2
Volume	50,800 m^3	100,100 m^3
Beach Slope	1:20 batter from crest to +0.0 m AHD 1:5 batter from +0.0 m AHD to natural surface	

7.1.3 South Kinka Beach

South Kinka Beach has historically experienced erosion on the northern side of the Shoalwater Creek entrance. Figure 7-7 shows a tidal lagoon formed between the shoreline dunes and a sand spit extending southwards, following the beach alignment. It appears a geotextile breakwall was constructed at the mouth of the lagoon, likely as a mitigation effort against erosion of the dune system. Review of aerial imagery over the following decade indicates a positive trend in sedimentation in this area, with the tidal lagoon accreting and the dune buffer extending seaward. As of May 2021, the mangrove population south of the geotextile wall has significantly increased and the wall is completely buried.

Figure 7-7 Comparison of South Kinka Beach, August 2012 to May 2021

Based on the May 2021 aerial imagery and the general trend in accretion, it's unlikely that a significant quantity of material will be required for beach nourishment purposes in this area. However, transport of dredged material via pipeline and booster pumps remains a viable pathway for this site. This option could be exercised in either of the below instances:

(1) A severe weather event prior to or during the dredging campaign leads to a critical loss of sediment reserve along the beach and presents an immediate threat to coastal infrastructure. In this instance, the dredged material would be used to partially restore the beach buffer, until natural accretion resumes.

(2) The full quantity of dredged material cannot be accommodated through a combination of nearshore reclamation sites within the Lake and beach nourishment at North Kinka Beach. In this instance, placement of material would not be limited to the southern end of Kinka Beach. Instead, the full length of Kinka Beach should be considered for potential placement, whether this be placement above the high-water mark, or placement into the intertidal zone for distribution into the system.

7.1.4 South Kemp Beach

The Scenic Highway runs adjacent to Kemp Beach, situated 2.5 – 4 km from the Lake. The dune buffer is narrowest at the southern end of the bay, where the vegetated dune is approximately 15 – 20 m wide. Although the southern end of this beach is of relatively similar distance to South Kinka Beach, the pipeline route would be more complex and likely require additional booster pump/s to navigate over or around Bluff Point. This option should only be considered if severe weather event prior to or during the dredging campaign results in a critical loss of sediment reserve along the beach and presents an immediate threat to coastal infrastructure. In this instance, the dredged material would be used to partially restore the beach buffer, until natural sedimentation processes resume.

7.1.5 Onshore Placement

7.1.5.1 Commercial Quarry

Barlow's Earthmoving own and operate from a parcel of land situated south-west of the Lake. Barlow's confirmed their interest in receiving dredged material in written email correspondence dated 21st July 2021. They specified that they have capacity to accommodate the dredged material onshore in a portion of their parcel.

Barlow's have proposed use of an area to the north of the quarry, located within their land parcel. The area is described as a large low-lying area with a natural bund around all sides. The open side is adjacent to the salt pan and tidal creek.

Figure 7-8 shows the location of this area relative to Causeway Lake. There are existing 4x4 tracks connecting the area north to the Lake, south towards Barlow's Earthmoving compound, and east to the Scenic Highway. Some sections of the road are likely to require widening to accommodate the pipe management equipment. It is expected that several booster pumps will be required along the route.

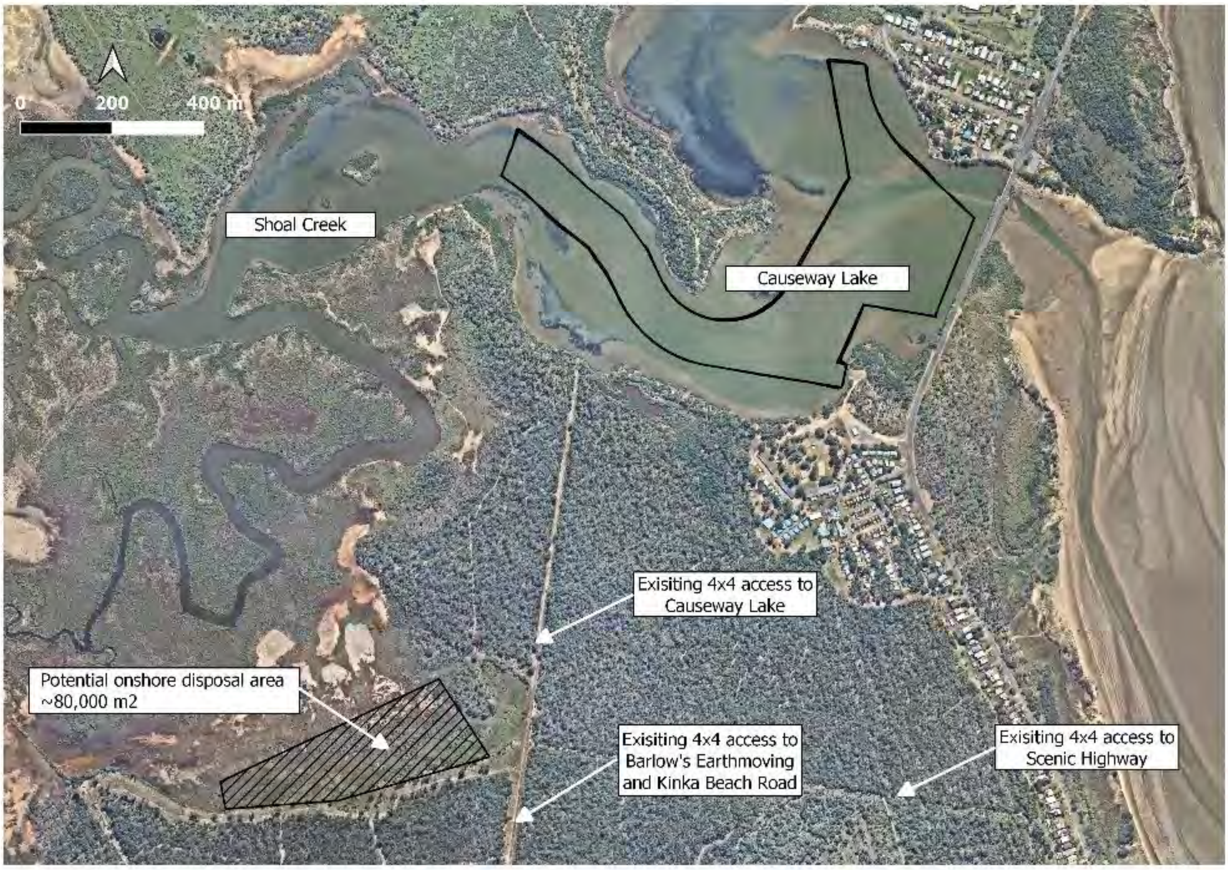

Figure 7-8 Potential indicative onshore disposal area

Additional bund walls will need to be constructed to contain the dredged material during and after placement. Excavation of material on site would be the most cost-effective solution for sourcing fill material to construct the bund walls. However, this depends on the sediment characteristics of the site, which would need to be confirmed in a geotechnical investigation. The design of the bund walls is dependent on the anticipated dredge volume, available disposal footprint and the existing ground elevations.

Onshore disposal areas are designed with an intake and an outlet point to manage the water of the dredged slurry. The dredged material is deposited as a slurry and flows towards the outlet point, allowing the suspended sediment particles to settle out of the slurry. Onshore disposal areas are typically designed in accordance with the anticipated sediment characteristics, to ensure there is sufficient time for the settling action. Depending on the surrounding environment and the associated environmental risk, the discharge water can either be released immediately through weirboxes, pumped to a secondary location or pumped back to the dredging area. For Causeway Lake, it's likely that 1 – 2 water pumps will be required to return the water back to the main basin, assuming one additional pump per kilometre of pumping distance. The potential disposal area lies adjacent to the tidal flats and the southern arm of Shoal Creek. Water could be discharged at these closer locations; however, the increased environmental risk would need to be assessed.

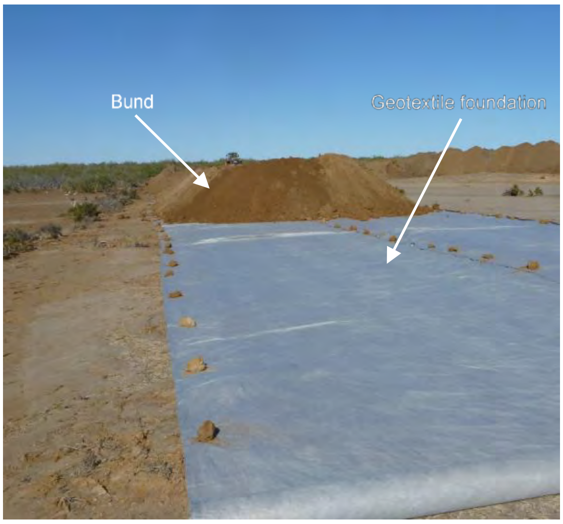

Figure 7-9 Example of an onshore bunded disposal area

There will be a comparatively larger scope of works, higher costs and time associated with the additional works associated with this work which include:

- earthworks enabling works to prepare the internal roads to accommodate the pipelines with potential of vegetation clearance which will require environmental planning and approvals
- earthmoving enabling works to prepare the onshore site which involve excavation of existing material, construction of bund walls, supply and installation of geotextile and potential quarry run material to protect the site, supply and installation of weir boxes, and earthmoving works during material placement to manage the integrity of site

- potential supply and installation of a series pumps to deliver dredged material to the site and to deliver the tailwater back to selected location
- potential environmental planning and monitoring during works to manage the quality of the tailwater
- This option for material placement is not relatively preferred because it has no beneficial re-use potential, and adds to the project scope, cost and time considerably. It is suggested that this placement option is considered as a third option only in the instance that nearshore reclamation and beach nourishment are fully unsuitable or there is excess material after placing of material at these sites.

7.2 Other Placement Considerations

7.2.1 Management of seagrass wrack

Seagrass covers a significant portion of the lakebed and although the dredging footprint was optimised to avoid and minimise impact to the dense meadows, some dredging of seagrass is still expected and needs to be managed. On top of the challenges seagrass adds to the dredging operations, often leading to entanglement of the cutter head, the disposal of the seagrass wrack requires careful consideration during planning. Seagrass wrack trapped in the Lake shores or beach intertidal zone, subject to continual or intermittent wetting, can generate bad sulfurous odour and be poorly received by community stakeholders. In addition, large quantities of seagrass on a sandy beach often reduce the beach amenity. The following options should be considered in the planning for the placement of the dredge material containing seagrass wrack:

- Burial of the seagrass wrack at the placement locations: The seagrass meadows are located on the surface of the lakebed and can therefore be dredged in initial cuts and placed as a base layer at the placement sites
- Re-use of the seagrass wrack as an agricultural resource: The seagrass wrack can be placed above the high-water mark, left to dry and collected in bulk quantities for distribution to interested agricultural parties for use as fertiliser
- Disposal into the intertidal zone for dispersion into the marine environment: Provided the coastal climate is appropriate, the material may be placed in the intertidal zone and allowed to disperse into the ocean by way of current and wave forces.

The anticipated scale of seagrass wrack disposal will need to be confirmed prior to dredging works commencing and there may be specific environmental regulatory requirements depending on the preferred disposal method(s).

7.2.2 Management of fine sediments

The dredged material is expected to be predominantly sand suitable for use in beach nourishment and land reclamation. However, there is a significant fines content in the southern section of the dredging footprint. This material will be ill-suited as an upper layer of a placement area, as it provides darker colour than colour of beach sand surroundings, less stability in the final reclamation or nourishment area and is also less pleasing for future users of the beach. To mitigate these issues, it’s suggested that the areas expected to contain high fines content be dredged first, and the material placed as a base layer in the reclamation area.

Fine material can also be placed in the beach intertidal zone. Additional environmental management and monitoring may be required to monitor the extents and intensity of plumes generated by placement of the fines.

8 Feasible Dredging and Placement Options

8.1 Active measures

Maintenance dredging in the Lake to restore historical seabed depths and recreational activities is feasible with varying degrees of constraints. The basis of assessment defined a volume of approximately 165,000m^3 of dredge-able material to achieve these objectives. This definition is for the purpose of this feasibility evaluation. In terms of cost and time effectiveness, it is preferred to undertake the full scope of dredging works in one campaign / session. The project can be staged in two or multiple sessions, but this will come at additional mobilisation / demobilisation costs and time, additional environmental impacts and management, and additional planning and administration works. Dredged volumes can also be reduced to suit costing and timing requirements by changing the defined channel parameters in terms of depth and width if needed but may impact the requirements for Lake uses.

In addition to being the most cost and time effective (Section 9), the preferred method in terms of technical efficiency is the use of small CSD equipment and placement of material for beneficial reuse along the Lake shoreline in coordination with future development plans for these shores. Placement of material along North Kinka Beach is recommended as a secondary suitable location for beneficial reuse of remaining dredged material. The key constraint with this preferred dredging and placement method is the current unsuitability of roads and ramps to transport and launch the small CSD. This can be actively mitigated by engaging with dredging contractors to assess practical requirements for accessibility, and reserving budget for road and ramp upgrades that would ideally align with broader development plans of the Lake.

A second preferred dredging method on technical grounds is the use of amphibious excavator and placement of material in the same Lake shoreline and North Kinka Beach locations. The amphibious excavator can move from shore to water autonomously negating the need for major upgrades to ramps but still requiring upgrade to internal transport roads. The main risk with this equipment is availability in the local market. This again can be actively mitigated by engaging with dredging contractors to try to secure a piece early in advance.

8.1.1 Future measures and maintenance requirements

BMT used the historical (1960 – 2007) raw survey data sets provided by LSC to conduct a high-level desktop assessment of the historical rate of sedimentation within the defined dredge footprints for Areas 1 and 2 (basis of assessment). The assessment was used to provide an indicative forecast of future sedimentation and hence advise on corresponding maintenance requirements.

Only the 1986 and 2007 survey data sets could be correlated with the recent 2021 survey. The 1960 survey data set was considered unreliable by BMT for comparison purposes due to its limited coverage and unknown datum and coordinate system used.

The 1986, 2007 and 2021 datasets had different parameters in terms of coverage areas and density of survey points with the 2021 survey providing the most detail. Interpolation was used to infer the depth and sediment volumes in the area gaps between the different surveys. Due to the large gaps, the accuracy of interpolation in these areas is considered low and should be used with caution. Figure 8-1 shows the changes to seabed elevation within the dredge footprint from 1986 to 2021.

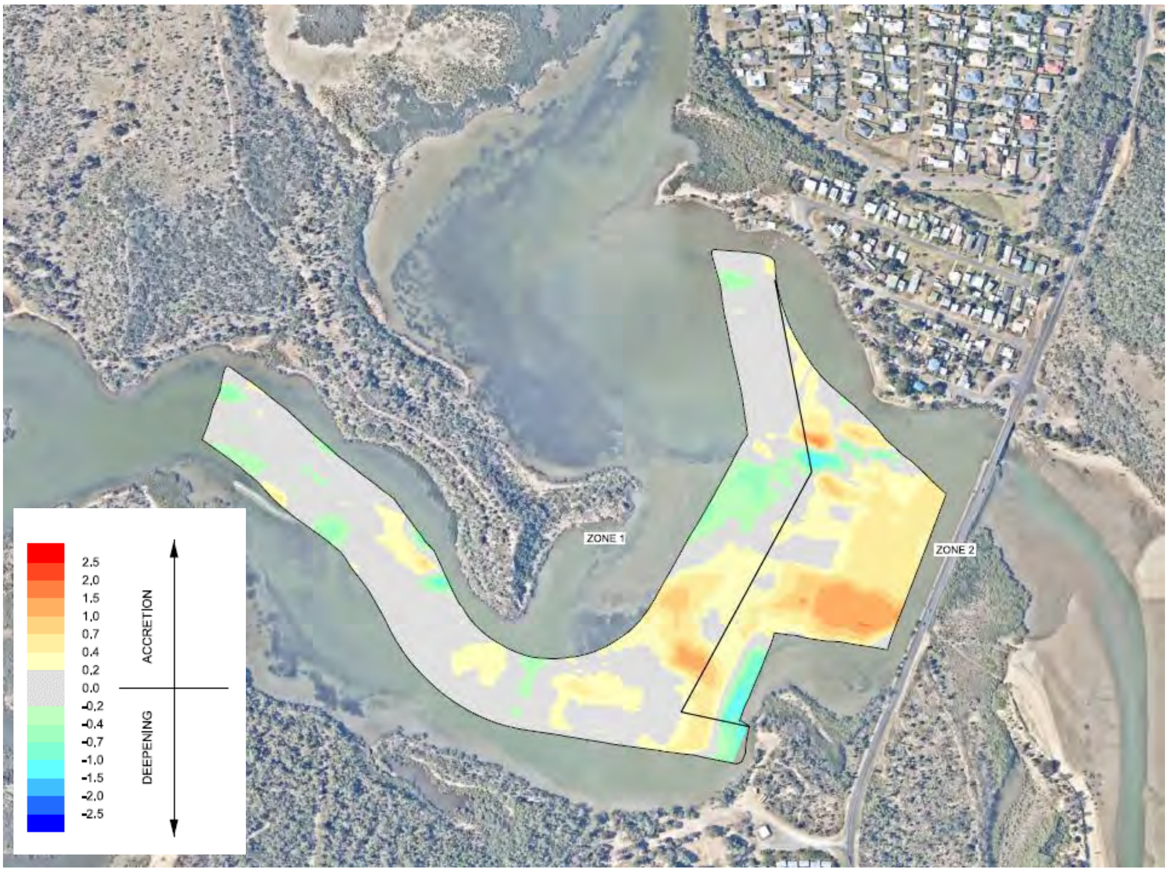

Figure 8-1 1986 – 2021 Survey difference and sediment movement within defined dredge areas

Based on examination of sedimentation rates within the defined dredging footprints in the Lake during the periods 1986-2007 and 2007-2021, the following is noted:

- The period 1986 – 2007 saw relatively higher levels of net sedimentation throughout most of the areas in the Lake with an average rate ~1,500m^3/year. This is lower than the average rates of 2,000m^3-4,000m^3 in record (Piorewicz, 2008) because the later included the whole Lake area and adopted different modelling approach.
- The period 2007 – 2021 saw relatively stable period with considerably lower average sedimentation rate halved to 750m^3/year.

The above suggests that most of the shallowing in the Lake has taken place slowly and gradually in the period from when the causeway was constructed in 1939 to 2007, with the annual average rate of sedimentation in more recent years. Overall, the sedimentation rates in the Lake are considered low over a relatively large area.

The information above has been used to estimate a conservative rate of sedimentation in dredge Areas 1 and 2 following the completion of the first dredging campaign. The forecast included the following key assumptions:

- More than 50% of the sedimentation will occur in dredge Area 2 near the centre of the Lake, based on the patterns observed over the period 1986 – 2021.
- Dredging artificially induces sedimentation in higher rates than natural ones by creating artificial traps for sediments to settle in. Sedimentation rates following dredging works are expected to be higher than historical normal rates.
- Allowance for significant flood events that may increase the historical average sedimentation rates.

Based on the above assumptions, the historical sedimentation rates have been conservatively factored by 50%:

- 1,500m^3/year for dredge Area 1
- 3,000m^3/year for dredge Area 2 (central Lake)

Minimum depth triggers within the Lake were assumed and once reached by sedimentation, will call for a maintenance dredging campaign. For dredge Area 1 with motorised activities, the trigger depth has been set at -0.2 mAHD, providing a 1.5 m water depth which is the minimum depth recommended for 1 m draft motorboats (AS3962). A nominal water depth of 1 m has been set as trigger minimum depth for swimming, wading and water activities in Area 2. Table 8-1 provides a summary of suggested maintenance dredging triggers, forecast maintenance dredging frequency and volumes.

Table 8-1 Maintenance dredging triggers, volumes and frequency

Dredging area	Dredge design depth	Trigger depth for future maintenance	Sedimentation rate (m^3/yr)	Accretion Volume (m^3)	Indicative duration
Area 1	-0.5mAHD	-0.20mAHD	1,500	44,000	30 years
Area 2	-0.5mAHD	+0.30mAHD	3,000	50,000	16 years

The above estimates are considered conservative. It is recommended that LSC undertakes a comprehensive bathymetric survey in the Lake at a minimum of every 5 years to ascertain actual sedimentation rates that are occurring.

It is preferred to combine dredging in Areas 1 and 2 in one campaign in the future. This is feasible given the conservatism in the assumptions and because the breach of Area 2 triggers will not impact the motorised and most water sports activities in the Lake. It is therefore reasonable to assume that maintenance dredging of approximately 140,000 m^3 may be required every 30 years in the Lake to manage sedimentation post the first dredging campaign.

It is also envisioned at this point in time that the same current preferred dredging methods will still apply including use of small CSD, amphibious excavators and mini CSD. As with other technologies, the dredging technology advances rapidly to become more efficient, fully electrical, easier to transport and more cost efficient. Assuming the maintenance material is suitable for beach nourishment, preference should be given to placement at North and South Kinka Beach, given that the Lakeshore will likely be saturated with material placed from the first campaign.

8.2 Passive measures to reduce siltation

The rate of sedimentation within the Lake has been analysed through comparison of historical bathymetric surveys described above and also via application of analytical and numerical modelling methods reported by others (e.g. Piorewicz and Soetanto, 1999; Soetanto and Piorewicz, 2005). The annual average sedimentation rate has been estimated between 2,000-4,500 m^3/year, acknowledging the limitations associated with the available datasets, data uncertainty and modelling approaches. Piorewicz and Soetanto (1999) suggest approximately half of the annual sedimentation volume is fine material associated with catchment runoff, while the other half is marine sand transported to the Lake by the higher tides that exceed the causeway bridge sill level. Recent sediment sampling and analysis showed a dominance of finer material at the Lake surface, with a sandy layer beneath (Section 4.3.1 & BMT 2021). The relative percentage of fines was greater on the western side of the Lake (towards Shoal Creek). Options to reduce the sedimentation rate therefore fall into two categories:

- Catchment management measures to reduce the transport of the generally fine sediments
- Further limiting of the tidal exchange to reduce the transport of marine sands

These are briefly discussed further below.

8.2.1 Catchment Management

The transport of catchment sediments to estuaries and ultimately the sea is a natural process. However, the clearing of catchment vegetation for agricultural purposes and urbanisation upstream of the Lake have likely increased the sedimentation rate, and since the construction of the causeway these sediments are unlikely to reach the sea. Catchment sedimentation management measures relevant to the Lake include:

- Increasing vegetation cover, which is a major factor in controlling catchment erosion, reduces the impact of rainfall runoff on bare soils and wind removing soil particles;
- Increasing riparian vegetation cover to stabilise the creek banks;
- Managing any potential runoff of sediment from urban areas (or areas proposed for development);
- Restricting livestock from access to the creek banks;
- Rehabilitate wetlands upstream from the Lake; and
- Fire management so the potential loss of vegetation to bushfire is minimised.

Council may already implement some or all these measures through existing catchment management and sediment control programs. If not, in addition to reducing Lake sedimentation adopting these measures will also provide other environmental benefits to the area.

Broad crested weirs to regulate creek flows have been previously identified as a potential catchment sediment control measure (e.g. Piorewicz, 2008). These structures may provide some benefit to Lake sedimentation; however, it is noted that the sediments trapped by the weirs would also need to be periodically removed and managed. Modifying the creek flows would require careful consideration to avoid adverse environmental outcomes and/or impacts to flooding.

8.2.2 Tidal Control

Reducing the volume of sediment reaching the Lake from the sea would likely require increasing the sill level or constructing a gate mechanism. Piorewicz (2008) described a variable gate system designed to allow passage of high tides up to a threshold (~4.1 m LAT) and then blocking the higher tides assumed to have the greatest sediment transport potential. Like the broad crested weirs, further modification of flows to the Lake from the sea would require careful consideration to avoid any undesirable outcomes, particularly to lake water quality.

8.2.3 Discussion

The Lake sedimentation rate is relatively low and therefore the cost to plan, design and construct flow regulating devices (such as weirs or gates) is unlikely to be justified, unless there were other mutually beneficial reasons for the structures and the potential environmental and/or flooding risks could be managed. It is noted that projected sea level rise may also drive the need for modification of the causeway and that tidal flow regulation would be a key consideration of the planning and design to mitigate sea level rise impacts to the Lake. The LSC Coastal Hazard Adaptation Strategy (CHAS) identified sea level rise risks to the Lake needing to be addressed by 2050 if sea level rise projections are realised (BMT 2021b).

All catchment management options are generally supported and represent relatively low-cost opportunities to reduce sedimentation and provide other environmental benefits. Programs that already support, or have the potential to support, these measures should be reviewed in the context of lake sedimentation. There may be federal and state government funding opportunities to assist with implementing catchment management initiatives that seek to reduce sediment and nutrient runoff to local waterways with a connection to the Great Barrier Reef.

9 Costing

9.1 Dredging project costs

9.1.1 Cost estimate options

A Rough Order of Magnitude Cost Estimate (ROM Estimate) exercise was performed for six identified scenarios, based on a bottom-up approach with inputs in the form of typical industry rates and analogous/comparative values from past BMT projects. The six scenarios are defined in Table 9-1.

Table 9-1 Cost estimation options

Scenario Number	Dredging Method	Material Placement Option
1	Small cutter suction dredge (CSD)[1]	Nearshore reclamation within Causeway Lake + Beach Nourishment at North Kinka Beach
2	Small cutter suction dredge (CSD)[1]	Onshore disposal area at local quarry
3	Amphibious excavator with rose cutter attachment	Nearshore reclamation within Causeway Lake + Beach Nourishment at North Kinka Beach
4	Amphibious excavator with rose cutter attachment	Onshore disposal area at local quarry
5	2 x mini auger dredge, operating simultaneously[2]	Nearshore reclamation within Causeway Lake + Beach Nourishment at North Kinka Beach
6	2 x mini auger dredge, operating simultaneously[2]	Onshore disposal area at local quarry

1. A 12" CSD was assumed for the purposes of this exercise

2. The campaign duration for a single mini auger dredge was assumed to be unfeasible

The skeleton of the ROM Estimate can be broadly categorised into four streams: preliminaries, costs associated with dredging activities, costs associated with the transportation and placement of dredged material, and costs associated with environmental offsets. The assumptions and inputs of these streams are discussed in more detail in the following sections. Specific assumptions and the detailed cost breakdowns are attached in Appendix D.

9.1.2 Preliminaries

The preliminary cost items associated with the project are listed below and were assigned as lump sum items, except for the weekly progress logs, consultancy fees and uncertainty allowance:

- Site enabling works includes costs associated with preparation of the site for the launching and retrieving of the dredge equipment.
- Mobilisation of dredging and land-based equipment includes costs associated with the site setout, the mobilisation and launching of the dredge, mobilisation of the earthmoving spread, the

mobilisation of the slurry transportation pipeline (maximum length of 2 km) and 1 additional booster pump, and the provision of signage and buoyage.

- De-mobilisation of dredging and land-based equipment includes costs associated with the retrieval and de-mobilisation of the dredge, the de-mobilisation of the earthmoving spread, slurry transportation pipeline and additional booster pump.
- Pre-campaign investigations encompass the hydrographic and benthic habitat surveys recommended to be conducted prior to dredging. The outcomes of these activities will influence the target dredging volume and the seagrass management strategy.
- The insurances, project management plan and weekly reporting items are standard requirements for all dredging projects.
- Engineering and project management consultancy services were assumed to be 5% of the total project costs.
- To account for uncertainties in the costing at this preliminary stage of the project, an additional 20% the project cost was included in the total. It is expected that this line item will be refined as the project progresses through further design stages.

The magnitude of the site enabling works, mobilisation, and demobilisation lump sums are dependent on the respective dredging method. The small CSD has been assumed to have the highest site enabling costs, due to its larger size and more complex mobilisation/de-mobilisation procedure. Although the mini auger dredges are assumed to require less site enabling works, the mobilisation/de-mobilisation costs are the highest as there are two units. The amphibious excavator has the lowest associated costs over all three-line items.

9.1.3 Costs associated with dredging activities

The dredging costs have been calculated based on the preliminary target dredge volume and the assumed dredging production rates, incorporating an operational availability percentage. The following assumptions apply to all six costing scenarios:

- A target dredge volume of 165,000 m^3, based on a -0.5mAHD design depth and the April 2021 bathymetry.
- A dredging availability of 60%, with an additional 20% of payable standby.
- The project duration assumed 10 hour working hours per day, and a 6-day working week.
- The dredging rates, shown in Table 9-2, encompass the operation of the dredge and the supporting workboat, including any site personnel. They do not include provision for the operation of additional booster pumps, which is treated as an additional line item.

Table 9-2 Assumed inputs for the associated dredging costs

Dredging Method	Production rate (m^3/hour)	Unit rate – working ($/hour)	Unit rate – standby ($/hour)
Small CSD	100	$1,450	$870
Amphibious excavator	60	$1,000	$600
2 x mini auger dredge	40 (2 x 20)	$1,250	$750

9.1.4 Costs associated with material management

9.1.4.1 Earthmoving spread

An earthmoving spread consisting of one excavator, one dozer, and one loader was assumed to be operation for the duration of the dredging campaign. This spread will oversee the management of the material placement sites, such as distributing material, constructing design slopes, and also manage the pipeline transportation system. The following assumptions apply to all six costing scenarios:

- The earthmoving spread was assumed to be dependent on the dredging duration, with the same availability (60% availability, with 20% payable standby)

Table 9-3 Assumed unit rates for the earthmoving spread

Earthmoving plant	Unit rate – working ($/hour)	Unit rate – standby ($/hour)
Excavator	$225	$135
Dozer	$225	$135
Loader	$150	$90

9.1.4.2 Additional transportation costs

The dredging unit rate is not inclusive of the operation of additional booster pumps or return water pumps. These are treated as a separate line item, with the following assumptions:

- A unit rate of 1$/$m^3$ is assumed for additional pumps, per item.
- An additional booster pump is required for every kilometre exceeding the initial 1 km.
- An additional return water pump is required for every kilometre exceeding the initial 1 km.

9.1.4.3 Onshore disposal area construction

The management and design of the nearshore reclamation and beach nourishment areas is assumed to be covered under the unit rates of the earthmoving spread. Conversely, the use of the onshore disposal area at the local quarry will require additional costs to cover the preliminary site preparation works. This will include clearing of the vegetation at the proposed site and construction of bund walls. The characteristics and assumptions of this scenario are listed below:

- The footprint of the proposed onshore area is assumed to be ~80,000 m^2
- A material bulking factor of 1.1

- A bund height of +2.75mRL (includes 0.3 m freeboard)
- Crest width of 3 m, with 1:3 batters
- Perimeter of 1,500 m
- Assumes that all material required for the bund construction can be sourced onsite, i.e. excavated in situ
- The tailing (excess) water will be required to be transported back to the main Causeway Lake basin (noting that other tailwater discharge and management options may be available)
- Site enabling costs have been excluded, i.e. there are suitable access roads for the earthmoving spread to access both the bunded area and the pipeline route.

9.1.5 Environmental offsets

For the purposes of this exercise, a unit rate per m^2 of impacted seagrass has been included. This unit rate was calculated from the initial lump sum generated by the Queensland Government financial offset calculator. Note that the impacted area used in the cost estimate includes only the area directly affected by the proposed dredging footprint and reclamation areas, as of the April 2021 benthic habitat survey. This cost is likely to vary as the project progresses through future design phases.

An offset is only payable if seagrass does not recover within 5 years; it may be possible to negotiate a 5-year monitoring program with the Department of Agriculture and Fisheries, so that a payment is only made where seagrass does not recover, reducing Council costs.

Council does have the option of a proponent-driven offset through a Direct Benefit Program; this would involve undertaking marine plant restoration and regeneration works on an appropriate land parcel that can be secured in perpetuity by Council and would require ongoing management for some time. Restoration and regeneration within the Lake catchment may also deliver a reduction in sedimentation (refer Section 8.2.1) and therefore assist with delaying the need for future maintenance dredging (refer Section 8.1.1). Council would have to consider the costs and time such an option would take in comparison to a financial offset.

9.1.6 General assumptions / exclusions

General assumptions and exclusions from this exercise are listed below:

- Costs associated with environmental approvals and/or monitoring before, during or after the dredging campaign have been excluded.
- Offset costs associated with habitat impacts other than seagrass (such as mangroves) has been excluded.
- It is assumed that a suitable area is available for use a pipe laydown area. Construction of a new area will incur additional costs.
- Costs associated with the construction of access routes to the material placement area have been excluded.

9.1.7 Cost summary

Table 9-4 summarises the total costs for each scenario, Figure 9-2 shows a more detailed breakdown of each cost component and Figure 9-2 shows the project durations estimated for each dredging scenario. The main findings of this exercises are listed below:

- The small CSD, disposing to the nearshore areas and North Kinka beach, has the least costs.
- The construction of the onshore disposal area has been estimated at ~$950,000 and the scenarios with this inclusion are ~$1.4M greater in total.
- The amphibious excavator is ~$1.2M higher in cost than the small CSD, although the actual dredging costs of the excavator are comparable. The main variation between these options is the costs associated with the earthmoving spread, as it is required to be operating for longer in the amphibious campaign due to the reduced production rate.
- The 2 mini dredges are ~$6.6M greater than the small CSD, largely due to the lower production, greater duration required, yielding higher rate per unit production.

Table 9-4 Summary of total costs

Option	Material placement on nearshore areas and North Kinka Beach			Material placement to the Onshore Disposal Area		
	Small CSD	Amphibious Excavator	2 x Mini Dredge	Small CSD	Amphibious Excavator	2 x Mini Dredge
Total Cost ($AUD)	$7,245,000	$8,453,000	$13,783,000	$8,603,000	$9,682,000	$15,200,00

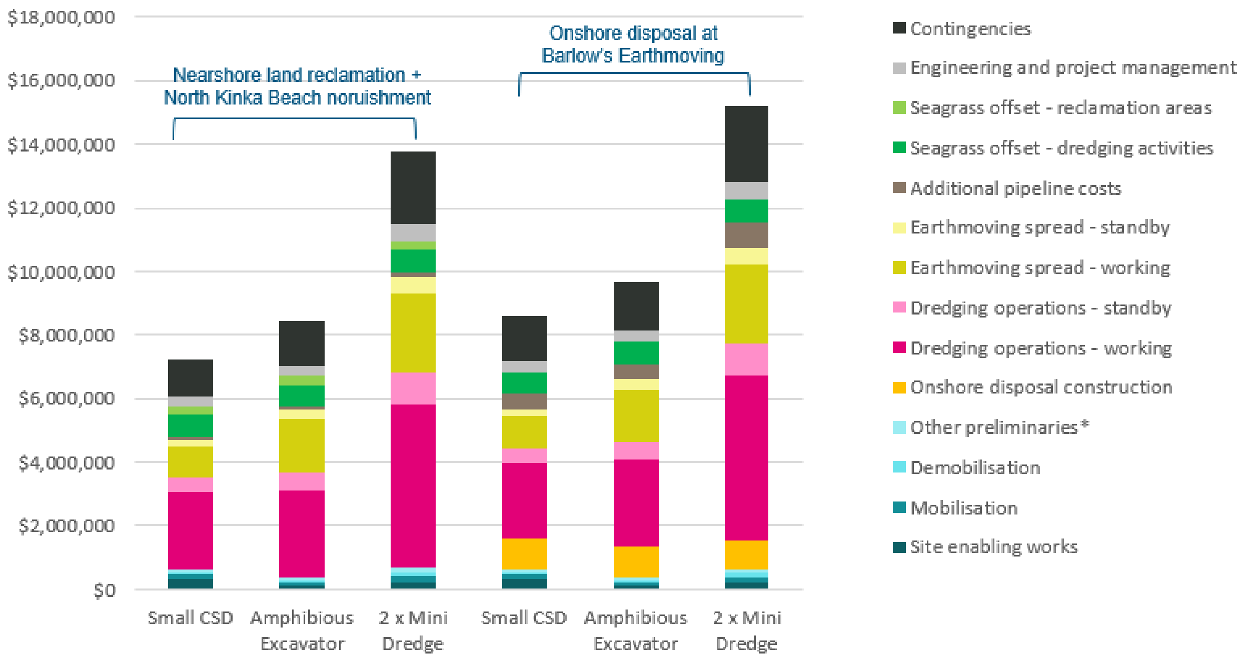

Figure 9-1 Comparison of dredging costs

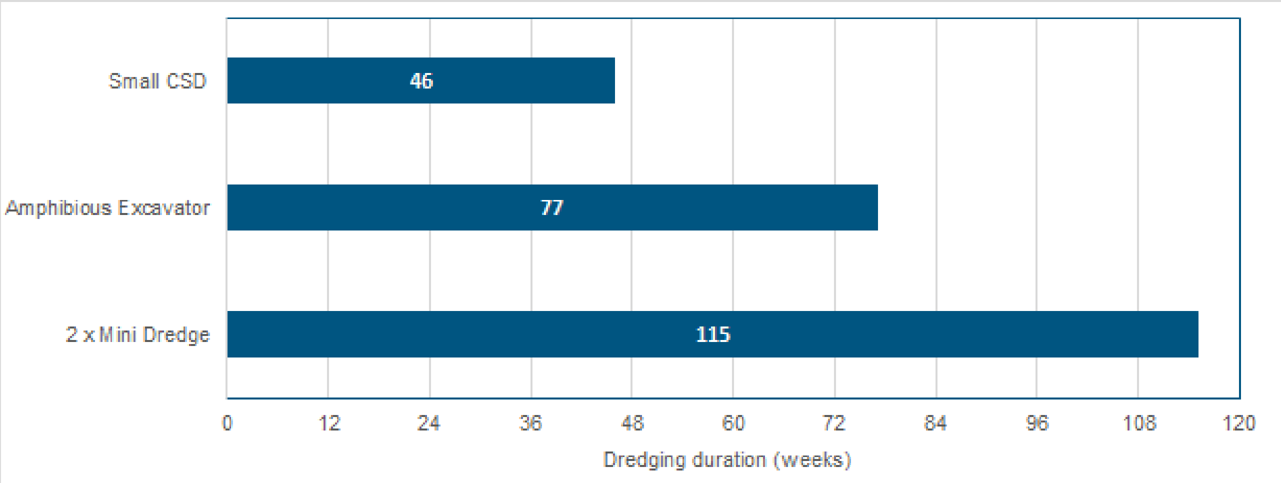

Figure 9-2 Estimated project durations

9.2 Future maintenance dredging costs

Reference to Section 8.1.1, it is assumed that future maintenance dredging of 140,000m^3 will be required in 30 years from the first dredging campaign to restore seabed depths in the Lake.

Three cost estimate options have been adopted for the purpose of this future works; use of small CSD, amphibious excavator and mini dredge. It was assumed that all material will be placed in North and South Kinka Beach. The net present cost (NPC) of these three cost estimate options assumed a project lifetime of 30 years. An annual real discount of 3% has been assumed.

Summary of estimated net present costs of future maintenance dredging works is provided in Table 9-5.

Table 9-5 Future maintenance dredging cost estimates

Option	Material placement on North and South Kinka Beach (140,000m^3)		
	Small CSD	Amphibious Excavator	2 x Mini Dredge
2021 Cost ($AUD)	$6,147,000	$7,172,000	$11,694,000
NPC (over 30 years)	$2,532,000	$2,955,000	$4,818,000

10 Risk Assessment

The feasible dredging and placement options evaluation has been considered through a risk assessment process, designed to align with Council's corporate risk framework. The following risks were considered in the context of social, economic and environmental consequences:

- Dredge method:
  - Site access
  - Dredging production rate
  - Direct impact to seagrass
  - Indirect impact to seagrass
  - Navigational hazards during dredging
  - Noise and other disruptions to community
- Placement method:
  - Access to placement site
  - Beneficial reuse
  - Impact to marine or terrestrial vegetation
  - Loss of fine material
  - Accumulation of dredged seagrass and other organics
  - Disruptions to the nearby community.

The risks associated with dredge material transport options has also been considered, noting that transport as a slurry via a pipeline is expected to be the only viable option.

Details of the risk assessment framework and results are provided in Appendix C and was prepared in consultation with the project team. In summary, the following potential high risks have been identified:

- Availability of suitable dredging equipment leading to a delay to project commencement and additional time and cost associated with using suboptimal dredging solutions
- Disruption to the community during the construction phase of the project, including temporary closure of roads, partial closure of Lake, high levels of noise, etc.
- Direct impacts to seagrass that cannot be avoided
- Access to material placement sites beyond the Lake shoreline
- Challenges gaining State and Federal environmental approvals.

These risks were initially assessed as 'high' but can likely be reduced to acceptable levels through a combination of early and ongoing engagement with:

- Dredging contractors to discuss fleet availability and scheduling, mobilisation/de-mobilisation requirements and pipeline alignment options
- Stakeholders and the community about the expected disruption associated with the works
- State and Federal regulators to confirm the approvals pathway and approach to managing unavoidable environmental impacts (such as an offset payment for the loss of seagrass).

Operational risks during dredging works have not been considered at this preliminary stage of the project. However, these risks should be defined and considered as part of the recommended early engagement with contractors who can offer suitable dredging solutions to the local area.

11 Summary and Conclusions

An engineering evaluation for determining the feasibility of dredging the Lake to restore its recreational and environmental functionality has been completed. The evaluation determined that dredging is feasible in the Lake with varying degrees of constraints. The key findings and outcomes include:

- In the dredging context, the evaluation considered the optimisation of future Lake uses and infrastructure development plans, suitability of seabed soil characteristics, minimisation of impact to the environment, effectiveness of cost and time, and mitigation of risks.
- The assessment is based on conceptional division of the Lake into two areas catering for motorised and non-motorised activities, a channel depth of 1.9m available at low water periods, and a channel width that ranges between 75-100m for motorised activities. The estimated dredging volume, including a 0.3m overdredging allowance, is approximately 165,000m^3
- Earlier site investigations conducted by BMT concluded that the seabed soil material is dominated by silty sands, except for the south eastern section which is dominated by soft silty and clayey materials. Overall, the material available to dredge in the Lake is considered ‘easy’ in terms of dredge-ability by most dredging equipment and suitable for transport and placement.
- The site investigations confirmed that large areas of the Lakebed are covered by seagrass meadows with varying densities. The definition of the dredging footprint has considered minimising impacts to seagrass by avoiding where practical these areas and without significantly affecting the future uses of the Lake. It is expected that an environmental offset would need to be paid to the State Government as part of the works. These offsets have been included in the cost estimates.
- Three methods have been identified as suitable for achieving the dredging scope in the Lake. These preferred options include the use of small cutter suction dredge (CSD), amphibious excavator with both backhoe and cutter attachments, and mini auger or cutter suction dredge.
- The evaluation recommends the use of Lake shores and North Kinka Beach to place material dredged from the Lake. In addition to being the most cost-effective, both sites provide sufficient capacity to accommodate the dredging volumes and provide an opportunity for sustainable beneficial re-use of dredge material for lakeshore future development and beach nourishment purposes. Dredged material with higher content of fines and seagrass wrack will require careful planning and management before placing on the Lake shores or beach areas.
- The cost estimates of the preferred dredging and placement options included allowance for site access enabling works, dredging and reclamation, seagrass offset costs, engineering and project management costs, and contingency allowance. The estimated total costs range between $7M and $13M depending on the method. A summary of project scope, costs, time and risks is provided in Table 11-1.
- The evaluation identified the major risks associated with the preferred dredging options and proposed suitable risk mitigation measures. The two highest risks include inaccessibility to the Lake site by heavy dredging machinery due to unsuitable roads and ramps, and unavailability of

suitable dredge equipment at the time of dredging due to limited supply of equipment in this niche market. Early engagement with dredging contractors is recommended as a key mitigation measure to both risks to secure equipment that is optimal for site access and completing the dredging scope. There may be a need to upgrade existing internal roads and boat ramps to enable access of selected dredge equipment to site. A nominal sum for these enabling works in addition to an increase in contingency sum have been included in the project cost estimates to cater for this financial risk. There is opportunity to align and coordinate the objectives of these site access enabling works with future Lake infrastructure development works for mutual benefit and cost effectiveness.

- The sedimentation and the extents and density of seagrass in the Lake change with time. The evaluation recommends that an additional bathymetric survey and benthic habitat surveys are completing during the detailed design phase to ascertain the dredge volumes and extents of seagrass prior to the commencement of dredging works. This will impact on project costs but not expected to be significant given the low sedimentation rates and current extents of seagrass.
- The evaluation confirmed that the historical sedimentation rates in the Lake is relatively low. This will result in low future maintenance dredging requirements. It is conservatively estimated that maintenance dredging of approximately 140,000m^3 seabed material from both dredge areas may be required every 30 years. At present, it is assumed that same preferred dredging methods will apply and that all material will be placed in North and South Kinka Beach. The estimated net present cost of these maintenance works over 30 years ranges from $2.5M to $4.8 depending on the dredge method. The above estimates are considered conservative. It is recommended that the Shire undertakes a comprehensive bathymetric survey in the Lake every 5 years to ascertain actual sedimentation rates and dredging requirements.
- The evaluation included high level assessment of alternative passive measures to reduce the future sedimentation rates and supported catchment management options that are considered low-cost and environmentally sustainable. These options include increasing vegetation cover, managing any potential runoff of sediment from urban areas, restricting livestock from access to banks, and rehabilitating wetlands upstream and enhancing fire management. There may be federal and state government funding opportunities to assist with implementing catchment management initiatives that seek to reduce sediment and nutrient runoff to local waterways with a connection to the Great Barrier Reef.

Table 11-1 Summary of project methods, cost, time and risks

	Estimated project cost	Estimated project duration	Summary comments
Small CSD	$7.245M	46 weeks	The best value for money and time efficient solution. Key constraint: accessibility to the Lake area
Amphibious excavator	$8.453M	77 weeks	The middle solution. Key constraint: very limited availability in the market
2x Mini dredges	$13.783M	115 weeks	The least preferred due to low inefficiency

Further planning and design studies are required to progress the option of dredging the Lake. An outline of the proposed workflow and timing is provided in Table 11-2.

Table 11-2 Proposed Workflow for Progressing the Planning and Design for Dredging the Lake

Activity	Description	Timing
Engagement & Master Plan Review/Update	• State agency engagement to discuss the outcomes of the dredging feasibility evaluation and development application requirements. • Considering the outcomes of the dredging feasibility assessment in the context of broader planning for Causeway Lake, including the opportunities and constraints associated with the proposed lakeshore reclamation footprints. • Stakeholder engagement.	6 months
Dredge and Placement Area Concept Design Phase	Building on the basis of assessment developed for this project and the proposed Master Plan Review/Update outcomes, refine the dredge and placement area design. The Concept design package to include: • Basis of Design report • Concept drawings • Outcomes from engagement with dredging contractors to confirm the availability of preferred equipment	6 months
Preliminary Design Phase (50%)	Preliminary design package to include: • Further geotechnical investigations • Design Drawing set including dredging and placement area general arrangement plans and cross sections • Technical Specifications • Proposed construction methodology (including engagement with dredging contractors) • Functional requirements such as shoreline access, amenity, drainage, vegetation management • Safety in Design report • Cost estimates	3 months
Environmental Approvals Phase *(also refer Appendix B; State approvals requirements to be confirmed through further engagement)*	Undertake studies to support a development application for tidal work and work in a coastal management district, marine plant removal, material change of use for an Environmental Relevant Activity to gain the relevant state and federal approvals, including: • Environmental impact assessment, reviewing impacts to the Great Barrier Reef World Heritage Area, wetland values and protected species • Impact assessment to coastal processes and water quality, likely to require monitoring data and numerical modelling • Detailed sediment sampling and analysis to National Assessment Guidelines for Dredging (NAGD) standard • Offset Agreement for any residual impacts on marine plants (e.g. seagrass and mangrove) • Detailed terrestrial vegetation survey if removal cannot be avoided during placement activities	12 months
Detailed Design Phase (90% and 100%)	• 90% detailed design package to include (issued for client review) to include updated Basis of Design Report, Design Drawings, Technical Specification and Cost Estimate. • 100% detailed design package to include Issued for Construction (IFC) Drawings, Bill of Quantities, Approvals Documentation and final versions of the design reports.	3 months
Tendering Phase	For construction tendering	2 months

12 References

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Appendix A Field Investigations Report

Causeway Lake Geotechnical and Site Investigations

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Executive Summary

Causeway Lake is an impounded tidal basin between Mulambin and Kinka Beach, south of Yeppoon on the Capricorn Coast. The lake is fed by Shoal Creek to the south and Mulambin Creek to the north. A rocky causeway was constructed in 1939 to link Yeppoon with Emu Park, resulting in the creation of the lake. The lake is flushed with seawater during spring tides but cut off from the ocean on alternating weeks following the approximately fortnightly patterning of neap and spring tide cycles. This regime makes the system very different tidally and ecologically from surrounding estuaries on the Queensland coast. Anecdotal and previous survey evidence suggests that the lake is becoming shallower.

Livingstone Shire Council intends to revitalise the Causeway Lake area with the goal of optimising recreational use opportunities on the lake and facilitating supportive development along the lake's north and south shores. Restoration of the lake system is also intended to preserve the present day environmental values that could be impacted by ongoing sedimentation. This technical report supports the intent to revitalise the Causeway Lake area by providing data to inform costs, benefits, and risks of potential lake management options. Specifically, bathymetric and land-survey data were collected, subtidal marine plants and benthic communities were mapped, instrumentation was deployed to examine the relationship between tides, salinity and temperature, and sediment coring was performed to examine the physical nature of sediments and potential contaminants in the lake bed.

Sentinel-2 false colour imagery, sidescan sonar mosaics and ground truthing were used to delineate an extensive bed of seagrass consisting of one species; *Halodule uninvervis.* The largest and densest meadows were located in Mulambin Creek and smaller but substantive meadows found along the creek margins and surrounding the islands of Shoal Creek. The meadows in Causeway Lake exhibit an unusual elongated growth form, are monospecific, and they do not enter the intertidal zone. This is likely the result of intermittent connectivity with the ocean where very shallow areas in the lake may be prone to high temperatures and excessive solar radiation. Rocky habitats were also present surrounding the base of the causeway and rock wall, along the northern lake bank and at the junction of the creeks. There were no sensitive receptors (such as hard or soft corals) living on any of the rocky habitats.

Deployed instrumentation showed a rapid rise in water level associated with incoming spring tides and relatively slow retreat of the tide down to the next point where the tide rose above the causeway sill. The largest tides did not have sufficient ebb duration to reach the sill level before the next flood tide, while smaller amplitude tides fell to approximately 3.77 m LAT. During the three day survey period water levels in the lake were always elevated above the sill level.

Elevation measurements made on the causeway sill showed the northern part of the sill had the greatest elevation (3.7 m LAT), while the southern part of the sill was 10 cm lower. The highest tide mark inside the lake was approximately 80 cm lower than highest astronomical tide (HAT); therefore, the causeway opening significantly constrains the extent of flood tides that are above 3.7 m LAT.

Particle size distribution data for cores and grab samples show that in most cases, samples were dominated by sandy sediments, with the exception of two locations that were instead dominated by silt and gravel, respectively. Areas of coarse grain-sizes were visible on the sidescan sonar mosaic as bright reflective seafloor elements.

There were no detects for any organotins (TBT etc), organochlorine pesticides (OCPs) or PCBs in any of the samples. Hydrocarbons were only detected at in the upper horizon of one site located near a boat ramp, and these were below screening levels. In addition, mercury and nickel concentrations at this site were above screening levels. Ammonia was elevated above screening levels at several locations. The material should be considered mostly clean with respect to NAGD (2009), with pockets of elevated ammonia.

Acid sulfate testing showed that the sediment at most sites had some acid generating potential that would not be completely offset by the natural load of calcium carbonate in the sediments. Recommended liming rates varied among sites from nil to 23 kg of lime per tonne of material.

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1 Introduction

1.1 Background

Causeway Lake is an impounded tidal basin between Mulambin and Kinka Beach, south of Yeppoon on the Capricorn Coast. The lake is fed by Shoal Creek to the south and Mulambin Creek to the north. A rocky causeway and road bridge were constructed in 1939 across the mouth of the creek to link Yeppoon with Emu Park.

A concrete sill beneath the road bridge has been surveyed to be 3.7 m above lowest astronomical tide (LAT) (Grigg and Piorewicz 1989). Tidal levels at nearby Rosslyn Bay provided by the Australian Hydrographic Office describe the highest astronomical tide (HAT) to be 5.1 m above LAT, with mean sea level (MSL) at 2.4 m. Therefore, the causeway has restricted tidal flow to the lake with tides below 3.7 m LAT not entering the lake, fully impeding 44% of high tides (Piorewicz and Setanto 2005).

Under the current situation, the lake is perfused with seawater during spring tides, but cut off from the ocean on alternating weeks following the approximately fortnightly patterning of neap and spring tide cycles. This resulting tidal regime in the lake mimics that of an intermittently closed and open lake or lagoon (ICOLL), except that access and closure alternates each week, rather than erratically or over longer periods. This regime makes the system very different tidally and ecologically from surrounding coastal estuaries. Marine plants including mangroves and seagrasses are found around, and within the lake, respectively. Anecdotal and previous survey evidence suggests that the lake is becoming shallower.

Previous studies have analysed lake bathymetries at a range of points in time. These have suggested that the maximum depth in the lake has become shallower, and a range of estimates of siltation rates and forecast lake levels have been made based on these comparisons. Some issues with past comparisons include making temporal comparisons among surveys with different horizontal and vertical datums and the use of inconsistent depth terminology, with 'water level' used interchangeably to describe both water below the causeway sill level and above Australian Height Datum (AHD; roughly equivalent to MSL). For example, the average elevation of the lake bed in 2007 was 0.34 m AHD (GDA 94), but this represented an average 'depth' of 0.95 m against the sill height of 3.7 m LAT (or 1.4 m AHD), which would be deeper during spring high tides.

Livingstone Shire Council intends to revitalise the Causeway Lake area with the goal of optimising recreational use opportunities on the lake and facilitating supportive development along the lake's north and south shores. Restoration of the lake system is also desired to preserve the present day environmental values that could be impacted by ongoing sedimentation. Long-term local efforts to identify a revitalisation path have consistently identified the lake's shallowing to be a major limitation.

In 2017, the Department of State Development, Manufacturing, Innovation and Planning (DSDMIP) engaged Bligh Tanner Pty Ltd and Otium Planning Group to undertake a Strategic Assessment of Service Requirement study (SASR) to evaluate the merit of Livingstone Shire Council's objectives for revitalisation of Causeway Lake. Council considers restoration of the lake's natural functions critical to achieving redevelopment of the broader precinct through support for increased recreational use on and adjacent to the lake and for generally fostering supportive economic development.

This technical report supports the intent to revitalise the Causeway Lake area by providing much needed data to inform costs, benefits, and risks of potential lake management options. Specifically, bathymetric and land-survey data were collected, subtidal marine plants and benthic communities were mapped, instrumentation was deployed to examine the relationship between tides, salinity and temperature, and sediment coring was performed to examine the physical nature of sediments and potential contaminants in the lake bed.

1.2 Objectives

Management actions to alter the causeway and/or dredge parts of the lake will initially require detailed bathymetry, mapping of subtidal marine plants and other significant habitats, and an understanding of the physical and chemical composition of surface and deeper sediments in potential dredge areas. Therefore, a site investigation was performed to provide the following data:

- **Bathymetry** of the lake and **land-survey** of the elevations of the existing sill, entrance channel, and beach east of the causeway
- **Marine plant mapping** within the potential dredge area of Causeway Lake
- **Sediment quality** and **particle sizing** at the lake bed surface, and 1m below surface.

2 Methods

2.1 Bathymetry and Land Survey

2.1.1 Bathymetry

BMT used a combination of 200 KHz single-beam acoustic soundings, real-time kinematic (RTK) GPS, and unmanned aerial vehicles (UAV) to rapidly acquire bathymetry and surface elevations across the study extent between April 9th -10th 2021. Figure 2-1 shows each of the tidally reduced and cleaned sounding points (79,064 soundings) collected and used to produce the sub-tidal marine digital elevation model (DEM). The 275 sounding points from the survey in 2007 are shown in pink for comparative purposes.

Data was collected primarily from north-south survey lines at less than 20 m intervals. The 200 KHz single-beam echo sounder was attached to a 3.2 m car-topper punt with a 20 cm draft beneath the sounderhead for shallow-water survey. Sidescan sonar (450 KHz) was also collected simultaneously to enable habitat mapping of rock and seagrasses. The vessel was mastered by an open coxswain.

Position relative to AHD (AusGeoid 2020) was achieved by pairing soundings to water level recorded with a tide gauge deployed at the Causeway Lake Boat Hire ramp (see sections 1.1 and 1.1). Water level was reduced to AHD by measuring levels with an RTK GPS at the point of deployment, mid-survey, and retrieval. The water level offset varied by up to 2 cm across these measurements. RTK differential corrections were taken from Rosslyn Bay (provided through the Auscors Network). RTK vertical error during fixed survey was between 1.3 and 6.4 cm RMSE and averaged 1.74 cm. Permanent survey mark (PSM 99308) at the causeway bridge was used as a check mark for vertical error. Three measurements over the PSM were within 5 cm of the GDA2020 elevation; however, each RTK GPS measurement was within 4 mm of the others. The described vertical accuracy of this mark on the survey sheet is 3.3 cm. The difference in elevation between the AusGeoid98 and GDA2020 ellipsoids at this PSM is 10.3 cm. This offset may need to be considered when comparing the 2021 survey with other historical survey datasets (noting the sill level of 3.7 m LAT has been previously used as the survey benchmark).

2.1.2 Unmanned Aerial Vehicle (UAV) and Land Survey

Elevations at the sill and entrance channel were collected using a combination of echo-sounding, RTK GPS roving, and UAV photogrammetry. A DJI Mavic collected aerial imagery along the northern and southern foreshores of Causeway Lake, and also east of the causeway at low tide. Point clouds and digital elevation models (DEMs) were developed using Agisoft Metascan. Point clouds were brought into GDA2020 coordinates using RTK GPS rectification points gathered at the time of flight. The UAV point cloud at the mouth of Causeway Lake had error at check points of 1-4 cm, while error was much higher at the northern (3-20 cm) and southern foreshore (20-60 cm). This was likely related to greater vertical complexity at these locations (vegetation and buildings) and the quality and quantity of both imagery and rectification points.

Water depths in the littoral margins (e.g. <0.2 m to waterline) were clipped to waterline using QGIS 18. Bathymetric and UAV-derived models were combined into one DEM in QGIS. Interpolations were performed with triangular irregular network interpolations and combined in order of accuracy, with soundings and the causeway mouth DEMs utilised over the foreshore DEMs in areas of overlap.

2.1.3 Conductivity, Temperature, and Depth

An *Insitu* conductivity, temperature and depth (CTD) instrument was deployed at the base of a post near the Causeway Lake Boat Hire building. This was a non-vented instrument, therefore, an atmospheric pressure gauge was deployed nearby to remove the effects of atmospheric pressure anomaly on the depth estimate. Barometric pressure reduction was conducted in Winsitu 5.0.

Legend

- RTK Land Survey Points
- 2021 Survey Points

Title:

2021 bathymetry and land survey points

Figure: 2-1

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2.2 Benthic Habitat Survey

The three independent methods used to map benthic habitats are summarised below.

2.2.1 Remote Sensing

A Sentinel 2 Satellite image from the 21st of February 2021 was downloaded and processed with the Sentinel Application Platform 7.0. Data were de-glinted (to remove reflection) masked to remove the land, and a false-colour composite was created using coastal blue, blue, and green bands (442.7 nm, 4921.4 nm and 559.8 nm central wavelengths, respectively). The coastal blue band was re-sampled from 60 m resolution down to 10 m to improve spatial resolution. This image was designed to maximise the detection of marine plants with increased signal penetration through marine waters. Marine plant boundaries determined through these desktop studies were ground-truthed using a small portable drop camera during the field survey (see Section 2.2.3).

2.2.2 Sidescan Sonar (SSS) Survey

450 KHz SSS data were collected concurrently with 200 KHz downscan bathymetry. This was used to develop SSS mosaics of the lake bed. SSS mosaics were used to map the distributions of marine plants, reflective sands, and rocky habitat, in combination with aerial and satellite imagery.

2.2.3 Marine Habitat Survey

A high-resolution drop camera with live surface feed was used to ground truth-seagrass meadows at locations shown in Figure 2-2. Transects were conducted over 10-20 m drifts as appropriate to the patch size of habitat in question. Seagrass was also sampled from meadows observed from the surface at four meadows to confirm species identifications.

Legend

- Seagrass grooound-truthing locations

Title:

Seagrass ground-truthing locations

Figure: 2-2

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2.3 Sediment Sampling

Sediment cores were taken using a hand corer and 100 mm diameter core barrels that varied between 2 and 3.5 m as appropriate to the depth of each sample location. Five cores and two grab samples were collected from the locations shown in Figure 2-3. The core barrel, homogenisation trays and trowels were cleaned with Decon-90 prior to each use. Nitrile gloves were worn and changed between sub-samples. A 0.028 m^2 van Veen grab was used to collect surface samples for particle sizing at two additional locations near the causeway entrance.

Cores were pushed to refusal depth, capped and returned to shore for processing. Sub samples were collected from two horizons from each core sample; from ground surface to 30 cm below ground level (BGL) and the final 30 cm of core to the end of retained core. The surface sub-sample was suffixed A, and the deeper subsample suffixed B. The locations, types of sampling, and depth of retained core sample are shown in Table 2-1. The contaminants list and target practical quantification limits are shown in Table 2-2.

Table 2-1 Core and grab locations and core depths

Location	Type	Lat	Long	Depth BGL (m)	Samples
BH1	Core	-23.199741	150.788080	1.06	Contaminants, PSD, ASS
BH2	Core	-23.200617	150.785264	1.20	Contaminants, PSD, ASS
BH3	Core	-23.203067	150.784941	1.18	Contaminants, PSD, ASS
BH4	Core	-23.197950	150.785392	1.20	Contaminants, PSD, ASS
BH5	Core	-23.201548	150.780630	0.70	Contaminants, PSD, ASS
G1	Grab	-23.199441	150.786922	0.15	PSD
G2	Grab	-23.199564	150.788337	0.15	PSD

Table 2-2 Contaminants List, Target PQLs and Screening Levels

Parameter	Target PQL	NAGD or other Screening Level
Basic Characteristics		
Particle Size Distribution	63 to 0.002 mm	
Moisture Content (%)	0.1	
Total Organic Carbon (%)	0.1	
Metals and metalloids (mg/kg)		
Aluminium	200	12,918
Antimony	0.5	2
Arsenic	1	20
Cadmium	0.1	1.5
Chromium	1	80
Copper	1	65
Iron	100	
Lead	1	50
Mercury	0.01	0.15
Nickel	1	21
Silver	0.1	1
Zinc	1	200
Organotin Compounds (µgSn/kg)		
MBT, DBT and TBT	1	9
Hydrocarbons (mg/kg)		
Total Petroleum Hydrocarbons	100	550
Benzene, Toluene, Ethylbenzene, Xylene (BTEX)	200	
Polycyclic Aromatic Hydrocarbons (PAHs)	0.005 (0.1 for sum)	10,000
OC Pesticides		
DDT, DDE, DDD	0.001	0.002, 0.002, 0.0016
Chlordane, Lindane, Dieldrin, Endosulfan, Endrin Methoxychlor and their metabolites	0.001	
PCBs	0.005	0.023
Nutrients		
Total Nitrogen as N	20	
Total Kjeldahl Nitrogen as N	20	
Total Phosphorus as P	1	
Nitrate and Nitrite as N	0.1	
Ammonia as N	0.1	4
Acid Sulfate Potential		
Chromium Suite	2 mole H^{+}/tonne	

Legend

- Boreholes and surface grabs

Title:

Borehole and surface grab locations

Figure: 2-3

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3 Results and Discussion

3.1 Bathymetry & Land Digital Elevation Model

A digital elevation model (DEM) produced using the bathymetry and land survey data described in Section 2.1 is shown in Figure 3-1. Discussion on the causeway sill elevation and recorded tides over the survey period are also provided below.

3.1.1 Causeway Sill Elevations

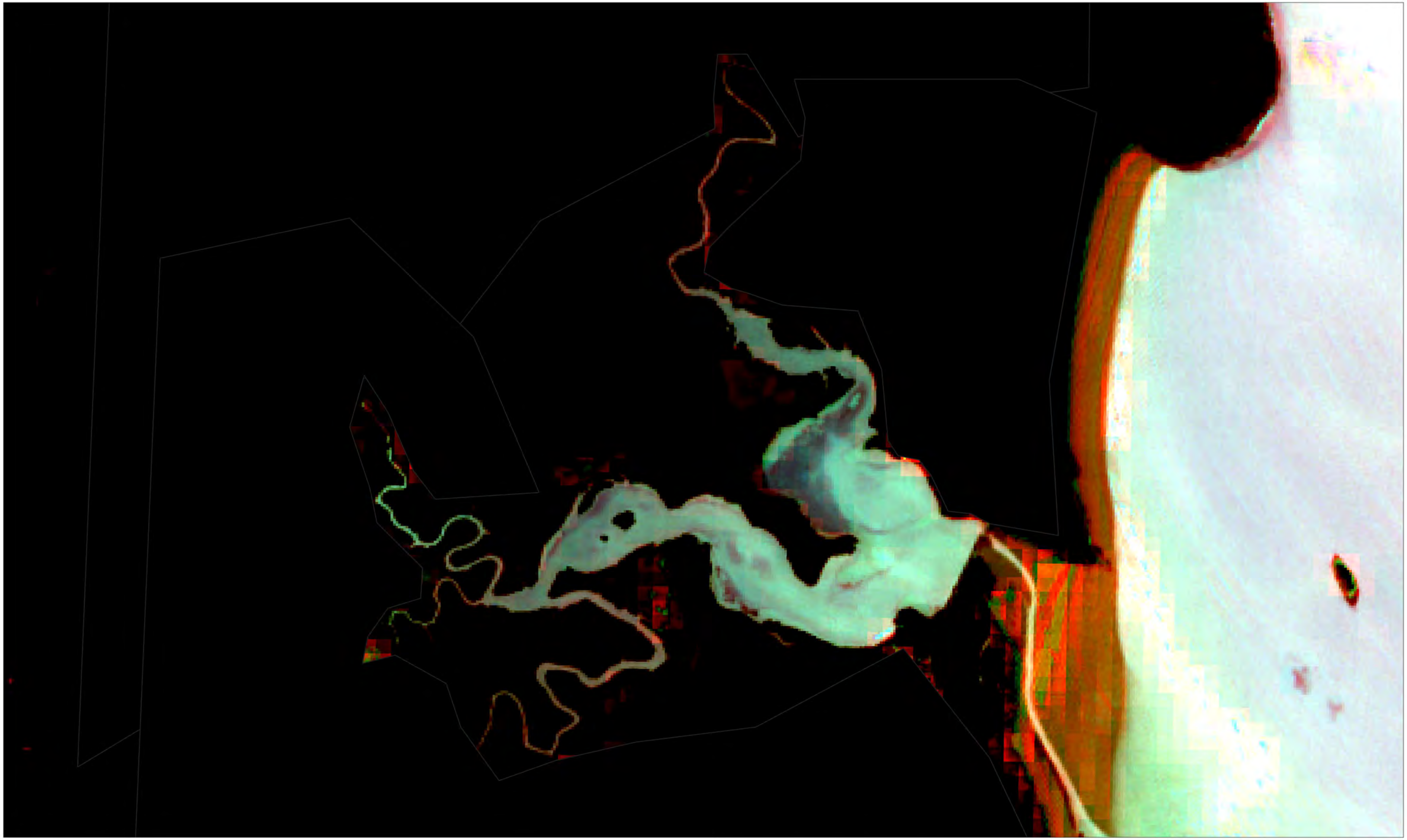
Ten measurements of elevation were made on the sill, immediately west of each bridge footing. Not every footing was able to be measured due to the speed of water at the time of survey. The northern section of the sill had the greatest elevation (3.7 m LAT [AusGeoid09] 3.8 m [AusGeoid2020]), while the southern part of the sill was 10 cm lower. This corresponds to the bulk of the water movement which was fastest along the southern section of the causeway.

The elevation was also measured (1.905 m AHD) at the base of the concrete slab at the Boat Hire shed. This was reportedly the highest tide level inside the lake, without rainfall. This elevation is approximately 4.3 m above LAT and 80 cm lower that HAT outside the causeway.

3.1.2 Tides, Salinity, and Temperature

The time series of water level (m LAT), salinity (practical salinity units), and temperature over the deployment period is shown in Figure 3-2. This shows a rapid rise in water level associated with incoming spring tides and relatively slow retreat of the tide down to the next point where the tide rises above the sill. The first high tide in the series was the largest, and the ebbing tide did not have sufficient time to reach the sill level before the next tide, unlike the smaller high tides which fell to approximately 3.77 m LAT. This shows that during the survey period, water levels were always elevated above the sill level (based on the previous and present reported sill height).

The salinity signal was highly variable and probably reflected carry-over freshwater from preceding rainfall mixing with saline ocean water. Peaks in salinity occurred at the top of the incoming tidal signal with sharp reductions and increases in salinity occurring at the onset of the incoming tide. This may be the result of eddying around the shallower bathymetry south of the boat hire building (see section 3.1). Temperature appeared less affected by tides and followed diel pattern (warmer in the day) more closely.



Legend

False-Colour image derived from Sentinel 2A courtesy of the European Space Agency captured 21-02-2021

Title:
Coastal blue false-colour composite

Figure: **3-1**

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Figure 3-2 Water level, temperature, and salinity (estimated LAT)

3.2 Benthic Habitat Mapping

Benthic habitat mapping is shown in Figure 3-5. Discussion on the basis for habitat identification and mapping is provided below.

3.2.1 Seagrass

Sentinel-2 false colour imagery (Figure 3-3) shows an extensive bed of dark material (seagrass) in Mulambin Creek, and smaller meadows in along the sides and surrounding the islands of Shoal Creek. Although ability to penetrate through the water column was improved by this image, the 10 m resolution ultimately limited the ability to resolve fine-scale features on its own.

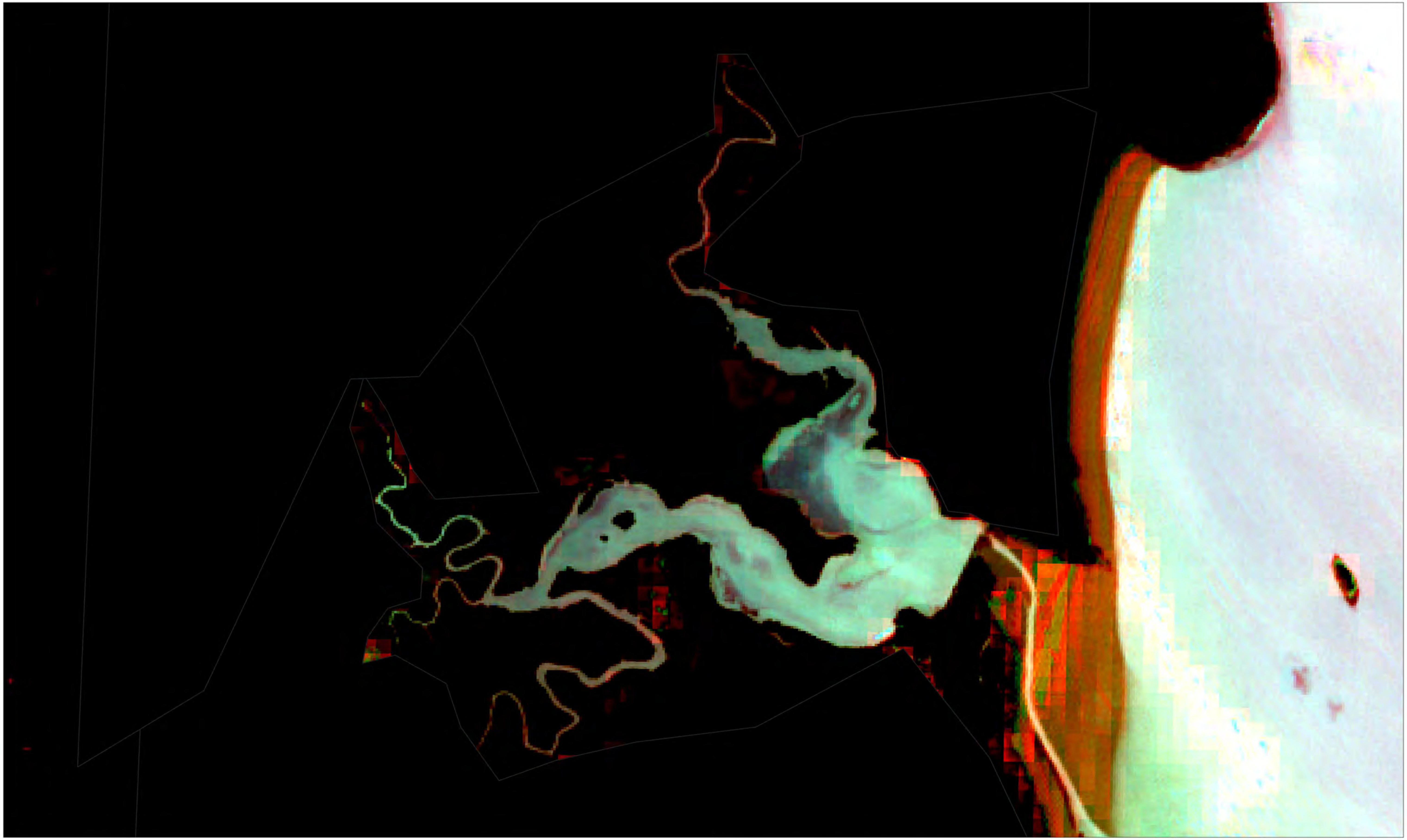
There was strong agreement between the areas of seagrass observable on aerial imagery, Sentinel-2, and on sidescan mosaics (Figure 3-4). Areas of dense (50-100%) seagrass cover and moderate to dense (20-50%) seagrass cover are shown in . It should be noted that low density seagrass (<5% cover) is likely to exist over a much larger area than the extent mapped in . This low density cover does not form meadows and was not observable from satellite or aerial imagery, nor did it appear to be consistent with regard to depth.

Only one species of seagrass (*Halodule uninvervis*) was observed in towed camera ground-truthing and in samples taken from various meadows. This is considered unusual, as surrounding estuaries such as Cawarral Creek (10 km south) contain *H uninervis* and other species including *Halophila* and *Zostera* species. The growth form of the *H. uninvervis* in Causeway Lake was also longer than usual. Seagrass was also upper- and lower-limited in its depth-distribution which was also unusual because meadows in south-east and central Queensland usually grow into the intertidal zone. The very shallowest parts of the lake did not have any seagrass, and there was no intertidal seagrass at all.

These unusual features are likely the result of the conditions in the lake, where tidal connection and complete obstruction from tidal influence alternate with neap and spring tide cycles. During neap tide cycles where the lake loses connectivity with the ocean, very shallow areas in the lake may be prone to high temperatures and excessive solar radiation.

3.2.2 Rocky Habitat

Rocky habitat was the other subtidal feature mapped in Causeway Lake. This was present surrounding the base of the causeway and rock wall, and at two other locations in the lake. There were no sensitive receptors (such as hard or soft corals) living on any of the rocky habitats. Epibenthic fauna consisted primarily of bivalves and sponges.



Legend

False-Colour image derived from Sentinel 2A courtesy of the European Space Agency captured 21-02-2021

Title:

Coastal blue false-colour composite

Figure: 3-3

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 300 600 m

BMT

www.bmt.org

Filepath: I:\A10946_I_CMJ_Causeway_Lake\DRG\ECO_006_210421_Sentinel2_BBG_false_colour.qgz

Title:

Sidescan sonar mosaic (450 KHz)

Figure: 3-4

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 300 600 m

BMT

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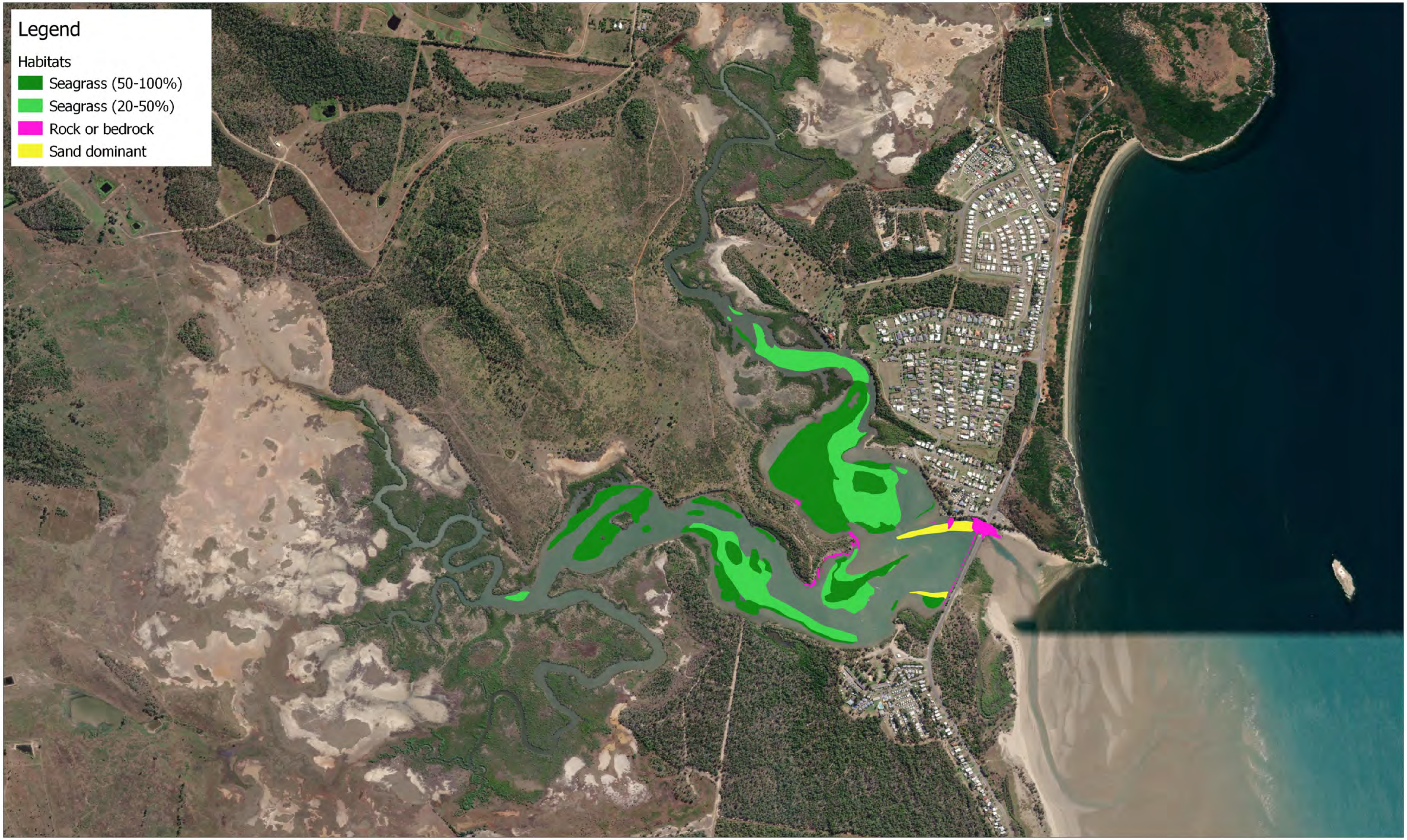
Filepath: I:\A10946_I_CMJ_Causeway_Lake\DRG\ECO_007_210421_SSS_mosaic.qgz



Title:

Benthic Habitats

Figure:

3-5

Rev:

A

www.bmt.org

Filepath: I:\A10946_I_CMJ_Causeway_Lake\DRG\ECO_008_210422_Habitat.qgz

3.3 Sediment Sample Characterisation

3.3.1 Physical Properties

Particle size distribution data for the cores and grab samples show that in most cases, samples were dominated by sandy sediments, with the exception of the surface horizon at BH3, and grab 1, which were dominated by silt and gravel, respectively (Figure 3-6). These differences in particle size were consistent with the SSS mosaic shown in , where most sites represent the 'average' condition, site BH3 shows the dominance of silts and clay particles in the darker areas of the mosaic, and the bright reflective parts of the mosaic correspond to areas of rock and gravel.

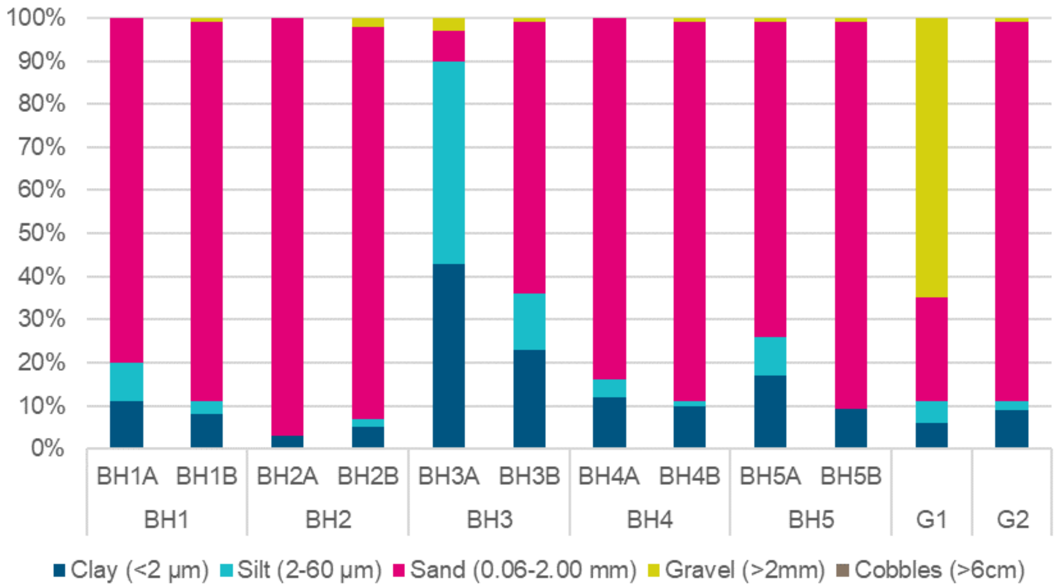


Figure 3-6 Particle size distributions for major grain-size fractions at each sample location

Images of cores are shown in Figure 3-7. With the exception of BH3, the upper and lower sampled horizons of each core were dominated by sands, with a lower contribution of fines (silt and clay) and occasional gravel pieces. Most sites had a lighter coloured silt layer in the upper 2 cm, with muddy sands beneath the upper silt layer, with or without organic intrusions, down to the final recoverable depth.

Site BH2 was noticeably sandier than the other locations, and the sand was a lighter brown colour, rather than dark grey. The other notably different site was BH3, which had a very deep layer of fines. Dark grey mud was present from 4-60 cm BGL, followed by a sandy mud layer from 60-110 cm BGL, before giving way to muddy sand from 110-118 cm BGL. This very abrupt change in sediment may coincide with sedimentation over the top the original sandy creek bed prior to the construction of the causeway.

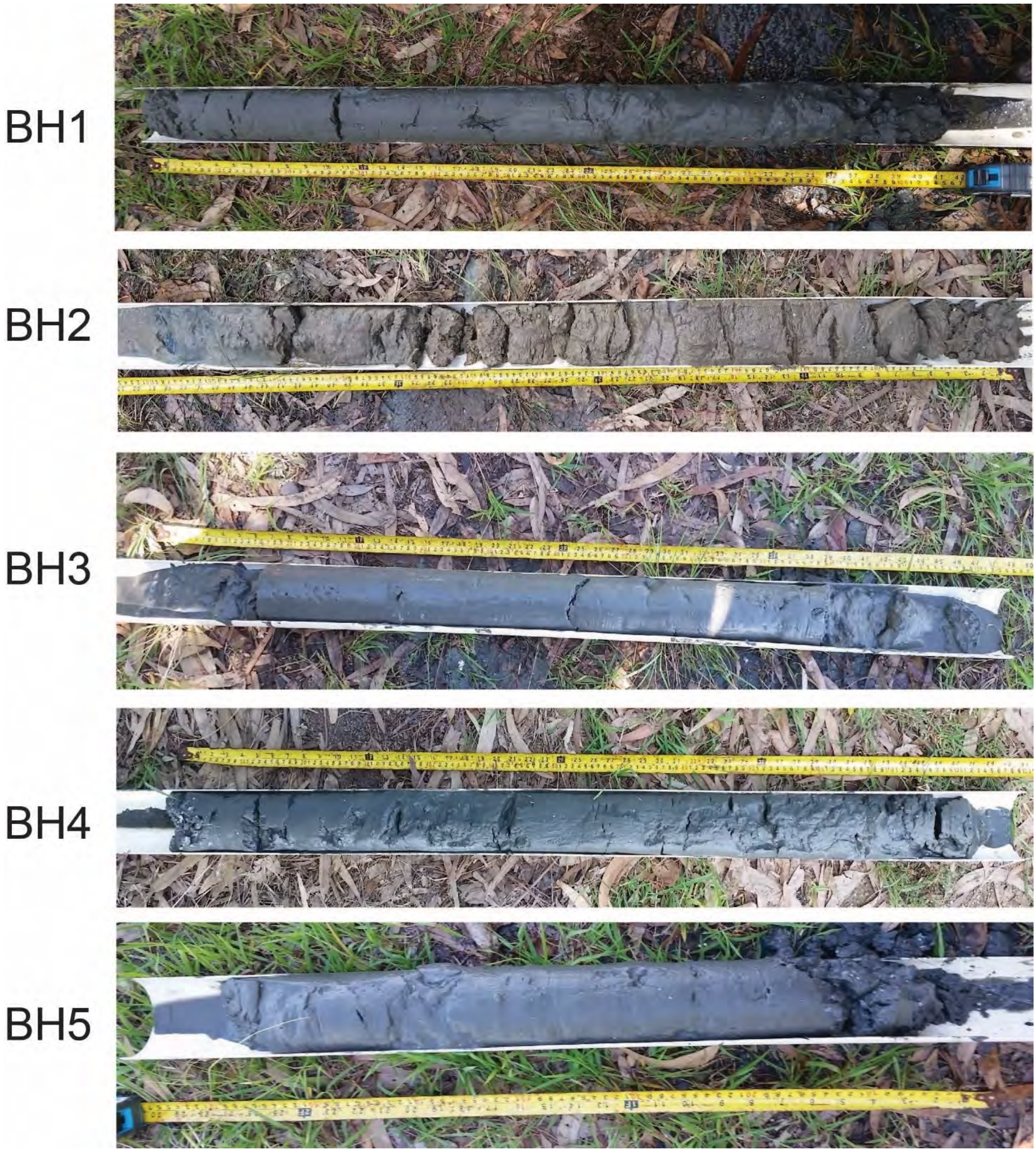


Figure 3-7 Photos of cores taken from sites BH1-BH5

3.3.2 Contamination

Concentrations of detected contaminants with respect to screening levels are presented in Table 3-1. There were no detects for any organotins (TBT etc), organochlorine pesticides (OCPs) or PCBs in any of the samples. Hydrocarbons were only detected at in the upper horizon of site BH3, and these were below screening levels.

Ammonia was elevated above screening levels at BH3 (both horizons) and in the lower horizon of BH4. The upper horizon of BH3 also had elevated concentrations of mercury and nickel. The proximity of this site to the boat ramp may reflect hydrocarbon and heavy metal contamination associated with boating activities, such as launching and retrieval and refuelling.

Laboratory QA/QC procedures did not find any method blank, duplicate, or laboratory control outliers. There were two matrix spike recoveries lower than the data quality objectives for two PAH parameters, and holding times were exceeded for nitrite in soil. Based on these results, the vast majority of analyses fall within the recommended quality limits. The material should be considered mostly clean with respect to NAGD (2009), with pockets of elevated ammonia.

3.3.3 Acid Sulfates

Acid base accounting shows that despite not being currently acidic, the sediment at most sites had some acid generating potential that would not be completely offset by the natural load of calcium carbonate in the sediments (Table 3-2). Site BH2 would require little if any liming, while sediments from BH3 had substantial acid generating capacity and would require up to 23 kg of lime per tonne of material if placed on land.

Table 3-1 Contaminant results (detects and screening level exceedances)

Parameter	Units	LOR	Screening Level	BH1A	BH1B	BH2A	BH2B	BH3A	BH3B	BH4A	BH4B	BH5A	BH5B
Moisture Content	%	1		30.7	22.2	20.2	20.6	65.8	36.4	29.6	26.2	37.3	24
Total Organic Carbon	%			0.22	0.11	0.09	0.10	1.18	0.33	0.26	0.16	0.37	0.15
Metals													
Aluminium	mg/kg	50		4190	2850	1730	1960	12900	5790	4240	3330	4710	3030
Iron	mg/kg	50		10500	7710	6020	6420	27300	13000	11400	9820	11300	8050
Antimony	mg/kg	0.1	2	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	mg/kg	1	20	7.54	7.23	7.12	6.93	11.9	8.59	8.49	7.72	7.48	6.64
Cadmium	mg/kg	1	1.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	mg/kg	50	80	12.2	9.4	6.4	7.3	32	15.6	12.9	11.6	13.4	10
Copper	mg/kg	1	65	4.4	3	1.5	1.8	15.2	6.3	3.9	2.8	4.6	2.4
Cobalt	mg/kg	0.01		6.4	5.2	4.3	4.4	12.6	6.8	7.3	6.8	7.3	5.9
Lead	mg/kg	1	50	3.8	2.6	1.9	2	11.1	5	3.5	2.7	4.3	2.5
Manganese	mg/kg	0.1		307	238	196	162	583	268	315	292	262	215
Nickel	mg/kg	1	21	9.6	6.8	4.7	5.4	**25.2**	12.1	9.5	8.2	10.2	6.9
Selenium	mg/kg	0.02	1	0.4	0.3	0.2	0.2	0.9	0.5	0.4	0.4	0.3	0.4
Silver	mg/kg	20		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Vanadium	mg/kg			17.7	13.8	11.3	12	42.5	22.1	17.7	15.7	18	13.5
Zinc	mg/kg			16.8	11.8	8.8	9.1	43.8	19.8	17.7	14.6	18.6	13.1
Mercury	mg/kg	20	0.15	<0.01	<0.01	<0.01	<0.01	**0.02**	<0.01	<0.01	<0.01	<0.01	<0.01
Nutrients													
Ammonia as N	mg/kg	1	4	<1	<1	<1	<1	**27**	**10**	<1	**6**	<1	<1
Nitrite as N (Sol.)	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate as N (Sol.)	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20		220	120	120	130	1280	390	240	190	390	140
Total Nitrogen as N	mg/kg	20		220	120	120	130	1280	390	240	190	390	140

Parameter	Units	LOR	Screening Level	BH1A	BH1B	BH2A	BH2B	BH3A	BH3B	BH4A	BH4B	BH5A	BH5B
Total Phosphorus as P	mg/kg	2		145	160	142	163	446	221	202	207	181	154
Total Petroleum Hydrocarbons													
C6 - C9 Fraction	mg/kg	3		<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
C10 - C14 Fraction	mg/kg	3		<3	<3	<3	<3	5	<3	<3	<3	<3	<3
C15 - C28 Fraction	mg/kg	3		<3	<3	<3	<3	10	<3	<3	<3	<3	<3
C29 - C36 Fraction	mg/kg	5		<5	<5	<5	<5	22	<5	<5	<5	<5	<5
C10 - C36 Fraction (sum)	mg/kg	3	550	<3	<3	<3	<3	37	<3	<3	<3	<3	<3

Table 3-2 Acid sulfate soil results (Chromium Suite)

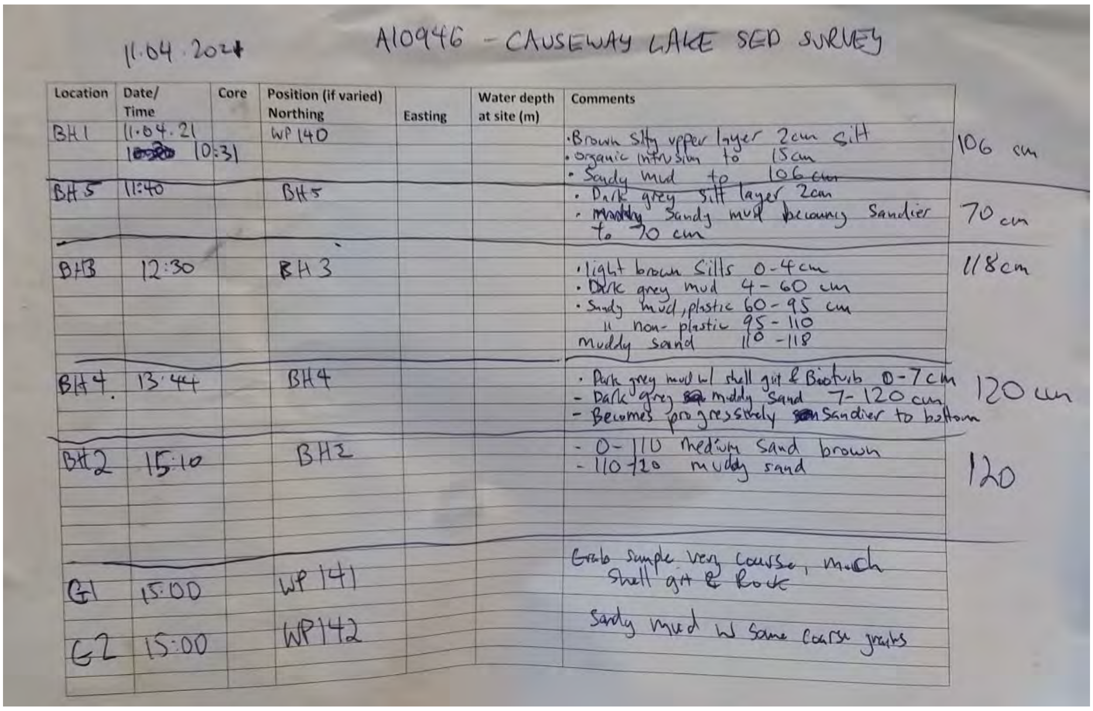
Parameter	Units	QPL	Site								
			BH1A	BH1B	BH2A	BH2B	BH3A	BH3B	BH4A	BH4B	BH5A
Actual Acidity											
pH KCl	pH Unit		9.3	9.5	9.6	9.6	8.8	9.2	9.3	9.5	9.2
Titratable Actual Acidity	mole H+ / t		<2	<2	<2	<2	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity	% pyrite S		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity											
Chromium Reducible Sulfur	% S		0.108	0.037	0.025	0.018	0.497	0.188	0.131	0.073	0.241
acidity - Chromium Reducible Sulfur)	mole H+ / t		68	23	16	11	310	117	82	45	150
Acid Neutralising Capacity											
Acid Neutralising Capacity	% CaCO3		6.96	6.84	5.46	7.66	5.23	7.29	9.22	9.66	8.38
acidity - Acid Neutralising Capacity)	mole H+ / t		1390	1370	1090	1530	1040	1460	1840	1930	1680
sulfidic - Acid Neutralising Capacity	% pyrite S		2.23	2.19	1.75	2.45	1.67	2.34	2.95	3.09	2.68
Acid Base Accounting											
ANC Fineness Factor			1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	% S		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t		<10	<10	<10	<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t		<1	<1	<1	<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S		0.11	0.04	0.02	<0.02	0.50	0.19	0.13	0.07	0.24
Net Acidity excluding ANC (acidity units)	mole H+ / t		68	23	16	11	310	117	82	45	150
Liming Rate excluding ANC	kg CaCO3/t		**5**	**2**	**1**	**<1**	**23**	**9**	**6**	**3**	**11**

4 References

Grigg WL, Piorewicz J (1989) Causeway Lake / Kinka Beach Study. Final Report, Capricornia Institute, James Goldston School of Engineering. Report prepared for Main Roads Department.

Piorewicz J, Soetanto B (2005) Sediment processes in a coastal lake: Causeway Lake, the Capricorn Coast. CQUniversity. Conference contribution. https://hdl.handle.net/10018/23514.

Appendix A Core Log



11.04.2024 A10946 – CAUSEWAY LAKE SED SURVEY

Location	Date/ Time	Core	Position (if varied) Northing	Easting	Water depth at site (m)	Comments	
BH1	11.04.21 10:31		WP140			• Brown silty upper layer 2cm silt • organic intrusion to 15cm • Sandy mud to 106cm	106 cm
BH5	11:40		BH5			• Dark grey silt layer 2cm • Sandy mud becoming sandier to 70 cm	70 cm
BH3	12:30		BH3			• light brown silts 0-4cm • Dark grey mud 4-60 cm • Sandy mud, plastic 60-95 cm " non-plastic 95-110 muddy sand 110-118	118cm
BH4	13:44		BH4			• Dark grey mud w/ shell grit & Bioturb 0-7cm - Dark grey muddy sand 7-120 cm - Becomes progressively sandier to bottom	120 cm
BH2	15:10		BH2			- 0-110 medium sand brown - 110-120 muddy sand	120
G1	15:00		WP141			Grab sample very course, much shell grit & Rock	
G2	15:00		WP142			Sandy mud w some coarse grains	

Appendix B Laboratory Results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2109794**	Page	: 1 of 16
Client	: **BMT COMMERCIAL AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: KATRINA O'MALLEY JONES	Contact	: Andrew Epps
Address	: PO BOX 203 SPRING HILL BRISBANE QLD 4004	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8639
Project	: A10946.01	Date Samples Received	: 12-Apr-2021 17:44
Order number	: ----	Date Analysis Commenced	: 14-Apr-2021
C-O-C number	: ----	Issue Date	: 27-Apr-2021 10:02
Sampler	: CONOR JONES		
Site	: ----		
Quote number	: BN/152/21		
No. of samples received	: 12		
No. of samples analysed	: 12		

NATA 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, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

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*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Diana Mesa	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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.

- EA150H: Soil particle density results fell outside the scope of AS1289.3.6.3. Results should be scrutinised accordingly.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- **Ultra Trace Organics and Ammonia in Sediments analysis is conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH1A	BH1B	BH2A	BH2B	BH3A
			Sampling date / time	11-Apr-2021 10:31	11-Apr-2021 10:31	11-Apr-2021 15:10	11-Apr-2021 15:10	11-Apr-2021 12:30
				EB2109794-001	EB2109794-002	EB2109794-003	EB2109794-004	EB2109794-005
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.3	9.5	9.6	9.6	8.8
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.108	0.037	0.025	0.018	0.497
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	68	23	16	11	310
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	6.96	6.84	5.46	7.66	5.23
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	1390	1370	1090	1530	1040
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	2.23	2.19	1.75	2.45	1.67
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.11	0.04	0.02	<0.02	0.50
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	68	23	16	11	310
Liming Rate excluding ANC	----	1	kg CaCO3/t	5	2	1	<1	23
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	30.7	22.2	20.2	20.6	65.8
EA150: Particle Sizing								
+75µm	----	1	%	79	88	96	93	9
+150µm	----	1	%	56	66	82	77	8
+300µm	----	1	%	5	6	5	10	7
+425µm	----	1	%	2	3	2	6	5
+600µm	----	1	%	2	2	1	4	4
+1180µm	----	1	%	<1	2	<1	3	4
+2.36mm	----	1	%	<1	<1	<1	1	2
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH1A	BH1B	BH2A	BH2B	BH3A
			Sampling date / time	11-Apr-2021 10:31	11-Apr-2021 10:31	11-Apr-2021 15:10	11-Apr-2021 15:10	11-Apr-2021 12:30
Compound	CAS Number	LOR	Unit	EB2109794-001	EB2109794-002	EB2109794-003	EB2109794-004	EB2109794-005
				Result	Result	Result	Result	Result
EA150: Particle Sizing - Continued								
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	11	8	3	5	43
Silt (2-60 µm)	----	1	%	9	3	<1	2	47
Sand (0.06-2.00 mm)	----	1	%	80	88	97	91	7
Gravel (>2mm)	----	1	%	<1	1	<1	2	3
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4190	2850	1730	1960	12900
Iron	7439-89-6	50	mg/kg	10500	7710	6020	6420	27300
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	7.54	7.23	7.12	6.93	11.9
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	12.2	9.4	6.4	7.3	32.0
Copper	7440-50-8	1.0	mg/kg	4.4	3.0	1.5	1.8	15.2
Cobalt	7440-48-4	0.5	mg/kg	6.4	5.2	4.3	4.4	12.6
Lead	7439-92-1	1.0	mg/kg	3.8	2.6	1.9	2.0	11.1
Manganese	7439-96-5	10	mg/kg	307	238	196	162	583
Nickel	7440-02-0	1.0	mg/kg	9.6	6.8	4.7	5.4	25.2
Selenium	7782-49-2	0.1	mg/kg	0.4	0.3	0.2	0.2	0.9
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Vanadium	7440-62-2	2.0	mg/kg	17.7	13.8	11.3	12.0	42.5
Zinc	7440-66-6	1.0	mg/kg	16.8	11.8	8.8	9.1	43.8
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	0.02
EK055: Ammonia as N								
Ammonia as N	7664-41-7	1	mg/kg	<1	<1	<1	<1	27
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH1A	BH1B	BH2A	BH2B	BH3A
			Sampling date / time	11-Apr-2021 10:31	11-Apr-2021 10:31	11-Apr-2021 15:10	11-Apr-2021 15:10	11-Apr-2021 12:30
Compound	CAS Number	LOR	Unit	EB2109794-001	EB2109794-002	EB2109794-003	EB2109794-004	EB2109794-005
				Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**220**	**120**	**120**	**130**	**1280**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**220**	**120**	**120**	**130**	**1280**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**145**	**160**	**142**	**163**	**446**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.22**	**0.11**	**0.09**	**0.10**	**1.18**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	**5**
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	**10**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	**22**
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	**37**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	**4**
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	**28**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	**7**
^ >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	**39**
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH1A	BH1B	BH2A	BH2B	BH3A
			Sampling date / time	11-Apr-2021 10:31	11-Apr-2021 10:31	11-Apr-2021 15:10	11-Apr-2021 15:10	11-Apr-2021 12:30
Compound	CAS Number	LOR	Unit	EB2109794-001	EB2109794-002	EB2109794-003	EB2109794-004	EB2109794-005
				Result	Result	Result	Result	Result
EP090: Organotin Compounds - Continued								
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
alpha-BHC	319-84-6	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
beta-BHC	319-85-7	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
delta-BHC	319-86-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
4.4`-DDD	72-54-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
4.4`-DDE	72-55-9	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
4.4`-DDT	50-29-3	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Dieldrin	60-57-1	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
alpha-Endosulfan	959-98-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
beta-Endosulfan	33213-65-9	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endosulfan sulfate	1031-07-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Endosulfan (sum)	115-29-7	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endrin	72-20-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endrin aldehyde	7421-93-4	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endrin ketone	53494-70-5	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Heptachlor	76-44-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Heptachlor epoxide	1024-57-3	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Hexachlorobenzene (HCB)	118-74-1	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
gamma-BHC	58-89-9	0.00025	mg/kg	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025
Methoxychlor	72-43-5	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
cis-Chlordane	5103-71-9	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
trans-Chlordane	5103-74-2	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Total Chlordane (sum)	----	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Oxychlordane	27304-13-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1016	12674-11-2	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1221	11104-28-2	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1232	11141-16-5	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH1A	BH1B	BH2A	BH2B	BH3A
			Sampling date / time	11-Apr-2021 10:31	11-Apr-2021 10:31	11-Apr-2021 15:10	11-Apr-2021 15:10	11-Apr-2021 12:30
Compound	CAS Number	LOR	Unit	EB2109794-001	EB2109794-002	EB2109794-003	EB2109794-004	EB2109794-005
				Result	Result	Result	Result	Result
EP131B: Polychlorinated Biphenyls (as Aroclors) - Continued								
Aroclor 1242	53469-21-9	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1248	12672-29-6	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1254	11097-69-1	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1260	11096-82-5	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	0.005	mg/kg	<0.005	<0.005	<0.005	<0.005	<0.005
2-Methylnaphthalene	91-57-6	0.005	mg/kg	<0.005	<0.005	<0.005	<0.005	<0.005
Acenaphthylene	208-96-8	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Acenaphthene	83-32-9	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Fluorene	86-73-7	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Phenanthrene	85-01-8	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Anthracene	120-12-7	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Fluoranthene	206-44-0	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Pyrene	129-00-0	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Benz(a)anthracene	56-55-3	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Chrysene	218-01-9	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Benzo(b+j)fluoranthene	205-99-2 205-82-3	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Benzo(k)fluoranthene	207-08-9	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Benzo(e)pyrene	192-97-2	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Benzo(a)pyrene	50-32-8	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Perylene	198-55-0	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Benzo(g.h.i)perylene	191-24-2	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Dibenz(a.h)anthracene	53-70-3	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Indeno(1.2.3.cd)pyrene	193-39-5	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
Coronene	191-07-1	0.005	mg/kg	<0.005	<0.005	<0.005	<0.005	<0.005
^ Sum of PAHs	----	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
^ Benzo(a)pyrene TEQ (zero)	----	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.005
^ Benzo(a)pyrene TEQ (half LOR)	----	0.004	mg/kg	**0.005**	**0.005**	**0.005**	**0.005**	<0.005
^ Benzo(a)pyrene TEQ (LOR)	----	0.004	mg/kg	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**92.2**	**87.7**	**82.3**	**74.7**	**66.3**
Toluene-D8	2037-26-5	0.2	%	**94.2**	**87.8**	**87.6**	**68.4**	**60.9**
4-Bromofluorobenzene	460-00-4	0.2	%	**105**	**97.4**	**98.4**	**86.2**	**75.0**
EP090S: Organotin Surrogate								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH1A	BH1B	BH2A	BH2B	BH3A
			Sampling date / time	11-Apr-2021 10:31	11-Apr-2021 10:31	11-Apr-2021 15:10	11-Apr-2021 15:10	11-Apr-2021 12:30
Compound	CAS Number	LOR	Unit	EB2109794-001	EB2109794-002	EB2109794-003	EB2109794-004	EB2109794-005
				Result	Result	Result	Result	Result
EP090S: Organotin Surrogate - Continued								
Tripropyltin	----	0.5	%	77.8	84.0	72.0	67.2	66.4
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	70.1	67.0	66.9	57.9	68.3
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	60.8	57.4	58.2	57.6	62.4
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	89.9	93.6	112	91.7	107
Anthracene-d10	1719-06-8	10	%	90.2	110	101	87.0	102
4-Terphenyl-d14	1718-51-0	10	%	78.4	94.6	87.8	77.5	98.0

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH3B	BH4A	BH4B	BH5A	BH5B
			Sampling date / time	11-Apr-2021 12:30	11-Apr-2021 13:44	11-Apr-2021 13:44	11-Apr-2021 11:41	11-Apr-2021 11:41
Compound	CAS Number	LOR	Unit	EB2109794-006	EB2109794-007	EB2109794-008	EB2109794-009	EB2109794-010
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.2	9.3	9.5	9.2	9.5
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.188	0.131	0.073	0.241	0.075
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	117	82	45	150	47
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	7.29	9.22	9.66	8.38	8.20
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	1460	1840	1930	1680	1640
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	2.34	2.95	3.09	2.68	2.62
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.19	0.13	0.07	0.24	0.07
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	117	82	45	150	47
Liming Rate excluding ANC	----	1	kg CaCO3/t	9	6	3	11	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	36.4	29.6	26.2	37.3	24.0
EA150: Particle Sizing								
+75µm	----	1	%	63	83	89	73	86
+150µm	----	1	%	48	36	33	41	44
+300µm	----	1	%	6	2	3	6	7
+425µm	----	1	%	3	1	2	4	3
+600µm	----	1	%	3	1	1	3	2
+1180µm	----	1	%	2	<1	<1	2	2
+2.36mm	----	1	%	1	<1	<1	1	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH3B	BH4A	BH4B	BH5A	BH5B
			Sampling date / time	11-Apr-2021 12:30	11-Apr-2021 13:44	11-Apr-2021 13:44	11-Apr-2021 11:41	11-Apr-2021 11:41
Compound	CAS Number	LOR	Unit	EB2109794-006	EB2109794-007	EB2109794-008	EB2109794-009	EB2109794-010
				Result	Result	Result	Result	Result
EA150: Particle Sizing - Continued								
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	23	12	10	17	9
Silt (2-60 µm)	----	1	%	13	4	1	9	3
Sand (0.06-2.00 mm)	----	1	%	63	84	88	73	87
Gravel (>2mm)	----	1	%	1	<1	1	1	1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	5790	4240	3330	4710	3030
Iron	7439-89-6	50	mg/kg	13000	11400	9820	11300	8050
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	8.59	8.49	7.72	7.48	6.64
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	15.6	12.9	11.6	13.4	10.0
Copper	7440-50-8	1.0	mg/kg	6.3	3.9	2.8	4.6	2.4
Cobalt	7440-48-4	0.5	mg/kg	6.8	7.3	6.8	7.3	5.9
Lead	7439-92-1	1.0	mg/kg	5.0	3.5	2.7	4.3	2.5
Manganese	7439-96-5	10	mg/kg	268	315	292	262	215
Nickel	7440-02-0	1.0	mg/kg	12.1	9.5	8.2	10.2	6.9
Selenium	7782-49-2	0.1	mg/kg	0.5	0.4	0.4	0.3	0.4
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Vanadium	7440-62-2	2.0	mg/kg	22.1	17.7	15.7	18.0	13.5
Zinc	7440-66-6	1.0	mg/kg	19.8	17.7	14.6	18.6	13.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK055: Ammonia as N								
Ammonia as N	7664-41-7	1	mg/kg	10	<1	6	<1	<1
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH3B	BH4A	BH4B	BH5A	BH5B
			Sampling date / time	11-Apr-2021 12:30	11-Apr-2021 13:44	11-Apr-2021 13:44	11-Apr-2021 11:41	11-Apr-2021 11:41
				EB2109794-006	EB2109794-007	EB2109794-008	EB2109794-009	EB2109794-010
				Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**390**	**240**	**190**	**390**	**140**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**390**	**240**	**190**	**390**	**140**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**221**	**202**	**207**	**181**	**154**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.33**	**0.26**	**0.16**	**0.37**	**0.15**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	**3**	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	**3**	<3
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH3B	BH4A	BH4B	BH5A	BH5B
			Sampling date / time	11-Apr-2021 12:30	11-Apr-2021 13:44	11-Apr-2021 13:44	11-Apr-2021 11:41	11-Apr-2021 11:41
Compound	CAS Number	LOR	Unit	EB2109794-006	EB2109794-007	EB2109794-008	EB2109794-009	EB2109794-010
				Result	Result	Result	Result	Result
EP090: Organotin Compounds - Continued								
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
alpha-BHC	319-84-6	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
beta-BHC	319-85-7	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
delta-BHC	319-86-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
4.4`-DDD	72-54-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
4.4`-DDE	72-55-9	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
4.4`-DDT	50-29-3	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Dieldrin	60-57-1	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
alpha-Endosulfan	959-98-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
beta-Endosulfan	33213-65-9	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endosulfan sulfate	1031-07-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Endosulfan (sum)	115-29-7	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endrin	72-20-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endrin aldehyde	7421-93-4	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Endrin ketone	53494-70-5	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Heptachlor	76-44-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Heptachlor epoxide	1024-57-3	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Hexachlorobenzene (HCB)	118-74-1	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
gamma-BHC	58-89-9	0.00025	mg/kg	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025
Methoxychlor	72-43-5	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
cis-Chlordane	5103-71-9	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
trans-Chlordane	5103-74-2	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Total Chlordane (sum)	----	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Oxychlordane	27304-13-8	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.00050	mg/kg	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1016	12674-11-2	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1221	11104-28-2	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1232	11141-16-5	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH3B	BH4A	BH4B	BH5A	BH5B
			Sampling date / time	11-Apr-2021 12:30	11-Apr-2021 13:44	11-Apr-2021 13:44	11-Apr-2021 11:41	11-Apr-2021 11:41
Compound	CAS Number	LOR	Unit	EB2109794-006	EB2109794-007	EB2109794-008	EB2109794-009	EB2109794-010
				Result	Result	Result	Result	Result
EP131B: Polychlorinated Biphenyls (as Aroclors) - Continued								
Aroclor 1242	53469-21-9	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1248	12672-29-6	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1254	11097-69-1	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aroclor 1260	11096-82-5	0.0050	mg/kg	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	0.005	mg/kg	<0.005	<0.005	<0.005	<0.005	<0.005
2-Methylnaphthalene	91-57-6	0.005	mg/kg	<0.005	<0.005	<0.005	<0.005	<0.005
Acenaphthylene	208-96-8	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Acenaphthene	83-32-9	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Fluorene	86-73-7	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Phenanthrene	85-01-8	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Anthracene	120-12-7	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Fluoranthene	206-44-0	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Pyrene	129-00-0	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Benz(a)anthracene	56-55-3	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Chrysene	218-01-9	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Benzo(b+j)fluoranthene	205-99-2 205-82-3	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Benzo(k)fluoranthene	207-08-9	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Benzo(e)pyrene	192-97-2	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Benzo(a)pyrene	50-32-8	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Perylene	198-55-0	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Benzo(g.h.i)perylene	191-24-2	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Dibenz(a.h)anthracene	53-70-3	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Indeno(1.2.3.cd)pyrene	193-39-5	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Coronene	191-07-1	0.005	mg/kg	<0.005	<0.005	<0.005	<0.005	<0.005
^ **Sum of PAHs**	----	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
^ **Benzo(a)pyrene TEQ (zero)**	----	0.004	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
^ **Benzo(a)pyrene TEQ (half LOR)**	----	0.004	mg/kg	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
^ **Benzo(a)pyrene TEQ (LOR)**	----	0.004	mg/kg	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**68.8**	**68.2**	**72.5**	**72.4**	**75.7**
Toluene-D8	2037-26-5	0.2	%	**62.6**	**59.4**	**65.4**	**64.6**	**68.4**
4-Bromofluorobenzene	460-00-4	0.2	%	**78.6**	**74.8**	**88.7**	**83.8**	**80.0**
EP090S: Organotin Surrogate								

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH3B	BH4A	BH4B	BH5A	BH5B
Sampling date / time				11-Apr-2021 12:30	11-Apr-2021 13:44	11-Apr-2021 13:44	11-Apr-2021 11:41	11-Apr-2021 11:41
				EB2109794-006	EB2109794-007	EB2109794-008	EB2109794-009	EB2109794-010
				Result	Result	Result	Result	Result
EP090S: Organotin Surrogate - Continued								
Tripropyltin	----	0.5	%	99.2	71.7	64.7	55.0	111
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	69.8	55.6	54.0	57.2	53.7
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	76.6	54.4	50.2	53.6	56.1
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	118	98.4	92.6	110	107
Anthracene-d10	1719-06-8	10	%	112	99.1	100.0	117	98.4
4-Terphenyl-d14	1718-51-0	10	%	97.2	86.3	86.1	101	88.4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	G1	G2	----	----	----
			Sampling date / time	11-Apr-2021 15:00	11-Apr-2021 15:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2109794-011	EB2109794-012	--------	--------	--------
				Result	Result	----	----	----
EA150: Particle Sizing								
+75µm	----	1	%	88	89	----	----	----
+150µm	----	1	%	86	70	----	----	----
+300µm	----	1	%	81	15	----	----	----
+425µm	----	1	%	79	7	----	----	----
+600µm	----	1	%	77	5	----	----	----
+1180µm	----	1	%	73	2	----	----	----
+2.36mm	----	1	%	62	<1	----	----	----
+4.75mm	----	1	%	43	<1	----	----	----
+9.5mm	----	1	%	<1	<1	----	----	----
+19.0mm	----	1	%	<1	<1	----	----	----
+37.5mm	----	1	%	<1	<1	----	----	----
+75.0mm	----	1	%	<1	<1	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	6	9	----	----	----
Silt (2-60 µm)	----	1	%	5	2	----	----	----
Sand (0.06-2.00 mm)	----	1	%	24	88	----	----	----
Gravel (>2mm)	----	1	%	65	1	----	----	----
Cobbles (>6cm)	----	1	%	<1	<1	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106
EP132T: Base/Neutral Extractable Surrogates			
2-Fluorobiphenyl	321-60-8	55	135
Anthracene-d10	1719-06-8	70	136
4-Terphenyl-d14	1718-51-0	57	127

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EK055: Ammonia as N

(SOIL) EP131A: Organochlorine Pesticides

(SOIL) EP131S: OC Pesticide Surrogate

(SOIL) EP131B: Polychlorinated Biphenyls (as Aroclors)

(SOIL) EP131T: PCB Surrogate

(SOIL) EP132B: Polynuclear Aromatic Hydrocarbons

(SOIL) EP132T: Base/Neutral Extractable Surrogates

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EB2109794**	Page	: 1 of 13
Client	: **BMT COMMERCIAL AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: KATRINA O'MALLEY JONES	Contact	: Andrew Epps
Address	: PO BOX 203 SPRING HILL BRISBANE QLD 4004	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8639
Project	: A10946.01	Date Samples Received	: 12-Apr-2021
Order number	: ----	Date Analysis Commenced	: 14-Apr-2021
C-O-C number	: ----	Issue Date	: 27-Apr-2021
Sampler	: CONOR JONES		
Site	: ----		
Quote number	: BN/152/21		
No. of samples received	: 12		
No. of samples analysed	: 12		

NATA
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, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

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*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Diana Mesa	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Acceptable RPD (%)*
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES (QC Lot: 3619148)									
EB2109794-001	BH1A	EG005-SD: Aluminium	7429-90-5	50	mg/kg	4190	4300	2.53	0% - 20%
		EG005-SD: Iron	7439-89-6	50	mg/kg	10500	10900	3.53	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (Low Level) (QC Lot: 3619150)									
EB2109794-001	BH1A	EG035T-LL: Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
EA033-A: Actual Acidity (QC Lot: 3625595)									
EB2109794-001	BH1A	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.00	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.00	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	9.3	9.3	0.00	0% - 20%
EM2106291-006	Anonymous	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.00	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.00	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	6.7	6.7	0.00	0% - 20%
EA033-B: Potential Acidity (QC Lot: 3625595)									
EB2109794-001	BH1A	EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	0.108	0.110	1.57	0% - 20%
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	68	69	1.57	No Limit
EM2106291-006	Anonymous	EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	0.015	0.017	14.3	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	11	0.00	No Limit
EA033-C: Acid Neutralising Capacity (QC Lot: 3625595)									
EB2109794-001	BH1A	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	6.96	6.94	0.202	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	2.23	2.22	0.00	0% - 20%
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	1390	1390	0.202	0% - 20%

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Acceptable RPD (%)*
EA033-C: Acid Neutralising Capacity (QC Lot: 3625595) - continued									
EM2106291-006	Anonymous	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	0.84	0.75	12.0	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	0.27	0.24	12.0	0% - 20%
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	169	150	12.0	0% - 50%
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 3619152)									
EB2109794-001	BH1A	EA055: Moisture Content	----	0.1	%	30.7	30.8	0.00	0% - 20%
EG020-SD: Total Metals in Sediments by ICPMS (QC Lot: 3619149)									
EB2109794-001	BH1A	EG020-SD: Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
		EG020-SD: Selenium	7782-49-2	0.1	mg/kg	0.4	0.3	0.00	No Limit
		EG020-SD: Silver	7440-22-4	0.1	mg/kg	<0.1	0.1	0.00	No Limit
		EG020-SD: Antimony	7440-36-0	0.5	mg/kg	<0.50	<0.50	0.00	No Limit
		EG020-SD: Cobalt	7440-48-4	0.5	mg/kg	6.4	6.6	2.31	0% - 50%
		EG020-SD: Arsenic	7440-38-2	1	mg/kg	7.54	7.76	2.94	No Limit
		EG020-SD: Chromium	7440-47-3	1	mg/kg	12.2	12.7	4.09	0% - 50%
		EG020-SD: Copper	7440-50-8	1	mg/kg	4.4	4.6	4.62	No Limit
		EG020-SD: Lead	7439-92-1	1	mg/kg	3.8	4.2	9.30	No Limit
		EG020-SD: Nickel	7440-02-0	1	mg/kg	9.6	9.6	0.00	No Limit
		EG020-SD: Zinc	7440-66-6	1	mg/kg	16.8	17.0	1.38	0% - 50%
		EG020-SD: Manganese	7439-96-5	10	mg/kg	307	300	2.26	0% - 20%
		EG020-SD: Vanadium	7440-62-2	2	mg/kg	17.7	18.4	3.62	No Limit
EK055: Ammonia as N (QC Lot: 3641443)									
EB2109794-001	BH1A	EK055-SD: Ammonia as N	7664-41-7	1	mg/kg	<1	<1	0.00	No Limit
EK057G: Nitrite as N by Discrete Analyser (QC Lot: 3619146)									
EB2109794-001	BH1A	EK057G: Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QC Lot: 3619145)									
EB2109794-001	BH1A	EK059G: Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QC Lot: 3619143)									
EB2109794-001	BH1A	EK061G: Total Kjeldahl Nitrogen as N	----	20	mg/kg	220	220	0.00	0% - 50%
EK067G: Total Phosphorus as P by Discrete Analyser (QC Lot: 3619144)									
EB2109794-001	BH1A	EK067G: Total Phosphorus as P	----	2	mg/kg	145	145	0.00	0% - 20%
EP003: Total Organic Carbon (TOC) in Soil (QC Lot: 3632840)									
EB2109794-001	BH1A	EP003: Total Organic Carbon	----	0.02	%	0.22	0.22	0.00	0% - 50%
ES2113186-001	Anonymous	EP003: Total Organic Carbon	----	0.02	%	0.02	0.04	48.2	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 3619147)									
EB2109794-001	BH1A	EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
EB2109794-010	BH5B	EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 3619151)									

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Acceptable RPD (%)*
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 3619151) - continued									
EB2109794-001	BH1A	EP071-SD-SV: C10 - C14 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD-SV: C15 - C28 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD-SV: C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD-SV: C29 - C36 Fraction	----	5	mg/kg	<5	<5	0.00	No Limit
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QC Lot: 3619147)									
EB2109794-001	BH1A	EP080-SD: C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	0.00	No Limit
EB2109794-010	BH5B	EP080-SD: C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	0.00	No Limit
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QC Lot: 3619151)									
EB2109794-001	BH1A	EP071-SD-SV: >C10 - C16 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD-SV: >C16 - C34 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD-SV: >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD-SV: >C34 - C40 Fraction	----	5	mg/kg	<5	<5	0.00	No Limit
EP080-SD: BTEXN (QC Lot: 3619147)									
EB2109794-001	BH1A	EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Total Xylenes	----	0.2	mg/kg	<0.5	<0.5	0.00	No Limit
		EP080-SD: Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
EB2109794-010	BH5B	EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Total Xylenes	----	0.2	mg/kg	<0.5	<0.5	0.00	No Limit
		EP080-SD: Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
EP090: Organotin Compounds (QC Lot: 3619025)									
EB2109794-001	BH1A	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.00	No Limit
		EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	0.00	No Limit
		EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	0.00	No Limit
EM2106095-001	Anonymous	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.00	No Limit
		EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	0.00	No Limit
		EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	0.00	No Limit
EP131A: Organochlorine Pesticides (QC Lot: 3631943)									
EB2109794-006	BH3B	EP131A: gamma-BHC	58-89-9	0.25	µg/kg	<0.00025 mg/kg	<0.25	0.00	No Limit
		EP131A: cis-Chlordane	5103-71-9	0.25	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Acceptable RPD (%)
				Laboratory Duplicate (DUP) Report					
EP131A: Organochlorine Pesticides (QC Lot: 3631943) - continued									
EB2109794-006	BH3B	EP131A: trans-Chlordane	5103-74-2	0.25	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Total Chlordane (sum)	----	0.25	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Aldrin	309-00-2	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: alpha-BHC	319-84-6	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: beta-BHC	319-85-7	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: delta-BHC	319-86-8	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: 4.4`-DDD	72-54-8	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: 4.4`-DDE	72-55-9	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: 4.4`-DDT	50-29-3	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Dieldrin	60-57-1	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: alpha-Endosulfan	959-98-8	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: beta-Endosulfan	33213-65-9	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Endosulfan sulfate	1031-07-8	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Endosulfan (sum)	115-29-7	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Endrin	72-20-8	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Endrin aldehyde	7421-93-4	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Endrin ketone	53494-70-5	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Heptachlor	76-44-8	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Heptachlor epoxide	1024-57-3	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Hexachlorobenzene (HCB)	118-74-1	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
		EP131A: Methoxychlor	72-43-5	0.5	µg/kg	<0.00050 mg/kg	<0.50	0.00	No Limit
EP131B: Polychlorinated Biphenyls (as Aroclors) (QC Lot: 3631942)									
EB2109794-006	BH3B	EP131B: Total Polychlorinated biphenyls	----	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1016	12674-11-2	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1221	11104-28-2	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1232	11141-16-5	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1242	53469-21-9	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1248	12672-29-6	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1254	11097-69-1	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
		EP131B: Aroclor 1260	11096-82-5	5	µg/kg	<0.0050 mg/kg	<5.0	0.00	No Limit
EP132B: Polynuclear Aromatic Hydrocarbons (QC Lot: 3631945)									
EB2109794-005	BH3A	EP132B-SD: Acenaphthylene	208-96-8	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Acenaphthene	83-32-9	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Fluorene	86-73-7	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Phenanthrene	85-01-8	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Anthracene	120-12-7	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Fluoranthene	206-44-0	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Pyrene	129-00-0	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Laboratory Duplicate (DUP) Report					
				LOR	Unit	Original Result	Duplicate Result	RPD (%)	Acceptable RPD (%)
EP132B: Polynuclear Aromatic Hydrocarbons (QC Lot: 3631945) - continued									
EB2109794-005	BH3A	EP132B-SD: Benz(a)anthracene	56-55-3	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Chrysene	218-01-9	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Benzo(k)fluoranthene	207-08-9	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Benzo(e)pyrene	192-97-2	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Benzo(a)pyrene	50-32-8	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Perylene	198-55-0	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Sum of PAHs	----	4	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Naphthalene	91-20-3	5	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: 2-Methylnaphthalene	91-57-6	5	µg/kg	<0.005 mg/kg	<5	0.00	No Limit
		EP132B-SD: Coronene	191-07-1	5	µg/kg	<0.005 mg/kg	<5	0.00	No Limit

Method Blank (MB) and Laboratory Control Sample (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES (QCLot: 3619148)								
EG005-SD: Aluminium	7429-90-5	50	mg/kg	<50	12361 mg/kg	105	70.0	130
EG005-SD: Iron	7439-89-6	50	mg/kg	<50	30024 mg/kg	104	70.0	130
EG035T: Total Recoverable Mercury by FIMS (Low Level) (QCLot: 3619150)								
EG035T-LL: Mercury	7439-97-6	0.01	mg/kg	<0.01	0.087 mg/kg	114	70.0	130
EA033-A: Actual Acidity (QCLot: 3625595)								
EA033: pH KCl (23A)	----	----	pH Unit	----	4.4 pH Unit	100	91.0	107
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	15 mole H+ / t	90.4	70.0	124
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity (QCLot: 3625595)								
EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	0.155 % S	94.6	77.0	121
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 3625595)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	10 % CaCO3	101	91.0	112
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
EG020-SD: Total Metals in Sediments by ICPMS (QCLot: 3619149)								
EG020-SD: Antimony	7440-36-0	0.5	mg/kg	<0.50	----	----	----	----
EG020-SD: Arsenic	7440-38-2	1	mg/kg	<1.00	101 mg/kg	99.0	80.0	124
EG020-SD: Cadmium	7440-43-9	0.1	mg/kg	<0.1	1.45816 mg/kg	91.4	87.0	122
EG020-SD: Chromium	7440-47-3	1	mg/kg	<1.0	16.7 mg/kg	111	79.0	129
EG020-SD: Copper	7440-50-8	1	mg/kg	<1.0	44.6 mg/kg	104	85.0	118
EG020-SD: Cobalt	7440-48-4	0.5	mg/kg	<0.5	10.3 mg/kg	96.1	70.0	130
EG020-SD: Lead	7439-92-1	1	mg/kg	<1.0	54.3 mg/kg	107	86.0	119
EG020-SD: Manganese	7439-96-5	10	mg/kg	<10	522 mg/kg	93.8	70.0	130
EG020-SD: Nickel	7440-02-0	1	mg/kg	<1.0	12.8 mg/kg	101	77.0	123
EG020-SD: Selenium	7782-49-2	0.1	mg/kg	<0.1	----	----	----	----
EG020-SD: Silver	7440-22-4	0.1	mg/kg	<0.1	2.35 mg/kg	103	70.0	130
EG020-SD: Vanadium	7440-62-2	2	mg/kg	<2.0	47.6 mg/kg	94.9	70.0	130
EG020-SD: Zinc	7440-66-6	1	mg/kg	<1.0	180.62184 mg/kg	95.4	71.0	127
EK055: Ammonia as N (QCLot: 3641443)								
EK055-SD: Ammonia as N	7664-41-7	1	mg/kg	<1	20 mg/kg	91.0	60.0	118
EK057G: Nitrite as N by Discrete Analyser (QCLot: 3619146)								
EK057G: Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	2.5 mg/kg	97.4	83.0	111

Sub-Matrix: **SOIL**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report Result	Laboratory Control Spike (LCS) Report Spike Concentration	Spike Recovery (%) LCS	Acceptable Limits (%) Low	Acceptable Limits (%) High
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 3619145)								
EK059G: Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	2.5 mg/kg	93.4	83.2	111
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 3619143)								
EK061G: Total Kjeldahl Nitrogen as N	----	20	mg/kg	<20	848 mg/kg	96.9	73.0	121
				<20	2180 mg/kg	92.1	72.0	128
EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 3619144)								
EK067G: Total Phosphorus as P	----	2	mg/kg	<2	939 mg/kg	92.7	80.0	115
				<2	1200 mg/kg	116	79.0	121
EP003: Total Organic Carbon (TOC) in Soil (QCLot: 3632840)								
EP003: Total Organic Carbon	----	0.02	%	<0.02	0.11 %	110	70.0	130
				<0.02	0.48 %	105	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 3619147)								
EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	18 mg/kg	93.4	66.0	120
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 3619151)								
EP071-SD-SV: C10 - C14 Fraction	----	3	mg/kg	<3	157 mg/kg	98.4	43.0	126
EP071-SD-SV: C15 - C28 Fraction	----	3	mg/kg	<3	245 mg/kg	101	66.0	140
EP071-SD-SV: C29 - C36 Fraction	----	5	mg/kg	<5	----	----	----	----
EP071-SD-SV: C10 - C36 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 3619147)								
EP080-SD: C6 - C10 Fraction	C6_C10	3	mg/kg	<3	22.5 mg/kg	90.8	66.0	119
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 3619151)								
EP071-SD-SV: >C10 - C16 Fraction	----	3	mg/kg	<3	227 mg/kg	101	40.0	134
EP071-SD-SV: >C16 - C34 Fraction	----	3	mg/kg	<3	162 mg/kg	101	66.0	136
EP071-SD-SV: >C34 - C40 Fraction	----	5	mg/kg	<5	----	----	----	----
EP071-SD-SV: >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD: BTEXN (QCLot: 3619147)								
EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	1 mg/kg	88.1	73.0	105
EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	1 mg/kg	89.9	73.0	105
EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	1 mg/kg	93.7	67.0	104
EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	2 mg/kg	90.0	66.0	106
EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	1 mg/kg	95.8	68.0	105
EP080-SD: Total Xylenes	----	0.2	mg/kg	<0.2	----	----	----	----
EP080-SD: Sum of BTEX	----	0.2	mg/kg	<0.2	----	----	----	----
EP080-SD: Naphthalene	91-20-3	0.2	mg/kg	<0.2	1 mg/kg	94.4	72.0	115
EP090: Organotin Compounds (QCLot: 3619025)								
EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	1.25 µgSn/kg	57.4	36.0	128
EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	1.25 µgSn/kg	76.0	42.0	132
EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	1.25 µgSn/kg	79.4	52.0	139

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EP131A: Organochlorine Pesticides (QCLot: 3631943)								
EP131A: Aldrin	309-00-2	0.5	µg/kg	<0.50	5 µg/kg	93.2	38.0	139
EP131A: alpha-BHC	319-84-6	0.5	µg/kg	<0.50	5 µg/kg	58.4	17.6	136
EP131A: beta-BHC	319-85-7	0.5	µg/kg	<0.50	5 µg/kg	65.3	30.5	131
EP131A: delta-BHC	319-86-8	0.5	µg/kg	<0.50	5 µg/kg	80.6	37.0	140
EP131A: 4.4`-DDD	72-54-8	0.5	µg/kg	<0.50	5 µg/kg	91.4	25.9	141
EP131A: 4.4`-DDE	72-55-9	0.5	µg/kg	<0.50	5 µg/kg	65.1	35.0	129
EP131A: 4.4`-DDT	50-29-3	0.5	µg/kg	<0.50	5 µg/kg	91.8	23.4	138
EP131A: Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.5	µg/kg	<0.50	----	----	----	----
EP131A: Dieldrin	60-57-1	0.5	µg/kg	<0.50	5 µg/kg	76.0	30.2	140
EP131A: alpha-Endosulfan	959-98-8	0.5	µg/kg	<0.50	5 µg/kg	82.8	38.0	140
EP131A: beta-Endosulfan	33213-65-9	0.5	µg/kg	<0.50	5 µg/kg	93.8	32.0	152
EP131A: Endosulfan sulfate	1031-07-8	0.5	µg/kg	<0.50	5 µg/kg	113	36.0	155
EP131A: Endosulfan (sum)	115-29-7	0.5	µg/kg	<0.50	----	----	----	----
EP131A: Endrin	72-20-8	0.5	µg/kg	<0.50	5 µg/kg	100	25.8	158
EP131A: Endrin aldehyde	7421-93-4	0.5	µg/kg	<0.50	5 µg/kg	78.9	20.1	118
EP131A: Endrin ketone	53494-70-5	0.5	µg/kg	<0.50	5 µg/kg	97.0	13.4	135
EP131A: Heptachlor	76-44-8	0.5	µg/kg	<0.50	5 µg/kg	69.6	39.0	155
EP131A: Heptachlor epoxide	1024-57-3	0.5	µg/kg	<0.50	5 µg/kg	82.3	34.0	148
EP131A: Hexachlorobenzene (HCB)	118-74-1	0.5	µg/kg	<0.50	5 µg/kg	63.3	26.1	152
EP131A: gamma-BHC	58-89-9	0.25	µg/kg	<0.25	5 µg/kg	65.0	31.2	137
EP131A: Methoxychlor	72-43-5	0.5	µg/kg	<0.50	5 µg/kg	102	36.0	152
EP131A: cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	5 µg/kg	90.8	36.0	142
EP131A: trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	5 µg/kg	75.4	29.5	138
EP131A: Total Chlordane (sum)	----	0.25	µg/kg	<0.25	----	----	----	----
EP131B: Polychlorinated Biphenyls (as Aroclors) (QCLot: 3631942)								
EP131B: Total Polychlorinated biphenyls	----	5	µg/kg	<5.0	50 µg/kg	69.8	45.0	115
EP131B: Aroclor 1016	12674-11-2	5	µg/kg	<5.0	----	----	----	----
EP131B: Aroclor 1221	11104-28-2	5	µg/kg	<5.0	----	----	----	----
EP131B: Aroclor 1232	11141-16-5	5	µg/kg	<5.0	----	----	----	----
EP131B: Aroclor 1242	53469-21-9	5	µg/kg	<5.0	----	----	----	----
EP131B: Aroclor 1248	12672-29-6	5	µg/kg	<5.0	----	----	----	----
EP131B: Aroclor 1254	11097-69-1	5	µg/kg	<5.0	50 µg/kg	69.8	45.0	115
EP131B: Aroclor 1260	11096-82-5	5	µg/kg	<5.0	----	----	----	----
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 3631945)								
EP132B-SD: Naphthalene	91-20-3	5	µg/kg	<5	25 µg/kg	90.6	63.0	129
EP132B-SD: 2-Methylnaphthalene	91-57-6	5	µg/kg	<5	25 µg/kg	95.2	64.0	128
EP132B-SD: Acenaphthylene	208-96-8	4	µg/kg	<4	25 µg/kg	98.0	65.0	129
EP132B-SD: Acenaphthene	83-32-9	4	µg/kg	<4	25 µg/kg	91.2	68.0	132

Sub-Matrix: **SOIL**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report Result	Laboratory Control Spike (LCS) Report Spike Concentration	Spike Recovery (%) LCS	Acceptable Limits (%) Low	Acceptable Limits (%) High
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 3631945) - continued								
EP132B-SD: Fluorene	86-73-7	4	µg/kg	<4	25 µg/kg	83.2	68.0	124
EP132B-SD: Phenanthrene	85-01-8	4	µg/kg	<4	25 µg/kg	90.2	64.0	134
EP132B-SD: Anthracene	120-12-7	4	µg/kg	<4	25 µg/kg	93.8	65.0	131
EP132B-SD: Fluoranthene	206-44-0	4	µg/kg	<4	25 µg/kg	83.2	64.0	130
EP132B-SD: Pyrene	129-00-0	4	µg/kg	<4	25 µg/kg	82.6	67.0	133
EP132B-SD: Benz(a)anthracene	56-55-3	4	µg/kg	<4	25 µg/kg	92.8	62.0	130
EP132B-SD: Chrysene	218-01-9	4	µg/kg	<4	25 µg/kg	88.0	65.0	133
EP132B-SD: Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	25 µg/kg	92.3	68.0	120
EP132B-SD: Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	25 µg/kg	82.3	61.0	133
EP132B-SD: Benzo(e)pyrene	192-97-2	4	µg/kg	<4	25 µg/kg	89.4	63.0	127
EP132B-SD: Benzo(a)pyrene	50-32-8	4	µg/kg	<4	25 µg/kg	89.8	66.0	118
EP132B-SD: Perylene	198-55-0	4	µg/kg	<4	25 µg/kg	90.1	69.0	119
EP132B-SD: Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	25 µg/kg	87.0	66.0	120
EP132B-SD: Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	25 µg/kg	87.7	64.0	122
EP132B-SD: Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	25 µg/kg	87.7	64.0	120
EP132B-SD: Coronene	191-07-1	5	µg/kg	<5	25 µg/kg	79.8	68.0	136
EP132B-SD: Sum of PAHs	----	4	µg/kg	<4	----	----	----	----

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Acceptable Limits (%) Low	Acceptable Limits (%) High
EG035T: Total Recoverable Mercury by FIMS (Low Level) (QCLot: 3619150)							
EB2109794-002	BH1B	EG035T-LL: Mercury	7439-97-6	0.5 mg/kg	107	70.0	130
EG020-SD: Total Metals in Sediments by ICPMS (QCLot: 3619149)							
EB2109794-002	BH1B	EG020-SD: Arsenic	7440-38-2	100 mg/kg	92.2	70.0	130
		EG020-SD: Cadmium	7440-43-9	25 mg/kg	90.9	70.0	130
		EG020-SD: Chromium	7440-47-3	100 mg/kg	90.3	70.0	130
		EG020-SD: Copper	7440-50-8	100 mg/kg	88.1	70.0	130
		EG020-SD: Cobalt	7440-48-4	100 mg/kg	78.7	70.0	130
		EG020-SD: Lead	7439-92-1	100 mg/kg	85.8	70.0	130
		EG020-SD: Manganese	7439-96-5	100 mg/kg	70.8	70.0	130
		EG020-SD: Nickel	7440-02-0	100 mg/kg	89.8	70.0	130
		EG020-SD: Vanadium	7440-62-2	100 mg/kg	86.4	70.0	130

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Acceptable Limits (%)	
				Concentration	MS	Low	High
EG020-SD: Total Metals in Sediments by ICPMS (QCLot: 3619149) - continued							
EB2109794-002	BH1B	EG020-SD: Zinc	7440-66-6	100 mg/kg	92.8	70.0	130
EK055: Ammonia as N (QCLot: 3641443)							
EB2109794-001	BH1A	EK055-SD: Ammonia as N	7664-41-7	20 mg/kg	88.2	70.0	130
EK057G: Nitrite as N by Discrete Analyser (QCLot: 3619146)							
EB2109794-002	BH1B	EK057G: Nitrite as N (Sol.)	14797-65-0	2 mg/kg	97.3	70.0	130
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 3619145)							
EB2109794-002	BH1B	EK059G: Nitrite + Nitrate as N (Sol.)	----	2 mg/kg	92.8	70.0	130
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 3619143)							
EB2109794-002	BH1B	EK061G: Total Kjeldahl Nitrogen as N	----	500 mg/kg	95.0	70.0	130
EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 3619144)							
EB2109794-002	BH1B	EK067G: Total Phosphorus as P	----	100 mg/kg	97.5	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 3619147)							
EB2109794-002	BH1B	EP080-SD: C6 - C9 Fraction	----	80 mg/kg	85.4	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 3619151)							
EB2109794-002	BH1B	EP071-SD-SV: C10 - C14 Fraction	----	157 mg/kg	106	70.0	130
		EP071-SD-SV: C15 - C28 Fraction	----	245 mg/kg	112	70.0	130
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 3619147)							
EB2109794-002	BH1B	EP080-SD: C6 - C10 Fraction	C6_C10	80 mg/kg	84.0	70.0	130
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 3619151)							
EB2109794-002	BH1B	EP071-SD-SV: >C10 - C16 Fraction	----	227 mg/kg	110	70.0	130
		EP071-SD-SV: >C16 - C34 Fraction	----	162 mg/kg	113	70.0	130
EP080-SD: BTEXN (QCLot: 3619147)							
EB2109794-002	BH1B	EP080-SD: Benzene	71-43-2	20 mg/kg	86.8	70.0	130
		EP080-SD: Toluene	108-88-3	20 mg/kg	81.9	70.0	130
EP090: Organotin Compounds (QCLot: 3619025)							
EB2109794-002	BH1B	EP090: Monobutyltin	78763-54-9	1.25 µgSn/kg	21.4	20.0	130
		EP090: Dibutyltin	1002-53-5	1.25 µgSn/kg	72.0	20.0	130
		EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	81.0	20.0	130
EP131A: Organochlorine Pesticides (QCLot: 3631943)							
EB2109794-007	BH4A	EP131A: Aldrin	309-00-2	5 µg/kg	91.5	23.4	153
		EP131A: alpha-BHC	319-84-6	5 µg/kg	58.5	17.6	156
		EP131A: beta-BHC	319-85-7	5 µg/kg	66.1	24.9	153
		EP131A: delta-BHC	319-86-8	5 µg/kg	77.7	25.2	147
		EP131A: 4.4`-DDD	72-54-8	5 µg/kg	67.5	25.9	150
		EP131A: 4.4`-DDE	72-55-9	5 µg/kg	50.6	31.2	125

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Acceptable Limits (%) Low	High
EP131A: Organochlorine Pesticides (QCLot: 3631943) - continued							
EB2109794-007	BH4A	EP131A: 4.4`-DDT	50-29-3	5 µg/kg	96.4	23.4	163
		EP131A: Dieldrin	60-57-1	5 µg/kg	68.8	30.2	140
		EP131A: alpha-Endosulfan	959-98-8	5 µg/kg	73.9	28.8	135
		EP131A: beta-Endosulfan	33213-65-9	5 µg/kg	86.3	22.6	141
		EP131A: Endosulfan sulfate	1031-07-8	5 µg/kg	86.5	16.1	156
		EP131A: Endrin	72-20-8	5 µg/kg	111	17.7	162
		EP131A: Endrin aldehyde	7421-93-4	5 µg/kg	71.6	20.1	116
		EP131A: Endrin ketone	53494-70-5	5 µg/kg	69.2	13.4	151
		EP131A: Heptachlor	76-44-8	5 µg/kg	94.5	23.8	170
		EP131A: Heptachlor epoxide	1024-57-3	5 µg/kg	81.4	28.3	140
		EP131A: Hexachlorobenzene (HCB)	118-74-1	5 µg/kg	64.9	17.7	144
		EP131A: gamma-BHC	58-89-9	5 µg/kg	59.0	21.8	158
		EP131A: Methoxychlor	72-43-5	5 µg/kg	80.4	24.4	158
		EP131A: cis-Chlordane	5103-71-9	5 µg/kg	71.8	27.3	139
		EP131A: trans-Chlordane	5103-74-2	5 µg/kg	64.8	29.5	138
EP131B: Polychlorinated Biphenyls (as Aroclors) (QCLot: 3631942)							
EB2109794-007	BH4A	EP131B: Total Polychlorinated biphenyls	----	50 µg/kg	58.9	44.0	136
		EP131B: Aroclor 1254	11097-69-1	50 µg/kg	58.9	44.0	136
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 3631945)							
EB2109794-005	BH3A	EP132B-SD: Naphthalene	91-20-3	25 µg/kg	88.7	70.0	130
		EP132B-SD: 2-Methylnaphthalene	91-57-6	25 µg/kg	95.4	70.0	130
		EP132B-SD: Acenaphthylene	208-96-8	25 µg/kg	73.1	70.0	130
		EP132B-SD: Acenaphthene	83-32-9	25 µg/kg	# 64.0	70.0	130
		EP132B-SD: Fluorene	86-73-7	25 µg/kg	# 60.4	70.0	130
		EP132B-SD: Phenanthrene	85-01-8	25 µg/kg	89.2	70.0	130
		EP132B-SD: Anthracene	120-12-7	25 µg/kg	95.1	70.0	130
		EP132B-SD: Fluoranthene	206-44-0	25 µg/kg	84.5	70.0	130
		EP132B-SD: Pyrene	129-00-0	25 µg/kg	83.9	70.0	130
		EP132B-SD: Benz(a)anthracene	56-55-3	25 µg/kg	93.8	70.0	130
		EP132B-SD: Chrysene	218-01-9	25 µg/kg	87.1	70.0	130
		EP132B-SD: Benzo(b+j)fluoranthene	205-99-2 205-82-3	25 µg/kg	88.3	70.0	130
		EP132B-SD: Benzo(k)fluoranthene	207-08-9	25 µg/kg	79.8	70.0	130
		EP132B-SD: Benzo(e)pyrene	192-97-2	25 µg/kg	86.9	70.0	130
		EP132B-SD: Benzo(a)pyrene	50-32-8	25 µg/kg	89.6	70.0	130
		EP132B-SD: Perylene	198-55-0	25 µg/kg	90.9	70.0	130
		EP132B-SD: Benzo(g.h.i)perylene	191-24-2	25 µg/kg	87.8	70.0	130
		EP132B-SD: Dibenz(a.h)anthracene	53-70-3	25 µg/kg	88.7	70.0	130
		EP132B-SD: Indeno(1.2.3.cd)pyrene	193-39-5	25 µg/kg	88.2	70.0	130

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Acceptable Limits (%)	
				Concentration	MS	Low	High
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 3631945) - continued							
EB2109794-005	BH3A	EP132B-SD: Coronene	191-07-1	25 µg/kg	83.5	70.0	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EB2109794**	Page	: 1 of 12
Client	: **BMT COMMERCIAL AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: KATRINA O'MALLEY JONES	Telephone	: +61 7 3552 8639
Project	: A10946.01	Date Samples Received	: 12-Apr-2021
Site	: ----	Issue Date	: 27-Apr-2021
Sampler	: CONOR JONES	No. of samples received	: 12
Order number	: ----	No. of samples analysed	: 12

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
EP132B: Polynuclear Aromatic Hydrocarbons	EB2109794--005	BH3A	**Acenaphthene**	83-32-9	64.0 %	70.0-130%	**Recovery less than lower data quality objective**
EP132B: Polynuclear Aromatic Hydrocarbons	EB2109794--005	BH3A	**Fluorene**	86-73-7	60.4 %	70.0-130%	**Recovery less than lower data quality objective**

Outliers : Analysis Holding Time Compliance

Matrix: **SOIL**

Method		Extraction / Preparation			Analysis		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EK057G: Nitrite as N by Discrete Analyser							
Soil Glass Jar - Unpreserved							
BH1A,	BH1B,	21-Apr-2021	18-Apr-2021	**3**	----	----	----
BH2A,	BH2B,						
BH3A,	BH3B,						
BH4A,	BH4B,						
BH5A,	BH5B						

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL** Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		***Sample Date***	Extraction / Preparation			Analysis		
Container / *Client Sample ID(s)*			***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EA033-A: Actual Acidity								
80* dried soil (EA033)								
BH1A,	BH1B,	**11-Apr-2021**	**19-Apr-2021**	11-Apr-2022	✓	**19-Apr-2021**	18-Jul-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA033-B: Potential Acidity								
80* dried soil (EA033)								
BH1A,	BH1B,	**11-Apr-2021**	**19-Apr-2021**	11-Apr-2022	✓	**19-Apr-2021**	18-Jul-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EA033-C: Acid Neutralising Capacity								
80* dried soil (EA033)								
BH1A,	BH1B,	**11-Apr-2021**	**19-Apr-2021**	11-Apr-2022	✓	**19-Apr-2021**	18-Jul-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EA033-D: Retained Acidity								
80* dried soil (EA033)								
BH1A,	BH1B,	**11-Apr-2021**	**19-Apr-2021**	11-Apr-2022	✓	**19-Apr-2021**	18-Jul-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EA033-E: Acid Base Accounting								
80* dried soil (EA033)								
BH1A,	BH1B,	**11-Apr-2021**	**19-Apr-2021**	11-Apr-2022	✓	**19-Apr-2021**	18-Jul-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EA055: Moisture Content (Dried @ 105-110°C)								
Soil Glass Jar - Unpreserved (EA055)								
BH1A,	BH1B,	**11-Apr-2021**	**----**	----	----	**14-Apr-2021**	25-Apr-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA150: Particle Sizing								
Snap Lock Bag (EA150H)								
G1,	G2	**11-Apr-2021**	**----**	----	----	**22-Apr-2021**	08-Oct-2021	✓
Snap Lock Bag - Friable Asbestos/PSD Bag (EA150H)								
BH1A, BH2A, BH3A, BH4A, BH5A,	BH1B, BH2B, BH3B, BH4B, BH5B	**11-Apr-2021**	**----**	----	----	**22-Apr-2021**	08-Oct-2021	✓
EA150: Soil Classification based on Particle Size								
Snap Lock Bag (EA150H)								
G1,	G2	**11-Apr-2021**	**----**	----	----	**22-Apr-2021**	08-Oct-2021	✓
Snap Lock Bag - Friable Asbestos/PSD Bag (EA150H)								
BH1A, BH2A, BH3A, BH4A, BH5A,	BH1B, BH2B, BH3B, BH4B, BH5B	**11-Apr-2021**	**----**	----	----	**22-Apr-2021**	08-Oct-2021	✓
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Soil Glass Jar - Unpreserved (EG005-SD)								
BH1A, BH2A, BH3A, BH4A, BH5A,	BH1B, BH2B, BH3B, BH4B, BH5B	**11-Apr-2021**	**21-Apr-2021**	08-Oct-2021	✓	**22-Apr-2021**	08-Oct-2021	✓
EG020-SD: Total Metals in Sediments by ICPMS								
Soil Glass Jar - Unpreserved (EG020-SD)								
BH1A, BH2A, BH3A, BH4A, BH5A,	BH1B, BH2B, BH3B, BH4B, BH5B	**11-Apr-2021**	**21-Apr-2021**	08-Oct-2021	✓	**22-Apr-2021**	08-Oct-2021	✓
EG035T: Total Recoverable Mercury by FIMS								
Soil Glass Jar - Unpreserved (EG035T-LL)								
BH1A, BH2A, BH3A, BH4A, BH5A,	BH1B, BH2B, BH3B, BH4B, BH5B	**11-Apr-2021**	**21-Apr-2021**	09-May-2021	✓	**22-Apr-2021**	09-May-2021	✓

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EK055: Ammonia as N								
Soil Glass Jar - Unpreserved (EK055-SD)								
BH1A,	BH1B,	**11-Apr-2021**	**----**	----	----	**26-Apr-2021**	09-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EK057G: Nitrite as N by Discrete Analyser								
Soil Glass Jar - Unpreserved (EK057G)								
BH1A,	BH1B,	**11-Apr-2021**	**21-Apr-2021**	18-Apr-2021	×	**21-Apr-2021**	23-Apr-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Soil Glass Jar - Unpreserved (EK059G)								
BH1A,	BH1B,	**11-Apr-2021**	**21-Apr-2021**	09-May-2021	✓	**21-Apr-2021**	23-Apr-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Soil Glass Jar - Unpreserved (EK061G)								
BH1A,	BH1B,	**11-Apr-2021**	**21-Apr-2021**	09-May-2021	✓	**21-Apr-2021**	19-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EK067G: Total Phosphorus as P by Discrete Analyser								
Soil Glass Jar - Unpreserved (EK067G)								
BH1A,	BH1B,	**11-Apr-2021**	**21-Apr-2021**	09-May-2021	✓	**21-Apr-2021**	19-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EP003: Total Organic Carbon (TOC) in Soil								
Pulp Bag (EP003)								
BH1A,	BH1B,	**11-Apr-2021**	**21-Apr-2021**	09-May-2021	✓	**21-Apr-2021**	09-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
Soil Glass Jar - Unpreserved (EP080-SD)								
BH1A,	BH1B,	**11-Apr-2021**	**17-Apr-2021**	25-Apr-2021	✓	**21-Apr-2021**	25-Apr-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
Soil Glass Jar - Unpreserved (EP071-SD-SV)								
BH1A,	BH1B,	**11-Apr-2021**	**20-Apr-2021**	25-Apr-2021	✓	**22-Apr-2021**	30-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
Soil Glass Jar - Unpreserved (EP080-SD)								
BH1A,	BH1B,	**11-Apr-2021**	**17-Apr-2021**	25-Apr-2021	✓	**21-Apr-2021**	25-Apr-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
Soil Glass Jar - Unpreserved (EP071-SD-SV)								
BH1A,	BH1B,	**11-Apr-2021**	**20-Apr-2021**	25-Apr-2021	✓	**22-Apr-2021**	30-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EP080-SD: BTEXN								
Soil Glass Jar - Unpreserved (EP080-SD)								
BH1A,	BH1B,	**11-Apr-2021**	**17-Apr-2021**	25-Apr-2021	✓	**21-Apr-2021**	25-Apr-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EP090: Organotin Compounds								
Soil Glass Jar - Unpreserved (EP090)								
BH1A,	BH1B,	**11-Apr-2021**	**16-Apr-2021**	25-Apr-2021	✓	**20-Apr-2021**	26-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Extraction / Preparation: Due for extraction	Extraction / Preparation: Evaluation	Analysis: Date analysed	Analysis: Due for analysis	Analysis: Evaluation
EP131A: Organochlorine Pesticides								
Soil Glass Jar - Unpreserved (EP131A)								
BH1A,	BH1B,	**11-Apr-2021**	**20-Apr-2021**	25-Apr-2021	✓	**22-Apr-2021**	30-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EP131B: Polychlorinated Biphenyls (as Aroclors)								
Soil Glass Jar - Unpreserved (EP131B)								
BH1A,	BH1B,	**11-Apr-2021**	**20-Apr-2021**	25-Apr-2021	✓	**22-Apr-2021**	30-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							
EP132B: Polynuclear Aromatic Hydrocarbons								
Soil Glass Jar - Unpreserved (EP132B-SD)								
BH1A,	BH1B,	**11-Apr-2021**	**20-Apr-2021**	25-Apr-2021	✓	**22-Apr-2021**	30-May-2021	✓
BH2A,	BH2B,							
BH3A,	BH3B,							
BH4A,	BH4B,							
BH5A,	BH5B							

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Buchi Ammonia - Low-Level in Sediment	EK055-SD	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chromium Suite for Acid Sulphate Soils	EA033	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Moisture Content	EA055	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N - Soluble by Discrete Analyser	EK057G	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organochlorine Pesticides (Ultra-trace)	EP131A	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organotin Analysis	EP090	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
PCB's (Ultra-trace)	EP131B	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TKN as N By Discrete Analyser	EK061G	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Fe and Al in Sediments by ICPAES	EG005-SD	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP003	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Phosporus By Discrete Analyser	EK067G	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fractions Only	EP071-SD-SV	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Buchi Ammonia - Low-Level in Sediment	EK055-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chromium Suite for Acid Sulphate Soils	EA033	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N - Soluble by Discrete Analyser	EK057G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organochlorine Pesticides (Ultra-trace)	EP131A	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organotin Analysis	EP090	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PCB's (Ultra-trace)	EP131B	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TKN as N By Discrete Analyser	EK061G	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Fe and Al in Sediments by ICPAES	EG005-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP003	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Phosporus By Discrete Analyser	EK067G	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fractions Only	EP071-SD-SV	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Matrix: **SOIL**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Method Blanks (MB)							
Buchi Ammonia - Low-Level in Sediment	EK055-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chromium Suite for Acid Sulphate Soils	EA033	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N - Soluble by Discrete Analyser	EK057G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organochlorine Pesticides (Ultra-trace)	EP131A	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organotin Analysis	EP090	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PCB's (Ultra-trace)	EP131B	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TKN as N By Discrete Analyser	EK061G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Fe and Al in Sediments by ICPAES	EG005-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP003	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Phosporus By Discrete Analyser	EK067G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fractions Only	EP071-SD-SV	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Buchi Ammonia - Low-Level in Sediment	EK055-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N - Soluble by Discrete Analyser	EK057G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organochlorine Pesticides (Ultra-trace)	EP131A	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organotin Analysis	EP090	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PCB's (Ultra-trace)	EP131B	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TKN as N By Discrete Analyser	EK061G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Phosporus By Discrete Analyser	EK067G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fractions Only	EP071-SD-SV	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Chromium Suite for Acid Sulphate Soils	EA033	SOIL	In house: Referenced to Ahern et al 2004. This method covers the determination of Chromium Reducible Sulfur (SCR); pHKCl; titratable actual acidity (TAA); acid neutralising capacity by back titration (ANC); and net acid soluble sulfur (SNAS) which incorporates peroxide sulfur. It applies to soils and sediments (including sands) derived from coastal regions. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
Moisture Content	EA055	SOIL	In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 105-110 degrees C. This method is compliant with NEPM Schedule B(3).
Particle Size Analysis by Hydrometer	EA150H	SOIL	Particle Size Analysis by Hydrometer according to AS1289.3.6.3
Total Fe and Al in Sediments by ICPAES	EG005-SD	SOIL	In house: Referenced to APHA 3120; USEPA SW 846 - 6010. Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM Schedule B(3). LORs per NODG
Total Metals in Sediments by ICPMS	EG020-SD	SOIL	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. Analyte list and LORs per NODG.
Total Mercury by FIMS (Low Level)	EG035T-LL	SOIL	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM Schedule B(3)
Buchi Ammonia - Low-Level in Sediment	EK055-SD	SOIL	In house: Referenced to APHA 4500-NH3 B&G, H Samples are steam distillated (Buchi) prior to analysis and quantified using titrimetric determination.
Nitrite as N - Soluble by Discrete Analyser	EK057G	SOIL	In house: Referenced to APHA 4500-NO3- B. Nitrite in a water extract is determined by direct colourimetry by Discrete Analyser.
Nitrate as N - Soluble by Discrete Analyser	EK058G	SOIL	In house: Referenced to APHA 4500-NO3- F. Nitrate in the 1:5 soil:water extract is reduced to nitrite by way of a chemical reduction followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results.
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	SOIL	In house: Thermo Scientific Method D08727 and NEMI (National Environmental Method Index) Method ID: 9171. This method covers the determination of total oxidised nitrogen (NOx-N) and nitrate (NO3-N) by calculation, Combined oxidised Nitrogen (NO2+NO3) in a water extract is determined by direct colourimetry by Discrete Analyser.
TKN as N By Discrete Analyser	EK061G	SOIL	In house: Referenced to APHA 4500-Norg-D Soil samples are digested using Kjeldahl digestion followed by determination by Discrete Analyser.
Total Nitrogen as N (TKN + NOx) By Discrete Analyser	EK062G	SOIL	In house: Referenced to APHA 4500 Norg/NO3- Total Nitrogen is determined as the sum of TKN and Oxidised Nitrogen, each determined seperately as N.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Total Phosporus By Discrete Analyser	EK067G	SOIL	In house: Referenced to APHA 4500 P-B&F This procedure involves sulfuric acid digestion and quantification using Discrete Analyser.
Total Organic Carbon	EP003	SOIL	In house C-IR17. Dried and pulverised sample is reacted with acid to remove inorganic Carbonates, then combusted in a furnace in the presence of strong oxidants / catalysts. The evolved (Organic) Carbon (as CO2) is automatically measured by infra-red detector.
TPH - Semivolatile Fractions Only	EP071-SD-SV	SOIL	In house: Referenced to USEPA SW 846 - 8270. Extracts are analysed by Capillary GC/FID and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM Schedule B(3)
TRH Volatiles/BTEX in Sediments	EP080-SD	SOIL	In house: Referenced to USEPA SW 846 - 8260 Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve.
Organotin Analysis	EP090	SOIL	In house: Referenced to USEPA SW 846 - 8270 Prepared sample extracts are analysed by GC/MS coupled with high volume injection, and quanitified against an established calibration curve.
Organochlorine Pesticides (Ultra-trace)	EP131A	SOIL	In house: Referenced to USEPA Method 3640 (GPC cleanup),3620 (Florisil), 8081/8082 (GC/µECD/µECD) This technique is compliant with NEPM Schedule B(3)
PCB's (Ultra-trace)	EP131B	SOIL	In house: Referenced to USEPA Method 3640 (GPC cleanup),3620 (Florisil), 8081/8082 (GC/µECD/µECD) This technique is compliant with NEPM Schedule B(3)
PAHs in Sediments by GCMS(SIM)	EP132B-SD	SOIL	In house: Referenced to USEPA 8270 GCMS Capillary column, SIM mode using large volume programmed temperature vaporisation injection.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
TKN/TP Digestion	EK061/EK067	SOIL	In house: Referenced to APHA 4500 Norg- D; APHA 4500 P - H. Macro Kjeldahl digestion.
Drying at 85 degrees, bagging and labelling (ASS)	EN020PR	SOIL	In house
1:5 solid / water leach for soluble analytes	EN34	SOIL	10 g of soil is mixed with 50 mL of reagent grade water and tumbled end over end for 1 hour. Water soluble salts are leached from the soil by the continuous suspension. Samples are settled and the water filtered off for analysis.
Hot Block Digest for metals in soils sediments and sludges	EN69	SOIL	In house: Referenced to USEPA 200.2. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM Schedule B(3).
Dry and Pulverise (up to 100g)	GEO30	SOIL	#
Methanolic Extraction of Soils for Purge and Trap	ORG16	SOIL	In house: Referenced to USEPA SW 846 - 5030A. 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.
Tumbler Extraction of Solids/ Sample Cleanup	ORG17A-UTP	SOIL	In house: Mechanical agitation (tumbler). 20g of sample, Na2SO4 and surrogate are extracted with 150mL 1:1 DCM/Acetone by end over end tumble. Samples are extracted, concentrated (by KD) and exchanged into an appropriate solvent for GPC and florisil cleanup as required.
Tumbler Extraction of Solids for LVI (Non-concentrating)	ORG17D	SOIL	In house: 10g of sample, Na2SO4 and surrogate are extracted with 50mL 1:1 DCM/Acetone by end over end tumbling. An aliquot is concentrated by nitrogen blowdown to a reduced volume for analysis if required.
Organotin Sample Preparation	ORG35	SOIL	In house: 20g sample is spiked with surrogate and leached in a methanol:acetic acid:UHP water mix and vacuum filtered. Reagents and solvents are added to the sample and the mixture tumbled. The butyltin compounds are simultaneously derivatised and extracted. The extract is further extracted with petroleum ether. The resultant extracts are combined and concentrated for analysis.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*

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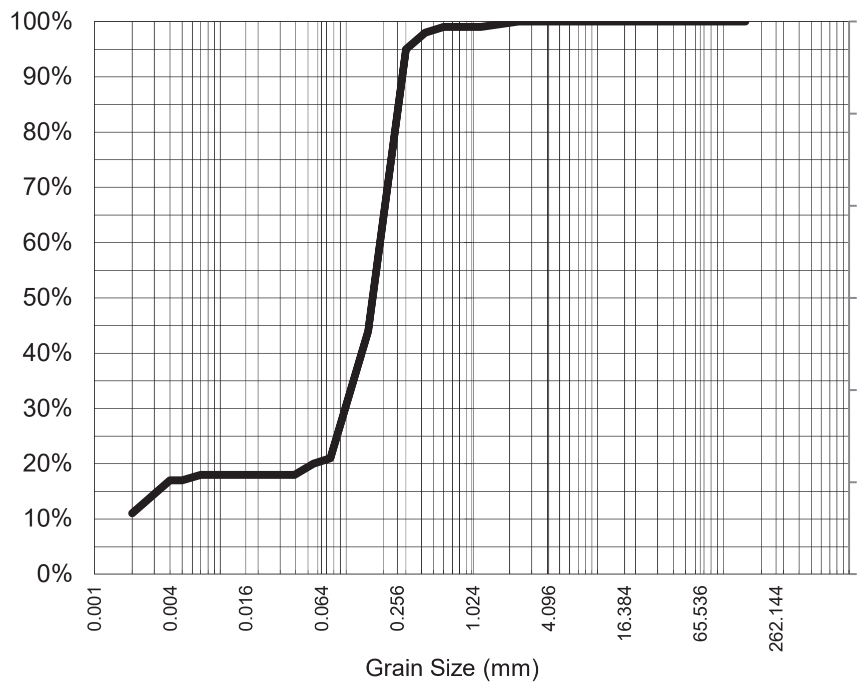
CLIENT:	KATRINA O'MALLEY JONES	**DATE REPORTED:**	22-Apr-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-001 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH1A

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	99%
0.425	98%
0.300	95%
0.150	44%
0.075	21%
Particle Size (microns)	
55	20%
39	18%
28	18%
19	18%
14	18%
10	18%
7	18%
5	17%
2	11%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.168

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.68

NATA Accreditation: 825 Site: Brisbane
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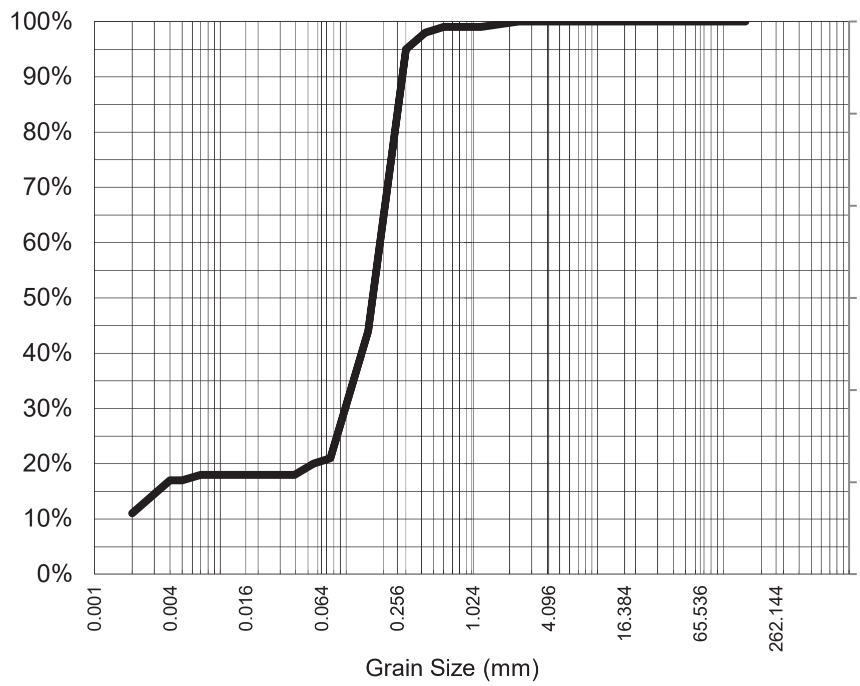
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-001DUP / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH1A

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	99%
0.425	98%
0.300	95%
0.150	44%
0.075	21%
Particle Size (microns)	
55	20%
39	18%
28	18%
19	18%
14	18%
10	18%
7	18%
5	17%
2	11%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.168

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.68

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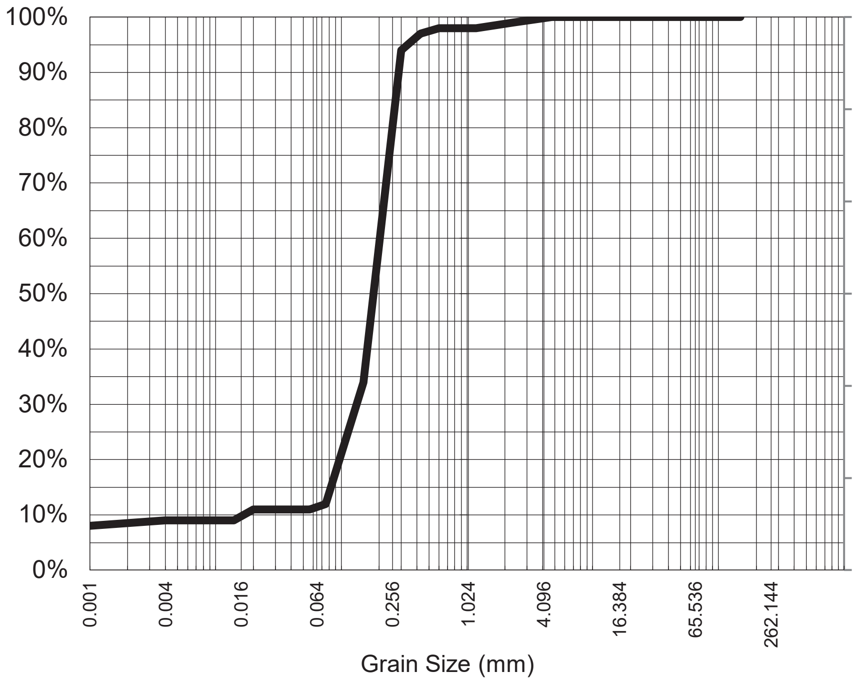
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-002 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH1B

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	98%
0.600	98%
0.425	97%
0.300	94%
0.150	34%
0.075	12%
Particle Size (microns)	
56	11%
39	11%
28	11%
20	11%
14	9%
10	9%
7	9%
5	9%
1	8%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.190

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.79

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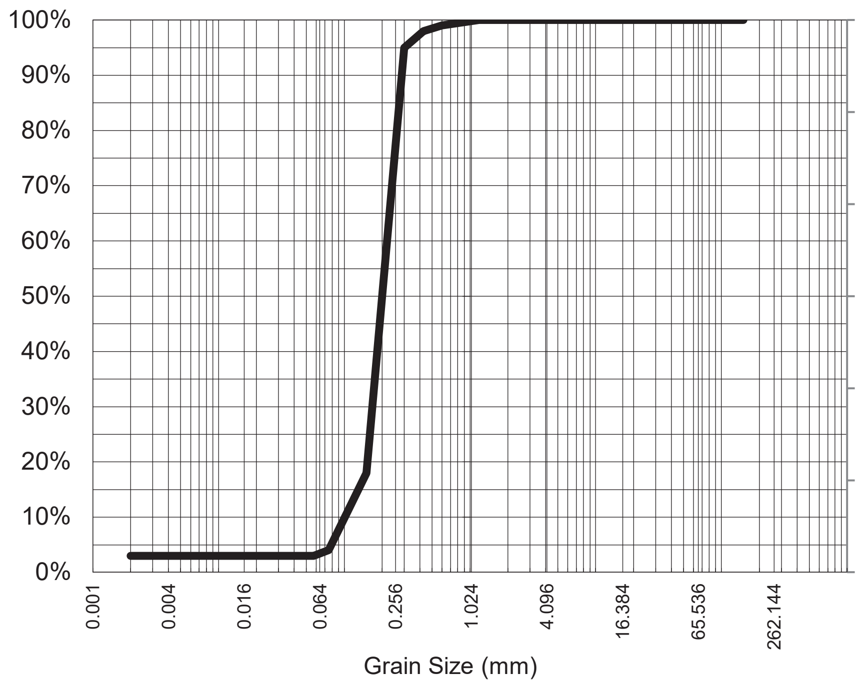
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-003 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH2A

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	99%
0.425	98%
0.300	95%
0.150	18%
0.075	4%
Particle Size (microns)	
57	3%
41	3%
29	3%
20	3%
15	3%
10	3%
7	3%
5	3%
2	3%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.212

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.69

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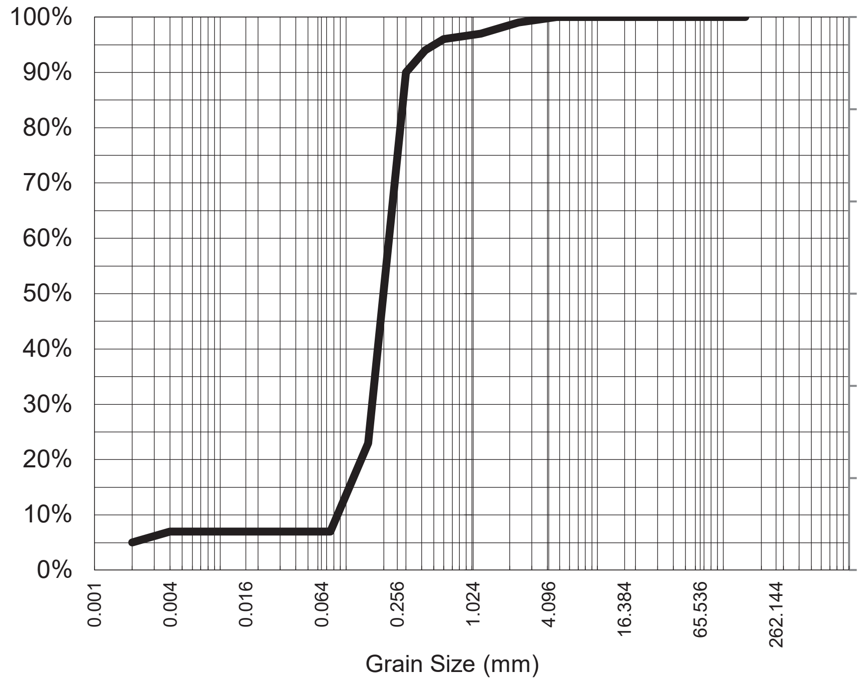
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-004 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH2B

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	97%
0.600	96%
0.425	94%
0.300	90%
0.150	23%
0.075	7%
Particle Size (microns)	
61	7%
43	7%
31	7%
22	7%
16	7%
11	7%
8	7%
6	7%
2	5%

Median Particle Size (mm)*	0.210

Analysis Notes

Samples analysed as received.
** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.35 (2.45)*

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CLIENT: KATRINA O'MALLEY JONES

DATE REPORTED: 22-Apr-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 12-Apr-2021

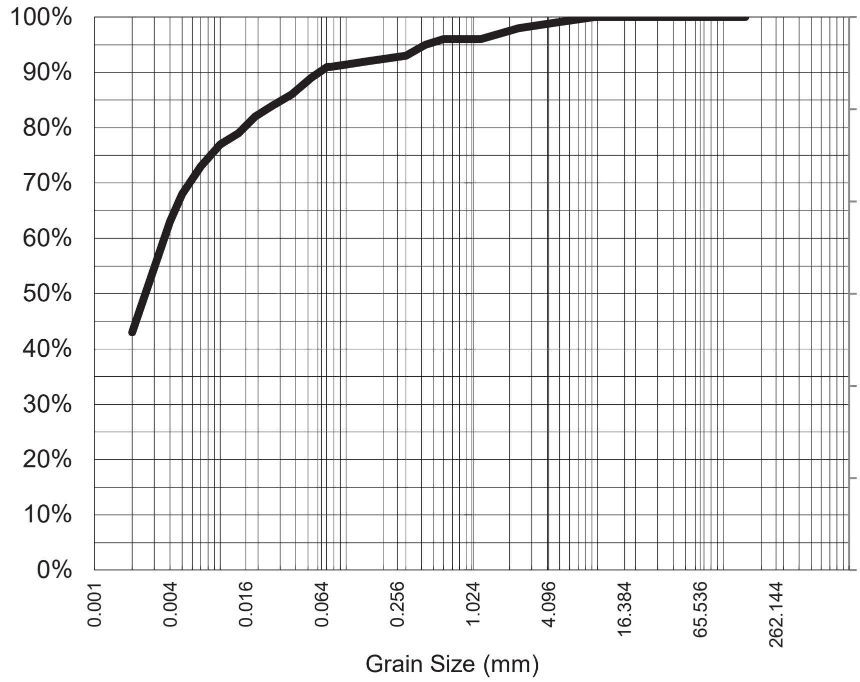
ADDRESS: Po Box 203
Spring Hill
Brisbane Qld

REPORT NO: EB2109794-005 / PSD

PROJECT: A10946.01

SAMPLE ID: BH3A

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	99%
2.36	98%
1.18	96%
0.600	96%
0.425	95%
0.300	93%
0.150	92%
0.075	91%
Particle Size (microns)	
53	89%
37	86%
26	84%
19	82%
14	79%
10	77%
7	73%
5	68%
2	43%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	<0.007

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.5

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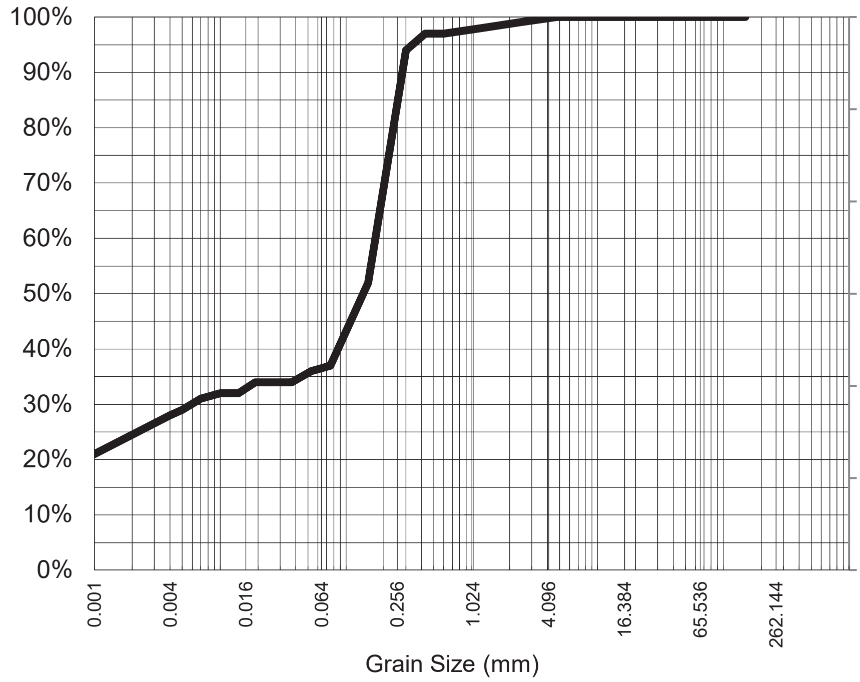
PROJECT:	A10946.01	**SAMPLE ID:**	BH3B

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	98%
0.600	97%
0.425	97%
0.300	94%
0.150	52%
0.075	37%
Particle Size (microns)	
53	36%
37	34%
26	34%
19	34%
14	32%
10	32%
7	31%
5	29%
1	21%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.140

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.67

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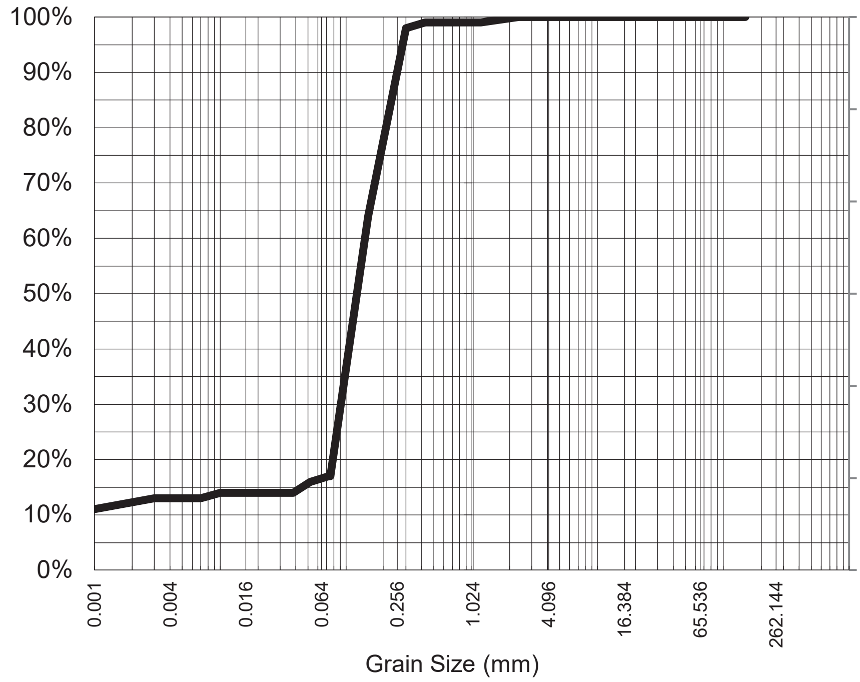
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-007 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH4A

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	99%
0.425	99%
0.300	98%
0.150	64%
0.075	17%
Particle Size (microns)	
52	16%
38	14%
27	14%
19	14%
14	14%
10	14%
7	13%
5	13%
1	11%

Median Particle Size (mm)*	0.128

Analysis Notes

Samples analysed as received.
** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.91 (2.85)*

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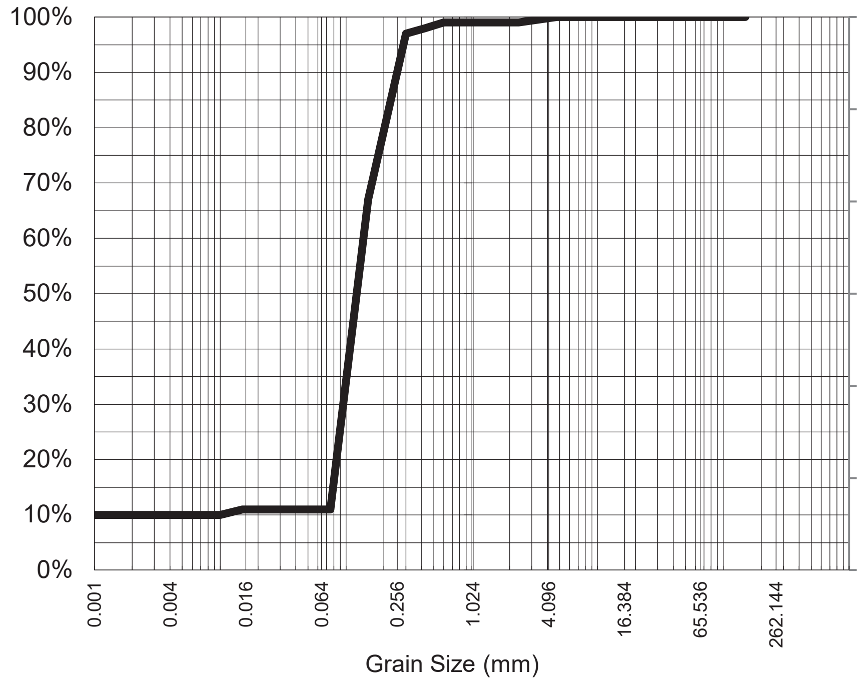
CLIENT:	KATRINA O'MALLEY JONES	**DATE REPORTED:**	22-Apr-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-008 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH4B

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	99%
0.600	99%
0.425	98%
0.300	97%
0.150	67%
0.075	11%
Particle Size (microns)	
56	11%
40	11%
28	11%
20	11%
15	11%
10	10%
7	10%
5	10%
1	10%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.127

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.73

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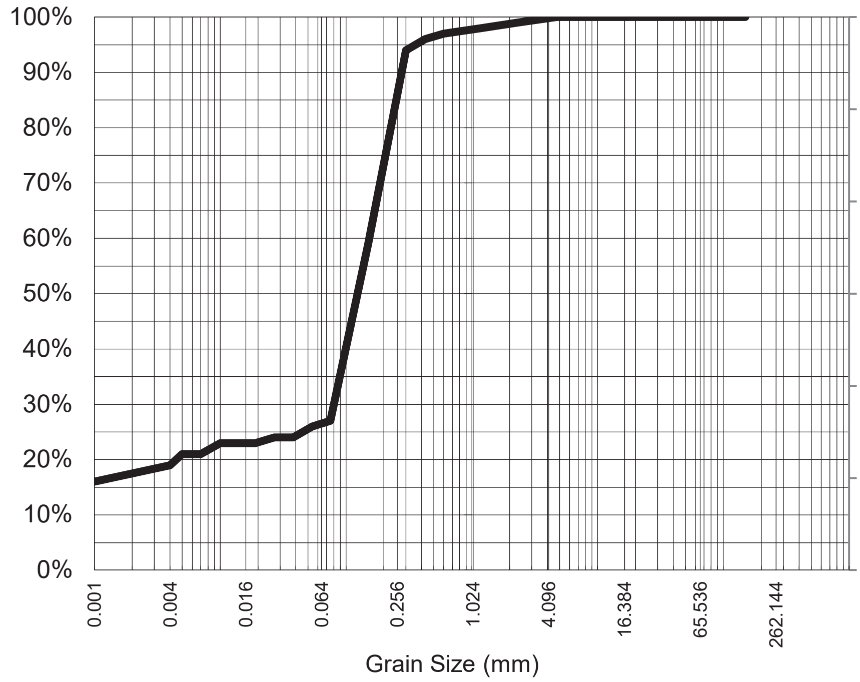
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-009 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH5A

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	98%
0.600	97%
0.425	96%
0.300	94%
0.150	59%
0.075	27%
Particle Size (microns)	
54	26%
38	24%
27	24%
19	23%
14	23%
10	23%
7	21%
5	21%
1	16%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.129

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.71

NATA Accreditation: 825 Site: Brisbane
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NATA
WORLD RECOGNISED ACCREDITATION

Satish Trivedi
Soil Senior Chemist
Authorised Signatory

Template Version PKV8.0 180919

Certificate of Analysis

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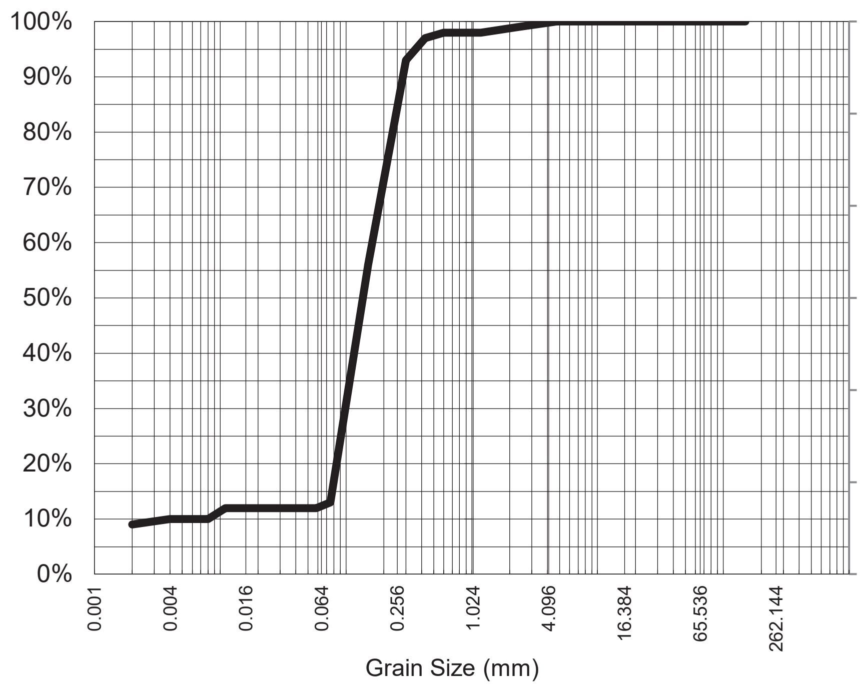
2 Byth Street
Stafford, QLD 4053
pH 07 3243 7222
samples.brisbane@alsenviro.com

ALS Environmental

Brisbane QLD

CLIENT:	KATRINA O'MALLEY JONES	**DATE REPORTED:**	22-Apr-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-010 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	BH5B

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	98%
0.600	98%
0.425	97%
0.300	93%
0.150	56%
0.075	13%
Particle Size (microns)	
58	12%
41	12%
29	12%
21	12%
15	12%
11	12%
8	10%
5	10%
2	9%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.140

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.62

NATA Accreditation: 825 Site: Brisbane
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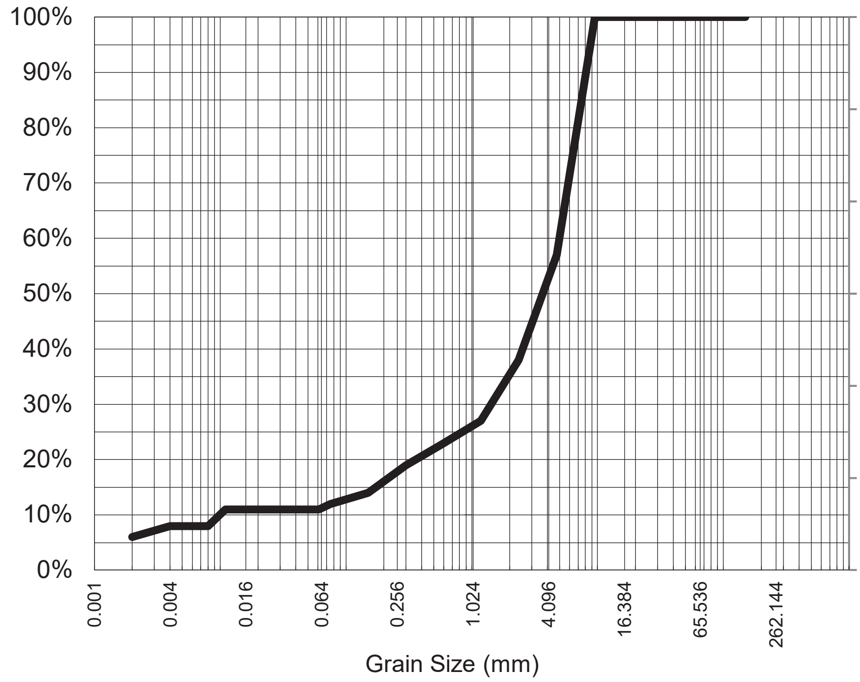
CLIENT:	KATRINA O'MALLEY JONES	**DATE REPORTED:**	22-Apr-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-011 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	G1

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	57%
2.36	38%
1.18	27%
0.600	23%
0.425	21%
0.300	19%
0.150	14%
0.075	12%
Particle Size (microns)	
61	11%
43	11%
31	11%
22	11%
16	11%
11	11%
8	8%
6	8%
2	6%

Analysis Notes

Samples analysed as received.
** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size (mm)*	3.869

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 1.89 (2.45)*

NATA Accreditation: 825 Site: Brisbane
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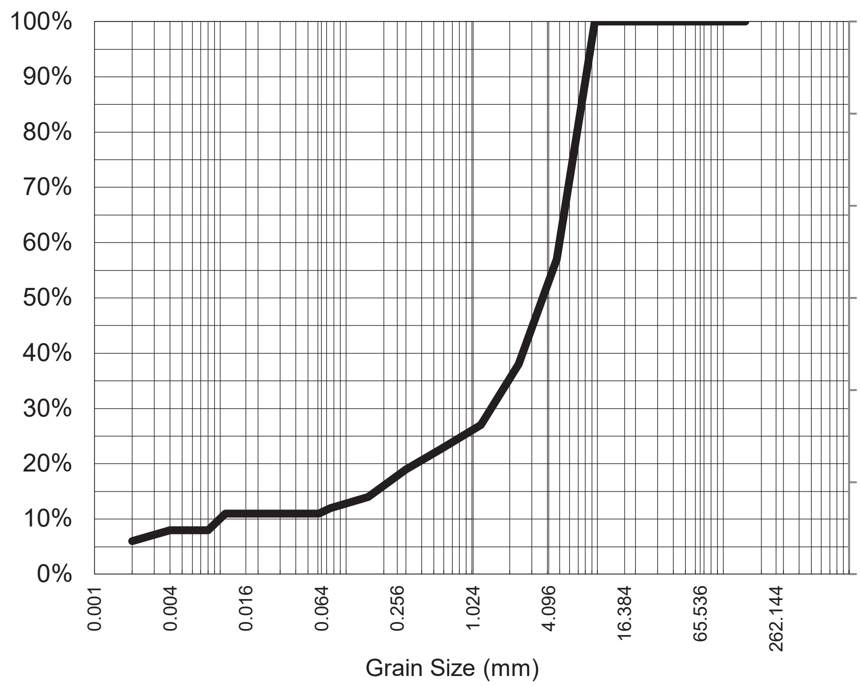
Brisbane QLD

CLIENT:	KATRINA O'MALLEY JONES	**DATE REPORTED:**	22-Apr-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-011DUP / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	G1

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	57%
2.36	38%
1.18	27%
0.600	23%
0.425	21%
0.300	19%
0.150	14%
0.075	12%
Particle Size (microns)	
61	11%
43	11%
31	11%
22	11%
16	11%
11	11%
8	8%
6	8%
2	6%

Median Particle Size (mm)*	3.869

Analysis Notes

Samples analysed as received.
** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 1.89 (2.45)*

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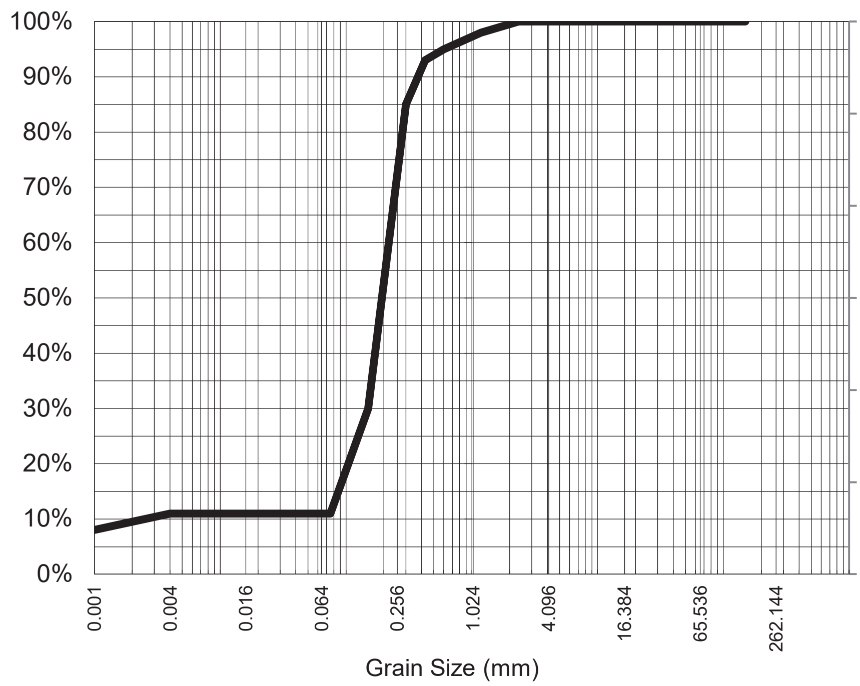
CLIENT:	KATRINA O'MALLEY JONES	**DATE REPORTED:**	22-Apr-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	12-Apr-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2109794-012 / PSD
PROJECT:	A10946.01	**SAMPLE ID:**	G2

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	98%
0.600	95%
0.425	93%
0.300	85%
0.150	30%
0.075	11%
Particle Size (microns)	
56	11%
40	11%
28	11%
20	11%
15	11%
10	11%
7	11%
5	11%
1	8%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.205

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 22-Apr-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.71

NATA Accreditation: 825 Site: Brisbane
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BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

BMT

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Appendix B Environmental Issues Briefing Paper

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Technical Memorandum

From:	Lisa McKinnon	To:	Livingstone Shire Council
Date:	1 September 2021	CC:	
Subject:	Causeway Lake Dredging Project – Environmental Values and Potential Impacts		

1 Introduction

Causeway Lake is an impounded tidal basin between Mulambin and Kinka Beach, south of Yeppoon on the Capricorn Coast. The lake is fed by Shoal Creek to the south and Mulambin Creek to the north. A rocky causeway and road bridge were constructed in 1939 across the mouth of the creek to link Yeppoon with Emu Park.

Livingstone Shire Council (the 'Shire') is considering options to revitalise the Causeway Lake area with the goal of optimising recreational use opportunities on the lake and facilitating supportive development along the lake's north and south shores. Restoration of the lake system is also desired to preserve the present-day environmental values that could be impacted by ongoing sedimentation.

In March 2021, the Shire engaged BMT Commercial Australia Pry Ltd (BMT) to study the feasibility of dredging the Causeway Lake to improve its recreational and environmental values and inform future applications for funding. This briefing paper discusses the existing environmental values of Causeway Lake and how these might be impacted by dredging and placement activity. The legislative regime and approvals that might be required to undertake dredging activity are also detailed.

2 Existing Environmental Values

2.1 Causeway Lake Dredging Footprint

2.1.1 Matters of National Environmental Significance

A Protected Matters Search was undertaken using the search tool to identify potential Matters of National Environmental Significance (MNES) (Figure 2-1). The area to be disturbed is within the Great Barrier Reef World Heritage Area (WHA) and the Yeppoon-Keppel Sands Tidal Nationally Important Wetland (NIW). The wetland has been listed because it provides an important source of recreation for the local population, as well as relatively undisturbed habitat in an otherwise highly disturbed and increasingly populated area (DNIW, 2021).

The search identified the potential for the following ecological values to be present within the study area:

- 46 threatened species (19 birds, 9 mammals, 9 reptiles, 6 plants and 3 shark/fish species)
- two Threatened Ecological Communities (Poplar Box Grassy Woodland on Alluvial Plains and Semi-evergreen vine thickets of the Brigalow Belt (north and south) and Nandawar Bioregions.

With the exception of shorebird species, it is unlikely that any of the listed species would be disturbed by dredging activity as they are mostly marine fauna (e.g. whales, turtles) or terrestrial species. Potentially works could disturb the Water Mouse (*Xeromys myoides*), which is often present where mangrove communities occur. The Queensland Wildnet Records (Department of Environment and Science, 2021) do show that a number of conservation significant shorebird species (i.e. Threatened, Vulnerable or Endangered) have been recorded within the vicinity of works; these are likely to utilise the saltmarsh habitat to north, west and south of the area to be disturbed. They also may occasionally feed within Causeway Lakes or its edges.

2.1.2 Matters of State Environmental Significance

The Queensland Globe mapping database was searched to identify any potential Matters of State Significance (MSES) that may be present within the study area, as shown in Figure 2-2.

The lake itself is not subject to any MSES, however the lake edges are mapped as Essential Habitat and Wildlife Habitat (Endangered or Vulnerable Species or Least Concern Species). Areas to the immediately south-west and east (Mulambin Beach) are part of the Queensland Protected Area Estate.

Large seagrass beds occur across the bed of the lake, which is also fringed with mangrove and saltmarsh vegetation communities; these are classified and protected as marine plants under the *Fisheries Act 1994* (FA). Whilst not mapped formally as a Fish Habitat Area (FHA) under the FA, the marine vegetation within and along the edges of Causeway Lake support fisheries values. Dredging activity will remove seagrass meadows in some areas however the concept design has minimised the area disturbed as much as possible.

2.1.3 Matters of Local Environmental Significance (MLES)

The Livingstone Shire Council Planning Scheme maps the lake as an MLES Wetland and a regional biodiversity corridor. It is also shown as a High-Risk area for acid sulfate soils. The lake edges are mapped as vegetation of local significance.

2.1.4 Other Environmental and Social Values

There is no data available on water quality within Causeway Lake. It is expected to be variable depending on tidal flushing and the time of year. With the shallow water depth across the lake, it is likely that water quality deteriorates in summer months when water temperatures are higher, and the risk of algal blooms and low oxygen levels increases. Dredging may contribute to a deterioration of water quality through the generation of turbid plumes.

The material to be dredged does contain some acid sulfate soils (refer to the dredging feasibility study (BMT, 2021); dredging will need to be undertaken in a manner that minimising exposure of this material. Should the acidic material remain underwater it should not oxidise; material exposed to air and placed on land will require some treatment with lime or some other means. Preliminary sediment testing did identify some elevated concentrations of ammonia, mercury and nickel, however the material should be considered mostly clean with respect to the National Assessment Guidelines for Dredging, and suitable for placement at sea or on land; some localised hotspots may need to be disposed to a licensed landfill however. Further testing will be required to confirm disposal requirements.

The sediment has not been tested for contaminants; there are no major sources of contaminants (e.g. industrial/agricultural areas) within the Causeway Lake catchment, therefore it is unlikely that sediment will contain significant levels of contaminants of concern; further testing will be required to confirm this assumption however.

Causeway Lake offers significant landscape and visual amenity for the community as well as offering recreational opportunities including swimming, boating and fishing. It has been anecdotally reported during the concept study that fishing catches have noticeably declined over recent years because of the lake shallowing. BMT have not undertaken a survey of aquatic fauna within the lake, so it is difficult to pinpoint why this decline may be occurring; it may be related to a number of matters including a change in habitat, water quality decline or overfishing. Certainly, the existing seagrass meadows and mangrove communities would be supporting juvenile fish species.

Maintaining social values and a level of serviceability during dredging activity will be a priority.

There are residential properties on the northern and southern banks of Causeway Lake that would be sensitive to noise nuisance generated by dredging activity.

2.1.5 Aboriginal heritage and other heritage

There are no known areas of indigenous or non-indigenous heritage, however further consultation with the community and traditional owners will be required to identify and protect any cultural values that might be disturbed by works.

2.2 Placement Options

The Dredging Feasibility Report (BMT, 2021) recommends that material dredged from Causeway Lake is either used for nearshore reclamation within the Lake itself or for beach nourishment of North Kinka Beach.

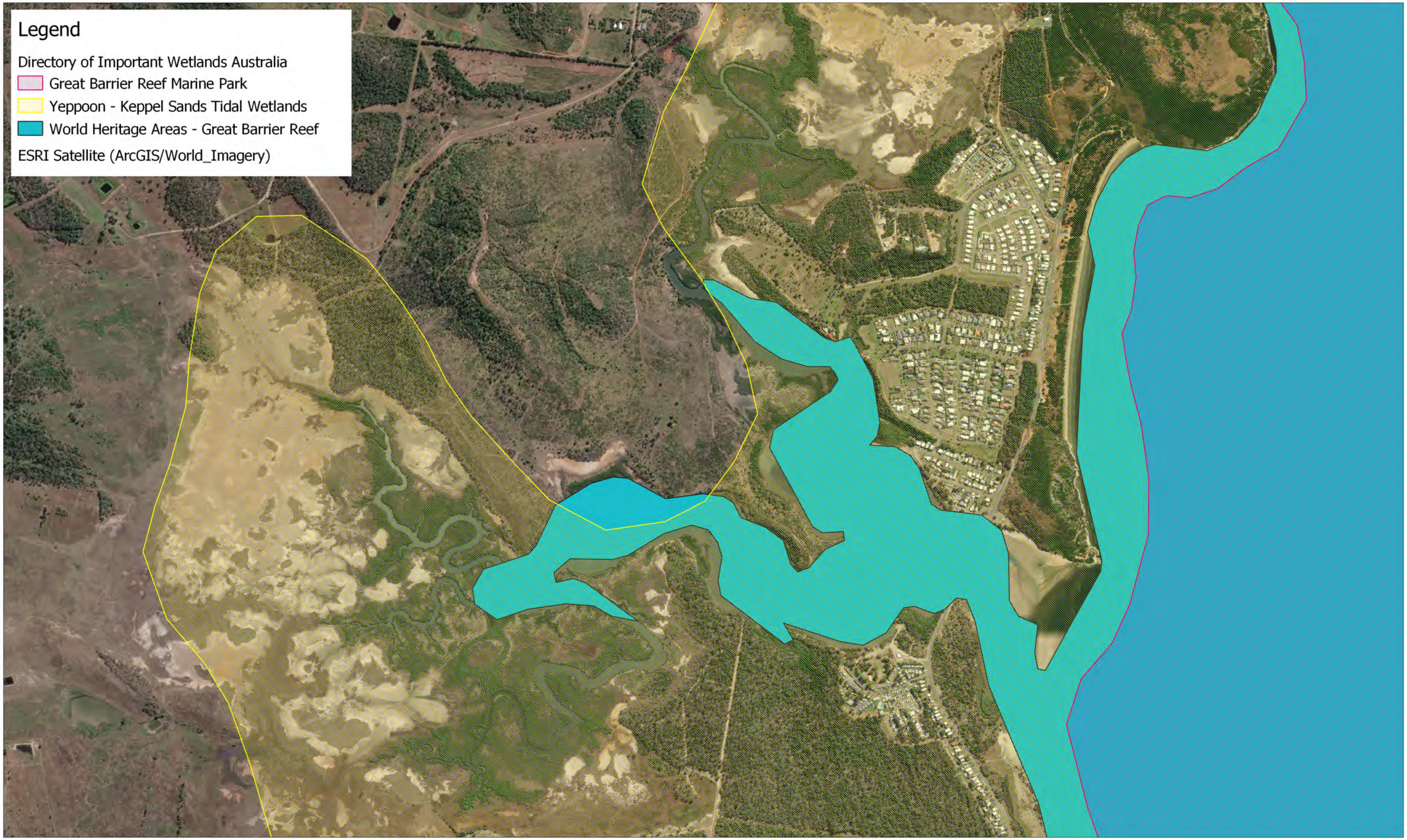
The environmental values of Causeway Lake are discussed in Section 2.1; the values of Kinka Beach are discussed below. The foreshore areas of Causeway Lake are more likely to support shorebird species, however the lake is not known as a roosting area, and the generally noisy and easily accessible shoreline is not likely to be favoured, as its doesn't offer protection from disturbance.

Like Causeway Lake, the nourishment area is within the Great Barrier Reef World Heritage Area and the Yeppoon-Keppel Sands Tidal Nationally Important Wetland. In addition, part of the area proposed to be nourished sits within the Great Barrier Reef Marine Park and Great Barrier Reef Coast State Marine Park.

Foreshore vegetation is mapped as habitat for endangered wildlife (which includes a large number of shorebird species as well as a number of frogs), essential habitat and contains remnant of concern vegetation (refer to Figure 2-2). It is also likely that this vegetation is considered to be marine plants, under the *Fisheries Act 1994*.

Whilst not listed, there is also potential for this stretch of beach to be utilised by nesting turtles.

A more detailed ecological survey would be required prior to placement to identify vegetation or habitat that is present and any areas that should be avoided during placement activity.



Title:

Matters of National Environmental Significance

Figure: 2-1

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 300 600 m

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Filepath: I:\A10946_I_CMJ_Causeway_Lake\DRG\ECO_013_210811_MNES.qgz

Title:	Figure:	Rev:
Matters of State Environmental Significance	**2-2**	**A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N 0 300 600 m

BMT www.bmt.org

Filepath: I:\A10946_I_CMJ_Causeway_Lake\DRG\ECO_012_210811_MSES.qgz

3 Potential Environmental Impacts

3.1 Dredging

Regardless of the removal method, dredging activity will have the following potential impacts:

- Creation of turbid plumes within the water column; these are typically of short duration, but within a relatively confined system may be persistent.
- Direct removal of seagrass beds and fisheries values; the current design proposes the removal of approximately 4.5ha of seagrass beds. There may also be some indirect disturbance of seagrass if turbid plumes shade meadows for an extended period which can cause a deterioration in their condition (i.e. reduced density or shoot length).
- Mobilisation of contaminants or acid sulfate soils present in the sediment to be disturbed, if not treated.
- The creation of nuisance noise for nearby residents.
- Noise that might disturb aquatic fauna or migratory shorebirds that cause them to avoid the area being dredged.
- Some odour and visual impact from seagrass wrack, following its removal from the lake bed.

Whilst these impacts may be locally significant, dredging would be unlikely to have a significant impact on any MNES matters (i.e. WHA's or listed species), based on the significance criteria defined in the Significant Impact Guidelines (Commonwealth of Australia, 2013).

At a state level, the only MSES triggered is the loss of marine plants (i.e. seagrass and potentially some mangroves). Under the Queensland Significant Residual Impact Guidelines (2014), a significant impact to marine plants is defined as the following:

- private infrastructure works impacting more than 17m^2 of fish habitat or public infrastructure works impacting more than 25m^2 of fish habitat; and
- temporary impacts are expected to take 5 years or more for the impact area to be restored to its predevelopment condition; or
- a proposed reduction in the extent of marine plants through removal, destruction or damage of marine plants; or
- fragmentation or increased fragmentation of a marine ecological community; or
- adverse changes affecting survival of marine plants through modifying or destroying abiotic (non-living) factors (such as water, nutrients, or soil) necessary for a marine plant's survival; or
- alteration in the species composition of marine plants in an ecological community, that causes a decline or loss of functionally important species; or
- interference with the natural recovery of marine plant communities.

Dredging will reduce the extent of marine plants within Causeway Lakes, and it is unlikely that seagrass would be fully restored within 5 years. This would attract an 'offset', under the *Environmental Offsets Act 1994*. The design has minimised the area of marine plants disturbed as much as possible by prioritising dredging in areas where seagrasses are not present or have a lower density.

It is unusual in Queensland to remove large quantities of seagrass detritus; placement of dredge material will need to consider the best method to avoid the creation of significant seagrass wrack at any one time, as this may cause some odour issue as it breaks down.

3.2 Material Placement

Should the material be placed on the banks of Causeway Lakes, it will have similar impacts to the dredging activity itself. Placement on the lake edges is likely to impact additional marine plants, however, and potentially interfere with flows to saltmarsh and mangrove communities along the lake edge and beyond, if not carefully placed and contoured. This is likely to be an issue raised by DAF during the assessment period.

Placement at North Kinka Beach will have the following potential impacts:

- Localised water quality impacts during placement
- Mobilisation of acidic or contaminated material
- Disturbance of dunal and other marine vegetation along the foreshore if not placed correctly
- Temporary and localised loss of habitat for endangered species, mostly shorebirds and potentially nesting turtles
- Loss of recreational access during placement activity
- Generation of nuisance noise for properties along the Esplanade, although this will be somewhat buffered by foreshore vegetation.

4 Environmental Management

The dredge design footprint has already minimised the disturbance to marine plants as much as possible, which is beneficial in reducing the environmental impacts of dredging (refer, BMT 2021).

There are a number of broad management measures that can reduce the potential environmental impacts of the project, including:

- Choosing a dredging methodology that minimises the generation of turbid plumes
- Dredging in winter months, to avoid the seagrass growth period and the summer months when shorebird numbers would be lower.
- Undertake water quality monitoring during dredging and having stop work procedures in place should turbidity thresholds be exceeded
- Undertake detailed marine plant mapping, so that placement activity can avoid interference with marine plants or other protected vegetation as much as possible
- Additional sediment testing to determine levels of acidic and contaminated sediments; it is likely that some level of lime treatment will be required for sediment placed on the lake edges or North Kinka Beach. Some material may also need to be disposed to a licenced landfill if contaminants greater than the NAGD limits are detected. This is not expected to be widespread, and likely localised around the boat ramp.

5 Legislation and approval requirements

Dredging and the placement of material is likely to require the approvals detailed below in Table 5-1. This draws on pre-lodgement advice provided by the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) in May 2018 (Attachment 1). The preliminary advice was that works would require a development application for:

- Operational works for tidal works and or works in a coastal management district

- Operational work involving marine plants
- Material change of use for an Environmentally Relevant Activity.

Any guidance provided in relation to supporting studies in the pre-lodgement advice has been included in Table 5-1.

The impacts to marine plants are likely to attract agency scrutiny, and a strong justification for project need (and the associated loss of marine plants) and exploration of alternatives will need to be provided. A number of additional supporting studies will be required to support applications, including further detailed marine plant mapping and sediment testing.

Table 5-1 Approval Requirements

Legislation	Approval	Timeframe	Supporting Studies
Environment Protection and Biodiversity Conservation Act 1999	Referral	2-3 months	Environmental impact assessment, reviewing impacts to the WHA, wetland values and protected species.
Planning Act 2016	Owners Consent	1-2 months	Brief covering letter detailing potential environmental impacts
Planning Act 2016 and *Coastal Protection and Management Act 1995*	Operational Work that is tidal works and works within a Coastal Management District and an Environmentally Relevant Activity (ERA 16 -dredging).	3-4 months	RPEQ drawings, an assessment of impacts to coastal processes both upstream and downstream. Marine Execution Plan to address maritime safety Possibly water quality monitoring and modelling to demonstrate no downstream impacts to water quality. Detailed sediment analysis to NAGD Standard An approved SAP An environmental assessment to detail any impacts to Matters of State Environmental Significance (MSES) Dredge Management Plan
Coastal Protection and Management Act 1995	Quarry Allocation Material (for removal of material from below tidal waters)	3-4 months	An assessment of impacts to coastal processes Hydrographic survey Dredging Plans

Legislation	Approval	Timeframe	Supporting Studies
Planning Act 2016 and Fisheries Act 2004	Operational Works that is the removal of Marine Plants	3-4 months	A detailed marine plant survey, marine plant rehabilitation plan, offsets, justification for the need to remove of marine plants Analysis of the potential impacts of dredging to fisheries values.
Environmental Offsets Act 2014	Offset Agreement for any residual impacts (i.e. permanent impact) on marine plants	1 month (for financial settlement) or 12+ months if choosing direct offset project)	Agreement to pay financial offset or undertake a direct offset project
Marine Parks Act	Works within the Commonwealth and State Marine Parks (for placement at North Kinka Beach only)	6 months	Environmental assessment of impacts to the marine park values
Vegetation Management Act 1999	Removal of remnant vegetation (for works at North Kinka Beach only, if areas of remnant vegetation cannot be avoided during placement)	6 months	Detailed vegetation survey.

Attachment 1: Pre-lodgement meeting advice

Queensland Government

Department of
State Development, Manufacturing, Infrastructure and Planning

Our reference: 1804-4856 SPL

9 May 2018

Mr David Hamlyn-Harris
Level 9, 269 Wickham St, PO Box 612
Fortitude Valley QLD 4006
david.hamlyn-harris@blightanner.com.au

Dear Mr Hamlyn-Harris

Pre-lodgement advice

Thank you for your correspondence received on 12 April 2018 in which you sought pre-lodgement advice from the Department of State Development, Manufacturing, Infrastructure and Planning regarding the proposed development described below.

Reference information

Departmental role:	Assessment manager or Referral Agency
Departmental jurisdiction:	Planning Regulation 2017 • 10.17.2.1 Tidal works or work in a coastal management district • 10.05.3.1 Environmentally relevant activity • 10.06.3.2.1 Marine plants

Location details

Street address:	Pinnacle St, Causeway Lake
Real property description:	1SP107101
Local government area:	Livingstone Shire Council
Existing use:	Lake / Recreation area

Details of proposal

Development type:	Material change of use and Operational work
Development description:	Causeway Lake (Yeppoon) Revitalisation and Development Project – Causeway Lake is suffering from significant siltation, which is affecting its value to, and use by, the community. Livingstone Shire Council is proposing to restore and enhance the environmental and recreational functionality for the community. The proposed works include:

Fitzroy/Central regional office
Level 2, 209 Bolsover Street,
Rockhampton
PO Box 113, Rockhampton QLD 4700

1. Dredging of the lake bed to reinstate past depths and remediate the over siltation that has occurred from both upstream flow and inflow of sediment from ocean tides.
2. Developing a solution to the ongoing sediment issue arising from ocean tidal inflow to reduce any future dredging need.
3. Upgrading existing public open space and developing new parkland and recreation facilities around the lake to support general use, club use, community events and competitive events.

Supporting information

Drawing/report title	Prepared by	Date	Reference no.	Version/issue
Causeway Lake – Stage One MIPPS Assessment – Recreation and Tourism	Otium Planning Group Pty Ltd	09.04.2018	-	-

The department has carried out a review of the information provided and the impacts of the proposal. The following advice outlines the matters of interest to the department and matters that should be addressed if you lodge your development application with the assessment manager.

Development application requirements

1. The proposed development will require the submission of a development application for the following:
   a. Operational works for tidal works and or works in a coastal management district
   b. Operational work involving marine plants
   c. Material change of use for an Environmentally Relevant Activity

   The department's role will either be the assessment manager or a referral agency and will depend upon the scope of the works proposed. If the initial works involve just creating or changing the configuration or characteristics of a navigation channel, the department will act as the assessment manager. Otherwise the department will be a referral agency. Information to be provided with the above applications is provided in detail below.

   Please note that owners Consent from Department of Natural Resources, Mines and Energy (DNRME) is required for the lodgement of a Development Application for tidal works. Owners Consent and/or tenure may be required for any activities to be conducted on State Land. A further pre-lodgement meeting is recommended once more detail on the proposed scope of works is developed.

Tidal work and work in a coastal management district

2. Any development application made involving coastal development and tidal works should provide a full response to the latest version of the State Development Assessment Provisions (SDAP) State code 7 - Maritime Safety and State code 8 – Coastal development and tidal works in its entirety, identifying how the proposed development meets each performance outcome. The latest version of SDAP is available at: https://planning.dsdmip.qld.gov.au/planning/spa-system/development-under-spa/development-assessment-under-spa/state-assessment-and-referral-agency/state-development-assessment-provisions-sdap. For more information regarding how to demonstrate compliance with the relevant State codes, please refer to the introductory sections of SDAP.

3. To demonstrate compliance with State Code 7 – Maritime Safety, the application should be supported by a Marine Execution Plan.

4. The applicant is also advised to refer to the *Guideline: State Development Assessment Provisions, State Code 8: Coastal development and tidal works in responding to State Code 8* available at https://www.ehp.qld.gov.au/coastal/development/pdf/state-code8-coastal-development-tidal-works.pdf. The guideline provides background information and key concepts relevant for coastal processes and resources and coastal protection and management applicable to complying with the code. The guideline also contains information on how to respond to particular performance outcomes (PO) and specific information requirements. It should be noted that if the PO has no relevance to the proposed development a response of "not applicable" and a statement as to why it is not relevant is required. The guideline also provides information regarding the content of supporting documents that may be required to assess a development application against the code.

   In particular please provide detailed responses to:

   - PO2, regarding the potential for impacts on coastal processes (e.g. sediment transport and deposition or erosion) as a result of the tidal works and as a result of the proposed removal of sediment from behind the causeway.

   - PO4 and PO5 regarding the potential of increasing coastal erosion and risks to people and property as a result of the works.

   - PO5, PO22 regarding the potential impact on the tidal prism of Mulambin Creek and Shoal Creeks as a result of the proposed works and subsequent water quality and erosion impacts within or downstream and offshore of the works site. Modelling may be required to look at these impacts.

     Information should also be provided on the potential impact to the upstream tidal extent of Mulambin and Shoal Creeks as a result of the proposed works and associated estuarine/brackish ecosystems.

   - PO11 regarding management of impacts from the works on water quality in tidal waters

   - PO16 identifying any Matters of State Environmental Significance (MSES) that may be impacted by the proposal and management of those impacts. MSES are defined under the Environmental Offsets Regulation 2014.

     The Department of Environment and Science's (DES) Environmental Reports Online (https://environment.ehp.qld.gov.au/report-request/environment/) can be used to conduct a desktop analysis to identify any mapped MSES that exists on (using the lot on plan option to search) and near the propose site (using the central coordinates option to search). Where MSES are identified:
       - Provide a targeted assessment to ground truth any MSES identified;
       - Demonstrate how the development avoids adverse impacts on each MSES to the greatest extent practicable;
       - Where the above is not reasonably possible, demonstrate how impacts on MSES have or will be minimised and/or mitigated to the greatest extent practicable;
       - Demonstrate whether the development will have a Significant Residual Impact on any identified MSES using the department's Significant Residual Impact Guideline (http://www.dilgp.qld.gov.au/resources/guideline/planning/dsdip-significant-residual-impact-guideline.pdf). An assessment will need to be undertaken for each MSES to

determine whether the proposed development will result in a significant residual impact; and
- Identify any potential offset obligation. For further advice on environmental offsets please visit the following website http://www.qld.gov.au/environment/pollution/management/offsets/ or contact DES to organise a meeting to discuss this.

The following tools may be helpful in your desktop analysis and assessment:
- EHP Environmental Reports Online https://environment.ehp.qld.gov.au/report-request/environment/
- DNRM Regulated Vegetation Mapping https://www.qld.gov.au/environment/land/vegetation/map-request/
- EHP Map of Referable Wetlands
- https://www.ehp.qld.gov.au/ecosystems/wetlands/referable-wetlands-form.php
- EHP WetlandInfo
- http://wetlandinfo.ehp.qld.gov.au/wetlands/
- EHP Protected Plants Flora Survey Trigger Map http://www.ehp.qld.gov.au/licences-permits/plants-animals/protected-plants/map-request.php
- EHP Species List
- https://environment.ehp.qld.gov.au/report-request/species-list/
- Queensland Wetland Buffer Guideline http://wetlandinfo.ehp.qld.gov.au/resources/static/pdf/resources/reports/buffer-guide/wetland-buffer-guideline-14-04-13.pdf
- DILGP SPP Interactive Mapping http://dilgp.qld.gov.au/planning/state-planning-instruments/spp-interactive-mapping-system.html

- PO19, PO20, PO21 – the proposal is for the removal of a considerable volume of saline dredged material. The application will need to identify viable disposal or reuse options for this material and demonstrate that any impacts from the disposal or reuse placement of dredged material can be adequately managed.

  If at-sea disposal is proposed, the application material should include consideration of Commonwealth and State restrictions on the disposal of dredged material in the Great Barrier Reef Marine Park and World Heritage Area and whether these apply to this project.

5. A plan showing the extent of tidal ranges in relation to the site, in particular the location of mean high water springs should be provided.

6. Details of the proposed works at the spillway and bridge to modify tidal ingress and sedimentation referred to in the Causeway Lake Stage one MIPPS Assessment – Recreation and Tourism report.

Environmentally Relevant Activity (ERA 16(1)(c) dredging)

7. A development application for a Material Change of Use (MCU) for ERA 16(1)(c) dredging more than 100,00t but not more than 1,000,000t in a year will be required to be submitted to the department. The development approval application will be taken as an EA application under section 115 of the Environmental Protection Act 1994. Please refer to https://www.business.qld.gov.au/business/running/environment/licences-permits/applying-environmental-authority/technical-information-requirements for a number of technical guidelines, which outline the technical information requirements for applications for an environmental authority.

8. The development application made should also provide a response to the latest version of the SDAP State code 22 – Environmentally Relevant Activities in its entirety, identifying how the proposed development meets each performance outcome by addressing all applicable acceptable outcomes.

9. For the environmental authority, any application should provide information on, but not limited to, the following:

   - Operational plans for the removal of dredge spoil including:
     - proposed footprint of the dredge area
     - method by which the dredge spoil will be removed
     - volume of dredge spoil to be removed
     - proposed depth of extraction
     - physical and chemical characteristics of the dredge spoil including potential contaminants.
   - Operational plans for the disposal of dredge spoil including:
     - proposed location for disposal of dredge spoil
     - method by which the dredge spoil will be transported and placed in the area
     - method by which the spoil is to be contained within the area
     - potential for interactions with surface and groundwaters
     - method by which the spoil will be dewatered
     - expected water quality parameters for the discharge
     - current and intended land use of the proposed disposal site
     - detail on how the dredge spoil disposal area will be made fit for future land use.
   - An acid sulfate soil management plan detailing how any acid sulfate soils are to be managed.
   - An ecological report identifying any significant ecological values (particularly matters of State environmental significance) within or adjacent to the proposed dredge footprint and disposal area that could be impacted as a result of the activity.

   The application must address the performance outcomes for the environmental objectives of the operational assessment prescribed in Schedule 5, Table 1 of the Environmental Protection Regulation 2008. The application must include a technical assessment of the environmental risks to the receiving environment in relation to air, water, noise, land and waste associated with the activities. The application must show how the performance outcomes for each environmental objective are met. Technical guidelines detailing the minimum information that should be supplied to support an application are available on the Business and Industry Portal:

   - Air: http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-air-impacts.pdf
   - Land: http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-land-impacts.pdf
   - Noise: http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-noise-impacts.pdf
   - Water: http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-water-impacts.pdf
   - Waste: http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-waste-impacts.pdf

   Please address the standard criteria as defined in Schedule 4 Dictionary of the *Environmental Protection Act 1994* in regards to the proposed activity (including the dredging aspects and disposal of dredge spoil aspects).

Marine Plants

10. Works within Causeway Lake, including the proposed dredging and construction of waterfront and parklands infrastructure, may involve the removal, destruction or damage of marine plants. Submitted

materials and the department's Development Assessment Mapping System are inconclusive as to whether or not marine plants are present within the proposed footprint or would be impacted by the works, however as Causeway Lake is an extensive wetland area subject to tidal influence, it is likely to be supportive of marine plant communities. It would be beneficial to conduct an on-site ecological survey to confirm which plant species are present and would be impacted by the works.
Marine plants include:

- any plant (a tidal plant (including marine algae) that usually grows on or adjacent to tidal lands whether it is living, dead, standing or fallen; or
- any plant material on tidal land (up to the level of Highest Astronomical Tide (HAT)).

Plants such as mangroves, mangrove fern, saltcouch or samphire species are considered marine plants regardless of whether or not they are above or below the level of HAT.
Marine plants do not include:

- a plant that is prohibited matter or restricted matter under the *Biosecurity Act 20*14; or
- a plant that is controlled biosecurity matter or regulated biosecurity matter under the *Biosecurity Act 2014*.

Marine plant protection applies irrespective of the tenure (e.g. unallocated state land and all state tenured lands, including private freehold and leasehold lands) of the land on which the plant occurs, the time the plant has been growing at the location, or the degree of or purpose of the disturbance.

11. It is evident from the submitted Stage One MIPPS Assessment that dredging of Causeway Lake is the preferred method of alleviating siltation issues and a high priority for the overall project. Dredging can impact directly and indirectly on fisheries resources, including marine plants, and impacts are usually long term. Dredging impacts include (but are not limited to) the removal of marine plants within the dredge area and degradation of fisheries resources due to smothering from suspended sediment or release of toxins.

    The applicant is therefore advised to consider lesser impact alternatives, and provide a summarised options analysis in any development application. There may be alternative methods which achieve significant reduction in siltation build-up through the encouragement of natural coastal processes – for example, restoring (some of the) flows which are currently impeded where the Scenic Highway crosses the mouth of Mulambin Creek. It would be beneficial to seek expert advice from suitably qualified coastal engineers to investigate any such options. If alternatives to dredging are available but not pursued, this decision will need to be fully justified in the application.

12. Under the Planning Regulation 2017, works involving the removal, destruction or damage of marine plants must be undertaken in accordance with the relevant accepted development requirements - ADR (https://www.daf.qld.gov.au/fisheries/habitats/fisheries-development/accepted-development) or under a development approval (assessable development).

    The dredging component of this proposal is not accepted development. Therefore if this option is progressed, it will be assessable development requiring a permit for the removal, destruction or damage of marine plants.

    It may be possible to undertake some limited marine plant disturbance to support the installation of new waterfront and parkland infrastructure (e.g. swimming safety enclosures, fishing platforms) in accordance with the ADR. The ADR document lists 'work types' which can be deemed accepted development, given compliance with all relevant requirements; the applicant should examine the work types in Section 4.2 (New work for a public purpose) to identify any applicable items. Note that it is mandatory to comply with all relevant requirements, including the overarching standards presented in Section 3.

If possible, avoiding marine plant disturbance would remove the need for an approval and potential fees for this component of the works.

13. If any aspect of the works involves marine plant disturbance but cannot comply with the ADR, the applicant will need to provide the following documentation in an application for a development approval:
    - DA form 1 (https://www.dilgp.qld.gov.au/planning-reform/resources/development-assessment.html);
    - A full response to the relevant sections of State Code 11 of the State Development Assessment Provisions (SDAP): Removal, destruction or damage of marine plants.
    - Relevant plans as per the department's *DA Forms guide: Relevant plans* (https://dilgpprd.blob.core.windows.net/general/DAFormsguide-Relevantplans.pdf) including:
        - the total amount of marine plants that will be disturbed, identifying portion of permanent and/or temporary disturbance (in square meters or hectares);
        - the location of the marine plants to be disturbed in relation to the development works;
        - the level of HAT, mean high water spring tide, and low water spring tide; and
        - if applicable, a plan clearly showing the location of the marine plants to be disturbed that will result in a significant residual impact (SRI) as defined under the *Environmental Offsets Act 2014*.

14. Relevant sections of the State Code 11 for the proposed works include:
    - All development – PO1 to PO15. This section of the SDAP addresses critical issues relating to coastal development proposals which create the need to remove, destroy or damage marine plants. The applicant will need to respond to all relevant performance outcomes (POs) and is advised to pay particular attention to:
        - (PO1) the need for the development and justify why alternatives which avoid impacts to marine plants are not viable;
        - (PO4) minimisation of the spatial extent of marine plant disturbance
        - (PO6) avoidance of the unnecessary loss, degradation or fragmentation of fish habitats
        - (PO8) that works are undertaken to encourage fish habitats and fisheries resource values to naturally regenerate
        - (PO9) prevention of contamination arising from drainage of, or disturbance to, acid sulfate soils
        - (PO10) the maintenance or restoration of tidal and freshwater inundation patterns so that ecological processes continue
        - (PO11) maintenance of natural erosion and accretion processes; no increased risk of waterway bed or bank scour or erosion
        - (PO12) avoidance of additional or indirect impacts to fish habitats (including dredging to maintain access; trimming of marine plants; and warning signs or protective structures)

    - Dredging – PO23 to PO25. This section of the SDAP addresses impacts from dredging, such as the removal of marine plants from the dredge footprint and degradation of fisheries resources due to smothering from suspended sediment or release of toxins. If the proposal includes dredging the applicant must respond (where relevant) to the following POs:

  - (PO23) dredging creates or provides access to public infrastructure. Dredging for access to private structures that do not provide public use is not supported;
  - (PO24) maintenance dredging is consistent with an existing development approval for dredging and within approved profiles for navigational purposes; and
  - (PO25) disposal of dredge spoil avoids adverse impacts on marine plants.

- Temporary works – PO26 to PO28. Temporary disturbance or temporary structures involving the removal, destruction or damage of marine plants can have both direct and indirect impacts and cause the loss of fisheries productivity. If temporary works involving marine plant disturbance are proposed, the applicant must demonstrate compliance with the following POs:
  - (PO26) impacted fish habitats and fisheries resources are restored to pre-existing or improved condition and extent;
  - (PO27) works will be in place or are undertaken for a specified period and for the shortest possible time; and
  - (PO28) a temporary structure is in place for a specified period and is designed to be completely removed.

- Matters of state environmental significance – PO31. Marine plants are a matter of State environmental significance under the *Environment Offsets Act 2014.* All applications must demonstrate full consideration of the 'avoid, minimise (mitigate), offset' hierarchy and must comply with:
  - (PO31) the 'avoid, minimise (mitigate), offset' framework requires in the first instance that impacts to marine plants are avoided; where avoidance cannot be achieved, it must be demonstrated that impacts have been carefully managed and minimised. If after all reasonable avoidance and mitigation measures have been taken, there is an acceptable but residual impact to marine plants, an offset may be required. The applicant may find the following guideline useful in determining the likelihood (or otherwise) of a significant residual impact: DILGP's significant residual impact guideline (see Section 3.9 of https://www.dilgp.qld.gov.au/resources/guideline/planning/dsdip-significant-residual-impact-guideline.pdf)

Allocation of quarry material

15. If the dredged material will be permanently removed from tidal waters then allocation of quarry material under the *Coastal Protection and Management Act 1995* will be required for the project. Applications for allocation of quarry material are made directly to DES and further information on allocations of quarry material is available at the following site https://www.ehp.qld.gov.au/coastal/development/pdf/gl-cd-allocation-quarry-material-em2046.pdf.

    If an application for an allocation of quarry material is submitted it should include the following information;

    - Plans drawn to a suitable scale to show;
      - The boundaries of the land to be dredged, adjacent river banks, sand banks and shorelines, showing the line of high water mark (mean high water spring), the limit of vegetation and any other details to permit the identification of the tidal land on the ground
      - A hydrographic survey of the land on lines not more than 20 metres apart

    - A proposed area(s) where the quarry material will be taken ashore or transported over, and the proposed location of any stockpile, reclamation, disposal or fill areas
    - Adjacent real property boundaries, roads and any esplanade
    - Navigation channels, navigation aids, pipelines, cables, wharves and any other structures or harbour works located in or adjacent to the land to be dredged
- Plans showing the depth of dredging and the anticipated final alignment and slope of batters, together with an indication as to whether this work will result in a stable alignment or if recurrent maintenance dredging will be required
- Characteristics of quarry material to be removed. For material to be disposed of within the marine environment, the characteristics of the material and potential impacts at the disposal site, as required under the *National Assessment Guidelines for Dredging 2009*.
- Purpose/use of the quarry material
- Methods of extraction of quarry material and disposal of dredge spoil (including equipment to be used).
- Maximum extraction rate of quarry material in cubic metres per year.
- A verifiable methodology for measuring the volume (in cubic metres) of material removed.
- Agreement from:
  - Owner(s) of land on which the material is to be deposited or stockpiled; and
  - Owner(s) of land which the material will be transported either by pipeline or truck
- A statement addressing how the proposed works meet section 75 and 104 of the *Coastal Management and Protection Act 1995*.
- The views of a local government about the removal of the quarry material or placement of spoil
- The views of a harbour master about the effect the removal or placement may have on marine safety in tidal water.

This pre-lodgement advice does not constitute an approval or an endorsement that the department supports the development proposal. Additional information may be required to allow the department to properly assess the development proposal when a formal application has been lodged.

For further information please contact Tracey Beath, Senior Planning Officer, on 0749242917 or via email RockhamptonSARA@dsdmip.qld.gov.au who will be pleased to assist.

Yours sincerely

Anthony Walsh
Manager Planning

Appendix C Risk Assessment Framework & Results

Table C-1 Risk Assessment Framework

Overall Rating (L) X (C)	Likelihood (L)	Consequence (C)			
			Social	Economic	Environmental
Critical > 20	**(5) Almost certain** There is a high possibility the event will occur as there is a history of frequent occurrence in equivalent situations. The event is expected to occur in most circumstances.	**(5) Catastrophic**	Widespread permanent impact to the community's services, wellbeing or culture (e.g. >50% of community affected) or popular activity/use disrupted permanently. High potential for injury or loss of life. Health system unable to cope for 5 or more days. Widespread loss of cultural significant objects. A large number of complaints resulting in negative attention from the public.	Widespread repair needed to damaged areas or properties, with cost to repair damage to individual properties equal (or almost equal) to the property value. Asset destruction across industry sectors leading to business failures and loss of employment. More than 30 days loss of critical infrastructure (e.g. major treatment plants, telecommunications, utilities). Tourism potential disrupted for long periods of time. Council faces financial outlay of more than $20 million.	Significant environmental impact with long-term effects. Examples include: • Serious environmental harm (irreversible, high impact, widespread, cases > $50,000 damage). • Immediate containment required, extensive clean-up, extensive or ongoing remediation needed. • Major impact to a protected species or habitat greatly contributing to or causing localised extinction risk in the Livingstone area, requiring long term recovery efforts (>40% loss of an ecosystem type, >40% loss of a species, locally). • Irrecoverable environmental damage.
High ≥ 13 & ≤ 19	**(4) Likely** It is likely the event will occur as there is a history of intermittent occurrence in similar situations. The event has occurred several times or more in the past.	**(4) Major**	Major permanent or widespread medium term (somewhat reversible) disruption to the community's services, wellbeing, or culture (e.g. up to 50% of community affected or popular activity/use disrupted for up to a year. Potential for injury or loss of life. Health system unable to cope for 2-5 days Potential for a large number of complaints resulting in negative attention from the public.	Major repairs needed to damaged areas within of properties a section of the community, with cost to repair damage to individual properties greater than 50% of the property value. Significant disruptions across industry sectors leading to multiple business failures. 1-14 days loss of critical infrastructure (e.g. major treatment plants, telecommunications, utilities). Tourism disrupted impacting a variety of businesses. Council faces outlay of $1 million to $20 million	Significant medium to long-term impact on natural or built environment, including loss of ecosystem function affecting many species or landscapes. Examples include: • Material environmental harm (significant effect and extent, causes $20,000 to $50,000 damage). • Immediate containment required, large clean up, significant remediation required. • Serious impact to a protected species or habitat significantly contributing to local shire extinction pressures, requiring medium to long-term recovery efforts (5-40% loss of an ecosystem type, 5-40% loss of a species, locally).
Moderate ≥ 5 & ≤ 12	**(3) Possible** The event has occurred at least once in the past in similar situations and may occur again.	**(3) Moderate**	Minor long term or major short term (mostly reversible) disruption to the community's services, wellbeing, or culture (e.g. up to 25% of community affected or regularly used activity/use disrupted for between 3-6 months). Potential for a number of complaints resulting in negative attention from the public. Health system unable to cope for 1-2 days. Important roads flooded on a regular basis	Some repairs needed to a number of properties, with cost to repair damage to individual properties between 20-50% of the property value. Less than 1 day's loss of critical infrastructure (e.g. major treatment plants, telecommunications, utilities). Specialist equipment required to repair or replace. Impacts leading to minor job losses. Supply chains disrupted. Widespread media concern about disruption. Negative unplanned financial outlay to council of between $220k to $1 million.	Medium-term effects on environment from single incident. Examples include: • Material environmental harm (significant effect and extent, causes $5,000 - $20,000 damage). • Immediate containment required, medium cleanup, some remediation required. • Impact to a protected species or habitat, requiring short-term recovery efforts (in the immediate area). (<5% loss of an ecosystem type, <5% loss of a species, locally).
Low ≥ 3 & ≤ 4	**(2) Unlikely** There is a low possibility that the event will occur, however, there is a history of infrequent and isolated occurrence.	**(2) Minor**	Small to medium term (reversible) disruption to the community's services, wellbeing, finances or culture (e.g. up to 10% of community affected or activity/use experiences minor disruption for a few weeks). Potential for a limited number of complaints resulting in negative attention from the public. Health system unable to cope for 1-24 hours.	Minor repairs needed to a small number of properties, with cost to repair damage to individual properties less than 20% of the property value. Negative financial outlay to council of $100k to $2201k. Minor interruption to critical infrastructure. Some repair needed. Impacts disrupt businesses with a small number of job losses.	Short-term effect on built or natural environment easily remedied. Examples include: • Minor short-term impact, almost no effect, potentially cumulative if not cleaned up, reversible. • Environmental nuisance. • Containment required, minor cleanup, no remediation required. • Minor impacts on protected species or habitat, no recovery efforts required.
Very Low ≤ 2	**(1) Rare** It is highly unlikely event will occur or is not applicable to the situation.	**(1) Insignificant**	Very small short-term disruption to the community's services, wellbeing, finances or culture (e.g. up to 5% of community affected or activity/use experiences minor disruption for a few weeks). Zero or a few complaints resulting in negative attention from the public.	Minimal or no repairs needed to a very small number of properties with minimal repair costs. Limited impact on infrastructure. Minimal disruption to businesses, no job losses. Negative financial outlay to council of less than $100k.	Minimal very short-term, temporary effects on habitat or species with recovery assured.

Table C-2 Risk Assessment Scores

Causeway Lake Dredging Risk Register													
ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures: Specific Actions	Cost Contingencies ($)	Time Contingencies (weeks)
												$0	0
	Dredging Methods												
1	**Large Cutter Suction Dredge (CSD) or other large hydraulic dredge type**	Site access constraints cannot be overcome, not considered further	5	5	25				0				
2	**Small Cutter Suction Dredge (CSD) , demountable and transported to site by road**			Total score	89			Total score	65				
2.1	Absence of existing, suitable dredge launching and retrieval site	Economic: additional mobilisation / demobilisation costs Site needs to be capable of supporting dredge, transport trucks and cranes for launching and retrieval of dredge	4	4	16	Early engagement with potential dredging contractors to discuss dredge mobilisation / demobilisation requirements. Undertake pre-campaign site access enabling works as required. Coordinate with future infrastructure development plans.	3	4	12				
2.2	Lack of suitable access routes for trailer transporting dredge to site	Economic/Environmental: Upgrading and widening of exisiting roads, vegetation loss, additonal approvals	4	3	12	Early engagement with potential dredging contractors to discuss transportation options, liase with regulators to confirm approvals pathway. Coordinate with future infrastructure development plans.	3	3	9				
2.3	Low dredging production rate and works schedule	Economic: extended works schedule and costs	3	3	9	Early engagement with potential dredging contractors to discuss dredge type availability and production rates	2	3	6				
2.4	Direct impact to seagrass within dredge footprint	Environmental/Economic: loss of seagrass habitat greater than expected, additional offset payment	5	4	20	Resurvey of seagrass area prior to commencing works	5	3	15				
2.5	Indirect impact to seagrass outside of the dredge footprint	Environmental/Economic: impact to seagrass habitat caused by dredge-related turbidity plumes, additional offset payment	4	3	12	Use of silt curtains to minimise the dispersion of plumes beyond the works area	3	3	9				
2.6	Navigational hazards during dredging operations	Social: partial lake closure and relocation of recreational activities	4	3	12	Managed via dredge traffic management plan, navigational aids/markers, notice to mariners and swimmers (including signage) for the duration of works	4	2	8				
2.7	Noise and other disruptions to nearby community	Social: complaints to Council during dredging operations	4	2	8	Early engagement with stakeholders and community about the expected disturbance during the works; limit the hours of dredging operations (e.g. 7am to 7pm)	3	2	6				
2.8	Limited dredge availability in market	Social/Economic: delays to project commencement, additional costs and time associated with using non-optimal dredge type	3	3	9	Early engagement with potential dredging contractors to discuss fleet availability and secure a dredge in advance	2	3	6				

Risk Assessment Framework & Results

ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures: Specific Actions	Details of Risk Reduction Measures: Cost Contingencies ($)	Details of Risk Reduction Measures: Time Contingencies (weeks)
												$0	0
3	**Amphibious excavator, transported to site by road**		**Total score**		58		**Total score**		41				
3.1	Absence of existing, suitable dredge launching and retrieval site	Economic: additional mobilisation / demobilisation costs Site needs to have suitable nearshore features for independent launching/retrieval	3	3	9	Early engagement with potential dredging contractors to discuss dredge mobilisation / demobilisation requirements. Undertake minor pre-campaign site modification works as required.	2	3	6				
3.2	Lack of suitable access routes for trailer transporting dredge to site	Economic/Environmental: Upgrading and widening of exisiting roads, vegetation loss, additonal approvals	3	3	9	Early engagement with potential dredging contractors to discuss transportation options, liase with regulators to confirm approvals pathway	2	3	6				
3.3	Low dredging production rate and works schedule	Economic: extended works schedule and costs	3	3	9	Early engagement with potential dredging contractors to discuss dredge type availability and production rates	2	3	6				
3.4	Direct impact to seagrass within dredge footprint	Environmental/Economic: loss of seagrass habitat greater than expected, additional offset payment	5	4	20	Resurvey of seagrass area prior to commencing works	5	3	15				
3.5	Indirect impact to seagrass outside of the dredge footprint	Environmental/Economic: impact to seagrass habitat caused by dredge-related turbidity plumes, additional offset payment	3	3	9	Use of silt curtains to minimise the dispersion of plumes beyond the works area	2	3	6				
3.6	Navigational hazards during dredging operations	Social: partial lake closure and relocation of recreational activities	4	3	12	Managed via dredge traffic management plan, navigational aids/markers, notice to mariners and swimmers (including signage) for the duration of works	4	2	8				
3.7	Noise and other disruptions to nearby community	Social: complaints to Council during dredging operations	4	2	8	Early engagement with stakeholders and community about the expected disturbance during the works; limit the hours of dredging operations (e.g. 7am to 7pm)	3	2	6				
3.8	Limited dredge availability in market	Social/Economic: delays to project commencement, additional costs and time associated with using non-optimal dredge type	4	4	16	Early engagement with potential dredging contractors to discuss fleet availability and scheduling	3	3	9				

Risk Assessment Framework & Results

ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures		
											Specific Actions	Cost Contingencies ($)	Time Contingencies (weeks)
												$0	0
4	**Mini auger dredge, launched from boat ramp or constructed sand ramp**			**Total score**	68			**Total score**	46				
4.1	Absence of existing, suitable dredge launching and retrieval site	Economic: additional mobilisation / demobilisation costs Site needs to be capable of supporting dredge, transport truck and crane for launching and retrieval of dredge	4	3	12	Early engagement with potential dredging contractors to discuss dredge mobilisation / demobilisation requirements. Undertake pre-campaign site modification works as required.	3	3	9				
4.2	Lack of suitable access routes for trailer transporting dredge to site	Economic/Environmental: Upgrading and widening of exisiting roads, vegetation loss, additonal approvals	4	3	12	Early engagement with potential dredging contractors to discuss transportation options, liase with regulators to confirm approvals pathway	3	3	9				
4.3	Low dredging production rate and works schedule	Economic: extended works schedule and costs	5	4	20	Early engagement with potential dredging contractors to discuss dredge type availability and production rates. Use two mini dredges.	4	4	16				
4.4	Direct impact to seagrass within dredge footprint	Environmental/Economic: loss of seagrass habitat greater than expected, additional offset payment	5	4	20	Resurvey of seagrass area prior to commencing works	5	3	15				
4.5	Indirect impact to seagrass outside of the dredge footprint	Environmental/Economic: impact to seagrass habitat caused by dredge-related turbidity plumes, additional offset payment	2	3	6	Use of silt curtains to minimise the dispersion of plumes beyond the works area	1	3	3				
4.6	Navigational hazards during dredging operations	Social: partial lake closure and relocation of recreational activities	4	4	16	Managed via dredge traffic management plan, navigational aids/markers, notice to mariners and swimmers (including signage) for the duration of works	4	2	8				
4.7	Noise and other disruptions to nearby community	Social: complaints to Council during dredging operations	3	2	6	Early engagement with stakeholders and community about the expected disturbance during the works; limit the hours of dredging operations (e.g. 7am to 7pm)	2	2	4				
4.8	Limited dredge availability in market	Social/Economic: delays to project commencement, additional costs and time associated with using non-optimal dredge type	3	3	9	Early engagement with potential dredging contractors to discuss fleet availability and scheduling	2	3	6				

Risk Assessment Framework & Results

ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures: Specific Actions	Cost Contingencies ($)	Time Contingencies (weeks)
												$0	0
	Dredge Material Transport												
5	**Mechanical transport of material on barges from dredge area to shore-based stockpile area**	Site access constraints cannot be overcome, not considered further	5	5	25				0				
6	**Hydraulic transport of dredge material as a slurry via pipeline(s) directly to placement site**				55				28				
6.1	Temporary pipeline requirements (e.g. size, length, availability) to meet dredge production rate potential	Economic: pipeline limits production rate and extends works schedule and costs	3	3	9	Early engagement with potential dredging contractors to discuss pipeline availability to suit dredge type and target production rates	2	3	6				
6.2	Temporary pipeline alignment	Economic: pipeline alignment cannot avoid road crossing(s) or other diversions adding to cost	3	4	12	Early engagement with potential dredging contractors to discuss pipeline alignment options	2	3	6				
6.3	Temporary pipeline alignment	Environmental: pipeline alignment disturbs native vegetation	3	3	9	Early engagement with potential dredging contractors to discuss pipeline alignment options	2	2	4				
6.4	Require booster pump(s) to reach placement site(s)	Economic: longer transport distances (approx. >1km depending on dredge plant) will require more booster pump(s) and will increase costs	3	3	9	Prioritise placement site(s) that minimise the need for booster pumps	2	3	6				
6.5	Require booster pump(s) to reach placement site(s)	Environmental: high noise levels within vicinity of pump(s)	4	4	16	If booster pumps cannot be avoided, seek to place away from populated areas and/or within an acoustically robust enclosure	3	2	6				
6.6	Availability of suitable pipe laydown area	Economic/Environmental: clearing of sufficient area for pipe laydown area, vegetation loss	4	4	16	Early engagaement with potential dredging contractors to discuss laydown area requirements, liase with regulators for approvals pathway	2	4	8				
6.7	Availability of suitable pipe laydown area	Social/environmental: laydown area near residential/community areas, complaints to council during site works, noise levels from machinery	3	2	6	Identification of suitable sites away from populated areas, early engagement with stakeholders and community about the expected disturbance during the works; limit the hours of dredging operations (e.g. 7am to 7pm)	2	2	4				

Risk Assessment Framework & Results

ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures		
											Specific Actions	Cost Contingencies ($)	Time Contingencies (weeks)
												$0	0
	Placement Sites and Methods												
7	**Reclamation along the Causeway Lake shoreline to support broader foreshore revitalisation objectives**				53				28				
7.1	Access to placement site (including tenure)	Economic: access constraints and/or difficult approvals pathway	2	4	8	Liaise with regulators to confirm approvals pathway	1	2	2				
7.2	Access to placement site (including tenure)	Environmental: vegetation loss associated with clearing access routes	3	2	6	Utilise existing access routes where possible	1	2	2				
7.3	Opportunity for beneficial reuse	Economic/Environmental: material not well suited for placement at shoreline, need to identify alternative option(s) offsite	3	3	9	Further sediment sampling and characterisation within dredge footprint prior to works	2	3	6				
7.4	Impact to marine or terrestrial vegetation at placement site	Environmental/Economic: impact to marine plants along shoreline or protected terrestrial vegetation, triggering environmental offsets	3	3	9	Complete a marine plant survey at placement sites prior to works	2	2	4				
7.5	Loss of fine material	Environmental: turbidity plumes at placement site and possible migration and infilling of dredged areas	3	2	6	Strategically place and contain material with higher percentage of fines	2	2	4				
7.6	Accumulation of dredged seagrass and other organic material	Social: impact to amenity and odour caused by decaying material	3	3	9	Strategically place and contain material with higher percentage of organic material	2	3	6				
7.7	Disruptions to nearby community	Social: restricted access to site during placement operations; concern if placed material differs to natural material	3	2	6	Early engagement with stakeholders and community to manage expectations during and after works	2	2	4				
8	**Placement on North Kinka Beach for beach nourishment purposes**			**Total score**	55			**Total score**	30				
8.1	Access to placement site (including tenure)	Economic: access constraints and/or difficult approvals pathway	3	4	12	Liaise with regulators to confirm approvals pathway	2	2	4				
8.2	Access to placement site	Environmental: vegetation loss associated with clearing access routes	2	2	4	Utilise existing access routes where possible	1	2	2				
8.3	Opportunity for beneficial reuse	Economic/Environmental: material not well suited for beach nourishment	3	3	9	Further sediment sampling and characterisation within dredge footprint prior to works	2	3	6				
8.4	Impact to marine or terrestrial vegetation at placement site	Environmental/Economic: impact to marine plants along shoreline or protected terrestrial vegetation, triggering environmental offsets	3	3	9	Complete a marine plant survey at placement sites prior to works	2	2	4				
8.5	Loss of fine material	Environmental: turbidity plumes at placement site	3	2	6	Strategically place and contain material with higher percentage of fines	2	2	4				
8.6	Accumulation of dredged seagrass and other organic material	Social: impact to amenity and odour caused by decaying material	3	3	9	Strategically place and contain material with higher percentage of organic material	2	3	6				
8.7	Disruptions to nearby community	Social: restricted access to site during placement operations; concern if placed material differs to natural material	3	2	6	Early engagement with stakeholders and community to manage expectations during and after works	2	2	4				

Risk Assessment Framework & Results

ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures		
											Specific Actions	Cost Contingencies ($)	Time Contingencies (weeks)
												$0	0
9	**Placement on Kemp Beach for beach nourishment purposes**		**Total score**		59		**Total score**		32				
9.1	Access to placement site (including tenure)	Economic: access constraints and/or difficult approvals pathway	4	4	16	Liaise with regulators to confirm approvals pathway	3	2	6				
9.2	Access to placement site	Environmental: vegetation loss associated with clearing access routes	2	2	4	Utilise existing access routes where possible	1	2	2				
9.3	Opportunity for beneficial reuse	Economic/Environmental: material not well suited for beach nourishment	3	3	9	Further sediment sampling and characterisation within dredge footprint prior to works	2	3	6				
9.4	Impact to marine or terrestrial vegetation at placement site	Environmental/Economic: impact to marine plants along shoreline or protected terrestrial vegetation, triggering environmental offsets	3	3	9	Complete a marine plant survey at placement sites prior to works	2	2	4				
9.5	Loss of fine material	Environmental: turbidity plumes at placement site	3	2	6	Strategically place and contain material with higher percentage of fines	2	2	4				
9.6	Accumulation of dredged seagrass and other organic material	Social: impact to amenity and odour caused by decaying material	3	3	9	Strategically place and contain material with higher percentage of organic material	2	3	6				
9.7	Disruptions to nearby community	Social: restricted access to site during placement operations; concern if placed material differs to natural material	3	2	6	Early engagement with stakeholders and community to manage expectations during and after works	2	2	4				
10	**Placement at quarry (Kinka Beach Road)**		**Total score**		49		**Total score**		35				
10.1	Access to placement site (including tenure)	Economic: access constraints and/or difficult approvals pathway	4	4	16	Liaise with quarry operator to confirm site availability, some challenges associated with dewatering material and tailwater management	3	4	12				
10.2	Access to placement site	Environmental: vegetation loss associated with clearing access routes	2	2	4	Utilise existing access routes where possible	1	2	2				
10.3	Opportunity for beneficial reuse	Economic/Environmental: material not well suited to quarry purposes	3	3	9	Further sediment sampling and characterisation within dredge footprint prior to works	2	3	6				
10.4	Impact to marine or terrestrial vegetation at placement site	Environmental/Economic: impact to marine plants along shoreline or protected terrestrial vegetation, triggering environmental offsets	1	1	1	Unlikely to encounter environmental constraints within quarry area	1	1	1				
10.5	Loss of fine material	Environmental: turbidity plumes at placement site	4	3	12	Operations would require a bunded area to contain and dewater material, some challenges potentially associated with tailwater management	3	3	9				
10.6	Accumulation of dredged seagrass and other organic material	Social: impact to amenity and odour caused by decaying material	2	3	6	Strategically place and contain material with higher percentage of organic material	2	2	4				
10.7	Disruptions to nearby community	Social: restricted access to site during placement operations; concern if placed material differs to natural material	1	1	1	Unlikely to cause impacts beyond quarry site	1	1	1				

Risk Assessment Framework & Results

ID	Description/Risk	Possible Consequences	Initial Likelihood	Initial Consequence	Risk level	Risk Reduction Measure (summary only)	Residual Likelihood	Residual Consequence	Residual Risk level	Responsibility	Details of Risk Reduction Measures: Specific Actions	Cost Contingencies ($)	Time Contingencies (weeks)
												$0	0
11	**Place at Rosslyn Bay offshore site**		**Total score**		74		**Total score**		62				
11.1	Access to placement site (including tenure)	Economic: access constraints and/or difficult approvals pathway	5	4	20	Liaise with regulators to confirm approvals pathway	5	4	20				
11.2	Opportunity for beneficial reuse	NA	5	4	20	offshore disposal option provides no beneficial reuse opportunities	5	4	20				
11.3	Impact to marine or terrestrial vegetation at placement site	Environmental/Economic: impact to marine plants near offshore site along shoreline or protected terrestrial vegetation, triggering environmental offsets	2	3	6	Benthic habitat survey may be required at disposal	2	2	4				
11.4	Loss of fine material	Environmental: turbidity plumes at placement site	5	4	20	Modelling assessment to determine impacts to marine water quality associated with placement activities	4	3	12				
11.5	Accumulation of dredged seagrass and other organic material	Social: impact to amenity and odour caused by decaying material	2	2	4	Dredged seagrass may disperse with the turbidity plumes	2	2	4				
11.6	Disruptions to nearby community	Social: restricted access to site during placement operations; concern if placed material differs to natural material	2	2	4	Notice to mariners regarding placement operations	2	1	2				

Appendix D Cost Estimate Assumptions

Small CSD | Land Reclamation + Beach Nourishment

Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	Cost Estimate		
Sheet Details:	Small CSD | Land Reclamation & Beach Nourishment		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT Clarity from complexity

1. Background

Dredging method — Small Cutter Suction Dredge (12" pipe)
Placement option — Nearshore locations within Causeway Lake and North Kinka Beach

2. Unit Rates

Item	Unit Rate ($/hour)		Notes / Assumptions
	Working	Standby	
Dredging rates	$1,450	$870	Based on typical industry rates at time of estimate
Dozer	$225	$135	Based on typical industry rates at time of estimate
Excavator	$225	$135	Based on typical industry rates at time of estimate
Loader	$150	$90	Based on typical industry rates at time of estimate

Item	Unit Rate ($/m^3)	
Booster pump	$1	Additional cost per booster per cubic metre

3. Project Duration

Item	Value	Unit	Notes / Assumptions
Dredging volume	165,000	m^3	Basis of assessment: -0.5mAHD design depth and April 2021 bathymetry
Production rate	100	m^3/hour	Average production rates for small CSD's. Varies depending on the actual size of dredge deployed
Availability	60%	-	Percentage of time for dredging at full production
Payable standby	20%	-	Included: weather delay, dredge and pipeline relocation, stoppages at clients directive Excluded: breakdown / repairs, maitenance, crew changes
Operational duration	1650	hours	
Total project hours	2750	hours	
	275	days	Assumes a 10 hour work day
	46	weeks	Assumes a 6 day work week

4. Project Costs

4.1 Preliminaries

Item	Quantity	Unit Rate	Cost	Notes / Assumptions
Site enabling works	1	300,000	$300,000	Nominal lump sum to allow for site enabling work for dredge launching and recovering May include the following: -> dirt road widening works to accommodate trucks to launch/retrieval site -> boat ramp modification works (exisiting natural ramp) -> ground reinforcement works to increase ground bearing capacity to accommodate crane/s
Mobilisation of dredging and land-based equipment	1	$150,000	$150,000	Nominal lump sum for mobilisation, including: -> Site setout -> Mobilisation of dredge and earthmoving spread -> Mobilisation of max 2 km pipeline and 1 additional booster -> Provision of signage and buoyage
De-mobilisation of dredging and land-based equipment	1	$100,000	$100,000	Nominal lump sum for demobilisation
Pre-campaign site investigations	1	$45,000	$45,000	2021 investigation with 10% inflation -> Bathymetry survey -> Benthic habitat (seagrass) survey
Insurances	1	$25,000	$25,000	

Project management plan preperation	1	$10,000	$10,000	Provide dredge management plan; quality plan; inspection & maintenance plan; safety management plan, and road and lake traffic management plan.
Weekly reporting	46	$400	$18,400	
		Total	$648,400	

4.2 Working - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	1650	$1,450	$2,392,500	
Earthmoving spread	1650	$600	$990,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works. Activities include: -> management of pipeline at placement site -> beach profiling works
		Total	$3,382,500	

4.3 Standby - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	550	$870	$478,500	
Additional equipment	550	$360	$198,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works.
		Total	$676,500	

4.4 Additional costs for pipeline transport

Placement Location	Approx. pipeline route distance	No. boosters	Unit rate ($/m3)	Volume percentage	Volume (m3)	Cost
			Booster Pumps			
Lakeshore reclamation	<1 km	0	$0	50%	82,500	$0
North Kinka Beach	<2 km	1	$1	50%	82,500	$82,500
					Total	$82,500

4.5 Total Costs

Description	Unit	Unit Rate	Qty	Cost	Notes / Assumptions
Preliminaries	sum	n/a	1	$648,400	
Dredging	m^3	$25.10	165,000	$4,141,500	
Seagrass offset - dredging activities	m^2	$15	46,000	$690,000	
Seagrass offset - northeast DMPA	m^2	$15	0	$0	DMPA - dredge material placement area
Seagrass offset - north DMPA	m^2	$15	6,000	$90,000	DMPA - dredge material placement area
Seagrass offset - south DMPA	m^2	$15	12,000	$180,000	DMPA - dredge material placement area
Engineering and project management	-	n/a	5%	$287,495	Nominal percentage to account for engineering and project management consultancy
Contingencies	-	n/a	20%	$1,207,479	Nominal percentage to account for uncertainties
			Total	**$7,244,874**	

5. General assumptions

-> assumes dredge will be disassembled for transport and require 2 cranes for mobilisation/demobilisation
-> exludes costs associated with environmental approvals and/or monitoring
-> seagrass offset cost is based on the 2021 April benthic survey, and only considers the area footprint directly impacted by the dredging footprint and reclamation footprints
-> cost estimate does not incluyde preliminary works at the reclamation areas (e.g. access for earthmoving equipment, vegetation clearing)
-> assumes a suitable area available for laydown site, additional costs would be associated with clearing land for this

Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	High Level Cost Estimate		
Sheet Details:	Small CSD | Onshore Placement		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT
Clarity from complexity

1. Background

Dredging method — Small Cutter Suction Dredge (12" pipe)
Placement option — Onshore placement at Barlow's Earthmoving

2. Unit Rates

Item	Unit Rate ($/hour)		Notes / Assumptions
	Working	Standby	
Dredging rates	$1,450	$870	Based on typical industry rates
Dozer	$225	$135	Based on typical industry rates
Excavator	$225	$135	Based on typical industry rates
Loader	$150	$90	Based on typical industry rates

Item	Unit Rate ($/$m^3$)	
Booster pump	$1	Additional cost per booster per cubic metre

3. Project Duration

Item	Value	Unit	Notes / Assumptions
Dredging volume	165,000	m^3	Based on -0.5mAHD design depth and April 2021 bathymetry
Production rate	100	m^3/hour	
Availability	60%	-	Percentage of time for dredging at full production
Payable standby	20%	-	Included: weather delay, dredge and pipeline relocation, stoppages at clients directive Exluded: breakdown / repairs, maitenance, crew changes
Operational duration	1650	hours	
Total project hours	2750	hours	
	275	days	Assumes a 10 hour work day
	46	weeks	Assumes a 6 day work week

4. Project Costs

4.1 Preliminaries

Item	Quantity	Unit Rate	Cost	Notes / Assumptions
Site enabling works	1	300,000	$300,000	Nominal lump sum to allow for site enabling work for dredge launching and recovering May include the following: -> road widening works to accommodate trucks to launch/retrieval site -> boat ramp modification works (exisiting natural ramp) -> ground reinforcement works to increase ground bearing capacity to accommodate crane/s
Mobilisation of dredging and land-based equipment	1	$150,000	$150,000	Nominal lump sum for mobilisation, including: -> Site setout -> Mobilisation of dredge and earthmoving spread -> Mobilisation of max 2 km pipeline and 1 additional booster -> Provision of signage and buoyage
De-mobilisation of dredging and land-based equipment	1	$100,000	$100,000	Nominal lump sum for demobilisation
Pre-campaign site investigations	1	$45,000	$45,000	2021 investigation with 10% inflation -> Bathymetry survey -> Benthic habitat (seagrass) survey
Insurances	1	$25,000	$25,000	

				Notes / Assumptions
Project management plan preperation	1	$10,000	$10,000	Provide dredge management plan; quality plan; inspection & maintenance plan; safety management plan, and road and lake traffic management plan.
Weekly reporting	46	$400	$18,400	
		Total	$648,400	

4.2 Working - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	1650	$1,450	$2,392,500	
Earthmoving spread	1650	$600	$990,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works. Activities include: -> management of pipeline at placement site -> beach profiling works
		Total	$3,382,500	

4.3 Standby - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	550	$870	$478,500	
Additional equipment	550	$360	$198,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works.
		Total	$676,500	

4.4 Additional costs for pipeline transport

Placement Location	Approx. pipeline route distance	No. boosters	Unit rate ($/m3)	Volume percentage	Volume (m3)	Cost
Booster Pump/s	<2.5 km	2	$2	100%	165,000	$330,000
Return water pump	<1.5 km	1	$1	100%	165,000	$165,000
					Total	$495,000

Notes / Assumptions

Assumes tailings (excess water and fines) must be returned to Causeway Lake basin.

4.5 Onshore bund construction

Notes / Assumptions

Footprint of onshore area assumed to be 80,000 m2
Material bulking factor assumed to be 1.1
Bund height assumed to be +2.75 m RL (0.3 m freeboard allowance and 0.2 m for uncertainty)
Crest width assumed to be 3 m, with 1:3 batters
Perimeter assumed as 1,500 m
Assumes that all material required for the bund construction can be sourced onsite, i.e. excavated insitu
Site enabling costs excluded, i.e. assumes suitable access roads for the earthmoving spread to access both the bunded area and pipleine route

Description	Unit	Qty	Unit Rate	Cost	Notes / Assumptions
Preliminary Items					
Site establishment and mobilisation	Item	1	$15,000	$15,000	
Develop and implement inspection and testing plan	Item	1	$20,000	$20,000	
Demobilisation	Item	1	$10,000	$10,000	
Initial earthworks					
Clear, mulch and stockpile all vegetation	m^2	80,000	$0.25	$20,000	
Trim and stockpile topsiol and unsuitable material	m^3	24,000	$3	$72,000	Assumes top 300mm to be stockpiled

Geotextile - supply and install to foundations	m^2	30,000	$5	$150,000	Footprint of the bund
Bund construction					
Bund foundation preparations	m^2	30,000	$1.5	$45,000	Footprint of bund
Bund excavate, place and compact fill	m^3	46,500	$7.5	$348,750	Assumes 0 m RL for entire perimeter
Supply and construct outlet structure	Item	5	$250	$1,250	
Finishing Earthworks					
Apply mulch	m^2	80,000	$2.5	$200,000	Mulching over entire disposal area
Quality Testing					
Compaction testing	Item	1	$30,000	$30,000	
As-constructed survey and plans	Item	1	$8,000	$8,000	
Additional					
Screen fill material	Item	1	$15,000	$15,000	Screen placed in bunded area to control discharge flow and promote settlement of material
			Total	**$935,000**	

4.6 Total Costs

Description	Unit	Unit Rate	Qty	Cost	Notes / Assumptions
Preliminaries	sum	n/a	1	$648,400	
Dredging	m^3	$27.60	165,000	$4,554,000	
Seagrass offset	m^2	$15	46,000	$690,000	
Onshore bunded area construction	sum	n/a	1	$935,000	
Engineering and project management	-	n/a	5%	$341,370	Nominal percentage to account for engineering and project management consultancy
Contingencies	-	n/a	20%	$1,433,754	Nominal percentage to account for uncertainties
			Total	**$8,602,524**	

5. General assumptions

-> assumes dredge will be disassembled for transport and require 2 cranes for mobilisation/demobilisation
-> exludes costs associated with environmental approvals and/or monitoring
-> seagrass offset cost is based on the 2021 April benthic survey, and only considers the area footprint directly impacted by the dredging footprint
-> assumes a suitable area available for laydown site, additional costs would be associated with clearing land for this

Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	Cost Estimate		
Sheet Details:	Amphibious Excavator | Land Reclamation & Beach Nourishment		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT Clarity from complexity

1. Background

Dredging method	Amphibious excavator with cutter head option
Placement option	Nearshore locations within Causeway Lake and North Kinka Beach

2. Unit Rates

Item	Unit Rate ($/hour)		Notes / Assumptions
	Working	Standby	
Dredging rates	$1,000	$600	Based on typical industry rates at time of estimate
Dozer	$225	$135	Based on typical industry rates at time of estimate
Excavator	$225	$135	Based on typical industry rates at time of estimate
Loader	$150	$90	Based on typical industry rates at time of estimate

Item	Unit Rate ($/m^3)	
Booster pump (if required)	$1	Additional cost per booster per cubic metre

3. Project Duration

Item	Value	Unit	Notes / Assumptions
Dredging volume	165,000	m^3	Based on -0.5mAHD design depth and April 2021 bathymetry
Production rate	60	m^3/hour	
Availability	60%	-	Percentage of time for dredging at full production
Payable standby	20%	-	Included: weather delay, dredge and pipeline relocation, stoppages at clients directive Exluded: breakdown / repairs, maitenance, crew changes
Operational duration	2750	hours	
Total project hours	4584	hours	
	459	days	Assumes a 10 hour work day
	77	weeks	Assumes a 6 day work week

4. Project Costs

4.1 Preliminaries

Item	Quantity	Unit Rate	Cost	Notes / Assumptions
Site enabling works	1	100,000	$100,000	Nominal lump sum to allow for site enabling work for dredge launching and recovering May include the following: -> road widening works to accommodate trucks to launch/retrieval site -> boat ramp modification works (widening exisiting natural ramp)
Mobilisation of dredging and land-based equipment	1	$105,000	$105,000	Nominal lump sum for mobilisation (70% of small CSD), including: -> Site setout -> Mobilisation of dredge and earthmoving spread -> Mobilisation of max 2 km pipeline and 1 additional booster -> Provision of signage and buoyage
De-mobilisation of dredging and land-based equipment	1	$70,000	$70,000	Nominal lump sum for demobilisation (70% of small CSD)
Pre-campaign site investigations	1	$45,000	$45,000	2021 investigation with 10% inflation -> Bathymetry survey -> Benthic habitat (seagrass) survey
Insurances	1	$25,000	$25,000	

Project management plan preperation	1	$10,000	$10,000	Provide dredge management plan; quality plan; inspection & maintenance plan; safety management plan, and road and lake traffic management plan.
Weekly reporting	77	$400	$30,800	
		Total	$385,800	

4.2 Working - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	2750	$1,000	$2,750,000	
Earthmoving spread	2750	$600	$1,650,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works. Activities include: -> management of pipeline at placement site -> beach profiling works
		Total	$4,400,000	

4.3 Standby - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	916.8	$600	$550,080	
Additional equipment	916.8	$360	$330,048	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works.
		Total	$880,128	

4.4 Additional costs for pipeline transport

Placement Location	Approx. pipeline route distance	No. boosters	Unit rate ($/m3)	Volume percentage	Volume (m3)	Cost
Booster Pumps						
Lakeshore reclamation	<1 km	0	$0	50%	82,500	$0
North Kinka Beach	<2 km	1	$1	50%	82,500	$82,500
					Total	$82,500

4.5 Total Costs

Description	Unit	Unit Rate	Qty	Cost	Notes / Assumptions
Preliminaries	sum	n/a	1	$385,800	
Dredging	m^3	$32.50	165,000	$5,362,628	
Seagrass offset - dredging activities	m^2	$15	46,000	$690,000	
Seagrass offset - northeast DMPA	m^2	$15	0	$0	DMPA - dredge material placement area
Seagrass offset - north DMPA	m^2	$15	6,000	$90,000	DMPA - dredge material placement area
Seagrass offset - south DMPA	m^2	$15	12,000	$180,000	DMPA - dredge material placement area
Engineering and project management	-	n/a	5%	$335,421	Nominal percentage to account for engineering and project management consultancy
Contingencies	-	n/a	20%	$1,408,770	Nominal percentage to account for uncertainties
			Total	**$8,452,619**	

5. General assumptions

-> assumes the amphibious excavator can be assembled onsite and does not require a crane
-> assumes the cutter head tool is used for all operations
-> exludes costs associated with environmental approvals and/or monitoring
-> seagrass offset cost is based on the 2021 April benthic survey, and only considers the area footprint directly impacted by the dredging footprint and reclamation areas
-> cost estimate does not account for any preliminary works at the reclamation areas (e.g. access for earthmoving equipment, vegetation clearing)
-> assumes a suitable area available for laydown site, additional costs would be associated with clearing land for this

Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	Cost Estimate		
Sheet Details:	Amphibious Excavator | Onshore Placement		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT
Clarity from complexity

1. Background

Dredging method — Amphibious excavator with rose cutter
Placement option — Onshore placement at Barlow's Earthmoving

2. Unit Rates

Item	Unit Rate ($/hour)		Notes / Assumptions
	Working	Standby	
Dredging rates	$1,000	$600	Based on typical industry rates at time of estimate
Dozer	$225	$135	Based on typical industry rates at time of estimate
Excavator	$225	$135	Based on typical industry rates at time of estimate
Loader	$150	$90	Based on typical industry rates at time of estimate

Item	Unit Rate ($/$m^3$)	Notes / Assumptions
Booster pump (if required)	$1	Additional cost per booster per cubic metre

3. Project Duration

Item	Value	Unit	Notes / Assumptions
Dredging volume	165,000	m^3	Based on -0.5mAHD design depth and April 2021 bathymetry
Production rate	60	m^3/hour	
Availability	60%	-	Percentage of time for dredging at full production
Payable standby	20%	-	Included: weather delay, dredge and pipeline relocation, stoppages at clients directive Exluded: breakdown / repairs, maitenance, crew changes
Operational duration	2750	hours	
Total project hours	4584	hours	
	459	days	Assumes a 10 hour work day
	77	weeks	Assumes a 6 day work week

4. Project Costs

4.1 Preliminaries

Item	Quantity	Unit Rate	Cost	Notes / Assumptions
Site enabling works	1	100,000	$100,000	Nominal lump sum to allow for site enabling work for dredge launching and recovering May include the following: -> road widening works to accommodate trucks to launch/retrieval site -> boat ramp modification works (widening exisiting natural ramp)
Mobilisation of dredging and land-based equipment	1	$105,000	$105,000	Nominal lump sum for mobilisation (70% of small CSD), including: -> Site setout -> Mobilisation of dredge and earthmoving spread -> Mobilisation of max 2 km pipeline and 1 additional booster -> Provision of signage and buoyage
De-mobilisation of dredging and land-based equipment	1	$70,000	$70,000	Nominal lump sum for demobilisation (70% of small CSD)
Pre-campaign site investigations	1	$45,000	$45,000	2021 investigation with 10% inflation -> Bathymetry survey -> Benthic habitat (seagrass) survey
Insurances	1	$25,000	$25,000	

Project management plan preperation	1	$10,000	$10,000	Provide dredge management plan; quality plan; inspection & maintenance plan; safety management plan, and road and lake traffic management plan.
Weekly reporting	77	$400	$30,800	
		Total	$385,800	

4.2 Working - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	2750	$1,000	$2,750,000	
Earthmoving spread	2750	$600	$1,650,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works. Activities include: -> management of pipeline at placement site -> beach profiling works
		Total	$4,400,000	

4.3 Standby - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	916.8	$600	$550,080	
Additional equipment	916.8	$360	$330,048	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works.
		Total	$880,128	

4.4 Additional costs for pipeline transport

Placement Location	Approx. pipeline route distance	No. boosters	Unit rate ($/m3)	Volume percentage	Volume (m3)	Cost
Booster Pump/s	<2.5 km	2	$2	100%	165,000	$330,000
Return water pump	<1.5 km	1	$1	100%	165,000	$165,000
					Total	$495,000

Notes / Assumptions

Assumes tailings (excess water and fines) must be returned to Causeway Lake basin.

4.5 Onshore bund construction

Notes / Assumptions

Footprint of onshore area assumed to be 80,000 m2

Material bulking factor assumed to be 1.1

Bund height assumed to be +2.75 m RL (0.3 m freeboard allowance and 0.2 m for uncertainty)

Crest width assumed to be 3 m, with 1:3 batters

Perimeter assumed as 1,500 m

Assumes that all material required for the bund construction can be sourced onsite, i.e. excavated insitu

Site enabling costs excluded, i.e. assumes suitable access roads for the earthmoving spread to access both the bunded area and pipleine route

Description	Unit	Qty	Unit Rate	Cost	Notes / Assumptions
Preliminary Items					
Site establishment and mobilisation	Item	1	$15,000	$15,000	
Develop and implement inspection and testing plan	Item	1	$20,000	$20,000	
Demobilisation	Item	1	$10,000	$10,000	
Initial earthworks					
Clear, mulch and stockpile all vegetation	m^2	80,000	$0.25	$20,000	

Trim and stockpile topsiol and unsuitable material	m^3	24,000	$3	$72,000	Assumes top 300mm to be stockpiled
Geotextile - supply and install to foundations	m^2	30,000	$5	$150,000	Footprint of the bund
Bund construction					
Bund foundation preparations	m^2	30,000	$1.5	$45,000	Footprint of bund
Bund excavate, place and compact fill	m^3	46,500	$7.5	$348,750	Assumes 0 m RL for entire perimeter
Supply and construct outlet structure	Item	5	$250	$1,250	
Finishing Earthworks					
Apply mulch	m^2	80,000	$2.5	$200,000	Mulching over entire disposal area
Quality Testing					
Compaction testing	Item	1	$30,000	$30,000	
As-constructed survey and plans	Item	1	$8,000	$8,000	
Additional					
Screen fill material	Item	1	$15,000	$15,000	Screen placed in bunded area to control discharge flow and promote settlement of material
			Total	**$935,000**	

4.6 Total Costs

Description	Unit	Unit Rate	Qty	Cost	Notes / Assumptions
Preliminaries	sum	n/a	1	$385,800	
Dredging	m^3	$32.00	165,000	$5,280,128	
Seagrass offset	m^2	$15	46,000	$690,000	
Onshore bunded construction	sum	n/a	1	$935,000	
Engineering and project management	-	n/a	5%	$364,546	Nominal percentage to account for engineering and project management consultancy
Contingencies	-	n/a	20%	$1,531,095	Nominal percentage to account for uncertainties
			Total	**$9,186,569**	

5. General assumptions

-> assumes dredge will be disassembled for transport and require 2 cranes for mobilisation/demobilisation
-> exludes costs associated with environmental approvals and/or monitoring
-> seagrass offset cost is based on the 2021 April benthic survey, and only considers the area footprint directly impacted by the dredging
-> assumes a suitable area available for laydown site, additional costs would be associated with clearing land for this

2 x mini dredge | Land Reclamation + Beach Nourishment

Project Name:	Causeway Lake
BMT Project Code:	A10946
Client:	Shire of Livingstone
Subject:	Cost Estimate
Sheet Details:	2 x mini dredge | Land Reclamation & Beach Nourishment
Revision:	A
By:	BMT
Date:	6/08/2021

BMT Clarity from complexity

1. Background

Dredging method: 2 x mini dredge

Placement option: Nearshore locations within Causeway Lake and North Kinka Beach

2. Unit Rates

Item	Unit Rate ($/hour)		Notes / Assumptions
	Working	Standby	
Dredging rates	$1,250	$750	Based on typical industry rates at time of estimate
Dozer	$225	$135	Based on typical industry rates at time of estimate
Excavator	$225	$135	Based on typical industry rates at time of estimate
Loader	$150	$90	Based on typical industry rates at time of estimate

Item	Unit Rate ($/m^3)	
Booster pump (if required)	$1	Additional cost per booster per cubic metre

3. Project Duration

Item	Value	Unit	Notes / Assumptions
Dredging volume	165,000	m^3	Based on -0.5mAHD design depth and April 2021 bathymetry
Production rate	40	m^3/hour	2 x 20 m^3/hr
Availability	60%	-	Percentage of time for dredging at full production
Payable standby	20%	-	Included: weather delay, dredge and pipeline relocation, stoppages at clients directive Exluded: breakdown / repairs, maitenance, crew changes
Operational duration	4125	hours	
Total project hours	6875	hours	
	688	days	Assumes a 10 hour work day
	115	weeks	Assumes a 6 day work week

4. Project Costs

4.1 Preliminaries

Item	Quantity	Unit Rate	Cost	Notes / Assumptions
Site enabling works	1	200,000	$200,000	Nominal lump sum to allow for site enabling work for dredge launching and recovering May include the following: -> road widening works to accommodate trucks to launch/retrieval site -> boat ramp modification works (widening exisiting natural ramp)
Mobilisation of dredging and land-based equipment	1	$200,000	$200,000	Nominal lump sum for mobilisation (1.5 x 80% of small CSD), including: -> Site setout -> Mobilisation of dredge and earthmoving spread -> Mobilisation of max 2 km pipeline and 1 additional booster, per dredge -> Provision of signage and buoyage
De-mobilisation of dredging and land-based equipment	1	$130,000	$130,000	Nominal lump sum for demobilisation (1.5 x 80% of small CSD)
Pre-campaign site investigations	1	$45,000	$45,000	2021 investigation with 10% inflation -> Bathymetry survey -> Benthic habitat (seagrass) survey
Insurances	1	$25,000	$25,000	

Project management plan preperation	1	$10,000	$10,000	Provide dredge management plan; quality plan; inspection & maintenance plan; safety management plan, and road and lake traffic management plan.
Weekly reporting	115	$400	$46,000	
		Total	$656,000	

4.2 Working - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	4125	$1,250	$5,156,250	
Earthmoving spread	4125	$600	$2,475,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works. Activities include: -> management of pipeline at placement site -> beach profiling works
		Total	$7,631,250	

4.3 Standby - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	1375	$750	$1,031,250	
Additional equipment	1375	$360	$495,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works.
		Total	$1,526,250	

4.4 Additional costs for pipeline transport

Placement Location	Approx. pipeline route distance	No. boosters	Unit rate ($/m3)	Volume percentage	Volume (m3)	Cost
Booster Pumps						
Lakeshore reclamation	<1 km	0	$0	50%	82,500	$0
North Kinka Beach	<2 km	2	$2	50%	82,500	$165,000
					Total	$165,000

Notes / Assumptions

Assumes each dredge will have separate pipeline to disposal site, each requiring independent booster pumps

4.5 Total Costs

Description	Unit	Unit Rate	Qty	Cost	Notes / Assumptions
Preliminaries	sum	n/a	1	$656,000	
Dredging	m^3	$56.50	165,000	$9,322,500	
Seagrass offset - dredging activities	m^2	$15	46,000	$690,000	
Seagrass offset - northeast DMPA	m^2	$15	0	$0	DMPA - dredge material placement area
Seagrass offset - north DMPA	m^2	$15	6,000	$90,000	DMPA - dredge material placement area
Seagrass offset - south DMPA	m^2	$15	12,000	$180,000	DMPA - dredge material placement area
Engineering and project management	-	n/a	5%	$546,925	Nominal percentage to account for engineering and project management consultancy
Contingencies	-	n/a	20%	$2,297,085	Nominal percentage to account for uncertainties
			Total	**$13,782,510**	

5. General assumptions

-> assumes the mini dredges can be assembled onsite and does not require a crane
-> exludes costs associated with environmental approvals and/or monitoring
-> seagrass offset cost is based on the 2021 April benthic survey, and only considers the area footprint directly impacted by the dredging footprint and reclamation areas
-> cost estimate does not account for any preliminary works at the reclamation areas (e.g. access for earthmoving equipment, vegetation clearing)
-> assumes a suitable area available for laydown site, additional costs would be associated with clearing land for this

2 x mini dredge | Onshore Placement

Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	Cost Estimate		
Sheet Details:	2 x mini dredge | Onshore Placement		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT Clarity from complexity

1. Background

Dredging method 2 x mini dredge
Placement option Onshore placement at Barlow's Earthmoving

2. Unit Rates

Item	Unit Rate ($/hour)		Notes / Assumptions
	Working	Standby	
Dredging rates	$1,250	$750	Based on typical industry rates at time of estimate
Dozer	$225	$135	Based on typical industry rates at time of estimate
Excavator	$225	$135	Based on typical industry rates at time of estimate
Loader	$150	$90	Based on typical industry rates at time of estimate

Item	Unit Rate ($/m^3)	
Booster pump (if required)	$1	Additional cost per booster per cubic metre

3. Project Duration

Item	Value	Unit	Notes / Assumptions
Dredging volume	165,000	m^3	Based on -0.5mAHD design depth and April 2021 bathymetry
Production rate	40	m^3/hour	2 x 20 m^3/hr
Availability	60%	-	Percentage of time for dredging at full production
Payable standby	20%	-	Included: weather delay, dredge and pipeline relocation, stoppages at clients directive Exluded: breakdown / repairs, maitenance, crew changes
Operational duration	4125	hours	
Total project hours	6875	hours	
	688	days	Assumes a 10 hour work day
	115	weeks	Assumes a 6 day work week

4. Project Costs

4.1 Preliminaries

Item	Quantity	Unit Rate	Cost	Notes / Assumptions
Site enabling works	1	200,000	$200,000	Nominal lump sum to allow for site enabling work for dredge launching and recovering May include the following: -> road widening works to accommodate trucks to launch/retrieval site -> boat ramp modification works (widening exisiting natural ramp)
Mobilisation of dredging and land-based equipment	1	$180,000	$180,000	Nominal lump sum for mobilisation (1.5 x 80% of small CSD), including: -> Site setout -> Mobilisation of dredge and earthmoving spread -> Mobilisation of max 2 km pipeline and 1 additional booster, per dredge -> Provision of signage and buoyage
De-mobilisation of dredging and land-based equipment	1	$120,000	$120,000	Nominal lump sum for demobilisation (1.5 x 80% of small CSD)
Pre-campaign site investigations	1	$45,000	$45,000	2021 investigation with 10% inflation -> Bathymetry survey -> Benthic habitat (seagrass) survey
Insurances	1	$25,000	$25,000	

				Notes / Assumptions
Project management plan preperation	1	$10,000	$10,000	Provide dredge management plan; quality plan; inspection & maintenance plan; safety management plan, and road and lake traffic management plan.
Weekly reporting	115	$400	$46,000	
		Total	$626,000	

4.2 Working - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	4125	$1,250	$5,156,250	
Earthmoving spread	4125	$600	$2,475,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works. Activities include: -> management of pipeline at placement site -> beach profiling works
		Total	$7,631,250	

4.3 Standby - dredging and management of placement sites

Item	Qty (hours)	Unit Rate	Cost	Notes / Assumptions
Dredging equipment	1375	$750	$1,031,250	
Additional equipment	1375	$360	$495,000	Assumes the earthmoving spread (1 x loader, 1 x excavator, 1 x dozer) operates on the same schedule / availability as the dredging works.
		Total	$1,526,250	

4.4 Additional costs for pipeline transport

Placement Location	Approx. pipeline route distance	No. boosters	Unit rate ($/m3)	Volume percentage	Volume (m3)	Cost
Booster Pump/s	<2.5 km	4	$4	100%	165,000	$660,000
Return water pump	<1.5 km	1	$1	100%	165,000	$165,000
					Total	$825,000

Notes / Assumptions
Assumes tailings (excess water and fines) must be returned to Causeway Lake basin.
Assumes each dredge will have separate pipeline to disposal site, each requiring independent booster pumps

4.5 Onshore bund construction

Notes / Assumptions
Footprint of onshore area assumed to be 80,000 m2
Material bulking factor assumed to be 1.1
Bund height assumed to be +2.75 m RL (0.3 m freeboard allowance and 0.2 m for uncertainty)
Crest width assumed to be 3 m, with 1:3 batters
Perimeter assumed as 1,500 m
Assumes that all material required for the bund construction can be sourced onsite, i.e. excavated insitu
Site enabling costs excluded, i.e. assumes suitable access roads for the earthmoving spread to access both the bunded area and pipleine route

Description	Unit	Qty	Unit Rate	Cost	Notes / Assumptions
Preliminary Items					
Site establishment and mobilisation	Item	1	$15,000	$15,000	
Develop and implement inspection and testing plan	Item	1	$20,000	$20,000	
Demobilisation	Item	1	$10,000	$10,000	
Initial earthworks					
Clear, mulch and stockpile all vegetation	m^2	80,000	$0.25	$20,000	
Trim and stockpile topsiol and unsuitable material	m^3	24,000	$3	$72,000	Assumes top 300mm to be stockpiled

Geotextile - supply and install to foundations	m^2	30,000	$5	$150,000	Footprint of the bund
Bund construction					
Bund foundation preparations	m^2	30,000	$1.5	$45,000	Footprint of bund
Bund excavate, place and compact fill	m^3	46,500	$7.5	$348,750	Assumes 0 m RL for entire perimeter
Supply and construct outlet structure	Item	5	$250	$1,250	
Finishing Earthworks					
Apply mulch	m^2	80,000	$2.5	$200,000	Mulching over entire disposal area
Quality Testing					
Compaction testing	Item	1	$30,000	$30,000	
As-constructed survey and plans	Item	1	$8,000	$8,000	
Additional					
Screen fill material	Item	1	$15,000	$15,000	Screen placed in bunded area to control discharge flow and promote settlement of material
			Total	**$935,000**	

4.6 Total Costs

Description	Unit	Unit Rate	Qty	Cost	Notes / Assumptions
Preliminaries	sum	n/a	1	$626,000	
Dredging	m^3	$55.50	165,000	$9,157,500	
Seagrass offset	m^2	$15	46,000	$690,000	
Onshore bunded construction	sum	n/a	1	$935,000	
Engineering and project management	-	n/a	5%	$570,425	Nominal percentage to account for engineering and project management consultancy
Contingencies	-	n/a	20%	$2,395,785	Nominal percentage to account for uncertainties
			Total	**$14,374,710**	

5. General assumptions

-> assumes the mini dredges can be assembled onsite and does not require a crane
-> exludes costs associated with environmental approvals and/or monitoring
-> seagrass offset cost is based on the 2021 April benthic survey, and only considers the area footprint directly impacted by the dredging footprint
-> cost estimate does not account for any preliminary works at the reclamation areas (e.g. access for earthmoving equipment, vegetation clearing)
-> assumes a suitable area available for laydown site, additional costs would be associated with clearing land for this

Option Comparison

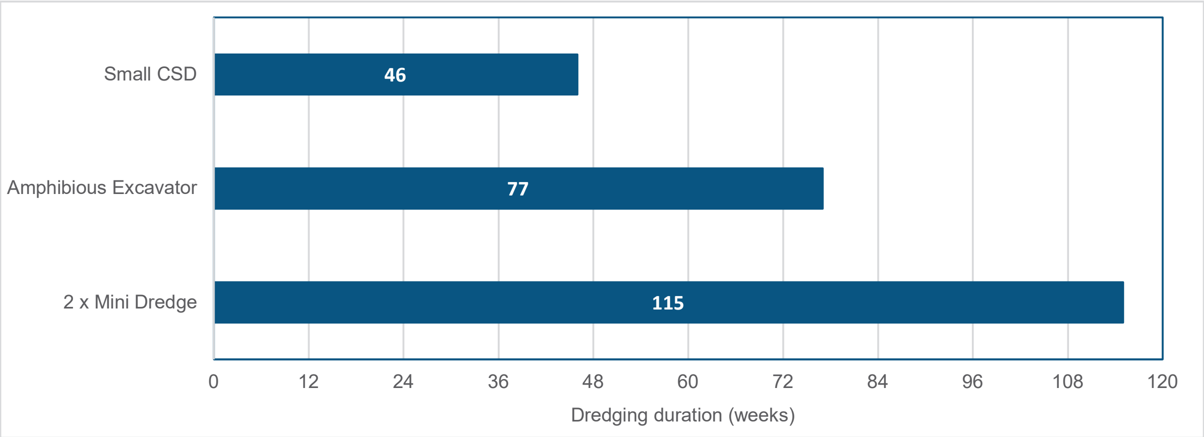
Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	Cost Estimate		
Sheet Details:	Comparison of options		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT
Clarity from complexity

1. Dredging Schedule Comparison

Option	Weeks
Small CSD	46
Amphibious Excavator	77
2 x Mini Dredge	115

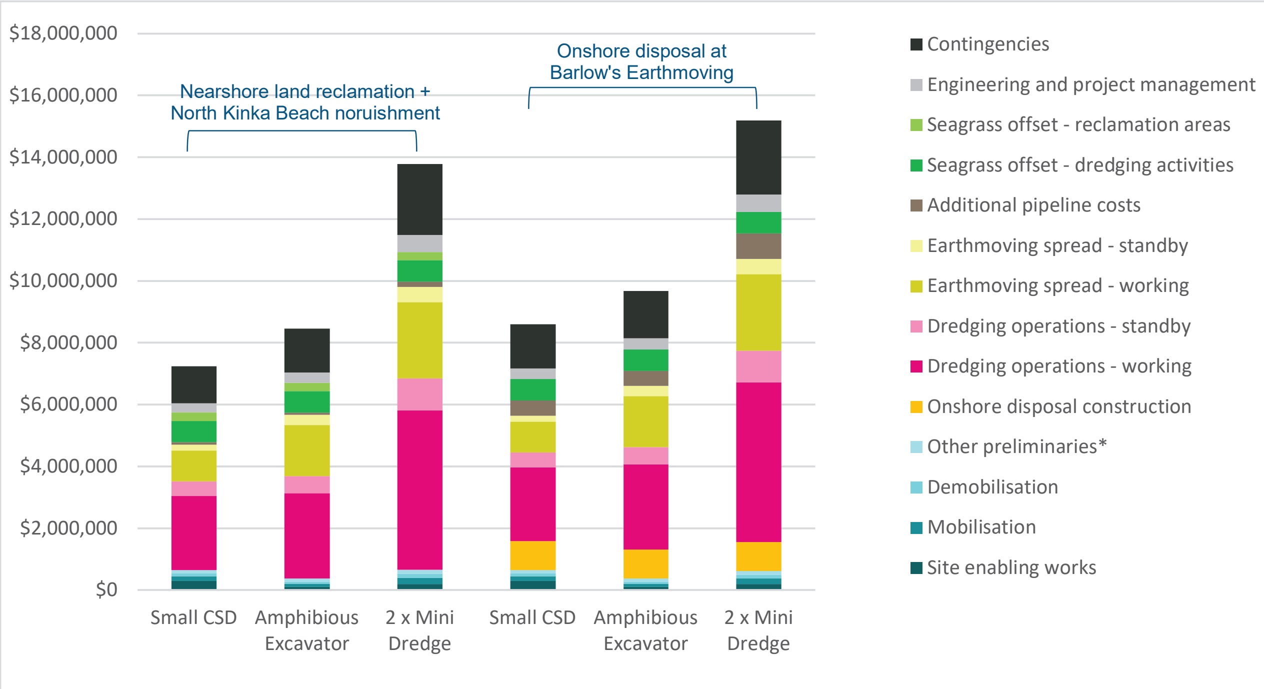
Note: this duration is for dredging activities only. The duration of site enabling, mobilisation and demobilisation have been excluded.



2. Cost Comparison

Option	Placement at Nearshore + North Kinka Beach			Onshore Disposal - local quarry		
	Small CSD	**Amphibious Excavator**	**2 x Mini Dredge**	**Small CSD**	**Amphibious Excavator**	**2 x Mini Dredge**
Site enabling works	$300,000	$100,000	$200,000	$300,000	$100,000	$200,000
Mobilisation	$150,000	$105,000	$200,000	$150,000	$105,000	$180,000
Demobilisation	$100,000	$70,000	$130,000	$100,000	$70,000	$120,000
Onshore disposal construction	$0	$0	$0	$935,000	$935,000	$935,000
Other preliminaries*	$98,400	$110,800	$126,000	$98,400	$110,800	$126,000
Dredging operations - working	$2,392,500	$2,750,000	$5,156,250	$2,392,500	$2,750,000	$5,156,250
Dredging operations - standby	$478,500	$550,080	$1,031,250	$478,500	$550,080	$1,031,250
Earthmoving spread - working	$990,000	$1,650,000	$2,475,000	$990,000	$1,650,000	$2,475,000
Earthmoving spread - standby	$198,000	$330,048	$495,000	$198,000	$330,048	$495,000
Additional pipeline costs	$82,500	$82,500	$165,000	$495,000	$495,000	$825,000
Seagrass offset - dredging activities	$690,000	$690,000	$690,000	$690,000	$690,000	$690,000
Seagrass offset - reclamation areas	$270,000	$270,000	$270,000	$0	$0	$0
Engineering and project manageme	$287,495	$335,421	$546,925	$341,370	$364,546	$570,425
Contingencies	$1,207,479	$1,408,770	$2,297,085	$1,433,754	$1,531,095	$2,395,785
Total	**$7,244,874**	**$8,452,619**	**$13,782,510**	**$8,602,524**	**$9,681,569**	**$15,199,710**

Option Comparison



Future Maintenance Costs

Project Name:	Causeway Lake		
BMT Project Code:	A10946		
Client:	Shire of Livingstone		
Subject:	Cost Estimate		
Sheet Details:	Future Maintenance Dredging Costs		
Revision:	A		
By:	BMT	**Date:**	6/08/2021

BMT Clarity from complexity

1. Costs

Maintenance dreding frequency	30	years	Section 8.2 of report
Maintenance dredging quantity	140000	m^3	Section 8.2 of report
Assume discount rate	3%		

Option	Small CSD	Amphibious Excavator	2 x Mini Dredge
2021 costs	$6,147,000	$7,172,000	$11,694,000
NPC over 30 years	$2,532,000	$2,955,000	$4,818,000

BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

BMT

BMT in Environment

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