# Rothera Wharf Reconstruction
# &
# Coastal Stabilisation

# Final Comprehensive Environmental Evaluation


BAS Environment Office


September 2018

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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# Non-Technical Summary

*Introduction*

This final Comprehensive Environmental Evaluation (CEE) has been prepared by the British Antarctic Survey (BAS) to assess the potential environmental impacts associated with two related projects at Rothera Research Station; the reconstruction of Rothera Wharf and associated coastal stabilisation works. Over the next ten years the combined Antarctic Infrastructure Modernisation Programme (AIMP) represent the largest UK Government investment in polar science since the 1980s and will enable BAS to continue to deliver world leading science capability in the Polar Regions. Rothera Wharf reconstruction and the coastal stabilisation are the first activities at Rothera included in the AIMP projects. BAS have appointed the civil engineering company BAM as their Construction Partner to deliver this project.

This CEE has been prepared in accordance with Article 8 and Annex I to the Protocol on Environmental Protection to the Antarctic Treaty (1991).

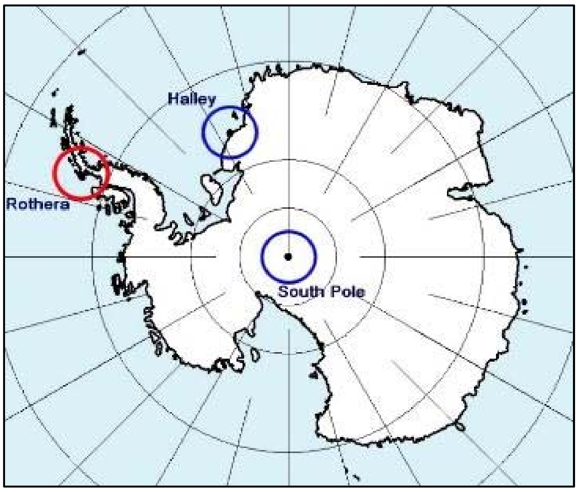


Fig 1. Map showing location of Rothera Research Station

*Description of Proposed Development 1 – Rothera Wharf Reconstruction*

The existing wharf at Rothera Research Station, referred to as the Biscoe Wharf is 25 years old and is now beyond economic repair. In addition the Natural Environment Research Council (NERC) have commissioned the construction of a new ship the Sir David Attenborough (SDA) which as a much larger research vessel than the current BAS ships, requires a new deeper and longer wharf, to be built at Rothera. The water depth at the existing Biscoe Wharf is too shallow for the SDA to berth alongside and it is not long enough to offload people and cargo safely. The proposed solution is to dismantle and replace the existing wharf with a new larger wharf built in the same location. The design of the new structure is similar to the existing 60m long wharf design but will have a berthing length of 76m and extend further out to provide greater water depth. The preferred option will be constructed over two Antarctic summer seasons 2018-2020. Demolition of the existing wharf and partial build of the new wharf will occur in the first season and completion of the construction will take place in the second season.


Fig 2. Aerial view of Rothera Research Station & Biscoe Wharf at Rothera Point

*Alternatives*

The 'do nothing" and the 'do minimum" options were evaluated but would not enable safe and efficient berthing and mooring of the SDA so were rejected. A number of alternative designs were evaluated but were not considered viable due to cost, logistics, safety or environmental constraints.

*Description of Proposed Development 2 – Sourcing Local Rock*

In order to provide the rock fill required for the Rothera Wharf reconstruction and the coastal stabilisation works, it is proposed to quarry rock from Rothera Point. The intended site which is approximately 6000 $m^2$, is within the current overall footprint of the station operations, directly adjacent to the current Biscoe Wharf. In order to produce the necessary rock fill, it is anticipated that a gross quantity of approximately 65,000 – 80,000 tonnes (24,000-30,000 $m^3$) of in-situ rock will be sourced.

In order to source the rock the following activities will have to be undertaken:

- drilling and blasting;
- loading and hauling rock; and
- processing, crushing and screening.

*Alternatives*

Sourcing the rock fill from alternative locations at Rothera Point and outside of Antarctica was considered. Other locations to source rock locally were discounted on environmental grounds because they were outside of the current operational footprint and in a more sensitive location or too close to station buildings. Sourcing rock fill from outside of Antarctica was rejected as an option owing to the high risk of accidentally importing non-native species.

*Description of Proposed Development 3 – Coastal Stabilisation*

In association with the construction works for the wharf, it is proposed to reinforce an area of shore protection. The location of these works is a small man-made cove situated between the runway at

Rothera and the current Biscoe Wharf. The rock embankment which is built up around the cove, provides shore protection to both the aforementioned structures. It is predicted that due to the new wharf design, which will protrude further into the sea than the current one, that there is a small risk that the wave and ice effects within the cove will be amplified. Any subsequent damage to the existing cove embankment could impact the safe operation of either the Rothera Runway or the wharf. It could also impede the main sea water intake location in the cove that is used to supply all drinking water at Rothera. As a result of a qualitative assessment (completed since the submission of the Draft CEE), which analysed the anticipated impact of the wharf on wave energy and subsequent erosion in the cove, the anticipated works are now smaller in scale. It is anticipated that the proposed works will require a gross quantity of approximately 1,600 tonnes, (800m$^3$) of in-situ rock also to be sourced from Rothera Point.

*Alternatives*

The 'do nothing' and 'do minimum' options were considered but discounted because neither option will maintain the performance of the shore protection for a further 25 years. The preferred option was chosen because it was considered to provide optimal protection with minimal maintenance.

*Description of Support Activities*

The anticipated volume of cargo required for the construction works will require the use of a commercial charter vessel at the start of the construction programme. Dependent on the future programming of BAS ships, it will be necessary to charter a vessel for demobilisation at the end of project. Construction personnel will be deployed to Rothera using existing BAS logistics. All personnel will be housed in either the existing permanent accommodation at Rothera or within temporary accommodation units proposed to be installed in the 2017-2018 season.

Power generation for all construction activities will be provided independently to normal BAS operations. Other site services such as water, power and sewerage required for domestic use by construction staff will be provided by existing BAS services.

A temporary jetty is proposed to be constructed in order to continue the normal BAS small boating operations, during the reconstruction of the wharf. The jetty will also be used during resupply of the station by the BAS ship's tender vessel whilst the wharf is unavailable for use. This will be located in South Cove.

*Description of the Environment*

Rothera Research Station has been used operationally on a continuous basis since 1975. The station was initially planned and constructed in phases, after which other infrastructure was added as operational requirements changed. The works proposed in this CEE are predominantly within the current operational footprint and previously developed areas of the site.

Levels of biodiversity at Rothera Point are not high compared to other equivalent areas in Antarctica. However, it does contain some examples of Antarctic fellfield environment, which is reasonably rare in the wider area. This is typically a dry, cold terrestrial habitat prone to rapid freezing and thawing, that experiences seasonal snow cover and long hours of daylight in summer and to which organisms have adapted in order to survive the extreme conditions. In contrast, the near shore marine environment is considerably more species diverse and the subject of most biological research in the area. South polar skuas are the most abundant breeding birds at Rothera with occasional pairs of kelp gulls nesting and one Wilson's storm petrel nest has been found. Adélie Penguins are regular visitors but do not breed at Rothera. Although no seals breed at Rothera, Weddell and leopard seals are present all year round. Crabeater, elephant and fur seals are also present during the summer months. Minke, humpback and killer whales are seen in Ryder Bay each summer.

Antarctic Specially Protected Area (ASPA) 129 is located on the northern end of Rothera Point, which was designated to protect scientific values, and to serve as a control site, against which the effects of human impact associated with the adjacent Rothera Research Station could be monitored in an Antarctic fellfield ecosystem. It is more than 500 metres away from the propose construction activity.

No non-native plants or invertebrates are known to be present at Rothera Point or in the adjacent marine environment.

### *Impact Identification & Mitigation*

A full assessment of the potential environmental impacts is included within this CEE. Most of the predicted impacts will be minimised by implementing existing BAS procedures or with the addition of specific mitigation and monitoring. The most significant potential impacts predicted are:

- Introduction of non-native species
- Terrestrial or marine pollution from fuel spills
- Removal of rock resulting in a change in the aesthetics of Rothera Point
- Loss of ice free ground for terrestrial habitat
- Disturbance to marine mammals by underwater noise
- Loss of marine benthic habitat

The introduction of non-native species as a result of importing cargo or the deployment of personnel could have a significant impact in the longer term, but these impacts are less likely because normal biosecurity procedures will be followed.

The most significant potential impact is the permanent removal of rock for use in the wharf construction. This will potentially alter the aesthetic value for Rothera Point and reduce the available ice free terrestrial habitat. The decision to quarry rock locally was influenced by the need to reduce the risks associated with the importation of large quantities of aggregate which have the potential to introduce non-native species.

The probability of impacts associated with fuel spills occurring will also be reduced by compliance with standard operating procedures with during refuelling. In the unlikely event of a spill, oil spill contingency plans are in place and will be followed to minimise the severity of impacts.

Disturbance or harm to marine mammals from changes in underwater noise could result in avoidance behaviour or hearing damage however, the robust mitigation measures outlined will be adhered to, to ensure that the risk of this occurring is minimised and where possible avoided.

The extension of the wharf will result in a small reduction in the local marine benthic habitat within the footprint of the new wharf. A further impact to the surrounding benthic communities could occur from disturbance through underwater construction activity. The wharf design has sought to reduce the amount of sea bed preparation required and therefore the extent of this potential impact. Additionally a long term monitoring programme is already underway in order to verify the predicted impacts.

The Rothera Wharf reconstruction and coastal stabilisation works, are essential activities for BAS to be able to fully utilise the new BAS ship, the SDA. The project has been designed to take account of environmental and social impacts which will be evidenced through the CEEQUAL assessment; this is a sustainability evaluation for infrastructure projects and undertaken by an independent verifier. The proposed plans largely avoid areas of ecological sensitivity and will predominantly occur in previously disturbed and developed locations at Rothera.

### *Monitoring & Audit Requirements*

A monitoring plan has been produced which defines the monitoring activities to be undertaken during the project. The monitoring tasks are split into two types of activities;

a) Short term monitoring of activities which could result in an immediate impact on the environment and can be modified during the construction programme to avoid adverse effects including:
   - Neutralisation of cement contaminated water
   - Sediment levels in seawater (turbidity)
   - Wildlife displacement
   - Noise from quarrying and construction activities
   - Vibration from quarrying and construction activities
   - Marine noise from construction activities
   - Airborne dust

b) Long term monitoring of activities which could result in impacts that can only be measured over several Antarctic seasons. Such activities are unlikely to be modified during the construction period. This will include monitoring of the following activities:
   - Skua breeding success on Rothera Point
   - Marine benthic invertebrate communities

### *Gaps in Knowledge and Uncertainties*

The information provided for the Draft CEE for Rothera Wharf was based on the '65% design details' available at the time of writing. There have been no significant departures from the 65% design to date Minor changes to the design have been incorporated into this document .Impacts associated with any minor changes to the design have been evaluated and included in this final version of the CEE.

Since the submission of the Draft CEE the amount of rock required for the wharf has decreased significantly from 140,000 - 155,000 tonnes (52,000-27,400m$^3$) to 65,000 – 80,000 tonnes (24,000-30,000 m$^3$).

The final solution for coastal stabilisation works, will be confirmed after further investigations on site have been completed which is likely to be in April 2019. An EIA update will be provided if the final solution differs to proposed option presented in this CEE.

The Rothera Modernisation project is a future programme funded by NERC, which aims to upgrade the station infrastructure at Rothera over a 5-10 year period. It is anticipated that an EIA will be prepared for the works once further design detail is completed in 2019. The EIA will assess the cumulative impacts associated with works included in this assessment and any other known future developments.

### *Conclusion*

Having prepared a full CEE and presented rigorous mitigation measures to reduce the risk of these impacts occurring, it is considered that some activities within the project will have a greater than minor or transitory impact. This level of impact is considered acceptable considering the significant scientific and operational advantage that will be gained as a result of the projects.

### *Authors of the CEE*

This CEE has been prepared by Clare Fothergill of the BAS Environment Office. The baseline section was written by Kevin A. Hughes with input from a number of expert contributors listed in the acknowledgements section. Construction specific mitigation measures, biosecurity procedures, spill response and waste management procedures were written in conjunction with Neil Goulding of BAM.

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# 1. INTRODUCTION

This final Comprehensive Environmental Evaluation (CEE) has been prepared by the British Antarctic Survey (BAS) to assess the potential environmental impacts associated with the proposed Rothera Wharf reconstruction and coastal stabilisation works. The proposed activities are part of the Natural Environment Research Council's (NERC) plans to modernise Rothera as the UK's gateway to Antarctica and to support the new polar research vessel, the Royal Research Ship *Sir David Attenborough* (SDA) currently being built and funded by the UK Government department Business, Energy and Industrial Strategy (BEIS).

## 1.1. Background to Development

Over the next ten years the combined Antarctic Infrastructure Modernisation Programme (AIMP) represent the largest UK Government investment in polar science since the 1980s and will enable BAS to continue to deliver world leading science capability in the Polar Regions. Rothera Wharf reconstruction and the coastal stabilisation are the first activities at Rothera included in the AIMP projects. BAS have appointed the engineering consultancy Ramboll as the Technical Advisors for the duration of the AIMP projects. BAM have been contracted as the Construction Partner, who in turn are partnered with design consultants Sweco UK.

## 1.2. Overview of Proposed Development

### 1.2.1. Rothera Wharf

NERC have commissioned the construction of the SDA, to replace the two existing British polar ships, the RRS *Ernest Shackleton* and the RRS *James Clark Ross*. Operated by BAS, it is anticipated that the SDA will be ready for use in the 2019/20 season. As a much larger research vessel than the current ships, the SDA will have an impact on the requirements for marine infrastructure and cargo storage at all the BAS research stations in Antarctica and South Georgia.

The SDA will require a greater depth of water at the quay side for safe operations than is currently available. The mooring and berthing forces on the existing Biscoe Wharf from the SDA will also be much higher than the existing ships and therefore the structural elements of the wharf will need to be more substantial. This means that the current wharf will have to be demolished and a new structure built that is fit for purpose.

### 1.2.2. Sourcing Local Rock

In order to provide the rock fill required for the Rothera Wharf reconstruction and the coastal stabilisation works, it is proposed to quarry rock from Rothera Point. The intended site which is approximately 6000 $m^2$, is within the current overall footprint of the station operations, directly adjacent to the current Biscoe Wharf. In order to produce the necessary rock fill, it is anticipated that a gross quantity of approximately 65,000 – 80,000 tonnes (24,000-30,000 $m^3$) of in-situ rock will be sourced. Due to refinements in the design of the wharf the quantity of insitu rocks required has decreased from the original anticipated amount of 140,000 - 155,000 tonnes (52,000-27,400$m^3$).

### 1.2.3. Coastal Stabilisation

The proposed location for the stabilisation works is small man-made inlet which is located strategically between the runway at Rothera and the edge of the existing Biscoe Wharf. Stabilisation works may be required to ensure that it remains resilient to wave action and sea ice for the next 25 years.

## 1.3. Purpose and Scope of Document

This CEE has been prepared in accordance with the requirements of Article 3 of Annex I to the Environmental Protocol to provide sufficient information on the Rothera Wharf reconstruction and associated coastal stabilisation works for an informed judgement to be made on the possible environmental impact of these activities on the Antarctic environment and whether or not they should proceed. The scope of this document covers the works associated with the Rothera Wharf reconstruction and coastal stabilisation only. Other development works which may be undertaken at Rothera in the future but have yet to be fully scoped, designed or funded are not included in this assessment. Such future initiatives have however been outlined in Section 14: Gaps in Knowledge and Uncertainties. The document has been split into the following sections;

- **Section 1** provides an introduction to the proposed project
- **Section 2** provides the approach to the environmental impact assessment
- **Sections 3-5** describe the split of the proposed development into three work packages, namely; the Rothera Wharf reconstruction, sourcing local rock and coastal stabilisation. Detail is included here on the need, scope, location, design plans and construction schedules.
- **Section 6** outlines the standard operational procedures that will be followed
- **Section 7** provides a description of the support activities that will be required to complete the works on station
- **Section 8** outlines the overall construction programme and works schedules
- **Section 9** provides a description of the current site and existing operations
- **Section 10** outlines the current baseline environment conditions
- **Section 11** identifies the potential environmental impacts and proposed mitigation
- **Section 12** presents the impact assessment
- **Section 13** presents the proposed monitoring and audit programme
- **Section 14** provides information on any known gaps in knowledge or uncertainties
- **Section 15** sets out the conclusions of the assessment
- **Section 16** provides contact details for the authors of the document
- **Section 17** acknowledges the contributors to the document
- **Section 18** provides the references
- **Section 19** provides the bibliography
- **Section 20** provides the appendices

A non-technical summary has been included at the beginning of the document to provide an overview of the CEE in a clear, concise and non-technical manner as well as outlining the conclusions achieved.

# 2. APPROACH TO ENVIRONMENTAL IMPACT ASSESSMENT

## 2.1. Statutory Requirements

To ensure the protection of the Antarctic environment, the Antarctic Treaty nations adopted the Protocol on Environmental Protection to the Antarctic Treaty in 1991 (hereafter referred to as the Environmental Protocol). The UK enforces the provisions of the Environmental Protocol through the 'Antarctic Act 1994 and Antarctic Act 2013' and 'Antarctic Regulations 1995/490 (as amended).

Article 8 to the Environmental Protocol requires that any activities in the Antarctica Treaty area shall be subject to an assessment, in accordance with the procedures set out in Annex I to the Environmental Protocol, Environmental Impact Assessment (EIA).

One of the guiding principles is that an EIA be carried out before any activity is allowed to proceed. Activities should be planned and conducted on the basis of *'information sufficient to allow prior assessments of, and informed judgements about, their possible impacts on the Antarctic environment'* (Article 3, Environmental Protocol).

Annex I to the Environmental Protocol sets out the detailed requirements for EIA in Antarctica, and establishes a three-stage procedure based on different levels of predicted impact.

The assessment levels are:

- Preliminary Stage;
- Initial Environmental Evaluation (IEE); and
- Comprehensive Environmental Evaluation (CEE).

If an activity is determined as having less than *a minor or transitory* impact, the activity may proceed. An IEE must be prepared if it is determined that an activity will have an impact equal to or no more than *minor or transitory*. A CEE is for activities that are likely to have more than a *minor or transitory* impact on the Antarctic environment.

Following the EIA process as outlined in Annex I and in agreement with the UK Foreign and Commonwealth Office, BAS concluded that a CEE is the appropriate level of assessment for the Rothera Wharf reconstruction & coastal stabilisation works.

It is acknowledged that EIA best practice is to take a holistic approach for multiple developments proposed at one particular site, over a number of years, in order to account for cumulative impacts. However due to a lack of detailed design available for other AIMP projects proposed for Rothera at the time of writing this CEE, it was considered appropriate to provide that information in a future EIA.

Cumulative impacts have been addressed where possible within this assessment. The activities in this assessment will also be assessed cumulatively in any future EIA submission for the overarching AIMP at Rothera.

This draft CEE is publicly available on the BAS website and has been circulated to the Antarctic Treaty Consultative Parties (ATCP) for comment for 90 days and has been submitted to the Committee for

Environmental Protection at least 120 days prior to the Antarctic Treaty Consultative Meeting (XLI ATCM) in 2018.

## 2.2. EIA Methodology

The approach taken when compiling this EIA followed the Environmental Impact Assessment Guidelines (ATS, 2016) prepared by the Committee for Environmental Protection (CEP). The guidelines provide advice and recommendations on appropriate document structure as well as methodologies for identifying and evaluating impacts. These suggestions have been followed wherever possible.

Other previously published CEEs and IEEs have been used as sources of information on the potential environmental impacts of activities within Antarctica, including how these have been assessed and how mitigation measures have been identified.

The purpose and need for the activities and a description of the principal characteristics of the Rothera Wharf reconstruction and coastal stabilisation works have been provided in an attempt to define the project (Sections 3-5). Design and construction details have been provided by the Construction Partner BAM and the Technical Advisor, Ramboll.

Baseline information on the current environmental state at Rothera has been included in order to evaluate the predicted impacts effectively. This information was largely sourced from scientific experts within BAS.

In order to forecast the potential impacts the construction activities have been divided into four main categories namely general construction; Rothera wharf; quarry, drilling and blasting; and coastal stabilisation. Individual construction activities were then considered in the context of the effect they could have on a relevant environmental resource. Factors considered included temporal and seasonal variations (of both the activities and the sensitivity of the environment), exposure rates, repetition of occurrence, and how multiple effects on a single resource could occur. The detailed information on the construction activities was obtained from the Construction Partner and expert advice from BAS scientists was sought to understand the potential cause and effect relationships.

Section 11 presents the impacts that have been identified. Where negative impacts are predicted, measures to mitigate or to prevent those impacts are identified and discussed. The impacts of support activities have been included in the Impacts of General Construction Activity in Section 11.1.Social impacts have been considered with regard to the potential impacts to the continuation of science on station during construction, on users of buildings in close proximity to the construction site and with regard to local heritage. Further consideration of these are included in the final section of Appendix B: Quarrying, Drilling and Blasting Management Plan.

As suggested by the CEP's EIA guidelines, and successfully used in previous EIAs, a matrix format has been used to present the impacts assessment. This method enables the impacts identified to be presented concisely along with the correlating assessment, suggested mitigation and risk score (pre and post mitigation).

The impacts have been predicted on the basis of professional opinion and experience of individual BAS scientists and the BAS Environment Office. Noise specialists Aquatera (and sub consultants Subacoustech) have provided the underwater noise assessment for blasting and rock breaking.

Direct, indirect, cumulative and unavoidable impacts have been examined and are ranked according to their extent, duration, probability and significance. A risk rating has been applied to each impact before and after mitigation. A more detailed explanation of the methodology used is outlined in Section 12 Impact Assessment.

A monitoring and audit plan has been developed to ensure that early warning of adverse effects can be identified quickly and modifications of activities can be made should they be necessary.

An overarching conclusion of the EIA process has been presented in Section 15.

## 2.3. CEEQUAL

CEEQUAL is the international evidence-based sustainability assessment, rating and awards scheme for civil engineering, infrastructure, landscaping and works in public spaces. It is a voluntary scheme which supports the UK Government approach on assessing, benchmarking and rating the sustainability performance of projects. The scheme rewards project and contract teams in which clients, designers and contractors go beyond the legal, environmental and social minima to achieve distinctive environmental, economic and social performance in their work.

All CEEQUAL Project or Contract Awards are based on a self-assessment carried out by a trained CEEQUAL Assessor that is then externally and independently verified by a CEEQUAL-appointed Verifier. The scheme uses a points-scoring-based assessment, which is applicable to any civil engineering project. The scheme is made up of 200 questions relating to environmental and social aspects of an infrastructure development such as the use of water, energy and land, impacts on ecology, landscape, neighbours, archaeology, as well as waste minimisation and management, and community relations and amenity. Individual questions deemed irrelevant to the project or contract can be scoped-out during the Scoping Process, following the discussion and agreement between Assessor and Verifier. Assessors then use a rigorous self-assessment process, collecting supporting documentary evidence for questions relevant to their project or contract, and scoring them accordingly. An Online Assessment Tool is used to capture the scores and evidence commentary. Upon completion of the assessment, the performance score is ratified by CEEQUAL, and the project or contract team is granted an Award.

There are several different CEEQUAL Award levels that a project can achieve, depending on the percentage number of points scored against the scoped-out question set.

These are:

- more than 25% - Pass
- more than 40% - Good
- more than 60% - Very Good
- more than 75% - Excellent

The Rothera Wharf and Coastal Stabilisation project is currently progressing through the process of gaining a CEEQUAL award. A CEEQUAL Whole Project Award has been applied for, meaning that the entire scope of the project from conception through to construction is subject to assessment and all parts of the team are working together to progress the award. The project has already been subject to CEEQUAL scoping. This is the process which helps select the questions that are relevant to the project and makes the assessment bespoke. The evidence collection phase continues until the construction activities end.  At this point the project assessment will be verified by CEEQUAL and the award given. This CEE will provide evidence for a number of key environmental considerations relevant to the assessment.

# 3. DESCRIPTION OF PROPOSED DEVELOPMENT 1 – Rothera Wharf

## 3.1. Purpose and Need

BAS are proposing to redevelop and extend the existing wharf at Rothera Research Station (hereafter referred to as Rothera) to be able to accommodate the new RRS *Sir David Attenborough* (SDA) and other vessels. The existing wharf at Rothera is known as Biscoe Wharf and was designed and constructed in 1990/91 by Pelly Construction.

The provision of the Biscoe Wharf greatly reduced the amount of time it previously took to resupply Rothera. This is due to the ability to offload bulk cargo and shipping containers from the BAS ships directly onto the wharf. The wharf at Rothera is now vital to BAS operations in Antarctica. The current BAS ships, the RRS *James Clark Ross* (JCR) and the RRS *Ernest Shackleton* (ES), bring passengers and essential supplies including food, fuel, scientific equipment, vehicles, building supplies and personal possessions to Rothera at least twice each austral summer. It is anticipated that the SDA (128m long) will replace the ES (80m long) in 2019 and the JCR (99m long) the following season. The SDA requires a minimum seabed level of -9 mCD (metres chart datum) to accommodate the draught of the ship and an additional allowance for the thrusters and motion under cargo handling. The water depth at the existing Biscoe Wharf is too shallow for the SDA to berth alongside. The existing berth (60 m long) also does not meet the British Standard BS6349: Maritime Structures recommendations, for the length of berth needed by the SDA. A new deeper, longer berth is therefore needed to enable safe and efficient berthing and mooring of the SDA, as well as safe and efficient transfer of personnel and cargo.

## 3.2. Location

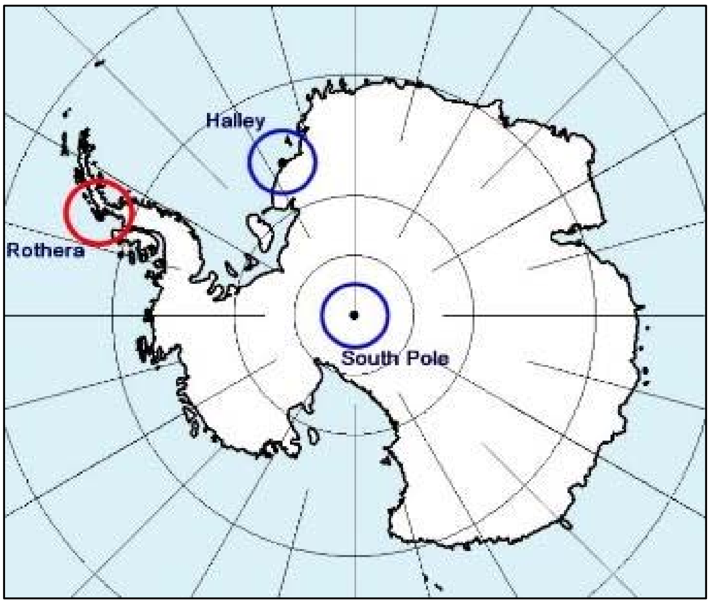


*Figure 3-1 Location of Rothera Research Station – Antarctic Peninsula*

The location of the proposed wharf is at Rothera which is located on the Antarctic Peninsula Lat. 67°35'8"S, Long. 68°7'59"W.


*Figure 3-2 Aerial view of Rothera*

## 3.3. Design details & scope of preferred option

The Biscoe Wharf was built as a sheet piled structure with upper and lower ties and is filled with stone material, which was locally quarried. The western return wall of the wharf was reconstructed following overload by an iceberg, and the eastern wall was extended as a precaution against erosion of the riprap revetment on that side. A repair was carried out to the western corner of the wharf in February 2016, following damage to the corner sheet pile, which split due to iceberg loading.

The proposed design solution (referred to as Option H) is to dismantle and replace the existing wharf with a new longer wharf, in deeper water, in the same location. The existing wharf will need to be dismantled, with the majority of existing elements fully removed, to allow the new larger structure to be built in the same location. The design of the new structure is similar to the original wharf design and consists of an outer sheet piled wall retained by a tubular pile mid wall and a sheet piled anchor wall. The new wharf will have a berthing length of 76m; the western side wall (nearest to the runway) will be 50m long and the eastern side wall will be 37.5m. The top of the wharf will be at +4.9mCD and the seabed, at the deepest point, will be at -11.5mCD. This option meets the recommendations of the British Standard BS6349: Maritime Structures.

The layout of the preferred option is shown in Figure 3-3.

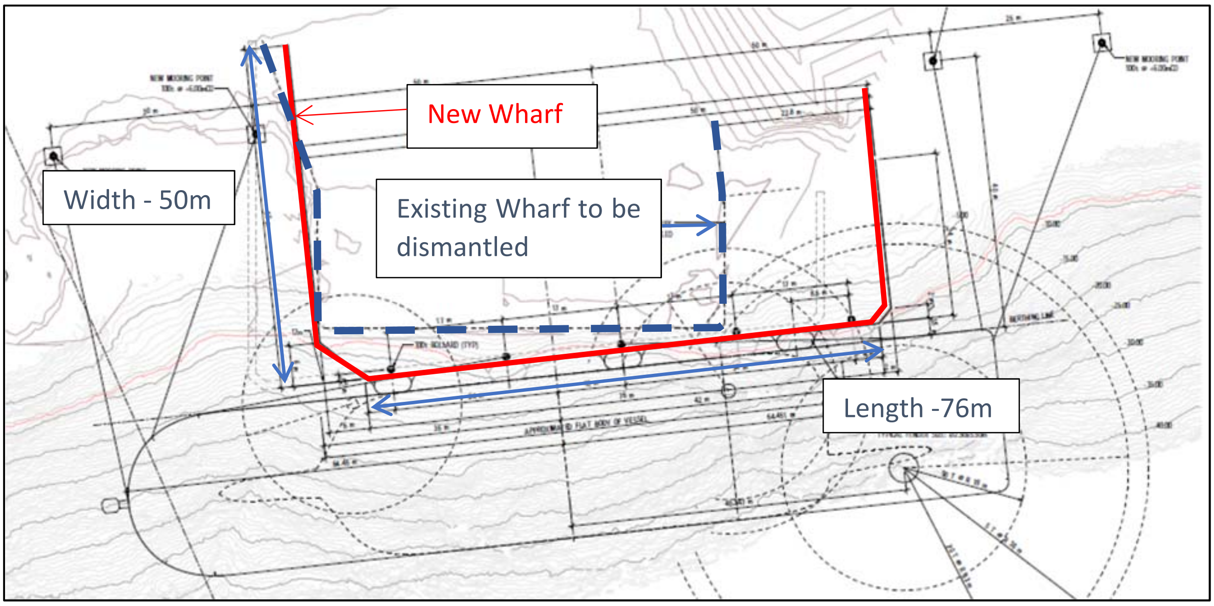


*Figure 3-3 Rothera Wharf Preferred Layout - Option H*

The alignment of the wharf has been optimised with respect to the contours of the seabed.

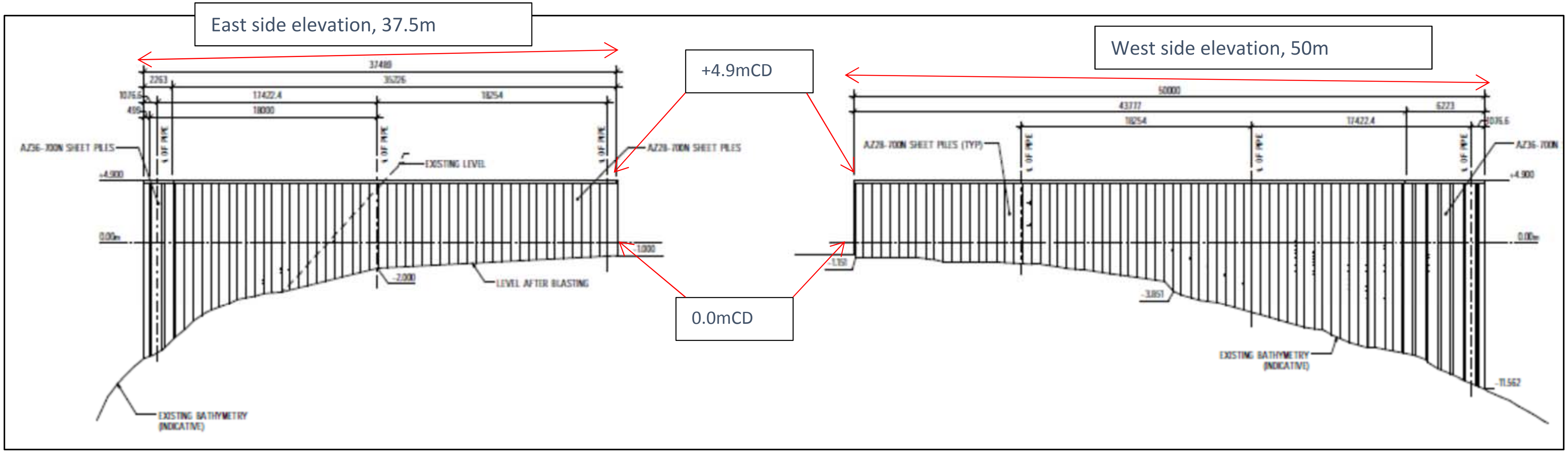


*Figure 3-4 Rothera Wharf Preferred Layout – Elevation of side walls*

Figure 3-4 and Figure 3-5 show the elevation of the side and front walls, illustrating the seabed profile, which falls away steeply at the eastern end.

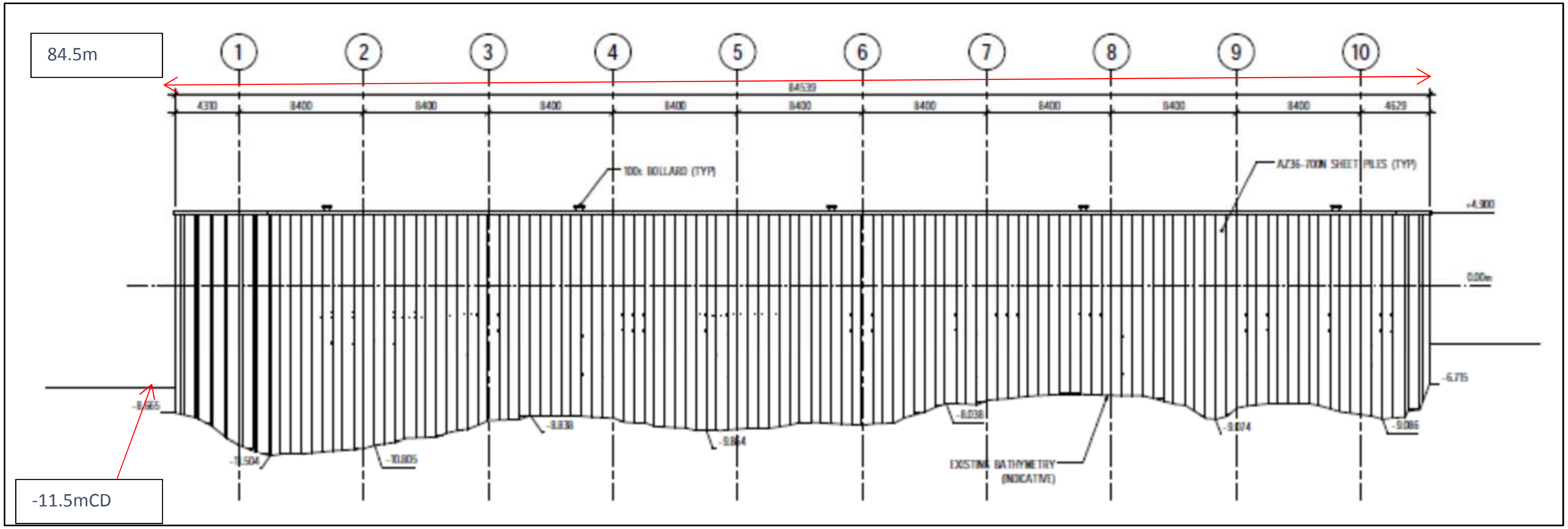


*Figure 3-5 Rothera Wharf Preferred Layout - Elevation of front wall*

Steel frames will be used to anchor the front wall to the mid wall and from the mid wall to the rear anchor wall, as shown in Figure 3-6. The frames will also be used as a temporary works platform to allow the anchored rock foundations for the front and mid walls to be drilled and installed. The frames will not require any tie rods to support the walls and they will be backfilled with rock quarried locally in the vicinity of the wharf site.

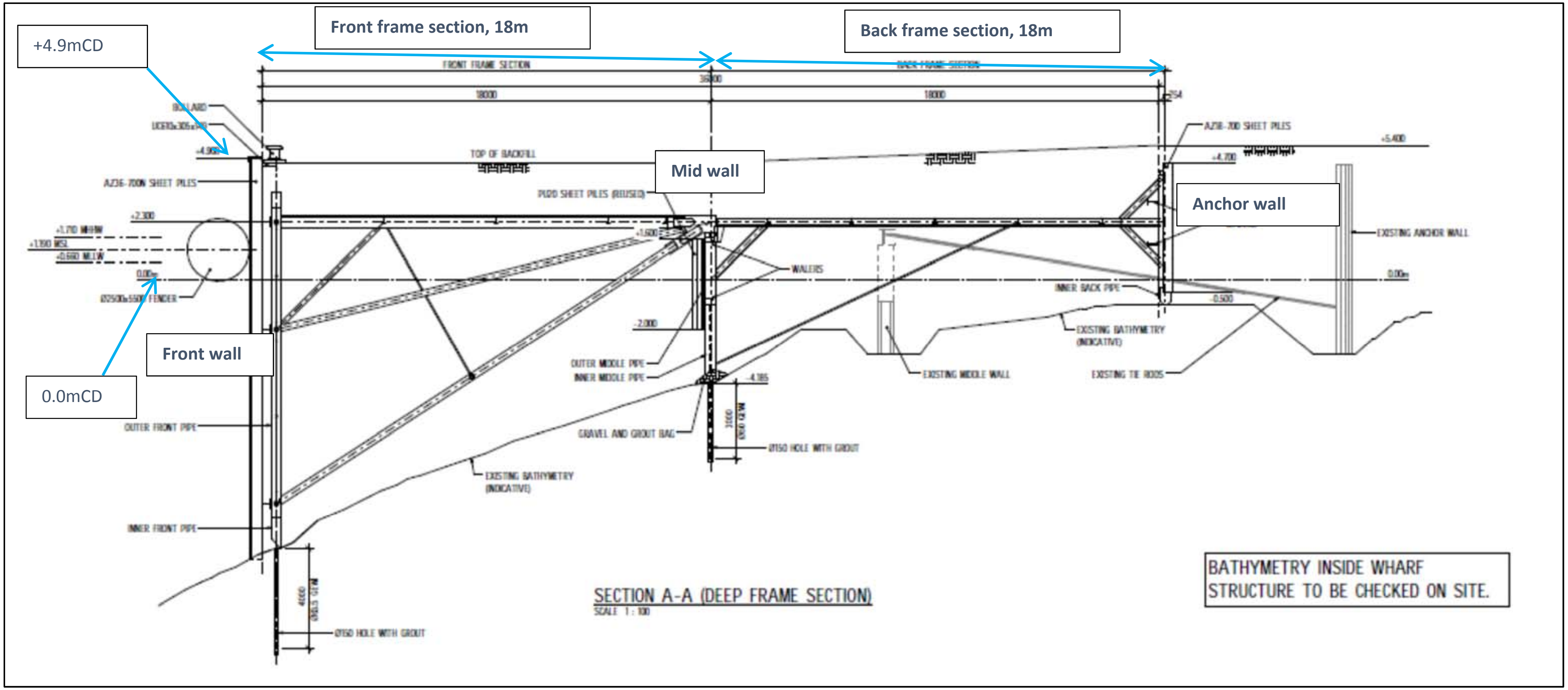


*Figure 3-6 Deep Frame Section – Front to Anchor Wall*

The wharf is proposed to be formed from prefabricated steel frames, which will be installed by 300T crawler crane and hydraulically jacked to the correct level. The Option H Method Statement (2017) outlined in Section 3.5 describes the methods that will be utilised to safely undertake the dismantling and construction activities, while minimising risks to personnel and the surrounding environment. The rendered image of the preferred option in Figure 3-7 shows the SDA alongside the new wharf, including the position of the runway and ice cliffs. Figure 3-8 shows the area where rock extraction will be required.

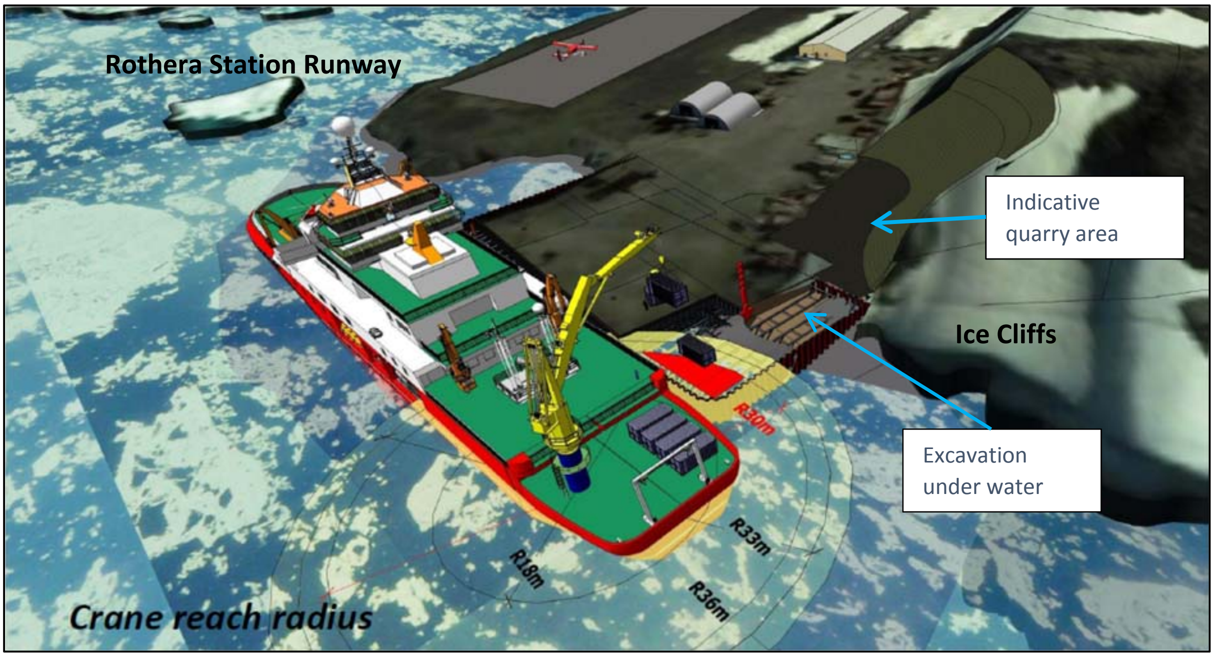


*Figure 3-7 Rendered Image – Option H with SDA alongside*

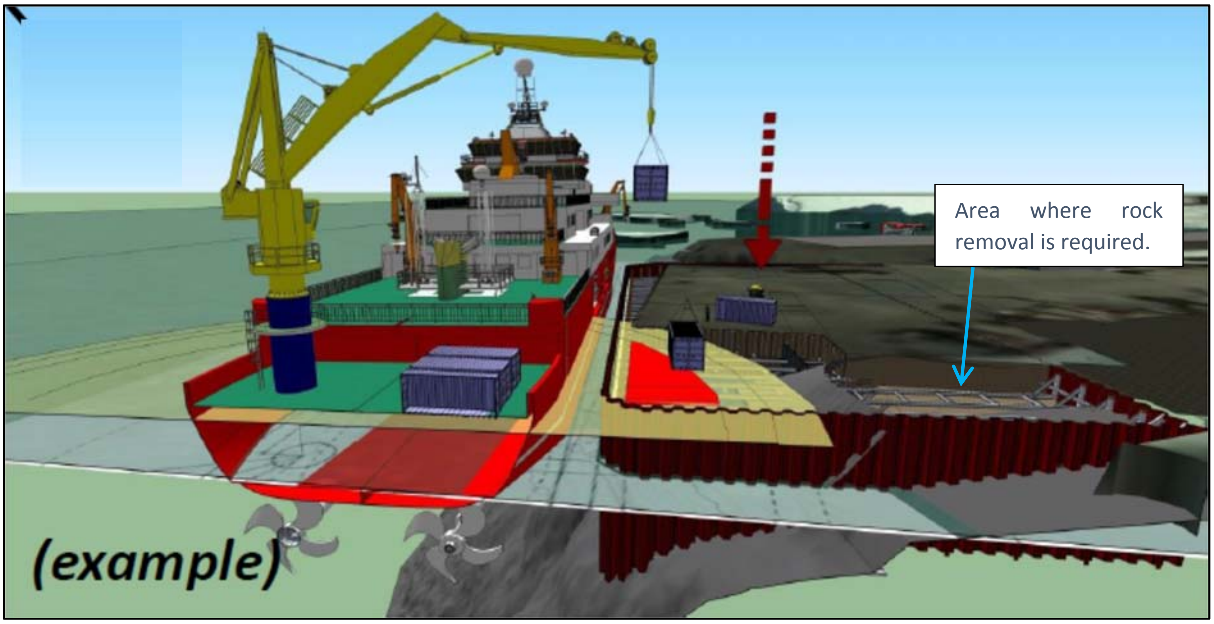


*Figure 3-8 Rendered Image – Eastern Wall. Area where rock extraction will be required.*

## 3.4. Alternatives Considered

The overall project has been undertaken as a series of consecutive work stages aimed to align with the Royal Institute of British Architects (RIBA) Plan of Work 2013 stages; a UK model for the building design and construction process. The stages are defined below.

*Table 3-1 Project Work Stages*

| Work stage (WS) | RIBA Plan of Work 2013 |
|---|---|
| WS 0 Strategic Project Definition | 0 –Strategic Definition |
| WS 1 Project Feasibility | 1 Preparation & Brief |
| WS 2 Assessment Study | 2 Concept Design |
| WS 3a Developed Design | 3 Developed Design |
| WS 3b Tender Preparation | |
| WS 3c Tender Invitation, Evaluation & Contract Awards | |
| WS 4 Technical Design | 4 Technical Design |
| WS 5 Construction | 5 Construction |
| WS 6 Completion & Handover | 6 Handover & close out |
| WS 7 Defects Period | 7 In Use |
| WS 8 Financial close | n/a |

The design of the wharf has evolved since Work Stage 1 in March 2016, when a long-list of options was reviewed, which included a “Do Nothing” and a “Do Minimum” option.

### 3.4.1. Do Nothing

Following an underwater inspection of the wharf in February 2016, the report concluded that there was moderate general corrosion to the sheet piles, but much greater corrosion (~40% of original thickness) to about 15% of the pile outpans (the outermost part of a sheet pile wall), in the zone between the water line and 5m below waterline. The “Do Nothing” option is therefore not viable with regard to the residual design life and durability of the wharf structure, since it would need to be repaired to reinstate its original strength, at least, to achieve a further minimum design life of 25 years. In addition to this, the “Do Nothing” option would not enable safe and efficient berthing and mooring of the SDA.

### 3.4.2. Do Minimum

A “Do Minimum” option would include repairs and possible strengthening of the wharf, but would not include any extension to the wharf for the berthing of the SDA. In the “Do Minimum” option, the wharf would not have sufficient length to undertake the berthing, mooring and cargo transfer operations safely and efficiently, since either (i) the stern cargo deck and main crane would protrude far off the east end of the quay (moored starboard side on) or (ii) the vessel would need to moor port side on with the bow protruding too far towards the ice cliff on the eastern side of the wharf. It was concluded that under certain weather conditions these mooring arrangements would significantly limit when the SDA could stay on berth. In addition these arrangements are not consistent with the design of the SDA for berthing starboard side on or for safe berthing.

### 3.4.3. Alternative Designs

*Options for extending the wharf at Work Stage 1*

During Work Stage 1 a number of options were considered for extending the wharf to the east, west or both to achieve the required berthing length. The key considerations at this stage were;

- the ability of the SDA's 50 tonne crane to operate over the quay, when berthed starboard and port side on;
- the proximity to the runway (to the west); and
- the proximity to the ice cliffs (to the east). (See Figure 3-7.)

*Construction Options at Work Stage 1*

A long list of options for berth construction was reviewed and a qualitative assessment made with regard to design and construction feasibility, ground conditions, ice loading, environmental issues and overall suitability for this location and purpose. This assessment included concrete gravity retaining walls, embedded retaining walls, suspended deck structures, a pontoon, an ice platform and a rock platform, in addition to options for strengthening the existing structure. Based on this qualitative assessment, the preferred options were either similar to the existing steel sheet pile wall construction, including tie rods and associated buried steelwork, or a combi-wall comprising socketed king piles and intermediate sheet piles. These options were carried forward to Work Stage 2 (Concept Design) of the design, with several layout options.

*Options for extending the wharf at Work Stage 2 and Work Stage 3 (Developed Design)*

Several layout options were assessed further during Work Stage 2, which were variations of:

- investigation, repair and strengthening of the existing wharf;
- local excavation to increase under keel clearance at berth, with and without extensions to the west and east; and
- construction of new quay wall in front of the existing one, in deeper water, with extensions to the west and east.

The preferred option at this stage was the construction of a new quay wall in deeper water. The selected layout, referred to as Option 4:

- met the requirements for secure berthing and mooring by the vessel in adequate water depth;
- provided a suitable area for transfer of cargo when berthing both port and starboard side to;
- avoided the risk and uncertainty associated with the investigation and repair of the existing wharf; and
- required less fill than the alternative option for this construction type.

The wall was proposed to include king piles socketed into the seabed, to avoid the need to install lower tie rods through the existing wharf. Upper tie rods would be installed back to an anchor wall. This option, as shown in Figures 3-7 and 3-8, was taken forward to the Work Stage 3 Develop Design phase.

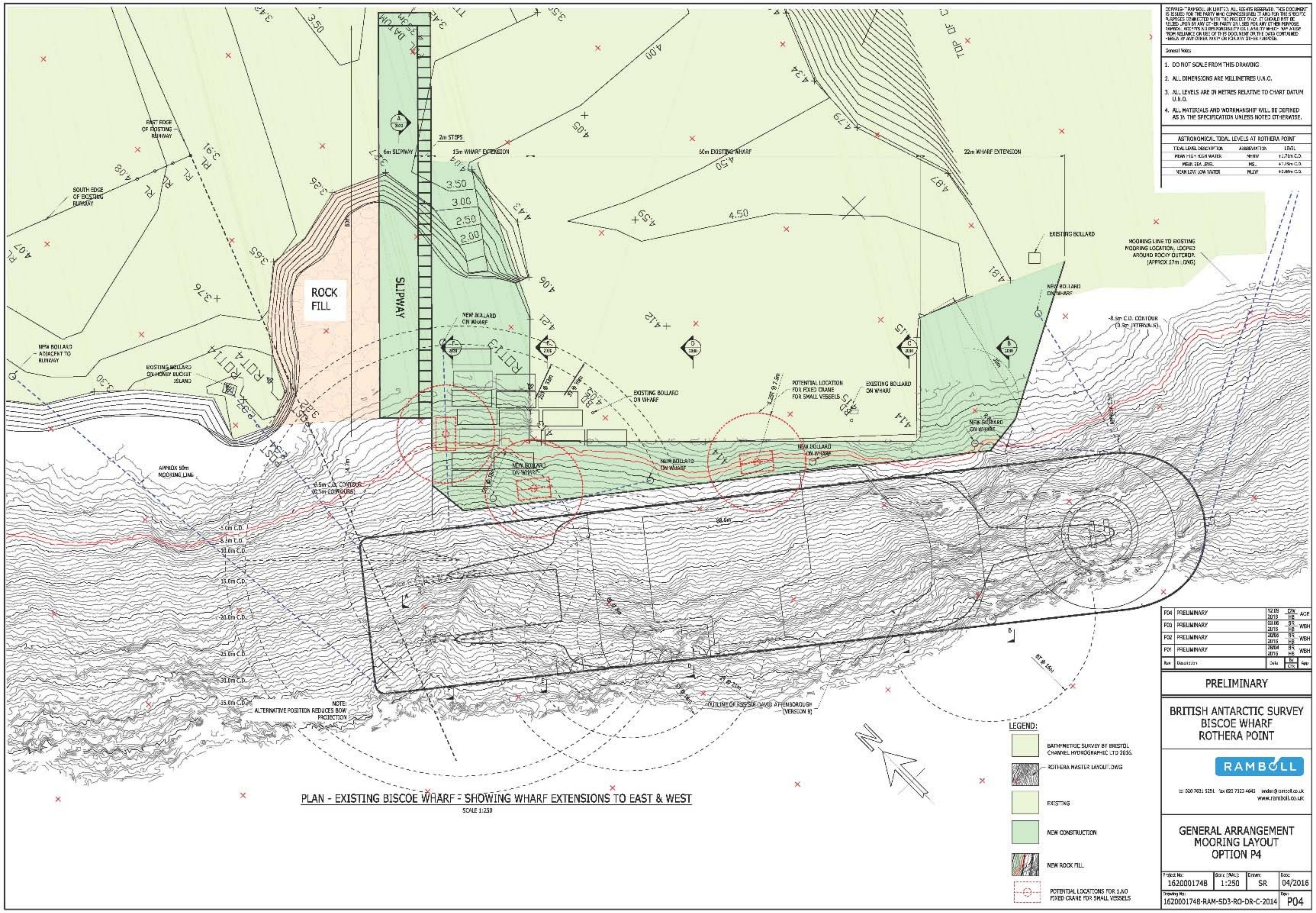


*Figure 3-9 option 4 Port side berthing*

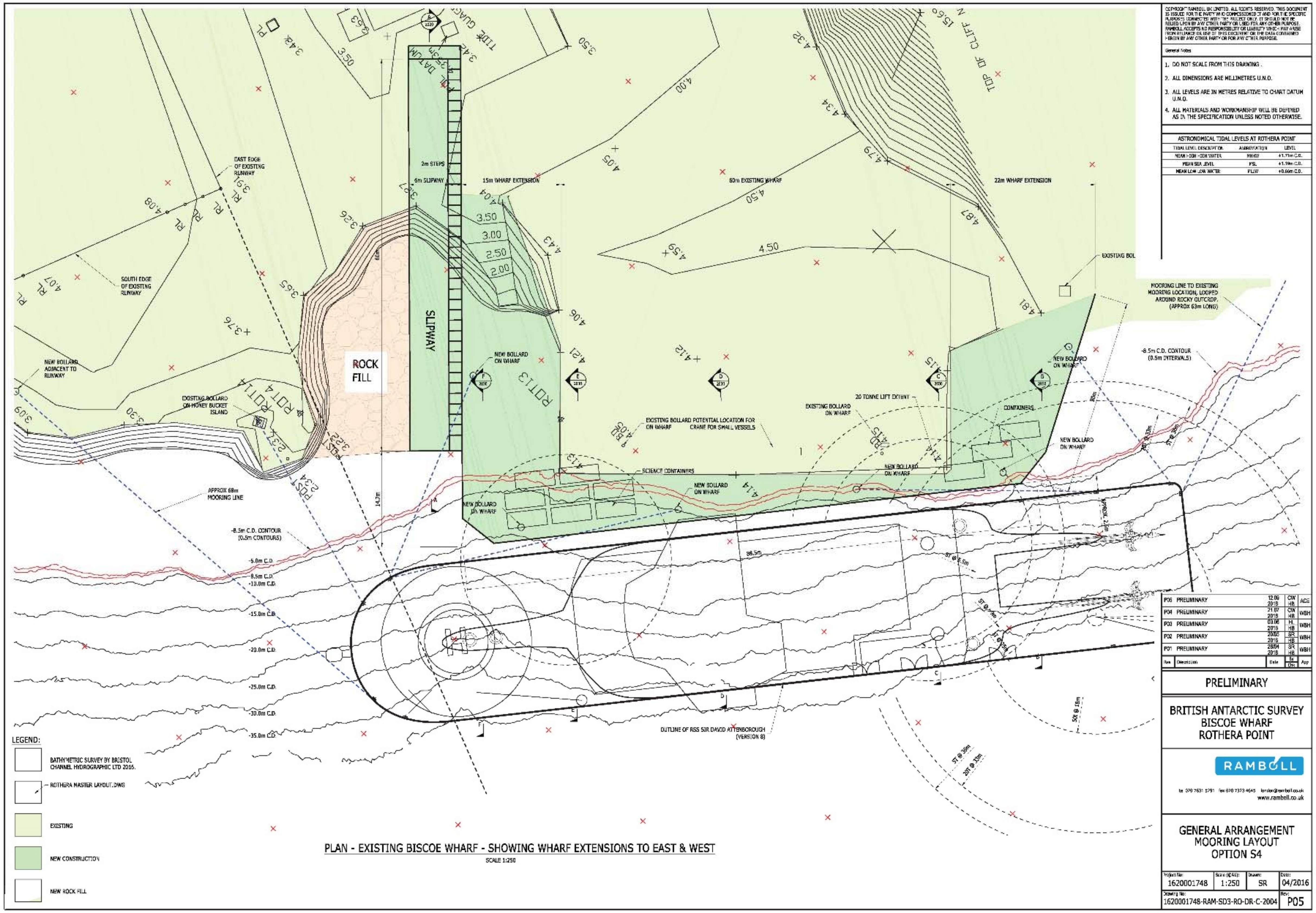


Figure 3-10 Option 4 – Starboard side berthing

The preferred solution was further refined to optimise the alignment with respect to the bathymetry and reduce the volume of rock fill needed.

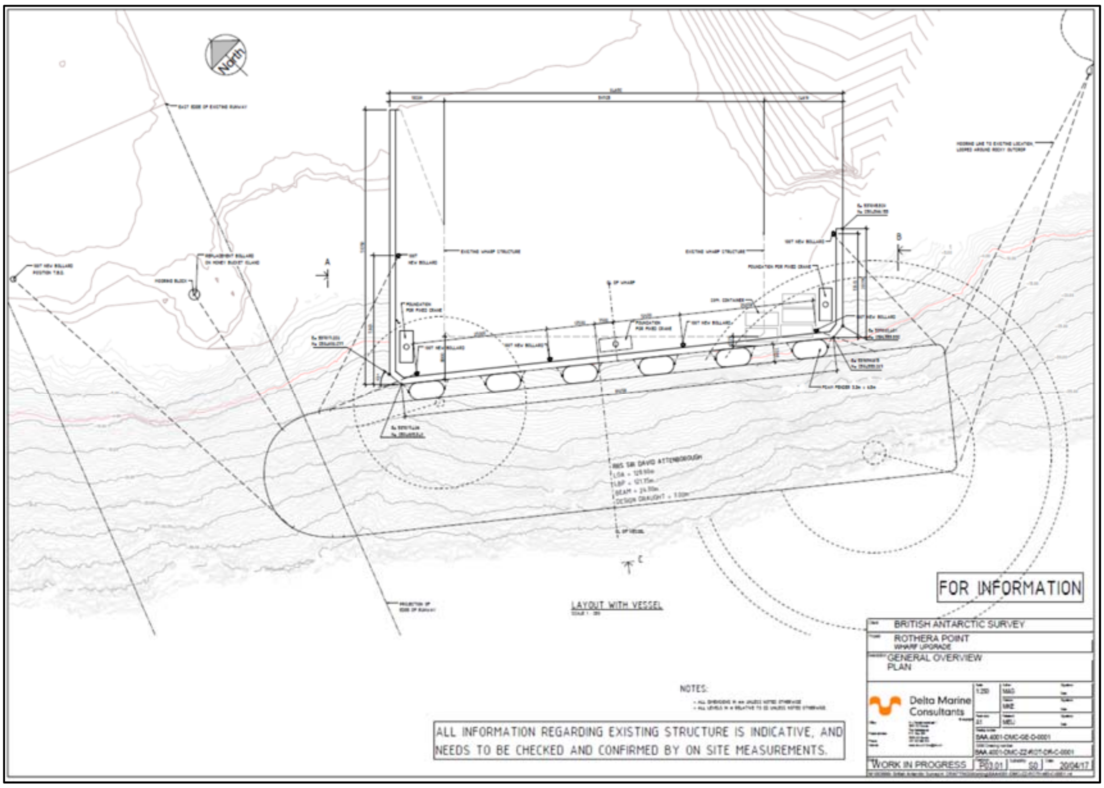


*Figure 3-11 Option 4 – Developed to 65% Design Stage*

This solution was developed to the 65% Design Stage and a target cost was prepared. The Detailed Design Phase is due to be completed in September 2018.

### *Optioneering Exercise*

The original design for the 65% Design Stage was based on assumptions of rock strength and fracturing which the results of the geotechnical site investigation demonstrated were overly optimistic. This increased the risk to the programme, chiefly the likelihood that an additional season may have been required to complete the construction. An additional optioneering exercise was carried out and this resulted in a design with far less reliance on the existing rock properties, thus greatly reducing the design and programme risk.

The options considered at this stage were:

- Option 1A – Upgrade existing wharf to provide a 25 year design life
- Option 1B – As Option 1A, but include a pontoon, barge or similar
- Option 2 – As Option 1A, but include removal of rock at the shore line and adjacent to Wharf
- Option 3 – Modify Existing Proposals such that rock removal at the shore line is not required. Operational Constraints introduced. SW corner reinforced.
- Option 4 – Combine Wharf Upgrade & Runway South End Stabilisation works
- Option 5 – Alternative Construction Type
- Option 6 – Relocated Wharf
- Inspect & Repair and Extend 18m East
- Wrap Existing Wharf
- Wrap Existing Wharf and Extend 18m East

Of these, the three options taken forward were:

- Wrap Existing Wharf and Extend East by 18m (Referred to Option E)
- Combine Wharf Upgrade with Runway South End Stabilisation works (includes existing wharf demolition) (Referred to as Option F)
- Demolish and Rebuild in Similar Location (Referred to Option H)

These are shown in outline in Figures 3-10, 3-11, 3-12.

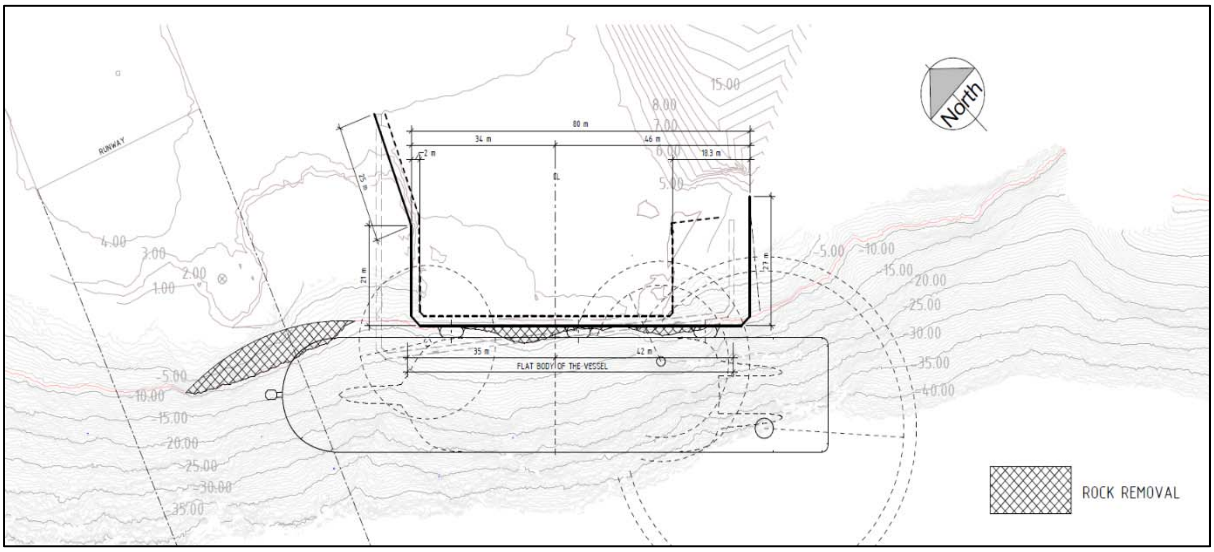


*Figure 3-12 Option E - Wrap Existing Wharf and Extend East by 18m*

Option E would be constructed within two seasons, the first would involve the wrapping of the front and west walls of the existing structure followed by an extension to the east in the second season. Underwater rock removal would be required and there would be operational restrictions in place whilst the ship manoeuvres. Additional operational costs may be expected in the ice cliff area.

A summary of how the risks associated with Option E were scored is presented below.

| **Risk table - Option E** | | **Confidence level** |
|---|---|---|
| | **Pro / Con / Risk** | **1 (low) – 5 (high)** |
| Environment | Limited underwater rock break out | 3 |
| Design | Complicated toe solution due to rock, 2 solutions required | 3 |
| Procurement | Bespoke / specialised details | 3 |
| Construction method | Challenging drilling methods, 3 types | 2 |
| Programme | High risk due to method & less contingency (as 2 season option) | 2 |
| Cost | Mid cost range at optioneering and risk of 3rd season has significant impact if realised | 3 |
| | **Total score** | **16/30** |

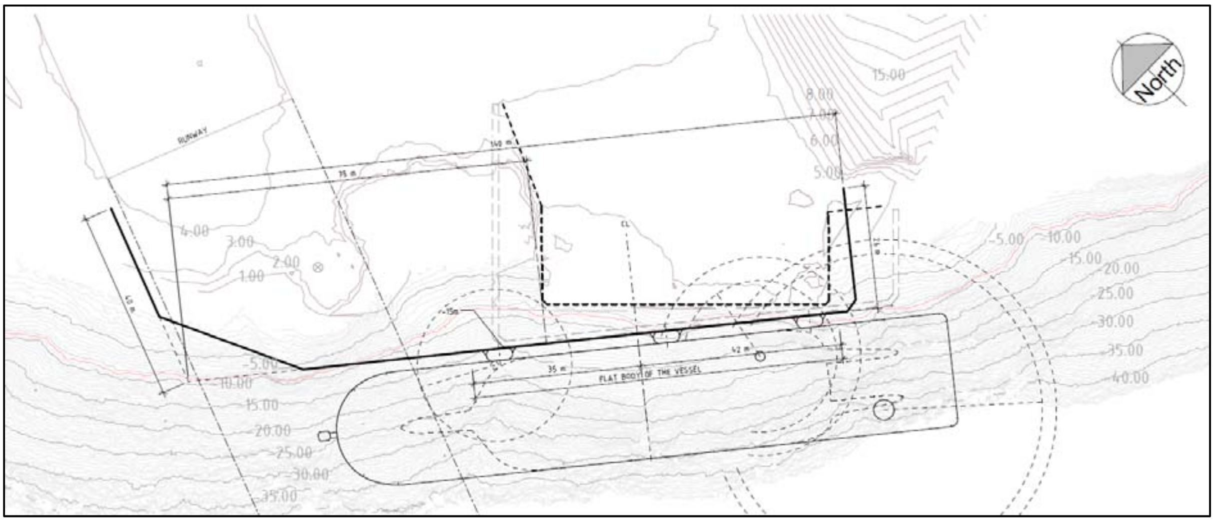


*Figure 3-13 Option F – Combine Wharf Upgrade with Runway South End Stabilisation works*

Option F would be constructed within three seasons due to the interface requirements with flights at the western end of the wharf. The solution has the potential to optimise the use of resources on the wharf and runway works and mitigates the risk of erosion in the inlet adjacent to the wharf, but required significant fill materials.

A summary of how the risks associated with Option F were scored is presented below.

| Risk table - Option F (inclined) | | Confidence level |
|---|---|---|
| | **Pro / Con / Risk** | **1 (low) – 5 (high)** |
| Environment | Limited rock breakout | 3 |
| Design | Assured simplified design but don't have full base design data – unknowns at runway | 3 |
| Procurement | Lead in times defined | 4 |
| Construction method | Historically assured | 4 |
| Programme | Challenging programme for 3 seasons, flight interface management increases risk of 4th season | 2 |
| Cost | Risk for 4th season cost | 2 |
| | **Total score** | **18/30** |

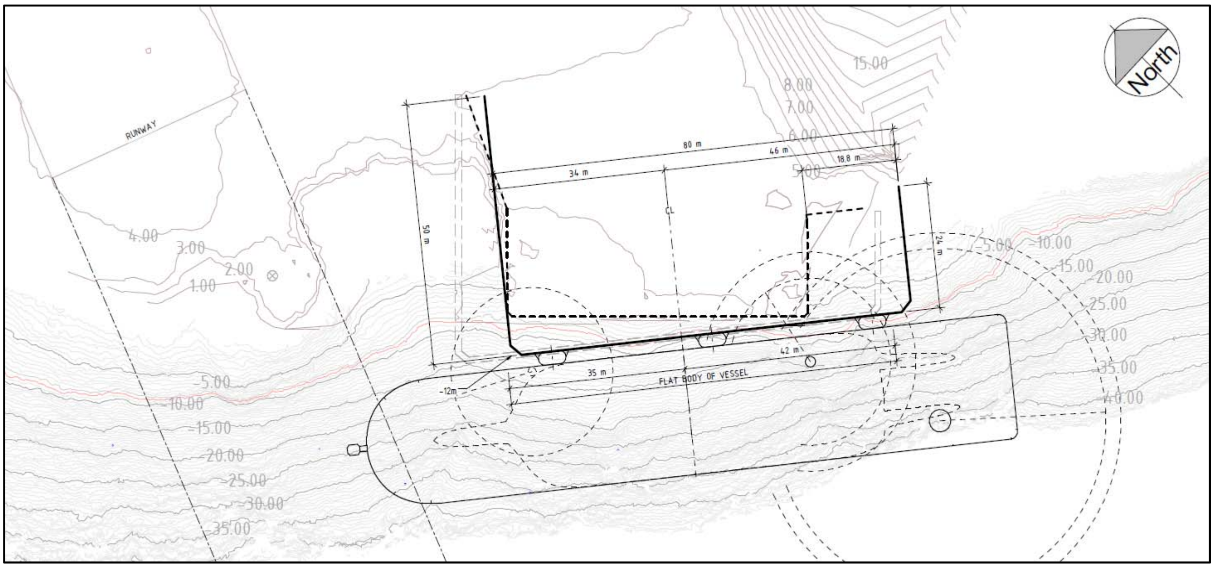


*Figure 3-14 Option H – Demolish and Rebuild in Similar Location*

Option H would be constructed within two seasons, with demolition of the existing wharf and build of the new wharf to the mid-wall in the first season and the completion of construction in the second. This option is similar in design concept to the original Biscoe Wharf and minimises drilling risks and requires less infill than Option F.

A summary of how the risks associated with Option H were scored is presented below.

| **Risk table - Option H** | | **Confidence level** |
|---|---|---|
| | **Pro / Con / Risk** | **1 (low) – 5 (high)** |
| Environment | No underwater blasting | 4 |
| Design | Assured simplified design | 5 |
| Procurement | Lead in times defined | 5 |
| Construction method / delivery | Historically assured for new build (detailed demolition method required) | 4 |
| Programme | Mitigates risk & allows contingency | 4 |
| Cost | Lowest cost range & greatest confidence at optioneering | 4 |
| | **Total score** | **26/30** |

Option H has been taken forward as the preferred option, which is described in detail in Section 3.3. At the time of writing the Draft CEE, the Detailed Design Stage was still being undertaken. Due to be completed in September 2018 the Detailed Design will not have any significant departures from the 65% design. Impacts associated with any minor changes to the design have been evaluated and included in this final version of the CEE.

## 3.5. Overview of Works

The Biscoe Wharf will need to be dismantled, with the majority of existing elements fully removed, to allow the new larger structure to be built in the same location. The design of the new structure is similar to the original wharf design constructed by Pelly and consists of an outer sheet piled wall retained by a tubular pile mid wall and a sheet piled anchor wall. Steel frames will be used to anchor the front wall to the mid wall and from the mid wall to the rear anchor wall. The frames will also be used as a temporary works platform to allow the anchored rock foundations for the front and mid walls to be drilled and installed. The frames will not require any tie rods[1] to support the walls and they will be backfilled with rock quarried locally in the vicinity of the wharf site.

The construction of the wharf is proposed to be completed over two Antarctic summer seasons commencing in December 2018, with completion anticipated to be in April 2020. A summary of the scope of works of the wharf construction consists of the following:

Season 2018 - 19:

- Dismantle and remove existing wharf
- Quarrying works to source local rock
- Install rear to mid wall frame, vertical ties and concrete infill to tubes
- Backfill between rear wall and mid wall

Season 2019 - 20:

- Install mid to front wall frame and vertical ties
- Backfill between mid-wall and front wall
- Installation of wharf furniture (bollards, fenders, davit crane bases)

## 3.6. Laydown Areas

Figures 3-15 and 3-16 illustrates the main laydown areas that are proposed to be used for storage of equipment, plant and temporary facilities, as well as identifying the main construction sites. Discussions between the appropriate BAS departments have taken place in order to identify the most appropriate location for these areas and have taken into account key operational and science requirements including:

- Sufficient clearance to allow flight operations to proceed with minimal interruption.
- Sufficient clearance to existing buildings to limit additional snow accumulation.
- Access routes which minimise crossings with existing services and facilities.
- Minimal disruption to ongoing science programmes and research.
- Utilising the existing station footprint and avoiding encroaching on relatively un-impacted areas.

[1] [1] steel bars used to brace the structure

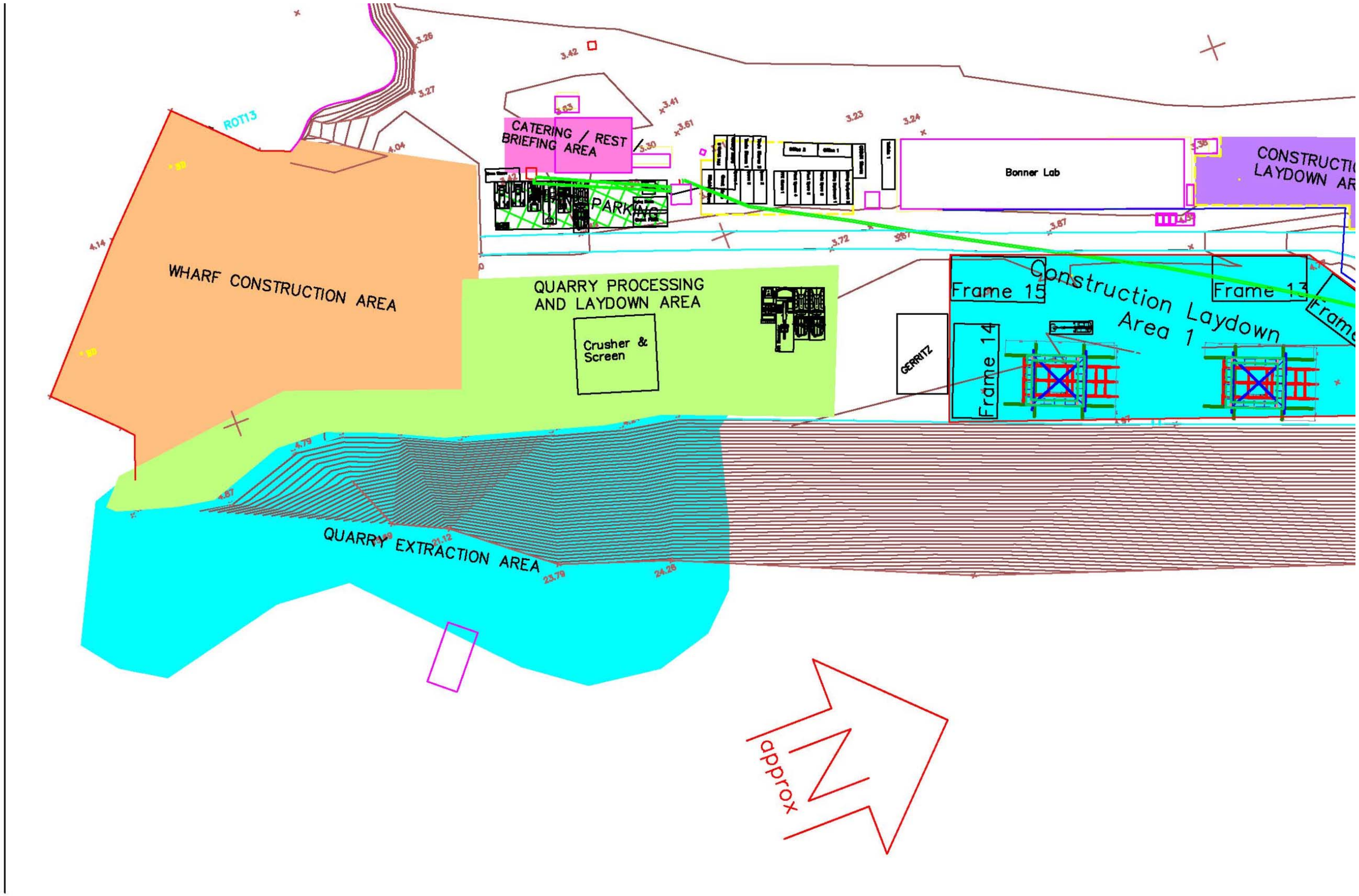


*Figure 3-15 Construction Site Layout South*


*Figure 3-16 Construction Site Layout North*

### *Wharf Construction Area*

The wharf construction area encompasses the existing wharf and the location where the new wharf will be installed. Initially the existing wharf will be deconstructed and all excess loose fill material removed. This will be temporarily stored in the quarry processing and laydown area before being reused in the new works. Reusing the fill material will reduce the quantity of virgin material required and therefore the overall volume of rock quarried. The new wharf will then be constructed in this location encompassing the footprint of the removed wharf.

The following equipment will be operational in this area:

- 2x 300t crawler cranes
- Excavators (100t, 50t, 35t, 20t, 8t)
- 80t mobile crane
- Tracked drill rigs
- Rock Crushing and processing plant
- Articulated Dump Trucks (ADT's)
- Vibrating pile installer
- Anchor drilling rig
- Safety / work boat

### *Construction Laydown Area 1*

Construction Laydown Area 1 is one of the two large laydown areas identified for use to prepare the works and store materials and equipment. As this area is closest to the wharf, this method will be used for the preparation of temporary works such as access platforms, walkways and piling guides as well as assembly of any permanent works prior to installation. In addition, various general activities will be carried out such as plant and equipment maintenance and small fabrication works. For this purpose, there will also be a number of workshops located in this area. There is not anticipated to be any production of concrete on site.

The following equipment will be operational in this area:

- 300 t Crane and Mobile Crane
- Mobile Elevated Work Platform
- Transport Trailer
- Various workshops consisting of:
    - 20ft specially equipped containers.
-

### *Construction Laydown Area 2*

This smaller laydown area is adjacent to Rothera's Bonner Laboratory and has been identified as susceptible to snow accumulation. Access is also limited due to the location of the base fuel supply line and a nearby service duct. For these reasons this area will only be used to store materials which are not required until a future season and only where there is insufficient space in one of the other laydown areas.

### *Construction Laydown Area 3*

Construction Laydown Area 3, shown on Figure 3-16, is the second large laydown area available for storage of construction materials. Due to the increased distance to the wharf this area will mainly be utilised for storage of temporary and permanent materials and the handling of waste steel.

The following equipment will be operational in this area:

- Rotating Tele handler
- 40 ft. flatbed articulated trailer
- Tractor Unit
- Mobile Crane

### *Rock Stockpile Areas 1, 2 and 3*

These areas shown on Figure 3-16, are for the storage of processed rock material during quarrying. . The height of the stockpile will not exceed the height of any of the surrounding buildings (excluding the control tower). The height and width of the stockpiles will be reviewed regularly with Station Management and the BAS Air Unit to ensure that they remain safe for all other operations on station.

### *Temporary Offices and Catering/Rest Area*

It is proposed that the area to the south of the Bonner Laboratory will be used for temporary offices and a tented area with catering facilities. The temporary offices will be limited to 5 desks in three 40ft containers or similar temporary office units. All other administrative works will be undertaken from within the existing station buildings. The rest area will utilise the existing marine facility and provide welfare facilities for the construction team. A toilet and sink will be provided which will be plumbed into and treated through the existing station sewage system meeting the requirements for sewage disposal of the Environmental Protocol. (Please see section 11.1.2 Impact Identification and Prediction) A

### *Plant Parking Area*

A plant and equipment parking area has been designated on the plan close to the wharf for securing plant and equipment overnight between shifts or when not in use. The 5,000 litre diesel bowser doubled skinned to 110% capacity will be stored in this area when not in use.

### *Temporary Access Road*

The existing station access roads will be utilised for most of the construction traffic and restrictions will be in place for BAS personnel. A temporary site road is proposed to be established to the west of the Bonner Laboratory for staff using the laboratory. . This temporary road lies within the existing developed area of the station. Works to establish this temporary access road will consist of setting out temporary demarcation, snow clearance and grading if required. See Figure 3.17 below.

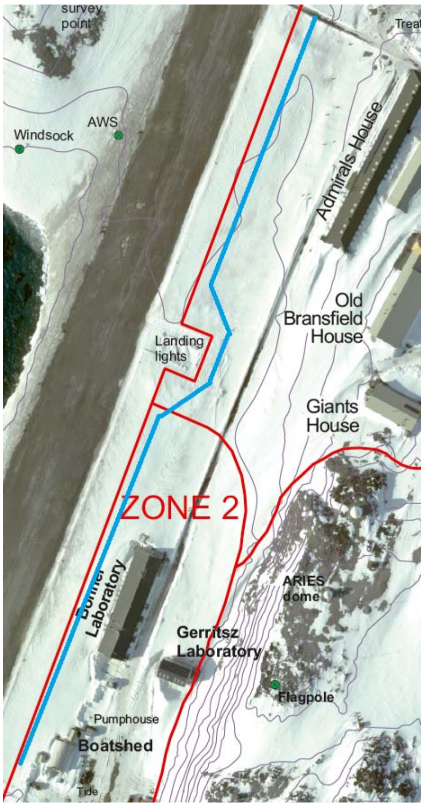

*Figure 3-17 Temporary Access Road*

Access restrictions to other site roads will be put in place by station management to ensure the safe operation of the station during construction activities.

## 3.7. Existing Wharf Dismantling Methodology

The construction of the wharf is proposed to be completed over two Antarctic summer seasons commencing at the end of 2018, with completion anticipated to be at the end of the austral summer season in 2020. In the first season the existing wharf will be dismantled and part of the new wharf will be constructed; from the rear wall (known as the anchor wall) to the mid wall. In the second season the remaining structure will be installed between the mid wall and front wall (seaward facing wall) and the wharf furniture installed. See Figure 3-16 below.

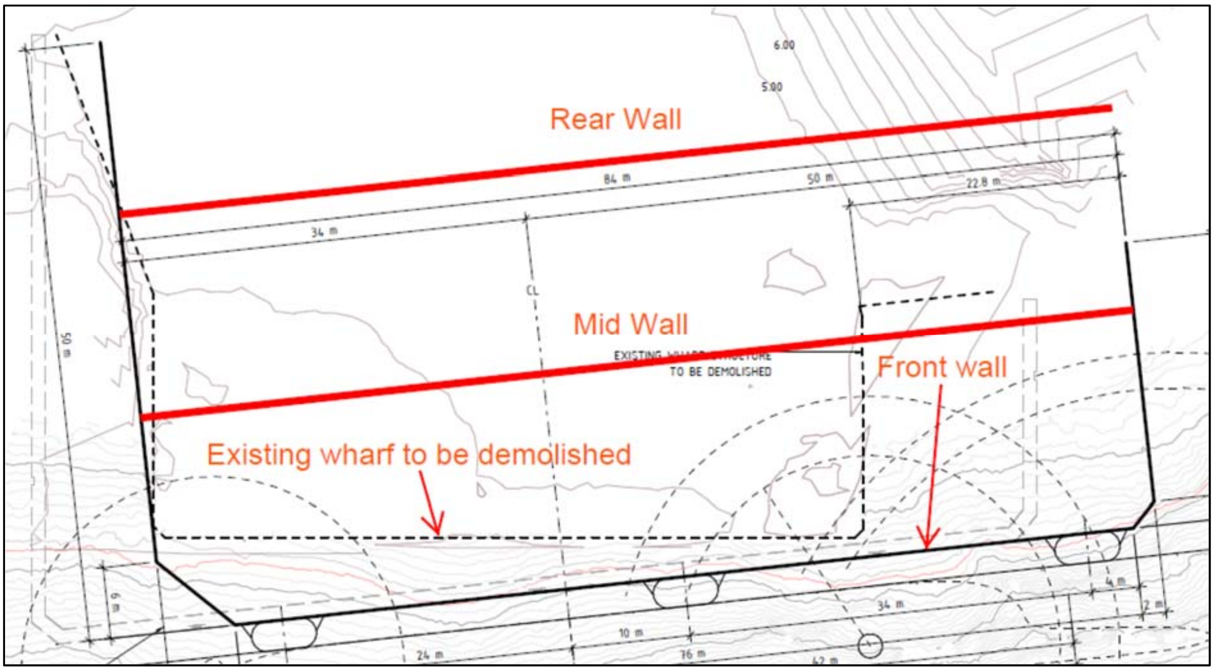

*Figure 3-18 New wharf layout showing rear, mid and front walls*

### 3.7.1. Assembly of Equipment (Construction Season 1)

Following the arrival of plant, equipment, personnel, temporary works and permanent materials at Rothera the assembly of the required plant and equipment will be undertaken. The assembly of the cranes, excavators and quarrying equipment will be undertaken by the site personnel under supervision of the designated operators and the plant manager. Exclusion zones will be established as required and maintained to all assembly areas. The plant manager will arrange for certification of the assembled equipment before first use. See Figure 3-15 and 3-16, for the laydown areas.

### 3.7.2. Dismantling of Existing Wharf

In order for the new wharf to be constructed the existing Biscoe Wharf will be dismantled in stages as detailed in a Dismantling Plan (outlined below. In principle, the dismantling will consist of a partial deconstruction of the existing wharf. The first stage will be to remove the existing rock fill material from inside the structure to relieve pressure from the side walls. The existing tie-rods will then be removed progressively along with the remaining rock fill. Once all the rock fill and tie rods are removed the sheet piles[2] along the front and sides of the wharf can be removed from the outer perimeter. Following this the steel frame can be deconstructed, completing dismantling of the front side of the wharf. The mid wall capping beam[3], bottom tie rods from the mid wall to the rear anchor wall and remaining fill material will then be removed. The existing mid wall and the rear anchor wall do not need to be removed because the new wharf walls will be built around them. The Dismantling Plan will be developed to ensure that the wharf can be removed in a safe manner without affecting the stability of the existing structure during the works.

### 3.7.3. Assembly of New Wharf Structure

Twenty steel frames, (approx. 8.4 m x 18 m), will be positioned by crane in two sections. Firstly between the anchor wall and the mid wall and subsequently the mid wall to front wall sections of the

[2] structural sections of steel which interlock to create a continuous wall

[3] Structural beams made from steel

new wharf. See Figure 3-17. U Vertical tie rods will be drilled into position in order to anchor the steel frames to the underlying rock.

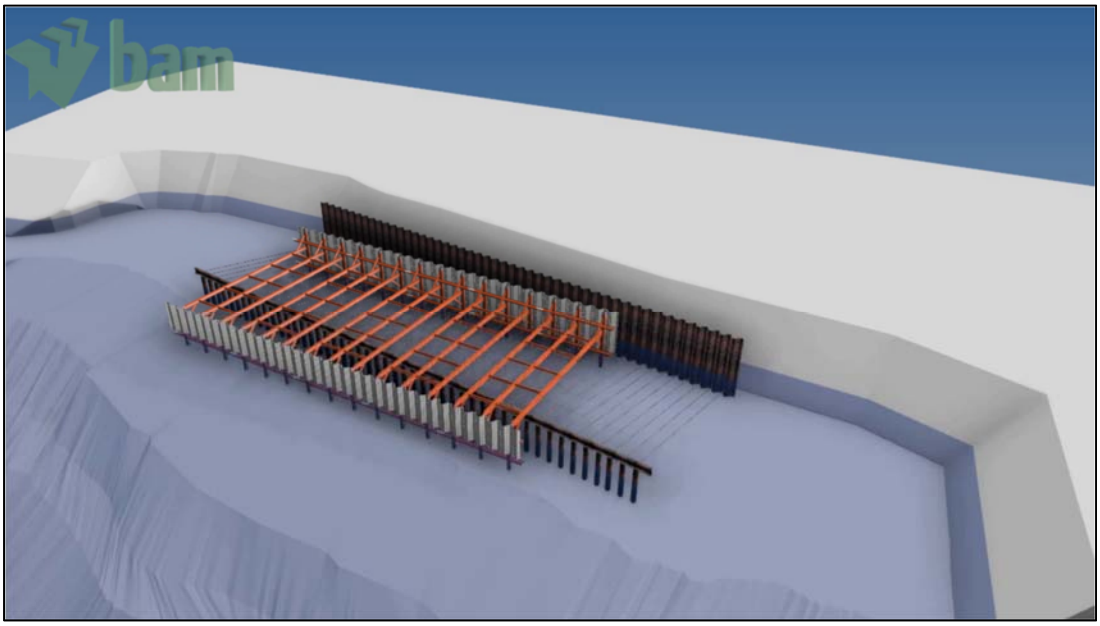

*Figure 3-19 Illustration of five steel frames between the rear to mid wall*

Due to their size, the steel frames will be transported to Rothera in modular sections and assembled on site. Each frame will take approximately one day to complete. The frames will be assembled on bespoke steel supports known as jigs, located in a segregated pre-assembly area adjacent to the wharf (within the Wharf Construction Area on Figure 3-15). Assembly will be completed by crawler crane with access to the frame from mobile elevating work platforms (MEWPs).

Each of the frames will be fixed together using a combination of pinned and bolted connections. The legs of each frame will be fitted with a hydraulic operating system, in order that each leg can be retracted or extended to allow the frames to be levelled to the correct position. During the assembly of the frames on land, sheet piles will also be pre-connected to the rear and mid wall frames.

All of the frames will be preassembled in advance of installation. Two sets of jigs will be used to allow one fully assembled frame to be stored ready for use while a second frame is being assembled, or to store two assembled frames.

### 3.7.4. Preliminary Works for Mid and Rear Walls

Prior to the installation of the rear to mid wall frame some preliminary works will be required. A trench for the rear anchor wall footing will be created using the 40t or 50t long reach excavator. The line of the new anchor wall is slightly different to the previous anchor wall and it is envisaged that a short section of the trench (approx. 15-25 m) at the west end may require rock to be broken out using a hydraulic breaker attached to the excavator.

Following dismantling of the old Biscoe Wharf and formation of the anchor wall trench, divers will survey the sea bed level for the mid and anchor wall footings. Additional preparation of the rock will be undertaken using the excavators if required to remove any remaining irregularities.

It is anticipated that there will be a requirement for some rock blasting on the eastern side of the new wharf. The total rock removal in this area is anticipated to be in the order of approximately 1300 $m^3$ on land, 300$m^3$ at the sea and land interface and a further 100 $m^3$ under water. The proposed details for this work is described in Section 3.8.6. All rock that is excavated will be loaded to articulated dump trucks (ADTs) by the excavator, transported and tipped at the material stockpile in rock stockpile areas (see Figure 3-16). An excavator will be used to manage the size and shape of the stockpile to ensure it does not exceed the agreed storage area and is safe for ADTs to access.

During the assembly of each frame, an empty circular grout bag with be installed encased in a frame and wrapped around the position where each mid wall pile will be located. The frame will protect the bag from puncturing but also assist with positioning the bag at the bottom of the footing when the frame is craned into position. Divers will also be used to check that the grout bags are suitably positioned before they are filled. Once filled the grout bags will set and this will be a permanent foundation between the pile and the rock bed. See Figure 3-18.

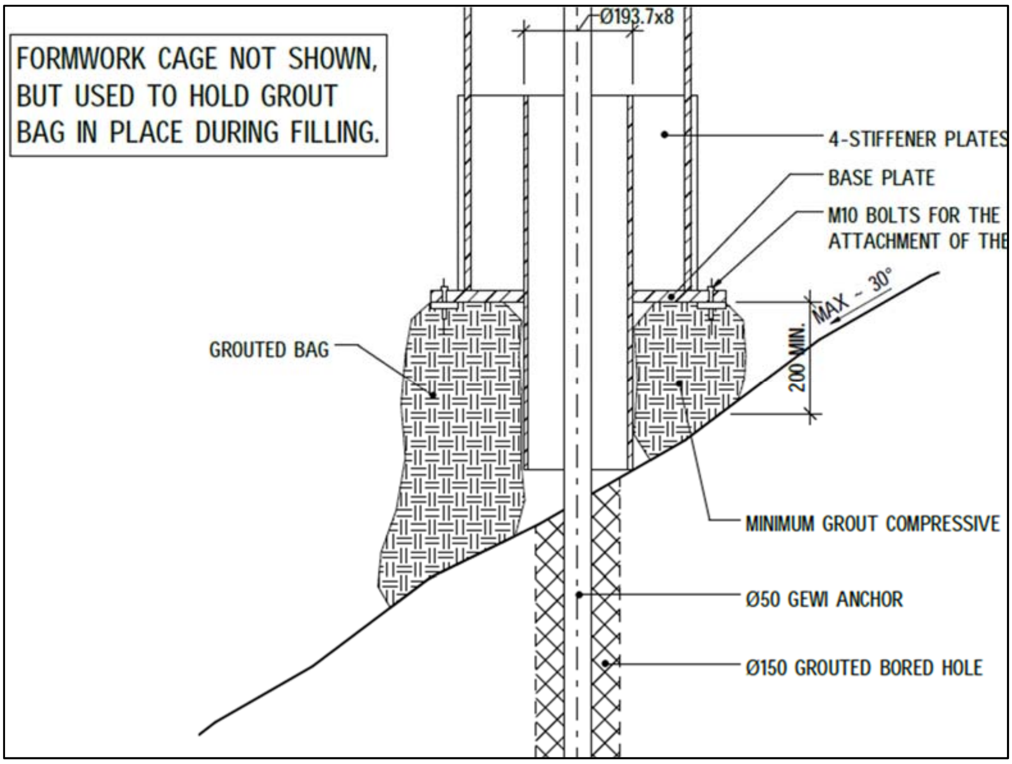


*Figure 3-20 Indicative Position of Grout Bag on Rock Bed*

A stone access ramp will also be formed onto the rear frame once installed using the excavated material from the dismantling works. This procedure is to allow the crawler crane and rotary drill rig ease of access to the work site.

## 3.8. Construction Methodology

### 3.8.1. Rear Wall to Mid Wall Construction

*Adjusting the frames*

10 pre-assembled steel frames will be installed between the rear wall and mid wall. The height of the frame legs, having been pre-set during assembly will now be altered to ensure the frames are level. In order to do this, data from a bed rock level survey will be used. (This can only be undertaken once

the dismantling works have been completed.)  This information will determine more accurately the required lengths of the legs.  Due to the irregularity of the rock it is anticipated that the level of each frame will need to be adjusted.  This will be achieved using the hydraulic legs to ensure that the top of the frame is set horizontally before it is released from the crane.  If further readjustment is required at this stage the position of each frame can be altered by the crane.

### *Filling the grout bags*

Once the frame has been installed correctly the grout bags at the mid wall footings will be filled with grout to create the permanent foundation. The grout will be mixed on the surface and pumped to the submerged grout bags via a pipeline.  Each bag will require approximately 0.4$m^3$ of grout.

The process of filling each grout bag is supervised by a diver in the water, who communicates to the dive supervisor (on land) who in turn directs the grout pump operator.  As each bag is filled the diver informs the dive supervisor via a hard wired communication system.  In turn this information is relayed to the pump operator who stops pumping. The pipeline will then be disconnected from the full bag and attached to the next grout bag to be filled.  The process will be repeated for all remaining bags and ensures that excess grout is not pumped inadvertently into the marine environment.  The grout will cure overnight, after which the vertical tie rods will be installed inside the piles.

The front of the frame will then be decked out with timber crane mats, (new and treated to International Phytosanitary Measure (ISPM) 15[4] as per the BAS Biosecurity Handbook) placed by the crawler crane to form a working platform. The remaining section of the access ramp will be formed to the rear of the frame for the rotary drill rig to track on to the platform. The drill rig will be tracked into position in order to drill centrally within the initial tubular leg of the mid wall.

### *Securing the mid wall piles*

In order to secure the central mid wall tubular pile in each rear frame, a dywidag[5] tie rod will be installed vertically.  A 150 mm diameter hole will be drilled centrally to each pile and to the correct depth into the rock.  Once the hole has been drilled the drill string will be retracted and the rig repositioned by the crane on the adjacent frame to drill the adjacent central pile in the same manner. This process will be repeated until all 10 of the mid wall anchors have been drilled.

Each dywidag tie rod will be installed one at a time using the crawler crane.  The bars will be pre-fixed with plastic centralisers to hold the bar in position centrally to the drilled hole and the leg of the frame. Each dywidag tie rod, will be grouted into the rock bed with a minimum of 3 m embedment.

The grouting process will use a tremie pipe, a vertical pipe by which the grout is transported to the bottom of the hole.  As the level of grout rises the tremie pipe will be gradually removed until the correct quantity of grout has been discharged.  The pipe will then be fully removed and installed to the adjacent pile and the same process repeated.  Following a minimum of 24hrs for the grout to cure the dywidag tie rods will be stressed and locked-off to the design torque. An exclusion zone will be established during stressing operations to prevent unauthorised access.

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[4] ISPM 15 is an International Phytosanitary Measure that directly addresses the need to treat wood materials of a thickness greater than 6mm. Its main purpose is to prevent the international transport and spread of disease and insects that could negatively affect plants or ecosystems.

[5] threaded steel bar

Once all ties have been stressed and locked off the tubular piles will be in-filled with concrete. Concrete will be batched on site using self-loading concrete mixer units and delivered to the wharf where it will be discharged into an articulated mobile concrete pump and placed within each pile to the correct level in turn. Concrete will be compacted using an electrically powered poker.

The sheet piled rear anchor wall will be pre-connected to the frame by a waling beam[6] in panels. Each panel will constitute five AZ sheet piles[7] wide.

A temporary ice-shield will be formed in panels connected to the mid wall piles using a waling beam. This is to protect the structure from sea ice and icebergs over winter whilst construction is paused. The panels will be fabricated in advance to the required length using the sheet piles removed during the dismantling works and will be installed using the crawler crane and connected to the waling beam. Once this process is complete for one frame, the decking will be removed to allow the frame to be backfilled and the works described above will be repeated to install the adjacent frame.

#### 3.8.2. Back Fill Rear Wall to Mid Wall

Back fill material will be transported from the stock pile areas to the wharf using ADTs and unloaded adjacent to the backfill location. Material will not be dumped directly into the void as this can cause damage to the frame during uncontrolled placement. Back fill will be placed using either the 40t excavator or 50t long reach excavator depending on the concurrent work fronts ongoing at the time and associated equipment availability. Care will be taken to ensure the frame is not damaged during this process. The backfill will be installed up to the level of the ice shield and will be compacted by tracking in from the excavators.

By the end of the first construction season the aim is to have completed the main construction activities from the anchor rear wall to the mid wall. This scope will provide a temporary front face of the wharf which, whilst unsuitable for mooring large vessels, will provide some protection against sea ice over the winter months in between construction seasons.

#### 3.8.3. Mid Wall to Front Wall Construction (Construction Season 2)

At the start of the second construction season, once all of the plant and equipment have been prepared for use, the mid wall ice shield will be reduced in height to allow the steel frames to be installed. At this stage the mid wall inner piles will be cut down to the correct level and the vertical connecting pin welded in position. The pre-assembled steel frame for the construction of the mid wall and front wall will be installed by the crawler crane. The front legs of the frame will have been pre-set in advance to the required length following a bed level survey completed after the demolition works have been completed. See Figure 3-19.

[6] A structural steel beam which helps to spread the load on the sheet pile and concentrate the load onto the tie rods.

[7] AZ sheet piles are interlocking sheets of metal used as retaining walls. Each sheet has segments with indented profiles (troughs) which interlock to form a wall with alternating indents and out dents. The troughs increase resistance to bending.

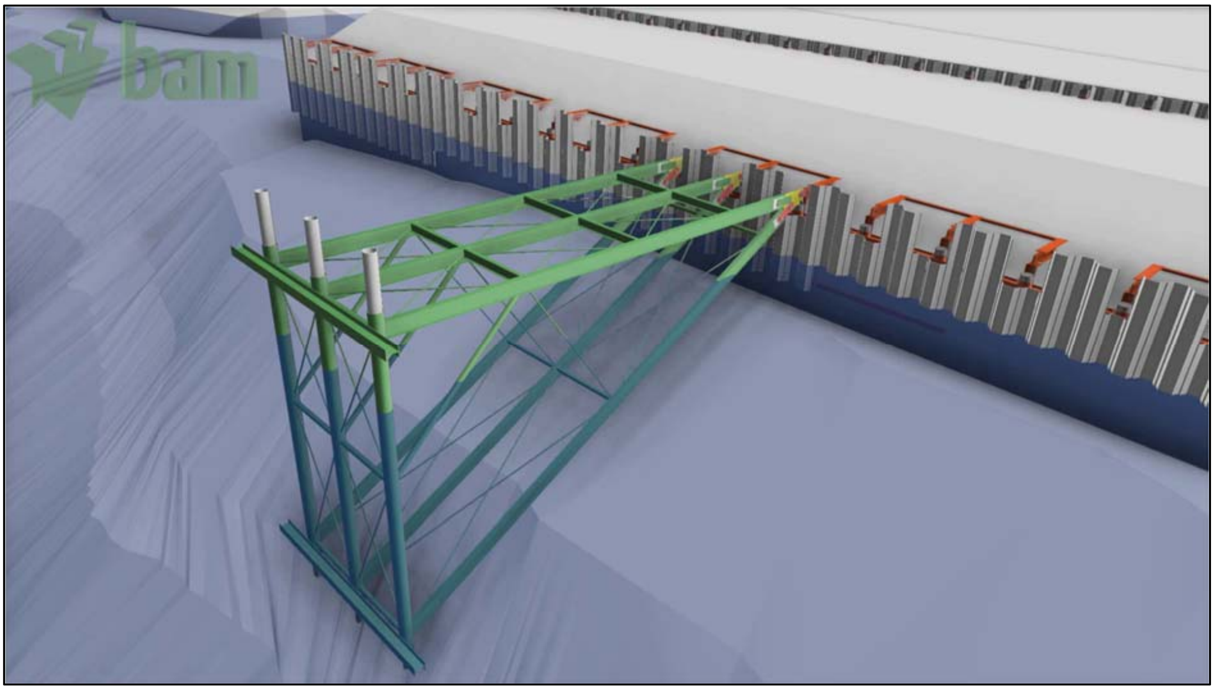

*Figure 3-21 Pre-assembled steel frame for the mid to front wall*

The frame will be positioned on to the vertical locating pin welded to the top of the mid wall inner pile and surveyed by the engineer. Due to the irregularity of the rock the level of the frame can be further adjusted using hydraulics to ensure that the top of the frame is set horizontally before releasing from the crane. If required the frames position will be adjusted by the crane and re-surveyed and re-levelled until the engineer confirms it has been correctly positioned.

The front frame will be connected to the rear frame using steel connection plates pinned together and then the Temporary Works Coordinator will inspect the frame before it is loaded. The front frame will then be decked out with timber crane mats, placed by the crawler crane to form a working platform. The drill rig will then track onto the rear frame and continue on to the front frame platform and positioned to drill centrally within the initial front tubular leg of the frame.

Each leg of the frame is secured using a vertical 63.5 mm diameter dywidag tie bar grouted to the rock bed with a minimum of 3m embedment. The rig will drill a 150 mm diameter hole centrally to the pile and to the correct depth into the rock. Once the hole has been drilled the drill string will be retracted and the rig repositioned on the frame to drill the adjacent leg in the same manner. Once the third leg of the frame has been drilled the drill rig will then be removed from the frame by the crawler crane. The same process for positioning the dywidag bars and securing them in place for the original frame will be followed.

The sheet piled front wall will be connected in panels to the front face of the frame by a waling beam in panels. Each panel is anticipated to be five AZ sheet piles wide; the specific size will be confirmed in the final detailed design. Sheet piles will have been pre-cut to suit the rock bed profile. Panels will be installed using the crawler crane and connected to the waling beams Once adjacent frames and ties have been placed a single AZ sheet pile will be installed to join the panels together. The pile will be pitched and lowered into the clutches using the crawler crane until fully engaged and resting on the rock bed. If the pile is unable to be lowered off under gravity the crane will be disconnected and a vibratory hammer will be used to drive the pile to the correct level.

Once the front wall has been installed a steel capping beam will be positioned on top of the sheet piles using the crawler crane and a welded connection made. The Site Engineer will ensure the capping beams are placed to the correct line and level.

### 3.8.4. Back Fill Mid Wall to Front Wall

Once a suitable sized section of the front wall and capping beam has been installed the void between mid-wall and front wall will be back filled to finished level. The same process as described above will be followed to transport and deposit the fill within the frames. The backfill will be installed up to the finished level, flush with the top of the front wall capping beam and to follow the design profile to provide the correct falls.

### 3.8.5. Installation of Bollards and Davit Crane Foundations.

After backfilling the ship's mooring bollards and davit crane bases will be installed. Six bollards (precast off site) and two crane bases will be constructed, The mooring bollard support steelwork, complete with predrilled bearing plate, will be installed at each bollard location and connected to the upper waling beams at the rear of the sheet piled front wall. Each bollard will be lifted into position to the bearing plate in turn using the crane, the bolts will then be installed to connect the bollard to the plate. This process will be repeated for all wharf bollards.

Once the back fill has been placed to the underside of the front frames in the South East and South West corners the pre-fabricated steel crane foundations will be lifted into position to the front side frames. The engineer will confirm the foundations are correctly positioned before the foundations are tack welded to secure them to the front side frame and prevent movement during installation of the precast concrete ballast blocks. The crane will install the ballast blocks (approximately 2500mm x 1260mm x 480mm) to each foundation steel work before the remaining backfill is placed to encapsulate the foundation and up to the finished level.

### 3.8.6. Underwater Rock Blasting

It is anticipated that up to 1,700 $m^3$ of rock will need to be removed by drilling and blasting in order for the frames to be positioned correctly (above and below the water level). The full methodology for undertaking this work is included in the procedural document in Appendix A, Marine Drilling and Blasting Management Plan: Rothera Wharf (2017). The key aspects of the methodology are included below.

There are three distinct parts to this activity:

- Rock that can be drilled and charged from above the water, with a design level above the low water level.
    - This is the same as blasting on land, but is in close proximity to the marine environment. This is represented in orange in Figure 3-20, and consists of approximately 300 $m^2$, (1,300 $m^3$) of rock between +5.0 to +1.0mCD.
    - This activity will also include the further extension of the excavated trench (as mentioned in Section 3.7.4) by blasting of a trench down to -1.0mCD not directly adjacent to the water, shown in beige on Figure 3-21 and 3-22.

- Rock that can be drilled and charged from above water, but has a free face in the water and a design level below the low water level.
    - This consists of the lower slopes shown in orange and the upper slopes shown in beige on Figure 3-20 and consists of approximately 200 $m^2$, (300 $m^3$) of rock between +1.0 to c. -3.0 mCD.

- Rock that is entirely below water.
    - This is represented in beige on Figure 3-20. This consists of approximately 60$m^2$, (100 $m^3$) of rock between -3.0 to -8.0 mCD  The requirement to blast the area shown in green on figure 3.20 has been removed during the wharf design process, avoiding damage to the bedrock close to the wharf face line and also the need to extensive temporary works.

For the purpose of drilling and charging, the methodology used for the first two activities listed above is the same as that used when blasting on land. See Section 4.4.2 Drill and Blast Methodology and Appendix B,  Quarrying, Drilling and Blasting Management Plan: Option H (2017). Due to the very close proximity to the marine environment, however, additional mitigation measures are required as discussed in Section 11.2 Rothera Wharf Impacts & Mitigation of this document.

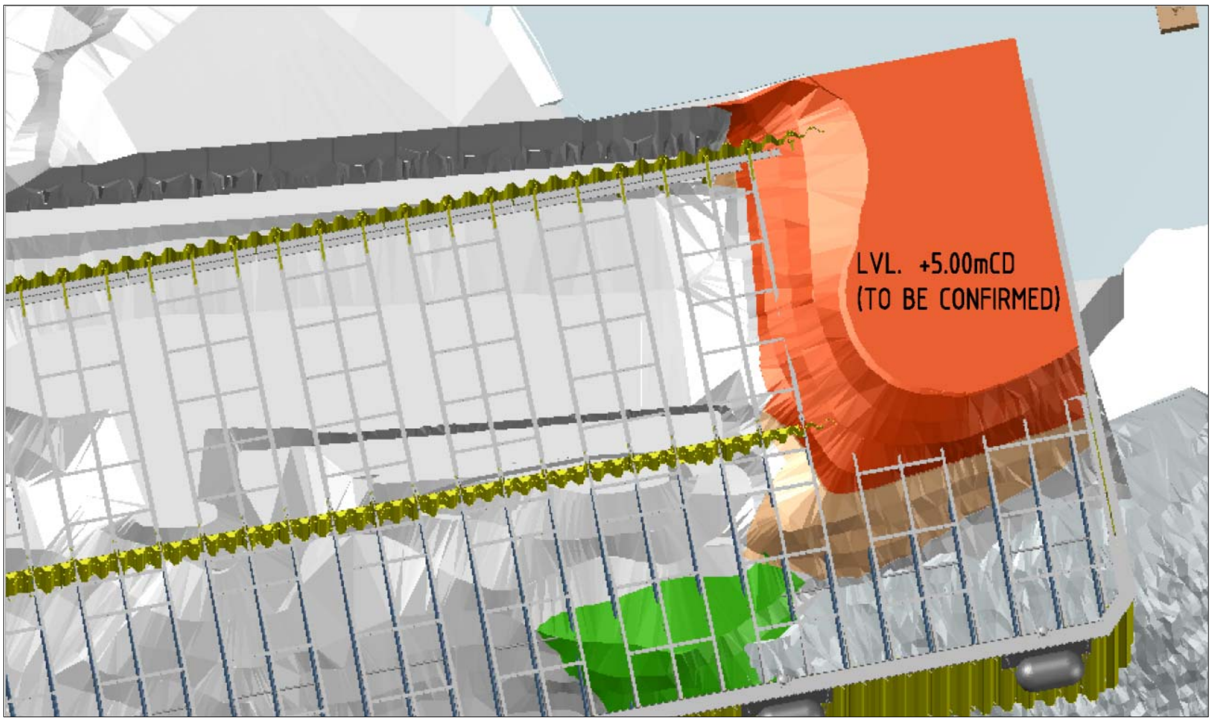


*Figure 3-22 Showing areas to be blasted in beige & green*

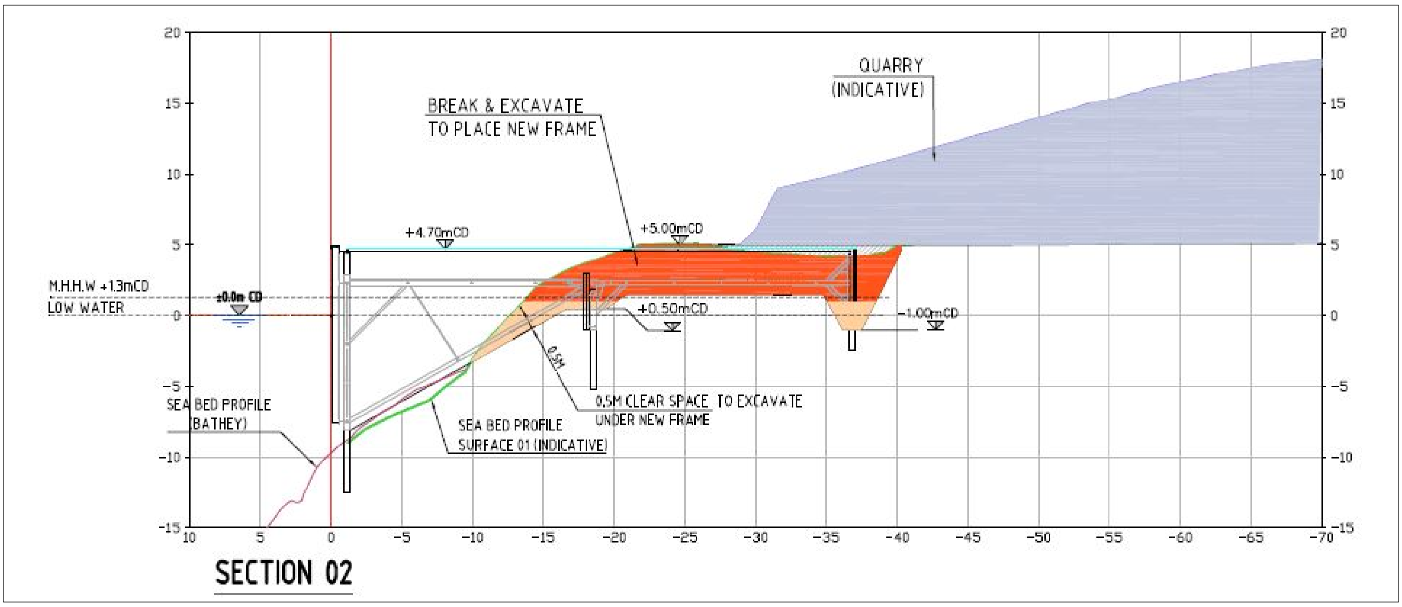


*Figure 3-23 Cross-section 2 showing the rock to be blasted.*

### Blast Design

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As drilling and blasting is only required in close proximity to the shore and in relatively shallow water depths, the following method will be used:

- A rock back-fill platform will be constructed over the blast area to a level of approximately 1m above high tide level, allowing safe access for the drill rig without using a barge or cantilever temporary works platform. This material should not contain a high proportion of large material and will ideally be constructed using recovered material from the existing wharf.
- The surveyor marks the areas to be drilled with paint on the ground, allowing the shotfirer to mark the actual hole positions for the driller. The surveyor can then confirm the required design depth for each location.
- The geotechnical drill rig is used to drill a casing through the rock backfill to the rock-head level. If necessary this can be collared a short distance into the rock. The drill string is then removed leaving the casing in place.
- The shot-hole drill string is lowered through the casing and the shot-hole drilled to the desired depth including any sub-drill below design level. This part can be achieved using either the geotechnical or quarry drill rig. Once completed, the drill string is removed and the shot-hole depth is confirmed using calibrated stemming rods or tape measure.
- A pvc pipe is inserted into the shot-hole collar allowing the casing to be removed and used for the next hole.
- Once sufficient holes have been completed, the Shotfirer charges the shot-hole by lowering the charges on their detonator shock tubes into the top of the pvc pipe down into the shot-hole. The shotfirer then checks the rise of the explosives in the hole. The shotfirer may use the stemming rods to push the charges gently into the hole if required. Further charges are then added, checking the rise each time.
    - A minimum of two detonators should be used in any one shot-hole.
    - A record of the number of charges and detonators in each hole must be recorded by the shotfirer.
    - Any anomaly in the charging must be recorded.

- Stemming (angular aggregate) is then poured into the hole to prevent the explosives floating free and to effectively confine the charge. The rise of this stemming should be confirmed. The pvc casing can be

removed if this is possible without risk of damaging to the detonator leads. If not this can be left in-situ and stemmed to the desired depth. Care should be taken to ensure that the annulus between the pvc pipe and hole wall does not pose a flyrock risk.
- The shot is connected, the danger zone cleared and the shot fired.
- After blasting, the platform and the newly blasted rock are recovered with an excavator.

The actual blasting parameters used during operations will be determined by environmental limitations, ground conditions and experience gained from previous blasts. An outline blasting specification will be prepared for each blast by the shotfirer and approved by the explosives supervisor, and will include any maximum charge weights allowed for under environmental mitigation measures. For marine blasting the actual charging is only known once drilling has been completed, but will be constrained by the outline specification limits. ??See Appendix A Marine Drill and Blast Management Plan.

In principle the blasting of the area will be carried out using a square / rectangular pattern of vertical holes over the design area. The actual design excavation location will be determined on-site in consultation with the Construction Manager and taking into account geological conditions. Trial excavation should ideally be undertaken after the first blasts and at regular intervals afterwards to confirm the results of blasting and allow feedback to the blast design. Due to the small extent of the area involved, this may not be possible.

The following indicative blast parameters will be fine-tuned to meet the requirements of each blast.

*Table 3-2 Blast Parameters*

| | |
|---|---|
| Hole diameter | 89/92mm |
| Burden (including spacing between rows) | 1.5m |
| Spacing (between holes in the same row) | 1.5m |
| Sub-grade drilling | 1.5m |
| Drilling pattern | Square |
| Number of holes per blast | Typically 10-20 |
| Net rock depth above design | Variable 0 to 3.0m |
| Stemming[8] | Minimum of 0.3m, though greater where water cover is less than 3m at the time of firing. |
| Type of explosive | 60mm Packaged Emulsion cartridges and cast boosters (See Section 4.4.2 for quantities) |
| Detonators | Non-electric 475/500ms delays |
| Surface Delays | non-electric connector detonators (eg.25ms and 42ms delays) |
| Maximum Instantaneous Charge (M.I.C.) - proposed | 10 kg |

[8] Non-explosive material placed in the top of the hole to confine the explosive and prevent ejection. For surface blasting this is normally aggregate chippings of approximately 0.1 to 0.15x the hole diameter.

It is anticipated that the total area to be blasted of 100 $m^2$ will result in approximately 2-3 blasting events taking place over one or two weeks subject to weather, sea ice conditions and proximity of wildlife. Mitigation measures to minimise impacts on wildlife are outlined in Section 11.

A blasting specification will be prepared for each blast. As a minimum this will include details of:

- All hole co-ordinates.
- Hole depths.
- Actual explosives, detonators and stemming used in each hole.
- Surface initiation timing diagram.
- Blasting Checklist completed during firing.
- Environmental monitoring results including wildlife observation data.

The blast specification will be signed as approved by the Shotfirer and Explosives Supervisor – roles as defined in the UK's Quarries Regulations 1999.

#### 3.8.7. Construction materials

The following key construction materials are expected for the new wharf:

- Structural steel ~ 740 tonnes
- AZ Sheet piles ~ 350 tonnes
- Vertical anchor ties ~140 no.
- 50$m^3$ Sand (for explosive storage)
- 40 tonnes of aggregate (for blasting ballast)
- Grout ~17 $m^3$
- Rock fill ~ 52,000 $m^3$ (quarried locally on site).

#### 3.8.8. Equipment and vehicles

A full list of plant and equipment can be found in Appendix C but the main equipment will consist of the following:

- 2x 300t crawler cranes
- Excavators (90t, 50t, 35t,, 8t)
- Tracked drill rigs
- Rock Crushing and processing plant
- Articulated Dump Trucks (ADTs)

Prior to mobilisation to site, several temporary works items need to be designed fabricated and transported to port. Design and fabrication will follow the completion of the detailed design and confirmation of the detailed working methods. All temporary works are to be certified as per the contractors internal procedures and issued a temporary works certificate.

The following major temporary works are expected:

- Steel supports for assembling steel frames
- Various access platforms
- Drill Rig Platform
- Lifting Frames

## 3.9. Anticipated Waste

All construction waste will be managed onsite by the construction team. Domestic waste will be incorporated into the standard BAS waste management system. See Section 11.2 Operational Procedures: Waste Management, for further detail and Appendix D Site Waste Management Plan. The anticipated tonnage and volumes for waste from the Rothera Wharf construction activities are listed below.

*Table 3-3 Excavation Waste*

| Type of Waste | European Waste Code | Estimated Quantity Tonnes/($m^3$) | | | |
|---|---|---|---|---|---|
| | | Total | Re-Use (onsite) | Recycle | Dispose |
| Crushed Stone | 17 05 04 | 27,750 (1,500) | 27,750 (1,500) | | |

*Table 3-4 Construction Waste*

| Type of Waste | EWC Code | Estimated Quantity kg/($m^3$) | | | |
|---|---|---|---|---|---|
| | | Total | Re-Use (onsite) | Recycle | Dispose |
| Steel | 17 04 05 | 20,000 (2.6) | | 20,000 (2.6) | |
| Concrete / Grout | 17 01 01 | 12,000 (5.2) | | 12,000 (5.2) | |
| Cementitious Wash Water | | 20,000 (20) | | | 20,000 (20) |
| Alkaline Batteries | 20 01 33 | 2 (0.01) | | 2 (0.01) | |
| Clothing / Textiles | 20 01 10 | 50 (c.1) | | 50 (c.1) | |
| Cardboard | 20 01 01 | 200 (0.3) | | 200 (0.3) | |
| Paper | 20 01 01 | 50 (0.3) | | 50 (0.3) | |
| Timber | 17 02 01 | 1000 (2) | 500 (1) | 500 (1) | |
| Plastic | 20 01 39 | 50 (0.05) | | 50 (0.05) | |
| Oil | 13 02 07 | 5000 (5) | | | 5000 (5) |
| Oil Filters | 16 01 07 | 50 (0.1) | | | 50 (0.1) |
| Oil Contaminated Rags | 15 02 02 | 50 (0.2) | | | 50 (0.2) |
| Aerosols | 16 05 04<br>16 05 05 | 10 (0.1) | | | 10 (0.1) |

*Table 3-5 Demolition Waste*

| Type of Waste | EWC Code | Estimated Quantity Tonnes/($m^3$) | | | |
|---|---|---|---|---|---|
| | | Total | Re-Use | Recycle | Dispose |
| Concrete | 17 01 01 | 61 (26.5) | 61 (26.5) | | |
| Steel | 17 04 05 | 550 (71) | | 550 (71) | |

## 3.10. Personnel

Construction personnel will be on site at Rothera from November to April/May in both construction seasons. Equipment and materials will be demobilised from Rothera by the end of austral summer in 2020 by sea.

It is anticipated that up to 51 construction personnel will on be on site in 2018 -2019 season, as listed below. The following personnel are anticipated to be required for the Rothera Wharf works:

- 1x Project Director
- 1x Project Manager
- 1x Sub Agent
- 1x Section Engineer
- 3x Site Engineers (one of whom will be the Environmental Engineer)
- 1x Drilling Engineer
- 1x General Foreman
- 1 x Foreman
- 2x Gangers
- 1x Piling Supervisor
- 5x Quarrying personnel (Supervision & Operatives)
- 5 Multi skilled diving squad
- 26 x Multi skilled operatives (Drillers, General Construction Equipment Operators, Pile Hands, Welders, Plant operators, Banksmen & dismantling squad)2x Plant fitters

### *Project Manager*

The Project Manager is the overall manager responsible for Health, Safety, Environmental, Security, Site Activities, Staff, Administration, Quality Assurance and Control and construction of the works.

### *Sub-Agent*

The Sub-Agent has the overall responsibility for the Engineers, Foremen and others employed to complete all the works. The Sub-Agent will also relay any problems and engineering issues back to the engineering department.
The Sub Agent will also assume the role of Temporary Works Coordinator.
Project Engineer
The Project Engineer is responsible for the development of work methods and coordination with the Quality team and the Designers. The Project Engineer ensures that all temporary works are certified and suitable for use. They will develop the detailed activity plans and associated risk assessments in conjunction with the Supervisors. The Project Engineer will also assume the role of Temporary Works Coordinator.

### *General Foreman*

The General Foreman will be the person responsible for completion of the individual activities which take place on and off shore. The Supervisors will ensure that all works are carried out safely and competently. They will be in control of the work force and any subcontractors. They will ensure toolbox briefings are undertaken either by themselves or other senior personnel. A daily report will be prepared by the Supervisor on the work completed on site.

### *Quality Control Engineer*

The quality control Engineer/Manager will monitor compliance to the specification and drawings related to the works.

*Health, Safety, Environment & Security*

Health, safety, environment and security will be the responsibility of the Project Director and the Project Manager.

The site construction works have been programmed on single 12 hour shifts 6 days per week. Non-working days will be scheduled to be concurrent with adverse weather as much as practical to minimise programme impact.

In addition to construction personnel, it is anticipated approximately 8 additional BAS support personnel will be needed on station for both seasons.

These will include the following roles:

- 1 x Project Management Officer representative
- 1 x Station General Assistant if required to manage waste
- 2 x extra Chef
- 2 x extra Domestic Support
- 1 x site supervision team (excluding liaison person)
- 1 x technical support (electrician)

## 3.11. Predicted Lifespan

The design life for the new wharf is for a minimum of 25 years.

## 3.12. Plans for Decommissioning

If the wharf were to be decommissioned in the future then the reverse of the construction methodology described above will be followed. The bullet points below outline the sequence of activities:

- Remove Backfill Material.
- Remove Outer Sheet Piles[9].
- Cut vertical ties holding down mid to front wall frames.
- Lift out steel frames between mid and front wall.
- Cut vertical ties holding down Rear to mid wall frames.
- Lift out steel frames between Rear and mid wall.
- Landscaping and making good of working areas.

The manner in which the wharf construction methodology has been designed will enable any future decommissioning to be undertaken with relative ease. The modular frame system will allow for a systematic deconstruction reducing risks to health and safety and the local environment.

[9] sheet piles are interlocking sheets of metal used as retaining walls

# 4. Description of Proposed Development 2 – Quarrying, Drilling & Blasting

## 4.1. Purpose and need

In order to provide the rock fill required for Rothera Wharf and the coastal stabilisation works it is proposed to quarry rock locally. The intended site is within the current overall footprint of station operations adjacent to the current Biscoe wharf. Rock extraction will only occur during the outlined construction period.

The following acitvites will have to be undertaken;

- drilling and blasting;
- loading and hauling rock; and
- processing, crushing and screening.

**Appendix A: Quarrying, Drilling and Blasting Management Plan: Rothera Wharf**, *describes* the methods to be used to undertake the rock extraction work and how the use of explosives will be controlled to prevent harm to people and the environment.

It is anticipated that approximately 26,000 m$^3$, (52,000 tonnes) of rock backfill will be required for the proposed wharf construction design. The total anticipated requirements are shown in the table below. Recycling / re-processing of fill materials recovered from the existing wharf can be undertaken to reduce the volume of rock extracted from the quarry. Although the extent of this recycling will be dependent on the grading of the existing rock backfill material available, an outline estimate indicates that c.15, 000m3, or 27,000t of recovered material can be reprocessed through the quarry plant along with quarried materials. The estimated yield from this process is 16,200t of rock-backfill. This quantity can be removed from the quarrying extraction requirement, both reducing the size of the excavation and use of explosives, though this material will still require processing.

For the products and quantities detailed above, the total anticipated extraction from the quarry is as follows:

| | | |
|---|---|---|
| *Total from above* | | *51,524t* |
| *Less material re-cycled material re-processed* | *16,200* | |
| *Net quantity required from quarrying of* | | ***35,324t*** |

In the event that it is possible to obtain larger rock of >400mm cubic (up to 600m$^3$ or 1,200t) and rock of 100-200mm in size (up to 200m$^3$ or 400t) the yield of this product will be maximised as far possible within the constraints of the rock-fill production schedule. This material will be used for the coastal stabilisation works.

To anticipate for future potential works which are proposed for the AIMP, but are not yet confirmed or designed, a further 14,850 tonnes of rock has been estimated for use. This would include any stabilisation works to the runway and any works redeveloping the station buildings or infrastructure. The estimated quantity has been included in the overall rock requirement here to ensure that the maxiumum extent of the rock removal can be appropriately assessed at this stage rather than having to assess the cumulative impact of additional quarrying activities in future EIAs.

*Table 4-1 Rock Fill Requirements*

| Project Requirement | Type | Grading | Net Quantity (tonnes) |
|---|---|---|---|
| Wharf | Rock Backfill | 30-80mm | 50,969 |
| Wharf | Rock for ice shield | 10-60kg | 555 |
| Coastal Stabilisation | Rock Backfill | >400mm | 1,200 |
| Coastal Stabilisation | Rock Backfill | 100-200mm | 400 |

For the products and quantities detailed above, the total amount of rock extraction will be controlled by the need to produce rock-fill material, with all other smaller material being produced from the by-product of this primary production. As some rock-fill is expected to be recoverable from recycled backfill materials from the existing wharf, the total rock extraction at Rothera is as follows:

*Table 4-2 Summary of total extraction*

| | Tonnage |
|---|---|
| Total rock fill requirement | 52,000 |
| | |
| Less material recycled and/ or reprocessed | 16,200t |
| **Net quantity rock fill required** | **35,000t** |
| **Gross total of rock to be quarried** | **C65,000 – 80,000t** |

In order to produce the required quarried rock products listed above, it is anticipated that a gross quantity of approximately 65,000-80,000 tonnes (24,000-30,000 $m^3$) of in-situ rock will be required. This quantity is based on estimated yields of rock products from the blasted rock-pile, so it may be necessary for rock extraction to be extended up to the red line boundary shown in Figure 4-1, or reduced in extent. The excess volume not required for the specific construction activity outlined here will be stockpiled and used in future construction and maintenance works.

## 4.2. Location

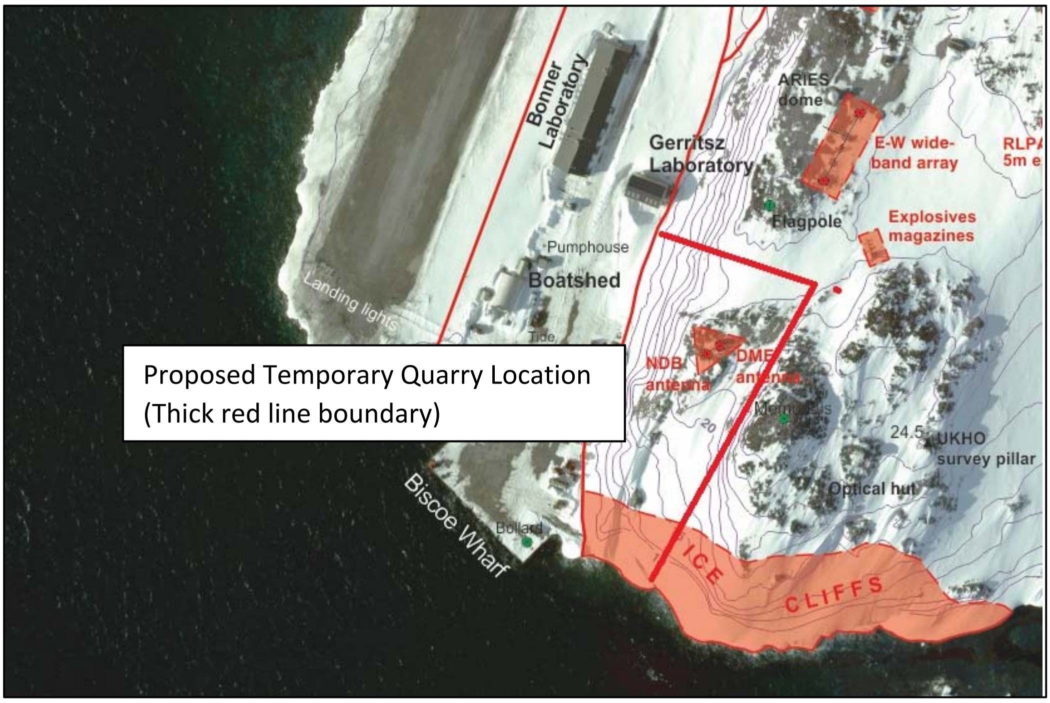


*Figure 4-1 Proposed Location of Temporary Quarry*

The choice of the temporary quarry location has been made to minimise the environmental impact of the excavation by keeping it within the existing footprint of the station. The proposed location is adjacent to the current wharf, an area which has been quarried previously when the wharf was originally built. Sourcing rock from this location will also minimise haulage distances and keep potential dust creating activities at the maximum possible distance from the ice ramp and residential buildings. Once the rock has been removed, the excavated area may be utilised for cargo movements adjacent to the wharf.

## 4.3. Design Details

The proposed extraction area is bounded to the west by the existing cliff face and the east by a small gulley between the extraction outcrop and the higher outcrop to the east. To the north the area is bounded by an area of lower ground just north of the DME/NDB location. Extraction is proposed to be in two benches (split approximately 10m above the existing working level) working north as far as required within the area defined to extract the required quantity. The top bench would advance ahead of the bottom allowing sufficient space for excavation and loading.

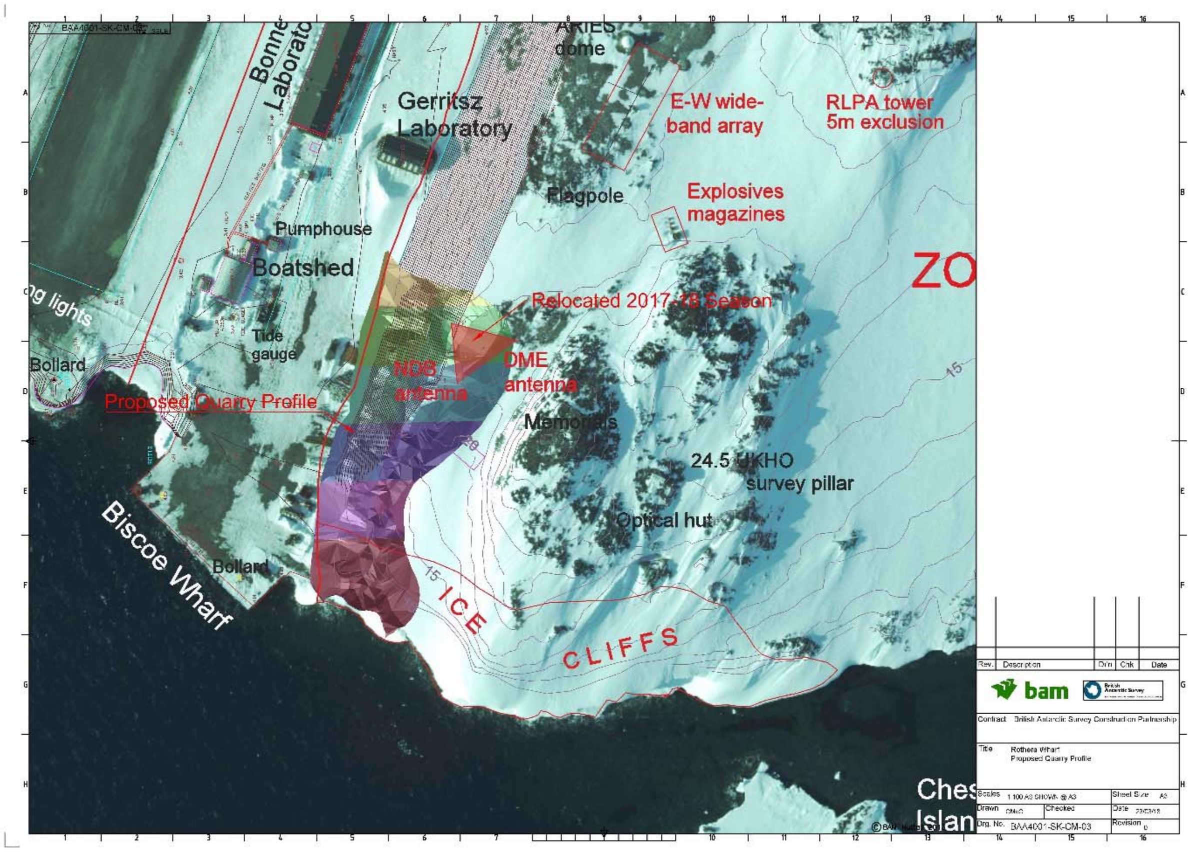


*Figure 4-2* Proposed Quarry Profile

*Figure 4-3 Rock extraction area from the south – the red line shows the approximate boundary.*

The temporary quarry will be developed in the following stages as outlined below:

**Stage 1 -** The lower area close to the wharf will be removed in one bench to create working space near the wharf and to allow a ramp to be created up to the upper quarry bench level. The blue line in Figure 4-4 represents the face position after preliminary blasts and this face will be at approximately 80 degrees from horizontal.

*Figure 4-4– Quarry stage one*

The image from the west, showing the rock to be removed in purple hatching.

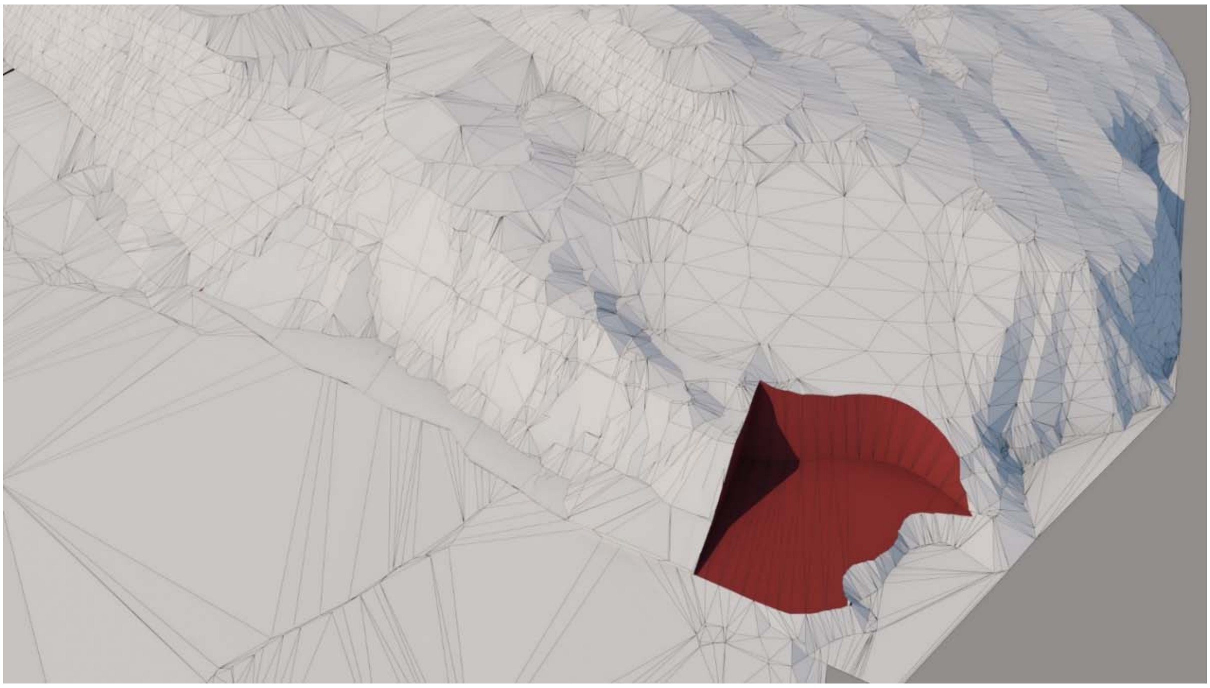

*Figure 4-5 Quarry Stage 1 – Isometric View*

**Stage 2 –** Production will continue on the upper bench with the working floor at +10m above the wharf level. This will be worked northwards, blast by blast. A temporary ramp will be created to access the upper bench from the wharf level using blasted material.

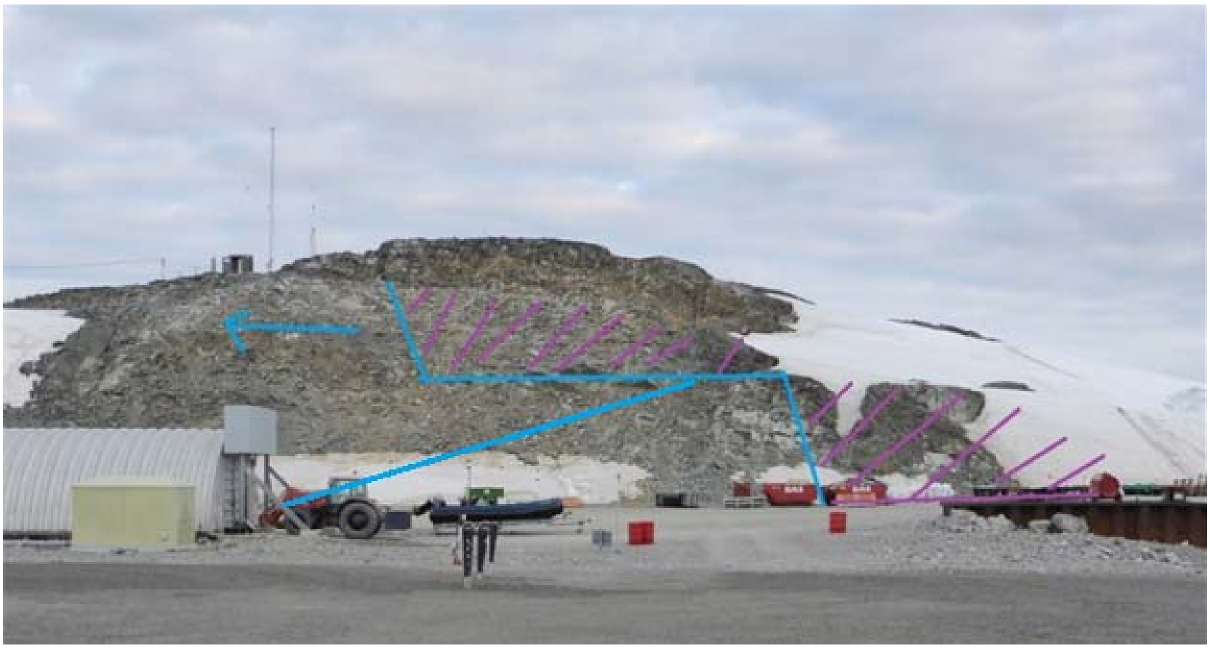

*Figure 4-6 Quarry Stage 2 -Upper face progression towards the north.*

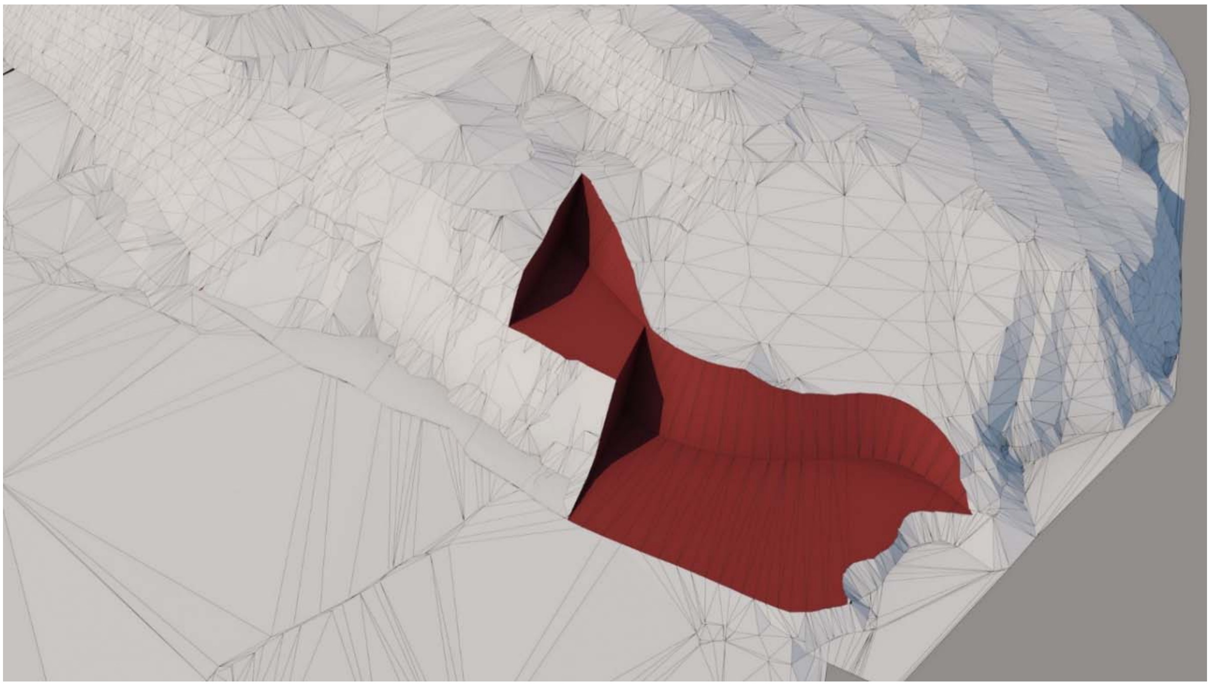

*Figure 4-7 – Quarry stage 2 -Isometric view.*

**Stage 3 –** Once the upper bench has been fully worked out the final face is dressed to a more natural angle of approximately 50 degrees from horizontal. Rock extraction continues on the lower bench. Access for drilling and blasting will be made to the upper bench level from above, whilst the lower ramp is removed during processing.


*Figure 4-8 Quarry stage 3 showing the upper bench worked out, production continuing on the lower bench.*

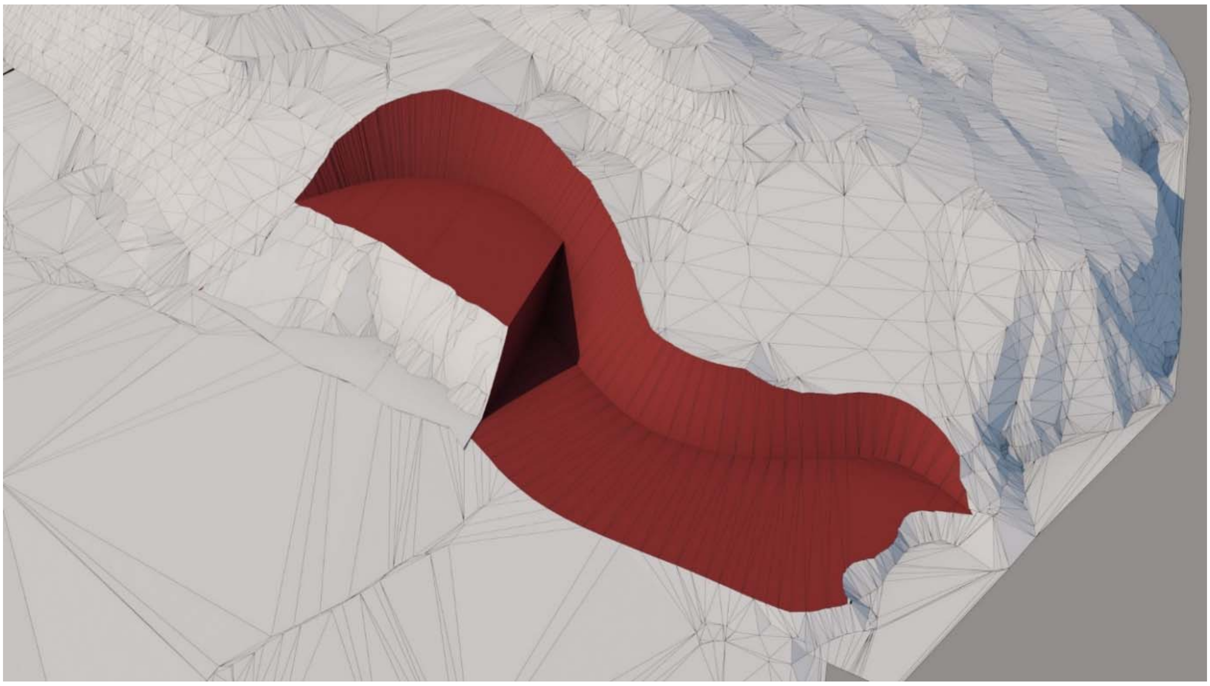

*Figure 4-9 Quarry Stage 3 - Isometric view.*

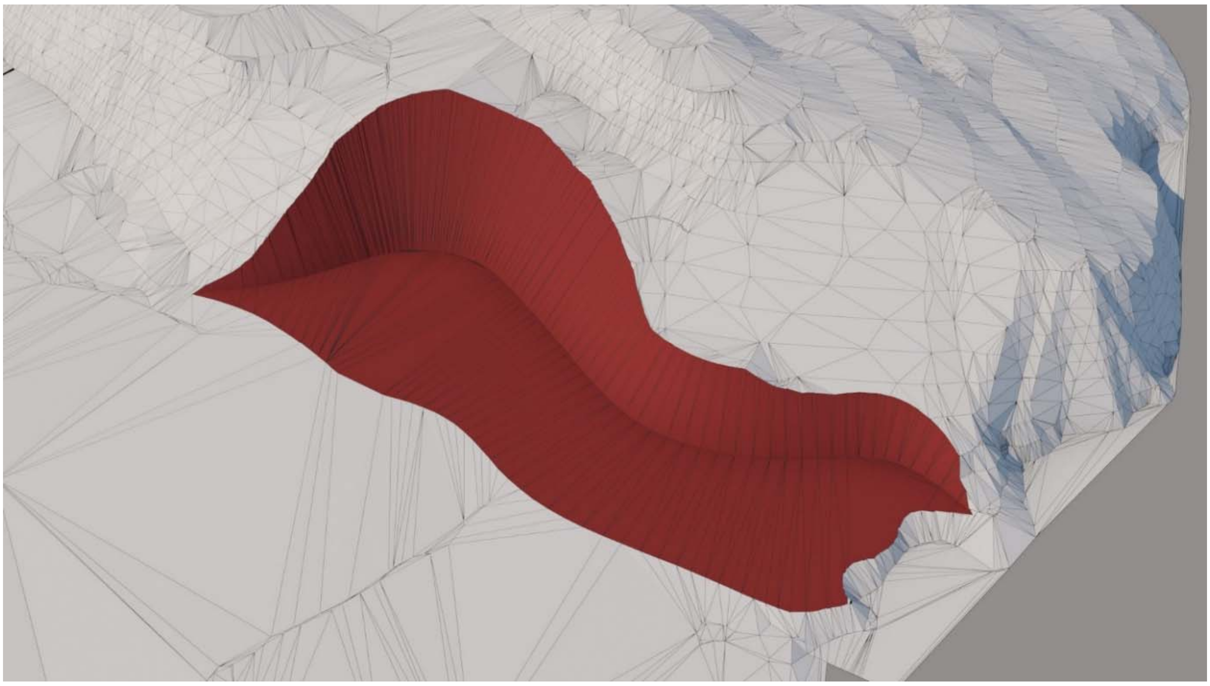

*Figure 4-10 Final extraction outline – isometric view.*

The final back-wall will be dressed to 50 degrees from horizontal, though it appears steeper in the image.

Working production faces will be inclined at approximately 10 degrees from the vertical. Final faces will be dressed back to around 50 degrees from horizontal to create stable and more natural looking slopes similar to existing slopes adjacent to the Gerritsz laboratory.

Face heights will be approximately 10m high, though will vary with the variable surface topography. During rock extraction, the ice cliff adjacent to the quarry will be removed by mechanical excavation from the land, or if necessary with the minimal use of explosive charges. Care will be taken to minimise disturbance to the ice cliff beyond the extraction area. Any other snow will be removed prior to drilling. The west facing open face is currently inclined at approximately 50 degrees from horizontal, so splitting the outcrop into two benches will allow access to the lower slope areas from above sufficient to obtain reasonable burdens (the rock thickness between a blast hole and the rock face) during blasting. To the north and east the area is bounded by snow gullies, except at the NE corner where access for the drill rig would be made.

Rock processing will be undertaken on the flat ground adjacent to the extraction area as shown in the schematic processing diagram Figure 4-11.

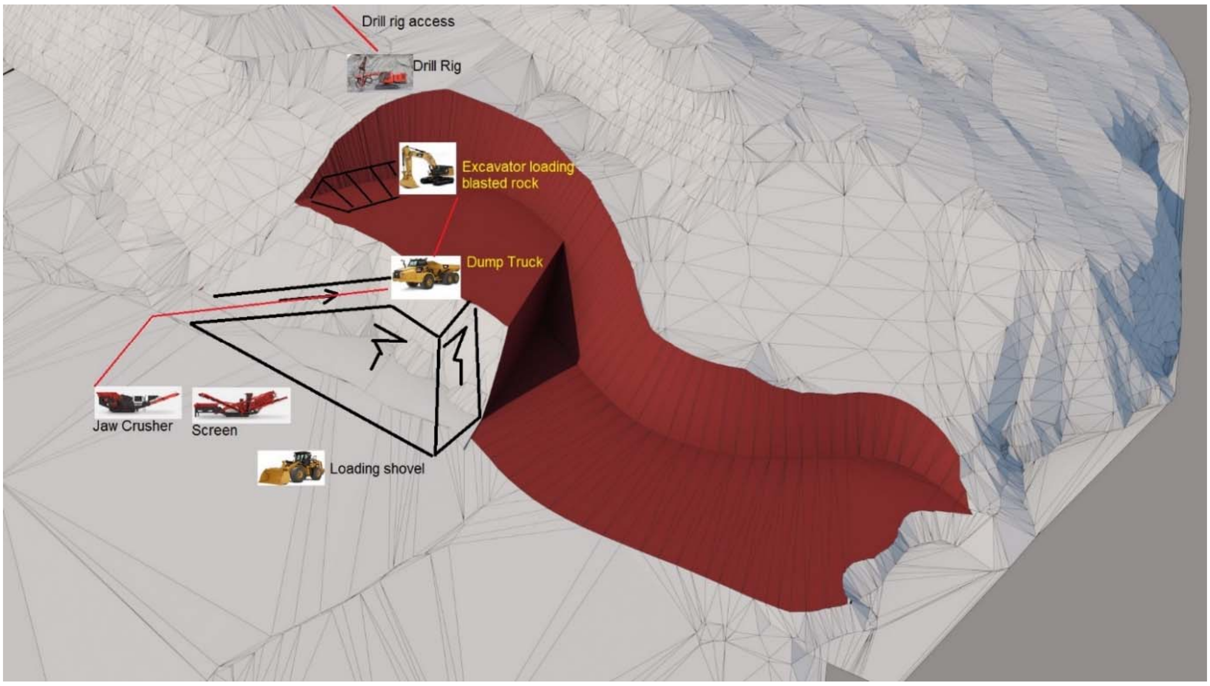


*Figure 4-11 Schematic Quarry processing diagram – set up for backfill production.*

## 4.4. Alternatives

### 4.4.1.Importing rock fill

Consideration was given to the option of importing rock fill from outside of the Antarctic Treaty area. This option was discounted on the basis that risks associated with the importation of non-native species would be too high. Obtaining the rock locally on site significantly reduces the risk of non-native species importation.

### 4.4.2.Sourcing rock at other local areas

Other potential rock extraction sites on Rothera Point were considered. These initially included sites on the western side of the runway and on the eastern side of Rothera Point. All the alternatives were discounted as it was considered the visual and ecological sensitivity would be greater than the proposed location. The preferred area is within the existing footprint of Rothera Research Station, adjacent to an area which has been developed previously and is remote from areas where seals and penguins are known to congregate.

## 4.5.Methodology

### 4.5.1.Access and Egress to the Drill and Blast Area

Access to the temporary quarry will be extended from an existing access route to the explosives storage location and other science installations, and directly from the floor adjacent to the wharf by constructing a ramp. These routes minimise the need for additional disruption to the environment for access and egress purposes as they are contained in the existing disturbed area.

Access for the drill rig onto the area will be created using an excavator, either to clear snow or loose rocks, and to make access ramps to drilling areas. Loose rocks will be used initially for the construction of these access ramps and later for processing as there is very little overburden material. Snow will be pushed into the sea.

### 4.5.2. Drill and Blasting Methodology

The specific methodologies to be followed during the drilling and blasting activities are set out in detail in Appendix A Quarrying, Drilling and Blasting Management Plan: Rothera Wharf. Primary rock extraction will be undertaken using drilling and blasting with explosives. This will involve the drilling of vertical, or near vertical holes, in the range of 64mm to 102mm diameter, with a tracked drill rig. These holes will be drilled in rows parallel and adjacent to an open face, or in a pattern to develop an open face. These holes will then be charged with explosives and stemmed with angular aggregates.

*Table 4-3 Quantities anticipated for explosives:*

| Explosives | Total quantity |
|---|---|
| Senatel Powerfrag packaged emulsion explosive | 18,000kg |
| Pentex Primers | 1632 no. |
| Exel MS in-hole non-electric detonators | 3200 no. |
| Exel Connectadet non-electric surface detonators | 1560 no. |
| Cordex detonating cord | 800m by12g/m |

Table 4-3 lists the anticipated quantities of explosives to be used. All explosives will be encapsulated and no exposure during normal handling is expected. To ensure that there is no exposure to personnel and the environment post-use, strict procedures outlined in the drilling and blasting plans in Appendix A and B will be followed at all times.

It is anticipated that the majority of blasting will be undertaken during the 2018-2019 austral summer, with approximately 20 – 25 individual blasts. The duration of each blast will typically be less than 0.5 seconds. Drilling will continue during working hours on most of the working days during this period. This drilling and blasting process will be strictly controlled following the contractors blasting procedures and following the requirements of the UK Quarries Regulations 1999. The Quarries Regulations 1999 provide the strictest requirements currently in place and also ensure compliance with BS5607:1998 Code Of Practice For The Safe Use Of Explosives In The Construction Industry. In addition the use of explosives will comply with British Antarctic Survey Code of Practice: Explosives, 3rd edition, 2007.

### 4.5.3. Load Haul & Rock Processing

It has been estimated that c.-65,000t to 80,000t (24,000m$^3$- 30,000 m$^3$) of blasted rock is required for processing feed to produce the c26,00 of 30-80mm backfill and other products, though this is subject to the yields obtained during production.

*Crushing and Screening Location*

In the initial stages of the project there will not be sufficient space for crushing plant in the extraction area, so rock will be loaded and taken to the crushing area located in Laydown Area 1 and the Additional Rock Stockpile Area See Figure 3-16. At a later date, and if space allows, the crushing and screening plant may be more conveniently located at the face in the extraction area

*Production of Backfill, Sub base, Base and Aggregate Production*

A series of grading and crushing processes will be undertaken to produce the different grades of rock required. The production processes for each stage involve the use of the same items of plant (as listed in Section 4.6) in different configurations to minimise overall plant requirements, and as such it is only possible to produce one product at any time. Approximately two days is required to change between any one production process and another.

### 4.5.4. Production rates

The following production rates are anticipated for the processing described above. These rates are based on 6 working days per week, and 10 operational hours per day excluding rest breaks. The process below describes one blast per week, with the blast size tailored to be less than a single load of explosives carried in a Twin Otter aircraft. Explosives will be stored at the Rothera ski-way and will be transported using a BAS Twin Otter or Sno-cat. All transportation of explosives will be undertaken in conjunction with Rothera Station Management. See Appendix A Quarrying, Drilling, and Blasting Management Plan for additional details.

*Pre-production development.*

Prior to drilling and blasting commencing it is anticipated that one week will be required to remove snow cover and create access for drilling equipment and prepare the processing area. No production will be undertaken during this week. Standard quarry equipment will be used for this process. Once drilling commences there will be approximately one further week prior to the start of processing.

*Drilling and Blasting*

It is anticipated that one blast will be fired per week, yielding around 7,000 tonnes of rock. The blast size will be chosen to match one load of explosives transported from the storage area.

A typical drill and blast cycle is as follows:

Day 1 and 2 - drilling. This can continue into days 3 to 5 if problems are encountered.
Day 3 to 5 - waiting for excavation of previous shot.
Day 5 pm - surveying and preparation of blasting specification.
Day 6 - fire blast.

The first blast would be fired as soon as the shot is drilled and the specification completed. During the first one or two weeks it may be necessary to fire smaller blasts during development. Production can commence as soon as the first blast is fired and the processing plant set-up.

*Excavation, load and haul*

Excavation, load and haul can only take place for five of the six day cycle, as no excavation can be undertaken from the time of the face survey until after the shot is fired. The equipment will work on other quarry duties on the sixth day.

- The excavator loads the 30t ADT which transports the blasted rock to the processing area. 7000t / 5 days = 1400t/day
    - 25t per dumper load = 56 loads per day.

*Processing rock backfill*

The loading shovel removes the 1167t to the crusher which then removes the product and waste from the screen. The loading shovel may also need to re-feed oversize material to the jaw-crusher.

Total loading shovel output per day is 2334 – 2684t.

Weekly production c.4, 500 tonnes of 30-80mm backfill.

*Loading out backfill.*

An anticipated 1,167t of backfill and 'waste' will be produced per day. If this is loaded to 25t articulated dump trucks, with 20t per load, a total of 58 loads per day are required. The number of dump trucks required will be dependent on the timing of the production in relation to use at the wharf site and/or location of the stockpiles. All waste material from this process becomes feed for smaller rock products, or stockpiled for future use in Laydown Area 1 or the Additional Stockpile Area. See Figures 3-15 and 3-16.

*Change over time between different types of production.*

As described earlier the different rock products will be produced with the same equipment as far as possible, therefore one or two days of non-production will be required to reconfigure the equipment.

*Production of sub-base, base course and 30-80mm products.*

A production rate 100 t/hr, or 800t/day is anticipated for these products. For a total of 11,240 tonnes, 14 working days or 2 weeks and 2 days.

### 4.5.5. Equipment and vehicles

All equipment, with the exception of the drill rig will be fully utilised during working hours. The drill rig is anticipated to be operational 2 to 3 days per week. The following equipment will be used for excavation, load, haul, production and loading of rock from the extraction area. This does not include equipment for transport to the work area, to/from stockpiles, or for stockpile management.

*Table 4-4 Equipment & Vehicles*

| Item | No. |
|---|---|
| Excavator for rock excavation<br><br>45t (Minimum size 35t) | 1 |
| Hydraulic rock breaker | 1 |
| Wheel loader<br><br>Cat 966 or equivalent | 1 |
| Articulated dump truck (ADT)<br><br>30t ADT | 1 |
| Drill rig – E.g. Atlas Copco FlexiROC T35 | 1 |
| | |
| Mobile Jaw Crusher | 1 |
| | |
| Mobile Double deck screen | 1 |

Additional ancillary equipment may be required, or be shared with the wharf construction activities. E.g. Water bowsers, fuel bowsers, maintenance equipment, tractors and trailers, and aircraft.

## 4.6. Anticipated Waste

All construction waste will be managed onsite by the construction team. Domestic waste generated will be incorporated into the standard BAS waste management system. See Section 11.2 Operational Procedures: Waste Management, for further detail.

## 4.7. Personnel

The following team of people will be deployed to Rothera to undertake the works:

- 1 Quarry Manager / Blasting Engineer
- 1 Shotfirer
- 1 Driller (possibly one person acting as Shotfirer/Driller)
- 1 Excavator / Crusher Operator
- 1 Loading Shovel Operator
- 1 Dumper Operator

The role of Explosives Supervisor will be held by the Quarry Manager. The roles of Laser Surveyor, Explosives Storekeeper will be held by the Shotfirer and / or Explosives Supervisor. One person will be trained, instructed and appointed Blast Controller. Sentries will be trained and appointed from the quarrying or construction personnel.

## 4.8. Predicted Lifespan

The active design life for the temporary quarry is for the extraction period anticipated to last for the first construction season. It is planned that the quarrying works will be completed by the end of April 2019. The quarrying equipment will stay on site until the end of the 2019/2020 season when it will be possible for a ship to come alongside the new wharf and remove the plant safely.

## 4.9. Plans for Decommissioning

Once extraction is complete the quarry will cease to operate and all equipment removed. The final angle of the quarry face will be dressed to an angle 50 degrees from horizontal, similar to the existing rock face.

# 5. DESCRIPTION OF PROPOSED DEVELOPMENT 3 – Coastal Stabilisation

## 5.1. Purpose and Need

The Rothera runway and supporting embankments were constructed between 1990 and 1992 from rock quarried and crushed on site. The work included land reclamation from the shoreline to a small island which formed the southern end of the runway. A cove was constructed between the southern end of the runway and Biscoe Wharf. Embankments were formed by placing crushed rock into the cove from land in order to extra provide shore protection. The outer layer of the embankment consisted of small sized locally sourced rock armour also known as rip rap.

Since the original construction, large swell waves have been known to develop within the cove. Brash ice regularly becomes trapped within the inlet, causing it to circulate for long periods of time and erode the embankment. The wave and ice action has caused some of the rock armour around the cove to displace, making the embankment vulnerable to the loss of both the protecting rock armour and the underlying rock fill. Photographic evidence has established that these effects have caused the smaller rip-rap material to be displaced and washed away from the embankment over time. Figure 5-1 shows the larger armour material at the base of the embankment within the cove.

*Figure 5-1: Current rock armour across the embankment around the cove*

The design of the new wharf at Rothera is to protrude further into Ryder Bay than the current alignment of Biscoe Wharf and because of this, it is predicted that there may be a small risk that the wave and ice effects within cove will be amplified. . Any significant damage to the cove could impact the safe operation of either the runway or the wharf. It could also impede the main sea water intake location in the cove that is used to supply all potable water at Rothera.

No formal assessment has been undertaken to establish the condition of the embankment specifically surrounding the cove. However, a condition survey has been undertaken for the southern end of the runway which has indicated repairs are required. If repair work is not undertaken, it is likely that wave and ice action within the cove will continue to dislodge armour material, causing more rapid erosion of the embankments. Furthermore, erosion will ultimately reduce the overall stability of the embankments that, in turn, increases the likelihood of collapse. In an extreme scenario, sheet piling could become undermined at the wharf end of the embankment, leading to erosion of the wharf backfill. There is a risk that this would lead to a structural failure of the wharf.

Figure 5-2 below shows the current rock revetment in front of the western wall of the wharf.

*Figure 5-2 Rock revetment in front of the western wall of Biscoe Wharf*

This essential coastal stabilisation repair work within the cove will prolong the life of the embankment for a further 25 years.

## 5.2. Location

Figure 5-3 shows the location of the cove in relation to Rothera Station.


*Figure 5-3 Aerial View of cove from south of runway*

## 5.3. Proposed Works

The proposed solution is to reinstate the embankment around the cove and, in doing so, ensure longevity to the adjacent infrastructure. A study has been undertaken to provide a qualitative assessment on the effect of the new wharf on the penetration of wave energy into the cove. It was concluded that for 95% of the time in any given year, the wave conditions inside the cove will be equal to or less than the current situation, after the new wharf has been constructed. For 5% of the time, it is predicted that there will be an increase in wave action in the cove.

During the first construction season an investigation will be undertaken to establish if the material required to reinstate the embankment can be obtained from the quarry. It is anticipated that a total of 1,600t of rock fill would be required. This is split into 600$m^3$, (1,200t) of c.>400mm rock fill and 200$m^3$ (400t) of 50-150mm rock fill.

If it is not possible to source the material locally the original proposal of using concrete armour will be reconsidered.

Concrete armour or rock armour would replace the existing rip rap armour along approximately 55m of the embankment as shown in Figure 5-4. The light green areas show where the new structure is proposed. The purple area shows the extent of the proposed wharf. The pink area is the existing runway.

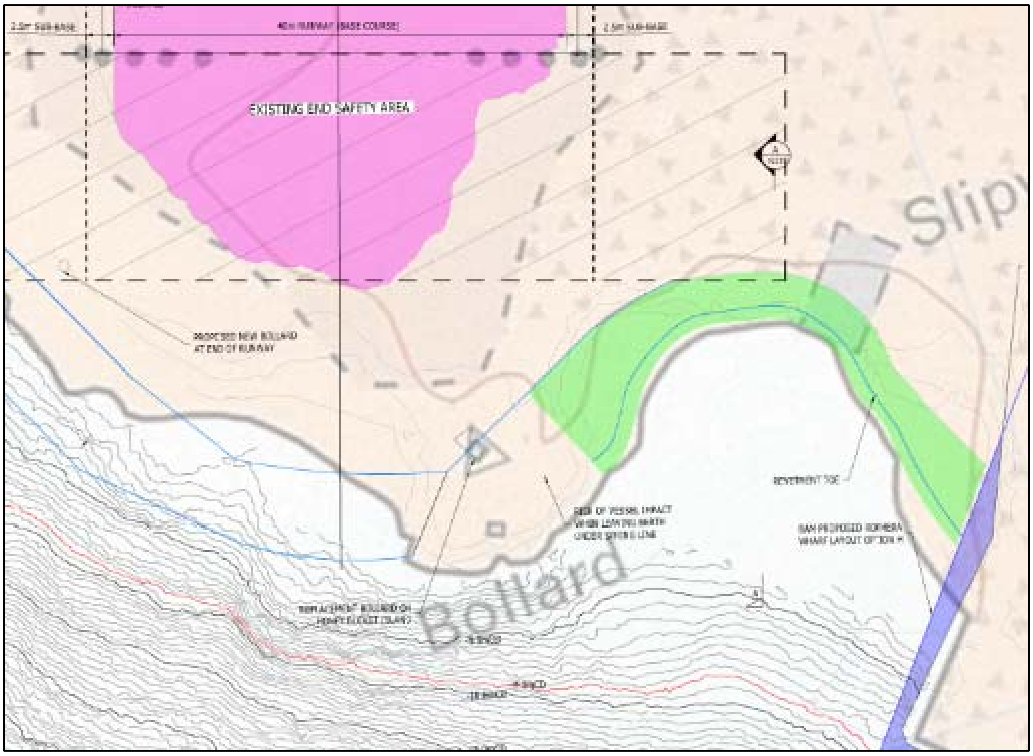


*Figure 5-4 Proposed Extent of Reconstruction of the Embankment*

The proposed scope for the repairs to the embankment is to replace existing fill material as necessary, re-profile the embankment to a slope of 1:1.5, install an under layer to prevent the fill material from washing away and to replace the existing rip rap rock armour.

## 5.4. Alternatives considered

The following alternatives for the coastal stabilisation works were considered.

### 5.4.1. Do Nothing

The 'do nothing' option was considered, but ruled out because if the repairs are not undertaken then the embankment may be susceptible to accelerated erosion which would ultimately lead to the temporary closure of the runway and wharf. In addition, the supply of vital water supplies to the station could also be compromised if the station water intake becomes damaged or blocked by silt, or small rip rap.  The intake pipe is located in the apex of the cove (within the area shaded green on figure 5-4). This would have a significant impact upon the operational viability of Rothera Research Station as a whole.

### 5.4.2. Do Minimum

Continued patch-repairs were also considered but discounted on the basis that such an approach will not address the underlying issues and as such are unlikely to maintain the performance of the shore protection for a further 25 years.

### 5.4.3. Alternative Works

Consideration was made to reclaim the entire area within the cove with the rock material excavated from Biscoe Wharf.  This option was discounted on the basis that the material could be better reused as backfill in the new wharf, thereby reducing quantities of rock to be quarried.

### 5.4.4. Alternative Techniques

It is considered that concrete armour or rock armour will provide adequate protection to the embankment with minimal maintenance.  The overall thickness of a rock armour or rip rap solution will be approximately twice that of a concrete armour solution. The extent of the work will need to be from approximately 4m above chart datum (the existing height of the reclamation) to between 2m and 3m below chart datum.

An initial analysis of the local geology indicates that whilst the local rock could be used for rip rap (300 mm in diameter), it is unlikely that it will be suitable for rock armour.  However further investigation into the suitability of local rock will be undertaken in the first construction season.

Unreinforced concrete armour is considered the preferred armour solution for the embankment but the final decision is subject to confirmation of its durability and constructability in the Antarctic environment. Depending on shipping constraints, concrete armour could be either imported as precast units, or cast on site. For the latter, the intent would be for the aggregate to be locally sourced from the temporary quarry whilst the sand and cement required for any cast on site concrete will have to be imported.

Several concrete armour types have been considered and at this stage the proposal is to use a single 1.7m thick layer of X-Bloc Plus units. Each unit has a volume of $2m^3$ and weighs 4.8t. X-Bloc Plus units are preferred because they have a high interlocking capacity resulting in good hydraulic stability. Placing the units as a single layer means they present a flat surface which it is considered, when compared to other forms of armour, provides improved resistance to being dislodged or levered through the action of ice. See Figure 5-5.

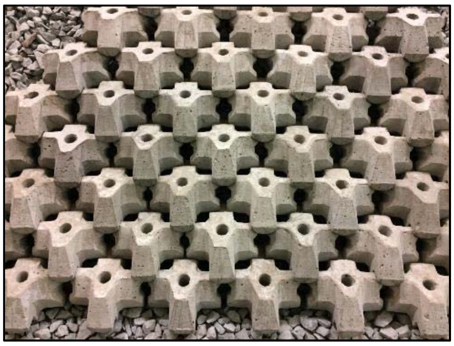

*Figure 5-5 Typical X-Bloc Plus Armour Arrangement*

Importing construction materials introduces the risk of accidentally introducing non-native species, which could have a serious impact on the native biodiversity. All imported materials will therefore undergo biosecurity screening as stipulated in the specific Biosecurity Plan: Rothera, Appendix E. Using precast concrete reduces the likelihood of inadvertently introducing non-native species as concrete is an inert substance. It is recognised that the location and method of storage introduces potential environmental issues that will require consideration.

## 5.5. Laydown Areas

The construction site layout is included in Figures 3-15 and 3-16.

### *Construction Laydown Area 1*

This area will mostly be used to support the works at the wharf, although for the coastal stabilisation works various general activities will be carried out here such as plant and equipment maintenance and small fabrication works. For this purpose, there will also be a number of workshops located in this area. For concreting works for the wharf a small concrete batching plant will be erected in this area. If the concrete armour blocks are to be cast on site this activity will be undertaken here as well. Completing the work at the wharf and the coastal stabilisation concurrently will minimise the duration of the construction impacts.

### *Construction Laydown Area 2*

This area will mainly be utilised for the storage of excess rock material from the quarry laydown area. If concrete armour blocks are cast on site, the finished blocks will be stored here. The plant stored here will include:

- Rotating Tele handler
- 40 ft. flatbed articulated trailer
- Tractor Unit

### *Construction Laydown Area 3*

This area will be used for multi season storage which is not currently required for the coastal stabilisation works. As such it is not anticipated that this will be used for these works.

## 5.6. Construction Methodology

The coastal stabilisation works will be split into a number of distinct stages summarised below:

- Removal of any existing armour material
- Sourcing of fill and filter layer material
- Levelling of the revetment toe
- Profiling of the existing material
- Installation of filter layer
- Production of precast concrete armour units (if undertaken on site)
- Installation of precast armour units
- Finishing works

Each of the above activities is described in further detail below. Although these are described as separate activities on site these may be progressed concurrently along the length of the work front.

### 5.6.1. Removal of Existing Armour Material

Any existing armour material will be removed using a long reach 50t excavator or similar and transferred to dump trucks for transport to a stock pile location anticipated to be located in Construction Laydown Area 3. This armour material may be reused in future works at Rothera not included in the scope of this EIA.

### 5.6.2. Sourcing of Fill and Filter Layer Material

Any additional fill material required to achieve the new profile will be sourced from the rock extraction area being established for Rothera Wharf. The volume of rock anticipated to be required is 2,700 tonnes. As two different grades of material are required, fill and filter which combined produce a suitable under layer, these will be produced independently and stored in separate stockpiles. The correct grades will be produced using the various crusher and screen arrangements.

### 5.6.3. Levelling of the Revetment Toe

At the base of the new embankment a revetment a toe will need to be created which involves creating a trench. This will ensure that once the concrete armour units are put in place they will remain stable. Figure 5-6 shows a cross section of the embankment once completed with the revetment toe highlighted in red.

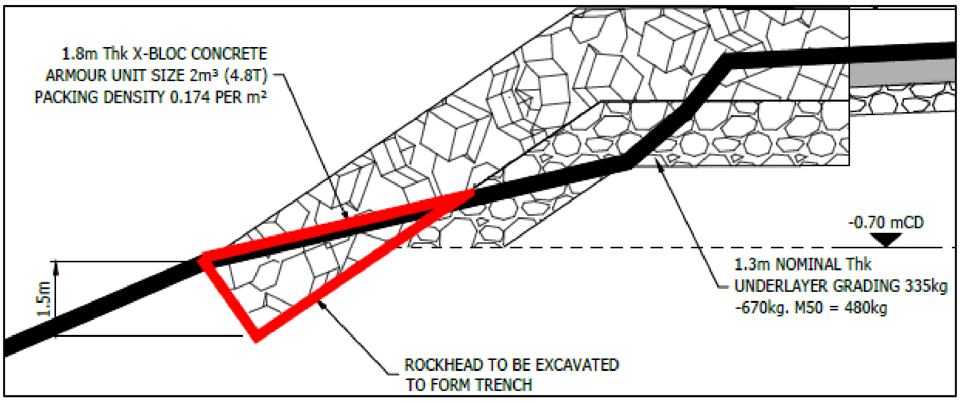


*Figure 5-6 Cross section with revetment toe highlighted*

The removal of the rock head will be undertaken using a rock breaker mounted on an excavator. Once broken the rock will be removed using an excavator with bucket installed which will transfer the material to a dump truck which will transport this to the quarry area for processing and recycling into fill material.

In some locations the excavator arm may not have sufficient reach from the shore line.  In this case a temporary bund may be created using recycled excavated material.  This will provide additional height and allow the excavator to get closer to the work area. This is shown indicatively in the Figure 5-7 by the blue line. The temporary bund will be removed on completion of the toe and the material reused in the profiling of the permanent slope.

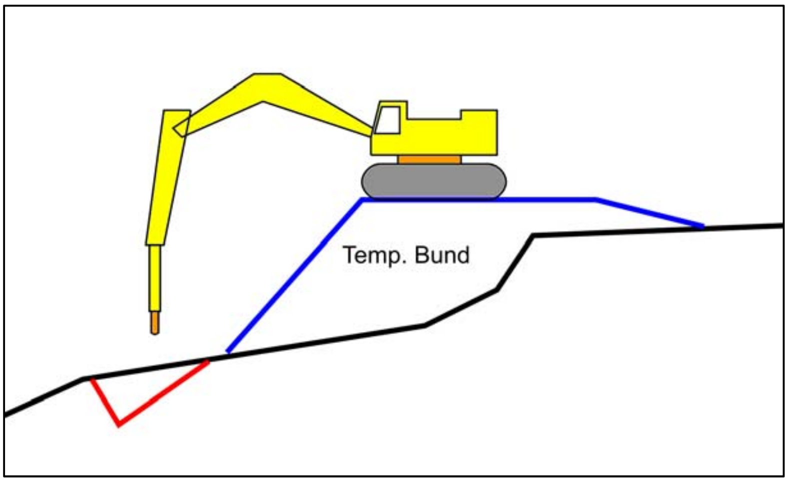


*Figure 5-7 temporary bund*

### 5.6.4. Profiling of the existing material

Following completion of the revetment toe, the existing material can be profiled as per the design to the level below the fill layer as shown in Figure 5-8. This work will be done using a long reach excavator and bucket combination. If additional material is required this is transported to the installation location using dump trucks from the quarry or a material stock pile where loading is undertaken using a wheel loader. Where possible and safe to do so material will be directly dumped in position by the dump truck. Final profiling is then still done using the long reach excavator.

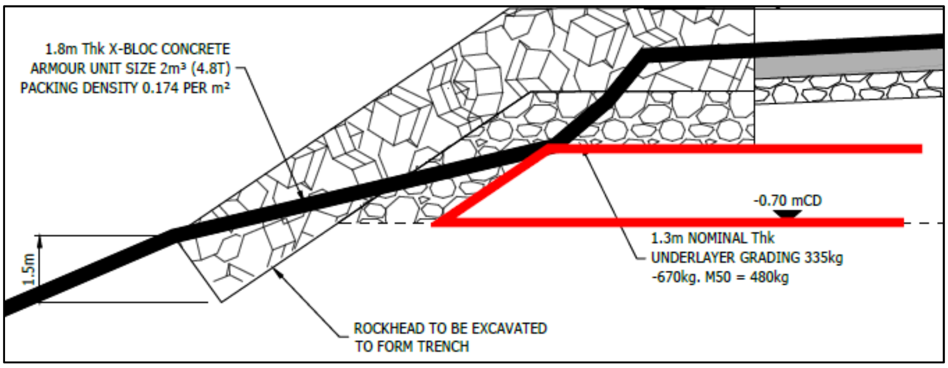


*Figure 5-8 Cross section of profiling*

### 5.6.5. Installation of Filter Layer

Following the profiling of the existing material the filter layer can be installed. This will be transported from the dedicated storage location using a dump truck loaded using a wheel loader and placed near the installation location within reach of the long reach excavator. The long reach excavator will place this as per the design profile as shown in Figure 5-9.

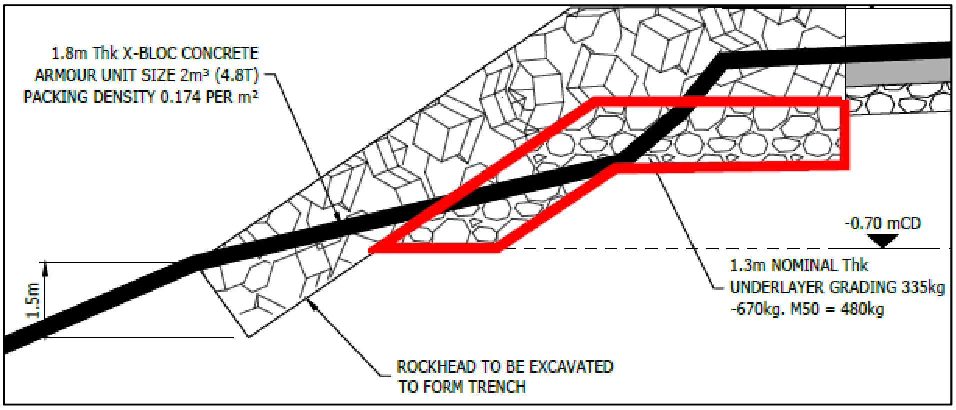


*Figure 5-9 Cross section of filter layer*

### 5.6.6. Production of Concrete Armour Blocks

If the investigation into using local rock concludes that it is not suitable, a cost benefit analysis will be undertaken to determine whether if used, the concrete armour blocks will be cast on site at Rothera or in a precast yard located outside of the Antarctic. This will involve consideration of the costs and energy requirements of transporting the units to Rothera in comparison to the costs and energy requirements of establishing a concrete casting facility on site. Environmental considerations, storage and accommodation will also be taken into account. Although unlikely, if the armour units are cast on site measures will be taken to limit the potential environmental impacts. These are outlined in Section 11.3 Coastal Stabilisation Impacts and Mitigation.

Moulds for the units will be made from steel consisting of two sections which are bolted together. Concrete will be batched in the batching plant and transported to the installation location using a concrete mixer truck. The mould will be filled directly using the chute of the concrete truck that will be positioned on a raised hard standing. The concrete will be poured in layers to ensure the correct compaction is achieved. Vibrator needles will be utilised to remove air from the mix and ensure the concrete is compacted evenly in the mould. Exposed surfaces are then finished smooth. Following the initial curing period, the mould is unbolted and removed from the concrete unit. The unit is then transferred to a storage location and the mould prepared for the next casting. Multiple units will be cast concurrently using separate moulds.

### 5.6.7. Installation of Concrete Armour Blocks

The precast armour units will be transported to the cove and unloaded using a mobile crane. Installation will be undertaken by mobile crane or a larger crawler crane depending on the installation radius. This will be determined by an engineered lift plan. The units will be placed one by one in an interlocking pattern. See Figure 5-10.

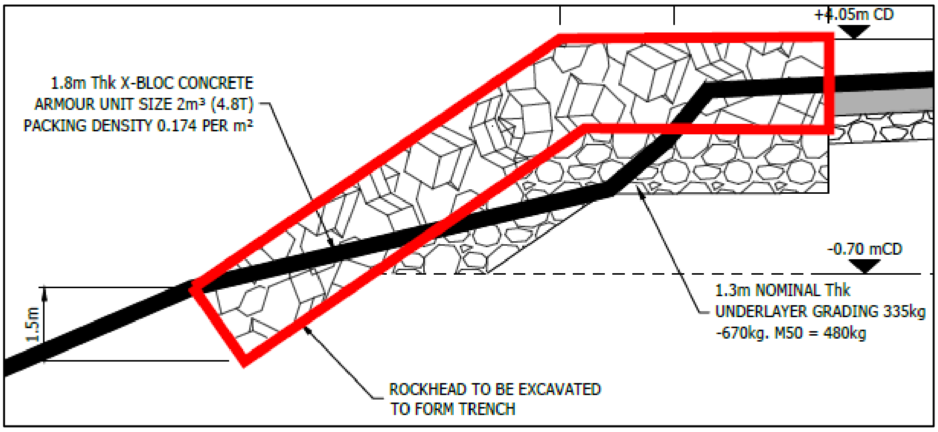


*Figure 5-10 the red line denotes the position of the concrete armour as the final layer on the embankment.*

### 5.6.8.Finishing Works

Following the completion of the main works, the area behind the X-blocks will be filled to the same height as the concrete units. This will be done with the use of wheel loaders and dump trucks as shown on Figure 5-11.

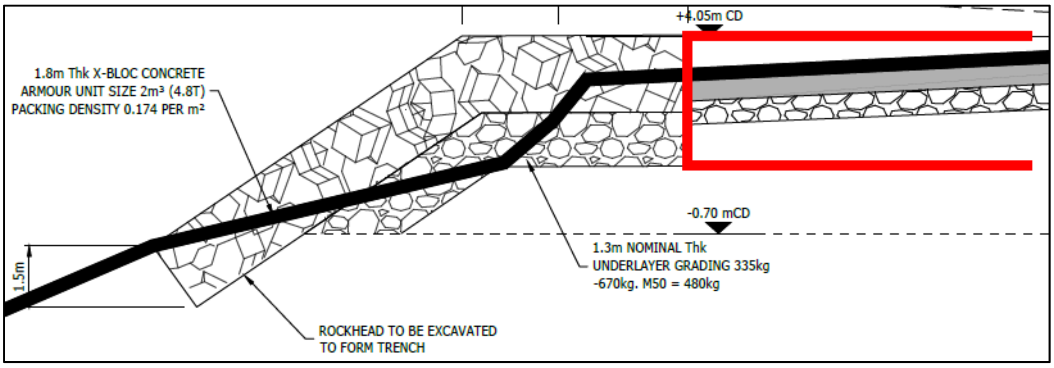


*Figure 5-11 Red line denotes are to be filled behind the X-blocks.*

All construction activities for the embankment are anticipated to be undertaken from land and hence no marine activities from floating equipment are anticipated.  A safety boat will be provided where works near or over water are undertaken.

### 5.6.9. Construction materials

The following construction materials will be required for the coastal stabilisation works:

*Table 5-1 Coastal Stabilisation Construction Materials*

| Coastal Stabilisation Key Construction Materials | | |
|---|---|---|
| Element | Material | Mass (t) |
| Embankment Repairs | Rock Fill[1] | 1,300 |
| Under Layer | Rock Fill[1] | 1,400 |
| Concrete Armour[2,3] | Concrete | 1,300 |
| Rock Armour[2, 4] | Rock | 2,200 |
| Total Concrete Armour Option | | 4,000 |
| Total Rock Armour Option | | 1,600 |

Notes:

1. It is anticipated that the material for the rock fill will be quarried and crushed locally. As much as possible will be sourced from the reprocessing of material from the wharf construction activities.
2. Use of concrete armour, imported rock armour or local rock rip rap to be determined during detailed design.
3. The concrete armour could either be imported or cast on site. For cast on site the aggregate for the concrete would be quarried and crushed locally but the sand and cement would need to be imported.
4. Only required if proposed concrete armour is not taken forward and rock armour is utilised.

All imported materials will be subjected to biosecurity preparations and inspections in accordance with the BAS Biosecurity Handbook and Biosecurity Plan in Appendix E.

### 5.6.10. Equipment and vehicles

The following equipment will be required for the works which will be shared with the wharf works in order to optimise utilisation and reduce the transport footprint.

- Long reach excavator.
- Wheel loader.
- Dump trucks (min 2 no.).
- Mobile or Crawler crane of minimum 100t capacity.
- Quarry arrangement including drill and blast equipment, crushers and screed frames.
- Batching plant (if casting is undertaken on site)

## 5.7. Anticipated waste

All waste anticipated to be generated is included in the waste arisings listed for Rothera Wharf. See Section 4.8 and Appendix D: Site Waste Management Plan.

Recovered rock material from dismantling works will be re-used in the stabilisation works where possible following re-processing as required by the quarry processing arrangement. Material not suitable for use in the works will be used for maintenance of existing and temporary infrastructure.

## 5.8. Personnel

Personnel will be shared with the wharf project in order to optimise utilisation as well as minimise cost and environmental impact related to transportation and accommodation of additional personnel in Antarctica. Site management will be part of the Rothera Wharf team already onsite and is not separately mentioned here.

The following specific personnel will be involved in the coastal stabilisation works:

- 1 Foreman
- 4 Machine Operators
- 1 Crane Driver
- 2 Banksmen

## 5.9. Predicted Lifespan

The reinstatement of the embankments is based on a 25 year design life before major maintenance work will be necessary. This design period is in line with the original design life for the embankment. Routine maintenance will still be necessary.

## 5.10. Plans for Decommissioning

The planning assumption is that there will be an enduring requirement for shore protection at Rothera Station as long as BAS retains its presence there. If or when a decision is made to vacate the site then a separate study will be necessary to assess decommissioning the armour. Due to the lack of connections between the blocks this is likely to be a straightforward retrieval of the armour which can then be removed for recycling.

# 1. OPERATIONAL PROCEDURES

## 1.1. Fuel Management & Oil Spill Response

The following information included in the Fuel Management Plan outlined in Section 6.1.5, has been specifically written for fuel handling procedures at Rothera during the Rothera Wharf reconstruction and coastal stabilisation works. The final procedure will be finalised prior to construction commencing.

All fuel which will be used for construction works will be delivered to Rothera by BAS logistics. Bulk Marine Gas Oil (MGO) otherwise known as marine grade diesel will be stored in the existing fuel tanks at the Rothera fuel farm. All refuelling will follow normal BAS refuelling procedures where possible.

### 1.1.1.Outline Ship to Shore Refuelling Method

Between –January 2019 and February 2020 whilst the wharf is under construction it will not be possible to carry out re-fuelling of the Rothera Station bulk tanks in the normal operational manner. This is because without a wharf the BAS ships will not be able to moor alongside. During this time the following method will be implemented and will be documented in a formal refuelling operating procedure.

Whichever BAS ship is refuelling, either the JCR or the ES, it will hold position 50 -100m offshore from the South end of the Rothera runway using dynamic positioning (DP). Up to a maximum of 500 $m^3$ of MGO and 350 $m^3$ of Aviation Kerosene (AVCAT) will be delivered at each ship visit. It is likely that there will be 2 visits from each ship during the construction period.

Lloyds Register approved (Angus Offshore 850) marine lay-flat hose will be used to connect the Rothera refuel point to the ships bunkering points. The 200m (one piece) lay-flat hoses will be deployed from a purpose made skid mounted, driven, hose deployment and retrieval reeler unit on shore. One hose will run along the ground to a point adjacent to the shore line where a dry break coupling is fitted to allow quick and clean disconnection in the case of an emergency. A drip tray shall be placed under the connection and monitored throughout the period of refuelling.

From the shore line to the ship a separate (one piece) length of the lay-flat hose will be floated to the ship with the aid of a small boat. Although the lay flat hose has some natural buoyancy there will also be additional flexible buoyancy collars attached. The ship will also connect using a dry break coupling to allow a quick and clean disconnection should the ship be required to leave the area. Additional flat hose clamps are also available as part of our refuel equipment package.

Prior to recovery of the hose it will be ‘pigged’ (drained/cleaned) using a compressed air driven plug. An industry standard ‘pig’ launcher, pig catcher and soft polyurethane plug will be used. Although the ships may be delivering MGO and Aviation fuel during their calls only one fuel type will be pumped at any one time.

Oil spill equipment including absorbents will be positioned adjacent to the dry break connection. The Rothera oil spill equipment container (which includes inflatable booms) will be located to a position as close to the shore as possible. In the event of a spill in the water or on the shore line, the Rothera Oil Spill Contingency Plan will be followed and the response coordinated by the Rothera Station Leader. The standard on-board procedures for refuelling from the ship will be followed. In the event of a spill on board, the Ships Oil Spill Emergency Procedures will be followed coordinated by the Ships Master.

During refuelling normal small boating operations will cease and instead will be used to monitor ice and hose conditions. Depending on fuel quantities delivered it will take approximately 7 hours for MGO and 5 hours for aviation fuel. Aviation fuel is not delivered as frequently as MGO

A full risk assessment will be produced to identify the risks associated with abrasion from rocks and ice damage on the hose, mechanical failure, hose stress, weather and tides. BAS emergency spill procedures will be followed in the event of a spill. Oil spill response training is provided on station twice a year and a specific training scenario will be undertaken prior to refuelling in this manner.

Fuel Use – Rothera Wharf
Itis estimated that the Rothera Wharf will use approximately 982, 2,000 litres of marine gas oil in the total over the two seasons. This includes fuel required for snow clearance at the beginning of each season as detailed in Figure 6-1. I

### 1.1.2. Fuel Use – Coastal Stabilisation

It has been estimated that the coastal stabilisation works will use 18,051 litres of marine gas oil as detailed in Figure 6-2.

### 1.1.3. Fuel Storage

In order to construct the wharf, the site set up will use 2 generators one of which will be coupled to a fuel tank with a capacity of 2,250 litres. Numerous items of mechanical plant will be used as detailed in the plant list and the site set up plan. Items of plant and the generator tanks will be refuelled using a towable 5,000 litre bunded steel bowser. This will be towed by a tractor or similar item of plant. Oil spill equipment will be located adjacent to the fuel tank and will accompany the fuel bowser at all times. All mechanical plant will carry spill kits as stipulated in Section 6.1.6.

### 1.1.4. Additional Fuel Storage

Due to the large quantities of fuel required on station during the construction works, additional storage tanks are required. It is proposed that 4x 24$m^3$ mobile fuel containers will be used as temporary storage between December 2018 and March 2020.
These containers will be stored outside and adjacent to the existing fuel tanks at Rothera. All four tanks will be located in a temporary, purpose built bund designed to hold in excess of 110% of the total volume of the tanks. The bund will be made of polyurethane with dimensions approximately 12mx 10m x 0.3.
A geotextile underlay will be used to minimise the risk of punctures. The bund will be examined regularly to ensure the integrity of the material is not compromised. Snow and water will be removed whenever necessary.

#### 1.1.5. Fuel Line Removal

Due to the increase laydown areas required for the construction works at Rothera, it is proposed to remove a 220m section of the existing fixed fuel line which is located above ground. This is the section that runs north from the Bonner Laboratory to the point at which it is routed below ground where it crosses the runway. The pipework will be fully drained prior to any works and spill trays will be located beneath each joint as is it is dismantled. Each of the pipes removed will be capped with a sealed blanking plate. Refuelling of the station will be undertaken as per the method described in section 6.1.1 Ship to Shore Refuelling, using marine lay-flat hoses.

| | | | | Fuel Factor | | AVERAGE ESTIMATED CONSUMPTION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item No. | Equipment | Quantity | Power<br><br>[kW] | Combined Fuel Factor<br><br>[-] | Theoratical Avg. Fuel Consumption [ltr/hr] | Actual Operational S1 [wk] | Actual Running Hours S1 [hr/day] | Actual Consumption S1 [ltr] | Actual Operational S2 [wk] | Actual Running Hours S2 [hr/day] | Actual Consumption S2 [ltr] | Actual Total Estimate<br><br>[ltr] |
| 1 | Mobile RT Crane 75t Tadano | 1 | 164 | 0.27 | 11.70 | 16.75 | 1,139 | 13,322 | 7.5 | 510 | 5,965 | **19,287** |
| 2 | Crawler Crane 68m Boom 300t Liebherr LR1300 | 1 | 390 | 0.37 | 37.09 | 22.25 | 1,513 | 56,111 | 20 | 1360 | 50,437 | **106,549** |
| 3 | Crawler Crane 44m Boom 300t Liebherr LR1300 | 1 | 390 | 0.37 | 37.09 | 22.25 | 1,513 | 56,111 | 16.25 | 1105 | 40,980 | **97,092** |
| 4 | Telehandler JCB 535-140 | 1 | 74.2 | 0.32 | 6.17 | 6.63 | 451 | 2,781 | 3.75 | 255 | 1,574 | **4,356** |
| 5 | Roto-Telehandler 5t Manitou MRT2150+ | 1 | 110 | 0.32 | 9.15 | 6.63 | 451 | 4,123 | 3.75 | 255 | 2,334 | **6,457** |
| 10 | MEWP Knuckleboom 18-20m ex-BAS Fleet | 1 | 35.8 | 0.32 | 2.98 | 6.00 | 408 | 1,215 | 5 | 340 | 1,013 | **2,228.13** |
| 11 | MEWP Knuckleboom 18-20m ex-BAS Fleet | 1 | 35.8 | 0.32 | 2.98 | 6.00 | 408 | 1,215 | 5 | 340 | 1,013 | **2,228** |
| 12 | MEWP Knuckleboom 18-20m | 1 | 35.8 | 0.32 | 2.98 | 0.00 | - | - | 0 | 0 | - | **-** |
| 23 | Agricultural Tractor 4x4 200hp New Holland T6090 | 1 | 150 | 0.30 | 11.89 | 22.25 | 1,513 | 17,984 | 21 | 1428 | 16,974 | **34,959** |
| 24 | Agricultural Tractor 4x4 200hp New Holland T6090 | 1 | 150 | 0.30 | 11.89 | 4.25 | 289 | 3,435 | 0 | 0 | - | **3,435** |
| 27 | RIB Rescue Boat Spec. TBC | 1 | 75 | 0.18 | 3.57 | 19.00 | 1,292 | 4,607 | 14 | 952 | 3,395 | **8,002** |
| 28 | Dory Workboat/ Divers Boat 20ft. | 1 | 75 | 0.18 | 3.57 | 14.00 | 952 | 3,395 | 13 | 884 | 3,152 | **6,547** |
| 30 | Grout Mixing Plant 410 | 1 | 16.5 | 0.20 | 0.85 | 4.00 | 272 | 231 | 10 | 680 | 578 | **809** |
| 31 | Grout Mixing Plant 410 | 1 | 16.5 | 0.20 | 0.85 | 0.00 | - | - | 0 | 0 | - | **-** |
| 33 | Mobile Jaw Crusher - Sandvik QJ341 | 1 | 261 | 0.30 | 20.68 | 19.00 | 1,292 | 26,722 | 0 | 0 | - | **26,722** |
| 34 | Mobile Double Screen 30-80mm Sandvik QE341 | 1 | 75 | 0.30 | 5.94 | 19.00 | 1,292 | 7,679 | 0 | 0 | - | **7,679** |
| 36 | Crawler Dozer ex-BAS Fleet CAT D5N | 1 | 88 | 0.44 | 10.11 | 11.00 | 748 | 7,563 | 7 | 476 | 4,813 | **12,377** |
| 37 | Wheel Loader c.w. forks 3500L CAT 966 | 1 | 207 | 0.44 | 23.79 | 21.50 | 1,462 | 34,774 | 15.25 | 1037 | 24,665 | **59,439** |
| 38 | Wheel Loader c.w. forks JCB 456ZX | 1 | 153 | 0.44 | 17.58 | 8.00 | 544 | 9,564 | 7 | 476 | 8,368 | **17,932** |
| 39 | Crawler Excavator 8t Caterpillar CAT308E | 1 | 48.5 | 0.44 | 5.57 | 9.50 | 646 | 3,600 | 5.5 | 374 | 2,084 | **5,684** |
| 49 | Crawler Excavator 29t Caterpillar | 1 | 150.6 | 0.44 | 17.30 | 15.25 | 1,037 | 17,945 | 12 | 816 | 14,120 | **32,065** |
| 50 | Crawler Excavator 29t Caterpillar | 1 | 150.6 | 0.44 | 17.30 | 7.25 | 493 | 8,531 | 0 | 0 | - | **8,531.13** |
| 51 | Crawler Excavator 49t Doosan DX490 | 1 | 283 | 0.44 | 32.52 | 25.00 | 1,700 | 55,280 | 11.5 | 782 | 25,429 | **80,709.15** |
| 52 | Crawler Excavator 29m boom and standard boom 90t Caterpillar 390 OLR | 1 | 390 | 0.44 | 44.81 | 17.00 | 1,156 | 51,803 | 5 | 340 | 15,236 | **67,039.50** |
| 53 | Crawler Excavator 29m boom and standard boom 90t Caterpillar 390 OLR | 1 | 390 | 0.44 | 44.81 | 12.50 | 850 | 38,091 | 0 | 0 | - | **38,090.62** |
| 54 | Roller Compactor Bomag/ CAT 120/ CB7 | 1 | 75 | 0.34 | 6.54 | 6.95 | 473 | 3,090 | 4 | 272 | 1,778 | **4,867.92** |
| 55 | Articulated Dump Truck 28t CAT 730 | 1 | 237 | 0.40 | 24.42 | 23.00 | 1,564 | 38,185 | 20.5 | 1394 | 34,035 | **72,219.82** |
| 56 | Articulated Dump Truck 28t CAT 730 | 1 | 237 | 0.40 | 24.42 | 21.00 | 1,428 | 34,865 | 10.25 | 697 | 17,017 | **51,882.05** |
| 57 | Articulated Dump Truck 28t CAT 730 | 1 | 237 | 0.40 | 24.42 | 11.25 | 765 | 18,678 | 2.5 | 170 | 4,151 | **22,828** |
| 58 | Articulated Dump Truck 28t CAT 730 | 1 | 237 | 0.40 | 24.42 | 3.00 | 204 | 4,981 | 0 | 0 | - | **4,981** |
| 59 | Water Pump 75mm | 1 | 5 | 0.29 | 0.38 | 22.00 | 1,496 | 563 | 17.6 | 1197 | 450 | **1,014** |
| 60 | Water Pump 75mm | 1 | 5 | 0.29 | 0.38 | 2.20 | 150 | 56 | 1.7 | 116 | 44 | **100** |
| 63 | Compressor 175cfm | 1 | 19 | 0.18 | 0.90 | 3.00 | 204 | 184 | 10 | 680 | 614 | **799** |
| 64 | Compressor 25m3 Atlas Copco | 1 | 242 | 0.18 | 11.51 | 9.50 | 646 | 7,433 | 0 | 0 | - | **7,433** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | Hydraulic Powerpack 10kW | 2 | 10 | 0.24 | 0.63 | 16.00 | 1,088 | 690 | 4 | 272 | 172 | **862** |
| 76 | Generator 75kVA | 1 | 55 | 0.96 | 13.73 | 23.00 | 3,864 | 53,049 | 25 | 4200 | 57,662 | **110,710.88** |
| 77 | Generator 75kVA | 1 | 55 | 0.96 | 13.73 | 0.00 | - | - | 0 | 0 | - | **-** |
| 78 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 79 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 80 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 81 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 82 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 83 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 84 | Diesel Lighting Units, LED & 110V Plugin, 4kW | 1 | 4 | 0.29 | 0.30 | 0.90 | 61 | 18 | 0.6 | 41 | 12 | **30.71** |
| 85 | Diesel Welder 580A | 1 | 31 | 0.29 | 2.33 | 20.00 | 1,360 | 3,174 | 5 | 340 | 793 | **3,967.35** |
| 86 | Diesel Welder 580A | 1 | 31 | 0.29 | 2.33 | 13.00 | 884 | 2,063 | 5 | 340 | 793 | **2,856.49** |
| 87 | Diesel Welder 300A | 1 | 31 | 0.29 | 2.33 | 5.50 | 374 | 873 | 6.25 | 425 | 992 | **1,864.66** |
| 89 | IHC Powerpack 500 | 1 | 395 | 0.24 | 25.04 | 4.50 | 306 | 7,663 | 2.75 | 187 | 4,683 | **12,345** |
| 90 | Drill Rig Cassegrande C6xp | 1 | 95 | 0.46 | 11.29 | 3.00 | 204 | 2,304 | 10 | 680 | 7,679 | **9,982** |
| 91 | Drill Rig Atlas Copco ROC D7 | 1 | 168 | 0.46 | 19.97 | 9.50 | 646 | 12,900 | 0 | 0 | - | **12,900** |
| 116 | Airshelter Heaters 5.5kW | 1 | 6 | 0.29 | 0.45 | 23.00 | 3,864 | 1,745 | 25 | 4200 | 1,897 | **3,642** |
| 117 | Airshelter Heaters 5.5kW | 1 | 6 | 0.29 | 0.45 | 23.00 | 3,864 | 1,745 | 25 | 4200 | 1,897 | **3,642** |
| 118 | Airshelter Heaters 5.5kW | 1 | 6 | 0.29 | 0.45 | 23.00 | 3,864 | 1,745 | 25 | 4200 | 1,897 | **3,642** |
| **53** | | | | | | | | **622,200** | | | **358,773** | **980,972** |

**Notes:**

- Average Fuel Factor based on 3120 hr/yr, correction factor: 1.14 [-]
- Based on work weeks of: 68 [hr]
- Max. fuel consumption mech. motor: 0.26 [l/kWh] = Fuel factor '1.0'
- Increase of Plant and Equipment, including bigger sizes;
- Increase of actual working hours: 12 %
- Hardship Fuel Factor: 1.34 [-]

**Summary:**

| | | |
|---|---|---|
| Season 1 | 622,200 | [ltr] |
| Season 2 | 358,773 | [ltr] |
| **Total:** | 982,273 | [ltr] |

*Figure 1-1 Rothera wharf anticpated fuel Consumption*

Coastal Stabilisation

| Item No. | Equipment | Quantity | Power [kW] | Correction Fuel Factor [-] | Aver. Fuel Consumption [ltr/hr] | Operational Weeks Season 2 [wk] | Daily Running Hours Season 2 [hr/day] | Working Days Season 2 [day/wk] | Fuel Consumption Season 2 [ltr] | Total Consumption Estimate [ltr] |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mobile AC Crane 150t | 1 | 224 | 0.18 | 10.48 | 4 | 8 | 6 | 2,013 | **2,013** |
| 2 | Telescopic Roto Telehandler 21m 4t | 1 | 76 | 0.21 | 4.15 | 4 | 8 | 6 | 797 | **797** |
| 3 | Fuel Bowser With Pump 5000L | 1 | 10 | 0.20 | 0.52 | 4 | 1 | 6 | 12 | **12** |
| 4 | Water Bowser 5000L | 1 | 5 | 0.19 | 0.25 | 4 | 8 | 6 | 47 | **47** |
| 5 | Agricultural Tractor 4x4 100hp | 1 | 73 | 0.19 | 3.61 | 4 | 5 | 6 | 433 | **433** |
| 6 | Gator 4x6 | 1 | 75 | 0.10 | 1.95 | 4 | 3 | 6 | 140 | **140** |
| 7 | RIB Rescue Boat Spec. TBC | 1 | 15 | 0.13 | 0.51 | 4 | 8 | 6 | 97 | **97** |
| 8 | Dory Workboat/ Divers Boat 20ft. | 1 | 30 | 0.13 | 1.01 | 4 | 8 | 6 | 195 | **195** |
| 9 | ROV for visual inspections | 1 | 15 | 0.20 | 0.78 | 4 | 5 | 6 | 94 | **94** |
| 10 | Wheel Loader c.w. forks 3500L CAT 966 | 1 | 175 | 0.29 | 13.20 | 4 | 5 | 6 | 1,583 | **1,583** |
| 11 | Crawler Excavator 49t Doosan DX490 | 1 | 250 | 0.29 | 18.85 | 4 | 8 | 6 | 3,619 | **3,619** |
| 12 | Crawler Excavator 29m boom and standard boom 90t Caterpillar 390 OLR | 1 | 382 | 0.29 | 28.80 | 4 | 8 | 6 | 5,530 | **5,530** |
| 13 | Articulated Dump Truck 28t CAT 730 | 1 | 228 | 0.26 | 15.41 | 4 | 8 | 6 | 2,959 | **2,959** |
| 14 | Water Pump 75mm | 1 | 5 | 0.19 | 0.25 | 4 | 8 | 6 | 47 | **47** |
| 15 | Compressor 175cfm | 1 | 19 | 0.12 | 0.59 | 4 | 8 | 6 | 114 | **114** |
| 16 | Grab for CAT390 Spec. TBC | 1 | 0 | 0.00 | 0.00 | 4 | 0 | 0 | - | **-** |
| 17 | Hydraulic Hammer CAT390 | 1 | 0 | 0.00 | 0.00 | 4 | 0 | 6 | - | **-** |
| 18 | Diesel Lighting Units/ Light Towers 4kW | 1 | 4 | 0.19 | 0.20 | 4 | 8 | 6 | 38 | **38** |
| 19 | Diesel Lighting Units/ Light Towers 4kW | 1 | 4 | 0.19 | 0.20 | 4 | 8 | 6 | 38 | **38** |
| 20 | Diesel Welder 580A | 1 | 31 | 0.19 | 1.53 | 4 | 8 | 6 | 294 | **294** |
| | | | | | | | | | 18,051 | 18,051 |

*Figure 1-2 Coastal stabilisation anticipated fuel consumption*

**Notes:**

- Based on work weeks of: 60 [hr]
- Max. fuel consumption mech. motor: 0.26 [l/kWh] = Fuel factor '1.0'
- No safety or inaccuracy factor included;
- Based on Planning; BAA4001-BAM-ZZ-PR-W-00XX Rothera Wharf Coastal Stabilisation Construction Programme 28 11 17 for CEE

**Summary:**

| | | |
|---|---|---|
| Season 2 | 18,051 | [ltr] |
| **Total:** | **18,051** | **[ltr]** |

### 1.1.7. Fuel Management Plan

*Refuelling Procedure*

Refuelling of plant and equipment will be carried out using a towable 5,000 litre bunded steel diesel bowser pulled by a tractor or similar item of plant. The procedure for carrying out this operation is detailed below. Only trained personnel will undertake this procedure.

*Filling the Towable Bowser.*

*Before Filling the Bowser*

- Ensure that spill kits are available and within easy reach of the refuelling location.
- Ensure that a suitable fire extinguisher ($CO_2$, dry powder or foam) is available and within easy reach of the refuelling location
- Make sure the item to be refuelled is as close to the refuelling point as possible but allows access to the bowser hoses.
- Switch off all item of plant in the vicinity and remove the keys.
- Ensure no other sources of ignition are present.

*Filling the Bowser*

Bowser are to be refilled from the branch connector from the circulation loop on the generator shed (metered).

- Put on PVC gloves
- Undo the diesel cap from the item of plant
- Take an absorbent pad from the spill kit and use a drip tray to catch any drips from the fuel hose.
- Connect pipe work from generator shed bowser fill point to the bowser.
- Open the inlet tap on the bowser and **open the man hole cover lid**- this is to aid venting- failure to do so will over pressurise the tank.
- Close valve M9A
- Open the valve M17A on the metered branch connector
- The bowser will have no latch on the supply hose so that the lever must be manually depressed in order to deliver fuel.
- Both the bowser and day tanks have vents to atmosphere. **Do not overfill**. This will also help prevent spillage when on uneven ground
- When using the Bowser ensure the man hole cover lid is open to aid venting, failure to do so will implode the tank

**Filling of fuel tanks must be attended at all times, under no circumstances must tanks be left to 'fill themselves'.**

*After Filling the Bowser*

- When the bowser is full close the valves in the reverse sequence
- Place the diesel delivery hose back into the generator shed, ensuring any drips are collected by the absorbent pad and drip tray.
- Place fuel cap back on the bowser.
- Place any diesel contaminated PPE or spill kit material in the oil contaminated waste drum.

### Refuelling Plant from the Towable Bowser.

#### Before Refuelling

- Ensure that spill kits are available and within easy reach of the refuelling location.
- Ensure that a suitable fire extinguisher ($CO_2$, dry powder or foam) is available and within easy reach of the refuelling location
- Make sure the bowser is as close to the item to be refuelled as possible but allows access to the bowser hoses.
- Switch off item of plant to be refuelled and remove the keys.
- Ensure no other sources of ignition are present.

#### Refuelling

- Put on PVC gloves
- Unlock the bowser
- Undo the diesel cap from the item of plant
- Take an absorbent pad from the spill kit and use a drip tray to catch any drips from the fuel hose.
- Place the fuel hose into the diesel refilling point on the item of plant.
- Start the diesel delivery pump.
- The bowser will have no latch on the supply hose so that the lever must be manually depressed in order to deliver fuel.
- **Never leave refuelling unattended**
- Do not fill the diesel tank to the brim; allow a little room to prevent spillage on uneven ground

#### After Refuelling

- Place the diesel delivery hose back into the compartment within the tank, ensuring any drips are collected by the absorbent pad or plant nappy.
- Relock the tank
- Place fuel cap back on the item of plant refuelled.
- Place any diesel contaminated PPE or spill kit material in the oil contaminated waste drum

### 1.1.8. Emergency Spill Contingency Plan

The plan below describes the procedures that will be used by personnel involved in construction activities in the event of a spill when working at Rothera. All spills are to be reported to the Rothera Station Leader and to the BAS Environment Office.

- For Tier 1 spills it will be the joint responsibility of the Site Environmental Engineer and General Foreman to manage the spill response. The Project Manager will still retain the overall responsibility for incident management.
- In the event of a spill greater than Tier 1 which is generally >205 litres the BAS Station Leader will co-ordinate the spill response.

**Fuel and chemical spills within BAS are classified as follows**

| | |
|---|---|
| **Tier 1** | Small spills which can be dealt with immediately by one or two people. Generally <205l on land. |
| **Tier 2** | Medium spills that require the Rothera Station Leader to co-ordinate the response. Will need as a minimum a dedicated response team or potentially the full resources of the station and assistance from BAS Cambridge. |
| **Tier 3** | Large spills which exceed the resources of the station and BAS Cambridge and require outside assistance |

**In the event of a fuel, oil or chemical spill the following procedure should be followed**

| | |
|---|---|
| 1 | Stop work immediately |
| 2 | If spillage is flammable, extinguish all possible ignition sources. |
| 3 | Identify the source of the pollution and prevent further leakage.<br>• Plug leaking drums<br>• Right upturned containers<br>• Switch off machinery with leaking hydraulic hoses |
| 4 | Quickly assess the spill. Determine:<br>• The risk of fire or harm to human health<br>• Time and location of spill<br>• Type of spilt material and quantity<br>(All spills on water are considered to be tier 2 or above) |

| **For Tier 1 Spills** | **For Tier 2 or 3 Spills** |
|---|---|
| Put on suitable PPE, including waterproof gloves | Immediately inform the Station Leader who will take responsibility for co-ordinating the spill response. |
| Prevent further spread of spill using absorbent socks. | Put on suitable PPE, including waterproof gloves |
| Attention to be taken to prevent oil from entering the sea, watercourses or drainage systems. | Follow the Station Leader's instructions. |
| Inform the Station Leader | |
| Recover spilt material using absorbent pads or skimmers. | |
| Dispose of waste fuel, contaminated spill kit materials and PPE in 205ltr drums. The Station Leader will identify the correct drums for disposal. | |

| For All Spills |
| --- |
| All personnel who may have come into contact with the spill are to receive a medical check up |
| All construction personnel are to assist the Station Leader in preparing a detailed spill report to be submitted to the BAS Accident, Incident, Near Miss & Environmental (AINME) database. |

### *Emergency Spill Response Equipment*

The following emergency spill response kits will be available on station in the event of a spill.
2 x Static Bins stored adjacent the 2,250 litre fuel tank as shown in Figure 3-15 Site Layout.

The spill kit will be contained in a 120 litre, yellow polyethylene static chest suitable for spills up to 205 litres containing:

- 60 No. 50cm x 40cm 'Superior' oil-only pad
- 4 No. 7.5cm x 1.2m 'Superior' Sock Oil
- 8 No. 38cm x 23cm oil absorbent pillow
- 10 No. 30cm black cable tie
- 10 No. 46cm x 90cm 200 gauge blue plastic disposal bag
- 1 No. Spill Kit instruction sheet
- 5 Pairs Goggles
- 5 Pairs PVC Gloves

12 heavy duty marine absorbent booms 13 cm x 3 m will be stored in the wharf construction area (see Figure 3-15) for deployment at the wharf or adjacent area.

All items of plant over 20 tonnes will carry a spill kit containing:

- 25 No. 50cm x 40cm 'Superior' oil-only pad
- 4 No. 7.5cm x 1.2m 'Superior' Sock Oil
- 5 No. 30cm black cable tie
- 5 No. 46cm x 90cm 200 gauge blue plastic disposal bag
- 1 No. Spill Kit instruction sheet
- 2 Pairs Goggles
- 2 Pairs PVC Gloves

The spill kit will be contained in a vinyl holdall.

All other mechanical plant will carry a spill kit containing:

- 18 No. 50cm x 40cm 'Superior' oil-only pad
- 24 No. 7.5cm x 1.2m Superior Sock Oil
- 3 No. 30cm black cable tie
- 3 No. 46cm x 90cm 200 gauge blue plastic disposal bag
- 1 No. Spill Kit instruction sheet
- 1 Pair Goggles
- 1 Pair PVC Gloves

The spill kit will be contained in a vinyl holdall.

Spare oil spill materials will be kept in the stores to replenish the kits if used.
These will consist of:

- 500 No. 50cm x 40cm 'Superior' oil-only pad
- 50 No. 7.5cm x 1.2m Superior Sock Oil
- 100 No. 38cm x 23cm oil Absorbent pillow
- 100 No. 30cm black cable tie
- 100 No. 46cm x 90cm 200 gauge blue plastic disposal bag

All operatives will be briefed on this Emergency Spill Contingency Plan by the Works Supervisor prior to works commencing. All spills are to be reported to the station leader and the BAS Environment Office at the time of occurrence

All plant will be inspected daily paying particular attention to possible leaks and condition of hydraulic oil hoses. These checks will be recorded on the 'Daily Plant Check Sheets' and in the 'Daily Activity Plan Compliance Record'. All refuelling will be carried out in line with the Rothera refuelling procedures as outlined above.

## 1.2. Waste Management

The contractor will be responsible for managing all construction waste on site at Rothera. Hazardous waste which will mostly be waste oil will be stored in oil drums inside a bunded shipping container in Construction Laydown Area 1 (Shown on Figure 3-15). Metal waste will be stored in skips. All other inert waste will be stored in shipping containers. All waste will be segregated and stored in weather proof containers and will be checked daily to ensure it is secure from wildlife and weather.

All construction waste will be removed from the Antarctic Treaty area and returned to the UK for appropriate disposal in accordance with the Protocol on Environmental Protection to the Antarctic Treaty. The waste hierarchy will be applied. See Appendix D Site Waste Management Plan.

Before unused materials are defined as waste they will be offered to the Station Leader and the Facilities Manager for re-use at Rothera.

The contractor's chartered demobilisation vessel will remove construction waste from Rothera. Consignments will be packed and labelled in accordance with international shipping regulations. Waste will be disposed of in the UK by licenced waste contractors meeting the requirements of the Waste (England and Wales) (Amendment) Regulations, 2014, the Duty of Care Regulations, 1991, and the Hazardous Waste Regulations, 2005.

Some waste may be consigned to BAS vessels for return to the UK. In such circumstances all waste will be packaged and consigned in accordance with BAS's standard waste management procedures set out in the BAS Waste Management Handbook.

A list of the predicted waste types, quantities and disposal options is provided in the draft Site Waste Management Plan (SWMP): Rothera, included in Appendix D. The final document will be produced once the final design of the Rothera Wharf has been completed, anticipated to be September 2018.

The Environmental Engineer will be responsible for onsite management of construction waste and ensuring appropriate final disposal. A target for an 80% diversion rate from landfill for construction waste generated on this project has been set.

All domestic waste generated during the construction period will be dealt with by BAS as per the Rothera waste management procedures. All staff will comply with the waste segregation requirements as directed by the Rothera Station Leader.

## 1.3. Biosecurity

The Rothera Wharf reconstruction and coastal stabilisation works will involve an increased input of personnel cargo, equipment and plant to Rothera. This intensification of activity has the potential to increase the risk of non-native species introductions into the local environment.

It is essential that all necessary precautions are taken to prevent the introduction of non-native species to Rothera from other locations. A specific Biosecurity Plan (see Appendix F) for the construction works at Rothera has been prepared, detailing the guidance and measures that will be taken along the material supply chain as well as for personnel working at Rothera. It has been developed with reference to the BAS Biosecurity Handbook (2016) and the CEP Non Native Species Manual (2016). All personnel will be briefed on the biosecurity plan and will need to read, and understand this prior to deployment.

The measures include actions that require pre-departure checks on personal items and cargo, checks during transit of cargo to Antarctica and pre and post disembarkation of cargo and personnel on arrival at Rothera. See Appendix F Biosecurity Plan for the full breakdown of the measures committed to. Evidence of the measures undertaken will be provided in the form of completed checklists. BAM will provide signed evidence that these checks have been completed appropriately. BAS will also audit the procedures during the project. Any biosecurity incursions will be reported immediately to the BAS Environment Office.

# 2. Description of Support Activities

## 2.1. Shipping & Air Freight - Cargo

The bulk of the required construction materials and equipment will be transported to Rothera by sea.

Although the works will be undertaken over two seasons, the majority of materials and equipment will be transported in one main shipment at the start of the project.

As a general strategy, as much cargo and equipment as possible will be transferred by utilising excess cargo tonnage on existing BAS ships. These are routine visits to Rothera which are generally scheduled at the start and end of the summer working season. In addition to this, spare capacity on scheduled visits by HMS Protector will also be utilised, where possible. Once SDA is commissioned, spare cargo space on this ship will also be utilised where possible.

Current estimates for the Rothera Wharf and the coastal stabilisation projects place the anticipated required cargo volume to be shipped south at approximately 4,200t. As a result, the volume available on existing transfers will not be sufficient and it will be necessary to charter a commercial vessel to undertake the main delivery at the start of the works.

To minimise both the environmental impact and costs associated with the charter of a commercial delivery vessel the delivery of materials and equipment will be planned in accordance with the master plan covering all activities included in this CEE. A maximum of one delivery per season is anticipated and, in addition, optimal use will also be made of the return voyages for the removal of construction waste and redundant equipment.

Each considered charter vessel will be reviewed and adherence to the International Maritime Organisation (IMO) International Code for Ships Operating in Polar Waters (Polar Code) will be confirmed. This will ensure that charters in addition to polar safety also adhere to guidelines set out with a focus to protecting the environment.

## 2.2. Shipping & Air Freight - Personnel

Personnel will be transported to Rothera either by sea or by air. Personnel will fly from the UK to South Atlantic gateways using established scheduled flights. The majority of personnel will then fly to Rothera on the BAS Dash 7 aircraft. In some instances, personnel may be transported by BAS vessel to or from Rothera. Specific personnel numbers are included in the relevant project descriptions earlier in this document.

All cargo and personnel will adhere to the BAS biosecurity procedures and the requirements set out in Appendix E, Rothera Wharf Biosecurity Plan.

## 2.3. Accommodation

All personnel will be housed in either the existing permanent accommodation at Rothera or within the temporary accommodation units proposed to be installed in the 2017-2018 season (as described in the Addendum Rothera Site Investigation Season 2 2017-2018: IEE, (2017). The temporary purpose built accommodation unit will sleep a maximum of 32 people and is intended to be relocated from the

UK's Halley research station. This will provide additional bed space whilst the construction teams are on site. The structure consists of 16 converted 20 ft shipping containers with a footprint of 19.5 m x 14.5 m. Eight of the containers will be used for sleeping accommodation sleeping four people each. The remaining eight containers will compromise a foyer, boot room, boiler room, showers, toilets and laundry. Two of the containers will be used for offices and storage. Waste water and human waste will be discharged via the main sewage treatment plant. The containers will require a maximum 5 Kw of power for lighting and electricity. In addition a small MGO fuelled water boiler will provide hot water to the shower and laundry facilities. It is anticipated that this will require 800 litres of fuel on a monthly basis. The fuel will be stored in an external self bunded tank.

## 2.4. Energy Use

Power generation for all construction activities will be provided independently to normal BAS operations. Domestic power for lighting, heating, and other domestic requirements will be provided through the existing systems. Currently the main power to the station is provided by two online diesel generators with a third on standby and a fourth being serviced. There are also some auxiliary units. Currently the station operates on the cusp of needing the third generator. Additional electrical load from construction works is likely to result in the third generator being used on a more regular basis rather than just for back up. Two portable generators are available on site for emergency power or additional power demand.

## 2.5. Water

BAS will provide all domestic and construction water required for the project. Where possible, sea water will be used for construction activities, e.g. dust suppression, casting concrete. The construction team will ensure that works in and around the wharf in no way compromise the seawater intake to the station, as this is the single supply for conversion into potable water.

## 2.6. Temporary Jetty and Boat House

During the construction of the wharf it will not be possible to use the existing slipway for launching small boats or to use any part of the remaining wharf for station relief. It is proposed that a temporary jetty is constructed in South Cove (see Figure 7-1) to enable small boats to be launched for the following purposes:

- provision of small boating for diving support;
- provision of small boating for science;
- provision of search and rescue (SAR) cover for aircraft operations; and
- station relief (resupply from BAS ships via the ship's tender vessel)

It is anticipated that the jetty will be used from December 2018 through to May 2019 and October 2019 through to March 2020. During the austral winter period, boating and diving operations will operate from the partially constructed wharf.

In close vicinity to the temporary jetty a number of shipping containers will be located for storage purposes. These will include:

- the transport aquarium;
- 2x ice core refrigerated units; and
- 7x refrigerated food storage containers

In order to provide power to these units a 150Kva generator will be installed which will also supply power to the aircraft hangar. It is proposed that the infrastructure on the western side of the runway will be removed from the main station grid in order to ensure sufficient power is available for the increased demand associated with the additional personnel and activities on station. The generator has an inbuilt fuel storage tank of 0.8$m^3$ with an additional storage tank of 3$m^3$, both of which are self-bunded

A temporary storage unit comprising of a 20ft shipping container and two weather haven tent will be located adjacent to the jetty to support small boat operations. The container will be used as an office and changing facility. The weather haven tents will be used for boat storage. The temporary units will not require any mains services and any power requirements will be supplied by the aforementioned generator. Small quantities of lubes and oils will be stored in the container in COSHH approved bunded storage units. Refuelling of boats and generators will be undertaken as per the BAS standard operating procedure currently employed at Rothera using the mobile fuel bowser.

The temporary jetty will consist of 6 open topped shipping containers which will be submerged into the water on the shoreline. The containers will be positioned in a ‘U’ shaped formation to provide a temporary jetty platform approximately 132$m^{2.}$ The intention is that a mobile crane unit will be deployed on the platform in order to load and offload cargo from the BAS tender vessels.

Each of the 6 containers will be filled with rock obtained from the quarry and / or the existing fill removed from the wharf during dismantling. To ensure the containers can support the weight of the outriggers from the mobile crane they will be fitted with rigid steel members. See figure 7-2 Reinforced Container.

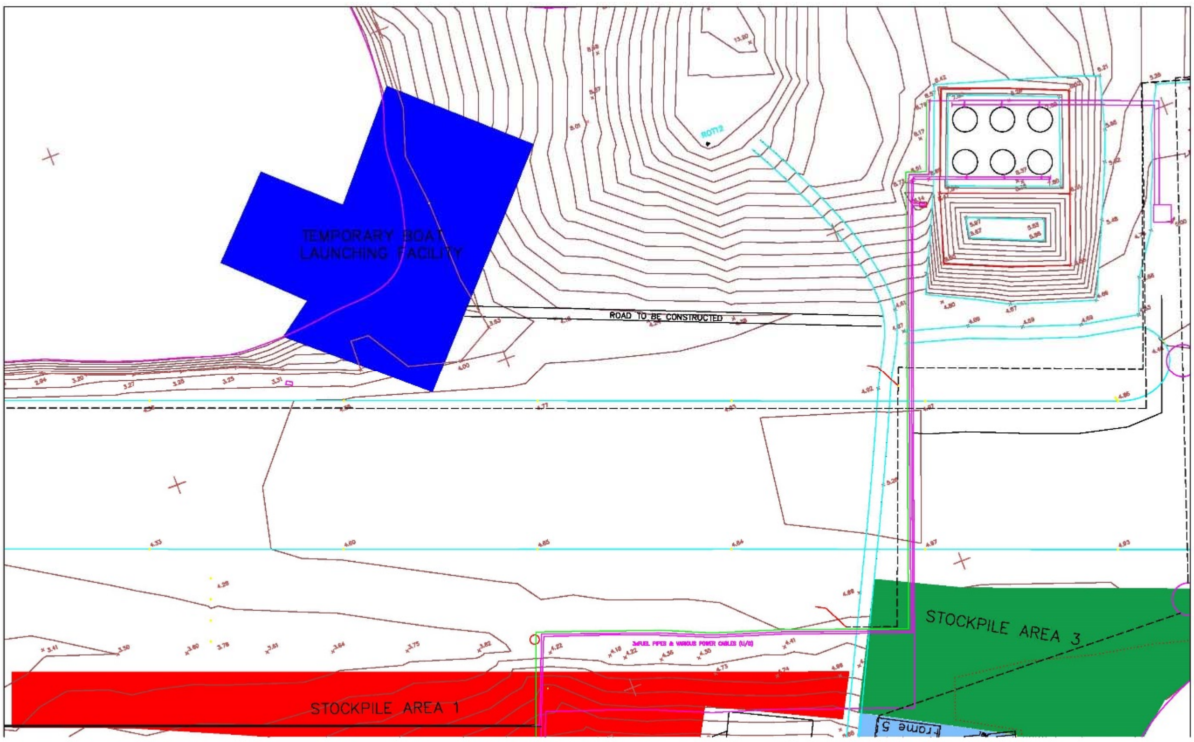


*Figure 2-1* Proposed Location of Temporary Jetty

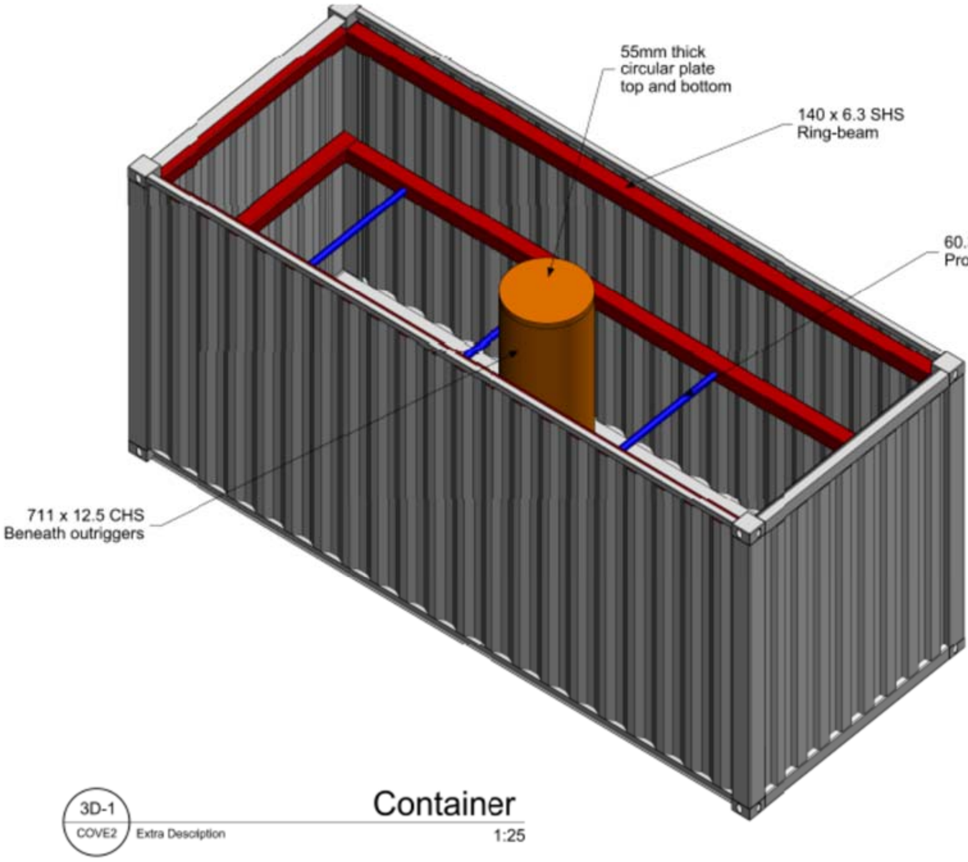


*Figure 2-2 Reinforced container*

Rock fill will also be deployed in-between each of the containers as shown in figure 7-3. A rock revetment will be constructed to link the access road to the edge of the temporary jetty. It is anticipated that at the seaward edge of the containers some rock will be placed on the sea floor to act as scour protection from ice. In total approximately 900t of rock will be required to construct the temporary jetty. Once the rock fill is in place timber crane mats will be positioned on the top surface of the jetty.

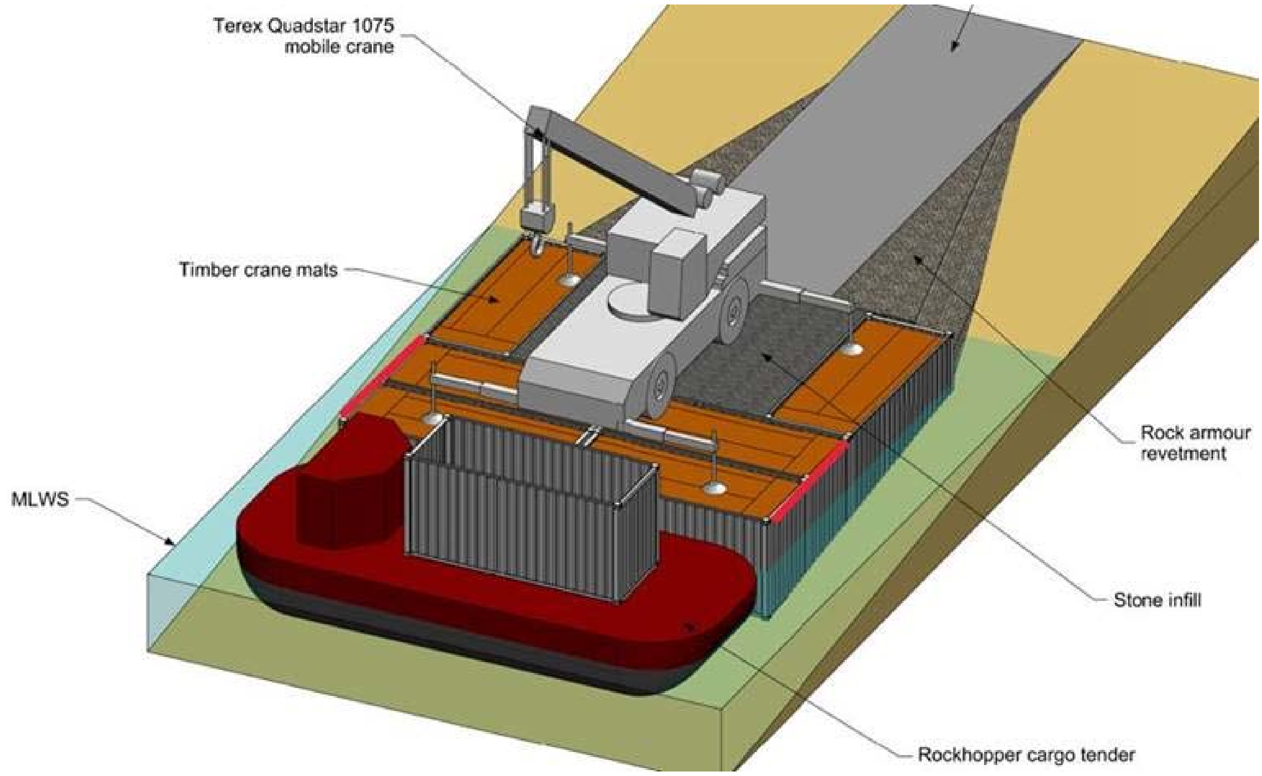


*Figure 2-3 South Cove Temporary Jetty*

The temporary facility will be in position from December 2018 to May 2020 during the construction of the new wharf. The containers will all be unpainted to avoid any pollution entering into the marine environment.

The installation and formation of the temporary jetty and the associated access road will take approximately 2 weeks.

A temporary access track will be established to allow vehicles and trailers to reach the jetty. It is not anticipated that any rock removal will be required to create this access route. Some minor grading of the surface may be required to provide a durable, flat surface during resupply of the station.

Figure 7-3 shows the proposed location for the jetty on the west side of the runway at South Cove, the access road and the temporary shelter.

During station relief, the ships tender will deliver cargo and shipping containers to the jetty where vehicles (tractor and trailer) will be loaded and cargo transported to the main station buildings. Instead of the normal traffic route undertaken during relief from the wharf to the main station, vehicles will run parallel to the runway on the western side and have to cross over it at the existing crossing point, to access the main station area.

It is anticipated that the construction cranes will be used to unload and load shipping containers at the slipway. It is anticipated that at the first ship call each season, which brings in the most supplies, approximately 40-80 vehicle movements from the jetty to the station will be required.

For SAR purposes a boat will remain at the jetty during the period of 'point of no return' (PNR) once the Dash 7 aircraft is on route from any South Atlantic gateway.

During the demobilisation of the main wharf construction project, the temporary jetty will be removed. This will be undertaken by excavating the rock from within the containers and removing the strengthening steel work. Once empty the containers will be lifted out of the water using the 80t mobile crane and transported to the new wharf for loading to a vessel and consigned north for disposal/recycling. The road and revetment will also be removed and the area "landscaped" to return it to its current condition.

# 3. Timescale, Duration & Intensity of Activities

## 3.1. Construction Programme

The Rothera Wharf construction works are planned to take place during the austral summers of the 2018-2019 season and 2019 -2020 season. Some site investigation works will be undertaken in 2017-2018 season; however, these are captured under a separate EIA submission and are not included in the scope of this document. The coastal stabilisation works will take place during the 2019-2020 season. See Figure 8-1 Rothera Wharf & Coastal Stabilisation Construction Programme.

### 3.1.1. 2018 -2019 Season

The works in the first construction season consist of four main activities.
These include:

- Establishment of temporary facilities workshops, and laydown areas;
- Dismantling of the existing wharf structure,
- Extracting rock material; and
- Construction of the rear portion of the new wharf.

The season starts with mobilisation of personnel to Rothera by BAS aircraft and/or vessel on first call optimising spare capacity on BAS transfers. Construction equipment and materials will be transported by commercial charter vessel. This transfer is planned to arrive in Rothera in mid-December following a southbound transit from the UK.

Following the arrival of the vessel on site there will be a 2 week site establishment period during which the vessel is offloaded, laydown areas are set out and established, and temporary facilities including workshops, and a small site office are installed. Safe working measures are also established during this period, such as designated access routes and demarcation of the working areas.

Following site establishment, the dismantling of the existing wharf structure will commence. This is programmed to take a total duration of 10 weeks, commencing with the removal of existing fill material followed by progressive removal of the main steel structural elements.

Concurrently with the dismantling of the existing structure, quarrying works will commence. Eighteen weeks have been allocated for in the programme to produce the required volume based on established production rates.

Once dismantling of the old Biscoe Wharf has been completed the construction of the new wharf can commence. The aim is to complete the rear section of the structure between the mid and rear anchor wall within the first construction season. A period of 8 weeks has been allowed in the programme for this work. Included in this time period is installation of the rear anchor wall, the rear support frame structure and the permanent mid wall support piles. A temporary sheet pile wall will be constructed using materials from the dismantled wharf to form an ice shield. The ice shield will protect the works during the winter between the two construction seasons.

At the end of the construction activities in 2018-2019 season a two-week demobilisation period is planned in order to prepare the working area for winter and to winterise the various pieces of plant and equipment. In addition to this, an agreed time risk allowance period has been included in order to accommodate any unforeseen situations or delays.

#### 3.1.2. 2019 – 2020 Season

The works in the 2019 -2020 season consist of the remainder of the construction activities required to install the front section of the wharf. The activities on site are expected to commence at the beginning of November 2019. This is 6 weeks earlier than the previous season and is due to the necessary equipment being on site already, and all the personnel will be mobilised by BAS Dash 7 aircraft, which is possible from late October.

Prior to commencing construction activities, a 2 week period for site mobilisation will again be allowed in order to de-winterise plant and equipment, undertake snow clearance and ensure the site is safe to commence works. At the same time the temporary protection measures such as the ice shield will be removed from the works.

Once the wharf structure is established the contained volume is filled with backfill material quarried in the previous season. The top surface will then be smoothed forming the finished top layer.

Following completion of the wharf structure, various finishing works will be completed including the installation of ladders, bollards, small boat access and provisions for the placement of a Davit crane. This will complete the construction works. A total of 15 weeks has been allocated to complete the wharf.

Finally, an additional 2 weeks has been included in the programme for demobilisation that will include making good the working areas, packing all equipment and plant for removal by sea or winterisation if utilised by BAS for operational support or other works in following seasons. In addition to this, an agreed time risk allowance period has been included as contingency in order to accommodate any unforeseen situations or delays.

The coastal stabilisation works will commence in at the end of January 2020 and are anticipated to take up to 33 days. The works are intended to be complete by the start of April 2020 by which time a 36 day demobilisation will have commenced.

All works for both the Rothera Wharf and coastal stabilisation are programmed to be complete by early May 2020.

Rothera Wharf & Coastal Stabilisation - Construction Programme for CEE

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **BAA4001-BAM-ZZ-YYY-PR-W-00xx - Construction Programme - Rothera Wharf and Coastal Stabilisation** | **712 days** | **Fri 04/08/17** | **Fri 08/05/20** |
| 78 | **WS5 - Construction - Summary Only** | **426 days** | **Mon 24/09/18** | **Fri 08/05/20** |
| 79 | **Season 2 - 2018/19** | **170 days** | **Mon 24/09/18** | **Fri 17/05/19** |
| 80 | Receive deliveries / Biosecurity / Port Logistics | 9.5 wks | Mon 24/09/18 | Sat 17/11/18 |
| 81 | Ship leaves UK | 0 days | Sun 18/11/18 | Sun 18/11/18 |
| 82 | Mobilisation - UK-Antartica | 26 days | Sun 18/11/18 | Fri 14/12/18 |
| 83 | RRS Ernest Shackleton arrives at Rothera | 0 days | Mon 10/12/18 | Mon 10/12/18 |
| 84 | BAM Charter Ship arrives at Rothera | 0 days | Fri 14/12/18 | Fri 14/12/18 |
| 85 | **Construction** | **157 days** | **Fri 16/11/18** | **Fri 17/05/19** |
| 86 | On-site mobilisation | 32 days | Fri 16/11/18 | Sat 22/12/18 |
| 87 | Quarrying | 118 days | Thu 13/12/18 | Mon 29/04/19 |
| 88 | Dismantle Existing Wharf | 70 days | Mon 24/12/18 | Thu 14/03/19 |
| 89 | Construct New Wharf (Rear Wall to Mid-wall) | 49 days | Fri 15/03/19 | Fri 10/05/19 |
| 90 | **Coastal Stabilisation** | **22 days** | **Thu 04/04/19** | **Mon 29/04/19** |
| 91 | Site investigation - Rock armour grading / availability | 18 days | Thu 04/04/19 | Mon 29/04/19 |
| 92 | Demobilisation | 10 days | Tue 07/05/19 | Fri 17/05/19 |
| 93 | **Winter Stand By** | **142 days** | **Fri 17/05/19** | **Tue 29/10/19** |
| 94 | Downtime duration | 166 days | Fri 17/05/19 | Tue 29/10/19 |
| 95 | **Season 3 2019/2020** | **173 days** | **Sun 20/10/19** | **Fri 08/05/20** |
| 96 | Mobilisation - UK-Antartica | 10 days | Sun 20/10/19 | Tue 29/10/19 |
| 97 | **Construction** | **165 days** | **Wed 30/10/19** | **Fri 08/05/20** |
| 98 | On-site mobilisation | 38 days | Wed 30/10/19 | Thu 12/12/19 |
| 99 | Construct New Wharf (Mid-wall to Front Wall) | 73 days | Thu 05/12/19 | Thu 27/02/20 |
| 100 | Install mooring bollards | 37 days | Fri 14/02/20 | Fri 27/03/20 |
| 101 | **Coastal Stabilisation** | **33 days** | **Fri 28/02/20** | **Mon 06/04/20** |
| 102 | Excavate existing armour to stockpile | 2 days | Fri 28/02/20 | Sat 29/02/20 |
| 103 | Construct temporary access bund | 3 days | Fri 28/02/20 | Mon 02/03/20 |
| 104 | Break out rock toe and step rock at cove | 7 days | Sat 29/02/20 | Sat 07/03/20 |
| 105 | Construct toe and grade lower half of revetment | 6 days | Wed 04/03/20 | Tue 10/03/20 |
| 106 | Place btm and top armour to lower half | 14 days | Wed 04/03/20 | Thu 19/03/20 |
| 107 | Grade and place armour to upper half | 15 days | Fri 20/03/20 | Mon 06/04/20 |
| 108 | Demobilisation | 36 days | Sat 28/03/20 | Fri 08/05/20 |


Project: BAA4001-BAM-ZZ-YYY-PR
Date: Wed 18/07/18

| | | | | |
|---|---|---|---|---|
| Task | Project Summary | Inactive Milestone | Manual Summary Rollup | Deadline |
| Split | External Tasks | Inactive Summary | Manual Summary | Progress |
| Milestone | External Milestone | Manual Task | Start-only | |
| Summary | Inactive Task | Duration-only | Finish-only | |

Page 1

*Figure 3-1 Rothera Wharf Construction Programme*

# 4. DESCRIPTION OF SITE

## 4.1. Location

Built on a rock promontory at the southern tip of the Wormald Ice Piedmont, Rothera Research Station is situated on Adelaide Island to the west of the Antarctic Peninsula Lat. 67°35'8"S, Long. 68°7'59"W.

## 4.2. History of site

Rothera Research Station has been used operationally, on a continuous basis since 25 Oct 1975. The station was initially planned and constructed in phases, after which other infrastructure was added as operational requirements changed (see Figure 9-1 and 9-2 and Table 9.1). The eastern side of Rothera Point is largely free of buildings; however, several antennae have been erected (see Figure 9.3).

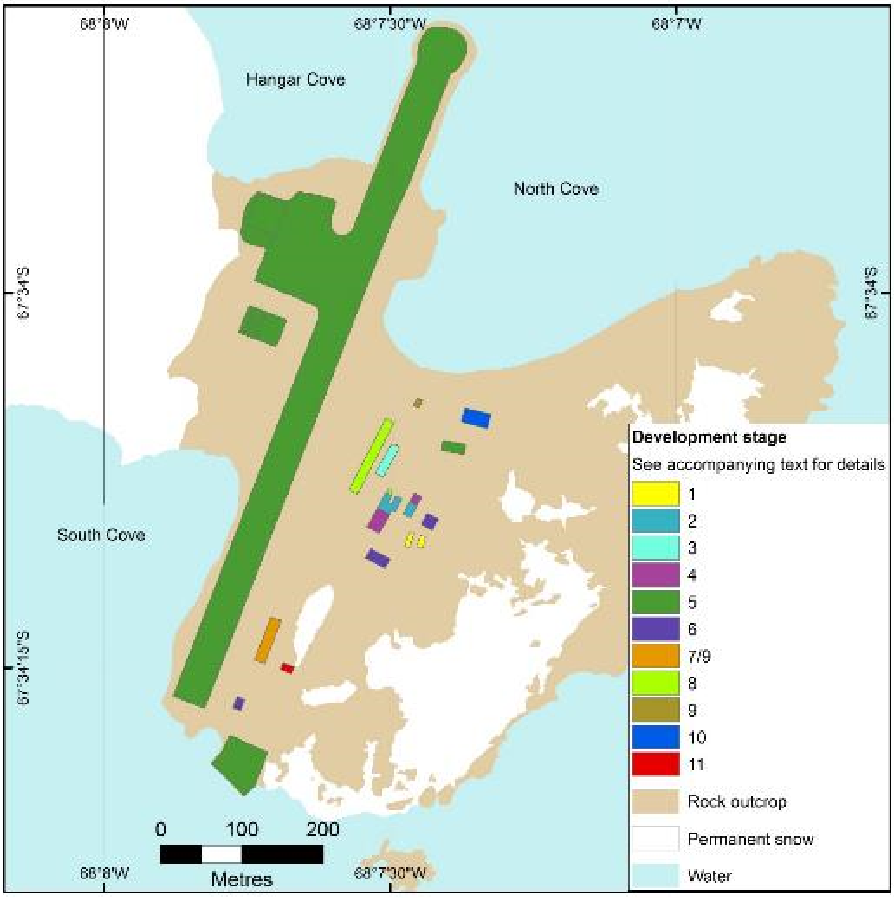


*Figure 4-1 Rothera Research Station buildings on Rothera Point, Adelaide Island.*

See Table 9-1 for an explanation of the colour coding.

Chronology of station facility construction on Rothera Point is outlined below and relates to the colour-coded map of station buildings in Figure 9-1.

*Table 4-1 Chronology of Construction on Rothera Point*

| Order | Phase or infrastructure | Notes |
|---|---|---|
| 1 | Phase I | A small accommodation hut was erected on 1 Feb 1976. |
| 2 | Phase II | Phase II was built in 1976/77, which included the main accommodation block, power house and tractor shed. An old storage shed from Adelaide (Station T) was erected close to Phase I and known as the Bingham building after Surgeon Commander EW Bingham, Leader of BAS 1945-47. |
| 3 | Phase III | Phase III was erected 1978/79 and included scientific offices and a travel store and cold room. In 2001 the travel store was named Fuchs House after Sir Vivian Fuchs, Director of BAS 1958-73. Further building work has been undertaken when required. |
| 4 | Phase IV | Phase IV, begun Nov 1985 and completed in the 1986/87 season was an extension to Phase II. In 2001 it was named Bransfield House (after BAS ship RRS *Bransfield*). |
| 5 | Runway and aircraft infrastructure | A wharf and gravel runway (with bulk fuel tanks and aircraft hangar) became operational in the 1991/92 season. Substantial rock blasting occurred, including the removal of 'Flagstaff Hill'. The wharf was named Biscoe Wharf after the BAS ship RRS *John Biscoe*. A new storage hut, called the Miracle Span, now used primarily for waste management activities, was also constructed in 1991/92. |
| 6 | Boat shed, accommodation and generator shed | Under the next phase of development, a boatshed was completed in 1994/95, a transit accommodation block in 1996/97 (named Giants House in 2001 after the Rothera sledge dog team "Giants"), and a new generator shed. |
| 7 | Bonner Laboratory | The Bonner Laboratory became operational in 1997, housing biological research facilities when Signy (Station H), was reduced to summer only operations. It was named after W N Bonner, biologist 1953-86 and Deputy Director of BAS 1986-88. |
| 8 | Accommodation and air operations control tower | A new accommodation building was erected during the 1999/00 and 2000/01 seasons. It was named Admirals House after the Rothera dog team **"**Admirals". Also in 1999/00 an air operations control tower was added to the north end of Bransfield House. |
| 9 | Replacement Bonner Lab and sewage treatment facility | The Bonner Laboratory was destroyed by fire on 29 Sep 2001 but rebuilt in the 2002/03 season, when a sewage treatment plant was also erected. |
| 10 | New Bransfield House | A new living block, including canteen, library and recreational facilities, was completed in 2007/08 and named New Bransfield House. The original Bransfield House then became known as 'Old Bransfield House'. |
| 11 | Dirck Gerritsz Laboratory | The Dirck Gerritsz Laboratory was opened on Sunday 27 Jan 2013 by Leo le Duc on behalf of the Ministry of Education, Culture and Science of the Netherlands. The laboratory is a collaboration between the British Antarctic Survey and the Netherlands Organisation for Scientific Research (NWO) and hosts four research projects. |

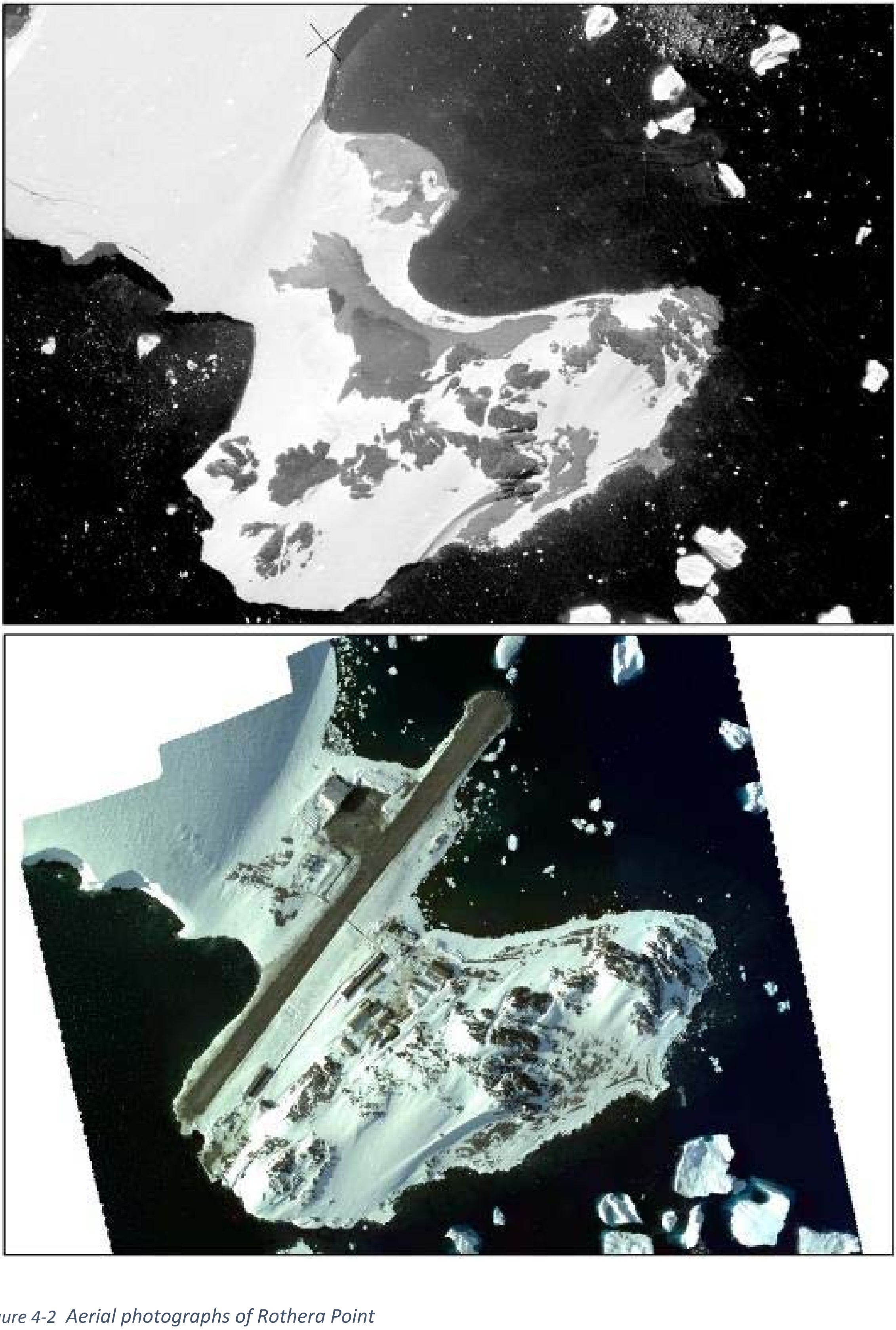

*Figure 4-2 Aerial photographs of Rothera Point*

The photos taken in 1957 (top) and 2013 (bottom) show the extent of human modification of the landscape in the intervening 57 years.

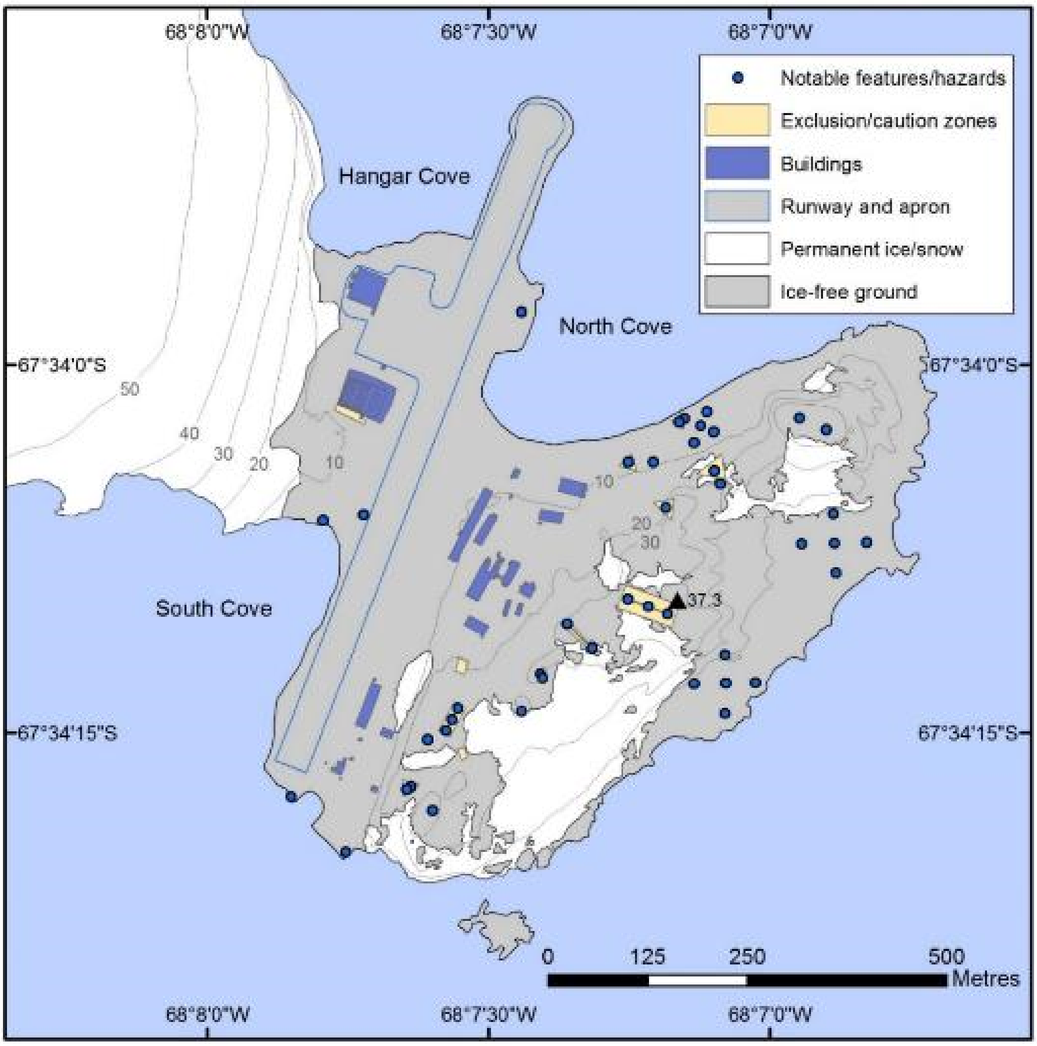


*Figure 4-3 Buildings and other minor infrastructure (aerials, masts, radars, cairns, etc.) located on Rothera Point 2016.*

## 4.3. Current Use of Site

### 4.3.1. Domestic

Rothera Station can support a maximum of 136 bed spaces during the austral summer which comprises both science and operational support personnel. During the 2016-2017 season the maximum number of people on station reached 110 people with average at 73 people. During the austral winter there are usually 20 people on station.

### 4.3.2. Science

Rothera supports a wide range of BAS, UK University and international collaborative science programmes including the Dirck Gerritsz laboratory that is staffed by scientists from the Netherlands polar research programme.

The scientific research conducted at Rothera spans a wide range of disciplines, including space weather, terrestrial biology, marine biology, oceanography, meteorology, atmospheric chemistry and ozone monitoring. The research at Rothera is led by three main BAS teams:

- Atmosphere, Ice and Climate (AIC)
- Space Weather and Atmosphere (SWA);and
- Biodiversity, Evolution and Adaptation (BEA)

*Atmosphere, Ice and Climate*

Meteorological data have been collected at Rothera since 1976, providing 41 years of continuous climatological data. These continuous data sets have provided the backbone of the important climate statistics from the Antarctic Peninsula, over the last four decades. Weather balloons are launched at over 400 locations around the world, at the same time each day. These data points are used in real-time by weather forecasters to get a global snapshot of the atmosphere. Climate scientists are also interested in the long-term records of temperatures at different heights in the atmosphere. At Rothera weather balloons are launched five times a week. There are only 18 launch sites in Antarctica so each site is crucial.

It is surprisingly hard to accurately measure precipitation quantities, particularly in windy and snowy conditions. At Rothera there is an array of precipitation sensors which, working side-by-side, gives us an idea of how much precipitation Rothera receives, and which sensors work best in which conditions.

There is a tide gauge installed at the wharf, which is calibrated once a week by conducting a tide dipping. This tide gauge forms part of the Global Sea Level Observing System.

It is vital that scientists continue to monitor the levels of ozone in the atmosphere so that they can understand the current state of the Antarctic ozone hole. At Rothera this is achieved using a SAOZ instrument (Systeme Automatique d'Observation Zenithal). SAOZ measures scattered sunlight in a way which allows scientists to determine how much ozone the light has passed through.

*Space Weather and Atmosphere*

Physical scientists use medium frequency radar and meteor radar to study wind and temperature in the upper atmosphere above Antarctica, and a low-power magnetometer at Rothera – one of a chain of instruments that BAS has installed across Antarctica – records variations in the Earth's magnetic field.

*Bonner laboratory & Biodiversity, Evolution and Adaptation*

The Bonner Laboratory supports station focused science projects predominantly in the areas of marine biology, oceanography and terrestrial biology. The BEA team aims to understand how past, present and future environmental change has and will affect polar biodiversity both on land and in the ocean, and how life adapts to extreme polar conditions. Their research outcomes will provide deep insight into the impact of environmental change on the natural world, make a strong contribution to future conservation measures, and generate new and innovative areas of research that have potential societal benefits.

The team has two research groups: Biodiversity and Adaptations. The Biodiversity group focuses its investigations on mapping species distributions, how they relate to current and past environments and how this information can be used to predict future distributions under environmental change. The Adaptations group investigates adaptations to extreme polar conditions, from the molecular level through physiology to ecology and, using experimental approaches, how these may affect species abilities to adapt under future change scenarios. Both groups work together towards the same aim: to develop a holistic picture of future patterns of biodiversity in a changing world.

The RaTS (Rothera Biological & Oceanographic Times Series) programme has been running at Rothera since 1997 and comprises an integrated suite of oceanographic and biochemistry data (e.g. temperature, salinity, macronutrients, chlorophyll) collected at a key site of rapid climate warming and high inter-annual variability on the Antarctic Peninsula. Changes in the ocean/climate system can occur over decades, and these changes are best detected using continuous, long-term monitoring programmes. The Rothera Time Series (RaTS) is one of the most important long-term monitoring programmes in Southern Ocean science, partly because it features winter-time measurements that are difficult to obtain.

As part of the NWO (Netherlands Organisation for Scientific Research) Netherlands Polar Program the Dirk Gerritsz Laboratory was opened at Rothera in 2013. It consists of four containerized laboratories and is the only Dutch funded laboratory in Antarctica. Researchers primarily come from Dutch universities or NWO research institutes and research focuses on climate change, glaciology, marine ecology and oceanography.

#### 4.3.3. Air Operations

To support science and logistics in Antarctica, BAS operate a fleet of five aircraft, specially adapted for flying in extreme Antarctic climate. The BAS aircraft consist of four De Havilland Canada Twin Otters and one De Havilland Canada Dash-7 equipped with modifications to allow them to carry out airborne science surveys. Between them they undertake a wide variety of transport and science missions.

Due to the 900 m gravel runway at Rothera the Dash-7 is able to undertake regular shuttle-flights to and from South Atlantic gateways and is able to carry fuel and provisions to the deep field site at Sky Blu which supports a blue ice runway. The Twin Otter aircraft whilst carry much smaller payloads are more versatile, being able to land on wheels or skis and regularly transport scientists to remote deep field study sites within Antarctica.

#### 4.3.4. Vehicle Operations

Vehicles at Rothera play a key role in moving people and equipment around the station. Maintenance of vehicles is undertaken by a team of vehicle mechanics and plant operators. The day-to-day coordination of vehicle use is arranged between the Facilities Engineer and the station management team. The following vehicles comprise the current fleet at Rothera:

- X15 Skidoos (Alpine 3) (including those deployed at Sky Blu, Fossil Bluff and with field parties)
- X10 Skidoos (Skandic V800)
- X10 Skidoos (ACE 600)
- X3 Tractors
- X10 Trailers
- X5 Loaders (forklift/bucket capability)
- X1 Snocat
- X1 Dozer
- X1 Crane (Nodwell 110c)
- X2 Tanker (for runway dust suppression)
- X6 Gators
- X1 ATV
- X1 Container Handler (SWL 20t)
- X1 Pick-up truck (fire response)
- X1 Digger 860 SX
- X1 JCB JS 130 (excavator)
- X2 Multi terrain loader/blower
- X3 Pedestrian snowblower
- X3 Attachment snowblower
- X1 Concrete Mixer
- X1 Access platform

#### 4.3.5. Boating Operations

Boating operations are a vital part of science and operations activities at Rothera. There are currently five boats within the Rothera fleet. These are:

- Stella - 5.5m Humber Destroyer RIB (Console)
- Erebus - 6.0 m Humber Destroyer RIB (Console)
- Nimrod - 6.0 m Humber Destroyer RIB (Console)
- Terra Nova - 4.8m Humber Defender (Tiller)
- Sea Rover - 6.4m Sea Rover HDPE (Console)

Sea Rover and Terra Nova are primarily used as science platforms, in particular for the deployment of CTDs. The three Humber Destroyers are used for diving and SAR cover for air operations as required.

#### 4.3.6. Fuel Storage

*Marine Gas Oil (MGO)*

Rothera has provision for the bulk storage of 716,200 litres of Marine Gas Oil (MGO) which is approximately 12.5 months' supply. All the storage tanks are made from steel and are either bunded or double skinned.

*Table 4-2 Bulk MGO storage at Rothera*

| Location | Capacity of tanks (litres) | Contingency Containment |
|---|---|---|
| Fuel Farm | 3 x 230,000ltrs (Total = 690,000) | Bund can contain >100% of tanks capacity |
| Generator shed | 2 x 5,500ltrs (Total = 11,000) | Self bunded tanks and concrete bund |
| Boiler House (OBH) | 6,400 | Doubled skinned tank |
| Garage | 1,800 | Doubled skinned tank |
| Giants | 2,000 | Concrete bund |
| Bonner Laboratory | 5,500 | Self bunded tank |
| NBH | 12,000 | Self bunded tank |
| Admirals House | 5,000 | Doubled skinned tank |

Supply to the fuel farm is through a combination of steel and flexible hosed pipes. The flexible hoses are laid out during ship's relief and connected to the above ground steel pipes. Avery-Hardall dry-break valves or fueling guns are fitted to all refueling hoses to eliminate any spillage. All refuelling follows set operational procedures which the Rothera Facilities Engineer maintains.

The bulk tanks feed the Generator shed, Old Bransfield House and the garage. These tanks are filled on a daily basis. Bulk fuel is delivered to the generator shed through two plastic coated steel pipes (100 mm) buried underground. The fuel is circulated and heat traced to prevent it from waxing. Each tank is fitted with control valves and a re-circulating pump is situated in an enclosed housing to the south east of the fuel farm. Other MGO tanks are filled using a 12,000 litre mobile bowser towed by either the Bull dozer or JCB 456.

### *Aviation Fuel*

The following table illustrates the quantity of aviation fuel (AVTUR) stored at Rothera and at depots out in the field during normal operations Aircraft are refuelled using the fuel dispenser pump on the apron as and when required. At deep field locations aircraft are refuelled using drummed AVTUR. The amount of fuel depoted in the field varies widely from year to year dependant on the requirement of scientific field project. The following table gives an approximation of AVTUR stored at Rothera and in the field:

*Table 4-3 AVTUR storage at Rothera*

| Location | Quantity |
|---|---|
| **Bulk fuel AVTUR at Rothera (litres)** | 3 x 230,000 ltrs (Total = 690,000) |
| **No. of drums at Rothera (205 litre capacity each)** | 400-800 |
| **No. of drums at Fossil Bluff (205 litre capacity each)** | 10-50 |
| **No. of drums at Sky-blu (205 litre capacity each)** | 500-800 |
| **No. of drums stored in field depots** | Varies seasonally |

### *Other Fuels*

Other equipment and plant at Rothera are operated with petrol and kerosene. The quantities stored at Rothera are listed below.

*Table 4-4 Other fuel storage at Rothera*

| Fuel Type | Quantity |
|---|---|
| **Petrol** –205 litre drums | **80 drums** (min. 40 required for winter & further 40 required for summer prior to ship relief) |
| **Kerosene** – 205 litre drums | **15 drums**(to allow for winter trips, early season and contingency) |

### 4.3.7. Power Generation

Electrical power at Rothera is provided by 4 x Volvo TAD 752GE diesel engines, producing 144kW, coupled to AC generators housed in the generator shed. 24 hour continuous power is provided by having two on line at any time but with an automated means of changing over from one set to another. There are two mobile generator sets Volvo TAD 752GE which can be plugged into New Bransfield house or the Bonner laboratory. There is an auxiliary power container behind the hangar housing Cummins generators for emergency purposes to power the hangar. Power usage is minimized wherever possible and any equipment to be installed at Rothera that requires electrical power must be approved through the planning process prior to installation.

Rothera requires on average 700 $m^3$ of MGO per year to maintain serviceability.

- 66% is required of power production
- 29% is used for heating
- 3% used by vehicles
- 2% is used for incineration

Most of the heating is supplied in conventional heating systems, oil boilers in larger building and electric heaters in small buildings. The larger building are also equipped with air handling units. Rothera uses on average 180kw to 200kw of power and any one time.

Rothera has several energy efficient measures in place:

- Heating controls and temperatures are closely monitored to improve efficiency
- Power is monitored and reduced where practicable.
- Energy efficient lighting
- Greater use of natural lighting
- Building Management System (BMS)

### 4.3.8. Water Generation

Fresh water is produced at Rothera by reverse osmosis (RO), converting salt water to fresh water through a process of desalination. The RO plant is online 24 hours a day and can produce up to 14$m^3$ per day. Water is readily available unless there is a mechanical failure. Efficient use of water use is encouraged to minimize fuel use.

Potable water is initially stored in the reverse osmosis room which has 3 tanks with a total volume of 28 $m^3$. It is then pumped to smaller satellite tanks situated in other buildings. A melt tank is also available for emergency use. All personnel are reminded to keep water usage to a minimum, particularly in summer when there are more people on Station.

Water figures fluctuate between the summer and winter usage. Salt water is used in 3 buildings for flushing toilets.

- Average use of potable water Mar-Sep 70 $m^3$ per month (21 x personnel).
- Average use of potable water Oct-Dec: 200$m^3$ per month (Station average 70-90 personnel).
- Average use of salt water use Mar-Sep 30 $m^3$ per month (21 x personnel).
- Average use of salt water Oct-Dec: 90$m^3$ per month (Station average 70-90 personnel).

# 5. DESCRIPTION OF THE ENVIRONMENT

Reference is made in this section to Rothera Point. This is the area of land to the east of the Wormald Ice Piedmont shown in Figure 10-1, which is largely ice free and within which the Rothera Research station is situated. Rothera Point is located within Antarctic Conservation Biogeographic Region (ACBR) No. 3 Northwest Antarctic Peninsula. Recent estimates suggest that ice-free ground may comprise as little as 0.18% of Antarctica (Burton-Johnson et al., 2016). Of the c. 25,000 km$^2$ of ice-free ground, only a small proportion is located close to the coast where climatic conditions are suitable for the development of substantial vegetation communities and where wildlife colonies and haul out sites are found (Fretwell et al., 2011). However, coastal sites are also often favoured as sites for logistic facilities by national operators and as visitation sites used by the tourism industry (Pertierra et al., 2017).

## 5.1. Ecology

Levels of biodiversity at Rothera Point are not high compared to other equivalent areas. For example the nearby islands in Ryder Bay have much higher levels of biodiversity. However, Rothera Point does contain some examples of Antarctic fellfield environments, which are reasonably rare in the wider area (Convey and Smith, 1997). In contrast the near shore marine environment is considerably more species diverse and the subject of most biological research in the area (Barnes, 2007). Species lists are provided in Appendix H.

### 5.1.1. Terrestrial Flora

Rothera Point contains no large areas of vegetation, with substantial continuous moss and liverwort patches limited to a single area of c. 100 m$^2$ adjacent to a transient melt stream in a gully 100 m east of the Miracle Span marked as Area A in Figure 10-1. Confirming this, analysis of remote sensing imagery (using Normalised Difference Vegetative Index (NDVI) methodology) revealed that areas of significant green vegetation are spatially limited (Hughes et al., 2016). Areas of high NDVI value on East Beach relate to algae and cyanobacteria in ephemeral pools fed seasonally by melting snow and ice (Figure.10-1, area B).

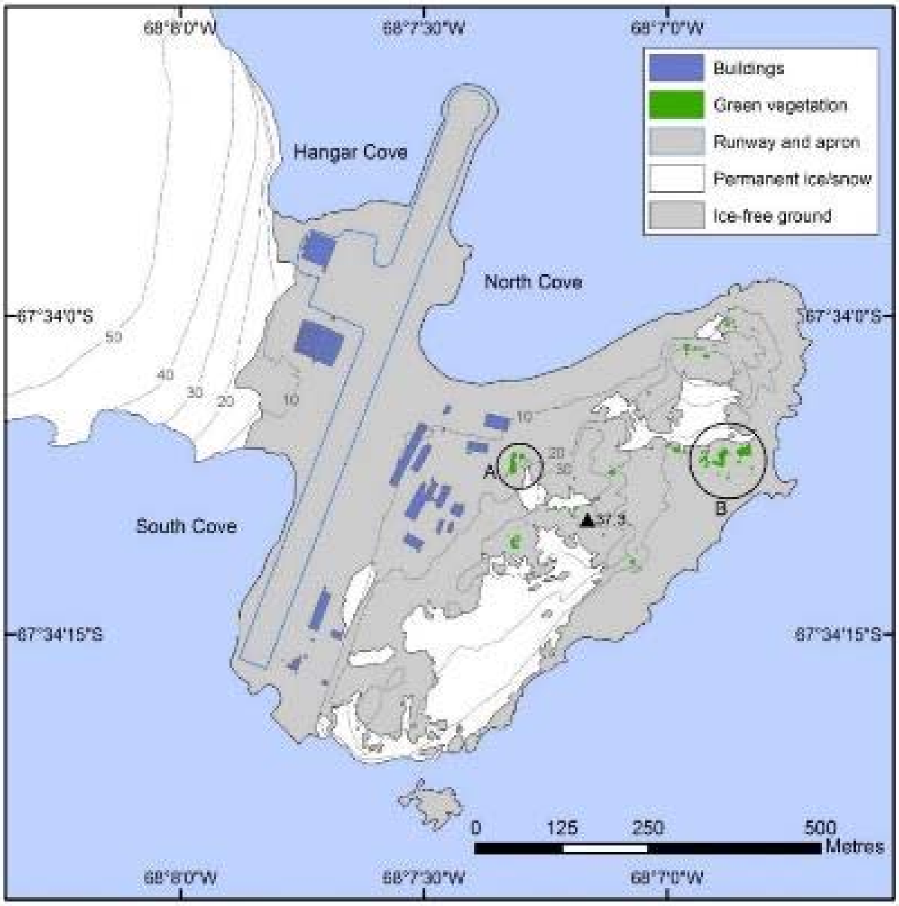


*Figure 5-1 Areas of green vegetation detected on Rothera Point using NDVI methodology.*

Circled areas A and B denote the location of particularly rich areas of moss/liverwort and algal vegetation, respectively. There is no vegetation in the vicinity of the area where it is proposed that rock required for construction will be quarried. See Figure 10-1.

### *Cryptogams (mosses, liverworts, lichens, algae)*

The limited terrestrial biological interest within the Rothera Point is confined to the rock bluffs where there is a locally abundant growth of lichens. There are no special or rare terrestrial fauna in the locality of Rothera Point (Antarctic Treaty Secretariat, 2017). The vegetation is representative of the southern "maritime" Antarctic fellfield ecosystem and is dominated by the fruticose lichens *Usnea antarctica, Usnea sphacelala*, and *Pseudephebe minuscula*, and the foliose lichen *Umbilicaria decussata* (Øvstedal and Smith 2001). Lichen vegetation is reasonably well developed and diverse, dominated by crustose and foliose species, and is typical of the southern maritime Antarctic, as previously described. Bryophytes are generally sparse (mainly *Andreaea* spp). Bryophytes are limited to two main habitats, these being around the relatively small areas of soil and sorted ground, and in rock crevice and epilithic habitats (Ochyra et al., 2008). In the former habitat, although sparse on the higher ice free area, there are some well-developed stands of *Andreaea* spp. especially below the western and south-western edges of the Antarctic Specially Protected Area (ASPA 129) (see Section 10.9 Protected Areas), and *Sanionia* sp. especially below the eastern and south-eastern edges. These are intermixed with a small amount of what appears to be *Bryum sp.* and possibly also *Ceratodon* and

*Cephaloziella*. Examples of crevice and epilithic species include Bartramia (some with sporophytes) and *Schistidium/Grimmia.*
The vegetation composition does appear to have remained constant since the mid-1990s. The total area of moss cushions or carpets, while remaining small, may have expanded slightly, including habitats along the spine of Rothera Point, and in the sandy/silty areas of East Beach (P. Convey, pers comm.) (See Figure10-1, point B).

### *Vascular plants*

A single very small population of Antarctic pearlwort (*Colobanthus quitensis*) has been observed below the northern cliff of the Point (Figures 10-2 and 10-3). A small population of Antarctic pearlwort (*Colobanthus quitensis)* may continue to persist in a small gully at the base of crags under the Point's north-west cliffs. Sixteen separate plants or clumps of varying sizes were noted previously, at least two of which included mature and open seedheads; however, these plants are vulnerable to long-term burial by snow and their persistence is uncertain. A single plant of Antarctic hairgrass (*Deschampsia antarctica*) was located in a small depression at the northern edge of the summit plateau of the Point (Figures 10-4 and 10-5). This plant also possessed a single mature seedhead. However, its on-going persistence at the site is in doubt.


*Figure 5-2. Small population of Antarctic Pearlwort C. quitensis.* *Figure 5-3 Plant with previous year's seed heads*


*Figure 5-4 Location of Antarctic Hairgrass Deschampsia antarctica.* *Figure 5-5 Inflorescence*

### 5.1.2.Terrestrial Fauna

The terrestrial invertebrate fauna is impoverished and consists only of a few species of mites and springtails, of which *Halozetes belgicae* and *Cryptopygus antarcticus* are the most common. Nematodes and rotifers have also been recorded in freshwater pools. There are no special or rare terrestrial fauna on Rothera Point (Convey and Smith, 1997).

### 5.1.3. Marine Benthic Communities

*Shallow water*

The shallow seas of Marguerite Bay (0-30m) are within the Southern Ocean, the coldest ocean on Earth with one of the smallest annual temperature ranges; typically -2 to +2°C (Barnes, 2007). In contrast, shallow polar waters experience one of the highest seasonal changes in primary productivity as photoperiod changes from 24 hour daylight to 24 hour darkness between summer and winter. Shallow water communities are also subject to high levels of disturbance from the impact of icebergs (Barnes and Tarling, 2017). However, while this might be considered a harsh physical environment, many marine benthic species flourish in the shallow waters. The shallow waters off the Western Antarctic Peninsula have experienced rapid warming over the last 50 years, which has led to reductions in sea ice, melting of glaciers and higher levels of iceberg disturbance (Convey et al., 2009). The change in the cryosphere has already led to changes in the patterns of primary productivity, which are expected to combine with warming and ocean acidification to result in severe impacts on shallow marine benthic communities (Aronson et al., 2011).

Iceberg disturbance is a major structuring force of shallow water polar communities, particularly those living on rocky reefs (Brown et al., 2004). The very high disturbance levels in the shallows result in a fauna that is dominated by mobile species that are able to rapidly recolonize areas after an iceberg impact. Typically this fauna consists of high numbers of gastropod molluscs and echinoderm species. It is only in deeper water, or in sheltered locations, where iceberg disturbance is reduced sufficiently, that sessile communities can develop.

To determine the baseline state of marine benthic communities, surveys were conducted in January 2016 on three sites off the South coast of Rothera Point in depths of 9-10 m. The sites were, below the front of the current wharf (67.5723 S, 68.1296 W), the end of the runway (67.5717 S, 68.1312 W) and inside of South Cove (67.5697 S, 68.1319 W). The survey followed reef life survey methodology (www.reeflifesurvey.com), which provides a global standard to facilitate description, monitoring and comparison of rocky reef marine communities. It involved laying a 50 m transect tape along a depth contour and then counting the number of individuals seen along this transect. Fish were counted in two 5 x 5 m bands parallel with the transect tape, which reduced to 3 x 3 m bands when the visibility dropped to 3 m. Selected groups of invertebrates were counted in 1 m wide by 2 m high bands on either side of the transect tape.

The bottom consisted of a mixture of bed rock and loose cobbles with occasional pockets of mixed cobbles and sediment. The end of the runway had the highest proportion of bedrock with the steepest underwater gradient. The gradient was shallowest in South Cove and the substratum subsequently had the highest number of pockets of mixed cobbles and sediment. The wharf was an intermediate slope but the substratum largely consisted of loose cobbles.

Whilst macro algae were relatively scarce in the shallow polar waters examined, there were occasional large clumps of the brown alga *Desmorestia antarctica* and an algal mat covered some of the seabed. Community analysis showed a high degree of variation in density between species (Figure 10-6), but all three sites had similar diversity and densities of species. At all three sites, the most abundant species was the Antarctic limpet, *Nacella concinna*, with up to 112 individual's $m^{-2}$, and the most speciose class was the Asteroidea with either 4 or 5 species. Fish numbers were very low, with only 5 individuals counted during the three surveys.

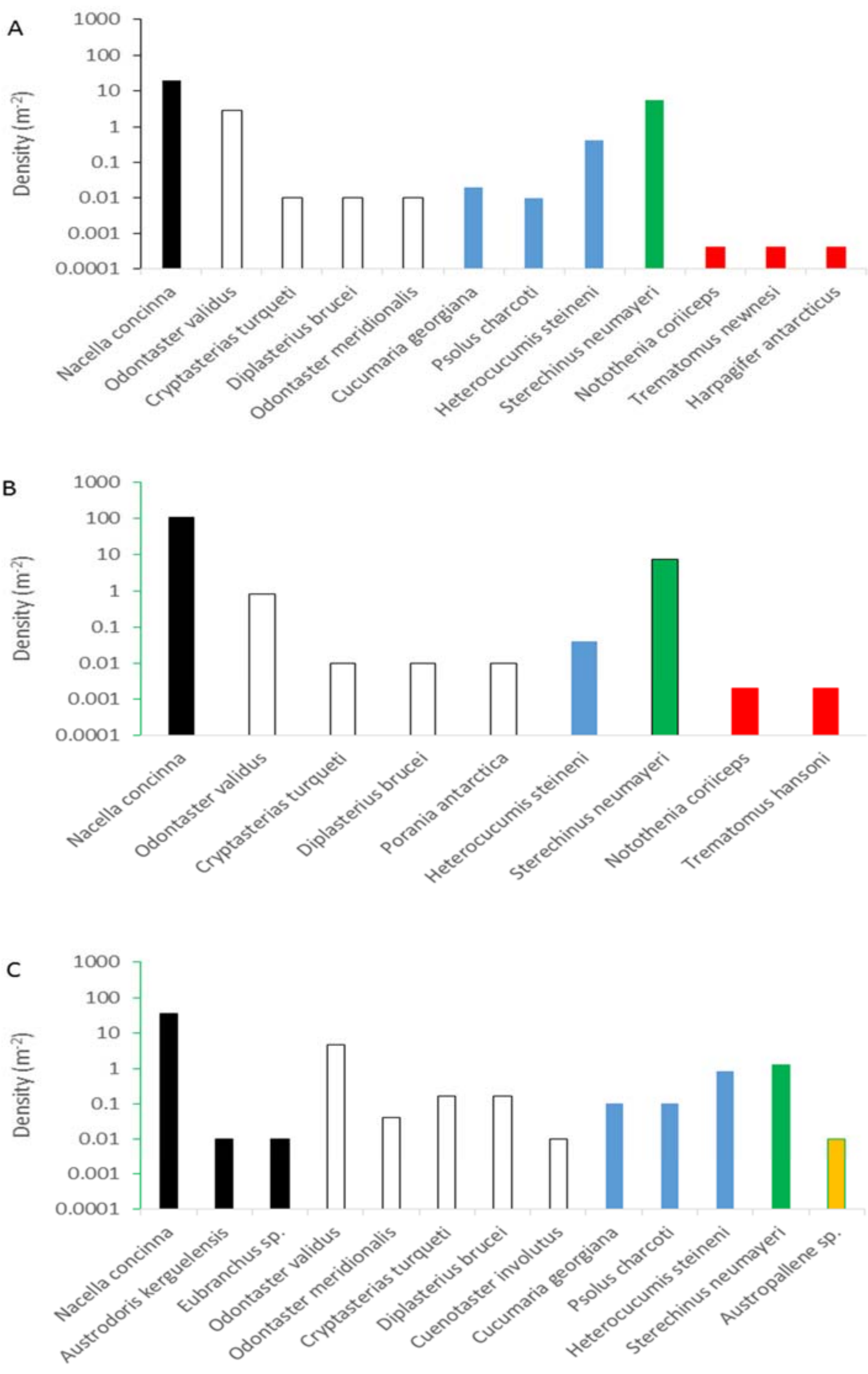


*Figure 5-6. Species densities at South Cove*

Taken from SCUBA diver counts using reef life survey methodology in depths of 9-10 m, A) Wharf, B) end of runway and C) South Cove. Black bars – snails and sea slugs, open bars – sea stars, blue bars – sea cucumbers, green bar – sea urchin, yellow bar – sea spider.

### *Deeper Water Benthic Communities*

A ROV (Remotely Operated Vehicle) was used to obtain underwater transect photos in the vicinity of the wharf to show the typical benthic community. The descriptions provided below are purely qualitative and the pictures are provided to give a representation of the typical communities that exist at each depth. See Appendix H for a preliminary species list at 100 m depth.

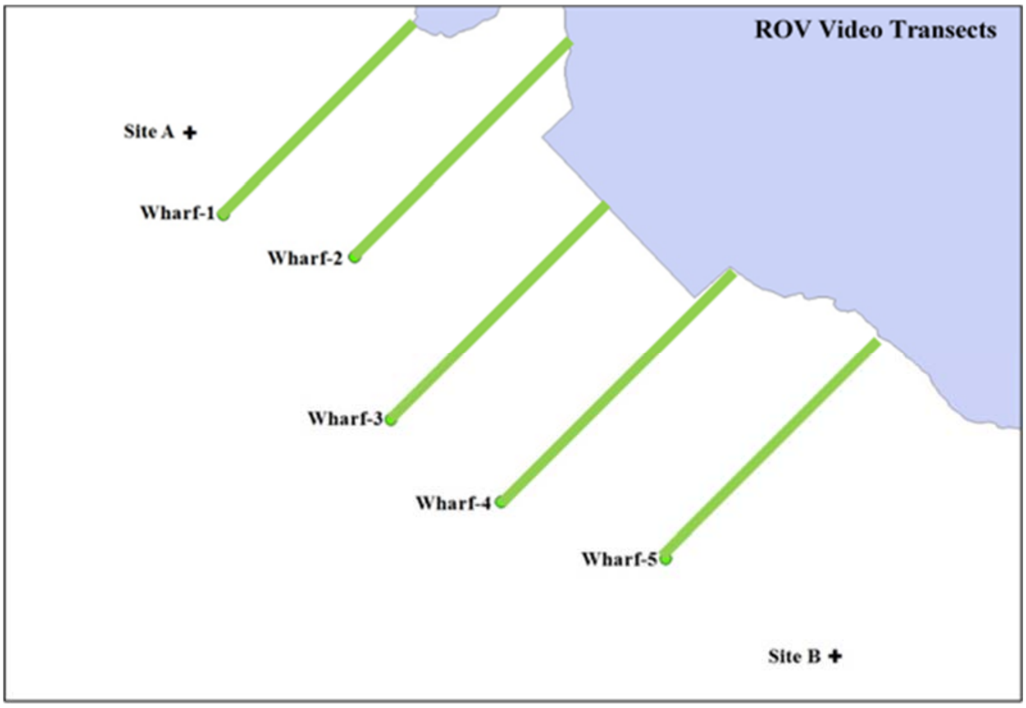


*Figure 5-7 ROV transect locations*

Figure 10.7 is a map showing the ROV transect locations around the wharf. Sites A and B are biodiversity reference sites.

Depth: 5 - 40 m

At 10 m depth the majority of species are *Nacella concinna* (limpets) and *Odontaster validus* (sea star) and pink encrusting algae with relatively sparse densities (Figure 10-8). At 20 m, holothurians (sea cucumbers) such as *Heterocucumis steineni* become more common but only in summer, in winter they are absent in the epifauna (on surface) and are believed to be dormant and hidden. At 30 m anemones, such as *Isotaelia lacunifera* and ascidians (sea squirts) and *Cnemidocarpa verrucosa,* are more abundant along with a greater diversity of asteroids (sea stars).

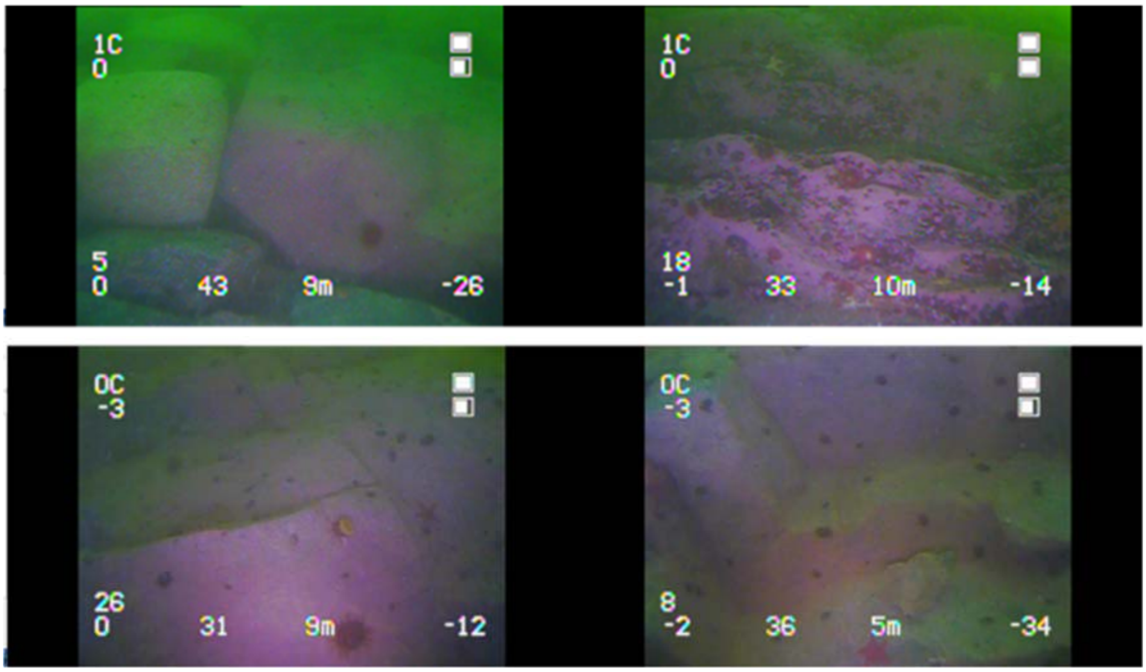


*Figure 5-8 Underwater photographs of benthic biodiversity at 5-10 m depth*

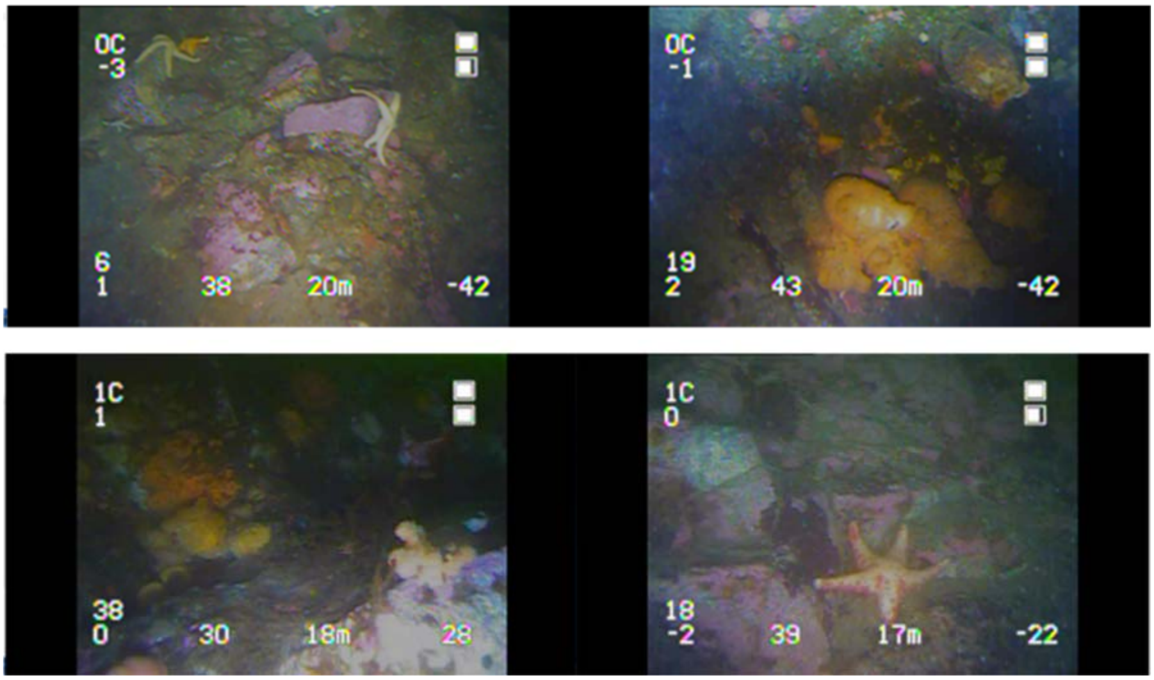


*Figure 5-9 Underwater photographs of benthic biodiversity at 10-20 m depth*

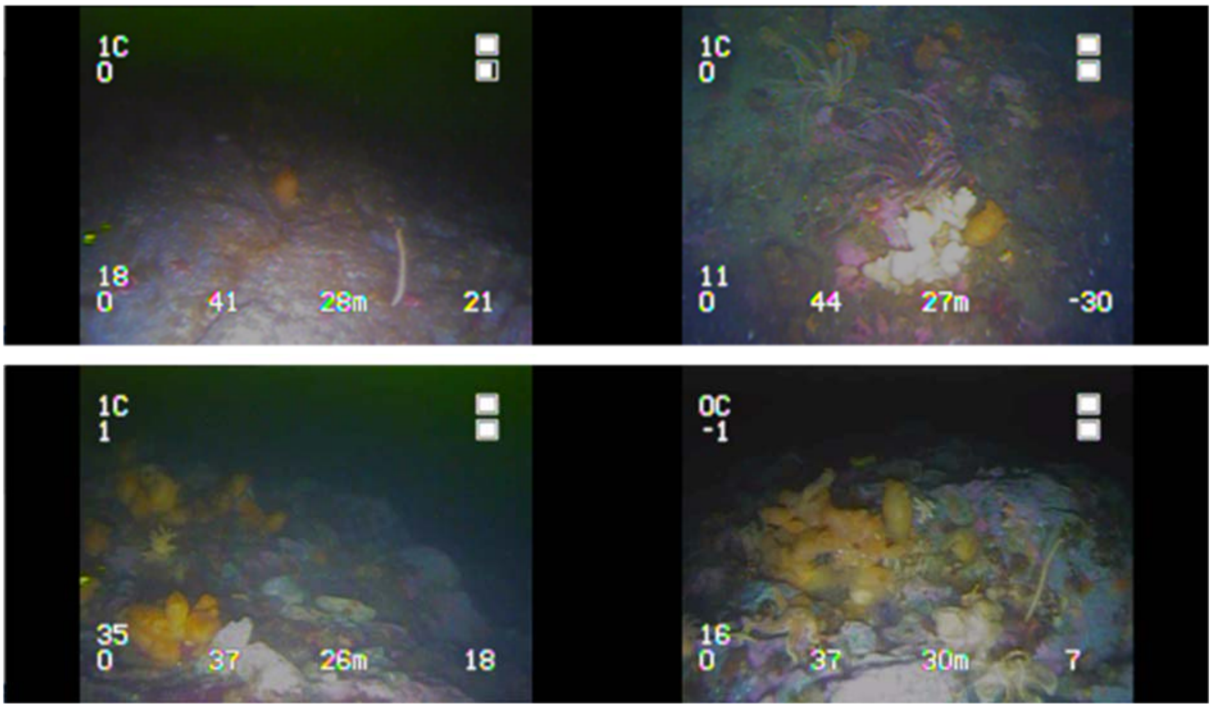


*Figure 5-10 Underwater photographs of benthic biodiversity at 20-30 m depth*

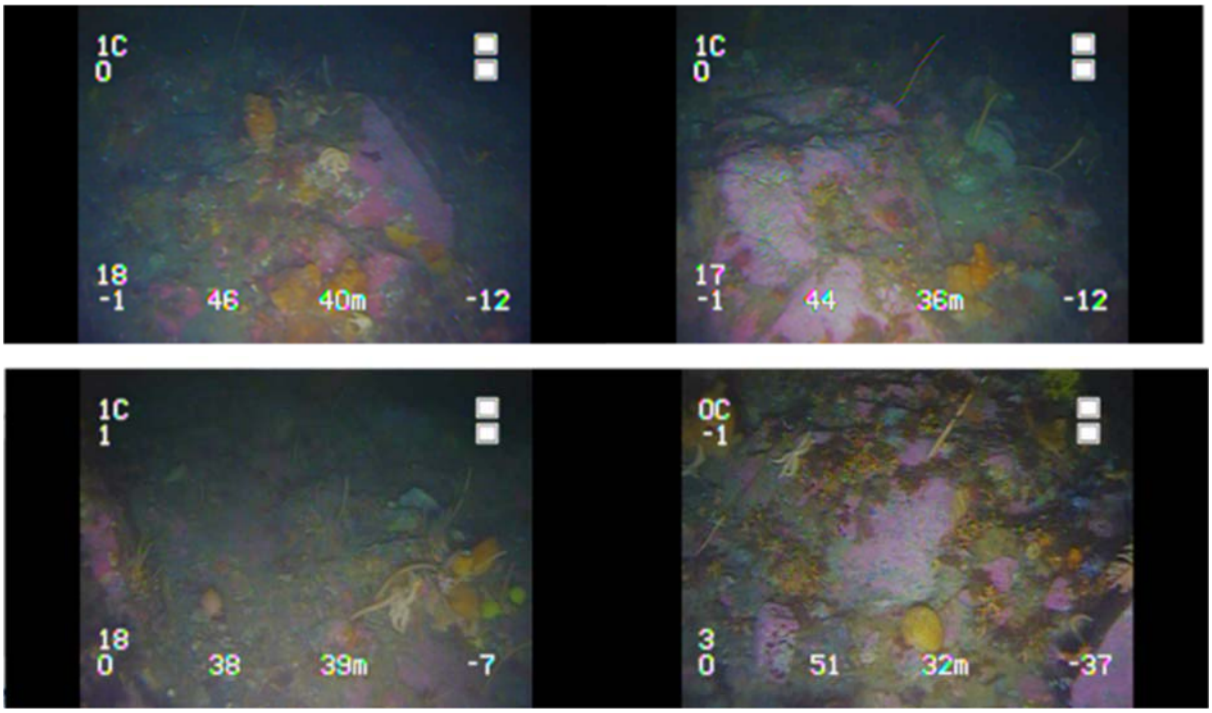


*Figure 5-11 Underwater photographs of benthic biodiversity at 30-40 m depth*

Depth: 40 - 70 m

Between 40 to 70 m, bryozoan colonies (sea mats) become more common and dominant, and they also increase in size and become more foliose (Figure 10-12, Figure 10-13 and Figure 10-14). There is also an increase in Octocorals, possibly *Primnoella* sp. The community tends to be less disturbed by iceberg impact and therefore more diverse. Species such as *Nacella concinna* (limpets) and *Odontaster validus* (sea star) are absent. The seafloor tends to be more silty, but where rocks are exposed, pink encrusting algae are still dominant, although at deeper depths these are replaced by other encrusting organisms such as sponges and bryozoans.

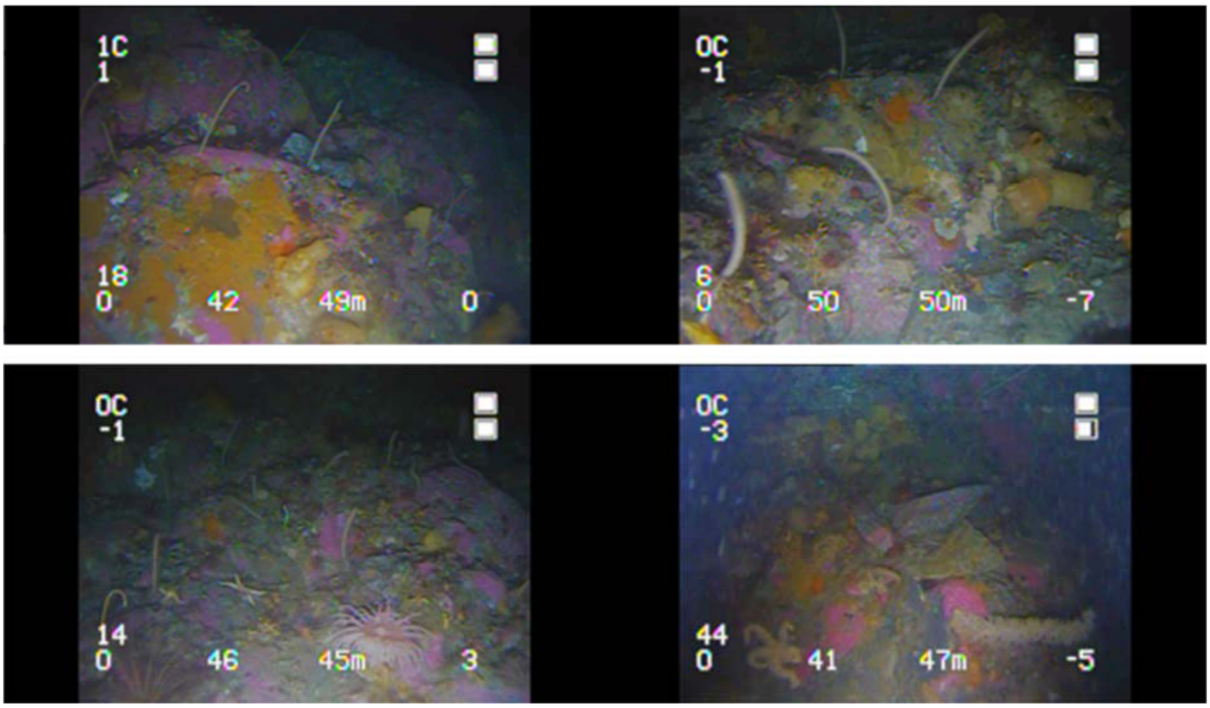

*Figure 5-12 Underwater photographs of benthic biodiversity at 40-50 m depth*

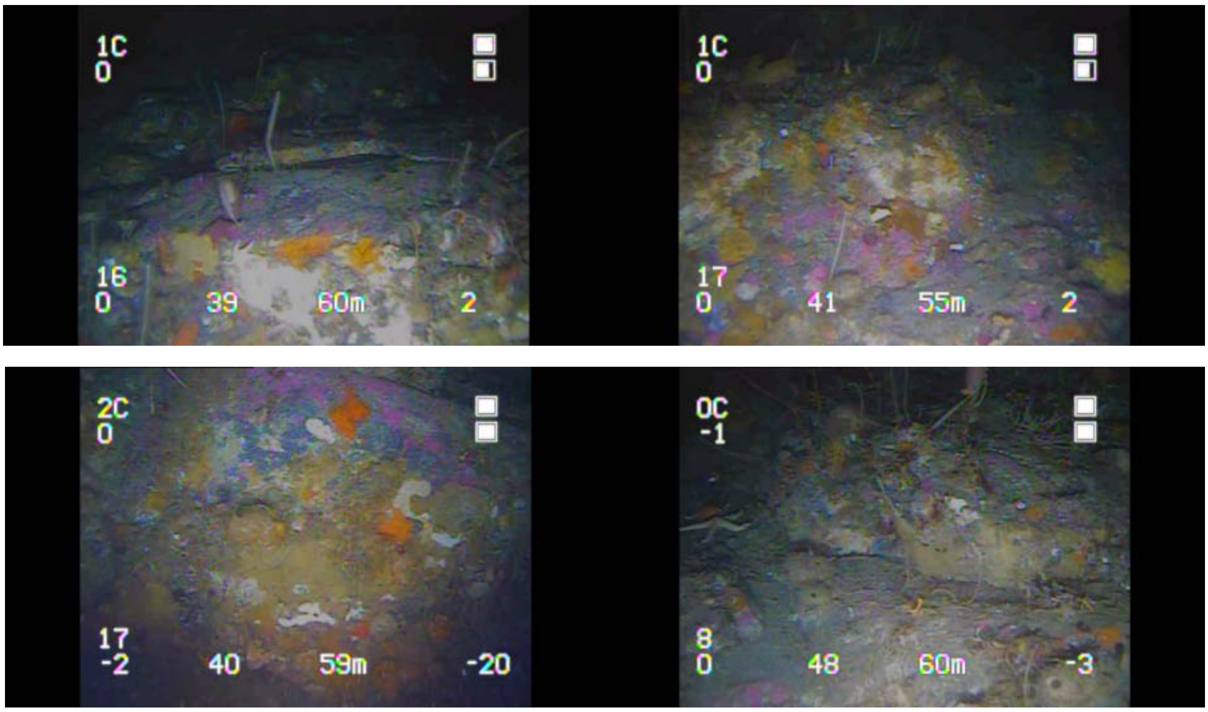

*Figure 5-13 Underwater photographs of benthic biodiversity at 50-60 m depth*

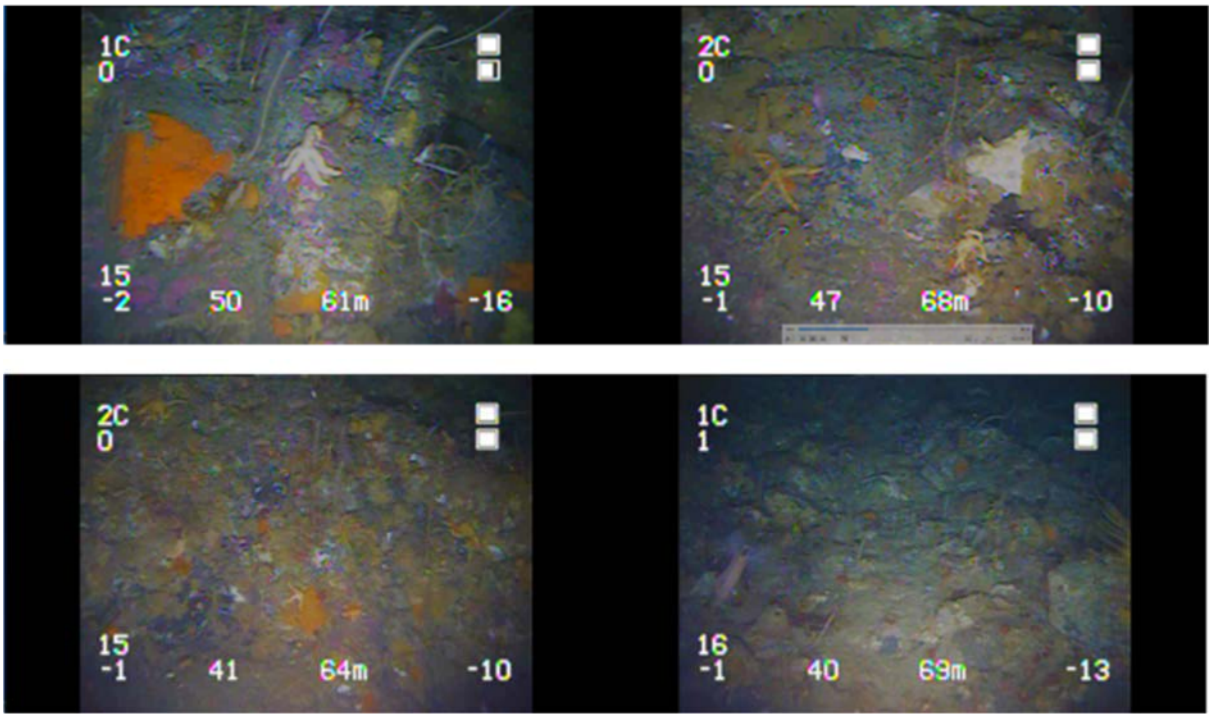


*Figure 5-14 Underwater photographs of benthic biodiversity at 60-70 m depth*

<u>Depth: 70 - 100 m</u>

At greater depth the benthic community is dominated by slow growing sponges such as *Rossella* sp., bryozoans (*Reteporella* sp.) and ascidians (*Pyura setosa*) (Figure 10-15, 16-18). Siltation continues to increase with depth, but the presence - even in silted areas - of species that require hard substrate to attach implies either sporadic siltation and/or hard substrate with a film of silt. Communities at these depths tend to be more complex and diverse with high competition for space, as is indicative of a low disturbance environment, which has taken a longer time to develop.

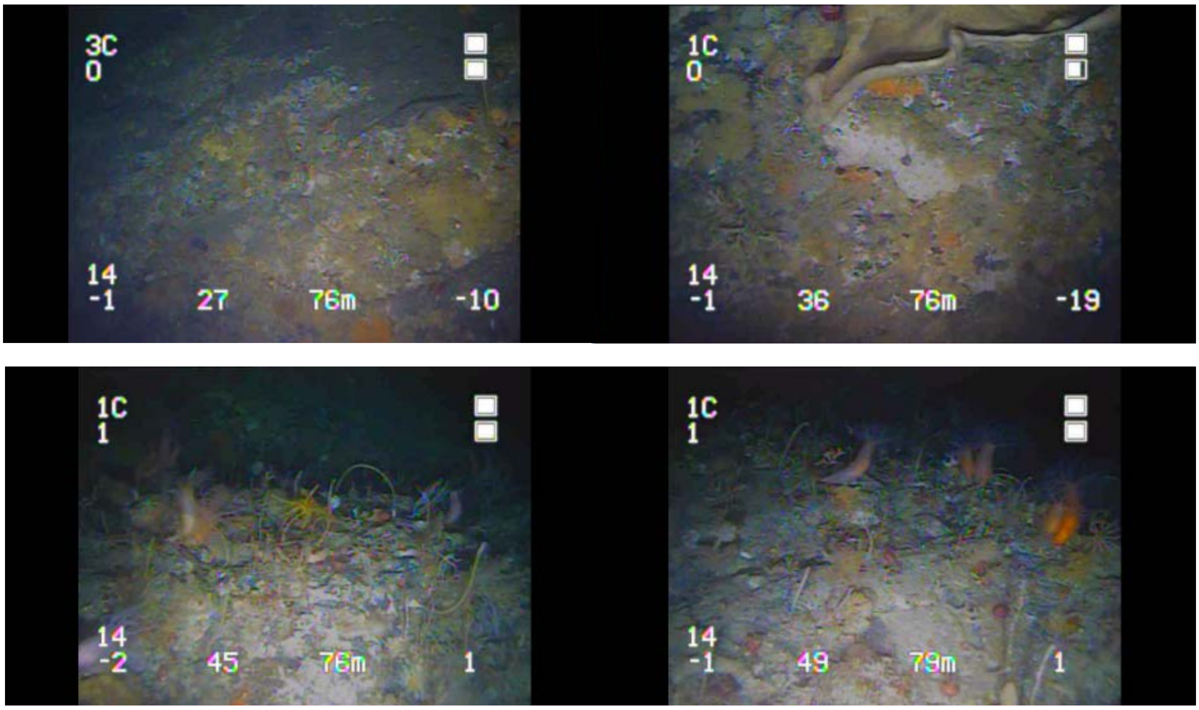


*Figure 5-15 Underwater photographs of benthic biodiversity at 70 - 100 m depth*

At shallower depths (< 30 m) communities tend to be more homogenous than their deeper counterparts. Communities that are present at greater depths tend to be more diverse and denser and some rare species such as Cephalopods (e.g. octopus), *Labidiaster radiosus* and *Gersemia antarctica* may be found. The spatial variability in community structure along Biscoe wharf makes it challenging to provide a concise description of the communities at each depth; however, below is a brief overview of abundant species identified using ROV and dive survey.

*Table 5-1 Abundant benthic species found at different depths in the vicinity of the wharf*

| Depth | Typical species or groups |
|---|---|
| 10 m | Pink encrusting algae |
| | *Nacella concinna* |
| | *Sterechinus agassizi* |
| 20 m | Pink encrusting algae |
| | *Cnemidocarpa verrucosa* |
| | *Odontaster validus* |
| 30 m | *Cnemidocarpa verrucosa* |
| | *Isotaelia antarctica* |
| | *Heterocucumis steineni* |
| 40 m | *Primonella* sp. |
| | *Promachocrinus kerguelensis* |
| | *Haliclona tenella* or *Calyx arcurius* |
| 50 m | *Primonella* sp. |
| | *Promachocrinus kerguelensis* |
| | *Haliclona tenella* or *Calyx arcurius* |
| | *Cnemidocarpa verrucosa* |
| 60 m | Encrusting sponges |
| | *Cucumaria* sp. |
| | Foliose bryozoans |
| 70 m | Foliose bryozoans |
| | *Branchiomma* sp. |
| | *Pryura setosa* |
| 80 m | Encrusting sponges |
| | *Branchiomma* sp. |
| | *Kirkpartrickia variolosa* |
| 90 m | Foliose bryozoans |
| | *Cucumaria* sp. |
| | *Pryura setosa* |
| | *Rossella racovitzae* |

### *Monitoring of benthic ice scour impact in South Cove*

Ice scour disturbance has a significant effect on the physical and biological characteristics of bottom-dwelling species in polar marine environments. To study this, grids, each consisting of 25 markers, have been deployed along depth transects in South Cove (adjacent to the runway and c. 50 m south of the proposed temporary wharf) since 2004. Each marker consisted of a cuboid concrete base (9 x 9 x 4 cm) with a non-toxic PVC-based modelling clay block (5 x 5 x 2 cm) secured onto the upper side.

*Table 10-2. Location of grid markers within South Cove, Rothera Point*

| | Depth | | |
|---|---|---|---|
| | 5 m | 10 m | 25 m |
| Transect 1 | 67° 34.216’ S<br>068° 07.947’ W | 67° 34.220’ S<br>068° 07.968’ W | 67° 34.232’ S<br>068° 08.005’ W |
| Transect 2 | 67° 34.200’ S<br>068° 07.911’ W | 67° 34.208’ S<br>068° 07.968’ W | 67° 34.219’ S<br>068° 08.003’ W |
| Transect 3 | 67° 34.167’ S<br>068° 07.845’ W | 67° 34.161’ S<br>068° 07.904’ W | 67° 34.185’ S<br>068° 08.020’ W |

Grid markers are surveyed and replaced every 3 months in order to assess the frequency and intensity of iceberg impacts. To date, the research has shown that depth, site, season and year are all highly significant factors influencing ice scouring frequency. In particular the research to date has revealed a high variation in the duration of winter fast ice between years, which had a marked effect on ice scouring frequency. The ecological effects of the disturbance regime are likely to include depth zonation of benthic species assemblages, patchiness of communities at varying stages of recovery and a general lack of species that live attached to rock and substrates in the shallow subtidal zone.
Smale, D. A., Barnes, D. K. A. and Fraser, K. P. P. (2007).

The long-term nature of this dataset (since the early 2000s), the complex diving effort required to collect the data and that the acquisition of monitoring information is on-going make this dataset of particular scientific value.

### 5.1.4. Avifauna

*Common Breeding Species at Rothera*

For a comprehensive review of birdlife at Rothera Point, including reference to relevant literature, see Milius, 2000. Of the bird species observed in the vicinity of Rothera Point, only some are known to breed locally: snow petrel (*Pagodroma nivea),* Wilson's storm petrel (*Oceanites oceanicus)*, imperial/Antarctic shag or cormorant (*Phalocrocorax [atriceps] bransfieldensis*), south polar skua (*Catharacta maccormicki*), and kelp/Dominican gull (*Larus dominicanus)* and Antarctic tern (*Sterna vittatta).* On Rothera Point itself, south polar skuas are the most abundant breeding birds with occasional pairs of kelp gulls nesting and one Wilson's storm petrel nest has been found.

Snow Petrel (*Pagodroma nivea*)
Snow petrels may breed in small numbers and are recorded throughout the year around Rothera Point, though less often in early and mid-summer. It is possible that they breed on some of the rock outcrops in the Rothera area.

Wilson's storm petrel (*Oceanites oceanicus*)
This species may breed in small numbers on Rothera Point, probably <15 pairs, although it also breeds on many (maybe all) of the other local islands in Ryder Bay, e.g. Lagoon Island. Birds return in late November or early December and although records are few, their departure is likely to be during April.

Imperial shag (*Phalacrocorax [atriceps] bransfieldensis*)
Up to 24 pairs of the Antarctic Shag or Cormorant breed on a small rock just to the north of Killingbeck Island (1.6 km east of Rothera Point), *c*. six pairs on the north end of Killingbeck Island and *c.* 50 pairs on another small rock close to Lagoon Island, although the exact numbers may vary considerably between years. Imperial shags can be seen at all times of the year, although their presence in winter is likely to be dependent on sea-ice conditions. Between late March and late June 1996, large flocks containing 300–400 adult and juvenile birds were seen with over 1000 recorded on 22 June, indicating that more than just the local breeding population was present.

South polar skua (*Stercorarius maccormicki*)
South polar skuas breed at Rothera Point and the population has been monitored annually since the 1988/89 season. The location of recorded nest sites over the past 18 years are shown in Figure 10-16) (UK Polar Data Centre, Rothera Point and Anchorage Skua data, 2017). Nest sites are often reused but may be inactive for a number of consecutive years. The skua nest closest to the proposed rock extraction area, was last used in 2015-16 but egg rearing was unsuccessful. The skua pair did not appear or lay eggs in 2016-17. However the 2015-16 and the 2016-17 seasons have been recorded as poor breeding years. There were no successfully reared chicks in 2015-16 and very few eggs laid and none hatching in 2016-17. It should be assumed therefore that any nest site identified on Figure 10-16 could become active in the future. The population size has remained fairly stable at around 20 pairs, with variable breeding success (Figure 10-18). Additionally, birds breed on most of the other islands in Ryder Bay (Lagoon, Leonie, Killingbeck, and Anchorage) and at least one incubating pair has been observed on Reptile Ridge. The spring return to Rothera usually falls between 15 and 25 October with departure in late April/early May, with the latest birds likely to be migrants from farther south. Large numbers of non-breeding skuas (up to 200) congregate in communal areas, often near shallow melt pools, particularly beside the melt pools on East Beach and at either end of the runway.

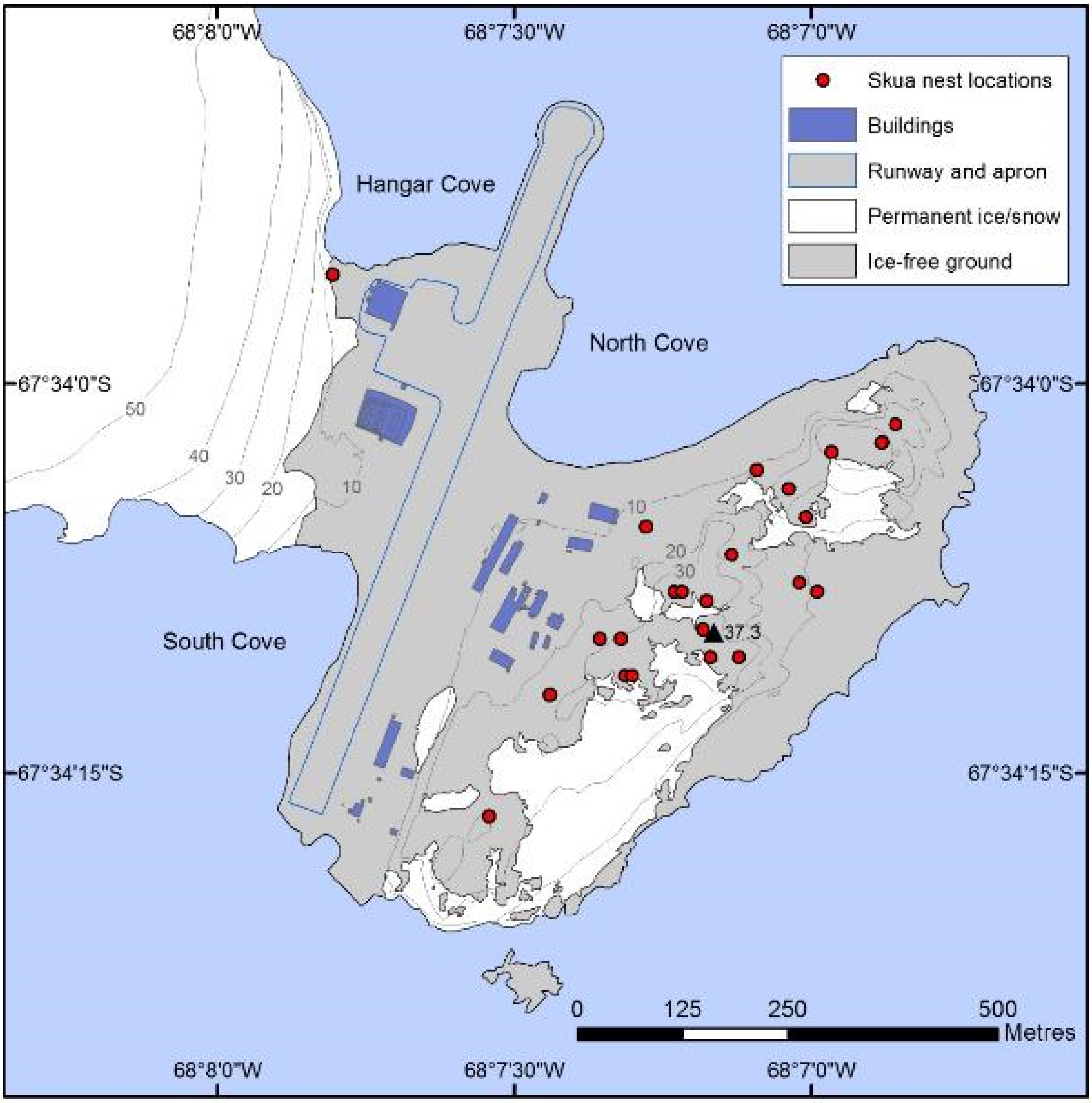


*Figure 5-16 Distribution of skua nesting sites on Rothera Point, Adelaide Island between 2005 and 2016.*

Note, the red circles mark the general areas in which nests are located as the precise location may vary by a few metres year on year. See Figure 4-1 for proposed location where rock fill will be sourced from.


*Figure 5-17 Location map of Ryder Bay and surrounding area*

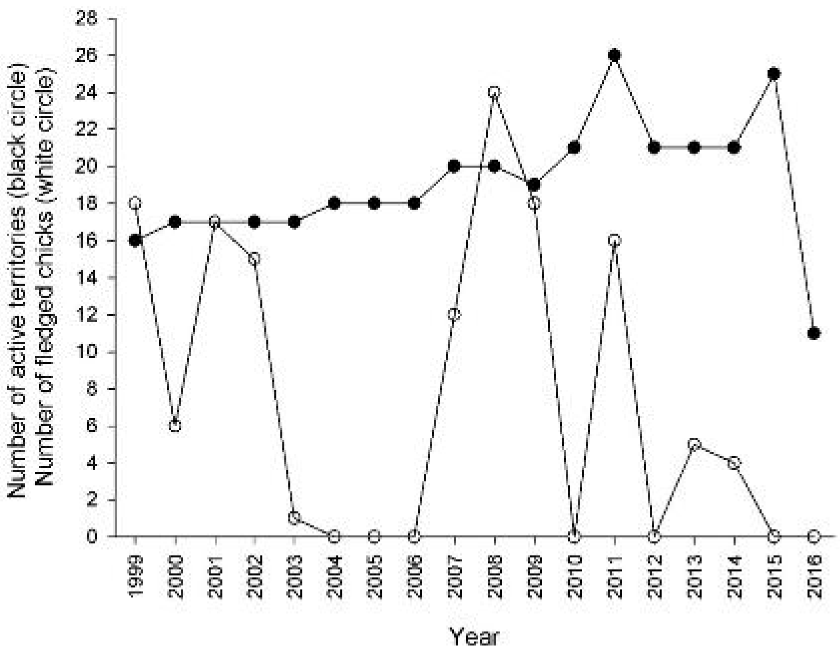


*Figure 5-18 Number of skua territories and fledged chicks at Rothera Point, 1999-2016*

<u>Kelp gull</u> (*Larus dominicanus*)

The Rothera Point breeding population varies from c. zero to four pairs. This species also breeds on the other local islands (Killingbeck, Lagoon, Anchorage and in larger numbers on Leonie). In winter, kelp gulls are one of the most regularly recorded species at Rothera.

Antarctic tern (*Sterna vittata*)
Breeds locally, on Killingbeck Island, Reptile Ridge (c. 100 pairs) and on Lagoon Island and possibly Anchorage Island. About 60 terns, some of which were on nests, were noted on Rothera Point in February 1962 and a nesting colony of 100+ birds was reported at Rothera Point on 16 January 1969. However, the colony disappeared after the establishment of the station in 1976. Birds are seen commonly around Rothera Point between late September/early October and March and far more rarely in winter.

#### *Common Non-breeding Species at Rothera*

Emperor penguin (*Aptenodytes forsteri*)
Emperor penguins are rare, although almost annual, visitors, with seldom more than single birds seen although a group of 19 was recorded on 7 November 1977. Nearly all records fall between August and November.

Adélie penguin (*Pygoscelis adeliae*)
Seen almost daily during the summer months (late October to March) and less frequently, but still regularly, throughout the remainder of the year. In summer, counts vary greatly with up to 120 birds observed on East Beach on a single day. Winter occurrence is probably largely dependent on sea ice coverage; available records suggest that they become quite scarce when the sea ice is at its most extensive. During February and March, many of the birds present come ashore to moult. From late February to April, a small number of first-year birds are regularly recorded, although during the winter almost all birds are adults. Fragments of bone and egg shell in soil provide evidence of ancient penguin (mid to late Holocene), probably Adélie penguin, colonies on Rothera Point (Emslie and McDaniel, 2002).

Chinstrap penguin (*Pygoscelis antarctica*)
Rare summer visitors with records usually involving single birds between January and March.

### 5.1.5. Marine mammals

#### *Seals*

No seals use Rothera Point as a breeding site. Weddell seals (*Leptonychotes weddelli*) are the most obvious mammal and are present all year round in the area around Rothera Point (Figure 10-19) (BAS, 2017). In late September, pups are born out on the sea ice. Crabeater seals (*Lobodon carcinophagus*) and elephant seals (*Mirounga leonina*) are also present, and fur seals (*Arctocephalus gazelle*) arrive in varying numbers at the end of each summer. The leopard seal (*Hydrurga leptonyx*) is present all year round and, in 2003, an attack resulted in the death of a marine biologist at Rothera Point (Muir et al., 2006).

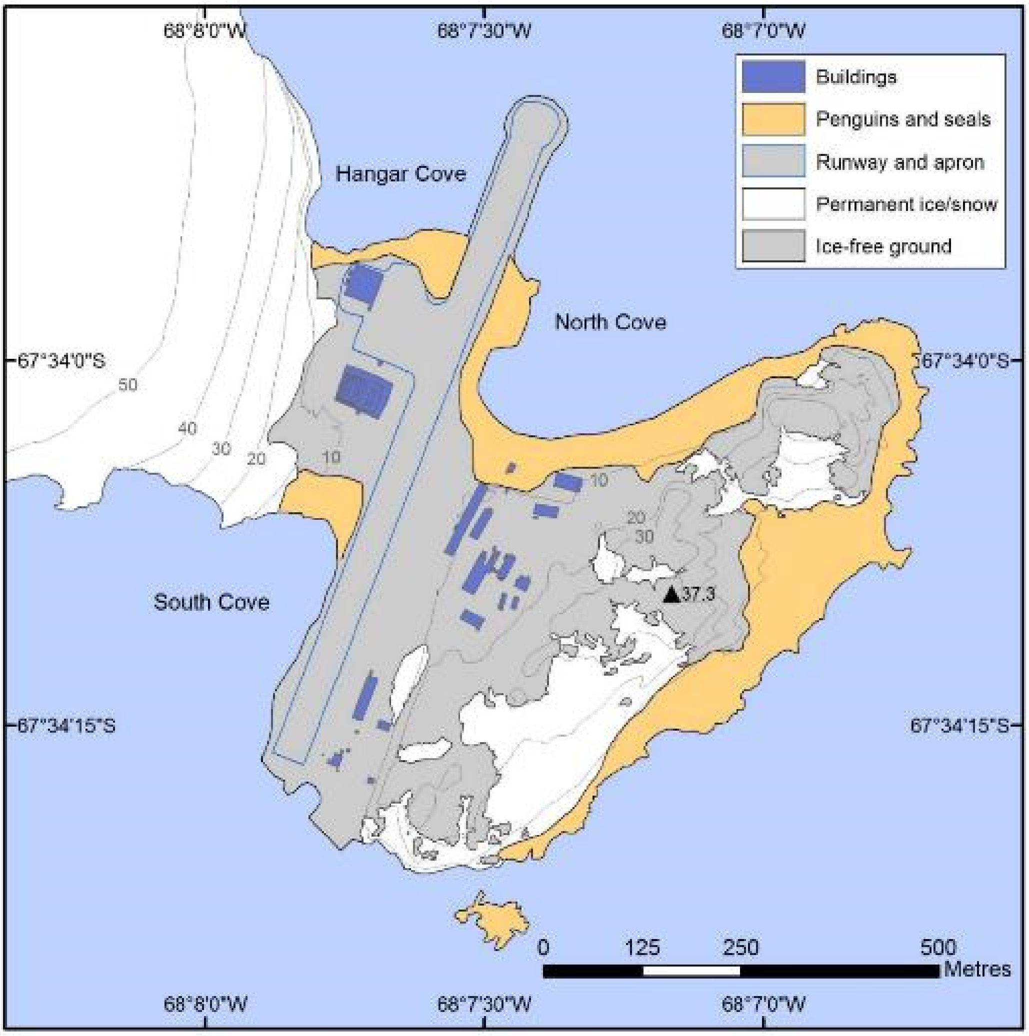


*Figure 5-19 Low lying area of Rothera Point where low densities of seals & penguins may be found commonly*

### *Whales*

Minke whales (*Balaenoptera bonaerensis)* and humpback whales (*Megaptera novaeangliae)* are seen in Ryder Bay each summer. During some years minke whales can be observed frequently and may be year-round residents, including within the ice pack if present. Some portion of the minke whale population may migrate seasonally, but little is known regarding this behaviour and what proportion of the population this represents. Tracking methodologies have shown that minke whales have a foraging hotspot on the western Antarctic Peninsula, with the Rothera Point area lying at the southern edge of this area (Ainley et al., 2012). Acoustic survey of blue whale vocalisations in the region found blue whales more likely to be located west of Adelaide Island with little evidence for substantial blue or fin whale activity in Marguerite Bay (Sirovic and Hildebrand, 2011). Killer whales (*Orcinus orca*) inhabit the larger Marguerite Bay area and are usually seen from the station several times each summer.

Humpback whales are seasonal residents, migrating between tropical breeding and calving grounds to feed along the Western Antarctic Peninsula in austral summer and autumn months. In spring and early summer, humpback whales are more generally observed at the pack edge, which shifts position as the season progresses. Antarctic krill are broadly distributed along the continental shelf and nearshore waters during the spring and early summer, and move closer to land during summer and autumn. More specifically, there are areas within Marguerite Bay with high krill predator occurrence rates including the area around Rothera Point and the northern extent of Marguerite Bay near the south eastern end of Adelaide Island (Friedlaender et al., 2011) (see Figure 10-19).

Observational data suggest that local waters around Rothera Point are summertime foraging habitat for humpback whales. Use of satellite-linked telemetry tags to monitor whale movements have corroborated these findings, showing whale distribution to reflect that of krill, i.e. spread broadly during summer with increasing proximity to shore as the season proceeds (Curtice et al., 2015). Niche partitioning has been observed between humpback and minke whales in this area, suggesting minke whales feed closer to the surface and humpbacks feed in deeper waters. Therefore, humpback whale occurrences are linked with prey availability, and numbers may increase as the summer season proceeds, with the peak period between December and April. These studies are further corroborated by observational data collected from Rothera Point (BAS, 2017) (see Figure 10-20). Minke whales are present year-round and may be more likely to be feed in shallower waters. Although more rarely observed from Rothera Point, blue whales may be more associated with water where sea ice persists, while fin whales are generally thought to reside further out to sea.

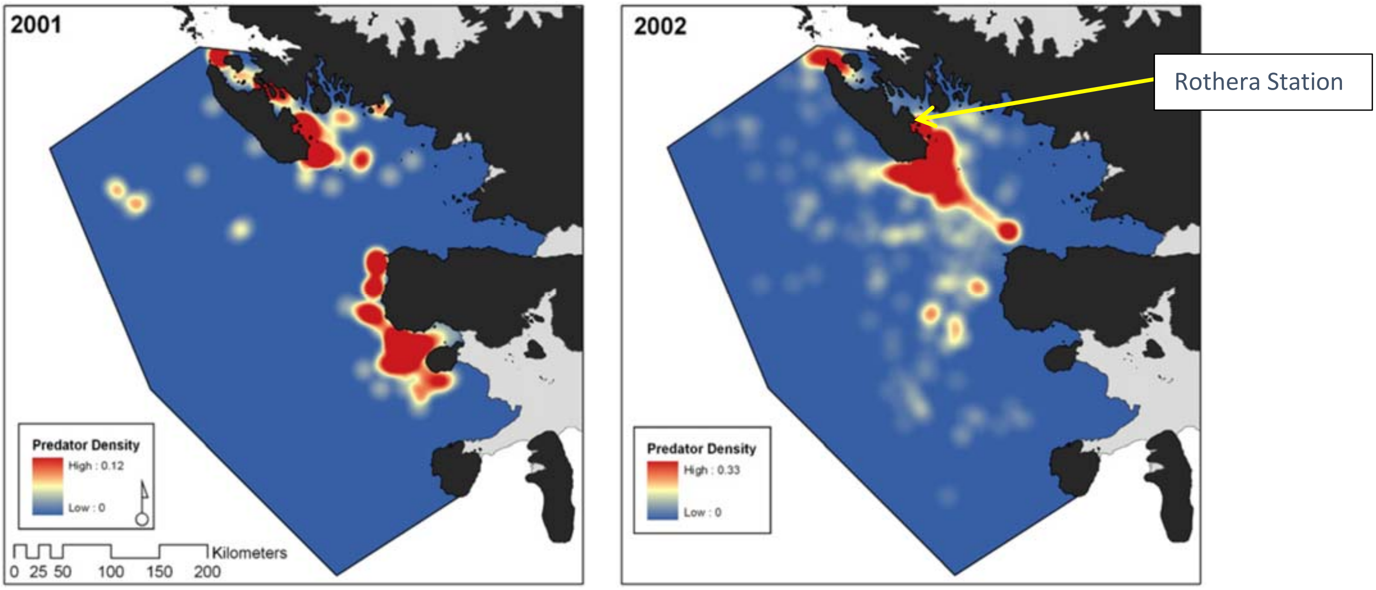


*Figure 5-20 Krill predatory distribution and habitat prediction plot for Marguerite Bay based on data collected during surveys undertaken in April to May (taken from Friedlaender et al., 2011)*

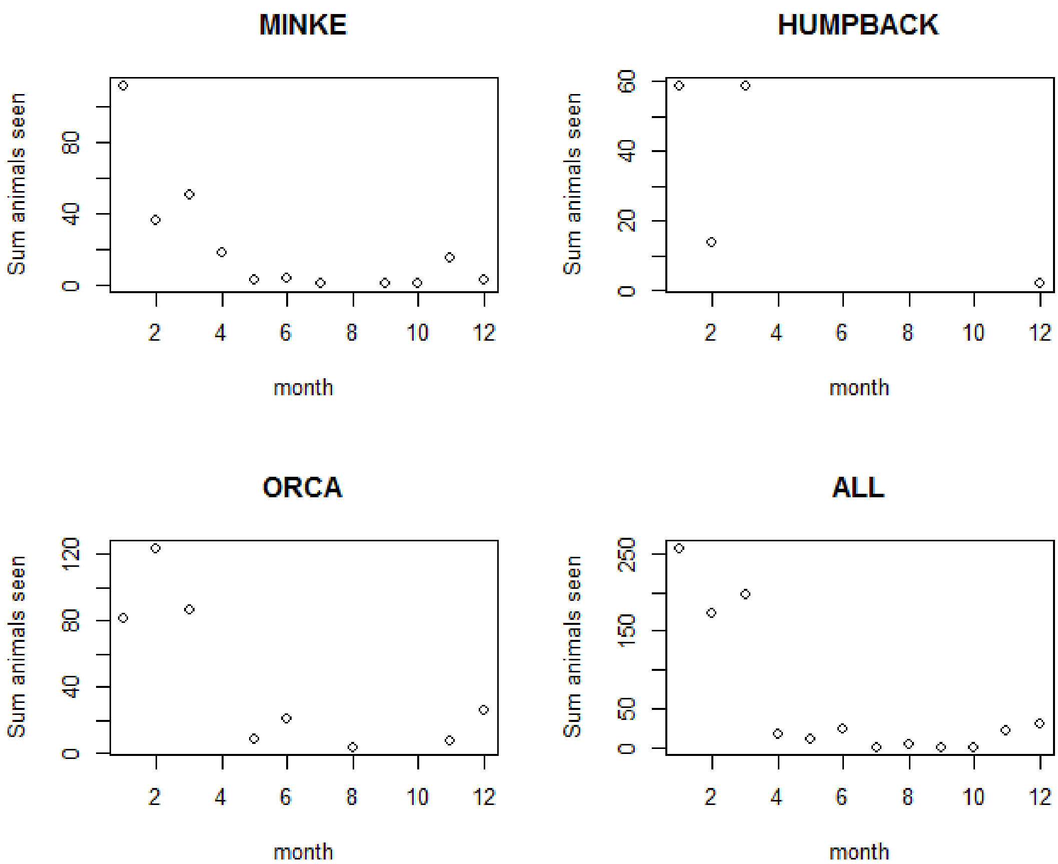


*Figure 5-21 Observational data of whale species from Rothera Point (2010-14)*

### 5.1.6. Non-native species

No non-native plants or invertebrates are known from Rothera Point or the adjacent marine environment. However, there was a report, dating from the mid-1990s, of the non-native collembolan (springtail) *Hypogastrura viatica* at Leonie Island, Marguerite Bay (Hughes et al., 2015). This is the most southerly record of the presence of a non-native species in the natural environment on the Antarctic Peninsula (see Figure 10-22).

As one of the most biologically rich terrestrial sites in the vicinity of Rothera Point, Leonie Island has been a focus of biological research visits for over two decades. Rothera Point acts as a logistics hub for aircraft operations across large areas of the Antarctic Peninsula and continental Antarctica. Should a non-native species be present at the station, there may be potential for this species to be inadvertently spread to other distant Antarctic locations via aircraft and also ship movements. A monitoring project was initiated in Jan 2015 to establish the presence and distribution of *Hypogastrura viatica* (non-native springtails) on the islands in Marguerite Bay and on Rothera Point (See Figure 10-23) (Hughes et al., 2017). Taxonomic expertise was provided by Dr. Penelope Greenslade of the University of Ballarat, Australia. No evidence for the presence of *Hypogastrura viatica* or any other non-native invertebrate was found in the c. 36,796 specimens collected. From these data we cannot categorically state that *H. viatica* is absent from the area, but given the number and distribution of samples collected, it is likely that it is present in only very low numbers and it is possible that it has become locally extinct.

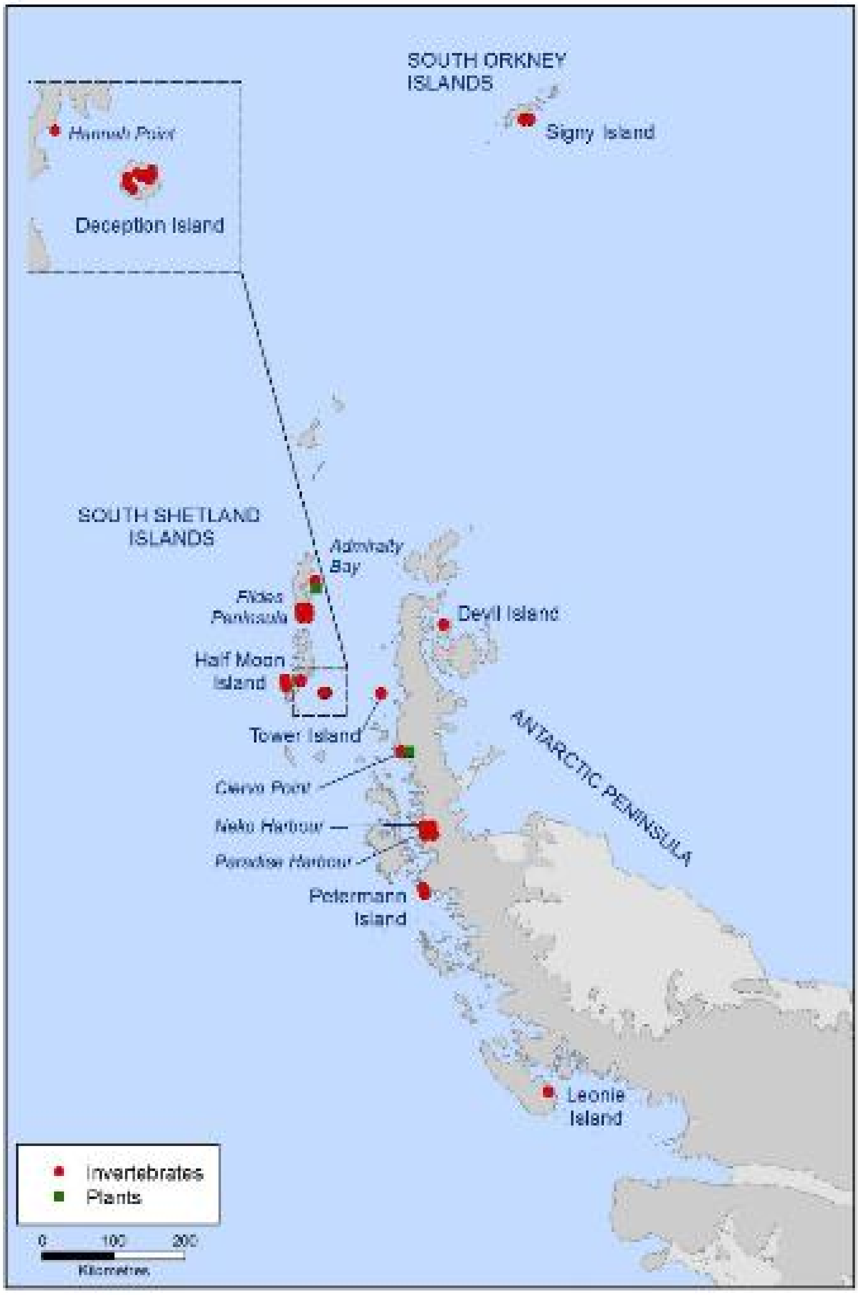


*Figure 5-22 Map of the Antarctic Peninsula region showing the distribution of known non-native species*

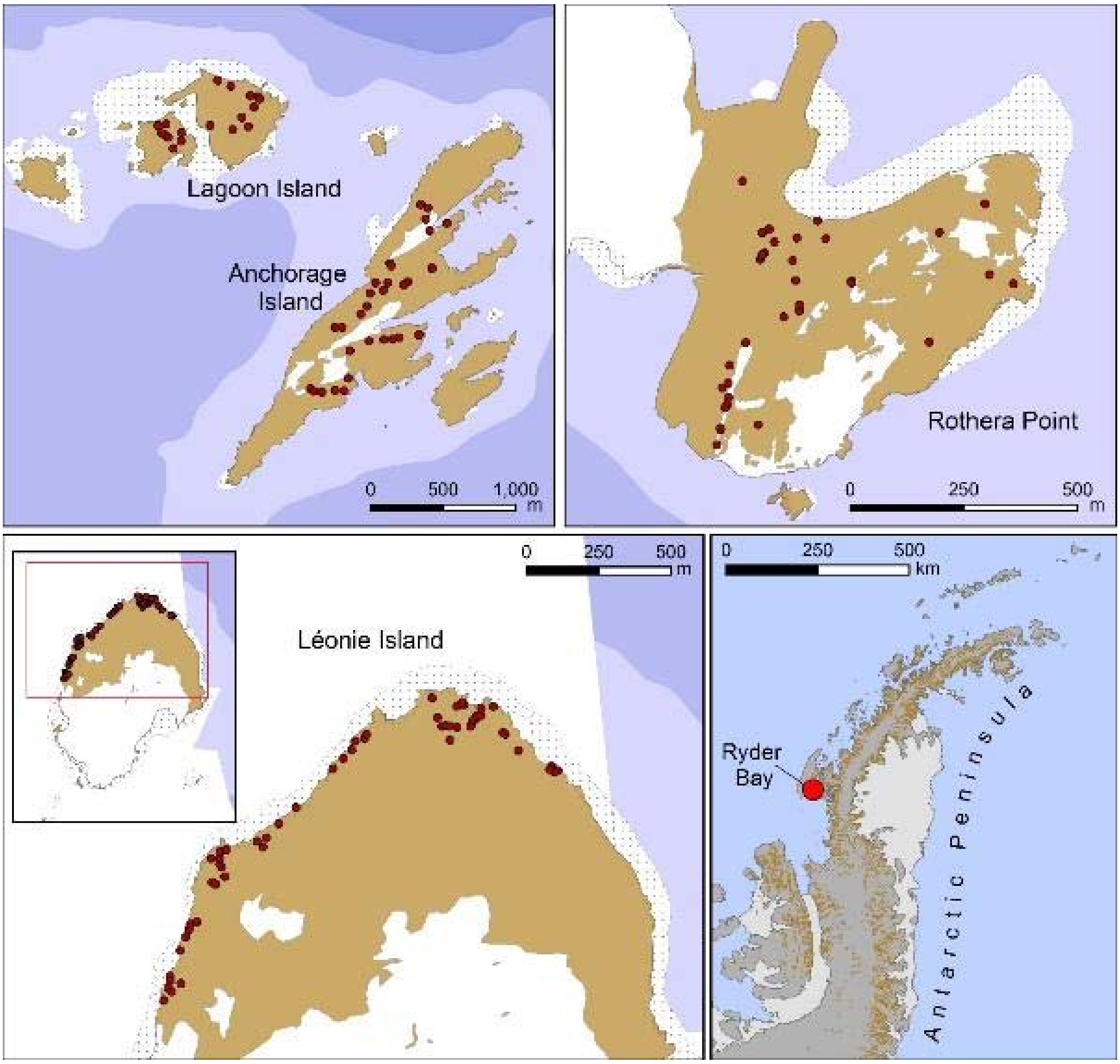


*Figure 5-23 Monitoring location for the non-native springtail* Hypogastrura viatica *in the vicinity of Rothera Point and islands of Marguerite Bay.*

## 5.2. Physical Characteristics

### 5.2.1. Meteorological Conditions

The climate is cold and dry and represents a transition from that typical of the more oceanically-influenced 'maritime' Antarctic to the north and the more extreme climate of 'continental' Antarctica to the south. A programme of surface synoptic meteorological measurements commenced at Rothera Research Station in 1977 (Turner et al., 2004). Mean monthly air temperatures range between c. -10.5 and + 1.4 °C (Figure 10-23), with the prevailing wind from the north-north-east and averaging at 12.1 m $s^{-1}$ (Figure10-25).

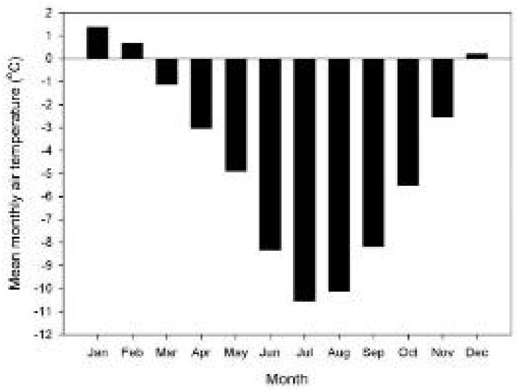


*Figure 5-24 Mean monthly air temperature at Rothera Point, Adelaide Island (1977-2015)*

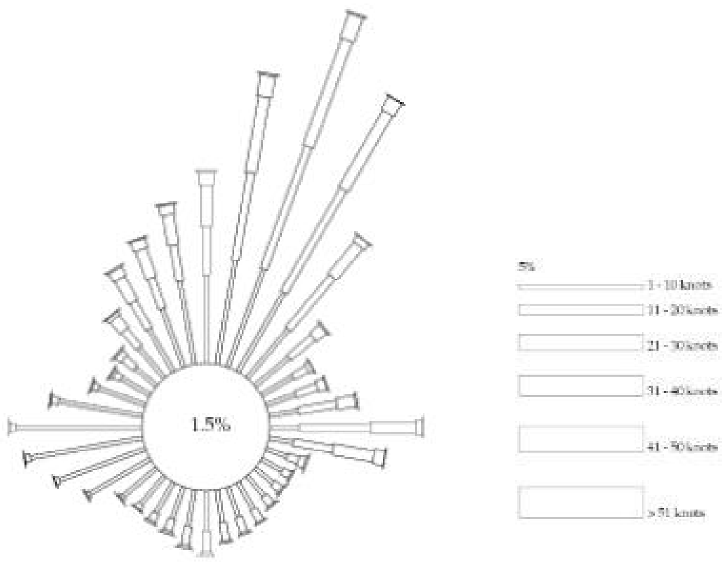


*Figure 5-25 Wind rose for Rothera Point, Adelaide Island*

### 5.2.2. Air Quality

No air quality data exist for Rothera Point; however, significant volumes of hydrocarbons are combusted in the vicinity of the station to power station generators and the engines of vehicles, ships, small boats and aircraft. Monitoring of heavy metals in lichens on Rothera Point undertaken between 1976 and 1989 showed pollution close to the station, particularly those areas affected by diesel generators and within c. 200 m to the northwest, north and northeast of the station, corresponding with the prevailing wind directions (Bonner et al., 1989). Beyond this area the concentrations progressively declined with increasing distance from the station. Nevertheless, the frequently high to moderate wind speeds in the area may rapidly disperse any pollutants, so minimising any impacts beyond the immediate vicinity of the pollution sources.

### 5.2.3. Tides and Waves

The tides at Rothera are diurnal (i.e. one high tide and one low tide each day). On some neap tides the difference between high and low water can be very small.

*Table 5-2 Tide Table*

Astronomical tides for Rothera Point are given on Admiralty chart 3462 as follows (CD: chart datum):

| State of the Tide | Abbrev. | Level |
|---|---|---|
| Mean High High Water | MHHW | +1.3 m CD |
| Mean Low Low Water | MLLW | +0.4 m CD |
| Mean Sea Level (taken as the mean of MHHW & MLLW) | MSL | +0.85 m CD |

### 5.2.4.Bathymetry

The seabed around Rothera Point shelves steeply and depths in excess of 500 m can be found within 5 km of the station. Water less than 50 m deep are restricted to the immediate fringes of the coastline. Currents along the coastline are minimal; however, the channel between Rothera Point and Killingbeck Island experiences current speeds in excess of 0.5 kts.

A bathymetric survey was conducted at Biscoe Wharf, Rothera Point, during February 2016 (Figure 10-26). The seabed was found to be steeply sloping (majority steeper than 25°angle) and consisted primarily of rock. Seawater depths reach 40 m within close proximity of the shoreline (c. 25 – 35 m).

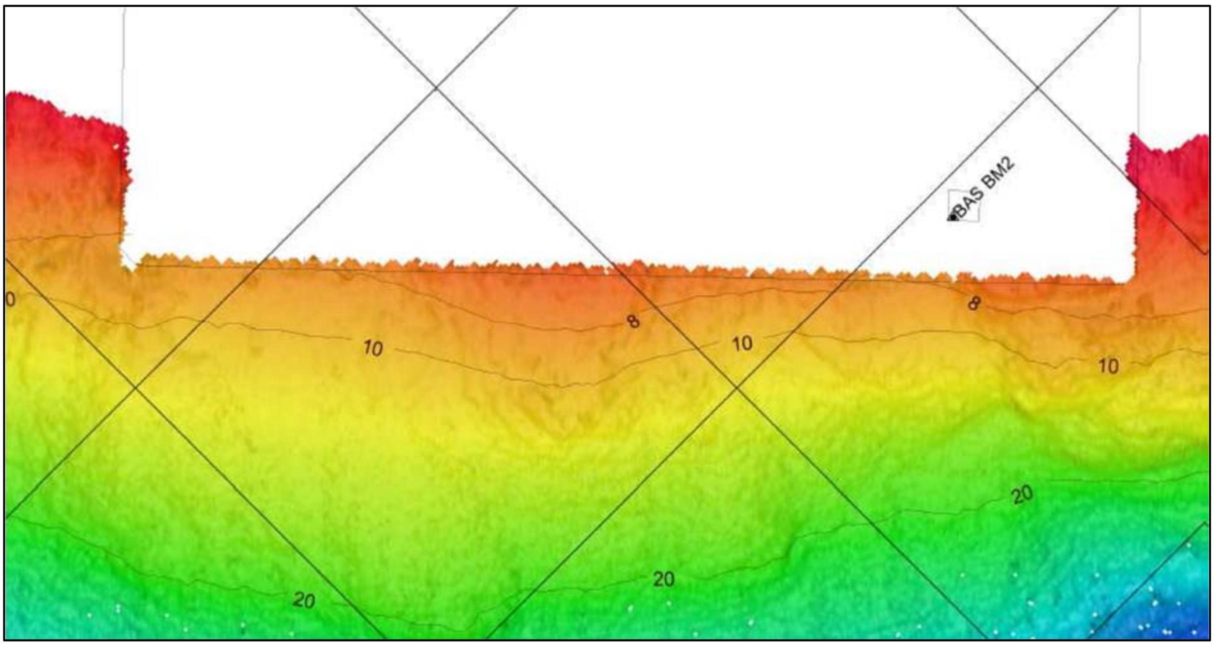


*Figure 5-26 Bathymetry data for the area immediately adjacent to the existing Biscoe Wharf*

## 5.3.Geomorphology

Rothera Point is a small peninsula situated on the southeast of Adelaide Island (Bonner et al., 1989). It is a low rocky headland of about 0.4 km$^2$ comprising a north-east to south-west trending, with a dissecting ridge rising to 39 m altitude. There is an area of raised beach composed of rounded boulders on the south-eastern side and similar but more extensive terrain (though composed of smaller stones and pebbles) on the north-west side. The latter forms an isthmus between North and South Cove and connects Rothera Point itself to Adelaide Island. The isthmus was extensively altered and widened during the construction of the gravel runway in the early 1990s. The sloping ice-ramp with a gradient of about 1:5 leads from the isthmus to the Wormald Ice Piedmont.

The rocks of Rothera Point have been subject to extensive frost shatter although some areas have been made smooth by the action of ice that has since retreated. A large ice-dammed melt pool that used to exist where Rothera Station now stands had disappeared by the early 1970s; its former shore lines were distinguished by more than 20 narrow terraces, but these are now largely indistinguishable due to station construction activities (Shears, 1995). Several poor quality raised beach terraces are present on East Beach, representing previous higher sea level episodes, and the process of isostatic rebound is thought to be on-going in the area. Raised beaches are also evident on the neighbouring Anchorage and Leonie islands and occur at 6, 18 and 23 m. Other areas of ice-free topography are widespread elsewhere in Laubeuf Fjord and northern Marguerite Bay, but few possess extensive level ground.

#### 5.3.1.Soils

Soil is restricted to small pockets of glacial till and sand intermixed with relictual penguin guano in depressions and amongst the rocks (ATS, 2017). Deeper deposits have permafrost and occur as scattered small circles and polygons of sorted material. There are no extensive areas of patterned ground and periglacial features are poorly represented. There are frequent accumulations of decaying limpet (*Nacella concinna*) shells deposited by gulls (*Lars dominicanus*), forming patches of calcareous 'soil'. The disappearance of snow and ice patches during the past 30 years has revealed deposits of organic mud, feathers and bones derived from an ancient Adelie penguin rookery (Emslie and McDaniel, 2002). Otherwise, there are no accumulations of organic matter, except for a very shallow layer of decaying moss peat beneath patches of moss.

#### 5.3.2.Surface Water

No large areas of freshwater exists on Rothera Point, with the exception of a c. 50 metre long transient pool located at the west fringe of the large area of permanent ice to the south of Rothera Point. Seasonal meltwater from the permanent ice feeds into this water body, which consequently fluctuates in level. During winter, and sometimes extending into the summer months, the surface of the water is not visible due to ice and snow cover. Transient streams may form at other locations around the Point, with flow rate depending upon the season and level of melt of the associated snow and ice bodies. The large relatively flat area of ground at East Beach may contain transient pools that may support algal and cyanobacterial communities. The flat area to the west of the Hangar may contain small transient meltwater pools.

### 5.4.Geology

The stratified rocks of central Adelaide Island are probably of Late Jurassic age, based on similarities to rocks from elsewhere on the west coast of the Antarctic Peninsula (Riley et al., 2012). The lithological unit that is directly relevant to Rothera Point and the surrounding area is the 'Adelaide Island intrusive suite' which is a series of isolated and composite granitoid plutons. A large part of the exposed geology on Adelaide Island consists of these plutonic rocks. Many of the plutons on Adelaide Island are heterogeneous and are characterised by concentrations of well-rounded xenoliths, which are typically more mafic than the host rock. The plutons can be seen to intrude the volcano-sedimentary sequences at several localities, including Reptile Ridge which lies at the top of the Rothera ice ramp.

The geology around Rothera Point is dominated by granodiorite, with minor amounts of quartz diorite and diorite. The geology of Rothera Point is interpreted to be consistent with the rest of the Adelaide Island intrusive suite and is therefore thought to be approximately 48 Ma (Eocene age). The mineralogy of the Rothera Point granodiorite consists of plagioclase, quartz, amphibole, biotite and variable amounts of chlorite and epidote, which has formed along cracks and joints in the rock, as a result of hydrothermal alteration. Malachite (copper) mineralisation is also a characteristic of the granodiorites of the Wright Peninsula and Rothera Point.

Close to the Memorial on Rothera Point (See Section 10.10), the primary lithology is granodiorite, although it is frequently characterised by abundant rounded mafic patches within the granodiorite host (Figure 10-27). The mafic 'blebs' are gabbroic in composition and are distinct to the xenolith-hosted granodiorite. The formation of this feature would have meant that the mafic blebs (gabbro) were relatively hot and less viscous compared to the 'colder' and more viscous granodiorite magma, therefore the gabbro would have 'frozen' when intruded into the granodiorite magma. This process where the gabbro and granodiorite magmas remain as distinct, recognizable rock types rather than becoming completely mixed is called 'magma-mingling'. With magma mingling there are some chemical interactions between the two magmas by slow and complex diffusional processes, but thermal equilibrium is reached long before chemical equilibrium, so the effects on the granodiorite composition are relatively minor.

*Figure 5-27 Magma mingling on Rothera Point.*

A geotechnical report has been produced based on the findings of a Site Investigation undertaken at Rothera in January 2017. This report has been included in Appendix I.

## 5.5.Glaciology

Access from Adelaide Island to Rothera Point is via an ice ramp forming the southern limit of the Wormald Ice Piedmont (Figure 10-27).

*Figure 5-28 The ice ramp that connects Rothera Point to the Wormald Ice Piedmont.*

The surface elevation of the ramp rises from 10 to 110 m asl, over a horizontal distance of around 600 m. Following the establishment of the scientific station in 1975, the ramp saw considerable year-round vehicle traffic, largely in support of aircraft operations from a skiway on the piedmont. This traffic increased steadily over the years. In early 1990, construction of a gravel runway between the station and ramp began and by 1992 all aircraft operations had been transferred to this runway. Subsequent traffic on the ramp has been light. A survey programme was initiated in February 1989 to monitor the ice ramp's mass balance and to detect any changes (Smith et al., 1998). The uppermost part of the ramp shows no clear decline in mass balance; however, lower sections of the ramp surface have lowered, in common with other sites on the Antarctic Peninsula (Figure 10-29). The deposition of dust on the ramp originating from the runway may also be contributing to surface lowering, and mitigation measures are employed to reduce dust dispersal from the runway. Studies suggest that the ramp has been subject to episodes of advance and retreat over longer timescales.

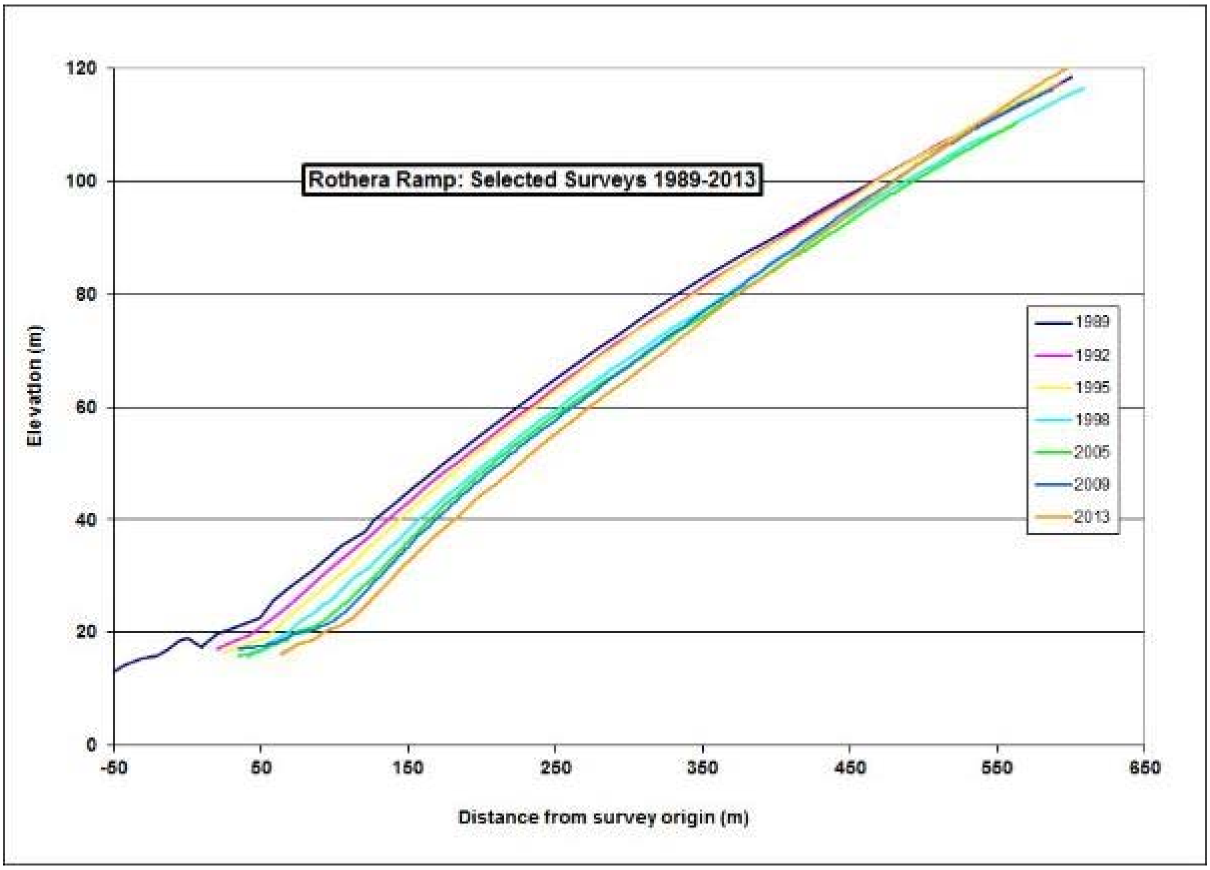


*Figure 5-29 Elevation of the Rothera ice ramp between 1989 and 2013.*

Several other areas of permanent ice exist on Rothera Point, notably to the south where ice cliffs have formed above the sea (to the east of the wharf) but also crossing the southern boundary of Antarctic Specially Protected Area No. 129 shown on Figure 10-30.

## 5.6. Permafrost

In February 2009 a new 30 m permafrost borehole was installed close to the British Antarctic Survey Station at Rothera Point, Adelaide Island (67.57195°S 68.12068°W) (Guglielmin et al., 2014). The borehole is situated at 31 m asl on a granodiorite knob with scattered lichen cover. Snow persistence is variable both spatially and temporally with snow free days per year ranging from 13 to more than 300, and maximum snow depths varying between 0.03 and 1.42 m. This variability is the main cause of high variability in ground surface temperatures, that ranged between − 3.7 and − 1.5 °C. The net effect of the snow cover is a cooling of the surface. The active layer thickness ranged between 0.76 and 1.40 m. Active layer thickness temporal variability was greater than reported at other sites at similar latitude in the Northern Hemisphere, or those with similar mean annual air temperature to the Maritime Antarctica, because vegetation and a soil organic horizon are absent at the study site. No change in temperatures during the year was observed at about 16 m depth, where the mean annual temperature was − 3 °C. Permafrost thickness was calculated to range between 112 and 157 m, depending on the heat flow values adopted. The presence of sub-sea permafrost cannot be excluded considering the depth of the shelf around Rothera Point and its glacial history.

## 5.7. Flood Risk

Tsunami risk is difficult to predict or mitigate against; however, the region lies within the influence of tectonic events around the Scotia Arc and may be subject to tsunami incidents at some points in the future. Nevertheless, the location of Rothera Point within Marguerite Bay on the east side of Adelaide Island, with the Antarctic Peninsula on the other side of Laubeuf Fjord, may afford some protection against the most severe impact of a tsunami with a more distant source.

Sea level rise is not expected to be sufficient over the anticipated lifespan of the wharf to present a significant threat and will be largely compensated for by on-going isostatic rebound in the region. Some local flood risk may be presented by the drainage of the freshwater pool located to the south of Rothera Point, should any alterations be made to the local topography during possible future construction work.

## 5.8. Noise & vibration

Rothera Point is already an area subject to substantial levels of noise originating from aircraft using the gravel runway, large vehicles for cargo transfer, construction purposes and snow movement, and occasional use of sirens to signal aircraft landings or a station emergency. Many of the marine mammals hauled out around the station and the non-breeding skuas that congregate, particularly at the north end of the runway, appear to be habituated to these noises and show little or no observable sign of disturbance. Adélie penguins that may congregate on East Beach are subject to less noise originating from the station and runway.

## 5.9. Protected Areas

The primary reason for the designation of ASPA No. 129 Rothera Point, Adelaide Island (Lat. 68°07’S, Long. 67°34’W), as an Antarctic Specially Protected Area (ASPA) is to protect scientific values, and primarily that the Area would serve as a control area. The intention was that the effects of human impact associated with the adjacent Rothera Research Station (UK) could be monitored in an Antarctic fellfield ecosystem (Figure 10-30) (ATS, 2017). Rothera Point was originally designated in Recommendation XIII-8 (1985, SSSI No. 9) after a proposal by the United Kingdom. The area itself has little intrinsic nature conservation value.

The ASPA is unique in Antarctica as it is the only protected area currently designated solely for its value in the monitoring of human impact. The objective is to use the ASPA as a control area that has been relatively unaffected by direct human impact, in assessing the impact of activities undertaken at Rothera Research Station on the Antarctic environment. Monitoring studies undertaken by the British Antarctic Survey (BAS) began at Rothera Point in 1976. On-going environmental monitoring activities within the Area and Rothera Point include: (i) assessment of heavy metal concentrations in lichens; (ii) measurement of hydrocarbon and metal concentrations in gravel and soils and (iii) survey of the breeding bird populations.

Entry into the ASPA is strictly prohibited unless in accordance with a permit issued by an appropriate national authority (e.g. the FCO Polar Regions Department).

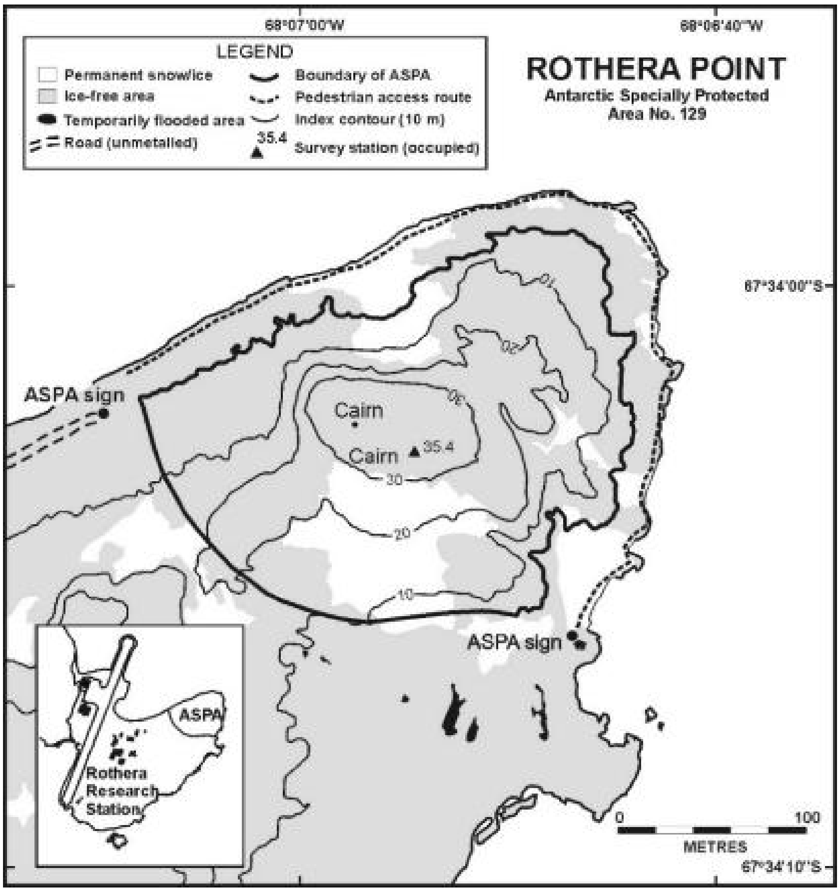


*Figure 5-30 Map of ASPA No. 129 Rothera Point, Adelaide Island*

## 5.10. Cultural Heritage

BAS has operated from Rothera since 1975, see Section 9.2. Whilst there are no formally designated Historic Sites and Monuments (HSMs) at Rothera, that station does have a rich cultural heritage which has developed over the years. Heritage is important to BAS and the wider UK Antarctic community so potential impacts to heritage are considered in this CEE.

A heritage survey was undertaken at Rothera in December 2016 by Ieuan Hopkins, BAS Archives Manager and Rachel Clarke, BAS Head of Environment, to identify objects with potential heritage significance.

The purpose of the survey was:

- to identify those items of heritage value which will require ongoing management and/or extraction prior to the Rothera re-development, to ensure that those items of heritage value put at risk by the station and wharf redevelopment are appropriately protected;
- to elicit the views of station personnel, as stakeholders, with regards heritage in general, and the heritage value of items at Rothera, to enable these views to be factored into the redevelopment process and assessments of heritage value.

The review was undertaken using the Heritage Selection Process, written in conjunction with the United Kingdom Antarctic Heritage Trust (UKAHT). This process aims to provide a systematic and consistent methodology for the identification of those objects (defined as either an artefact, building or site) with heritage value. Heritage is here defined as all inherited resources which people value for reasons beyond mere utility. (Historic England, 2008) This definition includes the widest range of physical 'things'. It also encompasses the range of emotional and intellectual values attached to them, (Hopkins, 2017).

The survey identified a number of objects with potentially broad heritage significance (i.e. significance to stakeholders other than station personnel, including former BAS staff, historians/heritage professionals and the general public). Numerous items were also found to have significance to those personnel living on the station, but not necessarily more broadly.

The views of staff on station with regards to the importance of heritage were also collected. A staff discussion on the subject of heritage was held, and involved a large proportion of the staff at Rothera. The importance of a sense of continuity and connection with the past was an aspect of heritage that was repeatedly voiced, as was a sense of trusteeship and respect for the heritage created and left by previous staff.

There are a number of memorial plaques, cairns and crosses at Rothera which hold heritage value for individuals, however none of them have been listed as an historic site or monument under the provisions of Article 8 of Annex V to the Environmental Protocol. The memorial plaques and crosses are for individuals who have lost their lives and were made or commissioned by colleagues of the deceased. Their construction or placement coincided with a memorial service. Their families were involved in, and greatly valued, these acts of commemoration.

After the heritage survey and on-station discussions were completed, it was concluded that the memorials at Rothera are regarded as having heritage significance for the UK nationally as well as for staff currently on station, former BAS staff and the families and friends of those who they commemorate. The specific location of these memorials, away from the station and facing away from station buildings, was also seen as important, and provides a space for reflection away from the pressures of station life.

In addition to the colleagues of the deceased, former BAS staff in general place importance on the commemoration of those who have died in the Antarctic. For current staff, the presence of the memorials enhances the sense of continuity with the past and provides a connection with their predecessors. As such, they are an important aspect of the identity of the station. Figure 10-31 shows the monuments in situ at the southern end of Rothera Point overlooking Ryder Bay.

*Figure 5-31 Rothera Monuments insitu*


*Figure 5-32 Location of  Rothera Monuments in relation to quarry*

The following memorials are sited at Rothera Point, Adelaide Island (67° 34' 1" S 68° 7' 44" W):

- Memorial plaque for Stanley E Black, David Statham and Geoffrey Stride, died 27 May 1958. Possibly erected in late 1970s but specific date unknown.
- Memorial cross, with plaque, for John H M Anderson and Robert Atkinson, died 16 May 1981 Erected March 1982.
- Memorial cairn, with plaque, for Kirsty M Brown, died 22 July 2003.  Erected 2004 - 2005
- Memorial plaque for N J Armstrong (Canada), D N Fredlund (Canada), J C Armstrong (Canada) and E P Odegard (Norway), died 23 Nov 1994. Erection date unknown.  It is understood that this is visited periodically and the hip flask on the side refilled.

- The British Antarctic Sledge Dog plaque. Erected 2009 (assumed).

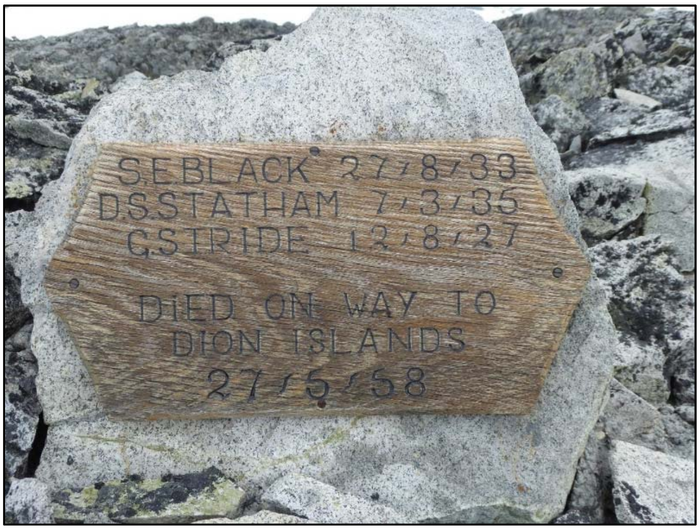


*Figure 5-33 Memorial plaque for Stanley E Black, David Statham and Geoffrey Stride*

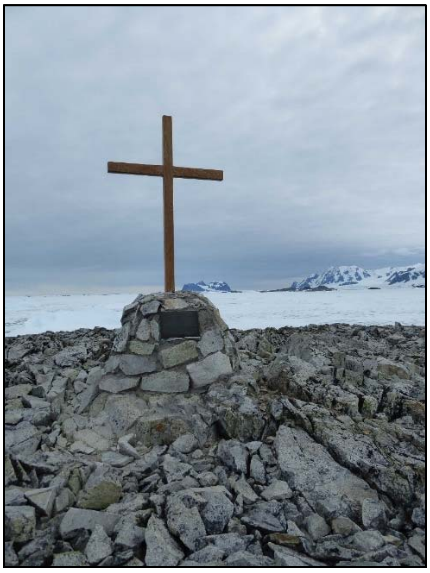


*Figure 5-34 Memorial cross (left), with plaque underneath (right), for John H M Anderson and Robert Atkinson*

*Figure 5-35 Memorial cairn, with plaque, for Kirsty M Brown insitu (left), and prior to deployment (right)*


*Figure 5-36 Memorial plaque from three angles, for N J Armstrong (Canada), D N Fredlund (Canada), J C Armstrong (Canada) and E P Odegard (Norway)*


*Figure 5-37 The British Antarctic Sledge Dog plaque.*

Within the ASPA (129) on Rothera Point there is a cairn, built from rocks. It was erected in September 1957 by Nigel Procter and used in October 1957 by John Rothera as a survey station during the first mapping of the area, referred to as Adelaide Island Trig Point (see relevant reports in BAS Archives, refs. AD6/2Y/1957/K13 and 14).

## 5.11. Wilderness & Aesthetic Value

Whilst there is not an internationally agreed definition of aesthetic value in Antarctica, it is generally characterised by the lack of visible evidence of human activity including permanent infrastructure. In addition the wilderness value of a location in Antarctica is often related to a feeling of remoteness (Tin and Summerson, 2013).

Rothera Research Station has been the main BAS research and operational hub within Antarctica for more than 40 years concentrating its infrastructure development largely within the confines of the 0.4 $km^2$ area of Rothera Point. This concentration of activity within a small area means that there has not been an on-going expansion of the station footprint (as observed at other Antarctic stations), not least because space for construction is limited.

A result of this constraint is that evidence of human presence is visible from most areas of Rothera Point; however, the great majority of infrastructure has been construction on the northwest side of the central rocky north-east to south-west trending ridge that dissects Rothera Point. Consequently, it is possible to experience a genuine wilderness experience when on East Beach and on the northern fringes of Antarctic Specially Protected Area No. 129. Indeed, it is common for station personnel wanting to get away from busy station life to go for a 'walk round the Point', which involves walking around the northern fringes of the ASPA to East Beach and then up to the memorial cross before returning to station. With most of the infrastructure confined to the Point itself, views in almost every direction away from the Point show near pristine Antarctic scenery of outstanding wilderness and aesthetic value (Figure 10-38). The proposed works are within what is considered to be the existing footprint of station.

*Figure 5-38 View from Rothera Point across Marguerite Bay to Leonie Island, and the Princess Royal Range beyond*

## 5.12. Climate Change Projections

Rothera Point has been subject to human activity for over 40 years and in that time some parts have been dramatically modified from their original state, while others remain relatively free of impacts. Coupled with this, climate variability has resulted in changes in marine, terrestrial and ice characteristics around Rothera Point with consequent impacts upon local marine and terrestrial ecosystems. On-going development of BAS' logistical capacity at Rothera will likely result in further modifications of the environment, with impacts likely to be minimised if constrained to areas of existing human activity and impact. Climate change impacts may be more difficult or impossible to mitigate, which may have substantial impacts on elements of the logistical capacity at the station.

### *Changes in ice scour of the benthic environment*

Recent research suggests losses of fast-ice around Rothera Research Station have contributed to higher iceberg scouring rates and rising mortality of some benthic species. It is considered that fast–ice provides a buffering effect to the movement of icebergs. Daily records of fast-ice presence/absence from 1986 to 2010 and annual ice-scour impact rates have shown a decreasing trend in the duration of fast-ice years and a coincident increase in scouring. However, three more years of data revealed that this is more aptly described as a decrease to a tipping point at 2006, after which fast-ice has been anomalously brief each year and ice scour has been high (see Figure 10-39 below).

The annual survey of iceberg disturbance at Rothera Research Station is thought to be the longest running and most comprehensive direct measure of marine ice disturbance (Barnes et al., 2014). The number of annual iceberg impacts has, similarly to fast-ice, varied much between years but impacts have increased in recent years. The fewest impacts matched the years which had the longest duration of fast-ice within the study period and likewise the years with most impacts were the two years with briefest fast-ice. The link between fast-ice duration and iceberg scouring is important because scouring is the dominant cause of mortality to fauna in the shallows. Survival from ice scouring at this depth can be less than 1% of the fauna. So both the shallows and deep shelf are mosaics of faunas recovering from impacts; the former are dominated by pioneers and free space whilst the latter are a mixture including 'climax' assemblages perhaps thousands of years old. The study by Barnes et al. (2014) was conducted in South Cove, which is generally shallower and more sheltered than the wharf area. It is likely that impact damage around the wharf could be more severe due to the larger scale of ice-bergs that can reach the wharf due to the deeper water and steeper sea bed slope angle (see section on Bathymetry).

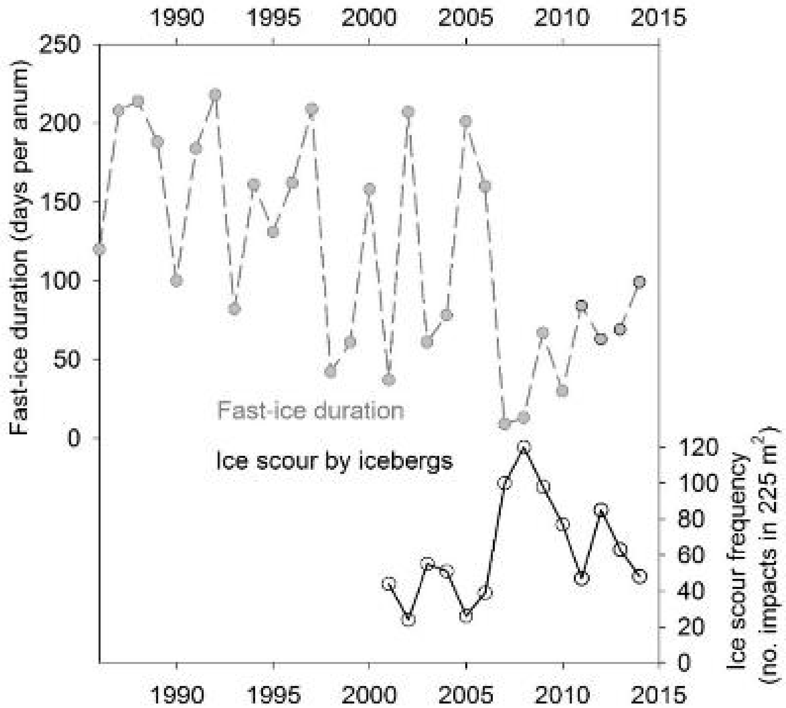


*Figure 5-39 Prevalence of fast ice and ice scour at South Cove, Rothera Point. Fast-ice duration (top), the number of experimental markers hit by icebergs (bottom).*

## 5.13. Future Environmental Reference State

The proposed Rothera Wharf reconstruction and coastal stabilisation works are within the current footprint of Rothera Research Station and are largely on previously disturbed ground. The wharf extension will slightly expand the current wharf footprint and reduce the existing marine benthic habitat. The area proposed to be used to source rock is within the current station footprint but has not previously been quarried. As a result the local topography will be altered by the quarrying works.

On completion of all construction activities it is not anticipated that the future state of the environment will differ greatly from the existing condition, as result of the works. The main impacts will be experienced during the two season construction period which are likely to be temporary. A full impact assessment of the activities is presented in Section 11: Impact Identification and Mitigation.

# 6. IMPACT IDENTIFICATION & MITIGATION

Environmental impacts associated with the activities described in this CEE have been identified in this chapter. The impacts have been divided into the following sections:

- Impacts of general construction activities;
- Rothera Wharf impacts;
- Quarry, drilling & blasting impacts; and
- Coastal stabilisation impacts.

Each impact has been identified as direct, indirect, cumulative and/or unavoidable, (definitions are provided in Section 12.1) Mitigation measures to minimise or avoid these impacts are provided in each section. Where relevant monitoring activities have also been listed however a detailed monitoring plan is included appendix F.

A full assessment of the impacts is provided in Section 12. Cumulative impacts are discussed in Section 12.3.

## 6.1. Impacts of General Construction Activity

### 6.1.1. Importation of cargo

**Potential Impact: Indirect**
Non-native species may be imported unintentionally to Rothera and the local vicinity in association with equipment and general cargo. Introduced species may become established in ice-free areas with negative impacts upon local ecosystem structure and function, endemic species and associated scientific research.

Consideration of this risk was factored into the project design when deciding whether to import rock fill for the wharf or whether to quarry locally. Obtaining the rock locally on site significantly reduces the risk of non-native species importation.

**Mitigation:**

- All personnel being deployed to Rothera will received a pre-deployment briefing from a member of the BAS Environment Office, which will cover biosecurity, waste management, oil spill response and wildlife interactions.
- All activities will be undertaken in accordance with the Biosecurity Plan: Rothera (included in Appendix E) and the BAS Biosecurity Handbook (compiled with reference to the CEP's Non Native Species Manual).
- A trained manager will inspect all plant, equipment, materials and personal belongings prior to loading onto the vessel and on disembarkation/offloading at Rothera.
- The following requirements will be placed in all plant and equipment to be shipped to Rothera:
  - All re-usable containers will be thoroughly cleaned and lined with plastic sheeting.
  - No polystyrene or organic packaging material, including hay straw or wood shavings, will be used.

- ➢ All wood packaging and wood products will be new and comply with ISPM 15[10].
- ➢ No corrugated cardboard packaging material will be used.
- ➢ Openings in structural members will be sealed.
- ➢ Containers will be cleaned and fumigated.

- All equipment and materials required for the proposed activity will be thoroughly cleaned before dispatch to Antarctica. This includes all the items of equipment listed in Appendix C Equipment List.
- Should soil, seeds or propagules be imported unintentionally, they must be carefully collected and removed. Rodents and insects must be exterminated immediately. Disposal may include incineration at Rothera or removal from Antarctica.
- The Rothera Station Leader and the BAS Environment Office must be informed immediately if a biosecurity incident occurs.

### 6.1.2. Deployment of personnel and associated luggage/cargo

**i) Potential Impact: Indirect**

Impacts upon Antarctic ecosystems as described above in Section 11.1.1.

**Mitigation:**

- All personnel being deployed to Rothera will receive a pre-deployment briefing from a member of the BAS Environment Office, which will include biosecurity.
- All personnel being deployed to Rothera will have read, and must comply with, the Biosecurity Plan: Rothera (Appendix E) before departing their home country.
- All personal items of clothing and cargo should be thoroughly cleaned and checked for soils, plants, propagules or insects.
- Should soil, seeds or propagules be imported accidentally, they must be carefully collected and removed. Rodents and insects must be exterminated immediately. Disposal may include incineration at Rothera or removal from Antarctica.
- The Rothera Station Leader and the BAS Environment Office will be informed immediately if a biosecurity incident occurs.

**ii) Potential Impact: Indirect & cumulative**

There will be a minor but cumulative contribution to global atmospheric pollution as a result of transporting people and cargo to site during construction.

The predicted greenhouse gas emissions associated with transporting personnel to Antarctica for the construction period is estimated at 443 tonnes $CO_2$ equivalent[11]. The predicted emissions associated with the use of a charter ship is anticipated to be between 1,800 – 2,600 tonnes of $CO_2$ equivalent per mobilisation, dependant on the actual ship, choice of routes and sea ice conditions.

**Monitoring:**

- Data will be collected and the increased contribution to atmospheric pollution from the deployment of personnel and cargo and any associated ship charter will be accounted for

[10] ISPM 15 is an International Phytosanitary Measure that directly addresses the need to treat wood materials of a thickness greater than 6mm. Its main purpose is to prevent the international transport and spread of disease and insects that could negatively affect plants or ecosystems.

[11] GHG emissions have been calculated using UK Government GHG conversion factors for company reporting 2017.

in the overall BAS carbon accounts.

### 6.1.3. Increased number of people on station

**(i) Potential Impact: Direct**

The potential impact is the pollution of the marine environment. The increased production of sewage and grey water will lead to a greater volume of waste discharged into the marine environment which could result in pollution and potentially disease in marine flora and fauna and could impact future science.

The discharge of sewage at Rothera meets the requirements of the Environmental Protocol through the process of maceration. Under normal operating conditions the sewage treatment plant (STP) at Rothera treats waste biologically and is UV irradiated prior to discharge. During the 2018-2019 season the STP will be undergoing maintenance works and will not be operational. It is anticipated that the STP will be fully functioning in the 2019-2020 season. During the maintenance period all sewage at Rothera will be macerated only prior to discharge into the sea.

**Mitigation:**

Any additional toilets and washing facilities will be connected to the existing foul drainage system. Human waste from the construction team will be macerated as per the rest of the Rothera Station waste and discharged into the sea at the current discharge point.

**(ii) Potential Impact:**

Increased water demand for domestic and construction activities resulting in increased use of power for additional reverse osmosis plant. BAS Estates have confirmed that potable water requirements can be provided by the existing system, based on current estimates.

If additional demand for potable water cannot be met using the current reverse osmosis plant, additional plant will be installed for the duration of the project.

**Mitigation:**

- Where possible sea water will be used for construction activities, damping down dust (in non-vegetated areas only), and cleaning equipment.

### 6.1.4. Waste Management

**(i) Potential Impact: Direct**

An increase in the volume of waste produced on station will occur as a result of the construction activity which in turn will lead to an increase in amount of waste to be removed from station and sent to landfill in the UK.

**Mitigation:**

- The Site Waste Management Plan: Rothera (See Appendix D) will be followed for all construction waste and the BAS Waste Management Handbook for all domestic waste.
- All construction waste will be returned to the UK and disposed of by licenced contractors.

- Minimise packaging materials wherever possible and practical.
- Commitment to achieving 80% diversion of waste from landfill for construction waste.

**Monitoring:**

- Waste statistics will be collated for future monitoring purposes.

**(ii)** **Potential Impact: Direct**

Increased risk of loss of waste to the local environment, which could cause marine and terrestrial pollution and be a hazard to local wildlife.

**Mitigation:**

- Current BAS waste management procedures to be followed.
- Dedicated areas for segregation and storage of construction waste on site. See Figure 3-15.
- Waste to be stored inside bunded containers or in skips (metal waste only).
- Provision of staff member dedicated to environmental management who will ensure waste is managed in accordance with BAS Waste Management Handbook and the Site Waste Management Plan.
- All construction staff will attend pre-deployment training on environmental management including waste management.

**Monitoring:**

- Daily checks will be undertaken to ensure that all equipment and packaging is appropriately weighed down to avoid being blown around site.

### 6.1.5.Use of vehicles, plant and generators

**(i)** **Potential Impact:**

There will be a fuel requirement for approximately 982,200 litres of MGO fuel for the wharf and 18,000 litres for the coastal stabilisation works.When combusted the impact will be a contribution to global atmospheric pollution and will increase metal and particulate fallout locally.

**Mitigation:**

- Fuel management procedures have been developed so as to actively regulate fuel use, minimise the risk of spills and respond effectively to a spill should one occur. Details are provided in Section 6.1 Fuel Management and Oil Spill Response.
  Emphasis in tool box talks for all plant operators to switch off engines when not in use. All equipment will be running on engines compliant with STAGE II or above EU emission regulations.

**Monitoring:**

- Fuel use will be recorded and included in the overall carbon data for BAS.
- Ongoing long term monitoring in the ASPA for metal and particulate fallout.

**(ii)** **Potential Impact: Direct & cumulative**

Minor but cumulative contribution to regional and global atmospheric pollution and an increase in heavy metal and particulate fallout locally.

The predicted greenhouse gas emissions for the fuel use associated with the Rothera

Wharf reconstruction and associated rock extraction works, equates to approximately 2,720 tonnes $CO_2$ equivalent. The estimation for the coastal stabilisation works equates to approx. 50 tonnes $CO_2$ equivalent.

**Mitigation:**

- Generators and plant will be selected that balance efficiency with reduced emissions.
- Regular maintenance and daily checks of vehicles and generators will be undertaken
- Staff will be instructed to turn off vehicles when not in use
- All equipment will be running on engines compliant with STAGE II or above EU emission regulations.

**Monitoring:**

- Fuel use will be recorded and included in the overall carbon data for BAS.

**(iii) Potential Impact: Direct & indirect**

Oil spills and fuel leaks could occur during refuelling of the excavators, or through damage to equipment during operation e.g. hydraulic hose burst. This could lead to contamination of the local area. A range of activities, from a minor fuel leak from hoses through to catastrophic failure of the fuel tank, could result in contamination of the terrestrial or marine environments. This could lead to mortality of fauna and flora in the local vicinity directly or indirectly through ingestion of contaminated food sources. Hazardous waste will be generated as a result of any spill response, e.g. contaminated absorbents.

**Mitigation:**

- All plant will be well maintained and inspected daily ensuring good fuel economy and reducing the risk of oil and hydraulic leaks. Daily plant inspections will be recorded.
- The equipment to be used on site will only require the use of small quantities of fuel.
- All refuelling will be carried out by trained personnel in accordance with the station's refuelling procedures. This will be coordinated and confirmed with Rothera Station Management.
- All construction staff will receive training on emergency spill procedures.
- Spill kits containing floating booms and floating oil absorbent pads will be kept with equipment and plant used near water throughout the works.
- The Rothera Oil Spill Contingency Plan (OSCP) is to be followed in the event of a spill.
- All spills will be reported to the Station Leader at the time of occurrence.
- As described in the Rothera OSCP, Tier 1 spills will be dealt with by the construction team.
- Tier 2 or 3 spills will be coordinated by Rothera Station Leader
- Any spills over water will be considered as a Tier 2 spill and will be reported to the Rothera Station Leader immediately.
- The construction team will assist with any spill response under the co-ordination of the Rothera Station Leader.
- All spills are to be reported to the BAS Environment Office.

**(iv) Potential Impact: Direct**

Disturbance by vehicles, plant or equipment to local fauna including seals, penguins and skuas could result in avoidant, aggressive or stress behaviour, injury or fatality of animal.

**Mitigation:**

- All access routes for plant and vehicles will be clearly demarcated.

- All vehicles to be inspected and wheels checked for presence of seals and penguins before engines started.
- If seal displacement is deemed essential this will be undertaken by a nominated trained staff member.
- All construction activity to take place away from areas frequented by penguins and seals.

**Monitoring:**

- All seal displacements will be recorded for monitoring purposes (See Appendix F for Monitoring Plan: Rothera).
- Long term BAS skua monitoring programme to continue throughout construction period.

### 6.1.6.General Construction Activity on Station

**Potential Impact: Direct**

An increase in personnel on station combined with the day to day disruption of construction works could result in fewer days of science being supported by Rothera during the next two seasons.

**Mitigation:** Access to the station for scientific personnel will be maintained as best as possible throughout the two year period and alternative arrangements provided where possible. Additional accommodation has been provided for construction staff to minimise the impact on bed nights for scientists. Field campaigns supported by Rothera will generally not be affected by the construction works.

It is acknowledged however that there will be some constraints for science activities within the Gerritsz Laboratory. There are normally four projects conducted in the Gerritsz Laboratory each season. Of these only one has been postponed due to the construction project. The others will be supported by the Rothera Bonner Laboratory or will have restricted access to Gerritsz Laboratory during appropriate times whilst construction is being undertaken.

Allowances for continuing normal boating operations to undertake marine science have been made as per Section 7.6 of this document.

The business case for the new wharf once it is operation is to improve the efficiency of BAS operations by accommodating the RRS Sir David Attenborough (SDA) at Rothera. The new operating dynamic will enable relief to be undertaken more rapidly enabling the SDA to undertake more science days.

## 6.2. Rothera Wharf Impacts

### 6.2.1. Dust deposition

**Potential Impact: Indirect & cumulative**

The process of removing rock infill from the existing wharf, either through blasting or excavation, will produce dust. In addition, once the new wharf structure has been built, infilling with rock will also produce dust. The generation of dust has potential to impact soil organisms and vegetation through direct contact and smothering.

**Mitigation:**

- Activities will be suspended by the Site Manager on excessively windy days or when wind is blowing in the direction of sensitive receptors, which include vegetated areas on the northern part of Rothera Point and the ice ramp. This will be arranged in liaison with the Station Leader.
- Dust from plant operations will be controlled by spraying plant and access roads with sea water (in non-vegetated areas only).
- The drop height of rock fill will be limited to minimise dust when infilling the new wharf.

### 6.2.2. Sound pressure waves in the marine environment (underwater rock breaking)

**Potential Impact: Direct**

The activity of rock breaking and drilling has the potential to disturb marine mammals potentially resulting in avoidance behaviour or hearing damage.

A noise assessment for the equipment proposed to be used for underwater rock breaking, rock blasting, piling and drilling has been conducted by noise experts, Aquatera. The following mitigation measures are a summary of the conclusions of that assessment included in Appendix G: Noise Assessment.

**Mitigation:**

- Two, trained Marine Fauna Observers (MFOs) employed by BAM, will be deployed when any submerged underwater rock breaking operations are in progress. One MFO will be positioned on the highest point of Rothera Point overlooking the wharf and Ryder Bay. The other will be positioned either at the wharf or at the end of the runway depending on where the works are being carried out.
- Each MFO will be equipped with binoculars and radios in order to be able to communicate with each other and directly to those responsible on site for rock breaking operations.
- The observational zone for rock breaking will extend to 500m and the MFOs must be satisfied that they have visibility throughout the entire zone. Each MFO will be in place 30 minutes before operations begin. The specific extent of the zone of observation will be mapped in advance by the MFOs for each rock breaking location. This will be an arc bounded by any promontories of adjacent shorelines, and will include any embayments within these and extend seaward to 500 m.
- A soft start period of 20 minutes will be adhered to. This will involve either a gradual working from shallow water where the tool is only partially submerged, to full

immersion. Or it will involve the gradual increase from short bursts of activity of a few seconds building up to continuous operations.

- A continuous watching brief will be maintained for cetaceans in the area. Special care will be required where there have been extended periods beyond 10 minutes where operations may have temporarily ceased, to ensure that animals have not entered this zone during such periods. Under these circumstances, soft start should be recommenced.
- Passive acoustic monitoring will be undertaken using a hydrophone to monitor the presence of marine mammals within the observation zone, prior to rock breaking. If mammals are present during the 30 minutes prior to operations, the 30 minute observations will be reset.

**Monitoring:**

- A log of marine mammal activity by species will be kept and details of any consequent actions will be maintained by each MFO throughout periods in which operations are taking place. These will be kept for auditing purposes and for use in any subsequent environmental impact assessments.

### 6.2.3.Sound pressure waves in the marine environment (underwater blasting)

**Potential Impact: Direct**

Peak pressure pulses in the water from the detonation of confined explosive[12] charges have the potential to harm divers, marine fauna or diving birds. Some minor fish kill is a possibility. This may be caused when blasting is under the water, or in close proximity to the water.

Where explosives are fired in water, a pressure pulse is generated which attenuates with time and distance in a similar way to sound waves in air. In addition, gases are released into the water causing bubbles to form which oscillate and collapse and may cause negative pressures. A brief summary of the result of this activity is included here. For further details refer to Appendix A Marine Drilling & Blasting Management Plan.

For charges suspended directly in a body of water a relationship exists between the peak pressure pulse, distance and charge weight as follows:

$$\text{Peak pressure pulse } P_{\text{unconfined}} = 55\text{x}10^3\ (D/W^{1/3})^{-1.13}$$

where W is the charge weight in kg, D the distance in metres and P the pressure in kpa.

Blasting will only be undertaken when no divers are in the water within the Rothera area and there are no non project vessels are within 1200m. Project vessels will be limited to 200m from the blasting. The level of the peak pressure pulse transmitted to the water is site specific and depends on factors such as geology and seabed topography, however, there are reduction factors for confined explosives that can be applied following experience or published texts. Langefors & Kihlstrom 1963 suggests

[12] If the explosive is 'confined' before detonation, the force produced is focused on a much smaller area, and the pressure is massively intensified. This results in explosive velocity that is higher than if the explosive had been detonated in open air.

levels of 0.10 to 0.14 of the unconfined pressure pulse. Oriard 2005 suggests levels of 0.1 to 0.33 of the unconfined value.

Data collected from two similar blasting projects gave measured average peak pressure of 0.08 (maximum 0.26) of that predicted for unconfined values (from 210 blasts). Using the maximum value recorded from 210 blasts and 326 measurements of $0.26*P_{unconfined}$ when the average value was $0.08*P_{unconfined}$ is considered conservative and comparative to the published texts.

Therefore Peak pressure pulse $P_{confined} = 14.3x10^3 (D/W^{1/3})^{-1.13}$

Peak pressure in Kilopascals for different distances have been converted to dB using a reference level of 1µPa and are shown below.

*Table 6-1 Predicted pressure peak pressure pulse for underwater blasting.*

| P=H(D/W^ | P=Peak pressure (kpa) | |
|---|---|---|
| | D=distance (m) | |
| | W= charge weight (kg) | |
| | H=55000*0.26 for confined | |
| **kg** | **10** | |
| | | |
| **m** | **Peak Pulse (Kpa)** | **Peak Pressure (dB) - ref 1x10^-6 Pa** |
| 100 | 187 | 225 |
| 200 | 85 | 219 |
| 300 | 54 | 215 |
| 400 | 39 | 212 |
| 500 | 30 | 210 |
| 600 | 25 | 208 |
| 700 | 21 | 206 |
| 800 | 18 | 205 |
| 900 | 16 | 204 |
| 1000 | 14 | 203 |
| 1100 | 12 | 202 |
| 1200 | 11 | 201 |
| 1300 | 10 | 200 |
| 1400 | 9 | 200 |
| 1500 | 9 | 199 |
| 1600 | 8 | 198 |
| 1700 | 8 | 198 |
| 1800 | 7 | 197 |
| 1900 | 7 | 197 |
| 2000 | 6 | 196 |
| 2100 | 6 | 196 |
| 2200 | 6 | 195 |
| 2300 | 5 | 195 |
| 2400 | 5 | 194 |

Note: 'm' is distance from blast point.

A noise assessment (included in Appendix G: Noise Assessment) for the equipment proposed to be used for underwater rock blasting, has been conducted by noise experts, Aquatera. Sensitive receptor species were identified and included cetaceans, seals, fish and diving birds. Most of these species were considered to be of low sensitivity based upon IUCN population status with a few species being considered on medium sensitivity (minke, orca and emperor penguin. Based on the source sound levels, proposed operational approaches and local sound conditions, sound propagation models were established.

This modelling indicated the following ranges for temporary and permanent effects on the difference species.

*Table 6-2Temporary and Permanenet Hearing Ranges*

Temporary hearing effects (modelled range in metres)

| Group | Blasting | | Rock breaking | Vibro piling | Drilling |
|---|---|---|---|---|---|
| | SPL | SEL | | | |
| LF cetaceans | 1000 | 4700 | 520 | 400 | 80 |
| MF cetaceans/fish | 150 | 29 | 41 | 70 | 6 |
| PW Pinnipeds | 1200 | 870 | 150 | 200 | 10 |
| OW Pinnipeds | 110 | 42 | 10 | 20 | 1 |

*SPL = sound pressure level; SEL = sound exposure level*

Permanent hearing effects (modelled range in metres)

| Group | Blasting | | Rock breaking | Vibro piling | Drilling |
|---|---|---|---|---|---|
| | SPL | SEL | | | |
| LF cetaceans | 370 | 350 | 23 | 30 | 5 |
| MF cetaceans/fish | 56 | 2 | 1 | 5 | 1 |
| PW Pinnipeds | 440 | 66 | 7 | 100 | 1 |
| OW Pinnipeds | 39 | 3 | <1 | 1 | <1 |

*SPL = sound pressure level; SEL = sound exposure level*

**Mitigation:**

- Taking into account the noise modelling data and established guidance including the National Marine Fisheries Service (2016) Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing, the following mitigation measures have been developed. See Appendix G: Noise Assessment for the complete evaluation.
- A marine fauna observation / exclusion zone and clearance protocol will be established with an exclusion zone of 1,200m. This zone, shown below will be controlled by marine fauna observers at strategic viewpoints to ensure no mammals are present from 30 minutes before blasting, until 10 minutes after blasting. Any sightings of marine fauna in the water will re-set the 30 minute countdown. If sightings of marine fauna in the full 1,200m zone are disruptive to operations, it may be necessary to implement the three separate recommended zones of 1,200m for cetaceans, 500m for seals and 300m for birds.
- A minimum of Two MFOs will be equipped with binoculars and radios in order to be able to communicate with each other and directly to those responsible on site for blasting operations.

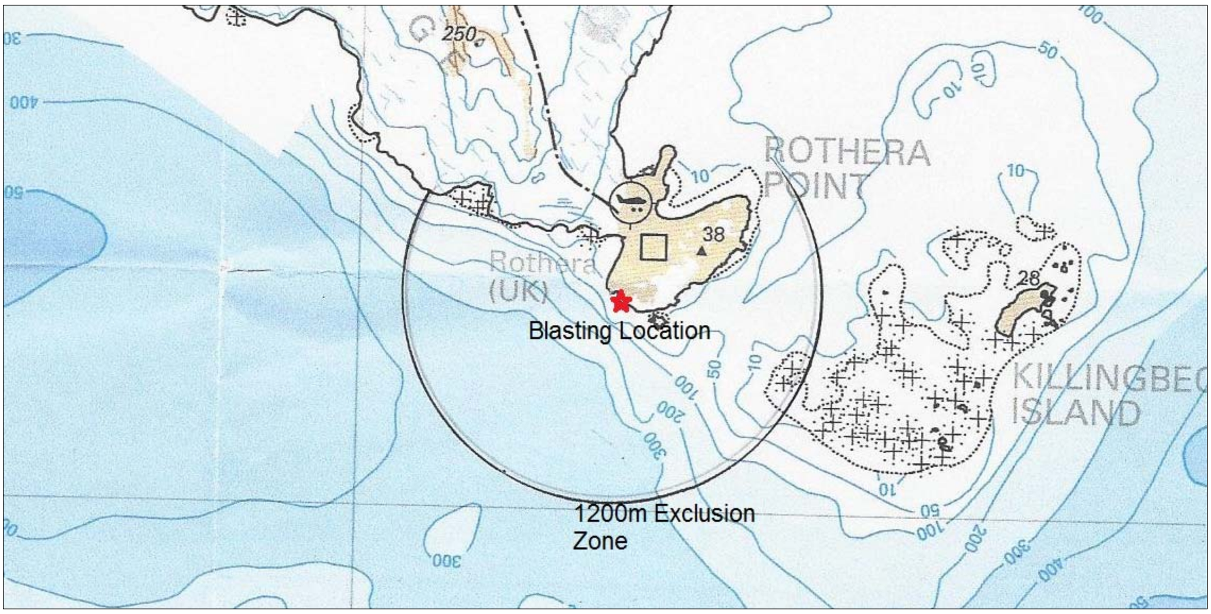


*Figure 6-1* Marine Fauna Exclusion and Observation Zone

-
- Passive acoustic monitoring (PAM) will be undertaken using a hydrophone to monitor the presence of marine mammals within the observation zone, prior to rock breaking. If mammals are present during the 30 minutes prior to operations, the 30 minute observations will be reset. If there is any doubt regarding the presence of cetaceans, blasting will be postponed.

  - Additionally PAM will be undertaken to monitor peak pressure pulse levels during blasting operations and to verify predictions. If measurements are higher than the predicted levels, operations will cease and the process re-evaluated.

  - All explosives will be placed in shot-holes drilled in the seabed and confined in the holes with angular aggregate of approximately 1/12th hole diameter. A minimum of 0.3m length will be used, greatly reducing the pressure pulse released to the water. Confining the explosives in this way has the effect of reducing the pressure pulse transmitted to the water.

  - Short delay detonators will be used between each blast hole. This process reduces the maximum charge weight fired and therefore the overall peak pressure pulse is kept to a minimum which in turn minimises the potential impact on marine mammals.

  - A strict blasting communications protocol will be developed between the MFOs and the Shotfirer to ensure the exclusion zone is clear.

### 6.2.4.Sound pressure waves in the marine environment (from blasting on land)

**Potential Impact: Direct**

Where land blasting is undertaken in close proximity to a water body, some of the ground vibration will be transmitted across the land / water boundary into the water. Within the water this energy is transmitted as a pressure pulse similar to noise in the air and may cause harm or disturbance to marine fauna at very close proximities. The following calculation has been made to predict the level of transmission into the water body based in part on Guidelines for the use of explosives in, or near Canadian Fisheries Waters – Wright and Hopky (1998) and the International Society of Explosives Engineers (ISCC) Blaster's Handbook 18th Edition. This assumes a perpendicular single boundary between the rock and water with no intermediate broken or weathered layers which, if present will act to attenuate noise and as such can be considered conservative.

*Table 6-3* Calculations relating to blasting adjacent to water

Equations from: Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters - Wright and Hopky 1998

**Step 1** Zw=DwCw Zr=DrCr

**Equation B**

| | | | | |
|---|---|---|---|---|
| Dw= | Density of water | 1.0 | $gcm^{-3}$ | |
| Dr= | Density of rock# | 2.70 | $gcm^{-3}$ | assumed |
| Cw= | Compressional wave vel in water | 146300 | $cms^{-1}$ | |
| Cr= | Compressional wave vel in rock# | 457200 | $cms^{-1}$ | assumed for granite |

| | |
|---|---|
| Zw= | 146300 |
| Zr= | 1234440 |
| Zw/Zr= | 0.1185 |

# estimate from Wright and Hopky

**Step 2** Pw = 2(Zw/Zr)Pr/(1+(Zw/Zr))

**Equation A**

| | | |
|---|---|---|
| Pw= | Pressure in water kPa | |
| Zw=DwCw | | 0.1185 |
| Zw= | Accoustic impedance water | 146300 |
| Zr= | Accoustic impedance rock | 1234440 |

Pw= 0.212 *Pr

**Step 3** Indicative Blast Vibration Prediction

ISEE Blasters PPV = a(D/MIC^0.5)^b

*where*

PPV = Peak Particle Velocity (mm/s)

D = Distance from blast to sensitive location (m)

MIC = Maximum instantaneous charge (kg)

a and b = Site factors

ISEE Blaster's Handbook values

| | Construction Upper Boundary |
|---|---|
| a | 1730 |
| b | -1.6 |

| M.I.C (kg) | | 15 | |
|---|---|---|---|
| Distance (m) | | PPV (mm/s) | PPV (cm/s) |
| 2 | | 4980.5 | 498.0 |
| 10 | | 379.2 | 37.9 |

convert to cm/s

**Step 4** Vr=2Pr/DrCr

therefore Pr=VrDrCr/2

| | | | | |
|---|---|---|---|---|
| 2m 15kg | Pressure rock= | 307405128 gcms2 | 30741 | kpa |
| 10m 15kg | Pressure rock= | 23407719 gcms2 | 2341 | kpa |

Pw= 0.216 *Pr

| | | | |
|---|---|---|---|
| 2m 15kg | Pressure water= | 6640 | kpa |
| 10m 15kg | Pressure water= | 506 | kpa |

**Step 5**

Peak Pressure (dB)= 20 x log($P/P_0$)

$P_0$ reference level 0.000001 Pa or 1µPa

| | | | |
|---|---|---|---|
| For | 2m 15kg | 196 | dB |
| For | 10m 15kg | 174 | dB |

## Mitigation:

- Although the calculations shown above indicate that levels of peak pressure will be below those that will cause harm to pinnipeds it is proposed that for the initial three blasts in this area closely adjacent to the water, the full marine fauna exclusion zone of 1200 m will be implemented as per mitigation in Section 11.2.3.
- During these initial blasts, actual peak pressure levels will be measured using a hydrophone. If after this period actual levels are shown to be low it may be possible to reduce the marine fauna exclusion zone after seeking the approval of the BAS Environment Office.

### 6.2.5. Expansion of wharf footprint

**i) Potential Impact: Direct**

There will be permanent removal of a small area of marine benthic habitat due to the construction activity and the extension of the wharf footprint. There will be a loss of the limited range of species within the removed habitat. Opportunities may exist for colonization of newly created underwater wharf surface.

**Mitigation:**

The preferred option for the new wharf has a smaller overall footprint than other options considered. The proposed construction methodology will cause less disturbance to the marine environment than other techniques originally considered e.g. underwater milling or drilling.

**Monitoring:**

A long term monitoring programme is being undertaken by BAS to determine the impacts on the benthic communities. See Appendix F - Monitoring Plan: Rothera.

**ii) Potential Impact: Direct**

Disturbance, injury or fatality of benthic marine species downslope of the wharf construction area (beyond the proposed wharf footprint) as a result of rocks or boulders displaced during construction activities.

**Mitigation:**

The design has sought to reduce the amount of preparation of the sea bed required for construction.

**Monitoring:**

A long term monitoring programme is being undertaken by BAS to determine the impacts on the benthic communities adjacent to the wharf. See Appendix F - Monitoring Plan: Rothera.

### 6.2.6. Sediment in marine environment

**Potential Impact: Direct**

Disturbance to or injury to marine benthic community through changes in water turbidity (sediment levels).

**Mitigation:**

The design has sought to reduce the amount of preparation of the sea bed required for construction and has eliminated the original proposal for milling a trench underwater to fix the toe of the sheet pile wall in position. This has reduced the quantity of both recoverable waste and unrecoverable waste in the form of sediments.

**Monitoring:**

A long term monitoring programme is being undertaken by BAS to determine the impacts of increased turbidity over the duration of the project. See Appendix F - Monitoring Plan: Rothera.

### 6.2.7.Ground displacement and vibration

The Marine Drilling and Blasting Management Plan: Rothera Wharf (2017) included in Appendix A, describes in detail the methodologies proposed to be followed during drilling and blasting operations underwater or adjacent to water.

The Quarrying, Drilling and Blasting Management Plan – Option H (2017) included in Appendix B describes in detail the methodologies proposed to be followed for rock extraction at Rothera.

**Potential Impact: Direct**

Ground vibrations from the blasting have the potential to affect structures adjacent to the blast area. Whilst this is not a direct environmental impact it has been included here to reflect the potential impact on station operations and science being undertaken.

For any specific site, the intensity of blast vibrations are related to the size of the charge fired, the distance from the blast site to the receiver, and the geological and topographical conditions at that location. Although the effect that specific geological and topographical conditions at Rothera will have on vibration attenuation is not yet known, it is possible to make outline predictions of the intensity of vibration levels at different distances for a given charge weight and use these predictions to guide the decision process.

At very close proximity to the blast i.e. within a few metres, it is permanent displacement rather than ground vibration that will have the controlling influence on structures. Beyond a few metres of the blast site the vibrations are transient with a small proportion of the explosive energy is transmitted into the rock mass as seismic waves. It is possible to make predictions of the likely intensity of the vibrations at each location based on an empirical relationship derived by the US Bureau of Mines relating ground vibration to distance and charge weight, taking into account local geological factors, as follows:

$PPV = a\,(SD)^{b}$

*Where:*

PPV = peak particle velocity (mm/s)

SD = scaled distance = Distance (D in metres) **/** maximum instantaneous charge (MIC in kg)$^{1/2}$

**a** and **b** are dimensionless site factors,

The peak particle velocity predictions shown in the table below use site factors from the ISEE Blaster's Handbook 18$^{th}$ Edition for predicting upper boundary limits for construction blasting. Values are given for anticipated maximum instantaneous charge weights for various sensitive receptors.

*Table 6-4 Indicative Blast Vibration Prediction*

Indicative Blast Vibration Prediction

PPV = a(D/MIC^0.5)^b

where

PPV = Peak Particle Velocity (mm/s)
D = Distance from blast to sensitive location (m)
MIC = Maximum instantaneous charge (kg)
a and b = Site factors

All distances are approximate

ISEE Blaster's Handbook values

| | Construction Upper Boundary |
|---|---|
| K | 1730 |
| B | -1.6 |

| Sensitive Receptor | Description | Limit | Limit Source | M.I.C (kg) | 10 | 15 |
|---|---|---|---|---|---|---|
| | | PPV (mm/s) | | Distance (m) | PPV (mm/s) | PPV (mm/s) |
| NDB antenna | Planned to be moved | N/A | | | | |
| DME antenna (to be moved) | Planned to be moved | N/A | | | | |
| DORIS | Planned to be moved | N/A | | | | |
| Sun Photometer | Can be removed if required dur | N/A | BAS MET & Science Co-ordinator | | | |
| GPS Receiver | | N/A | Newcastle University | 165 | 3.1 | 4.3 |
| Optical Hut | SAOZ, Sun photometer logger | N/A | BAS MET & Science Co-ordinator | 140 | 4.0 | 5.6 |
| Optical Hut | AG spectrometer, OH imager, All sky cam, IR all sky cam | N/A | BAS Electrical Engineer | 140 | 4.0 | 5.6 |
| Memorial for SE Black and others | | 15-50 | BS7385-2:1993 for buildings assumed | 110 | 5.9 | 8.2 |
| Memorial cross | | 15-50 | BS7385-2:1993 for buildings assumed | 110 | 5.9 | 8.2 |
| Memorial KM Brown | | 15-50 | BS7385-2:1993 for buildings assumed | 110 | 5.9 | 8.2 |
| Memorial NJ Armstrong and others | | 15-50 | BS7385-2:1993 for buildings assumed | 110 | 5.9 | 8.2 |
| Memorial for sledge dogs | | 15-50 | BS7385-2:1993 for buildings assumed | 110 | 5.9 | 8.2 |
| Memorial cairn ASPA | | 15-50 | BS7385-2:1993 for buildings assumed | 810 | 0.2 | 0.3 |
| UKHO survey pillar | | 15-50 | BS7385-2:1993 for buildings assumed | 170 | 2.9 | 4.1 |
| Flagpole | | 50 | BS7385-2:1993 for buildings assumed | 170 | 2.9 | 4.1 |
| Explosives Magazine | | N/A | Mobile steel structure | 185 | 2.6 | 3.6 |
| E-W wide band array | | N/A | BAS Comms. Manager | 190 | 2.5 | 3.4 |
| ARIES Dome | | N/A | BAS MET & Science Co-ordinator | 225 | 1.9 | 2.6 |
| RLPA tower | | N/A | BAS Comms. Manager | 275 | 1.4 | 1.9 |
| CODIS dome | | N/A | BAS Comms. Manager | 270 | 1.4 | 1.9 |
| MET tower | | N/A | BAS MET & Science Co-ordinator | 325 | 1.0 | 1.4 |
| Cloud-base recorder | | N/A | BAS MET & Science Co-ordinator | 325 | 1.0 | 1.4 |
| AWS | | N/A | BAS MET & Science Co-ordinator | 430 | 0.7 | 0.9 |
| Small N-S dipole | | N/A | BAS Comms. Manager | 390 | 0.8 | 1.1 |
| N-S wide band array | | N/A | BAS Electrical Engineer | 470 | 0.6 | 0.8 |
| MF radar receiver (east beach) | | N/A | BAS Electrical Engineer | 475 | 0.6 | 0.8 |
| MF radar receiver (Bransfield Hse) | | N/A | BAS Electrical Engineer | 540 | 0.5 | 0.6 |
| MF radar transmitter (closest) | | N/A | BAS Electrical Engineer | 580 | 0.4 | 0.6 |
| SkiYMet transmitter | | N/A | BAS Electrical Engineer | 620 | 0.4 | 0.5 |
| SkiYMet radar masts | | N/A | BAS Electrical Engineer | 670 | 0.3 | 0.5 |
| ASPA No.129 | | NA | Very remote to blast location | 680 | 0.3 | 0.4 |
| Tide gauge | | N/A | BAS MET & Science Co-ordinator | 90 | 8.2 | 11.3 |
| Boatshed | | 15-50 | BS7385-2:1993 for buildings | 100 | 6.9 | 9.5 |
| Bonnar Laboratory | | 15-50 | BS7385-2:1993 for buildings | 155 | 3.4 | 4.7 |
| Bonner Lab. Science | | N/A | BAS Science Leader | 155 | 3.4 | 4.7 |
| Gerritsz Laboratory | | 15-50 | BS7385-2:1993 for buildings | 150 | 3.6 | 5.0 |
| Gerritsz Lab. Science | | N/A | BAS Science Leader | 150 | 3.6 | 5.0 |
| Giants House | | 15-50 | BS7385-2:1993 for buildings | 300 | 1.2 | 1.6 |
| Old Bransfield House | | 15-50 | BS7385-2:1993 for buildings | 350 | 0.9 | 1.3 |
| Admirals House | | 15-50 | BS7385-2:1993 for buildings | 390 | 0.8 | 1.1 |
| Bransfield House | | 15-50 | BS7385-2:1993 for buildings | 530 | 0.5 | 0.7 |
| Fuel Tanks | | NA | Very remote to blast location | 560 | 0.4 | 0.6 |

**Mitigation:**

- The relative sensitivity of structures and instrumentation has been discussed with the owners / managers of the sensitive receptors, and will be reconfirmed prior to blasting. The values in the table above show low predicted levels of vibration in relation to limit values. Blasting may need to be controlled if it coincides with sensitive construction activities.

**Monitoring:**

- By monitoring blast vibration on-site, it will be possible to check predictions against actual results and confirm compliance with agreed limits. Blast vibration monitoring will be undertaken for the purpose of both compliance and for later refinement of predictions once sufficient data has been gathered.

### 6.2.8. Rock throw

**Potential Impact: Direct**

Rock throw is in general caused as a result of excessive energy projecting the rock rather than producing fragmentation and heave. This could have the potential to damage buildings or injure wildlife if located near to the blast.

**Mitigation:**

- Where there is a minimum of 3 m depth of water, the proposed ratio of explosives to rock will not result in rock throw.
- Where blasting is expected in shallower water depths, stemming levels will be progressively increased to prevent ejection from the blast.
- There are no buildings or known wildlife receptors in the vicinity of the proposed works. If any marine mammals were to come into the vicinity of the blast area then the marine mammal observers would halt operations (See Section 11.2.2)

### 6.2.9. Marine pollution

**Potential Impact: Direct**

Marine pollution could result from spilt hydraulic fluid, lubricant leaks from machinery used for Rothera Wharf construction and demolition works and explosives work.

**Mitigation:**

- Biodegradable fluids and lubricants will be used where practical
- Fuel and oil spill kits will be deployed on site.
- All contractors will be trained in oil spill response procedures.
- The mitigation measures outlined in Section 11.1.4 Use of vehicles, plant & generators which refer to actions to minimise the impact of fuel spills will also be implemented.

### 6.2.10. Use of lighting rig

**Potential Impact: Direct**

The use of artificial light in low light conditions could attract birds and lead to bird strikes, injury or fatalities.

**Mitigation:**

- Lighting rigs will only be used in low light not total darkness.
- Lights to be turned off when not in use or if a bird strike occurs.
- Continued use will only be allowed after consultation with the BAS Environment Office.
- Rothera Station Leader and BAS Environment Office to be informed should there be any bird strikes.

#### 6.2.11. Disturbance to benthic ice scour monitoring sites

**Potential Impact: Indirect**

- During the construction and operation of the temporary jetty there is the potential for the long term monitoring sites in south cove to be disturbed. BAS scientists have been monitoring the impact of ice scour on the marine benthic environment at this location for over 15 years. Deploying ship anchors, equipment or plant in this area could damage or have fatal consequences for the habitat or individual specimens.

**Mitigation**

- BAS and BAM ships have been notified of a 20 metre exclusion around the monitoring sites. The construction works for the temporary jetty will not extend into this area.

## 6.3. Quarry, Drilling & Blasting Impacts

The location for rock extraction was specifically chosen in an area of low sensitivity for environmental and human receptors. There is no vegetation in the vicinity of the temporary quarry (within 250 m) and it is remote from areas frequented by seals and penguins (within 150 m). The closest human receptors are those people working in the Gerritsz laboratory which is approximately 35 m away. Science activities have largely been postponed in the laboratory for the 2018-2019 season. The Bonner Laboratory and the Marine workshop are 50-55 m away from the area where rock extraction will take place, and BAS personnel will continue to work in these buildings during the construction period.

### 6.3.1. Permanent rock removal

**(i) Potential Impact: Direct**

The removal of up to 80,000 tonnes of natural rock will have a visual impact and potentially impact the aesthetic value of the area where rock will be extracted. This is a direct impact of using locally sourced rock. However on balance, quarrying rock locally on site was considered to be an important factor in reducing the risk of importing non-native species on imported aggregates.

Other potential rock extraction locations such as on the eastern side of Rothera Point were discounted as these were considered to have a greater visual and ecological sensitivity. The specific confines of the proposed site, is not considered a pristine wilderness because it is within the existing footprint of Rothera Research Station adjacent to an area which has been developed previously. However the setting or wider landscape of Rothera Point is considered to have a high wilderness value and once the rock extraction is complete, that value may be diminished to an extent.

**Mitigation:**

- Quarried rock face will be finished to 50 degrees from vertical matching the existing rock face.

**(ii) Potential Impact: Direct & cumulative**

Loss of ice free ground which is rare in Antarctica (0.18% of Antarctica is ice free).

**Mitigation:**

- The option of finishing the quarried rock face with a gentler slope (greater than 50 degrees from vertical) to reduce the visual impact has been considered and rejected in order to minimise the overall land take needed for rock extraction.

### 6.3.2. Use of explosives

**Potential Impact: Direct**

Ingredients contained within the explosives are toxic to humans and the environment. Under normal use and following the strict blasting procedures the risks are mitigated.

**Mitigation:**

Drill and blast management plans will be followed at all times. See Appendix A and B.

### 6.3.3. Use of explosives creating noise (air-over pressure)

**Potential Impact: Direct**

When an explosive is detonated, transient airborne pressure waves are generated. As these pressure waves pass a given position, the pressure of the air rises very rapidly to a value above the ambient pressure, then falls more slowly to a value below atmospheric pressure, before returning to the ambient value after a series of oscillations. The maximum pressure reached is the peak air overpressure.

These pressure waves are comprised of energy over a wide frequency range, with frequencies above 20 Hz audible to the human ear as sound, whilst those below 20 Hz are in the form of concussion. The sound and concussion together is known as air overpressure and is usually measured in decibels (dB) with no frequency filtering applied.

In a blast, these airborne pressure waves are produced from five main sources:

- Rock displacement from the face.
- Ground induced airborne vibration.
- Release of gases through natural fissures.
- Release of gases through stemming.
- Insufficiently confined explosive charges.

Although it is possible to make predictions of the attenuation of air-overpressure, it is considered unrealistic to do so due to the affect that meteorological factors and surface topography have on the transmission of this energy. UK guidance contained within mineral planning guidance MPG 9:1992 and MPG 14:1995, Minerals Technical Advice Note 1 (Welsh Government, 2004) and the UK Department of Environment Transport & the Regions (DETR) report: *The environmental effects of production blasting from surface mineral workings* (1998) recommend that air-overpressure should be controlled at source rather than setting a specific limit. These control measures are discussed below in the mitigation section.

It is not anticipated that any structural damage, even cosmetic damage, will be caused by air-overpressure due to the nature of the controlled blasting that will be undertaken for these works.

The only terrestrial fauna identified in close proximity to the blasting location are nesting Skuas as shown in Section 10, Figure 10-16. This plan shows the location of one nest site to the north-west of the blast site which has been confirmed as unoccupied for the past two years. Nest sites are often reused but may be inactive for a number of consecutive years. The skua nest closest to the proposed rock extraction area, was last used in 2015-16 but egg rearing was unsuccessful. The skua pair did not appear or lay eggs in 2016-17. However the 2015-16 and the 2016-17 seasons have been recorded as poor breeding years. There were no successfully reared chicks in 2015-16 and very few eggs laid and none hatching in 2016-17. It should be assumed therefore that any nest site identified on Figure 10-16 could become active in the future. Other known nesting sites are located at a distance of > 250 metres from the proposed quarry location. Consultation with the BAS Seabird Ecologist suggests that it is unlikely that the skuas will be adversely affected by the blasting air-overpressure.

**Mitigation:**

- Prior to blasting the Shotfirer will check the blast site to ensure that it is clear of any birds.
- The following Blast Design Control Measures will be followed to reduce air-overpressure at source.
  - Consider reducing the maximum instantaneous charge fired in any one delay period.
  - Record geological conditions during drilling to ensure that weak areas are decked in the hole with aggregates to avoid energy escape.
  - Correct confinement of explosives through use of correct burden and stemming.
  - Utilise laser surveying of open faces and shot-holes to allow correct explosive placement and to avoid low burdens that allow energy to escape to the atmosphere. Ensure quality stemming is used in the top of the holes to prevent energy release through the hole collar.
  - Use in-hole initiation systems.
  - Avoiding un-confined explosives, including detonating cord, by using non-electric surface initiation systems.
  - Avoid blasting when weather conditions may lead to increased propagation of air overpressure to the sensitive receptors; such as downwind conditions from the blasting site to the receptor(s) and when there is low cloud or an atmospheric temperature inversion.
  - Controlling the direction of firing shots to help limit sound travelling in unfavourable directions.
  - No secondary blasting of boulders.
  - Careful selection of the location of the quarried rock source in conjunction with BAS management to minimise the impact through distance and orientation in respect to sensitive receptors.

**Monitoring:**

- The BAS long term monitoring programme for skuas will continue throughout the construction period, which will record any impacts on breeding activity at Rothera.

### 6.3.4. Sound pressure waves in the marine environment

**Potential Impact: Direct**

Where blasting on land is undertaken in close proximity to a water body, a pressure pulse similar to noise in the air may cause harm or disturbance to marine fauna at very close proximities.

The following calculation has been made to predict the level of transmission into the water body based in part on *Guidelines for the use of explosives in, or near Canadian Fisheries Waters*, (Wright and Hopky 1998) and the ISEE Blaster's Handbook 18$^{th}$ Edition. It is not anticipated that the level of blast vibration transmitted to the water will be sufficiently high to cause harm to the marine environment.

*Table 6-5 Calculations relating to blasting adjacent to water*

Equations from: Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters - Wright and Hopky 1998

**Step 1** Zw=DwCw Zr=DrCr

**Equation B**

| | | | | |
|---|---|---|---|---|
| Dw= | Density of water | 1.0 | $gcm^{-3}$ | |
| Dr= | Density of rock# | 2.70 | $gcm^{-3}$ | assumed |
| Cw= | Compressional wave vel in water | 146300 | $cms^{-1}$ | |
| Cr= | Compressional wave vel in rock# | 457200 | $cms^{-1}$ | assumed for granite |

| | |
|---|---|
| Zw= | 146300 |
| Zr= | 1234440 |
| Zw/Zr= | 0.1185 |

# estimate from Wright and Hopky

**Step 2** Pw = 2(Zw/Zr)Pr/(1+(Zw/Zr))

**Equation A**

| | | |
|---|---|---|
| Pw= | Pressure in water kPa | |
| Zw=DwCw | | 0.1185 |
| Zw= | Accoustic impedance water | 146300 |
| Zr= | Accoustic impedance rock | 1234440 |

Pw= 0.212 *Pr

**Step 3** Indicative Blast Vibration Prediction

ISEE Blasters PPV = a(D/MIC^0.5)^b

*where*

PPV = Peak Particle Velocity (mm/s)

D = Distance from blast to sensitive location (m)

MIC = Maximum instantaneous charge (kg)

a and b = Site factors

ISEE Blaster's Handbook values

| | Construction Upper Boundary |
|---|---|
| a | 1730 |
| b | -1.6 |

| M.I.C (kg) | 20 | 35 | 50 |
|---|---|---|---|
| Distance (m) | PPV (mm/s) | | |
| 10 | 477.4 | | |
| 20 | | 246.4 | |
| convert to cm/s | 47.74 | 24.64 | |

**Step 4** Vr=2Pr/DrCr

therefore Pr=VrDrCr/2

| | | | | | |
|---|---|---|---|---|---|
| 10m 20kg | Pressure rock= | 29466083 | gcms2 | 2947 | kpa |
| 20m 35kg | Pressure rock= | 15208301 | gcms2 | 1521 | kpa |

Pw= 0.216 *Pr

| | | | |
|---|---|---|---|
| 10m 20kg | Pressure water= | 636 | kpa |
| 20m 35kg | Pressure water= | 328 | kpa |

**Step 5**

Peak Pressure (dB)= 20 x log($P/P_0$)

$P_0$ reference level 0.000001 Pa or 1µPa

| | | | |
|---|---|---|---|
| For | 10m 20kg | 176 | dB |
| For | 20m 35kg | 170 | dB |

**Mitigation:**

- To ensure that the predictions are accurate monitoring of actual peak pressure in the water will be undertaken on site. This will be undertaken with a hydrophone when blasting at distances greater than 20 m from the water's edge (before reaching the potentially harmful locations) to obtain real values of peak pressure levels. It is anticipated that the levels will be lower than those calculated above, however should the values be greater the following mitigation will be employed:

- Reduce explosive charge weights, or otherwise alter the blast design to reduce intensity.
- Implement a marine fauna watch to ensure that no marine fauna are in the vicinity at the time of blasting. See Section 11.2.3 for details on marine fauna observations and exclusion zone.

### 6.3.5. Ground displacement & vibration

**Potential Impact: Direct**

Disturbance due to permanent ground displacement beyond the blast area will only affect a very small area of a few metres beyond the extraction zone. This will be controlled through the blast design process to minimise back-break[13]. With current rock extraction requirements it is not anticipated that this will affect any activities in any way. Geological and geotechnical conditions will be taken into consideration to avoid ground failure that might extend beyond the blast area.

Please refer to section 11.2.6 for further details on the calculation of vibration levels.

The Rothera Quarry, Drill and Blast Plan Appendix B- lists the sensitive receptors identified at Rothera, their distance from the rock extraction area and predicted peak particle velocity values for each. Apart from land base fauna i.e. skuas, marine fauna and the memorials all other sensitive receptors are buildings, structure or scientific equipment. The relative sensitivity of structures and instrumentation has been discussed with the owners / managers of the sensitive receptors and mitigation measures agreed.

The predictions shown use site factors from the ISEE Blaster's Handbook 18th Edition for predicting upper boundary limits for construction blasting. Values are given for various maximum instantaneous charge weights (MIC) at various distances – the actual charge weights will be determined by the Explosives Supervisor and Shotfirer during the blast design process.

The specific requirements relating to each sensitive receptor are shown in Appendix B of the Rothera Quarrying, Drilling and Blasting Management Plan and are discussed briefly below:

- POM Sun Photometer – this can easily be removed and must be removed during blasting.
- Newcastle University GPS receiver – this is not predicted to be adversely affected by the proposed vibration; however, recording of blast times will be undertaken so as to allow removal of anomalous data from results.
- The search coil magnetometer – this is not predicted to be adversely affected by the proposed vibration, due to its location more than 800 m from the blast site; however, notification of blast times is required to remove anomalies from results.

[13] Back break is a phenomenon where rock unintentionally becomes broken beyond the limits of the rear row of blast holes. It can cause instability in the quarry walls and subsequent rock falls. See Appendix A: Quarry, Drilling and Blasting Management Plan.

- Other meteorological, science and communications equipment is not predicted to be adversely affected by the proposed vibration.
- It has been reported that no science being undertaken in the Bonner and Gerritsz laboratories will be affected by blasting vibration.
- No buildings have been identified as having any specific sensitivity to blasting vibration. Vibration will therefore be controlled as per the requirements of BS7385-2:1993 Evaluation and measurement for vibration in buildings.
- Biscoe wharf is shown in close proximity to the rock extraction area and despite being demolished, vibration levels will be monitored and charge weights limited at the closest proximity.

**Mitigation:**

- The following Blast Design Control Measures will be considered to reduce blast vibration:
    - Reduce the maximum instantaneous charge by reducing the face height, reducing the hole diameter, or introducing decks of explosives in the hole. The ratio of explosives to rock must be maintained to avoid increased vibration.
    - Strict control of drilling deviation, burdens and spacings to ensure even and appropriate distribution of explosives. Survey techniques and modelling will verify these parameters.
    - Maximise the use of free faces to allow the rock to expand and avoid transmission of vibration.
    - Use appropriate initiation sequences to ensure the rock moves in a controlled manner and new free faces are created.
    - Control sub-grade drilling levels.
    - Control the powder factor / blast ratio as reducing the explosive quantity may increase vibration if there is an insufficient quantity to break the rock. This is not just the ratio for the entire blast; individual heavy burdens may create high local blast ratios which will cause higher vibration.

- During operations, blasting vibration levels will be monitored using blasting seismographs to measure levels of peak particle velocity and air-overpressure at selected site sensitive locations. This monitoring will be both to ensure compliance with site threshold limits and to further increase the number and distribution of results, to allow continuous improvement of vibration prediction models and increasing confidence in MIC predictions.

**Monitoring:**

- Monitoring will initially be undertaken at the closest sensitive receptors of each type, or agreed on site with project and station management. Once confidence is gained that vibration limits will not be exceeded at these receptors, monitoring will continue at varied distances to obtain data for prediction models.

- There are five memorials located at Rothera Point that are considered of heritage value to current and past staff members, visitors and other interested parties (details listed in Section 10.11). In general, it is the plaques that are considered of high importance, whilst the base structures should be maintained in good condition. Whilst the plaques are considered to be robust in relation to damage potential from blast vibration, the base structures may be subject to minor cracking damage. In order to monitor the condition of the memorials, pre-blast photographs will be taken of each one from all sides to form a baseline from which to compare any deterioration. During blasting operations, regular inspections will be made of the condition of each memorial, and repairs implemented to maintain the original condition after discussion with the Station Leader and the BAS Environment Office. Should there be any risk of damage from rock projection to the actual plaques, then additional mitigation measures will be implemented, such as providing a protective covering, or temporarily removing the plaques to a safe location. This will not be undertaken before discussion with the BAS Environment Office has occurred.

- A survey cairn in the ASPA area is not considered to be at risk due to the considerable distance > 500 m from the blast area. However due to its heritage importance BAS staff permitted to enter the ASPA will monitor the cairn before, during and after blasting in conjunction with the Site Manager.

### 6.3.6. Dust deposition

**Potential Impact: Direct & cumulative**

The process of drilling, fragmenting, loading, transporting and crushing rock will produce dust which has the potential to damage soil organisms and vegetation through direct contact.

Another potential impact is that dust deposition on the ice ramp could result in increased melt during summer months.

**Mitigation:**

- The activities which create dust, in particular processing of rock, will be located at the southern end of Rothera Point, which is a significant distance from known vegetation and the ice ramp.
- The drill rig will be fitted with dust suppression equipment. This will normally consist of a dust hood at the foot of the mast, which makes a seal with the ground, a dust ring, which seals around the drill string, and a dust collection system which extracts the dust directly away from the hole and places it onto the ground. Although the dust is still susceptible to being picked up by wind, the effects are significantly reduced.
- Careful blast design will prevent excessive ejection of material into the air; however, in dry conditions, some dust cannot be avoided. The direction of firing may reduce the pick-up of dust into the air by using natural topography to create shelter.
- After the blast has been fired and before any crushing takes place the rock pile area that crushing/loading is to take place will be watered with seawater using a tractor and bowser.
- It should be possible, after the first few blasts, to feed the primary crusher directly with the excavator from the face; the primary crusher will have a covered conveyor as well as hanging skirts from the discharge belt to help curtail air-borne dust.
- The haul roads will be sprayed with the seawater, should the need arise.
- Grading screens and crushers will be fitted with seawater spray bars and dust skirts and all conveyors will be covered.
- Use of crushing and screening plant within its design capacity reduces excessive dust production.

- All routes used by the vehicles and plant will be well maintained and have compacted surfaces.
- All plant and equipment will be maintained on a regular basis.
- Limitation of material drop heights during stockpiling, processing and loading operations will help to minimise dust.
- Vehicle speeds limits on site will be set low (max 20 mph) and enforced.
- Double handling will, as far as practical, be minimised to reduce the overall number of tipping actions.
- During high winds, operations will be temporarily suspended. As with blasting, during excessively dry, windy conditions, especially where the wind direction will blow dust towards sensitive receptors, it may be necessary to suspend other operations if it is not possible to control dust by other means. This will be reviewed on a daily basis by the Site Manager. In conjunction with the Rothera Station Leader before charging commences.
-

### 6.3.7. Rock throw during blasting

**Potential Impact: Direct**
Damage to nearby buildings or injury to wildlife.

**Mitigation:**

- Rock throw will be strictly controlled through the blast design process, which involves laser surveys of the rock face, hole surveys and the production of a 3D model of the blast to allow carefully considered explosive placement.
- Rock throw is contained in the working area in front of the face, with minimal ejection behind the blast beyond a few metres. The size of the exclusion zone beyond the blast area is a safety measure and does not represent the extent of expected rock projection. More detail is provided in the Quarry, Drilling and Blasting Plan Appendix B.
- Rock throw will be contained within the quarry footprint and directly in front, e.g. within lay down area 3 and the adjacent access road. Rock throw or rock roll on the access road will be cleaned up using a loading shovel immediately after the blast.
- To prevent any potential damage to the Gerritsz Laboratory from rock fall/roll from the adjacent un-blasted face, a rock bund will be created between the building and face.
- Prior to blasting the Shotfirer will check the blast site to ensure that it is clear of any birds.

**Monitoring:**

- The BAS long term monitoring programme for skuas will continue throughout the construction period which will record any impact on breeding activity at Rothera.

## 6.4. Coastal Stabilisation Impacts

### 6.4.1. Concrete Casting

**Potential Impact: Direct**

There is the potential for damage to soil, organisms and vegetation due with highly alkaline cementitious liquids and cement dust.

**Mitigation:**

- Concrete batching plant will be located away from sensitive environmental receptors in lay down area 3 (see Figure 3-15).
- Cement silos will be maintained to be airtight
- Any stockpiles of aggregates will be kept damp with the use of seawater
- Conveyors will be covered and transfer points encapsulated
- Overfill protection will be installed on hoppers and silos.
- A silt buster tank will be used to filter equipment wash water before discharge. The collected silt will be removed from site and disposed of in a licensed waste management facility outside of the Antarctic Treaty area.
- Moulds will be checked regularly for water tightness
- Casting beds will be located on a bunded impermeable surface
- A designated lined and bunded washout basin will be used to clean equipment
- All runoff and waste water will be captured and treated before release
- All excess material from the casting process will be treated as waste and handled in accordance with the site waste management plan (Appendix D) and the BAS Waste Management Handbook.

### 6.4.2. Underwater rock breaking

**Potential Impact: Direct**

The activity of rock breaking to create the revetment toe for the coastal stabilisation works has the potential to disturb marine mammals potentially resulting in avoidance behaviour or hearing damage.

**Mitigation:**

The potential impacts will be no more than those outlined in Section 11.2.2 Sound pressure waves in the marine environment and the same mitigation measures will be implemented.

# 7. IMPACT ASSESSMENT

## 7.1. Methodology

*Impact Identification*

In Section 12.2 an impact matrix has been provided that lists the activity that may give rise to an impact, the specific environmental aspect (i.e. the interaction of the activity with the environment) and the potential outcome on the environment (i.e. the actual impact). Each impact has been identified as follows:

- Direct - result of a direct cause effect interaction on the environment
- Indirect - change in environmental value as a result of interactions of other impacts and the environment
- Cumulative - combined impact of past, present and reasonably foreseeable future activities
- Unavoidable - where no mitigation is possible

*Impact Assessment*

Each identified impact has been assessed on a five point scale against the following criteria:

- extent of impact;
- duration of impact;
- probability of the impact occurring; and
- severity of the impact if it were to occur.

Table 12.1 provides an explanation and definition of the scale used. The assessments have been made prior to the application of mitigation measures but do consider normal operating procedures currently followed by BAS and will be employed by the construction team.

*Table 7-1 Impact Assessment Criteria*

| Impact | Explanation of definition | | | | |
|---|---|---|---|---|---|
| | Very Low (VL) | Low (L) | Medium (M) | High (H) | Very High (VH) |
| Risk Grading | 1 | 2 | 3 | 4 | 5 |
| Extent of Impact | Site specific: Confined to the construction site & laydown areas | Local: Confined to Rothera Point and local marine environment | Regional: Northwest Antarctic Peninsula (Biogeographic region) | Continental: Antarctica and Southern Ocean south of 60°S | Global: Earth and atmosphere |
| Duration of Impact | Minutes to days | Weeks to months | Several seasons to several years | Decades | Centuries to millennia |
| Probability of Impact | Very unlikely to occur under any circumstance | Unlikely to occur under normal operations & following standard BAS procedures | Possible if standard BAS or project specific procedures are not followed. | Probable. Likely to occur during the project. | Unavoidable. Certain to occur |
| Significance/Severity of Impact | No direct impact on the environment and local ecosystems. Recovery is definite. | Impacts may occur but are less than minor or transitory. Reversible in the short term. | Changes to the environment and local ecosystem are minor or transitory. Recovery is likely. | Changes to environment and local ecosystem are greater than minor or transitory. Recovery is slow and uncertain. | Major changes to the environment and local ecosystem which are irreversible, certain to occur and unavoidable. Recovery unlikely. |

### *Risk Scoring*

A risk score has been calculated pre and post mitigation for each impact identified in order to identify those impacts which could cause significant environmental impact. The environmental risk for each activity is assessed by making a formal judgement on the extent, duration, probability and the severity using the following calculation:

Risk Score = Extent x duration x probability x severity

Each impact criteria is scored between 1 - 5 and the results multiplied to produce a risk score of between 1 and 625. This provides a simple means of risk comparison before and after implementation of mitigation. The higher the number, the greater the environmental risk. The risk scores have been colour coded as green, amber and red to reflect those impacts that present the greatest risks as per Table 12.2.

*Table 7-2 Risk Score & Description*

| Colour | Description | Risk Score |
|---|---|---|
| Green | Impact acceptable and will be managed through normal operating procedures and outlined mitigation measures | 1- 60 |
| Amber | Impact needs active management through mitigation measures and monitoring | 61 -120 |
| Red | Impact significant and requires BAS Senior Management sign off | 121 – 625 |

### *Risk Response*

Aligned with the risk score, a risk response has been identified for each impact. Three different overarching responses are identified:

- Avoid – apply mitigation so that the impact does not occur
- Reduce – apply mitigation to reduce the risk of the impact occurring
- Accept – acceptance of the risk of the impact occurring with no further mitigation

Where the first two responses have been assigned to an impact, mitigation measures have been provided in order to reduce the risk. A post mitigation risk score has then been calculated. The third response (accept) is assigned to activities where no practical mitigation measure exists. Therefore, if the activity is undertaken, the resulting impact must be accepted.

## 7.2. Impact Matrix

| General Construction Activity Impacts | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Activity | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, indirect, cumulative, or unavoidable) | Extent | Duration | Probability | Significance/Severity | Risk Score (pre-mitigation) | Risk Response | Preventative or mitigating measures | Extent | Duration | Probability | Significance/Severity | Risk Score (post mitigation) |
| 1 | Importation of cargo | Introduction of non-native species | Non-native species introduced and established.<br>Alteration to ecosystem.<br>Increased risk to endemic species.<br>Impact on future science. | Indirect | 2 | 4 | 3 | 4 | 96 | REDUCE | All staff to attend pre-deployment training on environmental management including biosecurity requirements.<br>Provision of staff member dedicated to environmental management who will undertake the biosecurity requirements.<br>Biosecurity Plan: Rothera (included in Appendix E) will be followed at all times.<br>All equipment and materials will be thoroughly cleaned before dispatch to Antarctica.<br>Inspection of all plant, equipment, materials and personal belongings prior to loading onto the vessel and prior to disembarkation at Rothera.<br>If accidental importation of a non-native species occurs it will be exterminated if possible, and disposed of appropriately.<br>All non-native species incursions will be reported to the Rothera Station Leader and the BAS Environment Office immediately. | 2 | 4 | 2 | 4 | 64 |
| 2 | Relocation of personnel and luggage/cargo | Introduction of non-native species | Non-native species introduced and established. Alteration to ecosystem. Increased risk to endemic species.<br>Impact on future science. | Indirect | 2 | 4 | 3 | 4 | 96 | REDUCE | All staff to attend pre-deployment training on environmental management including biosecurity requirements.<br>All personnel being deployed to Rothera will have read and must comply with the Biosecurity Plan: Rothera before departing their home country.<br>All personal items of clothing and cargo will be thoroughly cleaned and checked for soils, plants, propagules or insects. | 2 | 4 | 2 | 4 | 64 |
| 3 | Increased number of people on station | Increase volume of effluent discharged to marine environment | Pollution of marine environment.<br>Release of pathogens | Direct | 2 | 3 | 5 | 2 | 60 | ACCEPT | Any additional toilets on site to be connected to foul drainage in order for waste to be macerated prior to discharge. | 2 | 3 | 5 | 2 | 60 |
| | Increased number of people on station | Increase volume of waste arisings sent to landfill | Pollution of terrestrial environment (ex-Antarctica) | Direct | 2 | 3 | 3 | 3 | 54 | REDUCE | SWMP (Appendix D) to be followed for all construction waste. Waste to be returned to UK and disposed of by licensed contractor<br>Target of 80% diversion of waste from landfill<br>Waste statistics to be provided for monitoring purposes | 2 | 3 | 2 | 3 | 36 |
| | Increased number of people on station | Increased risk of waste released to local environment | Pollution of marine and terrestrial environment | Direct | 2 | 1 | 2 | 3 | 12 | REDUCE | SWMP to be followed for construction waste and BAS Waste Management Handbook to be followed for all domestic waste<br>Dedicated areas for segregation and storage of construction waste on site.<br>Provision of staff member dedicated to waste management<br>All staff to attend pre-deployment training on environmental management including waste management.<br>Daily checks will ensure that all equipment and packaging is appropriately weighed down to avoid wind blow | 1 | 1 | 2 | 2 | 4 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Increased number of people on station | Increased water consumption | Reduced availability of fresh water for station consumption | Direct | 2 | 3 | 4 | 2 | 48 | ACCEPT | If Rothera station is unable to meet increased water demands an additional temporary reverse osmosis plant will be installed for the duration of project<br>Use of sea water where possible for construction activities | 2 | 3 | 4 | 2 | 48 |
| | Increased number of people on station | Increased use of fuel to meet energy demand on station | Minor but cumulative contribution to regional and global atmospheric pollution | Cumulative | 1 | 3 | 5 | 2 | 30 | REDUCE | Energy awareness briefings to be provided on station for domestic use and within toolbox talks for construction purposes. | 1 | 3 | 4 | 2 | 24 |
| | Increased number of people on station | Increase in carbon footprint to deploy personnel by ship or plane | Minor but cumulative contribution to regional and global atmospheric pollution | Indirect/ cumulative | 1 | 3 | 5 | 2 | 30 | ACCEPT | Only essential construction personnel to be deployed to Rothera | 1 | 3 | 5 | 2 | 30 |
| 4 | Use of vehicles, plant and generators | Atmospheric emissions | Minor but cumulative contribution to regional and global atmospheric pollution.<br>Heavy metal and particulate fallout | Direct/ Cumulative | 1 | 3 | 5 | 2 | 30 | REDUCE | Generators and plant selected which balance efficiency and reduced emissions.<br>Regular maintenance and daily checks of vehicles and generators<br>Staff instructed to turn off vehicles when not in use | 1 | 3 | 4 | 2 | 24 |
| | Use of vehicles, plant and generators | Fuel spills and leaks | Terrestrial and marine pollution.<br>Mortality of flora & fauna in immediate area.<br>Secondary contamination to birds by ingestion of contaminated marine and terrestrial invertebrates.<br>Generation of spill response related waste. | Direct/indirect | 2 | 3 | 4 | 3 | 72 | REDUCE | All refuelling will be carried out by trained BAS personnel in line with the station's refuelling procedures.<br>Spill kits to be stored in key locations outlined in spill response plan See Section 6 Operational Procedures.<br>All staff will receive training on emergency spill procedures.<br>All spills will be reported to the Station Leader & BAS Environment Office<br>Tier 1 spills will be dealt with by construction team, tier 2 or 3 spills will be coordinated by Rothera Station Leader<br>Construction team will assist with any spill response under the co-ordination of the Rothera Station Leader.<br>Rothera Oil Spill Contingency Plan 5th edition 2015 to be followed in the event of a spill over water. | 2 | 3 | 3 | 3 | 54 |
| | Use of vehicles, plant and generators | Disturbance of seals & penguins | Injury to animal.<br>Avoidance, aggressive or stress behaviour. | Direct | 2 | 3 | 3 | 2 | 36 | REDUCE | All access routes for plant and vehicles will be clearly demarcated.<br>All vehicles to be inspected and wheels checked for presence of seals & penguins before engines started.<br>If seal displacement is deemed essential this will be undertaken by a nominated trained staff member.<br>All seal displacements will be recorded for monitoring purposes (See Appendix F Monitoring Plan: Rothera)<br>Long term BAS skua monitoring programme to continue throughout construction period.<br>All construction activity to take place away from areas where penguins and seal frequent. | 2 | 3 | 3 | 1 | 18 |
| 5 | General Construction Activity on Station (personnel and day to day disruption) | Science days supported by Rothera | Reduction in science days | Direct | 2 | 3 | 3 | 2 | 36 | REDUCE | Additional accommodation has been provided for construction staff to minimise the impact on bed nights for scientists<br>Field campaigns supported by Rothera will generally not be affected by the construction works. Alternative lab arrangements provide by the Bonner Lab when the Gerritsz is not available.<br>Allowances for continuing normal boating operations to undertake marine science have been made as per Section 7.6 of this document | 2 | 3 | 2 | 2 | 24 |

## Rothera Wharf Impacts

| No. | Activity | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, indirect, cumulative, or unavoidable) | Extent | Duration | Probability | Significance/Severity | Risk Score (pre-mitigation) | Risk Response | Preventative or mitigating measures | Extent | Duration | Probability | Significance/Severity | Risk Score (post mitigation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Demolition of Biscoe Wharf | Creation of dust whilst removing rock fill | Smothering of local flora | Direct | 2 | 2 | 3 | 3 | 36 | REDUCE | Suspension of blasting on days when excessively windy or blowing in the direction of sensitive receptors. Control of dust from plant operations e.g. spraying plant and roadways with seawater, limiting drop height of rock fill when relocating. | 2 | 2 | 2 | 2 | 16 |
| | | Creation of dust whilst removing rock fill | Dust deposition on ramp resulting in increased melt during summer | Direct/ cumulative | 2 | 2 | 4 | 3 | 48 | REDUCE | | 2 | 2 | 3 | 3 | 36 |
| 2 | Underwater drilling & rock breaking | Change in underwater noise levels | Disturbance to marine mammals resulting in avoidance behaviour or hearing damage. | Direct | 2 | 3 | 5 | 3 | 90 | REDUCE | No percussive drilling will be conducted underwater. Only rotary coring will be used.<br>Calculations undertaken indicate noise levels will be low and will not be significant to marine mammals.<br>Marine fauna observations will take place prior to and during underwater drilling activities up to 500m.<br>Soft starts to be used for all equipment where possible | 2 | 3 | 3 | 2 | 36 |
| | Underwater drilling & rock breaking | Change in underwater sediment levels | Disturbance or injury to marine benthic community | Direct | 2 | 2 | 3 | 3 | 36 | ACCEPT | Long term monitoring to be undertaken. Pre and post activity underwater surveys will be conducted by BAS to monitor the impact of this activity.<br>Turbidity monitoring to be undertaken in the cove where coastal stabilisation works will take place | 2 | 2 | 3 | 3 | 36 |
| 3 | Underwater blasting | Change in underwater noise levels | Disturbance to marine mammals resulting in avoidance behaviour or hearing damage | Direct | 2 | 2 | 5 | 4 | 80 | REDUCE | MFO to be deployed 30 mins before blasting to survey 1,200m exclusion zone for cetaceans, 500m for seals and 300m for diving birds.<br>No blasting to be undertaken if cetaceans are present within 1,200m<br>Underwater noise monitoring during blasting to be undertaken | 2 | 2 | 3 | 3 | 36 |
| 4 | Land blasting adjacent to water | Change in underwater noise level | Disturbance to marine mammals resulting in avoidance behaviour or hearing damage | Direct | 2 | 2 | 5 | 4 | 80 | REDUCE | MFO to be deployed 30 mins before blasting to survey 1,200m exclusion zone<br>Peak pressure levels will be measured using a hydrophone and operations modified if different to predicted calculations | 2 | 2 | 3 | 3 | 36 |
| 5 | Extension of wharf footprint | Permanent removal of benthic habitat | Loss of small area of habitat for benthic species | Direct/ cumulative | 1 | 5 | 5 | 4 | 100 | ACCEPT | Preferred design minimises overall additional land required. Opportunities may exist for colonization of newly created underwater wharf surface. | 1 | 5 | 5 | 4 | 100 |
| | | Displacement of rocks and boulders downslope of the wharf construction area. | Disturbance, injury or fatality to benthic marine species downslope of the wharf. | Indirect | 1 | 3 | 4 | 4 | 64 | ACCEPT | The design has sought to reduce the amount of preparation of the sea bed required for construction. A long term monitoring programme is being undertaken by BAS to determine the impacts on the benthic communities adjacent to the wharf. | 1 | 3 | 4 | 4 | 64 |
| 7 | Land blasting adjacent to water | Ground vibration & displacement | Damage to Gerrtisz Lab and Bonner Lab foundations | Direct | 2 | 2 | 3 | 3 | 36 | REDUCE | Monitoring of blast vibration on-site and checking predictions against actual results to confirm compliance with agreed limits. Refinements to blasting procedures can be made if not compliant. | 2 | 2 | 2 | 3 | 24 |
| 8 | Working over / near to water | Marine pollution, hydraulic fluid, lubricant leaks | Marine pollution | Direct | 2 | 3 | 3 | 3 | 54 | REDUCE | Use of biodegradable fluids and lubricants. Spill kits deployed on site. | 2 | 3 | 2 | 3 | 36 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Use of Lighting Rig | Creation of artificial light which may attract birds | Bird strikes resulting in bird injury or fatality | Direct | 1 | 3 | 4 | 4 | 48 | REDUCE | Lighting rigs only to be used in low light and not total darkness<br>Drill team to remain vigilant at all times and note the presence of birds<br>Lights to be turned off when not in use or if a bird strike occurs.<br>Station Leader & Environment Office to be informed immediately of any bird strikes and procedure to be reviewed. | 1 | 3 | 3 | 4 | 36 |
| 10 | Construction and operation of temporary jetty | Change in underwater sediment/dust levels, displacement of rocks. | Disturbance or injury to marine benthic community and data sets from long term monitoring sites | Indirect | 2 | 2 | 3 | 3 | 36 | REDUCE | BAM and BAS ships advised of 20m exclusion zone in south cove to protect monitoring sites<br>Construction of temporary jetty will not extend into exclusion zone | 2 | 2 | 2 | 2 | 16 |

## Quarry, Drilling & Blasting Impacts

| No. | Activity | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, indirect, cumulative, or unavoidable) | Extent | Duration | Probability | Significance/Severity | Risk Score (pre-mitigation) | Risk Response | Preventative or mitigating measures | Extent | Duration | Probability | Significance/Severity | Risk Score (post mitigation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Quarrying rock | Removal of up to 30,000m$^3$ of rock | Permanent visual change to natural landscape altering aesthetic & wilderness value of Rothera Point | Direct/ cumulative | 2 | 5 | 5 | 5 | 250 | ACCEPT | Proposed rock extraction site within current footprint of Rothera Research Station adjacent to an area which has been developed previously.<br>Specific proposed site not considered a pristine wilderness location.<br>Finished quarried rock face will be 50 degrees from horizontal reflecting the current rock face. | 2 | 5 | 5 | 5 | 250 |
| | Quarrying rock | Removal of up to 30,000m$^3$ of rock | Permanent loss of ice free ground, rare environment in Antarctica | Direct/ cumulative | 1 | 5 | 5 | 5 | 125 | ACCEPT | Rock fill requirements calculated to minimise land take<br>No landscaping measures are proposed in order to avoid taking additional ice free ground. | 1 | 5 | 5 | 5 | 125 |
| | Quarrying rock | Use of explosives creating noise (air-over pressure) | Disturbance to nesting skuas which could result in nest desertion. Avoidant, aggressive or stressful behaviour of birds. | Direct | 2 | 2 | 4 | 3 | 48 | REDUCE | Noise model determines noise below TTS for birds<br>Long term monitoring programme for skua to continue & will record changes in nesting behaviours<br>Blast design control measures will be implemented to reduce air over pressure at source. | 2 | 2 | 3 | 3 | 36 |
| | Quarrying rock | Sound pressure waves in the marine environment | Disturbance to marine mammals resulting in avoidance behaviour or hearing damage. | Direct | 2 | 2 | 4 | 4 | 64 | REDUCE | Noise model determines blasting noise below TTS for cetaceans 10m & 20m from shoreline<br>Underwater noise monitoring during blasting to be undertaken to enable modifications in operations if greater impacts are measured. MFO and exclusion zone to be implemented if live monitoring demonstrates an increased risk from predictions. | 2 | 2 | 3 | 4 | 48 |
| | Quarrying rock | Ground displacement & vibration which may | Damage to Gerrtisz Lab and Bonner Lab foundations | Direct | 2 | 2 | 3 | 3 | 36 | REDUCE | Vibration to be controlled to BS7385-2:1993<br>BAS Estates confirmed Gerrtisz and Bonner Laboratories not vibration sensitive | 2 | 2 | 2 | 3 | 24 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | affect integrity of building structures | | | | | | | | | Blast design process to ensure ground displacement only occurs within a few metres of the extraction zone.<br>Outline predictions of anticipated vibration calculated per charge.<br>Monitoring of peak particle velocity and air-over pressure throughout blasting using seismographs will occur to ensure compliance to threshold levels & to collect data to allow continuous improvement of prediction models. | | | | | |
| | Quarrying rock | Interaction with scientific equipment and research | Interruption to staff working in Gerrtisz Lab, Bonner Lab and Boatshed activities resulting in reduction to science | Direct | 2 | 2 | 5 | 3 | 60 | REDUCE | No vibration sensitive equipment used in either labs or boatshed.<br>All three buildings to be evacuated during blasting as per Drill & Blast Management plan.<br>Programme of blasting to be agreed with Rothera Station Leader prior to execution. | 2 | 2 | 4 | 3 | 48 |
| | Quarrying rock | Interaction with scientific equipment and research | Damage or disturbance to other science equipment | Direct | 1 | 2 | 3 | 2 | 12 | REDUCE | Liaison with Rothera Science Coordinator will be undertaken prior to blasting to ensure POM Sun Photometer, Newcastle University GPS receiver and search coil magnetometer are suitably protected or relocated. | 1 | 2 | 2 | 2 | 8 |
| | Quarrying rock | Ground displacement & vibration which may affect integrity of building structures | Damage or deterioration to local heritage memorials. | Direct | 1 | 2 | 3 | 3 | 18 | REDUCE | Memorials will be monitored before, during and after blasting activities and record any changes by taking photos.<br>Construction team will inform the BAS Environment Office of any damage and prior to any repairs being undertaken.<br>Any damage to the structures upon which the memorials are fixed or the memorials themselves will be repaired. | 1 | 2 | 3 | 2 | 12 |
| | Quarrying rock | Dust deposition on flora | Smothering of flora. | Direct | 2 | 2 | 3 | 3 | 36 | REDUCE | Position dust creation activities downwind of sensitive receptors and the ramp where possible. | 2 | 2 | 2 | 2 | 16 |
| | | | Dust deposition on ramp resulting in increased melt during summer. | Direct/ cumulative | 2 | 2 | 4 | 3 | 48 | REDUCE | Use of dust suppression equipment during drilling e.g. dust hood and collection system.<br>Careful blast design to minimise ejection of material into the air.<br>Suspension of blasting on days when excessively windy or blowing in the direction of sensitive receptors.<br>Control of dust from plant operations e.g. spraying plant and roadways with seawater, limiting drop height of materials. | 2 | 2 | 3 | 3 | 36 |
| | Quarrying rock | Rock throw during blasting | Damage to people, buildings or fauna during blasting. | Direct | 1 | 2 | 3 | 3 | 18 | REDUCE | Blast process designed to minimise rock throw. Rock ejection to be contained within a few metres of rock face inside quarry footprint and laydown area 2.<br>Rock bund to be created to protect Gerritsz lab.<br>Use of exclusion zone during blasting.<br>Site walkover prior to blasting to ensure birds are not within the blasting zone | 1 | 2 | 2 | 3 | 12 |

## Coastal Stabilisation Impacts

| No. | Activity | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, indirect, cumulative, or unavoidable) | Extent | Duration | Probability | Significance/Severity | Risk Score (pre-mitigation) | Risk Response | Preventative or mitigating measures | Extent | Duration | Probability | Significance/Severity | Risk Score (post mitigation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Concrete Casting | Dust deposition | Potential damage to soil organisms and vegetation due to high alkalinity of cementitious liquids and cement dust. | Direct | 2 | 3 | 3 | 3 | 54 | REDUCE | Concrete batching plant will be positioned away from sensitive receptors<br>Cement silos will be airtight<br>Locally sourced aggregates will be kept damp<br>Conveyors will be covered and transfer point encapsulated<br>Overfill protection installed on hopers and silos<br>Silt buster tank will be used to filter water before discharge | 2 | 3 | 2 | 3 | 36 |
| 2 | Underwater rock breaking | Sound pressure waves in the marine environment | Disturbance to marine mammals resulting in avoidance behaviour or hearing damage. | Direct | 2 | 2 | 4 | 4 | 64 | REDUCE | Noise model determines blasting noise below TTS for cetaceans 10m & 20m from shoreline. MFO and exclusion zone to be implemented if live monitoring demonstrates an increased risk from predictions. | 2 | 2 | 3 | 4 | 48 |

## 7.3. Cumulative Impacts

Cumulative impacts are the combined impact of past, present and reasonably foreseeable activities which may occur over time and space and be interactive (ATS, 2016). When considered in this wider context of other actions, an activity may result in a potentially significant impact that may occur over a longer period of time, at a particular location and in conjunction with other events.

Rothera Point has been used operationally since 1975 (See Section 9.2) and has been developed and expanded ever since. The proposed works will marginally increase the overall footprint of the current station by extending the wharf. The proposed works will not change the current operational or scientific activities undertaken at Rothera, but they will enable those activities to continue into the future.

In anticipation of a future need for rock fill for the Rothera Modernisation project (as described in Section 14 Gaps and Uncertainties), the volume of rock proposed to be quarried locally and outlined in this document, includes any additional requirement for those works. As described in Section 3, the quarrying activity will occur over one seasons and be complete by the end of the 2019 season. By taking this approach the cumulative impacts associated with all quarrying activities have been fully assessed within this EIA and are confined to the time period outlined for this project.

The activities which have been identified as having a potentially cumulative impact for the Rothera Wharf reconstruction and coastal stabilisation works are listed below:

- Dust deposition on the ice ramp
- Loss of ice free ground for terrestrial habitat
- Removal of rock resulting in a change in the aesthetics of Rothera Point
- Increase in station footprint resulting in the loss of marine benthic habitat
- Contribution to global atmospheric pollution

A full description of the impacts and the proposed mitigation measures for each of these activities within the context of this project are included in Section 11. However considered in the wider context of the Rothera Modernisation works an additional assessment of these specific activities will be made when preparing relevant EIAs in the future.

# 8. MONITORING & AUDIT REQUIREMENTS

## 8.1. Monitoring Plan

Article 5 of Annex I to the Environmental Protocol explicitly requires appropriate monitoring of key environmental indicators to be put in place to assess and verify the predicted impacts following completion of a CEE. It states that monitoring needs to "*be designed to provide regular and verifiable records of the impacts of the activity*" (Article 5(2)) and to *"provide information useful for minimising or mitigating impacts, and, where appropriate, information on the need for suspension, cancellation or modification of the activity"* (Annex I, Article 5, (2) (b) Environmental Protocol, 1991). Provision should also be made for regular and effective monitoring to be in place to facilitate early detection of possible unforeseen effects of activities (Article 3 (2) (e) Environmental Protocol, 1991).

Within Appendix F a monitoring plan has been included outlining the monitoring activities to be undertaken during the project.

The main impacts identified in this assessment for which there are key environmental indicators include the contamination of the terrestrial and marine environment, habitat loss, noise, vibration, dust and wildlife displacement.

The monitoring tasks are split into two types of activities;

1) Short term monitoring of activities which could result in an immediate impact on the environment and can be modified during the construction programme to avoid adverse effects. This will include monitoring of the following activities:

    - Neutralisation of cement contaminated water
    - Sediment levels in seawater (turbidity)
    - Wildlife displacement
    - Noise from quarrying and construction activities
    - Vibration from quarrying and construction activities
    - Marine noise from construction activities
    - Airborne dust

2) Monitoring of environmental parameters which may reflect impacts that can only be measured in the long term (i.e. over several Antarctic seasons) and subsequently are unlikely to be modified beyond the original mitigation identified in the CEE. This will include monitoring of the following parameters:

    - Skua breeding success on Rothera Point
    - Marine benthic invertebrate communities

Any changes to activities proposed as a result of the monitoring data, will be made by the Construction Manager in conjunction with the BAS Environment Office. All monitoring data will be communicated to the BAS Environment Office and be available on request for auditing purposes.

## 8.2. Environmental Management

A number of standard environmental management activities will be undertaken during the construction period and the associated relevant data will be collated for use in BAS's general environmental reporting. These data will include the following:

- Waste statistics
- Fuel use for construction activities
- Fuel use for carbon accounting e.g. flights, ships etc.
- Ongoing monitoring in the ASPA

This information will be reported in the BAS Annual Environmental Report and submitted to the FCO, as the UK's competent authority.

## 8.3. Audit Programme

An audit programme will be undertaken during the construction works by the BAS Environment Office to ensure that the actions and mitigation measures committed to in this document are being adhered to. The audits will also be conducted against the ISO14001:2015 standard to which BAS is registered. A minimum of two onsite audits will be undertaken during the construction programme and a further EIA review which will include a site visit to Rothera will be undertaken on completion of the works.

# 9. GAPS IN KNOWLEDGE & UNCERTAINTIES

## 9.1. Rothera Wharf

*Rothera Wharf design*

The original design information provided for Rothera Wharf was based on the '65% design details' available at the time of writing. The Detailed Design Stage is due for completion in Sept 2018. There were no significant departures from the 65% design. Impacts associated with any minor changes to the design have been evaluated and included in this final version of the CEE. Since the submission of the draft CEE the amount of rock required for the wharf has decreased significantly from 140,000 - 155,000 tonnes (52,000-27,400$m^3$) to 65,000 – 80,000 tonnes (24,000-30,000 $m^3$).

*Site setup locations and logistics*

The locations of material and plant laydown and storage areas available have been identified indicatively on the Site Layout Drawing Figures 3-15 and 3-16. Further discussions will be undertaken with BAS Operations Delivery to finalise and agree these locations once site logistics are developed in 2018 during the Detailed Design Stage.

*Resource quantities*

The volume of rock needed to be quarried is dependent on both the useable yield of quarried material and also the amount of material that can be reused from the existing wharf. The volumes provided in this CEE are based on worst case estimations derived from information provided by the Site Investigation and the experience that the contractor has from working with similar rock properties.

Anticipated volumes of water and fuel presented in this document are based on estimations on the current design detail. Once the detailed design is complete in September 2018 more accurate figures will be available.

*Plant & Equipment*

The large plant items listed are unlikely to change, however, it is anticipated there may be minor changes in the types of smaller plant such as tractors, trailers, generators and compressors.

## 9.2. Coastal Stabilisation

The final solution for coastal stabilisation works, will be confirmed after further investigations on site have been completed which is likely to be in April 2019. The proposed methodology included in this CEE is the current anticipated design. Further consideration of the most appropriate materials to be used for the toe and armour will be made. Investigation into whether excess material from the quarrying works can be utilised will be undertaken in the first construction season any changes to the design will be re-evaluated and an EIA update provided.

## 9.3. Rothera Modernisation

The Rothera Modernisation project is a future AIMP programme funded by NERC, which aims to upgrade the station infrastructure at Rothera over a 5-10 year period. Many of the existing buildings have reached or are fast approaching the end of their economic life, driving up maintenance costs and reducing organisational resilience. The objective of the project is to constrain operating costs at Rothera, whilst maintaining the current level of Antarctic presence. The scope of the project currently includes:

- Replacing aged buildings with modern more flexible spaces to minimise future maintenance and operating costs and significantly improve the energy efficiency.

- Consolidating and rationalising the existing estate to provide infrastructure which minimise energy use, reduce the costs of snow clearance and maintenance of services.

The project will consider future science and logistical requirements to ensure that Rothera continues to be the keystone of UK Antarctic Operations, providing support for science around Rothera and across the continent. Minimising the environmental impact and developing sustainable infrastructure at Rothera Research Station is one of the critical success factors for the project.

A master planning exercise has been undertaken and a draft report; *Rothera Modernisation Project, Master Planning Repor*t, (Ramboll, 2017), has been produced by BAS' technical advisors Ramboll at work stage 0. Phase 1 of the Project includes the replacement of:

- scientific operations buildings;
- estates and vehicles buildings; and
- site services dependent on the outcome of a revised BAS Energy Strategy which could include combined heat generators with solar thermal and PV.

An EIA will be prepared for the Phase 1 and be ready for submission in 2019, once the Developed Design Report and Works Information have been completed at the end of Work Stage 3b. The EIA will assess the cumulative impacts associated with works included in this assessment and any other known future developments.

The expected time frame for the future stages of the Rothera Modernisation Project Phase 1 are as follows:

*Table 9-1 Future Work Stages for Rothera Modernisation*

| Work Stages | Anticipated Start Date | Anticipated Finish Date |
|---|---|---|
| WS 0 Strategic Project Definition | January 2017 | December 2017 |
| WS 1 Project Feasibility | January 2018 | June 2018 |
| WS 2 Assessment Study | June 2018 | September 2018 |
| WS 3a Developed Design | September 2018 | October 2018 |
| WS 3b Tender Preparation | October 2018 | November 2018 |
| WS 3c Tender Invitation, Evaluation & Contract Awards | November 2018 | June 2019 |
| WS 4 Technical Design and pre-construction | June 2019 | April 2020 |
| WS 5 Construction Enabling Works Groundworks and Footings | January 2020 | April 2020 |
| WS 5 Construction Main Works | November 2020 | December 2021 |
| WS 6 Completion & Handover | January 2022 | April 2022 |
| WS 7 Defects Period | June 2023 | June 2023 |
| WS 8 Financial close | | June 2024 |

## 9.4. Other Future Projects

In addition to the project outlined above there are future aspirations for replacing the aircraft hangar, the fuel farm and the marine building at Rothera. Whilst these are included in the Master plan these projects have not yet been funded and no commitment to progressing these projects has been made by NERC or BAS. These aspirational projects have been nominally divided into two further phases of the Rothera Modernisation Project which could potentially include the following;

Phase 2:

- replacement of an accommodation building (Giants);
- marine facility;
- aircraft and vehicle hangar; and
- development of further renewable energy to reduce demand for fuel.

Phase 3 (Beyond 2030)

- replacement of remaining accommodation (New Bransfield and Admirals House);
- science laboratory (replacing Bonner Lab);
- sewage treatment works; and
- improved communications.

# 10. CONCLUSIONS

The Rothera Wharf reconstruction and coastal stabilisation works, are an essential project for BAS to be able to fully utilise the new BAS ship, the SDA. The project has been designed to take account of environmental and social impacts which will be evidenced through the CEEQUAL assessment. The proposed plans largely avoid areas of ecological sensitivity and will predominantly occur in previously disturbed and developed locations at Rothera.

A full assessment of the potential environmental impacts are included in this CEE within Section 11. Most of the impacts can be managed within existing BAS procedures or with the addition of specific mitigation and monitoring.

The most significant potential impacts predicted are:

- Introduction of non-native species
- Terrestrial or marine pollution from fuel spills
- Removal of rock resulting in a change in the aesthetics of Rothera Point
- Loss of ice free ground for terrestrial habitat
- Disturbance to marine mammals from underwater noise
- Loss of marine benthic habitat

The introduction of non-native species as a result of importing cargo or the deployment of personnel could have a significant impact in the longer term, but these impacts are less likely if normal operational procedures and enhanced mitigation measures are followed.

The most significant potential impact is the permanent removal of rock for use in the wharf construction. This will potentially alter the aesthetic value for Rothera Point and reduce the available ice free terrestrial habitat. The decision to quarry rock locally was influenced by the need to reduce the risks associated with the importation of large quantities of aggregate which have the potential to introduce non-native species. Since the submission of the draft CEE the amount of rock required for the wharf has decreased significantly from 140,000 - 155,000 tonnes (52,000-27,400$m^3$) to 65,000 – 80,000 tonnes (24,000-30,000 $m^3$).

The probability of impacts associated with fuel spills occurring will also be reduced if standard operating procedures are complied with during refuelling. In the unlikely event of a spill, oil spill contingency plans are in place and will be followed to minimise the severity of impacts.

Disturbance or harm to marine mammals from changes in underwater noise could result in a significant impact however the robust mitigation measures outlined will be adhered to, to ensure that the risk of this occurring is minimised and where possible avoided.

The extension of the wharf will result in a small reduction in the local marine benthic habitat within the footprint of the new wharf. A further impact on the surrounding benthic communities could occur from general construction activity. The wharf design has sought to reduce the amount of sea bed preparation required and therefore the extent of the potential impact, and a long term monitoring programme is already underway in order to verify the predicted impacts.

Having prepared this CEE and presented rigorous mitigation measures to reduce the risk of these impacts occurring, it is considered that some activities within the project will have a greater than minor or transitory impact.  This level of impact is considered acceptable considering the significant operational and scientific advantage that will be gained as a result of the project.

# 11. AUTHORS OF THE CEE

This CEE has been prepared by Clare Fothergill of the BAS Environment Office. The baseline section was written by Kevin A. Hughes with input from a number of expert contributors listed below in the acknowledgements section. Construction specific mitigation measures, biosecurity procedures, spill response and waste management procedures were written in conjunction with Neil Goulding of BAM.

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# 12. ACKNOWLEDGEMENTS


Expert contributors to the Baseline Section include the following BAS personnel; David Barnes, Steve Colwell, Peter Convey, Rosey Grant, Laura Gerrish, Ieuan Hopkins, Louise Ireland, Jennifer Jackson, Anna Malaos, Simon Morley, Lloyd Peck, Teal Riley, Helen Peat, Richard Phillips, Joanna Rae, Ben Robinson, Andrew Smith and Iain Staniland. Detail on facilities management at Rothera was provided by Tim Jackson.

Detail on the design elements of the project have been provided by BAM personnel Gerard Turk, Martha McGowan, Chris McGuiness Ian Wenkenbach, and Billy Thursfield and Ramboll personnel Helen Baker, Beccy Cusworth, Alan Eggleton, Alan Roper and Nick Smith. Jan Cordon of BAM has provided detail on the quarry, drill and blast procedures.

Aquatera and their subcontractors, Subacoustech, produced the noise assessments included in Appendix G.

This CEE has been reviewed internally at BAS by Tim Stockings Director of Operations, David Vaughan Director of Science, David Seaton Project Manager for AIMP and Rachel Clarke Head of Environment Office. An external review has been completed by Neil Gilbert of Constantia Consulting Ltd. Stuart Doubleday, Deputy Head of the Polar Regions Department at the Foreign and Commonwealth Office has also completed a review of the final CEE.

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# 15. APPENDICES

## 15.1. Appendix A – Marine Drilling and Blasting Management Plan: Rothera Wharf

## 15.2. Appendix B - Quarrying, Drilling and Blasting Management Plan: Option H

## 15.3. Appendix C – Equipment List: Rothera Wharf

## 15.4. Appendix D – Site Waste Management Plan: Rothera

## 15.5. Appendix E – Biosecurity Plan: Rothera

## 15.6. Appendix F - Monitoring Plan: Rothera

## 15.7. Appendix G - Noise Assessment

## 15.8. Appendix H – Ecological Species List

## 15.9. Appendix I – Geotechnical Interpretative Report

## 15.10. Appendix J – Coastal Stabilisation Technical Note

## 15.11. Appendix K – Response to comments received by the CEP and Treaty Parties