Appendix 1 - Wharf Structural Assessment Report

BAA.4010 KING EDWARD POINT, SOUTH GEORGIA – NEW WHARF

SITE INVESTIGATION – NOVEMBER 2018 INSPECTION OF EXISTING WHARF STRUCTURE – FACTUAL REPORT

	Name	Position	Date	Signature
Prepared by:	David Kilburn	Design Manager	03 / 01 / 2019	
Checked by:	Stewart Craigie	Lead Designer	21/01/2019	
Approved by:	Stewart Craigie	Lead Designer	21/01/2019	

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1.0 INTRODUCTION

BAM Nuttall Ltd have been commissioned the British Antarctic Survey (BAS) to develop the existing berthing facility at King Edward Point on South Georgia to accommodate the new BAS research vessel RRS Sir David Attenborough currently under construction in the United Kingdom. The berthing facility is and will be run and operated by the Government of South Georgia and the South Sandwich Islands (GSGSSI) who can therefore be considered a major stakeholder in the design and construction of the new facility.

To facilitate the construction of the new wharf structure the contractor plans intends to use the existing wharf structure to support heavy construction equipment, most notably a tracked crawler crane and a heavy duty telehandler, and possibly some temporary works, such as piling gates. Therefore for the safety of the construction personnel involved, as well as the expeditious and successful construction of the new wharf structure, it is imperative that the contractor undertakes a visual check on its condition with a view to:

1. Identifying any areas of damage.
2. Determining the nature, magnitude and position of any corrosion.
3. Identifying any deviations in the construction from the design drawings.

Following the inspection the existing wharf structure a design check will be undertaken to determine whether the existing wharf structure has sufficient capacity for the planned loadings and / or determine other more suitable locations for the heavy equipment.

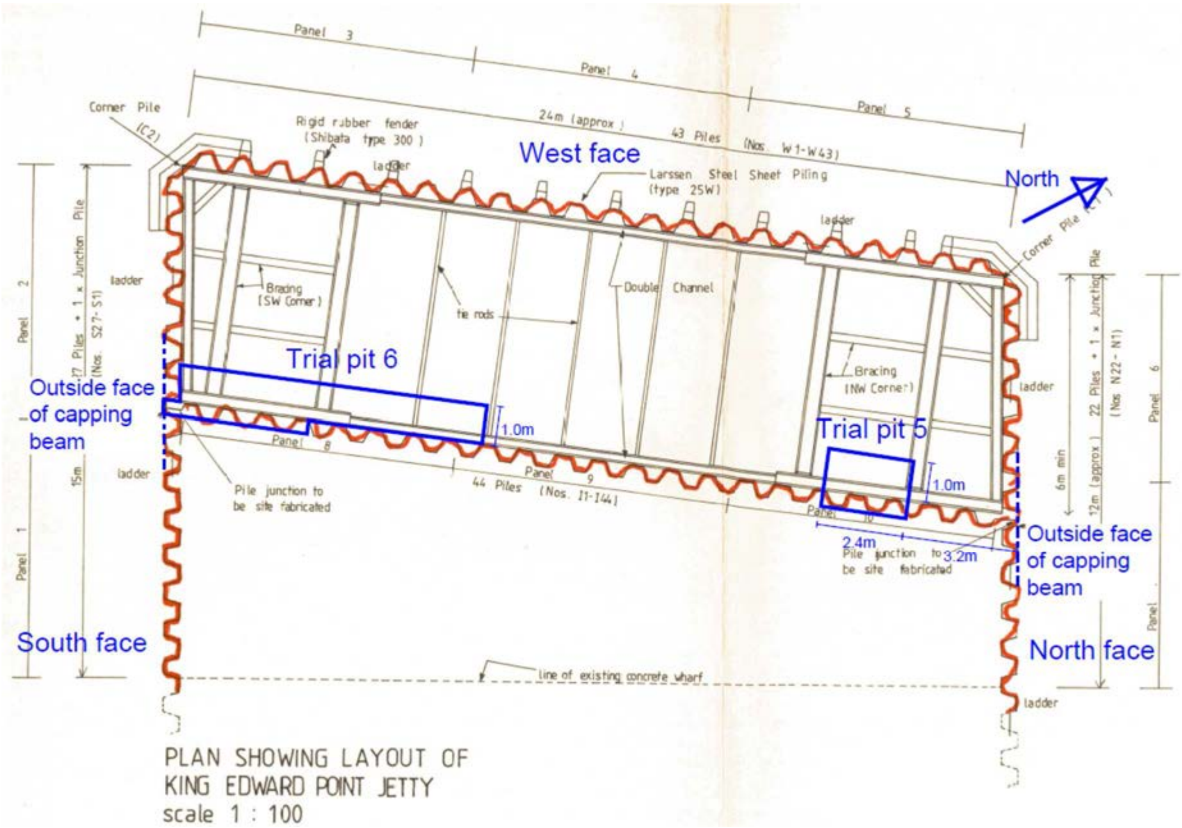
The existing wharf structure was constructed in 1986 by the Royal Engineers. Drawings and reports on the design and construction are available for inspection as part of the Site Information.

This observation report therefore is on the site investigation undertaken by BAM Nuttall Ltd during the 17 – 21 November 2018.

Date of site visit:	17-21 November 2018
BAM Participants:	David Kilburn (BAM Nuttall) Jan Cordon (BAM Ritchies)
GSGSSI operatives	Adrian Faill (General Foreman) supported by operatives Steve and Darren.

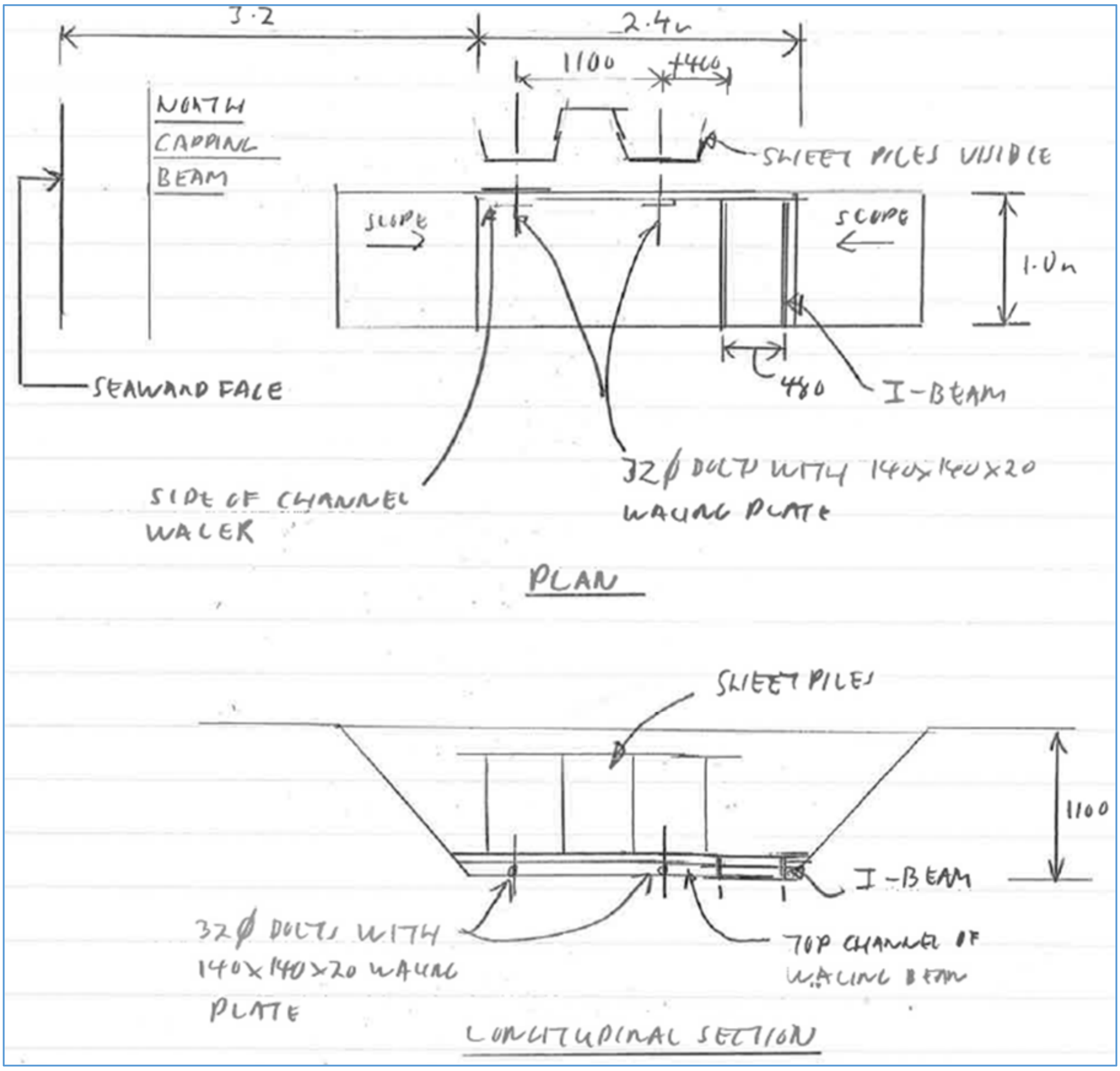
2.0 SITE INVESTIGATION, NOVEMBER 2018

Please see the layout plan below for the locations of the site investigations.



TRIAL PIT 5

Location: Trench in front of anchor wall on west side of wharf.
Date of investigation: 17th November 2018
Trial pit photographs: See Trial Pit 5 on Projectwise
Means of access: Excavation by 8 tonne excavator; some pumping to reduce water level.



View along trial pit

`View on sheet piles to anchor wall

View on waling to anchor wall

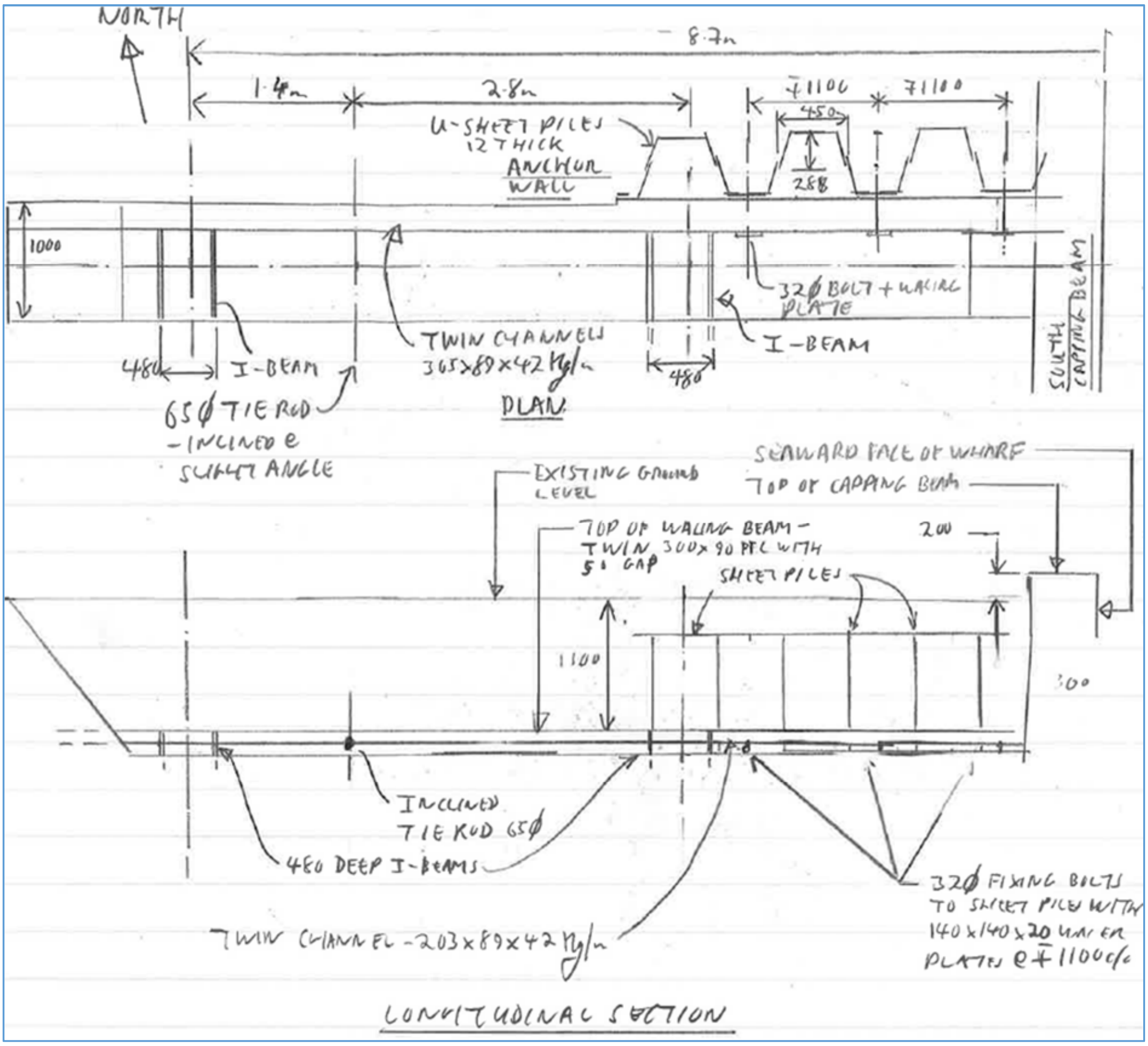
Bolt, waling beam and waling plate to anchor wall

Observations

No.	Element	Observation
1	Sheet piles	• No signs of distress. • Light red scaling due to corrosion. • Reasonable condition
2	Waling beams	• No signs of distress. • No signs of corrosion. • Good condition.
3	Connecting bolt between waling beam and sheet piles	• No signs of distress. • No signs of corrosion. • Good condition.
4	Waling plates to connection bolts between waling beams and sheet piles.	• No signs of distress. • No signs of corrosion. • Good condition.
5	Connecting universal beams between anchor wall waling and and front wall	• No signs of distress. • No signs of corrosion. • Good condition.

Trial Pit 6

Location:	Trench in front of anchor wall starting adjacent to east wall of wharf and extending approximately one third across wharf structure in east-west direction
Date of investigation:	17th November 2018
Trial pit photographs	See Trial Pit 6 on Projectwise
Means of access:	Excavation by 8 tonne excavator; some pumping to reduce water level.



View along trial pit

Waling beam to anchor wall and connecting inclined tie rod to front wall

View along trial pit

View on sheet piles to anchor wall

View on sheet piles to anchor wall

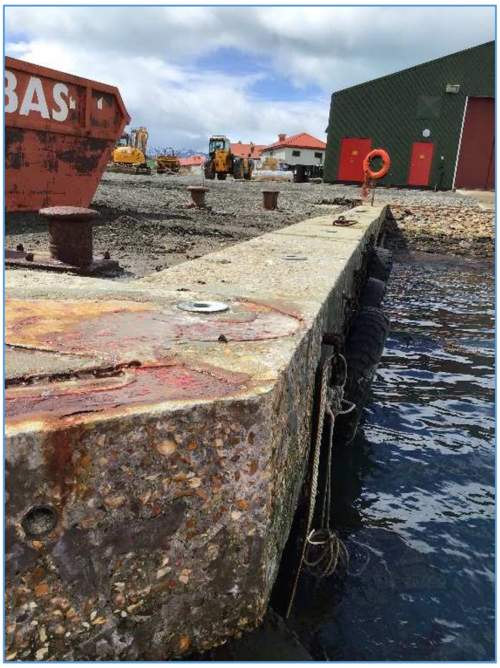
Bolt, waling beam and waling plate to anchor wall

Observations

No.	Element	Observation
1	Sheet piles	• No signs of distress. • Light red scaling due to corrosion. • Reasonable condition
2	Waling beams	• No signs of distress. • No signs of corrosion. • Good condition.
3	Connecting bolt between waling beam and sheet piles	• No signs of distress. • No signs of corrosion. • Good condition.
4	Waling plates to connection bolts between waling beams and sheet piles.	• No signs of distress. • No signs of corrosion. • Good condition.
5	Connecting universal beams between anchor wall waling and and front wall	• No signs of distress. • No signs of corrosion. • Good condition.
6	Tie rod between front sheet pile wall and anchor wall	• No signs of distress. • No signs of corrosion. • Good condition. • Slightly inclined towards front wall.

SOUTH SIDE SHEET PILE WALL

Location:	South sheet pile wall of existing wharf.
Date of investigation:	20th November 2018
Photographs:	See South Side on Projectwise
Means of access:	By boat at low tide.



View along top of capping beam

View along most of length of wall

View on west end of south wall

View along east section of south wall

Close up view on east section of south wall

Close up view on west section of south wall

Observations

No.	Element	Observation
1	Sheet piles – visible	• Good alignment. • No sign of any distress or damage. • Corrosion generally light and confined to tidal and splash zones. • No signs of accelerated low water corrosion. • Some green algae above low water. • Green algae and seaweed attached below low water level
2	Capping beam	• Generally intact. • Some damage with bottom corners missing. • Exposed aggregate on front face.

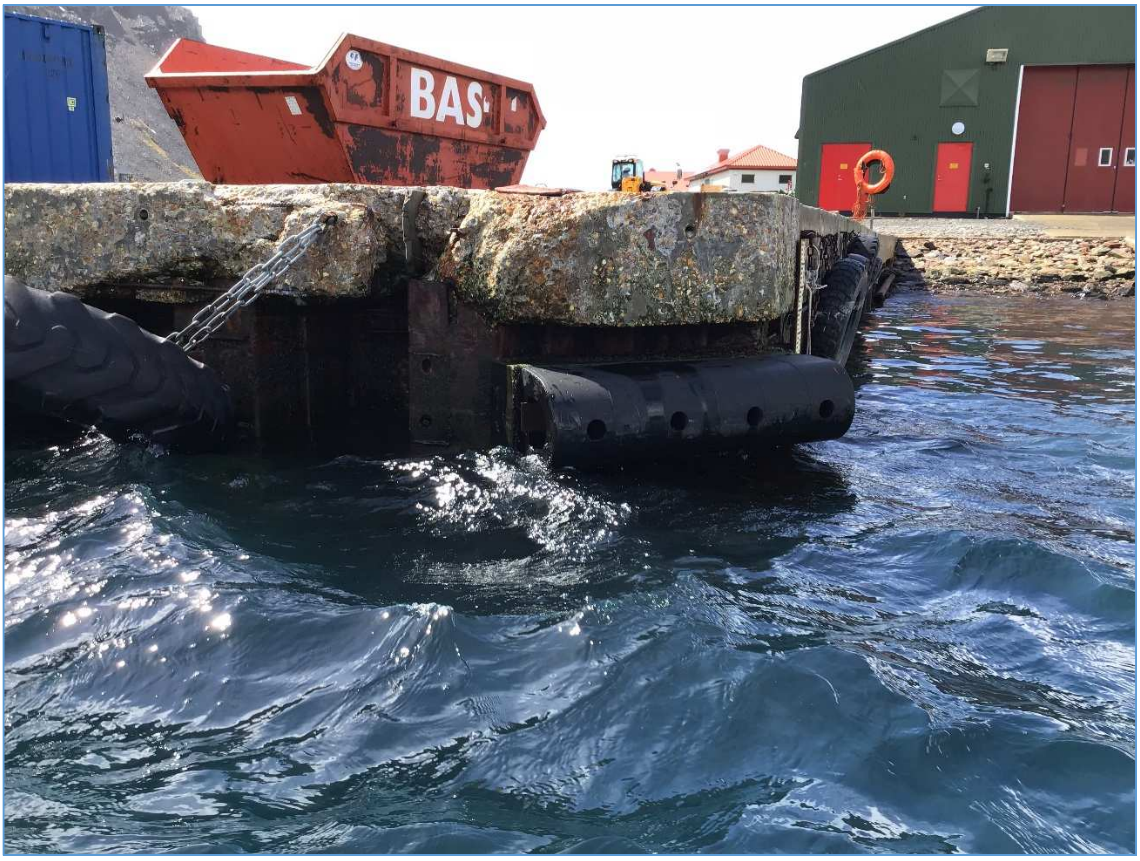
WEST SIDE SHEET PILE WALL

Location:	West sheet pile wall of existing wharf
Date of investigation:	20-21 November 2018
Photographs:	See West Side on Projectwise
Videos:	See Underwater videos on Projectwise
Means of access:	By boat at low tide; top views at low tide.

View on south and west walls

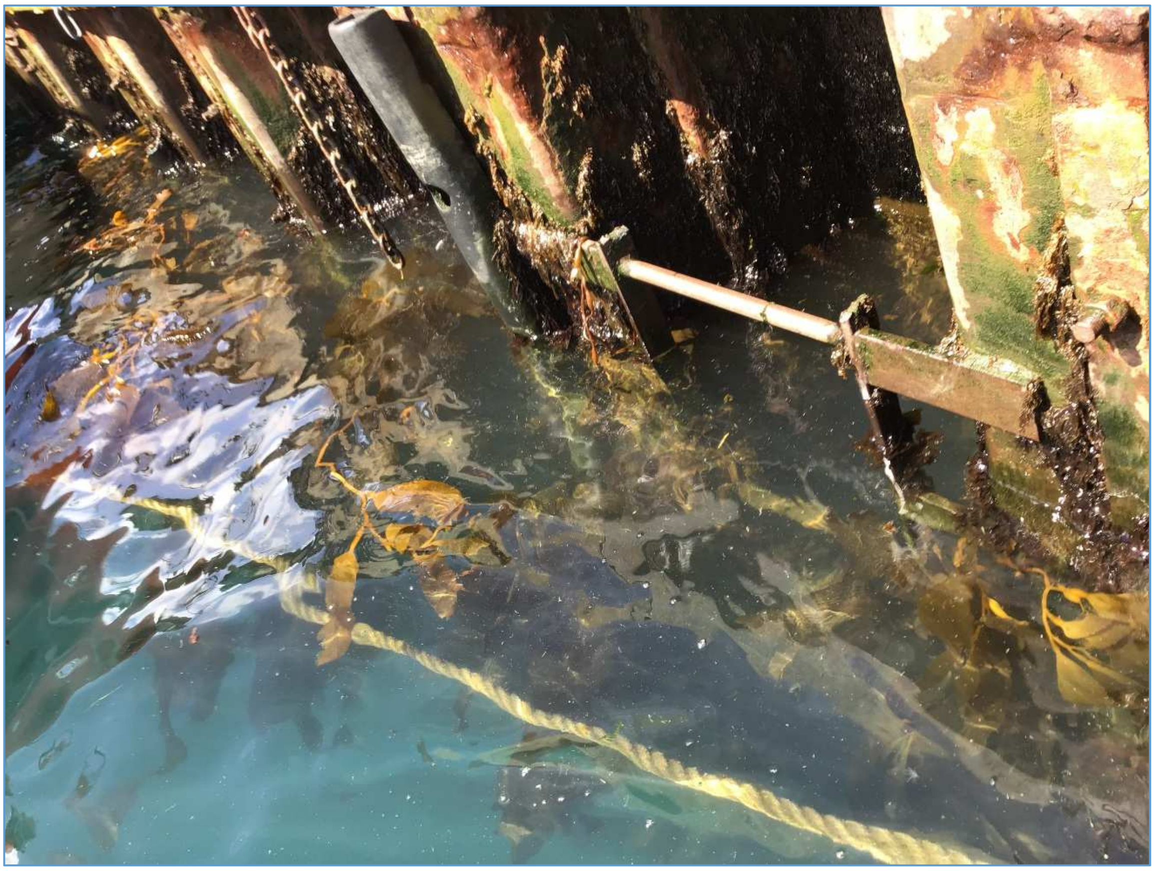
View on south section of west wall

View on central section of west wall



View on south end of west wall

Typical view on sheet piles



View on sheet piles and ladder

End view on sheet pile and tie rod

Top view on sheet piles and tie rod on south wall – note threads on tie rod visible

Capping beam – exposed aggregate on front face and missing corners at ends of beams

Capping beam – north west corner

Observations

No.	Element	Observation
1	Sheet piles – visible	• Good alignment. • No sign of any distress or damage. • Corrosion generally light and confined to tidal and splash zones. • No signs of accelerated low water corrosion. • Some green algae above low water. • Green algae and seaweed attached below low water level
2	Tie rods	• Good condition – threads visible. • See underwater video showing thread on PW link Underwater videos. • Covered in green algae. • No signs of accelerated low water corrosion.
3	Outside waling plates	• Good condition. • No noticeable signs of corrosion
4	Capping beam	• Generally intact. • Substantially damaged with bottom corners missing. • Exposed aggregate on front face. • South west corner – displaced, cracked, missing corners.

NORTH SIDE SHEET PILE WALL

Location: North sheet pile wall of existing wharf.
Date of investigation: 20th November 2018
Photographs: See North side on Projectwise
Means of access: By boat at low tide. Not observed in detail due to limited time available and on-going boat movements

View along central and west sections of north sheet pile wall

View along east section of north sheet pile wall

Observations – note restricted access due to limited time available and on-going ship movements

No.	Element	Observation
1	Sheet piles – visible	• Good alignment. • No sign of any distress or damage. • Corrosion generally light and confined to tidal and splash zones. • Accelerated low water corrosion – no detailed check undertaken but none observed.
2	Capping beam	• Generally intact. • Some damage with bottom corners missing. • Exposed aggregate on front face.

3.0 OTHER SITE INVESTIGATIONS

Although it formed part of another site investigation for completeness it should be mentioned that diving surveys were undertaken in November 2016 by HMS Protector of both the KEP wharf and the Grytviken jetty. The report along with underwater photographs and videos can be found at the link BAA4010-RAM-ZZ-WRF-TR-KA-0040.

Appendix 2 – KEP Ground Investigation (Trial Pits)

BAA.4010 – KEP, South Georgia – New Wharf

New Wharf Construction
Factual Report on Ground Investigation, November 2018
Trial Pit Logs

Document ref:						
Revision	Purpose description	Originator	Checked	Reviewed	Authorised	Date
C02	Issue for information	D. Kilburn				05/12/2018
	Issue for review	D. Kilburn				02/04/2019
	Issue for construction	David Kilburn	James Elson	James Elson	David Kilburn	15/04/2019
C03	Issue for construction	David Kilburn	James Elson		David Kilburn	07/05/2019

Document number: BAA4010-BAM-ZZ-YYY-RP-YG-0001

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Report on site investigation, November 2018
Trial Pit Logs

INTRODUCTION

BAM Nuttall Ltd have been commissioned the British Antarctic Survey (BAS) to develop the existing berthing facility at King Edward Point on South Georgia to accommodate the new BAS research vessel RRS Sir David Attenborough currently under construction in the United Kingdom.

To facilitate an effective design it was necessary to undertake a number of trial pits at different locations to determine the following:

- The soil conditions at those locations.
- The presence and nature of any obstructions.
- The presence and nature of any contaminants.
- The condition of the steelwork on the existing wharf structure.

The latter has been reported in detail in a separate report.

Date of 1st site visit:	17-21 November 2018
BAM Personnel:	David Kilburn (BAM Nuttall) Jan Cordon (BAM Ritchies)
Date of 2nd site visit (trial pit 11 only):	February and March 2019
BAM Personnel	Lloyd Wickens

GSGSSI operatives Adrian Faill (GSGSSI Foreman) supported by operatives Steve and Darren.

Laboratory results See ProjectWise - Wharf Lab Results - collated

Report on site investigation, November 2018
Trial Pit Logs

Location plan of trial pits

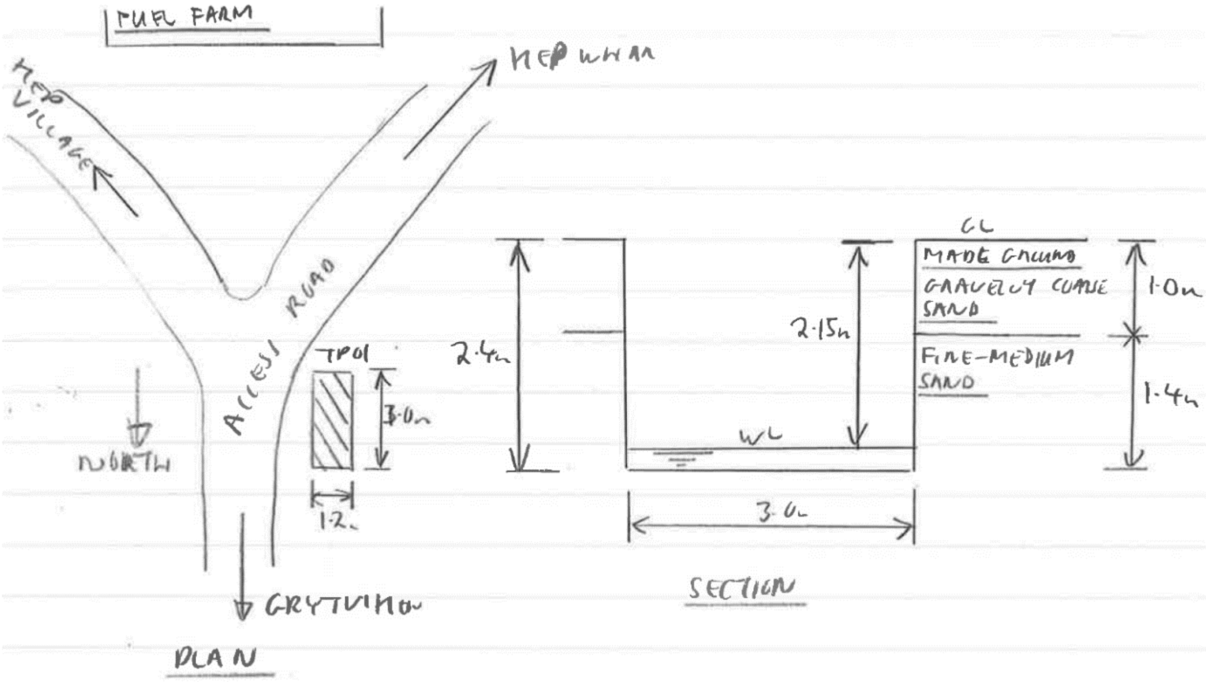
TRIAL PIT LOGS

TRIAL PIT 1

Location: New wharf – mooring point 1.

Date of investigation: 18th November 2018

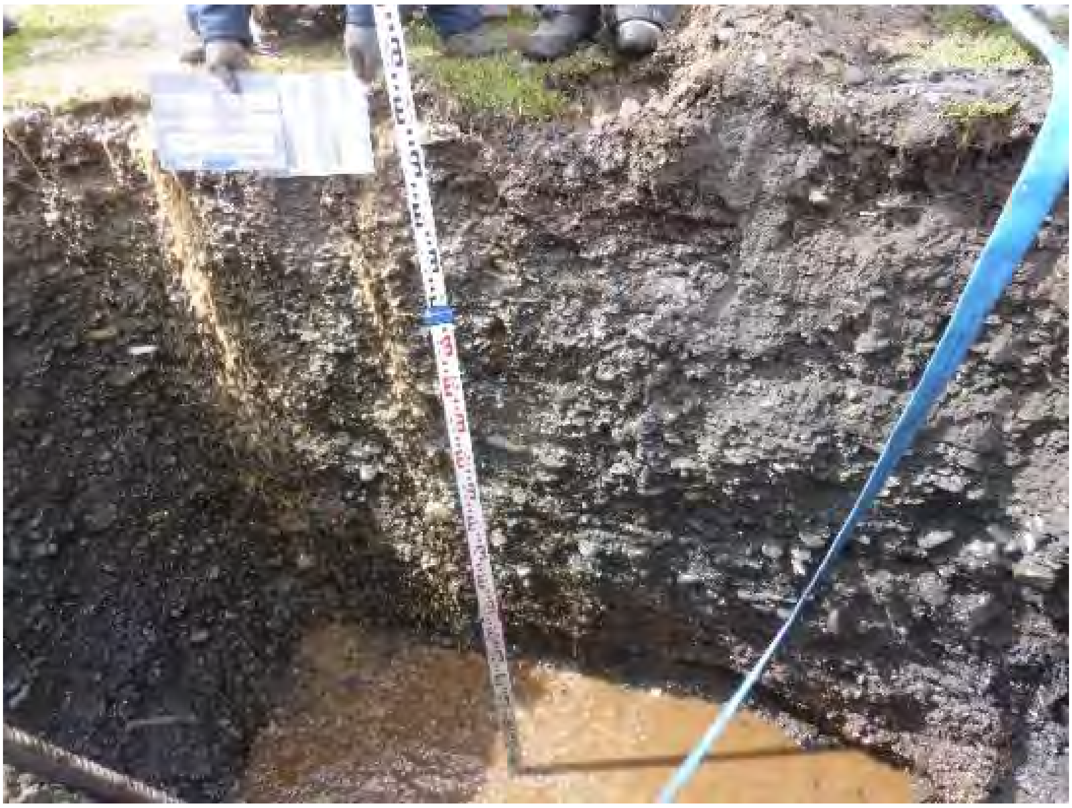
See photos Trial Pit 1



Description:

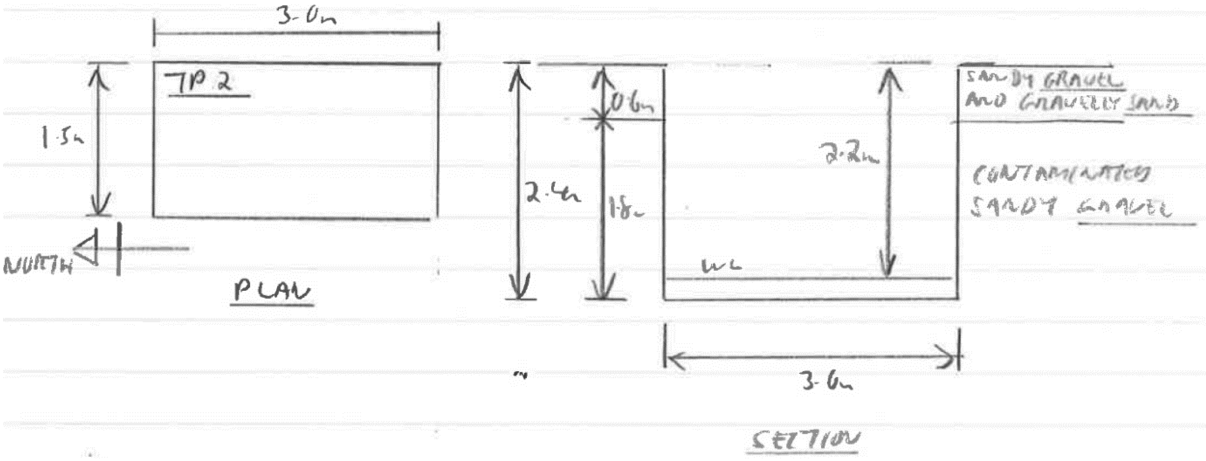
Depth below existing ground (m)	Description
0.0 – 1.0	MADE GROUND. Loose yellow and grey slightly silty fine to coarse gravel with occasional cobbles and pieces of brick. Sand - medium to coarse. Gravel – low sphericity, angular and sub-rounded.
1.0 – 2.4	Medium dense yellow and grey medium to coarse SAND and fine to coarse GRAVEL. Gravel – low sphericity, angular and sub-rounded. Contaminated with weathered diesel – hydrocarbon odour. Water inflow – fast at 2.15m dig depth. Trench terminated due to limited reach of excavator.

Trial pit stable during excavation period of approximately ½ hour period.



TRIAL PIT 2

Location: New wharf – mooring point 2.
Date of investigation: 18th November 2018
See Trial Pit 2



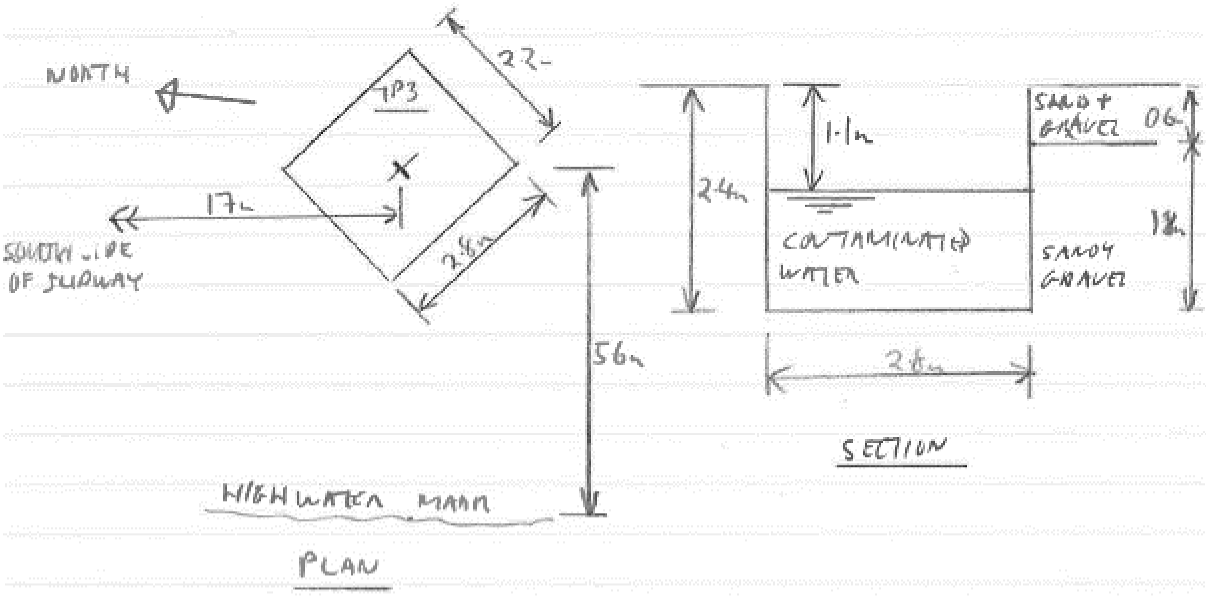
Description:

Depth below existing ground (m)	Description
0.0 – 0.6	MADE GROUND. Very dense yellow and grey slightly silty very sandy fine to coarse gravel with some cobbles and pieces of brick. Sand – medium to coarse. Gravel – low sphericity, angular.
0.6 – 2.4	Dense black oily very sandy fine to coarse GRAVEL with some cobbles and boulders up to 200mm – probably beach material. Sand – medium and coarse. Gravel, cobbles and boulders – low sphericity, sub-rounded. Heavily contaminated with hydrocarbons – black oily with weathered diesel, hydrocarbon odour. Water inflow – fast at 2.2m dig depth. Trench terminated due to limited reach of excavator.

Trial pit stable during excavation period of approximately ½ hour period.

TRIAL PIT 3

Location: New wharf – mooring point 3.
Date of investigation: 17th November 2018
See Trial Pit 3



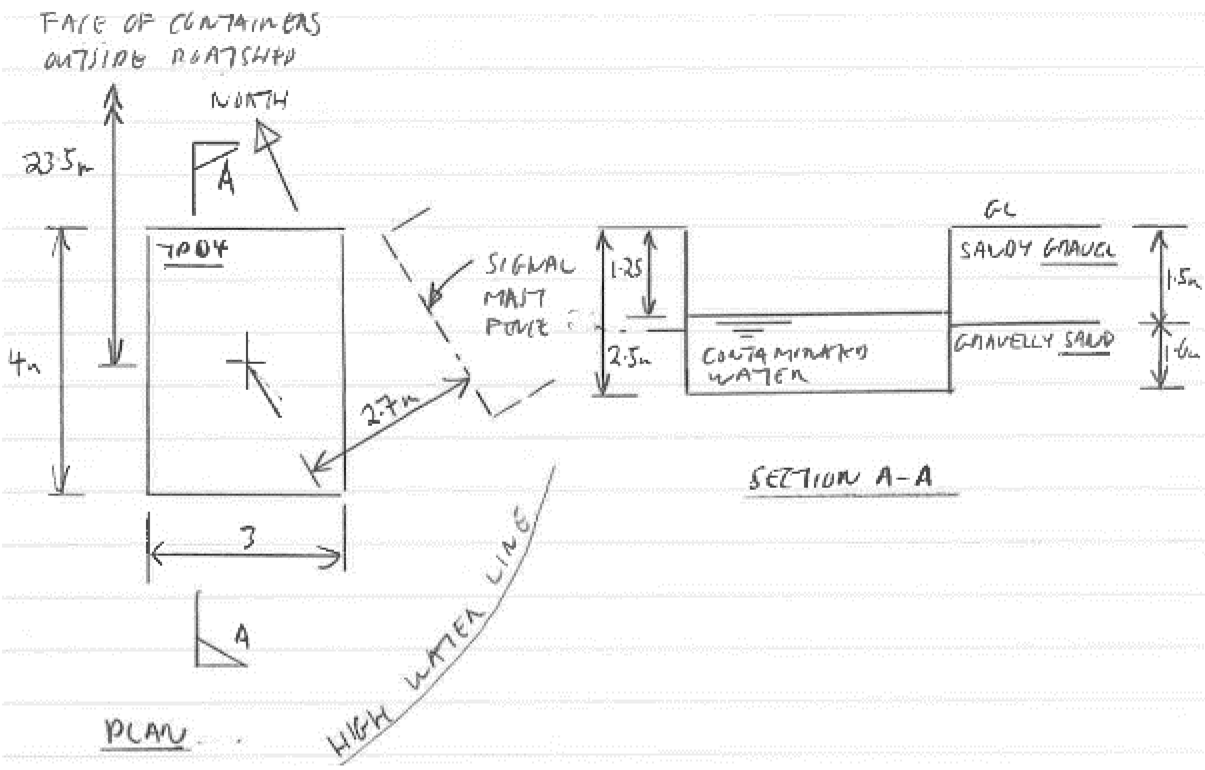
Description:

Depth below existing ground (m)	Description
0.0 – 0.6	MADE GROUND. Medium dense yellow and grey gravelly fine to coarse sand and sandy medium dense gravel with some cobbles and pieces of brick. Gravel – low sphericity, angular. NB. Visual description only – no PSD's undertaken.
0.6 – 2.4	MADE GROUND. Dense black oily / grey fine to medium sandy gravel with some cobbles – probably beach material. Gravel, cobbles and boulders – low sphericity, sub-rounded. Whale bone also present. Hydrocarbon contamination – black oily with weathered diesel, strong hydrocarbon odour. NB. Visual description only – no PSD's undertaken. Water inflow – fast at 1.1m dig depth. Trench terminated due to limited reach of excavator.

Trial pit stable during excavation period of approximately ½ hour period.

TRIAL PIT 4

Location: New wharf – mooring point 4.
Date of investigation: 18th November 2018
See Trial Pit 4



Description:

Depth below existing ground (m)	Description
0.0 – 1.5	Medium dense grey slightly oily fine to coarse sandy GRAVEL with some cobbles. Sand – medium to coarse. Gravel, cobbles and boulders – low sphericity, sub-rounded. 0.15m deep timber exposed on one face.
1.5 – 2.5	Dense black oily sandy fine to coarse GRAVEL. Sand – medium to coarse. Gravel – low sphericity, sub-rounded. Contaminated with weathered diesel, hydrocarbon odour. Water inflow – fast at 1.25m dig depth. Trench terminated due to limited reach of excavator.

Trial pit stable during excavation period of approximately ½ hour period.

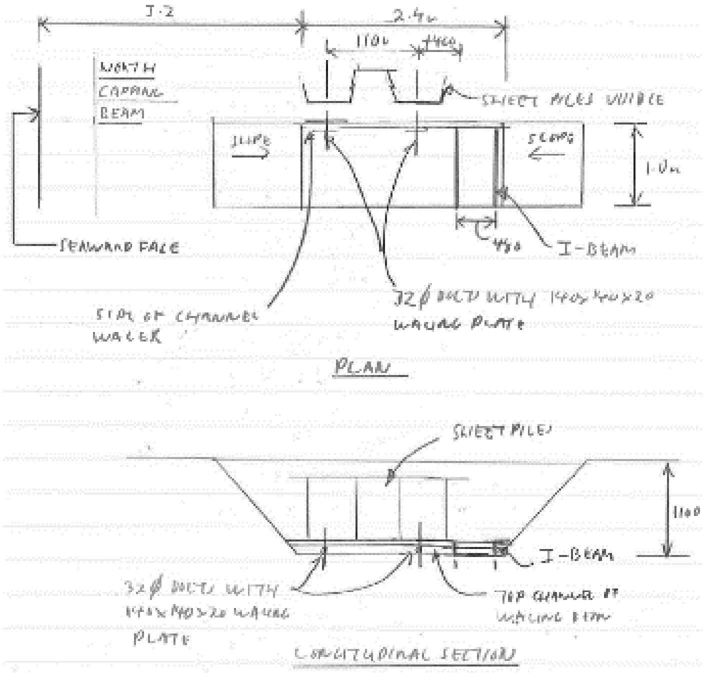
Report on site investigation, November 2018
Trial Pit Logs

TRIAL PIT 5

Location: New wharf – existing wharf anchor wall area.

Date of investigation: 17th November 2018

See Trial Pit 5



Description:

Depth below existing ground (m)	Depth below top of capping beam (m)	Description
0.0 – 1.4	0.2 – 1.6	MADE GROUND. Dense to very dense well compacted approximately 150mm thick layers of slightly silty sandy grey / yellow / orange fine to coarse gravel. Sand – fine to coarse. Gravel – low sphericity, sub-rounded. Sand – medium to coarse. Steel walings and sheet piles on north side of trench; universal beams crossing trench at right angles – see diagrams and separate report. Some contamination with weathered diesel below 0.9m, hydrocarbon odour. Water inflow – fast at 1m dig depth. Trench terminated due to limited reach of excavator.

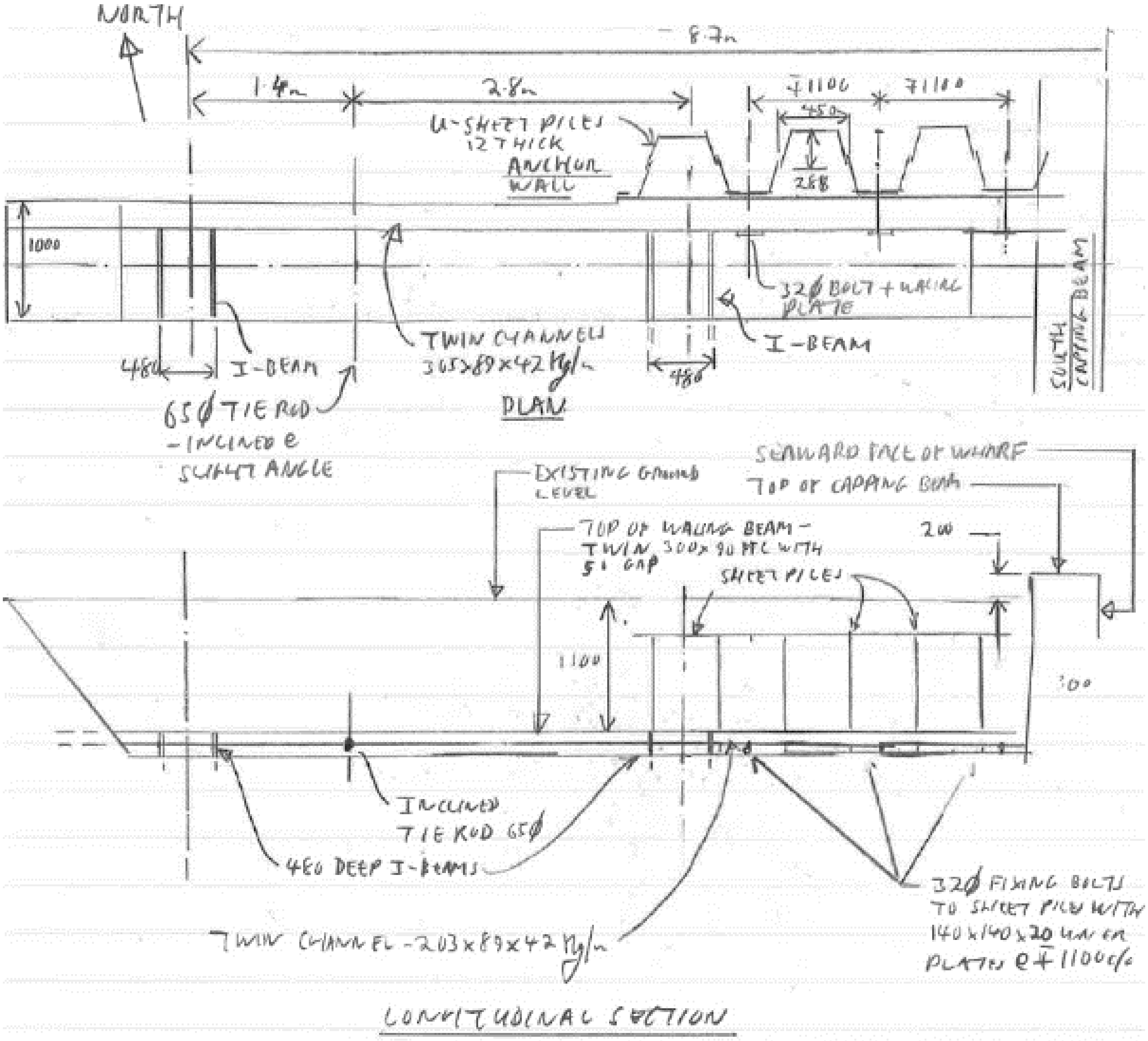
Trial pit stable during excavation period of approximately 1½ hour period.

TRIAL PIT 6

Location: New wharf – existing wharf anchor wall area.

Date of investigation: 17th November 2018

Trial Pit 6



Description:

Depth below existing ground (m)	Depth below top of capping beam (m)	Description
0.0 – 1.3	0.2 – 1.5	MADE GROUND. Dense to very dense well compacted approximately 150mm thick layers of grey / yellow slightly silty sandy fine to coarse gravel. Sand – medium to coarse. Gravel – low sphericity, sub-rounded. Steel walings and sheet piles on north side of trench; universal beams and tie rods crossing trench at right angles – see diagrams and separate report. Some contamination with weathered diesel below 0.9m, hydrocarbon odour. Water inflow – fast at 1.1m dig depth. Trench terminated due to limited reach of excavator.

Trial pit stable during excavation period of approximately 1 hour period.

TRIAL PIT 7

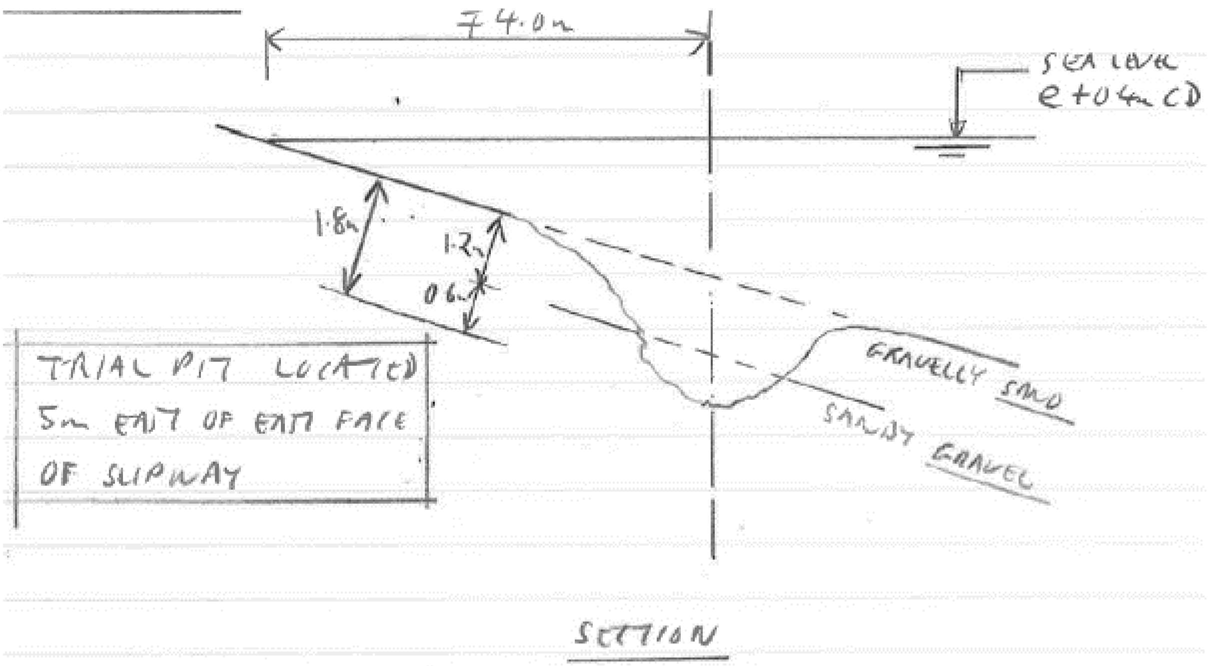
Location: Beach – 5m east of edge of existing slipway.

Date of investigation: 20th November 2018

See Trial Pit 7

Description:

Depth below existing ground (m)	Description
0.0 – 1.2	Grey black very sandy fine to coarse GRAVEL with some cobbles. Sand – medium to coarse. Gravel and cobbles – low sphericity, rounded. Gravel content increasing with depth. NB. Trench dug below sea level – impossible to assess density of material.
1.2 – 1.8	Grey black very sandy fine to coarse GRAVEL with some cobbles and occasional boulders up to 400mm. Sand – medium to coarse. Gravel – low sphericity, rounded. Cobbles and boulders – low sphericity, sub-rounded. NB. Trench dug below sea level – impossible to assess density of material or trench stability.



0.0 – 1.2m

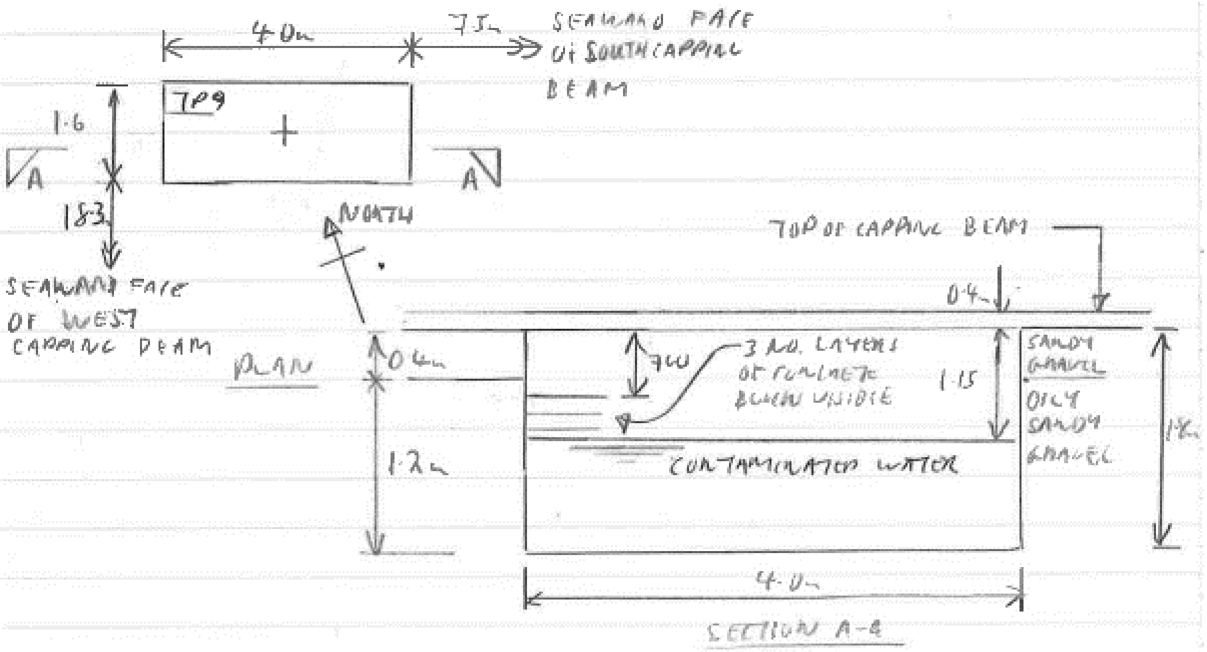
1.2 – 1.8m

TRIAL PIT 9

Location: New wharf – proposed anchor wall location

Date of investigation: 17th November 2018

See Trial Pit 9



Description:

Depth below existing ground (m)	Depth below top of capping beam (m)	Description
0.0 – 0.4	0.2 – 0.6	MADE GROUND. Dense well compacted grey slightly silty very sandy fine to coarse gravel with cobbles. Sand – medium to coarse. Gravel – low sphericity, sub-rounded. Cobbles – low sphericity, very angular.
0.4 – 1.6	0.6 – 1.8	MADE GROUND. Black slightly silty very sandy fine to coarse gravel with cobbles and boulders up to 400mm heavily contaminated with heavy diesel. Sand – medium to coarse. Gravel – low sphericity, sub-rounded. Cobbles and boulders – low sphericity, very angular. Also present – steel container, old glass bottle, whale bone, brick steel pipes and machinery parts. On south side only – 3 no. layers of 200mm high concrete block commencing at 700mm depth. Hydrocarbon contamination – black oily, high viscosity, strong hydrocarbon odour. Water inflow – fast at 1.15m dig depth. Trench terminated due to limited reach of excavator.

Trial pit not stable during excavation period of approximately ¾ hour period i.e. collapsing sides.

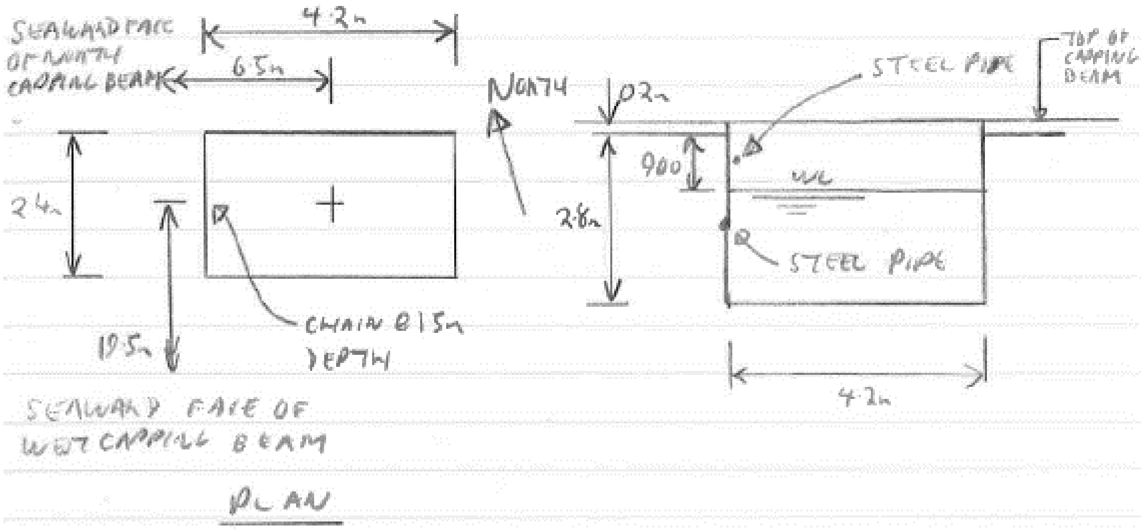

JCB

TRIAL PIT 10

Location: New wharf anchor wall

Date of investigation: 18th November 2018

See Trial Pit 10



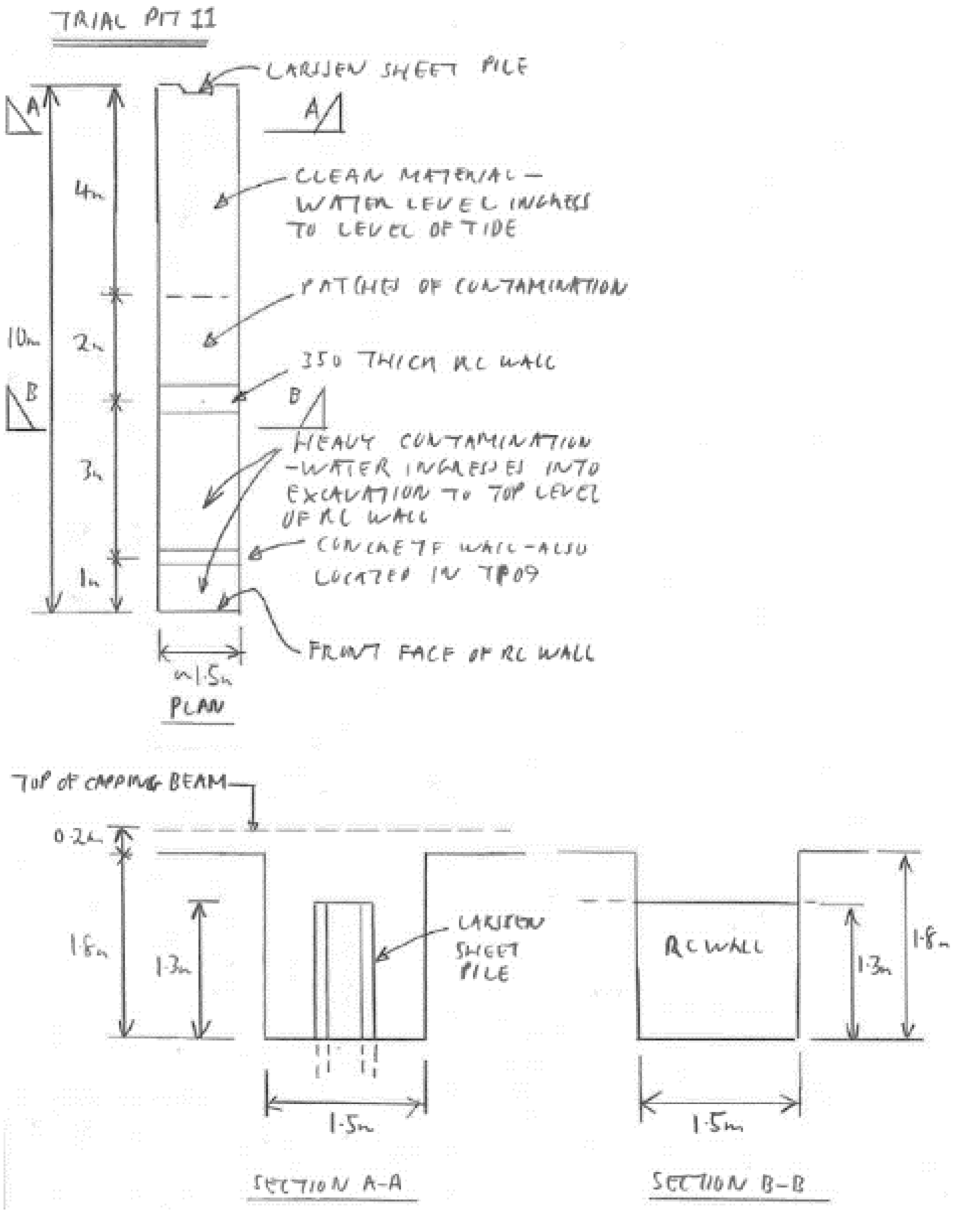
Description:

Depth below existing ground (m)	Depth below top of capping beam (m)	Description
0.0 – 0.4	0.2 – 0.6	MADE GROUND. Dense well compacted grey sandy gravel with cobbles. Sand – fine to coarse. Gravel – low sphericity, sub-rounded. Cobbles – low sphericity, very angular. NB. Visual description only – no PSD's undertaken.
0.4 – 2.8	0.6 – 3.0	MADE GROUND. Dense to very dense well compacted black slightly silty very sandy fine to coarse gravel with cobbles and boulders up to 400mm heavily contaminated with weathered diesel. Sand – medium to coarse. Gravel – low sphericity, sub-rounded. Cobbles and boulders – low sphericity, very angular. Also present – thin metal plate, steel machine parts, steel chain, brick and whale bone. Hydrocarbon contamination – black oily, high viscosity, strong hydrocarbon odour, appears to increase with depth. Water inflow – fast at 0.9m dig depth. Trench terminated due to limited reach of excavator.

Trial pit not stable during excavation period of approximately ¾ hour period i.e. collapsing sides.

TRIAL PIT 11

Location: Between new wharf anchor wall and rear wall of existing wharf structure
Date of investigation: 20th February 2018
No samples taken.



Depth below existing ground (m)	Depth below top of capping beam (m)	Description
0.0 – 0.8	0.2 – 1.0	Compacted layers (approximately 150mm thick) sand, gravel, small angular shale
0.8 – 1.8	1.0 – 2.0	Shale, flat 6—200mm. Large boulders up to 0.5m x 0.2m flat unbroken shale. Contaminated with hydrocarbons.

SCHEDULE OF SAMPLES

AREA AND LOCATION	TRIAL PIT REFERENCE	SAMPLE NOS.	SAMPLE WEIGHT (kg)	DEPTH * (metres below ground level)	HYDROCARBON CONTAMINATION	SAMPLE JAR	COMMENTS
WHARF - MOORING POINTS	TP01:01	1-4 of 4	approx. 18kg each	1.0 - 2.3	**Yes**		
	TP01:02	1-4 of 4	approx. 18kg each	0.0 - 1.0	**Yes**		
	TP02:01	1-4 of 4	approx. 18kg each	1.0 - 2.3	**Yes**	Yes	
	TP02:02	1-4 of 4	approx. 18kg each	0.0 - 1.0	**Yes**		
	TP03:01	1-4 of 4	approx. 18kg each	1.5 - 2.5	**Yes**		
	TP03:02	1-4 of 4	approx. 18kg each	0.5 - 1.5	**Yes**	Yes	
	TP04:01	1-4 of 4	approx. 18kg each	0.5 - 1.5	**Light**		
	TP04:02	1-4 of 4	approx. 18kg each	1.5 - 2.5	**Light**	Yes	
WHARF - FRONT STRUCTURE	TP05	1 of 1	approx. 18kg each	1.0m	**Light**	Yes	
	TP06	1-3 of 3	approx. 18kg each	1.0m	**Yes**		
WHARF - SLIPWAY (5m offset south)	TP07:01	1-4 of 4	approx. 18kg each	0.0 - 1.2	None		1. Formerly TP08 (mistake made in labelling)
	TP07:02	1-4 of 4	approx. 18kg each	1.2 - 1.8	None		2. 2 no. rock samples taken
WHARF - ANCHOR WALL	TP09:01	1-4 of 4	approx. 18kg each	1.0	**HEAVY**		
	TP09:02	1-2 of 2	approx. 18kg each	2.0	**HEAVY**	Yes	
	TP10	1-4 of 4	approx. 18kg each	1.0 - 2.0	**HEAVY**	Yes	**Suspected asbestos found**

Appendix 3 – KEP Water Environment Risk Assessment

King Edward Point Wharf, South Georgia

Contamination Risk Assessment

King Edward Point, South Georgia

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31 May 2019
Project Reference: 121018
Document Reference: 121018/KEP/RA/2019
Issue: 1
Prepared For: British Antarctic Survey

Status / Revisions

Rev.	Date	Reason for issue	Prepared		Reviewed		Approved	
1	31/5/19	Draft for Client Comment	KF, ML	31/5/19	RH	31/5/19	AS	31/5/19

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Appendices

1. Introduction

1.1 General

Upgrade of the existing wharf at King Edward Point on South Georgia is required by the British Antarctic Survey (BAS) to accommodate the new polar vessel, the RRS Sir David Attenborough, which is currently undergoing fit-out.

Limited site investigations were carried out on and around the existing wharf in November 2018, to determine ground conditions and potential geoenvironmental constraints to proposed works associated with the wharf upgrade. Visual and olfactory evidence of hydrocarbon contamination was encountered at a number of locations during excavation of trial pits. Analyses of soil and water samples confirmed the presence of concentrations of organic compounds, predominantly Total Petroleum Hydrocarbons (TPH). Due to the proximity of the site to a sensitive marine environment, an assessment of potential risk to the water environment from this contamination is required prior to construction works, to inform the design and construction methodology and identify any remedial considerations.

This report details the risk assessment, which considers risks to the water environment before, during and after construction of the new wharf, and which has been undertaken in accordance with the Risk Assessment Method Statement (King Edward Point Wharf, South Georgia, Contamination Risk Assessment Method Statement, 1st May 2019, 121018/KEP/MS/2019 Rev 1). In general, the risk assessment has been carried out using UK legislation, guidance and best practice to determine whether any unacceptable risks exist that require specific action or alteration of construction techniques.

1.2 Development Proposals

Proposed works to update and expand the existing wharf include the following:

- Construction of a new wharf as a wrap-around structure to the existing wharf, and new anchor wall.
- A new berthing and mooring dolphin located offshore to the south of the existing wharf boat ramp/slipway.
- Refurbishment and extension of the small craft/boat ramp/slipway.
- Installation of three new onshore mooring points.

1.3 Report Structure

The report structure is as follows:

- ***Section 2*** outlines the guidelines, legislation and standards that have been applied, with justification for their selection.
- ***Section 3*** summaries the available data, outlines data limitations and gaps, and provides a summary of the history of the Site.
- ***Section 4*** describes the ground conditions, using desk-based sources and available intrusive investigation data.
- ***Section 5*** provides an initial assessment of potential risks to the water environment, including a Tier 1 assessment of the chemical analysis data, and consideration of potential risks through the development of a Conceptual Site Model.
- ***Section 6*** includes a detailed quantitative assessment of potential water environment risks, including the derivation of the most appropriate soil and water screening criteria to be applied during the construction works.

- ***Section 7*** provides a qualitative assessment of potential risks to construction, with associated recommendations.
- ***Section 8*** updates the contamination assessment following the detailed quantitative assessment and summarises the overall conclusions and recommendations.

2. Guidance and Legislation

2.1 General

South Georgia and the South Sandwich Islands (SGSSI) is a United Kingdom Overseas Territory therefore it is appropriate to consider UK legislation and standard practice as well as available local government guidance.

Additionally, the EU/UK legislation and associated guidance related to contamination is one of the most comprehensive and well-developed regimes available, and so is considered appropriate to provide adequate protection the sensitive environment of SGSSI.

2.2 Regulatory Guidance

The following hierarchy of legislation and guidance for Contamination Assessment have been considered for use for the purposes of this risk assessment:

- Local Government (GSGSSI).
- UK Contaminated Land Regime (EU) Legislation.
- UK Guidance Documents.

2.3 Local Government

GSGSSI Contaminated Ground Policy was established on 1st April 2019. The policy states that:

> *'There is currently no legislation in place that relates specifically to contaminated ground. However, all activity on South Georgia is only allowed through stringent permitting rules.*
>
> *As part of our Marine Protected Areas announcements in December 2018 we prohibited (through no permits being granted) the extraction and transportation of minerals and hydrocarbons. This will be placed in to legislation in due course'.*

Considering the basic recommendations within the policy with respect to handling contaminated ground, this assessment follow UK guidelines and legislation, which provides a more robust level of environmental protection that exceeds the requirements of the GSGSSI policy.

2.4 UK Contaminated Land Regime

2.4.1 Part IIA of the Environmental Protection Act

The Environmental Protection Act 1990: Part IIA Contaminated Land in the UK defines pollution of the water environment in terms of the direct or indirect introduction into the water environment of substances which may give rise to harm to human health (i.e. through abstraction for drinking water) or the quality of aquatic ecosystems or terrestrial ecosystems directly depending of aquatic ecosystems, result in damage to material property that impair or interfere with amenities and other legitimate uses of the water environment.

Under the Part IIA regulatory regime, land is only to be considered contaminated land in cases where resulting pollution resulting is significant or where there is a "significant" possibility of significant pollution or harm occurring.

As stated in the Statutory Guidance accompanying the EPA (1990): Part IIA Contaminated Land, measures of significant pollution include:

- Whether there is a breach of any statutory quality standard for the water environment at an appropriate pollution assessment point. In the absence of any suitable UK or EU standard, other international standards can be used where demonstrated to be appropriate;
- Whether the pollution results in:

- Deterioration in the status of a water body or failure to meet good status objectives, as defined in the Water Framework Directive 2000/60/EC, and/or;
- The failure of a Protected Area to meet its objectives, as defined in the Water Framework Directive.

- Whether there is a significant and sustained upward trend in the concentration of pollutants in groundwater being affected by the land in question, and;
- Whether there is a material and adverse impact on the economic, social and/or amenity use associated with a particular water environment.

2.4.2 Water Framework Directive Legislation

UK legislation follows the prevent and limit requirements of the Water Framework Directive (Directive 200/60/ED) (WFD) to ensure:

- Inputs of hazardous substances are prevented; and,
- Inputs of non-hazardous substances are limited.

Hazardous substances are defined in the WFD as substances or groups of substances that are toxic, persistent and liable to bioaccumulate, and other substances or groups of substances which give rise to an equivalent level of concern.

This is based on the consideration that some substances are so hazardous that all practical and reasonable measures must be taken to prevent them entering the water environment.

2.5 Guidance Documents

The contamination assessment has been undertaken following key UK guidance documents, which form the basis for the process of risk assessment in accordance with UK and EU legislation.

- SEPA Position Statement (WAT-PS-10-01), SEPA, August 2014.
- SEPA Supporting Guidance (WAT-SG-53), SEPA, February 2018.
- The Water Supply (Water Quality) Regulations England and Wales 2016.
- BS 10175:2011+A2:2017 Investigation of potentially contaminated sites - Code of practice, British Standards Institution, 2017.
- CIRIA C552 Contaminated Land Risk Assessment, A Guide to Good Practice, CIRIA, 2001.
- CLR 11 - Model Procedures for the Management of Contaminated Land, Environment Agency, 2004.

It is noted that although all UK Environment Agency and SEPA marine water standards originate from the same source, the Water Framework Directive, and SEPA guidance documents have been selected for their comprehensive nature and ease of use.

For the assessment of groundwater, where applicable, SEPA has derived a set of Resource Protection Values (RPV) or standards based on a hierarchy of EC and Scottish Drinking Water Standards, the WHO Drinking Quality Guidelines and US EPA National Primary Drinking Water Regulations which are considered appropriate for this assessment.

Where there is no RPV, drinking water standards have been applied through The England and Wales Water Supply Regulations, 2016.

If applicable, the use of Minimum Reporting Values (MRV) may be employed should any hazardous substances be present at detectable concentrations.

2.6 Limitations

The contamination assessment has been undertaken in accordance with the above legislation and guidance, but in consideration of the data available and the limitations imposed by the remote location of the site. The identified data gaps introduce limitations on the understanding of the extent, nature and movement of contamination at the Site and so where appropriate, suitable conservative assumptions have been made.

Where data gaps exist, or assumptions are made, these have been clearly highlighted, and the potential effect on the conclusions has been considered as part of the risk assessment process.

3. Site Description

3.1 Location

South Georgia forms part of the South Georgia and South Sandwich Islands (SGSSI) UK Overseas Territory, with its nominal capital at King Edward Point. The King Edward Point BAS research base and existing wharf is located in King Edward Cove in Cumberland Bay East, on the northern side of the island, latitude 54 16’59.34”S and longitude 36 29’47.25W. The islands lie approximately 1,400km southeast of the Falkland Islands.

Former land use at King Edward Cove includes sealing and whaling, military activity, and more recently scientific surveys and research.

3.2 Designations

In June 1999, the Foreign & Commonwealth Office (FCO) and the UK Overseas Territories Conservation Forum discussed ideas for an Environment Charter for the Overseas Territories. The resulting Charters, adopted in September 2001, provide a framework for all Overseas Territories to play a part in developing policies on the environment, as well as helping them to implement effectively appropriate multilateral environmental agreements to which Britain is a party.

The Wildlife and Protected Areas (WPA) Ordinance was enacted in 2011 and provides a legal basis for the strict environmental policies of the Government of SGSSI (GSGSSI). Under the Ordinance it is an offence to wilfully or carelessly introduce non-native species, to handle or harm any flora or fauna or conduct activities that are likely to result in damage to habitats.

In 2012 GSGSSI created one of the world’s largest Marine Protected Areas (MPA), covering 1.07million km^2 and including South Georgia. This puts in place measures to ensure the protection and conservation of the region’s rich and diverse marine life, which includes land-based birds and mammals, marine based mammals, and fish.

The Convention on Biological Diversity was extended to South Georgia & the South Sandwich Islands in 2014. Following that, the Government published its National Biodiversity Action Plan which sets out the conservation plan.

The GSGSSI has proposed legislation, referred to as Environment Enhancements, to protect the environment of the Territory by prohibiting the commercial exploitation of mineral or hydrocarbon resources, whilst allowing for scientific research and related activities, modelled on the legal position on Antarctica under international law. This will include prohibition on the use and carriage of Heavy Fuel Oil.

3.3 Data Availability and Limitations

Available data provided by BAS and BAM was sourced from BAS, GSGSSI, BAM Nuttall Ltd, and Delta Marine Consultants and is listed in the table below.

TABLE 3-1: AVAILABLE DOCUMENTS AND REPORTS

Document	Form	Author
Photos - existing wharf, new wharf design structure locations and Site Investigations	Photos	BAM
Design drawings - dolphin, mooring points, new wharf, slipway	Drawings	Delta Marine Consultants
Laboratory testing geotechnical and geoenvironmental results - quarries and wharf trial pits	Laboratory result reports	BAM Ritchies
Tidal data	Data spreadsheet	-
Various background information documents on South Georgia	Documents	GSGSSI

Document	Form	Author
Detailed Reconnaissance and Planning Report, South Georgia, King Edward Point Base, Volume 1, General	Report	MOD
Geological map of South Georgia	Map	BAS
Geomorphology articles - South Georgia	Scientific articles	BAS
Rainfall data	BAS weblink	BAS
New Wharf Construction Site Investigation - Inspection of existing Wharf Structure - Factual Report, November 2018	Report	BAM Nuttall Ltd
Site Visit Report - King Edward Point - quarried rock backfill for Wharf, November 2018	Report	BAM Ritchies
King Edward Point Wharf Design Geotechnical Interpretative Report, March 2019	Report	Delta Marine Consultants
New Wharf Construction Factual Report on Ground Investigation, May 2019	Report	BAM
Meeting notes - risk mitigation for contaminated ground, February 2019	Note	BAM Nuttall Ltd
KEP New Wharf Construction - Note on Contamination, February 2019	Note	BAM Nuttall Ltd
Presentation slides - design review meeting, August 2018	PowerPoint slides	Delta Marine Consultants
Historical Drawings (Former MOD facility)	JPG files	Supplied by BAS

3.3.1 Data Limitations

A preliminary review of the available data in the context of standard UK site investigation and contamination risk assessment practice has identified the following data limitations and gaps:

- Detailed historical mapping of the area.
- Limited information on former activities and land use relating to former military and whaling operation, especially fuel storage locations.
- Site investigation is limited to trial pitting as drilling equipment for boreholes was not available.
- Trial pit depths were limited by the size of the excavator and by water ingress due to proximity to the coast. The majority of trial pit depths are between 1.6m and 2.5m depth, with one location excavated to 3m.
- The depth to bedrock was assessed through a geophysical survey but the trial pits could not extend deep enough to confirm the findings.
- The extent or source of the hydrocarbon plume inland has not been established as the site investigation area was limited to the near-shore area where construction is proposed.
- Investigation of the vertical extent of the contamination is limited due to the generally shallow depths of the trial pits.
- Only one laboratory test permeability value is available and there is no in-situ permeability data.

- Water samples are grab samples from trial pits, which may not be representative of groundwater chemistry, and are assumed to represent saline water, although this could not be established from available results.
- There is no available chemical analysis data from the receiving surface water, the marine environment at King Edward Cove.
- There was a significant delay between sampling and chemical analysis, including potentially considerable unrefrigerated transportation time, which may have resulted in some loss of volatile fractions.

3.4 Site History

The following section summarises the history of the site based on the available data. It should be noted that detailed historical information (such as historical mapping) is limited, and so the majority of the following historical summary uses the British Military Reconnaissance and Planning Reports, written during the 1980s (*Detailed Reconnaissance And Planning Report, South Georgia, King Edward Point Base, Volume 1, General 10th January 1986*, *Major GC Kershaw RE BSc (Eng) C Eng MICE et al* BAM file number BAA4010-RAM-ZZ-WRF-TR-KA-003).

The information has been reviewed and considered with respect to relevant historical features and environmental data, their proximity to the study site, the local topography and likely surface and groundwater flow direction, for consideration within the Initial Conceptual Site Model (CSM).

The information indicates that a whaling station was established at Grytviken in 1904 at the rear of the bay, and that the original government administration station was set up at KEP in 1908. In 1925, Discovery Investigations built a laboratory in KEP and it is estimated a jetty was constructed here at roughly the same time.

In 1950 BAS established a meteorological station, which was subsequently re-established in 1969 as a scientific base. In 1980/81 the jetty was improved but in 1985 was severely damaged when a ship tried to dock in high winds and severely impacted the jetty.

The reconnaissance report indicates two pollution incidents, although no dates are provided:

- The first incident occurred to the rear of Shackleton House when seawater entered the fuel feeder lines cause the pipes to freeze and burst resulting in a direct discharge of fuel in to the superficial deposits.
- The second incident occurred near the power house (generator shed), caused by the overflow pipes from the generator's fuel header tanks discharging directly onto the ground.

The provided plans of the site show that there have been changes in the site layout over the past few decades, including the demolition and construction of various buildings and the redevelopment of wharf and jetty structures. A number of potential sources of hydrocarbon contamination are shown on these plans, including a fuel drum storage area, fuel farm, diesel fuel tank and generator shed (as shown on ***Figure 1***). Anecdotal evidence from John Hall covering some of the period of MOD occupation of the site indicates that the diesel fuel tank was subject to ongoing leaks.

4. Ground Conditions

4.1 Anticipated Ground Conditions

Anticipated geological and hydrogeological conditions within the Site were established using extracts from the British Antarctic Survey (BAS) 1:250,000 series, the British Antarctic Survey Scientific Reports Series (No.70 Geomorphology Of The Stromness Bay – Cumberland Bay Area, South Georgia) and the British Antarctic Survey Kind Edward Point Wharf Design Geotechnical Interpretative Report, March 2019 (File reference: BAA.4010-DMC-ZZ-KEP-RP-C-0003).

4.1.1 Artificial Deposits

The available BAS mapping and reports do not indicate the presence of made ground on site, however, it should be noted that due to the presence of the former whaling processing facility at Grytviken adjacent to KEP within Kind Edward Cove, there was considered to be potential for made ground materials to be located on site, as evidenced by investigation works (***Section 4.3***).

4.1.2 Drift Geology

The 1:250,000 geological map series does not provide information or show the presence of superficial deposits within the site or within the wider site area.

The BAS No.70 report and Wharf Design Geotechnical Report indicate that the superficial geology of the wider area is dictated by the geological processes associated with glacial maximums and retreats during the Pleistocene and Holocene. It is expected that the glacial processes have resulted in moraine deposits comprising of unsorted sand and rock particles with cobble and boulder content. All particles are likely to be subrounded and subangular.

It is also expected that post-glacial deposits are located within the site area, resulting from raised beaches, potential peat bogs, wave-cut platforms and solifluction deposits. At surface level within the Wharf Design area beach deposits are also expected, of a similar material to the moraine deposits but with particles expected to be more rounded.

4.1.3 Solid Geology

Historical borehole data is not available so all information on the solid geology of the site and wider area is derived from the BAS Geology 1:250,000 series. BAS GEOMAP 2 Series, Sheet 4, Edition 1 shows the site is underlain by the Cumberland Bay Formation comprising of Andesitic volcaniclastic turbidite sequence up to 8km thick with Moderate deformation including large scale folds with associated tectonic foliation. The map also indicates Macro fossils of the Aptian Age located in the KEP wider area. The Cumberland Bay Formation is likely to comprise unsorted, clastic sediments comprising sandstones, clayey and silty sandstones, and mudstones.

An inferred fault is shown at the western edge of King Edward Cove traversing roughly North to South. A normal fault is shown traversing North East to South West through the Moraine Ford up to the opening of Cumberland East Bay with the downthrow indicated to the west towards KEP.

4.1.4 Hydrology

The most significant surface water likely to be affected by site works is King Edward Cove, a marine coastal environment immediately adjacent to the Site. No data is available on the water quality/chemistry of the cove. The tidal range is less than 1.0m (see ***Appendix C*** for more details).

4.1.5 Hydrogeology

The available background data does not show any information on groundwater presence or quality. Considering the probably granular soils and the proximity to the adjacent marine environment, it was considered that groundwater would be present and that it will be tidally influenced.

4.2 Intrusive Site Investigation

An intrusive ground investigation was instructed by BAS and undertaken by BAM Nuttall Ltd between 17th November to 20th November 2018, which is reported to primarily have been designed to determine the following:

- The soil conditions on site.
- The presence and nature of any obstructions.
- The presence and nature of any contaminants.
- The condition of the steel piles of the existing wharf structure.

Table 4-1 summarises the works which were undertaken and ***Figure 1*** shows the location of the Site investigation positions.

TABLE 4-1: GROUND INVESTIGATION WORKS UNDERTAKEN

Category	Location	Item
Trial pits	Mooring Point 1 Mooring Point 2 Mooring Point 3 (removed from scheme) Mooring Point 4 Wharf Dolphin/Slipway	TP01 TP02 TP03 TP04 TP05, 06, 09 & 10 TP07 (offshore)

4.3 Encountered Ground Conditions

The following section summarises the ground conditions recorded during the investigation.

4.3.1 Made Ground

Made Ground was encountered as variations of sand and/or gravel with cobble and boulder content across all trial pit locations with the exception of TP4 and TP7 where no made ground was encountered. The made ground variably contained brick, whale bone, hydrocarbons, tar, glass, machinery parts and some fibrous material. In addition, steel wailings and sheet piles were encountered in TP6.

4.3.2 Drift Geology

Natural drift deposits were encountered from ground surface in two locations (TP4 and TP7). Natural ground was encountered in TP1 and TP2, overlain by between 0.6m, and 1.0m of made ground. The base of the natural deposits was not ascertained.

The drift deposits in TP1 & TP4 are describe as a fine to medium sand with some gravel, and in both cases the strata is described as contaminated with hydrocarbons. The natural soils in TP2 are recorded as a fine to medium sandy gravel with cobble and boulders, also noted to be contaminated with hydrocarbons. TP7 encountered a grey black fine to coarse sand with cobbles from 0.0-1.2m bgl underlain by a grey black sandy gravel with some cobbles and occasional boulders from 1.2-1.8m bgl.

The natural drift deposits encountered during site works are typical of near-shore beach deposits, as expected based on their location.

4.3.3 Groundwater

Groundwater was encountered in all trial pit locations at an approximate depth of 1-2m bgl, although precise depths of groundwater strikes were not provided in the trial pit logs. Considering the trial pits were located within close proximity to the shoreline and the granular nature of the superficial deposits it is likely that groundwater is in continuity with the sea.

4.3.4 Contamination Observations

As noted above and in the trial pit logs hydrocarbon contamination was noted in all locations with the exception of TP7, generally within made ground but also within the natural deposits in TP1, TP2 & TP4.

Hydrocarbon contamination was noted in locations TP1, TP2, TP3, TP4, TP5, TP6, TP9 and TP10 from a minimum depth of ground level (oily gravel in TP4) but more generally from below 0.4m - 0.9m bgl. The lowered extent of the impacted fill could not be ascertained clearly from the logs, presumably due to groundwater and free product inflow to the pits.

4.4 Contamination Investigation

4.4.1 Chemical Analysis

The Ground Investigation undertaken during November 2018 was designed to assess ground conditions to allow for the redevelopment of the wharf at KEP. The trial pits subsequently undertaken highlighted visual and olfactory evidence of hydrocarbon contamination within the development area of the proposed works. Based on this evidence communicated at the time of excavation, an appropriate suite of contaminants, including Speciated Total Petroleum Hydrocarbons, was tested for in soil samples taken during the GI.

It should be noted that the rates of degradation for the samples taken are different in comparison to a typical site in the UK, especially considering the difference in climate and the total time taken to transport the samples to a suitable lab for assessment (a difference of weeks rather than days).

This should suggest that any results assessed in this report are potentially a “best-case” scenario.

It should also be noted that the only receptor considered in this report is the water environment, so the results are being assessed in this context.

4.4.2 Assessment Methodology

The interpretation includes the development of a conceptual site model, a Tier 1 qualitative risk assessment, an assessment of the dilution capacity in the receiving water and a Quantitative assessment to derive target criteria in accordance with the Sweco King Edward Point Wharf, South Georgia, Contamination Risk Assessment Method Statement.

5. Tier 1 Assessment

A tier 1 qualitative assessment of available data has been carried out in line with standard risk assessment practice, to determine potential contaminants of concern at the Site. This assessment addresses risk to the water environment.

5.1 Available Data

As outlined in ***Section 2.6***, available environmental data is limited compared with standard site investigations. The following results were available for the assessment:

- Test results for soil samples from trial pits TP01, TP02, TP03, TP04, TP05, TP06, TP07, TP09, TP10;
- Test results for water samples from trial pits TP04 and TP09.

5.2 Soil Analysis

Six soil samples were taken from trial pits TP1, TP2, TP3, TP5, TP6 and TP10 between 18th and 20th November 2018 at KEP and submitted to Chemtest on 25th January 2019 for analysis. Laboratory reports are presented in ***Appendix A***. The sampling suite included metals, speciated Total Petroleum Hydrocarbons (TPH), Poly Aromatic Hydrocarbons (PAH), Volatile Organic Carbons (VOC), Semi Volatile Organic Carbons (SVOC) and Total Phenols.

5.2.1 Results review

No soil leachate analysis was carried out therefore no comparison of soil contamination concentrations could be made with water environment standards. However, soil concentrations were compared against Limit of Detection (LOD) values to identify potential contaminants that are present and therefore have the potential to leach from the soil to the water environment.

The results of the analysis show metal concentrations above the LOD, with generally higher concentrations recorded in the sample from TP10 (e.g. zinc at 2,500mg/kg and cadmium at 8.1mg/kg). PAH contaminants are generally below the Limit of Detection, with the exception of TP5 where three compounds were encountered at concentrations of up to 0.21mg/kg (phenanthrene, fluoranthene and pyrene). SVOCs and VOCs are generally below LOD with the exception of results from TP02 which record concentrations of benzene, toluene, ethylbenzene and xylenes at concentrations of up to 3,200mg/kg.

Concentrations of speciated TPH contaminants are observed above the limit of detection at locations TP2, TP3 and TP10 (total TPH of between 9,300mg/kg and 24,000mg/kg) and TP6 at lower concentrations (total TPH of 650mg/kg). These recorded concentrations of TPH hydrocarbons confirm the olfactory and visual evidence of the presence of diesel reported during the site investigation (BAM - New Wharf Construction Factual Report on Ground Investigation, May 2019).

5.3 Water Analysis

Two samples were taken from trial pits TP4 and TP9, respectively, between 18th and 20th November 2018 at KEP and submitted to Chemtest on 23rd January 2019 for analysis. Laboratory reports are presented in ***Appendix A***. The sampling suite included metals, speciated Total Petroleum Hydrocarbons (TPH), Poly Aromatic Hydrocarbons (PAH), Volatile Organic Carbons (VOC), Semi Volatile Organic Carbons (SVOC) and Total Phenols. The water is assumed to be a mixture of groundwater and saline water, although this could not be confirmed from the limited site investigation data.

The suite of analysis was compared with the standard Sweco test suite. It includes most of the standard contaminants and parameters with the exception of the following: thiocyanate, sulphate, sulphur, sulphide, vanadium, ammonium, electrical conductivity, hardness, calcium, dissolved organic carbon. Although these parameters would have provided useful results, there omission is not considered to significantly affect the risk assessment.

5.3.1 Published Criteria

Water results were screened separately against published criteria protective of the surface water and groundwater environment. Environmental Quality Standards (EQS) protective of the marine environment have been applied, as sourced from SEPA Supporting Guidance (WAT-53-01, February 2018). EQS are derived from the following legislation:

- Directive 2008/105/EC of the European Parliament and of the Council on Environmental Quality Standards;
- The Scotland River Basin District (Standards) Amendment Directions 2015; and,
- Proposals for Environmental Quality Standards for Annex VIII Substances, UKTAG.

Resource Protection Values (RPV) were applied to groundwater results, as sourced from SEPA Position Statement (WAT-10-01, August 2014). These criteria are based on the following hierarchy as indicated in the SEPA guidance: EC and Scottish Drinking Water Standards, the WHO Drinking Quality Guidelines and US EPA National Primary Drinking Water Regulations.

Available MRV values were applied where considered appropriate i.e. where elevated concentrations of hazardous substances were present.

5.3.2 Tier 1 screening (Protective of Surface water)

Exceedances of published criteria are highlighted, as well as exceedances of LOD values, in the absence of a published EQS. The screening sheet is presented in ***Appendix B***.

The screening indicates that metals are generally below EQS values, with the zinc concentration exceeding the EQS at TP4 and the mercury concentration exceeding the EQS at TP9. No exceedances of PAH compounds are observed although it is noted that the EQS for benzo(a)pyrene and fluoranthene is less the LOD. A concentration of toluene above LOD but below the EQS was noted and no other VOC or SVOC contaminant concentrations were observed above the LOD. TPH compounds in the range C8-C35 are recorded above LOD or EQS within TP4 (total TPH concentration of 530mug/l), with concentrations in TP9 that are lower but still recorded above the LOD.

These high concentrations of TPH hydrocarbons confirm the presence of diesel free product as observed during site investigations.

5.3.3 Tier 1 screening (Protective of Groundwater)

Exceedances of published criteria are highlighted, as well as exceedances of LOD values in the absence of a published criteria, and the screening sheet is presented in ***Appendix B***. The results indicate a number of metals exceeding criteria, including arsenic, mercury, selenium and chromium.

No exceedances of the screening values for PAH compounds are observed.

A concentration of toluene of 25ug/l, above the MRV of 4ug/l, was noted, and no VOC or SVOC compounds were recorded above the LOD. TPH compounds in the range C8-C35 are recorded above LOD within TP4 (total TPH concentration of 530mug/l), although no exceedances of RPV are noted, with concentrations in TP9 that are lower but still recorded above the LOD. These high concentrations of TPH hydrocarbons confirm the presence of diesel free product as observed during site investigations.

5.4 Limitations

It is important to note that natural degradation of TPH contaminants (including VOCs, and SVOCs) will have taken place in the 9 weeks between sampling and analysis. Although high concentrations of organic contaminants were identified within soil and water samples, the results are considered to represent a 'best case scenario' and concentrations associated with diesel free product may be higher at the Site. Additionally, the water samples were taken from trial pits and are unlikely to be representative of actual groundwater beneath the site.

5.5 Discussion

The Tier 1 assessment has identified a number of contaminants exceeding published criteria or elevated above the LOD within soil and water samples that are considered as potential contaminants of concern to be taken forward for further assessment.

TABLE 5-1 CONTAMINANTS OF CONCERN

Potential Contaminants of Concern		
Soil	**Water (protective of the Marine Environment)**	**Water (protective of Groundwater)**
Cyanide	Mercury	Arsenic
Arsenic	Selenium	Mercury
Boron	Zinc	Selenium
Cadmium	Chromium	Zinc
Copper	Toluene	Chromium
Mercury	Speciated TPH (C8-C35)	Toluene
Nickel		Speciated TPH (C8-C35)
Lead		
Zinc		
Speciated TPH (C5-C44)		
Benzene		
Toluene		
Ethylbenzene		
Xylene		
Phenanthrene		
Fluoranthene		
1,3,5-Trimethylbenzene		
Tert-Butylbenzene		

6. Initial Conceptual Site Model

The following section presents an assessment of the investigation data with respect to potential risks to the water environment.

The following assessment is qualitative, in that professional value judgments have been applied to the available site data in order to assess levels of risk. The framework for these assessments is set out in CIRIA C552, "Contaminated Land Risk Assessment, A Guide to Good Practice". This guidance states that the assessment of risk should be based on both the likelihood of an event and the severity of its potential consequences. One of the following six risk levels has been assigned to each potential pollutant linkage identified: Very Low, Low, Low/Moderate, Moderate, High and Very High. A risk of Low/Moderate or above indicates that further assessment, investigation or possibly remediation will be required.

It is proposed to extend the existing wharf, which will include the construction of various new structures. The following assessment is intended to inform understanding of potential contamination liabilities with the Site in its current use, during construction and with respect to its future proposed use.

6.1.1 Source

Hydrocarbons have been recorded within the Site soils through a combination of site investigation, historical data and anecdotal evidence.

Two known incidents of hydrocarbon pollution were noted by the military to have occurred prior to 1985, with one incident occurring in the generator shed and one incident occurring to the rear of the Shackleton Villa. Additionally, oil drums are known to have been buried in the area around the fuel farm, and anecdotal evidence indicates that a former diesel tank on the facility had a long-term history of leakage. More recently, diesel free product was observed during trial pit excavations in soils and water along the shoreline and organic contamination was observed during construction of the boatshed and garage (date unknown).

Soil and water samples from trial pits undertaken in 2018 were screened against suitable Tier 1 screening values. Water samples were screened against surface water EQS values and RPVs, whilst soil samples were compared with the limit of detection (as soil leachate data was not available).

Analysis of samples taken during the site investigation confirms the presence of petroleum hydrocarbons (and other metal and organic compounds) at concentrations above the Tier 1 screening values, although due to the time lapse between sampling and testing, these results may not reflect existing conditions, as degradation of hydrocarbons will have taken place. The extent of hydrocarbons within the soil, as shown by chemical analysis, is shown on ***Figure 1***. The figure also shows that the *potential* extent of the hydrocarbon impacted soils extends further inland and along the coast, based on the possible historical sources, reported spillages and leaks, and in consideration of the likely tidally-influenced groundwater movement within the granular superficial soils.

6.1.2 Pathway

Identified possible pathways for the migration of contamination of risk to the water environment are shown on ***Figure 2*** and summarised as follows:

- Leaching within granular superficial made ground and natural deposits, including free product washing off the surface of granular materials.
- Vertical movement within the groundwater/saline water (through tidal movement).
- Migration as free product and dissolved phase hydrocarbon via near shore deposits and to a lesser extent through unsealed joints/holes in the existing structures resulting in release to the marine environment.

6.1.3 Water Environment Receptor

The nearest surface water body is King Edward Cove which forms the western boundary of the Site. King Edward Cove is considered environmentally sensitive and has been designated accordingly (***Section 3.2***). King Edward Cove is considered a major discharge zone according to the SEPA definition "*surface water feature beyond which groundwater is not expected to flow*" (SEPA WAT-PS-10-01, August 2014). In accordance with SEPA "*where present, future land-use limits the exploitation of the groundwater resource for the foreseeable future*", "*the assessment point should be located at the down gradient extent of the limiting land use, subject to a maximum distance of 250m*".

An assessment point distance of 5m has been selected based on the proximity of the Site to King Edward Cove. Groundwater is therefore not being considered as a receptor and will not be assessed further. Research did not identify any available information on the water quality of King Edward Cove.

6.2 Risk Assessment

6.2.1 Current Status

As there is no direct evidence of oil contamination in the near shore marine environment in the form of water chemistry data, the presence of dissolved phase hydrocarbons in the marine environment cannot be ruled out therefore a Low probability has been assumed (rather than Unlikely). Similarly, while no visible evidence of non-aqueous phase hydrocarbons has been reported on the water surface, the proximity of free product in the shallow groundwater is such that some release into the environment is expected to be occurring. Given the lack of indications of contamination, a Medium severity is considered appropriate.

TABLE 6-1 RISK ASSESSMENT – CURRENT USE

Source	Potential Pathways	Receptors	Potential severity of Consequence	Probability of pollutant linkage occurring	Risk Classification
Hydrocarbon and metal contaminants in superficial deposits	1. Leaching/wash-out from granular superficial deposits 2. Vertical movement within groundwater/saline water (tidal movement) 3. Migration as free product and dissolved contamination	Surface Water (1-3)	Medium	Low	Low/Moderate

On a qualitative level, risks to the water environment for the Site in its current status are considered to be Low/Moderate.

6.2.2 Construction Stage

Any works involving open excavation within the contaminated material are likely to disrupt the equilibrium of the sub-surface environment, increasing the risk that contaminated groundwater and free product will migrate laterally, and increasing the potential for remobilisation of contamination currently adhering to particulate matter. Further, excavated soils have the potential to release contamination if not handled correctly. Dewatering is anticipated to be required in order to allow open excavation; as well as generating potentially significant volumes of contaminated water, oil or emulsions, dewatering will disrupt the status quo, potentially drawing contamination from the wider plume and/or drawing in and contaminating previously clean water.

Any works involving piling within or around the contaminated material are similarly likely to disrupt the equilibrium of the sub-surface environment, increasing the risk that contaminated groundwater and free product will migrate laterally, and increasing the potential for contamination adhering to particulate matter to be remobilised as a result of ground borne vibration. The existing wharf structure is considered to act as a barrier to some contaminant migration however is porous (i.e. not fully sealed) and works involving pile driving in the vicinity have the potential to exacerbate any weakness or open joints resulting in additional release of contamination.

Irrespective of construction method, the requirement to disturb contaminated ground in close proximity to the marine environment is considered likely to increase the probability of a more significant pollution incident. Therefore, the potential severity has been increased to Severe, and the probability to Likely.

TABLE 6-2 RISK ASSESSMENT – CONSTRUCTION

Source	Potential Pathways	Receptors	Potential severity of Consequence	Probability of pollutant linkage occurring	Risk Classification
Hydrocarbon and metal contaminants in superficial deposits	1. Leaching/wash-out from granular superficial deposits 2. Vertical movement within groundwater/saline water (tidal movement) 3. Migration as free product and dissolved contamination	Surface Water (1-3)	Severe	Likely	High

On a qualitative level, risks to the water environment in the construction stage are considered to be High. Generally the risk is considered elevated irrespective of construction method, however we note that other considerations will influence the construction methodology, in particular minimising the quantity of contaminated solid and liquid which requires to be managed on-site.

6.2.3 In-Use

The proposed structures comprise on-shore mooring points and an off-shore dolphin, none of which are anticipated to present any significant barrier to contaminant migration. Similarly, the new wharf structure and upgraded slipway provide only a localised reduction in migration potential, without offering any more significant barrier than the existing equivalents. Accordingly, the in-use risk and severity have been assumed to offer no reduction from the current status.

TABLE 6-3 RISK ASSESSMENT – IN-USE

Source	Potential Pathways	Receptors	Potential severity of Consequence	Probability of pollutant linkage occurring	Risk Classification
Hydrocarbon and metal contaminants in superficial deposits	1. Leaching/wash-out from granular superficial deposits 2. Vertical movement within groundwater/saline water (tidal movement) 3. Migration as free product and dissolved contamination	Surface Water (1-3)	Medium	Low	Low/Moderate

On a qualitative level, risks to the water environment in the in-use status is considered to be Low/Moderate.

6.2.4 Summary

A potential pollutant linkage has been identified at the Site which poses risk to the marine water environment (King Edwards Cove), ranging from Low/Moderate risk in the current site condition and future in-use status, to High risk during the construction phase. The following contaminants within soil and water have been identified from the Tier 1 risk assessment to require further quantitative assessment: cyanide, arsenic, boron, cadmium, chromium, copper, mercury, nickel, lead, zinc, TPHs, SVOCs, PAHs, benzene, toluene, ethylbenzene and xylene.

7. Quantitative Risk Assessment

The risk posed to the King Edward Cove from the identified contaminants of concern (excluding free phase hydrocarbons) will now be addressed through a Tier 3 assessment.

7.1 Methodology

The Tier 3 quantitative risk assessment has been carried out in accordance with the Environment Agency's Remedial Target Methodology, using Level 3 Soils within the P20 spreadsheets. Remedial target values are derived using Site specific and literature derived inputs, to reduce conservatism.

The dilution capacity within King Edward Cove is also considered within the risk assessment by determining an appropriate dilution factor.

The intention is for derived Tier 3 Remedial Target (RT) values and an applied dilution factor to be used to assess the contaminants of concern and the risks posed by the noted concentrations on King Edward Cove. These values will if necessary be used as Earthworks Screening Criteria for the new Wharf construction works.

It is noted that any soil analysis and validation during earthworks (if required) will be limited to on-site testing as the time between sampling and laboratory analysis is not considered acceptable to return meaningful results by traditional lab methods. In the event that on-site testing can be carried out at KEP, this is anticipated to be limited to handheld x-ray fluorescence for metallic elements, and ultra-violet fluorescence organic testing which will be limited to Total Gasoline Range Organics (GRO), Total Diesel Range Organics (DRO) and Total Polycyclic Aromatic Hydrocarbons (PAH).

7.1.1 Organic Contamination

With reference to the SoBRA CL:AIRE document (Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies, CL:AIRE 2017), the lighter chain Gasoline Range Organics (GRO C5-C10) are generally highly mobile in groundwater due to their high solubility compared with the Diesel Range Organics (DRO C10-C26) which have a general moderate/low mobility in groundwater. It is therefore considered appropriate to further consider risk to the water environment from the GROs.

It is not considered appropriate to apply risk-based methodology to the assessment of free product hydrocarbon release into the marine environment, therefore the less mobile DROs are assumed to be addressed through qualitative assessment and the use of construction phase physical mitigation measures as discussed in ***Section 8***.

High concentrations of the C8-C10 range are evident in soil and water indicating this contamination is likely to be present as a proportion of the observed free product.

7.1.2 Contaminants of Concern

Due to the limitations of any future testing at the Site, the PAH contaminants phenanthrene and fluoranthene will be included within Total PAHs. Benzene and toluene will be represented within the GRO TPH range and ethylbenzene and xylene will be represented within the DRO TPH range. The SVOCs 1,3,5-Trimethylbenzene and Tert-Butylbenzene will not be subject to detailed assessment as no SVOC testing is anticipated to be possible in future works.

The insoluble free-phase hydrocarbon contamination, TPH C8-C26, is considered to present a direct risk if released into the environment, and cannot be appropriately included in this assessment. Due to the potential adverse impact of oil release, mitigation rather than risk assessment is considered necessary.

Therefore, the revised contaminants of concern being considered are: cyanide, arsenic, boron, cadmium, chromium, copper, mercury, nickel, lead, zinc, total GRO and total PAHs.

7.2 P20 Inputs

Level 3 soil worksheet within the P20 spreadsheets have been completed for each of the identified contaminants above using the Environment Agency Remedial Target Methodology and are presented in Appendix B. Site specific inputs are presented in Tables 5.2, 5.3 and 5.4 and described in following sections.

Literature derived Henrys law values and half-life values are presented in ***Appendix C***.

TABLE 7-1 P20 INPUT LEVEL 1

Input Parameter	Units	Value	Justification / Reference Source
Level 1			
Henry's Law Constant	-		Contaminant specific – See ***Appendix C***
Porosity, air-filled	Fraction	0.078	Calculated from site specific moisture content and bulk density values using the RTM porosity calculator.
Porosity, water-filled	Fraction	0.35	
Bulk Density	g/cm^3	2.00	Site specific average using results from 8 no. trial pit locations
Organic Carbon Partition Coefficient or Soil Water Partition coefficient	L/kg		Contaminant specific – See ***Appendix C***

TABLE 7-2 P20 INPUT LEVEL 2

Input Parameter	Units	Value	Justification / Reference Source
Level 2			
Area of Made Ground Source	Area of Made Ground Source	Area of Made Ground Source	Area of Made Ground Source
Length of plume in the direction of groundwater flow	Length of plume in the direction of groundwater flow	Length of plume in the direction of groundwater flow	Length of plume in the direction of groundwater flow
Width of plume in the direction of groundwater flow	Width of plume in the direction of groundwater flow	Width of plume in the direction of groundwater flow	Width of plume in the direction of groundwater flow
Infiltration	Infiltration	Infiltration	Infiltration
Aquifer thickness	Aquifer thickness	Aquifer thickness	Aquifer thickness
Hydraulic Conductivity	m/day	3.05e-5 m/s (2.6m/day)	Based on laboratory constant head test of sample from TP1
Hydraulic Gradient	dimensionless	0.005	Calculated using water levels from TP5 and TP9

TABLE 7-3 P20 INPUT LEVEL 3

Input Parameter	Units	Value	Justification / Reference Source
Level 3			
Half-life degradation in groundwater	Days	See ***Appendix D***	Contaminant specific – See ***Appendix C***
Bulk Density (Aquifer)	g/cm	1.93	Site specific (average of 9 tests).
Effective porosity (aquifer)	-	0.15	(literature value).
Organic Carbon Partition Coefficient, Koc or Soil Water Partition coefficient, Kd	L/kg	See ***Appendix C***	Contaminant specific – See ***Appendix C***
Distance to Compliance Point	m	250	WAT-PS-10-01 guidance
Dispersivity	-	-	Xu and Eckstein dispersivity option chosen in model. More conservative than 10%, 1%, 0.1% dispersivity option.

7.2.1 Soil Characteristics

Bulk density tests were carried out on sand and gravel samples from trial pit locations TP1, TP2, TP4, TP5, TP6, TP7, TP9 and TP10 as presented in ***Appendix A***. Samples were taken from the top 1m and up to 2.3m depth. The average bulk density for 0-1m depth samples was 1.99 and 2.02 for 1-2.3m depth samples. A value of 2 will be applied within the P20 spreadsheets.

Moisture content tests were carried out on samples from TP1, TP2, TP4, TP5 and TP7 taken from depths of between 1.2m and 2.5m (1 sample from the top 1.2m from TP7). Results range from 1.6 to 4.9 with an average of 3.32 applied within the P20 spreadsheets.

Porosity values for both water filled and air-filled porosity have been calculated using the porosity calculator embedded in the P20 spreadsheet, based on site specific natural moisture content and dry bulk density data.

7.2.2 Partition Coefficients

Not enough site specific information was available to calculate Partition coefficients for contaminants of concern therefore suitable literature values have been applied as presented in ***Appendix C***.

7.2.3 Source dimensions

All dimensions were measured using Autocad and based on site investigation evidence, historical information and anectodal evidence. Source length in groundwater flow direction is 65m (the extent of the wharf and the inland extent), source width perpendicular to groundwater flow of 219m and source area of 14,235m^2.

7.2.4 Henrys Law Constant and Degradation Half Lives

Henry's Law and degradation Half Life literature values used in the models are presented in ***Appendix C***. Where relevant, Henry's Law constants were derived using the EA (2008) guidance, or sourced from other literature as detailed in ***Appendix C***.

7.2.5 Hydraulic Conductivity

Permeability testing was limited to one laboratory test of a sample from TP1 carried out on 8th February 2018. Results indicate a hydraulic conductivity of 3.05m/s or 2.6m/day. By way of comparison, published literature values for sands range from less than 0.01 m/day to 86.4 m/day.

7.2.6 Saturated Thickness

Site investigations were limited to excavation depths of 3m due to limitations of available equipment therefore the vertical extent of the beach sand and gravels was not proven. Bathymetric profiling was carried out as detailed in the GIR report. Results indicate a depth to bedrock of 5m at the shoreline. Water levels encountered in the trial pits ranged from 0.9m to 2.15m with an average of 1.26m. This indicates 3.74m as the average saturated thickness of superficial deposits.

7.2.7 Hydraulic Gradient

Water levels encountered within trial pits have been used to determine an estimated hydraulic gradient beneath the Site. This is in the absence of boreholes which would have provided information on groundwater/saline water conditions at the Site. The difference in water levels between trial pits TP5 and TP9 indicates a hydraulic gradient of 0.005, which is considered representative of the generally low-lying ground surface across the Site.

7.2.8 Infiltration

Average monthly rainfall data was obtained from the BAS database (downloaded data in ***Appendix C***), for the period 2004 to 2019 resulting in an average rate of 842mm/year. Assuming a 50% loss due to evapotranspiration and runoff, the infiltration rate is 421mm/year (0.0011m/day). This has been applied to the P20 spreadsheets.

7.2.9 Sensitivity Analysis

A sensitivity analysis was undertaken in accordance with the Environment Agency's 'Remedial targets methodology, Hydrogeological risk assessment for land contamination' to test the robustness of the model. The following were included in the analysis as they are deemed to represent the more sensitive of the input parameters:

- Hydraulic gradient; and,
- Infiltration.

The sensitivity analysis was carried out using P20 spreadsheets for the contaminants arsenic and aromatic (C5-C7). Each of the input parameter values were varied individually. The results are presented in ***Appendix D***.

7.2.10 Hydraulic Gradient

There was no groundwater level data available to assess variation in hydraulic gradient. However based on the general flat lying topography of the Site, a relatively low range has been selected for the sensitivity analysis. Therefore minimum and maximum values of 0.0009 and 0.008, respectively, were included in the sensitivity analysis along with the derived value of 0.005.

It can be seen from the table in ***Appendix D*** that as hydraulic gradient increases, the corresponding RT values for arsenic and aromatic (C5-C7) increases although it is noted that the selected value of 0.005 results in the smallest RT value for aromatic (C5-C7). By applying the hydraulic gradient value of 0.005 it is considered suitably conservative and representative of site conditions considering the data limitations.

7.2.11 Infiltration

Minimum and maximum infiltration values of 0.00069m/day (30% infiltration) and 0.0014m/day (60% infiltration), respectively, were selected for sensitivity analysis as they account for variations in permeabilities of potential surface cover. The selected value is 0.0011m/day based on 50% infiltration. It can be seen from the table in ***Appendix D*** that as infiltration increases, the corresponding RT values for arsenic and aromatic (C5-C7) decreases. Therefore, the applied value of 0.0011m/day is considered suitably conservative and representative of current site conditions. Following construction this value will be reviewed to ensure it remains representative of Site conditions.

7.2.12 Discussion

The sensitivity analysis concludes that based on the selected values for hydraulic gradient and infiltration, derived remedial target values are appropriate for application to the Site.

7.3 Tier 3 Soil Screening

Soil results have been screened against derived Tier 3 criteria and the screening sheet is presented in ***Appendix B***. Results indicate remaining exceedances for a number of metal and organic contaminants. The DRO contaminant concentration Tier 1 exceedances have not been screened against Tier 3 criteria as this is not considered appropriate, as described in previously. As a conservative measure, the remedial target value derived for Aromatic C5-C7 will be applied to C5-C8 TPHs.

7.4 Dilution Capacity

It is considered appropriate to further assess risk from remaining contaminants of concern by considering the dilution potential within the receiving water, King Edward Cove. Dilution available within a receiving water from an industrial discharge can be modelled using robust site specific However, adequate site-specific data is not available for the KEP Site and therefore modelling is not considered appropriate. Instead, a dilution factor has been estimated by comparing the potential discharge rate to the Cove from the superficial deposits with a potential daily tidal flow rate within the Cove. The dilution factor will be applied to soil Tier 3 remedial targets (in the absence of soil leachate data) and it is therefore assumed that all contamination in the soil is leaching to the water environment which is considered a conservative approach.

The discharge rate of water entering the Cove has been estimated using Darcy's Law:

Q=kiA where:
Q is the discharge rate in m^3/day
K is the permeability of the superficial material – 2.6m/day
i is the hydraulic gradient - 0.005
A is the cross-sectional area through which water flows into the Cove (using width of plume 219m and saturated thickness 3.74m) – 819.1m^2

Using values as listed above, the discharge rate is calculated as 10.6m^3/day or 10600 litres/day.

Daily tidal flow is estimated by calculating the potential volume of water likely to be displaced by tidal movement. This has been limited to 10m from the coast line along a length of 219m to represent the potential contaminant plume width. Tidal data is presented in ***Appendix C***. Full tide and half tide heights are available for the years 2008-2014. Average differences in tidal heights from January, March and May/June 2014 were compared and vary from 83.9cm to 87.2cm. This results in a range in potential volume of water displaced by the tide of between 1837.4m^3 or 1837400 litres and 1909.7m^3 or 1909700 litres. This is the water assumed to be displaced in 1 day. The ratio between groundwater discharge to the Cove and tidal flow, indicates a dilution factor of between 172 and 180. This is considered a conservative estimate.

By applying the more conservative factor of 172, only one concentration of cadmium at trial pit location TP10 and 2 concentrations of TPH aliphatic C6-C8 at locations TP2 and TP3, remain as contaminants of concern.

7.4.1 Dilution Sensitivity Analysis

For each of the trial pit locations, the actual dilution factor required, has been derived as presented in the table below.

TABLE 7-4 DILUTION FACTORS

Contaminant of Concern	TP1	TP2	TP3	TP5	TP6	TP10
Cyanide (Total)	0	0	0	0	0	10
Arsenic	10	10	10	10	10	30
Boron	0	0	0	0	0	0
Cadmium	0	0	0	0	80	>1000
Chromium	70	70	70	80	80	140
Copper	0	0	0	0	0	10
Mercury	0	0	0	0	0	0
Nickel	10	20	20	20	20	40
Lead	10	10	10	10	20	40
Selenium	0	0	0	0	0	0
Zinc	10	10	10	10	10	150
Aromatic (C5-C7)	0	0	0	0	0	0
Aliphatic (C5-C6)	0	90	0	0	0	0
Aromatic (C7-C8)	0	0	0	0	0	0
Aliphatic (C6-C8)	0	950	330	0	0	0
Benzene	0	0	0	0	0	0
Toluene	0	30	0	0	0	0
Total PAHs (17)	0	0	0	0	0	0
Aliphatic (C6-C8)	0	80	30	0	0	0

It can be seen that the majority of contaminants require a dilution factor of less than 100. Some concentrations at location TP10 require higher dilution factors and the cadmium concentration at this location requires a dilution factor in excess of 1000. The TPH aliphatic C6-C8 band requires dilution of 330 and 950 at locations TP3 and TP2 respectively.

This contamination will require further consideration and will be discussed further in ***Section 8***.

7.5 Discussion

Tier 3 assessment of contamination encountered within soils at the Site has demonstrated required dilution of up to 100 which is within the conservative estimate of **172**. Higher dilution factors are required at TP10 (cadmium), TP2 and TP3 (Aliphatic C6-C8 Hydrocarbons) that exceed the calculated factor indicating that dilution cannot be relied on to mitigate any adverse impact from dissolved contamination. It is noted however that this is based on significant conservatism as discussed in Section 7.7 below.

Regardless, this should be considered during earthworks on the site, in conjunction with then known free-product hydrocarbon contamination (not addressed by dilution).

7.6 Earthworks Screening Criteria

Screening criteria have been derived by applying a dilution factor of 150 to the derived Tier 3 screening values. The following table presents the Tier 1 values, the derived Tier 3 Criteria values and the derived Earthworks criteria (with dilution applied) applicable to soils during earthworks for the construction of the new Wharf.

TABLE 7-5 EARTHWORKS SCREENING CRITERIA

Contaminant of Concern	Tier 1 EQS (Marine Environment) mg/l	Tier 3 Screening Criteria		Earthworks Criteria with dilution applied	
		Soils (mg/kg)	Soil Leachates (mg/l)	Soils (mg/kg)	Soil Leachates (mg/l)
Cyanide (Total)	0.05	0.834	0.084	125.1	12.6
Arsenic	0.025	1.3	0.042	195	6.3
Boron	7	11800	11.8	1770000	1770
Cadmium	0.0002	0.005	3.36e-4	0.75	0.0504
Chromium	0.0034	0.172	0.0057	25.8	0.855
Copper	0.001	63.2	0.0063	9480	0.945
Mercury	0.00007	0.451	1.18e-4	67.65	0.0177
Nickel	0.0086	2.08	0.014	312	2.1
Lead	0.0013	2.44	0.00218	366	0.327
Selenium	0.001	0.03	0.00168	4.5	0.252
Zinc	0.0079	17.3	0.0133	2595	1.995
Total GRO	0.008	0.0295	0.0347	4.425	5.205
Total PAHs (17)	0.0002	3.28	0.00345	492	0.5175

7.7 Conservatisms

The Tier 3 assessment has been carried out with the following conservatisms built in:

- In the absence of soil leachate analysis, soil concentrations have been assessed on the assumption that all contamination is leaching from soils into the water environment. This does not allow for the process of soil/water partitioning i.e. a portion of the contamination remaining within the soil. The assessment therefore considers a ‘worst case’.
- The hydraulic conductivity applied to the P20 spreadsheets is considered to represent the lower range of likely permeability values associated with encountered sands and gravels.
- The dilution calculation assumes that the amount of water available for dilution within the Cove is limited to an area within a distance of 10m from the shoreline. Due to the relative size of the Cove, the amount of water available for dilution is likely to be far greater.

7.8 Summary

The DQRA works described above are summarised as follows:

- The majority of soluble contaminants are considered unlikely to pose a significant risk to the marine environment due to the dilution capacity of the receiving watercourse;
- Localised elevated Cadmium and Aliphatic Hydrocarbons in the C6-C8 range may pose a risk (albeit low due to significant conservatism in the assessment process), and should be considered in any earthworks as part of meeting the earthworks criteria in Table 7-5 above for any re-use of excavated material; and,
- Dilution is not considered appropriate for free product hydrocarbon contamination, and mitigation of free product release must be managed during construction.

8. Conclusions and Recommendations

8.1 General

The previous sections of the report have highlighted sources of contamination on site and subsequent risks to the water environment in the current and proposed use, and an increased risk of pollution during construction.

This section discusses the conclusions of the risk assessment, the developed construction constraints on the site and the recommendations for addressing these issues.

8.2 Updated Conceptual Site Model

Initial Tier 1 qualitative risk assessment for the site and the proposed development identified a number of metals and hydrocarbon fractions with the potential to pollute the marine water environment.

Detailed quantitative risk assessment as described in Section 7 has reduced the number of non-free phase contaminants of concern with the site soils to two (Cadmium and Aliphatic C6-C8 hydrocarbons), but has not indicated that the risk can be excluded. The potential impacts on the environment associated with free-phase hydrocarbons remains elevated

8.2.1 Current Status

The potential for contamination in the near shore marine environment from cadmium and Aliphatic C6-C8 hydrocarbons is considered to be extremely low due to only localised elevated concentrations and the significant inherent conservatism in the assessment. However as there is no available marine water chemistry data, the presence of dissolved contaminants in the marine environment cannot be ruled out therefore a continued low risk has been assumed (rather than unlikely).

As in the initial assessment, the proximity of free product in the shallow groundwater is such that some release into the environment is expected to occur. Given the lack of indications of contamination, a medium severity has been retained.

TABLE 8-1 REVISED RISK ASSESSMENT – CURRENT USE

Source	Potential Pathways	Receptors	Potential severity of Consequence	Probability of pollutant linkage occurring	Risk Classification
Free phase Hydrocarbons, cadmium and C6-C8 Aliphatic Hydrocarbons in superficial deposits	1. Leaching/wash-out from granular superficial deposits 2. Vertical movement within groundwater/saline water (tidal movement) 3. Migration as free product and dissolved contamination	Surface Water (1-3)	Medium (due to limited volumes gradually released to the environment)	Low	Low/Moderate

On a qualitative level, risks to the water environment in the current site status are considered to be Low/Moderate.

8.2.2 Construction Stage

As noted in the initial assessment, irrespective of construction method, the requirement to disturb contaminated ground in close proximity to the marine environment is considered likely to increase the risk of a pollution incident.

TABLE 8-2 REVISED RISK ASSESSMENT – CONSTRUCTION

Source	Potential Pathways	Receptors	Potential severity of Consequence	Probability of pollutant linkage occurring	Risk Classification
Free phase Hydrocarbons, cadmium and C6-C8 Aliphatic Hydrocarbons in superficial deposits	1. Leaching/wash-out from granular superficial deposits 2. Vertical movement within groundwater/saline water (tidal movement) 3. Migration as free product and dissolved contamination	Surface Water (1-3)	Severe (due to the potential for sudden release of large quantities of oil to the environment)	Likely	High

On a qualitative level, risks to the water environment in the construction stage are considered to be High. Generally, the risk is considered elevated, irrespective of construction method as noted previously.

8.2.3 In-Use

The proposed structures are not anticipated to present any significant barrier to contaminant migration, specifically no more protective than the existing equivalents. Accordingly, the in-use risk and severity have been assumed to offer no reduction in risk from the current status.

TABLE 8-3 REVISED RISK ASSESSMENT – IN-USE

Source	Potential Pathways	Receptors	Potential severity of Consequence	Probability of pollutant linkage occurring	Risk Classification
Free phase Hydrocarbons, cadmium and C6-C8 Aliphatic Hydrocarbons in superficial deposits	1. Leaching/wash-out from granular superficial deposits 2. Vertical movement within groundwater/saline water (tidal movement) 3. Migration as free product and dissolved contamination	Surface Water (1-3)	Medium (due to limited volumes gradually released to the environment)	Low	Low/Moderate

On a qualitative level, risks to the water environment in the in-use status is considered to be Low/Moderate.

It should be noted that this assessment considers the normal use of the structure, assuming ongoing maintenance. As noted previously although not acting as a complete barrier to contamination migration, the current and proposed sheet piled wharf structure is acting to limit discharge to the environment. In the event of a failure of the structure through degradation or as a result of accident (e.g. a vessel strike) the potential for significant release of the hydrocarbon free product identified behind the existing wharf structure would be considered to pose a High risk.

8.3 Construction Constraints

Assessment of the risks to the marine environment from contamination at King Edward Point (in particular free-phase contamination) has identified an increased (high) risk of release of pollution during the construction phase, associated with either a driven pile or excavated construction methodology.

Either methodology is considered likely to increase the potential for contaminant mobilisation, .

8.3.1 Open Excavation

Any works involving open excavation within the contaminated material are likely to disrupt the relatively static sub-surface environment, increasing the risk that contaminated groundwater and free product will migrate laterally, and increasing the potential for contamination adhering to particulate matter to be remobilised. Further, excavated of contaminated material has the potential to release contamination if not handled correctly. Dewatering is anticipated to be required in order to allow open excavation, which will disrupt the status quo, potentially drawing contamination from the wider plume and/or drawing in and contaminating previously clean water.

The materials identified during the ground investigation do not appear to present a significant constraint to excavation, however fill within the existing wharf area appears to contain waste materials assumed to arise from former users of the site, including materials which may reduce excavation stability and result in a need to over-excavate.

Works involving open excavation will result in a quantity of contaminated solid materials which will require appropriate segregation, handling and containment to prevent cross contamination of surrounding clean materials or contamination of the environment through leaching and run-off. Any materials generated through excavation are likely to require assessment and treatment prior to re-use, and may require disposal if they cannot be managed on-site at King Edward Point.

Dewatering of excavations where undertaken has the potential to generate significant volumes of contaminated water, oil and/or emulsions which cannot be discharged into the wider environment, and which will similarly require containment, treatment and potential disposal if they can't be rendered suitable for re-use.

8.3.2 Piling

Any works involving piling within or around the contaminated material are similarly likely to disrupt the relatively static sub-surface environment, increasing the risk that contaminated groundwater and free product will migrate laterally, and increasing the potential for contamination adhering to particulate matter to be remobilised as a result of ground borne vibration. The existing wharf structure is considered to act as a barrier to some contaminant migration however is porous (i.e. not filly sealed) and works involving pile driving in the vicinity have the potential to exacerbate any weakness or open joints resulting in additional release of contamination.

The materials identified during the ground investigation do not appear to present a significant constraint to piling, however fill within the existing wharf is noted to incorporate materials which may obstruct driven piles. Accordingly, some limited allowance for excavation (and subsequent contaminated arisings) should be allowed for in a piled solution, however be understand that it may be practical to remove pile obstructions without significant dewatering.

8.3.3 Construction Mitigation

Visual and olfactory evidence of hydrocarbon contamination combined with lab test results indicate hydrocarbon contamination is significant across the site. Given data limitations, determining a construction method that does not involve disturbing hydrocarbon impacted materials is not achievable. Any construction method that disturbs the ground is considered likely to cause an unintentional release of oil contaminated water in to the ocean.

Accordingly, we would recommend that suitable spill-control be employed during any construction works in the area involving ground disturbance, for the duration of the works and for an observation period afterwards (duration to be determined based on site programme, but as long as practicable) as a precautionary measure.

8.4 Remediation Recommendations

Contamination (primarily free-phase hydrocarbons) beneath the KEP site has been assessed as posing low to moderate risk to the marine water environment in both the current site condition and following completion of construction works, i.e. while the new facility is in use.

A Low/Moderate risk indicates that there is the possibility that harm to the receptor could arise from the identified contamination hazard, but that it is unlikely that such harm would be severe. This classification assumes that the structures will be subject to ongoing maintenance and excludes any event which may result in the structures being breached.

Regardless, a risk classification of low/moderate would ordinarily result in a recommendation for the design and implementation of remedial works to either address the contamination source (by treatment or removal) or to improve containment and disrupt potential pollutant pathways and thus reduce ongoing risks to a low or very low level.

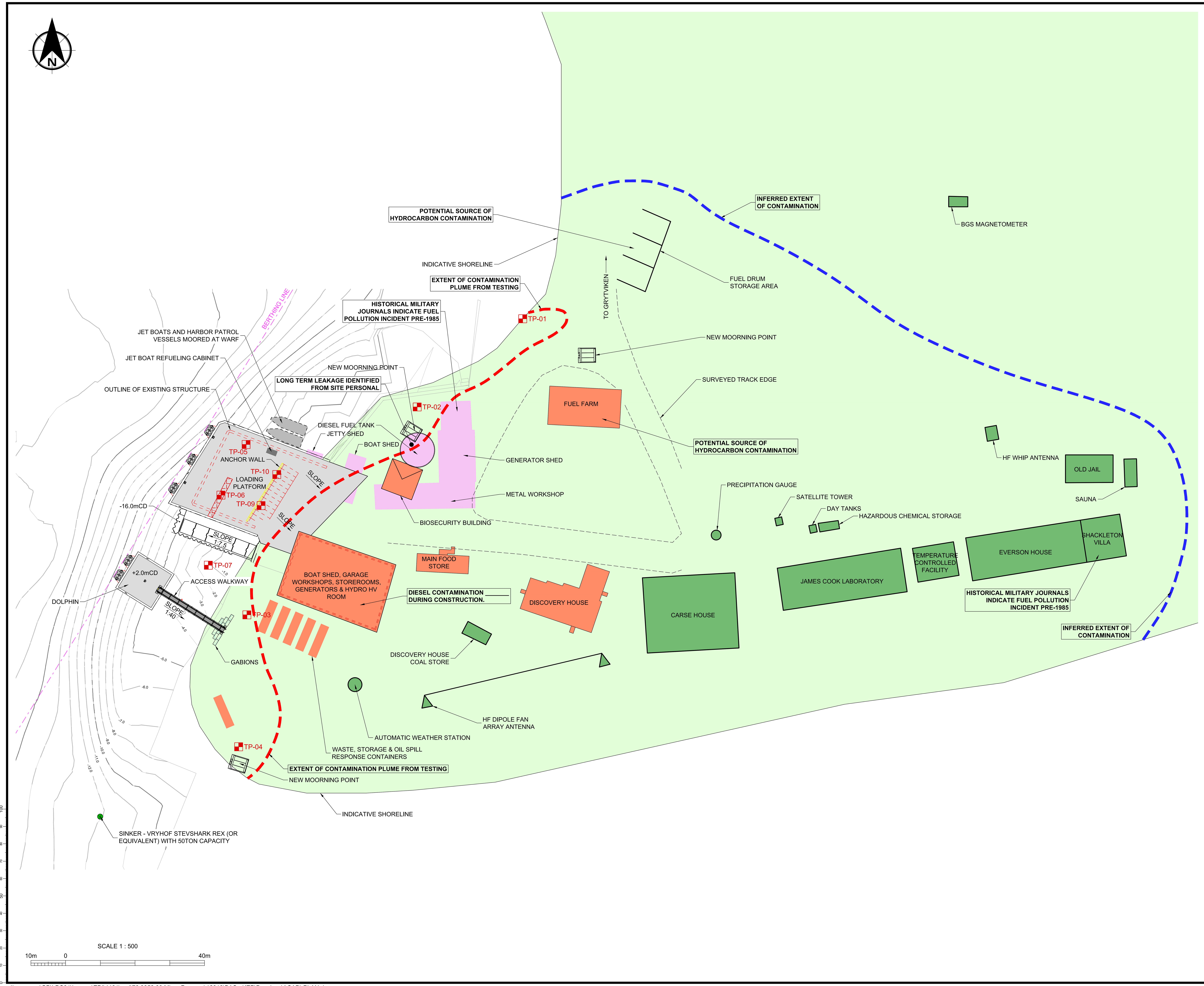
It is Sweco's understanding that significant remedial works are unlikely to be feasible on King Edward Point due to the technical constraints and costs associated with the remote location, however as a minimum when design and construction methods are finalised, a methodology should be developed to manage any contaminated arisings (solid or liquid) which are likely to be generated by the works, including methods for containment, disposal and/or treatment for re-use if required.

As noted above, we would recommend that appropriate environmental mitigation measures are employed by the contractor during construction to prevent or contain any pollution release.

Figures and Appendices

Provided electronically as individual files in the accompanying report folder.

Appendix 4 - Extent of ground contamination



NOTES

1. ALL LEVELS ARE IN METRES AOD UNLESS SHOWN OTHERWISE.
2. SITE LAYOUT BASED UPON DELTA MARINE CONSULTANTS DRAWING "BAA-4010-DMC-ZZ-KEP-DR-C-0002_P03_SG_MSG".

LEGEND:

- SURVEYED BUILDINGS
- LOADING PLATFORM
- BUILDING INFRASTRUCTURE AS PER LOCATION PLAN
- HISTORIC INFRASTRUCTURE
- TRIAL PIT LOCATION — TP-00
- MINOR CONTOUR
- MAJOR CONTOUR
- CONTAMINATION PLUME EXTENT BASED ON GEOCHEMICAL DATA
- POTENTIAL CONTAMINATION PLUME EXTENT INFERRED FROM HISTORICAL INFORMATION

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KING EDWARD POINT NEW WARF

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EXTENTS OF CONTAMINATION PLAN VIEW

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Appendix 5 - DEEP Offshore Survey Report

SURVEY REPORT
South Georgia - King Edward Point

Multibeam, Sidescan Sonar, Seismic and Topographic Survey

AUTHORISATION

Document title	King Edward Point - survey report
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EXECUTIVE SUMMARY

To facilitate larger cargo and research vessels the existing jetty at the King Edward Point base, on the island of South Georgia, will be renewed. The design and construction of the new jetty is the responsibility of BAM Nuttall (UK). To provide BAM Nuttall with a detailed overview of the current situation around the jetty Deep BV has performed multibeam, sidescan sonar, sparker and topographic surveys in February and March 2019.

Using existing benchmark ISTS-61as a base, a local grid was established for both the marine and the land-based surveys. Four new benchmarks have been established around King Edward Point, in local grid/chart datum and ITRF 2014/EGM2008. The creation of these new benchmarks is described in a separate report, *P3506_Benchmarks_REP_190225_R00*.

The multibeam survey was done using a Norbit iWBMS, and shows the bathymetry around the jetty. Data quality is good, meeting and exceeding the IHO special Order norm. Full coverage was achieved in all areas, except the shallow parts that could not be reached safely. The lower part of the existing sheet piling is clearly visible. Water depths start from around 20m below CD in the deepest part, while water depths directly along the front of the existing jetty are between 6m and 10m below CD .

The sidescan sonar survey was executed using a Klein 3900 operating at 900kHz. It covered the same area as the multibeam survey. The data was of good quality, though the presence of kelp in the area did restrict where the survey could be executed. Objects on the seabed consisted mainly of some loose cables in the shallows north of the existing jetty, some debris close to the jetty and a group of tires around 15m from the jetty.

The sparker survey was performed using a GeoMarine single-channel sparker system. To improve the data interpretability the survey was executed at 400 Joules first, and re-done at 900 Joules afterwards. Throughout the entire sparker dataset, there is no reflector which clearly indicates the presence of solid bedrock. This could mean the bedrock is too deep for detection. However, there is a reflector visible which could represent the top of a harder layer. The depth of this layer varies between 11 and 47 meters below seabed.

The topographic survey has been done using RTK corrected GPS readings of the existing jetty and associated structures, beach areas, current buildings at KEP, tracks and possible quarry areas. Additional topographic work was done by using the Trimble C5 total station to measure reference points on various buildings, allowing previously recorded laser scan data to be placed within the local grid.

All surveys were executed as expected by the survey team. The recorded data proved to be of good quality.

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COMMON ABBREVIATIONS

AIS	Automatic Identification System
BAS	British Antarctic Survey
BV	Besloten Vennootschap (Dutch equivalent to Ltd.)
CD	Chart Datum
CMG	Course Made Good
C-O	Computed-Observed
CoG	Centre of Gravity
dGPS	differential Global Positioning System
DPR	Daily Progress Report
DTM	Digital Terrain Model
EEZ	Economic Exclusive Zone
ETRS	European Terrestrial Reference System
Fm	Formation (used in a litho-stratigraphic system)
GLONASS	(Russian) Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS	Geodetic Reference System
GSGSSI	Government of South Georgia and the Southern Sandwich Islands
HSE	Health, Safety and Environment
ITRF	International Terrestrial Reference Frame
KEP	King Edward Point
MBES	Multibeam Echosounder
MDR	Master Document Register
MRU	Motion Reference Unit
MSL	Mean Sea Level
M.V.	Motor Vessel
PEP	Project Execution Plan
PPE	Personal Protective Equipment
PPS	Pulse Per Second
PQP	Project Quality Plan
QC	Quality Control
QMS	Quality Management System
RTK	Real Time Kinematic
SBP	Sub-bottom Profiler
SD	Standard Deviation
SCS	Single Channel Sparker
SNR	Signal to Noise Ratio
SoG	Speed over Ground
SSS	Sidescan Sonar
SVP	Sound Velocity Probe
TVU	Total Vertical Uncertainty
TWTT	Two Way Travel Time
USBL	Ultra-Short Baseline underwater positioning
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WGS	World Geodetic System
WoW	Waiting on Weather

1. INTRODUCTION

King Edward Point on South Georgia is home to a British Antarctic Survey (BAS) base camp. The camp houses BAS personnel, scientists and technicians, and operates in close cooperation with the Government of South Georgia and the Southern Sandwich Islands (GSGSSI). The existing jetty at King Edward Point will be extended next year, allowing larger research and supply vessels to moor at the station, most noticeably the BAS' new polar research ship the Sir David Attenborough. The design and construction of the new jetty is the responsibility of BAM Nuttall (UK). Figure 1-1 below shows a recent shot of King Edward Point, with the existing jetty in the foreground.

Figure 1-1; King Edward Point with jetty.

A site survey has been executed by Deep BV to provide a complete picture of the current situation around the existing jetty. This involved bathymetric, sidescan sonar, seismic and topographic surveys. The aim for all surveys was to provide the client with a detailed and accurate overview of the site, both above and below water.

This report describes the results of all these surveys, and the methods used to derive the data.

1.1. Location overview

Kind Edward Point is located within Cumberland Bay on the island of South Georgia. South Georgia is a British dependency, governed by the Government of South Georgia and the Southern Sandwich Islands. It is located in Antarctic waters, approximately 800 miles from the Falkland Islands. The bay at King Edward Point, King Edward Cove, also houses the former whaling station of Grytviken. This station was abandoned in the 1960's, and is currently undergoing continual restoration. It is a berthing place for many Antarctic cruises, not least because the polar explorer Ernest Shackleton is buried in the Grytviken cemetery.

Figure 1-2 shows an overview shot of King Edward Cove, looking north-eastward. King Edward Point can be seen on the peninsula, indicated by the red circle. The remains of Grytviken are seen in the foreground along the bay edge. The circular nature of the bay can be clearly seen.

The survey area focussed on the existing jetty at King Edward Point. The area extended around 15m from the northern edge of the jetty, and 130m from the southern edge. From the jetty outwards the area extended 50m, with an additional 50m requested to gain a better overview.

Figure 1-2; View of King Edward Cove.

1.2. Used equipment

The different surveys, both marine and land-based, required the use of a large equipment spread. Table 1-1 gives an overview of the equipment and what it was used for. Besides the equipment mentioned below a lot of special cables, brackets, poles and other survey-related paraphernalia was brought to site to facilitate the surveys.

Equipment overview			
Make	**Type**	**Qty.**	**Used for**
Hardware			
Trimble SPS855	GPS receiver	3x	RTK base station, topographic survey, benchmark creation, RINEX logging
Norbit iWBMS	Multibeam system	1x	MBES survey
Applanix PosMV MRU	Motion & heading unit (integral with Norbit)	1x	MBES survey, SSS survey, SCS survey
AML Minos X	Sound velocity probe	1x	MBES survey, SSS survey
Klein 3900	Sidescan sonar	1x	SSS survey
GeoMarine LW200 sparker source	Single channel sparker	1x	SCS survey
GeoMarine 8 element Mini Streamers	Single channel sparker	2x	SCS survey
Satel 3ASd-Epic	UHF communication	4x	RTK base station, MBES survey, SSS survey, SCS survey, topographic survey, benchmark creation
Nautiz PDA	Handheld computer	1x	Topographic survey, benchmark creation
Trimble C5	Total station	1x	Topographic survey
Sokkia C3-2	Levelling instrument	1x	Benchmark creation

Software			
QPS QINSy	Recording and processing software	2x	MBES survey; SSS survey, SCS survey, topographic survey
GeoSuite	Recording and processing software	2x	SCS survey
SurvCE	Recording software	1x	Topographic survey
Terramodel	Processing software	1x	MBES survey; SSS survey, SCS survey, topographic survey
Autoclean	Processing software	1x	MBES survey
Cloud Compare	Processing/presentation software	1x	MBES survey

Table 1-1; Project equipment overview.

2. SCOPE OF WORK

The existing jetty at King Edward Point was found insufficient for the growing supply and research ships that visit the base. To allow the design and installation of a bigger jetty a marine and land-based survey was required. The scope of work for this has been defined as follows:

- Project preparation and compilation of survey procedures;
- Mobilisation of personnel and equipment to project location;
- Establishment of survey control around the site:
  - Establishing a local grid for use around KEP;
  - Three new benchmarks created from existing benchmarks;
  - Levelling new benchmarks to existing benchmarks as a further check.
- Topographic survey:
  - Measure coordinates on fixed points to place previously recorded laser scan data into the project coordinate system;
  - Topographic measurements of the existing jetty and surroundings. Including capping beams, mooring and anchor points, deck levels, slipway, retaining wall and all other wharf furniture;
- Bathymetric and sidescan sonar survey:
  - Installation, verification and calibration of equipment on survey vessel;
  - Multibeam survey to measure bathymetry around existing jetty. 100% coverage;
  - Sidescan sonar survey to detect objects/obstructions on the seabed and clusters of kelp.
- Sub-bottom survey (single channel sparker):
  - To identify and classify the sub-surface geology and map bedrock level.
- Demobilisation of vessel, personnel and equipment;
- Data processing and reporting.

Extra focus was placed on the construction of the local coordinate grid and the creation of the new benchmarks. While both the land-based and the sub-sea areas have been surveyed before, often this was done using unclear geodetic settings. Therefore tying all previously recorded survey data together proved very difficult. Providing the client with detailed marine and land-based survey data *to one clearly defined geodetic system* was therefore important.

The available time on the project locations was more than initially thought, due to the later arrival of the supply vessel and part of the sparker survey spread. The extra time was used to perform a more complete topographic survey around the project area, including DTM's around the boat house and in possible two quarry areas, and indicative positions of the existing structures at KEP and the track to Grytviken.

2.1. Reference documents

Table 2-1 below shows the reference documents for this project. These documents are leading in regards to the project scope of work and execution of fieldwork and processing.

Document	Description	By	Version
Q2018_JCO_DOC_6267_R02.pdf	Quotation	Deep BV	rev. 02
Q6267_MS_R02.pdf	Brief method statement	Deep BV	rev. 02
KEP Bathymetric and Topographic Survey	Quotation document	BAM	
Area for Seismic Surveys.pdf	Survey area definition	send by BAM	
1805 Site Cal CD2.pdf	Site calibration	SWECO (BAM consultant)	
P3506_Benchmarks_190225_R00.pdf	Benchmark creation report	Deep BV	Rev. 00

Table 2-1; Project reference documents.

3. RESULTS

The multibeam, sidescan sonar, sparker and topographic surveys have been performed in one fieldwork phase at Kind Edward Point in February and early March 2019. The surveys have been executed by Deep BV using their own equipment and one of the British Antarctic Survey's jet boats.

3.1. Multibeam survey

The multibeam data is of good quality, easily meeting the IHO special norm. The survey area has been covered with full coverage, and along the coastline the measurements have been done as far as safety would allow. The water depths directly in front of the jetty are between 6 and 10 metres below chart datum. The slopes towards the coastline are steep, running from an average depth of around 16 metres to around 2 metres below chart datum over a lateral distance of just 35 metres. The seabed in the deeper areas shows some clear linear marks, possible caused by ships anchoring. The underwater structure of the existing jetty has been mapped as best as could be done. The existing sheet piling can be seen on the three sides. Figure 3-1 shows a screenshot of the multibeam data in a 3D viewer. The sheet piling has been coloured grey to distinguish it from the surrounding seabed. Red indicates shallow, with blue showing the deeper areas.

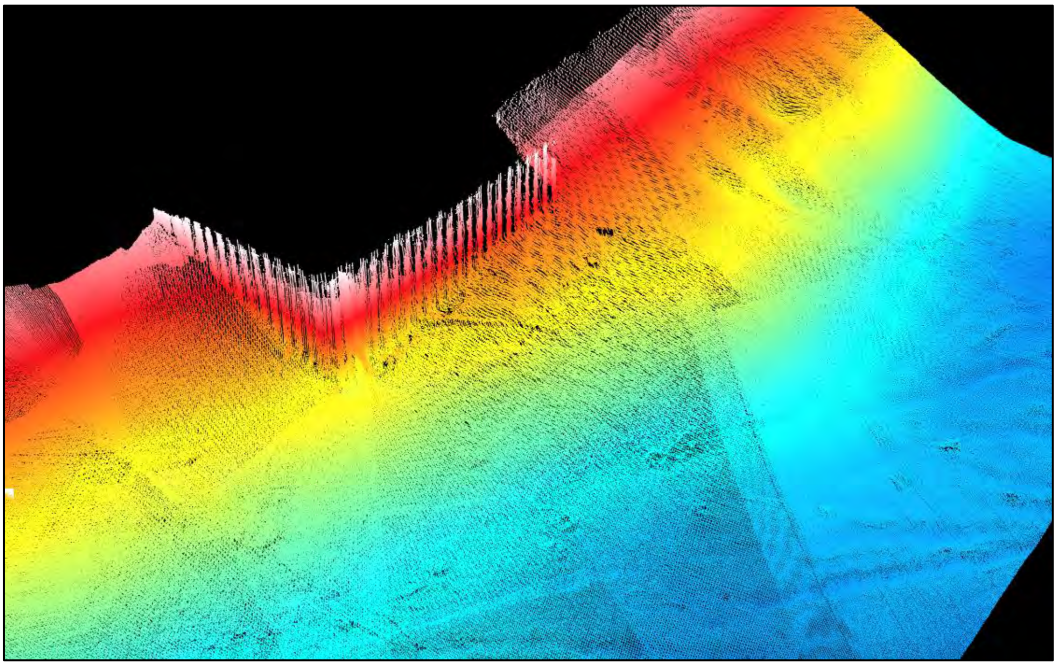


Figure 3-1; MBES data with existing jetty foundation.

3.2. Sidescan sonar survey

The sidescan sonar survey shows objects on the seabed. Throughout the survey area small rocks or boulders were seen in the data. Given the location of the survey area, on the slopes of the mountains, this is to be expected. Most of these can be found in the deeper areas, having rolled down the slopes. During processing foreign objects (i.e. excluding small boulders) have been picked within the survey area. Near the existing jetty all objects have been picked. A total of 28 objects have been detected. Noticeable is a cluster of tires more than 15 metre from the existing jetty (see Figure 3-4). These have likely fallen off ships, as old tires have frequently been used as fenders. The north-eastern part of the survey area shows some cables and a length of pipe. In the direct vicinity of the existing jetty some debris has been found. This is also visible on the multibeam data. The deeper areas show linear marks, probably related to ships anchoring, as illustrated in Figure 3-3.

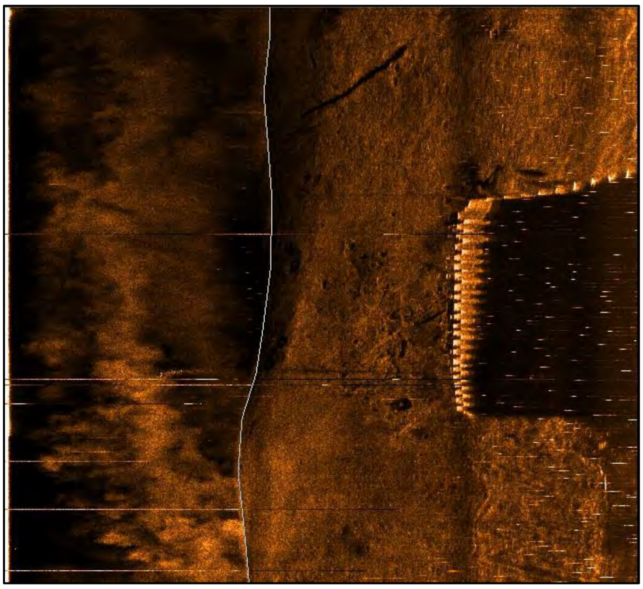


Figure 3-2; Sidescan sonar data showing the existing jetty.

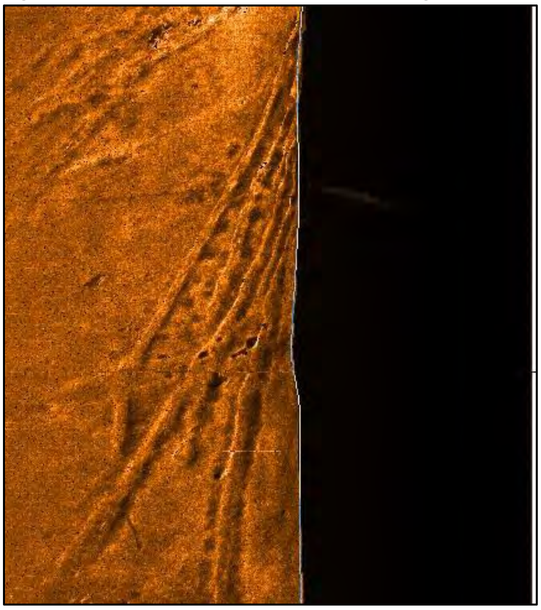


Figure 3-3; Anchor marks in the seabed (only port channel shown).

Figure 3-4; Cluster of tires (only port channel shown).

3.3. Sparker sub-bottom profiling

The sparker survey was executed to allow an insight into the shallow geology (10m below seabed where possible, as per scope of work) to allow an assessment as to the viability of the sheet-pile base design. A GeoMarine single channel sparker was used for this survey. The survey was performed twice, at 400 Joule (lower penetration but higher data density) and at 900 Joule (higher penetration but lowered data density). By performing the survey with two different settings higher changes of accurate interpretation are offered. The usable data for such a system is generally up to the multiple reflections (i.e. up to twice the water depth from the water surface down).

Shingle, gravel to small boulder sized rocks, are the major components of the seabed sediments in the survey area. The shingle will have low penetration characteristics compared to softer sediments, like sand. This means the sub-bottom signal quickly loses its strength when penetrating the sub-surface. This could be the reason that none of the sparker profiles show any indication of a strong, well defined reflector that could be interpreted as the top of bedrock. However, there is a reflector visible which could represent the top of a harder layer. This reflector is marked as top of unit 2 in the charts, as illustrated in Figure 3-5, its depth varies between 11 and 47 meters below seabed. Please note, without geotechnical data, it is not possible to confirm this reflector as the correct transition of unit one and two, as well further interpretation of sediment types.

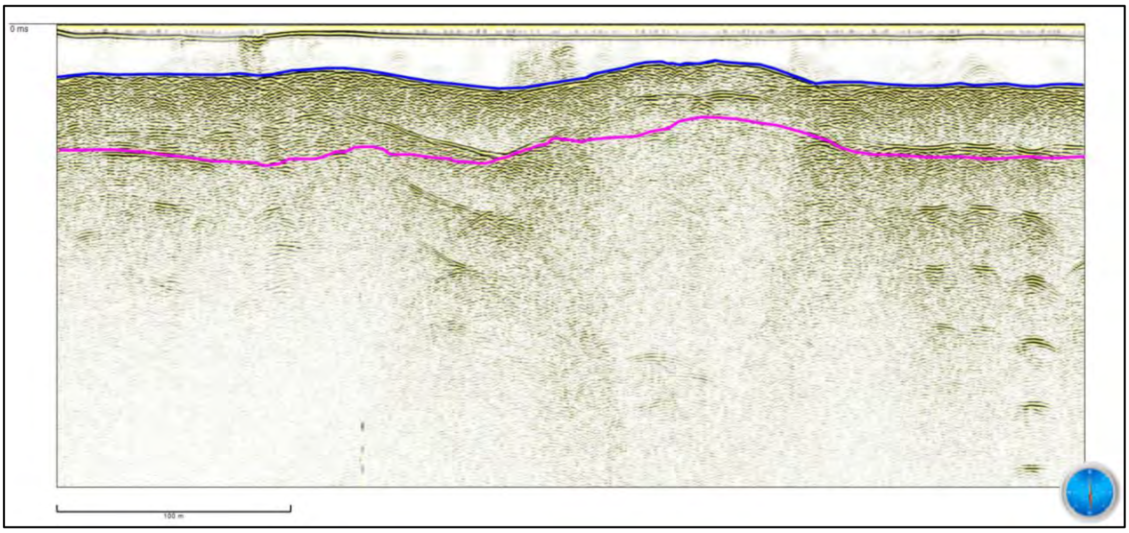


Figure 3-5; Profile P1 with top of seabed in blue and top of unit 2 in pink.

Disclaimer
In the processing and interpretation of the geophysical data, Deep employees have relied on experience and have exercised their best judgment. Furthermore, everything possible has been done to maintain a constant processing staff for this project, ensuring unambiguous results. However, all interpretations are opinions based on interferences from acoustical, magnetic and/or other measurements. Features that do not produce measurable geophysical anomalies or are hidden by other features may remain undetected. Geophysical surveys may complement invasive/destructive methods and provide a tool for investigating the subsurface; they do not produce data that can be taken to represent all of the ground conditions found within the surveyed area. Areas that have not been surveyed due to obstructed access or any other reason are excluded from the interpretation. Therefore Deep cannot and does not guarantee the accuracy or the correctness of any interpretation. As such, Deep shall not be liable for any loss, damages or expenses resulting from reliance on such interpretation.

If any third party data is used or included in a Deep data delivery, report or chart Deep does not guarantee the accuracy or the correctness of the third party data and Deep shall not be liable for any loss, damages or expenses resulting from reliance on third party data.

3.4. Topographic survey

Setting up the local grid and the associated benchmark establishment has been executed with no problems encountered. A total of four new benchmarks have been made, producing a grid across King Edward Point. Their position has been determined using three independent techniques. The benchmark establishment is described in detail in a separate report (*P3506_Benchmarks_REP_190225_R00*).

Topographic measurements with RTK GPS have been taken of the existing jetty, including mooring points, other furniture and the slipway. The area around the boat house and the beach area on either side of the jetty have been measured, allowing an interpolated DTM to be produced. To provide an approximate overview of the King Edward Point layout the corners of buildings haven been recorded (easting and northing only). The tracks at KEP, the track to Grytviken, a HV cable, a fuel pipe and two possible quarry areas have been measured as well. All topographic work has been performed in the same geodetic system as the marine works. Figure 3-6 shows an overview of all topographic results. King Edward Point itself is situated at the lower right-hand corner. The track runs along the side of the water to Grytviken, where the second quarry area can be seen.

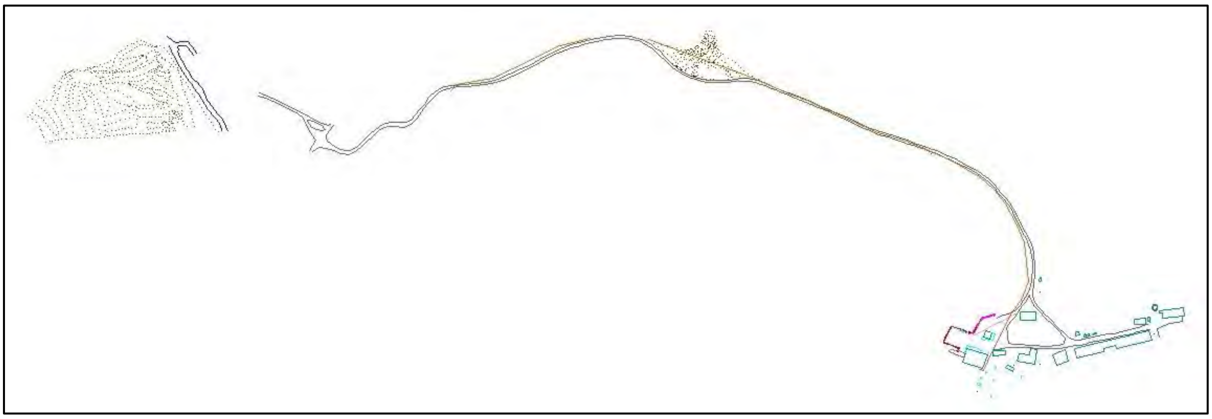


Figure 3-6; Topographic measurements around KEP.

4. OPERATIONAL METHODS

This chapter describes the operation methods used during the fieldwork phase of the project. After discussing the geodetic settings each paragraph focusses on one technique at a time, concerning equipment used, possible calibrations and execution of survey.

4.1. Health, safety and the environment

The party chief had an overall responsibility for the survey activities, procedures and contact with the client. All undertaken activities during the survey operations were described in daily reports which were signed by the party chief and send to the client.

All personnel from Deep BV is committed to the HSE policy of the company, and to the project specific risk assessment. Additionally the role of the party chief was to inform the client in case of any health, safety or environmental hazards as well as any near-miss. No project related health, environmental hazards or near-misses occurred.

4.2. Key dates

An overview of key dates during the fieldwork phase of the project is given in Table 4-1 below. A more detailed day-per-day overview of the activities can be seen in the daily progress reports (see appendix A).

Date	Activity
21 Jan	Equipment dropped off at BAS Cambridge (UK).
10 Feb - 11 Feb	Personnel transport Amsterdam (NL) to Stanley (FLK).
11 Feb	Informed that seismic streamers are still in UK at BAS; problems with transport. Transport ship Shackleton is broken down at Falklands.
12 Feb - 15 Feb	Personnel and equipment transport Stanley (FLK) to KEP (SG) by cruise ship Fram.
16 Feb - 18 Feb	Mobilisation, MBES and SSS survey.
19 Feb - 27 Feb	Topographic measurements and data processing while waiting on arrival of streamers.
28 Feb	Streamers arrive on Ernest Shackleton. Mobilising sparker setup.
1 Mar	Additional MBES survey around jetty. Sailing tests with sparker setup.
2 Mar - 3 Mar	Sparker data analysis and data processing.
4 Mar	Sparker survey at 400J and 900J.
5 Mar - 7 Mar	Initial sparker processing and preparation for equipment transport.
8 Mar - 12 Mar	Personnel and equipment transport KEP (SG) to Stanley (FLK) by RRS Ernest Shackleton.
15 Mar - 16 Mar	Personnel transport Stanley (FLK) to Amsterdam (NL).

Table 4-1; Overview of key project dates.

4.3. Geodetics

Horizontal reference

A local construction grid has been used for the KEP site survey on request of the client. ITRF2014 (Ellipsoid GRS1980) was used as datum. To create the local grid results a Transverse Mercator projection with the origin defined on benchmark ISTS-61 and a scale factor of 1 was used. Thereafter the local grid was created by applying the following:

Shift Easting: *+4000.00m*
Shift Northing: *+3000.00m*
Azimuth: *-2.839167°*

Coordinates of two existing benchmarks (ISTS-61 and KEPA) have been provided prior to the start of the project in both GNSS and local coordinates. In defining the projection Deep made sure these two positions stayed fixed.

Vertical reference

Vertical reference for all survey data is chart datum, which has been defined by the client to be 1.6m below EGM2008 in the survey area. The ISTS-61 height (3.07m) has been used as a reference for the new survey operations. Both the EGM2008 model and fixed 1.6m shift have been applied online to get results to requested chart datum level. Both the marine and the land-based survey results are in chart datum.

Conversion check

The correct geodetic conversions for the local grid have been added in the QPS QINSy survey software. The conversion results shown in the client provided site calibration report (*1805 Site Cal CD2.pdf*) have been used to verify the Deep geodetics for the work site. Figure 4-1 below shows a screenshot of the QPS QINSy conversion results for point ISTS-61, showing this to work correctly.

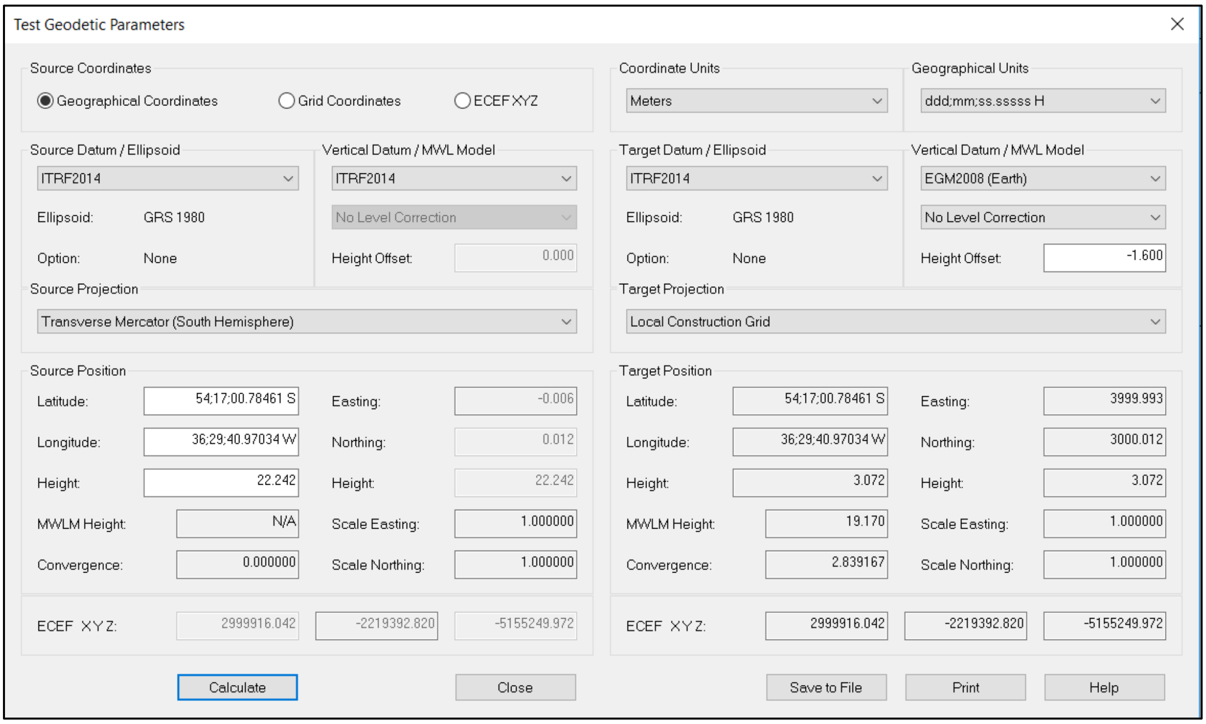


Figure 4-1; Geodetic parameters check.

A similar conversion check was performed for all four points mentioned in the site calibration report. When comparing the grid results from the report to those of the QPS QINSy survey software, only minor differences are found. These measure a few centimetres at most and are probably caused by the different ITRS version and slightly different rotation used. Below table gives the QPS QINSy results for each point.

Point ID	Latitude (ITRF2014)	Longitude (ITRF2014)	Height (ITRF2014)	Easting (local)	Northing (local)	Height (CD)
KEPA	54;17;42.88115 S	36;30;51.44249 W	346.209	2791.454	1636.693	326.806
ISTS-61	54;17;00.78461 S	36;29;40.97034 W	22.242	3999.993	3000.012	3.072
Point 1	54;16;56.88001 S	36;30;57.01009 W	135.400	2620.004	3052.244	116.173
Point 2	54;17;43.45001 S	36;29;38.08006 W	39.400	4117.547	1685.025	20.071

Table 4-2; Conversion results.

4.4. RTK base station

On arrival at King Edward Point the existing benchmarks ISTS-61 and UKHO-9798 were located and used to set up and check a local RTK network. This local network was used for all marine and land-based survey operations. Ellipsoidal coordinates of UKHO-9798 have been taken from document "*KEP Bathymetric and Topographic Survey*", provided to Deep during the quotation phase.

The base station was first set up on ISTS-61. Thereafter a second receiver was used to log the position results at UKHO-9798. The average resulting position after 10 minutes of logging was compared to the reported position. The difference was about 7cm, which can be caused by the benchmark using an unknown datum. The results were sufficient to continue operations and use the RTK network to log a new base station position, fixed on top of the equipment container. The antenna on top of the container was subsequently used as the RTK base station. The 'container antenna' position was logged and averaged over 10 minutes.

Figure 4-2; RTK base set up on the container.

After setting up the new base station a position check was done on both ISTS-61 and UKHO-9798. Results of both these checks can be found in the appendices and are within the system accuracies. During all position checks the amount of satellites was monitored, as well as the quality of their resulting positions. Although the mountains around KEP did block of signals from certain directions the coverage was found to be more than sufficient, showing an average of about 18 satellites during survey operations.

Figure 4-3; Position logging on ISTS-61.

4.5. Vessel

The vessel used to perform all marine surveys was a client-provided jet boat. The BAS has two identical jet boats that are used for harbour patrol, scientific research and GSGSSI governmental tasks. Both are approximately 10 metre long monohulls with twin engine jet propulsion. The jet propulsion allowed the vessel to manoeuvre confidently in tight spaces, allowing multibeam data to be gathered closely around the existing jetty.

BAS personnel had constructed a frame on the starboard side of the vessel 'Pipit' to allow the installation of GPS antennas and Norbit multibeam system. Sidescan sonar and single channel sparker could be deployed from the back deck and safely towed behind the vessel.

Figure 4-4; KEP jet boats. 'Pipit' on the right.

4.6. Multibeam echosounder

A Norbit iWBMS multibeam system was used during the bathymetric survey, operating at a frequency of 400 kHz. The integration of the PosMV combined GPS and motion reference unit reduces mobilisation and calibration times. Since it was not possible to keep the equipment permanently installed on board the jet boat a calibration/start-up procedure was required each time the unit was deployed for survey operations. This basically includes:

- Update sensor offsets
- Calibrate the PosMV MRU/INS
- Measure the sound speed profile
- Calibrate the multibeam sonar

All offsets between relevant sensors on-board the vessel have been measured using a tape measure and adjusted in the survey software.

The gyro and motion sensor are built into the Norbit multibeam system. These sensors are already calibrated with the primary positioning system. By sailing figure of 8 patterns the system can calibrate the sensors with the mounting of the antennas to ensure the accuracy of the gyro compass sensor.

For the multibeam echo sounder an additional calibration procedure, commonly referred to as a patch test, was used to derive actual offset values, which were then applied to the data in order to bring the system in proper alignment with the motion reference unit. The procedure involves collecting data over certain types of terrain and processing it by means of a set of patch test tools, integrated in the survey software. The patch test was performed just outside the survey area over a small trench in the seabed. Path test results are presented in Table 4-3 below.

Calibration results Norbit iWBMS			
	Initial mounting angle	**Calibrated correction results**	**Final angle**
Roll Angle	*0.00°*	*0.05°*	*0.05°*
Pitch Angle	*0.00°*	*0.33°*	*0.33°*
Yaw Angle	*0.00°*	*-0.15°*	*-0.15°*

Table 4-3; Patch test results.

After applying the corrections a check was done by sailing two crossing lines over an area with depths varying between 14 and 17m. Figure 4-5 below shows the resulting seabed bathymetry on the left with on the right the standard deviation of each individual grid cell. Showing SD values lower than 10cm the patch test was proven to be performed correctly and survey operations could commence.

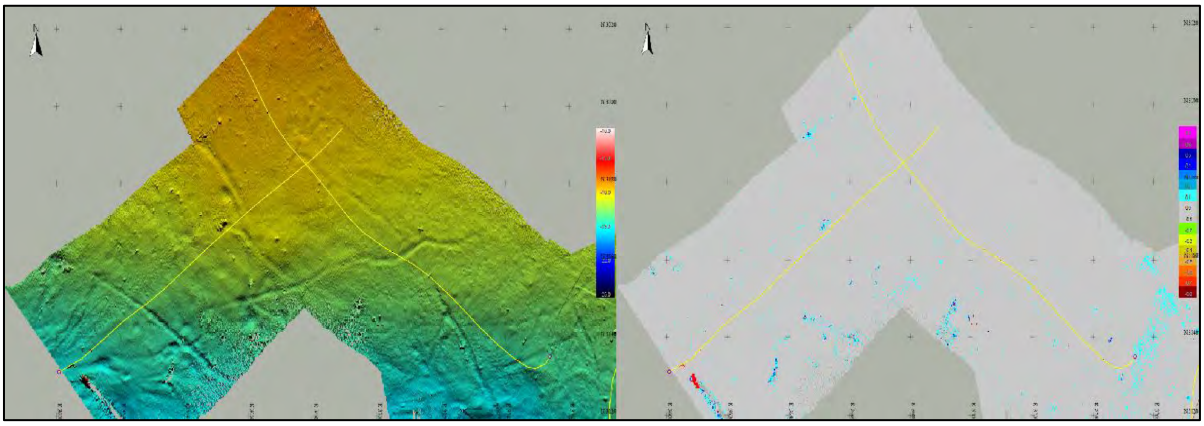


Figure 4-5; Post-patch test check lines.

At the beginning of each survey period a sound velocity profile was recorded at one metre intervals to the maximum water depth. This profile was entered in the survey software to correct the depth measurements. In addition to this the sound velocity at the multibeam head was continuously measured and compared to the used velocity profile.

During the survey the team made sure to continuously monitor the SD values and the survey was stopped several times to remove kelp that was stuck at the multibeam sensor. These can potentially cause small vibrations of the mounting bracket, enough to cause some minor artefacts in the resulting data. Affected areas were resailed as much as possible. After covering the pre-defined survey area an additional line was sailed crossing all previous ones for possible errors. The overall difference between the survey grid and check line was less than 10cm. This can be seen in Figure 4-6 below.

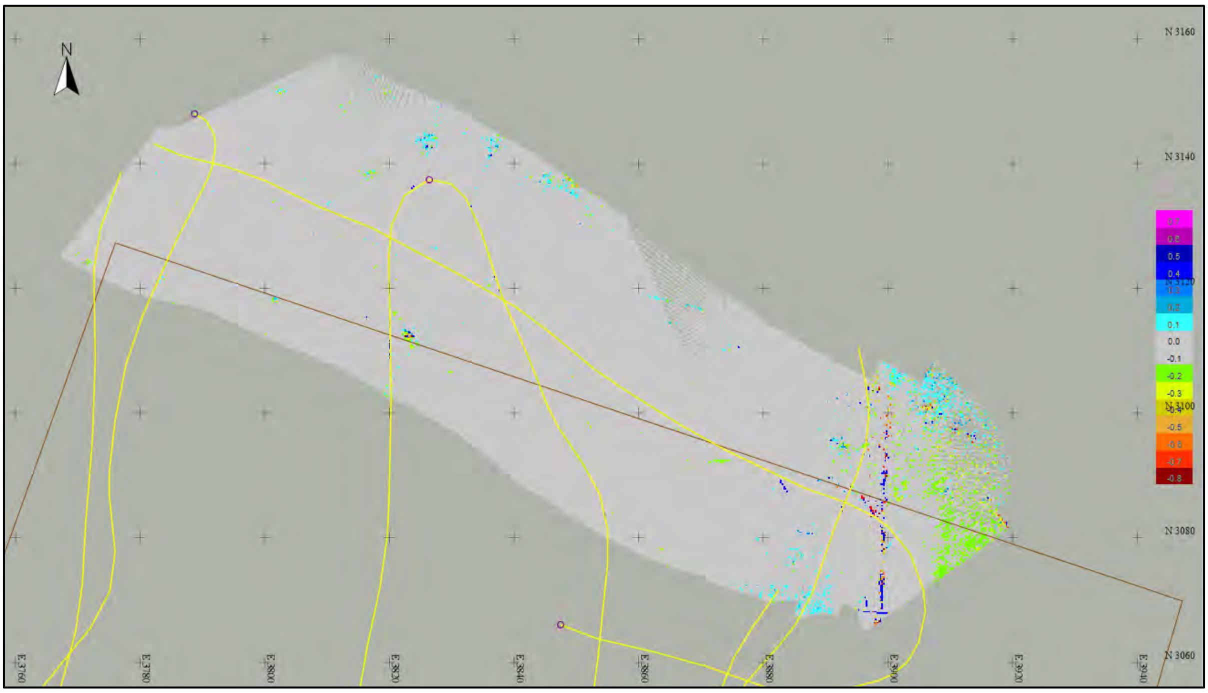


Figure 4-6; Post-survey check lines.

The survey accuracy was checked with the AMUST tool and it proved its compliance with IHO Special Order requirements for swath opening angle of up to 140°. The depth used for the calculation is 10m. Figures below show the results of the calculation.

Depth	10m
Speed of sound	1460m/s
Survey speed	5m/s

Table 4-4 Environmental conditions used for calculation

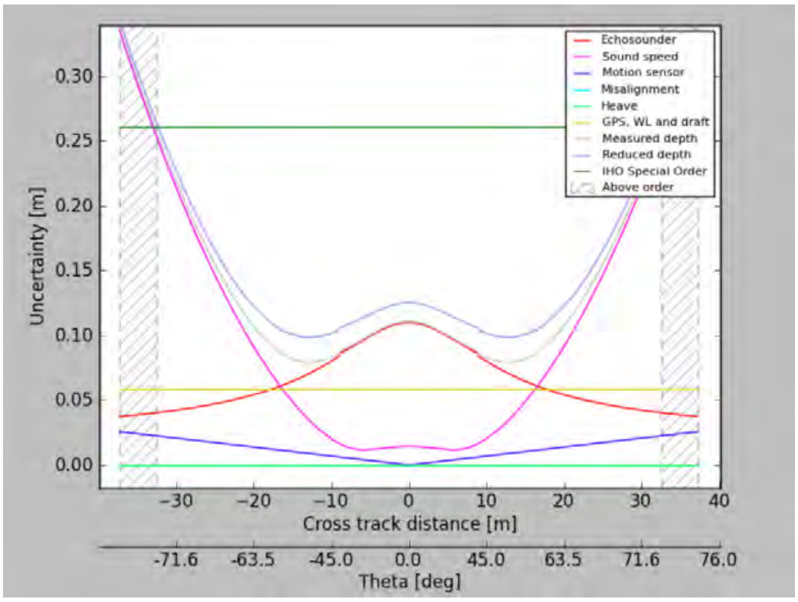


Figure 4-7; TVU for used survey system

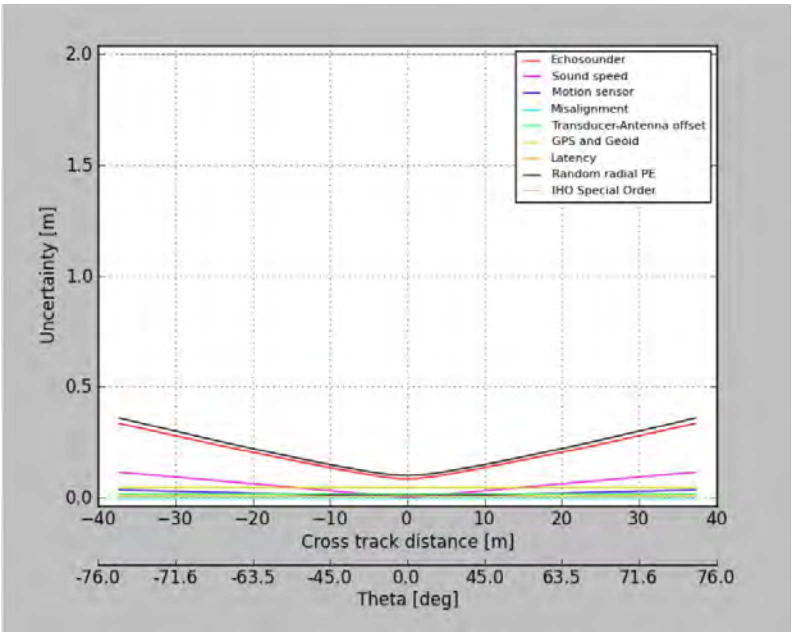


Figure 4-8 THU for used survey system

Indicative survey areas were provided by the client in the document "*Area for Seismic Surveys.pdf*". These have been digitised (taking some buffer zones around the outside) for inclusion in the survey software. This area has been amply filled with the bathymetric data. The shallow coastline has been surveyed as far possible without compromising the safety of vessel, equipment and personnel. The steep slopes near the coastline meant that the -2m water level mark has not been met along the entire survey area. Likewise, the areas on either side of the existing jetty have been surveyed as far as safety would allow. Figure 4-9 below shows an overview of the recorded bathymetric data and extends of the survey.

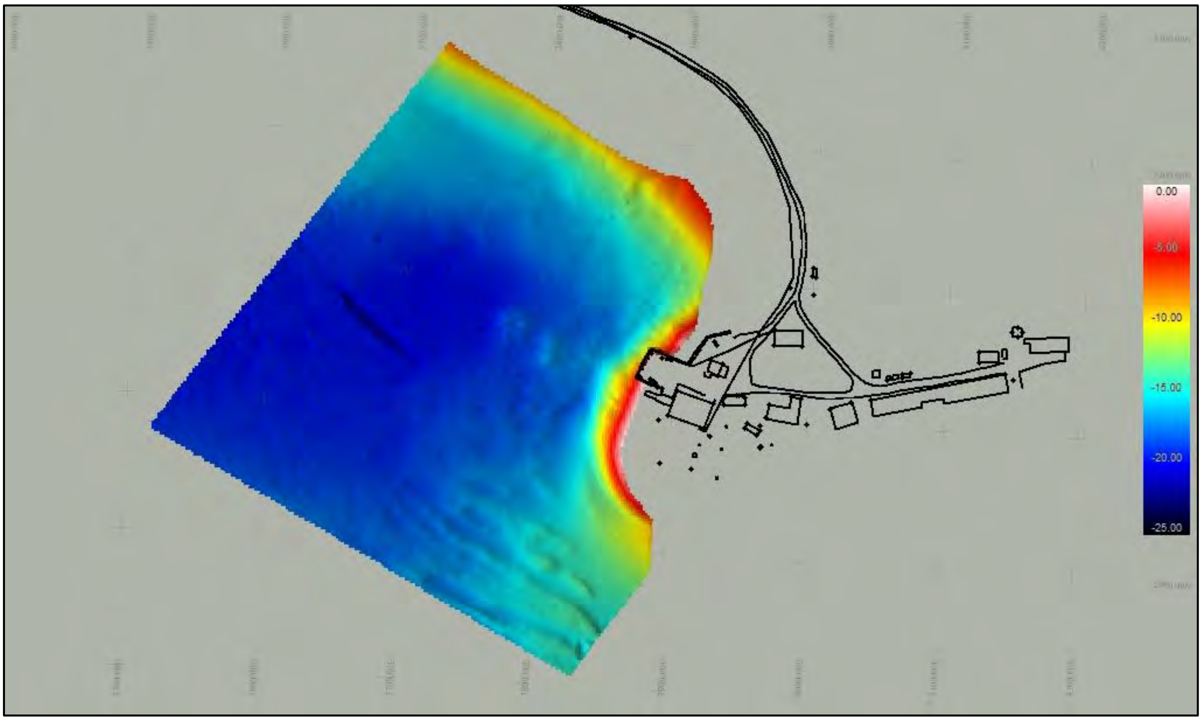


Figure 4-9; Extend of recorded MBEs data.

4.7. Sidescan sonar

The sidescan sonar is used to create an image of the seafloor by emitting conical or fan-shaped sound pulses across a wide angle perpendicular to the path of the sensor through the water. The intensity of the acoustic reflections is recorded in a series of cross-track slices. When stitched together along the direction of motion, these slices form an image of the sea bottom within the swath (coverage width) of the beam. Objects on the seabed can be identified by their high reflection and sharp edges, coupled to a shadow behind them. The shadow will give an indication of the height of the object above the seabed

The sidescan sonar survey was executed using a Klein 3900 sidescan sonar system. This system operates at 455 kHz or 900 kHz. Operation at the higher frequencies gives higher resolution data, but decreases the usable range. Given that the survey area was small, and that high-detail was required, the 900 kHz frequency was used. The towfish position was determined by the survey software, using a layback calculation. The amount of cable out is entered into the software, and the position calculated by combining cable out, vessel heading and speed. The resulting position accuracy for the towfish is within 2.5 metres. Heading inaccuracies in the sidescan data can result in the target position accuracy of more than 2.5 metres.

The survey was performed by towing the sidescan sonar towfish behind the survey vessel. Prior to performing the sidescan sonar survey the multibeam survey was done to allow the operators to judge the conditions for the sidescan work. The shallow(-er) areas on either side of the survey area and the presence of kelp throughout the bay meant that the towfish was towed at approximately 10 metres above the seabed in the deeper areas. This allowed the vessel to turn at the end of the survey area without grounding the towfish. Kelp also meant that during some survey lines the vessel had to deviate from the line to avoid entanglement with the kelp. Initially the sidescan range was set at 30 metres on either side. Due to the need to deviate from the survey lines the range was increased to 40 metres, giving a little more coverage at barely reduced resolution. Figure 4-10 below shows a sidescan image with kelp present. The vague reflections are the kelp stems and leaves, their shadows are visible in the data. The range in this case was 30 metre in either side. The location of kelp presence has been indicated in the data.

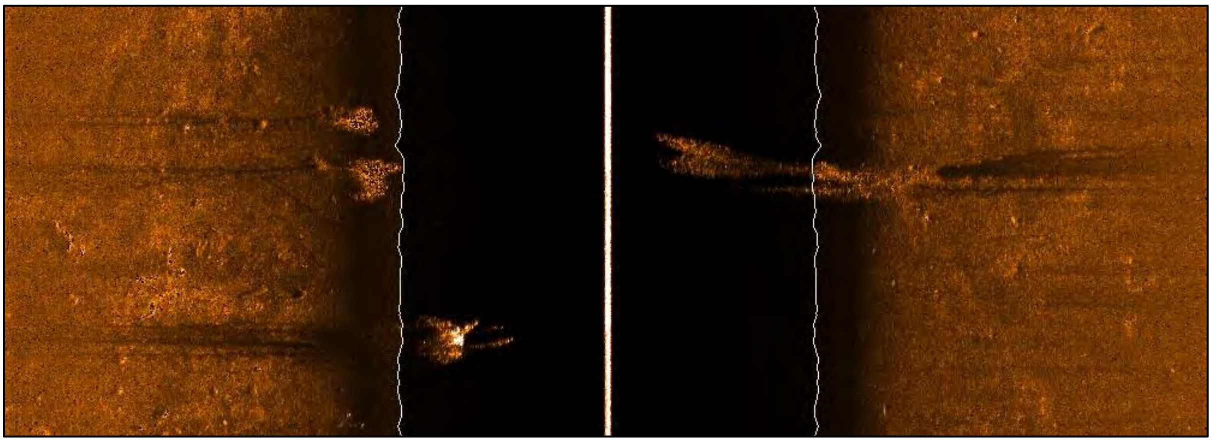


Figure 4-10; Kelp in sidescan sonar data.

4.8. Sparker sub-bottom profiling

In order to determine the level of the bedrock beneath the seabed a GeoMarine single channel sparker system was used. The sparker consists of two towed bodies. The LW200 source produces an acoustic signal by having 200 electrodes short a 6.000 volt burst to the source frame. The resulting acoustic signal will reflect on clearly defined reflectors within the sub-soil, as well as on the seabed itself. These reflections are recorded by the streamer, which carries eight sensitive hydrophones. The sparker can be set to various energy levels, with higher levels producing bigger sub-soil penetration properties, at the cost of a reduced shot rate.

The sparker system was towed approximately 20 metres behind the survey vessel. The source was towed from the starboard aft bollard, while the streamer was towed from a pole extended over the starboard side. This arrangement kept the source and streamer away from the vessel's wake. By having both in still waters the signal-to-noise ratio is improved. Positioning of the sparker system was done by using a layback calculation in the QPS QINSy recording software.

Prior to starting the survey a number of test lines were sailed to determine the optimum geometry (source vs. streamer) and to test various power settings. The outcome of these test lines determined the settings used during the survey. The survey was initially performed at 400 Joule, shooting at 600ms. Survey lines were sailed parallel to the existing jetty, with additional lines sailed perpendicular, allowing the data to be tied-in between the different lines. This complete survey was re-done at 900 Joule, shooting at 1000ms. The use of two complete datasets allows the high-resolution survey at 400J to be combined with the higher penetration of the 900J survey.

4.9. Topographic measurements

A Trimble SPS855 receiver using corrections from the local base station was used to do several topographic measurements on the site. All equipment was stored in a backpack for convenience. The points were stored on a waterproof hand-held computer. The accuracy of these results is about 3cm in X, Y and Z. Areas measured with the RTK backpack consist of:

- Existing quay wall with mooring bollards;
- Slipway and wall next to the quay;
- Mooring points for larger vessels;
- DTM of the land area adjacent to the bathymetric survey and around the boat house;
- Position of existing buildings at KEP (X and Y only);
- Two possible quarry areas towards Grytviken;
- The tracks at King Edward Point and the track towards Grytviken;
- 4 new benchmark locations (10min loggings).

The extra available time due to vessel delays meant more topographic work was done than was laid out in the scope of work. The extent of the topographic scope was determined on-site by the survey team and the BAM representative.

Figure 4-11; Topographic measurements at KEP.

4.10. Total station measurements

The exact location of a number of buildings at King Edward Point was needed to align previously recorded laser scan data. This concerned the buildings from Discovery House to the existing jetty. To achieve this a Trimble C5 total station was set up on three locations, each with two or three known points in sight. After calibrating the total station for position measurements were taken of roof corner points. The quality of the measurements was checked by measuring point from different total station locations. Point were recorded with the main focus at Discovery House, the nearby coal shed, stores building, the bio security building and the boat shed. Additional readings from buildings further back were taken when possible. The clearly defined roof corner points of the buildings can be used to align the laser scan data to the local grid. Figure 4-12 shows the corner point of the coal shed behind Discovery House indicated.

Figure 4-12; Indicated measure point on the coal shed.

4.11. Benchmark creation

To aid future survey and construction works around KEP four new benchmarks were created. All of these consisted of measuring nails driven into solid objects, like concrete slabs or rock. The position of these new benchmarks was logged using RTK corrected GPS over a period of 10 minutes. As an additional check RINEX data was logged on each benchmark for a minimum of 12 hours. A height check was done by transferring the ISTS-61 height to each benchmark by level and staff. The four benchmark locations were chosen in such a way to allow the creation of a wide grid over KEP.

A complete description of the benchmarks and the methods used to achieve the results can be found in the separate benchmark creation report *P3506_Benchmarks_REP_190225_R00*. The summarised results are presented in the tables below.

Benchmark DEEP_001	
ITRF 2014	
Latitude	54° 16’ 51.58483”’ S
Longitude	36° 29’ 48.16021” W
Height (m)	20.918
Local grid / Chart datum coordinates	
Easting (m)	3855.98
Northing (m)	3277.67
Height (m)	1.7760

Table 4-5; Benchmark DEEP_001.

Benchmark DEEP_002	
ITRF 2014	
Latitude	54° 16’ 57.69260” S
Longitude	36° 29’ 40.71122” W
Height (m)	21.863
Local grid / Chart datum coordinates	
Easting (m)	3999.94
Northing (m)	3095.73
Height (m)	2.7055

Table 4-6; Benchmark DEEP_002.

Benchmark DEEP_003	
ITRF 2014	
Latitude	54° 17’ 01.82127” S
Longitude	36° 29’ 45.66514” W
Height (m)	21.284
Local grid /Chart datum coordinates	
Easting (m)	3916.75
Northing (m)	2963.79
Height (m)	2.1060

Table 4-7; Benchmark DEEP_003.

Benchmark DEEP_004	
ITRF 2014	
Latitude	54° 16’ 59.73441” S
Longitude	36° 29’ 32.57964” W
Height	22.404
Local grid / Chart datum coordinates	
Easting (m)	4150.00
Northing (m)	3039.96
Height (m)	3.2465

Table 4-8; Benchmark DEEP_004.

5. DATA PROCESSING

Data processing was done on location at King Edward Point and in the Deep office in Amsterdam (NL). This chapter describes the processing steps per technique.

5.1. Multibeam

The recorded multibeam data has been processed in BeamworX Autoclean. Apart from data filtering this software package allows the user to visualize and edit the dataset in 2D or 3D.The first step was to check for GPS height jumps in individual files and shift them to the correct height or disable the effected sections in case sufficient overlap from adjacent lines was available. The second processing step was to apply a filter to the data. One of the standard Autoclean filters (Bwx Coarse) was used to remove large outliers or spikes from the dataset.

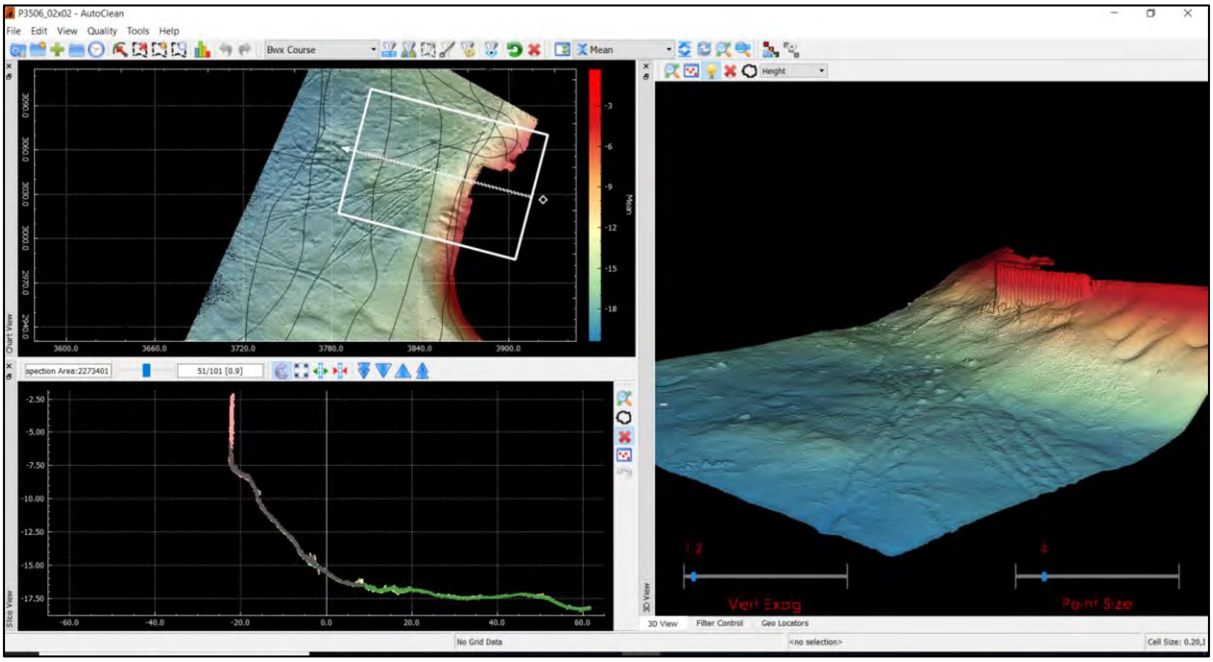


Figure 5-1; Autoclean processing tool.

With all files at the correct level and the larger spikes removed the data was manually 'cleaned', paying extra attention to the area around the existing quay structure. The SD values were taken to detect areas that needed further processing. Most areas with higher SD values were caused by the amount of kelp in the survey area. The negative effects of the kelp is either data noise near the seabed (since the sonar is struggling to detect the sea bottom) or in some cases patches of kelp stuck on the survey bracket (causing it to slightly vibrate, giving incorrect measurements). Lines that did not meet the required IHO S44 special norm were removed from the dataset and the noise caused by kelp has been removed as much as possible.

The resulting dataset was imported in a 20cm x 20cm grid in QPS QINSy. Occasional empty cells (mostly at the survey's outer edges) were interpolated before the data was used to create the required bathymetry deliverables.

5.2. Sidescan sonar

The sidescan sonar data has been recorded and processed using QPG QINSy survey software. The sidescan sonar files were each inspected for quality and positioning errors. While no GPS position jumps were noted, heading changes in the vessel could cause the layback calculation to deviate from the truth. This causes wrong positions and can lead to towfish heading inaccuracies. Manually correcting the positions is then called for.

When positioning is satisfactory the bottom track (the first returned signal) is manually checked, and if needed adjusted. This is important when calculating the object heights, a calculation that uses the shadow behind an object and the towfish' flying height. The lasts step prior to target picking is to apply a normalisation filter. The various processing steps are outlined in Figure 5-2 below. The bottom track in the top image shows faults due to turbulence (i.e. prop wash) in the water column. These have been manually removed in the second image. The normalisation effect can be seen in the bottom image.

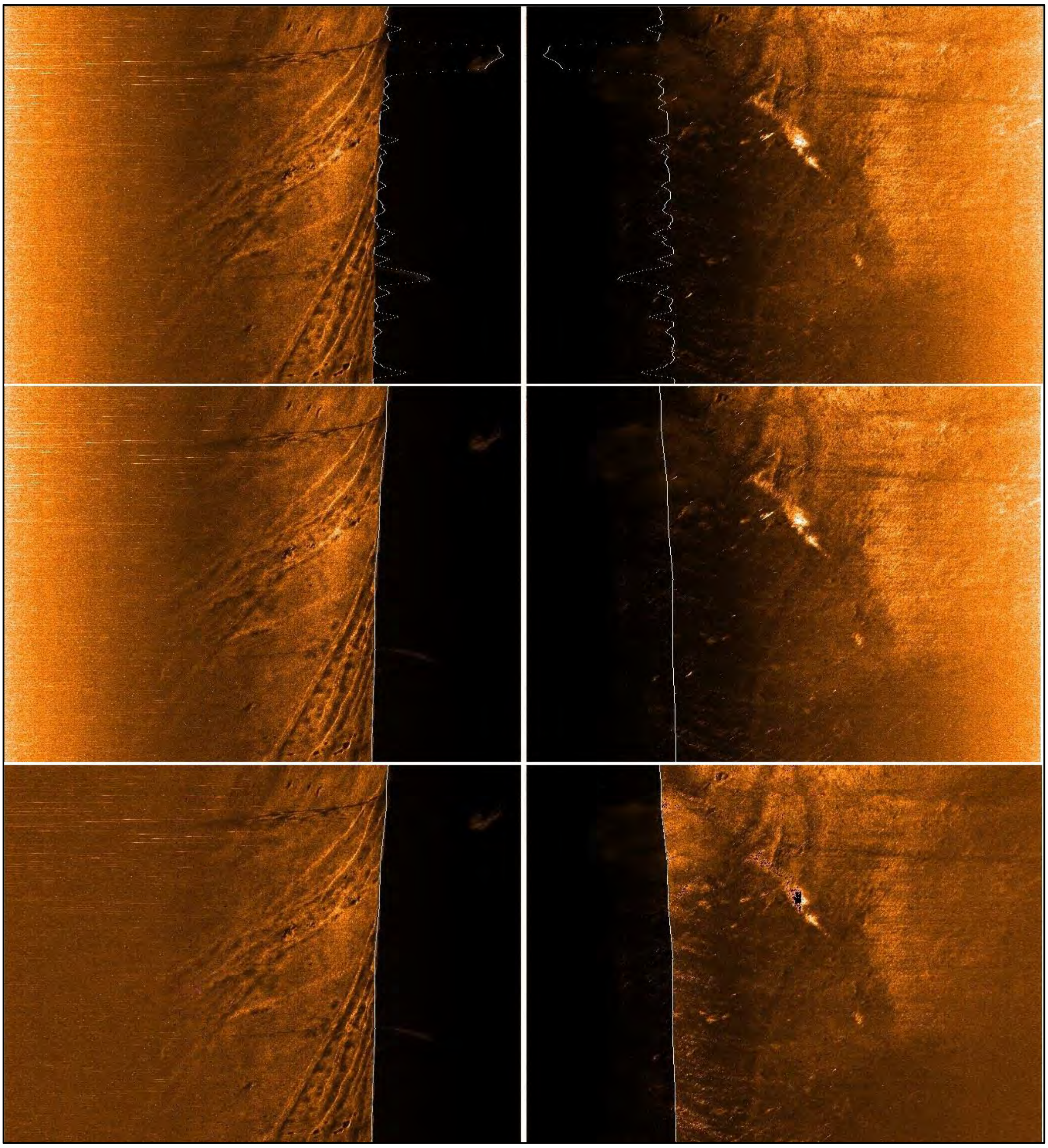


Figure 5-2; Sidescan sonar processing steps.

Targets picking is done manually, using de waterfall display for highest data resolution. The outline of each target is determined as accurately as possible; allowing the software to produces a list, including target ID, position, dimensions and possible classification. The height of any target can be determined by measuring the shadow length. By combining this with the fish's height above seabed a calculation can give (an indication of) the object's height. When no shadow is visible, or only a small shadow, no height is given.

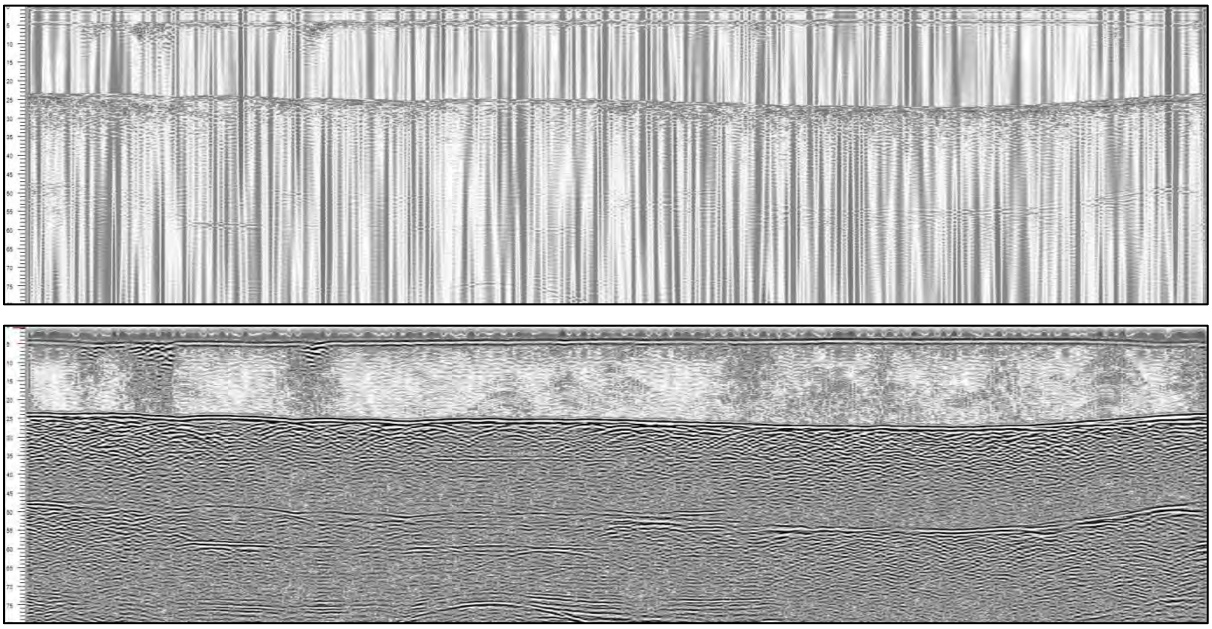
All resulting targets are loaded in a CAD program, allowing overlapping targets to be removed. Due to the large amount of overlap in a sidescan survey (generally around 200%) targets will be seen in multiple survey files. This allows for a positioning check to be performed on the target. Eventually the multiple targets will be reduced to one.

The centre point for smaller objects, and the outline for larger ones, is presented in the charts. A target listing is produced giving the vital information for all targets, including length, width, height (when available), position and classification (when possible).

5.3. Sparker

The sparker data was recorded in survey lines running parallel to the shore, giving profiles through the survey area. The data processing was done using GeoSuite processing software. This software is capable of processing the recorded seismic data (in *.sgy* format), and is specifically designed for use with the GeoMarine sparker systems.

The raw recorded data files show no usable information. While online filtering is applied to check the data quality during the survey, these filter steps are not included in the recorded data. Prior to interpretation the *.sgy* files are loaded into the GeoSuite Processing software. A map overview was used to detect any positioning errors, but none were present. A number of filtering steps was used on the data to give the best results. These consist of a debias filter, bandwidth filter (200-3500) and linear or time varied gain (number decided per file). This can be seen in the two top images of Figure 5-3. After these filter steps the colour scales can be changed during data interpretation. A different colour scale can present different features, making it useful to frequently change between colour scales.



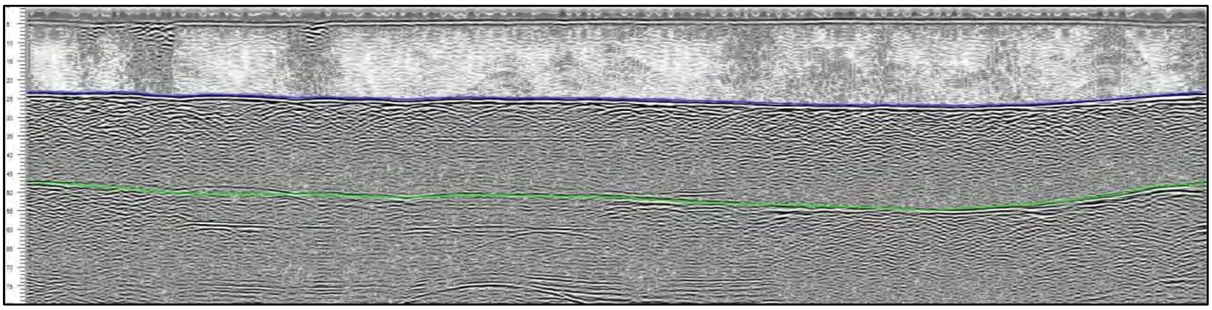


Figure 5-3; Processing steps on the sparker data.

Data interpretation (i.e. reflector picking) started with marking the seabed, followed by marking the multiple reflector to ease reflector interpretation, as shown in the third image of Figure 5-3. A recognisable reflector was picked and exported in an X, Y, Z format. To convert from Two Way Travel Time (TWTT) to depth the sound velocity through the sediments must be used. As this is not known an assumption of 1700 m/s was used. By subtracting the seabed's depth from the reflector depth the data converted into X, Y, Thickness format. This file is ready for presentation in an AutoCad environment, by placing the thickness file underneath the accurate multibeam data. Another processing step would be to compare the picked reflector with geotechnical data, to confirm the sediment transition and to determine the sediment type. In this case, no geotechnical data was available, and the interpretation is purely based on the sparker data.

The charts show five profiles, three close to the existing jetty, and two further out. This way a good overview of the geology within the survey area is given. Naturally, more lines than the five presented were sailed, the complete data sets were used to interpret the data presented in the five profiles. Table below lists the coordinates of profile lines.

Profile ID	Start Easting	Start Northing	End Easting	End Northing
P1	3801.57	2831.61	3898.10	3131.84
P2	3780.30	2838.82	3881.20	3137.62
P3	3760.79	2845.43	3861.58	3144.46
P4	3721.89	2858.62	3824.08	3157.16
P5	3688.45	2869.95	3788.75	3169.25

Table 5-1; Coordinates of profiles presented in charts

5.4. Topographic measurements

The topographic measurements were taken using an RTK GPS receiver with a hand-held computer to store data points. The stored point could be exported as a text file, showing ID number, easting, northing and description. The exported points were loaded into a CAD file showing all topographic readings. The points were checked for false readings. These can be caused by GPS errors and are easily spotted. If found these were removed from the drawing.

The points were stored in separate layers (i.e. 'buildings', 'tracks' or 'foundations') to allow a user to quickly get acquainted with the drawing. Points measuring one object (on building or one side of the track) were joined together in a set. Figure 5-4 shows the topographic data set around King Edward Point. Buildings, jetty and tracks are easily seen. The separate points around the jetty and in front of Larsen House can be gridded to create a DTM of the area. These points are delivered in separate ASCII files.

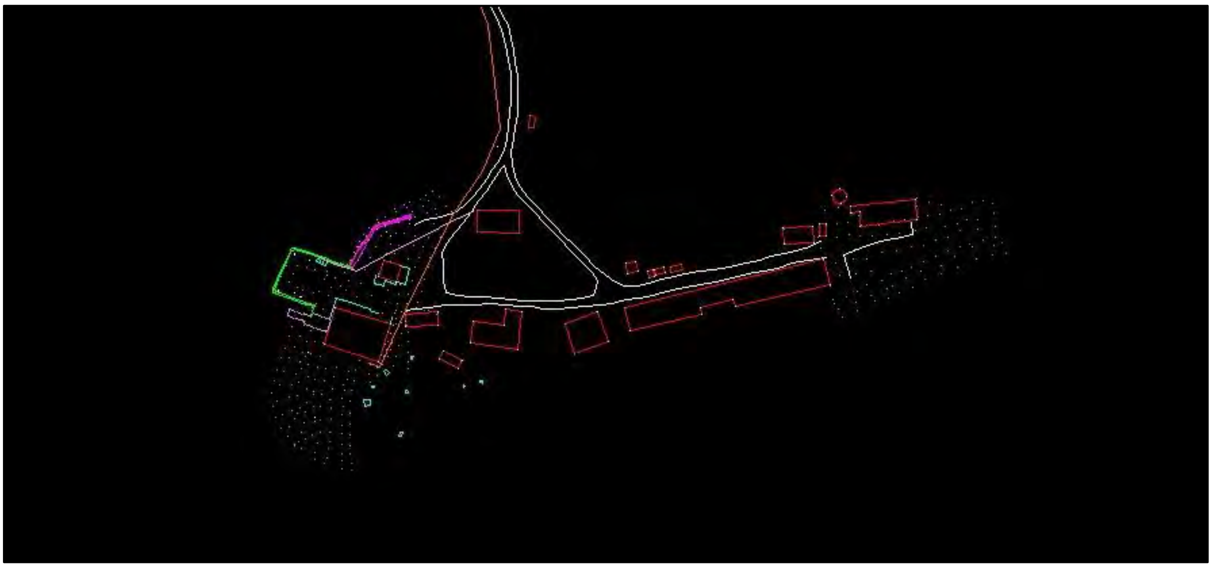


Figure 5-4; Topographic points around KEP.

5.5. Total station

The total station was used to determine the position of recognisable points on the existing buildings, to allow an existing laser scan dataset to be positioned within the local grid. Readings were taken with a Trimble C5total station. After the survey the coordinates of the measured point, in local datum, were exported from the total station as a text file.

The results were loaded into a CAD file containing all topographic readings. This allowed for a comparison with the topographic GPS data and allowed the user to identify and measuring errors.

5.6. RINEX measurements

Processing RINEX data is a specialist area of expertise. The recorded data on the newly made benchmarks was send off to a specialist company. More information on the RINEX data and processing can be found in the benchmark creation report *P3506_Benchmarks_REP_190225_R00.*

5.7. Deliverables

The following paragraphs summarise the deliverables accompanying the project.

5.7.1. Data

Electronic copies of processed data were delivered in various formats. ***Table 5-2*** below shows an overview of the delivered data.

Deliverable	Format	Comment
P3506_SUR_REP_190329_R00	.docx/.pdf	Survey report
P3506_Benchmarks_REP_190225_R00	.docx/.pdf	Benchmark creation report
P3506_KEP_MB_GRD_20CM_CD_Local_190329_R00	.pts	Gridded bathymetry data
P3506_KEP_TOPO_DTM1_CD_Local_190329_R00	.pts	Topographic survey adjacent to bathymetry survey
P3506_KEP_TOPO_DTM2_CD_Local_190329_R00	.pts	Topographic survey in front of Larssen House
P3506_KEP_TOPO_Q1_CD_Local_190329_R00	.pts	Possible quarry area Q1

P3506_KEP_TOPO_Q6_CD_Local_190329_R00	.pts	Possible quarry area Q6
P3506_KEP_MB_3D_Quay_190329_R00	.bin	Bathymetric result around the jetty in 3D
P3506_KEP_TOPO_MOD_CD_Local_190329_R00	.dxf	Topographic results for buildings
P3506_KEP_CONB_MOD_CD_Local_190329_R00.dxf	.dxf	Bathymetry contours at 0.5m interval
P3506_KEP_SSSO_LIST_190329_R00	.pdf	Sidescan sonar target listing (Appx. C)
P3506_KEP_XXX_R00	.pdf	Charts
P3506_KEPQuay_LS_aligned_R00	.e57	Aligned laser data
P3506_KEPWharf_LS_aligned_R00	.e57	Aligned laser data

Table 5-2; List of deliverables.

5.7.2. Charts

The survey data has been presented in three A1 sized charts. These show the bathymetry, plan view with the locations of SSS targets as well as geological profiles, and five geological profiles.

Chart	Size	Content
P3506_KEP_MB_R00	A1	MBES bathymetric data
P3506_KEP_SSS_R00	A1	Location of SSS targets and SCS lines
P3506_KEP_SBP_R00	A1	Geological profiles

Table 5-3; List of charts.

5.7.3. 3D digital scenes

The multibeam data directly around the existing jetty has been presented in a 3D scene, allowing the user to have a detailed overview of the area affected by the upcoming construction works. The data is presented by using Cloud Compare 3D visualisation software. A short manual on how to use the software is provided in document *P3506 Tips for Cloud Compare 3D viewer*. Figure 5-5 shows a screenshot, with the existing jetty and surrounding seabed.

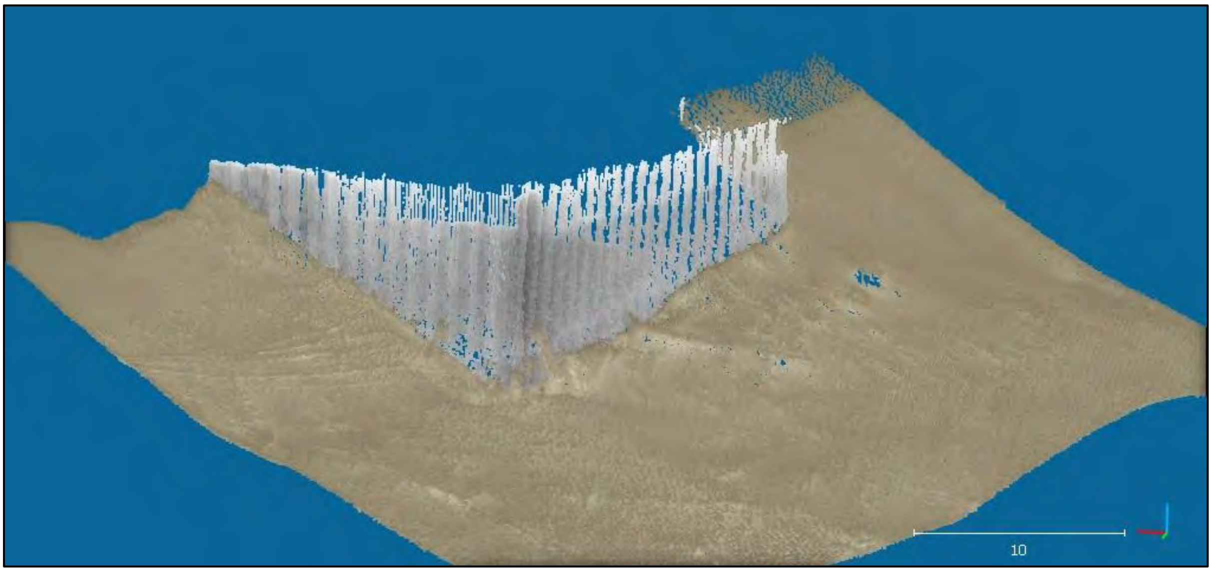


Figure 5-5; Screenshot of Cloud Compare with jetty and surrounding seabed.

5.7.4. Laser scan data

Laser scan data were provided by the client for alignment with the local coordinate system. Two files were received in .e57 format:

- BAA4010-BAM-ZZ-YYY-RC-WA-0001;
- KEPWharf.

The point clouds were imported separately to CloudCompare software together with points measured during the topographic survey. The alignment tool was used in the process, which allows to pair points from 2 separate data sets. Reference points must be well distinguished in both point clouds for reliable results.
The transformation parameters were calculated based on at least 5 point pairs.
The aligned data show slight discrepancy between each other which might be result of combined inaccuracy of the applied transformation and poor quality of points scanned in far distance.

Figure 5-6; Example of mismatch between provided point clouds after alignment

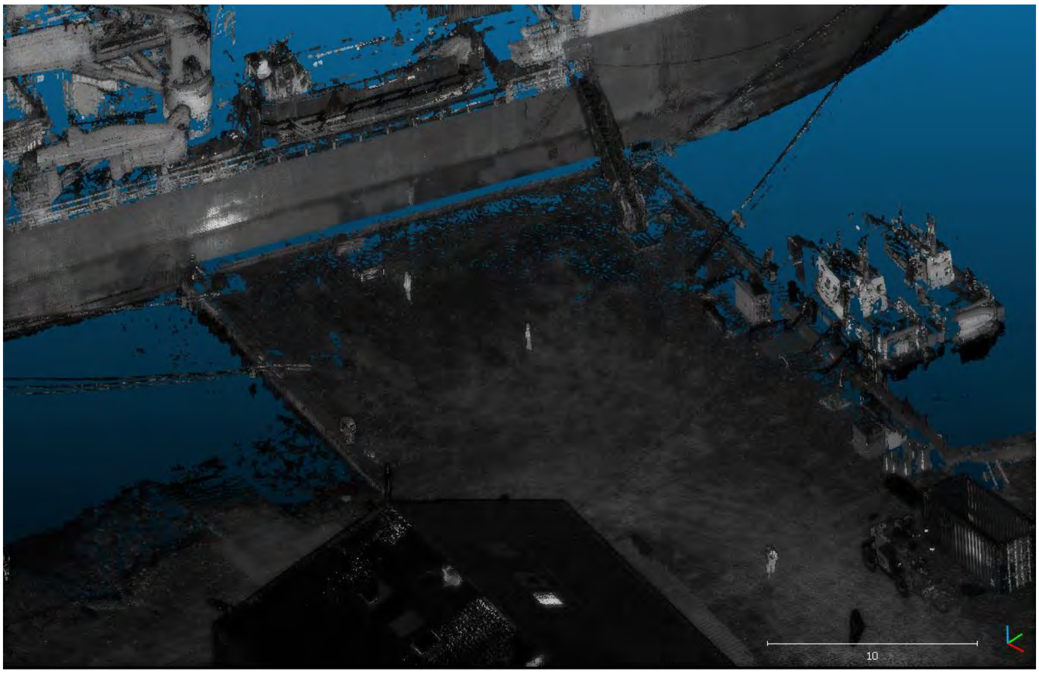


Figure 5-7; Aligned laser data overview

6. APPENDICES

- A DAILY PROGESS REPORTS
- B TARGET LISTING SIDESCAN SONAR
- C CALIBRATION SHEETS
- D EQUIPMENT SPECIFICATIONS

A Daily Progress Reports

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

DEEP BV
Johan van Hasseltweg 39D
1021 KN Amsterdam
T: +31-20-6343676
WWW.DEEPBV.NL

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	15/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day / arrival at SG*			
11:15	*Transit from Fram to KEP base*			
	To bio security building to cehck equipment			
12:00	*Site induction*			
	Continue checking equipment			
14:00	*SG government induction*			
14:40	*Moving equipment to storage container*			
	Walk around survey area to check for suitable benchmark locations			
16:30	*Power up GPS receivers --> GPS coverage seems ok*			
	Discuss equipment installation on survey vessel			
	unpack RTK setup			
18:00	*Back to accomodation*			
	End of day			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

DEEP BV
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deep
Hydrography & Geophysics

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	16/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*5cm difference found on UKHO 9798*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Setting up RTK base station on ISTS-61			
	Building multibeam brackter on survey vessel			
9:30	*Position check of RTK system on UKHO 9798 (about 5cm difference found)*			
	Logging new base station loccation at the storage container			
	Setting up base station at container			
	Pos check of new base on ISTS-61 (3cm diff found) -> base ok			
12:00	*Prepare multibeam system*			
	install MBE equipment on survey vessel			
15:30	*Testing MBE system in the water --> all ok*			
	Creating 4 new benchmarks (still have to be measured by RTK and RINEX)			
17:45	*Charge base and rover batteries*			
	project administration			
19:00	*end of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS
LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	17/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Discuss planning for today*			
8:15	*Start logging positions of new benchmarks*			
	Additional position check using corrections from new base on UKHO			
11:00	*Completed RTK loggings*			
	Start preparing / mobilising SSS equipment			
	Prepare RINEX loggers			
12:18	*Testing SVP --> working ok*			
	Testing SSS --> system ok			
14:57	*Setting up RINEX logging station on DEEP_002 (Antenna heigth 0.716m)*			
15:24	*Seafasten equipment on board vessel*			
16:00	*Back to accomodation*			
	prepare qinsy project for survey operations (MBE / SSS)			
	- Primary GPS to MBE offset still have to be measured before the survey			
	Project admnistration			
19:00	*End o day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

DEEP BV
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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	18/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Discuss planning for today*			
	Prepare equipment for survey (MBE and SSS on board, base station active)			
8:00	*Check RINIEX loger --> still ok, decided to go for 24h logfile*			
8:30	*Weekly site meeting*			
	- discussed survey operations			
9:15	*Back on board*			
	- mounting MBE for survey			
	- switching on systems and check software settings			
9:45	*All ok, systems ready for calibration*			
	- wind too strong / skipper decides to wait until the weather improves			
	- Survey team standby (working on landsurvey equipment while waiting)			
14:30	*Weather good enough to start operations*			
	- MRU calibration			
	- MBE calibration			
15:10	*Start survey operations*			
17:20	*MBE and SSS survey completed*			
	remove MBE survey pole			
17:40	*Demob RINEX logger from DEEP_002*			
	project administration / data back up			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

DEEP BV
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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	19/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	**Activity**	**Survey area**		
7:00	*Start of day*			
	prepare topo set			
	testting topo equipment on new benchmarks			
11:00	*Processing yesterday''s MBE and SSS data*			
13:30	*Discuss preliminary results with BAM*			
14:20	*TOPO survey of quay outline*			
15:45	*Continue working on SSS and MBE data*			
	Creating TM drawing of topo points			
16:15	*Measure points on wall East of guay*			
	Continue processing data			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

DEEP BV
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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	20/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Topo survey/ water too high for survey of slipway			
	Crating additional benchmarks for total station survey			
9:53	*SSS processigna and prepare TS setup*			
10:30	*TS set up near survey container to measure some corner points of Boathouse*			
	and Discovery house.			
11:30	*Back at accomodation / project administration*			
12:15	*Continue topo and total station operations*			
	Check results ad process topo data			
16:45	*Setting up Rinex logger on Deep_001*			
17:15	*Start logging data at Deep_001*			
	clean and check topo and total station equipment			
	Data back up and anministration			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS
LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	21/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Levelling between ISTS-61 and DEEP-002, DEEP-003, DEEP-004			
11:45	*Back at office / checking differences between Level and RTK*			
	Project administration			
	data back-up			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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deep Hydrography & Geophysics

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	22/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	**Activity**	**Survey area**		
7:00	*Start of day*			
	Check RTK hegith results for DEEP-001 using levelling instrument			
	check heigth of UKHO-9798 relative to ISTS-61 (resulting heigth 1.33CD)			
10:30	*Topo of Quary area 1*			
12:00	*Back at accomodation*			
	administration / check results			
13;00	*To Quary are6 for topo survey*			
16:30	*Back at KEP*			
	- charge equipment			
16:46	*Start processing topo data*			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506		**SURVEYOR:**	JGA / WVI
CLIENT:	BAM		**VESSEL:**	
LOCATION:	KEP South Georgia		**PAGE:**	1 of 1
DATE:	23/02/2019			

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	**Activity**	**Survey area**		
7:00	*Start of day*			
8:00	*measure indicative outline of buildings on KEP (1m accuracy)*			
	survey 4 mooring points for vessel			
	Survey road to Q6			
10:20	*Back on KEP*			
	- download data			
	- check results			
13:51	*Rinex logger installed on DEEP_003 (heigth 1.122m)*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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Hydrography & Geophysics

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	24/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	**Activity**	**Survey area**		
7:00	*Start of day*			
	Waiting for sparker equipment to arrive on site / standby			
	Working on reporting			
	Downloading RAW GPS data from logger at DEEP_003			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	25/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Waiting for sparker equipment to arrive on site / standby			
	Working on reporting			
	Check survey equipment			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS
LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	26/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Waiting for sparker equipment to arrive on site / standby			
8:00	*Measuring aditional corners of buldings using total station*			
11:00	*Back at accomodation / check results*			
12:15	*Unpack available sparker equipment and prepare sparker source*			
14:00	*Try to locate and map trajectory of HV cable to KEP*			
16:45	*Back at KEP*			
	- set up Rinex logger station at DEEP_004 (heigth 1.348+APC)			
16:52	*downloading data from topo handheld for back-up*			
	check results			
	Project administration			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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deep Hydrography & Geophysics

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	27/02/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Waiting for sparker equipment to arrive on site / standby			
	Check rinex logger and export available data			
9:00	*Assist with thickness measurement of existing sheetpiles*			
10:45	*Back at accomodation*			
12;15	*Mobilising topside of sparker on board survey vessel*			
14:00	*Working on reporting*			
17:00	*Shackleton arrival on KEP*			
	- Streamers can be checked tomorrow morning			
17:30	*Downloading data from GPS logging station*			
	charging batteries			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS
LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No: P3506
CLIENT: BAM
LOCATION: KEP South Georgia
DATE: 28/02/2019
SURVEYOR: JGA / WVI
VESSEL:
PAGE: 1 of 1

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
8:45	*Sparker streamers offloaded from Shackleton*			
	- start filling sttreamers			
10:15	*Streamers ready*			
	Continue mob of sparker system on boar survey vessel			
	- testing sparker source and strreamer			
15:38	*Back to accomodation to check logged test data*			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		Today's progress	Project progress
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS
LOGSHEET - DAILY PROGRESS REPORT

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deep Hydrography & Geophysics

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	01/03/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Install multibeam bracket and sparker streamers			
10:15	*Ready to start survey operations*			
	- extend MBE coverage			
12:30	*Back alongside at KEP*			
	prepare fro sparker survey			
13:45	*Start sparker test runs*			
17:00	*Stopped sparker runs*			
	Check data			
	Start processing additional MBE data			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	02/03/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	Further processing of multibeam data			
	Additional checks on sparker data			
	Swap GPS on board vessel			
	Demob MBE setup from vessel			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		Today's progress	Project progress
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	03/03/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	Activity	Survey area		
7:00	*Start of day*			
	No boat operations on Sunday			
	- wether on Monday suitable for sparker survey			
	- prepare vessel setup and check equipment for Monday			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

FIELD OPERATIONS

LOGSHEET - DAILY PROGRESS REPORT

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PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
CLIENT:	BAM	**VESSEL:**	
LOCATION:	KEP South Georgia	**PAGE:**	1 of 1
DATE:	04/03/2019		

Daily checks	
Findings of workplace risk assessment (HSE § 4.1):	*all ok*
Results height check (waterline or benchmark):	*n/a*
Averaged sound velocity:	*n/a*
Results absolute depth check on known object:	*n/a*
Results overlap old survey data:	*n/a*

Time	**Activity**	**Survey area**		
7:00	*Start of day*			
	- starting up survey setup and check settings			
9:30	*Start sparker survey*			
13:30	*Completed sparker lines*			
	swap to SSS setup to do some additional lines			
14:30	*Start SSS survey*			
15:45	*SSS lines surveyed*			
	- power off systems			
16:19	*Back at accomodation*			
	- check survey results			
	- data back-up			
	- project administration			
19:00	*End of day*			
		Survey		hours
		Standby		hours

Weather conditions		**Today's progress**	**Project progress**
Wind			
Sea state			
Visibility			
Weather forecast 24 hours			
Wind			
Sea state			
Visibility			

Checked (Deep BV): {Date} **Approved (client):** {Date}

B Target listing sidescan sonar

Side Scan Sonar Target List

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Date:	19/03/19	Location:	King Edward Point	Coordinate System:	Local grid
Revision:	0	Vessel:	Pipit	Height	Chart Datum

King Edward Point - sidescan sonar target list

ID	Contact	Comment	Dimensions (m)			Position (centre point)	
			Length	Width	Height	Easting (m)	Northing (m)
SSS_001	unknown contact		0.89	0.54	n/a	3717.97	2922.04
SSS_002	linear contact		3.07	0.62	n/a	3734.67	2972.87
SSS_003	tire		0.39	0.21	n/a	3742.21	2906.69
SSS_004	linear contact		0.99	0.00	n/a	3761.17	2985.19
SSS_005	linear contact		4.09	0.00	n/a	3799.86	2992.96
SSS_006	unknown contact		1.29	0.72	n/a	3781.26	3018.93
SSS_007	linear contact		2.39	0.00	0.36	3823.05	3062.09
SSS_008	unknown contact		1.52	1.23	n/a	3823.62	3070.54
SSS_009	unknown contact	Standing on seabed. Possible remnant of whaling?	2.39	1.31	n/a	3817.55	3094.91
SSS_010	debris field		3.94	3.89	n/a	3826.47	3094.95
SSS_011	linear contact		2.68	0.00	n/a	3829.02	3070.49
SSS_012	unknown contact		3.14	0.77	n/a	3820.27	3038.08
SSS_013	unknown contact		0.66	0.61	0.23	3832.90	2964.69
SSS_014	boulder		0.63	0.18	n/a	3824.90	2953.09
SSS_015	boulder		0.36	0.15	n/a	3847.40	2934.60
SSS_016	boulder		0.31	0.23	n/a	3848.32	2946.88
SSS_017	boulder		0.88	0.39	n/a	3821.75	2933.18
SSS_018	boulder		0.68	0.32	n/a	3818.97	2932.64
SSS_019	unknown contact		0.76	0.50	0.27	3875.60	3023.56
SSS_020	linear contact		11.15	0.88	n/a	3894.09	3088.16
SSS_021	linear contact		5.62	0.74	n/a	3899.63	3089.63
SSS_022	linear contact	Possible pipe	8.70	0.38	n/a	3903.67	3092.87
SSS_023	linear contact		9.25	0.60	n/a	3886.21	3080.06
SSS_024	unknown contact		1.07	0.88	n/a	3815.72	3058.60
SSS_025	tire		1.05	0.81	n/a	3868.74	3030.24
SSS_026	cluster of tires		35.10	13.17	n/a	3860.05	3051.09
SSS_027	unknown contact		0.62	0.34	n/a	3892.16	3060.36
SSS_028	Linear object		6.45	0.54	n/a	3858.58	3062.44

C Calibration sheets

Calibration delivered as separate pdf files as listed below:

File name	Contents
check CD 1.6m template shift.pdf	Position check for base station; Chart Datum height
P3506_KEP_MB_calib_190218.pdf	Multibeam calibration report

FIELD OPERATIONS

CALIBRATION - MULTIBEAM

DEEP BV
Johan van Hasseltweg 39D
1021 KN Amsterdam
T: +31-20-6343676
WWW.DEEPBV.NL

PROJECT No:	P3506	**SURVEYOR:**	JGA / WVI
LOCATION:	KEP South georgia	**VESSEL:**	Pipit
DATE:	18-02-2019	**REMARKS:**	none
PAGE:	1 of 1		

Equipment

Multibeam: ☐ Seabat 8101 ☐ Seabat 8125 ☐ R2Sonic 2022 ☐ R2Sonic 2024 ☑ *Norbit iWBMS*
☐ SeaSwath+ H ☐ Seaswath+ M

Frequency: ***400*** kHz

☑ PPS input ☐ Roll stabilized ☑ Sound Velocity at head

Calibration results

	Method	Logfiles	Correction
☑ Roll	Deep & flat bottom, opposite directions, same speed	*1007* *1010*	*0.05* °
☑ Pitch	Perpendicular to slope, opposite sailing direction, same speed	*1007* *1010*	*0.33* °
☑ Yaw	Perpendicular to slope or typical feature, same direction, same speed 50 % overlap in swath, slope or typical feature in the overlap	*1007* *1009*	*-0.15* °

Values calculated by using

☑ QINSy Calibrate alignment ☐ Autopatch

Checked (Deep BV): {SIGNATURE} 18-02-2019 **Approved (client):** {SIGNATURE} 18-02-2019

D Equipment specifications

Specifications delivered as separate pdf files as listed below:

File name	Specification sheet of:
Deep BV - Specifications TRIMBLE SPS855 GNSS receiver.pdf	GPS receiver
Trimble-GA810-GNSS-Antenna-Specifications-Sheet.pdf	GPS Antenna
Trimble-GA830-GNSS-Antenna-Specifications-Sheet.pdf	GPS Antenna
DEEP BV - Specifications - Norbit iWBMS MBES.pdf	Multibeam Echosounder
POS-MV-WaveMaster-II.pdf	Motion and Heading Unit
DEEP BV - Specifications AML base x2 SVP.pdf	Sound Velocity Probe
DEEP BV - Klein_System3900.pdf	Sidescan Sonar
2010 IBJ Geo-source 200 Light.pdf	Single channel sparker
DEEP BV Geo-Sense_mini streamers_single channel array.pdf	Single channel sparker (Mini Streamers)
Brochure-Trimble-C5.pdf	Total Station
Sokkia_c300_310_320_330.pdf	Levelling instrument
Satel_3AS Epic.pdf	UHF Communication

Appendix 6 – KEP Biosecurity Plan

Antarctic Construction Partnership –
King Edward Point Wharf

Employer	NERC/British Antarctic Survey	Project Number	BAA4010
Tech Adv	Ramboll	Document Number	BAA4010-BAM-ZZ-YYY-RC-YE-0002
Contractor	BAM Nuttall	Revision	P-01.02

King Edward Point Biosecurity Plan

Reference Sheet

Document Number	Description
BAS	BAS Biosecurity Regulations January 2019
	Non-native plants on South Georgia – Season report 2017/18
	GSGSSI Biosecurity Handbook 2018-2019
	BAS Biosecurity Policy with Contractors

Revision History

Revision	Date	Revision Description
P-01	28-08-18	First Draft
P-01.02	14-03-19	Revised to include management of existing invasive species

Prepared by	Checked by		Approved by
NDG			
Author	Project	Corporate / Area Process Owner	Project Manager

Status Definition (latest revision)	**Total number of pages** (including attachments)
For Issue	19

 0.17

Table of contents

1. Introduction

Many plant and animal species have been moved around the world through human activities to areas they would not reach naturally. Once in a new location, these 'non-native' species may establish, with potentially severe impacts on local species and ecosystems. The introduction of invasive species, including vertebrates, invertebrates and plants, has greatly altered the ecosystems of many sub-Antarctic islands. Future increases in human presence in the South Georgia/Antarctic region, either through tourism, governmental operators or other commercial activities, will increase the risk of further non-native species introductions. At the same time, climate change may increase the chances of non-native species establishment and range expansion.

The Wildlife and Protected Areas Ordinance (2011) legislates to minimise the risk of non-native species introductions in the South Georgia and the South Sandwich Islands, and BAM is obliged to conform to this legislation.

BAMs projects in the Sub-Antarctic Islands cover several locations of distinct biological diversity. It is essential that all necessary precautions are taken to prevent the introduction of non-native species to King Edward Point and the surrounding area from other locations, including Europe, South America or any of the other BAS Research Stations or logistics hubs.

Invasive species such as Bittercress are already established in areas of King Edward Point. Management measures will be required to prevent the spread of established invasive species.

This document provides guidance to BAM personnel on the measures to be taken when moving plant, materials or personnel to King Edward Point Research Station.

1.1. Prohibited Items

No BAM personnel or their subcontractors will be permitted to take any of the items below to South Georgia or Antarctica:

- Any living plant, animal or microorganism.
- Non-sterile soil or compost.
- Any plant propagules (e.g. seeds, bulbs, cuttings) or invertebrate eggs (e.g. brine shrimp or sea monkey eggs).
- Untreated wood where bark remains attached.
- Any perishable foods including fruit, vegetables, cheese, fish or meat in personal cargo (no personal foods are allowed but fresh foods as part of the construction team food supply will be arranged).
- Packing materials of polystyrene beads or chips, used sacking, hay, straw, chaff or wood shavings.

1.2. Roles & Responsibilities

- Environmental Lead – Neil Goulding, neil.goulding@bamnuttall.co.uk - 07770 223441
  - Overall responsibility for environmental management of the project.
  - Ensuring that the designers, buyers and construction team are aware of the biosecurity issues covered in this document.
  - Nominating and training of biosecurity inspectors.
  - Training of the Environmental Engineer

- Answer any queries or questions from BAM staff on environmental or biosecurity issues.

- Project Manager – Daan Aldenberg, daan.aldenberg@bam.com – +31 646 938573
    - Responsible for all construction works including mobilisation and demobilisation
    - Appointing an Environmental Engineer from within the site team.
    - Ensuring cargo is biosecure before off loading at KEP
    - Responsible for management of existing invasive species

- BAM Environmental Engineer: TBC (appointed from within the King Edward Point construction team on site)
    - Responsible for managing and monitoring the environmental performance and biosecurity measures on site.
    - Responsible for managing the Biosecurity Inspectors on site.
    - Carries out all final biosecurity inspections before cargo is offloaded from the ship to KEP
    - Completes the relevant biosecurity checklists (Checklists 2, 3, 4, 5 and Form 1)
    - Reports to the BAM Environmental Lead

- BAM Biosecurity Inspectors: TBC (at least one member of the KEP construction team and at least one BAM staff member responsible for checking cargo at packing and loading stages in the UK and other gateways)
    - Responsible for ensuring that all plant and materials are thoroughly inspected and pose no biosecurity risk.
    - Responsible for completing the relevant biosecurity checklists (Checklists 2, 3, 4, 5)
    - Inspections will be required at all port where materials are loaded
    - Report to the BAM Environmental Lead unless at KEP in which case reports to the Environmental Engineer

- All BAM Personnel
    - Personnel will be responsible for ensuring that there personal belongings are biosecure and do not contain any prohibited items.

2. Pre-departure Biosecurity

2.1. Personal Biosecurity

- Immediately before leaving home for KEP, South Georgia or Antarctica, BAM personnel should ensure that all outer clothing has been washed, at the hottest temperature suitable for the garment, to remove seeds, soil and other propagules. Particular attention should be paid to Velcro, gaiters, pockets, turn-ups in trousers and hoods of jackets. (Please see Appendix A. Checklist 1).
- Footwear should be cleaned (inside and out) to remove soil, seeds or any other plant material.
- Personal clothing and equipment shall also be checked on the ship prior to arrival in South Georgia/Antarctica (see section 3.2 and 6.1.1).
- Avoid picking up soil, seeds and other propagules on your clothing during travel to South Georgia/Antarctica (i.e. be careful to ensure clothing is clean after walking in the countryside in any South American countries or South Atlantic gateways prior to departure)
- If possible, before entering South Georgia/Antarctica wear new items of outer clothing which will be free of non-native species and propagules.
- If moving between BAS stations please check clothing and personal belongings to prevent transport of biological material between sites (especially from South Georgia station to Antarctic locations).
- Ensure all clothing and personal effects are packed indoors in a clean environment.
- Before handing in any personal items to the BAM Logistics Stores in the UK, Netherlands or Chile for transportation to South Georgia/Antarctica, ensure that they are clean and free of soil and propagules.

2.2. Cargo Packing Areas

Plant and materials bound for the KEP Wharf project will be loaded onto ships at Rotterdam, Southampton, Teesport or Punta Arenas. Logistic centres will be established close to the ports for storing plant and material before loading onto vessels. The following biosecurity measures will be adopted for cargo packing areas (Please see Appendix A. Checklist 2).

- Cargo packing and storage areas shall be deep cleaned prior to the commencement of use by BAM and, thereafter, at least once per year or as deemed necessary.
- Internal and external cargo storage and packing areas shall be free of weeds, plants and invertebrate infestations. (i.e. regular spraying of weeds that emerge on hard standing).
- Any pallets stored outside shall be checked for bird nests and invertebrates before use, and if found should be removed and the pallet cleaned.
- Rodent and insect pest control measures will be in place in cargo packing and storage areas (i.e. regularly inspected sticky traps for insects and bait boxes for rodents).
- Store doors are to be kept closed, whenever possible.
- Cargo will be stored inside, where possible.
- Shipping containers should be stored on concrete surfaces (as opposed to bare earth). When containers cannot be stored on concrete, they will be raised above the ground on batons of, either timber, concrete or steel, and additional checks shall be made to ensure they are free from soil and biological material prior to on-ward transportation.

2.3. Packaging

The following packaging materials are prohibited:

- No used meat, fruit or plant product cartons will be reused.
- No polystyrene beads or chips, soil, moss, used sacking, hay, straw, chaff or wood shavings will be used.

The following packaging types are acceptable:

- Reusable packaging (e.g. reusable Nefab boxes or aluminium or plastic trunks) as long as it is new or has been inspected and thoroughly cleaned (preferably with disinfectant) prior to repacking.
- All packaging containers (boxes, Nefab, trunks etc.) shall contain an internal sealed plastic liner and all containers shall be taped and sealed shut on all sides.
- Packaging and filling materials may include shredded paper, vermiculite, bubble wrap and other air-filled cushioning materials.
- Wood packaging (such as cases, crates, dunnage, pallets and timbers for the purpose of bracing, separating, protecting or securing cargo) as long as it is new and complies with the International Standards for Phytosanitary Measures No. 15 (ISPM 15).
- Where other cost-effective options exist, use of corrugated card board boxes should be minimized, as they may carry non-native invertebrates within the corrugations.

2.4. Break Bulk Cargo

Break bulk cargo may present a more substantial biosecurity risk than containerised cargo, therefore, it is important that the amount of break bulk cargo generated is kept to a minimum. Break bulk cargo can vary greatly in shape, size and type (e.g. construction materials, timber, scaffolding poles, etc.). All break bulk cargo must be clean and free of soil and biological material before loading on the ship. Therefore, all items of break bulk cargo, including packaging, shall be visually inspected for signs of rodent gnawing or rodent ingress. Cargo shall also be checked for any soil or biological material and if found the item shall be cleaned. During off loading, a nominated BAM staff member will check the item against the manifest and then allow it to be transported to the station. If a biosecurity issue is noted, the cargo shall not be off-loaded until this issue is resolved.

2.5. Small Plant & Tools

Prior to packing any previously used small tools or small plant items for transport to, or between, South Georgia/Antarctic Research Stations, the following procedure is to be followed. The high levels of cleanliness apply to all mechanical plant and tools, irrespective of size; however, individual hand tools do not need to be listed separately in the Appendix A. Biosecurity Checklist 3 Small Plant and Tools.

- Plant items are to be placed on a clean concrete or asphalt hard standing.
- Where practical, plant is to be cleaned externally using high pressure steam or hot water to ensure that no soil, mud or biological material is left on the items. Where the use of water is not possible, the item will be cleaned using a combination of hard and soft brushes and/or a damp cloth.
- Following cleaning, small tools and plant are to be inspected by a nominated Biosecurity Inspector to ensure that they are free of visible soil and biological material (e.g. plant fragments, seeds and insects) This information is to be recorded for auditing purposes (Please see section Appendix A. Checklist 3)
- Care should be taken not to contaminate the small tools and plant prior to loading onto the ship or aircraft. Plant storage facilities should minimise the potential for recontamination of cleaned small plant and tools to transport and, if necessary, arrangements should be made to thoroughly clean the small plant and tools at the ship or aircraft loading site.

- Immediately before being loaded onto the ship or aircraft for transportation, all small tools and plant should be checked by a nominated Environmental Engineer to ensure they are free of soil and biological material. If any soil or biological material is found, the contaminated item should be cleaned and re-inspected before being transported.

2.6. Vehicles & Large Mechanical Plant

Mechanical plant (particularly tracked vehicles) pose a high risk to biosecurity. The undercarriage of wheeled or tracked plant can pick up soil which could contain plant fragments, seeds, invertebrates or invertebrate eggs.

Prior to loading any item of large mechanical plant for transport to or between South Georgia/Antarctic Research Stations, the following procedure is to be followed (Please see Appendix A. Checklist 4):

- Plant items are to be placed on a clean concrete or asphalt hard standing.
- Plant is to be cleaned externally using a high pressure jet wash to ensure that no soil, mud or biological material is left on the vehicle, including the wheels, wheel arches, tracks and areas underneath the vehicle. Any external surfaces of the vehicle that come into contact with the ground will be washed with Virkon S disinfectant or similar. Plant accessories, such as forks and buckets, should be cleaned in a similar manner.
- Where the plant has a cab, upholstery and mats should be brushed and/or vacuum cleaned to remove any soil or biological material.
- Following cleaning, plant is to be inspected by a nominated Biosecurity Inspector to ensure that they are free of visible soil and biological material (e.g. plant fragments, seeds and insects).
- Care should be taken not to contaminate the plant prior to loading onto the ship or aircraft. Plant storage facilities should minimise the potential for recontamination of cleaned vehicles prior to transport and, if necessary, arrangements should be made to thoroughly clean the vehicles at the ship or aircraft loading site.
- Immediately before being loaded onto the ship or aircraft for transportation, all vehicles should be checked by a nominated Biosecurity Inspector to ensure they are free of soil and biological material. If any soil or biological material is found, the contaminated vehicle should be cleaned and re-inspected before being transported.
- Motorised plant is to have its engines started before loading, to ensure rats and mice are not living in the engine compartments.
- The interior of vehicles are to be fumigated with a pyrethrum-based insecticide prior to being shipped

2.7. Construction Materials

The following section does not constitute a complete list of the construction materials but simply identifies the materials considered to pose the highest biosecurity risk and details the specific measures to be taken.

2.7.1. Aggregates

Aggregate is defined as any course particulate material used in construction, including sand, gravel, crushed stone, boulders, pebbles or slag. It presents a biosecurity risk because biological material such as seeds, soil and invertebrates can easily become entrained during production and transport.

- Aggregate to be obtained from marine sources.

- To prevent seed contamination during storage and transport aggregate must be contained in clean sealed packaging (such as FIBCs).
- Packaged aggregate will be transported in clean ISO containers.
- Aggregate must be carefully handled to prevent damage to the packaging.
- Only the minimum amount of aggregate needed for the project will be sent to the site.
- All aggregate will be used as quickly as possible after delivery to the site to reduce the risk of establishment of any non-native species present in the aggregate.
- Aggregate must be stored in a defined area at the construction site. Any spilled aggregate must be cleaned up immediately and contained within packaging, until used.
- Aggregate will be stored in its sealed packaging at the site and will not be left open to the environment.
- When aggregate is removed from its packaging for use, it must be used as soon as possible.
- Aggregate must be encapsulated as a component of concrete, or buried so that propagule release is not possible.

In the event that one or more of these management steps are not possible, further consultation with the BAS Environment Office must take place. Consultation with the BAS Environment Office must occur prior to any aggregate being purchased from suppliers.

Currently, there are no plans to import aggregates to South Georgia. All aggregates required will be sourced from the island.

2.7.2. Timber

Timber will be required as a construction material and required for packaging materials. Due to the risk of infestation by pests the following precautions must be observed before timber can be imported to South Georgia/Antarctica:

- Timber materials must be heated in accordance with a specific time–temperature schedule that achieves a minimum temperature of 56 °C for a minimum duration of 30 continuous minutes throughout the entire profile of the wood (including at its core).
- All timber products are to be inspected for signs of wood borrowing animals such as wood boring beetles and woodworm (a beetle larvae) before being shipped.
- If any evidence wood burrowing animals is discovered the timber must be treated with a pesticide or fumigated in a sealed container.
- All packaging timber should conform to the requirements of International Standards for Phytosanitary Measures No. 15 (ISPM 15) and be stamped with IPPC logo, country of origin and method of treatment.

2.7.3. Sheet Piles

Whilst sheet piles have relatively smooth faces, when stacked large voids are produced which are hard to inspect, particularly when using long piles. Voids also exist within the clutches of the piles, i.e. where the piles interlock with each other. Checks shall be made by a BAM staff member when packing and shipping these materials to ensure that no invertebrates or their eggs are hidden between the sheets.

2.7.4. Scaffold Tubes

Scaffold tubes will be used for temporary works such as handrails to the wharf. The hollow section forms an ideal place for invertebrates to hide from predation. Scaffold tubes shall be cleaned using a pressure washer, taking care to clean any invertebrates or their eggs from the inside of the tubes. After cleaning, scaffolding tube ends are to be sealed with duct tape to prevent the future ingress of contaminants.

2.8. ISO Containers

Prior to loading any ISO or other sealed container for transport to or between South Georgia/Antarctic Research Stations, the following procedure is to be followed.

- Shipping containers are to be stored on concrete surfaces (as opposed to bare earth).
- Shipping containers are to be kept clean and free of soil, mud, spiders' webs, invertebrates, debris, wood fragments (e.g. from pallets) and plant material. A record shall be kept of this inspection for auditing purposes (Please see Appendix A. Checklist 5). If deemed necessary by the nominated Environmental Engineer, containers shall be washed inside and out and sprayed with Virkon S disinfectant or similar before being sent to South Georgia.
- Prior to being sealed for the last time before being sent South, a sticky insect trap and rodent bait box should be included in the container (near the door).
- Prior to being sealed for the last time before being sent South, containers (except those containing fresh foods) shall be fumigated using a single-use pyrethrum fogger, to eradicate any invertebrates within.
- Prior to loading, if deemed necessary by the nominated Environmental Engineer, the exterior of the containers are to be washed with a high pressure jet wash. Particular attention is to be paid to underneath and to the corner fastening systems.

2.9. Fresh foods

Provisions for biosecurity measures associated with fresh foods have not been detailed in this document, as all fresh foods for BAM personnel will be supplied by BAS and will follow the BAS Biosecurity Regulations.

3. In-transit Biosecurity

3.1. Ships

Any ship chartered by BAM for the transport of cargo and personnel must meet the following biosecurity measures and evidence needs to be provided to BAS that the following biosecurity requirements are included in the contract:

- All ships must have a Ship Sanitation Certificate (SSC).
- All ships must conform with Resolution MEPC.163(56) Guidelines For Ballast Water Exchange In The Antarctic Treaty Area.
- All ships must be thoroughly cleaned prior to cargo loading in the UK.
- All ships cargo holds must be fumigated prior to cargo loading in the UK.
- A biosecurity inspection of the transporting vessel will be carried out before cargo is loaded. (please see appendix A, checklist 7). If the ship shows any signs of soil or of infestation (invertebrates or rodents) then the ship will be required to carry out additional cleaning, fumigating and disinfecting prior to cargo loading.
- All ships shall have rodent (rats and mice) boxes with poison bait and mechanical traps that are inspected before, during and after each port visit and a record of all inspections maintained. At least one rat and one mouse poison bait box should be placed in all rooms or compartments. If the room/compartment floor area is greater than 100m^2, then an additional rat and an additional mouse poison bait box should be deployed per additional 100m^2. In areas where fresh foods are stored, mechanical rodent traps (rather than poison bait) traps should used.
- If rodents are discovered on board, the vessel will be required to leave the South Georgia and South Sandwich Islands Maritime Zone to another port for remedial action and for a new sanitation inspection.
- Insect sticky traps should be placed in all food storage areas, and replaced when necessary. For non-fresh food areas, one trap is required per room or compartment. If the room floor area is greater than 25m^2, then an additional sticky trap should be deployed per additional 25m^2. For fresh food storage areas then one insect trap per 10m^2 is needed.
- Electric UV insect killers shall be used in food storage areas.
- Biosecurity inspections of all ship and station cargo shall be undertaken prior to loading and off-loading. (Please see checklists 3, 4, and 5)

3.1.1. When in Port

- Ships must have rat guards on the mooring lines.
- The gangway shall be lifted at night, or if lowered, lit with flood lights. An ultrasonic rat deterrent must be available and switched on.
- External doors and windows should be closed, wherever possible, to minimise the attraction of insects onto the ship.
- Boot/shoe washing facilities must be made available at the gangway to allow boot/shoe washing ON and OFF the ship.
- The inside of the tenders shall be cleaned between each landing to remove soil and other biological material knocked off passengers' boots.
- It is important that the boots and clothing of those arriving in South Georgia/Antarctica by ship is adequately cleaned before disembarkation. At a suitable interval before the arrival date, BAM should

inform landing personnel and crew that clothing must be cleaned to remove soil, seed and other propagules. Spot check shall be undertaken to ensure compliance.

- Just prior to disembarkation at locations in South Georgia/Antarctica, all footwear must be cleaned in disinfectant (e.g. Virkon S).
- Disinfectants can become ineffective over time, or if contaminated excessively with soil or organic material. Therefore, disinfectant solutions provided for footwear cleaning shall be changed regularly (at least once per week), and a specific individual assigned this task as part of their duties.

3.2. Cargo Inspection Pre-offload

3.2.1. Cargo Boxes and Break Bulk

All items of break bulk cargo, including packaging, shall be visually inspected by the Biosecurity Inspector for signs of rodent gnawing or rodent ingress. They shall also be checked for any soil or biological material and if found the item shall be cleaned. Once these checks are complete and the item is biosecure, a nominated BAM staff member will check the item against the manifest and then allow it to be transported to the station. If a biosecurity issue is noted, the cargo shall not be off-loaded until this issue is resolved.

3.2.2. Vehicles and Large Mechanical Plant

All vehicles must be inspected before off-loading and a record of this made (Please see Appendix A. Checklist 4). If contamination is found, further cleaning must be done before off-loading.

3.2.1. ISO Containers

ISO containers shall be inspected externally for soil, plant material and invertebrates prior to off-loading. Details of the check shall be kept for auditing purposes (Please see Appendix A. Checklist 5)

4. Biosecurity on Arrival at KEP

4.1. Personnel Disembarkation

- Personnel disembarking at King Edward Point or elsewhere in Antarctica or South Georgia must adequately clean their clothing, personal belongings and boots before they leave the ship and upon returning to the ship (see Appendix A: Biosecurity Checklist 1. Personal Biosecurity).
- Clothing and personal belongings (such as bags, camera cases etc.) must be checked for biological material at a suitable time before arrival - remove any seeds, soil and other propagules found whilst still on the ship. Check Velcro, gaiters, pockets, turn-ups in trousers and hoods of jackets.
- Boots must be inspected and cleaned and any soil or seeds removed before arrival at KEP.
- All personnel must use the boot washing facilities (provided by the vessel) at the gangway to disinfect their footwear before disembarkation.

4.2. Inspection of Cargo

External surfaces shall be checked to ensure cargo items are free of soil, biological material and signs of gnawing, or other routes of rat ingress. Those opening ISO containers upon arrival, should stay vigilant for signs of live invertebrates. If found, these invertebrates should be eradicated immediately.
When opening cargo boxes, remain vigilant for imported soil or biological material.

4.3. Aggregate

- On arrival at KEP, aggregate should be contained in sealed packaging and stored in a demarked area (preferably hard standing/concrete or on a tarpaulin.
- If aggregate is to be used in concrete, this should be done at a designated concrete batching area and then the concrete moved out to the site where it is to be used

4.4. General Awareness

When on station all personnel shall remain vigilant for any indications of:

- biosecurity breaches
- evidence of non-South Georgia soil importation
- non-native species colonisation, including within buildings
- rats or rodents
- spiders or other invertebrates

If in doubt, personnel should report any potential issues to the BAM Environmental Lead, who will assess the situation and, as appropriate, take any immediate action and complete and submit an AINME report. If a rodent is seen then action must be taken immediately and the Station Leader and GSGSSI Government Officer informed in order for the KEP Rodent Contingency Plan to be put into immediate action.

5. On-Site Biosecurity

- Bittercress (Cardamine glacialis), an invasive species to South Georgia, has become established in areas around King Edward Point, particularly on the Village Green.

- Other invasive plant species may be present in the vicinity of Grytviken These may include:
  - Heath wood-rush (Luzula multiflora var congesta)
  - Sweet vernal grass (Anthoxanthum odoratum)
  - Cow parsley (Anthriscus sylvestris)
  - Tufted hair-grass (Deschampsia cespitosa)
  - Red fescue (Festuca rubra)
  - Creeping buttercup (Ranunculus repens)
  - Sheep's sorrel (Rumex acetosella)
  - Thyme-leaved speedwell (Veronica serpyllifolia)
  - Common bent (Agrostis capillaris)
  - Smooth meadow grass (Poa pratensis)
  - Spike trisetum (Trisetum spicatum)

- All staff will be briefed on invasive species, how they spread and tips for identification. Pictures of invasive plant species will be displayed in the site office.

5.1. Village Green

It is proposed that the Village Green, situated between the Fuel Farm and Discovery House, is to be used for the storage of aggregates produced from local rock extraction. The area is known to be infested with the invasive plant Bittercress.

Before materials are stored on the Village Green, a permeable root barrier membrane will be laid on the existing surface and this covered with a minimum depth of 250mm of fine aggregate produced from quarry site 1. The fine aggregate will be spread using an excavator.

It is important during this process that the no plant comes into contact with the topsoil/vegetation of the Village Green before it is covered with the root barrier membrane. However, once the root barrier membrane is in place and anchored down, all vehicles and equipment used in the installation will be cleaned using the jetwash in the KEP boatshed as a precaution. All personnel will also scrub their boots clean and ensure their outer clothing is free of soil or seeds.

The stockpile of locally excavated aggregate stored on the now lined village green will be damped down during dry conditions to prevent material from being windblown. Sheeting over the stockpile would not be practical due to the size of the stockpile and the potential high wind speeds making any sheeting hard to secure.

The root barrier membrane together with the 250mm of aggregate will prevent any of the seedbank contained in the soil of the village green from coming into contact with construction plant. For this reason, and because there are no known invasive species at the quarry sites, it is not considered that the washing of vehicles moving between sites will be required.

5.2. Quarry Sites

Neither of the two selected quarry sites are known to have invasive species present. Haul routes into and out of the quarry sites will be made of quarried stone to prevent mud from becoming attached to the tyres of the vehicles. A jet wash will be available if required to clean vehicles if mud builds up on the wheels or tracks, but it is not envisaged that this will be required. If used, water from the jet wash will be left to drain away at the quarry site.

5.3. Vehicle Movements

Aggregates will be transported from the quarry to the stockpile on the Village Green by two tractors and trailers. The trailers will be covered with sheets to prevent material from falling or dust being blown from the vehicle. Drivers will be briefed on the importance of keeping all wheels on the stone tracks and avoiding contact with the grass verges to prevent the spread of invasive non native species. Vehicles and plant will not be permitted to enter Grytviken.

6. Export and Exit from KEP

Transport of cargo, equipment, vehicles and personal belongings from KEP to other locations in South Georgia, Antarctica, FI or the UK must be inspected, cleaned and as free of soil as practically possible before leaving KEP. If materials are being transported to another South Georgia or Antarctic station then all the necessary checks and inspections must also be carried out again on the ship before offload can occur. The relevant checklists must be used during export from station and prior to offloading to a new location.

7. Non-conformances

- All biosecurity breaches and near misses should be reported to the BAM Environmental Lead, the BAM Project Manager, the BAS Station Leader, the GSGSSI Government Officer and the BAS Environment Office at the time of the incident.

- A near miss/environmental incident report must be produced and provided to the BAS Station Leader for inclusion in the Accident, Incident, Near-Miss and Environment (AINME) Reporting System as soon as relevant information is available and at most within 48 hours.

- The BAS Environment Office will review any incidents, breaches or incursions and consult with the GSGSSI. Decisions and any necessary course of action or response will be communicated to the following personnel at KEP for coordination on site: BAS KEP Project Manager, BAS KEP Station Leader, the BAM Construction Manager and the GSGSSI Government Officer.

- Examples of biosecurity breaches may include, but are not limited to, the following:
  - Non-South Georgia soil or biological material (e.g. weeds) found on vehicles or other plant after unloading at KEP
  - Live invertebrates within cargo
  - ISO containers with soil or biological material on the interior and exterior surfaces
  - Any rodent sighting or any evidence of rodents (gnawing, etc.)
  - Failure to clean items delivered to station
  - Failure for biosecurity measures to be performed at appropriate stage of the supply chain
  - Failure for personnel to adequately clean their clothing or personal equipment.
  - Unintentional or deliberate importation of soil or biological material by BAM staff.
  - Importation of wood with bark still attached.
  - Failure for appropriate biosecurity checks of cargo packing areas to be performed.

Appendix A: Biosecurity Checklists

Biosecurity Checklist 1. Personal Biosecurity

(Pre-departure and pre-arrival for individuals going to South Georgia/Antarctica)

This checklist will be circulated to all BAM personnel prior to their deployment to South Georgia/Antarctica and is intended as a guide to assist individuals in undertaking their own biosecurity checks before travelling south.

Non-native species are those species that do not occur naturally in an area, but have been introduced by human activities, either intentionally or unintentionally. Unpermitted importation of non-native species is a breach of UK legislation and is in contravention of the Environmental Protocol and could lead to serious consequences for the responsible individual and BAM, including up to two years imprisonment and/or an unlimited fine.

Use the following checklist to reduce your risk of importing non-native species:

Personal Biosecurity Checklist		✓
Name and Signature		
All clothing is either new (i.e. straight out of the packet) <u>or</u> has been washed to remove plant seeds, invertebrates and soil (*Tip: check any Velcro® is clean and pay particular attention to pockets!*)		
All footwear has been scrubbed free of all plant seeds, invertebrates and soil (*Tip: check under the insole and tongue too!*)		
All bags and personal equipment have been cleaned, washed and/or vacuumed and are free of plant seeds, invertebrates and soil.		
All personal recreational equipment (including climbing gear, walking poles, ski and snow board equipment, kiting equipment and bicycles) has been cleaned and is free of soil and biological material.		
The following items have NOT been packed:		
• Any living plant, animal or microorganism - unless in possession of an appropriate permit		
• Non-sterile soil or compost		
• Any plant propagules (e.g. seeds, bulbs, cuttings) or invertebrate eggs (e.g. brine shrimp or sea monkey eggs) - growing plants and animals in Antarctica and South Georgia is <u>NOT</u> permitted		
• Untreated wood where bark remains attached		
• Any perishable foods including fruit, vegetables, cheese, fish or meat.		
You have explained the above restrictions to any person that is likely to send gifts or packages to you while in South Georgia or Antarctica.		

Biosecurity Checklist 2. Cargo Packing Areas

For each Cargo Packing Area that BAM utilises, a weekly checklist will be completed (for the duration of the packing period). The checklists will be stored on file and made available for auditing purposes either by BAM or by BAS personnel.

Weekly Cargo Packing Area Biosecurity Checklist	**Yes/No**	**Date checked**	**Any subsequent action or other notes**
Name of Facility Being Inspected			
Name (print) and Signature of Inspector			
Site is free of weeds and vegetation[1]			
Site is free of wind-blown seeds (e.g. from dandelions)			
Site is free of invertebrate infestation			
Site is free of rodents			
Rodent bait boxes are charged with poison bait[2]			
Insect sticky traps are present and still effective[3]			
Storage area doors are kept closed as much as possible			
Pallets and packing materials are kept inside in a clean area			
ISO containers are stored on hard standing			

[1]Regular use of herbicides may be required
[2]Using the AINME system, provide details of any rodents caught in bait stations.
[3]State the date when the insect sticky traps are replaced (typically every 2 months)

Biosecurity Checklist 3. Small Plant & Tools

All small plant and tools that have been used on jobs in other parts of the world shall be cleaned and checked prior to being sent to South Georgia/Antarctica.

Checks prior to off-loading shall be simple visual checks as described for all general cargo. If for some reason any checks are not possible at any stage of the supply chain, please note details of the circumstances here and report using the AINME system. Individual hand tools do not need to be listed separately using this checklist, but do need to be free of soil and biological material before transfer to KEP. The checklists will be stored on file and made available for auditing purposes either by BAM or BAS personnel.

Small plant/tools identification details:		
Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Name (print) and Signature of Inspector		
Post-cleaning check	**Date completed**	**Notes (including details of any associated AINME reporting)**
Exterior surfaces (top and side)		
Exterior underneath surfaces		
Interior surfaces (as possible)		
Insect spray in crevices (as possible)		

Small plant/tools identification details:		
Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Name (print) and Signature of Inspector		
Post-cleaning check	**Date completed**	**Notes (including details of any associated AINME reporting)**
Exterior surfaces (top and side)		
Exterior underneath surfaces		
Interior surfaces (as possible)		

Small plant/tools identification details:		
Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Name (print) and Signature of Inspector		
Post-cleaning check	**Date completed**	**Notes (including details of any associated AINME reporting)**
Exterior surfaces (top and side)		
Exterior underneath surfaces		
Interior surfaces (as possible)		

Biosecurity Checklist 4. Vehicle & Large Mechanical Plant

Mechanical plant (particularly tracked vehicles) pose a high risk to biosecurity. The undercarriage of wheeled or tracked plant can pick up soil which could contain plant fragments, seeds, invertebrates or invertebrate eggs.

The following checklist and the procedures listed in Section 2.6 of this document will be followed to ensure vehicles and large mechanical plant arrive in South Georgia/Antarctica free of soil and biological material. If these checks are not completed at any stage of the supply chain, please note details of the circumstances here and report using the BAS AINME system

A checklist for each vehicle or plant consigned to KEP will be stored on file and made available for auditing purposes either by BAM or by BAS personnel.

Vehicle model and identification details:		
Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Name (print) and Signature of Inspector		
Post-cleaning check: remain vigilant for mud, soil, debris, plant material, webbing or live spiders, other invertebrates or signs of rodents	**Date completed**	**Notes (including details of any associated AINME reporting)**
Vehicle exterior (top and sides)		
Vehicle wing mirrors and windscreen		
Vehicle exterior (underneath)		
Wheels and wheel arches		
Vehicle interior (including under floor mats, door pockets, down the sides and below the front seats, the boot/trunk, and under the spare tyre).		
Vehicle accessories (forks, buckets, etc.)		
Engine started to ensure no rodents/birds in vehicle interior		
Use insecticide spray in crevices where possible		
Virkon applied to surfaces that come into contact with the ground		

Name (print) and Signature of Inspector		
Check prior to loading onto vessel remain vigilant for mud, soil, debris, plant material, webbing or live spiders, other invertebrates or signs of rodents	**Date completed**	**Notes (including details of any associated AINME reporting)**
Vehicle exterior (top and sides)		
Vehicle wing mirrors and windscreen		
Vehicle exterior (underneath)		
Wheels and wheel arches		
Vehicle interior (including under floor mats, door pockets, down the sides and below the front seats, the boot/trunk, and under the spare tyre).		
Vehicle accessories (forks, buckets, etc.)		
Engine started to ensure no rodents/birds in vehicle interior		
Use insecticide spray in crevices where possible		
Virkon applied to surfaces that come into contact with the ground		
Name (print) and Signature of Inspector		
Check prior to off-loading at BAS station	**Date completed**	**Notes (including details of any associated AINME reporting)**
Vehicle exterior (top and sides)		
Vehicle wing mirrors and windscreen		
Vehicle exterior (underneath)		
Wheels and wheel arches		
Vehicle interior (including under floor mats, door pockets, down the sides and below the front seats, the boot/trunk, and under the spare tyre).		
Vehicle accessories (forks, buckets, etc.)		

Use insecticide spray in crevices where possible		

Biosecurity Checklist 5. ISO Containers

All ISO containers must be checked prior to loading on the ship and prior to off-loading at the stations. Appropriate cleaning equipment must be made available during checks.

For each ISO container consigned to KEP a checklist will be completed and stored on file. The checklist will be made available for auditing purposes either by BAM or by BAS personnel.

If these checks are not completed at any stage of the supply chain, please note details of the circumstances here and report using the BAS AINME system

ISO container or Bunk-a-bin identification details:		
Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Name (print) and Signature of Inspector		
Check prior to packing container*	**Date completed**	**Notes (including details of any associated AINME reporting)**
Container exterior surfaces (top and sides)		
Container exterior doors and hinges		
Container exterior underneath surfaces (as possible)		
Container interior surfaces		
Container interior high and low level corners and door hinges		
Sticky insect trap and rodent bait box installed near the doors		
Container fumigated prior to locking doors		
Name (print) and Signature of Inspector		
Check prior to loading onto vessel*	**Date completed**	**Notes (including details of any associated AINME reporting)**
Container exterior surfaces (top and sides)		
Container exterior doors and hinges		

Container exterior underneath surfaces (as possible)		
Name (print) and Signature of Inspector		
Check prior to off-loading at BAS station*	**Date completed**	**Notes (including details of any associated AINME reporting)**
Container exterior surfaces (top and sides)		
Container exterior doors and hinges		
Container exterior underneath surfaces (as possible)		
Sticky trap and rodent bait box inspected as soon as doors are opened for the first time.		

Biosecurity Checklist 6. All break-bulk items (any item which is not containerised and not covered by a specific checklist)

All breakbulk (individual boxes/crates, timber, cladding and other cargo which is not containerised) must be checked prior to loading on the ship and prior to off-loading at the stations. Appropriate cleaning equipment must be made available during checks. If these checks are not completed at any stage, please note details of the circumstances here and report using the BAS AINME system.

For each break-bulk inspection a checklist will be completed and stored on file detailing the items inspected and any outcomes. The checklist will be made available for auditing purposes either by BAM or by BAS personnel.

Description of all break-bulk inspected (i.e. 10 x wooden crates, 10 x zarges boxes, 20 x bundles of timber, 15 x bundles of cladding)		
Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Name (print) and Signature of Inspector		
Check break bulk items prior to loading onto vessel	**Date completed**	**Notes (including details of any associated AINME reporting)**
Items exterior surfaces (top and sides)		
Items exterior underneath surfaces (where possible)		
Items clean and free of soil, biological material and any signs of rodent gnawing or ingress, invertebrates such as spider webbing or cocoons.		
Name (print) and Signature of Inspector		
Check break bulk items prior to off-loading at BAS station	**Date completed**	**Notes (including details of any associated AINME reporting)**
Items exterior surfaces (top and sides)		
Items exterior underneath surfaces (where possible)		
Items clean and free of soil, biological material and any signs of rodent gnawing or ingress, invertebrates such as spider webbing or cocoons.		

Biosecurity Checklist 7. Vessels

Any vessel used to transport materials to KEP must be inspected prior to loading any cargo. If these checks are not completed at any stage, please note details of the circumstances here and report using the BAS AINME system.

For each vessel inspection a checklist will be completed and stored on file detailing the items inspected and any outcomes. The checklist will be made available for auditing purposes either by BAM or by BAS personnel.

Details of journey initial and final destinations (e.g. UK to KEP):		
Transporting vessel (e.g. RRS Shackleton):		
Details of journey; initial and final destinations and any stops on the voyage		
Name (print) and Signature of Inspector		
Vessel prior to loading cargo	**Date completed**	**Notes (including details of any associated AINME reporting)**
Ship's hold is clean and free of soil and insect and rodent infestation		
Sticky insect traps or electric UV traps are placed in hold and food storage areas.		
Rat bait boxes with poison bait are on board.		
Rat bait box inspection regime is in place		
Mooring line rat guards are available and in place when in port.		
Ultrasonic rat deterrent available and in place.		
Floodlights available at gangway and used when the gangway is lowered in the hours of darkness.		
Boot/shoe washing facilities are available at the gangway and topped up with Virkon S or similar		
Ship sanitation certificate (SSC) is available and in date.		

Appendix 7 – Construction Materials

KEP - Construction Materials

Sheet pile walls	Sheet piles			Total	
	Type	Weight	Length	Total no.	Weight
		[kg/m]	[m]	[-]	[ton]
Loading platform					
Front wall PF-1 - PF-11	AZ52-700	174.1	22.7	22	86.9
Front wall PF-12 - PF-19	AZ42-700N	142.1	20.7	16	47.0
Side wall North PN-1 - PN-6	AZ42-700N	142.1	19.7	12	33.6
Side wall North PN-7 - PN-12	AZ24-700	95.7	15.7	12	18.0
Side wall North PN-13 - PN-16	AZ24-700	95.7	9.7	8	7.4
Side wall North PN-17 - PN-24	AZ24-700	95.7	5.7	16	8.7
Side wall South PS-1 - PS-5	AZ24-700	95.7	15.7	10	15.0
Side wall South PS-6 - PS-8	AZ24-700	95.7	9.7	6	5.6
Side wall South PS-9 - PS-17	AZ24-700	95.7	5.7	18	9.8
Anchor wall PA-1 - PA-11	AZ36-700N	118.6	8.4	22	21.8
Anchor wall PA-12 - PA-16	AZ36-700N	118.6	7.1	10	8.4
Dolphin					
Front wall	AZ52-700	174.1	17.2	14	41.9
Side wall North	AZ52-700	174.1	17.2	14	41.9
Side wall South	AZ52-700	174.1	17.2	14	41.9
Back wall	AZ52-700	174.1	17.2	14	41.9
Slipway					
Front wall	AZ24-700	95.7	14.4	12	16.5
Side wall South 1	AZ24-700	95.7	14.65	2	2.8
Side wall South 2	AZ24-700	95.7	9.2	6	5.3
Side wall South 3	AZ24-700	95.7	6.25	6	3.6
Side wall South 4	AZ24-700	95.7	4.85	6	2.8
Side wall South 5	AZ24-700	95.7	3.9	6	2.2
Side wall South 6	AZ24-700	95.7	4.35	6	2.5
Mooring points					
Mooring point 1	AZ36-700N	118.6	5.0	32	19.0
Mooring point 2	AZ36-700N	118.6	5.0	32	19.0
Mooring point 3	AZ36-700N	118.6	5.0	32	19.0
Total				**400**	**600.9**

Horizontal tie rods	**Anchors**					
	Dia steel	Dia shaft	A_steel	Length	Total anchors	Weight
	[mm]	[mm]	[mm2]	[m]	[-]	[ton]
Loading platform						
Front wall deep	64	M72	3217	28	9	6.5
Side wall seaside	64	M72	3217	27	7	4.8
Side wall landside inclined	64	M72	3217	27	1	0.7
South corner	64	M72	3217	3	1	0.1
Total					**17**	**11.9**

Steel work	**Element**				**Total**	
	Type	Weight	Length	No./system	Total no.	Weight
		[kg/m]	[m]	[-]		[ton]
Loading platform						
Waler Front wall	PFC 430x100x64	64	26.6	2	2	3.4
Waler Side wall North	PFC 430x100x64	64	33.1	2	2	4.2
Waler Side wall South	PFC 430x100x64	64	23.5	2	2	3
Extra support for bollards	550x740x750	64	10	2	2	0.1
Waler Anchorwall	PFC 430x100x64	64	22.4	2	2	2.9
Dolphin – Top frame						
Waler Front wall	PFC 430x100x64	64	11.2	2	2	1.4
Waler Side wall North	PFC 430x100x64	64	11.2	2	2	1.4
Waler Side wall South	PFC 430x100x64	64	11.2	2	2	1.4
Waler Back wall	PFC 430x100x64	64	11.2	2	2	1.4
Diagonals	Ø273x12.5	80	7.6	1	4	2.4
Corner diagonals	PFC 430x100x64	64	3.3	2	8	1.7
Transfers for bollard	UC 356x368x177	177	11.2	1	2	4
Extra support for bollards	413x413x880	64	0.88	2	2	0.1
Capping beam						
Front wall	250+600+350 - t=15	141	26.6	1	1	3.8
Side wall North	250+600+350 - t=15	141	33.1	1	1	4.7
Side wall South	250+600+350 - t=15	141	26.6	1	1	3.8
Dolphin	250+600+350 - t=15	141	10.6	1	4	6
Mooring point						
Waler front & back wall	PFC 300x100x46	46	5.6	2	12	3.1
Waler side walls	PFC 300x100x46	46	5	2	12	2.8
Diagonals	Ø168x10	39	3.8	1	12	1.8
Transfers for bollard	UC 356x368x153	153	5	1	6	4.6
Total						**80.1**

Steel work	**Pipe/SHS/Grating**					**Total**	
	Ø/Height	Width	Thickness	Weight	Length	Total no.	Weight
	[mm]	[mm]	[mm]	[kg/m]	[m]	[-]	[ton]
Access Walkway							
Main horizontal beams	200	100	8	36	21.5	4	3.1
Transverse beams top (cross)	150	150	8	36	1.7	8	0.5
Transverse beams bottom (cross)	150	100	8	29	1.7	9	0.4
Diagonal cross braces bottom	80	80	8	18	3.3	8	0.5
Vertical cross braces 2 sides	114.3		8	21	2.52	32	1.7
Vertical brace	114.3		8	21	0.5	16	0.2
Support stub	150	150	10	44	0.2	4	0
Angled plinth	200	100	10	24	22	2	1
Handrail	42.4		6.3	6	50	2	0.6
Handrail stubs	42.4		6.3	6	0.2	64	0.1
Grating (1.0 m wide)				40	22	1	0.9
Gate to close walkway						1	0.1
Total							**12.6**

Precast concrete work	**Number of elements**	**Dimension of elements**					**Lifting weight**
	No.	W	L/H	Thickness	Volume per no.	Total volume	Per element
	[-]	[m]	[m]	[m]	[m3]	[m3]	[ton]
Access walkway							
Abutment blocks shore (fixed)	1	2.5	0.6	0.9	1.4	1.35	3.4
Abutment blocks dolphin (sliding)	1	2.5	0.8	0.6	1.2	1.2	3
Slipway (see sketches below)							
Concrete slab start plate	1	4	1.8	0.2	1.4	1.44	3.6
Concrete slab	4	4	4	0.2	3.2	12.8	8
Concrete slab end plate	1	4	4	0.2	3.3	3.34	8.4
Onshore abutment block	1	5.6	0.7	1	3.9	3.92	9.8
Total						**27.7**	

Fenders and bollards	**Totals**				
	Type	Length [m]	Diameter [m]	No. [-]	No. of chains [- / per fender]
Fender type loading platform	Shibata FenderTeam Foam Ocean Cushion Standard Capacity - or eq.	3	1.4	3	2
Fender type dolphin	Shibata FenderTeam Foam Ocean Cushion High Capacity - or eq.	3	1.4	2	2
Bollards on loading platform, dolphin & mooring points	Shibata FenderTeam 50t Teehead bollard - or equivalent			3	
Nearshore mooring point	Sinker for 50t MBL			1	

Quay furniture	Loading platform	Dolphin
Safety ladders	3	2
Mooring rings	4	
Access ladder on northern wall	1	
Lifesaving rings	2	1

Appendix 8 – Equipment and Plant

KEP Equipment and Plant

EQUIPMENT	No.
Setting out equipment	
Automatic level	2
Rotating laser	2
Total Station	1
Total Station robotic	1
Cat and Genny cable detection equipment	2
Gas monitoring equipment	2
Survey consumables	-
Environmental Monitoring Equipment	
Mabey class 1 microphones	2
Mabey triaxial vibration monitors	2
Mabey dust monitors	2
Mabey environmental monitoring loggers	2
General Equipment	
300AMP Welding sets	2
Burning gear and gasses	2
Compactor plate	2
3' submersible pump and hoses	2
Tool (175cfm) Compressor	2
10kVa Generator	3
Towed fuel bowsers, 2,250lts; to service quarry operations	1
Water bowsers, 5,000lts	1
Oily water waste tank	1
5/3.5 mixer	1
110v hand drill and consumables	1
Stihlsaw and consumables	1
Power washer	1
Heavy duty electric breaker and consumables	1
2kVA generator and consumables	1
Plant Working - Onsite	
Crawler crane 300t	1
Roto-telehandler	1
Man riding cage	1
Clam shell bucket (3m3)	1
Tractor 165hp	2
Trailer 24t, 20ft with ramps	1
Rock tipping trailer, 18T capacity	2
30t Excavator (Quarry)	1

45t Excavator (Wharf)	1
Pumps, 6' c/w siltbuster unit	2
Hydraulic breaker for 30t excavator	1
Diving	
Diving equipment	-
Pile installation	
Vibro hammer (52M), incl power pack and hoses	2
Impact hammer (S70), incl power pack and hoses	1
Quarrying	
Mobile screener (Finlay 883 / Sandvik QE341)	1
Marine Plant	
Safety boat, ex-Bird Island	1
Unifloat (and modular pontoon elements)	2+6
Work Boat, push/pull boat (BAMI, ex-US Army)	1
Lifting equipment	
General lifting equipment - chains straps etc.	-
Crane mats, 5m*1m*150mm deep	20
12m Articulated MEWP	1
On site at KEP	
Stores, 10'unit, COSHH store	1
Tool container, ex-bird island	1
Stores, 20'unit	5
Workshop - 10' unit, ex-Bird Island	1
Weatherhaven storage tents, ex-Bird Island	2
Weatherhaven POD, ex-Bird Island	1
Food freezers / refrigerators, ex-Bird Island	3
Freezer container	1

Appendix 9 – Site Waste Management Plan (SWMP)

Site Waste Management Plan

This declaration is to be used in conjunction with and uploaded into BAM Site – the web-based sustainability monitoring and reporting tool

Project reference	BAA.4010
Project title	King Edward Point Wharf
Client	Natural Environmental Research Council / British Antarctic Survey
Principal contractor	BAM
Site waste coordinator / Environment engineer	Neil Goulding
Contract value	
Address/location	King Edward Point Research Station, King Edward Point, South Georgia.
Project description	Design and Build contract to extend the existing wharf at KEP to accommodate the new research ship, the RRS Sir David Attenborough. The wharf wall is to be constructed using steel sheet piles, and the wharf will be filled with locally quarried rock.
Document prepared by	Neil Goulding

Declaration:

We the Employer and principal contractor confirm that all reasonable steps will be taken to ensure that:

a) all waste from the site is dealt with in accordance with the duty of care in section 34 of the Environmental Protection Act

b) materials will be handled efficiently and waste managed appropriately

Employer:	Signed:
Principal contractor:	Signed:
Key subcontractor(s):	Signed:

This plan is reviewed at least every three months by the site waste coordinator and updated as necessary to ensure that waste management practices are in accordance with this plan.

Reviewed by	Date	Rev no.	Revision details (where applicable)

Introduction

This site waste management plan identifies and monitors:

- reuse of materials on the project e.g. cut and fill, site won materials
- waste minimisation implemented on the project
- waste management options for waste generated during the works including waste generated by subcontractors
- any cost savings achieved through waste minimisation

Materials identified within this SWMP are not necessarily statutory waste, as they do not fall within the legal definition of waste i.e. 'any substance or object which the holder discards intends to discard or is required to discard.' There is no intention to discard materials such as:

- site won excavated materials
- aggregates crushed in accordance with the WRAP Quality Protocol (on or off site)
- pre-planned use of materials

All materials whether they are imported, reused 'as is' on site, recycled (on or off site) or sent off site for disposal are identified within the plan.

(See Appendix 1 for roles and responsibilities.)

Legislation

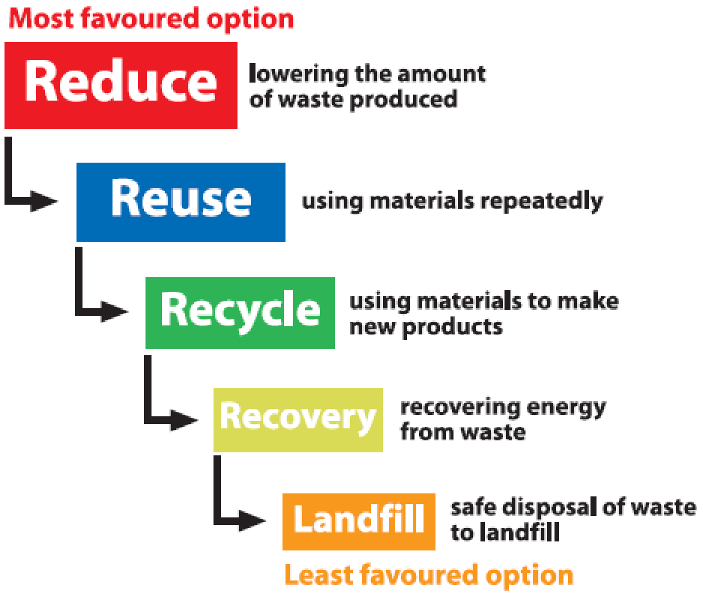
UK Environmental Legislation

UK Environmental Legislation

Whilst UK legislation is not applicable to South Georgia it should be regarded as, good practice and followed wherever practical. UK waste legislation is applicable to the disposal of waste from the South Georgia in the UK.

The Waste (England and Wales) (Amendment) Regulations, 2014

The Waste Framework Directive, which is the primary European legislation for the management of waste, is implemented through the Waste (England and Wales) (Amendment) Regulations 2014. It places great emphasis on the waste hierarchy to ensure that organisations deal with waste in the priority order of:



The waste hierarchy is partly implemented through the amended Duty of Care regulations.

The Duty of Care Regulations, 1991

Under the Environmental Protection (Duty of Care) Regulations, 1991, BAM is required to take all reasonable steps to keep its waste safe and secure so that it does not cause pollution or injury.

In particular, BAM must:

- Fulfil the legal requirement to apply the waste hierarchy.
- Ensure safe and correct packing and containment. This is of particular importance while the waste is in transit.
- Check that waste contractors are appropriately registered with the Environment Agency.
- Describe the waste on a Duty of Care transfer note so that the waste carrier can avoid committing an offence under the Regulations.

Failure to comply with the Duty of Care Regulations is a criminal offence, and could result in a fine of an unlimited amount. The Environment Manager is responsible for compliance with the Environmental Protection (Duty of Care) Regulations, 1991 with regard to wastes returned by BAM from Antarctica for disposal in the UK.

The Hazardous Waste Regulations, 2005

Hazardous wastes are amongst the most harmful and difficult wastes to deal with. The Hazardous Waste Regulations 2005 control the licensing, transfer and disposal of such waste in the UK.

Classification of our wastes as hazardous

- Correct separation and storage of hazardous waste
- Use of authorised businesses to collect, recycle or dispose of our hazardous waste
- Preparation of consignment notes for every movement of hazardous waste in the UK.
- Keep records for 3 years of all produced and stored waste

Materials resource efficiency

The following waste reduction and reuse measures have been included in the design and/or specification for this project:

(To be further developed on completion of the 65% design)

Design specifications	The specification for the fill material required for the wharf and the dolphin has been developed to allow maximum quantities of the quarried rock to be used, reducing the waste from quarrying.
Choice of materials	During the development of the design, the mooring points and anchor wall have been changed from pre-cast concrete to sheet piled solutions. Although this change was made due to ground contamination, the resulting design change will reduce the embedded carbon of the project.
Methods of construction	The wharf and dolphin will be filled with locally sourced and quarried materials reducing the energy needed to transport fill materials and the biosecurity risks associated with importing fill materials.
Pre-fabrication off site	All concrete elements will be prefabricated. These consist of elements of the slipway

Forecast of the types and quantities of waste

It is estimated that this site will produce the following types and quantities of waste: Tbc following development of design.

Excavation Waste

Type of Waste	EWC Code	Estimated Quantity Tonnes/(m^3)				Waste Management Action in Detail	Storage Arrangements
		Total	Re-Use	Recycle	Dispose		
Crushed Stone	17 05 04	4,685 (2,129)			4,685 (2,129)	Re-use as fill in quarry	Stockpile

Construction Waste

Type of Waste	EWC Code	Estimated Quantity kg/(m^3)				Waste Management Action in Detail	Storage Arrangements
		Total	Re-Use	Recycle	Dispose		
Steel	17 04 05	500 (0.06)		500 (0.06)		Cut into manageable pieces. Returned to the UK for recycling	Skip or ISO Container
Cementitious Wash Water		10,000 (10)			10,000 (10)	Cementitious wash waters to be neutralised using carbon dioxide or citric acid and solids filtered out before being discharged to the sea.	Skip or Siltbuster

Alkaline Batteries	20 01 33	0.5 (<0.01)		0.5 (<0.01)		Tape up terminals. Separate into the different types where practicable. Bag and labelled accordingly. Pack bags into separate sections of a plastic-lined UN nefab box filled with vermiculite. Paint the case yellow, stencil with green recycling triangle and mark the top and sides with the case number and “ASSORTED WASTE BATTERIES, NON REGULATED”. They do not require hazard labels under the IMDG code for shipping. Consign to the UK.	UN boxes 4GV or 4DV with tops and upper parts of the sides painted yellow
Clothing / Textiles	20 01 10	5 (≈0.1)		5 (≈0.1)		Stored in FIBC with green recycling logo marked “WASTE TEXTILES FOR RECYCLING” and returned to the UK	FIBC with green recycling logo marked “WASTE TEXTILES FOR RECYCLING”
Cardboard	20 01 01	40 (0.06)		40 (0.06)		Broken down, baled and stored in FIBC with green recycling logo or palletised. Returned to the UK for recycling	FIBC with green recycling logo marked ‘WASTE CARDBOARD FOR RECYCLING or Pallet
Paper	20 01 01	5 (0.03)		5 (0.03)		Re-use on site for packaging where suitable. Placed in BAS recycling bins	BAS recycling bins
Timber	17 02 01	200 (0.4)	100 (0.2)	100 (0.2)		Wood that can be used on station should be given to the Station Manager. Other wood is stored in wooden crates and marked “WASTE WOOD”. Returned to the UK for recycling	Wooden crates and marked “WASTE WOOD”
Plastic	20 01 39	10 (0.01)		10 (0.01)		Compacted and stored in 205ltr drum marked with recycling logo and the word “PLASTICS”. Returned to the UK for recycling.	205 ltr Drum marked with green recycling logo and “PLASTICS”

Oil	13 02 07	500 (0.5)			500 (0.5)	Store in 205 ltr drums painted yellow and marked "WASTE LUBRICANT" and with the recycling triangle. Returned to the UK for recycling.	205 ltr drums painted yellow and marked "WASTE LUBRICANT" and with the recycling triangle
Oil Filters	16 01 07	5 (0.01)			5 (0.01)	Empty oil filter and store in yellow 205 ltr drum marked "OIL FILTERS" and "UN 3077 Class 9 Environmentally Hazardous Substance, solid, n.o.s (oil filters)". Return to the UK for disposal.	Yellow 205 ltr drum marked "OIL FILTERS" and "UN 3077 Class 9 Environmentally Hazardous Substance, solid, n.o.s (oil filters"
Oil Contaminated Rags	15 02 02	10 (0.04)			10 (0.04)	Store in 205 ltr drum painted yellow and labelled "WASTE RAGS, OILY". Allocate hazard class 4.2, UN no. 1856. Return to the UK for disposal	205 ltr drum painted yellow and labelled "WASTE RAGS, OILY"
Aerosols	16 05 04 16 05 05	10 (0.1)			10 (0.1)	Seal tops of aerosols with packing tape and place in a plastic lined UN approved case filled with vermiculite and painted yellow with the words "WASTE AEROSOLS" on the top and sides. Affix appropriate hazard labels and label the case UN no. 1950. Where possible aerosols with different hazard classes should be packed separately. If a case contains a mixture of aerosols with different hazard classes, then label with all relevant hazard classes. Return to the UK for disposal	Yellow plastic lined UN approved case marked "AEROSOLS" with appropriate hazard class and UN no. 1950

All hazardous material will be stored in containers with suitable bunding to contain 110% of any liquids stored.

Domestic waste produced by BAM staff will be managed and disposed of by BAS

Demolition Waste

Type of Waste	EWC Code	Estimated Quantity Tonnes/(m^3)				Waste Management Action in Detail	Storage Arrangements
		Total	Re-Use	Recycle	Dispose		
Concrete	17 01 01	9.2 (4.0)	9.2 (4.0)			Re-use as formation for new slipway	On the beach at slipway location
Steel	17 04 05	2.5 (0.5)		2.5 (0.5)		Return to UK for recycling	Stockpile

Management of waste

The production of waste material on this site during the construction phase is avoided wherever possible by following the '*reduce, reuse, recycle, recover'* measures outlined below. Only where these options have been exhausted is waste sent for disposal.

Reduction and reuse measures

BAM's target is to divert from landfill 90% of all waste and 80% of construction waste.

The following measures will be employed to reduce and reuse waste on this site:

General	
Reduction measures	**Reuse measures**
• Accurate measurement, and minimal wastage will be allowed when using materials	• All waste materials to be offered to the Research Station Manager for re-use within the station. The BAM and BAS Project Managers will contact the Environment Office prior to leaving any waste materials behind in order to receive approval.
• Materials are to be stored and transported correctly so as to avoid damage	
• All operatives are to receive training on the agreed reduction measures	
Concrete and hardcore	
Reduction measures	**Reuse measures**
• Accurate measurement, and minimal wastage will be allowed when batching cementitious materials	• Re-use of suitable fill material from existing wharf
• Cementitious materials are to be kept off the ground by the use of pallets or timber bites	•

Excavated material (soil & stones)	
Reduction measures	**Reuse measures**
• Trenches to be sheeted rather than battered to reduce excavated material	• Excavated soil and stone to stockpiled for future use on site
Timber	
Reduction measures	**Reuse measures**
THIS SECTION TO BE COMPLETED AFTER FURTHER PLANNING WORK	***THIS SECTION TO BE COMPLETED AFTER FURTHER PLANNING WORK***

Metals	
Reduction measures	**Reuse measures**
• Accurate seabed survey to be carried out to enable piles to be pre-cut to correct length.	• Re-use of steel elements from existing wharf for temporary elements of new construction
•	• All waste materials to be offered to the Research Station Manager for re-use within the station

Recycle and recovery measures

The following waste streams are to be segregated for recycling/ recovery off site:

Waste stream	EWC code	Storage option	Management option
Ferrous Metal	17 04 05	Pallet or 205 ltr drum	Secured to pallet painted green or in green 205 ltr drum and returned to the UK for recycling
Timber	17 02 01	Wooden crates and marked "WASTE WOOD"	Wood that can be used on station should be given to the Station Manager. Other wood is stored in wooden crates and marked "WASTE WOOD". Returned to the UK for recycling or waste to energy
Paper	20 01 01	FIBC marked "PAPER" and with the recycling triangle.	Re-use on site for packaging where suitable. Store in FIBC marked "PAPER" and with the recycling triangle. Return to the UK for recycling
Cardboard	20 01 01	FIBC or Pallet	Broken down, baled and stored in FIBC with recycling logo or palletised. Returned to the UK for recycling
Alkaline Batteries	20 01 33	Yellow UN nefab box	Tape up terminals. Separate into the different types where practicable. Bag and labelled accordingly. Pack bags into separate sections of a plastic-lined UN nefab box filled with vermiculite. Paint the case yellow, stencil with green recycling triangle and mark the top and sides with the case number and "ASSORTED WASTE BATTERIES, NON REGULATED". They do not require hazard labels under the IMDG code for shipping. Return to the UK for disposal.
Clothing / Textiles	20 01 10	FIBC marked "WASTE TEXTILES FOR RECYCLING"	Stored in FIBC with recycling logo marked "WASTE TEXTILES FOR RECYCLING" and returned to the UK
Plastic	20 01 39	205 ltr Drum marked with recycling logo and "PLASTICS"	Compacted and stored in 205ltr drum marked with recycling logo and the word "PLASTICS". Returned to the UK for recycling.

Oil	13 02 07	25 ltr plastic container marked “WASTE LUBRICANTS” and with the recycling triangle.	Store in 25 ltr plastic containers painted yellow and marked “WASTE LUBRICANT” and with the recycling triangle. Return to the UK for disposal.
Oil Filters	16 01 07	Yellow 205 ltr drum marked “OIL FILTERS” and “UN 3077 Class 9 Environmentally Hazardous Substance, solid, n.o.s.”	Empty oil filter and store in yellow 205 ltr drum marked “OIL FILTERS” and “UN 3077 Class 9 Environmentally Hazardous Substance, solid, n.o.s.”. Return to the UK for disposal.
Oil Contaminated Rags	15 02 02	205 ltr drum painted yellow and labelled “WASTE OILY RAGS”	Store in 205 ltr drum painted yellow and labelled “WASTE OILY RAGS”. Allocate hazard class 4.2, UN no. 1856. Return to the UK for disposal
Aerosols	16 05 04 16 05 05	Yellow plastic lined UN approved case marked “AEROSOLS”	Seal tops of aerosols with packing tape and place in a plastic lined UN approved case filled with vermiculite and painted yellow with the words “WASTE AEROSOLS” on the top and sides. Affix appropriate hazard labels and label the case UN no. 1950. If a case contains a mixture of aerosols with different hazard classes, then label with all relevant hazard classes. Return to the UK for disposal
Detergents and Disinfectants	20 01 30	In original bottles within a yellow UN approved case marked WASTE “DETERGENTS AND DISINFECTANTS”	Offer to KEP Station Manager. If not required keep in original bottles within a yellow UN approved case marked WASTE “DETERGENTS AND DISINFECTANTS”. Return to the UK for disposal

Packaging, Labelling, Transfer and Shipping Documentation

It is currently envisaged that BAM will charter ships for the disposal of waste arising from the wharf construction and deconstruction works. Should it be agreed that BAS ships are to be used for the removal of this waste, the packaging requirements set out in the BAS Waste Management Handbook will be adhered to and all waste will be given the prefix 'BAM-KEP' to distinguish it from BAS produced waste.

It is essential that waste materials are securely packaged, are clearly marked and have the appropriate documentation attached. The following procedures should be followed to ensure consignments are safe for handling and are transported according to legal requirements.

Packing

Containers

Varieties of containers are available for packing waste as listed in the table below.

Type of Waste	Container	Waste
Non-Hazardous Inert	Flexible intermediate bulk bags, (FIBCs) – with green recycling logo	Segregated dry recyclable waste (e.g. card, plastics, textiles etc.)
	NB FIBCs should not be used for general cargo	
	Clean 205 ltr drums	Plastic
	Pallets	Wood waste
	Skips	Scrap metal
Hazardous	Old 205 ltr AVTUR drums	Waste fuel (not petrol), lubes, oil and oily rags
	Old petrol drums	Only for waste petrol
	Wooden containers and crates (lined with plastic)	Fluorescent light bulbs and WEEE waste
	UN approved boxes	Batteries, aerosols and empty paint containers
	UN approved 25l, 30l or 60l metal and plastic drums	Waste chemicals

Packaging Materials

Packaging materials that have been sent in containers carrying items to bases should be reused as much as possible. For example:

- Vermiculite (for all liquids);
- Shredded paper;
- Bubble wrap; and
- Cardboard.

Packing Groups and UN Approved Packaging

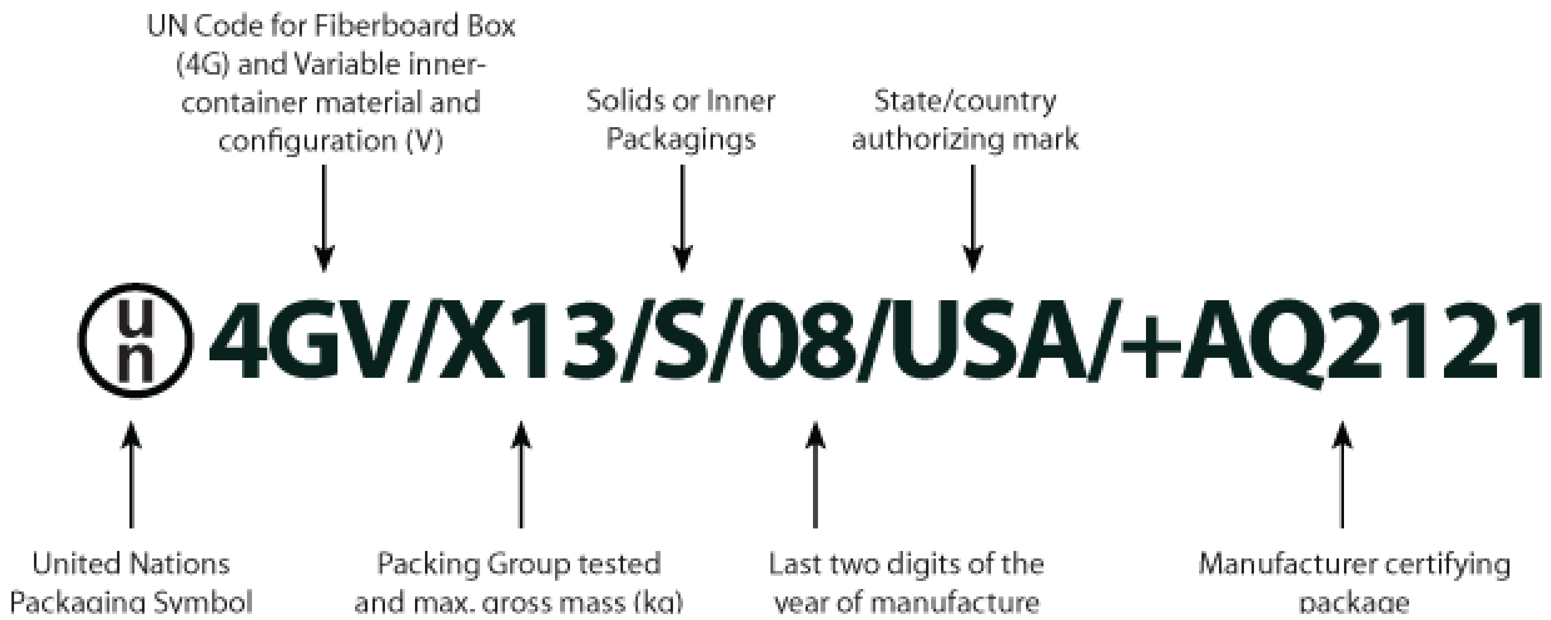
All hazardous waste must be packed in correct Group I, II or III packing containers. The packing groups are based on the degree of danger associated with the material.

- Packing Group I — Materials are highly dangerous
- Packing Group II — Materials are of medium danger
- Packing Group III — Materials are of low danger

All enquiries for general hazardous materials packaging and transportation should be directed Neil Goulding neil.goulding@bamnuttall.co.uk.

Packaging has to be designed and constructed to UN specification standards and must pass practical transport related tests such as being dropped, held in a stack and subjected to pressure demands. It must also meet the needs of the substance it is to contain. A national competent authority must certify packaging. UN approved packaging is marked with the prefix 'UN' and followed by a series of codes representing; type of container, packing group, quantity of contents, year of manufacture, country of origin and certification of the package.

An example is shown below.



Packing Hazardous Waste

Liquids
Hazardous liquid wastes are generally transported in UN approved 25, 30 or 60 litre chemical drums. Check the drums for leaks and that the seals on caps are intact. Be particularly vigilant when using dented or rust-marked drums.

Solids
UN approved cartons or crates should be used to return solid hazardous waste or small bottles containing hazardous liquids.
All contents must be sealed in a heavy gauge plastic liners and sufficient vermiculite to protect the contents and absorb any spillage. Do not overload boxes or cases.

A copy of the Bill of Lading (BOL) *see shipping documentation*, sealed in a plastic wallet must be securely taped to the outside of any container containing hazardous wastes. The following should be considered when packing hazardous waste:
• Previous hazardous cargo labels and markings must be removed or painted over (not just crossed out);
• Do not paint over container dimensions or UN marking (shown above);
• All sides (except the bottom) of the package must be labelled;
• All sides (except the bottom) must have the appropriate hazard class labels; and
• Top and upper part of containers should be painted yellow.

Manual handling

All waste is man-handled several times over, from when it is first disposed of and packaged on base, to being loaded onto chartered vessels in the Antarctic, offloaded in the UK, loaded onto waste contractor lorries and then offloaded at its final disposal point.

It is essential therefore to pack waste appropriately to avoid injury to those handling it. The following points should be considered by anyone involved in packing waste:

- FIBC's should be checked prior to being hoisted by crane onto chartered vessels to ensure that they do not contain sharp objects which may injure handlers or tear bags;
- Boxes and crates must be in good condition and not overloaded;
- Waste loaded onto pallets should be carefully packed to ensure there are no sharp edges and that protruding nails or screws are removed;
- Old fuel drums should be fully drained and wiped with absorbents to ensure no vapours or liquid remains;
- Drums should not be over-filled as they become too heavy for people to easily handle;
- When storing liquids in drums, space should be allowed for expansion at warmer temperatures; and
- Drums that have been fitted with a lid and ring clamp must not be lifted using drum lifting clamps; instead, they should be netted when loaded by crane.

Storage

It is extremely important that waste ready for shipment is stored appropriately, i.e. according to the hazard, it may create. This could be inside the designated waste store, in an ISO container, or outside on the dockside. If waste is stored outside it must be secured in case of strong winds (in particular empty drums), and properly sealed to prevent ingress of water. Hazardous wastes must be kept in the designated storage facilities within the construction compounds. Drums should always be stored upright in designated waste stores on the stations and ships.

N.B. Lithium Batteries are a FIRE HAZARD when wet and must be kept dry at all times!

Labelling

Each consignment of waste must be appropriately colour coded and clearly marked with the type of waste it contains. In addition, each consignment must have a BAS case number. See Shipping Documentation for further details.
For hazardous waste, the cases must also be marked on the outside with the following information:

- Proper shipping name (PSN)
- UN hazard class label(s)
- Flashpoint (if applicable)
- UN number

This information can be found listed in the 'Hazcheck' software tools used on BAS stations or from Neil Goulding neil.goulding@bamnuttall.co.uk.
As an example, a drum containing waste methanol/water mixture would be recorded as:

• ***Waste methanol mixture (methyl alcohol) / water >70%***
• ***Hazard class 3***
• ***Flashpoint 20°C***
• ***UN No 1230***

If the waste has a primary hazard and a subsidiary risk then both hazard labels must be stuck onto the package.
The *Approved Carriage List* (Health and Safety Executive, 1994), available on stations and ships, contains a comprehensive listing of chemicals and hazardous substances.

Colour Coding

All containers carrying waste should be colour coded to reflect the final disposal location and waste contractor. For solid containers this will involve painting the tops and upper part of the sides of the unit. FIBC's are generally ready supplied with a colour code in the form of a green recycling logo. **All old labels and hazard markings for any previous contents must be removed or painted over.**

Type of Waste	Colour Coding	Disposal Locations
Non-hazardous landfill	Blue	UK
Fuels and oils	Yellow with recycling logo	UK
Resale items	No colour	Locally or UK
Recyclables	Green plus recycling logo	UK
Hazardous waste, radioactive materials and other chemicals	Yellow	UK

Hazardous Wastes Classification

Hazardous wastes must be carried in accordance with the *International Marine Dangerous Goods (IMDG) Code*. This covers the carriage of dangerous goods at sea. It is the vessels responsibility to ensure that the regulations are followed on-board ship. Hazardous materials must be separated into nine different general classes based on the United Nations (UN) hazard classification.
The general classes and subclasses are as follows:

Hazard Class	Class Description
Class 1	Explosive
Class 2.1	Flammable gas
Class 2.2	Compressed gas (non-flammable, non-toxic)
Class 2.3	Toxic gas
Class 3	Flammable liquid *
Class 4.1	Flammable solid
Class 4.2	Spontaneously combustible
Class 4.3	Dangerous when wet
Class 5.1	Oxidising agent
Class 5.2	Organic peroxide
Class 6.1	Toxic
Class 6.2	Infectious substance
Class 7	Radioactive material
Class 8	Corrosive
Class 9	Miscellaneous substance
*** Packing Groups for flammable liquids:**	
I	Flammable liquids - flash point below -18°C
II	Flammable liquids - flash point -18°C up to +22°C
III	Flammable liquids - flash point +23°C up to +61°C

If chemicals of the same class are mixed, a list should be attached to the container identifying the approximate volumes of each different chemical it contains.
NEVER mix substances with different UN hazard classes. This is highly dangerous.

Special attention must be given to ensure that oxidising agents (Hazard Class 5.1) are kept separate from other chemicals
Acids and alkalis (hazard class 8) are not to be packed in the same container. They must be clearly labelled in separate containers.

Shipping Documentation

What is a Bill of Lading (BOL)?

All waste sent out from BAS research stations and ships must be accompanied by an accurate Bill of Lading (BOL). BOLs are the principal documentation for waste removed from Antarctica. They are primarily used to ensure goods are loaded and transported appropriately and discharged in the correct location.
In addition the BOL's for waste are used to agree waste disposal contracts, verifying disposal invoices, auditing the waste management system and monitoring the quantity of waste that is produced in Antarctica. **Waste data has to be reported to the Antarctic Treaty Parties, HM Treasury, BAM Nuttall, NERC and the BAS Board.** It is therefore essential that the information provided on the BOL is complete, accurate and dated.

BOLs will be prepared by a nominated person; this person is yet to be confirmed

BOLs for major construction activity need to specify which project the waste originated from so that these records can be attributed to the correct project. BAM waste should be given the prefix "BAM-KEP".

Each base has been provided with a pallet truck that has built in scales. Standard weights and volumes for use on BOL's are shown below. These should be used **only** in the absence of weighing or measuring facilities. **It is important that the weights and volumes are as accurate as possible.**

Waste	Volume (m^3)	Weight (kg)
205 litre drum – Empty	0.3	20
205 litre drum - Filled e.g. fuel, seawater (do not fill to the top - part fill only)	0.3	185
205 litre drum - Crushed	0.065	20
25 litre drum – Filled e.g. chemicals (do not fill to the top - part fill only)	0.04	30
ISO-container empty	25.0	As per tare plate on container
ISO-container full (crushed drums)	25.0	14,500
Skips	6	Dependent on contents
Small FIBC	0.5(max)	Dependent on contents
Large FIBC	0.75(max)	Dependent on contents

Completing a BOL
The following information is required on all waste BOLs:

- Date
- Consignor
- Consignee
- Station/vessel generating waste
- Vessel used for transportation of waste
- Special stowage instructions (if applicable)

- Case number
- Quantity and type of package
- Full description of contents
- Case/drum number (new number for each individual item)
- Case dimensions (cm)
- Weight (kg)
- Volume (m3) per item

Estimated value (if applicable)

BOLs for hazardous wastes

A BOL must be prepared for each individual case/drum of hazardous waste. However, there may be times when large numbers of drums of identical size and content may be included together on one single BOL.

All enquiries for general hazardous materials packaging and transportation should be directed to neil.goulding@bamnuttall.co.uk.

Project close-out review

This section of the plan is completed prior to the project close-out review, and discussed as part of the review meeting. The estimated quantities are drawn from the table in section 2, and reconciled against the actual quantities removed from site as detailed in BAM SMaRT.

Comparison of estimated and actual quantities

Actual waste quantities from BAM SMaRT. Will be issued upon completion

Source and type of waste	EWC Code	Estimated quantity of waste (tonnes)	Actual quantity of waste (tonnes)
Excavation waste			
Hazardous excavated material	17 05 03*		
Non-hazardous soil and stones	17 05 04		
Inert soil and stones	17 05 04		
Construction (skip) waste			
Concrete	17 01 01		
Mixed hardcore	17 01 07		
Timber	17 02 01		
Glass	17 02 02		
Plastic	17 02 03		
Mixed metals	17 04 07		
Other mixed construction waste	17 09 04		
Hazardous construction waste	Various		
Mixed municipal waste	20 03 01		
Demolition waste			
Concrete	17 01 01		
Bricks	17 01 02		
Mixed hardcore	17 01 07		
Timber	17 02 01		
Glass	17 02 02		
Plastic	17 02 03		
Mixed metals	17 04 07		
Other mixed demolition waste	17 09 04		
	Totals	0	0
		Difference	0

Delete / add waste streams as appropriate by double clicking on this table.

Explanation of any deviation from the original plan

N/A

Appendix 10 - KEP Quarry Site Investigation Report

PROJECT TITLE:
BAS Projects

Site Visit Report – King Edward Point Quarried rock backfill for wharf

For internal information only.

	Name	Position	Date	Signature
Prepared by:	J Cordon	BAM Ritchies	29/11/18	na
Checked by:	David	Kilburn	30/11/2018	na
Approved by:				

1 INTRODUCTION

As part of the wharf redevelopment at King Edward Point, approximately 4,800m^3 of quarried rock will be required to backfill the wharf. This report details the site investigation to identify possible locations for this quarried material. The same team carried out site investigation work around the existing wharf, details of which are covered in a separate report by David Kilburn.

Date of site visit: 17-21 Nov 2018

BAM Participants: David Kilburn (BAM Nuttall)
Jan Cordon (BAM Ritchies)
GSGSSI Adrian Faill supported by Steve and Darren Livermore.

Outline information:

- For the purpose of the site investigation it is understood that 30-80mm, or possibly 30-150mm backfill material will be required, although this grading will be optimised by the designers based on feedback from the site visit and laboratory testing of samples.
- Approximately 4,800m^3 net is required, say 9,600 tonnes.
- There is a strong preference from the South Georgia government to source rock without drilling and blasting, by using either scree, moraine or beach deposits. It is also preferable from a cost point of view to obtain the rock fill by screening / selection alone, unless crushing is absolutely necessary.
- Grytviken, close to KEP, receives approximately 8000 visitors a year, so it is important to consider the impact on these visitors during the selection of quarry location, both the visual impact of the quarry and access road, and the interaction of dump trucks with distracted visitors.
- The assessment must consider the impact on seals, birds and areas of tussock grass.
- From each potentially suitable, site two samples of approximately 75kg are required, one from each site to be sent to Pony's Pass Quarry in the Falkland Islands for PSD testing, the other to the UK for testing as per the designers' instructions.
- Prior to the site visit, permits were obtained to allow trial pits and sampling at four potential quarry locations identified during discussions with BAM and GSGSSI officials. During the site visit two additional areas were identified and added to this permit.
- Prior to excavation, all locations were inspected by BAS personnel to ensure that no wildlife would be disturbed by the investigation. In addition trial pits were sited to avoid vegetated ground where possible, or at least kept clear of tussock grass areas.
- An activity plan and risk assessment was prepared and briefed. This included the requirement to review service plans and test with a CAT scanner where necessary. These details are not discussed further in this report.
- Trial pits were excavated using a JCB 8085 8t excavator.

2 QUARRY INSPECTION AND SAMPLING METHODOLOGY

In total seven sites were considered for quarrying, six with permits for site investigation and sampling, plus one for inspection only. In order to minimise the impact of the investigations, the site selection process started with the least intrusive method first to eliminate unsuitable sites without disturbance.

Outline of the site investigation:

1. Walkover of each location to determine if there appeared to be a sufficient rock content for viable extraction, either for the full requirement, or a significant portion of it. It was clear at an early stage that more than one location may be needed.

2. Visual inspection to check that material could be safely extracted by mechanical means only. This also included discussion with the GSGSSI representative to determine if the site contained unexploded ordnance, waste materials or asbestos contamination.

3. Provided that the above requirements in 1 and 2 were met, trial pits were excavated. Where possible three trial pit locations were selected for each location, distributed either in a triangular pattern, or a straight line to cover as much of the area as possible. Each pit was then dug to the maximum reach of the site 8t excavator, approximately 2.3m, or refusal where hard material was encountered.

4. The trial pits, and material extracted, were examined to determine suitability in terms of potential yield and consistency between each trial pit. It should be noted that the trial pits only give an indication of the nature of each deposit, and at 2.3m deep does not test the full depth of extraction.

5. Finally, if the material extracted from the trial pits appeared suitable, dual samples were taken as described in the introduction. The material for each sample being selected to be as representative of the site as possible, avoiding surface material which contained organic material.

6. In addition, environmental impact, access constraints, and interaction with the public and site activities were considered.

3 OVERVIEW OF POTENTIAL QUARRY SITES

Figure 1 shows the four potential quarry locations identified prior to the site visit – Q1 to Q4 as shown in their approximate positions. Figure 2 shows the corrected positions and additional locations identified. Each quarry is discussed separately below.

Permit Number: South Georgia & the South Sandwich Islands - Regulated Activity Permit number 2018/049.

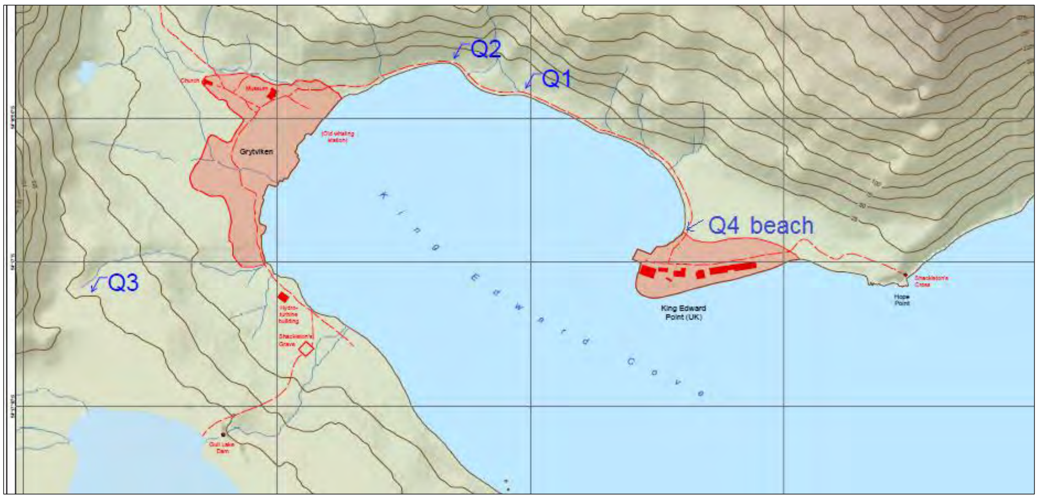


Figure 1 – Shows the original four locations determined prior to the site visit.

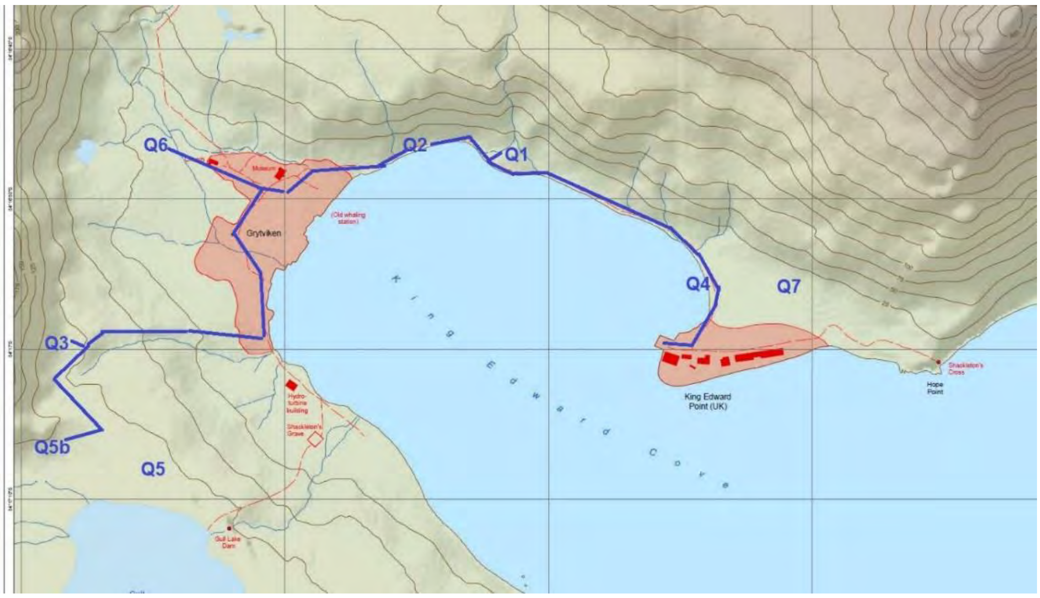


Figure 2 – The actual locations of sites inspected indicated by the references Q1, Q2… and the access routes to those sites later considered as potential sources indicated by the blue lines.

3.1 Quarry 1

Quarry one consists of an alluvial fan located approximately 700m from the wharf along the track between KEP and Grytviken. This appears to have been formed by the accumulation of scree washed-out from the gully above. There is some evidence of previous extraction at the western edge of the deposit that shows a reasonable rock content. The area is bounded by scree to the north-west and north-east and by the Grytviken/KEP track which curves around the area to the south. The deposit slopes gradually from the level of the road to a point 8m above the road at the base of the gully. The area is covered by rough grass and tussock grass. Some fur seals (approximately 15 no.) reside in the turssock grass. There was however no signs of any penguins being present in this area. The site is approximately 2500m^2, and contains an estimated 6000m^3 of feed material above the level of the road. The possibility of relocating the road from its current position to allow extraction below the level of the road into the shore area as shown in figure 5 should be considered.

Safety and environmental considerations:

- Extraction will not involve excavation into the adjacent scree slopes, so will not affect its stability provided the finished faces are dressed at the same angle. The base of the gully is at a gentle angle which would indicate that it is not especially prone to rock fall. Some minor rock fall may be expected, though this should be controllable using appropriate extraction methods with catch pits in front of the excavator.
- These slopes are prone to avalanches in the winter, but almost no snow was present at the time of the visit in mid-November. Care should be taken after periods of heavy rain.
- An HV cable traverses the site west-east and will need relocated prior to extraction – figure 5 shows the approximate route.
- The area has two areas of tussock grass considered important for local habitat. These will need to be removed and stored for use during the remediation process.
- Although seals occupy the area from time to time, it is understood that they can be relocated and kept clear fairly easily. Barriers may be required.
- The access road between the KEP wharf and Q1 is level and 3.5 – 4.0m wide. This is close to the width of a 25-30t ADT, though sufficient. Some filling of potholes and placement of fill over drainage pipes may be required. During one cruise ship visit it was observed that no tourists used this route.
- It should be noted that the access route between Grytviken and KEP, used in part for quarry 1 and over the full length for all other viable options, is frequently used, or crossed, by seals and birds. A local speed limit of 15km is maintained to prevent accidents as it is not practical, or desirable, to restrict access to this fauna.

Figure 3 – Quarry 1 from Grytviken.

Figure 4 – Quarry 1 from the base of the gully.

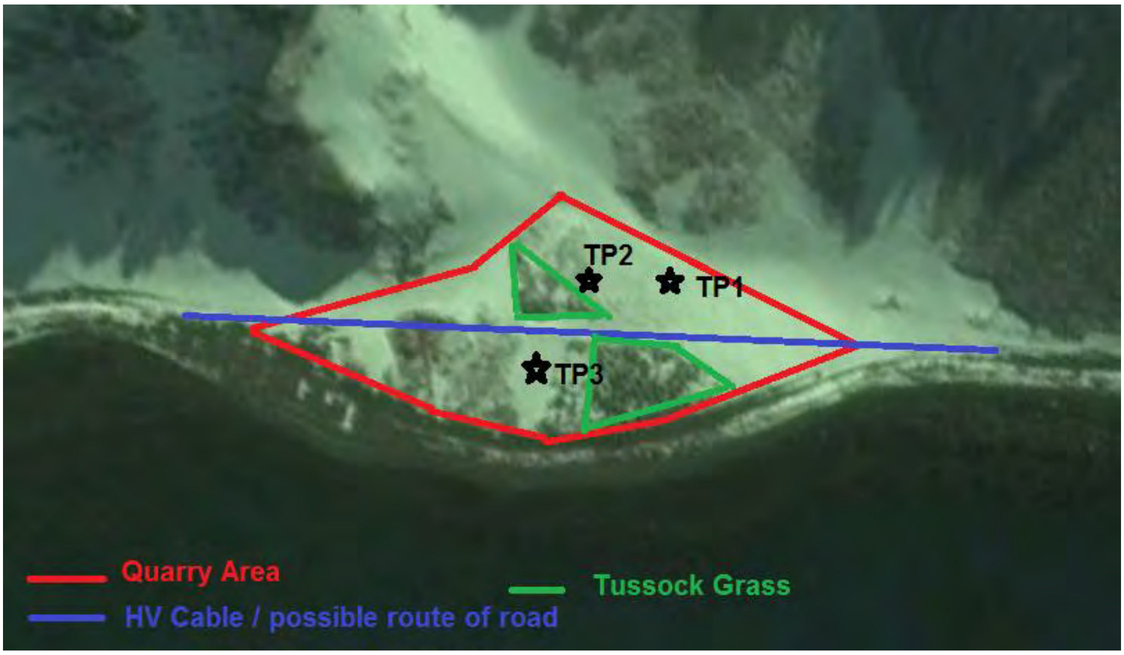


Figure 5 – Google earth image of site.

Three trial pits were excavated at locations accessible by the excavator and avoided both the HV cable and tussock grass – see figure 5. The material extracted appeared consistent between trial pits and the area previously worked at the west of the site.

Trial pit notes – all trial pits gave the same results:

- Depth of trial pits 2.3 to 2.5m, limited by the reach of excavator.
- Top soil approx. 0.2m thick.
- Easy excavation with 8t excavator.
- All holes dry during excavation.
- Brown, fine to coarse sand, with angular gravel and some cobbles. Most pieces below 300mm, though occasionally larger. Cobbles tend to be angular, with larger pieces tabular. Individual cobbles tend to vary in strength with some fairly strong and resistant to hammer impact, and others brittle and easily fractured. Some reddish oxidation evident in some pieces. No clay encountered.
- Rock appears to be fine grained meta-sediment as previously described.
- Estimate of yield of material above 30mm – 35%.
- Two representative samples were taken of approximately 80kg each. Each sample split into four sample bags.

On the last day of the site visit the opportunity was taken to screen approximately 1 tonne of material using the site screener. Q1 was selected. The screener was fitted with the available 30mm and 7mm screens and processed as follows:

- A representative sample was excavated, loaded in a bulk bag and weighed using a telehandler at 936kg.
- The entire sample was passed over the vibrating screen fitted with 30mm mesh (Techno Screen TS-200 made by Doyle Engineering and Manufacturing Ltd) and the material passing carefully collected and weighed. 596kg passing the 30mm screen, leaving 342kg of 30mm product retained. This gave a yield of 37% at >30mm- see figure 9.
- The retained 0-30mm material was then passed over the 7mm screen. Although this second screening was inconclusive, as a lot of fine material was also retained, it should be noted that a substantial proportion of gravel in the 15-30mm range was recovered – see figure 10.

This small sample screening gave some confidence in the assessment of 35% yield above 30mm. In addition, should it be possible for the designers to accept smaller material, it is anticipated that the yield will be improved to above 50%. The results of the laboratory particle size distributions should aid this assessment.

Figure 6 – Quarry 1, Trial pit 1 looking west.

Figure 7 – Quarry 1, Trial pit 1

Figure 8 – Material recovered from quarry 1, trial pit 1.

Figure 9 – Material retained on the 30mm screen.

Figure 10 – Material retained on the 7mm screen.

3.2 Quarry 2

Quarry 2 refers to an area of scree close to Grytviken on the road from KEP where extraction has previously been undertaken. This area has almost been worked-out back to the bedrock and is considered unsafe for further extraction. No trial pits were undertaken.

With the exception of quarry 1, it should be noted that no other location between KEP and Grytviken is considered suitable for practical extraction due to potential instability of the scree slopes once undermined.

Figures 11 and 12 – Quarry 2 location

3.3 Quarry 3

Quarry 3 is located at approximately +100m asl to the south west of Grytviken and appears to consist of moraine deposits lying against the foot of a scree slope. The ground at the top of this area is relatively flat with slopes at around 10 degrees to the east and north. The area of the deposit, was approximately 25m by 60m, 1500m^2 and of unknown thickness. There is evidence of previous disturbance at this location, though the site has been reinstated.

Safety and environmental considerations:

- Extraction will not involve excavation into the adjacent scree slopes, so will not affect their stability, provided that the boundary of the quarry continues the same slope angle with finished faces. Some minor rock fall may be possible, though this should be controllable using appropriate extraction methods with catch pits in front of the excavator.
- The slopes above the site may be prone to avalanches in the winter, but almost no snow was present at the time of the visit in mid-November.
- The area is covered by rough grass and bare earth, with no tussock grass, seals or nesting birds.
- Although the area is visible from KEP and Grytviken, careful extraction would leave a relatively low visual impact when viewed from below and landscaping could be used to minimise the long term impact from other viewpoints.
- There are no services at this location to interfere with extraction.
- The haulage route from KEP is 2000m and follows the road from KEP to Grytviken, passes through Grytviken and out towards Shackleton's grave before turning steeply up the hillside immediately after the leaving the storage area. The angle of the access road up the hill is generally 8 degrees, with one section of 50m+ metres up to 16 degrees. It is recommended that the steeper sections be graded to a maximum of 8 degrees and some improvement to the surface carried should this site be used. It would require extensive work to reduce this angle further.
- The haulage route through Grytviken is used extensively by tourists when cruise ships visit, and the interaction of tourists with heavy plant would be difficult to control without extensive fencing, tourist restrictions, or by avoiding quarry transport at the time of cruise ship visits. Tourists appear to be landed at the beach adjacent to Shackleton's grave and then walk to the Grytviken museum where they are collected – two thirds of this route would be shared with dump trucks and considered a high risk.

Figure 13 - Location of Quarry 3 shown in red.

Figure 14 – Quarry haulage route shown in red. Main tourist route shown in blue.

Figure 15 – Steeper section of the haul route to Q3 and Q5 locations.

Three trial pits were excavated in a line west to east across the centre of the area, with one at the foot of the scree slope (pre-prepared) and two in-line down the slope, at 18m and 12m spacings chosen to minimize impact on vegetation.

Trial pit notes:

TP 1 – see figures 16 & 17.
- Depth 2.5m
- Top soil approx. 0.2m thick.
- Easy excavation with 8t excavator.
- All holes dry during excavation.
- Brown / reddish brown, coarse sand, with angular gravel and some cobbles. Most pieces below 300mm, though occasionally larger. Cobbles tend to be angular / sub-rounded, with larger pieces tabular. Individual cobbles tend to vary in strength with some fairly strong and resistant to hammer impact, and others brittle and fracturing easily.
- Appears to be fine grained meta-sediment as previously described.
- Yield of >30mm material estimated at 35%.

TP 2 - Description as per TP1 except:
- The excavator hit hard material at 2.2m. It was not possible to determine if this was bedrock, though this resistance continued when the pit was extended laterally for 2m.
- The estimated yield of >30mm material was lower than trial pit 1, at say 20%
- See figures 18 & 19.

TP 3
- Brown coarse sand, with minimal gravel and limited cobbles.
- Excavator refusal at 2.0m.
- Yield too low.

Two representative samples were taken of approximately 80kg, mixed in equal parts from trial pits 1 and 2 - each sample split into four sample bags.

Although this location is a potential source of material, the variation of rock yield over short distances, potentially limited depth, the steep access and conflicts with visitors are significant concerns.


Figures 16 & 17 – Quarry 3, trial pit 1.


Figures 18 & 19 – Quarry 3, trial pit 2.

3.4 Quarry 4

Quarry 4 is the beach 100 to 200m to the north, and directly adjacent to the KEP wharf. Although the surface material was not promising, three trial pits were excavated at 25m spacings just above the low water mark. These trial pits encountered fine to coarse sand, with minimal gravel and almost no cobbles. The location was considered unsuitable and no samples were taken. Contamination from hydrocarbons – diesel and some oil – was also observed in the trial pits.

Figure 20 – Beach labelled Quarry 4. TP 2 being excavated in the foreground, with TP 1 being backfilled behind. Figure 21 shows Quarry 4, TP 2.

3.5 Quarry 5

Quarry 5 is located at approximately +110m asl on the natural moraine dam in front of Gull Lake, and is 2300m from the KEP wharf. The location is almost level and devoid of vegetation, seals and birds. The area consists of an area on the top of the moraine 35 to 70m east-west and 50m wide, total area c.2600m^2. Access to the site follows the same route as far as quarry 3, with an additional 300m on soft undulating terrain beyond. The access shares the same potential problems as quarry 3.

Three trial pits were excavated in a triangle approximately 30m apart and 2.3m deep. These trial pits encountered brown fine to coarse sand, with minimal gravel and occasional cobbles. The rock yield was considered very low and no samples were taken.

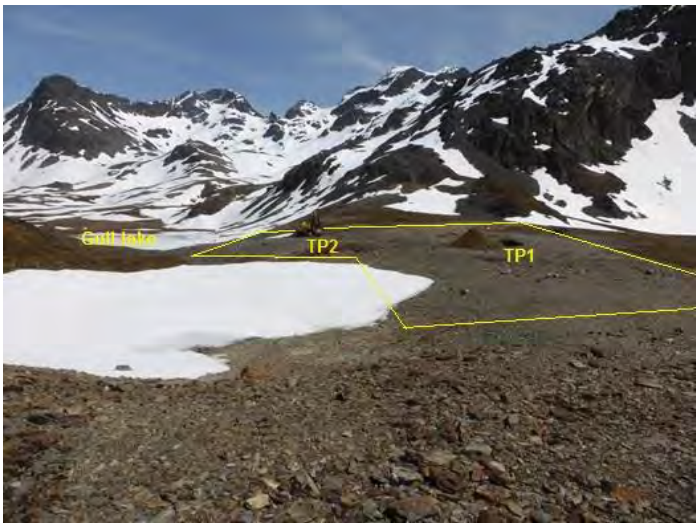


Figure 22 – Quarry 5 from the east.

Figure 23 – Quarry 5, trial pit 1. The label indicates 'hole 1' to avoid confusion with wharf TP1.

3.6 Quarry 5b

The area described as Quarry 5 covered a large area of the moraine dam, so after the disappointing results during the investigation for Quarry 5, an additional area was selected at the western end where the moraine merged into a short scree slope – as shown in figure 24. This area consisted of a scree slope approximately 100m long westwards from the moraine dam and 15m high. At the time of the investigation, access for the excavator was only possible at the extreme eastern edge close to the crest of the moraine dam.

Safety and environmental considerations:

- Extraction will involve excavation into the scree slopes, but these are of minimal height should not pose a risk. It should be possible to remove material in two benches starting on the upper level, roughly level with the access from the moraine dam, thus minimising the risk from slope failure. A ramp could then be made to access the lower level.
- The slopes above the site may be prone to avalanches in the winter, but snow conditions were stable at the time of the visit in mid-November.
- The area is entirely scree, with no tussock grass, seals or nesting birds to be disturbed.
- The area is not visible from KEP and Grytviken but extraction would make a considerable impact when viewed from the vicinity of Gull Lake.
- There are no services at this location to interfere with extraction.
- The haulage route is as described for quarry 3 and quarry 5.

Figure 24 – Approximate boundary of Q5b – Only two trial pits were possible due to limited access for the excavator to the slopes beyond and in order to stay in the permit area. A path can be seen from the centre of the image down to the left side.

Figure 25 – Looking back to the moraine dam along the path shown in figure 27.

Trial pit notes:

TP 1 – see figures 26 & 27.

- Depth 2.5m with material split into layers:
  - 0 to 0.1m Surface scree consisting of grey angular tabular cobbles.
  - 0.1 to 0.4m fine to coarse grey sand, with small angular gravel.
  - 0.4 to 1.0m fine to coarse reddish sand, with angular gravel and angular cobbles
  - 1.0 to 1.6m fine to coarse brown sand, with angular gravel and cobbles
  - 1.6 to 2.6m pale grey/brown fine to coarse sand, with angular gravel and cobbles.
- Easy excavation with 8t excavator.
- All holes dry during excavation.
- Appears to be fine grained meta-sediment as previously described.
- Yield of >30mm material estimated at 25%.

TP 2 – see figure 28

- 0.2m of surface scree consisting of grey angular tabular cobbles, with brown and grey fine to coarse sand, angular gravel and tabular cobbles below.
- Depth 2m - limited by the excavator's ability to work on the sloping ground.
- Easy excavation with 8t excavator.
- All holes dry during excavation.
- Appears to be fine grained meta-sediment as previously described.
- Yield of >30mm material estimated at 20%.

Two representative samples were taken of approximately 80kg each. Each sample split into four sample bags.

Although this location is a potential source of material, the trial pits were located at the extreme end of the area and may not be representative of the area as a whole. Access to and from KEP to this location also involves the steep climb from Grytviken, conflicts with cruise ship tourists at Gritviken, and a high local visual impact in the Gull Lake area.

Figures 26 & 27 – Quarry 5b, trial pit 1 with the upper layers visible.

Figure 28 – Quarry 5b, trial pit 2.

3.7 Quarry 6

Quarry 6 is located behind the Norwegian church and football pitch in Grytviken and is part of a large moraine deposit – see figure 29. The extent of the area should be sufficient for large quantities of material if it is of consistent yield.

Figure 29 – Quarry 6 outlined in red as viewed from KEP. Total extraction is unlikely to involve this entire area.

Safety and environmental considerations:

- It should be possible to manage extraction to avoid excessive bench heights for the excavator chosen, either working full height or in two benches.
- The area is free of risk from external rock fall or avalanches.
- The area consists of coarse grass, with no tussock grass, seals or nesting birds to be disturbed.
- The haulage route from KEP is approximately 1400m and level.
- The access route passes through part of Grytviken, including the road adjacent to the museums and church so there will be some conflicts with tourists.
- A temporary bridge will be required to span a stream close to the site – see figure 30.
- The quarry will have a visual impact when seen from Grytviken, though it should be possible to excavate into the hillside leaving most of the visible slopes in place. Landscaping should be practical as part of long term restoration. It should not be necessary to disturb the entire area shown in figure 30.
- There are no services present to affect excavation.

Figure 30 – The access route to quarry 6 passes to the south of the Norwegian church and crosses the small stream which is approximately 6m from the top of bank to top of bank.

Two trial pits were excavated into the base of the moraine, one in an existing cut close to the northern edge of the football pitch, the other 75m to the north and in-line with the church – see figure 31. A third trial pit was not possible due to wet ground preventing access for the excavator. This wet ground would not affect full scale production.

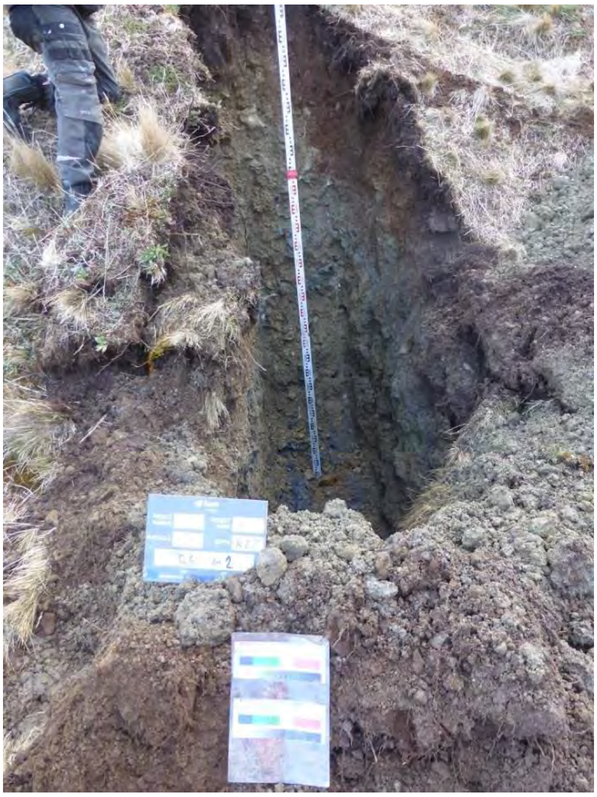
Figure 31 – Quarry 6. Trial pit 1 is located just to the right of the excavator and trial pit 2 is just to the right of the image and 75m to the north of TP1.

Trial pit notes:

TP 1 – see figures 32 & 33.
- Depth approximately 2.0m, though this was cut into sloping ground to the maximum reach of the excavator.
- The area generally had top soil of c.0.2m thick, though this had previously been removed at the test site.
- Easy excavation with 8t excavator to 1.5m, then becoming harder.
- All holes dry during excavation.
- 0-1.5m - Brown fine to coarse sand, angular gravel and some cobbles. Most pieces below 300mm, though occasionally larger. Cobbles tend to be angular / sub-rounded.
- 1.5-2.0 - Grey fine to coarse sand, angular gravel and some cobbles. Most pieces below 300mm, though occasionally larger. Cobbles tend to be angular / sub-rounded.
- Appears to be fine grained meta-sediment as previously described.
- Yield of >30mm material estimated at 30-35%

TP 2 – see figures 34 & 35
- Depth approximately 2.0m, though this was cut into sloping ground to the maximum reach of the excavator.
- Top soil of 0.2m – 0.4m thick.
- Easy excavation with 8t excavator.
- All holes dry during excavation.
- Pale brown, fine to coarse sand, angular gravel and some cobbles. Most pieces below 300mm, though occasionally larger. Cobbles tend to be angular / sub-rounded.
- Yield considered lower than TP 1 for of >30mm material – say 25%

Figures 32 & 33 – Quarry 6, trial pit 1. The large material at the bottom of figure 32 is as a result of sorting during tipping from the bucket.



Figures 34 & 35 – Quarry 6, trial pit 2

3.8 Quarry 7

During discussions with Steve Brown of the GSGSSI it was agreed that the investigation would review the vegetated area adjacent to KEP, though would not include any physical investigations without further approval. As part of this area was restricted to avoid spreading invasive species, permission was received from the GSGSSI officer at KEP to allow a walkover study.

This area consists of the low lying tussock grass directly adjacent to the KEP buildings (see figure 36 marked in red) and an area of flat land where MOD barracks were previously located (see figure 36 marked in orange) – it is understood that Steve Brown was referring only to the area directly behind the KEP buildings, but both areas were visited and discussed with GSGSSI personnel.

It is understood that the flat area previously occupied by the MOD barracks is heavily contaminated, and that during demolition a large hole was excavated and filled with waste - including asbestos. No further investigation was made of this area.

The area directly behind the KEP station was covered mainly with areas of tussock grass and marsh land, and there were no visible indications of rock except for the high scree slopes behind. The area was generally low lying and heavily populated with seals and birds. It was not possible to determine if there was any reasonable possibility of finding suitable rock during the walkover study and due to the limited time available and difficulty in access to the area, no further investigation was made.

Figure 36 – Potential quarry 7 location

4 Summary / Recommendations

There appears to be some variability in the strength of individual rock samples, with some strong and others failing on the first hammer blow (when testing a few random samples to destruction with a hammer), however there appeared to be relatively little variation in these rock qualities between the different sites. As a result of this apparent lack of variability between rock samples at different locations, the preliminary selection of sites has been based mainly on other factors - principally estimated rock yield, safety and environmental impact, and access considerations. Samples have been taken for testing in the UK and the Falkland Islands, and the results of these tests should be considered prior to confirming the final site selections.

It should also be noted that preliminary estimations of yield are based mainly on visual observation of material taken from a small number of shallow trial pits, and both the extent and yield of each deposit may vary during production. It is also understood that apart from obtaining the results from laboratory testing of samples taken, there will be no further opportunity to improve these predictions. The practical solution to this lack of certainty is to obtain permission to exploit sufficient volumes of in-situ material to allow for variable yields during production, and to ensure that the equipment selected has surplus production capacity.

It is recommended that the designers consider the option of widening the acceptable grading to accept material lower than 30mm and up to – say 300mm - to improve yields and allow simple production methods.

Outline summary of the sites:

Site	Safety	Environmental impact	Estimated yield / volume	Access	Rank
Q1	Minimal interaction with tourists. Low risk of face collapse though some minor rock fall is possible. HV cable will need relocated.	Some tussock grass will need removed / reinstated. Seals currently use the area. Some visual impact where extraction meets the scree slopes.	35% above 30mm. Gross volume 6000+m^3. Potential for increase	700m. Flat. Narrow though reasonable with minimum repairs.	1st choice
Q2	Scree at risk of collapse during excavation. High risk.	Not considered.	Yield not considered. Volume low.	Good	Excluded.
Q3	Interaction with tourists – site low risk, access high risk. Low risk of face collapse. Steep access road.	Some visual impact of the site from KEP / Grytviken. The access road will have a higher visual impact. Minimal effect on flora and fauna at site, though the access route is heavily used by seals near Grytviken.	Yield highly variable across the site up to a maximum of 35% above 30mm. Volume moderate and difficult to determine.	2000m. Steep in places - up to 16 degrees. Surface improvement necessary. Conflicts with tourist in Gritviken	Back-up option.
Q4	na	na	Fine and contaminated material only.	na	Excluded
Q5	na	na	Fine material only	na	Excluded
Q5b	Interaction with tourists – site low risk, access high risk. Low risk of face collapse though some moderate rock fall is possible. Steep access road.	Not visible from KEP and Grytviken. High visual impact from Gull lake. Minimal effect on flora and fauna at site, though the access route is heavily used by seals near Grytviken.	20-25% above 30mm though samples may not be representative of the entire site. Volume moderate and difficult to determine.	2300m. Steep in places - up to 16 degrees. Surface improvement necessary. Conflicts with tourist in Gritviken	Back-up option.
Q6	Interaction with tourists at site low, but a short section of the access route is high risk. Low risk of face collapse with correct extraction methods.	There is a visual impact from Grytviken and KEP, though this could be minimised if the front grass covered slope is left mostly intact. No seals, nesting birds or tussock grass identified.	Yield 25 – 35% above 30mm. Only two trial pits possible with some variability. Volume difficult to determine, though potentially very large.	1400m. Flat. One bridge required to span 6m, plus 100-200m of road require improvement. Some conflicts with tourist in Gritviken	2nd choice
Q7	na	na	Yield and volume entirely unknown. Some areas contain contaminated material.	na	Excluded

With reference to the summary table above, and subject to sample test results, quarry 1 is suggested as the primary site for exploitation, having a relatively high rock yield, short access route, low interaction with tourists and low risk during extraction and haulage. Extraction from this site would initially involve processing all material down to the level of the road, though it may be possible to re-align the road and continue extraction below this level, subject to further trial pits being dug during production to confirm yield.

Quarry 1 – Indicative exploitation stages:

Stage 1

- Re-align the HV cable.
- Strip vegetation, tussock grass, and overburden and stockpile separately. Possibly close to the Q2 location.
- Level the processing area closest to Grytviken.

Stage 2 – see figure 37

- Commence extraction working from the previously exploited area towards KEP.
- Waste material should be stockpiled against the slopes in the worked-out areas.
- Exploitation down to the road level.
- Excavate trial pits in the floor to identify if the material is suitable for further extraction.

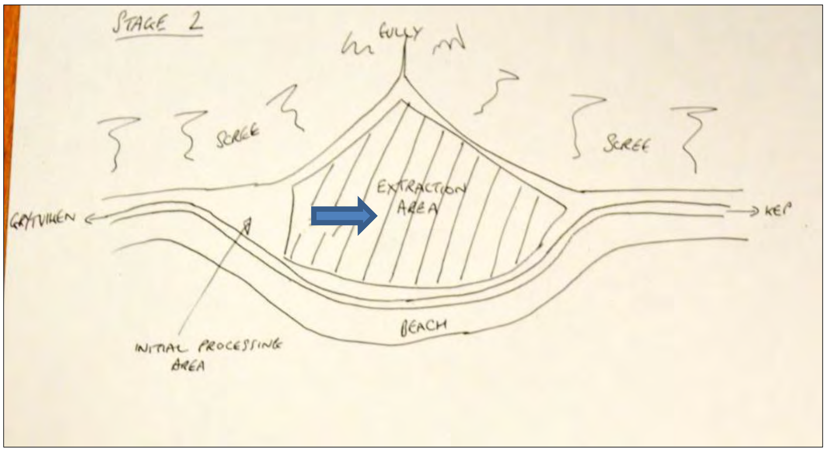


Figure 37 – Sketch of quarry 1, stage 2.

Stage 3 – see figure 38 and presuming trial pits show favourable results.

- Re-align the road to free up lower reserves towards the beach, whilst leaving sufficient area against the screes for stockpiling. It may not be possible to straignten the road to the extent shown in figure 38.
- Extract material from below the road level working away from the shore. Waste material can be placed against the slope or used to reform the beach in the worked-out areas.

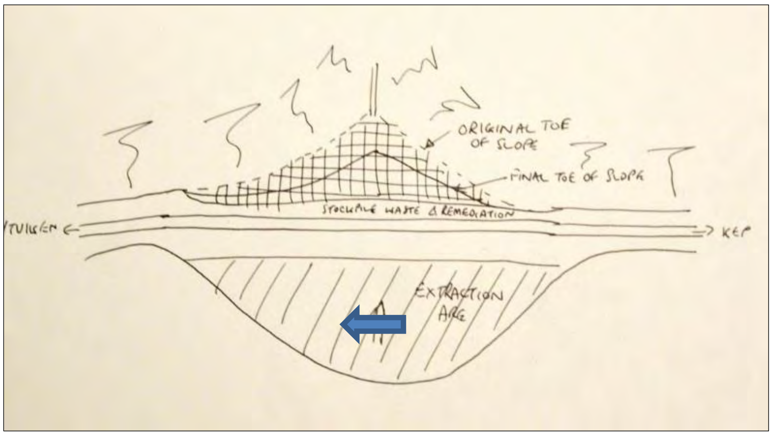


Figure 38 – Sketch of quarry 1, stage 3

Stage 4
- Landscape the waste material and reinstate the vegetation.
- HV cable laid along final route if required.

There is a reasonable likelihood that quarry 1 will be insufficient to meet the entire needs of the project and a second site is recommended to supplement this, though only once Q1 is close to being exhausted will the shortfall become apparent. Quarry 6 is recommended for this purpose as the haulage distance is relatively short and flat, and although there is interaction with tourists and, the distance is shorter than other options.

Figure 39 shows an indicative layout for quarry 6. It should be possible to minimise the visual impact from Grytviken by leaving the front of the moraine intact as far as possible. Topsoil and vegetation should be stored for reinstatement and waste material used for landscaping.

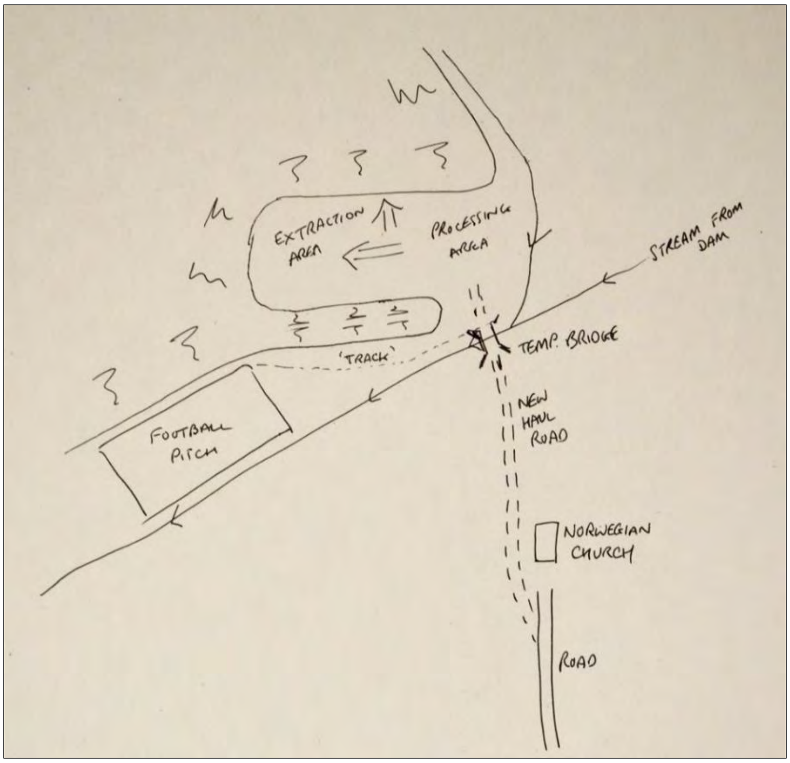


Figure 39 – Sketch of quarry 6 layout.

5 OUTLINE PRODUCTION RATES AND EQUIPMENT

Production requirements:
- Requirement considered - 4,800m^3, or 9,600 tonnes of rock backfill above 30mm. No upper grading except large material eg >300/400mm.
- Gross production 9600t / 0.35 = c.27,500t.
- Using a mobile screener eg. Sandvik QE341 or Terex Finlay 883 (as used at Rothera), feed per week up to c.5000t/week.
- All material will need to be handled at least twice in the quarry, once when excavated and used as feed to the screener, then again as product to site, or waste.

Stage 1: Indicative production from Quarry 1:

- Extraction of 6000m3, 12000t gross with a yield of 35% above 30mm. 5000t/week gross, producing 1750t/week of rock-fill (working 6 days / week, say 2-3 weeks production and continuous delivery).
- Production Equipment - 50t Excavator (min 35t), mobile screener eg. Sandvik QE341, loading shovel eg CAT966.
- Transport to wharf - 300 t/day, or 15 trips using a 25t ADT (1.5km round trip at 15km per hour 6 minutes, plus loading, tipping and waiting – say 20 minutes per trip, 24 in 8 hours or 30 in 10 hours.
- Waste repositioned locally mostly using the loading shovel.
- Yield of back fill from quarry 1 4200t, or 2400m3.

Stage 2: Indicative production from quarry 6.

- Remaining requirement 2400m3, 4800t net. Yield as per TP2 at 25%. 19,200t gross.
- The excavator screen and loading shovel transfer from quarry 1.
- 5000t/week gross, producing 1250t / week of product (working 6 days / week, say 4 weeks production and continuous delivery).
- Transport to wharf at 210 t/day, or 11 trips using a 25t ADT 3km round trip at 10-15km per hour, minutes, plus loading, tipping and waiting – say 40 minutes per trip, 12 in 8 hours or 15 in 10 hours. A bit tight for one truck if delays considered, so 2 x 25t ADTs would be recommended.
- Waste repositioned locally mostly using the loading shovel.

Overall main equipment and personnel:

- 1 x 50t Excavator (min 35t)
- 1 x Mobile screener eg. Sandvik QE341
- 1 x Loading shovel eg CAT966.
- 2 x 25t ADT
- 4 operators and supervisor.
- Temporary 10m span bridge over stream for access to quarry 6.

Note:

- All pre-production activities eg. preparing roads, stripping overburden, installing bridge over stream at quarry 6 and restoration is outside the production times suggested.

Appendix 11 – Monitoring Plan

Monitoring Plan: KEP Wharf Redevelopment

Introduction

The monitoring activities at KEP Research Station detailed in this section are those that will require the collection of information or data to verify the effectiveness of the impact prediction and proposed monitoring described in the KEP EIA.

The monitoring tasks are divided into two groups.

- 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.
- 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 EIA.
- Monitoring of environmental management activities identified in the EIA and Project Execution Plan including those outlined in the KEP Specific Biosecurity Plan, Site Waste Management Plan and fuel management.

Any changes to activities proposed as a result of the monitoring data, will be made by the BAM 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.

Monitoring activities:

Short-term monitoring

A. Managed Wildlife displacement
B. Distribution of breeding birds
C. Noise from quarrying and construction activities
D. Vibration from quarrying and construction activities
E. Marine noise from construction activities
F. Airborne dust

Longer-term monitoring

G. Marine benthic invertebrate communities

Environmental management monitoring

H. Environmental management activities and reporting

A. Managed wildlife displacement

1	**Monitoring type and purpose:**
	Recording of wildlife displacement, i.e. herding of seals and penguins located on land to remove them from areas and protect them from work which is being undertaken or from vehicle access routes.
2	**Description of the monitoring activity**
	Records must be kept of all wildlife displacement events involving seals and penguins. Such events may include the movement or herding of seals or penguins to allow the site to be secured (to enable, for example, building work to commence) or for vehicle movement.
3	**Methodology used (equipment, thresholds)**
	• All those moving or herding wildlife must have undergone training on station by BAS management. • No bird nest sites are to be moved or physically disturbed by individuals or machinery, without prior consultation with the BAS Environment Office. Visual observations and recording of the species displaced. Thresholds: • more than two seal displacement events per day (averaged over a one-week period), or • more than five penguin displacement events per day (averaged over a one-week period)
4	**Designated person undertaking the monitoring**
	BAM Site Environmental Engineer
5	**Period over which monitoring will occur**
	Recording shall be undertaken during the period when BAM is present on site
6	**Frequency of monitoring**
	Displacement events must be recorded following every occurrence.
7	**Action(s) should any thresholds be exceeded**
	Should the thresholds be exceeded, then BAM shall contact the Environment Office within 24 h to discuss the feasibility of mitigation measures.
8	**Recording and management of monitoring data**
	For each displacement event record the following information: • Number, type, and maturity of displaced seals or penguins (where known) • Reason for displacement (e.g. vehicle movements) • Location where wildlife was moved from and where it was moved to
9	**Method of results communication to the Environment Office**
	• The monitoring data must be presented to the Environment Office monthly, and in a final report submitted six months after the commencement of the construction work at KEP Research Station. • Any wildlife injury or fatality associated with the work should be reported immediately to the Environment Office, Station Leader and Government Officer and an AINME report submitted within 24 h.

B. Distribution and monitoring of breeding birds

1	**Monitoring type and purpose:**
	Nesting or burrowing birds in areas impacted by construction works. Breeding birds may be vulnerable to disturbance from construction activities therefore monitoring is essential to determine the extent and severity of impact. The data will also identify the locations of sensitive receptors near the quarry locations and the wharf construction works and will aid in the final positioning of noise, vibration and dust monitoring equipment.
2	**Description of the monitoring activity**
	Pre-construction and during construction monitoring to determine the impacts of wharf construction activities on breeding birds in the vicinity of works.
3	**Methodology used (equipment, thresholds)**
	The earliest arrival data for some species of breeding birds is expected during the month of September and the latest fledging expected in June. A walkover visual survey for nests and burrows, supported by call play back techniques for burrowing birds, will be undertaken once a month starting in early September and continuing until January (prior to construction works) in the following areas: ▪ Proposed quarry locations (quarry 1 and quarry 2) and extending the search to 100m from the quarry edge. ▪ All along the road/track between quarry 2 and KEP and up to 50m either side of the track ▪ All tussock grasses within KEP station The survey will record the locations (using GPS) of all occupied nests or burrows in these areas and monitor their progress from September to January prior to construction works beginning. Once construction works begin the survey frequency will change from monthly to twice a month until the completion of the project or the last birds have fledged.
4	**Designated person undertaking the monitoring**
	BAS: KEP Scientist
5	**Period over which monitoring will occur**
	▪ Monthly survey September 2019 to January 2020 (pre-construction) ▪ Twice a month survey January 2020 to completion of project (during construction)
6	**Frequency of monitoring**
	Monthly prior to construction and twice a month during construction
7	**Action(s) should any thresholds be exceeded**
	Any nests found within the tussock of quarry site 1 (which is due to be removed by excavation in January 2019) will need to be closely monitored to ensure that the site is free of birds when excavation is due to begin: ▪ Any eggs found in the tussock grass prior to mid-December will likely hatch and fledge before the construction works are due to begin and can be left undisturbed. ▪ Any nests or new eggs laid in the tussock from early January onwards are likely to delay the start of construction works by up to 2 weeks until the chicks fledge. In this situation, the nests and eggs will be removed from the tussock in quarry 1 and placed in a new location prior to hatching to ensure that no birds are nesting in quarry 1 when construction is due to begin.

8	**Recording and management of monitoring data**
	The data shall record all locations of nesting or burrowing birds by species indicating: new nests, abandoned nests and successful fledging.
9	**Method of results communication to the Environment Office**
	The data shall be presented to the Environment Office on a monthly basis until January and twice a month from January until the completion of the project.

C. Terrestrial noise from quarrying and construction activities

1	**Monitoring type and purpose:**
	Noise from quarrying and construction activities. Excessive noise may cause disturbance to local wildlife and needs to be monitored to ensure thresholds are not exceeded. Seals, which will not be breeding during the construction period, have the ability to move away from the source of noise. Birds which may be breeding during the construction period will have already established nesting sites and will therefore not be able to move from the source of noise without abandoning their eggs or chicks. For this reason, noise monitors will be positioned to monitor the noise at potential nesting areas in cliffs and tussock grass rather than the beaches.
2	**Description of the monitoring activity**
	Terrestrial Noise from quarrying and construction activities Monitoring will be carried out to measure the noise generated by construction activities, quarrying, rock screening, and plant operation.
3	**Methodology used (equipment, thresholds)**
	Noise shall be monitored using a Mabey Class 1 Noise Monitor One monitor shall be positioned at each of the following sites: • For construction works, in the vicinity of the tussock grass to the south of the boatshed. • For quarrying works, in either the tussock grass or the cliffs adjacent to quarry sites. The final positions of the monitors will be agreed on site, with the BAS Environment Office and KEP Zoological Assistant following the outcome of the monitoring for breeding birds (as described in section B of this plan). The daily sound exposure level (SEL) at these locations should not exceed 118.5 dB_A (onset of Temporary Threshold Shift in seals) The daily sound pressure level (SPL) at these locations should not exceed 93 $dB_{A12hour}$ (onset of Temporary Threshold Shift in Birds) The derivation of these limits are discussed in the terrestrial noise assessment.
4	**Designated person undertaking the monitoring**
	BAM Site Environmental Engineer
5	**Period over which monitoring will occur**
	Monitoring of construction works to continue for the entire construction period. Monitoring of quarrying to continue for the entire quarrying period
6	**Frequency of monitoring**
	Continuous
7	**Recording, reporting and management of monitoring data**

	• Noise data will be collected at the end of each day's work. • SPLs ($L_{Aeq\ 12\ Hour}$) and SELs ($LE_{A\ 12\ Hour}$) will be reported to the BAM construction manager and both the BAM and BAS Project Managers before the start of the next shift. Any instances of agreed limit exceedance will be reported immediately to the BAS Environment Office and an AINME raised. • All noise data will be backed up and sent to the BAS Environment Office on a monthly basis.
8.	**Routine noise mitigation methods to be employed**
	Before commencing use of particularly noisy equipment (e.g. piling hammer, hydraulic breaker or screener) consideration should be given to the impact upon wildlife. Animals on land (except nesting birds) are likely to move away from the noise source at the commencement of the activity. To allow this to occur a 'soft start' should be employed. This involves the gradual increasing of the noise of an activity. For example, if the drop hammer is used (the loudest item of plant), first the crane will be started, then the hammer power pack, then the hammer will be dropped from a small height and the height of the drop increased gradually until full height of drop is achieved. A resilient pad or dolly is to be used between the pile and the hammer head when the drop hammer is used to reduce the noise generated when the hammer strikes the pile.
9.	**Action(s) should any thresholds be exceeded**
	If limits are exceeded, works in the area where the exceedance was recorded will cease until consent to re-start is received from the BAS Environment Office. This may require the use of additional mitigation measures e.g. reduce hours of use or re-site high noise generating equipment, create bunds from extracted material, reduce the power of piling hammers etc.

D. Vibration from quarrying and construction activities

1	**Monitoring type and purpose:**
	Vibration from quarrying and construction activities. Excessive vibration is likely to cause damage to buildings. Vibration may also cause disturbance to local wildlife. Vibration levels will be monitored to ensure thresholds are not exceeded. Data on the effects of vibration on animals (particularly birds and seals) is not available. The effects of vibration on humans and limits for human exposure to vibration is well documented. Vibration levels that may cause damage to buildings are measured as an instantaneous level in mms-1. Human health vibration is measured over the working day in mms-1.75. Therefore the both measurements need to be taken to assess the impact on buildings and humans. Vibration meters will therefore be positioned close to buildings and humans where applicable.
2	**Description of the monitoring activity**
	Vibration from quarrying and construction activities Monitoring will be carried out to measure the vibration generated by construction activities, quarrying, rock screening, and plant operation.
3	**Methodology used (equipment, thresholds)**
	Vibration shall be monitored using a Mabey Triaxial Vibration Monitor One monitor shall be positioned at each of the following sites: • For construction works, on the concrete slab adjacent to the boatshed (nearest building). • For quarrying works, at the cliffs adjacent to quarry sites (buildings too far away to be affected where as birds sometimes nest in the cliffs). The final positions of the monitors are to be agreed on site with the BAS Environment Office and KEP Zoological Assistant following the outcome of the monitoring for breeding birds (as described in section B of this plan). Vibration levels should not exceed 15mms^{-1}* The Vibration Dose Value should not exceed 15ms$^{-1.75}$ for the 12 hour working day˜ * Based on transient vibration guide values for cosmetic damage in BS 7385 part 2. ˜ Based on the daily exposure limit to vibration in BS 6840:1987
4	**Designated person undertaking the monitoring**
	BAM Site Environmental Engineer
5	**Period over which monitoring will occur**
	Monitoring of construction works to continue for the entire construction period. Monitoring of quarrying to continue for the entire quarrying period
6	**Frequency of monitoring**
	Continuous

7	**Recording, reporting and management of monitoring data**
	• Vibration data will be collected at the end of each day's work. • Vibration levels and vibration dose values will be reported to the BAM construction manager and both the BAM and BAS Project Managers before the start of the next shift. Any exceedances of agreed limits will be highlighted and reported to the BAS Environment Office immediately and an AINME raised. • All vibration data will be backed up and sent to the BAS Environment Office on a monthly basis.
8.	**Routine vibration mitigation methods to be employed**
	Before commencing use of high vibration equipment (e.g. piling hammer, hydraulic breaker or screener) consideration should be given to the impact upon wildlife. Animals on land (except nesting birds) are likely to move away from the vibration source at the commencement of the activity. To allow this to occur a 'soft start' should be employed. This involves the gradual increasing of the vibration caused by an activity. For example, if the drop hammer is used (the loudest item of plant), first the crane will be started, then the hammer power pack, then the hammer will be dropped from a small height and the height of the drop increased gradually until full height of drop is achieved. A resilient pad or dolly is to be used between the pile and the hammer head when the drop hammer is used to reduce the vibration generated when the hammer strikes the pile.
9.	**Action(s) should any thresholds be exceeded**
	If limits are exceeded, works in the area where the exceedance was recorded will cease until consent to re-start is received from the BAS Environment Office. This may require the use of additional mitigation measures e.g. reduce hours of use or re-site high noise generating equipment, reduce the power of piling hammers etc. The behavior of wildlife in the area of monitoring (particularly nesting birds) should be closely monitored to determine whether the Vibration Dose Value limits set are applicable. As the effects of vibration on animal species are little understood, the limits chosen may need to be adjusted depending upon observed behavior.

E. Marine noise from construction activities

N.B. Marine activities likely to generate substantial levels of noise (vibro pilling, impact pilling,) shall not occur concurrently.

1	**Monitoring type and purpose:**
	Marine noise from construction activities (e.g. pile driving, compacting etc.). Marine noise has the potential to cause disturbance to marine wildlife. The underwater noise assessment modelling exercise (see appendix 13) indicated that noise levels at the source of the piling are relatively high but that it will attenuate/reduce rapidly as it travels away from its source. • Noise produced by vibro pilling and received by the key sensitive receptors (seals and seabirds) at the source is considered to have a negligible impact. • Noise produced by impact piling and received by the key sensitive receptors (seals and seabirds) at the source is considered to have a minor adverse impact. • Noise produced by both vibro and impact pilling and received by the key sensitive receptors outside of a 10m radius of the piling activity will have attenuated enough to no longer have an impact on hearing or behaviour. Within 500m from the source of piling (the approximate size of King Edward Cove), the received levels of noise are comparable to the source level of noise produced by a small or medium sized vessel. Monitoring is required to ensure that marine mammals and seabirds within a 10m radius of the works are not impacted by the noise produced by pilling activities.
2	**Description of the monitoring activity**
	Marine Mammal Observers (MMOs) will be deployed to watch for the presence of marine mammals in the vicinity of the wharf activities prior to the commencement of and during the activity.
3	**Monitoring Methodology (equipment, thresholds)**

	• Trained Marine Mammal Observers (MMOs) should be deployed prior to and during (1) vibro pilling and (2) impact pilling. • The MMOs shall be properly equipped for this purpose and be able to communicate with those responsible for the operations generating the noise. <u>Pre-pilling watch period</u> • The MMO should be satisfied that they have visibility within a 500m radius of the pilling, and should b e in place 10 minutes before operations begin. The MMO watch period prior to all pilling will be 10mins (no piling may occur during this time). - If whales are spotted within a 500m radius during the watch period then pilling cannot commence until the whale has left the area. The MMO must be satisfied that whales have left the area prior to pilling commencing. - The MMO will record the presence (by species) of seals and seabirds within a 10m radius (disturbance zone) during the 10 min watch period. - After the 10 min watch period, pilling can commence regardless of whether seals or birds are in the area. Standard soft start procedure will take place at the start of each piling activity. <u>Pilling soft-start</u> • The MMO must be satisfied that the standard soft start procedure for vibro and impact pilling (see below) is being followed. • The MMO will record the presence (by species) of seals within a 10m radius during the soft start procedure. • If whales are spotted within a 500m radius the soft start procedure will stop. <u>During pilling</u> • The MMO will record the presence (by species) of seals within a 10m radius during the pilling activities. • Any signs of unusual seal behavior will be reported to the BAS Environment Office within 24hrs and if necessary mitigation measures reviewed. • If whales are spotted within a 500m radius the MMO will instruct the pilling to stop until the whales have left the area.
4	**Designated person undertaking the monitoring**
	Designated MMO
5	**Period over which monitoring will occur**
	During periods of marine pilling in the vicinity of the wharf.
6	**Frequency of monitoring**
	Prior to the commencement and during pile driving.
	Routine noise mitigation measures
	• <u>Vibro pilling soft start</u> A soft start procedure (duration of 20mins) will be implemented prior to the start of vibro piling. The power will be gradually increased over this time to give marine mammals the opportunity to move away. • <u>Impact pilling soft start</u> A soft start procedure will be implemented prior to the full start of impact pilling. The height of the hammer drop will be gradually increased over time before it reaches its full height and full potential noise level.
7	**Action(s) should any thresholds be exceeded**
	• Piling activities will cease if whales are seen within the 500m radius. • Mitigation measures will be reviewed if the MMO reports unusual seal behavior changes.

8	**Recording and management of monitoring data**
	A log of marine mammal activity, by species where possible, and any consequent actions shall be maintained by each MMO throughout periods in which operations are taking place
9	**Method of results communication to the Environment Office**
	• The monitoring data must be presented to the Environment Office on a monthly basis. • If unusual behavior changes are observed, contact must be made with the Environment Office within 24 hours to discuss further options. • Any wildlife injury or fatality associated with the work should be reported immediately to the Environment Office and an AINME report submitted within 24 h.

F. Airborne dust

1	**Monitoring type and purpose:**
	Dus*t and Particulates* Dust and particulate are likely to be generated by quarrying activities and the transportation and deposition of the aggregates produced. Particulates could have a detrimental impact of the respiratory systems of birds, seals and visitors to KEP. The deposition of dust may have adverse impacts upon areas of vegetation.
2	**Description of the monitoring activity**
	Dus*t and Particulates from quarrying and construction activities* Monitoring will be carried out to measure the dust and particulates generated by construction activities, quarrying, rock screening, and plant operation.
3	**Methodology used (equipment, thresholds)**
	Vibration shall be monitored using a Mabey TSP Dust Monitor One monitor shall be positioned at each of the following sites: • For construction works, in the vicinity of the tussock grass to the south of the boatshed. • For quarrying works, in either the tussock grass or the cliffs adjacent to quarry sites. The final positions of the monitors will be agreed on site with the BAS Environment Office and KEP Zoological Assistant following the outcome of the monitoring for breeding birds (as described in section B of this plan). PM10 levels should not exceed 50µg/m^3 averaged over a 24 hour period* * Based on EU air quality standards.
4	**Designated person undertaking the monitoring**
	BAM Site Environmental Engineer
5	**Period over which monitoring will occur**
	Monitoring of construction works to continue for the entire construction period. Monitoring of quarrying to continue for the entire quarrying period
6	**Frequency of monitoring**
	Continuous
7	**Recording, reporting and management of monitoring data**

	• Dust data will be collected at the end of each day's work. • PM10 levels will be reported to the BAM construction manager and both the BAM and BAS Project Managers before the start of the next shift. Any exceedances of agreed limits will be highlighted and reported to the BAS Environment Office immediately and an AINME raised. • All dust data will be backed up and sent to the BAS Environment Office on a monthly basis.
8	**Routine dust mitigation methods to be employed**
	The screener and crusher will either be fitted with seawater spray bars or a member of staff will be on hand to water down the activities. Stockpiles are to be damped down with sea water if required Backfill material to be damped down with sea water if required
9	**Action(s) should any thresholds be exceeded**
	If limits are exceeded, works in the area where the exceedance was recorded will cease until consent to re-start is received from the BAS Environment Office. This may require the use of additional mitigation measures e.g. reduction of hours of dust generating plant use particularly when the prevailing wind is blowing toward sensitive receptors.

G. Marine benthic invertebrate communities

1	**Monitoring type and purpose:**
	Marine benthic invertebrate communities. Marine invertebrate communities on the sea floor may be vulnerable to disturbance from construction activities, making monitoring essential to determine the extent and severity of impact.
2	**Description of the monitoring activity**
	Post-construction monitoring to determine the impacts of wharf construction activities on the benthic marine communities in the vicinity of the wharf.
3	**Methodology used (equipment, thresholds)**
	ROV survey will be used in 2020/2021 to determine the degree of change in benthic community, relative to survey undertaken in June 2018.
4	**Designated person undertaking the monitoring**
	Ben Robinson (NERC PhD student with Southampton University)
5	**Period over which monitoring will occur**
	June 2018 and April 2021.
6	**Frequency of monitoring**
	Before construction programme commences and after the construction programme has been completed
7	**Action(s) should any thresholds be exceeded**
	N/A
8	**Recording and management of monitoring data**
	All data will be managed in accordance with existing BAS standards and curation protocols.
9	**Method of results communication to the Environment Office**
	Summary reports will be delivered to the Environment Office, as data is analysed. A report will also be prepared for BAS Environment Office at the end of the benthic monitoring.

H. Environmental management activities and reporting

A number of specific environmental management activities will be undertaken by the construction partner, as indicated in the table below and as referenced in more detail throughout the EIA and its appendices, and the data or findings will be reported to the BAS Environment Office.

Environmental Management Activity	Location in EIA	Reporting Output
Biosecurity: Implementation of the KEP Biosecurity Plan at all stages of cargo and personnel movement	Appendix 6 – KEP Biosecurity Plan	▪ Biosecurity Checklists ▪ Biosecurity breaches reported
Waste Management: segregation, packaging, storage and disposal of waste as per the SWMP and BAS WMH	Appendix 9 – Site Waste Management Plan	▪ Waste Transfer Notes ▪ Waste Data
Fuel Management: daily refuelling as per refuelling procedure.	BAM refuelling procedure – Section 5.1.1.	▪ Training records of refuellers ▪ Fuel spills reported ▪ Fuel consumption for carbon accounting
Oil Spill response: BAM staff will respond to all Tier 1 spills and follow the direction of KEP Station Leader for all Tier 2 and Tier 3 spills. BAM will provide appropriate spill response equipment.	BAM Oil Spill Contingency – Section 5.1.2 BAM Spill Response Equipment – Section 5.1.3	▪ Fuel spills reported ▪ Spill kits used and disposed of appropriately
Noise reduction: BAM staff will implement a soft start procedure for all noisy equipment and trial a resilient pad when using the impact hammer.	Noise mitigation measures Sections 10.2.15 and 10.2.16 Sections C and E of this monitoring plan	▪ Written feedback on the implementation and success of these measures as part of the EIA review process.
Dust suppression: BAM staff will implement a number of measures to suppress airborne dust during construction works including halting work during periods of high wind and damping down dust producing activities.	Dust mitigation measures Section 10.2.14 Section F of this monitoring plan	▪ Written feedback on the implementation and success of these measures as part of the EIA review process.
Quarry tussock grass replanting: BAM staff will attempt to replant the removed tussock to quarry site 1 after completion of works	Tussock mitigation measures – Section 10.2.21	▪ Written feedback on the success of the tussock replanting as part of the EIA review process.

Appendix 12 – Terrestrial Noise Assessment

Antarctic Construction Partnership – King Edward Point

Employer	NERC/British Antarctic Survey	Project Number	BAA4010
Tech Adv	Ramboll	Document Number	BAA4010-BAM-ZZ-YYY-RC-YE-0004
Contractor	BAM	Revision	P02

King Edward Point - Terrestrial Noise Assessment

Reference Sheet

Document Number	Description
BAA4010-BAM-ZZ-YYY-MS-W-0001	King Edward Point Method Statement
BAA4010-BAM-ZZ-YYY-SP-W-0002	Project Execution Plan
BAA4010-BAM-ZZ-YYY-RC-YE-0003	Construction Environmental Management Plan
BAA4010-BAM-ZZ-YYY-RP-YG-0005	KEP Site Visit Report – Quarrying
	Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (published by NOAA)
	Fieldwork at Año Nuevo. Colleen Reichmuth, Caroline Casey, and others
	In-air and underwater hearing sensitivity of a northern elephant seal (Mirounga angustirostris) by D. Kastak and R.J. Schusterman (1999)
	Effects of Continuous Noise on Avian Hearing and Vocal Development by Peter Marler et al.
	Effects of Traffic Noise and Road Construction Noise on Birds (published by the California Department of Transport)
	University of Rhode Island – Discovery of Sound in the Sea (Website)
	BS5228 Part 1

Revision History

Revision	Date	Revision Description

Prepared by		Approved by
NGO		DAL
Author	Project	Operations Director/Other

Status Definition (latest revision)	Total number of pages (Excluding attachments)
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Uncontrolled when printed, unless stamped in RED to the contrary.

Table of contents

1 Introduction

1.1 Purpose

This assessment has been carried out to evaluate the environmental impact of noise generated from the reconstruction of the wharf at King Edward Point (KEP) research station and the associated quarrying works.

The main noise generating activities associated with the wharf construction which have been assessed for their impact are;

- Piling operations
- Quarry operations
- Material transportation
- Backfilling operations

1.2 Project Background

King Edward Point (KEP) research station is situated within East Cumberland Bay on the island of South Georgia; a British Overseas Territory in the southern Atlantic Ocean. South Georgia is approximately 1,600 km east south-east of the Falkland Islands. KEP research station is operated by the British Antarctic Survey (BAS) on behalf of the Government of South Georgia and South Sandwich Islands (GSGSSI). The research station comprises: living accommodation, science laboratories, boatshed, biosecurity facility, fuel storage facilities, meteorological and communications equipment, equipment storage and waste treatment facilities. Access can only be made by sea via the existing wharf at KEP. A gravel track leads from KEP to a former whaling station at Grytviken.

In summer, elephant seals and fur seals breed on the beach in front of the research station. Across Cumberland East Bay, the Barff Peninsula is a favourite area for King Edward Point staff to take recreational travel trips to visit the king penguins at St Andrew’s Bay.

South Georgia has abundant populations of seabirds, including penguins. Several sites are within walking distance of King Edward Point.

BAS plan to upgrade the existing wharf at KEP research station for use by the Royal Research Ship (RRS) Sir David Attenborough (SDA). Funding for the project is divided between the GSGSSI and the Natural Environment Research Council (NERC). The primary aim of the project is to upgrade the existing wharf as necessary to enable safe and efficient berthing and mooring of the SDA and other defined vessels, as well as safe and efficient transfer of personnel and cargo.

A supplementary aim is to upgrade the small boat facility for the safe and efficient launch and retrieval of small boats, and for transfer of their personnel and cargoes. This is to be achieved through upgrading the existing slipway.

2 Legislative Framework and Policy Context

South Georgia & the South Sandwich Islands are a self-governing Overseas Territory of the United Kingdom. Laws for South Georgia & the South Sandwich Islands are made by the Commissioner for the Territory who can make 'Ordinances', which are primary legislation, and can make secondary legislation 'Orders and Regulations'.

Wildlife in South Georgia is protected in legislation by The Wildlife and Protected Areas Ordnance 2011. Under the provisions of this legislation it is an offence to kills, injure, capture, handle or molest any wild bird or mammal.

Construction works on South Georgia require the completion of a Regulated Activities Permit. This permit requires the completion of an environmental risk assessment. This document will be used to inform of the risks associated with construction noise at KEP and Grytviken.

3 Assessment Methodology

This assessment consists of two parts

- An assessment of the sensitive receptors in the vicinity of the works and their sensitivity to noise
- simple calculations to predict the noise levels at sensitive receptors

An assessment of sensitive terrestrial environmental receptors at KEP has been undertaken by Kevin Hughes of BAS. This has provided information on species present in the area, their location and their breeding dates. Information on species sensitivity to noise has been sought from academic papers on the subject.

Calculations of noise propagation have been carried out in accordance with BS5228 Part 1, Code of Practice for Noise and Vibration Control on Construction and Open Sites. Noise levels for construction operations have been taken from Annex C. Where the exact activity and plant item are not available, the next largest piece of plant has been used in order to produce a conservative assessment.

4 Receptors

4.1 Ecology

4.1.1 Seals

Southern Elephant Seals (Mirounga leonine) breed on the long gravel beach next to the buildings at King Edward Point. During the breeding season from September to December, territorial males defend their harems. Females give birth shortly after coming ashore and stay with the pup throughout the 28-day lactation period. Adults then return to the sea. The pups enter the sea by the end of the year. Adults return to the shore to moult between November and April depending on their size and age. Elephant and fur seals can be found on land around the cove at any time of the year (see table 4.1.1).

South Georgia Fur Seals (Arctocephalus tropicalis) breed from November to January, their main breeding areas are near Horse Head on the opposite side of King Edward Cove. Breeding bulls return in late October to early November, with females following and peaking in pupping in mid-December. Females continue to feed in South Georgia waters spending four days on average foraging at sea. Pups wean in April at which time females disperse from the Island. Although the majority disperse during winter, the fur seals can be seen year-round (noticeably young males).

Figure 4.1.1 Areas habituated by Seals

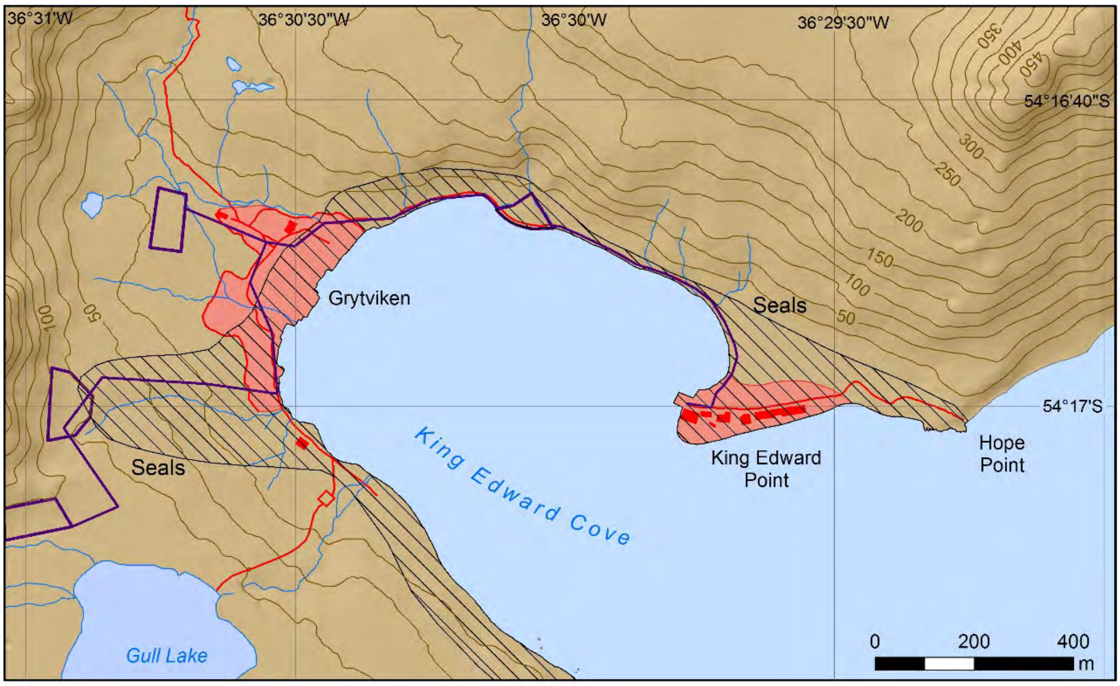


Table 4.1.1 Ecological Calendar for Elephant Seals

CLASS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Pups									X	X	X	Rare
Weanlings	X									X	X	X
Yearlings	M	Rare	Rare	Rare	X	X	X	X	X	Rare	M	M
Juveniles	M	M	Rare	Rare	Rare	X	X	X	X	Rare	M	M
Sub-adult males	Rare	M	M						B	B	B	B
Adult males		Rare	M	M					B	B	B	B
Adult females	M	M							B	B	B	B M

Key: Elephant seals on land. B = breeding; M = moulting; X = general presence

(Elephant Seal Research Group & FIG Environmental Department).

4.1.2 Birds

King Penguins (Aptenodytes patagonicus) and Gentoo Penguins (Pygoscelis papua) do not breed in the King Edward Cove but are present throughout the year.

The South Georgia Pintail (Anas georgica georgica) is endemic to South Georgia. It nests in in fresh water ponds above King Edward Cove. They have a long breeding season from late October to early March.

The South Georgia Pipit is also endemic to South Georgia. It breeds at low elevation in tussac grassland, often near streams and inland pools. It is often seen foraging on rocky shores among kelp. The breeding season occurs between mid-November and January/February.

White-chinned Petrels (Procellaria aequinoctialis) nest in burrows in the tussock grass close to the station. They lay their single egg between November and December and the chick fledges in April or May. They are attracted to light sources make the species vulnerable to bird strikes.

Antarctic Terns (Sterna vittata) nest in the scree behind Grytviken. Eggs are laid in November/December and both adults incubate for 23-25 days. They fledge 27-32 days after hatching. They are still fed by the adults for some days more.

South Georgia Terns (Sterna vittata) nest on the scree between Grytviken and King Edward Point. Eggs are laid in November and are incubated for 23 days. The chicks fledge after 27 days.

Kelp Gulls nest in Grytviken between September and January with the chicks fledging in January or February.

Light Mantled Albatross (Phoebetria palpebrata) breed biannually n the cliffs above KEP. They lay their eggs in October or November with chicks fledging 141-170 days later (June).

Figure 4.1.2 Breeding Sites for Birds at KEP and Grytviken

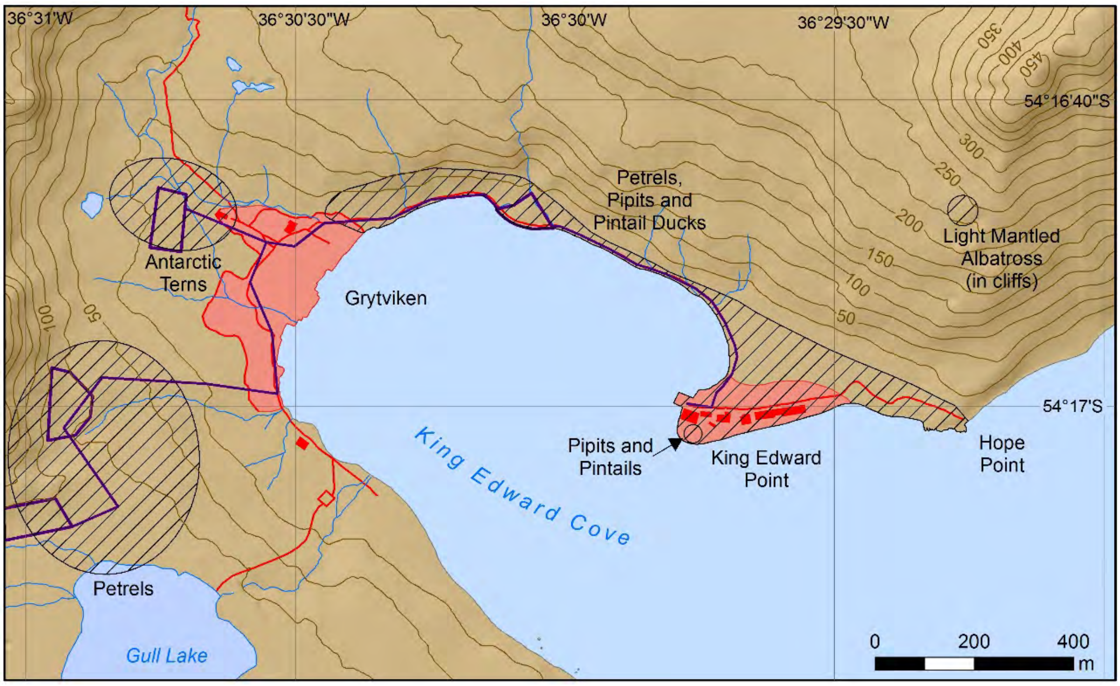


Table 4.1.2 Breeding Dates for Birds at KEP and Grytviken

	Breeding Species	Earliest Laying	Latest Fledging
1	light-mantled albatross	October	June
2	Wilson's storm petrel	December	March
3	white-chinned petrel	November	April
4	South Georgia pintail	November	March
5	South Georgia pipit	November	February
6	Antarctic tern	November	March
7	Brown Skua	November	February

4.2 Humans

A number of BAS scientist and support staff work at King Edward Point Research Station. Grytviken, close to King Edward Point, is a popular tourist destination, attracting around 9,000 cruise passengers a year plus up to 6,000 ships crew. Tourist visit to see the abundant wildlife as well as to visit the old whaling station, museum and church.

4.3 Receptor Locations to be Assessed.

Based on the distribution of the receptors discussed and the areas where the majority of noise will be generated from construction activities, three locations have been chosen.

- The beach adjacent to the Wharf. Assessed for the effects of construction noise on Seals.
- The beach adjacent to proposed Quarry location 1. Assessed for the effects of construction noise on nesting birds.
- Grytviken Museum. Assessed for the effects of construction noise on humans.

Noise will be modelled at these locations and compared with thresholds which are discussed in the next section of this assessment.

5 Sensitivity of Receptors

5.1 Seals

Much research has been carried out into the levels of noise that cause both temporary threshold shift (TTS) and permanent threshold shift (PTS) in marine mammals, although this research typically looks at underwater sources of anthropogenic noise. The National Oceanic and Atmospheric Administration (NOAA) has published Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing which was last revised in April 2018. This document classifies marine mammals into 6 categories and provides underwater noise levels for the onset of TTS and PTS in each category. The 2 categories of interest for this assessment are Otariids (incl. Fur Seals) and Phocids (incl. Elephant Seals).

No information on the noise levels required to induce hearing loss in seals in air has been found.

The NOAA Technical Guidance gives the following levels for the onset of TTS in water

- Otariids 199 dB SEL re 1 $\mu Pa^2 s$
- Phocids 180 dB SEL re 1 $\mu Pa^2 s$

Sound waves with the same intensities in water and air when measured in watts per square meter have relative intensities that differ by 61.5 dB. This amount must be subtracted from sound levels in water referenced to 1 micro Pascal (μPa) to obtain the sound levels of sound waves in air referenced to 20 micro Pascals (μPa) that have the same absolute intensity in watts per square meter. The difference in reference pressures causes 26 dB of the 61.5 dB difference. The differences in densities and sound speeds account for the other 35.5 dB. (From University of Rhode Island – Discovery of Sound in the Sea Website)

Therefore, referenced to 20 micro Pascals in air the following levels for the onset of TTS can be calculated.

- Otariids 137.5 dB SEL re 20 $\mu Pa^2 s$
- Phocids 118.5 dB SEL re 20 $\mu Pa^2 s$

Sound Exposure Level (SEL) is the numerically equivalent to the total sound energy and is normalised to 1 second.

Whilst this method for developing a threshold for TTS in air cannot be proved, experiments by D. Kastak and R.J. Schusterman (1999) show that the threshold of hearing of Elephant seals in water is 19 dB lower than corresponding in-air thresholds when compared in terms of sound pressure, and 52 dB lower when compared in terms of sound intensity. The Sound exposure levels calculated for the onset of TTS are therefore probably conservative.

Further evidence of the poor hearing of elephant seals in air is also discussed in the paper. Acoustic signals produced by this animal in air are loud and repetitious and are sometimes accompanied by exaggerated visual displays (Bartholomew and Collias 1962). Additionally, it has been suggested that seismic cues, produced by displaying males slamming their forequarters on the ground, are important in intra-individual signalling (Shipley et al. 1992)

Elephant Seal calls on land need to be loud in order to overcome ambient noise, especially that of the wind and surf. The peak loudness has been recorded at 126 dB, which is among the loudest of mammal sounds on land, according to fieldwork carried out at Año Nuevo by Colleen Reichmuth, Caroline Casey, and others (No weighting was mentioned in this report).

5.2 Birds

Construction noise can have several effects on birds. Low levels of noise can produce behavioural and/or physiological response. Increasing levels of noise will mask communication signals between birds. Still higher levels of noise are likely to cause temporary or permanent damage to the hearing organs which is shown as a shift in the hearing threshold.

Marler et al (1973) subjected canaries to sound pressure levels of 95 to 100 dB for 40 days which produce a 20dB threshold shift. Although the frequency spectrum was not entirely flat, it covered the hearing range of the canary and was not heavily weighted in any one part of it. The paper, “the paper Effects of Continuous Noise on Avian Hearing and Vocal Development” looked at the development of vocalisation in canaries and did not consider the levels of onset of threshold shifts.

The California Department of Transport published guidelines in 2016 on the Effects of Traffic Noise and Road Construction Noise on Birds. This document suggests that continuous traffic and construction noise above a sound pressure level of 93 dB_A may cause TTS.

5.3 Humans

The effects of noise on humans can be considered in two ways; disturbance and health.

BS5228 looks at the disturbance caused by construction noise and outlines methods for methods for assessing the significance of the disturbance to humans. The two main methods outlined are;

- Significance based on fixed noise limits
- Significance based upon noise change

As background noise level across all areas where construction noise may cause an impact is not available, only significance based on fixed noise limits can currently be assessed.

The standard states that, where construction noise exceeds ambient noise levels, between 07.00 and 19.00 Monday to Friday (07.00−13.00 Saturdays), construction noise should not exceed 70dB. A significant effect is deemed to occur if the total A weighted equivalent sound pressure level (L_{Aeq}) for the period increases by more than 3 dB due to construction activity.

The Minerals Policy Statement (MPS2) suggests limits for works involving the haulage of materials. MPS2 suggests that the A weighted equivalent sound pressure level limit of 55 dB $_{LAeq,\,1\,h}$ is adopted for daytime construction noise for these types of activities, but only where the works are likely to occur for a period in excess of six months. This limit is to be measured as a free field measurement at noise-sensitive properties.

Under the Health and Safety of Work Act, producers of noise associated with work activities have a duty of care toward the public. The Control of Noise at Work regulations require employers to protect persons against risk to their health and safety arising from exposure to noise at work. These regulations only cover the protection of employees, however the action levels set in the regulations can be useful in assessing the impacts of noise on the public. Three action levels are set:

- Lower exposure action value — a daily or weekly personal noise exposure of 80dBA
- Upper exposure action level — a daily or weekly personal noise exposure of 85dBA
- Exposure limit value — a daily or weekly personal noise exposure of 87dBA

If an employee is subjected to the lower exposure action level, the employee must make hearing protection available. Above the upper exposure action level, hearing protection is compulsory. The exposure limit value is an absolute limit of the level of noise an employee can be subjected to (after attenuation from hearing protection is taken into account).

Unlike employees, tourists at Grytviken have the option of moving away from the source of construction noise, but all efforts should be made to reduce the noise levels in public places to below 80dB L_{Aeq}

6 Construction Noise Sources

6.1 Derivation of Construction Noise Outputs

This assessment has considered the predicted noise produced by the construction works on a single theoretical day where the majority of large plant on site will be in use. The plant on this theoretical day will be distributed across 4 work sites. An assessment has been made of the actual working time of each piece of plant. Noise levels for each piece of plant are obtained from appendix C of BS 5228 Part 1. Where data for the exact item of plant and activity it's performing are not available, the closest similar plant item / activity has been used.

Table 6.1 Derivation of Construction Noise Outputs

Plant Item Used	Plant Item used in Assessment	Activity	Location	Data Source	L_{Aeq} at 10m (dB_A)
30 Tonne Excavator	47 Tonne Excavator	Face shovel loading dump trucks	Quarry 6 or 1	Table C9-6	91
Screener	Crusher	Breaking boulders/oversized material	Quarry 6 or 1	Table C9-15	96
24 Tonne Wheeled Loader	25 Tonne Wheeled Loader	Loading materials in open cast sites	Quarry 6 or 1	Table C6-33	82
25 Tonne Dump truck	25 Tonne Dump truck	Distributing Materials	Moving between Quarry and Wharf	Table C4-1	81
Crane with Piling Hammer	Hydraulic Hammer Rig	Tubular steel piling – hydraulic hammer	Wharf	Table C3-3	88
	Vibratory Piling Rig	Sheet steel piling – vibratory		Table C3-8	
30 Tonne Excavator	30 Tonne Excavator	Excavation / Earthworks	Mooring Dolphin	Table C2-17	75
Plate Compactor	Plate Compactor	Site Preparation	Mooring Dolphin	Table C2-41	80

6.2 Adjustment to Noise Outputs

The noise outputs derived above show the A weighted continuous sound pressure levels (L_{Aeq}) at a distance of 10m from the plant item. The calculation of noise levels at the position of the receptor requires adjustments to be made to account for the attenuation of the sound waves due to the distance travelled and any screening of the sound waves between source and receptor.

6.2.1 Topography

KEP is situated at the entrance to King Edward Cove, a small bay within Cumberland East Bay. Grytviken, a disused whaling station popular with tourists, lies at the head of the Cove approximately 800m from KEP.

The works will be located at the wharf in KEP with ancillary quarry sites at either Q1, Q6 or both (see figure 6.2.1).

Whilst the topography of South Georgia is extremely mountainous, both Grytviken and KEP lie on the coast on relatively flat terrain. There is an almost clear line of sight from the proposed construction areas to all areas of KEP and Grytviken, therefore it is assumed in this assessment that no attenuation of sound waves will occur.

Figure 6.2.1 Location of Construction Activities

6.3 Units of results

Construction noise is normally reported as equivalent continuous sound pressure levels (L_{eq}) and calculations using BS5228 also produce outputs in L_{eq}. The level of onset of TTS is reported as a sound exposure level (SEL). In order to produce outputs of construction noise as an SEL, the total energy of the construction works over the 12-hour period calculated in BS5228 will need to be expressed as a single event of 1 second. This can be calculated using the formula below.

$SEL = L_{Aeq} + 10\log T/T_0$ where T_0 = 1 second and T = 43,200 seconds (12 hours)

7 Calculations

7.1 Receptor - Grytviken Museum, (Calculations based on Quarry 1 operation)

Plant Item	Location	L_{Aeq} at 10m	Distance d	Distance Adjustment 20xlog(10/d)	Resultant L_{Aeq}	Distance Ratio*	Equivalent On Time**	Duration of Activity	Duration as a % of 12h D	Correction to Resultant L_{Aeq} 10xlog(D/10)	Max Activity SPL	Activity SPL 12 Hour	Activity SEL L_{Aeq} + 46.3
		(dB_A)	(m)	(dB)	(dB)			(h)	(%)	(dB)	(dB_A)	($dB_{Aeq\ 12\ h}$)	(dB)
30 Tonne Excavator	Quarry 1	91	530	-34	57			6	50	-3	57	54	100
Screener	Quarry 1	96	530	-34	62			6	50	-3	62	59	105
24 Tonne Wheeled Loader	Quarry 1	82	530	-34	48			5	42	-4	48	44	90
25 Tonne Dump truck	Between Quarry 1 and the Wharf	81	530	-34	47	1.0	0.63	6	40	-4	47	41	88
Crane with Piling Hammer	Wharf	87	840	-38	49			4	33	-5	49	44	90
30 Tonne Excavator	Mooring Dolphin	75	840	-38	37			3	25	-6	37	30	77
Plate Compactor	Mooring Dolphin	80	840	-38	42			4	33	-5	42	37	83
Totals (logarithmic addition)											**66**	**60**	**106**

*Distance Ratio = Traverse Length / Minimum Distance

**Equivalent On Time derived from Distance Ratio and taken from F.2 in BS5228 Part 1

7.2 Receptor - Grytviken Museum, (Calculations based on Quarry 2 operation)

Plant Item	Location	L_{Aeq} at 10m	Distance d	Distance Adjustment 20xlog(10/d)	Resultant L_{Aeq}	Distance Ratio*	Equivalent On Time**	Duration of Activity	Duration as a % of 12h D	Correction to Resultant L_{Aeq} 10xlog(D/10)	Max Activity SPL	Activity SPL 12 Hour	Activity SEL L_{Aeq} + 46.3
		(dB_A)	(m)	(dB)	(dB)			(h)	(%)	(dB)	(dB_A)	($dB_{Aeq\ 12\ h}$)	(dB)
30 Tonne Excavator	Quarry 2	91	380	-32	59			6	50	-3	59	56	102
Screener	Quarry 2	96	380	-32	64			6	50	-3	64	61	107
24 Tonne Wheeled Loader	Quarry 2	82	380	-32	50			5	42	-4	50	47	93
25 Tonne Dump truck	Between Quarry 2 and the Wharf	81	380	-32	49	1.9	0.4	6	40	-4	49	42	88
Crane with Piling Hammer	Wharf	87	840	-38	49			4	33	-5	49	44	90
30 Tonne Excavator	Mooring Dolphin	75	840	-38	37			3	25	-6	37	30	76
Plate Compactor	Mooring Dolphin	80	840	-38	42			4	33	-5	42	37	83
Totals (logarithmic addition)											**66**	**63**	**109**

*Distance Ratio = Traverse Length / Minimum Distance

**Equivalent On Time derived from Distance Ratio and taken from F.2 in BS5228 Part 1

7.3 Receptor – Beach Adjacent to Quarry 1, (Calculations based on Quarry 1 operation)

Plant Item	Location	L_{Aeq} at 10m	Distance d	Distance Adjustment 20xlog(10/d)	Resultant L_{Aeq}	Distance Ratio*	Equivalent On Time**	Duration of Activity	Duration as a % of 12h D	Correction to Resultant L_{Aeq} 10xlog(D/10)	Max Activity SPL	Activity SPL 12 Hour	Activity SEL L_{Aeq} + 46.3
		(dB_A)	(m)	(dB)	(dB)			(h)	(%)	(dB)	(dB_A)	($dB_{Aeq\ 12\ h}$)	(dB)
30 Tonne Excavator	Quarry 1	91	10	0	91			6	50	-3	91	88	134
Screener	Quarry 1	96	10	0	96			6	50	-3	96	93	139
24 Tonne Wheeled Loader	Quarry 1	82	10	0	82			5	42	-4	82	78	124
25 Tonne Dump truck	Between Quarry 1 and the Wharf	81	10	0	81	54.5	0.06	6	40	-15	81	66	112
Crane with Piling Hammer	Wharf	87	400	-32	55			4	33	-5	55	50	96
30 Tonne Excavator	Mooring Dolphin	75	400	-32	45			3	25	-6	45	39	85
Plate Compactor	Mooring Dolphin	80	400	-32	48			4	33	-5	48	43	89
Totals (logarithmic addition)											**97**	**94**	**140**

*Distance Ratio = Traverse Length / Minimum Distance

**Equivalent On Time derived from Distance Ratio and taken from F.2 in BS5228 Part 1

7.4 Receptor – Beach Adjacent to Wharf, (Calculations based on Quarry 1 operation)

Plant Item	Location	L_{Aeq} at 10m	Distance d	Distance Adjustment 20xlog(10/d)	Resultant L_{Aeq}	Distance Ratio*	Equivalent On Time**	Duration of Activity	Duration as a % of 12h D	Correction to Resultant L_{Aeq} 10xlog(D/10)	Max Activity SPL	Activity SPL 12 Hour	Activity SEL L_{Aeq} + 46.3
		(dB_A)	(m)	(dB)	(dB)			(h)	(%)	(dB)	(dB_A)	($dB_{Aeq\ 12\ h}$)	(dB)
30 Tonne Excavator	Quarry 1	91	400	-32	59			6	50	-3	59	56	102
Screener	Quarry 1	96	400	-32	64			6	50	-3	64	61	107
24 Tonne Wheeled Loader	Quarry 1	82	400	-32	50			5	42	-4	50	46	92
25 Tonne Dump truck	Between Quarry 1 and the Wharf	81	10	0	81	54.5	0.06	6	40	-15	81	66	112
Crane with Piling Hammer	Wharf	87	10	0	87			4	33	-5	87	82	128
30 Tonne Excavator	Mooring Dolphin	75	10	0	75			3	25	-6	75	69	115
Plate Compactor	Mooring Dolphin	80	10	0	80			4	33	-5	80	75	121
Totals (logarithmic addition)											**89**	**83**	**129**

*Distance Ratio = Traverse Length / Minimum Distance

**Equivalent On Time derived from Distance Ratio and taken from F.2 in BS5228 Part 1

7.5 Summary of Calculations

With Quarry 1 in operation, the predicted noise levels are as follows:

Receptor Location	SPL Limit	SEL Limit	Predicted Max SPL	Predicted SPL 12 Hour	Predicted SEL
	($dB_{A\ 12\ hour}$)	(dB)	(dB_{A})	($dB_{A\ 12\ hour}$)	(dB)
Grytviken Museum	80*	N/A	66	60	106
Adjacent to Quarry 1	$93^{\sim}$	118.5^{+}	97	94	140
Adjacent to Wharf	$93^{\sim}$	118.5^{+}	89	83	129

With Quarry 2 in operation, the predicted noise levels are as follows:

Receptor Location	SPL Limit	SEL Limit	Predicted Max SPL	Predicted SPL 12 Hour	Predicted SEL
	($dB_{A\ 12\ hour}$)	(dB)	(dB_{A})	($dB_{A\ 12\ hour}$)	(dB)
Grytviken Museum	80*	N/A	66	63	109
Adjacent to Quarry 1	$93^{\sim}$	118.5^{+}	Not assessed	Not assessed	Not assessed
Adjacent to Wharf	$93^{\sim}$	118.5^{+}	Not assessed	Not assessed	Not assessed

* Limit applicable for humans and to be compared with max SPL
$^{\sim}$ Limit applicable for birds and to be compared with 12-hour SPL
$^{+}$ Limit applicable for seals and to be compared with SEL

8 Results and Conclusions

8.1 Quarry 1 Operational

With quarry 1 operational and piling and backfilling operations taking place at the Wharf and Mooring Dolphin respectively, the predicted maximum sound pressure levels in Grytviken will be suitably low so as not to cause a significant disturbance to humans without additional mitigation measures.

The beach close to the quarry site is predicted to experience sound pressure levels of 94 $dB_{LAeq\ 12\ hour}$ and sound exposure levels over the 12 hours of 140 dB. These levels are just above the sound pressure level threshold for TTL in birds and significantly above the sound exposure level threshold for TTL in seals.

The beach close to the piling operations is predicted to experience sound pressure levels of 89 $dB_{LAeq\ 12\ hour}$ and sound exposure levels of 129dB. These levels are below the sound pressure level threshold for TTL in birds and significantly above the sound exposure level threshold for TTL in seals.

8.2 Quarry 2 Operational

With quarry 2 operational and piling and backfilling operation taking place at the Wharf and Mooring Dolphin respectively, the predicted maximum sound pressure levels in Grytviken will be suitably low so as not to cause a significant disturbance to humans without additional mitigation measures. The predicted sound pressure levels at the beach adjacent to Quarry 1 have not been assessed as these will be less than with quarry 1 operational. The sound pressure levels close to quarry 2, whilst quarry 2 is operational will however be similar to those at quarry 1 with quarry 1 operational i.e. just above the limit of 93 dB. The sound exposure level at the seal breeding areas close to the wharf have not been assessed as these will be less than with quarry 1 operational. However, they will still be above the sound exposure level threshold.

8.3 Conclusions

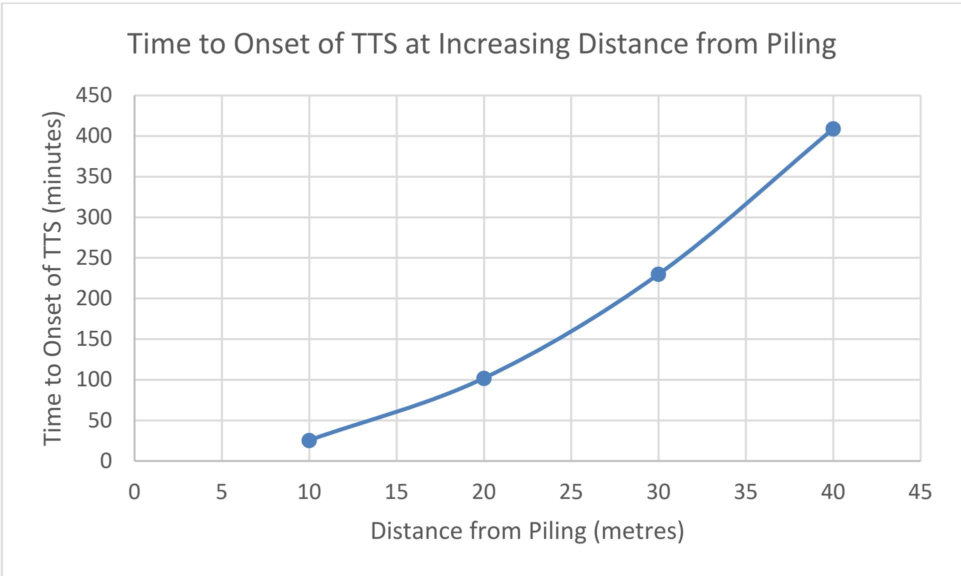
With quarry 1 operational, the sound exposure levels at both 10m from the wharf and 10m from the quarry are such that they pose a risk to damaging the hearing of seals in these locations. There is also a lesser risk of impairing the hearing of birds at 10m from the quarry.

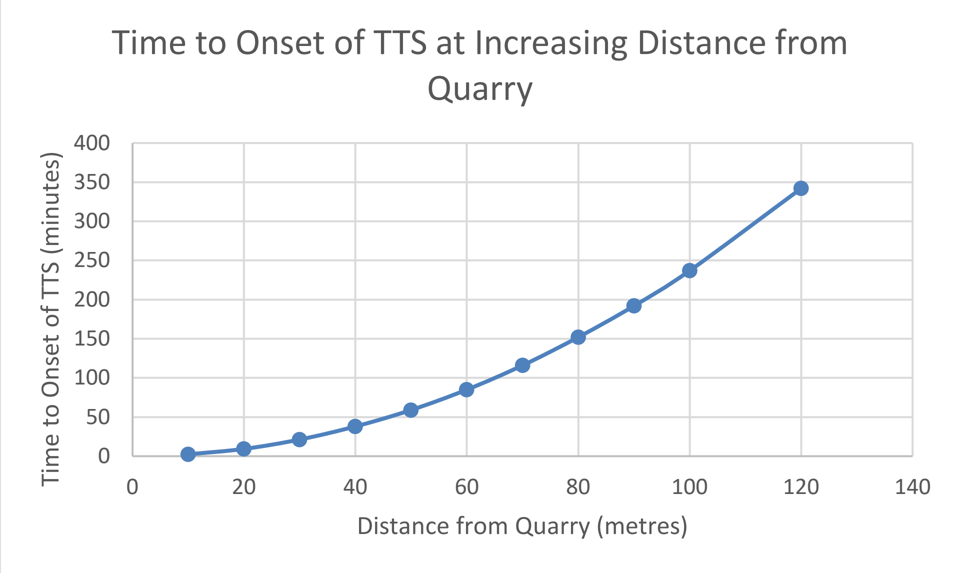
With quarry 2 operational, the risk of damaging the hearing of seals at 10m from the piling and 10m from the quarry remain as does the lesser risk of impairing the hearing of birds 10m from the quarry.

The sound pressure levels at Grytviken Museum are predicted to be suitably low so as not to cause a significant disturbance to humans without additional mitigation measures.

At both the quarry and the piling sites, it has been assumed in this assessment that the receptors, be they seals or birds, will be 10m from the source of the noise. The assessment does not consider the freedom of movement of seals. Noise levels falls away sharply with an increase in distance from the source, and if disturbed it can be assumed that seals will move further away from the source of the noise.

The graphs below show the increase in time of exposure leading to temporary threshold shift in seals at increasing distance from both the piling and quarrying works.





Predictions from the construction team are that the plant involved in piling works are likely to be operational for 4 hours per day and quarrying plant for 6 hours per day. The distance to which seals would need to retreat in order to avoid temporary threshold shift would therefore be 120m from the quarry and 30m from the piling works.

This simplified approach of this assessment considers the noise source to be coincident, when in reality sources of noise could be between 10m and 100m apart, particularly at the quarry. For this reason, the distances calculated for the onset of temporary threshold shift are very conservative.

With quarry 1 operational, the sound pressure level at a distance of 10m is just above the level at which temporary threshold shift in birds could occur and above levels at which communication signals between birds will be masked. As the area is a breeding ground for numerous bird species (including the islands only song bird, the Pipit), mitigation measures should be employed to limit the noise produced by the construction works.

8.4 Mitigation measures

The following mitigation measure may be used to reduce the impact of construction noise.

<u>Programme works to avoid breeding seasons</u>

Birds and seals will be more susceptible to the impacts of noise during the breeding season as the presence of eggs or pups may prevent parents from moving away from the sources of noise. Quarrying and piling works are due to start in the first week of February by which time elephant seals pups will have left the beaches although fur seal pups may still be present on the beaches and the surrounding tussock grass. Although pipets chicks fledge in February, petrels and pintail chicks are unlikely to fledge until March or April.

<u>Positioning of Plant</u>

Careful positioning of plant items, ensuring exhaust outlets point away from sensitive receptors, can help reduce the noise received by those receptors. Positioning plant as far as possible from site boundaries with environmentally sensitive areas will also reduce noise received by receptors.

A survey of suitable nesting habitat adjacent to the quarry sites should be carried out in conjunction with a BAS ecologist in order to position the screener as far as practical from any established nest sites. Moving the quarry plant 10m further from a receptor will reduce the sound pressure level by 6dB, a fourfold reduction in sound energy.

<u>Reduction in hours of operation of construction plant.</u>

Both the equivalent sound pressure level (L_{Aeq}) and the sound exposure level (SEL) take into account the number of hours that a machine works. A judgement has been made when carrying out the calculations as to the probable number of hours each piece of plant will be operating. Reducing the hours, the plant works for, will reduce the sound pressure level and the SEL. A reduction in operating hours will however prolong the programme and is therefore not a viable option.

Avoidance of Concurrent Noisy Activity

By avoiding running multiple items of noisy plant at the same time, sound pressure levels could be slightly reduced. If filling and compaction of the mooring dolphin is not carried out during piling works, a reduction of 1dB in sound pressure level can be achieved at a distance of 10m from the piling. A similar reduction in sound pressure level can be achieved at 10m from the quarry if the excavator is not used at the same time as the screener and loading shovel. The sound exposure level will remain unchanged as the total daily operational hours of each item of plant will remain unchanged. As the reductions in sound pressure level are minimal and there is no reduction in sound exposure level, this mitigation method is unlikely to be adopted.

Acoustic Screening

Acoustic screening can attenuate noise by up to 20dB in an ideal situation although attenuation of 10dB is more likely. Screening is most effective if erected either close to the source or close to the receptor. Screening of the crusher will be difficult to achieve as access is required to hopper and the stockpiles of graded stone produced.

Screening of Piling Hammers

Acoustic dampening jackets are available for covering piling hammers. They enclose the hammer head and the top of pile in an acoustic screen, attenuating noise at source. Suitable acoustic jackets will be procured for the hammers to be used.

Maintenance of Plant

Well maintained plant will generate less noise. A fitter will be available on site to ensure that plant is regularly inspected and maintained.

Dampening Sheet Piles

Acoustically dampening sheet steel piles reduces the level of resonant vibration. Care must be taken when dampening the vibration of piles as this could affect the ease of embedment. This method of mitigation will be investigated further to determine its effectiveness and whether it will hinder the performance of the piling system.

Dampening the Hammer Head

The use of a resilient pad or dolly between the pile and the hammer head reduces the noise generated when the hammer strikes the pile. The packing needs to be kept in good condition to maintain effectiveness. The most effective material for the dolly will be investigated and appropriate dollies will be procured for the hammers to be used.

Appendix 13 – ABP Marine Noise Assessment

BAM Nuttall Limited

King Edward Point Wharf Redevelopment

Underwater noise assessment

June 2019

Innovative Thinking - Sustainable Solutions

ABP mer

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King Edward Point Wharf Redevelopment

Underwater noise assessment

June 2019

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	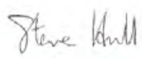

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Contents

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1 Introduction

This Technical Note presents the results of the underwater noise assessment required to support the Environmental Impact Assessment (EIA) for the proposed wharf redevelopment project at King Edward Point (KEP) Research Station in South Georgia.

Elevated noise levels and vibration underwater (caused by construction activities such as piling) can potentially disturb marine fauna by causing physiological damage and/or inducing adverse behavioural reactions. Furthermore, the ability to detect and localise the source of a sound is of considerable biological importance to marine fauna, particularly marine mammals and fish. For example, it is used to assess the suitability of a potential mate or during territorial displays and predator prey interactions. It can also act as a barrier, preventing movement to key foraging, spawning/breeding or nursery grounds.

The wharf is proposed to be constructed using sheet piles driven primarily by a vibro hammer. A drop hammer may also be required if the vibro hammer is not able to drive the piles to the required bed level. The wharf will then be filled with stone and compacted. The propagation of underwater noise from these construction activities has been modelled to assess the potential impact on local marine fauna and to identify the need for mitigation.

This Technical Note has been structured as follows:

Section 1: **Introduction** provides a brief introduction to the project and need for this assessment;

Section 2: **Principles of Underwater Acoustics** presents the basic principles which are fundamental to undertaking robust underwater noise assessments;

Section 3: **Underwater Noise Propagation** reviews the key factors influencing the propagation of underwater noise and presents the preferred underwater noise propagation model;

Section 4: **Characteristics of Marine Construction Noise** presents the specific characteristics of the proposed construction activities;

Section 5: **Hearing Sensitivity and Responses of Marine Fauna** reviews the potential sensitivity and physiological and behavioural responses of local marine fauna to underwater noise;

Section 6: **Potential Effects** presents the outputs of the underwater noise modelling and reviews the potential effects on local marine fauna; and

Section 7: **Mitigation** presents the recommended practicable mitigation measures and the residual effects on local marine fauna following the application of these measures.

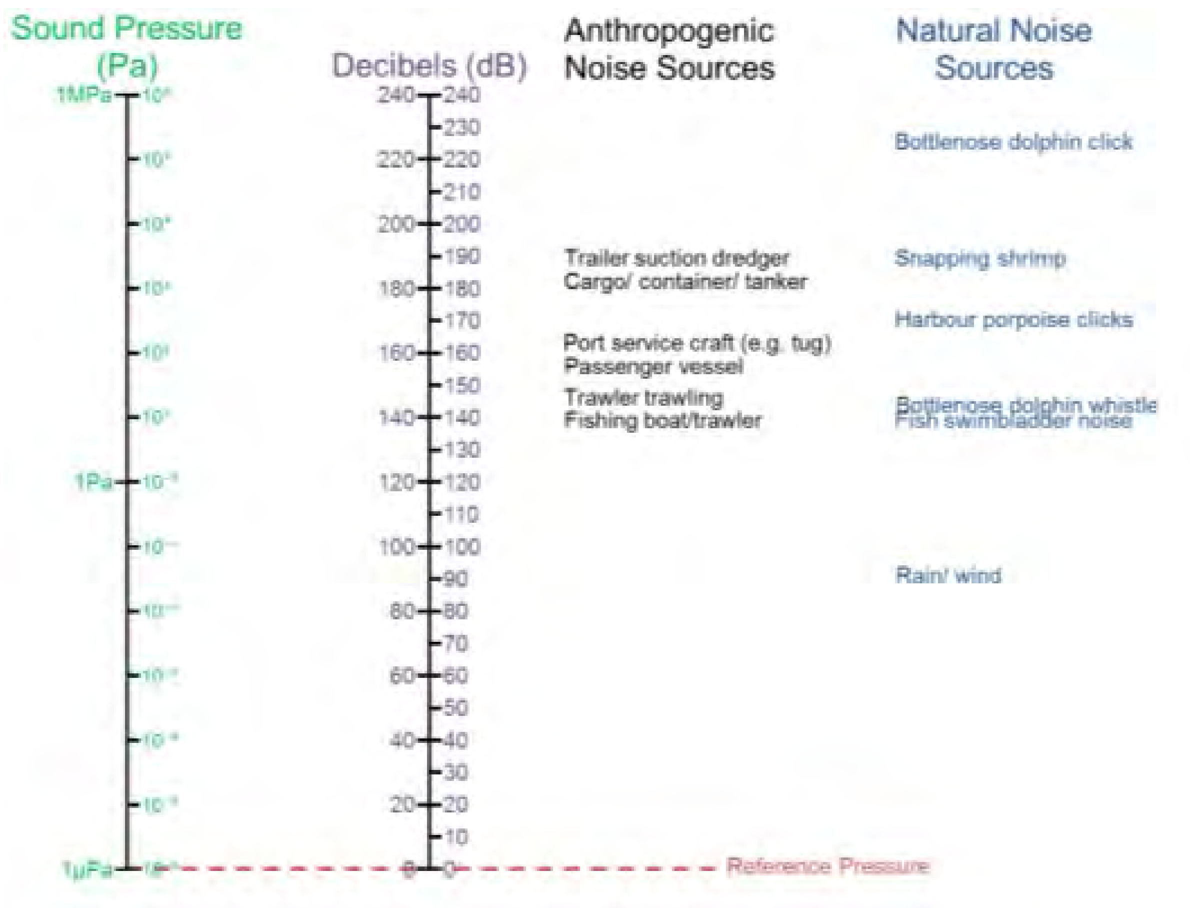
2 Principles of Underwater Acoustics

Underwater sound is generated by the movement or vibration of any immersed object in water. Sound can be detected: (a) as pressure fluctuations in the medium above and below the local hydrostatic pressure (sound pressure); and (b) by the back and forth motion of the medium, referred to as particle motion (ISO/DIS, 2016).

2.1 Sound pressure

Sound pressure acts in all directions and is a scalar quantity that can be described in terms of its magnitude and its temporal and frequency characteristics. An important property of sound or 'noise' is its loudness. A loud noise usually has a larger pressure variation and a weak one has a smaller pressure variation. Sound pressure is most commonly expressed using a logarithmic scale, the decibel (dB) scale.

Pressure and pressure variations are expressed in Pascal, abbreviated as Pa, which is defined as Newton per square metre (Nm-2). It is not appropriate to express sound or noise in terms of Pa because it would involve dealing with numbers from as small as 0.000001 to as big as 2,000,000. The use of a logarithmic scale, of which the most commonly used is the decibel (dB) scale, compresses the range so that it can be easily described. Figure 1 shows how sounds can be expressed both linearly in Pa and logarithmically in dB.



Source: MMO, 2015

Figure 1. The sound pressure (Pa) and decibel (dB) scale

2.2 Particle motion

Particle motion is an oscillation back and forth in a particular direction; it is a vector quantity that can only be fully described by specifying both the magnitude and direction of the motion, as well as its magnitude, temporal, and frequency characteristics. The particle motion component of underwater sound comprises both the velocity ($m \cdot s^{-1}$) and the acceleration ($m \cdot s^{-2}$) of molecules in the sound wave.

Particle motion was previously considered impossible to record (Wysocki and Ladich, 2005). However, two approaches have been used in research to estimate particle acceleration (Radford *et al.*, 2012): 1) accelerometers and 2) the recording of pressure differences between two hydrophones. This was followed closely by the development of a particle motion sensor (Sigray and Andersson, 2011), which has been validated in field studies near an offshore wind farm in the western part of the Baltic Sea.

Detection of particle motion requires different types of sensor than those utilized by a conventional hydrophone (Hawkins and Popper, 2016). Such sensors must specify the particle motion in terms of the particle displacement, or its time derivatives (particle velocity or particle acceleration) in three dimensions.

2.3 Underwater noise metrics

There are a number of different metrics that may be used as measures of sound pressure (National Physical Laboratory (NPL), 2014). The key metrics that are used to characterise noise are as follows:

- **Peak sound pressure (or zero-peak sound pressure).** The maximum sound pressure during a stated time interval. A peak sound pressure may arise from a positive or negative sound pressure, and the unit is Pa. This quantity is typically useful as a metric for a pulsed waveform, though it may also be used to describe a periodic waveform;
- **Peak-peak sound pressure.** The sum of the peak compressional pressure and the peak rarefactional pressure during a stated time interval. This quantity is typically most useful as a metric for a pulsed waveform, though it may also be used to describe a periodic waveform. Peak-peak sound pressure is expressed in Pa;
- **Root mean square (RMS) sound pressure.** The square root of the mean square pressure, where the mean square pressure is the time integral of squared sound pressure over a specified time interval divided by the duration of the time interval. The RMS sound pressure is expressed in Pa;
- **Sound exposure level (SEL).** The integral of the square of the sound pressure over a stated time interval or event (such as an acoustic pulse). Sound exposure is expressed in units of $Pa^2 \cdot s$. The quantity is sometimes taken as a proxy for the energy content of the sound wave. Note that SEL is a useful measure of the exposure of a receptor to a sound field, and a frequency weighting is commonly applied; and
- **Frequency weighting.** Frequency-dependent normalised factor(s) by which spectral components are multiplied, resulting in the modification of the amplitude of some components. Frequency weightings are normalised factors and have no units or dimensions but are sometimes expressed as relative factors in decibels (with no reference value). The main motivation for applying a frequency weighting is to account for the frequency-dependent sensitivity of a receptor.

The type of pressure measurement used is an important consideration when comparing noise levels and criteria and the type of pressure measurement should be stated when quoting noise levels.

3 Underwater Noise Propagation

The process of noise travelling through a medium is referred to as noise propagation. The factors that influence the propagation of noise in the ocean and contribute to propagation (or transmission) loss[1] broadly include the following (NPL, 2014):

- The reduction (or attenuation) of sound away from the source due to geometrical spreading;
- Absorption of the sound by the sea-water and the seabed;
- The interaction with the sea-surface (reflection and scattering);
- The interaction with (and transmission through) the seabed;
- The refraction of the sound due to the sound speed gradient;
- The bathymetry (water depth) between source and receiver positions; and
- Source and receiver depth.

The propagation of underwater noise is a very complex process and therefore predicting the received sound pressure levels at distance from a source is extremely difficult. Use is generally made of theoretical models or empirical models based on field measurements.

In accordance with good practice guidance (NPL, 2014), a simple logarithmic spreading model has been used to predict the propagation of sound pressure from the various sources of construction noise associated with the proposed redevelopment of the wharf at KEP. This model is represented by a logarithmic equation and incorporates factors for noise attenuation and absorption losses. The advantage of this model is that it is simple to use and quick to provide first order calculations of the received sound pressure level (SPL) with distance from the source due to geometric spreading.

Equation 1 Simple logarithmic spreading model

$$L(R) = SL - N\ log_{10}(R) - \alpha R$$

where:

L(R)	is the SPL at distance R from a source (i.e. the received level) and is generally expressed in terms of decibels (dB) for a reference pressure of 1 µPa and a reference range of 1 m (dB re 1 µPa m);
R	is the distance in metres from the source to the receiver;
SL	is the Source Level (i.e. the level of sound generated by the source) also generally expressed as dB re 1 µPa m;
N	is a factor for attenuation due to geometric spreading; and
α	is a factor for the absorption of sound in water and boundaries (i.e. the sediment or water surface) in dB m^{-1}.

The Environment Agency has compiled observed data representing factors for attenuation (N coefficient) and absorption (α coefficient) which were presented at the Institute of Fisheries Management (IFM) Conference on 23 May 2013.

These observed data were collected for a range of construction projects undertaken in shallow water estuarine and coastal locations as follows:

[1] The reduction in signal as sound propagates from source to receiver.

- Russian River New Bridge in Geyserville, California (Illinworth and Rodkin, 2007);
- San Rafael Sea Wall in San Francisco Bay, California (Illinworth and Rodkin, 2007);
- Scroby Sands Offshore Wind Farm located off the coast of Great Yarmouth (Nedwell *et al*., 2007a);
- North Hoyle Offshore Wind Farm in Liverpool Bay (Nedwell *et al*., 2007a);
- Kentish Flats Offshore Wind Farm located off the coast of Kent (Nedwell *et al*., 2007a);
- Burbo Bank Offshore Wind Farm in Liverpool Bay (Nedwell *et al*., 2007a);
- Barrow Offshore Wind Farm located south west of Walney Island (Nedwell *et al*., 2007a); and
- Belvedere Energy-from-Waste Plant on Thames Estuary (measurements collected by Subacoustech Ltd on behalf of the Environment Agency and Costain).

These provide a mean N coefficient of 17.91 (Standard Deviation (SD) 3.05) and α coefficient of 0.00523 dB m^{-1} (SD 0.00377 dB m^{-1}) based on 11 and 9 observations respectively. The Environment Agency has in the past recommended the application of these model input values in underwater noise assessments undertaken in shallow water environments (e.g. URS Scott Wilson, 2011; ABPmer, 2015). These values are therefore considered to be appropriate to use for this assessment.

It is important to recognise that there are a number of limitations associated with the use of simple logarithmic spreading models (NPL, 2014). Such models do not account for changes in bathymetry, and therefore are not able to predict the changes in sound propagation caused by sand banks and complex changes in water depths. In addition, they do not include frequency dependence explicitly, and so cannot predict the increased transmission loss at high frequencies due to increased sound absorption. Farcas *et al*. (2016) also demonstrated how use of these simple models in complex environments typical of coastal and inland waters can underestimate noise levels close to the source and substantially overestimate noise levels further from the source. In other words, they can underestimate the risk of injury or disturbance to marine fauna close to the source whilst giving the impression that a larger area would be affected.

Although this equation generally represents a simplistic model of propagation loss, its use is an established approach in EIAs that has been widely accepted by UK regulators in the past. Furthermore, the National Oceanic and Atmospheric Administration (NOAA) Fisheries in the United States recommends the use of the practical spreading model to developers and has incorporated this model in their pile driving calculation spreadsheet to assess the potential impacts of pile driving on fish (ICF Jones & Stokes and Illingworth and Rodkin, 2009). The proposed wharf redevelopment project at KEP takes place in relatively shallow water (9 to 11 m depth at the mooring face). The project is relatively small-scale in nature and the piling noise generated is relatively short-term (a period of around 40 days in total). Overall, therefore, a simple logarithmic spreading model is considered proportionate and appropriate to use for this underwater noise assessment.

4 Characteristics of Marine Construction Noise

4.1 Vibro piling

A PVE 40VM vibro hammer with variable moment is proposed to be used to drive the sheet piles involved in the redevelopment of the wharf at KEP, specifically AZ52-700s up to 24.2 m in length, AZ42-700s up to 22.2 m in length, AZ24-700s up to 16.2 m in length.

Vibratory hammers use oscillatory hammers that vibrate the pile, causing the sediment surrounding the pile to liquefy and allow pile penetration (ICF Jones & Stokes and Illingworth & Rodkin, 2009). Peak sound pressure levels for vibratory hammers can exceed 180 dB; however, the sound from these hammers rises relatively slowly. The vibratory hammer produces sound energy that is spread out over time and is generally 10 to 20 dB lower than impact pile driving. Although peak sound levels can be substantially less than those produced by impact hammers, the total energy imparted can be comparable to impact driving because the vibratory hammer operates continuously and requires more time to install the pile.

The source level (SL) for vibratory sheet piling at KEP is assumed based on near-source (10 m from the source) sound pressure measurements for a 0.6 m steel sheet vibratory piling installation within a shallow water environment (Illinworth & Rodkin, 2007; ICF Jones & Stokes and Illingworth and Rodkin, 2009). Back-calculating to 1 m using the simple logarithmic spreading model (equation 1) provides an estimated SL of 183 dB re 1 µPa m (RMS sound pressure) and 200 dB re 1 µPa m (zero-peak sound pressure).

4.2 Impact piling

If refusal is reached before the required bed level is achieved by vibro piling, impact (or percussive) piling will be required. Impact piling involves a large weight or "ram" being dropped or driven onto the top of the pile, driving it into the seabed. A BSP CX85 impact hammer is proposed to be used to drive the sheet piles to the required depth at KEP.

Should any impact piling be required, this will generate the greatest underwater noise levels. Noise is created in air by the hammer, as a direct result of the impact of the hammer with the pile. Some of this airborne noise is transmitted into the water. Of more significance to the underwater noise, however, is the direct radiation of noise from the surface of the pile into the water as a consequence of the compressional, flexural or other complex structural waves that travel down the pile following the impact of the hammer on its head. As water is of similar density to steel and, in addition, due to its high sound speed, waves in the submerged section of the pile couple sound efficiently into the surrounding water. These waterborne waves will radiate outwards, usually providing the greatest contribution to the underwater noise.

At the end of the pile, force is exerted on the substrate not only by the force transmitted from the hammer by the pile, but also by the structural waves travelling down the pile which induce lateral waves in the seabed. These may travel as both compressional waves, in a similar manner to the sound in the water, or as a seismic wave, where the displacement travels as Rayleigh waves (Brekhovskikh, 1960). The waves can travel outwards through the seabed or by reflection from deeper sediments. As they propagate, sound will tend to "leak" upwards into the water, contributing to the waterborne wave. Since the speed of sound is generally greater in consolidated sediments than in water, these waves usually arrive first as a precursor to the waterborne wave. Generally, the level of the seismic wave is typically 10 – 20 dB below the waterborne arrival, and hence it is the latter that dominates the noise.

Impulsive sources such as pile driving should have source levels expressed for a single pulse as either a sound exposure level (SEL) with units of dB re 1 µPa^2 s, or as a peak-peak or zero-peak SPL, with units of dB re 1 µPa (Farcas *et al.*, 2016).

Impact piling is impulsive in character with multiple pulses occurring at blow rates in the order of 30 to 60 impacts per minute. Typical source levels range from peak SPL of 190 to 245 dB re 1 µPa (DPTI, 2012). Most of the sound energy usually occurs at lower frequencies between 100 Hz and 1 kHz. Factors that influence the source level include the size, shape, length and material of the pile, the weight and drop height of the hammer, and the seabed material and depth.

The peak SPL source level (SL) for impact sheet piling at KEP is assumed based on a near-source (10 m from the source) peak sound pressure measurement for a 0.6 m steel sheet impact piling installation within a shallow water environment (Illinworth & Rodkin, 2007; ICF Jones & Stokes and Illingworth and Rodkin, 2009). Back-calculating to 1 m using the simple logarithmic spreading model (equation 1) provides an estimated peak SPL SL of 223 dB re 1 µPa m.

4.3 Rock placement

Following the sheet piling works, the wharf extension will be infilled with rock fill material using an articulated dump truck and compacted.

Underwater noise generated by rock dumping activities is mainly as a result of the splash, tumble and grinding of rocks during the placement process (SLR Consulting, 2019). Generally, noise from one rock placement event has a slow signal rise time and then reaches its peak level, then followed by a slow drop in levels. Placement activities can be regarded as a sporadic occurrence.

There is little available information on noise emissions from rock placement in marine environments. However, the underwater noise emissions for rock dumping activities during marine cable laying operations are low compared to vessel propulsion noise and pile driving (Nedwell and Howell, 2004; Wyatt, 2008; Nedwell *et al.,* 2012).

The rock infilling operations required as part of the KEP wharf extension works will take place onshore and therefore there will be no direct coupling between the infill works and the water environment. The noise from infilling activities will therefore be considerably reduced due to the absorption of the sound by the air and by the solid wharf structure, the interaction with the ground surface (reflection and scattering) and the interaction with and transmission through the seabed. Overall, given that any rock infilling operations would generate relatively low levels of sound and would take place outside the water environment, they are unlikely to be measurable in the water environment. Furthermore, the wharf and wider area is already exposed to underwater noise from vessel movements which marine fauna are already habituated to and generate higher levels of underwater sound compared to marine rock dumping activities. The potential effects on marine fauna are therefore considered to be negligible and these effects are there not considered further in this underwater noise assessment.

5 Hearing Sensitivity and Responses in Marine Fauna

The impact of underwater noise upon wildlife is primarily dependent on the sensitivity of the species likely to be affected. The following sections describe the hearing sensitivity of marine fauna that occur in the study area, their potential physiological and behavioural responses to underwater noise and the published criteria that exist to inform the impact assessment.

5.1 Marine mammals

5.1.1 Hearing sensitivity

Marine mammals are particularly sensitive to underwater noise at higher frequencies and generally have a wider range of hearing than other marine fauna, namely fish (i.e. their hearing ability spans a larger range of frequencies). The hearing sensitivity and frequency range of marine mammals varies between different species and is dependent on their physiology.

The key marine mammal species that occur in the study area are fur seals and elephant seals. Fur seals are otariid pinnipeds (eared seals). These are sensitive over the frequency band 60 Hz to 39 kHz with a minimum hearing threshold of approximately 66 dB re 1 µPa at around 10 kHz (NOAA, 2018). Elephant seals are phocid pinnipeds (earless seals or "true seals"). These are sensitive over the frequency band 50 Hz to 86 kHz with a minimum hearing threshold of approximately 50 dB re 1 µPa at around 10 kHz (NOAA, 2018). This indicates that fur seals are slightly less sensitive to underwater noise compared to elephant seals.

5.1.2 Responses of marine mammals to noise

The impacts of underwater noise on marine mammals can broadly be split into lethal and physical injury, auditory injury and behavioural response. The possibility exists for lethality and physical damage to occur at very high exposure levels, such as those typically close to underwater explosive operations or offshore impact piling operations. A permanent threshold shift (PTS) is permanent hearing damage caused by very intensive noise or by prolonged exposure to noise. A temporary threshold shift (TTS) involves a temporary reduction of hearing capability caused by exposure to underwater noise. An intense short exposure can produce the same scale of TTS as a long-term, repeated exposure to lower sound levels. The significance of the TTS varies among species depending on their dependence on sound as a sensory cue for ecologically relevant functions. Both PTS and TTS are considered to be auditory/physiological injuries.

At lower sound pressure levels, it is more likely that behavioural responses to underwater sound will be observed. These reactions may include the animals leaving the area for a period of time, or a brief startle reaction. Masking effects may also occur at lower levels of noise. Masking is the interference with the detection of biologically relevant communication signals such as echolocation clicks or social signals. Masking has been shown in acoustic signals used for communication among marine mammals (see Clark *et al.,* 2009). Masking may in some cases hinder echolocation of prey or detection of predators. If the signal-to-noise ratio prevents detection of subtle or even prominent pieces of information, inappropriate or ineffective responses may be shown by the receiving organism.

NOAA (2018) provides technical guidance for assessing the effects of underwater anthropogenic (human-made) sound on the hearing of marine mammal species. Specifically, the received levels, or acoustic thresholds, at which individual marine mammals are predicted to experience changes in their hearing sensitivity (either temporary or permanent) for acute, incidental exposure to underwater anthropogenic sound sources are provided. These thresholds update and replace the previously proposed criteria in Southall *et al.* (2007) for preventing auditory/physiological injuries in marine mammals.

The NOAA (2018) thresholds are categorised according to marine mammal hearing groups. The key marine mammal species found in the study area comprise fur seal and elephant seal. According to NOAA (2018), fur seal is categorised as an otariid pinniped and elephant seal as a phocid pinniped.

The cumulative SEL[2] weighted thresholds for the onset of TTS and PTS due to non-impulsive sound sources (e.g. vibro piling) and the peak SPL acoustic thresholds for the onset of TTS and PTS due to impulsive sound sources (e.g. percussive piling) for the relevant marine mammal groups are presented in Table 1.

There are no equivalent SPL behavioural response criteria that would represent the sources of piling noise during the construction of the proposed wharf redevelopment at KEP. Behavioural reactions to acoustic exposure are less predictable and difficult to quantify than effects of noise exposure on hearing or physiology as reactions are highly variable and context specific (Southall *et al.*, 2007). A number of field observations of pinnipeds to multiple pulse sounds have been made and are reviewed by Southall *et al.* (2007). The results of these studies are considered too variable and context-specific to allow single disturbance criteria for broad categories of taxa and of sounds to be developed. However, the data provide an indication of the levels of received noise that may result in a moderate behavioural reaction (e.g. avoidance of sound source, startle response). These indicative levels have therefore been applied in this assessment as general approximation of the potential scale of disturbance to seals.

Table 1. Marine mammal response criteria applied in this assessment

Marine Mammal Hearing Group	PTS	TTS	Behavioural
Otariid pinniped (fur seal)	219 dB re 1 μPa²s (vibro piling) 232 dB re 1 μPa (impact piling)	199 dB re 1 μPa²s (vibro piling) 226 dB re 1 μPa (impact piling)	195 dB re 1 μPa
Phocid pinniped (elephant seal, leopard seal)	201 dB re 1 μPa²s (vibro piling) 218 dB re 1 μPa (impact piling)	181 dB re 1 μPa²s (vibro piling) 212 dB re 1 μPa (impact piling)	195 dB re 1 μPa

5.2 Fish

5.2.1 Hearing sensitivity

In comparison to marine mammals, fish are more sensitive to noise at lower frequencies and generally have a reduced range of hearing than marine mammals (i.e. their hearing ability spans a restricted range of frequencies).

There is a wide diversity in hearing structures in fish which leads to different auditory capabilities across species (Webb *et al.*, 2008). All fish can sense the particle motion[3] component of an acoustic field via the inner ear as a result of whole-body accelerations (Radford *et al.*, 2012), and noise

[2] With a reference value of 1 μPa² s over a 24 hour period.

[3] Particle motion is a back and forth motion of the medium in a particular direction; it is a vector quantity that can only be fully described by specifying both the magnitude and direction of the motion, as well as its magnitude, temporal, and frequency characteristics.

detection ('hearing') becomes more specialised with the addition of further hearing structures. Particle motion is especially important for locating sound sources through directional hearing (Popper *et al.*, 2014; Hawkins *et al.*, 2015; Nedelec *et al.*, 2016). Although many fish are also likely to detect sound pressure[4], particle motion is considered equally or potentially more important (Hawkins and Popper, 2016).

From the few studies of hearing capabilities in fishes that have been conducted, it is evident that there are potentially substantial differences in auditory capabilities from one fish species to another (Hawkins and Popper, 2016). Since it is not feasible to determine hearing sensitivity for all fish species, one approach to understand hearing has been to distinguish fish groups on the basis of differences in their anatomy and what is known about hearing in other species with comparable anatomy (Popper *et al.*, 2014).

The key fish species that occur in the study area are Antarctic dragonfish (*Parachaenichthys georgianus*), and a number of icefishes, namely blackfin icefish (*Chaenocephalus aceratus*) Marbled rock cod (*Notothenia rossii*), Humped rock cod (*Gobionotothen gibberifrons*) and Black rock cod (*Notothenia coriiceps*). As far is known from available research, all these fish species lack swim bladders. They therefore fall under the Popper *et al.* (2014) hearing group of fish with no swim bladder. This category comprise fish (e.g. flatfishes, sharks, skates and rays) that are predominantly sensitive to sound particle motion and show sensitivity to only a narrow band of frequencies.

Particle motion rather than sound pressure is considered to be potentially more important to fish without swim bladders. Acoustic particle motion in the water and seabed, for example, has been shown to induce behavioural reactions in sole (Mueler-Blenkle *et al.*, 2010). However, there is no published literature on the levels of particle motion generated during construction activities (e.g. pile-driving) and the distance at which they can be detected. This may be due to the fact that there are far fewer devices (and less skill in their use) for detection and analysis of particle motion compared to hydrophone devices for detection of sound pressure (Martin *et al.*, 2016). Direct measurements of particle motion have also been hampered by the lack of guidance on data analysis methods.

Particle velocity can be calculated indirectly from sound pressure measurements using rather simple models (MacGillivray *et al.*, 2004). However, such estimates of sound particle velocity are only valid in environments that are distant from reflecting boundaries and other acoustic discontinuities. These conditions are rarely met in the shelf-sea and shallow-water habitats that most aquatic organisms inhabit and that are applicable to the study area (Nedelec *et al.*, 2016).

Steps that are required to improve knowledge of the effects of particle motion on marine fauna have recently been set out (Popper and Hawkins, 2018). However, at present there continues to be a lack of particle motion measurement standards, lack of easy to use and reasonably priced instrumentation to measure particle motion, and lack of sound exposure criteria for particle motion. As such, the scope for considering particle motion in underwater noise assessments is currently limited (Faulkner *et al.*, 2018). This assessment has therefore been based on the latest available evidence and focused on the effects of sound pressure on marine fauna.

5.2.2 Responses of fish to noise

The extent to which intense underwater sound might cause an adverse environmental impact in a particular fish species is dependent upon the level of sound pressure or particle motion, its frequency,

[4] Pressure fluctuations in the medium above and below the local hydrostatic pressure; it acts in all directions and is a scalar quantity that can be described in terms of its magnitude and its temporal and frequency characteristics.

duration and/or repetition (Hastings and Popper, 2005). The range of potential effects from intense sound sources, such as pile driving, includes immediate death, permanent or temporary tissue damage and hearing loss, behavioural changes and masking effects. Tissue damage can result in eventual death or may make the fish less fit until healing occurs, resulting in lower survival rates. Hearing loss can also lower fitness until hearing recovers. Behavioural changes can potentially result in animals avoiding migratory routes or leaving feeding or reproduction grounds with potential population level consequences. Biologically important sounds can also be masked where the received levels are marginally above existing background levels (Hawkins and Myrberg Jr, 1983). The ability to detect and localise the source of a sound is of considerable biological importance to many fish species and is often used to assess the suitability of a potential mate or during territorial displays and during predator prey interactions.

The noise exposure criteria for fish that have been used in this underwater noise assessment are presented in Table 2. The Popper *et al.* (2014) peak SPL criteria for impact piling have been used to determine the mortality/potential mortal injury and recoverable injury for the fish hearing group applicable to key fish species that occur in the study area. These guidelines are based on an understanding that fish will respond to sounds and their hearing sensitivity.

While these noise exposure criteria provide thresholds for auditory impairment, there are many data gaps that preclude the setting of specific noise exposure criteria for behavioural responses in fish (Popper *et al*., 2014; Hawkins and Popper, 2016; Faulkner *et al*., 2018). The onset of behavioural responses is much more difficult to quantify as reactions are likely to be strongly influenced by behavioural or ecological context and the effect of a particular response is often unclear and may not necessarily scale with received sound level (Hawkins and Popper, 2014; Hawkins *et al*., 2015; Faulkner *et al*., 2018). In other words, behaviour may be more strongly related to the particular circumstances of the animal, the activities in which it is engaged, and the context in which it is exposed to sounds (Ellison *et al*., 2012; Pena *et al*., 2013). For example, a startle or reflex response to the onset of a noise source does not necessarily lead to displacement from the ensonified area.

This uncertainty is further compounded by the limitations of observing fish behavioural responses in a natural context. Few studies have conducted behavioural field experiments with wild fish and laboratory experiments may not give a realistic measure of how fish will respond in their natural environment (Hastings and Popper, 2005; Kastelein *et al*., 2008; Popper and Hastings, 2009). As a consequence, only hearing data based on behavioural experiments is acceptable for assessing the ability of fish to detect sound (Sisneros *et al*., 2016).

Recent studies have considered approaches to quantify the risk of behavioural responses, for example through dual criteria based on dose-response curves for proximity to the sound source and received sound level (Dunlop *et al*., 2017). An empirical behavioural threshold could also be adopted using *in situ* observed responses of fish to similar sound sources (Faulkner *et al*., 2018). A study observing the responses of caged fish to nearby air gun operations found that initial increases in swimming behaviour may occur at a level of 156 dB re 1µPa rms (McCauley *et al*., 2000). At levels of around 161-168 dB re 1µPa rms active avoidance of the air gun source would be expected to occur (Pearson *et al*., 1992; McCauley *et al*., 2000). These responses may however differ from those of unconfined fish.

More recent work has been undertaken by Hawkins *et al.* (2014) reporting behavioural responses of schools of wild sprat and mackerel to playbacks of pile driving. At a single-pulse peak-to-peak SPL of 163 dB re 1 µPa (equivalent to peak SPL of 157 dB re 1 µPa), schools of sprat and mackerel were observed to disperse or change depth on 50 % of presentations. Sprat and mackerel have specialised hearing structures. Fish species in the study area lack a swim bladder and therefore this threshold is likely to be an indicator of minor behavioural responses in these fish (e.g. subtle change in swimming speed or direction). In the absence of similar data for other species, this threshold has been applied for all fish species (see Table 2).

Table 2. Fish response criteria[5] applied in this assessment

Fish Hearing Group	Mortality/ Potential Mortal Injury/ Recoverable Injury	Minor Behaviour/ Displacement
No swim bladder (particle motion detection)	> 213 dB re 1 µPa (Peak)	> 157 dB re 1 µPa (Peak)

Potential behavioural effects in the past have also been inferred by comparing the received sound level with the auditory threshold of marine fauna. Richardson *et al.* (1995) and Thomsen *et al.* (2006), for example, have used received levels of noise in comparison with the corresponding hearing thresholds of marine fauna in order to estimate the range of audibility and zones of influence from underwater sound sources. This form of analysis has been taken a stage further by Nedwell *et al.* (2007b), where the underwater noise is compared with receptor hearing threshold across the entire receptor auditory bandwidth in the same manner that the dB(A) is used to assess noise sources in air for humans. These include behavioural thresholds, where received sound levels around 90 dB above hearing threshold (dB_{ht}) are considered to cause a strong behavioural avoidance, levels around 75 dB_{ht} a moderate behavioural response and levels around 50 dB_{ht} a minor response.

The dB_{ht} criteria have been applied in a number of offshore renewables EIAs and the Environment Agency has previously recommended it to be used in impact assessments in coastal/estuarine environments (e.g. ABPmer, 2008; URS Scott Wilson, 2011). However, it is worth noting that the dB_{ht} criteria have not been validated by experimental study and have not been published in an independent peer-reviewed paper. The dB_{ht} approach does not take into account potential for sound sensitivity to changes with that of the life stage of the organism, time of year, animal motivation, or other factors that might affect hearing and behavioural responses to sound (Hawkins and Popper, 2016). Furthermore, the dB_{ht} criteria are based on measures of inner ear responses and should rather be based on behavioural threshold determinations (Popper *et al.*, 2014; Hawkins and Popper, 2016). The use of dB_{ht} criteria is therefore not advisable and has not been applied to this assessment (Hawkins and Popper, 2016).

5.3 Seabirds

5.3.1 Hearing sensitivity

The key diving seabird species that occur in the study area and may be exposed to elevated underwater noise levels are South Georgia shag, light-mantled albatross, Antarctic tern, Wilson's storm petrel, white-chinned petrel and penguins. South Georgia shag is a pursuit diver and will therefore dive the deepest in the water column. Light-mantled albatross and Antarctic tern can plunge dive and the petrels can undertake shallow (approximately 10 m) surface dives. There a no breeding penguins at KEP. Gentoo and King Penguins rest on the beaches and are known to moult in the area. Penguins are considered relatively transient in the study area and predominantly dive in and out of water until they reach deepwater.

Recent research generally suggests that diving seabirds could be more sensitive to underwater noise than previously assumed. For example, hearing thresholds for great cormorant were found to be comparable to seals and toothed whales in the frequency band 1 to 4 kHz (Hansen *et al.,* 2017). In

5 All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist (Popper *et al.*, 2014).

another study, African penguins were found to have a hearing range to be between 0.1 to 15 kHz, but peak sensitivities were between 0.6 and 4 kHz (Wever *et al*., 1969). In comparison, humans hear between 0.2 and 20 kHz.

5.3.2 Responses of seabirds to noise

In general, there is very limited research on the effects of underwater noise on seabirds. Despite this, penguins may be expected to be particularly affected by loud underwater sounds, due to their largely aquatic nature and therefore degree of exposure. Pichegru *et al*. (2017) investigated the behavioural response of breeding endangered African penguins to seismic surveys within 100 km of their colony in South Africa, using a multi-year GPS tracking dataset. Penguins showed a strong avoidance of their preferred foraging areas during seismic activities, foraging significantly further from the survey vessel when in operation, while increasing their overall foraging effort.

Observations of impacts to seabirds from pile driving during the construction of Offshore Windfarm Egmond aan Zee in the North Sea, concluded that underwater noise effects were negligible, however, this may be in part due to the application of appropriate mitigation measures, including the use of pingers and soft start techniques to encourage potentially sensitive birds to disperse away from the site (Leopold and Camphuysen, 2007).

A number of assessments have, based on the limited information available, and the similar frequency ranges between seabirds and phocid pinniped and cetacean species, applied methodologies developed for pinnipeds or low frequency cetaceans in assessing seabird sensitivity to underwater noise (Teachout, 2012; Jacobs, 2014). The NOAA (2018) acoustic thresholds for the onset of TTS and PTS due to non-impulsive (e.g. vibro piling) and impulsive sound sources (e.g. impact piling) for phocid pinnipeds are marginally lower than the corresponding NOAA (2018) thresholds for low frequency cetaceans. The response criteria for phocid pinnipeds have therefore been applied to this underwater noise assessment as a worst case approximation for considering potential effects on seabirds (see Table 1).

6 Potential Effects

An underwater noise assessment of the construction components of the proposed works has been carried out to assess the impacts on marine fauna in the study area. To evaluate the potential effects of construction activities it is necessary to understand the character of underwater noise propagation and the potential response of marine fauna to that noise.

The logarithmic noise propagation model (Equation 1) has been run to determine the unweighted received levels with range during the proposed vibro piling and any required impact piling. These received levels represent unweighted metrics as recommended in NPL (2014). Table 3 shows the results of this analysis at various distances from the source of piling. Levels of underwater noise are relatively high close to the source of the sheet piling and attenuate rapidly with distance from the source. Within 500 m from the source of piling (the approximate width of the entrance to King Edward Cove at KEP), the received levels of noise will be comparable to the source level generated by a small to medium sized vessel (MMO, 2015).

Table 3. Unweighted received levels during vibro and impact piling

Range (m)	Unweighted Received Levels (dB re 1 µPa m)	
	Vibro Piling	Impact Piling
1	200	223
10	182	205
50	169	192
100	164	187
500	149	172
1,000	141	164

6.1 Marine mammals

6.1.1 Vibro piling

The distance at which the predicted cumulative SEL weighted levels of underwater noise during vibro piling is within the limits of PTS and TTS in fur seal is 2 m and 25 m respectively (Table 4). The distance at which the predicted cumulative SEL weighted levels of underwater noise during vibro piling is within the limits of PTS and TTS in elephant seal is 18 m and 230 m respectively (Table 4).

This indicates that if seals were to remain stationary within these distances from the source of vibro piling over a 24 hour period, temporary and/or permanent hearing injury could occur in both fur seal and elephant seal. However, it is considered highly unlikely that a seal will stay within this "injury zone" for an entire 24 hour period over piling operations. True seals, such as fur seals, usually swim at about 3 m/s and can reach speeds as fast as 8 m/s. Fur seal pups are likely to have lower swim speeds. Elephant seals have a recorded average swimming speed of 1 to 2 m/s (Crocker *et al.*, 1994). Assuming a lower worst case speed of 1 m/s, and that seals evade the noise source, the time taken for an individual fur seal to leave the PTS and TTS injury zone is 2 seconds and 25 seconds respectively. The time taken for an individual elephant seal to move out of the PTS and TTS injury zone is 18 seconds and 4 minutes respectively. This is less 0.003% of the time that would be required for an injury to occur and therefore assuming seals evade the injury effects zone, they are not considered to be at risk of any permanent or temporary injury during vibro piling.

Any potential behavioural effects would be highly localised and within a couple of metres from the source of vibro piling (Table 4). Overall, the potential effects of underwater noise generated during vibro piling activities on marine mammals in the study area are considered **negligible**.

Table 4. Approximate distances (metres) marine mammal response criteria are reached during vibro piling

Marine Mammal Hearing Group	PTS	TTS	Behavioural
Otariid pinniped (fur seal)	2	25	2
Phocid pinniped (elephant seal, leopard seal)	18	230	2

6.1.2 Impact piling

The peak SPL SL generated by impact piling the proposed sheet piles is below the published criteria for PTS and TTS in fur seal but marginally above the equivalent criteria for elephant seal (Table 5). The distance at which the received level of noise is within the limits of PTS and TTS in elephant seal is 2 m and 4 m respectively. This suggests that there will be no auditory injury to fur seals but a highly localised potential risk of auditory injury in elephant seals in the immediate vicinity of the source of the impact piling.

Behavioural reactions in both fur seals and elephant seals are predicted to be limited to within around 40 m from the source of impact piling (Table 5). Behavioural responses of these species within these distances could include movement away from a sound source and visible startle response (Southall *et al.*, 2007). Any marine mammals that happen to be present are likely to evade the zone of potential behavioural effect. However, the zone of potential behavioural effect is very small and will not constrain seal movements in and out of the King Edward Cove.

Table 5. Approximate distances (metres) marine mammal response criteria are reached during impact piling

Marine Mammal Hearing Group	PTS	TTS	Behavioural
Otariid pinniped (fur seal)	-	-	36
Phocid pinniped (elephant seal, leopard seal)	2	4	36

The elephant seal breeding season in South Georgia is September to November. Based on tracking data from other sites, it is anticipated that weaned elephant seal pups will have departed the breeding beaches and the local area by early January (McConnel *et al.*, 2002). Should any weaned elephant seals remain in the area then they will not be expected to dive for more than 5 to 10 minutes (Hindell *et al.*, 1999) and will therefore be quite conspicuous. Adult elephant seals and returning juveniles are expected to be in the area between January to April during their moulting period and are therefore expected to spend most of their time ashore although some time may also be spent in the shallow water. However, adult elephant seals are not expected to do any deep diving during this period and within the survey area as deep dives usually only occur during feeding in open water. Therefore, it is expected that adult and juvenile elephant seals (when not moulting ashore) rather than pups have the potential to be exposed to underwater noise.

The fur seal breeding season is December to January and therefore it is expected that fur seals (adults and pups) will be both in the shallow waters and on the shore during the piling period currently scheduled to take place between February and March 2020. Adult fur seals will be transiting the area between feeding in the open ocean and returning to land to feed their pups and fur seal pups may be learning to swim in shallow waters. The numbers of all fur seals in the shallow waters may increase in periods of extreme heat or hard rainfall. Adult fur seals in shallow waters within the King Edward Cove area are only expected to dive for short periods (less than 2 minutes) as deep dives for feeding usually only occur in open ocean and fur seal pups will be restricted to shallow waters and diving for only seconds at a time and will therefore be very conspicuous.

The effects of piling noise on marine mammals also need to be considered in terms of the duration of exposure. Piling noise will take place between February and March 2020 over a period of around 40 days in total. Piling will not take place continuously as there will be periods of downtime, pile positioning and set up. The working day will be 12 hours, but it is anticipated that the piling hammer will only be operational for 4 hours per day. There will therefore be significant periods over a 24 hour period when seals will not be disturbed by any underwater noise.

It is also important to consider that the area in which the construction will take place already experiences regular vessel operations, and, therefore, marine mammals are likely to be habituated to a certain level of anthropogenic background noise.

Overall, based on the above discussion, the potential effects of underwater noise during impact piling on marine mammals at KEP are considered **minor adverse**.

6.2 Fish

6.2.1 Vibro piling

The peak SPL SL generated by vibro piling is below the published criteria for lethal effects and recoverable physical injury in fish that occur in the study (Table 6). This indicates that vibro piling will not result in any physical injury to fish. Potential behavioural effects would be relatively localised and within around 200 m from the source of vibro piling (Table 6). Given the unconstrained nature of King Edward Cove, vibro piling will not result in a noise barrier and fish will be able to swim away from any zone of disturbance. Overall, the potential effects of underwater noise generated during vibro piling activities on fish in the study area are considered **negligible**.

Table 6. Approximate distances (metres) fish response criteria are reached during vibro piling

Fish Hearing Group	Mortality/ Potential Mortal Injury/ Recoverable Injury	Minor Behaviour/ Displacement
No swim bladder (particle motion detection)	-	218

6.2.2 Impact piling

The peak SPL SL generated by impact piling the proposed sheet piles involved in the redevelopment of the wharf at KEP is above the published criteria for lethal effects and recoverable physical injury. The distance at which the received level of underwater noise is within the limits of injury in fish with no swim bladder (i.e. all key fish species that occur in the study area) is 4 m (Table 7). This suggests that there will be a highly localised potential risk of auditory injury in any fish that swim in the immediate vicinity of the source of the impact piling.

The distance at which the received level is within the limits of a behavioural reaction in fish is 1.6 km (Table 7). This indicates that fish are expected to elicit a behavioural reaction within this distance or "behavioural effects zone" during periods of impact piling. The scale of the reaction is partly dependent on the hearing sensitivity of the species and the size of fish (which affects maximum swimming speed). The key fish in the study area generally do not have swim bladders and are therefore considered relatively insensitive to sound pressure (see Section 5.2.1). These species are anticipated to only show very subtle changes in behaviour in this zone.

Table 7. Approximate distances (metres) fish response criteria are reached during impact piling

Fish Hearing Group	Mortality/ Potential Mortal Injury/ Recoverable Injury	Minor Behaviour/ Displacement
No swim bladder (particle motion detection)	4	1,624

The spawning season for fish species that occur in the study area could potentially overlap with the piling period which is scheduled to take place between February and March 2020. Smaller fish, juveniles and fish larvae swim at slower speeds and are likely to move passively with the current. Larger fish are more likely to actively swim and therefore are able to move out of the behavioural effects zone in less time. However, as discussed above, the key fish species that occur in the study area are relatively insensitive to noise and therefore are only likely to exhibit marginal behavioural responses within the behavioural effects zone.

The effects of piling noise on fish also need to be considered in terms of the duration of exposure. Piling noise will take place between February and March 2020 over a period of around 40 days in total. Piling will not take place continuously as there will be periods of downtime, pile positioning and set up. The working day will be 12 hours, but it is anticipated that the piling hammer will only be operational for 4 hours per day. There will therefore be significant periods over a 24 hour period when fish will not be disturbed by any underwater noise.

It is also important to consider that the area in which the construction will take place already experiences regular vessel operations, and, therefore, fish are likely to be habituated to a certain level of anthropogenic background noise.

Overall, based on the above discussion, the potential effects of underwater noise during impact piling on fish that occur in the study area are considered **minor adverse**.

6.3 Seabirds

6.3.1 Vibro piling

The distance at which the predicted cumulative SEL weighted levels of underwater noise during vibro piling is within the limits of PTS and TTS in diving seabirds is 18 m and 230 m respectively (Table 8).

This indicates that if seabirds were to remain underwater within these distances from the source of vibro piling over a 24 hour period, temporary and/or permanent hearing injury could occur. However, it is considered highly unlikely that a seabird will stay underwater within this "injury zone" for an entire 24 hour period over piling operations. Assuming that seabirds can swim a lower worst case speed of 1 m/s, and that they evade the noise source, the time taken for an individual seabird to leave the PTS and TTS injury zone is 18 seconds and 4 minutes respectively. This is less 0.003% of the time that would be required for an injury to occur and therefore assuming diving seabirds evade the injury effects zone, they are not considered to be at risk of any permanent or temporary injury during vibro piling.

Any potential behavioural effects are likely to be highly localised and within a couple of metres from the source of vibro piling (Table 8). Overall, the potential effects of underwater noise generated during vibro piling activities on diving seabirds in the study area are considered **negligible**.

Table 8. Approximate distances (metres) diving seabird response criteria are reached during vibro piling

Marine Mammal Hearing Group	PTS	TTS	Behavioural
Phocid pinniped (elephant seal, leopard seal)*	18	230	2
* The injury and behavioural thresholds for phocid pinnipeds is used as a proxy for response criteria in seabirds.			

6.3.2 Impact piling

The peak SPL SL generated by impact piling the proposed sheet piles is marginally above the indicative criteria for PTS and TTS in diving seabirds (Table 9). The distance at which the received level of noise is within the limits of PTS and TTS in diving seabirds is 2 m and 4 m respectively. This suggests that there will be a highly localised potential risk of auditory injury in elephant seals in the immediate vicinity of the source of the impact piling.

Behavioural reactions in both diving seabirds are predicted to be limited to within around 40 m from the source of impact piling (Table 9). Any diving seabirds that happen to be present are likely to evade this area of potential behavioural effect. However, the zone of potential behavioural effect is very small and will not displace any diving seabirds from key foraging areas. Overall, the potential effects of underwater noise during impact piling on diving seabirds at KEP are considered **minor adverse**.

Table 9. Approximate distances (metres) diving seabird response criteria are reached during impact piling

Marine Mammal Hearing Group	PTS	TTS	Behavioural
Phocid pinniped (elephant seal, leopard seal)*	2	4	36
* The injury and behavioural thresholds for phocid pinnipeds is used as a proxy for response criteria in seabirds.			

7 Mitigation

The assessment provided in Section 6 indicates that in the absence of any further mitigation, the underwater noise generated by impact piling activities associated with the KEP project is likely to result in minor adverse effects on marine fauna in the study area.

Given the highly sensitive nature of the study area and the high number of seals and diving seabirds that occur at KEP, the following mitigation measures are proposed to reduce or minimise adverse effects:

- Vibro piling: Vibro piling is proposed to be used where possible (which produces lower source noise levels than impact piling) and is likely to constitute the majority of the piling operations. However, in order to drive the piles to the required design level in certain circumstances impact piling is likely to be required.

- Soft start: The gradual increase of piling power, incrementally, until full operational power is achieved will be used as part of the piling methodology. This will give fish and marine mammals the opportunity to move away from the area before the onset of full impact strikes. The duration of the soft start is proposed to be 20 minutes in line with the JNCC "Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals during piling" (JNCC, 2010).

- Impact piling protocol: The guiding principles of the JNCC "Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals during piling" (JNCC, 2010) was designed to be implemented as part of large scale marine construction works (e.g. offshore wind farms) involving the percussive piling of large diameter steel tubular piles that generate very high levels of impulsive noise. These are not considered appropriate for the KEP wharf redevelopment given the localised and small scale nature of potential effects that have been predicted to occur during the proposed impact piling of sheet piles at KEP. A modified version of the piling protocol is therefore proposed involving the following key steps:
  - Establishing a 'mitigation zone' with a 10 m radius around the KEP construction site prior to any impact piling. A 10 m radius is considered appropriate in this instance given the predicted injury effects zones for marine fauna (see Section 6);
  - Prior to the commencement of impact piling, a trained observer undertaking a search of phocid pinnipeds (true seals) and diving seabirds within this mitigation zone;
  - In the event that any phocid pinnipeds and diving seabirds are identified within the mitigation zone, soft start will encourage them to leave the zone (see above); and
  - Should any phocid pinnipeds and diving seabirds enter the mitigation zone during impact piling, the piling works will continue on the basis that they are not causing a significant disturbance or harm to these animals.

Taking account of proposed mitigation measures, the likely residual effects on all marine fauna from the construction works at KEP are considered **negligible**.

8 References

ABPmer, 2008. Environmental Statement for Port of Southampton: Berth 201/202 Works. ABPmer Report No. R.1494.

ABPmer, 2015. Royal Pier Waterfront EIA: Marine and Estuarine Ecology. Report for RPW (Southampton) Ltd. ABPmer Report No. R.2438.

Brekhovskikh, 1960. Propagation of surface Rayleigh waves along the uneven boundary of an elastic body. Soviet Physics-Acoustics 5: 288-295.

Clark, C. W., Ellison, W. T., Southall, B.L., Hatch, L., Van Parijs, S.M., Frankel, A., and D. Ponirakis, 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series 395: 201-222.

Crocker, D. E., 5. J. Le Boeuf, Y. Naito, T. Asaga, and D. P. Costa 1994. Swim speed and dive function in a female northern elephant seal. In: Elephant Seals: Population Ecology, Behavior, and Physiology, edited by R J 1.e Roeuf and R M I.am Rwkeley Llniv. of California Press, 1994, p. 328-339.

DPTI, 2012. Underwater Piling Noise Guidelines. Government of South Australia, Department of Planning, Transport and Infrastructure. First published: November 2012. Version 1.

Dunlop, R. A., Noad, M. J., McCauley, R. D., Scott-Hayward, L., Kniest, E., Slade, R., Cato, D. H. (2017). Determining the behavioural dose response relationship of marine mammals to air gun noise and source proximity. Journal of Experimental Biology, 220, 2878–2886. https://doi.org/10.1242/jeb.160192

Ellison, W.T., Southall B.L., Clark C.W., Frankel A.S., 2012. A new context-based approach to assess marine mammal behavioural responses to anthropogenic sounds. Conservation Biology 26: 21 8.

Farcas, A., Thompson, P.M. and Merchant, N.D., 2016. Underwater noise modelling for environmental impact assessment. *Environmental Impact Assessment Review*, *57*, pp.114-122.

Faulkner, R.C., Farcas, A., and Merchant, N.D., 2018. Guiding principles for assessing the impact of underwater noise. Journal of Applied Ecology: 2018; 00:1-6.

Hansen, K. A., Maxwell, A., Siebert, U., Larsen, O. N., & Wahlberg, M, 2017. Great cormorants (Phalacrocorax carbo) can detect auditory cues while diving. The Science of Nature, 104(5-6), 45.

Hastings, M. C. & Popper, A. N., 2005. Effects of sound on fish. California Department of Transportation. Division of Research and Innovation Office Materials and Infrastructure.

Hawkins, A. D. & Myrberg Jr, A. A., 1983. Hearing and sound communication under water. In: Bioacoustics: A Comparative Approach (Ed. by B. Lewis), pp. 347-405: Academic Press.

Hawkins, A.D., Roberts, L. & Cheesman, S., 2014. Responses of free-living coastal pelagic fish to impulsive sounds. *The Journal of the Acoustical Society of America* 135: 3101-3116.

Hawkins, A. D., Pembroke, A., & Popper, A., (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. *Reviews in Fish Biology and Fisheries*, 25: 39–64.

Hawkins, A.D., and Popper, A.N. (2014). Assessing the impacts of underwater sounds on fishes and other forms of marine life. Acoustics Today, 10: 30-41.

Hawkins A. D., & Popper, A. N. (2016). A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science, Volume 74, Issue 3, 1 March 2017, Pages 635–651. Available from: https://doi.org/10.1093/icesjms/fsw205

Hindell, M.A., McConnell, B.J., Fedak, M.A., and McMahon, C.J., 1999. Environmental and physiological determinants of successful foraging by naive southern elephant seal pups during their first trip to sea. 1999. Canadian Journal of Zoology 77(11):1807-1821

ICF Jones & Stokes and Illingworth & Rodkin, 2009. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish. Prepared for: California Department of Transportation. Available at: http://www.dot.ca.gov/hq/env/bio/files/Guidance_Manual_2_09.pdf

Illingworth & Rodkin, 2007. Compendium of Pile Driving Sound Data. Prepared for: The California Department of Transportation

ISO/DIS. 2016. 8405.2 Underwater acoustics—terminology. Available at http://www.iso.org/iso/catalogue_detail.htm?csnumber=62406.

Jacobs, 2014. Central Eyre Iron Project EIS: Appendix S Marine Environmental Noise Assessment Prepared For Jacobs

JNCC, 2010. Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise.

Kastelein, R. A., Verboom, W. C., Jennings, N., de Haan, D., & van der Heul, S. (2008). The influence of 70 and 120 kHz tonal signals on the behaviour of harbor porpoises (*Phocoena phocoena*) in a floating pen. Marine Environmental Research, 66(3), 319-326.

Leopold, Mardik & Camphuysen, C.J., 2007. Did the pile driving during the construction of the Offshore Wind Farm Egmond aan Zee, the Netherlands, imapct local seabirds?. Report C062/07 produced for NordzeeWind.

MacGillivray, A., Austin, M., and Hannay, D. (2004). Underwater sound level and velocity measurements from study of airgun noise impacts on Mackenzie River fish species. JASCO Research Pvt. Ltd., Japan.

Martin, B., Zeddies, D. G., Gaudet, B., & Richard, J. 2016. Evaluation of three sensor types for particle motion measurement. In: The Effects of Noise on Aquatic Life II, pp. 679–686. Ed. by A. N. Popper, and A. D. Hawkins. Springer, New York.

McCauley, R. D., Fewtrell, J., Duncan, A. J., Jenner, C., Jenner, M-N., Penrose, J. D., Prince, R. I. T., Adhitya, A., Murdoch, J. and McCabe, K. (2000). Marine seismic surveys – A study of environmental implications. Appea Journal, pp. 692-707.

McConnel, B., Fedak, M., Burton, H.R., Engelhard, G.H., and Reijnders, P.J.H. (2002). Movements and foraging areas of naïve, recently weaned southern elephant seal pups. Journal of Animal Ecology. Available at: https://doi.org/10.1046/j.0021-8790.2001.00576.x

MMO (2015). Modelled Mapping of Continuous Underwater Noise Generated by Activities. A report produced for the Marine Management Organisation, Technical Annex, pp 43. MMO Project No: 1097. ISBN: 978-1-909452-87-9.

Mueller-Blenkle, C., McGregor, P. K., Gill, A. B., Andersson, M. H., Metcalfe, J., Bendall, V., Sigray, P., Wood, D. & Thomsen, F., 2010. Effects of pile-driving noise on the behaviour of marine fish. COWRIE Ref: Fish 06-08, Technical Report 31st March 2010.

Nedelec, S.L., Campbell, J., Radford, A.N., Simpson, S.D., Mercant, N.D., 2016. Particle motion: the missing link in underwater acoustic ecology. Methods in Ecology and Evolution 7:836-842

Nedwell, J. and Howell, D. (2004). A review of offshore wind farm related underwater noise sources. Report No. 544 R 0308

Nedwell, J.R., Parvin, S.J., Edwards, B., Workman, R., Brooker, A.G., Kynoch, J.E., 2007a. Measurement and interpretation of underwater noise during construction and operation of offshore wind farms in UK waters. Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0-9554279-5-4.

Nedwell, J.R., Turnpenny, A.W.H. Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L. and Howell, D., 2007b. A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report No. 534R1231

Nedwell, J.R., Brooker, A.G., and Barham, R.J., 2012. Assessment of underwater noise during the installation of export power cables at the Beatrice Offshore Wind Farm. Subacoustech Environmental Report No. E318R0106.

NPL, 2014. Good Practice Guide for Underwater Noise Measurement, National Measurement Office, Marine Scotland, The Crown Estate, Robinson, S.P., Lepper, P. A. and Hazelwood, R.A., NPL Good Practice Guide No. 133, ISSN: 1368-6550, 2014.

NOAA (2018). 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

Pena, H., Handegard, N. O., and Ona, E. (2013). Feeding herring schools do not react to seismic air gun surveys. ICES Journal of Marine Science, 70: 1174–1180.

Pearson, W. H., Skalski, J. R. and Malme, C. I. (1992). Effects of sounds from a geophysical survey device on behaviour of captive rockfish (Sebastes spp.). Can. J. Fish. Aquat. Sci., 49, pp. 1343-1355.

Pichegru, L., Nyengera, R., McInnes, A. M., & Pistorius, P., 2017. Avoidance of seismic survey activities by penguins. Scientific reports, 7(1), 16305.

Popper, A.N., and Hawkins, A.D., 2018. The importance of particle motion to fishes and invertebrates. Journal of the Acoustical Society of America 143(1): 470-488.

Popper, A.N. and Hastings, M.C., 2009. The effects of anthropogenic sources of sound on fishes. Journal of Fish Biology 75: 455-489.

Popper A. N., Hawkins A. D., Fay R. R., Mann D. A., Bartol S., Carlson T. J., Coombs S., Ellison W. T., Gentry R. L., Halvorsen M. B., Løkkeborg S., Rogers P. H., Southall B. L., Zeddies D. G., & Tavolga W. N., 2014. Sound exposure guidelines for fishes and sea turtles: a technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. ASA S3/SC1.4 TR-2014. Springer and ASA Press, Cham, Switzerland

Radford, C .A., Montgomery, J. C., Caiger, P. & Higgs, D. M., 2012. Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *Journal of Experimental Biology*, *215*(19), pp.3429-3435.

Richardson, W.J., Green Jr, C.R., Malme, C.I. & Thomson, D.H. 1995. Marine Mammals and Noise. Academic Press, New York.

Sigray, R. and Andersson, M.H. 2011. Particle motion measured at an operational wind turbine in relation to hearing sensitivity in fish. Journal of the Acoustical Society of America 130, 200–207.

Sisneros, J. A., Popper, A. N., Hawkins, A. D., and Fay, R. R. (2016). Auditory Evoked Potential audiograms compared to behavioural audiograms in aquatic animals. In The Effects of Noise on Aquatic Life, II, pp. 1049–1056. Ed. by A. N. Popper, and A. D. Hawkins. Springer SciencepBusiness Media, New York.

SLR Consulting, 2019. Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project Underwater Noise Impact Assessment. Prepared for: Aurecon Australasia Pty Ltd. February 2019.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene Jr, C. R., Kastak, D., Miller, J.H., Nachigall, P.E., Richardson, W,.J., Thomas, J.A and Tyack, P.L. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals* 33:411–521.

Teachout, E., 2012. Evaluating the effects of underwater sound from pile driving on the marbled murrelet and the bull trout. Prepared by the U.S. Fish and Wildlife Service's Washington Fish and Wildlife Office

Thomsen F, Lüdemann K, Kafemann R and Piper W, 2006. Effects of offshore wind farm noise on marine mammals and fish, on behalf of COWRIE Ltd

URS Scott Wilson (2011). Green Port Hull Environmental Statement.

Webb, J. F., Popper, A. N. and Fay, R. R., 2008. Fish Bioacoustics. New York, NY: Springer.

Wyatt, 2008. Review of Existing Data on Underwater Sounds Produced by the Oil and Gas Industry. Joint Industry Programme on Sound and Marine Life. Seiche Measurements Limited August 2008

Wysocki, L.E. and Ladich, F., 2005. Hearing in fishes under noise conditions. Journal of the Association of Research in Otolaryngology 6, 28–36.

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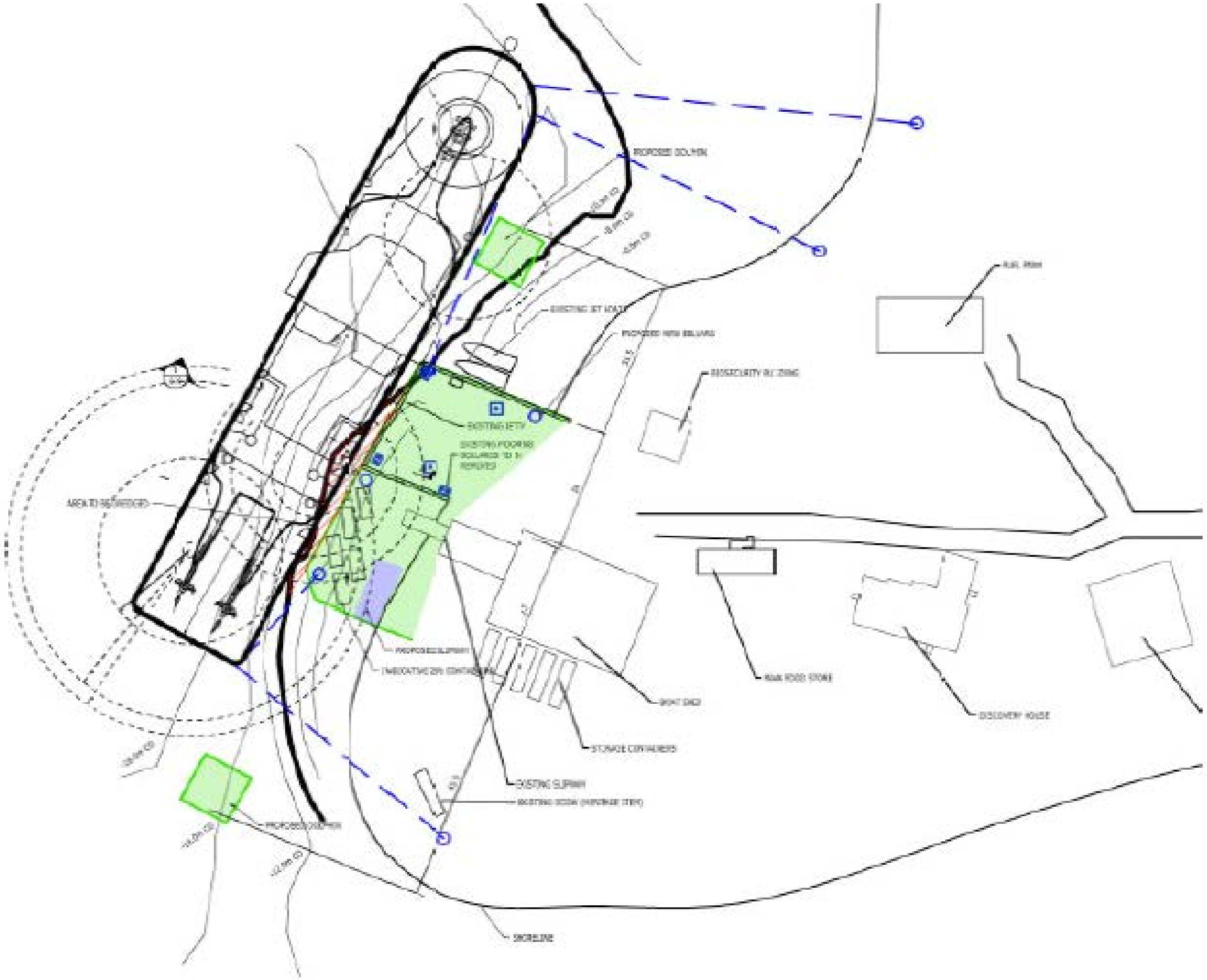
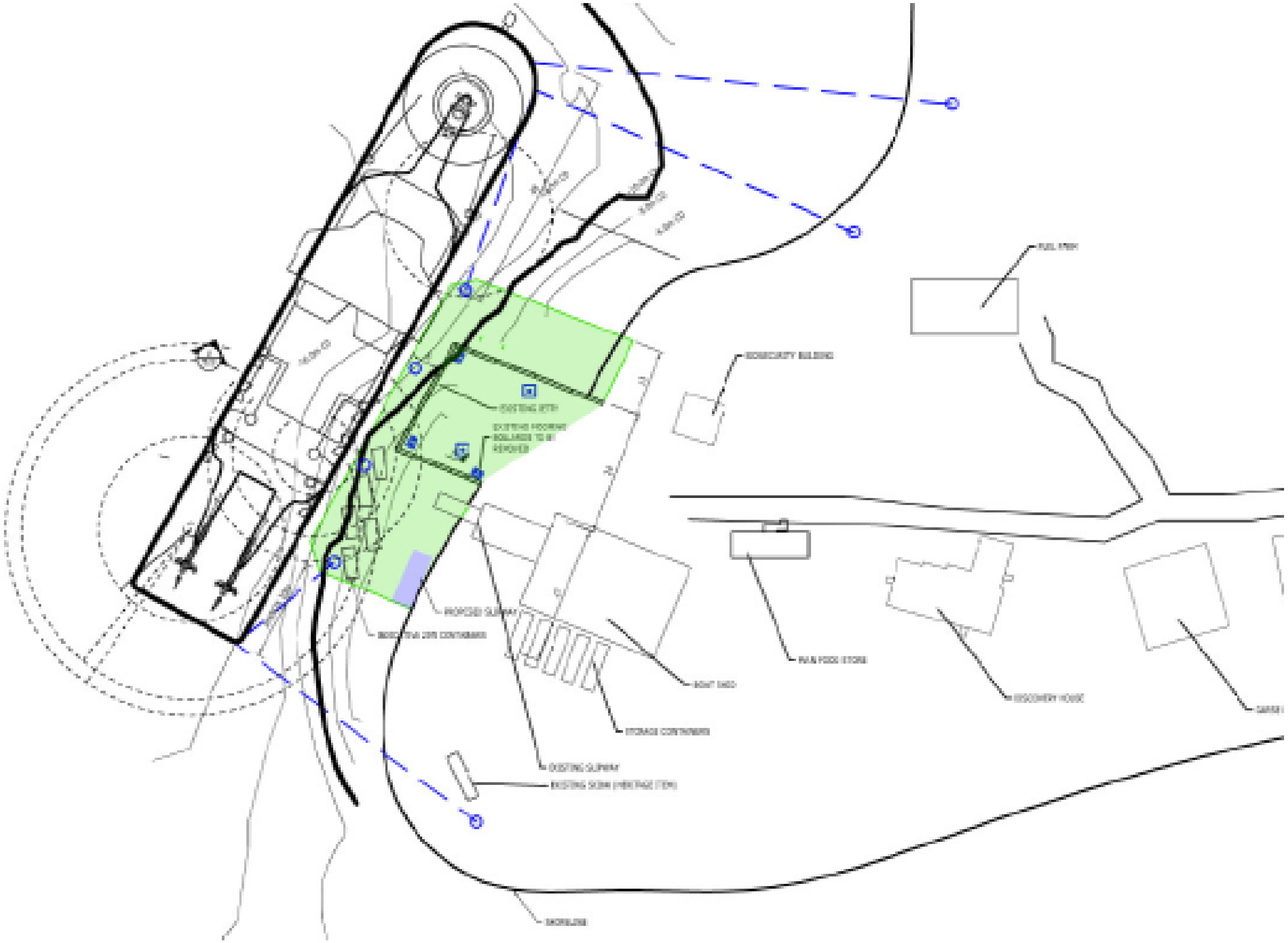
Appendix 14 – Alternative wharf designs

Work Stage 2 – Layout Option 1



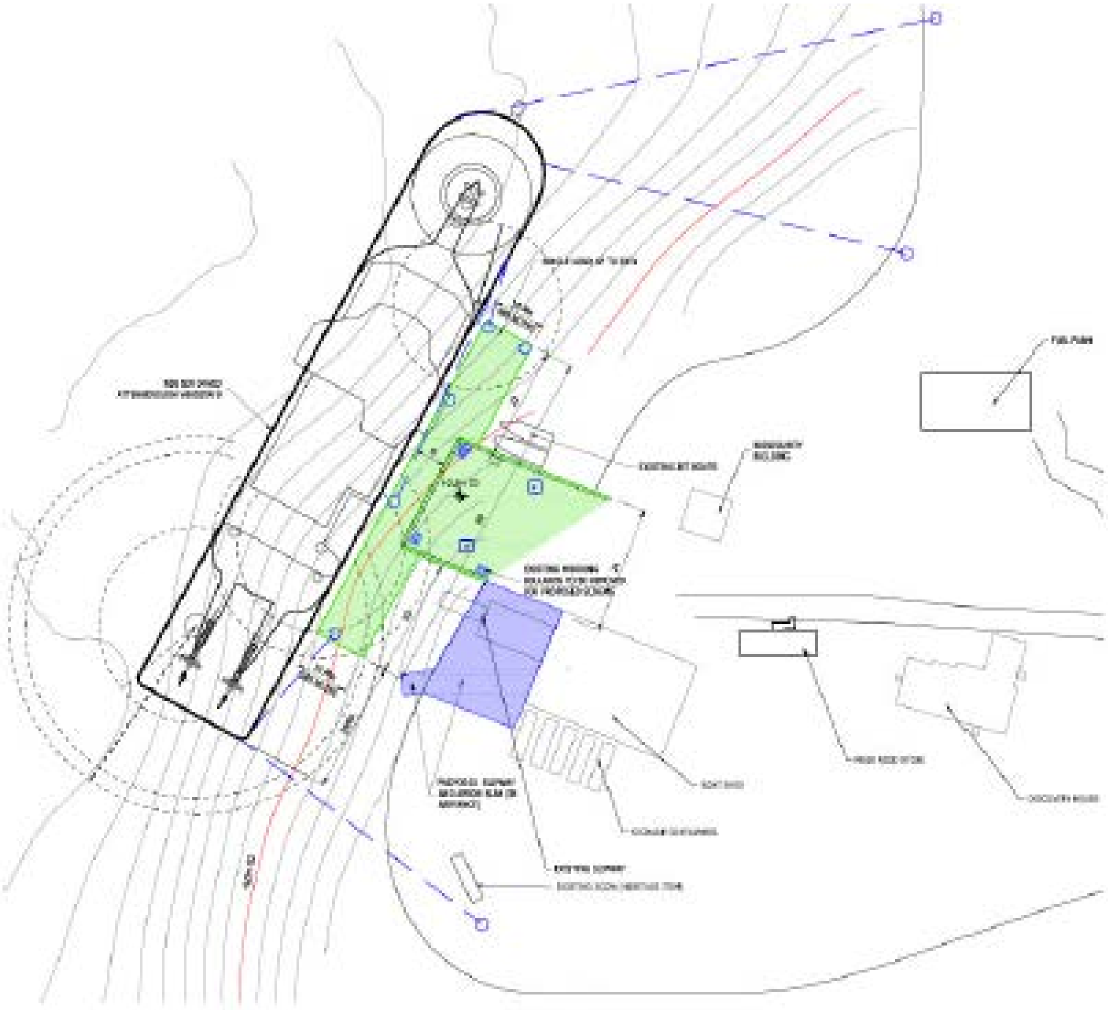
Layout Option 1

Work Stage 2 – Layout Option 2



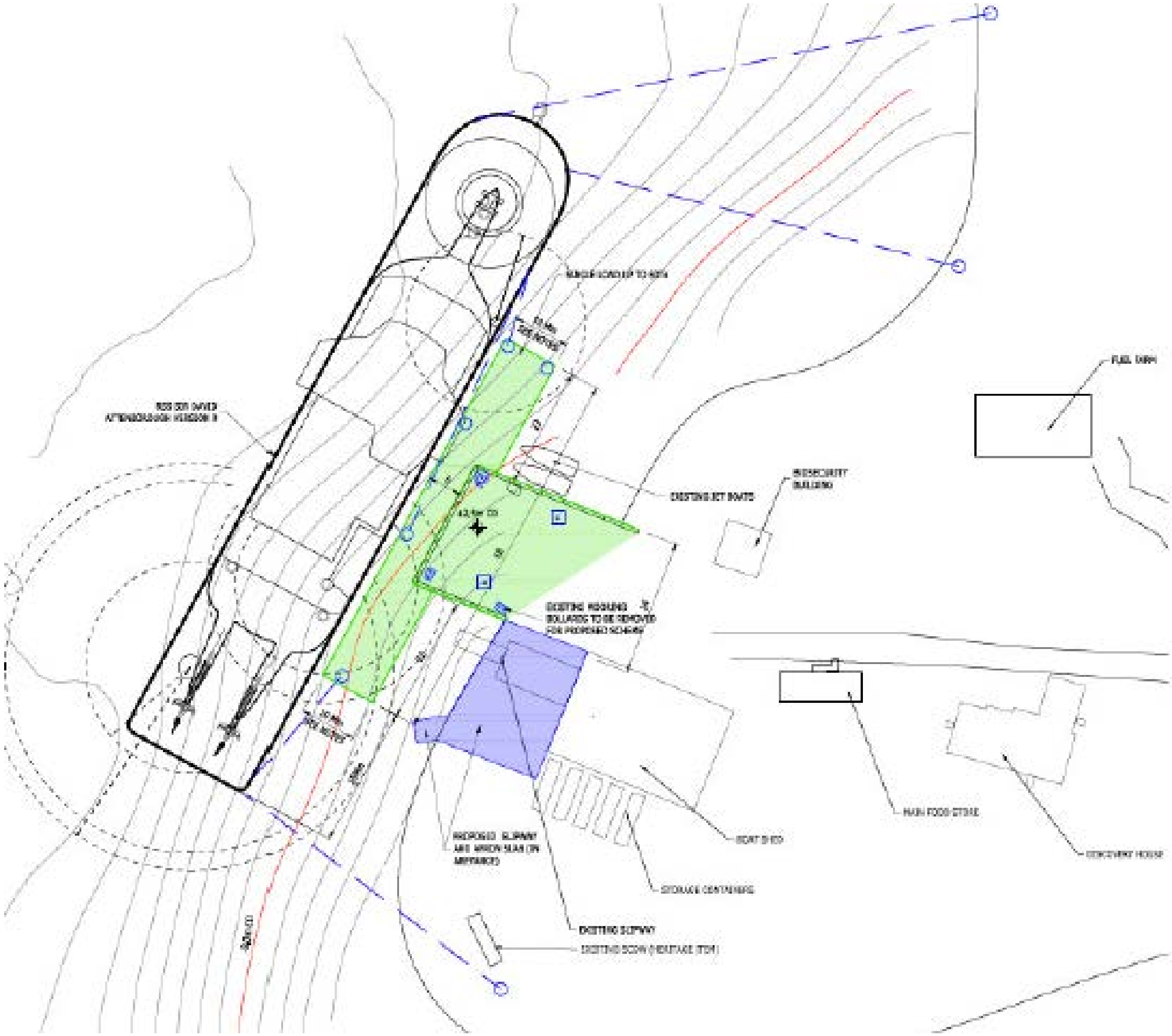
Layout Option 2

Work Stage 2 – Layout Option 3

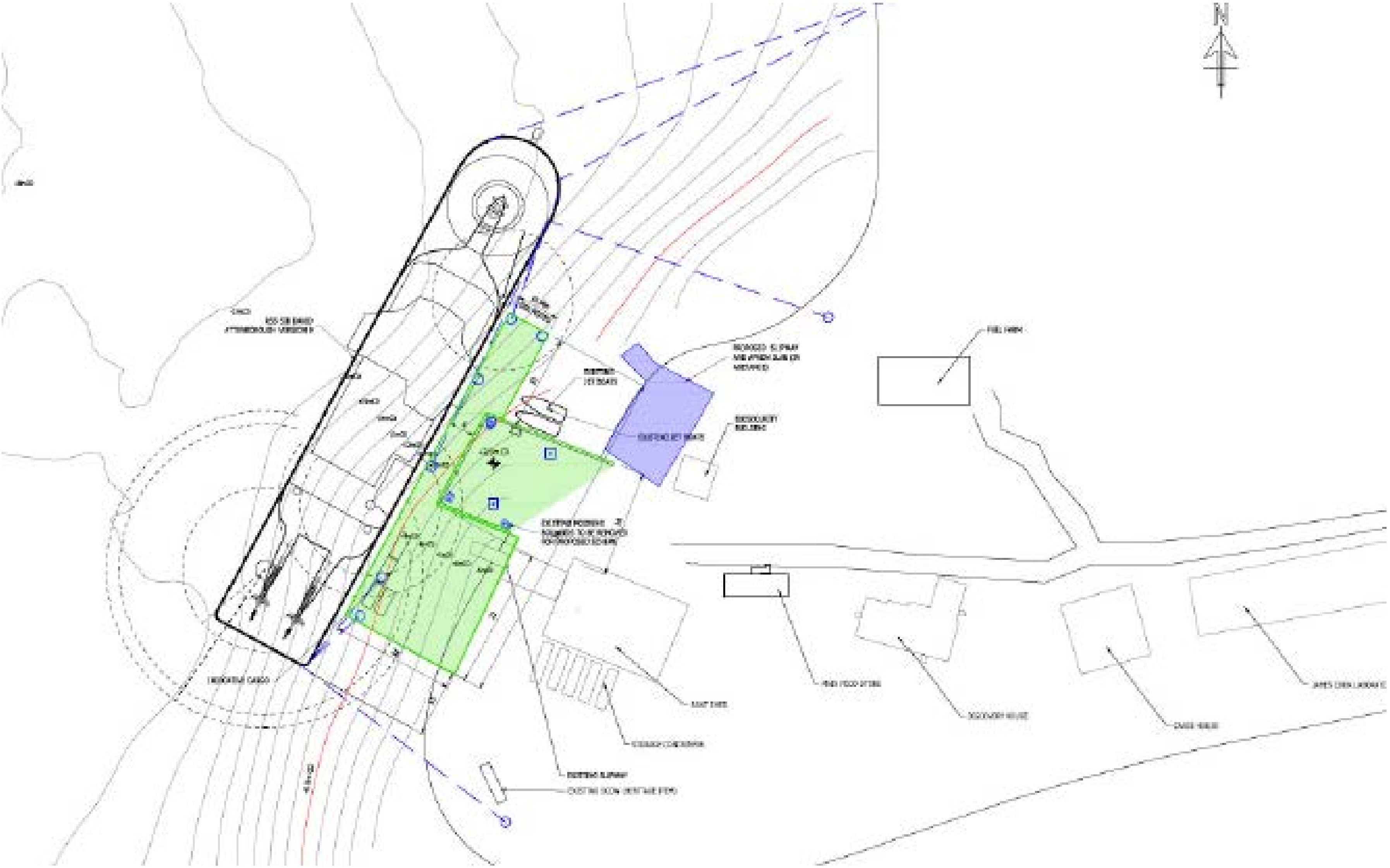


Layout Option 3

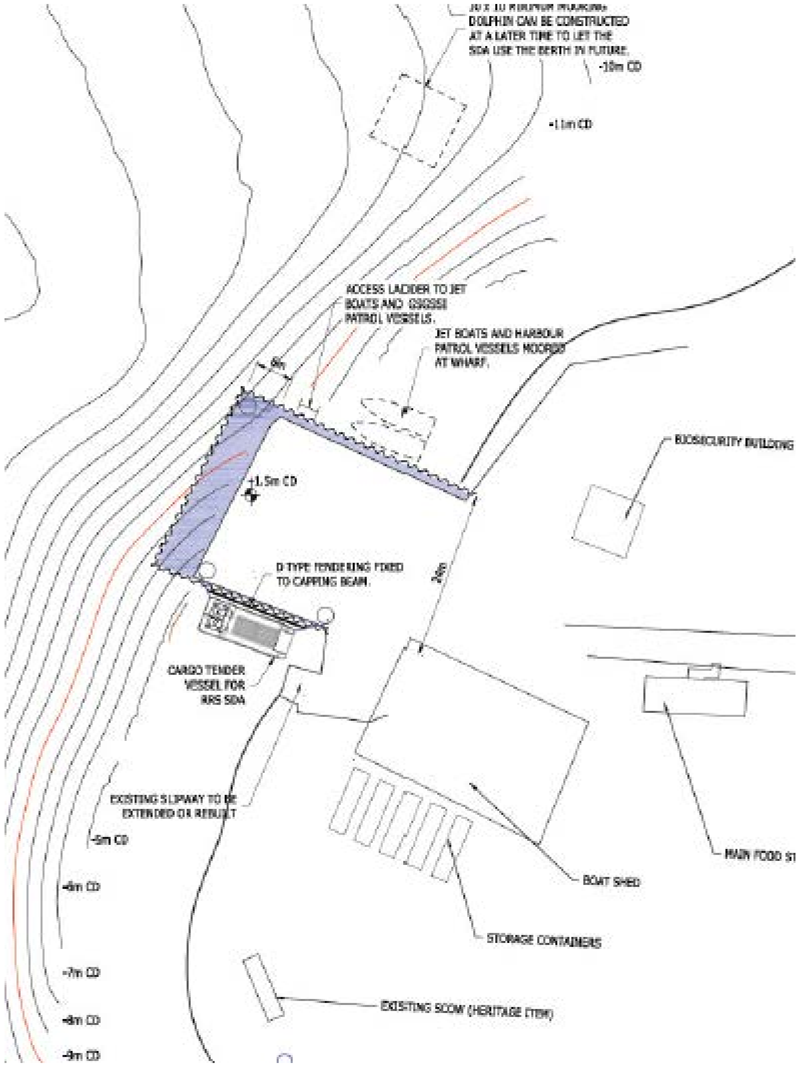
Work Stage 2 – Layout Option 3 Minimum Enhancement



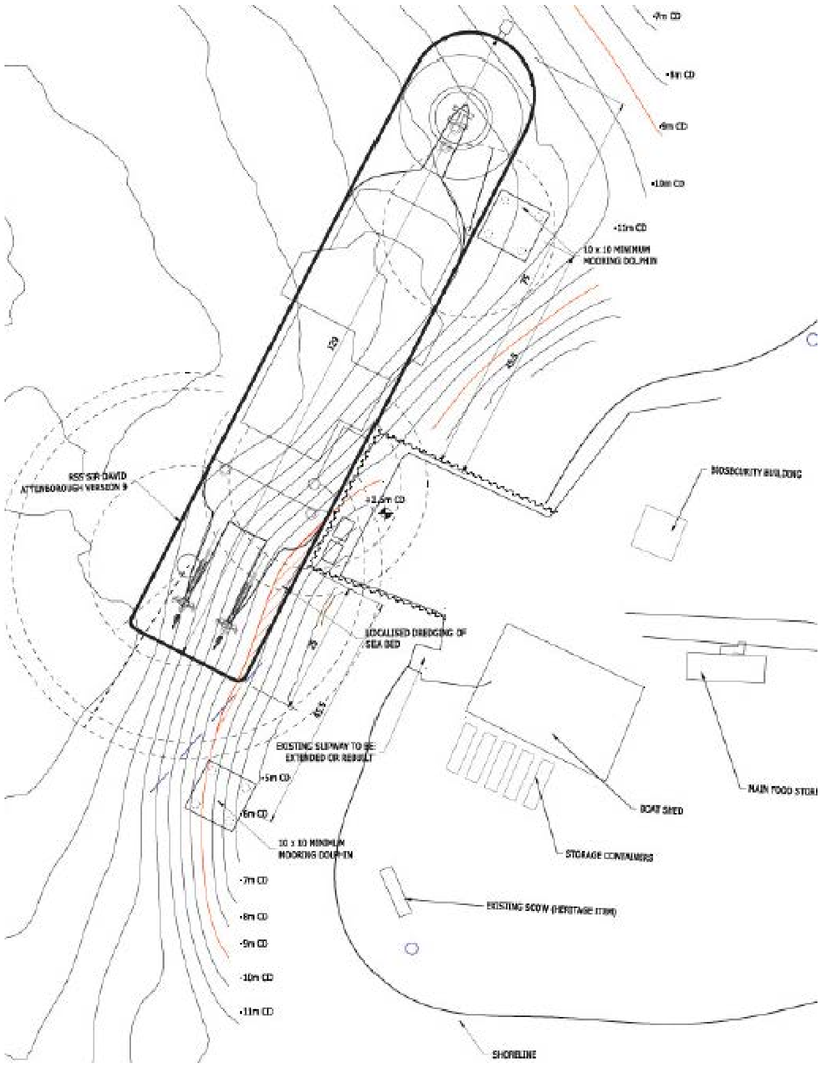
Work Stage 2 – Layout Option 3 Moderate Enhancement



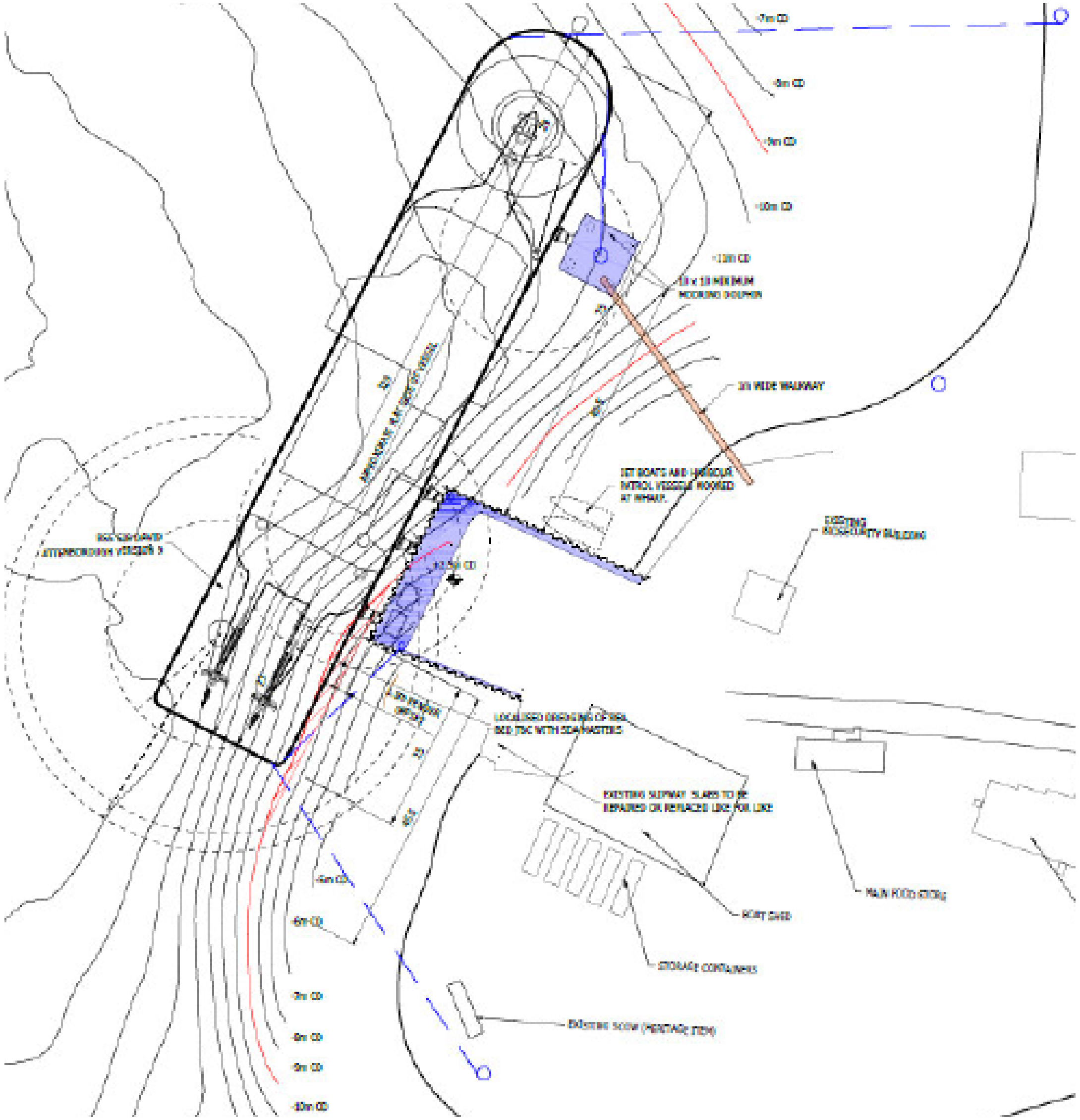
Work Stage 2 – Value Engineering - Wraparound existing wharf "Alternative Minimum Enhancement"



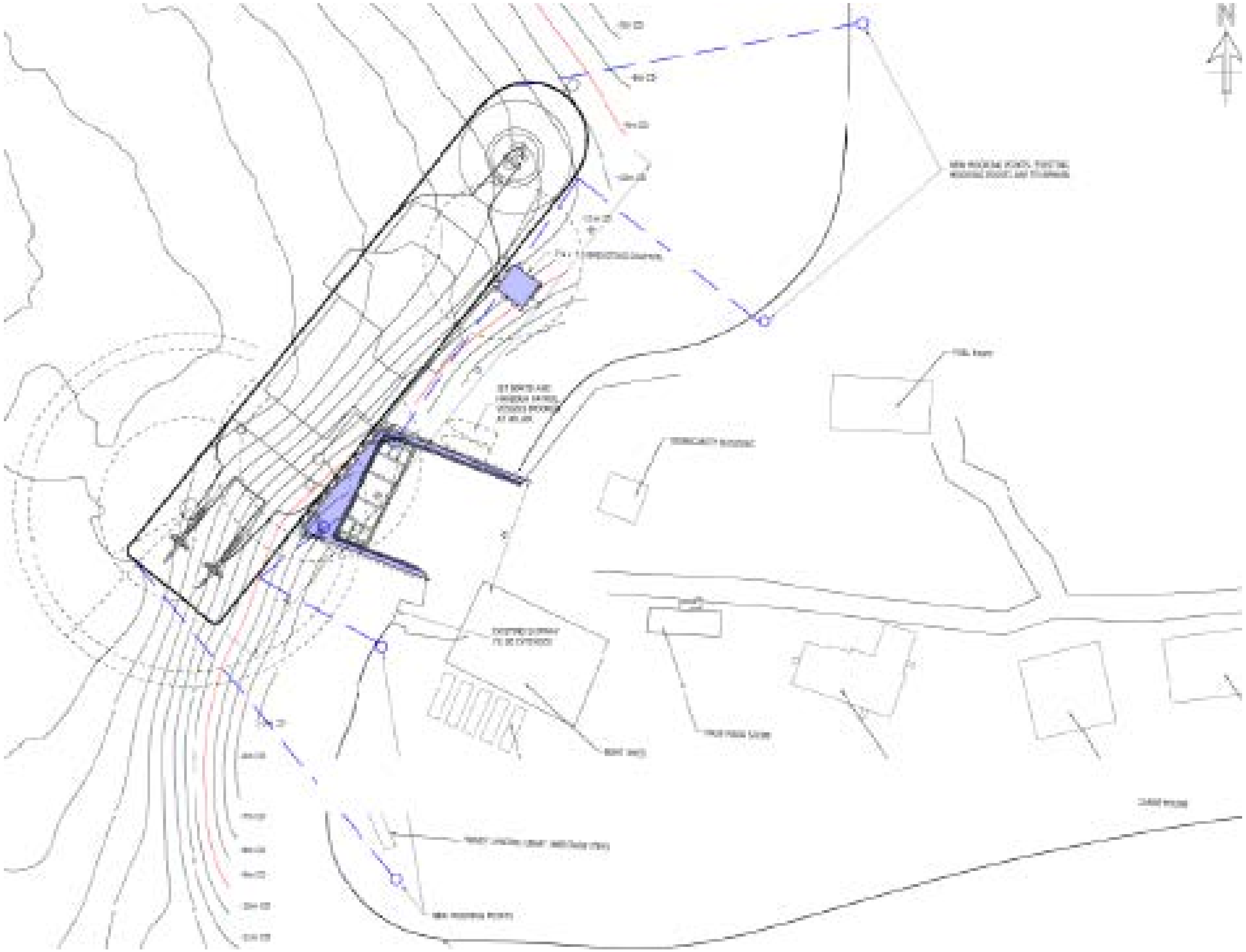
Work Stage 2 – Value Engineering - Wraparound wharf with port and starboard dolphins



Work Stage 2 – Value Engineering - Wraparound wharf with starboard mooring dolphin “Alternative Moderate Enhancement”



Work Stage 3 – Option 3 - 7.5 x 7.7m starboard breasting dolphin



Work Stage 3 – Option 2 – Realigned wrap-round wharf with 10x10m starboard mooring dolphin