Mooloolaba Boat Harbour Eastern Breakwater Extension

Constructability Report

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Prepared for:
DEPARTMENT OF TRANSPORT AND MAIN ROADS

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Limitations Statement

The sole purpose of this report and the associated services performed by Kellogg Brown & Root Pty Ltd (KBR) is to outline the basis for the design of the eastern breakwater extension works at the Mooloolaba Boat Harbour, assess the constructability of the eastern breakwater extension works at the Mooloolaba Boat Harbour, assess the constructability of the eastern breakwater extension works at the Mooloolaba Boat Harbour in accordance with the scope of services set out in the contract between KBR and Queensland Department of Transport and Main Roads Queensland Department of Transport and Main Roads ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

KBR derived the data in this report primarily from visual inspections, site surveys, previous detailed design documentation and information supplied by the Client visual inspections, site surveys, previous detailed design documentation and information supplied by the Client. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, KBR has relied upon and presumed accurate certain information (or absence thereof) relative to the site the site provided by government officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, KBR has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by KBR in this report are not, and should not be considered, an opinion concerning areas outside of the eastern Mooloolaba Boat Harbour breakwater extension project areas outside of the eastern Mooloolaba Boat Harbour breakwater extension project. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon site conditions, information and drawings supplied by the Client site conditions, information and drawings supplied by the Client in existence at the time of the investigation.

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Revision History

Revision	Date	Comment	Signatures			
			Originated by	Checked by	Technical Approval	Project Approval
A	30/04/19	Issued for Client Review	personal information			
B	12/07/19	Issued for Client Approval				
C	21/7/20	Issued for Client Approval				
0	16/12/21	Issued for Use				

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1 Introduction

1.1 COMMISSION

Kellogg Brown & Root Pty Ltd (KBR) has been commissioned by Department of Transport and Main Roads (TMR) to undertake services in relation to extending the Mooloolaba eastern breakwater, specifically the design and necessary approvals for the breakwater extension. As part of these services TMR has requested KBR undertake a constructability report outlining the potential construction methodologies.

1.2 BACKGROUND

The original Mooloolaba breakwater design was undertaken in 1966 and the upgrade of the navigation beacon was designed in 1987 (refer to supplied engineering drawings, Department Harbours and Marine). The current works comprise extending the existing eastern breakwater (Figure 1.1) and are required to provide increased protection from entrance channel siltation caused by longshore drift around Point Cartwright.

While details of the initial breakwater construction and ongoing maintenance are speculative, it is likely that the existing eastern breakwater was constructed and maintained using on-land construction techniques.

Figure 1.1 Site locality

1.3 PURPOSE

Since initial construction in 1966, there have been advancements in the design standards and alternative construction methodologies of rock armoured coastal structures. Correspondingly, there have been significant changes in the land use, vehicle transport corridors, and marine traffic locally at the Mooloolaba site.

At project inception it was identified that site constraints, restricted accessibility, and the high level of development on approach to the site by land, posed potential challenges for the constructability of the proposed breakwater extension. TMR has therefore commissioned KBR to broadly investigate potential constructability issues that would have a bearing on the access. Adequate supplies of rock required for breakwater construction as well as methodologies that could be potentially utilised were also considered.

An overview of four potential construction methodologies are described for further consideration and discussion with TMR.

1.4 SCOPE

The scope of this constructability investigation includes:

- High level assessment of four construction options for the proposed Eastern Mooloolaba Breakwater Extension, including land and water-based construction methods;
- Site inspection assessment for accessibility of heavy plant and equipment, transport routes and laydown areas (See Appendix B);
- Viability assessment of nearby quarry sites as sources of rock armour and suitable materials, and;
- Desktop review of five concrete armour units. See Appendix C for the full technical memorandum

2 Material Availability

2.1 PROJECT ROCK REQUIREMENTS

For constructability discussion we assume:

Rock density of ρ = 2600 kg/m^3

Breakwater trunk primary rock armour 9 tonne, 2 layers

Round head 12 tonne rock, 2 layers

Under-layers and core material based on Terzaghi filter rules and porosity considerations

Breakwater extension 60m

Crest level 5.5 to 6.8m

Seabed excavation to founding rock and toe elevation at -5.5m AHD.

Estimated rock quantities are summarised in Table 2.1

Table 2.1 Preliminary rock size and volume estimates

Component	Estimated D_{n50} (m)[1]	Estimated Volume (m^3)
Core	0.1	13,000
Filter	0.3	3,000
Secondary Armour	0.8	3,000
Armour – Trunk Armour - Roundhead[2]	1.5 1.7	4,200 1,800
Toe – Trunk Toe – Roundhead[2]	1.5 1.7	2,100 900

Notes:
[1] D_{n50} is the nominal average rock diameter, related to the M50 by the following relationship $M_{50} = \rho(D_{n50})^3$ (CUR Rock Manual)
[2] Roundhead/Trunk armour quantities proportioned based on the anticipated perimeter length

Size and volume of concrete armour units will be investigated in Section 2.6.

2.2 ROCK SOURCES

Two rock quarries were inspected as part of the constructability inspection. A high-level assessment of these sites is provided in the following sections.

Available information for each site is provided in Appendix A and B. Further investigation is recommended to identify suitable rock for the project.

2.2.1 Kuluin Quarry (Maroochydore)

The Department of Transport and Main Roads currently holds a strategic quarry asset at Kuluin (Lot 481 on Plan GC2895). Key points about this site are:

Quarry is located approximately 14 km from Point Cartwright on the corner of Commercial and Advance Road, Kuluin opposite the Maroochy Shire Council sewage treatment plant, and has a total area of 106,000 square meters. The terrain is mostly steep and hilly and is heavily wooded with large eucalyptus trees. The actual quarry face/site is secured by 2 m chain-wire fencing and gates;

Original resource of rock material for revetment and breakwater construction (mid 1960s) and maintenance at the Mooloolaba State boat harbour (rare resource for heavy rock armour in this region);

Geology of the site materials is generally a combination of a grey granitoid material with mica crystal structures (Mount Urah Granodiorite) and Landsborough Sandstone materials. Granodiorite is generally observed to be of sound quality (Refer Appendix A);

An Extractive Industry Statistical Return is completed and submitted by TMR to the Department of Natural Resources and Mines (DNRM) on an annual basis. The last blasting operation at this site was undertaken in 2002, where 9,000 cubic metres of material was released from halfway up the quarry face so as to create a new bench which improved stability. Rock has been sourced from the site to carry out remedial works on an as needed basis to both the breakwaters and the inner revetments, however no recent remedial works are known.

From a roadside inspection of the quarry conducted on 15 March 2019, the stockpiled rock appeared to be of reasonable quality. Joint spacing appeared acceptable from the visible rock armour stockpiles (Figure 2.1). However, it could not be established if primary armour rock sizes greater than previously used for the Mooloolaba Breakwater could be quarried at this site.


Figure 2.1 View into Kuluin Quarry and rock armour stockpiles from Commercial Road, Kuluin. Larger pictured armour is estimated to have a median diameter (D_{50}) of about 1.2 m at 15 March 2019.

In order to provide a more informed assessment of the rock availability at the Kuluin Quarry site, on 17 and 18 October 2019, KBR performed a more detailed site visit to identify if the rock may have some use as core or secondary armour and broadly quantify the amount of material within the stockpiles. Observations from this site investigation are provided in Appendix B and concluded that:

- Up to 4,700m3 of material may be present within the existing stockpiles, with individual rocks that typically ranged from 15 kg to 3.0 t although only a limited number of larger rocks between 3.0 t and 6.0 t were noted (~10 No.). Therefore the primary and secondary armour quarry yield is likely to be low.
- Quality of material on site is highly variable. While some armour may be of reasonable quality, each stone would require inspection and sorting by a qualified geologist to discard lower quality material.

- The quarry site is not suited to the extraction of core material as considerable effort will be required to process the larger size rocks left behind from past quarry blasts into the core grading, assuming no new blasting..

As quarry operations (e.g., drilling, blasting and heavy vehicle traffic) will adversely impact on the neighbouring residential and commercial areas. It is therefore assumed that no more rock can be extracted from the quarry face by blasting, leaving the currently stockpiled material as the only source of material from Kuluin.

2.2.2 Glass House Quarry

The Glass House Quarry is actively operated by Hanson Australia Pty Ltd, and is located on Mt Beerwah Road, Glass House Mountains – approximately 44 km from Point Cartwright. Key points about this site are:

Rock is hard, welded, crystal-lithic tuff (latite tuff) of the North Arm Volcanics. It occurs as a window beneath younger, overlying sandstone. Overburden depth varies from 1 to 12 m, and averages about 4.5 m.

A wide of rock sizes from gravel to rock armour is quarried. Maximum rock sizes of 5 to 6 tonnes (Figure 2.2) are likely. Quarry operators indicated that blasting tests would be required to examine the feasibility of supplying rock larger than 5 to 6 tonnes.

Rock samples observed during a quarry inspection appeared to contain close joint spacing, cleavage planes and weathered rock inclusions. Quartz banding was also observed in armour rock (300mm) from this quarry as used for bank protection in the Maroochy River (Bradman Avenue).

It was concluded from the quarry inspection on 15 March 2019 that the rock may be prone to fractures, decomposition and weathering in an exposed breakwater environment. Further petrographic and mechanical testing would be needed to confirm if the Glass House Quarry material is suitable for rock primary and secondary armour applications. This quarry material could supply the core or underlayer material in sufficient quantities.


Figure 2.2 Left: stockpile of Glass House Quarry armour rock with estimated D_{50} of 0.75 m. Right: large boulder (D_{50} approximately 1.7 m).

2.2.3 Quarry Supplies

Kuluin and Glass House quarries do not appear able to supply the heavy primary rock armour (9 tonnes or more) in sufficient quantity.

Given the available volume of rock and the distance to the Mooloolaba breakwater, the Glass House Quarry is considered to be a viable source of underlayer armour and core rock.

A number of potential rock quarries remain to be considered in the Brisbane, Moreton Bay, Sunshine Coast and Somerset regions. Since the rock sourcing studies were out-of-scope for the constructability assessment, further investigations are recommended to identify appropriate sources of rock armour for the breakwater extension. Large armour rocks are now a rare resource in the Mooloolaba region. Parameters for consideration in selecting an appropriate source include:

- Rock size grading, rock quality and suitability for application as primary armour for breakwater design;
- Quarry equipment and applicability for large rock grades;
- Potential quarry risks (e.g., blasting, operability, quarry rock yields, timing factors);
- Haul distance and routes/transport methods (e.g., load ratings of road infrastructure, residential corridors); and
- Lead times for producing desired rock sizes and volumes
- Quarry yield and wastage associated with producing large armour rocks

Production rates and lead times for the armour-stone are largely unknown and are highly dependent on the individual quarry and their operating capabilities. High level discussion with quarry operators indicate that a minimum 8 months lead time could be expected for the production of armourstone. This may have a significant impact on the construction schedule.

Combined with limited stockpile availability, the production and delivery of material will need to be actively managed by the Contractor in consultation with the quarry and TMR.

2.3 QUARRY ADVANTAGES AND CONSTRAINTS

Neither quarry inspected has a pronounced over the other.

Table 2.2 summarises advantages and constraints associated with the two quarries inspected. Laboratory testing would be required to confirm the observations made in Table 2.2.

Table 2.2 Advantages and constraints for inspected quarries.

Location	Advantages	Constraints
Kuluin Quarry		
	Some small quantities of Granodiorite appear to be of high quality, high strength rock Located 14km from Mooloolaba breakwater Owned and operated by TMR Visually consistent with the existing breakwater rock	Close to residential and commercial land – blasting, machinery and hauling issues. Community consultation required. Primary armour rock size may not meet design specification. Quantity of Granodiorite is insufficient as armourstone. Inclusion of inferior quality rock in stockpiles. Rare heavy armour resource for region. Unlikely it would be used for core material and light grades.
Glass House Quarry		
	Large and fully operational quarry. Potentially larger rock size available than Kuluin Quarry. Wide range of rock sizing available. Suitable rock for use in underlayer and core.	Rock quality. Identified weathered inclusions, cleavage planes, and short spacing between quartz seams. Potential issues with durability. Largest rocks 5-6 tonnes and would not meet breakwater design specification. Heavy haulage vehicles would be required for transport of large rock armour. Quarry is 44km from site.

Location	Advantages	Constraints
		Trucks outgoing from Glass House Quarry limited to 57.5 tonne.

2.4 ROAD ACCESS

Potential land-based transport routes from the Kuluin and Glasshouse Quarries are presented in Figures 2.3 and 2.4, respectively. The routes shown have not been examined under TMR's 'Excess mass and dimension' guidelines. Contractors would be required to obtain permits as an Approved Heavy Haulage Operator (AHHO) and obtain an Authority to Operate (ATO).

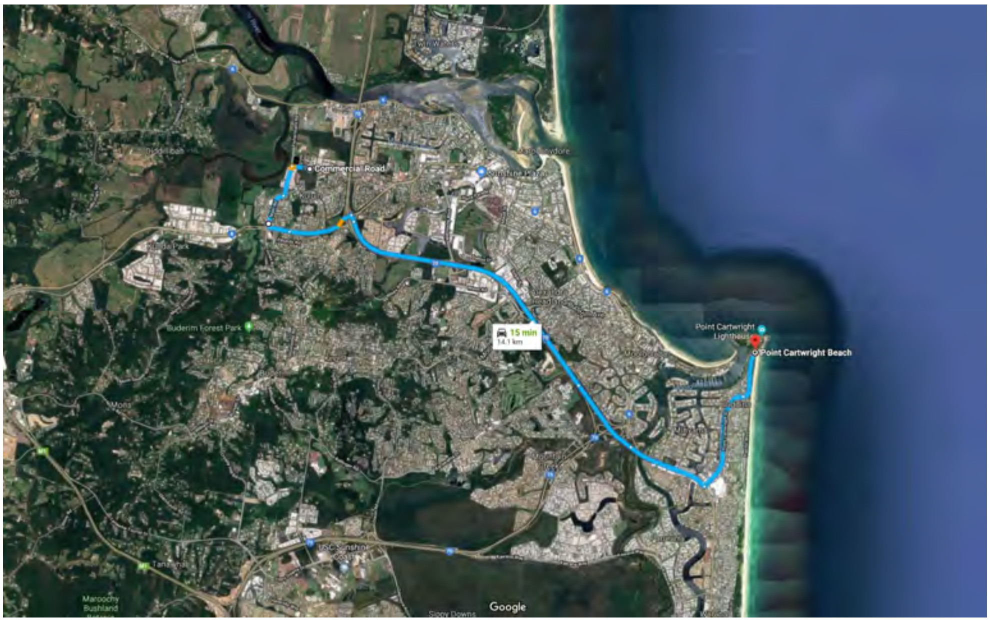

Figure 2.3 Potential land-based haul route from Kuluin Quarry to the Eastern Mooloolaba Breakwater approx. 14km. Source: Google Maps.

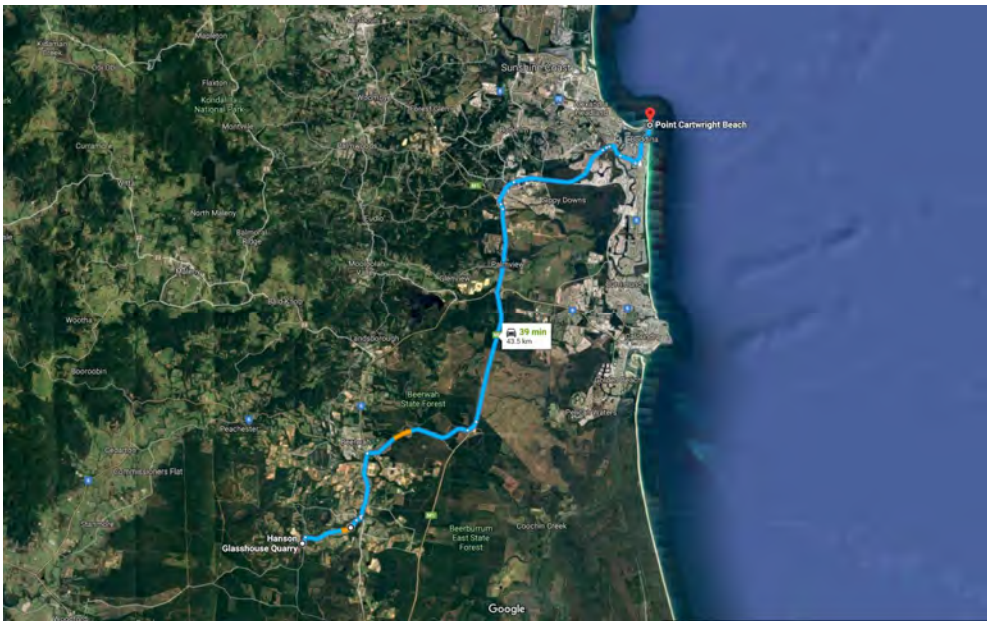

Figure 2.4 Potential land-based haul route from Glass House Quarry to the Eastern Mooloolaba Breakwater approx. 44km. Source: Google Maps.

Road access during the original construction of the breakwaters in the mid-1960s was largely free of development. Buddina is now an urbanised area including high-rise apartments/motels on Pacific Boulevard.

For this constructability discussion, it is estimated over 3,000 haulage trips are required to deliver the rock quantities in Table 2.1 to the site (based on an average net load capacity of 20 tonnes).

2.5 MARINE ACCESS

Marine access from within the Mooloolah River is constrained by water depth, small craft mooring areas, loading areas, and availability of contractors' plant and equipment.

Marine access to the site requires:

The same number of road haulage trips as in Section 2.4 and additional transfer times;

An existing boat ramp facility (closed to public) that can be acquired for the construction period;

Laydown areas at the nominated boat ramp for transferring rock via stockpiles onto barges. A laydown area of approx. 5,000 m^2 is assumed necessary;

Marine-based transport using a 55 m × 18 m flat top barge with hungry boards and a dead-weight tonnage of 2,000 tonnes is assumed. Over 30 trips are estimated from the boat ramp stockpile to the breakwater.

A temporary Material Offloading Facility (MOF) may also be required (depends on the intended construction methodology). This MOF would be established adjacent to the breakwater site to enable sufficient draft clearance for the barge and tug (2m) to reach the temporary MOF. Depths greater than 2m constrain use of areas upstream of Minyama Island.

2.6 CONCRETE ARMOUR UNITS

An alternative for rock primary armour is precast concrete armour units, which will provide effective wave protection for the breakwater extension. Some types of units offer a single layer design. Some benefits of using concrete armour units include:

- Armour units are built in a casting yard therefore lead times can be actively managed. By comparison natural armour rock lead times will depend on individual quarries' yield which is currently uncertain. Likely that multiple quarries with varied lead times may be utilised.
- Since concrete units are lighter than rock, marine transport can utilise shallow draft barges and stacked arrangement of precast units that reduce the number of trips
- Improved ability to control the quality and size
- Single-layer precast concrete units will reduce the material requirement and footprint of the works
- Steeper batter slopes can be used (and are recommended by some units' suppliers) further reducing the overall footprint of the works
- A lighter, interlocking precast concrete unit will provide similar performance to a heavier natural rock
- GPS controlled placement of units
- Cast-in lifting points to simplify the safe lifting of the armour units

The construction sequencing and techniques will follow the general methodology adopted for rock armour with some different constructability considerations:

- Building a casting bed
- Building the moulds
- Concrete casting using form vibration
- Stripping the formwork after initial hardening of the concrete (around 24 hours),
- Curing
- Removal from the casting bed

There are a number of precast concrete unit designs that could be used at the site. A single-layer system (such as Coreloc™, Xbloc™ or similar products) would be preferred to minimise the number of concrete armour units. However tight quality controls and supervision are required for single layer systems. This cost and risk associated with this tight control should be compared to more conventional double layer systems that have control that is less strict.

Suppliers of the concrete armour units will provide armour unit moulds, for a construction contractor to use. In most cases royalties would apply to the moulds. Additionally, some suppliers require physical model testing to confirm the design.

See Appendix C for Review of Concrete Units Technical Memorandum for additional construction information and selection considerations.

3 Project Site

3.1 EXISTING BREAKWATER

An inspection of the existing eastern breakwater and the access via the eastern side of the river was undertaken. The main points of observation were:

- Breakwater crest condition and rubble mound side slopes;
- Aid to navigation potential relocation;
- Rock armour condition and size;
- Constructability of breakwater extension; and
- Accessibility of potential plant and equipment to the breakwater.

3.1.1 Breakwater crest

The breakwater crest is approximately 5 m wide. The crest bitumen path has an approximate width of 3.3 m along the length of the breakwater.

A concrete blinding layer was observed as the base for a bitumen path along the breakwater crest, however it doesn’t appear to be reinforced. No drawings were supplied showing a path along the breakwater crest.

The drawings supplied by TMR indicate that the original design specified 1V:1.25H, batters, however the a survey conducted during the inspection measured batter slopes between 1V:1.4H and 1V:1.5H on the lee side of the breakwater.

3.1.2 Observed armour size and condition

The inspection identified a variety of rock armour types, including some sandstone in amongst harder granite rock armour. Where sandstone was observed it displayed significant weathering and deterioration and had sizes of 1.0 metre or less. A small percentage of the primary armour contained obvious fracture planes or had fragmented under movement from wave action (or construction activities). Evidence of repair works was inferred from the variety of rock types found along the breakwater (Figure 3.2).

Displaced armour rock was observed on the leeward side of the breakwater and adjacent to the toe on the Mooloolah River seabed.

Figure 3.1 Existing Mooloolaba breakwater. Left: looking southeast along the seaward side of the breakwater. Right: Looking northwest along the leeward side of the breakwater. Signs of rock slumping and undermining of the concrete blinding layer under the footpath observed. Wide rock grading also observed.

Larger rock sizes were estimated at approximately 1.5 m diameter (D). Based on a density of ρ = 2600 kg/m^3 and a volume of 0.66D^3, the mass is estimated at 5 to 6 tonnes.

In some instances the existing breakwater armour has a poor aspect ratio shape (Figure 3.2) that is not good practice as it affects the random placement of layers and may become dislodged. AS2758.6-2008 advises for a heavy rock grading no more than 5% by number of blocks are to have a length to thickness ratio (L/E = aspect ratio) greater than 3. Large cracks were noted on some armour rocks (e.g., Figure 3.3), however for the most part, armourstone integrity appeared to be acceptable (no testing was undertaken).

Figure 3.2 Primary rock armour along the existing eastern Mooloolaba breakwater. Considerable rock aspect ratio deficiencies noted in some instances. Right: aspect ratio approximated to be L/E = 2.5 m/0.5 m = 5.

Figure 3.3 Left: cracking of rock armour on the leeward crest of the existing breakwater. Rock believed to have been sourced from the Kuluin Quarry. Right: potential signs of rock instability on the leeward side of the existing breakwater.

3.1.3 Aid to Navigation

The navigation aid at the head of the existing breakwater was originally installed in 1987 and is to be relocated to the head of the extension (Figure 3.4).

The navigation aid footing (Figure 3.5) was measured as 3 m × 3 m as per drawings supplied. The navigation aid has a height of 4.4 m and a width of approximately 1.7 m. Drawings indicate the navigation aid is constructed from GRP (glass reinforced plastic) and with a wall thickness of 85 mm. The total mass of the beacon is currently unconfirmed. For the purposes of this investigation, the beacon is assumed to have an approximate mass of 4 tonnes, inclusive of the internal aluminium platform and lamp stand.

Without access to the door of the navigation beacon, an external inspection was conducted. No lifting lugs were noted on the structure. It appears to be structurally sound with no signs of external deterioration. Therefore it should be able to be relocated and reused (subject to internal inspection).

Figure 3.4 Existing navigation beacon. Left: landward perspective towards the northwest. Right: seaward perspective looking towards the southeast.

Figure 3.5 Base of existing navigation beacon and pad footing slab. Left: landward perspective towards the northwest. Right: seaward perspective looking towards the southeast.

3.2 SITE ACCESSIBILITY

Potential access paths to the breakwater are provided along the alignment of two pedestrian footpaths that connect the northern reaches of Buddina to Point Cartwright. These existing paths are not designed for heavy vehicle loading. Therefore, temporary strengthening works would be required.

Rock / concrete unit barges can access via the Mooloolah River from the sea. They can be moored close the breakwater abutment where they will be protected from the weather in the lee of the breakwater.

4 Construction Methodologies

4.1 GENERAL CONSTRUCTION METHODOLGY

The Mooloolaba breakwater extension design proposes a conventional layered rubble mound, incorporating:

- double layer of primary armour
- double layer of secondary armour / underlayer
- core fill (quarry run material).

Due to the existing site access issues, four construction methodologies are considered, both land and water-based construction methods and hybrids of the two. The construction methods described are summarised in Table 4.1.

Table 4.1 Concept Design Options

Option	Description
1	Vehicle Access via Existing Pathway
2	Vehicle Access to Point Cartwright Beach via the end of Pacific Boulevard and the lighthouse access track
3	Waterborne Material Delivery and Construction
4	Overwater Construction and Reconfiguration of Existing Breakwater Design for Land-Based Access
5	Combined options with land-based core construction and overwater construction of the rock armour

Common to each construction method, the following establishment activities are required:

Establishment of the site/exclusion zones (i.e., installation of fencing, stockpile site and construction laydown areas)

Demolition and removal of existing concrete footing for navigation light.

Removal of the existing navigation light (glass fibre reinforced structure) – to be reinstated upon completion of the breakwater extension.

Removal of armourstone at the existing breakwater roundhead – to be stockpiled and later reused in the extension construction.

The construction methodologies presented in this report are prepared on the basis that the breakwater extension will be constructed in stages by first dredging the sand layer to the bedrock level under the breakwater footprint, placing the core, underlay materials and finally the individual placement of armourstones. This sequence is assumed to be completed in stages to minimise exposure of the core.

The aid to navigation footing and existing navigation light structure is to be reinstated after the breakwater construction. A 3 m wide concrete crest path suitable for a T44 service vehicle truck, in accordance with the project Design Basis Report (BEJ952-TD-ST-DBA-0001).

4.2 OPTION 1 – LAND BASED CONSTRUCTION VIA EXISTING TRACK

Land-based construction via the existing pathway on the eastern bank of the Mooloolah River is treated as the base constructability case. Core rock material would be transported via trucks while large primary rock armour or concrete units would be individually transported on flat-bed trucks. Access would potentially be via the car park located at the corner of Harbour Parade and Gulai Street. Plant and equipment would also use this same route.

4.2.1 Access

The path along the eastern bank of the Mooloolah River leading from the car park at the corners of Harbour Parade and Gulai Street served as the original haulage route for the construction of the existing breakwater. The existing 3 m wide bitumen footpath is owned and maintained by Sunshine Coast Council.

The path has a flat grade along its length and has adequate width for a single truck following tree trimming and in some cases, tree removal (refer to Figure 4.1Error! Reference source not found.). No guard-railing is presently in place along the Mooloolah River revetment.

Figure 4.1 Existing footpath along the eastern bank of the Mooloolah River progressing from the car park at the northern end of Harbour Parade, Buddina towards the Mooloolah River entrance.

The land-based construction via the Eastern Mooloolah Riverbank will require approximately 800m of temporary fencing to restrict pedestrian access (Figure 4.2Error! Reference source not found.). Access to the Mooloolah River lagoon would therefore be restricted over the construction period and requires stakeholder consultation and liaison with Sunshine Coast Council.

Figure 4.2 Minimum requirement for temporary fencing for land-based construction along eastern bank of Mooloolah River. Total length is 800 m.

Land-based material transport to the breakwater will also require a turning bay for trucks and machinery to turn-around at the end of the haul route (adjacent to the existing breakwater). A potential site for a "T-type" turning bay was identified at the landward end of the existing breakwater.

Areas indicated in Figure 4.4 (corresponding to the '200m^2' clearing and '300m^2' clearing) are proposed as the truck turn around areas to avoid reversing the length of the construction route with heavy machinery. Photo observations of the two northern-most clearings are provided in Figure 4.3.The photos indicate a restricted truck turn-around area unless clearing is undertaken.

The areas will require temporary works and vegetation clearing to be reinstated after completion of the extension.

Figure 4.3 Observations indicating minimal area available for land-based laydown areas near the breakwater. Left: laydown area approximately 200 m^2 along the Mooloolah River entrance seawall. Right: laydown area approximately 300 m^2 at the Point Cartwright Beach, adjacent to the existing breakwater. (Refer Figure 4.2 for locality)

A contractor using access via the eastern bank of the Mooloolah River will have to overlay the existing path with a 300 mm layer of crushed gravel to protect it. The path will then have to be reinstated at the completion of the breakwater extension.

4.2.2 Stockpiling and Laydown Area Requirement

Cleared areas are required for: laydown areas (heavy equipment and site office), rock or concrete unit stockpiles, and truck turn-arounds to support the land-based construction. Areas to be cleared along the proposed eastern Mooloolah River construction route are indicated in Figure 4.4Error! Reference source not found. and could potentially be used for any of the above three purposes.

The areas identified are limited in size to restrict removal of vegetation in the Council reserve area. The largest open area identified from the site visit is approx. 1500 m^2 (situated in a clearing at the centre of Point Cartwright).

To maximise the use of these areas (subject to the contractor's requirements), vegetation clearing permits would be required. Reinstatement and revegetation would be required at project completion.

An outdoor exercise gym and park is currently located adjacent to the carpark at the corner of Harbour Parade and Gulai Street. Consequently, this area is not suitable for stockpiling but may be appropriate for temporary construction facilities (site office, ablutions, etc.).

Figure 4.4 Identified clearing areas for use as potential laydown areas, stockpiling or turn-around areas for land-based construction

4.2.3 Plant and Equipment

For land-based construction methodologies, it is envisaged that T44 haulage trucks are used for the direct placing of bulk core-material and ongoing maintenance. A 50 to 60 tonne, long-arm excavator (Figure 4.5), with a maximum corresponding reach of 8.8 m (see *CUR Rock Manual,* CIRIA, 2007), would be used for individual placement of rock armour. Due to the large, anticipated rock sizes, transport of individual primary armour on flat-bed trucks is assumed. Existing access paths and the new breakwater pathway will have to strengthened for such loads.

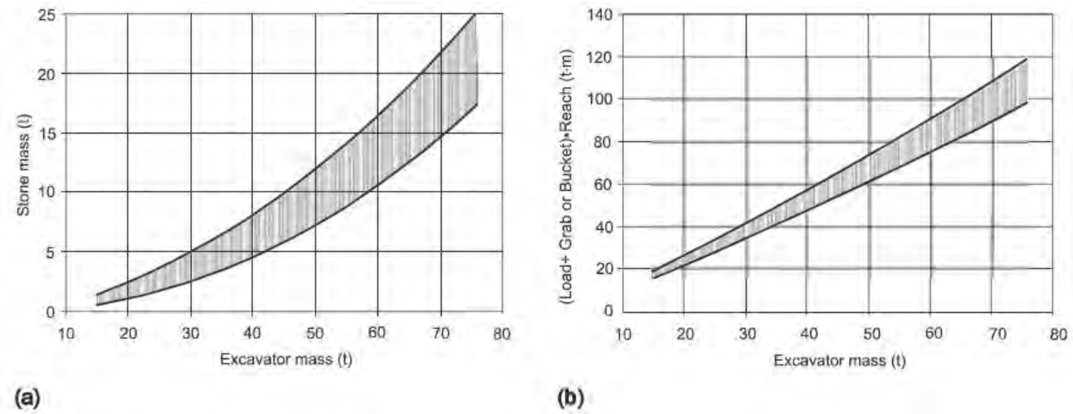

Figure 4.5 Required excavator size (A) and maximum excavator reach. From CUR Rock Manual (Figure 9.16).

4.2.4 Option Summary

Key advantages and disadvantages associated with this option are summarised as follows:

Advantages

- Follows the route used to originally construct the existing breakwater.
- Pre-existing pathway in place – minimal impact to parks.
- Flat grade – suitable for trucks with large loads.
- No material transfers over water – safer.
- No barges required – minimal impacts to river navigability.
- Land construction is typically faster than water based if the material stockpile can be replenished at a suitable rate.
- Wider availability of contractors suitable to conduct the work.
- Pedestrian access to Point Cartwright lighthouse and vehicle access to Pacific Boulevard/Kawana Beach unaffected.

Disadvantages

- Existing path infrastructure requires protection to minimise damage.
- Trees lining path require trimming to provide clearance for trucks and excavators. Some trees may require removal.
- Dust and noise impacts to nearby apartments/motels.
- Mooloolah River lagoon will not be accessible via the footpath during the construction timeframe.
- No public access to carpark at corner of Gulai Street and Harbour Parade or adjacent exercise equipment during construction.
- Only small laydown areas available.
- Truck access via residential areas – noise, dust and traffic impacts.
- One-lane traffic out to breakwater – reduces material transfer rates
- Confined space for truck turn-around.

4.3 OPTION 2 – LAND BASED CONSTRUCTION VIA POINT CARTWRIGHT BEACH

This option considers the land-based construction with access via the walkway leading from the Pacific Boulevard carpark, bypassing the Point Cartwright Lighthouse and reservoir, and ultimately via Point Cartwright Beach (Figure 4.6).

Figure 4.6 Option 2 land-based vehicle access and potential laydown areas.

4.3.1 Lighthouse / Reservoir Pathway

Following inspection of the Pacific Boulevard carpark and footpath access, access via the lighthouse pathway was identified as impracticableError! Reference source not found..

The Pacific Boulevard carpark serves the northern end of Kawana Beach and has significant space restrictions in addition to steep grades for heavy vehicles. Option 2 will require the closure of public access to this carpark. Pacific Boulevard is quite narrow. Truck thoroughfare will have considerable negative impacts to accessibility, plus noise and dust impacts to the existing apartments in this area.

Figure 4.7 Pathway leading to Point Cartwright water reservoir and lighthouse from the car park located at the termination of Pacific Boulevard.

The existing path is considered too narrow for truck access (2 to 2.5m) plus it requires protection from truck wheel loads by (e.g.) installation of a temporary 300 mm crushed gravel layer, followed by removal and reinstatement after construction is finalised.

Tree removal will be required over the length of the route to provide vehicle accessibility, which will require approval by Council.

The terrain from the Point Cartwright lighthouse to the Port Cartwright beach is relatively steep (in parts ~1V:10H) plus truck transit along the beach might be difficult because of tide level and soft sands.

4.3.2 Stockpiling and Laydown Area Requirement

Laydown areas for Option 2 are presented in Figure 4.6. A 1350 m2 laydown area is considered to be required for material stockpiling, Due to the steep terrain and access limitations, cleared lands to the west of the Point Cartwright Lighthouse and the small valley at the centre of Point Cartwright are not considered to be usable. Also transport over the Point Cartwright Beach may prove difficult. Minor clearing of existing vegetation is required.

4.3.3 Plant and Equipment

Plant and equipment would be similar to that described for the land-based construction in Option 1 (Section 4.2.3).

4.3.4 Option Summary

Key advantages and disadvantages associated with this option are summarised as follows:

Advantages

- Land construction is typically faster than water based if the material stockpile can be replenished at a suitable rate.
- Wider availability of contractors suitable to conduct the work.
- Existing path infrastructure in place – reduced damage to vegetation.
- Recreational access to Mooloolah River embayment and walkway unaffected.
- No barges required – minimal impacts to boat navigability.

Disadvantages

- Noise, dust and accessibility impacts to residents on Pacific Boulevard.
- No public access to Kawana Beach car-park during construction.
- High potential of Point Cartwright dune and beach damage due to truck traffic
- Steep terrain.
- Marginal laydown areas available, plus limited space for vehicle turn-around.
- Beach access required – issues for vehicle trafficablity.
- More clearing/trimming of existing vegetation required than Option 1.
- The access track between the Pacific Boulevard car park and Point Cartwright is narrow with no shoulders available for track widening, compared to Option 1.

4.4 OPTION 3 – MARINE BASED CONSTRUCTION

Option 3 minimises disruptions to public pedestrian access to Point Cartwright and reduces the impact of heavy delivery trucks transiting through residential areas, by delivering the quarry rock and/or concrete armour units via barges. An appropriate barge loading site would have to be provided by TMR.

Floating construction plant and equipment could utilise over-water construction techniques.

4.4.1 Access

Access to the site would start from a temporary loading facility to enable marine transfer of all necessary construction plant and materials via barges. The loading facility requires sufficient laydown areas for equipment storage, stockpile areas and turnaround bays for trucks, as well as sufficient room for the transfer of equipment and plant onto the barges. A heavy duty boat ramp or quay is necessary.

For marine transfer, sufficient for tugs and barges that draw about 2.0 to 2.5mof water is required, i.e. about 3m water depth. Based on the available chart information in AusChart AUS 235, tug and barge access is restricted inland beyond Minyama Island. Bridges inland of Minyama Island also restrict access for marine plant.

After some investigations, it appears suitable loading facilities in the Mooloolah River don't exist..

The following boat ramps were examined, however are not considered suitable:

- Mooloolaba Marina TMR boat ramps are not considered suitable for barge transfer operations due to the narrow one way access along the end of Parkyn Parade and the high traffic volume in the Mooloolaba Spit area.
- Harbour Parade boat ramp is considered to have insufficient space for the proposed activities.

Alternatively, barge transport via the Port of Brisbane may be feasible.

4.4.2 Stockpiling and Laydown Area Requirement

No land-side stockpiling is proposed near to the breakwater site as barges could be used for rock and concrete armour unit supply and storage.

If a suitable material off-loading facility could be identified locally, areas for additional stockpiling of material and an equipment would be required there as well.

4.4.3 Plant and Equipment

The following floating plant has been assumed:

One flat-top barge equipped with hungry-boards as required for the transport and handling of materials;

Another barge for the construction plant.

The initial filter layer on the exposed bedrock would be placed via a marine-based rock dumping with trimming by floating excavator. The rock dumper and excavator is then used to construct the lower layers of the core.

A crane or long-armed excavator equipped with an orange-peel or rock grab would be used to place toe rocks and armour layers following behind the offshore-progress of the breakwater core. Concrete armour units have the advantage of cast-in lifting eyes which simplifies handling.

4.4.4 Operability conditions

Due to the nature of the marine-based construction, this method is vulnerable to adverse weather. Construction should be conducted in the cyclone off-season (May to October), plus have weather monitoring in place to forecast and manage safe work practices.

Concrete armour units are more vulnerable to damage compared to rock armour. For this reason, if concrete units are selected the operational criteria should be stricter than rock armour.

4.4.5 Navigation Safety

The stockpile barge would be positioned on the leeward (western) side of the breakwater, protected within the Mooloolah River entrance. This will have implications for navigability of the Mooloolah River entrance which must be communicated to the boating community (in addition to the issuance of Notices to Mariners).

Temporary navigation lights will be required to delineate the stockpile and equipment barges in addition to a temporary navigation buoy used to mark the breakwater after removal of the existing navigation aid.

4.4.6 Option Summary

Key advantages and disadvantages associated with this option are summarised as follows:

Advantages

- Large load carrying capacity of barges.
- Significantly reduced land impacts and minimal need for clearing.
- Significantly reduced accessibility implications to the Point Cartwright, the Mooloolah River embayment and Kawana Beach recreational areas.
- Reduced noise and dust impact to residents at Point Cartwright.
- Potential to reduce truck impacts to residential area – depending on the selection of the barge loading site.

Disadvantages

- Increased construction duration and longer transfer times.
- Limited viable options for boat ramp access (draft clearance, truck accessibility, laydown areas, heavy duty boat ramp).
- Impacts to stakeholders due to temporary public closure of boat ramp facility (if adopted).
- Increased water traffic and navigability restrictions.
- Increased weather dependency.

4.5 OPTION 4 – TEMPORARY MOF WITH MARINE ACCESS (TO FACILITATE LAND-BASED CONSTRUCTION)

This option considers land-based construction by reconfiguring the existing breakwater design to incorporate a temporary loading/unloading facility at the breakwater site to provide land-based access.

4.5.1 Access

In the event that appropriate boat ramp facilities for barge loading are not available and land-based construction is not viable, this option considers the construction of a Materials Offload Facility (MOF) at the breakwater site. The MOF is used to load and unload barges at a temporary dock located adjacent to the breakwater abutment to get equipment and material to the breakwater abutment for land based construction.

Access to a TMR nominated boat ramp will also be required for the loading of materials and equipment onto the barges, destined for the breakwater site.

The proposed MOF would entail the construction of a temporary groyne approximately 100 m to the east of the existing breakwater to provide protection for a temporary barge ramp. An indicative sketch of the proposed MOF arrangement is provided in Figure 4.8.

Figure 4.8 Diagrammatic layout plan of the MOF

Sand trapping on the eastern side of the groyne could be a permanent addition to the proposed sand-trapping by the proposed breakwater extension. Future dredging strategies could be adapted to include removal of sand from this sand trap using land based equipment, thus reducing the Mooloolah River entrance dredging requirement.

This proposed groyne and ramp is situated outside the extent of the current TMR board harbour boundaries hence this TMR will have acquire access to this area for this construction.

4.5.2 Stockpiling and Laydown Area Requirement

As noted above, access to a TMR nominated boat ramp is required for the loading of materials and equipment onto the barges. This boat ramp site will need sufficient area for stockpiling of materials and equipment prior to loading onto the barges (Similar to Option 3).

Additional stockpiling of material is required at the breakwater site, sufficient to keep up with the construction. Laydown areas for equipment and plant are also required adjacent to the breakwater site for the land-based construction equipment. The stockpile site could be smaller than required for Option 1, depending on the timing of barge deliveries.

Alternatively, some material could be stored on barges moored adjacent to the site in the Mooloolah River (similar to Option 3).

4.5.3 Plant and Equipment

Plant and equipment requirements are similar to those listed for Option 3 (Section 4.4.3) for barge operations; or similar to Option 1 for land-based construction operations.

Once a rubble mound temporary groyne has been built, construction of a temporary ramp will follow. This phase requires two barges: a stockpile barge and an equipment barge.

Plant and equipment will be transferred to the land for land-based construction, and will remain on Point Cartwright over the construction period. A flat-top barge equipped with hungry-boards will operate as a materials transfer barge and/or a stockpile barge during construction of the breakwater extension.

As described in Section 4.2.3, a 50-tonne long arm excavator will be required for construction.

4.5.4 Navigation Safety

Navigation requirements are similar to those prescribed for Option 3 (Section 4.4.5). Temporary navigation lights will be required to mark navigational hazards including the temporary/permanent eastern groyne.

4.5.5 Option Summary

Key advantages and disadvantages associated with this option are summarised as follows:

Advantages

- Minimal need for land clearing.
- Temporary groyne will act as a sand trap which will reduce the requirement to dredge the entrance of the Mooloolah River using floating plant.
- Reduced noise and dust impact to residences at Point Cartwright.
- Potentially reduced trucking impacts to residential areas – dependent upon TMR's elected boat ramp site.
- Minor impact to public access to the Point Cartwright, the Mooloolah River embayment and Kawana Beach recreational areas.

Disadvantages

- Increased weather dependency until the temporary groyne and ramp is in place, thereafter construction weather dependence is similar to Option 1, materials supply via barge continues to be weather dependent.
- Increased construction duration and larger transfer times.
- Increased construction requirements (i.e. temporary groyne and ramp)
- Increased construction footprint
- Temporary groyne requires further land access by TMR.

4.6 OPTION 5 – COMBINED OPTION (LAND-BASED CORE CONSTRUCTION WITH MARINE-BASED ARMOUR CONSTRUCTION)

A fifth option is considered, being a combination of elements from the above-mentioned optiions. This option has land-based construction of the breakwater core, with primary armour and underlayers constructed using marine-based equipment.

4.6.1 Access

The land-based construction of the breakwater core would use access via the existing track along the Mooloolah River (Option 2). The primary armour and underlayers would be constructed using marine-based equipment. This equipment and materials are loaded onto barges via a boat ramp similar to Option 3.

4.6.2 Stockpiling and Laydown Area Requirement

As noted above, access to a TMR nominated boat ramp is required for the loading of armour materials and equipment onto the barges, destined for the breakwater site. This boat ramp site must have sufficient areas for stockpiling of materials and equipment (As noted in Option 3).

Additional stockpiling of material will be required at the breakwater site for the core construction.

4.6.3 Plant and Equipment

As with Options 1 and 2, for land-based construction methodologies, it is envisaged that dump trucks are used for the end dumping of core material. An excavator either on land, or on a barge then trims the core prior to placement of the armour layers.

As with Option 3, at least two barges will be required for a marine-based construction of the core and underlayers – one for the transport and handling of rocks and the other for the construction plant.

A crane or long-armed excavator on a barge, equipped with an orange-peel or rock grab will be used to place toe rocks and armour layers closely following the onshore construction of the breakwater core. Concrete armour units have the flexibility of cast-in lifting eyes which improves handling compared to large rocks.

4.6.4 Navigation Safety

Navigation requirements are similar to those prescribed for Option 3 (Section 4.4.5).

4.6.5 Option Summary

Key advantages and disadvantages associated with this option are summarised as follows:

Advantages

- Core construction access follows the route used to construct the existing breakwater.
- Pre-existing pathway in place – minimal impact to park areas.
- Flat grade – suitable for trucks with large loads.
- Pedestrian access to the Point Cartwright lighthouse and vehicle access to Pacific Boulevard/Kawana Beach unaffected.
- Armour construction uses the large load carrying capacity of barges.
- Reduced need for land clearing material stockpiles
- Reduced noise and dust impact to residences at Point Cartwright during armour placement.

- Some reduced trucking impacts to residential area because armour is delivered by barge. Some trucking impacts may be occur at the nominated barge loading site – dependent upon TMR's elected boat ramp site.

Disadvantages

- Increased construction duration and larger transfer times for armour materials which will need to be managed with the relatively faster land-based construction of the core
- Existing path infrastructure requires protection to minimise damage.
- Trees lining the path will require trimming to make clearance for trucks and excavators. Some trees may also require removal.
- Dust and noise impacts to nearby residences.
- Mooloolah River lagoon will not be accessible via the footpath during the construction time-frame.
- No public access to the car-park at corner of Gulai Street and Harbour Parade or the adjacent exercise equipment during construction.
- Limited viable options for barge loading (draft clearance, truck accessibility, laydown areas, heavy duty boat ramp).
- Impacts to stakeholders due to the temporary closure of a public boat ramp facility.
- Impacts to the public and/or residences due to the closure of the eastern Mooloolah River bank access
- Increased water traffic and navigability restrictions.
- Increased weather dependency.

5 Hazard and Risk

5.1 HAZARD IDENTIFICATION AND RISK ASSESSMENT

A hazard analysis has been performed to identify the hazards, assess the risks, and define the controls necessary to eliminate or mitigate the risks for the four proposed construction work activities. These hazards have been included in an OH&S (Operational Health & Safety) Hazard and Risk Register in Appendix D.

It is expected that the identified hazards and risks will be used to inform key project decisions relating to the future construction activities and construction access constraints.

The key identified residual risks which will require further consideration throughout the design, and during the construction are summarised as follows:

- Weather impacts. Due to the open ocean exposure, the breakwater site is susceptible to adverse weather conditions such as tropical cyclones. It is advised that construction is conducted over April – November to minimise the likelihood of exposure to adverse weather. Weather monitoring systems must be used during construction.
- Navigation. The relocation of the existing navigation marker requires installation of temporary markers during construction. Navigation markers should also be used to delineate barges, plant and potential underwater hazards during the construction period. Notices to Mariners must be issued to warn of potential construction hazards and clearance areas.
- Road access. Heavy truck traffic will have increase traffic hazards in the high density residential areas of Buddina. This can be mitigated by reducing land-based construction and increasing barge-based methods. The barge loading location(s) could create traffic hazards.
- Working over water. Breakwater construction unavoidably requires construction near water. Land-based construction have a lower safety risk compared marine-based construction, however in both instances, the use of appropriate safety systems is essential.
- Public accessibility. To adequately manage public safety during construction, temporary fencing is required. FError! Reference source not found.encing will restrict land-based access by the public, however water-based access by the public is more difficult to control. The public may access the site via the Mooloolah River revetment, staircases that access the Mooloolah River and via Point Cartwright Beach. Public access to the breakwater construction presents a range of dangers to the public including crushing risks from large rocks and vehicles to unstable rock stockpiles.
- Stability of the existing breakwater. As identified in Section 3.1.2, the existing breakwater displays signs of slumping and also has a large number of rocks with a length to thickness ratios (L/E) greater than 3. The adverse L/E ratios of the existing breakwater rocks pose rock instability risks, with resultant crushing risks to construction personnel and the public. Further assessment of the stability and safe loads for the existing breakwater prior to construction is advised. Repair works and replacement of rocks with adverse length to thickness ratios may be required in combination with the breakwater extension works.

A full description of the identified risks and currently identified treatment strategies are provided in the attached register.

6 Conclusion and recommended further actions

Based on a review of the existing available information pertaining to the site, in combination with an inspection of the site, and general site inspection of potential material sources carried out on 15 March 2019, four potential construction methodologies for the Mooloolah River breakwater extension have been reviewed:

Option 1 – Land-based construction via the existing Mooloolah River track.

Option 2 – Land-based construction via Point Cartwright Beach.

Option 3 – Marine-based construction via the Mooloolah River.

Option 4 – Land-based construction via the construction of a temporary MOF and barge access ramp.

Option 5 - Combined option (land-based core construction with marine-based armour construction).

The logistics and practicalities of the above construction options for the 60 m long extension of the Mooloolaba eastern breakwater were reviewed and it was identified that:

- Land-based access is restricted. Road access would be via high density residential areas in Buddina and the heavy vehicle trip frequency, as well as increased noise, dust, and the narrow approach path to the breakwater which requires vegetation removal and fence installation would likely trigger community objections. Only small areas are available for stockpiling rock and concrete armour units adjacent to the breakwater site.
- Land-based access has the advantage that it follows the route used to construct the existing breakwater in the early 1960s . The access flat grade is suitable for trucks with large loads. This option appears to offer a shorter construction schedule and may attract a more contractors capable of building from land than from the water.
- Mooloolah River water access is limited by vessel drafts to downstream of Minyama Island. The viability of potential boat ramp sites must include boat ramp load carrying capacity, laydown areas, barge and tug accessibility, implications to marine navigability, haulage truck accessibility, and impacts to stakeholders. A boat ramp based barge loading facility will require closure of the ramp to the public during the breakwater construction. It is not obvious that such a suitable ramp is available on the Mooloolah River. Therefore water-based access may have to be via the Port of Brisbane.
- Quarry sources of suitable rock armour are limited. Preliminary estimates indicate a median rock size of 9 to 12 tonnes is required. It appears that Kuluin Quarry cannot supply a sufficient quantity of large armour rocks (i.e. 5+ tonnes). Larger quantities of larger armour rock (approximately 6 tonnes) are potentially available from the Glass House Quarry; however, the quality of the rock from this quarry is questionable. Further investigation is needed to identify an acceptable rock armour source.
- Concrete units are lighter than large rocks and can be stacked more efficiently for transport via barge or on flatbed trucks, with fewer vehicle movements compared to rocks. The concrete units could be cast close to the Port of Brisbane or else close to Mooloolaba, before loading and transportation to the site. Concrete units are at a higher risk of breakage during handling and transportation. A weather monitoring program should be employed to help manage this risk.

In summary, all options are feasible. Access via Pacific Boulevard is largely impractical, however land-based access is not precluded if required. The clearing and strengthening of temporary pathways is possible. Each construction option requires further investigation of the following:

- Securing a suitable rock source which meets required size, quality, quantity and subsequent lead times for sourcing the material.
- Transport of materials to site via road network or via a designated barge loading ramp.
- Transfer times, stockpile and laydown areas and accessibility.
- Access and use of substantial heavy machinery in a heavily populated and trafficked area.
- Impacts of haulage routes, plant and equipment, and laydown areas on the built and natural environment including traffic, safety, dust, noise, and the clearing of vegetation.

Construction considerations specifically for concrete armour units:

- Suitable casting yard location for the concrete units.
- Availability of moulds once the concrete unit type is selected.
- The number of moulds that are needed for the optimal construction method.
- Royalty fees and support from the patent holder.
- Reduced construction time if a single layer design is selected over a double layer system.

Next steps for consideration include:

- Confirmation of the stability and loads for the existing breakwater prior to construction.
- Stakeholder liaison including Sunshine Coast Regional Council to confirm viability of proposed road and/or park closures. Discuss and possibly select eco-friendly additions to the breakwater extension.
- Selection of rock or concrete primary armour unit type. If concrete selection of the unit size. Design of the concrete unit may need physical modelling at as a patent holder requirement.

7 References

Australian Hydrographic Office (2019) AusChart AUS00235

CIRIA (2007) CUR The Rock Manual: The use of rock in hydraulic engineering (2nd Edition)

Appendix A

Quarry Data

Queensland
Government

Department of
Transport and Main Roads

2nd May 2018

personal information
Technical Manager
Hanson Construction Materials Pty Ltd
PO BOX 3250
SOUTH BRISBANE QLD 4101

Dear personal information

TMR QUARRY REGISTRATIONS SYSTEM (QRS): RQ031 - GLASSHOUSE QUARRY REREGISTRATION

The quarry registration application submitted for the above quarry (TMR Quarry Database No. RQ031), has been evaluated and your application for reregistration of the nominated products has been approved as per TMR Quarry Registrations System (QRS).

The Quarry Reregistration Certificate (No.2018-42) together with the Approved Testing Frequency Schedule, is enclosed and will need to be produced in accordance with TMR specifications prior to delivery of materials to Departmental jobs.

The approved nominated products must be tested in accordance to the attached Quarry Registration Certificate Testing Frequency Schedule. The assigned testing frequency for each nominated product is the minimum testing frequency level required by Transport and Main Roads to maintain this registration unless otherwise stated in project contracts.

If you have any questions regarding this reregistration, please do not hesitate to contact me.

Yours sincerely

personal information

Ajith (Diss) Dissanayake
TECHNICAL MANAGER (QUARRY REGISTRATIONS SYSTEM)

Department of Transport and Main Roads
Engineering & Technology Branch
Pavements, Materials & Geotechnical Section
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ABN 39 407 690 291

Quarry Registration Certificate

Certificate Number	2018-42	Expiry Date	4 May 2020
TMR Quarry Reference	RQ031	Issue Date	2 May 2018
Quarry Name	Glasshouse Quarry		
Assigned Overall Testing Frequency Level	Low		
Real Property Location	Lots 1 & 2 on SP103730, Parish of Beerwah, County of Canning		
Quarry Address	Cnr Old Gympie Road & Beerwah Mountain Road, Glass House Mountains QLD 4518		
Local Government	Sunshine Coast Regional Council		
Latitude	-26.910	Longitude	152.918
Rock/Material Types	Latite Tuff		
Rock Material Group	Intermediate Igneous		
Nominated Products:	Unbound Paving Material (Types 1 (HSG), 2 & 3) Cover Aggregate (Types A, B, C & D) Asphalt Aggregate (Fine aggregate only) Concrete Aggregate (Coarse & Fine)		
Comments	The petrographic reports submitted indicate the source rock has up to 11% chlorite, 7% sericite, 5% calcite, 3% biotite, 3% hematite and 1% pyrite.		
Applicant Name	Hanson Construction Materials Pty Ltd		
Applicant Address	PO Box 3250, South Brisbane QLD 4101		
Quarry Operator	Hanson Construction Materials Pty Ltd		
Approvers Signature	personal information		

Technical Manager (Quarry Registrations System)

Notes:

1. This registration certificate should be read in conjunction with the attached Quarry Registration Certificate Testing Frequency Schedule.
2. Departmental Quarry Registration indicates the following:
- The source rock properties submitted are generally superior to those required in the relevant departmental technical specifications.
- The quarry operator will at a minimum, carry out regular source rock testing at frequency levels listed on the attached registered Testing Frequency Schedule.
3. Quarry Registration does not guarantee ongoing product with relevant departmental technical specifications. This is because product properties can also be influenced by many day to day operational factors. These include extraction and production procedures, transportation and construction processes as well as source rock variability.
4.TMR Quarry Registration is conditional on quarry compliance with all relevant Federal, State and Local Government legislation.

Quarry Registration Certificate Testing Frequency Schedule

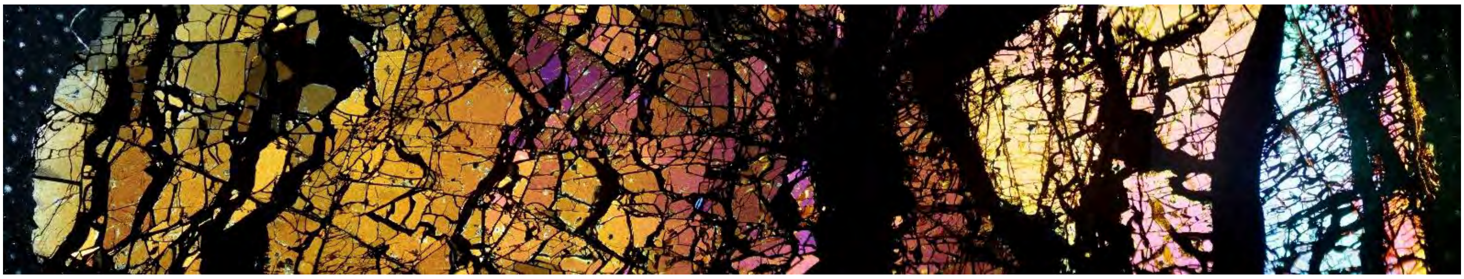
Quarry Name:	**Glasshouse Quarry**	**TMR Quarry Ref No:**	**RQ031**
Quarry Certificate No:	**2018-42**	**Approved by:**	**Technical Manager (QRS)**
Issue Date:	**2/05/2018**	**Expiry Date:**	**4/05/2020**

Approved Overall Testing Frequency Matrix Level: LOW

Relevant Specifications	Nominated Product *(Refer Note 1)*	Source Rock Test Property	Suggested Testing Frequency Level *(Refer Note 2)*
MRTS05/08 Unbound Paving Material	**Type 1 (HSG)**	Petrographic analysis	LOW
		Wet ten percent fines value	LOW
		Wet/dry strength variation	LOW
		Degradation factor	LOW
	Type 2	Petrographic analysis	LOW
		Wet ten percent fines value	LOW
		Wet/dry strength variation	LOW
		Degradation factor	LOW
	Type 3	Petrographic analysis	LOW
		Wet ten percent fines value	LOW
MRTS11/12/22 Cover Aggregate	**Type A, B, C and D**	Petrographic analysis	LOW
		Wet ten percent fines value	LOW
		Wet/dry strength variation	LOW
		Degradation factor	LOW
		Water absorption	LOW
MRTS30/101 Aggregates for Asphalt (Including superseded version of MRTS31)	**Asphalt Aggregate (Fine Aggregate Only)**	Petrographic analysis	LOW
		Wet ten percent fines value	LOW
		Wet/dry strength variation	LOW
		Degradation factor	LOW
		Water absorption	LOW
MRTS70 Concrete	**Concrete Aggregate (Coarse & Fine)**	Petrographic analysis	LOW
		Wet ten percent fines value	LOW
		Wet/dry strength variation	LOW
		Water absorption	LOW

Note 1: Detailed source rock property testing frequency tables for nominated products are listed in QRS4: Assigning Quarry- Specific Testing Frequencies for Source Rock Tests and detailed product property tests are identified within each respective TMR Technical Specification.

Note 2: Testing frequency levels can be varied by application. To ensure this attachment contains the most recent levels, contact TMR Manager (QRS).



Geochempet Services

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www.geochempet.com

PETROGRAPHIC REPORT
ON A 10 mm AGGREGATE SAMPLE (WEL17-13358-Q02)
FROM GLASSHOUSE QUARRY

prepared for

HANSON CONSTRUCTION MATERIALS PTY LTD
TECHNICAL SERVICES, BRISBANE

Purchase Order: 4502353800

Invoice Number: 00007997

Client Ref: personal information

personal information

Issued by T. F. D. Spring BAppSc. MAppSc
22 January 2018

Sample Number:	WEL17-13358-Q02	**Date Sampled**:	08/12/2017
Product Type:	10 mm aggregate	**Date Received**:	18/12/2017
Sample Source:	Glasshouse Quarry		

Work Requested Petrographic analysis in relation to use as concrete aggregate; petrographic assessment of potential for alkali-silica reactivity

Methods Account taken of ASTM C295 Standard Guide for *Petrographic Assessment of Aggregates for Concrete*, the AS2758.1 – 2014 *Aggregates and rock for engineering purposes part 1; Concrete aggregates (Appendix B)*, the AS1141 Standard Guide for the *Method for sampling and testing aggregates*, of the content of the 2015 joint publication of the Cement and Concrete Association of Australia and Standards Australia, entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*

Identification Latite tuff

Description

The nominal 10 mm aggregate sample consisted of about 5 kg of crushed, angular fragments of hard, robust, now finely crystalline rock of unweathered, olive-grey to pinkish to reddish-grey appearance with pink phenocrysts of feldspar and conspicuous patches of hematitic pigmentation. It is lightly coated by an easily removed pale red dust.

Plate 1: Photograph of a washed sub-sample of the supplied 10 mm aggregate.

A thin section was prepared from 22 random fragments to allow detailed microscopic examination in transmitted, polarized light. An approximate average mineralogical composition of the aggregate, expressed in volume percent and based on a brief count of 100 widely spaced points falling within random fragments in thin section, is:

Hard, strong minerals

15%	feldspars (plagioclase phenoclasts and subordinate K-feldspar phenoclasts)
20%	coarser grains of feldspar
16%	finely microcrystalline grains of plagioclase/orthoclase and 4% quartz)
4%	fine quartz
2%	coarser grains or phenocryst of quartz
2%	hornblende phenoclasts
1%	opaque oxide (magnetite and/or ilmenite)
12%	epidote group minerals
5%	sphene
2%	hematite

Moderately Robust minerals

5%	calcite

Soft, Weak and Deleterious minerals

11%	chlorite
3%	sericite
1%	biotite phenoclasts
1%	pyrite

In thin section, the rock plainly displays textures of tuffaceous style, involving many smoothly corroded, subhedral and commonly broken phenoclasts (about 0.1 to 2 mm in size) and many lithic clasts (0.5 to 5 mm size) of intermediate volcanic rock and blebs of former pumiceous or similar material dispersed through a now mosaic devitrified matrix (<0.01 mm to about 0.05 in grainsize) with recognisable ghost textures after former moderately welded vitric shards and a few lithic clasts of latite.

The most abundant phenoclasts are twinned, zoned, prismatic plagioclase, with alteration to epidote, chlorite and sericite and less commonly to calcite. Former prismatic phenocrysts of pyroxene are now completely pseudomorphed by chlorite-epidote-sphene. Other phenocrysts include corroded and well embayed quartz of beta form, clouded K-feldspar, opaque oxide (magnetite and/or ilmenite partly altered to sphene and/or hematite), brown hornblende and flakes of brown biotite (partly altered to chlorite, calcite, epidote and sphene).

Somewhat rounded lithic clasts vary a little in internal textures, but seem to represent porphyritic, hypidiomorphic, holocrystalline latite. More ragged or lenticular lithic clasts which may well have been pumiceous or at least partly glassy when deposited also appear to have been of latite composition, but they now display fewer phenocrysts dispersed through a now densely allotriomorphic microcrystalline matrix of mainly feldspars and quartz. The formerly vitroclastic matrix between the phenoclasts and lithic clasts now consists of a finely microcrystalline mosaic of mainly feldspars, but with minor quartz, opaque oxide, epidote, chlorite and sphene. Hematite is present conspicuously although in minor amounts as a pigment within the matrix and in some the former vitric shards, lithic clasts and phenoclasts.

Comments and Interpretations

This supplied nominal 10 mm aggregate sample (labelled WEL17-13358-Q02) from Glasshouse Quarry is considered to represent intermediate tuff (or more specifically moderately welded crystal lithic vitric tuff of latite composition) which is in a slightly oxidized (hematitic) condition. It seems that the oxidation may be of diagenetic or alteration origin, rather than necessarily an expression of weathering.

Latite is an intermediate volcanic igneous name used to describe a composition transitional between trachyte (an alkaline rock type) and andesite (a calcic rock type): the term latite may be interchanged with the term trachy-andesite.

For engineering purposes, the rock in the supplied aggregate sample may be summarised as:

- **welded tuff** with a composition equivalent to **quartz latite**, an intermediate volcanic igneous rock type
- now finely crystalline
- non-porous
- apparently unweathered, but carrying about 2% robust hematite of probable deuteric origin
- carrying about 15% of soft or weak minerals including 11% chlorite, 3% sericite and 1% biotite
- about 5% calcite, a moderately robust mineral
- about 1% sulphide (pyrite), an oxidisable mineral
- **hard**
- **strong**

The rock is predicted to be **durable**.

The rock is predicted to be **innocuous in relation to alkali-silica reactivity in concrete**. Free silica amounts to only about 10%, including about 4% in finely microcrystalline form which is considered to be insufficient to be deleterious.

Latite tuff of the type represented by the supplied sample is predicted to be **suitable for use as concrete aggregate**.

Free Silica Content

About 10% (in the form of quartz locked within a finely crystalline matrix).

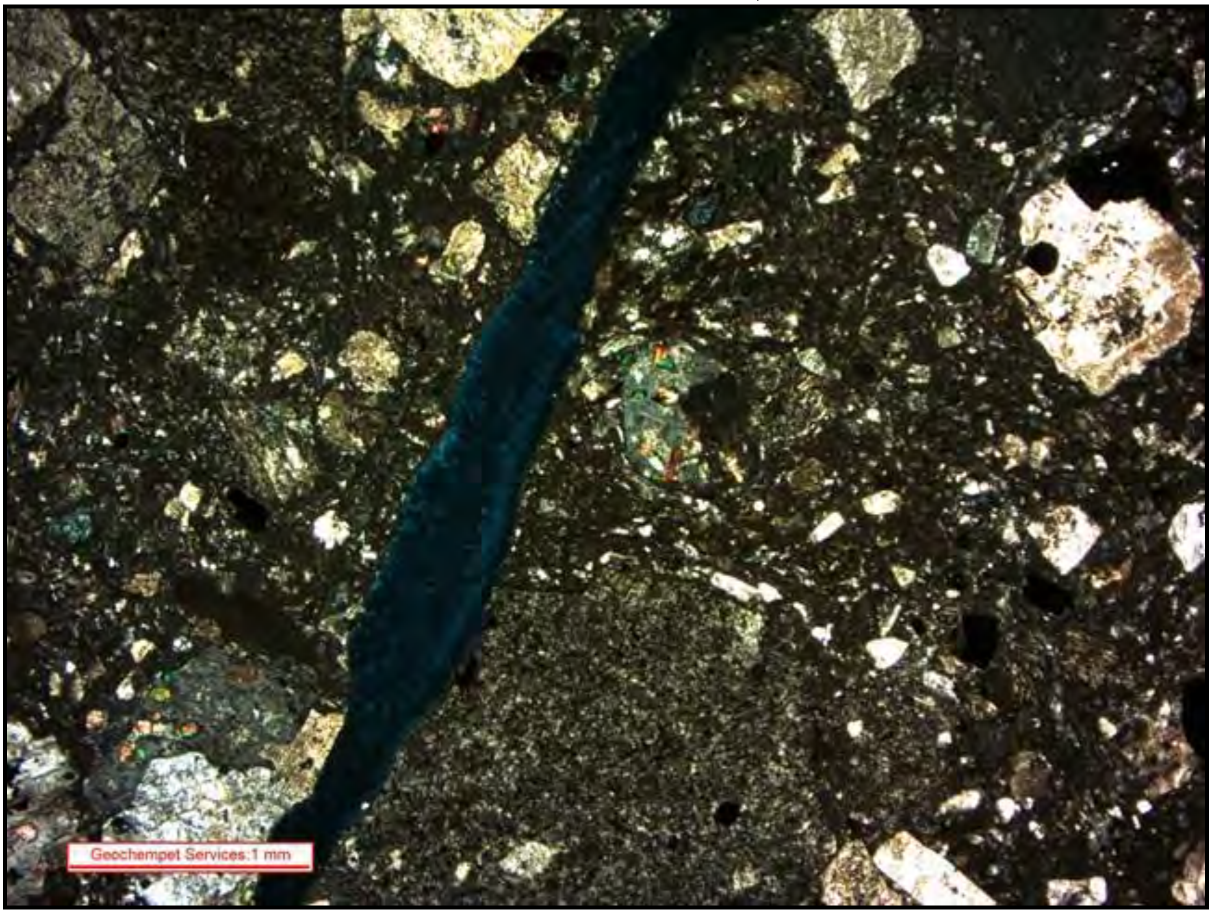

Plate 2: Micrograph taken at low magnification, cross polarised, transmitted light image of a typical latite tuff fragment. It shows the abundantly phenoclastic rock, the phenoclasts are largely feldspar, some with alteration to epidote and sericite and smaller chloritized former mafic phenoclasts (bluish-green) in a murky feldspathic matrix.

Sunshine Coast COUNCIL

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Our reference: D2016/1357389
Your reference: 215/00019

6 December 2016

Mr Craig Hough
Director (Property Management)
Department of Transport and Main Roads
GPO Box 1412
BRISBANE QLD 4034

Dear Mr Hough,

Re: Kuluin Quarry – Lot 481 on SP 2895, Commercial Road, Kuluin

I refer to your letter dated 25 November 2016, to the Chief Executive Officer, in which you advise of the Department's intentions to undertake blasting and final extraction at this quarry, and seek Council's views on this proposal. The Chief Executive Officer has asked me to respond on his behalf, and I provide the following information.

Firstly, it is important to note that Council holds very limited records of this property. As such, Council does not have access to any information pertaining to any quarrying activities on the site. However, if the quarry was established in the 1960s, as seems to be agreed, then this is prior to the introduction of any regulatory planning instrument. Therefore, this would mean that use was lawfully established.

Further, based on the information previously provided by the Office of the Harbour Master, it appears that the quarry has been continually used since its initial establishment for the supply of rock, indicating that there has been no "abandonment" of the lawful use.

Accordingly, Council raises no objection to your proposed activity, on the basis that the quarry (extractive industry) use over this site has not been abandoned and the site, therefore, has <u>continuing use rights</u> for quarrying activities. As such, the use can continue as if it were "as of right" development.

Notwithstanding the above, as advised to the Boat Harbour Controller, by email dated 16 July 2014, Council strongly recommends that, given the location of the site very close to surrounding dwellings, it would be wise to inform the community in advance of intended quarry activities expected to occur on the site (particularly blasting). If you wish, Council's Customer Service Centre can supply the up-to-date names and addresses of surrounding residents.

Caloundra 1 Omrah Avenue Caloundra Qld 4551
Maroochydore 10 First Avenue Maroochydore Qld 4558
Nambour Cnr Currie and Bury Streets Nambour Qld 4560

Sunshine Coast COUNCIL

It is understood that Council had previously been advised by the State Government that quarrying activities on this site were no longer intended. Accordingly, Council did not include any “extractive resource” designation for this site in its new Sunshine Coast Planning Scheme (whereby the previous Maroochy Plan did identify the site as an extractive resource). Hence, the communities’ expectations of the future use of the site may be different. This further supports the need for thorough community consultation.

It is also recommended that you prepare a public statement, prior to commencing operations, particularly blasting, and this should be forwarded to Council’s Development Information Centre prior to the works so that any concerns can be readily answered.

Yours sincerely,

personal information

MANAGER
DEVELOPMENT SERVICES

SUNSHINE COAST REGIONAL COUNCIL
Kuluin
Fishermans Rd
Commercial Rd
Depot St
Service St
Progress Rd
Advance Rd
Harbour Heights Ln
Main Rd
Grenfell Ct
Orlando Cres
Tallow Wood Dr
Cadagi Ct
Kinsdale Ct
Calais Ct
Cypress St
Pathway
Daintree Ct
Pindari St

Appendix B

Kuluin Quarry Visit

Mooloolaba Breakwater Extension - Kuluin Quarry Inspection

1 Introduction

The Department of Transport and Main Roads (TMR) currently holds a strategic quarry asset at Kuluin (Lot 481 on Plan GC2895). A locality plan of the quarry site is shown in Figure 1.1.

An inspection of the quarry was conducted on 15 March 2019 without entering the quarry. From the cursory inspection (from outside the quarry fence line) the rock appeared to be sound and of reasonable quality. Seam spacing at the vertical quarry face some distance away appeared acceptable and the rock armour stockpiles, where visible, showed reasonable size units. However, without close inspection, rock size and inferred properties for use as primary armour on the Mooloolaba Breakwater could not be established.

It was initially estimated that the seam spacing observed on the exposed quarry face would not yield rock armour larger than 4 to 5 tonnes. Rock volumes in situ at the quarry may be insufficient for the breakwater extension. Images showing the quarry and rock stockpiled on March 2019 are provided in Figure 1.2.

In order to provide a more informed assessment of the rock availability at the Kuluin Quarry site, TMR commissioned KBR to perform another Kuluin Quarry site visit to assess if the rock could be used as core material or secondary armour and roughly estimate quantities.

This technical memorandum describes KBR's on site observations and assessment of the material suitability based on an understanding of the technical rock requirements for the Mooloolaba Breakwater Extension.

Details of specific rock requirements for the project are available in the Mooloolaba Breakwater Extension – Constructability Report (BEJ952-TD-ST-REP-0002).

Figure 1.1 Kuluin Quarry Site

Figure 1.2 Kuluin Quarry from fence-line (15 March 2019). Estimated rock D_{50} is approx. 1.2 m.

2 Objectives & Focus of the Site Visit

A visual inspection of the site was undertaken on 17-18 October 2019 by KBR. The purpose of the site visit was to obtain rock size estimates, stockpile extents, and visual quality of material in order to:

a) Estimate if the rock is suitable for use as under-layer material for the Mooloolaba Breakwater Extension via visual inspection

b) Approximate the quantity of the available material

No direct measurements or laboratory testing was involved to assess the mass grading or material properties of the quarry rock – only visual estimates of the rock size and general type and condition was noted.

Photographs of the site condition at the date of the inspection, as well as a location plan of the observations made during the site visit are provided in Appendix A and B.

3 Site Description

The Kuluin Quarry site covers a land parcel area of 106,000 m^2 and besides the surrounding vegetation and tree line, is adjacent to low to medium impact industrial zones and low density residential properties.

The accessible quarry area is limited to an approximately 6,000 m^2 area to the north of the site due to the terrain. This area is where the residual quarry rock is currently stockpiled.

Given this limited available area, no substantial room is currently available for sorting or processing the rock (such as crushing for core material). Establishment of quarry operations including heavy machinery and/or a rock crusher may be required offsite to facilitate the inspection, sorting and processing of the existing Kuluin Quarry material.

3.1 REGIONAL GEOLOGY

No site-specific geologic investigations are available to date to characterise the material encountered at Kuluin Quarry. To broadly understand the material, regional geologic mapping was consulted, with descriptions of the material likely encountered on site provided in Table 3.1.

Table 3.1 Regional Geology – Kuluin Quarry Site (Surface Geological units)

Source	Name	Rock Type	Description

Detailed Solid Geology (1:100k) - Queensland	Mount Urah Granodiorite	intrusive unit	Igneous rock, Mica present in well-formed hexagonal crystals
	Hornblende-biotite granodiorite	intrusive unit	Igneous rock, Mica present in well-formed hexagonal crystals
	Pyroxene-hornblende microdiorite		Igneous rock, Mica present in well-formed hexagonal crystals
AUS GA 2500k GUPoly Lithology	Triassic sedimentary rocks 76707	lithostratigraphic unit	Surface geology, predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias
AUS GA 1M GUPoly Lithology	Landsborough Sandstone	lithostratigraphic unit	Surface geology, Lithofeldspathic labile and quartzose sandstone, siltstone, shale, minor coal, ferruginous oolite marker.
	Alluvium 38485	lithostratigraphic unit	Surface geology, Channel and flood plain alluvium; gravel, sand, silt, clay; may be locally calcreted

Geology of the site materials is generally a combination of a grey granitoid material with mica crystal structures (Mount Urah Granodiorite) and Landsborough Sandstone materials.

Where sedimentary rock (i.e. Landsborough sandstone) is present, this material is generally considered unsuitable for armourstone applications in accordance with AS 2758.6-2008 Clause 8.2.

3.2 STOCKPILE AREAS

It is understood that all the rock stockpiled on site was sourced from the Kuluin Quarry face, however the site has not been actively used for blasting or extraction activities since 2002.

Five main armour rock stockpile areas were identified at the site: Western Stockpile Area, Eastern Stockpile Area, Southern Stockpile Area (below the quarry face) and the 'Top' Stockpile Area (located on the far eastern uphill section of the site). A fifth 'older' stockpile was identified to the far west of the site but was inaccessible for visual inspection as the stockpile was heavily vegetated. The locality of these stockpiles areas as well as the locations of key reference points used for measurements is provided in Figure 3.1. No substantial stockpiles of material exists beyond this area.

Stockpile heights have been inferred based on spot height measurements taken at the date of inspection and compared to 1 m Digital Elevation Model (DEM) at 2008 and 2014 (generally prior to the presence of the stockpile materials at their current position). A summary of the measurements taken and the location of observations is provided in the Site Plan in Appendix B.

Rock stockpiles were found to be widely graded, with no separation of materials into distinct grades (i.e. AS 2758.6 standard gradings). A more accurate assessment could be made if a machine fitted with a load sensor was used to sort material in the stockpiles into appropriate standard mass gradings.

Figure 3.1 General locations and shapes of stockpile areas

4 Rock Size and Quality

4.1 CRITERIA

Armourstone for use on breakwaters (either as primary or secondary armour) is susceptible to more severe environmental conditions than general armourstone. This includes:

a. Susceptibility to hydraulic forces (i.e. wave action) causing rocking/motion which could displace armour or result in breakdown of the armour material.

b. Weathering including cyclic wetting/drying, abrasion (such as from sand) and salt attack

The rock durability (physical and chemical properties) and the low incidence of defects (joints, cleavage, shear planes or fracturing) are therefore important to ensure the armour is able to withstand the environmental conditions in the marine environment without significant loss of size during the life of the structure which would result in a loss in breakwater stability in high-energy conditions.

Additionally, armourstone shapes are also important as it affects armour layer stability, packing density and constructability. For breakwater armour, no more than 5% of individual armourstone pieces shall have an aspect ratio (length to thickness ratio) greater than 3.

Assessments on the adequacy of the Kuluin Quarry rock therefore focused on observations of rock sizes (and inferred mass), aspect ratio and the presence of any visible defects.

4.2 OBSERVATIONS

4.2.1 Rock sizing

To broadly quantify the rock sizes and masses of material at the site, a small sample of accessible rocks was measured reflecting the typical rock sizes observed at the site. The dimensions and 'blockiness' (shape factor) were assessed based on CUR Rock Manual guidance (refer Figure 4.1).

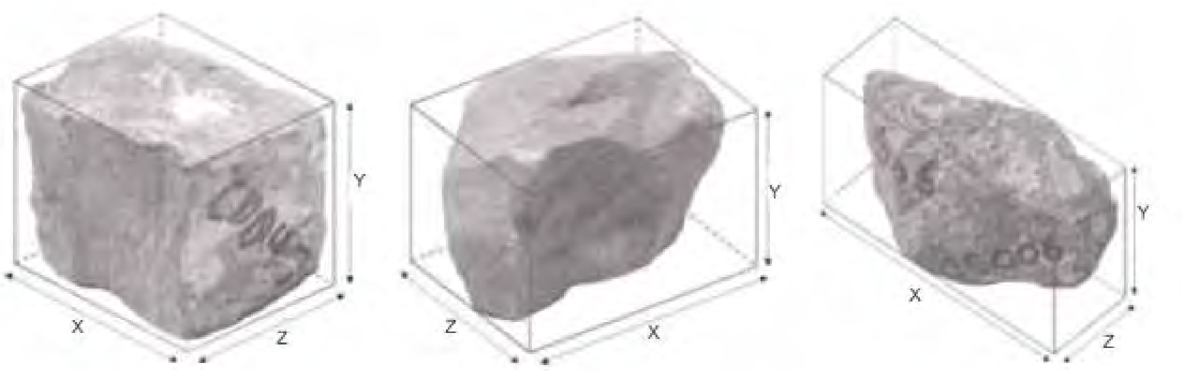

Figure 3.14 *Examples of different blockiness values (from left to right, BLc = 80%, 60% and 40%)*

Figure 4.1 Examples of blockiness values (from left to right, BLc = 80%, 60% and 40%) (Source: Figure 3.14, CUR Rock Manual, CIRIA 2007)

From the sample of stockpiled material, armourstone was generally observed in the range from approximately 15 kg and 3 t. The average rock size based on the measurements taken was 1.7 t.

Some select armour rocks (approximately 10 units) were observed of between 3 and 6 t. These units were predominantly located in the western stockpile ('W-2' Stockpile in Figure 3.1) and the southern stockpile, near to the quarry face ('S-1' stockpile in Figure 3.1).

4.2.2 Quantities

It is estimated that up to 4,700 tonnes of material may be available on site, however the exact quantities of individual classes of material are unknown. These estimates are derived from high-level measurements of the stockpile footprints and heights in Appendix B.

Recovery of suitable armourstone for use as breakwater armour (either primary or secondary armour) would require visual inspection and testing of individually selected rocks and sorting into specific rock grades using heavy machinery.

The rates of recovery of suitable armourstone material from the total available stockpile material may be as low as 10% to 20%. As little as approximately 470 tonnes of this stockpiled material may be usable (using typical recovery rates from AS 2758.6), dependent on the material quality and durability. This is proportionally low compared with the approximately 3,000m^3 of secondary armour rock estimated for the Mooloolaba Breakwater Extension (Refer Section 2.1 of BEJ952-TD-ST-REP-0002).

4.2.3 Quality

As part of KBR's initial constructability assessment, an inspection of the quarry was conducted on 15 March 2019 without entering the quarry. From the cursory inspection (from outside the quarry fence line) the rock appeared to be sound and of reasonable quality with the seam spacing of the quarry face appearing to be acceptable assuming the visible rock armour stockpiles were sourced from there.

Upon closer inspection, however, it appears that there are fractures in a number of samples, which indicate compromises in the integrity of the rock.

A number of larger armourstone pieces observed at the site were also elongated and hence would not satisfy the aspect ratio requirements outlined in AS 2758.6 (where length to thickness ratios should be no greater than 3).

A broad overview of the eastern area stockpile is shown in Figure 4.2 and Figure 4.3.

Figure 4.2 Panoramic view of E-2 Stockpile (Eastern area) showing widely graded rock (approx. 15 kg to 40kg rock to the left and approx. 0.8 to 2.4t rock toward the right)

Figure 4.3 Panoramic view of Stockpile W-2 (Western area) showing large armourstone (up to 4t approx.)

It is evident that the rock armour at the Kuluin Quarry is generally consistent with the armour material observed on the Mooloolaba Breakwater, as demonstrated in Figure 4.4 (a) (quarry rock at Kuluin Quarry) and Figure 4.4 (b) (Rock observed on Mooloolaba Breakwater).

Figure 4.4 (a) Stockpiled Kuluin Quarry Rock and (b) Armour rock on the crest of the Mooloolaba Breakwater (seaward side)

Observations of the breakwater rock indicate material that is prone to fractures, decomposition and weathering in an exposed breakwater environment (shown in Figure 4.5a and b). Evidence of fracturing of material was also noted for a sample of pieces at the quarry site (refer observations in Appendix A).

Figure 4.5 (a) weathering of the Kuluin Quarry Rock on the crest of the Mooloolaba Breakwater (seaward side) and (b) fracturing of larger rock armour (lee side)

5 Conclusion

The investigation of the rock armour suitability at the Kuluin Quarry observed the following:

- Up to 4,700m^3 of material may be present within the existing stockpiles.
- Quality of the material observed on site is highly variable with a wide grading and would require careful selection of individual pieces that may be suited for application to the breakwater extension.

Recovery rates of heavy armourstone suitable for the marine environment is typically low therefore it would be expected that only a small proportion of the onsite material could be utilised.

- Individual armourstone units typically ranged from 15 kg to 3 t although a limited number or larger units between 3 t and 6 t were noted (~10 units max.). The site visit however confirms that the quarry would not yield a sufficient quantity of large armour units (i.e. 5+ t).
- Material origins are likely to be a combination of igneous rock (granitoid) with sedimentary Landsborough Sandstone. Only the Mt Urah (granitoid) material is suitable for use as armourstone.

On this basis, the following is concluded:

- No substantial quantities of rock were found to be suitable for primary armour for the Mooloolaba Breakwater Extension
- The quarry site is not suited to the extraction of core material. Considerable effort would be required to crush the existing material on site (particularly large armour rocks). There are a number of well-established quarries locally that can supply core material which would likely be more cost effective compared with the establishment of the Kuluin Quarry for this purpose.
- Secondary armour requires up to a 1 – 3t standard grading. While some material of this size is available on site, its suitability in terms of quality is uncertain given:
    a. Some material on site displayed signs of fracturing
    b. Indicatively, Kuluin Quarry material observed on the existing Mooloolaba Breakwater display signs of fracturing and weathering. This results in a reduction in the rock mass over time, leaving the breakwater at greater risk of instabilities under high-energy (design) wave events during the life of the structure
- Quarry operations (e.g., blasting) would impact on the neighbouring residential and commercial areas. It is unlikely additional rock can be blasted at the site due to the proximity to private property in order to obtain the quantities required.

6 References

CIRIA (2007) CUR The Rock Manual: The use of rock in hydraulic Engineering

Geoscience Australia (2019) Australian Geoscience Information Network (AUSGIN) Geoscience Portal: Geological units (lithostratigraphy)

Standards Australia (2008) AS 2758.6 – 2018 Aggregates and rock for engineering purposes, Part 6: Guidelines for the specification of armourstone

State of Queensland, Department of Natural Resources, Mines and Energy (DNRME) (2018) Detailed solid geology mapping (1:100k)

Appendix A – Rock sizing

Table 6.1 Rock sizing samples

#ID	Length (X)	Breadth (Z)	Height (Y)	V	ρ_r	BLc	Mass
	(m)	(m)	(m)	(m3)	(t/m3)	(-)	(t)
1	1.80	1.10	0.70	1.39	2.65	0.60	2.20
2	1.10	0.70	0.60	0.46	2.65	0.70	0.86
3	1.30	0.75	0.90	0.88	2.65	0.60	1.40
4	0.80	0.90	0.75	0.54	2.65	0.70	1.00
5	0.75	0.85	0.95	0.61	2.65	0.70	1.12
6	0.80	1.20	1.00	0.96	2.65	0.50	1.27
7	1.10	0.65	0.50	0.36	2.65	0.80	0.76
8	0.40	0.40	0.20	0.03	2.65	0.50	0.04
9	1.50	0.75	0.70	0.79	2.65	0.50	1.04
10	1.15	0.70	0.80	0.64	2.65	0.70	1.19
11	2.00	1.40	0.55	1.54	2.65	0.60	2.45
12	1.60	1.50	1.30	3.12	2.65	0.66	5.46
13	1.70	1.40	0.70	1.67	2.65	0.90	3.97
14	2.00	1.00	0.70	1.40	2.65	0.90	3.34
15	1.00	0.60	0.50	0.30	2.65	0.80	0.64
16	1.00	1.50	0.50	0.75	2.65	0.70	1.39
17	1.00	0.50	0.30	0.15	2.65	0.70	0.28
18	1.10	2.10	0.50	1.16	2.65	0.80	2.45
			All rock measurements:			ave. rock size 1.7 t	
			Only Large Rocks > 2t:			ave. rock size 3.3 t	

Table 6.2 Rock Observations – Measurements (see Table 6.1)

#ID	Photograph
1	
2	
3	
4	

5		
6		
7		
8		

9		
10		
11		
12		

13		
14		
15		
16		
17		

18		

Appendix B – Stockpile Measurements

Figure 6.1 Site Plan for stockpile height observations and reference locations

Project Name:	Mooloolaba Breakater Extension
Project Description:	Kuluin Quarry Inspection
Job No.:	BEJ952
Date:	17 - 18 October 2019

Relative to:	lat	lon
Stand location 1	-26.653	153.059
Stand height	1.25	m
Stand elevation	9.6	mAHD

# ID	Feature	Dist	Angle	Height to ground level (adjusted for stand level)	Elevation (mAHD)	Horiz. Dist	Notes:
1	Distance to west face of quarry	28.49	14.40	8.34	17.94	27.59	RH Stockpile (West)
2	Distance to tan vertical rock at top of stockpile (RH)	31.17	3.10	2.94	12.54	31.12	South-facing:
3	Distance to small grey rock at toe of stockpile	24.75	4.70	3.28	12.88	24.67	
4	Distance to top of black cube rock	7.39	6.80	2.13	11.73	7.34	
5	Distance to precarious tan rock (north end of RH stockpile)	14.13	8.90	3.44	13.04	13.96	
							
							
							North-facing: 

6	Distance to cube rock (at end of stockpile, LH)	16.00	-1.00	0.97	10.57	16.00	
7	Base of end rock (south-facing)	15.40	-4.40	0.07	9.67	15.35	
8	Distance to white "Pillar" rock @ LH stockpile (north-facing)	13.60	6.60	2.81	12.41	13.51	
9	Distance to tall grey 'block' rock (south-facing)	15.18	19.20	6.24	15.84	14.34	South-facing:
							
							North-facing: 

Relative to:	lat	lon
Stand location 2	-26.653	153.059
Stand height	1.25	m
Stand elevation	9.76	mAHD

# ID	Feature	Dist	Angle	Height to ground level (adjusted for stand level)	Elevation (mAHD)	Horiz. Dist	Notes:
10	Distance to white speckeled rock (@ peak of stockpile)	18.19	19.20	7.23	16.99	17.18	
11	Distance to tan rock near branch at top of tall stockpile	17.16	18.90	6.81	16.57	16.23	
12	Distance to bottom rock of stockpile.	3.16	-18.70	0.24	10.00	2.99	
13	Distance to plate ~0.5m above toe of stockpile	2.50	-27.70	0.09	9.85	2.21	
14	Top of stockpile (tan rock next to white rock)	6.57	20.13	3.51	13.27	6.17	

Relative to:	lat	lon
Stand location 3	-26.653	153.059
Stand height	1.3	m
Stand elevation	9.5	mAHD

# ID	Feature	Dist	Angle	Height to ground level (adjusted for stand level)	Elevation (mAHD)	Horiz. Dist	Notes:
15	Distance to edge of stockpile ('Top Stockpile')	25.29	6.40	4.12	13.62	25.13	
16	Post to edge of stockpile / change of grade	15.58	11.00	4.27	13.77	15.29	
17	Top of stockpile (Top stockpile) (uphill)	16.21	11.40	4.50	14.00	15.89	

Relative to:	lat	lon
Stand location 4	-26.653	153.059
Stand height	1.3	m
Stand elevation	13.2	mAHD

# ID	Feature	Dist	Angle	Height to ground level (adjusted for stand level)	Elevation (mAHD)	Horiz. Dist	Notes:
18	Distance from Stand Loc to the accessible end of fire trail ('Top Stockpile')	12.11	14.90	4.41	17.61	11.70	
19	" to top of "square" rock near front (top stockpile)	6.90	6.90	2.13	15.33	6.85	
20	" to light grey rock (top of stockpile) note: rock features a wedge 'cutout'	17.53	13.90	5.51	18.71	17.02	
21	" sandy coloured rock at the top, back of the 'top' stockpile (immediately infront of back right gumtree)	24.44	11.30	6.09	19.29	23.97	
22	" rock, left of the two peaks	15.26	8.40	3.53	16.73	15.10	

Relative to:	lat	lon
Stand location 1	-26.653	153.059
Stand height	1.3	m
Stand elevation	9.6	mAHD

# ID	Feature	Dist	Angle	Height to ground level (adjusted for stand level)	Elevation (mAHD)	Horiz. Dist	Notes:
23	Top of large vertical rock at southern stockpile	63.75	3.20	4.86	18.06	63.65	
24	Bottom of large vertical rock at southern stockpile	63.15	0.90	2.29	15.49	63.14	
25	Top of rock stockpile (reference: "blocky" rock)	69.54	5.10	7.48	20.68	69.26	

Relative to:	lat	lon
Stand location 5	-26.653	153.059
Stand height	1.3	m
Stand elevation	9.6	mAHD

# ID	Feature	Dist	Angle	Height to ground level (adjusted for stand level)	Elevation (mAHD)	Horiz. Dist	Notes:

26	Quarry face (rock to the right of shrub)	69.39	19.70	24.69	34.29	65.33	
27	Toe of stockpile (small rock pile)	16.19	-3.30	0.37	9.97	16.16	

Appendix C

Concrete Armour Unit Options Review

TECHNICAL MEMORANDUM

DATE	1 October 2020
TO	Charles-Dean A Sorbello, Department of Transport and Main Roads
FROM	personal information
COPY	Click or tap here to enter text.
PROJECT	BEJ952 MOOLOOLABA BREAKWATER EXTENSION
SUBJECT	CONCRETE ARMOUR UNIT REVIEW

INTRODUCTION

During the initial stages of the Mooloolaba breakwater extension design, rock sourcing investigations by TMR and KBR were unable to identify any local quarries able to supply the required sizes (up to 8 tonnes) and specifications of primary armourstone, in sufficient quantities, in the Mooloolaba / Maroochydore region.

As part of a separate constructability assessment carried out by KBR, it was also identified that transporting and installing this rock will be difficult due to restricted access to the site caused by the congested road network in Buddina. This suburb has been fully developed since the breakwater was built in the early 1960s.

Sourcing armour stone from more distant sources was investigated separately by TMR. Potential primary armour rock sources at Mt Petrie were identified (Rocksberg greenstone), however it was found that supply of the primary armour rock had substantial lead times (8 to 12 months minimum), plus sourcing from this location would probably increase capital expenses due to additional transport costs. As described in the Constructability Report (BEJ952-TD-ST-REP-0001) transporting the armour via the road network from Mt Petrie is not a good solution because of the potential damage to existing road infrastructure and the relatively long haul from Mt Petrie to Mooloolaba.

Physical modelling was undertaken by the Queensland Government Hydraulics Laboratory (QGHL) to evaluate the performance of smaller and more easier available rock. This initial testing found that the rock cannot be reduced, because higher than acceptable damage will occur if the rock size is reduced to 6 tonnes.

As an alternative to armour stone is prefabricated concrete armour units. Typically, these materials can be cost effective where suitable quality rock of the required size and quality is unavailable, or where quarry lead times may exceed the project requirement. This appears to be the situation at Mooloolaba, hence this technical note.

OBJECTIVES AND FOCUS OF THE ASSESSMENT

The objective of this investigation is to provide TMR with several concrete armour unit options to consider and select from. This document is intended to provide general information on each of the units to provide a comparison.

Five concrete armour units have been investigated. This is a broad cross-section of available units, considering both double and single-layered systems, licensed and royalty-free options, and varied geometric complexities.

It is understood that TMR are also interested in the possibility of integrating eco-friendly features into the breakwater extension works. Therefore four potential eco-friendly options have therefore also been reviewed.

CONCRETE ARMOUR UNITS REVIEW

Concrete armour units have several benefits:

- Greater control around the source and quality of the primary armour. As rock sizes are increased, there is increased risk that the large armour rocks may be of a lower quality and susceptible to defects. By using concrete armour units, quality can be actively managed through quality assurance during casting.
- Lighter weight. Interlocking precast units will provide a similar performance to a heavier natural rock.
- Cast-in lifting points to simplify lifting if desired. Large rocks are lifted using a special grab fitted to a crane.

Disadvantages of concrete armour units compared to rocks:

- Rocks have a more “natural” appearance
- Rocks are stronger
- Suitable rocks are cheaper if available nearby.
- Secondary armour, filter and core rock will still be required

Further discussion on the generic benefits of implementing concrete armour units is provided in Section 2.6 of the Constructability Report (BEJ952-TD-ST-REP-0001).

Five concrete unit types have been selected for further desktop review. The geometry of each of these units is provided in Figure 1. The selection of units was based on consideration of their known use in other coastal protection structures, licensing arrangements, as well as considering a range of common design functions (i.e. single layered vs double layered systems).

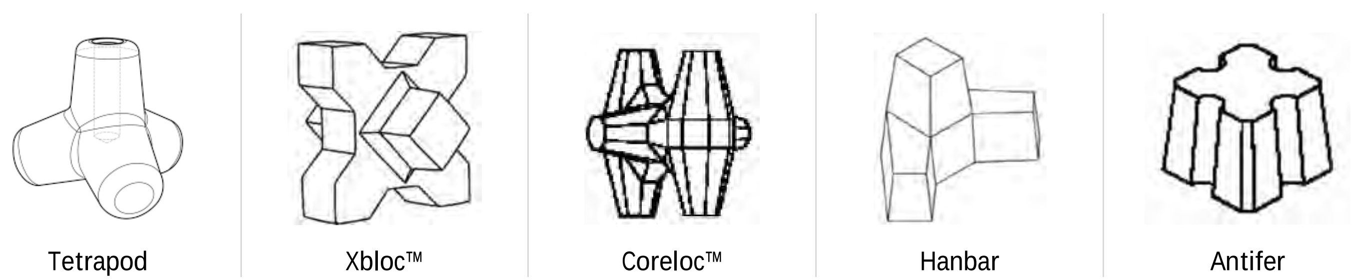

Figure 1 Concrete units under review

These units can be reinforced (USA usage) or unreinforced (European usage). We have assumed unreinforced; some minor breakage and wastage can be excepted during handling.

Tetrapod

Tetrapod units have been used as early as the 1950's and are widely used throughout the world. The tetrapod units therefore have a proven effectiveness as an alternative to rock protection and are free of royalties compared with other proprietary concrete armour unit products.

The tetrapod unit was designed for ease of fabrication and shaped to increase stability through interlocking, self-weight and friction on the breakwater face. Due to its improved interlocking compared with rock armour, a comparatively smaller weight unit can be used compared with rock.

Tetrapod armour is a double-layered system, placed at similar slopes to a traditional rock armour. Accurate unit placement is not a critical as the single layer systems like Xbloc and CoreLoc.

Given the long history of tetrapod implementation, there is comprehensive guidance for tetrapod mould manufacturing, procurement, storage and placement. Design of tetrapod breakwaters can be undertaken via desktop methods (such as Hudson's and Van Der Meer formulations) as well as physical model testing. Implementation is therefore relatively straight-forward and well documented and does not require input from suppliers as is the case with proprietary units.

Usually Tetrapods are non-reinforced following the European fashion, however they can also be reinforced if desired (following the USA style). The use of reinforcement has been found to have little influence on damage during placement (Hudson, 1974), although reinforced options are expected to have an improved ability to withstand breakage during storms. However, reinforcement costs more. Additionally, when using steel reinforcement, if the reinforcement corrodes, the adverse effect on durability can outweigh the advantages of using it (CIRIA 2007) which is why unreinforced units are typically used. Corrosion of the reinforcement shouldn't occur if adequate concrete cover is provided.

Re-usable steel moulds are used . Given the broad use of Tetrapods globally, it is likely that premade forms exist, and several international manufacturers are also able to produce the forms.

There is no code requirement for physical modelling requirements for this unit outside the normal recommendations of the British Standard, BS 6349-7 Part 7 which advocates physical testing on the basis that it is the most efficient and reliable way of determining the stability of a breakwater design.

It is understood that TMR's preference is for no further physical modelling to be undertaken. Whilst physical modelling for confirmation of the design is recommended by KBR, a conservative desktop tetrapod design could be done followed by a discussion regarding the desirability of more physical model testing. In KBR's experience physical model testing almost always results in a net cost saving.

A summary of Tetrapod units:

- Long track record around the world and in Australia.
- 4-piece moulds consisting of 1 bottom and 3 lateral pieces.
- Testing has shown that steel reinforcement is unnecessary
- Stability factor contribution by self-weight, interlocking and friction
- Random, double layer placement
- Unit wear and failure is well documented, such as rocking under wave motions
- Used moulds are available for purchase without any associated royalty fees
- Physical modelling not explicitly required but is recommended as it will almost certainly realise a cost saving.
- A 1V: 1.5H batter is used which is a bit flatter than the existing.

Xbloc™

The Xbloc was designed in the Netherlands in 2003 by Delta Marine Consultants (DMC) who are the patent holder and distributor of the Xbloc unit. Xbloc is a single-layer unreinforced concrete armour system, with a highly efficient geometry and interlocking performance. The Xbloc unit has been implemented at a number of locations worldwide, including the breakwater for the Gorgon LNG Project harbor in Western Australia, which KBR designed.

The single-layer system requires less concrete than a double-layer system and reduces the number of units for placement, significantly reducing construction times and costs.

On a mild slope (i.e. 1V:2H or 1V:1.5H which is typical for rock armour), the interlocking of the armour units is less effective and as a consequence the stability is reduced. The optimal batter slopes are typically steeper, around 3V:4H which is the required slope for Xblocs. This steep slope offers a reduced footprint compared with the rock armoured design, as well as an easier transition to the steep batters of the existing breakwater.

Xblocs are not produced by the patent holder but are fabricated and placed by a contractor who in return pays a license fee. Such an agreement involves certain technical support activities by Delta Marine to ensure the correct application of the protection system.

This unit license fees are paid by the contractor on a ‘per unit’ basis and cover the provision of documentation (including specifications) and construction support services to ensure the Xbloc units are installed and fit for purpose. Typically, the fees would be around 8 – 15 Euro (Around $25) per unit. If project is small enough then fees are a fixed sum rather than a unit rate. These royalty costs can usually be offset by the savings realised from the reduced concrete use, casting & placement times compared to a double layer of armour system.

DMC usually require that physical model tests are carried out to confirm or optimise the design. These costs are in addition to the license fees. DMC can supply units at model scales for the testing and the testing can be conducted locally (i.e. at QGHL in Brisbane). The time taken to ship the model units from the Netherlands has to be added to the physical modelling program Suitable Xbloc model units might be available at the UNSW Water Research Laboratory in Sydney where the Gorgon modelling was done.

A summary of Xbloc units:

- Units placed with random orientations on a pre-defined grid in a single layer. Pre-defined coordinates are provided by DMC, with GPS tracking for each placement to ensure that the units are installed correctly.
- Based on several past projects an achievable placement rate of Xbloc armour units is between 4 – 6 units/hr although in some instances 8 or more units/hour can be placed using experienced operators where placement is above the waterline.
- Royalty fees to be paid by the builder or owner to Delta Marine Consultants. Extra fees to cover installation, quality assurance and construction oversight.
- Single layer with the main stability factor being strong interlocking.
- Moulds are purchased from DMC and come in two pieces. One mould typically produces one unit per day. For small projects usually only one mould is required depending on the project timing.
- Steep 1V: 1.25H batter is used which reduces the breakwater volume and is similar to the existing.

Core-loc™

The Core-loc unit was developed in 1996 by the US Corps of Engineers (USA) with the initial objective of repairing armour facings made with Dolosse units. Since then, the unit has been widely used around the world as primary armour for maritime structures.

Approximately 19 breakwaters worldwide have been built with Core-loc. Concrete Layer Innovations (CLI) is the exclusive distributor of this technology in a number of countries including Australia.

Core-loc is a single layer unreinforced concrete armour system. As with the Xbloc, Core-loc requires a smaller number of units and less concrete than traditional double-layer systems. CLI indicates that the potential savings of using Core-loc compared with more traditional concrete armour units is:

- 40% less than with Tetrapod units.
- 50% less than with Antifer cubes.

These savings are primarily in material savings costs due to the reduced number of required units.

The armour slopes are also typically steeper than a rock armoured breakwater, thereby reducing the overall footprint of the breakwater, with the optimum slopes being 2V:3H or 3V:4H compared with a typical 1V:2H to 1V:1.5H for rock armoured slopes. These steeper slopes can produce somewhat higher rates of overtopping, leading to potential increases in crest heights over the rock option, to limit the overtopping flowrate. This increased crest height might not be desired by TMR.

Physical modelling is usually advised by CLI for breakwater projects for sites that are particularly exposed to wave action, or where overtopping is a decisive factor, on long batters with a large number of armour rows. Therefore, it is likely that physical modelling would be required for the Mooloolaba Breakwater design.

Physical model units are available from licence holder. The modelling can be done locally (i.e. no specific requirements to be modelled by the supplier). The units are typically provided to the laboratory free of charge for the construction and duration of the physical model tests (anticipated timeframes of around 8-week program for a 3D basin model), with the shipment costs to and from the supplier being covered by laboratory. Shipment timeframes from France would need to be factored in addition to the program for sourcing and delivery of the model units.

Royalty fees are paid by the Contractor / Owner to CLI for the right to use the Core-loc unit and to access the assistance provided by CLI. This covers:

- Suppling the Contractors with formwork drawings after the sublicensing agreement comes into effect

- Assistance provided to the contractor (not supervision)

- Provision of documentation including specifications and quality assurance plans

- Training to ensure correct implementation of the Core-loc product.

Similar to the arrangements for Xbloc, the Core-loc units are not produced by the licensor. The cost for producing the moulds is also excluded from the royalty costs. The moulds must be sourced or built by the Contractor using the provided formwork plans.

A summary of Core-loc units:

- Single layer with the main stability factor being interlocking.
- Expect placement of 30 - 40 blocks per day (approximately 3 – 6 per hour) using GPS, once the team is fully trained. Moulds are able to produce one unit per day per mould.
- Royalty fees are associated with the use of Core-loc. U.S. Army Corps of Engineers is to be paid by the contractor.
- Royalty fees cover documentation, specifications, training and assistance to make sure that the technologies are correctly used
- Further physical modelling likely based on supplier requirement
- Core-loc moulds are not included in the fees (indicatively, prices of around 6,000 to 7,000 AUD per mould may be expected)
- Steep 1V: 1.25H batter is used which reduces the breakwater volume and is similar to the existing.

Hanbar

The Hanbar is an unreinforced concrete armour unit, that is simpler and hence more economical to construct than most other concrete armour units including the Dolosse, Tetrapod, and Tribar. The Hanbar concrete armour unit was initially proposed and used by the NSW Public Works Department in the late 1970s, on breakwaters along the NSW south coast. The Hanbar unit is now widely used throughout the New South Wales coast for the construction, repair and upgrade of breakwaters. Examples of the placement of large Hanbars (12 to 20 tonne) includes the Coffs Harbour Eastern Breakwater project and Port Kembla Breakwater.

Hanbar units are designed to be placed in a double-layer.

The Hanbar is a three-legged concrete armour unit that was designed to have a simple geometry that was easier to construct and be more durable than most other concrete armour units. Its economy is in large part due to the simplified one-piece formwork required to cast the unit. It has an asymmetric shape which facilitates random placement

The forms are open at both ends which allows filling from the top. The form has no base, with the formwork typically being set up on a flat concrete bed. The form is tapered so it can simply be lifted off. This enables the formwork to be removed in a significantly shorter time than other concrete armour unit forms.

The unit can then be left, sitting on the ground curing. The rate of production is quite fast, meaning that shorter lead times are required for casting the units. The units are lifted from the casting bed with the assistance of a bond breaker as used for tilt-up slabs.

Of the five units considered, the Hanbar unit provides the simplest geometry to construct.

There has been extensive physical modelling of breakwaters using Hanbars on a project by project basis. The geometry of the Hanbar unit lends itself to many different placement methods, with somewhat different hydraulic performances (Blacka et al. 2005). Due to the varied performance of the unit, physical modelling is advised to confirm stability. Model units are available at UNSW WRL and NSW PWD MHL, Manly, Sydney.

UNSW's Water Research Laboratory (WRL) has recently completed a 3D physical modelling campaign for the Coffs Harbour Northern Breakwater repair and upgrade project.

A summary of Hanbar units

- Simple shape for procurement with single piece mould
- The moulds should be easy to obtain from NSW
- Used on a significant number of projects along the NSW coast
- Stability due to a combination self-weight, interlocking and friction
- Random double layer placement
- Likely that physical modelling is required
- A 1V: 1.5H batter is used which is a bit flatter than the existing.

Antifer

The Antifer cube is a modification of a simple cube unit designed in France 1973. There is a groove on four sides of the shape to improve interlocking stability and to promote random placement. Regular placement with resulting weakness planes is a risk with a simple unit like a cube. The unit has sloping faces to facilitate form stripping. Following a number of catastrophic failures of Dolosse structures in the 1970s and 1980s, there was a decline in the use of Interlocking units (i.e. Tetrapod, Tribar), and a return to the use of simple blocky units (i.e. cubes).

Antifer units were initially used as a simple and royalty free unit for repairing Dolosse unit breakwaters. They are also regarded as a superior alternative to the simple cube units, with similar capital costs.

The Antifer unit is relatively straight-forward to produce given that they are a variation to a simple cube. The grooves of the Antifer provided better interlocking and stability than a normal cube unit. They also decrease the risk of uniform face-to-face placement which can cause an undesirable smooth run-up batter and hence more overtopping than random placements (CIRIA, 2007). This unit is similar rock armour as its stability arises mainly from its mass. They are however less efficient in terms of the concrete material usage compared with Interlocking units due to their reliance on mass rather than interlocking for stability.

Antifer moulds are also similar in construction to a simple cube, with only four sides to the mould. As with the Hanbar, the Antifer formwork is a 'drawer' style, that is cast directly on a flat casting bed, with concrete poured into the top of the mould. The mould can then be lifted directly off the unit which makes it must more efficient than more complex shapes like the Tetrapod. The units are lifted from the casting bed with the assistance of a bond breaker as used for tilt-up slabs.

As with the tetrapod unit, no royalty fees apply. Consequently, there are no explicit physical modelling requirements for this unit outside the normal recommendations of the British Standard, BS 6349-7 Part 7 which advocates physical testing on the basis that it is the most efficient and reliable way of determining the stability of a breakwater design.

A summary of Antifer cube:

- Usually placed with the smallest face upwards
- Placed in a random double layer pattern
- Bulky unit that primarily relies on it's self-weight for stability
- Improved hydraulic stability compared with a simple cube with increased interlocking provided by the grooves and tapered shape
- Requires large volume of concrete for each unit however is simple to cast and place
- A 1V: 1.5H batter is used which is a bit flatter than the existing.

CONCRETE ARMOUR UNIT SUMMARY

Findings from the concrete armour assessment are summarized in the table below to enable comparison between each of the armour units. The comparisons focus on key features or criteria raised in discussions with TMR, relating to:

- Structure geometry (including footprint, number of layers)
- Whether royalties apply
- Requirements for physical modelling

Table 1 Summary of concrete armour unit review

Description	Tetrapod	Xbloc	Core-loc	Hanbar	Antifer
Unit type	Interlocking	Interlocking	Interlocking	Interlocking / Dead weight	Dead weight
Armour placement configuration	Double-layer, random placement	Single-layer, random placement to predefined coordinates	Single-layer, random placement to predefined coordinates	Double-layer, random placement. Placement pattern varies depending on placement of lifting points	Double-layer, random placement.
Footprint	Similar footprint to rock armour	Reduced footprint due to a single-layer of armour plus steepened batter slope	Reduced footprint due to single layer of armour plus steepened batter slope. Increased crest elevation may be necessary to limit control overtopping	Similar footprint to rock armour	Similar footprint to rock armour
Royalties?	No	Yes	Yes	No	No

Availability of Moulds	To be manufactured by the Contractor. Some second-hand Tetrapod moulds should be obtainable due to widespread usage worldwide	Available for hire from the licence holder. Unique sizes may require manufacture by the Contractor to specified dimensions.	Specifications and plans provided by the licence holder. To be manufactured by the Contractor	To be manufactured by the Contractor. Some second-hand moulds may be available due to widespread usage in NSW. Moulds are one-piece so easy to produce.	To be manufactured by the Contractor. Simple mould construction
Is physical testing required?	Recommended but no explicit physical testing requirements	Yes.	Yes.	Recommended but no explicit physical testing requirements	Recommended but no explicit physical testing requirements
Are scale model units available?	Model units may have to be made by the testing laboratory. Possible that some model units may be obtainable due to widespread usage.	Yes. From the licence holder	Yes. From the licence holder	Likely that scaled moulds are available at Water Research Laboratory (UNSW)	Model units may have to be made by the testing laboratory. Possible that some model units may be obtainable due to widespread usage.

ECO-FRIENDLY ADDITIONS

Several eco-friendly additions have been investigated, which could be considered further if desired by TMR. The objective of incorporating these features is to enhance the ecological value of the site in parallel with providing an extension to the breakwater.

The Mooloolaba breakwater is relatively exposed and is a highly dynamic environment. It also provides a rocky substrate which is favourable for marine life. Therefore it's likely that the site currently supports significant ecosystems of marine plants or fish. The leeside (or 'riverside') of the breakwater, is relatively sheltered, plus there is good water movement in the Mooloolah River. Therefore it is a good environment for the establishment of pioneer marine species (e.g. intertidal species such as oysters, seagrasses or other marine growth) which may in turn promote further development of other marine plant species and provided good fish habitats.

The inclusion of eco-friendly additions will increase the cost of the breakwater somewhat but will provide enhanced environmental benefits. The eco-friendly features investigate din this report are confined to the sheltered riverside of the breakwater, below the high-tide mark.   Ecological enhancements within this zone are expected to provide the greatest ecological benefit, with less risk of being damaged in storms, thus providing the greatest value for money.

Living Seawall

The living Seawalls project is an initiative between the Sydney Institute of Marine Science (SIMS), University of New South Wales (UNSW), Macquarie University and Reef Design Lab. The program has implemented the installation of several pilot programs at Clontarf and Fairlight on Sydney's Northern Beaches, Milson's Point and McMahons Point, also in Sydney. The installations involve the installation of specially designed 3-dimensional 'tiles' by bolting and/or grouting onto existing seawalls. Each tile is around 55cm in diameter and have impressions which imitate the natural intertidal habitats (e.g. rock pools). An example of the installation of a living seawall in Sydney is shown in Figure 2.

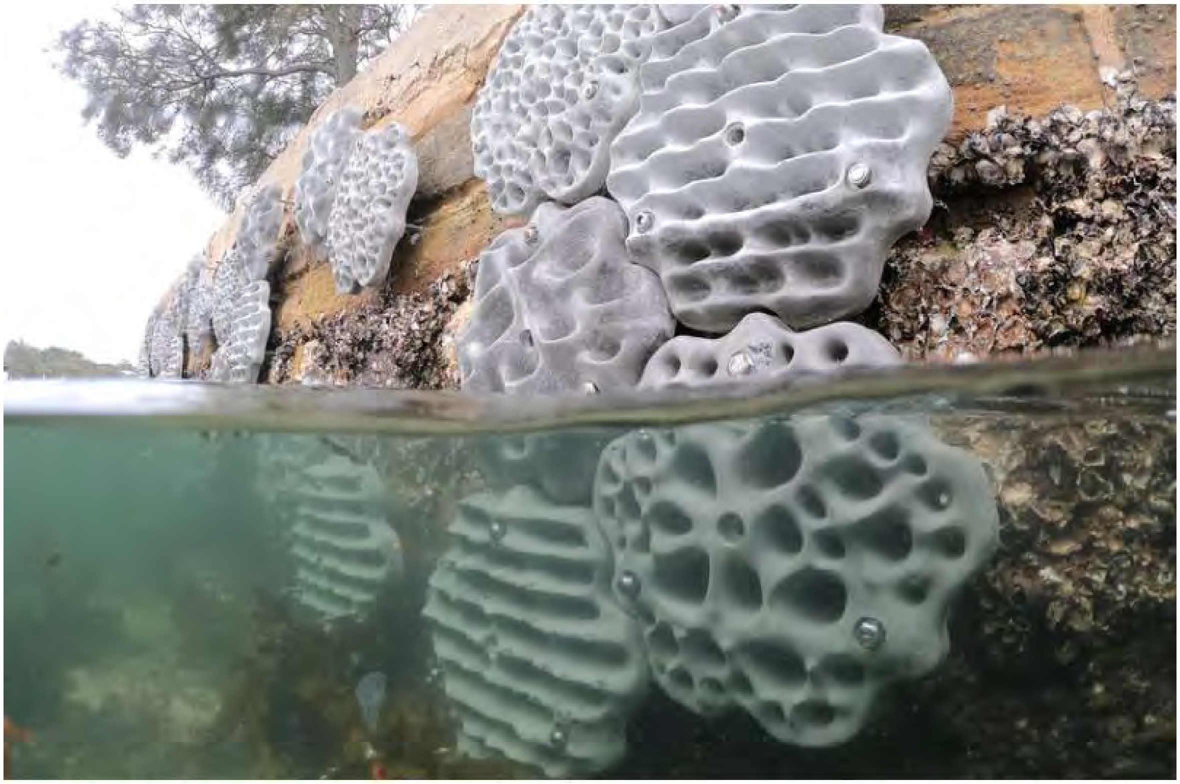

Figure 2 Living Seawalls installation in Sydney (Source: Reef Design Lab)

At present, the living seawalls initiative is suited to installations on vertical walls. There are presently no known examples of their installation on rubble mound style seawalls or breakwaters.

Fitting the tiles to concrete armour units is simple (drilling, grouting and bolting). If stainless steel fixings are used there will be no damage to the units.

The application of a living seawall units directly on the breakwater extension units on the river side therefore appears feasible. It is safer to fix the tiles before unit placement however some tiles might be damaged during placement. Fixing after placement will avoid this damage but will require proper management of safety.

Reef Balls / Reef Modules

Reef balls are hollow concrete dome-shaped units or modules that are used to form artificial reefs. Several variations of reef balls or other reef modules (domes, pyramids etc.) are available. Most of these units have patent holders.

The breakwater rock or concrete armour units provide a good marine habitat, however the addition of reef balls has the potential to improve this habitat.

The external structure of the reef ball provides a surface to promote the growth of marine plants and organisms, while the voids within the dome or pyramid shape mimic the coral reef environment, providing habitats for fish, invertebrates and other marine fauna.

Artificial reef products are available in Australia through suppliers such as Subcon Blue Solutions (Shown in Figure 3). There are also several clusters of reef ball reefs that have deployed in Moreton Bay including offshore of Peel and Coochiemudlo Islands since 2011. Reef balls have also been deployed in the toe of canals and seawalls at Mandurah, Western Australia. They are currently being researched by the New South Wales Department of Primary Industries (NSW Department of Environment and Climate Change, 2009).

Whilst reef balls are not a substitute for concrete armour units, the reef balls or reef modules could be integrated into the design as part of the revetment toe on the lee-side of the breakwater. The reduction in navigation depth due to such a deployment would have to be checked. Compared with other Eco products available, the Reef Balls can be easily sourced and easily installed.

Figure 3 Subcon Blue Solutions Reef Habitat Modules (Left: Apollo Reef Units, Top Right: Abitat, Bottom Right: Abitat Module insitu).

ECOncrete

ECOncrete is a relatively new product which has been designed to enhance local ecological benefits through improved biodiversity, carbon sink (through the reduced usage of Portland cement), as well as habitat creation using bio-enhancing concrete technology. ECOncrete. Several variations of the ECOncrete product are available including rock pool units, armour blocks, reef mats and admixture.

ECOncrete Armour

As part of the ECOncrete product range a modular concrete armour unit, the ECO Armour Block, has been designed for rip rap, breakwaters and revetment applications. An example of the application of the ECOncrete ECO Armour block is provided in Figures 4 and 5. The ecological benefit of the ECOncrete Armour blocks is provided from:

- The geometry of the unit and surface pattern, which provides a complex surface to encourage marine growth,
- Add-on elements (shown in Figure 5) to target species including oysters, fish or seagrasses,
- The material composition which uses a patented ECO admix in the concrete.

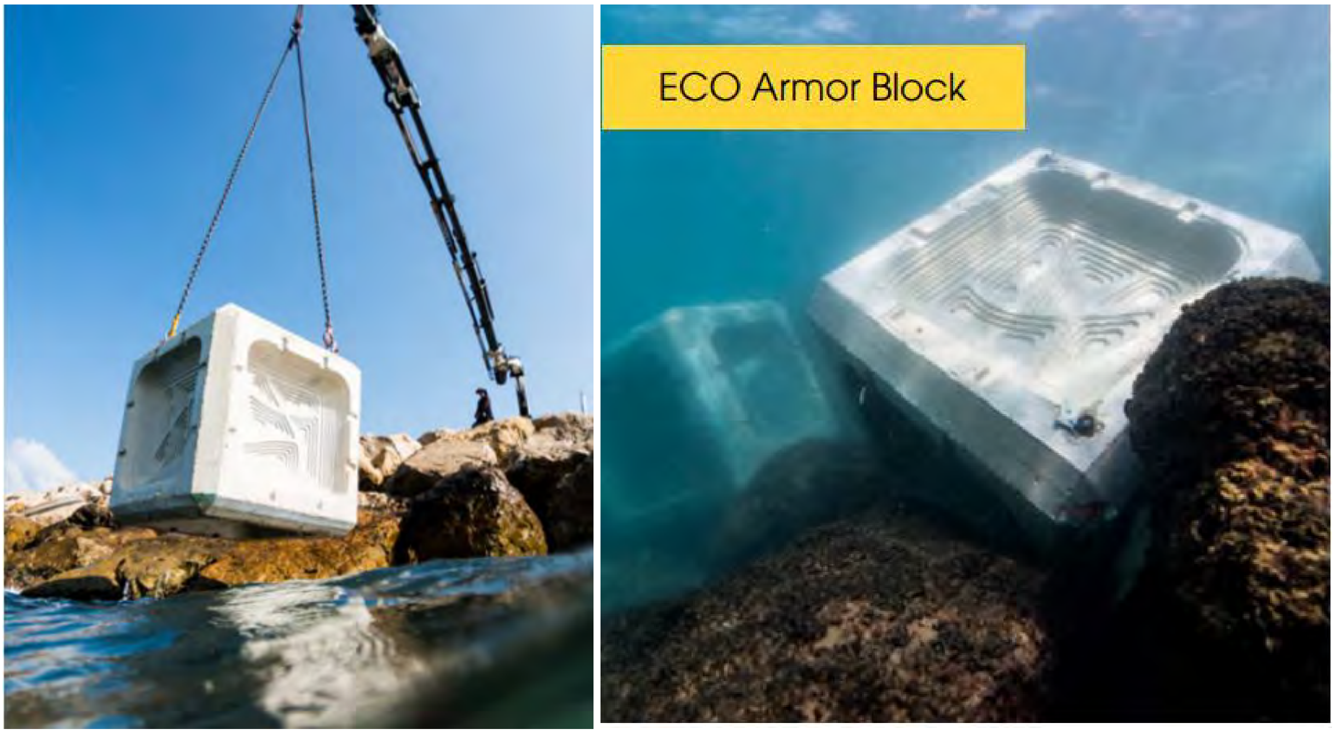

Figure 4 Placement of ECOncrete ECO Armour Blocks

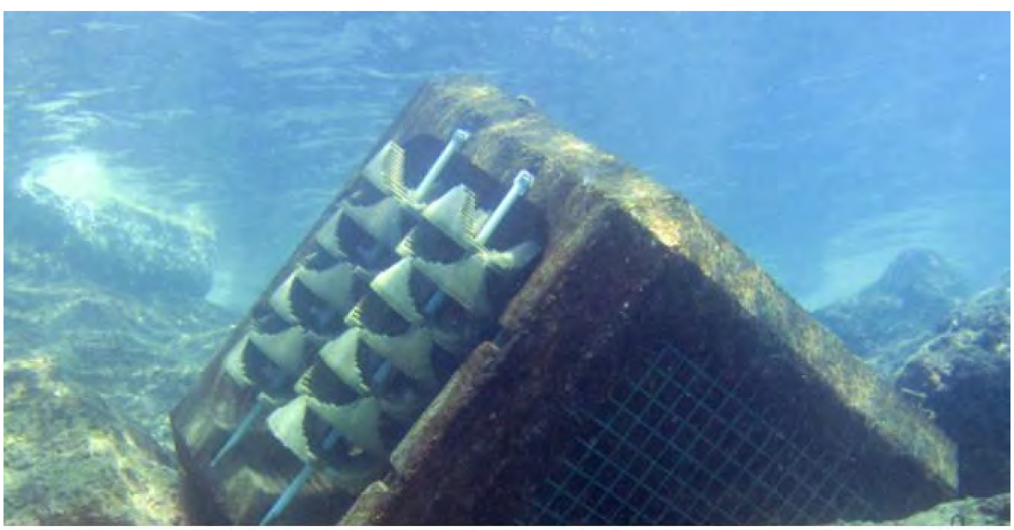

Figure 5 Insitu ECOncrete ECO Armour Block with add-on elements attached to the block faces

ECOncrete has patented designs and typically provides the moulds plus the liners plus the ECO admix, a patented admixture to be added to the concrete (in a quantity typically 10% of the content of cement of the concrete mix). Licensing fees also apply.

The current size of the standard ECO Armour unit is 1.0m^3, although advice from the supplier (Econcretetech) indicates that the sizes could be scaled as needed to fit the project needs. In theory these cubes could be Antifer cube substitutes (although at an increased cost), unlike the reef balls which would be placed in addition.

The units could be produced locally using similar techniques to those of any other concrete armour unit. ECOncrete supplies the specifications for the ECOncrete elements to the Contractor and supervises the concrete mix plus the production and placement of the units. The admixtures for the concrete would be supplied by ECOncrete, who are a US-based company.

ECONcrete Additives

ECOncrete® 's bio-enhancing admix is integrated into concrete mixes for precast products, both dry cast and wet cast, as well as in situ casting projects. The admixture has been laboratory tested to EU, UK, and Australian standards as a workability improvement agent.

The patented ECO admix is used in all of ECOncrete's products (i.e. the Armour Block), however it can also be applied to any concrete armour unit.

ECOncrete® 's admixture, added as ~10% of the cement content in the mix, strengthens the concrete's strength, reduces permeability and should reduce the amount of Portland cement in the mix, thus reducing the project/product CO_2 footprint. Ecological friendly cements mainly contain magnesia. The magnesia reacts with carbon dioxide in the atmosphere to create magnesite, thus acting as a carbon dioxide sink. This is an expansive reaction which could disrupt the concrete, hence only small amounts of ECOncrete can be added, and this admixture also contains fly ash and burnt clay to control the expansion. This reaction with carbon dioxide might not occur underwater; a similar reaction between quicklime and carbon dioxide does not occur underwater.

The admixture supply is tailored for each project according to the proposed batching process, and can be shipped in small bags, one Ton bags, and in bulk depending on the project requirements.

Costs are project-dependent and there are currently no known instances where the ECOncrete has been applied in Australia to use as a point of comparison. High-level indications from the supplier indicate the increment on costs is in the range of 7-15% compared to "grey" concrete, although when factoring the additional expenditure of delivery of the admixture it is likely to be higher than this percentage.

In theory some of the of the Mooloolaba breakwater extensions concrete armour units that are not subject to licence holder controls (e.g. Antifer cubes) could contain this admixture to improve their ecological value. The units could also have roughened surfaces as shown above, but this will require special formwork linings. Due to neither the ECOncrete nor the ECO Armour cubes having a long track record in breakwaters, and the cost of the special formwork and admixture, we believe this is an expensive and somewhat risky option that we don't recommend.

CONSTRUCTABILITY CONSIDERATIONS

The installation of concrete units is similar to large rock armour, although greater care and precision is required during transport and placement of concrete than rock. An in-depth analysis of several rock armoured breakwater construction methods (i.e. land-based or water-based construction) is provided in the Constructability Report (BEJ952-TD-ST-REP-0001).

Casting

Construction of concrete armour units involves:

- Build a casting bed

- Build the moulds
- Concrete casting using form vibration,
- Stripping the formwork after initial hardening of the concrete (around 24 hours),
- Curing
- Removal from the casting bed

Lead times for the fabrication of concrete units are governed by the number of moulds and available casting and stockpile area. Casting can be undertaken anywhere that sufficient space and materials (cement, aggregate etc.) are available, and can facilitate transport to site, either by road or barge.

Casting yards may be located closer to site than the existing local quarries, provided that sufficient room is available. Casting on site does not appear feasible due to lack of space, and poor access for transit mixers.

For most concrete armour units, production rates are typically in the order of 1 unit per mould per day. On small-scale projects, only one mould is necessary provided that the production and transport is ahead of placement.

Transport to site

Transportation to site is similar to that of rock armour. As discussed in the Constructability Report (BEJ952-TD-ST-REP-0001) material may be delivered to site via one of a number of methods including:

1. Land-based via the local road network
2. Water-based with storage directly on barges
3. Water and land-based where material is delivered by barge to a material offloading facility established either close to the site (i.e. on the beach) or at a nearby boat ramp/offloading site. The armour units are then trucked in via the road network.

A land based transport method will require hundreds of truck movements. As identified in BEJ952-TD-ST-REP-0001, transporting large armour units (be it rock or concrete) via the Buddina road network is not ideal because of the potential damage to existing road infrastructure, relatively long haul (depending on the location of the casting yard), narrow access paths and high level of development along these suburban roads.

By comparison, concrete units are lighter and can be stacked for transport via barge, with fewer barge movements compared with rock. The units could be cast close to the Port of Brisbane, before loading and barging to Mooloolaba (as was proposed for rock). Only a few barges will be required.

Barging is more vulnerable to adverse weather than trucking, but placement of the units is not possible in bad weather either. There must be a cyclone and east coast low safety management plan. The second half of the year is dominated northerly winds which could interfere with construction due to the northerly exposure of the Mooloolaba breakwater. A weather monitoring program must be used to forecast and manage safe work practices.

Placement

The core material is placed and trimmed to the required slope. Then the geotextile filter blanket is rolled down the batter and quickly covered with a double layer of secondary armour rock before it get washed away. Finally, the primary armour material is placed. Underlayer rock will be can be obtained from local quarries, or from Mt Petrie depending on the quality and quantities available.

Most construction activities can be carried by land-based construction.

The construction of the breakwater could be carried out in stages, initially constructing the core from the landside out to the offshore area at a level that provides a workable platform for cranes and dump trucks just above high tide level. Some demolition of the crest of the existing breakwater will be required in order to create a splice between new and old. The filter materials and primary concrete armour would then be gradually placed from offshore landward. Temporary low level working platforms might be required for the construction of the breakwater toe

If the construction was undertaken from the water, then core placement via split hopper barges could be undertaken. A backhoe (either Backhoe dredge or a Backhoe mounted on a barge) would then be required to trim and shape the dumped material. It is likely faster and cheaper land-based construction would take over once the core has been built above high tide level

Some breakage of armor units can be expected if they are placed by floating plant in exposed locations (Hudson, 1974). For units where careful placement and interlocking is important, such as Xbloc or Core-loc units, placement from land is preferable to minimize breakage risks.

Timing

As a rough guide, construction is likely to take about 18 - 22 weeks excluding any allowances for weather down-time. This assessment is based on the following underlying assumptions:

- Material is readily available on site (or the rate of delivery to the site can support the placement rate)
- Placement of core and filter layers at a rate of ~2,000m3 per day assuming land-based construction. (i.e. a truck every 5 minutes)
- Placement of concrete armour units at a rate of 30 – 40 units per day (i.e. one unit every 5 minutes)
- Assuming approximately 3,000 concrete primary armour units are required to be delivered and placed (based on a double-layered tetrapod system).
- Placement rates are typical for an experienced contractor. For concrete armour units the placement rate is much slower initially and under water, but improves over time.
- Excludes the time taken for foundation preparation dredging works.

By adopting a single-layered system over a double-layered system, placement timing could be reduced by around 4 – 5 weeks.

REFERENCES

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Danel, P (1953) Coastal Engineering Proceedings 469. "The Tetrapod"

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https://www.xbloc.com/sites/default/files/domain-671/documents/xbloc-guidelines_2018-671-15329497302876383300.pdf

Hudson (1974) Concrete Armour Units for Protection Against Wave Attack

Main et al (2016) COFFS HARBOUR NORTHERN BREAKWATER – NOT YOUR AVERAGE UPGRADE

NSW Department of Environment and Climate Change (2009) Environmentally Friendly Seawalls: A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries
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Appendix D

Safety in Design

Assessment Activity: Safety in Design Assessment	Location: Mooloolaba Breakwater, Point Cartwright
Date of Assessment: 11/07/19	Assessment Team: personal information
Date of Re-Assessment:	Prepared By: personal information
General Comments Review and update register as required throughout the design process. It is assumed that further assessments will be carried out throughout the life of the project to identify any additional risks and to refine mitigation measures.	Reference No. 001

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
Construction	Land and sea-based construction site access – pedestrians/public risk. Public at risk of injury by machinery or construction activities.	Extensive injuries or fatality.	5	2	M	Secure the area to minimise public interactions as far as reasonable during construction.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification. Treatments will depend on the Contract and Contractor's work method.
Construction	Personnel and visitors not being aware of hazards on site (both land and sea-based).	Significant injury or fatality.	5	3	H	No public access will be available during construction. Site access restrictions are to be implemented. Tenderer/Contractor is required to prepare a Work Health and Safety Management Plan for inclusion in the tender documentation or technical specification during detailed design to address hazards specific to the Works.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification. Treatments will depend on the Contract and Contractor's intended work method.

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
						All personnel and visitors to the site required to undergo a site-specific safety induction and wear appropriate Personal Protective Equipment (PPE).		
Construction	Site access for construction poses some difficulties for large and heavy machines.	Significant injury or fatality.	5	3	H	Contractor shall be required to prepare a Work Health and Safety Management Plan to address hazards specific to the works including risk of over-water construction. For land-based construction, contractor shall be required to install temporary water filled barriers lining pathways adjacent to waterways subject to truck haulage. Adequate area for vehicle manoeuvring shall be provided within project constraints. Recommended that the following is included in technical specifications: • Preparation and implementation of a JHA/SWMS required for all works. • Machine operator must be suitably qualified and experienced in the activity (to be assessed during tender phase).	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification. Treatment measures will depend on the Contract and Contractor's work method.
Construction	Handling of heavy construction materials (e.g., rock armour) from floating barge or land-based cranes/excavators – drowning or crushing risk.	Significant injury; risk of drowning or fatality.	5	3	H	Contractor shall be required to prepare a Work Health and Safety Management Plan to address hazards specific to the works including risk of over-water construction. Works shall be undertaken by competent and qualified operators. Recommended that the following is included in technical specifications: • Preparation and implementation of a JHA/SWMS required for all works. • Machine operator must be suitably qualified and experienced in the activity.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification. Treatment measures will depend on the Contract and Contractor's intended work method. Contractor staff to wear appropriate PPE (self-inflating vests) where identified in SWMS.

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
Construction / maintenance	Construction near or over water – drowning risk.	Personnel falling into water and drowning.	5	3	H	Contractor to develop and implement SWMS. Contractor staff to wear appropriate PPE (self-inflating vests) where identified in SWMS. Contractor personnel must be suitably qualified and experienced in the activity.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification. Contractor to implement site specific worksite inductions, develop and implement SWMS and wear appropriate PPE.
Construction	Increased traffic movements between sites with heavy vehicles increases risk of collision.	Significant injury or fatality.	5	3	H	TMR to notify residents of the increased traffic movements and associated hazards through consultation during the design process. Roads or public access may need to be restricted or closed. Depending on chosen construction method, car-parks and/or boat ramps may also require closure. The requirement for a Traffic Management Plan is to be included in tender documentation or technical specification during detailed design. Contractor to identify Traffic hazards and Traffic control measures to be implemented. Contractor to implement timing limitations on construction activities (e.g., restrict heavy vehicle movement during school holidays). Contractor is required to consider and limit impacts to nearby community infrastructure and stakeholders (e.g., sporting grounds, shopping centres, schools, boat ramps, parks).	M	STATUS: Active Consultation with residents required to notify of traffic changes. Risk treatments to be addressed by Contractor in preparing Technical Specification. Treatments will depend on the Contract and Contractor's intended work method to be considered at tender stage.
Construction	Pre-dredging sand material – use of suction dredge in potentially dangerous surf conditions.	Significant injury; risk of drowning or fatality.	5	5	C	Avoid conducting works over November – April to reduce likelihood of subjection to cyclone conditions and storms. Contractor to develop and implement SWMS.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification.

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
						Contractor staff to wear appropriate PPE (self-inflating vests) where identified in SWMS. Contractor personnel must be suitably qualified and experienced in the activity.		Contractor to implement site specific worksite inductions, develop and implement SWMS and wear appropriate PPE.
Construction	Unstable slopes – rock stockpiles – crushing risk.	Significant injury or fatality.	5	3	H	Secure the rock pile away to minimise public interactions as far as reasonable during construction. Contractors and sub-contractors to follow CEMP and SWMS. Public consultation and notice to mariners.	M	STATUS: Active Stockpile to be in an exclusion zone and not near public areas. Contractors and sub-contractors to follow CEMP and SWMS. Public consultation and notice to mariners.
Construction	Adverse weather, including storms, high wind events and exceptionally high tides.	Significant injury; risk of drowning or fatality.	5	4	C	Suitable procedures to be put in place during construction to monitor storms and secure the partially structures against damage in the event a storm is anticipated to affect the works. Avoid conducting works over November – April to reduce likelihood of subjection to cyclone conditions and storms. The following treatments to be incorporated in project technical specification by detailed designers and is to be assessed at tender stage: • Tenderer/Contractor to nominate intended work method for construction at the site. • Construction to be completed in stages where practical to prevent exposure of partially constructed structure/revetment during construction. • Tenderers to be familiar with site conditions and have prior experience in similar construction projects.	M	STATUS: Active Construction treatments will depend on the Contract and Contractor's intended work method. Consultation with stakeholders may be required to notify of construction hazards associated with carrying out work during high storm event risk period.
Construction / maintenance	Altered marine navigation approaches – vessel collision risk (partially built submerged	Significant injury; risk of drowning or fatality.	5	3	M	Contractor to issue a notice to mariners to declare obstacles during construction/maintenance.	2	STATUS: Active

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
	breakwater, barges and cranes).					Contractor to use temporary navigation markers/buoys during construction/maintenance. Low likelihood as mariners are familiar with mooring of dredge equipment at Mooloolah River entrance, with sufficient width for marine traffic.		Contractor to issue notice to mariners for navigational hazards. Contractor to install navigational markers/buoys to delineate possible navigational hazards. Contractor to consult Harbour Master to seek advice for temporary construction works.
Construction / maintenance	UV exposure.	Minor injury – sunburn, heatstroke	2	5	H	Contractor staff to wear appropriate PPE (hats, long sleeve shirts, plants, sunscreen, and eyewear) where identified in SWMS.	L	STATUS: Active Contractors and sub-contractors to follow CEMP and SWMS.
Construction	Inferior products/materials utilised in construction which may deteriorate over life of the project.	Significant injury; crushing risk, risk of drowning or fatality.	5	3	H	Inspections and hold points to be incorporated in project technical specification. Construction supervision required to ensure material compliance with relevant standards and project specifications.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification. TMR to ensure appropriate construction supervision is implemented.
Construction	Location of services, including any underground and overhead power cables is unknown.	Risk of electrocution causing significant injury or fatality.	5	2	M	Services location survey to be carried out during detailed design process. The following treatments to be incorporated in project technical specification and is to be assessed at tender stage: • The Contractor shall ascertain from the appropriate Authorities the position and the depth/height of all public utility or other services which may be affected during the works.	M	STATUS: Active TMR to consider services location survey in future design stage. Requirement for Contractors to identify location of services to be addressed by Contractor in preparing Technical Specification.
Construction / decommissioning	Hot works – UV burns including to eyes. Burns due to heat. Gas cylinders containing	Serious injury/lost time injury or fatality	5	2	M	Contractor/sub-contractor to develop and implement SWMS concerning welding work and cutting, including the use of qualified technicians and appropriate PPE.	M	STATUS: Active Contractors and sub-contractors to follow CEMP and SWMS.

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
	explosive gases. Explosion of leaked gases.							
Construction / maintenance	Environmental contamination / spillage causing harmful impacts to marine flora.	Fauna death/injury, environmental damage or incident, pollution.	4	5	C	Contractor to actively implement pollution controls for the existing environment (e.g., pollution control booms, construction waste management, localised spill kits). Designer to consider measures to reduce environmental impact through space planning.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification.
Construction	Fall from height resulting in injury and death. For example, falling from top of breakwater onto underlying rocks.	Significant injury or fatality.	5	4	C	Safety barriers, contractors to exercise minimum of three-points of contact at all times, fall restraint harness, safety inductions. Contractor / sub-contractor to implement training and use competent and qualified personnel.	M	STATUS: Active Contractors and sub-contractors to follow CEMP and SWMS. Risk treatments to be addressed by Contractor in preparing Technical Specification.
Construction / maintenance	Contact or exposure to hazardous materials; working with flammable / combustible materials (e.g., fuel).	Serious injury/lost time injury	5	2	M	Restrict access to hazardous materials to qualified personnel and provide PPE. Maintain various piping connections (fuel) and ensure safe methods are practiced.	M	STATUS: Active Contractors and sub-contractors to follow CEMP and SWMS.
Construction / maintenance	Over-night collision of water vehicle with breakwater and/or equipment during construction or maintenance.	Significant injury; Risk of drowning or fatality.	5	4	C	Proper lighting during construction and life of structure, notice to mariners of works and potential hazards, harbour master approval of breakwater and construction site boundaries, frequent inspections to ensure lighting is working.	M	STATUS: Active Contractors and sub-contractors to follow CEMP and SWMS. Risk treatments to be addressed by Contractor in preparing Technical Specification.
Construction / maintenance	Impact from drifting boats during severe weather events.	Significant injury; Risk of drowning or fatality.	5	4	C	Contractor shall have a spotter during severe weather events and a service boat equipped for towing/pushing if required.	M	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification.

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
Maintenance	Solar lighting maintenance – working at heights risk.	Permanent disability or fatality.	5	2	M	Contractor to minimise frequency of maintenance through appropriate design (e.g., long-life bulbs/LED). Contractor to use collapsible lighting posts wherever appropriate. Contractor to ensure fittings have appropriate safeguards against electrocution by meeting appropriate Australian Standards. Contractor to develop implement appropriate SWMS for maintenance activity prior to conducting maintenance. Use only appropriately trained/experienced staff to conduct maintenance.	L	STATUS: Active Risk treatments to be addressed by Contractor in preparing Technical Specification.
Maintenance	Condition inspections of breakwater including underwater areas risks injury to inspectors.	Serious injury/lost time injury	3	2	M	Designer to consider condition inspection and assessment during design phase. Consider remote methods for inspections (i.e., laser scan/drones + multibeam survey). Develop implement appropriate SWMS for maintenance inspection activity prior to conducting maintenance	L	STATUS: Active Contractor/TMR to consider remote inspection methods and develop and implement SWMS for maintenance/condition inspections.
In service	Wave overtopping – pedestrians swept off their feet and/or swept off breakwater into water.	Significant injury; Risk of drowning or fatality.	5	5	C	Allow visibility of the ocean where practicable. Design crest elevation to account for pedestrian access during 1-year ARI wave event and subsequent overtopping. Signs to warn pedestrians that breakwater can be overtopped and don't enter during storms/large wave events.	L	STATUS: Active Design to be safe during 1 year ARI event. Signage to warn of risks for more severe events.
In service	Risk of people climbing breakwater / jumping from breakwater.	Significant injury; risk of drowning or fatality.	5	5	C	Signage to be erected to notify of shallow water hazards and deter people from climbing/jumping.	H	STATUS: Active Contractor to ensure life ring and appropriate signage

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
						A life ring mounted on a stand shall be provided on the breakwater head.		requirements are captured in technical specification.
In service	Risk of fishermen falling from breakwater/swept away by waves.	Significant injury; risk of drowning or fatality.	5	5	C	Signage to be erected to notify of hazards and discourage users to access breakwater rocks. Bolted harness locations or fishing rod holders to encourage fishermen to fish from locations where it is safer to do so. A life ring mounted on a stand shall be provided on the breakwater head.	H	STATUS: Active Contractor to ensure life ring and appropriate signage requirements are captured in technical specification.
In service	Pedestrians using breakwater during an earthquake may be unsafe. Prior warning to evacuate is not possible.	Significant injury	2	1	L	As per AS 1170.4-2007 the likelihood and earthquake intensity in Sunshine Coast Region is low and wave loads govern the design. Combined probability that earthquakes and waves occur at the same time as maximum wave loading extremely low. Design for maximum wave loads to ensure breakwater stability.	L	STATUS: Active Contractor to design for maximum wave loads to ensure breakwater stability.
In service	Vessel berthing – potential catastrophic damage to vessel.	Significant injury; Risk of drowning or fatality.	5	4	C	Deter vessels from docking at breakwater with the use of appropriate signage and absence of mooring berths/ladders. Installation of speed limit signage. Installation of appropriate lighting to delineate a navigation obstruction.	H	STATUS: Active Appropriate signage to deter vessel berthing and impose speed limits in proximity of jetty to be addressed by TMR. Public consultation and notice to mariners.
In service	UV exposure.	Insignificant first aid treatment.	2	5	H	Signage to remind public to use adequate protection to sun exposure.	L	STATUS: Active TMR to consider appropriate signage to advise public to use adequate sun protection.
In service	Solar lighting failure – Marine navigation lights – vessel collision risk.	Extensive injuries.	5	4	C	Design with safety and redundancy and provide adequate reflective surfaces on the breakwater. Maintain lighting to minimise reliability issues.	L	STATUS: Active Contractor to incorporate sufficient redundancy/factor of

Activity	Hazard	Maximum credible hazard impact	Consequence	Likelihood	Risk	Risk treatment strategies	Residual Risk	Comments
						Installation of bird-deterrent measures around lighting solar panels as per MRTS98.		safety to ensure sufficient reliability. Contractor to seek to incorporate reflective (night-time) treatments on breakwater. Contractor to install anti-roosting measures around lighting solar panels. TMR to maintain lighting to minimise reliability issues. TMR to update marine navigation charts to be issued together with associated notices to mariners. TMR to implement navigational speed limits to reduce vessel speeds.
In service	Solar lighting failure – Land – based lights - slip/trip/fall risk.	Medical treatment.	3	2	M	Design to minimise risk. Maintain lighting to minimise likelihood of lighting failure.	L	STATUS: Active Contractor to meet requirements of appropriate design standard and Specifications. TMR to conduct lighting maintenance and replacement in accordance with operation and maintenance manual / manufacturers recommendations.

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AUSTRALIAN HEALTH AND SAFETY RISK ANALYSIS

What is reasonably practicable in ensuring health and safety

AsinallAustralianWHSLegislation–reasonablypracticable,inrelationtoadutytoensurehealthand safety,meansthatwhichis,orwasataparticulartime,reasonablyabletobedoneinrelationtoensuring health and safety, taking into account and weighing up all relevant matters including –

(a) the likelihood of the hazard or the risk concerned occurring; and

(b) the degree of harm that might result from the hazard or the risk; and

(c) what the person concerned knows, or ought reasonably to know, about—

(i) the hazard or the risk; and

(ii) ways of eliminating or minimising the risk; and

(d) the availability and suitability of ways to eliminate or minimise the risk; and

(e)afterassessingtheextentoftheriskandtheavailablewaysofeliminatingorminimising therisk,thecostassociatedwithavailablewaysofeliminatingorminimisingtherisk,including whether the cost is grossly disproportionate to the risk.

	POTENTIAL CONSEQUENCES				LIKELIHOOD RATING				
CONSEQUENCE	PERSONNEL	ENVIRONMENT	REPUTATION	PROPERTY	RARE Expected to occur > 30 years	UNLIKELY Expected to occur 10-30 years	POSSIBLE Expected to occur 3-10 years	PROBABLE Expected to occur 1-3 years	CERTAIN Expected to occur < 1 year
SLIGHT	Minor injury or illness (e.g. simple First Aid)	Slight site impact No impact on the environment	Slight, local, easily repairable damage	Slight damage $0-$10,000 USD	MINOR	MINOR	MINOR	MINOR	MODERATE
MINOR	Medical treatment, some work restrictions	Minor local impact Restoration in 1 day	Localised short term repairable damage	Minor damage $10,000-$100,000USD	MINOR	MINOR	MODERATE	MODERATE	HIGH
MODERATE	Short-term disability (e.g. restricted work)	Short term or controllable damage Restoration within 1 day to 1 month	Localised long term damagebutrepairable	Local damage $100,000-$1,000,000 USD	MINOR	MODERATE	MODERATE	HIGH	HIGH
MAJOR	Major injury or impairment (e.g. serious loss)	Medium term damage or effect upon natural environment Restoration expected 1 month to 2 years	Localised long term majordamageunmanageable	Major damage $1,000,000-$10,000,000 USD	MINOR	MODERATE	HIGH	HIGH	CRITICAL
EXTENSIVE	Fatality or extensive irreversible illness	Long term damage or effect upon natural environment Restoration > 2 years	Long term regional damage	Extensive Damage >$10,000,000 USD	MODERATE	HIGH	HIGH	CRITICAL	CRITICAL

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AUSTRALIAN HEALTH AND SAFETY RISK ANALYSIS

Control Measure Criteria

RISK LEVEL	CONTROL MEASURE
(red)	Unacceptable Risk: Risk reducing measures must be taken before commencing activity
(orange)	Acceptable Risk: Project work activity may proceed following REVIEW and APPROVAL by the Project Sponsor prior to starting work; after all practicable risk-reducing measures have been taken. For state office activities, review is required by the Director Operations and Senior Manager HSE prior to starting work.
(yellow)	Acceptable Risk: Project work activity may proceed following REVIEW and APPROVAL by the Project Sponsor prior to starting work; after all practicable risk-reducing measures have been taken. For state office activities, review is required by the location Market Sector Manager and/ or Operations Manager prior to starting work.
(green)	Acceptable Risk: Work activity may proceed.

Likelihood table

LIKELIHOOD	LIKELIHOOD DESCRIPTION	FREQUENCY
RARE	Heard of something like that occurring elsewhere. Only in exceptional circumstances	Expected to occur > 30 years
UNLIKELY	The event does occur somewhere from time to time. Not likely to occur	Expected to occur every 10-30 years
POSSIBLE	The event might occur once in your career. Could occur 50/50 chance	Expected to occur every 3-10 years
PROBABLE	The event has occurred several times or more	Expected to occur every 1-3 years
CERTAIN	The consequence expected to occur on an annual basis	Expected to occur < 1 year

Maximum Credible Hazard Impact

The maximum credible hazard impact is based on the maximum reasonable consequence and the likelihood of that consequence occurring.

The maximum reasonable consequence is the largest realistic or credible consequence from and event, considering the credible failure of controls. It is generally a higher consequence than the "most likely" consequence and less severe than the "worst case" consequence, which considers the failure of all controls.

Hierarchy of controls

Elimination: Eliminating hazardous plant, processes and toxic substances that are not necessary to a system of work.

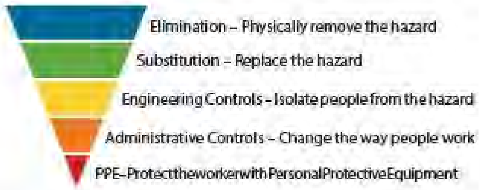
Substitution: Substituting a hazardous process, piece of plant or toxic substance with one known to be less harmful to health.

Isolation: Enclosing or isolating a hazard from employees.

Engineering: Changing processes, equipment or tools.

Administrative Changing work procedures to reduce exposure to existing hazards.

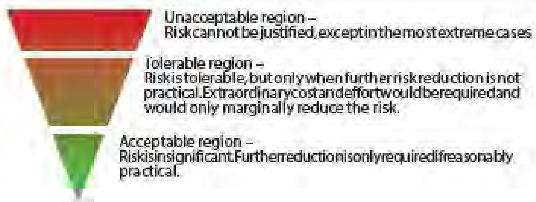
Personal Protective Equipment: Devices and clothing, which provide individual employee with some protection from hazards.



ALARP (As Low As Reasonably Practicable) Model

Risk acceptance criteria that can form part of the risk evaluation is 'as low as reasonably practicable or ALARP'. There are some levels of risk that are not acceptable under any circumstances (red section) and those that are very low that do newarrant further considerations (green section).

The level of risk between these levels should be treated as per regulatory requirements that defines 'reasonably practicable'. (AS31000:2009 Risk Management Guidelines; Handbook HB436:2013, Appendix C).



Consequence	Likelihood Rating				
	1 Rare	2 Unlikely	3 Possible	4 Probable	5 Certain
1 - Slight	LOW	LOW	LOW	LOW	MODERATE
2 - Minor	LOW	LOW	MODERATE	MODERATE	HIGH
3 - Moderate	LOW	MODERATE	MODERATE	MODERATE	HIGH
4 - Major	LOW	MODERATE	HIGH	HIGH	CRITICAL
5 - Extensive	MODERATE	MODERATE	HIGH	CRITICAL	CRITICAL

NOTE: Items highlighted above that are deemed to have a SIGNIFICANT RESIDUAL RISK should be communicated on the drawings and in asset owner's maintenance manual as appropriate.

An example SHE (Safety, Health and Environment) Box that can be included on drawings is shown below;

SAFETY HEALTH AND ENVIRONMENTAL INFORMATION
In addition to the hazards normally associated with the types of work detailed on this drawing, note the following risks and information:
It is assumed works will be carried out by a competent contractor working, where appropriate to an approved method statement