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DEVELOPMENT APPROVAL

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Queensland Government

Redland CITY COUNCIL

DRAFT DESIGN REPORT

Foreshore Protection Esplanade (Moores Rd), Redland Bay

Project Number

44692-2

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Document Status

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1 Introduction

JBP is undertaking the detailed design of foreshore protection works at Moores Road in Redland Bay following emergency stabilisation works completed in June 2025. The foreshore at this location has experienced ongoing coastal erosion which is threatening nearby infrastructure including Esplanade Road, carparks, utilities and public access areas.

The purpose of this design project is to develop a long-term engineered solution to stabilise the foreshore, formalise the temporary protection works and ensure the protection of Council assets while maintaining the environmental and recreational values of the area.

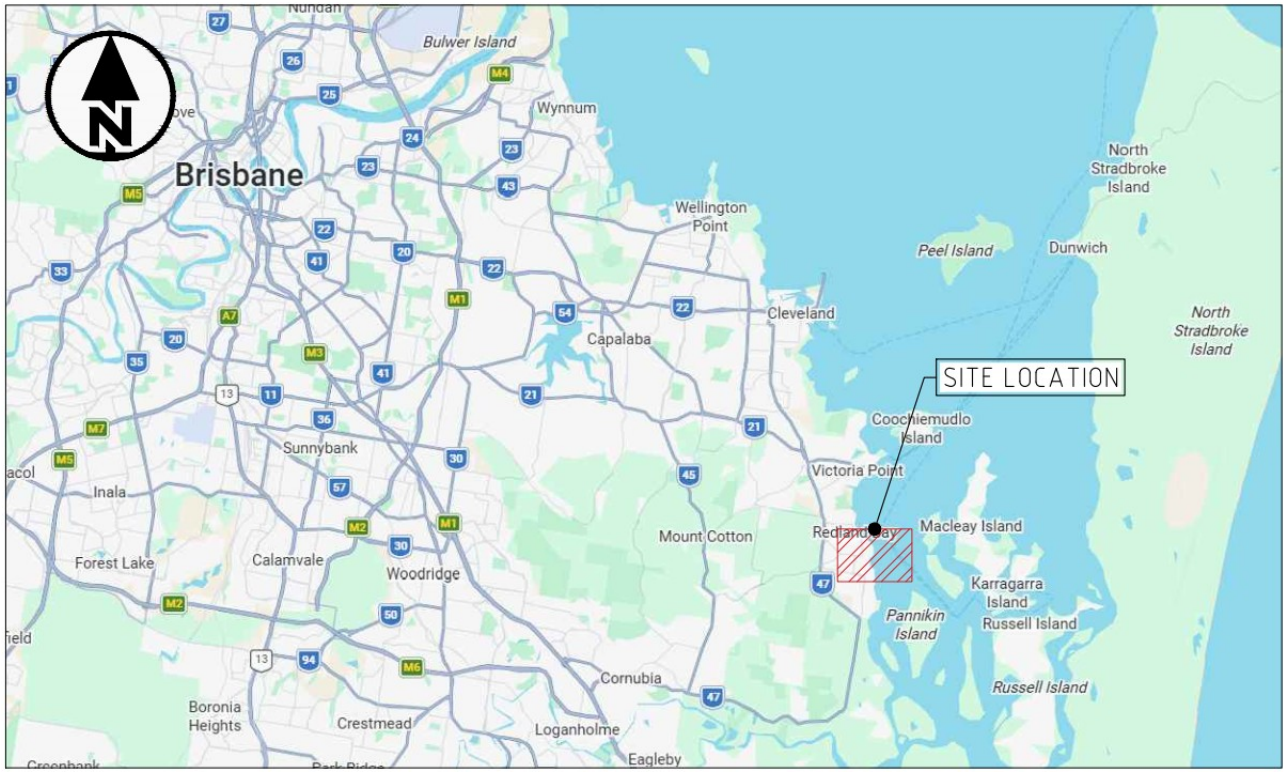


Figure 1-1: Site location

1.1 Project Description

The project involves the design of permanent foreshore protection works along the shoreline adjacent to Moores Road and The Esplanade in Redland Bay, Queensland. The site has experienced progressive coastal erosion requiring temporary emergency rock protection works in 2025 to stabilise the foreshore.

A key project constraint is the presence of cultural heritage sensitivities within the foreshore area. Accordingly, both the emergency protection works and permanent foreshore protection solution have been developed in accordance with a no-dig design philosophy to minimise disturbance of existing ground and avoid excavation within culturally sensitive areas.

This report presents the detailed design of a long-term engineered coastal protection structure to formalise and extend the existing emergency protection works. The design aims to stabilise the foreshore, protect adjacent infrastructure, and maintain the safety and accessibility of the area for the local community, while considering environmental, cultural heritage and planning constraints associated with the site.

The permanent foreshore protection works have been developed to incorporate the existing emergency rock protection installed in June 2025. The emergency works were designed as an interim stabilisation measure that could be incorporated into the future permanent works and are intended to form an integral component of the completed structure, functioning as the underlying filter layer beneath the permanent armour rock revetment.

1.2 Design Objectives

The primary objectives of the design are:

- Provide a long-term engineered foreshore protection structure extending and formalising the existing emergency rock protection.
- Protect existing Council infrastructure and public assets, including roads, carparks and utilities.
- Improve safety and accessibility for community users of the foreshore area. Minimise impacts on coastal processes and the visual amenity of the foreshore where practicable.
- Ensure compliance with relevant planning, environmental and cultural heritage requirements.

1.3 Design Stages

The design services for the project are divided into the following stages:

- Stage 1 – Geotechnical Investigation
- Stage 2 – Detailed Design
- Stage 3 – Permits, Applications and Approvals
- Stage 4 – Issued for Construction (IFC) Design

These stages progressively develop the concept solution into a fully detailed and certified design suitable regulatory approval and for construction.

1.4 Limits of Study Area

The study area comprises the foreshore section adjacent to Moores Road and The Esplanade in Redland Bay. The limits of the project extend along the section of shoreline where erosion has occurred and where emergency rock protection works were installed in June 2025.

The study area includes the immediate foreshore, the crest of the coastal bank and the adjacent infrastructure potentially affected by coastal erosion, including road and public access areas. The project location is illustrated in Figure 1-1.

1.5 Adopted Methodology

To achieve the project objectives, the following methodology has been adopted:

- Initial project briefing and ongoing liaison with Redland City Council and key stakeholders.
- Desktop review of available information including emergency works documentation, planning constraints and existing data.
- Site inspection and visual assessment of the foreshore conditions and existing protection works.
- Completion of a geotechnical investigation including boreholes, in-situ testing and laboratory testing to determine subsurface conditions.

- Development of detailed design drawings including plans, sections and typical cross-sections of the foreshore protection structure.
- Preparation of supporting design documentation including design report, safety in design assessment and cost estimates.
- Consultation and coordination with relevant stakeholders and authorities.
- Preparation and lodgement of permit and approval applications where required.
- Finalisation of Issued for Construction (IFC) drawings, specifications and documentation.

2 Data Collection

The required input data for the design is split into five main categories:

- Datum
- Existing utilities
- Topographic data
- Geotechnical data
- Geology data
- Vegetation
- Historical data
- Hydraulic data.

2.1 Datum

All elevation/depth measurements used throughout the project are quoted to metres Australian Height Datum (mAHD).

2.1.1 Horizontal grid

All coordinates used throughout the project are quoted in metres, easting and northing to MGA Zone 56.

2.2 Existing Utilities

This section lists the existing utilities identified through RCC supplied survey and Before You Dig Australia:

- In proximity but not within the site:
    - Overhead electricity cables
    - Communication cables (NBN CO. and Telstra asset).

2.3 Topographic Survey

The detailed design was developed based on the survey data provided by RCC as part of this commission. It is assumed that these levels will not change significantly before construction.

2.3.1 Property data

Cadastre property boundaries were provided by the RCC survey data.

2.3.2 Services

As part of the design phase, JBP has undertaken a Dial Before You Dig (BYDA) search to identify existing underground utilities. No communication or electrical cables were identified within the site in the BYDA results.

The risk of encountering undocumented services is considered low based on the site conditions and existing information.

Overhead powerlines are located near the site boundary but are not expected to be directly impacted by the proposed works. Nonetheless, the contractor will be required to submit a Safe Work Method Statement (SWMS) addressing overhead service risks, as specified in JBP's technical specification documentation.

2.4 Geotechnical Investigation

A geotechnical investigation (GI) was conducted by PDC Geotechnical in 2026.

The investigation comprised drilling of three boreholes (BH1 to BH3) along the crest of the foreshore bank to depths of 6.0 m below ground level (BGL), together with in-situ strength testing and laboratory testing.

Subsurface conditions encountered in the boreholes can be summarised as follows:

- Topsoil – an upper layer of silty sand with some organics, typically about 100 mm thick; overlying
- Fill – medium dense to dense clayey sand fill, generally extending to depths of approximately 0.3 m to 0.6 m BGL; underlain by
- Residual Soil – very stiff to hard silty and gravelly clays of high plasticity (residual basaltic clays), encountered from below the fill to the borehole termination depths of 6.0 m BGL in all boreholes.

In addition, dynamic cone penetrometer (DCP) testing undertaken along the intertidal beach area below the seawall alignment indicated the presence of soft to firm or loose materials to depths of approximately 1.5 m BGL in the northern and central sections of the site, underlain by stiff to dense materials at greater depths. In the southern extent of the site, shallow refusal was recorded on hard to very dense basaltic duricrust at depths of approximately 0.3 m BGL.

Groundwater seepage was encountered in boreholes BH1 and BH2 at depths of approximately 2.2 m and 2.8 m BGL, respectively. Groundwater levels are expected to correlate with tidal levels in Redland Bay and may fluctuate depending on tidal cycles, seasonal conditions, and rainfall events.

2.5 Geology

The geological context of the site is characterized by the regional Petrie Formation, comprising sedimentary rock with notable deposits of Olivine Basalt, identified as ferricrete/ironstone substrate through geotechnical assessments in the Southern Moreton Bay Islands. The site's geology predominantly consists of Palaeocene-age material overlain by Quaternary and Holocene alluvial and unconsolidated deposits. The regional geology, illustrated in Figure 2-1 includes four primary units:

- Tpb: Late Palaeocene to early Eocene Olivine Basalt.
- Qa: Early Quaternary clay, silt, sand, gravel, and floodplain alluvium.
- Qhct: Holocene sediments of coastal tidal flats, mangrove flats, supratidal flats, saltpans, and grasslands.
- Qhm: Holocene sand, muddy sand, sandy mud, mud, and modern marine sediments.

This stratigraphy underpins the site's geological framework and informs its geotechnical characteristics.

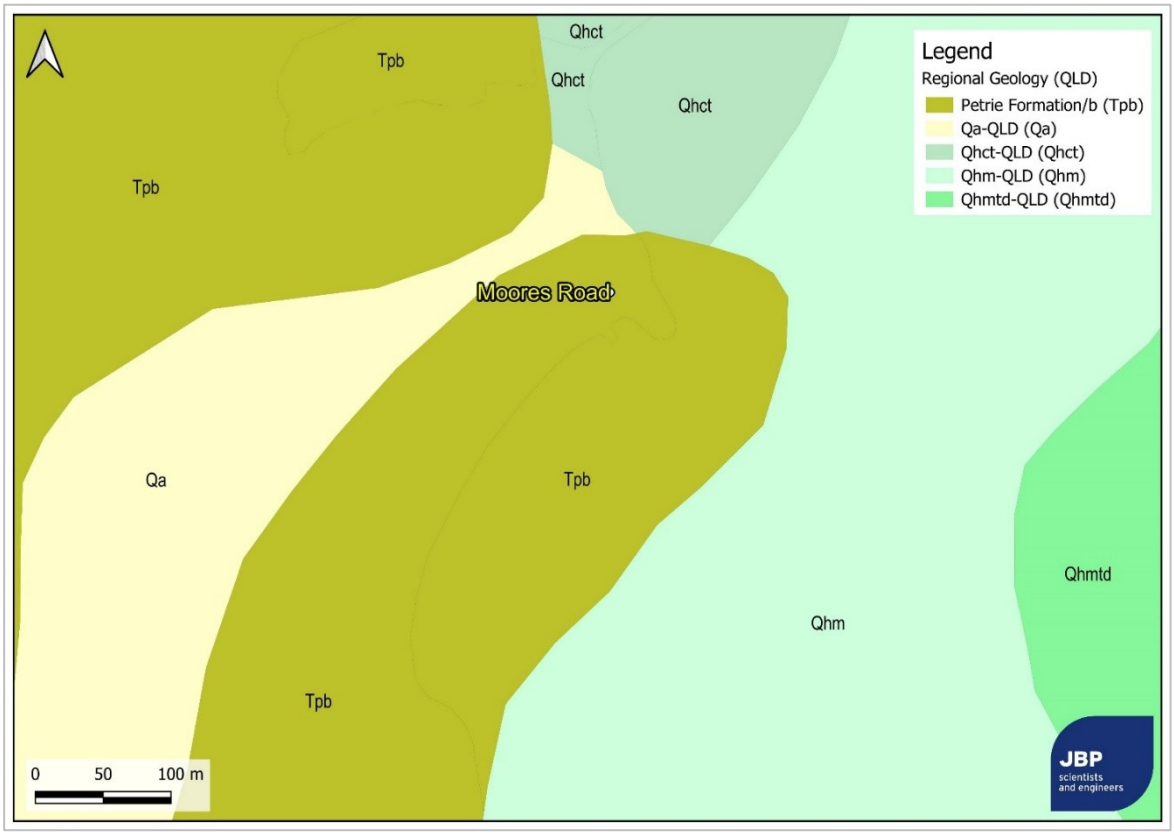


Figure 2-1 Regional Geological Map (Source: Queensland Globe)

2.6 Vegetation

The dominant vegetation class in the area comprises open forest eucalypt species on remnant tertiary surfaces. However, site inspections revealed minimal vegetation, limited to a row of eucalypt and she-oak (Casuarina sp.) species along the roadside. Vegetation mapping by the Department of Environment, Land, and Water (ELW) identifies two primary vegetation groups at the site (Figure 3 10):

- Mangroves and saltmarshes
- Moist to dry eucalypt open forests to woodlands, typically found on coastal lowlands and ranges.



Figure 2-2 Broad Vegetation Mapping (BVM) (Source: Queensland Globe).

2.7 Historical changes in shoreline and bathymetry

A trend of shoreline erosion can be observed across the length of the site, and can be observed as up to -1 m per year (Figure 2-3 and Figure 2-4). Only a few locations recorded negligible changes.



Figure 2-3 Moores Road - Intertidal Bathymetry; Rate of Shoreline Change (1988 - 2023) (Geoscience Australia). From CPS Foreshore Protection project.



Figure 2-4 Moores Road - Annual Shoreline Extent (1988 - 2023) (Geoscience Australia). From CPS Foreshore Protection project.

2.8 Hydraulic data

2.8.1 Tides and climate change

Tidal plane data, sourced from the Queensland Tide Tables for Redland Bay 2026, has been adjusted to mAHD using the Permanent Survey Mark. Climate change allowances have been included in tide levels. Current projections are based on the Intergovernmental Panel on Climate Change (IPCC) within their Sixth Assessment Report (AR6). This includes a range of Shared Social Economic Pathways (SSP) that account for different emissions scenarios (WG1 of IPCC, 2021)[1]. Figure 2-5 shows the projected sea level rise under SSP5-8.5 relative to a 1995-2014 baseline, under different certainty bands. Adopting the SSP5-8.5, 50th percentile (median) projections for Moores Road, the anticipated sea level rise is:

- 2026: +0.08 (Anticipated construction)
- 2076: +0.39 m
- 2100: +0.69 m

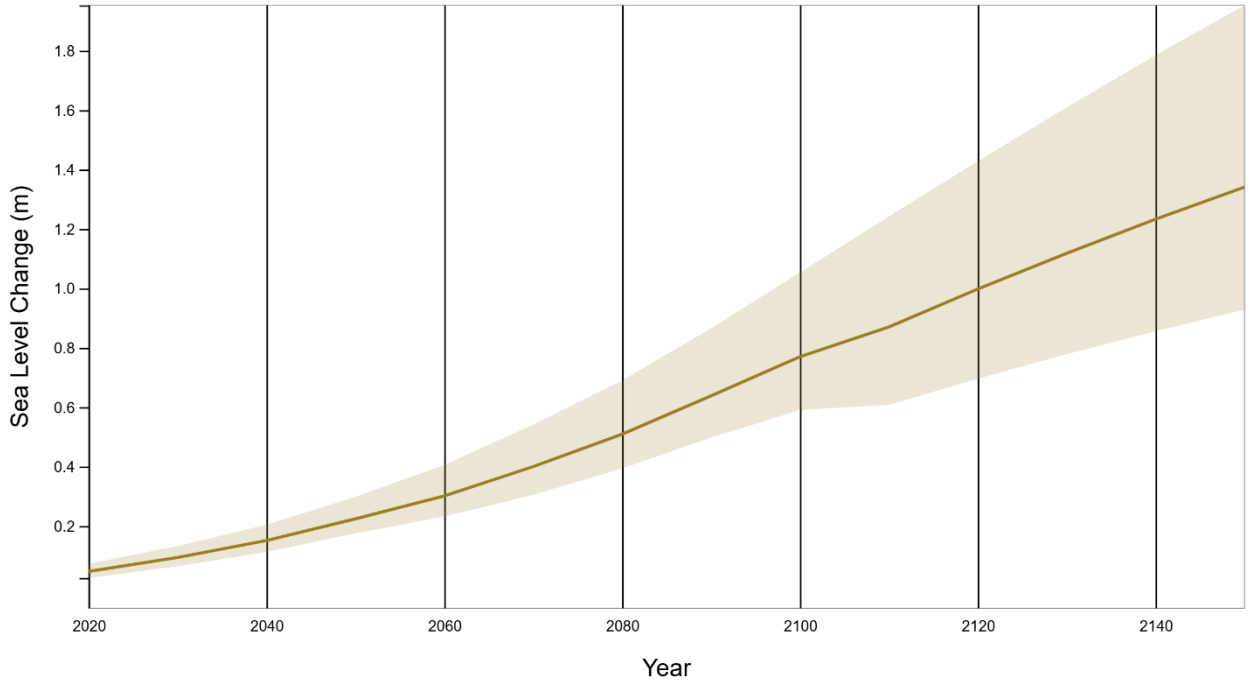


Figure 2-5 Projected Sea Level Rise under SSP5-8.5 – relative to 1995-2014 baseline (IPCC 6AR).

Table 2-1: Moores Road tidal data (PMS Ref 42645)

Tide level	2026 (mLAT)	2026 (mAHD)*	2076 (mAHD)	2100 (mAHD)
HAT	3.03	1.70	2.09	2.39
MHWS	2.42	1.09	1.48	1.78

1 Fox-Kemper, B., H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, A. B. A. Slangen, Y. Yu, 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In press.

MHWN	2	0.67	1.06	1.36
MSL	1.4	0.07	0.46	0.76
MLWN	0.88	-0.45	-0.06	0.24
MLWS	0.46	-0.87	-0.48	-0.18
PSM42645	3.485	2.15	2.54	2.85
AHD	1.33	0.00	0.39	0.69
LAT	0	-1.33	-0.94	-0.64
*: AHD quoted based on PSM42645.				

2.8.2 Extreme sea levels

Extreme sea levels increase to 2.36 mAHD for a 500-year event, and the anticipated sea level rise is expected to increase tide and extreme sea levels by +0.77m by 2100. This sea level rise will cause more wind-generated waves to break against the exposed bank during high tides.

Extreme sea levels are available from the Redlands Storm Tide Hazard Study (Cardno, 2011). These are summarised in Table 2-2 for Redland-032, which has been identified as the closest output point to the site. No sea level adjustment has been used.

Table 2-2 Moores Road Extreme Sea levels (Redland 032)

Horizon	Return Period	ESL (inc wave setup)	ESL (exc wave setup) mAHD	Wave runup (2% - beach) m	Wave runup (2% - rev't) m
2011	20	2.14	2.06	2.44	3.26
2011	50	2.22	2.14	2.58	3.40
2011	100	2.29	2.21	2.67	3.49
2011	200	2.36	2.27	2.77	3.59
2011	500	2.49	2.36	2.90	3.72
2011	1000	2.58	2.45	2.99	3.81
2011	10000	2.91	2.78	3.32	4.14
2100	20	2.16	2.04	2.55	3.31
2100	50	2.35	2.22	2.74	3.57
2100	100	2.48	2.35	2.87	3.70
2100	200	2.61	2.48	3.08	3.95
2100	500	2.78	2.65	3.25	4.12
2100	1000	2.91	2.78	3.38	4.25
2100	10000	3.34	3.21	3.81	4.68

Table 2-3 Moores Road Design Extreme Sea levels (interpolated)

Epoch [year]	Return Period	ESL (exc wave setup) [mAHD]	ESL (incl wave setup) [mAHD]
2026	500	2.41	2.54
2076	500	2.57	2.70
2100	500	2.65	2.78

2.8.3 Extreme wave conditions

Wave conditions are most likely during winds blowing between ENE to SE, where the fetch extends to ~2.6km. Table 2-4 shows extreme wave conditions available from the Redlands Storm Tide Hazard Study (Cardno, 2011) for Redland-032, which is considered to have a representative fetch and wave climate to the site. New seasonal wave estimates have been added, based on a 1 in 1-year extreme wind speed derived the Australian wind standard AS 1170, sustained over 1-hour. Wave conditions for the 1-year event are based on equations developed within the Joint North Sea Wave Project (JONSWAP) as presented in Kamphuis (2000). Future wave conditions are based on Cardno (2011) with a scaling factor applied for the 1 in 1-year, based on the growth trends shown in the Cardno 20-year wave scenario.

Table 2-4 Moores Road Extreme Wave Conditions (JONSWAP & Cardno, 2011)

Horizon	Return Period	Fetch (km)	1-hour windspeed, Ut (m/s)	Wave Height, Hs (m)	Wave Period, Tp/Tz (s)	Dir, Deg (oN)
2011	1	2.64	7.89	0.21	1.72	114.00
2011	20	Adopted from Cardno (2011)		0.54	2.00	114.00
2011	50			0.55	2.00	114.00
2011	100			0.57	2.00	114.00
2011	200			0.58	2.00	114.00
2011	500			0.59	2.00	114.00
2100	1	Adopted from Cardno (2011)		0.33	2.15	104.00
2100	20			0.85	2.50	107.00
2100	50			0.88	2.70	41.00
2100	100			0.88	2.70	43.00
2100	200			1.01	2.60	84.00
2100	500			1.01	2.60	84.00

Table 2-5 Moores Road Design Extreme Wave Conditions (JONSWAP & Cardno, 2011)

Epoch [year]	Return Period	Wave Height, Hs [m]	Wave Period, Tp/Tz [s]	ESL (exc wave setup) [mAHD]
2026	500	0.66	2.1	2.41
2076	500	0.9	2.44	2.57
2100	500	1.01	2.60	2.65

2.8.4 Wind wave sensitivity checks and nearshore wave condition calculations

The seawall running along the Esplanade are considered subjecting to wind waves due to the presence of Garden Island on front of the site.

Extreme 3-second wind speeds from the AS 1170.2[2] have been used for region B1 and converted to a 5-minute sustained wind speed using the methods described in the U.S. Army Corps of Engineers (USACE) Coastal Engineering Manual EM 1110-2-1100 (Part II)[3], Figure II-2-13.

2 Australian Standard (2021) 'Structural Design Actions - Part 2: Wind Actions. AS/NZS 1170.2:2021'.

3 USACE (2003) Coastal Engineering Manual (CEM) - Chapter 2, Meteorology and Wave Climate. US Army Corps of Engineers (USACE) (EM 1110-2-1100 (Part II)).

As a result, the 0.2% AEP wind-generated wave is similar to the extreme wave conditions available from the Redlands Storm Tide Hazard Study (Cardno, 2011), therefore the Cardno (2011) values have been adopted.

Nearshore wave conditions have been estimated using wave growth equations developed within the Joint North Sea Wave Project (JONSWAP) as presented in Kamphuis (2000)[4].

The mid-shore wave estimates are located in relatively deep water and will require consideration of additional processes to estimate waves at the structure toe. This includes:

1. Refraction into Morton Bay
2. Shoaling, as the bathymetry changes
3. Nearshore depth limitations

All processes would require a nearshore numerical model to be accurately represented. In the absence of a model, several empirical approaches have been used to estimate nearshore waves.

As the bathymetry changes, it will initiate shoaling and wave breaking. Wave shoaling has been estimated following Kamphuis (2010)5, using the linear-wave shoaling coefficient:

$$K_s = \sqrt{C_{go}/C_g}$$

where $C_{g0}$and $C_g$are the deep-water and local group velocities. Wave breaking has been determined from the largest value of three depth- or steepness-limited criteria, following Kamphuis (2010)[5] for irregular waves and the classical formulations of McCowan (1894)[6] and Munk (1949)[7]. The various formulations are shown in Table 2-6.

As a result, the 0.2% AEP depth-limited wind-generated wave is 0.87m, with peak period 2.44s.

Table 2-6: Various wave breaking formulations.

Wave breaking method/s	Formulae
McCowan (1894) and Munk (1949)	$H_b = 0.78\, d_b$
Kamphuis (1991) Steepness limited wave height	$H_{sb} = 0.095e^{4.0m}\, L_{bp}\tanh(\frac{2\pi d_b}{L_{bp}})$
Kamphuis (1991) Depth limited wave height	$H_{sb} = 0.56e^{3.5m} d_b$
Where $H_{sb}$is the shoaled, breaking wave height, $h_b$is the breaking depth, $L_b$is the wavelength at breaking, m is the foreshore slope.	

4 Kamphuis (2000) Introduction to Coastal Engineering and Management. Section 5; Wave Generation.

5 Kamphuis, J.W. (2010). Introduction to Coastal Engineering and Management (3rd ed.). World Scientific, Singapore

6 McCowan, J. (1894). On the highest wave of permanent type. Philosophical Magazine, 38, 351–358.

7 Munk, W.H. (1949). Surf beats. Eos, Transactions American Geophysical Union, 30(6), 849–854.

3 Design Parameters

3.1 Design Standards Adopted

The design has been carried out in accordance with the design standards, guidelines and technical specifications as set out in the following documents:

Table 3-1: Projects standards and guidelines

Designation	Title	Typical Usage
Australian Standards		
AS 1000	The International System of Units (SI) and its application	Units to be used on the Project
AS 1141	Methods for sampling and testing aggregates	Soil laboratory testing
AS 1726:2017	Geotechnical Site Investigations, Australian Standard	Site investigation and geotechnical assessment
AS 2758.6	Guidelines for the specification of armourstone	Armourstone durability
AS 3798:2007	Guidelines on Earthworks for Commercial and Residential Developments	Earthworks specification and quality control
AS 4678:2002	Earth-Retaining Structures	Design of retaining walls and earth retaining systems
AS 4997:2005	Guidelines for the design of maritime structures	General design requirements. Extreme wave loads for structural design; Design Loads; Load combinations.
Queensland standards guidance and technical specifications		
Department of Environment and Heritage Protection (DEHP)	Building and Engineering Standards for tidal works	Operational Policy providing minimum design criteria for tidal works under SPA Act 2009
RCC City Plan	Redland City Council City Plan	Local planning and development requirements
RCC Standard Drawings	Redland City Council Standard Drawings	Local infrastructure design standards
International standards and guidelines		
ASTM C295	Standard guide for petrographic examination of aggregates for concrete	Rock quality
BS 6349	(Part 1 & 7) British Standard Code of Practice for Maritime Structures	Design wave loadings; Design of revetment.
CIRIA C683	The Rock Manual, the Use of Rock in Hydraulic Engineering (2nd Edition), 2007.	Rock armour design
Institute of civil engineering (ICE)	Design of Vertical Gravity Sea and Quay Walls	Seawall design
Eurotop (II) Manual	EurOtop II – Manual on wave overtopping of sea defences and related structures, 2018.	Overtopping analysis and crest level determination
Legislative and Regulatory Requirements		
WHS Act 2011	Work Health and Safety Act 2011	Workplace safety legislation
WHS Regulation 2011	Work Health and Safety Regulation 2011	Workplace safety compliance
ACH Act 2003	Aboriginal Cultural Heritage Act 2003	Protection of Indigenous cultural heritage
Building Act 1975	Building Act 1975	Building and construction regulation
EPBC Act 1999	Environment Protection and Biodiversity Conservation Act	Environmental approvals
Environmental Protection Act 1994	Queensland Environmental Protection Act	Environmental protection and regulation
Codes of Practice and Other Guidelines		
Demolition Work Code of Practice 2013	Safe Work Australia Demolition Work Code of Practice	Demolition safety requirements
Australian Human Rights Commission	Accessibility and inclusion guidelines	Accessibility compliance

Other relevant documentation on tides, waves, materials, and geotechnical information includes:

- Queensland Tide Tables, 2026
- 44692-2 Project Brief
- JBP concept study report (Appendix F- 2024s1564-JBAP-00-00-RP-0003-A1-C01-Final_Report)
- Geotechnical assessment report by PDC Geotechnical (Appendix E).

3.2 Design Life

Determining the appropriate design life for infrastructure has an important effect on maintenance and operational costs. A longer design life typically provides better life cycle costs, however a design life that is too long may translate to uneconomical, obsolete infrastructure which is difficult to adapt to future use.

The existing rock revetment at Moores Road has a crest level of around 2.22 mAHD. It will increasingly be exposed to wave overtopping in the future as sea levels and Extreme Sea Levels (ESL) increase. Whilst land and assets exist behind the existing and proposed structure, these are not permanent residents and loss-of-life is not expected if emergency management approaches are implemented.

No specific requirements exist for the establishment of performance targets for seawalls. Under Australian Standard (AS) 4997 ‘Guidelines for Design of Maritime Structures’, the design life is subject to the asset owner's requirements and suggest a design life of 50 years for normal maritime structures. RCC has specified a design life of 50 years for the rock armour material. Performance against wave overtopping and coastal inundation protection are not specifically defined, and a risk-based approach is typically used. The adopted design incorporates durable armourstone and a robust revetment configuration to achieve the required 50-year design life. Beyond the nominated design life, continued performance will be dependent on ongoing inspection, maintenance and future adaptation measures where required. This design life requirement is not applicable to beach nourishment, footpath, and replaceable elements such as joint sealant, check valves, and geotextile materials exposed to UV.

Regardless of design life, the structures will require maintenance to uphold performance standards, particularly following adverse weather conditions, occasional damage, dilapidation, or significant toe scour. Monitoring, maintenance, and repair are critical in maintaining and extending asset design life.

3.3 Function category and design event

The designs have considered Ultimate limit State (ULS) and Serviceability limit State (SLS) for main design elements of concrete and structural steel.

- ULS: Wave loading from a 1 in 500-year ARI event with a probability of exceedance (EP) of 0.2% in every year of design life, and a cumulative EP of 9.5% over 50 years of design life.
- SLS: Wave loading from a 1 in 100-year ARI event has an EP of 1% in every year of design life, and a cumulative EP of 39% over 50 years of design life.
- Geotechnical assessment and recommendations have been adopted from the PDC Geotechnical report provided in Appendix E.

The design event is as defined in Table 3-2.

Table 3-2: Design event definition.

Design event year	Storm AEP	Extreme Sea Level (mAHD)	Significant wave height (m)	Peak wave period (s)
2076	0.2%	2.57	0.87	2.44

Performance criteria (overtopping) are as below:

- 10 litre/s/m in 1% AEP in year 2076 at seawall (EurOtop manual suggested value).

Armour stability has been assessed against the 0.2% AEP (1 in 500-year ARI) design event, while overtopping performance has been assessed against the 1% AEP event in the design year 2076.

3.4 Health and safety act

The design of the proposed works has included measures to mitigate or reduce risks to health and safety throughout the project. The main objectives are to provide a safe delivery in the design phase, to provide positive outcomes and measurable operational costs over the lifecycle of the structure.

In accordance with internal occupational health and safety protocols and the Queensland Governments Work Health and Safety Act 2011, foreseeable risks have been eliminated where possible. If a risk cannot be eliminated, measures to minimise that risk have been considered, as far as is reasonably practicable. A safety in design risk register has been completed for each of the design elements throughout its lifecycle.

3.5 Sustainable design

The design has been optimised to achieve the best balance between required design performance standards and minimising material usage to reduce its carbon footprint, including reservation of marine plants where possible. Potential raise of crest level to further limit overtopping and coastal inundation has been considered.

3.6 Design Calculations

Following acceptance of options appraisal, detailed design was undertaken to confirm structural performance, armour design, overtopping performance, and geotechnical stability. This section documents detailed design decisions for civil and coastal design elements of the Detailed Design. For geotechnical assessment of various elements, refer to PDC Geotechnical report in Appendix E.

3.6.1 Structural performance

The performance of the seawall can be assessed against two criteria:

- Rock armour stability: The structure has been designed as an erosion protection structure; therefore, rock armour stability has been assessed. Further details regarding the design of the rock armour are shown in Section 3.6.4.
- Overtopping performance: The structure has been designed to control overtopping to a tolerable level. Desktop-based modelling has been undertaken to quantify overtopping performance, to provide information on safe operation conditions and to develop inspection and maintenance schedule. This round of design presents crest levels derived from desktop overtopping assessment.

3.6.2 General arrangement

The general layout of the rock foreshore protection structure seeks to formalise the shoreline and provide protection against erosion. The alignment is kept straight following existing topography of escarpment with minimum bend to facilitate construction and reduce material usage.

The resulting alignment is shown in Figure 3-1.

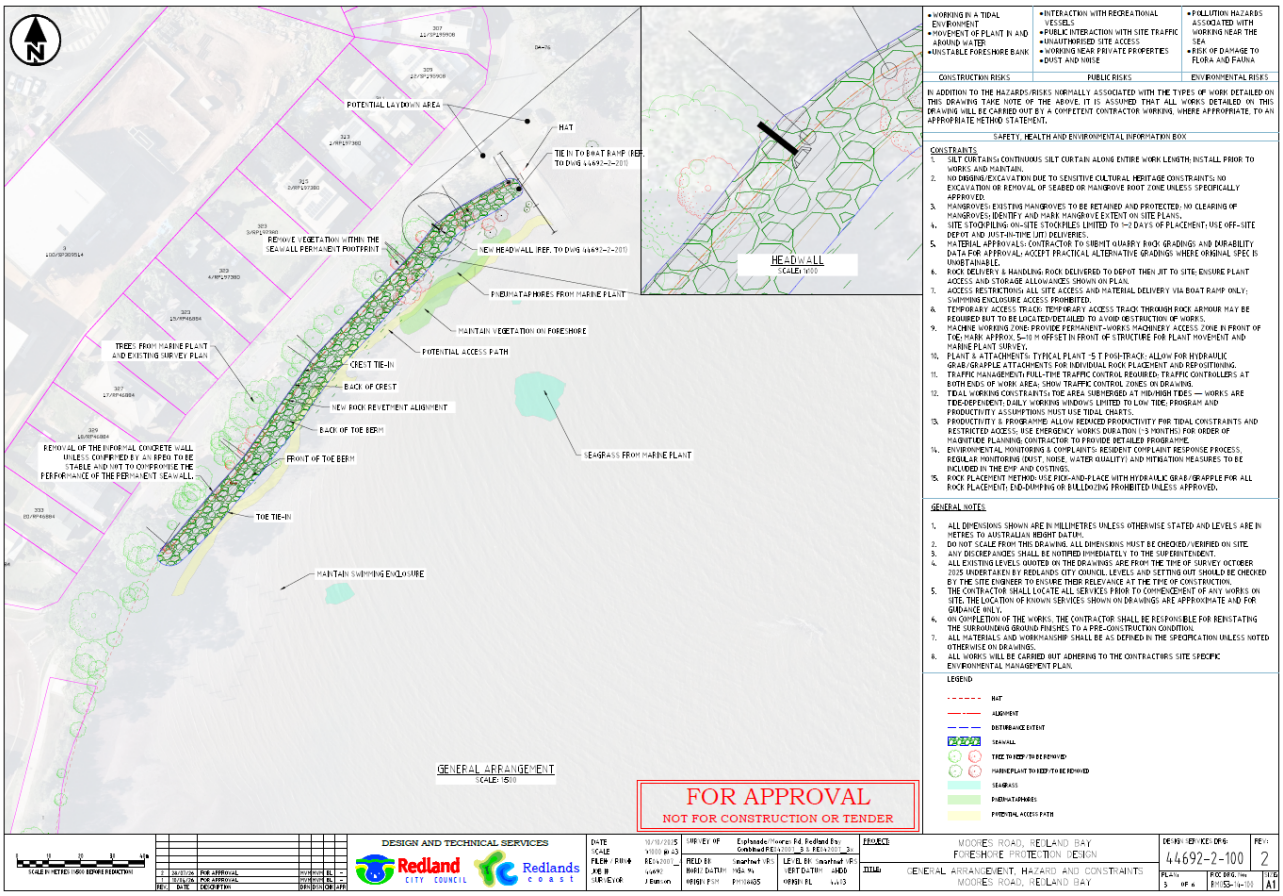


Figure 3-1 General arrangement.

3.6.3 Existing emergency works

Emergency stabilisation works were completed in June 2025 following storm-induced erosion at the site. These works were originally developed with consideration of the long-term protection requirements and have subsequently been assessed for incorporation into the permanent foreshore protection scheme. The existing rock protection is retained as part of the permanent works and functions as the underlying filter layer beneath the proposed armour revetment. This approach minimises disturbance to culturally sensitive areas while reducing waste and maximising the value of previously completed works.

3.6.4 Armour design

To calculate the overall rock armour stability the Van der Meer (VDM) deep[8] and shallow water[9] condition methods were adopted. The formula is used to predict the stability of a uniform rock

8 Van der Meer, J W (1988). Rock slopes and gravel beaches under wave attack. PhD thesis, Delft University of Technology, Delft. Aldo Delft Hydraulics publication NO. 396.

9 Van Gent, M R A, Smale, A J and Kuiper, C (2004). “Stability of rock slopes with shallow foreshores”. In: J A Melby (ed), Proc 4th int coastal structures conf, Portland, OR, 26–30 Aug 2003. ASCE, Reston, VA.

armour slope. The method includes the effect of storm duration, wave period, structure permeability, and damage level. The main benefit of this method is its distinction between plunging waves and surging waves, which is typically a result of wave period.

A coincident 1 in 500-year ARI Storm Tide Level and wave event is adopted as the design storm event, as defined in Section 3.3. The selected rock armour mass was designed to offer stability during the design storm event. The permanent armour layer has been designed to work in conjunction with the existing emergency rock protection, which is retained and incorporated into the permanent structure as the underlying filter layer.

The general cross section has been selected to minimise structure footprint whilst maintaining constructability and stability with rock size in mind. As a result, the revetment has a 1V:2H sloped primary face with a crest level at 2.6mAHD in initial construction stage.

Table 3-3 shows the parameters used to determine the median required rock mass (M50) to achieve protection against the design event. These parameters have a significant impact on the M50 result.

The required Dn50 for primary armour is 0.4m, translating to a M50 of 166.8kg.

Table 3-3 Armour design parameters

Parameter	Value
Armour rock density	2.65 t/m^3
Seawater density	1.025 t/m^3
Storm duration	6 hours adopted to account for cyclonic effects.
Storm damage for SLS	A value of 2 used correlating with a maximum 5% of armour units becoming dislodged.
Storm damage for ULS	A value of 3 used correlating with a maximum 10% of armour units becoming dislodged.
Notional permeability for initial stage rock structure	0.1 has been selected as the structure uses geotextile as part of the filter and is backed by the existing seawall.
Slope	1V: 2H
FoS	1.5 applied to Dn50 to account for negative impact of semi-round armoustones shape on stability[10] and other uncertainties.

3.6.5 Crest design

The primary armour crest is a minimum of three D_{n50} rocks wide to maximise interlocking and reduce damage during the design storm. The crest level has been set at approximately 2.6 mAHD following overtopping assessment, while also generally matching the existing ground level

10 Latham, J-P, Mannion, M B, Poole A B, Bradbury A P and Allsop, N W H (1988). The influence of armourstone shape and rounding on the stability of breakwater armour layers. Queen Mary College, University of London.

landward of the structure to minimise impacts on adjacent infrastructure, maintain public access and reduce visual impacts.

Overtopping assessment has confirmed that the adopted crest level achieves the nominated overtopping performance criteria for the design event.

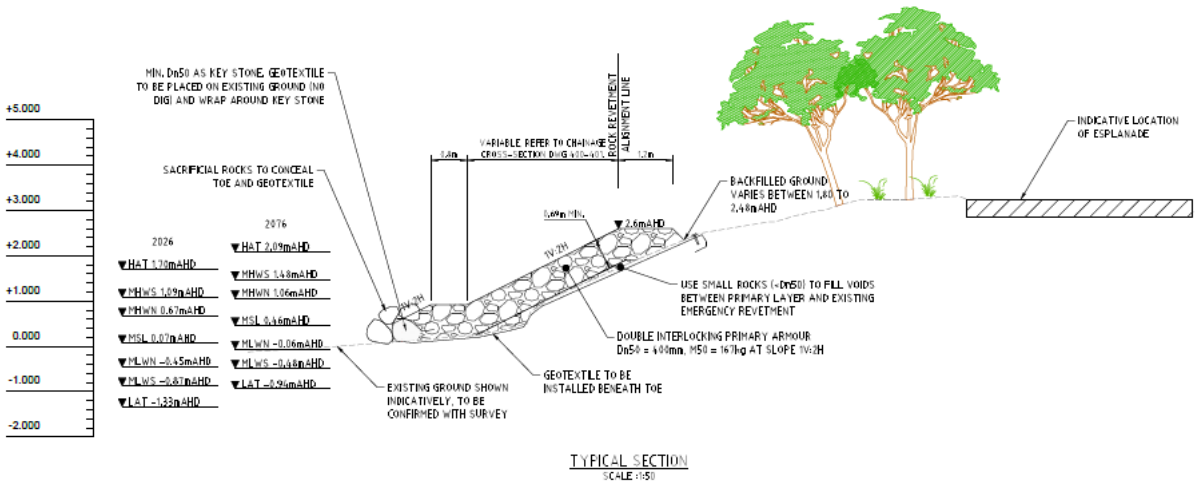


Figure 3-2 Typical section of the seawall.

3.6.6 Toe design

Consistent with the no-dig design philosophy adopted for the project and the potential presence of soft underlying materials within the foreshore, a buried toe trench has not been incorporated into the design. Toe stability is instead achieved through a widened sacrificial rock toe arrangement designed to accommodate localised settlement, scour and beach recession while minimising disturbance to culturally sensitive ground. This self-adjusting arrangement allows displacement of individual rock units without compromising the overall stability of the revetment and facilitates future maintenance through reformation of the toe where required.

A three-rock wide toe has been adopted in consideration of high scour possibility in response to the dynamic environment. The estimated scour and recess of ground is difficult to predict. It is common practice for seawalls on the open coast of eastern Australia to design for a scour level of -1 mAHD for sloping rubble walls (Carley, J. et al. 2015). The adopted toe configuration provides additional resilience against scour-induced instability and loss of support at the toe of the structure.

According to the Acid Sulfate Soil Map[11] released by the Queensland Government, the risk of Acid Sulfate Soils (ASS) at the site is generally low. Management and treatment of these soils are unlikely to be required.

3.6.7 Underlying rock layer

The existing emergency rock protection is incorporated into the permanent works and forms an integral component of the revetment structure beneath the proposed primary armour layer. The emergency works were originally designed and constructed with consideration of future incorporation into a permanent foreshore protection solution.

11 Acid sulfate soils map - South section - Acid Sulfate Soils of Tweed Heads to Teewah - South East Queensland - SEA - Publications | Queensland Government (accessed on 11/03/2026)

Retention of the existing rock protection is consistent with the project's no-dig design philosophy and minimises disturbance within culturally sensitive areas. The retained rock protection provides a stable platform for placement of the permanent armour layer and contributes to the overall stability and performance of the revetment system.

The existing geotextile beneath the emergency works remains in place and continues to provide filtration between the rock structure and underlying soils.

3.6.8 Geotextile

Geotextiles are used within rock armour to mitigate bed material washing out through the interstices of a rock matrix which can lead to bed lowering causing lowering of the rock structure. This lowering may continue until it becomes embedded, similar to the process of liquefaction.

A geotextile layer is already present beneath the emergency works; To maintain continuity of filtration and erosion protection, geotextile is to be installed beneath newly constructed revetment elements.

Due to lack of readily available standards on selection of geotextile in Australia, manufacturer information presented within the 'Coastal and River Defence Systems: Design Guidance' provided by GEOFABRICS has been adopted. Geotextile Texcel 1200R has been selected based on its resistance to damage during placement of armour rocks and its filtration properties.

3.6.9 Packing density

The packing density of the primary armour layer has a direct impact on the performance of the structure as well as the total volume occupied. The following assumptions have been made in calculating the packing density and total required volumes for the defence configuration:

- Packing density calculation used: CIRIA -The Rock Manual - The Use of Rock In Hydraulic Engineering (page 124).
- Volumetric layer porosity (n_v). CIRIA - The Rock Manual - The Use of Rock In Hydraulic Engineering (page 126) states that: ‘for a double layer of irregular rock placed in dense packing, a value of 35% should be used for the volumetric layer porosity’.
- Layer thickness coefficient (k_t). CIRIA - The Rock Manual - The Use of Rock In Hydraulic Engineering (page 126) states that: ‘for a double layer of irregular rock placed in dense packing, a coefficient of 0.87 should be used for the layer thickness coefficient’.
- The rock is assumed to have a porosity (p) of 0.14.
- The degree of saturation (S_r). CIRIA - The Rock Manual - The Use of Rock in Hydraulic Engineering (page 97) states that: ‘for an armour stone that is not in permanent contact with water, a saturation of 0.25 should be used’.
- $\rho_p = (1 - n_v)\rho_{app} = \frac{(1-n_v)}{k_t}(\rho_{rock} + \rho_w p S_r) = \frac{(1-n_v)}{k_t}\left((1-p)\cdot\rho_r + \rho_w p S_r\right)$
- Using the above parameters, the packing density has been calculated to be 1.80t/m^3. Packing density is determined assuming an irregular rock of 50% and a density of 2.65t/m^3. If these parameters differ, which is reasonably expected due to the unknown quarry source of future armourstone, the packing density will subsequently change. For example, if a quarry is sourced that produces a rock density of 2.70t/m^3, then the packing density would increase to 1.84t/m^3. It is likely that this figure will be revisited once a suitable rock source is determined. Nonetheless, packing density as constructed should not differ more than 2% compared to the design figure of 1.80t/m^3 (± 0.036t/m^3).

The required Dn50 are summarised in Table 3-4.

Table 3-4: Armour design summary (subject to wave modelling check)

Primary armour Dn50 (m)	Primary armour M50 (kg)	Filter layer Dn50 (m)	Filter layer M50 (kg)
0.4	167	0.18	16

3.6.10 Wave Overtopping assessment

3.6.10.1 Overview

Wave overtopping estimates for the proposed revetment have been calculated using the methods outlined within the industry standard European Wave Overtopping Manual (EurOtop)[12]. This manual includes three different methods and associated guidelines for the prediction of wave overtopping for different structure types, with the Neural Network approach (NN2) used. The NN tool is considered the most suitable methodology for evaluating wave overtopping for composite defences, which may include changes in grade, crest structures, of different materials. A structure is schematised into geometric parameters including crest height (Rc); armour height (Ac); armour width (Gc); berm elevation (hb); berm width (B); upper slope (αu); lower slope (αd); and roughness (γf) (see Figure 3-3)

The designed revetment and its overtopping geometric schematisation is shown in Figure 3-3 and Figure 3-4.

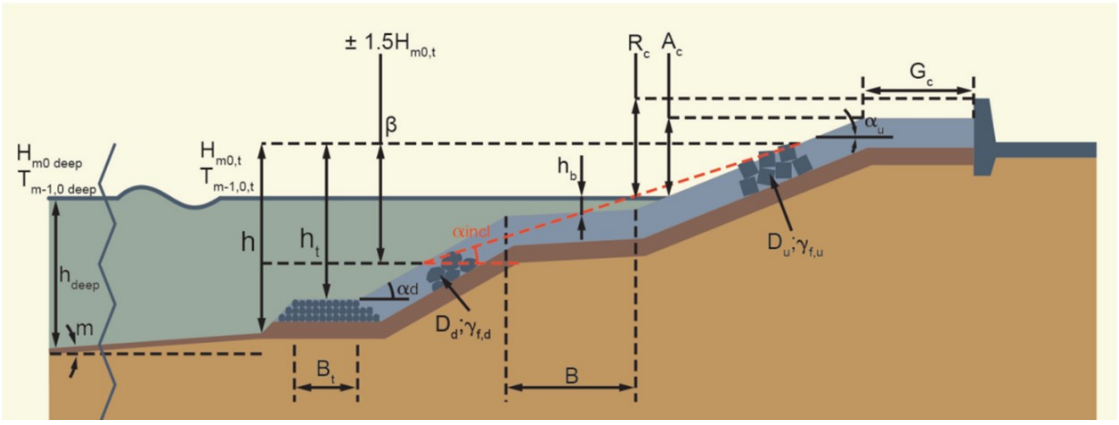


Figure 3-3: Example Neural Network 2 schematisation and calculation parameters

12 EurOtop. 2018. Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. www.overtopping-manual.com

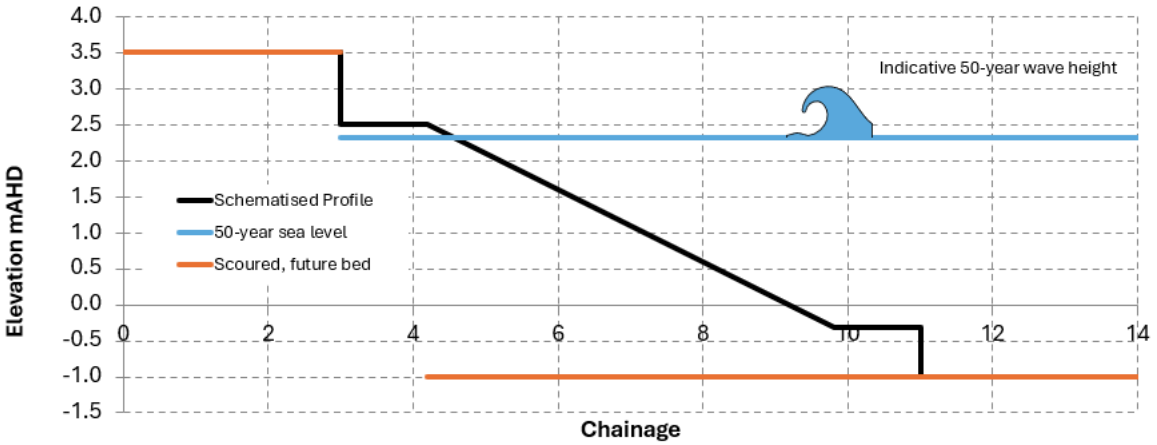


Figure 3-4 Design revetment schematisation

Using the Neural Network model, the average rate of overtopping can be calculated for a structure cross-section. The overtopping rate at the crest, or at a setback position, can then be related to guidance provided in the EurOtop Manual which links hazardous situations to overtopping rates and volumes. These relevant volumes (in mean discharge) are summarised below:

- Mean overtopping rates over 1 l/s/m - Unsafe for pedestrians, but accessible for trained staff
- Mean overtopping rates over 10 l/s/m - Unsafe for trained staff
- Mean overtopping rates over 50 l/s/m - Damage and excessive scour to grassed areas and pavers/promenades
- Mean overtopping rates over 200 l/s/m - Damage to well protected embankment/seawall

The tool can estimate overtopping at landward distances within the range of up to 5m behind the coastal profile. For distances beyond this range, overtopping must be approximated using the 'rule of thumb' presented within the EurOtop Manual (2007)[13], where the hazardous effect of overtopping discharge at a landward position is expected to reduce by a factor of x (distance). This is expressed as:

Overtopping (landward) = Overtopping (crest) / distance (over a range of 5–25 m).

3.6.10.2 Inputs for overtopping calculations

Overtopping calculations have been undertaken under the most conservative 1% AEP scenario based on:

- 2076 ESL level (1% AEP) excluding wave setup 2.31 mAHD, combined with
- Estimated nearshore extreme wave conditions for a coincident 1% AEP event Hs=0.8m, Tp=2.51s.

3.6.10.3 Determination of revetment crest level

An iterative design process has been used to increase the crest height of the proposed revetment, simulating overtopping under the 1 in 100-year (1% AEP) storm conditions in 2076 shows the different overtopping rates vs potential crest levels, where:

13 Pullen, Allsop, Bruce, Kortenhaus, Schüttrumpf, van der Meer (2007) EurOtop - Wave Overtopping of Sea Defences and Related Structures: Assessment Manual. Equation 3.1,pp 33

- 2.92 m AHD crest = 1 l/m/s = safe for pedestrians to walk behind the wall during the storm
- 2.52 m AHD crest = 10 l/m/s = safe for trained staff to walk behind the wall during the storm

Given that the performance standard is proposed to limit wave overtopping to 10 l/s/m – which is the limit for trained staff, a design crest height of around 2.6 mAHD has been adopted which is slightly higher than the standard required.

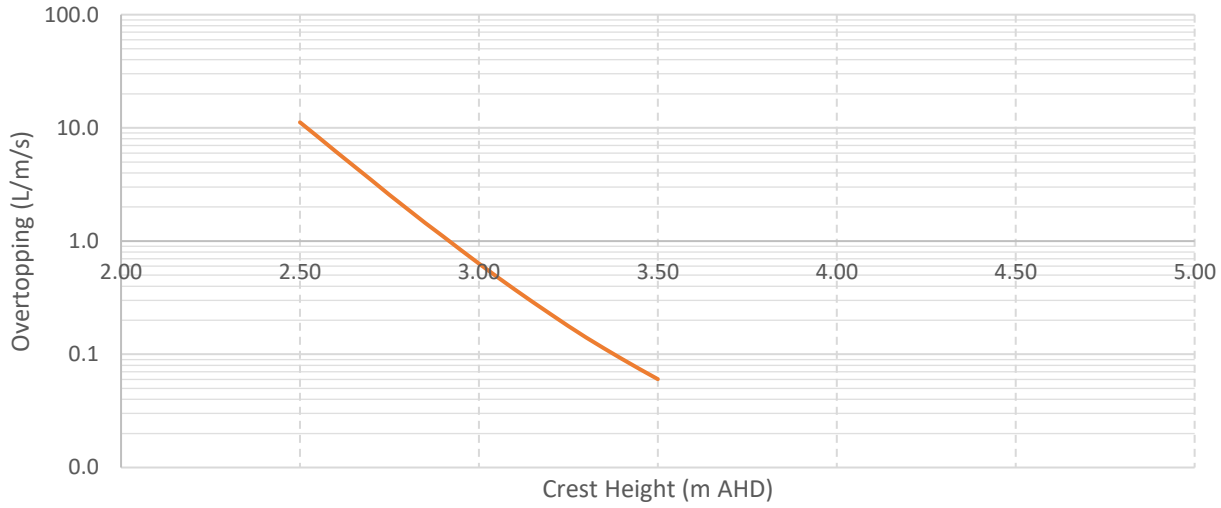


Figure 3-5 Different overtopping rates vs potential crest levels for the 100-year event in 2076

3.7 Design Assumptions

The design incorporates the existing emergency rock protection as part of the permanent revetment system. The existing emergency works and underlying geotextile are assumed to remain generally intact and suitable for incorporation into the permanent works.

The design further assumes that localised settlement, scour and movement of toe materials may occur throughout the service life of the structure. The widened sacrificial toe arrangement has been adopted to accommodate these processes without significant reduction in overall revetment performance.

4 Construction

4.1 Introduction

This document outlines the assumed construction methodology for renewal/upgrade of a rock armour seawall where the existing emergency rock revetment is rock-only and will be used in-situ as the filter/core layer. No digging or excavation is permitted under this methodology. The methodology is guidance only and must be read in conjunction with the Contract Drawings, Technical Specification, environmental approvals and other Contract documents.

4.2 General requirements

The Contractor shall be entirely responsible for the construction and sequencing of the works.

The Contractor is to ensure acceptable work practices are used in accordance with the requirements of the Technical Specification and to the satisfaction of the Superintendent.

The Contractor is responsible for occupational health and safety of site personnel and the public in accordance with Work Health and Safety Act 2011.

The Contractor shall prepare a Work Method Statement for the works, including excavation, fill and compaction, site stockpiles placement and management, etc., before site works commence in accordance with the Technical Specification.

The Contractor shall supply suitably qualified and experienced personnel, plant, PPE and vessel support. Personnel shall be trained in marine operations, confined space (if applicable), and environmental protection measures.

The Contractor is to comply with all legislation, codes, and industry guidelines applicable to all works being undertaken by this Contract. Where applicable, all construction works shall be carried out in accordance with the latest version of the Specification, Drawings and the applicable Australian Standards and Codes.

No digging/excavation or penetration of the existing formation is permitted. All works must be confined to movement and placement of rock on the existing surface only.

All placement of material shall be carried out to minimise disturbance to the seabed, foreshore and adjacent assets. If excessive disturbance occurs, placing operations shall cease until rectified.

The Contractor shall cause the least possible interference with existing amenities whether natural or manmade. Any removal/temporary relocation of private assets shall be coordinated and approved by the Superintendent.

4.3 Site access

The Contractor shall provide all necessary and safe vehicular and pedestrian access to carry out the works.

The Contractor shall specify a Traffic Management Plan and provide it for RCC review.

The Contractor shall provide a tide-based schedule of works, with respect to the tides at Moores Road, demonstrating safe working windows and sequencing around tides. RCC to review it prior to commencement of the works on site.

Barricading, exclusion zones, spotters, signage and traffic control shall be provided to protect the public and site personnel.

Note that:

- Access via the swimming enclosure side is not feasible.
- All access and material delivery shall be from the boat ramp.
- Full-time traffic control shall be required at both ends of the work area.
- Silt curtains shall be required along the entire length of the works.

4.4 Detailed methodology

The following describes the assumed construction sequence and tasks. The Contractor is responsible for final sequencing, temporary works design and safety arrangements.

- Site establishment
    1. Setup site compound and welfare facilities. Establish secure storage compounds for rock, tools and plant. Install fencing and public exclusion measures.
    2. Deliver and install marine safety measures (navigation warnings, exclusion buoys, silt curtains if required).
    3. Confirm all required permits, heritage/archaeological requirements and service isolation arrangements.
- Pre-construction survey, inspection and testing of existing revetment
    1. Undertake baseline photographic, topographic and hydrographic survey of the existing revetment (crest, slope, toe) and adjacent assets.
    2. Conduct visual inspection to identify grout/concrete contamination, buried heritage fabric, utilities or marine debris.
    3. Sample existing revetment rocks for grading analysis and toughness (LA value or equivalent) at predetermined intervals. Proposed sampling frequency to be submitted in ITP; minimum representative sampling at 5%, 30%, 50%, 70% and 100% of the existing revetment extent or per Contract sampling plan.
    4. Submit laboratory results and engineer’s assessment for acceptance of in-situ material as filter layer. Acceptance criteria (example — to be confirmed by Engineer):
        - Gradation matches or lies within specified filter gradation curve (i.e., particle sizes smaller than design armour but larger than formation fines).
        - Absence of significant mortar/concrete contamination that would hinder permeability or interlock.
        - Fines content below the value specified in Contract (or permeability within acceptable range).
    5. If existing material does not meet filter requirements, Contractor to propose remedial option (supplementary imported filter, partial regrading, or removal and new filter).
    6. No geotechnical probing that disturbs formation (i.e., no DCP/CPT) unless approved by Superintendent in writing; acceptance to rely on surface inspection and sampling.
- Temporary works and environmental controls
    1. Install temporary working platforms/ramps or barge-based access as required to minimise seabed disturbance.

2. Install silt curtains, turbidity controls and spill response equipment as required by approvals.
3. Ensure exclusion zones and public protection are maintained.

- Filter layer

  Where existing emergency revetment works are present, the emergency works shall act as the filter layer and shall remain in situ. Geotextile is already installed beneath the existing emergency works. Where the permanent works extend beyond the footprint of the emergency revetment, geotextile shall be installed at the new toe area, in accordance with the project specifications.

  The filter layer shall be constructed and prepared as follows:

  1. Retain the existing emergency rock in place to function as the filter layer beneath the new armour.
  2. Clean and selectively rework surface stones by pick and place to remove fines, debris, and unsuitable material, and to achieve the required filter profile and continuity for armour placement.
  3. Where necessary, locally lift and re spread existing stones in short, controlled sections to re establish a stable, interlocked filter surface, without excavation, penetration, or disturbance of the underlying formation.
  4. At locations where the new toe extends beyond the footprint of the emergency works, install geotextile beneath the new toe prior to placement of filter and armour rock.
  5. Place new armour rock directly onto the prepared filter layer.
  6. All works shall comply with the site no dig constraints and be undertaken in a non invasive manner.

- Removal, cleaning and stockpiling (no digging)

  1. Peel back rocks only where necessary in short sections (e.g., 5–15 m lengths) by pick-and-place, stockpile sorted stones on temporary rock mats or within fenced compound (on impermeable mats if required), ensuring stockpiles do not surcharge or disturb formation.
  2. Remove and segregate any non-rock debris (e.g., trash, vegetation). If any cementitious fragments are encountered, remove and dispose off-site; avoid further disturbance to formation.
  3. Photographic and log records for all lifted and re-used rocks.

- Reworking the existing filter surface (no excavation)

  1. Regrade reworked/stored stones to form a stable, interlocked filter platform to the design batter and thickness as far as achievable without excavation.
  2. Avoid the creation of voids or undermined pockets—place stones to fill voids and provide a continuous bearing surface for armour.
  3. Where necessary, supplement with imported filter placed on top of existing material.

- Toe and crest treatments

  1. Construct toe berms, keyed toes or buried rock mattresses by placing rock on the existing surface. Do not penetrate, excavate or cut formation.

2. Tie the toe into existing revetment progressively (overlap stones) to avoid discontinuities. Use pick-and-place to interlock toe stones.
3. Crest to be formed by pick-and-place of larger armour stones to the specified elevation.

- Armour placement (pick-and-place rock revetment)
  1. Place armour rock by pick-and-place only (no end-dumping, no pushing). Use barge-mounted crane, long-reach pick placement or tracked excavator working from rock ramp or shore-based pick-and-place plant.
  2. Place rocks to achieve interlock and orientation consistent with design using a hydraulic grab/grapple attachment; ensure progressive stability (generally toe-to-crest sequence).
  3. Avoid heavy machine compaction on geotextile/top-sheet; use stone ballast to secure geotextile where required.
  4. Where manual handling is required (tidal zone or heritage constraints), use manual/slight mechanical assistance for delivery only.
- Tie-ins and transitions
  1. Prepare tie-in zones by clean reworking and interlocking stones to existing revetment. Do not cut, drill or fix into any existing structure.
  2. Provide progressive stone gradation changes over transition length to avoid abrupt batter changes.
  3. All ties to be mechanical interlock via stone arrangement only.
- Reinstatement of landward area and assets
  1. Reinstatement of backshore surfaces, footpaths, fences and services in accordance with the Contract Documents and without damaging new works.
  2. Restore public access and landscaping per drawings.
- Demobilisation
  1. Remove temporary works and plant; tidy and reinstate areas not forming part of the works.
  2. Dispose of waste materials and contaminated stone to approved facilities.
  3. Clean site and reinstate any temporary access platforms (rock ramps) to an agreed condition.

4.5 Procedure in event of inclement weather and temporary cessation of work

When heavy weather endangering the works is forecast, or when for some other reason placement of work must cease, the Contractor shall immediately protect the embankment from deterioration of the core and/or rock armour layers.

At the conclusion of the weather event the protection shall be removed to permit the proper re-placement of the armour as detailed for the design cross-section.

All protection and reinstatement work shall be at the cost of the Contractor.

The Contractor shall provide in the tender its procedure for heavy weather for Superintendent approval.

4.6 Key constraints and practical recommendations

1. Community & environmental controls: implement dust suppression (regular water cart spraying) and noise control; include costs in methodology.
2. Silt curtains: continuous silt curtain along entire work length; install prior to works and maintain.
3. No digging/excavation: no excavation or removal of seabed or mangrove root zone unless specifically approved in writing.
4. Mangroves: existing mangroves are to be retained and protected; no clearing of mangroves; identify and mark mangrove extent on site plans.
5. Site stockpiling: on-site stockpiles limited to 1–2 days of placement; use off-site depot and just-in-time (JIT) deliveries.
6. Material approvals: contractor to submit quarry rock gradings and durability data for approval; alternative practical gradings to be accepted where original spec is unobtainable.
7. Rock delivery & handling: rock delivered to depot then JIT to site; ensure crane/plant access and storage allowances shown on plan.
8. Access restrictions: all site access and material delivery via boat ramp only; swimming enclosure access prohibited.
9. Temporary access track: temporary access track through rock armour may be required for construction but to be located and detailed on plan to avoid obstruction of emergency works.
10. Machine working zone: provide permanent works machinery access zone in front of toe; mark an approximate 5–10 m offset in front of the structure for plant movement and marine plant survey.
11. Plant & attachments: typical plant ~5 t posi-track; allowance for grabber/rock-handling attachments for individual rock placement and re-positioning.
12. Traffic management: full-time traffic control required; traffic controllers at both ends of work area; show traffic control zones on drawing.
13. Tidal working constraints: toe area submerged at mid/high tides — works are tide-dependent; daily working windows limited to low tide periods; program and productivity assumptions must use tidal charts.
14. Productivity & programme: allow reduced productivity for tidal constraints and restricted access; use emergency works duration (~3 months) for order-of-magnitude planning; contractor to provide detailed programme.

5 Safety in Design

JBP has a statutory duty to ensure control measures are implemented in the early stages of the engineering design process to reduce risks to health and safety throughout the project. The objective is to provide safe delivery in the design phase and provide positive outcomes and measurable operational costs over the lifecycle of the project. In addition, this design has followed a process to meet:

- Responsibilities to ensure our safe design process complies with our internal occupational health and safety protocols and the QLD Government's Work Health and Safety Act 2011.
- Requirements for consultation with other duty holders including, but not limited to, the Client, Principal Contractor and construction workers who are involved in the project.

JBP has been practising a systemic approach to safe design using the risk management approach. The risk management approach includes identifying potential hazards and risks of the design and minimising and/or alleviating the risks through the evaluation and implementation of relevant mitigating control measures. This approach is incorporated into our design objective to eliminate risk to health and safety and maximise safe delivery throughout the design phase. The document is to be passed on and updated through the procurement, construction, and delivery phases to achieve satisfactory outcomes.

5.1 Safety in design version

This report, the drawings, risk register, and technical specification will continue to be updated as the design develops through the detailed design and "For Construction" phases of the design.

On submission of the ‘For Construction’ documentation and the final Safety in Design risk register, the responsibility for ongoing risk management transfers to RCC and the appointed Contractor. At this stage, JBP’s role in updating design documentation concludes, but the risk register and associated design intent should continue to guide safe delivery and ongoing management. This process allows RCC and the Principal Contractor to review, update, and incorporate any new risks in the contract risk register(s) and to communicate to the Client if amendments are required to improve safety.

The safety in design risk register focuses on the design of the Moores Road seawall. It outlines the anticipated project set up, data collection and review, project plan, design, and tender phases for the project.

Any future stages of work associated with the Moores Road Seawall Designs has been the responsibility of the Client, contractors, and future stakeholders. They will need to consider future risks and update and modify this document as JBP's design responsibilities end.

5.2 Safety objectives

The objectives of safety in design are to identify work health and safety (WHS) hazards associated with the design and mitigate those hazards as far as reasonably practicable using control measures. The safety objectives for this phase of the project will include:

- Identify the scope and complexity of the project.
- Identify, assess and control potential hazards and risks throughout the design process.
- Consider relevant legislation, codes of practice and standards.
- Recognise the required design standards for the structures as well as identifying the roles and responsibilities of respective parties in relation to the project.

5.3 Internal and external stakeholders

The construction works will potentially affect the following stakeholders:

- Redland City Council.
- QLD State Government.
- Principal Contractor.
- Sub-contractors.
- Maintenance contractors.
- Local community.
- General public.
- Builders and homeowners nearby the works.

5.4 Systematic risk management process

This section describes the risk management process JBP has undertaken to ensure safe design is achieved. The risk management process includes identification, assessment and control processes.

5.4.1 Hazard and risk identification

The following process was used to identify and manage hazards and risks associated with this design:

- Consultation with the Client.
- Review of potential design options.
- Research on common hazards for seawalls, tidal work, and structural remediation.
- Review of WHS regulations.

The risks are assessed before any control measures are applied (raw risk level) and reassessed after implementation of any applicable standards and design control measures (revised risk level).

5.4.2 Risk assessment matrix

To assess the measures needed to control a hazard so far as reasonably practicable, it is useful to assign a level of risk to each hazard. This has been achieved through a simple product score grid.

JBP utilises the 5 x 5 risk assessment matrix:

Severity x Likelihood = Risk Factor (S X L = RF)

to assess risks associated with any identified hazards (see Table 5-1).

Table 5-1: Risk assessment matrix.

Risk Matrix			
Severity		**Likelihood**	
1	No injuries, damage or loss	1	Highly unlikely
2	Minor injury, damage or loss	2	Unlikely
3	Moderate injury, damage or loss	3	Likely
4	Major injury, damage or loss	4	Very Likely
5	Fatality / fatalities	5	Certain

Risk Matrix				**Severity** (Where an event has more than one 'Loss Type', choose the 'Consequence' with the highest rating)				
	Loss Type (Additional 'Loss Types' may exist for an event; identify & rate accordingly)			**Insignificant** 1	**Minor** 2	**Moderate** 3	**Major** 4	**Catastrophic** 5
Likelihood	**Certain** 5	The event is expected to occur in most circumstances	>90%	5	10	15	20	25
	Very Likely 4	The event will probably occur in most circumstances.	>50–90%	4	8	12	16	20
	Likely 3	The event might occur, but not expected to occur under normal circumstances.	>10–50%	3	6	9	12	15
	Unlikely 2	The event could occur at some time, but only in unusual circumstances	>2–10%	2	4	6	8	10
	Highly Unlikely 1	The event could occur only in exceptional circumstances	<2%	1	2	3	4	5

Table 5-2: Consequence Table.

Priority	Consequences Table – provides guidance on the severity of a risk
Catastrophic	- Governance: Services disrupted to the community resulting in adverse or punitive impact. Impact on organisational sustainability. Third party intervention required. Sustained and widespread community dissatisfaction/sustained negative media coverage. Reputational damage. - Social: Harm at a level resulting in the fatality of a person or people. Significant and long-lasting effect on health, wellbeing, community lifestyles, amenity, and liveability. - Economic: Impact greater than 20% of budget. A permanent economic impact on the financial sustainability of the community. - Environmental: Permanent significant impact to an area of high ecological significance or sensitive environment i.e., habitat loss, impacts to waterways and flora and fauna. Immediate containment: large clean up, ongoing remediation required if possible. Mandatory regulatory reporting required. Regulatory investigation will occur with prosecution likely.
Severe	- Governance: Services disrupted to a significant section of the community for an extended period, resulting in adverse or punitive impact. Additional support required from external party. Significant outcry from community/ongoing media coverage. Long-term impact on the reputation of the organisation.

Priority	Consequences Table – provides guidance on the severity of a risk
	- Social: Significant harm to health and wellbeing, requiring hospitalisation or ongoing impact to way of life. Significant, medium-term effect on community lifestyles, amenity, and liveability. - Economic: Impact greater than 10% to 20% of budget. A long-term economic impact on the financial sustainability of the community. - Environmental: Long-term significant impact to an area of high ecological significance or sensitive environment i.e., habitat loss, impacts to waterways and flora and fauna. Immediate containment: large clean up, major remediation required. Mandatory regulatory reporting required. Regulatory investigation likely.
Moderate	- Governance: Services disrupted to a large section of the community resulting in adverse or punitive impact on organisational objectives. Concerns raised by a cross-section of the community/ongoing local media coverage. Short-term impact on the reputation of the organisation. - Social: Harm occurs to health and wellbeing, requiring medical treatment or short-term impact on way of life. Moderate or short-term effect on community lifestyles, amenity, and liveability. - Economic: Impact greater than 5% to 10% of budget. A short-term economic impact on the financial sustainability of the community. - Environmental: Medium-term impact to an area of high ecological significance i.e., habitat loss, impacts to waterways and flora and fauna. Immediate containment: clean up and some remediation required. Mandatory regulatory reporting required. Regulatory investigation possible.
Minor	- Governance: Minimal adverse or punitive impact on organisational objectives from a decision. Services disrupted but minimal impact on end user. Concerns raised by a small section of the community/one-off local media coverage. - Social: Minor harm occurs to health, wellbeing, and way of life, requiring minor medical treatment. Minimal effect on community lifestyles, amenity, and liveability. - Economic: Impact greater than 2% to 5% of budget. A minor economic impact on the financial sustainability of the community. - Environmental: Minor breach of environmental standards. Short-term effect on natural or built environment. Easily remediated.

Priority	Consequences Table – provides guidance on the severity of a risk
Insignificant	- Governance: No adverse or punitive impact on organisational objectives from a decision. - Social: No harm can come to people, including health, wellbeing, earning ability and way of life. - Economic: Impact within approved budget. No adverse economic impact on the community. - Environmental: There are no environmental impacts.

5.4.3 Safety in design risk register

A safety in design risk register has been attached as Appendix B. The register captures the key identified hazards, risks and decisions relating to their mitigation as the project has progressed so far.

As the design work progresses, the register can be updated. The register is to be carried through the design process, with the final update of the register concurrent with the issue of "For Construction" drawings. JBP then transfers the responsibility associated with risk control to the relevant parties.

5.4.4 Liaison with Client

Throughout the design phase, there are formal opportunities for the project stakeholders to participate in the safety in design process.

An inception meeting with the Client was held at the beginning of the project to discuss the scope, key objectives and locations, data requirements, and risks of the project. Throughout the design stages, regular meetings were held to discuss critical design decisions and relevant design risks and hazards. Risks and hazards during the construction, operation, and maintenance phases were also discussed and have been included in the safety in design documentation. These hazards and associated risks have been used to establish relevant control measures.

5.5 Responsibilities and reporting

The achievement of safety in design objectives is dependent upon:

- Consultant, Client, and stakeholder commitment to the safety management process.
- Communication of this report, the risk assessment matrix and the safety in design risk register to those parties with nominated actions.
- Implementation of recommended actions by nominated parties.

5.5.1 Designer responsibilities

JBP has a responsibility and accountability to provide a safe design that satisfies relevant legislation, codes of practice, and standards. We also have a responsibility to identify, assess and minimise health and safety risks at the earliest possible opportunity within our activities.

JBP is required to actively identify hazards and assess risks with the aim of eliminating hazards and reducing work health and safety risks so far as is reasonably practicable throughout the life cycle of the asset in the design process.

JBP has a responsibility to:

- Advise the Client of identified hazards, associated risks and proposed control measures.
- Incorporate relevant control measures into the design.

5.5.2 Client responsibilities

RCC has a responsibility to:

- Review the safety in design risk register.
- Inform key stakeholders, contractors and owners of any relevant control measures, including the risk assessment matrix and risk register.
- Manage risks identified in the construction, operational and maintenance phases together with Contractor.

6 Whole of Life Cost

6.1 Introduction

This Whole of Life Cost section was undertaken by JBPacific to support the design, construction and service life of the proposed Moores Road foreshore protection structure on behalf of Redland City Council (RCC).

The Whole Life Costing (WLC) contained within this report is an economic evaluation technique that considers the total cost of an asset over its operating life, including initial capital costs, maintenance costs, operating costs and the cost or benefit of the eventual disposal of the asset at the end of its life[14]. Assumptions in calculating Life Cycle Cost (LCC) have been detailed in the report following the construction phase.

6.1.1 Objective and scope

The objective of this report is to provide a WLC for the proposed work, across the 50 years design life.

The LCC formula adopted in this project is as shown:

$$Life\ Cycle\ Cost = Capital\ Cost + Lifetime\ operation\ cost$$
$$+lifetime\ maintenance\ cost + Disposal\ cost$$
$$-Residual\ value$$

A breakdown of each cost and value are as shown in Table 6-1.

Table 6-1: Typical life cycle cost breakdown

Cost category	Cost breakdown
Capital cost	Design and permit application cost
	Construction, manufacture, and/or purchase cost
Life-time operation cost*	Insurances etc
Life-time maintenance cost**	Inspection cost
	Consumables (material replacement) ***
	Maintenance cost
Disposal cost	Demolition cost
	Safe disposing cost
Residual value	Material value
*: Generally not applicable to this type of structure. **: Detailed inspection and maintenance requirement and assumptions in Section 6.2. ***: Merged into maintenance cost calculation.	

6.1.2 References

The following documents prepared by JBP have been used to identify whole life costs.

- Appendix_A _ Drawing package
- Appendix_D_Cost Estimate

14 Sci-network, 2011. Whole Life Costing. Preliminary Report. Retrieved from: http://docshare01.docshare.tips/files/30638/306385243.pdf

6.2 Maintenance and operation guide

This section supports the management and operation (M&O) procedures and the WLC of the proposed Moores Road foreshore protection structure. The existing site with the proposed layout and cross section shown in Figure 3-1 and Figure 3-2.

The proposed defence has been designed to stabilise the foreshore, protect adjacent infrastructure and ensure the safety and accessibility of the area for the local community while considering environmental and heritage constraints associated with the site. Designs have been based on 1 in 500-year Average Recurrence Interval (ARI) storm event, occurring at the end of its expected asset life of 50 years, with an expected construction year of 2026. The coastal defence is designed to mitigate erosion primarily, with peak sea levels able to overtop the structure in extreme events, which may cause inundation behind the defence. The selected crest level provides protection against overtopping in present day, however, increase in overtopping rate is expected with climate change. As the structure may be overtopped in extreme events, it will require periodic inspections and maintenance over its design life.

6.2.1 Asset documentation

Following construction, the seawall and stormwater drainage system will be assets of RCC and shall be entered in their marine infrastructure and stormwater drainage databases, respectively. The following sections provide information on the asset type, location, materials, and dimensions.

6.2.2 Asset class

Assets can be clearly recorded using a standard asset naming hierarchy by their Class, Sub class, and ID.

The recommended asset class for Moores Road foreshore protection is defined as:

- Asset Class: Marine Infrastructure
- Sub class: Rock Seawall
- Identification (ID): to be specified by RCC

6.2.3 Asset Location

The starting and end points of the asset are defined for clarification of maintenance responsibility and the convenience of inspections.

The location is:

- Address: 307 Esplanade, Redland Bay, QLD, 4165
- Start (lat/long): -27.622467, 153.310166
- End (lat/long): -27.621399, 153.311327
- Approximate length: 160m.

6.2.4 Dominant material

The dominant material of an asset influences the type and frequency of inspections, failure modes, repair costs and the specialists that will be involved in future maintenance. This field describes the principal structural material of each asset.

The dominant material is:

- Rock

Notes: The design has specified primary armour rocks with D_{n50} of 0.4m. All rocks will have a density around 2650 kg/m^3 with an igneous nature.

6.2.5 Asset dimensions

An asset's dimensions are key indicators of deterioration degree and shall be documented over its design life for comparison. An asset undergoes continuous deterioration over its design lives. For marine assets, the deterioration is the result of exposure to wind, heat, wave, human actions and repeatedly drying, wetting by saltwater while for open drainage assets, it is because of fast flows, sun exposure, human, fauna, and flora actions. Typical deterioration for seawalls may include slumping, scouring, settling, displacing, and spalling, which may lead to changes in the structure geometry. For open channels, deteriorations are typically in the forms of damage to materials (erosion matting), blockage caused by foreign objects, scour, and excessive vegetation growth.

The following information should be entered within the Asset Database, which are summarised from the prepared 'Preliminary' drawings.

The dimensions of are:

- Crest: 2.6mAHD, consisted of a double layer of armour rock, 1.2m wide (at least one primary armour rock wide).
- Exposed slope: a double-layer of armourstone, with a slope of 1 (vertical) to 2 (horizontal) consisted of primary armour rocks with geotextile underneath.
- Toe: Depth varies depending on the underlying subsurface material. Based on available borehole information, the design proposes a toe level of approximately 0.07 mAHD. Consistent with the project's no-dig philosophy, toe stability is achieved through a widened rock toe arrangement rather than embedment into the underlying stratum.

6.2.6 Inspections

The level of time and effort spent on inspection activities are related to the asset type, the value of infrastructures it protects, its condition and other external influences. Background guidance for marine asset inspection types is available in various resources, including:

- Coastal handbook – A guide for all those working on the coast (UK Defra / Environment Agency)
- The Rock Manual - The use of rock in hydraulic engineering (CIRIA)
- Toe Structures Management Manual (UK Defra / Environment Agency)
- Various structures inspection manuals (e.g. QLD Transport and Main Roads).

6.2.6.1 Type

Three types of inspections are recommended for Moores Road foreshore protection, level A to C:

a. Public/operational safety check – a visual inspection to check general serviceability and safety.
b. Visual Condition assessment – a regular visual inspection to assess the condition of a structure.
c. Specialised Inspection – an inspection to provide improved knowledge of the structure by a specialist upon request.

Level A – Visual Public/operational safety Check

This is a visual inspection to check general serviceability and safety of the seawall and drainage system, carried out when council personnel are near the site, to consider any required maintenance of structure elements with public use functions such as walkways, handrails etc. The aim of this inspection is:

- To ensure the asset is safe and functional.
- For RCC to identify any emerging problems and/or maintenance requirements that fall outside of the expertise and resources at hand of the council.
- To identify maintenance priorities and propose actions, including remediation works or Level B/C inspections when unusual behaviours of the asset or signs of distress is observed.
- To document the overall condition and any defects using sketches, pictures and descriptions in RCC's database in the required format.

Level A inspections will consider key structure elements that are in use by members of the public. The inspector can visit locations along the asset and focus on elements of the asset that are above ground and water level. The inspectors should be considered as competent to conduct visual inspections by RCC and have extensive practical experience in asset maintenance which enables them to judge the condition of an asset visually.

The inspection shall be prepared by the inspection personnel, following RCC processes, inspection equipment and safety related equipment. Safety plans must be prepared and approved by RCC.

Emerging problems related with the Moores Road foreshore protection include but not limited to:

- Scouring at toe.
- Displaced armour rocks.
- Varying alignment, both in elevation (settling of the crest) and at toe (slumping).
- Forming of large voids on the exposed slope and exposure of geotextile.
- Signs of outflanking behind crest and at tie-in.
- Any damage to rocks, such as spalling and cracks.
- Any large vegetation growing on the asset.
- Exposed geotextile.
- Bare slope indicating minor land slide immediately above seawall crest.

Identification of the above issues should trigger a subsequent inspection (either Level B or Level C) depending on the severity of identified issues. It may also necessitate closure of public access to the asset, when public safety and health is threatened. Alternatively, when the emerging issues can be solved by RCC, small scale maintenance/remediation shall be arranged.

Level B - Visual Condition Assessment

This is a visual inspection to assess the condition of the asset by considering its physical, material and structural conditions, material defects, its performance, safety issues and aesthetic values. This type of inspection should cover the entire asset. It is typically non-intrusive, considering elements located above the ground and water level. The aim of this inspection is:

- To identify and quantify structure or material defects, potentially through measurement.
- To identify maintenance priorities and propose actions, including remediation works.
- To evaluate residual lifetime of the asset and its performance.
- To assess the effectiveness of remediation works and re-rating the asset if conducted after major maintenance works.
- To report on the condition of the asset through visual assessment, photographs, and a report. It is recommended to adopt a standardised scale, e.g. the 1 (very good) to 5 (very poor). This is further described in the following sections.

- Where a deeper understanding of the asset and its behaviour is required a level C inspection will be triggered.

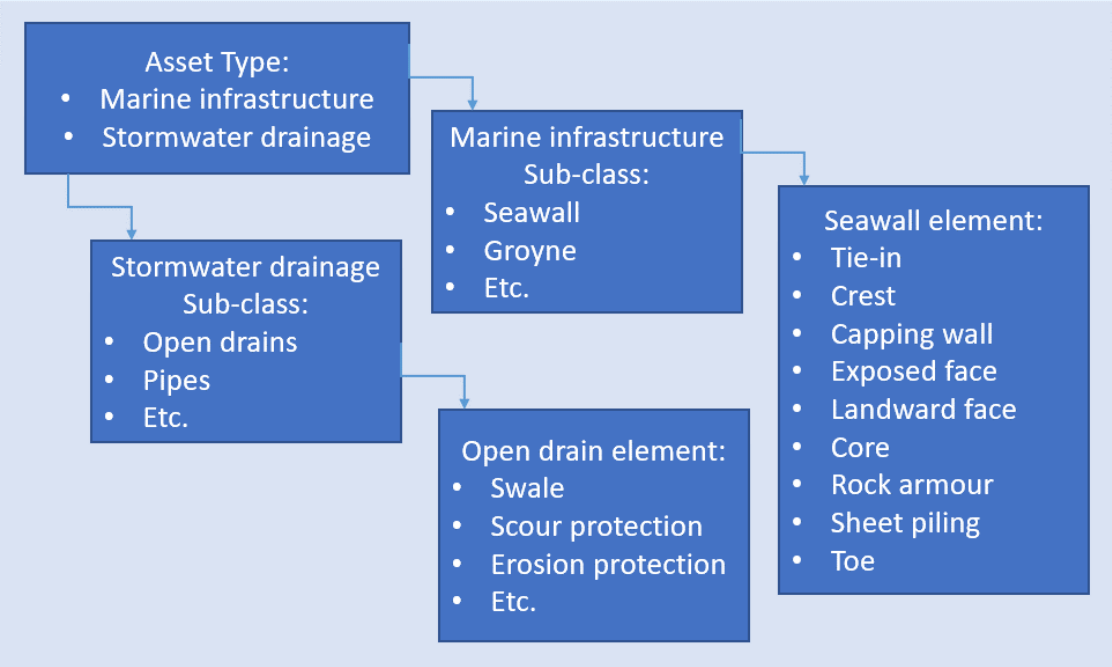
The inspector should be a coastal/civil engineer, or a coastal/civil officer trained and appointed by RCC, with practical experience in asset maintenance. The personnel must have the knowledge in inspection, maintenance, construction, design, and repair to properly rate the asset, to identify causes of defects and issues emerged when there is any. The responsibility of the inspector can cover proposing solutions to restore the asset to its intended performance upon agreement with RCC.

The inspection shall be prepared by the inspection personnel, as RCC requires, including all relevant documents, inspection equipment and safety related equipment. Safety plans must be prepared and approved by RCC, especially for inspections on assets suspected to be failing.

Visual Condition Assessment - Terminology

Coastal assets are a varied group of structures that include a number of shapes, forms and materials. Inconsistent identification and naming of structures and their components has been a common problem for asset managers, due to the over or under-classification of assets. A naming hierarchy and indicative structure elements are shown below for a range of typical structures.

Table 6-2: Asset naming hierarchy.





Visual Condition Assessment - Approach

Visual condition assessments will consider an assets condition against a baseline standard, using visual indicators to consider the physical, material and structural condition, its performance standard, safety issues, or aesthetic values. The condition assessment inspection process should follow the following:

Defence condition assessment – Condition Assessment Manual (document reference 166_03_SD01)

Using the visual descriptors within the Condition Assessment Manual, each asset can be assigned a condition grade.

Table 6-3: Asset naming hierarchy.

Grade	Description	Extent of defects
1	Very Good	Cosmetic defects that will have no effect on performance.
2	Good	Minor defects that will not reduce the overall performance of asset.
3	Fair	Defects that could reduce performance of asset.
4	Poor	Defects that would significantly reduce performance of asset.
5	Very Poor	Severe defects resulting in complete performance failure.

Within the Condition Assessment Manual, condition grades are provided for embankments, rock and stone revetments, concrete structures, steel structures, timber structures, channels, and culverts.

For each defence type and each condition grade, specific descriptors and key features are described. An example is shown below for Rock Revetment, Condition Grade 2 (Good)

Table 6-4: Example Condition Grading Reference for Rock Revetment – Condition 2 (Good)

<table>
<tr>
<td>
Example picture</td>
<td>Rock and stone revetment

Condition 2: Good

General: Minor defects that will not reduce overall performance of the asset</td>
</tr>
<tr>
<td>Specific description:
Minor movement of structure, though crest and bank profile remain intact. Rock density consistent over full bank height. Minor sediment infill to toe. Minor vegetation growth present.</td>
<td>Key features:
Minor settlement of crest but no cracking of crest or damage to pavement. Minor bulging at toe or minor sliding of revetment. Minor undermining but no loss of depth or signs of movement. Only minor reduction in thickness or loss of material. No animal burrowing or foreign objects present.</td>
</tr>
</table>

Level C - Specialised Inspection

This is an engineering inspection to provide improved knowledge of the asset by a specialist who uses advanced techniques. This level of inspection can be undertaken over the entire asset, or limited to specific locations, depending on the investigation required. Level C inspection provides the opportunity to investigate asset conditions underground, under water, or in any other situations that a visual inspection is limited. The inspection may include:

- Non-intrusive testing, such as new field survey, bathymetric survey or in-situ measurements.
- Intrusive field investigation, such as structural assessments (e.g. rock armour peel backs, excavation of test pits), geotechnical assessments (e.g. coring, standard penetration tests), chemical tests or destructive/extractive tests on sample materials taken from the asset.

The aim of this inspection is:

- To assess the physical condition of an asset and identify failure modes with their causes.
- To estimates the performance and residual lifetime of the asset.
- To investigate the geometry of the asset and compare with 'As-built' construction records.
- To gather information for proposing remediation works or preparing update of the existing asset.

The inspector should be a specialist who is competent to determine material properties, structure behaviours, understand failure mechanism, causes and/or examine hydraulic performance of the asset depending on the purpose of the inspection. Potential specialists can be RPEQ (civil, structural, geotechnical or maritime engineers), scientists, laboratory technicians etc.

The inspection shall be prepared by the inspection personnel, as RCC requires, including all relevant documents, inspection equipment and safety related equipment. Safety plans must be prepared and approved by RCC, especially for inspections on assets suspected to be failing.

6.2.6.2 Frequency

The determination of inspection frequency to a fixed interval is difficult, and needs to consider the structure, level of use, environmental characteristics, repair history, and materials. A range of information is available through documents such as:

- ISO 55000 series of Asset Management standards
- Coastal handbook – A guide for all those working on the coast (UK Defra / Environment Agency)
- The Rock Manual - The use of rock in hydraulic engineering (CIRIA)
- Toe Structures Management Manual (UK Defra / Environment Agency).

The majority of coastal guidance documents recommend a risk-based approach, where higher profile assets are inspected at a greater frequency. At a minimum this should consider repeated condition inspections (e.g. Level B) between 1-3 years, depending on local conditions, repair

history, frequency of extreme weather events etc. JBPs recommended guidance for typical coastal structures is provided in Table 6-5.

Table 6-5: Recommended inspection frequencies for typical coastal assets

Type of structure	Level A: Public/operational safety	Level B: Visual condition	Level C: Specialised inspection
Structure elements with public use function (e.g. walkways, handrails etc)	Monthly*		
New structures	Annually (in between level B's)	Annually**	As requested
Structures in poor condition	Annually (in between level B's)	Annually	
Structures in moderate condition	Annually	2 years	
Established structures in good condition	Annually	3 years***	
All structures	After storm events. On report of problem.		

*: Recommended maintenance schedule but can be adjusted to fit RCC maintenance schedule.
**: Newly constructed coastal defences may exhibit movement or settlement and should be inspected more frequently.
***: After an asset is stabilised and its performance in its environment is proved three consecutive inspections (without major and abnormal deterioration), it is economically efficient to reduce inspection frequency. Table 6-5 reflects this concept by assigning lower inspection frequency to old structures rated in good condition after three rounds of level B inspection.

For the Moores Road foreshore protection:

a. Public/operational safety check:
   i. Annually
   ii. Following a reported significant storm event (recommended as events of 1-in-20-year and bigger.)
   iii. Following reports of any safety hazards.
b. Visual Condition assessment:
   i. Following construction: annually
   ii. Following three successive years of no change, whilst in a good condition: every 3 years
   iii. Following three successive years of no change, whilst in a moderate condition: every 2 years.
c. Specialised Inspection – As requested.

6.3 Life cycle costing

Whole of life costs for the proposed seawall and foreshore access ramp are broken down as mentioned in Section 6.1.1 and details shown in Table 6-6.

Table 6-6: LCC cost breakdown

Items	Assumptions	Estimates (AUD)
Design fee	-	$ 100,000
Development Approval (DA)	-	$ 40,000
Construction tendering and review of tendering documents	1% of construction fee (with no contingency)	$ 8,013
RCC Administration cost	1% of construction fee (with no contingency)	$ 8,013
Construction	Require Culture Heritage Monitors - QLC Estimates with 15% detailed phase contingency.	$ 801,323
Maintenance (per yr.)	More detail in Section 6.3.1.	$ 4,970

Total capital expenditure (CAPEX)	-	$ 957,349
Total 50-year cost	**No discount rate applied, not present net value**	**$ 1,205,849**

6.3.1 Ongoing cost

Ongoing costs have two categories:

- Inspection costs
- Maintenance/ repair costs.

The frequency of inspection has been discussed in previous sections and the ongoing costs are calculated based on following assumptions:

Level A inspections:

- Annually public/safety check (Level A) on the rock revetment.
- Additional Level A inspection following a 1 in 20-year event (i.e. there are 2 inspections in that year).
- Quarterly Level A inspections during the first year to assess rock stability, placement, and initial ground settlement.
- Quarterly Level A inspections during the final ten years of the design life to identify deterioration or component failure and determine maintenance needs.

Level B inspections:

- Annual visual condition assessments (Level B) will be performed for three years after construction (2026 to 2029).
- Tri-annual Level B assessments will be performed from 2029 to 2050 assuming the structure has stayed in a good condition for the early stage of its design life.
- Bi-annual Level B assessments will be performed from 2050 to 2075 assuming the structure will shift from a good to moderate condition around 2051, therefore requiring a level B inspection every 2 years for the remaining design life.

Level C inspections:

- A specialised inspection (Level C) has been assumed to be required once in the design life, 30-years after construction.

Table 6-7: Estimated cost per inspection

Inspection type	Cost per inspection	Assumptions
Level A	$100	Performed by RCC personnel.
Level B	$5,000	Performed by external Consultant including reporting.
Level C	$20,000	Performed by external Consultant including investigations other than visual defect identification.

The rock revetment has been designed with a 50-year design life. However, it is foreseeable that some elements will require maintenance and/or repairs. Table 6-8 summarises the items and estimated associated costs. All costs quoted in the table are estimates based on first principle estimates with no market research.

Table 6-8 Estimated cost for maintenance/repairs per time

Remediation item	Maintenance works	Cost
1	Works on rock revetment	$ 20,000
2	Vegetation maintenance	$ 2,000
3	Stormwater maintenance	$ 2,500

A detailed cost table has been prepared based on assumptions as shown in Table 4 4. The average ongoing cost per year is estimated as $4,746, approximately 0.6% of the unfactored construction fee.

Following construction, it is estimated the remaining costs for the structures are approximately $237,300.

- Inspections: $138,500
- Miscellaneous maintenance/repairs: $110,000
- SUM: $248,500

Table 6-9 Ongoing cost breakdown

Report use

	Inspection cost				Maintenance cost			
Type	A	B	C		works on rock revetment	Vegetation maintenance	Stormwater maintenance	
Price	$ 100	$ 5,000	$ 20,000		$ 20,000	$ 2,000	$ 2,500	
Year	Inspection per year			Total (Non-discounted)	Maintenance per year			Total (Non-discounted)
2026	4	0	0	$ 400	0	0		$ -
2027	1	1	0	$ 5,100	0	0		$ -
2028	1	1	0	$ 5,100	0	0		$ -
2029	1	1	0	$ 5,100	0	0		$ -
2030	1	0	0	$ 100	0	1		$ 2,000
2031	1	0	0	$ 100	0	0		$ -
2032	1	1	0	$ 5,100	0	0		$ -
2033	1	0	0	$ 100	0	0		$ -
2034	1	0	0	$ 100	0	0		$ -
2035	1	1	0	$ 5,100	0	1		$ 2,000
2036	1	0	0	$ 100	0	0		$ -
2037	1	0	0	$ 100	0	0		$ -
2038	1	1	0	$ 5,100	0	0		$ -
2039	1	0	0	$ 100	0	0		$ -
2040	1	0	0	$ 100	1	1	1	$ 24,500
2041	1	1	0	$ 5,100	0	0		$ -
2042	1	0	0	$ 100	0	0		$ -
2043	1	0	0	$ 100	0	0		$ -
2044	1	1	0	$ 5,100	0	0		$ -
2045	2	0	0	$ 200	0	1		$ 2,000
2046	1	0	0	$ 100	0	0		$ -
2047	1	1	0	$ 5,100	0	0		$ -
2048	1	0	0	$ 100	0	0		$ -
2049	1	0	0	$ 100	0	0		$ -
2050	1	1	0	$ 5,100	0	1		$ 2,000
2051	1	0	0	$ 100	0	0		$ -
2052	1	1	0	$ 5,100	0	0		$ -
2053	1	0	0	$ 100	0	0		$ -
2054	1	1	0	$ 5,100	0	0		$ -
2055	1	0	1	$ 20,100	1	1	1	$ 24,500
2056	1	1	0	$ 5,100	0	0		$ -
2057	1	0	0	$ 100	0	0		$ -
2058	1	1	0	$ 5,100	0	0		$ -
2059	1	0	0	$ 100	0	0		$ -
2060	1	1	0	$ 5,100	0	1		$ 2,000
2061	1	0	0	$ 100	0	0		$ -
2062	1	1	0	$ 5,100	0	0		$ -
2063	1	0	0	$ 100	0	0		$ -
2064	1	1	0	$ 5,100	0	0		$ -
2065	2	0	0	$ 200	1	1	1	$ 24,500
2066	4	1	0	$ 5,400	0	0		$ -
2067	4	0	0	$ 400	0	0		$ -
2068	4	1	0	$ 5,400	0	0		$ -
2069	4	0	0	$ 400	0	0		$ -
2070	4	1	0	$ 5,400	0	1		$ 2,000
2071	4	0	0	$ 400	0	0		$ -
2072	4	1	0	$ 5,400	0	0		$ -
2073	4	0	0	$ 400	0	0		$ -
2074	4	1	0	$ 5,400	0	0		$ -
2075	4	0	0	$ 400	1	1	1	$ 24,500
Inspection total (Non-discounted and PV)				$ 138,500	Maintenance total (Non-discounted and PV)			$ 110,000
Average inspection cost per year (Non-discou				$ 2,770	Average maintenance cost per year (Non-discounted and PV			$ 2,200
Average maintenance and inspection cost per year (Non-discounted and PV)								$ 4,970
Total maintenance and inspection cost (Non-discounted and PV)								$ 248,500

7 Appendix A: Drawings

8 Appendix B: Safety in Design Risk Register

9 Appendix C: Technical specification

10 Appendix D: Cost Estimate

11 Appendix E: Geotechnical Report